Technical Assessment of Dry Ice Blasting as surface preparation method for cleaning of steel surfaces and removal of coatings

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Technical Assessment of Dry Ice Blasting as surface preparation method for cleaning of steel surfaces and removal of coatings

by

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Executive summary

Within Shell assets, there is a tendency to source alternative methods for surface preparation in order to save costs and increase productivity. The common used surface preparation method is abrasive grit blasting which uses compressed air or water to direct a high velocity stream of an abrasive material to clean an object or surface and to prepare it for the application of a coating.

As part of their Fabric Maintenance campaign, Shell Corrib has been looking into other means of surface preparation that could help reducing the optional safety hazard while increasing productivity. They have sourced a new method called Dry Ice Blasting.

As part of the Technology Replication Trust (TRT) third party technology program, the Dry Ice Blasting method was identified as a technology with great potential. To provide global technical approval of this technology, Shell PTE was invited to witness the Dry Ice Blasting process at the Corrib site and evaluate this technology.

Based on the documentation and test trials, Dry Ice Blasting is technically approved as surface preparation method to remove coating layers and corrosion scales to be used for Shell projects and assets.

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1. Introduction & Objectives

Within Shell assets, there is a tendency to source alternative methods for surface preparation in order to save costs and increase productivity. The common used surface preparation method is abrasive grit blasting which uses compressed air or water to direct a high velocity stream of an abrasive material to clean an object or surface and to prepare it for the application of a coating. This technique produces a lot of waste due to the abrasive grit material and coating material removal from the steel surface. It can produce hazardous dust levels and toxic metals that may be generated from both the blasting material and the underlying substrate and coatings being blasted. This raises safety concerns and the employers need to ensure that the workers are properly equipped with personal protection equipment.

As part of their Fabric Maintenance campaign, Shell Corrib has been looking into other means of surface preparation that could reduce the optional safety hazard while increasing productivity. They have sourced a new method called Dry Ice Blasting.

In July 2016, Shell Corrib has invited the company “DRY-ICE Scotland” to the Corrib site to perform live trials & on-site training on a defined scope of work.

It is the intention of the Technology Replication Thrust to extend the use of alternative surface preparation methods to other Shell assets globally as there is a considerable interest within Shell.

This report describes the technical assessment of the Dry Ice Blasting method based on manufacturer information, results of field trials, live demonstration and testing and inspection of blasted surfaces.

2. Scope of the TRT program

As part of the Technology Replication Trust (TRT) 3rd party technology program, the Dry Ice Blasting method was identified as a technology with great potential. To provide global technical approval of this technology, Shell PTE was invited to witness the Dry Ice Blasting process at the Corrib site and evaluate this technology based on the following requirements:

1. HSSE review
2. Review and assess the surface preparation performance
3. Review and assess the coating performance when applied on the prepared steel surfaces
4. Review and assess risks for low temperature brittle fracture during the surface preparation
5. Compare this technology with other surface preparation methods

The first trial started in July 2016 at the Shell Corrib asset in Ireland. The global roll out plan has identified target assets like Shell UK onshore and offshore, Nigeria and Gulf of Mexico. The deployment process of this technology to Fabric Maintenance work will start in Q4 2016 and continue in 2017.

2.1. The Dry Ice Blasting technology

Dry Ice Blasting is a form of controlled precision cleaning used in many different industries.

Dry Ice Blasting removes scales/contaminants in three ways:

1. Supersonic speed of dry ice pellets being propelled by compressed air
2. Thermal effect of the dry ice hitting the scale/contaminate/coating to lose adhesion
3. Expansion of dry ice sublimating to gaseous state expanding 800 times its original area space to lift the scale/contaminate/coating from substrate

Instead of using standard hard abrasive blasting media such as iron silicate, garnet or aluminium oxide, dry ice (CO_2 pellets) is comparatively a much softer media. When the CO_2 pellet hit the surface, it instantly changes its phase from a solid to a gas. When changing to gas, it absorbs a large amount of heat energy from the surface. The sharp temperature change causes high shear stresses on the micro layers of the coating. This causes rapid cracking on the microscopic level, causing the bond to fail and the coating to start peeling off rapidly. In addition, when the dry ice hits the surface, it tends to cause a micro explosion when changing from solid to gas. This micro explosion causes additional lift of the surface needing to be removed.

