Technical Description
DICE – Dry Ice Cleaning Equipment
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1 Environmental friendly cleaning concept

1.1 Introduction

The concept consists in using waste gas (CO2 produced by the chemical industries) in order to recycle it by cleaning any dirty surface. Rather than managing CO2 as a waste posing serious problems of storage and to prevent illegal discharge into the atmosphere, our concept follows the trend of the sustainable development.

1.2 The production of Ammonia

The CO2 ice that we use can be made, for example, from the process of ammonia manufacture. Production of ammonia is a direct synthesis of di-hydrogen and di-nitrogen in the air and hydrogen gas methane.

This process generates CO2, waste that is recovered, purified through a charcoal filter, liquefied by compression and cooling for storage in a cryogenic tank at a pressure of 20 bars and a temperature of -20 °C.
1.3 Purification stage of the CO2

The utilisation and valorisation of CO2 for cleaning operations allows to save water, which is an extremely valuable resource that tends to become rare in some areas. It also preserves the quality of water and soils simply by removing the need of using chemical cleaning agents (detergents, solvents, etc…).

**Important Note:** The CO2 that we use is not produced specifically for our application. It is recovered during gas manufacturing process of industrial products. This is the reason why it can be used in accordance with the concept of sustainable development and preservation of the environment.
1.4 Advantages of cryogenic cleaning concept

Thus, for our applications, our concept of cryogenic cleaning has several advantages in relation to the quality of the environment (the list is not exhaustive):

- Innovative promotion of a greenhouse gas, CO2 which otherwise would be treated as a waste;
- Saving on water consumption;
- Respect for the integrity of the water;
- Replacement of the current water cleaning processes;
- No pollution of soil in which the cleaning water flows;
- Economy of resources for soil remediation,
- Economy on investment and maintenance required for the facilities involved in the collection and treatment of polluted liquid effluents;
- Reduction of volatile organic compound (VOC).
2 PRESENTATION OF THE DRY ICE

2.1 Description

Carbon dioxide is the combination of two elements: One atom of Carbon and two atoms of Oxygen.

Carbon dioxide

Dry ice sticks (called "pellets") are obtained from carbon dioxide. Dry ice in chips or sticks are obtained from the produced dry ice liquid (20bars/ -20°C) by compressing and cooling the gaseous and / or liquid carbon dioxide (low-pressure detente).

Crystal structure of "dry ice"

This snow is compressed with a hydraulic press and extruded through a die, in order to obtain pellets of ice. The dry-ice pellets we use are 3mm diameter, length can vary from 1 cm to few centimetres – provided it stays under 3 to 4cm, length is not so important. In fact, length is depending on the extruding pressure of the ice when the ice is pushed into the die cast.

The density of the dry ice is a function of applied pressure and time duration of the application of this pressure. It can reach 1560 kg per cubic meter (1.56 kg/dm3).

The sublimation temperature of the dry ice is -78.64 ° C at atmospheric pressure.

The dry ice, which consists only of carbon dioxide sublimes without any residue. We use this property for the cleaning process.

The above properties make it also an extremely valuable refrigerant, not only for chemical and industrial applications, but also to a large extent for the food industry.
2.2 Storage

Use of this consumable reduces waste because its packaging is reusable and does not require special maintenance between loadings.

For our application, the product is under solid form. Its power of self-preservation allows an interesting flexibility of operation and management. The conservation time of the product is related to the quantity and packaging. A simple calculation allows us to anticipate material losses:

\[
QT = \text{DELTAT} \times K \times S \times \text{TIME} \times 3600/150000/4.18
\]

**Details of the calculation:**

**DELTAT**: Temperature difference between the inside and outside of the package (general case with an outside temperature of 20°C, take a value of 100).

**K**: Conductivity coefficient of the package (about 0.4 W / sq m / °C).

This coefficient is either provided by the manufacturer or determined by experimentation (generally between 0.1 and 0.5).

**S**: Outer surface of the package (in sq.m).

**TIME**: Required conservation time (in hours).

The coefficient 150,000 comes from the latent heat of sublimation of ice (150 kcal / kg).

The factor 4.18 comes from the conversion calories / joules.

