The Magic of Dry Ice in Thermoset Mold Cleaning & Part Deflashing

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Global Business Unit Director – Plastics, Rubber & Composites
Now You See it

Now You Don’t
OBJECTIVES

• How Things Used To Be Done and The Top 5 Reasons To Use Dry Ice In Thermoset Mold Cleaning & Deflashing

• Intro To Dry Ice and Commonly Used Types In Thermoset Molding & Deflashing

• The Theory & Process

• The Magic of Dry Ice in Thermoset Mold Cleaning & Deflashing

• Common Solutions & Video’s

• Questions & Answers
Let’s take a step back in time 50 years…
Mold Cleaning — Past 50 Years

Legacy Based Cleaning vs. Meaningful Cleaning Innovations

Dirt stays in the rag

1960 - 1975

1976 - 1990

1991 - 2000

Today
5 Reasons To Use Dry Ice In Thermoset Molding & Deflashing
5 Reasons To Use Dry Ice In Plastics & Rubber

1. **Improve Quality**
   - **Make Better Parts**: Improve part quality, reduce rejects – now you see rejects due to dirty mold cavities & vents, now you don’t

2. **Increase Productivity**
   - **Make More Parts**: Increase uptime, in-situ, at operating temps, extended runs – now see excessive downtimes, now you don’t

3. **Extend Asset Life**
   - **Molds Last Longer**: Non-abrasive cleaning method – now you may see damage when cleaning, now you don’t

4. **Reduce Costs**
   - **Save Money**: Reduced manpower, faster cleans, less expensive media – now you see the high cost of cleaning, now you don’t

5. **Environmental Quality**
   - **Better Environment**: Zero Waste – elimination of solvents, worker safety – now you see cleaning materials going to landfill, now you don’t
The Process is **CLEAN**: Make Better Parts

- Better Clean: Penetrates small, complex geometries - low surface tension

- Food grade CO2 (FDA, EPA, USDA, AIB & GFSI). The same gas commonly added to water for carbonation

- No solvent residue – no secondary cleaning with alcohol

- Easy to keep cavities and vents clean

- Result: Higher quality parts

- Why? Mold Cleaning is now proactive, not reactive or “fire-fighting”

Eliminate molding problems caused by dirty cavities and vents
Make Better Parts - Increase Yield
Eliminate Problems Associated with Dirty Cavities & Vents

Sources: 1) Sun Micro-Systems Cosmetic & Structural Defects Manual, 2) FIMMTECH Standardizing Validations, Common Defects in Injection Molding
“Dry ice blasting definitely results in a superior clean, and with less downtime, we have been able to increase production. Our automotive customers have very stringent quality control procedures and demands, and dry ice blasting has helped us meet those requirements. The detail of cleaning we get with Cold Jet’s system allows us to clean areas that otherwise could not be cleaned.”

- Mike Wohlfarth, Miniature Precision Components

“The i3 MicroClean systems are more efficient with relation to the quality of the clean, and the speed has improved our business.” – Mr. Koncsek, Electrolux
Make More Parts

• The Process is **LEAN:**

  Cleans 4-6 times faster, in place, at operating temperature

  – Cleaning is now pro-active, managed, not reactive
  – Downtime measured in hours is now measured in minutes
  – Result: More good parts as uptime is increased
Increase Productivity
Eliminate Traditional Cleaning Multi-Step Processes

Total Potential Downtime

**Pre-Clean**
- Stop Production
- Cool
- Disassemble
- Transport
- Mask/Shield

**Cleaning**
- How clean?
  - Scrap rate
- How fast?
  - Hours labor
- Cost?
  - Equipment
  - Consumable

**Post-Clean**
- Waste Collection
- Disposal
- Unmask/Deshield
- Inspect
- Transport
- Assemble
- Reheat
- Test
“The greatest value of the Cold Jet system to our operations has been the ability to extend our running times,” said Bailey. “We no longer have to pull the molds in order to clean them and this has greatly enhanced our productivity.”

Mr. Schotte, Tyco

Our focus on lean manufacturing and the Cold Jet machine’s capability of improving total production process was one of the main reasons that dry ice cleaning captured our attention,” said Mr. Schotte. “In addition to cleaning our molds faster and more frequently, we no longer need a team of people to help us disassemble, clean and reassemble molding equipment.