Using frozen Carbon Dioxide in 3mm pellet form as the blasting medium, this technique leaves no residue as the blasting medium returns to gaseous state upon impact. This allows the cleaning to take place with minimal disruption to machinery or processes around the cleaning area. Dry Ice Blasting is a controlled method of cleaning; by selecting the correct nozzles, rates of pellet usage and pressures, it can be used to gently clean surfaces such as soft plastics, or adjusted to remove hard rust and paint from metal surfaces. Dry Ice Blasting works with pressurized air, a minimum of 80psi/50cfm can be used for the process. At Shell assets, Dry Ice Blasting can be used for Surface Preparation for Fabric Maintenance purposes. This technology allows blasting off existing coatings and removing rust layers for FM surface preparation.

Dry Ice Blasting cannot create a surface profile and uses the original surface profile left from previous abrasive blasting operations. This method is similar to hydro blasting as this also uses the original surface profile, however with Dry Ice Blasting the substrate is left dry, and the process is more controllable and does not use dangerous high water pressures (28,000 psi). Typical water blasting operations use from 250 – 3500 liters potable water per hour.

Standard Dry Ice Blasting was historically a method used for cleaning surfaces. It did not have the capability to remove heavy corrosion scale and heavy coatings and as such the technology was not producing acceptable results for surface preparation for maintenance painting applications. The new method created by Dry Ice Scotland uses a large number of small revolutions across the blasting media, blasting machine and delivery system to achieve much stronger results.

The blasting media is created using CO_2 that is manufactured and stored so as to be optimum for the media production process. The media is then manufactured using a patented process and delivered through a proprietary blasting mechanism. Both systems have been designed by Dry Ice Scotland, and the combined effect delivers a result that is significantly more powerful that what has previously been possible for traditional Dry Ice Blasting.

2.2. The Dry Ice blasting contractor - Dry Ice Scotland

Dry Ice Scotland is the operating company for this Dry Ice Blasting technology. They have developed a dedicated surface preparation process to remove paint layers and corrosion scaling by using specially designed and modified dry ice in conjunction with a proprietary blasting system. They provide rental of media production and blasting systems and technical support. They have been selected as the main partner for the Dry Ice Blasting field trail at Shell Corrib.

The company has a number of track records available on their website:

- Valero – Pembroke Refinery
- PX – St Fergus Gas Terminal
- Nexen – Buzzard Platform
- EnQuest – Northern Producer

Other customers include Vallourec, GSK, Lafarge Tarmac, Wyman Gordon, and WL Gore.

2.2.1. Technical support

Dry Ice Scotland offers a mobile technical support function that includes offshore-trained technicians and a global network of offices. The company has a global network of CO_2 supply through their working relationship with Air Liquide, the world's largest CO_2 supply company. All equipment is manufactured in the UK and/or US and distributed through Air Liquide's distribution and logistics network. Dry-Ice Scotland delivers CO_2 and equipment to destination and guarantee to work closely with the asset to ensure that the delivery of CO_2 is correctly planned and causes no disruption to ongoing works. Dry Ice Scotland has a readily available fleet of machinery and the lead-time for new equipment to be delivered to assets is 3-4 weeks.

Dry-Ice Global has the ability to carry out training at any specified location. Common practice is to carry out a yard demonstration and training with the persons involved in the activities. Yard training takes approximatively 1 to 3 days depending on the size of group.

