CO_2 Blast Cleaning Process

Technical Report

CO_2 Blast Cleaning Process

1006617

Final Report, February 2002

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CITATIONS

This report was prepared by

R & P Consulting
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Rising Sun, MD 21911

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This report describes research sponsored by EPRI.

The report is a corporate document that should be cited in the literature in the following manner:
CO_2 Blast Cleaning Process, EPRI, Palo Alto, CA: 2002. 1006617.

REPORT SUMMARY

CO_2 (dry ice) cleaning is a process in which dry ice particles, accelerated by compressed air or nitrogen, are propelled at high velocities to impact and clean a surface. Because CO_2 technology produces no secondary waste, the CO_2 blast cleaning process has many applications for the cleaning of electrical equipment.

Background

Traditionally, large generators, motors, and transformers that need cleaning are removed during the repair shutdown and are sent to an electrical shop to be steam cleaned, baked to remove moisture, turned and undercut, insulated reinstalled. The steam cleaning method is the preferred process because of its superior cleaning but is very labor intensive for large equipment, lengthens shutdown time, and increases the potential of damage during removal and reinstallation. The CO_2 blast cleaning process is environmentally friendly, minimizes waste, and eliminates the chance of grit entrapment. This process safely allows motors, generators and transformers to be cleaned in place, thus reducing costly downtime and eliminating equipment removal and reinstallation.

Objectives

To provide utilities a primer on the use of CO_2 blast technology to replace and/or augment traditional methods of cleaning electric equipment.

Approach

The project team prepared a concise but comprehensive primer on the use of CO_2 blast technology to clean electrical equipment. To identify the advantages and disadvantages of the technology, the team surveyed current CO_2 blast cleaning users and summarized their responses.

Results

CO_2 blasting is emerging as an effective option in the cleaning of motors and their insulation systems. CO_2 cleaning uses conventional blasting technology combined with dry ice pellets as the media. These pellets evaporate during the process and produce minimal secondary waste. When the CO_2 blast cleaning process is used properly, it is a totally dry process and is environmentally safe and friendly. It can be used in a wide range of applications for the cleaning of electrical equipment including motors, generators, switchgear and relays, motor control panels, circuit boards, and transformers.

CO_2 blasting works best removing loose surface contamination on hard non-porous surfaces. Depending on the skill of the operator, the contaminants are reduced considerably on the first pass and nearly eliminated after two or more passes. In most cases the overall cleaning process is much faster then conventional cleaning methods using walnut shell, corncob, or baking soda as

an abrasive. The savings in time is due primarily to the shorter cleanup time involved in removing and processing generated waste products. If a comparison is made between the production rate of CO_2 blast cleaning process and other abrasive blast processes, CO_2 will be slower because of its non-abrasive properties. However there is very little, if any, drying time and very little cleanup involved and no chemical or secondary waste generated. For these reasons, CO_2 blast cleaning is quicker and very competitive in cost when all factors are considered. The CO_2 blast cleaning process takes only about 20% of the time as compared with steam cleaning.

Testing and inspections can be performed prior to and after cleaning. CO_2 blast cleaning can be used during outages to facilitate maintenance activities by reducing the down time of the plant and allowing for the timely return to service and production of critical plant components. Many users have seen dramatic increases in insulation resistance readings after CO_2 blasting is performed.

EPRI Perspective

The CO_2 dry ice blast cleaning process has several advantages; but, like any cleaning process, it has limitations as well. For example, CO_2 blasting requires line of sight for the operator and some areas of a motor can not be cleaned even with recent advances in nozzle configurations. More generally, the technology can be very aggressive and lead to insulation damage and coating removal if CO_2 pellet size is too large and/or air pressure is too high. Finally, the CO_2 pellets used in the process must be stored on location and not only require storage space, but have a limited shelf life. This report summarizes the advantages and disadvantages of the CO_2 dry ice blast cleaning process as reflected in the actual experience of utility personnel.