Brian Bailey, Facilities Manager, Vernay Rubber

Preform mold cleaning can be a time-consuming process, particularly for high-cavitation molds. By using cold Jet’s system, our customers will find a fast and easy cleaning solution that will help them significantly reduce system downtime and improve productivity” - Mike Urquhart, VP of PET Husky

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Molds are expensive, complex, and the heart beat of molding. Traditional “cleaning techniques” can contribute to mold wear, reducing the life of the tool.
No Wear Mechanically
Kettering University Studies – No Wear

“The picture below shows a picture of the blasted and un-blasted are of the die steel after blasting (stationary) for 60 seconds, 90 degree, at a distance of 25mm.”

“The sample had no noticeable damage after blasting with shape block ice”
Using Dry Ice in the Press

How CO2 Blasting Works

- Cold Jet is a company that produces this kind of equipment, www.coldjet.com. You buy dry ice pellets or shavings that come in plastic containers roughly 3' x 3' x 4' in size (one supplier of dry ice is Air Gas Inc.). The pellets are scooped out of the container and poured into the dry ice blaster. The dry ice comes out as a spray and the pressure is set at 150 PSI. There is no wear or damage to the tooling and all the spray turns to a gas.

- Cold Jet dry ice blasting can clean entire blow and injection mold cavities completely and effectively. Many leading blow molding bottle manufacturers have discovered that dry ice blasting systems cut their daily mold cleaning time by about 80% simply by cleaning molds hot and in place. Today, even the back 1/3 of the blow-mold surface and the entire deep-cavity injection molds used to make test-tube shaped slugs are cleaned by dry ice blasting whereas it used to have to be cleaned by hand.

- Cold Jet dry ice blasting uses compressed air to accelerate frozen carbon dioxide (CO2) “dry ice” pellets to a high velocity. A compressed air supply of 80 PSI/50 scfm can be used in this process. (see picture above)

- CO2 blasting works because of three primary factors: pellet kinetic energy, thermal shock effect and thermal-kinetic effect.

- Once a week – about 30 minutes with 72 cavity.

- Once every 4 weeks – dry ice, wipe down with cloth, then dry ice.
“Cleaning with Cold Jet will not roll parting lines, change or destroy the metal. And best of all, it allows our running time to be extended. We use it every day, on every shift. I would say that using the Cold Jet cleaning process extends the running time of our molds by 200-500 percent. I would tell others to try this out...the benefits are well worth it.” – Tom Mendel, Performance Plastics

“The process is quick, does not dull the tools and the portability of Cold Jet’s i3MicroClean is a huge advantage as we can wheel it up to any machine in the plant and take it to the molds for online cleaning. It has drastically improved our productivity and helped us cut costs. Simply put, dry ice blasting is the best cleaning solution for our needs.” – Mike Wohlfarth, MPC
National Geographic “Challenge of the Unbeatables”
Case Study: Performance Plastics

- The Situation: High Performance Molding (PTFE, PEEK, FEP (Hot Molds))
- Location: Cincinnati, OH
- Problem: Off-gassing on injection molds
- Previous Solution: Manual mold cleaning
No Wear Thermally
A study conducted by James Snide, *C02 Pellet Cleaning – A preliminary Evaluation*, Materials & Process Associates, Inc. (Oct. 12, 1992), to measure any thermal stress during dry ice cleaning. This study showed that the temperature decrease occurs on the surface only, so that there is no chance of thermal stress occurring to the substrate metal.

To illustrate this principle, an experiment was performed where thermocouples were imbedded into a steel substrate at varying depths (flush with the surface to 2mm deep),
A dry ice particle stream was constantly swept across the test specimen for 30 seconds (a relatively long time for this process) and the thermocouple recorded the changing temperatures at the various depths. As shown in graph below, the surface-mounted thermocouple recorded a temperature drop each time the particle stream passed directly upon it (50 degree C in about 5 seconds). In contrast, the thermocouples imbedded at various depths in the substrate recorded a slow gradual drop in temperature corresponding to the overall test plate temperature drop. The **thermocouple 2mm deep only dropped 10 degree C after 30 seconds**. This curve illustrates that the Thermal Effect occurs only at the surface where the contaminate is bonded to the mold substrate and has no detrimental effect on the mold.
James Snide also conducted another study on the thermal effect of dry ice cleaning in the rubber industry, a thermoset application, where the molds are hot. In this study the molders were operating at 149 + degree C (300+ degree F) and were cleaned with – 78.3 degree C dry ice particles. He noted, “The temperature differences between the hot mold and cold dry ice will not cause cracking.”
He notes, there are two reasons for this phenomenon. First, as seen in previous chart, the temperature gradient occurs at the surface. Second, the thermal stresses involved are much less than those encountered during normal heat treat.