The training consists of:

- CO_2 safety awareness
- Dry-Ice set up familiarisation
- Pelletiser set up and usage
- Blast set up familiarisation
- Blast pot usage
- Blast techniques and handling skills
- Safety awareness for adjacent work parties
- Final Dry-Ice assessment

For overseas projects or case specific work scopes, Dry-Ice Global can send a technician to a site (onshore and offshore) to train and help during the initial 1 to 2 week period. Upon completion of training, each member of the workforce who has been certified will be added to the Dry-Ice Global training certification database.

2.2.2. CO_2 Supply Arrangements

The refill process is handled through Dry-Ice's partnership with Air Liquide, who owns the world's largest CO_2 distribution fleet. They are able to distribute the necessary tanks and liquid CO_2 supply by land and sea to any location at short notice. Refilling can take place without a break in blasting operations. For onshore locations, Dry Ice Scotland refills the tanks off or on-site (depending on site preferences) within 3 hours. For offshore locations, there is a schedule that allows for replacement tanks to be sent in line with requirements.

2.3. Equipment

The following equipment is needed to execute surface cleaning with Dry Ice Blasting:

- Liquid CO_2 tank & supply arrangements

A mobile tank of liquid CO_2 is needed on site for the bulk supply. Dry Ice Scotland refills and disposes as appropriate as part of the contract. The refill process is carried out by a truck; this can be carried out off site if preferable and takes a couple of hours. The tank is delivered and collected by a truck. The options are to lift the tank using a crane (36t when full) or leave it on the trailer.

According to Dry Ice Scotland, a large tank holds enough CO_2 to last 15-20 days for two blasters continuously blasting.

- Dry Ice Production

The technical name of the production machine is the HI-CO_2 Media Production System. The process consists of specialist liquid CO_2 coming from the tank that is fed into the containerised production system. The liquid CO_2 is extracted into the production machine. It is released through a specialised nozzle into a chamber where it turns into "snow". This snow is then compacted to form specialist dry ice and pushed through a 3 mm die to form the pellets.

The proprietary nature of the process, from the CO_2 to storage to media production and blasting delivery is critical to achieve the final surface cleaning process to remove old paint layers and corrosion scales.

- The blast plot

This blasting machine is fully pneumatic and small enough to fit into a manhole. The machine is fed by an air compressor and operates in the 8-15 bar range.

- The blasting tools

The length of the blasting hose can be up to 30 meters for horizontal access, but for vertical operation it is recommended to use maximum 15 meters. The hose is encased in nylon casing to avoid cross-contamination between sites. Blasting is controlled by the operator with an on/off dead-man's switch, a trigger and a control allowing the operator to switch between dry ice and fresh air to dry. There is also an Emergency Stop at the blasting machine.

2.4. Safety

2.4.1. Personal safety

Using the Dry-Ice is considered safer than conventional blasting due to the following:

- Low risk of injury to the operator due to lower pressures used (less than 8 bar)
- Ergonomic design of equipment
- Non-abrasive nature of media (will not cut through safety boots)
- Blast media will not travel beyond the berried work area
- Will not cut through ropes (if rope access equipment used)
- No HAVS or other vibration issues
- Low level of “kick-back” to operator
- No dust produced by media, mask shall be worn to protect operator from removed contaminants only
- Less PPE needed – easier to use and reduces the effect of fatigue/overheating
- Correct PPE (gloves) protects operator from only additional media hazard, skin burns due to cold temperature

2.4.2. Environmental Safety

- Waste disposal reduced by over 99% compared to grit blasting (cf Dry Ice Scotland)
- Residual waste consist only of removed contaminant, no water, sand or grit
- Carbon footprint reduced due to:
  - CO_2 used is recycled
  - Reduced media transportation (to and from)
  - No media dust contamination to surrounding area

2.4.3. Process Safety

- Non-abrasive media – does not damage metal substrates
- Can be used to clean valve faces, seals and even plastic areas without damage
- Removes corrosion without removing layer of metal substrate – regular cleaning without reducing surface profile
- Can clean metal surfaces <1mm thick without risk of puncture when appropriate pressure levels are applied
- No risk of pin-hole fracture to pipework, pressure vessels and delicate structures (unless fully/completely corroded)
- Lack of dust/solid media waste – no clogging of valves, air intakes, filters

3. Technical evaluation of Dry Ice Basting method

3.1. Scope of work

The Fabric Maintenance team of Shell Corrib has decided to test Dry Ice Blasting on a specified scope of work. These consist of various equipment such as piping, bolts, flanges and weld areas.