Keywords

CO_2 blast cleaning
Maintenance
Electric motors
Electrical equipment

INTRODUCTION

CO_2 (dry ice) cleaning is a process in which dry ice particles are propelled at high velocities to impact and clean a surface. The dry ice particles are accelerated by compressed air, just as with other blasting technologies (Nitrogen can also be used). At this point the CO_2 technology becomes more user and environmentally friendly. With conventional blast media, secondary waste is produced whereas CO_2 blasting media evaporates. The CO_2 blast cleaning process is so friendly that it is used in a wide range of applications for the cleaning of electrical equipment such as:

- Motors
- Generators
- Switchgear and Relays
- Motor Control Panels.
- Circuit Boards
- Transformers
- Welding Equipment
- Robotic Equipment
- Wiring Runs and Cable Trays

Traditionally large generators, motors, and transformers that need cleaning are removed during the repair shutdown and are sent to an electrical shop to be steam cleaned, baked to remove moisture, turned and undercut, insulated reinstalled. The steam cleaning method is the preferred process because of its superior cleaning, but is very labor intensive for large equipment. Adding to the shutdown time, and increases the potential of damage during removal and reinstallation. The CO_2 blast cleaning process is environmentally friendly, minimizes waste, and eliminates the chance of grit entrapment. This process safely allows motors, generators and transformers to be cleaned in place, thus reducing costly downtime and eliminating equipment removal and reinstallation.

The following properties make CO_2 ideal for use in electrical applications:

- Non-Destructive
- Non-Conductive
- Non-Abrasive on most materials
- Environmentally safe nontoxic materials
- Does not generate any secondary or mixed wastes

When the CO_2 blast cleaning process is used properly, it is a totally dry process and environmentally safe and friendly. In addition to the application above, the following equipment can be cleaned:

- Circuit Boards
- Wiring Runs
- Precipitators
- Turbine Blades and Rotors
- Heat Recovery Steam Generating Tubes
- Transformer Cooling Banks

The system works best removing loose surface contamination on hard non-porous surfaces. Depending on the skill of the operator, the contaminants are reduced considerably on the first pass and nearly eliminated after two or more passes. In most cases the overall cleaning process is much faster then conventional cleaning methods using other blasé methods such as walnut shell, corncob, or baking soda. The savings in time is due primarily to the shorter cleanup time involved in removing and processing generated waste products. If a comparison is made between the production rate of CO_2 blast cleaning process and other abrasive blast processes, CO_2 will be slower because of its non-abrasive properties. However there is very little, if any, drying time and very little cleanup involved, and no chemical or secondary waste generated, thus CO_2 blast cleaning is quicker and very competitive in cost when all factors are considered. The CO_2 blast cleaning process takes only about 20% of the time as compared with steam cleaning.

Testing and inspections can be performed prior to and after cleaning. Testing may include megger, polarization index, cold resistance, pole drop, bar to bar etc. Inspections include commutators, coil connections, signs of flashovers, solder joints, insulators, ventilation ducts, etc. CO_2 blast cleaning can be used during outages to facilitate maintenance activities by reducing the down time of the plant and allowing for the timely return to service and production of critical plant components. Many users have seen dramatic increases in IR readings after CO_2 blasting is performed.

ABSTRACT

Utilities, like any other business are constantly searching for new, better and more cost effective methods to maintain their electric motors. CO_2 blasting is emerging as an effective option in the cleaning of motors and its insulation systems. CO_2 cleaning uses conventional blasting technology combined with dry ice pellets as the media. These pellets evaporate during the process, and thus produce minimal secondary waste.

This guideline is a primer for those interested in the technology as it is used to replace and/or augment the traditional methods of motor cleaning. CO_2 blasting minimizes waste and allows in-place cleaning of large motors. From its inception in the aircraft industry to its' use in nuclear power plants, this guide provides various system descriptions, and system operations. The theory of why the system works and the practical applications used today are also discussed. For readers that are concerned with applicability in their situation, advances in equipment have brought the technology from a tractor-trailer size unit to today's that rival the size of a compact refrigerator. Nozzle varieties, energy requirements, and supporting equipment are also reviewed.

As with any technology there are advantages and disadvantages. As part of the guideline preparation, a survey of current CO_2 blast cleaning users was performed. This survey is summarized to include successes and room for improvement in using this technology to clean electric motors and insulation systems.