He went on to note in his study, the thermal stress due to a temperature differential can be estimated using the following equation where “sy” is stress (psi), “DT” is temperature gradient (degree F), “a” is coefficient of expansion and “g” is Poisson’s Ratio.

The corresponding parameter values are:

\[
\sigma_y = \frac{(\Delta T \times E \times a)}{(1 - \gamma)}
\]

\[
\sigma_y = \frac{(30 \times 10^6) \times (5 \times 10^{-6}) \times \Delta T}{(1 - 0.33)}
\]
Where the temperature differential will be 135 degrees F / 57.2 degree C (Based on first graph_. He noted, “This temperature gradient leads to a low tensile stress of 30,240 psi / 2085 bar. Even if the mold temperature was brought down to the temperature of the ice (an unrealistic extreme), the temperature gradient would be -109F – 350F which gives 459 F / 2237.2 C, for which the corresponding tensile stress is 102,800 psi / 7088 bar. This calculated stress is below the yield point of steel in the hardened condition. Again, these thermal stresses would be far less than those encountered during normal heat treatment, where the temperature differentials would exceed 500 degree F / 260 degree C.”
He concluded, “even at high impact velocities and direct ‘head-on’ impact angles, the kinetic effect of solid C02 particles is minimal when compared to other media (grit, sand, PMB, etc.). This is due to the relative lack of hardness of the dry ice particles and the almost instantaneous phase change to a gas on impact, which effectively provides an almost nonexistent coefficient of restitution in the impact equation. Because dry ice blasting is considered non-abrasive and relies on the thermal effect discussed above, the process may be applied to a wide range of materials without damage. Soft metals such as brass, beryllium, and aluminum cladding can be dry ice cleaned for the removal of coatings or contaminates without creating surface stresses (pinging, pitting or roughness).”
Customer Study – No Thermal Shock

Micrographic examination of metallurgical structures of Martensitic Stainless Steel 440C

Unaltered Carbon Particles @ Core & Surface

After tests customer implemented i3 in 17 plants
No Wear Chemically
The Chemistry of CO$_2$

- Non-Polar
- Stable Molecule
- Not a Bent Molecule (unlike water, that will react with the mold)
- No Reactivity
- No Charge
- Inert
- Non Toxic
- Doesn’t react with anything – no chemical change in the mold
### Eliminate Extended Downtime – The Cost of Downtime

#### The Yearly Cost of Wasting 15 Minutes per Day/Machine

<table>
<thead>
<tr>
<th>Machine Hourly Rate ($/Hour)</th>
<th>Number of Machines</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5</td>
</tr>
<tr>
<td><strong>Dollars ($) Lost per Year</strong></td>
<td></td>
</tr>
<tr>
<td>$20</td>
<td>$6,375</td>
</tr>
<tr>
<td>$30</td>
<td>$9,563</td>
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<tr>
<td>$40</td>
<td>$12,750</td>
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<tr>
<td><strong>$50</strong></td>
<td><strong>$15,938</strong></td>
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<tr>
<td>$70</td>
<td>$22,313</td>
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<tr>
<td>$90</td>
<td>$28,688</td>
</tr>
<tr>
<td>$110</td>
<td>$35,063</td>
</tr>
</tbody>
</table>

Note: Data based on an 8-hour day, 255 working days/year.

- 60-70% of mold maintenance is mold cleaning – Tooling Docs
- Unscheduled mold stops cost 5X scheduled stops and is the single most prevalent and costly reason for not achieving efficiency goals – TD (labor costs remain a dominate cost)
“The process is quick, does not dull the tools and the portability of Cold Jet’s i3MicroClean is a huge advantage as we can wheel it up to any machine in the plant and take it to the molds for online cleaning. **It has drastically improved our productivity and helped us cut costs.** Simply put, dry ice blasting is the best cleaning solution for our needs.” – Mike Wohlfarth, Miniature Precision Components (MPC)

“The i3 MicroClean **reduced our cleaning time up to 95%** and paid for Itself within a very short time.” – Dieter Stais, Marquardt
The Process is GREEN & SUSTAINABLE:

- No secondary waste - sublimates
- Eliminate chemicals. No Volatile Organic Compounds (VOC)
- Improves worker safety
- No hazardous waste disposal
- Users of recycled CO2 are not considered generators of CO2, contributors to greenhouse effect by USEPA
Improve Environmental Quality