As part of the technical evaluation of the Dry Ice Blasting method the following trials were arranged to be witnessed by Shell PTE:

A) Trials on equipment and piping
B) Dry Ice Blasting on test plates
C) Application of a) Humidur FP and b) PPG Hi-Temp 1027 coating on test plates and measure the coating performance as follows:
   - visual appearance
   - holiday detection
   - dry film thickness
   - adhesion

The workforce for this trial consists of the Shell Fabric Maintenance coordinator (Scott Maidman) and three operators from the site contractor, WOOD Group. The Fabric Maintenance coordinator followed the training given by Dry Ice Blasting and then trained the contractor operators.

Shell PTE witnessed all trials and evaluated the surface preparation and final coating performance.

3.2. Trials on live equipment

The operators blasted several pieces of piping, flanges and structural steel. It resulted in a full removal of the old paint layer and corrosion scales. The operator slowly moved the blast gun over the steel surface at a distance of about 20 cm from the steel surface. The steel surface became wet due to condensation and some flush rust occurred.

The operator was wearing PPE and the blasting gun could be handled relatively easily. The operator could access all areas of the piping the noise level was still quite high. Concerning previous measurements, the noise level was around 105 dB for two blast pots side by side working. For that reason, it is expected that the operators have to wear hearing protections.

There was no contamination found due to evaporation of the dry ice material.

The following observations were made:

- Pipe work completely clean, free from oil, grease, dust or any other contaminants prior to coating
- As the blasting is going on, the existing surface profile reveals itself under the removed coating Where no existing profile was present (for welded areas or surfaces with a low surface profile), bristle blaster was used to give the appropriate key required for the use of a surface tolerant coating
- Salt contamination could be removed, the salt level after was blasting was measured to be in the range 0 to 1 mg/m^2, which is an acceptable measurement cf DEP?
- The steel surface might not look as clean as the Sa2.5 finish due to the possible difference in color. This is a well-known phenomenon when using hand power tools or UHP. Prior to coating application, an inspector should do the appropriate “cleanliness” checks to ensure that the surface is prepared accordingly to specification and painting manufacturer guidelines.

3.3. Dry Ice Blasting technical assessment

3.3.1. Dry Ice Blasting on test plates

To evaluate the effectiveness of the Dry Ice Blasting method, test plates with different corrosion patterns and coating were treated:

- Heavily corroded steel grade D
- Lightly corroded steel grade A
- Painted steel with Humidur (about 1500 μm)

After Dry Ice Blasting has been carried out, the following parameters were measured on every test plates:

- surface profile in accordance with ISO 8503
- steel cleanliness in accordance with ISO 8501-1
- salt contamination in accordance with ISO 8502-6

After the dry-ice blasting process, no differences could be found between the different steel plates. For all three plates the corrosion scales and coating were completely removed. The heavily corroded steel plates took some more time than the lightly corroded steel plates. Surface profile measurements indicated a value of 50 to 60 μm. This was the original surface profile of the steel plates. Salt contamination measurements indicate that the salt contamination was removed by this method and levels of 0 to 0.4 mg/m^2 were measured.

No dust could be found on the steel plates after the surface cleaning because by the dry-ice blasting method there is no dust formation (as is with grit blasting) due to the evaporation of the dry ice material.

3.3.2. Application of coating systems after Dry Ice Blasting

To assess the coating performance on dry ice blasted test panels, Humidur FP and PPG Hi-Temp 1027 coating were applied on the panels which were cleaned with Dry Ice Blasting.