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1
CO_2 BLAST CLEANING PROCESS

History of CO_2 Blast Cleaning

During the 1970s, Lockheed engineers were searching for a way to reclaim the primers on aircraft. They did not want to use chemicals or damage the aircraft substrate during the process. The thought of using CO_2 (dry ice) pellets was explored and they decided to try it. This group worked for several years on the concept and developed the first CO_2 blast cleaning system and called it CO_2CleanBlast™ [1].

In 1987 Alpheus Cleaning Technologies licensed the technology from Lockheed and installed the first commercial unit at an Air Force base. These original units were hardly portable. Many of them were mounted in large trailers that did not allow the system to be brought into a plant environment. The first portable units shrunk the size of the system to that of a refrigerator. Now in plant cleaning or Cleaning In Place (CIP) was possible and this was only two (2) years after the first commercial systems were introduced.

Today, there are many different models and types of CO_2 blast cleaning units as well as several manufacturers. Figure 1-1 below is a typical portable blast unit, hose, gun and nozzle. As the photo illustrates, in plant use is easily accomplished with the size of this unit.

System Description

Dry ice, the solid form of carbon dioxide passes directly from a solid state to a gaseous state without going through a liquid phase. This is called sublimation and this characteristic makes dry ice a very versatile blast medium. The CO_2 blast cleaning technology works very similar to commercial blast operations such as walnut shell, corncob, or other abrasive blast technologies. The CO_2 blast system uses dry compressed air or nitrogen gas as the propellant. Current systems in use are pneumatic or electrical/pneumatic operation. The dry compressed air or propellant gas provides the motive force for transporting and blasting the pellets of dry ice. Usage of consumables on these portable units is dependent upon the blast pressure and nozzle configurations as well as pellet size.