Spraying Baseline Hexane Aerosol on Mold
Dry Ice Cleaning on Mold
### Annualized Cost Comparison of All Cleaning Options

<table>
<thead>
<tr>
<th>Option</th>
<th>Annualized Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hexane Aerosol Cleaning</strong></td>
<td>$56,174</td>
</tr>
<tr>
<td>Acetone/Glycol Ether Cleaning (five gallon pails)</td>
<td>$22,914</td>
</tr>
<tr>
<td>Acetone/Glycol Ether Cleaning (drums)</td>
<td>$11,454</td>
</tr>
<tr>
<td>Acetone/PCBTF Cleaning (five gallon pails)</td>
<td>$34,681</td>
</tr>
<tr>
<td>Acetone/PCBTF Cleaning (drums)</td>
<td>$26,020</td>
</tr>
<tr>
<td>Dry Ice Blasting (no system purchase, same labor)</td>
<td>$3,546</td>
</tr>
<tr>
<td>Dry Ice Blasting (no system purchase, double labor hours)</td>
<td>$7,113</td>
</tr>
<tr>
<td><strong>Dry Ice Blasting (system purchase, same labor)</strong></td>
<td><strong>$6,198</strong></td>
</tr>
<tr>
<td>Dry Ice Blasting (system purchase, double labor hours)</td>
<td>$10,680</td>
</tr>
</tbody>
</table>

Source: “Alternative Low-VOC Release Agents and Mold Cleaners for Industrial Molding”
Prepared for: South Coast Air Quality Management District EPA Region IX
Prepared by: Katy Wolf, Institute for Research and Technical Assistance, October 2013
“**The biggest advantage to using dry ice blast cleaning is safety.** We have to clean a number of molds, which are all very hot while online. With dry ice blasting we have been able to clean the molds much faster than using chemicals, which has reduced downtime, and *increased productivity and employee safety.*”

Mike Wohlfarth, MPC

“The Cold Jet i3 MicroClean systems reduce scrap, maintenance and time costs, improve productivity, **align with our environmental initiatives and reduce overall risk.**” said Mr. Koncsek of Electrolux.

“We have increased the process security for this product group by 25 % using dry ice cleaning,” said Preller. “At the same time, **the safety of the workers has been increased and the process is environmentally friendly, because the use of solvents has been reduced.**”

A. Raymond
Intro to Dry Ice

Commonly Used Types In Thermoset Molding & Deflashing
What is Dry Ice?

• Generic name for solid or “frozen” phase of CO₂
• CO₂ is what we exhale during breathing and the gas that plants use in photosynthesis
• CO₂ is a by-Product - industrial processes
• Dry Ice is made from reclaimed CO₂
• CO₂ is scrubbed, liquefied, transported

25,000 tons/day, 95% from a by-product

Stored around 300 psi as a liquid
History of Solid Phase Carbon Dioxide (C0₂)

Early 1930’s

1945

U.S. Navy – degreasing & electrical switchgear

Reginald Lindall – patent “method of removing meat from bone”

Early 1980’s - Today

Manufacturing was possible

1963

Cold Jet

the force of nature
Pelletized Dry Ice – Compressed C02 Snow

1, 3, 6, 9, 12, 16, 19 mm
Block/Slice Dry Ice
**Intro To Dry Ice - Benefits Of Particle Size**

**3mm Pellets**
- More Mass = more Aggression
- Usually Better thick, brittle contaminates

**MicroParticles (0.3mm)**
- Less Mass = Less Aggression
- Usually Better for thin, hard contaminates
Intro To Dry Ice - Benefits Of Particle Size

3.0 mm Pellets  0.3mm MicroParticles

- **Greater Flux Density**: 1,00X more Surface Strikes = more uniform clean
- **Quieter**: Less air required to fully accelerate
- **Safer**: Less kinetic energy on delicate substrates
- **Economical**: Less dry ice & less air
Fragmentation

3.0 mm

0.6 mm

3.0 mm – 1.5 mm
Pick your machine

Typical PPE:
- Hearing Protection
- Gloves to Handle Dry Ice
- Safety Glasses
- Plant Ventilation
Dry Ice Cleaning Machines — Past 25 Years