The following tests were performed:

- General aspect by visual inspection
- Dry film thickness
- Adhesion test

The original test panels were grit blasted or bristle blasted (see Table 1) and coated with a Humidur coating in July 2016. Then, at the end of August 2016, the original Humidur coating was removed by Dry Ice Blasting and a new coating system was applied on the dry-ice blasted areas. The Humidur FP coating was re-applied on the test panels according to the guidelines from the manufacturer and a uniform coating thickness of around 500 μm was achieved. 1 month after application, as Humidur FP was fully cured, adhesion tests were performed at a third party laboratory (COT Haarlem) with the results listed in Table 1.

Table 1 results show that the adhesion of the re-applied Humidur FP coating is very high for all tested panels, in most cases more than 20 MPa, compared to 10-15 MPa for a regular Shell approved 3-layers coating. These results confirm the high adhesion of the Humidur FP coating that was observed during other pilot tests in Shell UK.

For the PPG Hi-Temp 1027 coating, the adhesion strength was 2.5 MPa with a cohesive failure mode in the coating system. This 2.5 MPa result is acceptable for this type of coating (inert multi polymeric matrix coating).

Table 1: Adhesion test result after Dry Ice Blasting of coated steel surface

Plate no	Original surface prep	Surface profile, µm	Coating applied	Adhesion (when coating applied on Dry Ice Blasted area)
1	Grit blasting	85	Humidur FP 410 µm	> 20 MPa
2	Grit blasting	85	Humidur FP 500 µm	> 20 MPa
3	Grit blasting	90	Humidur FP 410 µm	15 -19 MPa
4	Bristle blasting	67	Humidur FP 450 µm	15 -18 MPa
5	Bristle blasting		PPG Hi-Temp 1027	2.5 MPa

Both ACOTEC (supplier of Humidur) and PPG have done their own testing and trials on dry ice blasted steel. They have both endorsed the use of dry-ice blasting as a means of surface preparation and have supplied documentation (see Appendix 1).

3.4. Low temperature brittle fracture risk evaluation

3.4.1. General

During dry-ice blasting, the use of the solid ice pellets at a temperature in the region of -78.5°C could initially give cause for concern, with respect to the minimum temperature that the component (piping, flange, vessel, etc.) would reach during cleaning.

In general the use of CS piping is restricted to -29°C (-20°F) whereas LTCS is selected for temperatures below -29°C (-20°F). For temperatures below -45.6°C (- 50°F), 304L SS would normally be selected because of improved ductile-brittle transition at low temperatures.

The company Enspec was requested to carry out a review of the effects of the Dry-Ice Blasting process [1], to determine whether the low-temperature cleaning procedure would cause any type of metallurgical change, which could lead to the temporary or permanent embrittlement of the metal or alloy being cleaned. The test procedure and results are described in [1].

The results of the investigation showed that although the solid ice pellets make contact with the component at a mass temperature of approximately -78.5°C, the minimum temperature on the surface and sub-surface layers would not fall lower than -9°C. It can be concluded that at the minimum temperature, there would not be any risk of embrittlement of the metal.

The Corrib Fabric Maintenance team performed temperature measurements with temperature probes to verify steel temperatures during the Dry Ice Blasting process, see results in Table 2 to Table 4. The measurements were completed on three out of four grades of steel present on site at Corrib (A106, A333 and A333-NACE grade carbon steel).