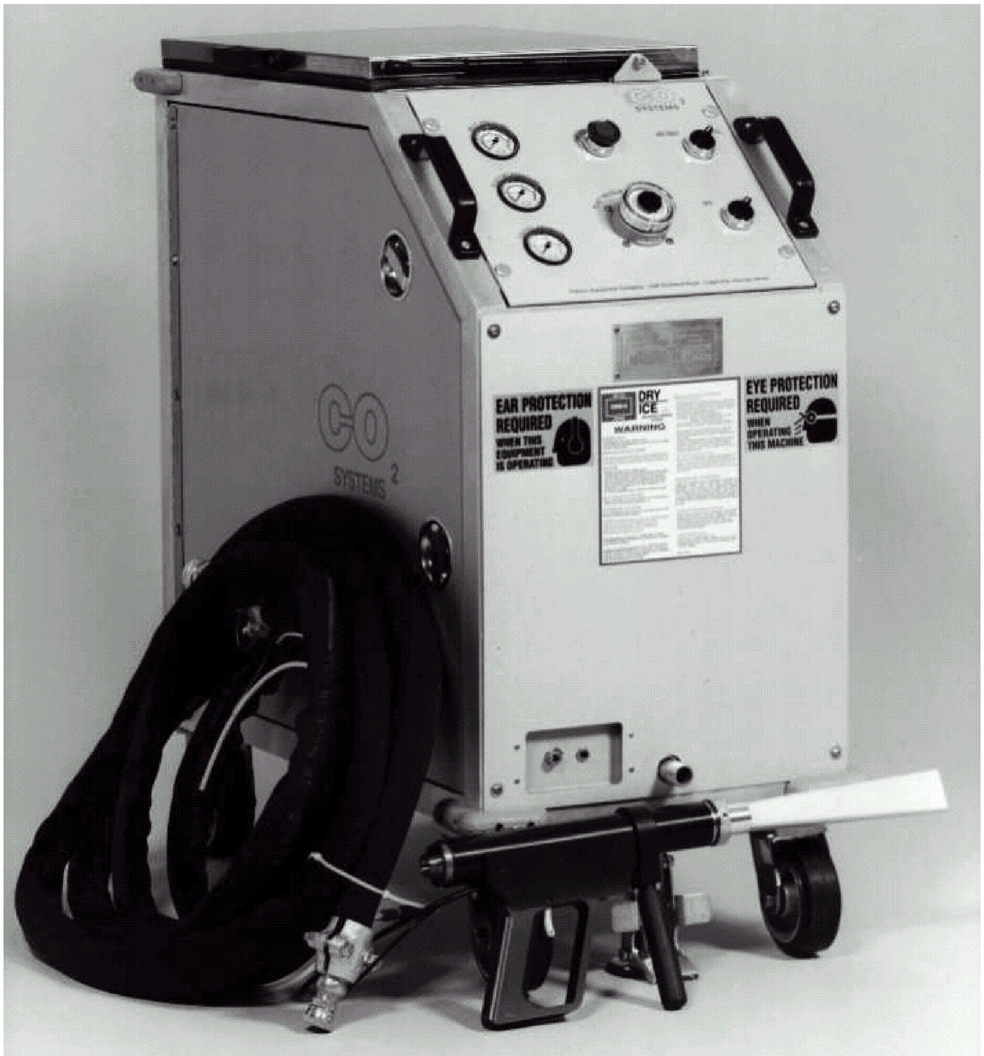

Figure 1-1
Portable CO_2 System

System Operation

The CO_2 cleaning process utilizes pellets of dry ice propelled by dry compressed air or nitrogen gas at the surface to be cleaned. The process works using three (3) factors at once, and is unique to CO_2 cleaning. The three (3) factors are Kinetic, Thermal and Molecular. This process is unique in that “Traditional abrasive blasting methods clean through a chiseling action, much like using an ice pick, but often take away part of the substrate as well.”[1] This chiseling action is depicted below in Figure 1-2. The diagram clearly shows the removal of substrate. This type of cleaning action and substrate removal is excellent if a profile is required but will cause possible damage to soft material such as those used for insulation.

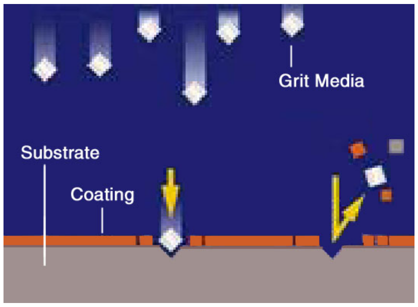

Figure 1-2
Grit Blasting

"Dry ice, on the other hand, might better be compared to a spatula as it lifts away the contaminant."[1] The spatula action is a much less intrusive/destructive action and is well suited for motor cleaning. The contaminants are removed with little or no substrate damage. Figure 1-3 below illustrates the CO_2 blasting process. Substrate material can be protected because some modern Ice Blasting machines can very the size of the ice pellets used in the process to be more or less aggressive. Additionally, the air pressure can be varied to aid in this effort.

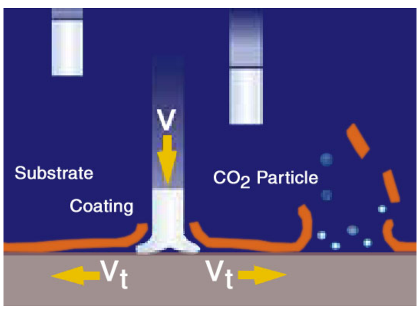

Figure 1-3
Dry Ice Blast Cleaning [1]

How can CO_2 blasting perform this task? As mentioned above, there are three (3) factors at work during the process. They are kinetic energy, thermal differentials and molecular expansion. These forces act together to remove contaminants with little damage and are explained below.

Kinetic Energy (Mechanical Abrasion)

As with conventional blast type technologies the velocity of the media impacting on the surface transfers kinetic energy to the surface being cleaned and abrades the surface of contaminants. This kinetic energy is responsible for most of the work done by other blast technologies. The primary difference between dry ice blast cleaning and traditional blasting technologies is that the dry ice cleaning process is non-abrasive and will not damage critical electronic and electrical equipment or plant structures. One of the best features of the CO_2 blast cleaning process is that the kinetic energy imparted on the surface can be easily controlled by adjusting the following parameters:

- Pressure of the propellant (Nitrogen or Air)
- Ice pellet flow rate
- Velocity of the ice pellets
- Size of the pellets

Thermal Differentials

As the motive force impacts the pellets of dry ice on the surface being cleaned, a slight temperature differential is established between the surface being cleaned and the contaminate. Each surface exhibits a specific rate at which it will accept the BTUs of the dry ice media. The thermal differential that is established between the surface being cleaned and the contaminate will initiate or assist in the removal process. In essence the thermal differential breaks the contaminants bond with the surface and aids the removal.