1985-1990
- $250,000

1991-1995
- $45,000 - $60,000
- 70psi/150scfm

1996-2005
- $45,000 - $60,000
- 300psi/350scfm

Today
- $15,000 - $35,000
- 60psi/12scfm

Meaningful Innovation
Theory and Process
I = Impact

Kinetic Energy Effect

- Dry Ice Particles have little hardness (Non-Abrasive)
- Velocities of 600-1,000’/second
- $KE = \frac{1}{2} M \times V^2$
Dry Ice is a Soft Media

Mohs Hardness Scale for Minerals

1 – Talc (Dry Ice ≈ 1.5 - 2.0)
2 – Gypsum, Fingernail ≈ 2.5), Gold 2.5-3.0
3 – Calcite (a copper penny) Plastic Media (Polyester, Acrylic ≈ 3.0-3.5)
4 – Fluorite Plastics Media (Melamine ≈ 4.0) (Rockwell A-Scale: 66)
5 – Apatite (Glass, Glass Beads & Nut Shells ≈ 5.5), Tooth Enamel, Knife Blade 5.5
6 – Orthoclase (Feldspar, Spectrolite) Steel file ≈ 7.0, Black Diamond 6.0, HRA84
7 – Quartz (Amethyst, Citrine, Agate) Sand ≈ 7.0
8 – Topaz (Beryl, Emerald, Aquamarine) Garnet ≈ 7.5
9 – Corundum (Ruby, Sapphire) Alum. Oxide ≈ 8.5, Tungsten Carbide
10 – Diamond

Dry ice is frangible, no Rockwell Hardness number

Source for media relative scale Randell Heath, ColdSweep, Inc.
Kinetic Energy Effect

- Dry Ice Particles have mass, but little hardness, has no sharp edges (Non-Abrasive)
- Dry Ice is frangible – an impulse impact for a very short time
- Velocities of 600-1,000’/second
- \[ K.E = \frac{1}{2} m v^2 \]
C = Cold

Thermal Effect – unique characteristic

- CO2 is -109.3 degrees F (-79.5 C)
- Delta-T causes contaminates to embrittle
E = Expansion

Gas Expansion Effect – Unique characteristic

- Volume (Vt) expands 800 times
- Micro explosions
- Sublimates (phases back to gas) on impact without going through liquid phase – thus its name “dry ice”.
Theory – The Cleaning Process
Theory – The Cleaning Process
Dry Ice Solutions In Thermoset Molding & Deflashing
i3 In-Machine Mold Cleaning
In-Machine Mold Cleaning

Lighted, small applicator for tight daylight spaces
In-Machine Mold Cleaning

Before

Now You See It

After

Now You Don’t
Mold Cleaning Video
In-Machine Mold Cleaning - Automotive
In-Machine Mold Cleaning Video
Automotive Steering Wheel
In-Machine Mold Cleaning - Rubber

Off-gassing soiling mold cavity

Before

After

Previously lost 6-8 hours with multi-step with traditional cleaning methods – now 30 minutes
Class A 1 Mold Cleaning
Medical In-Machine Mold Cleaning

Class 100,000 clean rooms (ISO 8)

Qmed QUALIFIED Supplier

ISO 14644
Gone In A Flash: Deflashing Solutions

BMC

Phenolics
Deflashing

Kinetic Energy Effect over Tg of material (Thermal Effect)

Dry Ice has mass, but no real hardness or sharp edges – frangible,
An impulse impact for a very short time

Type of plastic, additives & thickness matters
Deburring & Deflashing Video
Automated Parting Line – Deflashing Cell
Automated Deflashing Cell
Automated Deflashing Cell Solution
Automated Surface Preparation Prior to Painting

Reduced Operating Costs ~ 50%, saving $1M / Year

Thermoplastics, thermosets, composites
Automation / Integrated with Dry Ice Production
Surface Preparation Solutions
Surface Prep of Bumper
Do You Believe in Magic?

We clean just about anything!
Conclusions

Prepare to Believe in Magic

- **Proven technology in the thermoset molding and deflashing applications with reasons to celebrate:**
  - **Increase Yield** by Improving Part Quality
  - **Increase Productivity** by Increasing Uptime/Extending Runs
  - **Extend the Asset Life** of Your Molds by Getting The Wear Out
  - **Reduce Costs** by Cleaning Faster & Eliminating Chemicals
  - **Improve Environmental Quality** & Worker Safety

The most effective way to clean your molds while still in the press
Take Progress for a Test Ride!

Equipment Vans

On-Site Performance Evaluation Programs

In-House Test Cell
Questions & Answers

Visit us at: www.coldjet.com/plastics

swilson@coldjet.com