Table 2: Steel temperature readings during dry-ice blasting process (A106 carbon steel)

Blast exposure time	Initial temperature of test sample (°C)		
	Ambient (17°C)	**Low (-20°C)**	**High (30°C)**
20 seconds	3.9°C	-17.3°C	16°C
1 minute	1.3°C	-15.7°C	6°C
3 minutes	-5.3°C	-11.2°C	-4°C
5 minutes	-8°C	-11.1°C	-8°C
30 minutes	-8.1°C	-11.1°C	-8.2°C

Table 3: Steel temperature readings during dry-ice blasting process (A333 carbon steel)

Blast exposure time	Initial temperature of test sample (°C)		
	Ambient (17°C)	**Low (-20°C)**	**High (30°C)**
20 seconds	3.5°C	-18.2°C	17°C
1 minute	1.5°C	-15.8°C	4.5°C
3 minutes	-5.4°C	-13.1°C	-2.5°C
5 minutes	-5.4°C	-12.2°C	-5.1°C
30 minutes	-5.5°C	-12.2°C	-5.2°C

Table 4: Steel temperature readings during dry-ice blasting process (A333 NACE carbon steel)

Blast exposure time	Initial temperature of test sample (°C)		
	Ambient (17°C)	**Low (-20°C)**	**High (30°C)**
20 seconds	3.3°C	-16.2°C	16°C
1 minute	1°C	-15.4°C	1.1°C
3 minutes	-5.2°C	-11.4°C	-4.8°C
5 minutes	-8°C	-11.1°C	-6.5°C
30 minutes	-8°C	-11.1°C	-6.7°C

It is shown that the temperature measurements at Corrib, confirm the Enspec report, no temperature of less than -9°C was measured when the initial temperature was ambient (17 °C) or higher. When the initial temperature was -20°C, the temperature increased to around -11°C.

It can be concluded that 'low temperature brittle fracture' is not a risk for the steel materials used at Corrib.

It is recommended that each asset should carry a temperature test on the specific used metals that will encounter Dry Ice Blasting.

4. Comparison between grit blasting and Dry Ice Blasting

The main advantage of Dry Ice Blasting compared to grit blasting is that there is no abrasive grit material is involved. This reduces the amount of waste to a minimum and also masking and cleaning of equipment is not required.

At Corrib, a comparison was made between grit blasting and Dry Ice Blasting mainly related to time and cost savings. In Appendix 2, the results are shown for a trial with one length of piping. It was shown that the total man hours required for this trial was 17 hours for grit blasting and 2.5 hours by Dry Ice Blasting. So, there is a large time saving by using the Dry Ice Blasting method.

Based on the total scope of work for Corrib trial, the estimated costs for conventional grit blasting versus Dry Ice Blasting were calculated including all steps in the overall process such as scaffolding, masking, blasting and painting [2]. It was shown that most of the time savings were caused by less scaffolding required, less masking and sheeting and almost no clean up required after blasting. Additionally, with Dry Ice Blasting more blasting pots and operators could be in operation simultaneously where for the grit blasting only one blasting pot with one operator could operate during this scope of work. The Technology Replication Thrust team estimated the productivity gain of Dry Ice Blasting + Humidur compared to grit blasting + conventional 3 layers coating as almost 300 %. It is obvious that this productivity gain results in large cost savings.

5. Overall evaluation

5.1. Dry Ice Blasting as surface preparation method

Dry Ice Blasting was evaluated as surface preparation method to remove coating layers and corrosion scales.

Dry Ice Blasting has proven to be used to remove old paint layers and corrosion scales. The full coating layers with thicknesses up to 1000 μm can easily be removed. Also heavily corroded steel surfaces could be cleaned to the original surface profile and cleanliness. It was also shown that this cleaning method effectively removed salt contamination, which can be cumbersome for maintenance paint application.

There were no limitations found for type of coating and/or severity of corrosion.

Dry Ice Blasting does not result in any surface roughness, the existing surface roughness of the treated steel becomes visible and 'is used' as profile for the coating application. If required, another surface preparation method such as bristle blasting can be used to create a surface profile (i.e. for welds areas).

The main advantages of Dry Ice Blasting are first the reduction of time spent in preparing the work area and the reduction in post-work clean-up. With this technique, there is no need to build an encapsulation, sheet up, mask up and clean up post blasting. It also allows the contractors to apply the paint at close proximity while Dry Ice Blasting operations are still carried out. Operation of the Dry Ice Blasting unit seems to be user-friendly for the operators. The handling of the equipment is easy to manage and no dust or hazardous vapours are released. The main HSE issue for the operator is the noise production. Proper ear protection shall be worn to prevent ear damage.