**Example:**

For a box with a developed surface of 1 sq.m and with an external temperature of 20 °C, the loss of dry-ice after 48 hours will be:

\[
QT = 100 \times 0.4 \times 1 \times 48 \times 3600 / (150000 \times 4.18) = 11.023 \text{ kg}
\]

Therefore for cryogenics treatment, insulated containers can retain very good quality of the pellets over a period of 48-72 hours.

The storage boxes can be mobile (on wheels) and can be moved by hand or with a forklift. The storage of these containers (empty or full) requires no special infrastructure.

Example of various types of isothermal boxes available on the market:

<table>
<thead>
<tr>
<th>Model</th>
<th>width</th>
<th>depth</th>
<th>height</th>
<th>width</th>
<th>depth</th>
<th>height</th>
<th>in Kg</th>
<th>in litre</th>
<th>Coef.K W/M²x</th>
</tr>
</thead>
<tbody>
<tr>
<td>Box 55</td>
<td>600</td>
<td>500</td>
<td>580</td>
<td>415</td>
<td>315</td>
<td>410</td>
<td>16</td>
<td>53</td>
<td>0.38</td>
</tr>
<tr>
<td>Box 120</td>
<td>765</td>
<td>600</td>
<td>614</td>
<td>610</td>
<td>445</td>
<td>430</td>
<td>30</td>
<td>117</td>
<td>0.36</td>
</tr>
<tr>
<td>Box 150</td>
<td>800</td>
<td>640</td>
<td>660</td>
<td>625</td>
<td>470</td>
<td>480</td>
<td>32</td>
<td>141</td>
<td>0.34</td>
</tr>
<tr>
<td>Box 250</td>
<td>980</td>
<td>900</td>
<td>650</td>
<td>800</td>
<td>720</td>
<td>455</td>
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<tr>
<td>Box 420</td>
<td>1200</td>
<td>800</td>
<td>1050</td>
<td>1000</td>
<td>600</td>
<td>700</td>
<td>90</td>
<td>420</td>
<td>0.27</td>
</tr>
</tbody>
</table>
2.3 Major risks from the use of CO2

2.3.1 Definition of risk according to the states of CO2

CO2 used for cryogenic treatment comes in two forms: gaseous and solid. Both forms involve different risks:
- In gaseous form, when ice sublimes or stored in an enclosed place, the risks are related to the concentration of air in the atmosphere.
- In its solid form, risks are related to physical contact causing skin burns.

2.3.2 Toxicity

The air now contains about 0.04% CO2. From a certain concentration in the air, this gas is dangerous. The exposure limit is 3% over a period of 15 minutes. This value must never be exceeded. Beyond the effects on health are much more serious than the CO2 content increases.

Thus, 2% CO2 in air, respiratory amplitude increases. At 4%, the respiratory rate is accelerating.
At 10%, visual disturbances may occur, shakiness and sweating.
At 15%, sudden loss of consciousness could occur.
At 25%, respiratory arrest.

Operators need basic protection (goggles, gloves, hearing protection). Wearing a mask may be considered depending on the substrates to eliminate toxicity. It should be noted that the use of this technique preserves the health of people who are no longer subject to the risks related to exposure over long periods of chemical projections. The CO2 used is compliant to Food Standards.
2.3.3 Major risks in solid form

Solid risks are associated with skin contact and the risk of burns.

2.3.4 Summary of instructions

- Mandatory wear of IPPE (gloves, goggles).
- Storage of dry-ice containers in a ventilated room.
- Definition of work areas
3 Principle of operation

The dry ice pellets are projected at a speed of about 300 m / s on the surface of the object to be cleaned, which causes a thermal shock and kinetic point. Accordingly, the dirt layer to be removed contracts, tears and breaks away from the surface of the object. After impact, only the impurity layer is separated from the surface of the object. Dry ice, for its part, sustains an immediate change from solid to gaseous state. Dielectric properties will allow the cleaning of installations of electrical elements. With this technique, the cleaned surface remains intact because it does not produce any abrasion or other types of aggression at the time of impact.

3.1 Needs technical

The use of our materials either involves a network of industrial compressed air or use of an independent thermal compressor. In the currently validated cases, an air flow of 4200 to 5000 litres per minute and a pressure of 7 bar are sufficient. Our equipment may operate on unfiltered networks.

In order to optimize the ergonomics of workstations based on operating conditions, the rolling wheels are defined to provide the easiest utilization. Well pipes are defined by the projection to use not to increase unnecessarily the spear. The machines are delivered with an umbilical air system / machine 10 meters. It is possible to increase the quantity surveying. Connections to the network of air are defined with the customer.