Molecular Expansion

The gaseous molecules of the motive force and carbon dioxide enter the pore spaces of the contaminate and pore spaces of the surface being cleaned. As the molecules expand they push the contaminate from underneath further assisting the removal process

Equipment

There are three (3) overall equipment types available today. The most economical units to purchase use ice pellets that are manufactured, delivered to the site and stored in iceboxes during the blasting process. The second type are larger units using block dry ice to make its own pellets. The third type of unit uses block dry ice to make its' own pellets of variable size. This unit provides the most control during cleaning. Most units allow pressure adjustments to change the aggressiveness of the blasting operation. This type of unit will allow pellet size variation coupled with pressure adjustment to control the cleaning rate.

CO_2 Blast Unit Type Summary

Pellets pre-made and delivered to the site

Pellets manufactured by the unit from block dry ice

  Single pellet size

  Variable ice pellets

Cleaning Equipment Portability and Flexibility

The new generation CO_2 machines are wheel mounted systems and are very portable with a foot print of 4 ft by 2 ½ ft. and one model has a 18 inch square, foot print. The overall size of this unit allows it to be easily moved from one area to the next area through standard doorways and personnel elevators. The older generation machines required a blasting pressure of

90 to 125 psi to clean motor and generator windings, whereas some new generation machines require lower blasting pressure of 50 to 100 psi for satisfactory cleaning. One model of the new generation CO_2 blasting machines has a 45-degree nozzle for getting into tighter places. Being that this equipment is so portable it allows motors, generators, switchgear, etc. to be Cleaned-In-Place (CIP), which eliminates days of downtime needed to remove and transport the equipment to a cleaning facility and then having to reinstall the equipment. Figures 1-4 and 1-5 illustrate the various blast guns and nozzles available today. There are pinpoint nozzles of varying diameters, fan nozzles of different widths as well as curved nozzles of different radii. All of these nozzle configurations aid in accessibility of cleaning all the nooks of a piece of equipment.

Figure 1-4
Blasting Guns and Nozzles [1]

Figure 1-5
Nozzles [4]

Today's modern CO_2 blast equipment can fit into any environment and budget. For example, the budget conscious can purchase a system that uses CO_2 dry ice pellets which are manufactured off site. The unit itself is inexpensive but the cost of the pellets is higher than the cost of block dry ice. The initial purchase price of a unit which produces pellets from blocks of dry ice is higher and it allows for greater control of the aggressiveness of the cleaning process by the operator. Figure 1-6 shows typical ice pellets used in CO_2 blasting.

Figure 1-6
Pellets [4]

On all blast units the pellet flow rates and propellant supply pressure are adjustable from the control panel of the blasting unit. Several manufacturers have systems that allow pellet size adjustment during the cleaning process. This is the **ultimate in control!** Variable pellet size along with air flow and pressure adjustment produce a type of unit that will allow aggressive size pellets to remove heavy contaminants as well as adjust down to small pellets for fine cleaning of insulation and other soft parts.

Because of the portability of the modern day CO_2 Blast units, the equipment can be taken to the location of the equipment. Unit's support 50 feet of hose between the unit and the nozzle, and the new generation larger unit will support up to 100' of blasting hose.

Energy Requirements

No power supplies other then 110V electricity is required for this process. Dry compressed air or gaseous nitrogen is used as the propellant and control power for the system. The compressed air requirements are met by a portable air compressor and air dryer, and if nitrogen is used the requirements are met with bulk liquid nitrogen containers which can be strategically located.
A one (1) inch hose conveys the dry compressed air or nitrogen gas to the blasting unit and can be as far as 300 to 400 feet away.

Manpower Requirements

One shift supervisor is required per shift to oversee operations and cleaning performance, perform process control adjustments, monitor gas flows, and dry ice pellet consumption.
Two (2) additional technicians may be provided per shift to support blast operations and ice delivery to the unit in use. No customer personnel are required to assist in the off loading and setup of equipment following on site arrival other then the use of a fork lift for 30 minutes at the beginning of the job and at the completion of the job.