All operators should receive proper training and certification before they are allowed to use the Dry Ice Blasting unit.

5.2. Dry Ice Blasting used in combination with surface tolerant coating systems

This form of surface preparation in combination with surface tolerant coating systems seems to be an excellent tool to increase productivity and reduce costs.

Corrib used the Dry Ice Blasting in combination with different other technologies:

- Bristle Blasters: for any areas of low surface profile, welded areas
- Humidur coating systems
- PPG Hi-Temp 1027 coating system

This maintenance strategy (Dry Ice Blasting with surface tolerant paint application) results in efficient process which is more cost effective related to grit blasting combined with conventional paint application. Another advantage is that Dry Ice Blasting is more HSSE friendly (for the blaster and the environment) compared to grit blasting.

It should be recognised that Dry Ice Blasting cannot replace grit blasting for new equipment. It is strictly meant for maintenance purposes. In addition, Dry Ice Blasting is not recommended for large areas like large tanks where grit blasting will show more productivity. But for relatively smaller pieces of equipment, such as piping, pipelines, valves & fittings, Dry Ice Blasting can be used to prepare the steel surface for maintenance painting.

6. Conclusion and recommendations

Dry Ice Blasting is a suitable surface preparation technique to remove coating layers and corrosion scales.

Dry Ice Blasting does not provide any additional surface profile. If required, an additional technique (Bristle Blaster) should be used to achieve the required surface profile.
Dry Ice Blasting is a relative environmental friendly technique because it leaves no blasting residues due to evaporation of the blasting medium.
Dry Ice Blasting can be used on live equipment and in the area of other (rotating) equipment without masking because there is no dust or other solid particles contamination (except from the old coating and corrosion scale particles). But the size and amount of these particles are limited and do not interfere with the other equipment.

Surface tolerant coating systems can be applied on 'dry ice blasted 'steel surfaces directly.

The combination of Dry Ice Blasting with application of surface tolerant coating has shown to be an effective and cost –saving process compared to conventional grit blasting.
There is no risk for low temperature brittle fracture of the used steel materials.

Based on the documentation and test trials, Dry Ice Blasting is technically approved as a surface preparation method to remove coating layers and corrosion scales to be used for Shell projects and assets.

It is recommended to prepare a procedure (including acceptance criteria, tool description, etc.) for Dry Ice Blasting application for maintenance purposes within plant environment.

References

[1] Review of the effects of the dry-ice cleaning process on the surface embrittlement of carbon and stainless steels; Enspec Technology, Case No. EN2719 Rev 0, 14th of June 2016.

[2] Internal email correspondence Scott Maidman, SEPIL-UPO/W/OC.

Appendix 1. Information received from paint suppliers concerning coating on dry ice blasted steel

Carboline Report Dry Ice Plate.pdf

dry ice scotland confirmation letter PP

Dry Ice Scotland Test Report 16 05 20

Specification For Dry Ice Scotland 2016.pd

Appendix 2. Comparison grit blasting versus dry ice blasting

GRIT BLASTING V DRY ICE

- Time taken to tape up stainless steel and encapsulate ***first half***:

1 hour 30mins for x3 men

- Time taken to blast the ***first half***:

2 hours of trigger time x1man

- 27 bags of garnet
- 675 kgs of garnet
- Clean up all of Garnet:

1hour x2 men

- Total Man hours for ***first half*** Set-up, blast, clean up:

8hours 30 mins

- Time taken to tape up stainless steel and encapsulate ***full works***:

10mins x1man

- Time taken to blast the ***FULL works***

1 hour of trigger time x2 men

10 mins of Bristle blast x1 man

- 100kg of Dry Ice
- Clean up- N/A
- Total Man hours for ***FULL works*** set-up, blast clean up:

2 hours 20mins

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