This equipment complies with labor legislation and CE standards. It implies, however, that the operator is equipped with individual personal protective equipment (IPPE).

3.2 Operation

Refer to the User Guide for information on:

1. Preparation of cleaning
2. Initiation
3. Cleaning the actual
4. Resolutions faults and malfunctions
5. The safety recall
3.3 Training

Design trials have revealed some peculiarities of long-term cryogenic treatment allowing to define detailed and specific job description.

The cleaning process requires ideally two operators with one operator cleaning the lights while the second takes care of filling the machine with dry ice pellets, preparing and anticipating equipment requirement and positioning the vehicle.

These two positions are interchangeable. It was observed during the tests that exchanging positions every 30 minutes keeps quality and performance of work without unnecessary tiredness of the operators.

The training program is defined as:

- Definition of the machine (specifies the limits of normal use)
- List of cons-indications
- Description of workstations
- Description of the function and location of the control and information devices
- Definition of use
- Description of walk cycles
- Descriptions of personal protective equipment
- Tasks to be performed by the operator during normal or degraded
- Description of the behavior in the event of an incident
- Definition of interventions (frequency and nature of maintenance)
- Limit interventions that can make operators
- Products and tools needed for maintenance
4  GENERAL DESCRIPTION OF SYSTEM DICE

The system is composed of three sub-systems:

- The DICE machine
- A trailer (optional)
- A compressor (optional)

Depending on the customer's choice, we can offer the following configurations:

- DICE Machine alone. The client provides the vehicle and one towed compressor.
- DICE Machine with a compressor installed on skids inside the customer’s or FB Technology’s supplied vehicle;
- DICE Machine and the compressor on a trailer.

In all cases above, the DICE machine can either be kept in the vehicle or on the trailer or placed on the runways/taxiways by the operator to be closer to the AGL lights that have to be cleaned.

4.1  Trailer configuration

The trailer supports the cleaning equipment, storage box of dry ice, and the compressor. It allows you to operate everywhere on the airside as well as on open roads giving the possibility to perform cleaning services on other sites.

Features:
- Flatbed trailer type RI 2202 with approx dimensions: 2.64 m x 1.67 m;
- 2 axles trailer with brakes - inner wheels type 185/70 R13;
- V type shaft with inertial brake control;
- Telescopic jockey wheel;
- Anti-skid floor on the trailer;
- Rear road-lighting;
- Galvanized chassis and frame.

Options:
- Spare wheel + bracket:
- Cover + hoops H = 1.40 m:
- Storage case for hoses
- Storage box for clothing and IPPE

With the trailer, the compressor would be positioned along the length of the trailer, the DICE machine next to the compressor and the container at the back (see figures in appendix).
4.2 The compressor

The compressor should be able to optimally deliver 4,200 liters / min under a pressure of 7 bar. More powerful compressors can be used after having been adjusted - this is done by us at the time of commissioning. We recommend a compressor type Kaeser M43 or equivalent.

It is a site compressor, using lubricated screws, soundproof. It will be installed on skids on the trailer that is towed by the service vehicle. It has the following features:

- Flow: 4.2 cu.m per min
- Pressure: 7 bar - pressure range 5-8 bar
- Standard Color: Yellow
- Diesel Engine:
  - KUBOTA V1505-kind T - 4 cylinders
  - Liquid Cooled
  - Horsepower installed: 30.1 kilowatts
- Air pressure: 2 x valves G" 3/4

Configuration and towed
- Jockey wheel – brake
- traction ring system

Dimensions and weight:
- Total length with drawbar: 3430mm // skid model : 2025mm
- Width: 1440mm // skid model : 1160mm
- Height: 1350mm // skid model : 1120mm
- GVWR: 860 Kg

Preferred option:
Final cooler with water separator: this provides an improved air quality, reduced humidity, reduces the risk of freezing air tools (elimination of condensates under the compressor).
4.3 The cleaning machine – DICE

The DICE can be used either secured onto the trailer or autonomously by moving freely around the trailer releasing the operator of the vehicle positioning constraints giving an operative radius of 10 to 20 metres around the machine. The DICE machine on wheels is connected to the compressor with an air hose (10 m up to 20 m).
5 Guarantee

The guarantee is one (1) year on all equipment
6 Annex