Auxiliary Equipment

As with any type of blast cleaning technology, there is a requirement for support equipment. CO_2 blasting requires a similar setup as is used with other blast media. A tent may be required to contain the residue during the blasting process. To ensure that there is not a buildup of CO_2 gas a forced air ventilation system would be a must. In confined spaces and airline system may be a requirement. The blast media (blocks of Dry Ice and/or Pellets) itself has to be stored near the work area. Most vendors can supply the necessary coolers to accomplish this. The last piece of equipment required is a vacuum to remove the residual material that was dislodged during the blasting process.

A special consideration may involve high humidity applications. This atmospheric condition may lead to condensation on the motor windings. To reduce the condensation issue, some uses employ the use of a preheater on the venturi nozzle. This preheater is said to be effective in reducing condensation.

Inspection After Cleaning

The CO_2 blast cleaning process is such an efficient cleaning process, that burned brusholders, prior flashovers, burned insulators, poor solder joints, thrown solder etc. can be readily observed after cleaning.

In Summary

Prior to CO_2 cleaning, the major mediums available for motors included walnut shells, corncob, and baking soda. These media have the disadvantage of generating secondary waste and usually require the removal of the motor to another location. These factors add to the overall cost of the cleaning process, as well as downtime of the equipment. Additionally, these media reduce operator visibility during blasting operations.

The advantage of walnut shells, corncob and baking soda is that they are more aggressive and the actual blasting operations take less time than CO_2. CO_2 is slower because it is non-abrasive and will cause less substrate damage. With some CO_2 units, aggressiveness can be controlled by changing the size of the pellets produced by the unit. Additionally, because CO_2 produces no secondary waste, the work area is cleaner and more precise cleaning can be achieved.

The advantages of using the CO_2 dry ice blast cleaning process are:

- Saves equipment down time
- Non-abrasive
- Non-waste generating
- Non-toxic
- Non-conductive

- Inert
- Self contained
- Dry
- Portable
- Cost effective
- Energy efficient
- Environmentally friendly

As with any process there are limitations and CO_2 blasting is no exception. This method of blasting still requires line of sight for the operator to clean the area. Even with the recent advances in nozzle configurations, some areas of a motor can not be cleaned with CO_2 blasting. For those areas, hand cleaning seems to be the most effective method to finish the job. Another area of concern has been with driving of contaminants into areas of a motor. That issue can be avoided by the use of an experienced operator. The operator must be familiar with the equipment he or she is cleaning. This technology can be very aggressive and lead to insulation damage and coating removal if CO_2 pellet size is too large and/or air pressure is too high. Finally, the blast media or CO_2 pellets (dry ice) must be stored on location and they not only require storage space, but also have a shelf life.

A summary of the limitations of CO_2 Blast Cleaning are:

- Line of sight cleaning process
- High air volume requirements
- Some systems use Nitrogen as a propellant which may lead to oxygen deficiency
- Loud
- Source of dry ice blocks and/or pellets
- Experienced operator required

Examples and Testimonials

Figure 1-7 shows a Hydro motor being cleaned. As you can see in the photo the process is underway and there is no dust or other contaminants to impair the operator's view of the surface to be cleaned. The figure also depicts areas that have been cleaned and those that have not.

Figure 1-7
Hydro Motor [1]

Figure 1-8 shows a generator being cleaned as well as how clean the process is. In this figure, a definite difference can be seen.

Figure 1-8
Before and After

Some users responded to a survey and here are a few things they mentioned about their own experiences with CO_2 Blasting:

“Mostly used to clean the end windings without pulling the coils from the slots. Works for generator stator cleanup in some cases.”

“The cleaning was very good where the operator could get the nozzle of his spray equipment in, but due to the length and some lack of flexibility of the nozzle not all parts of the end-winding could be reached, these parts were minor and could be cleaned up reasonably well using other methods.

“This method is best suited for applications where moisture is undesirable, and compressed air is not effective enough.”

“Dry ice cleaning was utilized on a 500 mw generator rotor that experienced electric flashover. The flashover produced carbon based products which were carried around the machine with the gas flow and resulted in deposits on the rotor conductors. The reason for using dry ice was that all other methods had failed to improve the rotor insulation resistance.”

“Quick way to improve IR readings short of rewind. Does not require major disassembly; only retaining ring removal.”

“Penetrates further into cracks and appears to clean more thoroughly than traditional methods, proven by higher test results.”

