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A patented vacuum cleaning system using low-boiling point solvents in a hermetically sealed vacuum monochamber performing thermocompression distillation

In recent years, surface cleaning technologies have seen a strong development towards higher environmental sustainability, cost-effectiveness, and ever-higher cleanliness results. It is now decades since trichloroethylene and perchloroethylene were employed without exceptions in the mechanical components sector. Hermetic machines allowed using them while reducing environmental impact and increasing safety. However, with the introduction of stricter legal restrictions, modified alcohols and hydrocarbons appeared on the market: these were more sophisticated products with very high detergent power, requiring the use of modern machines equipped with solvent recovery and recirculation systems to make their use economically viable. Now, based on its experience in the design of multi-tank cleaning lines, MEG Srl has conceived a patented hermetic monochamber machine for using a new generation of solvents called "low-boiling point solvents".

This patented innovation is the result of a long-standing collaboration between MEG and engineer Claudio Sama, who jointly developed a project for the creation of an innovative, new generation solvent cleaning system, in which MEG has always invested since its foundation and for which it found in CHEM SOLUTIONS Srl, distributor of 3M™ products, a partner with whom to establish a thirty-year relationship. At present, MEG has built a prototype of the new machine, with which it has started to perform cleaning tests with 3M™ solvents (in particular, 3M™ Novec™ 73DE) for a few selected users interested in this new technology.

An innovation

Most industrial cleaning plants currently on the international market are monochamber systems. This means that the material to be treated is introduced into a vacuum-tight chamber, in which the cleaning solvent is recirculated one or more times with a gradually increasing

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degree of purity at each process stage. Some systems include variants such as, for example, immersion cleaning with the aid of ultrasound or steam cleaning, all of which take place within the chamber. In any case, at the end of the cycle, vacuum is generated in the process chamber to evaporate any residual solvent thanks to the very low pressure.
Monochamber plants mainly use organic solvents, water-based solutions, or sometimes a combination of water and solvent as the cleaning liquids. The most commonly used solvents are modified alcohols with a boiling point above 155 °C, chlorinated solvents such as tetrachloroethylene, and low-boiling point solvents such as methylene chloride, HFEs, HFOs, and HFCs products, i.e. solvents that boil between 15 and 60 °C at atmospheric pressure.
All solvents are normally regenerated by distillation. This process is an integral part of the cleaning process and is normally performed in the same plant. Currently, high-boiling point solvents are distilled, albeit under vacuum, with heating systems using electric resistors or hot water produced with electric resistors or fuels; the steam produced is then condensed, usually with chilled water. Therefore, high-boiling point solvents require a certain amount of energy both to evaporate them and to condense the vapours produced during distillation. Solvents such as HFEs, HFOs, and HFCs, which have a boiling point around 40 °C at atmospheric pressure, can be distilled with the same systems used for modified alcohols, but also with heat pumps, or, much more conveniently, through vapour mechanical compression.
In the industrial cleaning sector, however, the thermocompression distillation (or vapour compression) technology has never been used. MEG's patent, which is based on Claudio Sama's invention, relates precisely to a process for the industrial cleaning of both metallic and non-metallic industrial products (e.g. precision small parts, mechanical parts, printed circuit boards, lenses, watchmaking components, jewellery and eyewear components, and so on) through thermocompression distillation, as well as the plant implementing this process, in which the main component, namely the compressor (i.e. a dry vacuum pump), allows the following functions to be performed:

- Distillation of the solvent used for cleaning;
- Vacuum drying in the chamber at the end of the cycle;
- Distillation of the solvent under vacuum to minimise its percentage in the distillation waste.

This patented innovation finds particular and effective application in monochamber-type industrial cleaning plants performing a final vacuum drying phase and using organic solvents with a boiling point between 15 and 60 °C at atmospheric pressure.

Benefits of the MEG machine + 3M™ Novec™ combination

- Distillation by mechanical vapour compression for distilling the solvent with reduced consumption (calculated to be 5 to 10 times lower than traditional distillation – the larger the plant, the greater the energy saving);
- Use of non-flammable, low-boiling point solvents (starting from 40-50 °C);
- Drying under high vacuum: the machine reaches a few mbar of absolute pressure during this phase;
- Good cleaning quality even with complex-shaped parts whose cavities usually retain a lot of solvent.

Energy consumption

The distillation phase, especially if a large quantity of pure distillate is required for cleaning, is the most energy-consuming one in the entire cycle, particularly in large plants.
According to calculations made by Claudio Sama and MEG and backed up by actual tests, for a machine with a distillation capacity of more than 300 kg/h, with the new system the energy cost is several times less than that of a conventional distiller.
Distillation tests with the 3M™ Novec™ 73DE solvent have shown that only 5 kilowatt-hours enable to distil more than 300 kg of solvent or a little less methylene chloride, due to the different densities of vapours. When fully operational, a thermocompression distiller uses only mechanical energy; it has no heating elements and it does not require other heat sources such as hot water, steam, or thermal oil, nor does it need cooling water, which also has a significant energy cost.
A layperson may struggle to understand how a distiller can function with no vapour heating nor cooling sources. Actually, by creating a pressure difference between the solvent contained in the distiller and the vapours downstream of the compressor, thermocompression raises the condensation temperature of the vapours by a few degrees, which are condensed in an exchanger at the expense of the liquid, which is at a slightly lower temperature.
Therefore, all the heat required to condense the vapours is transferred to the boiling liquid, so there is no need to introduce either heat or cold from outside, but only to supply energy to bring the vapours to a pressure slightly above that of the liquid.
The maximum temperature reached by the solvents at the hottest point, i.e. the compressor outlet, is usually between 40 and 50 °C. Solvents never come into contact with hot walls and can therefore be distilled an infinite number of times without suffering thermal stress.
By combining a thermocompression distiller with a small standard vacuum distiller, e.g. with a distillation capacity over 10 times lower than the thermocompressor, a distillation system is built that can produce a large quantity of distillate at a very low cost and dispose of the oil removed from the parts to be cleaned with a residual solvent concentration around 1%.