“The field coils can be bead blasted during a field rewind but the stator core iron can not be cleaned with bead blasting. So the choices are CO_2 or hand cleaning of the core iron.”

“Easy cleanup, no liquids or hazardous chemicals. Faster and better results than hand cleaning on bus work. Does not require dry out of insulation as with steam cleaning. Bus work up to 6.9 kV may be cleaned while energized.”

“Although expensive, it is more cost effective in the long run and does not require the high levels of manpower/time that hand cleaning methods do. Typically a contaminated rotor can be cleaned within 2-3 days. A stator can be cleaned in the same time scale to a clean standard suitable to test (PI>3).”

Not all experiences with this technology are good. Below are a few of the downsides to using CO_2 blasting:

“May, in some cases, drive contamination into areas where you don’t want it. Doesn’t cut oil as well as solvents but then its much less intrusive and easier (less restrictive).”

“Pre-calibration is required to adjust the *CO_2 spray pressure*. If too high, it can actually remove the insulation, therefore, experience personnel with electrical machines is an absolute requirement.”

"May need to control the ambient in high humidity climate. Because the environmental humidity was very high and dry ice cleaning causes a considerable temperature drop of the object, everything became very wet."

"Burnt patches in insulation material or corrosion on metal are not cleaned away."

"Does not always remove baked on epoxies and resins."

"Mixed results when try to remove epoxies that have a good bond to the field coils or the core iron during rewinds."

"If not very careful when used on end windings of a stator it will remove insulation off of the stator bars very easily."

"It is difficult to get between coils and behind blocking, etc. On one of the machines the unit was very heavily caked and we actually removed the caked and oil soaked dirt with plastic putty knives, then the process worked fairly well. Cleaning of core vents seemed to also be a weakness."

"Does not do well with greasy contamination-tends to just push it around rather than remove it."

"Requires breathing air supply for operator if in enclosed area (e.g. motor stator)."

Users comments concerning the overall effectiveness of the process when tried at their facilities seemed to be positive in general and were similar to the comments below:

"We have been, in general, very satisfied with this process and found it to be very effctive with the exception of greasy contamination."

"A) The post job clean-up required was minimal; B) The IR readings following the job were satisfactory but not as good as we get using corncob blasting."

Precautions raised by the user's survey centered around the use of an experience operator and low humidity conditions during the process. Many were similar to these:

"The person running the equipment has to have some knowledge of the equipment he is doing the CO_2 blasting on. There was one case where the lead technician doing the blasting decided to take a break and one of his co-workers took over and was a little too aggressive and took off some insulation on the stator end windings."

"Most important is a low relative humidity to prevent condensation of water on the object, which is being cleaned."

"Formation of moisture on the parts may be problem. The technique must be used by trained personnel, because it is very risky for the integrity of the insulation of windings."

Most users believed that setup was fairly simple except for the ventilation and tents required. Experience was the theme and their views are shown below:

"Easy when using an experienced crew. Clean up also easy, again by an experienced crew."

"Setup is more involved than with steam, solvent, or compressed air cleaning. It is similar to corncob blast cleaning. Clean up is easier than steam, solvent or corncob blast cleaning."

"The equipment is very noisy and the area around the job needs to be cordoned off and clear of both other personnel and equipment that might become cross contaminated."

Additional Information

Because the use of CO_2 blasting to clean motors is a new application for most vendors, a large variety of photographs are not available. We have included additional references, which can be used for more information on this topic. Additionally, the Alpheus Corporation has a video tape that reviews the process of CO_2 blasting and can be obtained by contacting them directly.

References

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2. Master-Lee Industrial, 350 Miller Road, Medford, NJ 08055, (609) 953-3200
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4. Tomco$_2$ Equipment Company, 3340 Rosebud Road, Loganville, GA 30052, www.carbondioxideequipment.com , (800) 979-9791
5. Applied Surface Technologies, 15 Hawthorne Drive, New Providence, NJ 07974, www.co2clean.com, (908) 464-6675
6. Millenium Automation, 47339 Warm Springs Blvd., Fremont, CA 94539-7462, www.millenniumautomation.com , (510) 683-5942

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Steam Turbines, Generators, and Balance-of-Plant

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