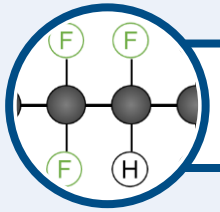
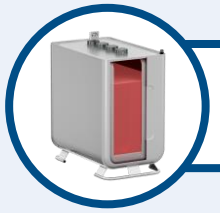
Agenda



1. Chemical basics of fluorination technology

2. Construction of offline fluorination plant

3. Benefits of fluorination technology



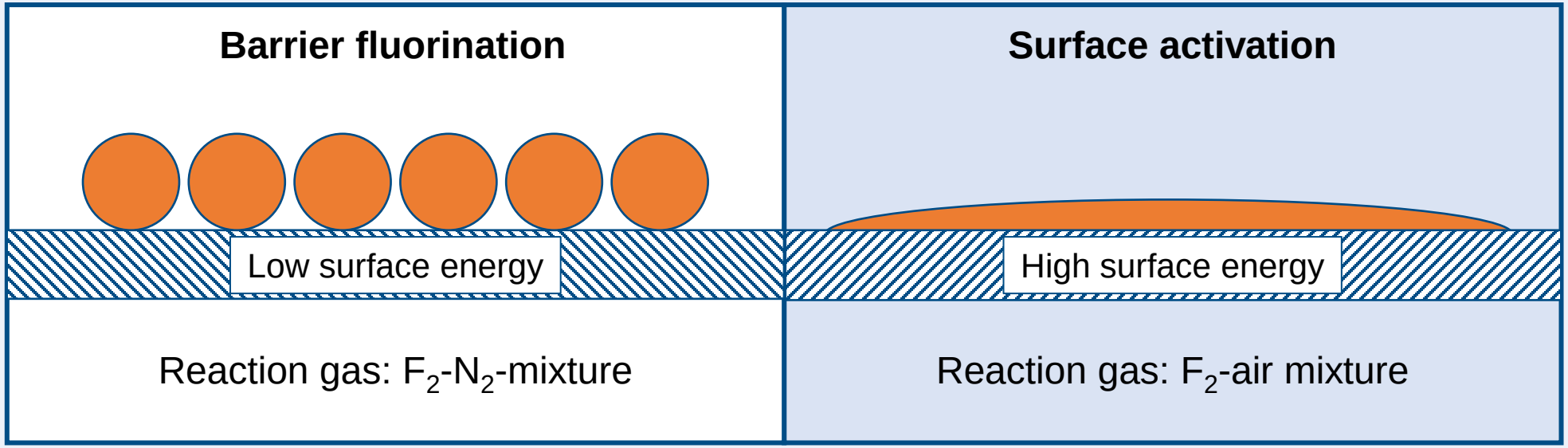
4. Application examples

Property of the chemical element fluorine

- Fluorine is part of the seventh main group of the periodic table, the elementary group of halogens, and has the structural formula F2.
- Fluorine is gaseous at room temperatures and has a green-yellow colour.
- Fluorine is a highly toxic and corrosive gas. Handling it requires the highest safety standards.
- Fluorine is the most reactive element and therefore does not occur in nature in its elemental pure form. Fluorine was first discovered in fluorspar.
- Fluorine is obtained through the electrochemical reaction of the electrolysis of fluorides.

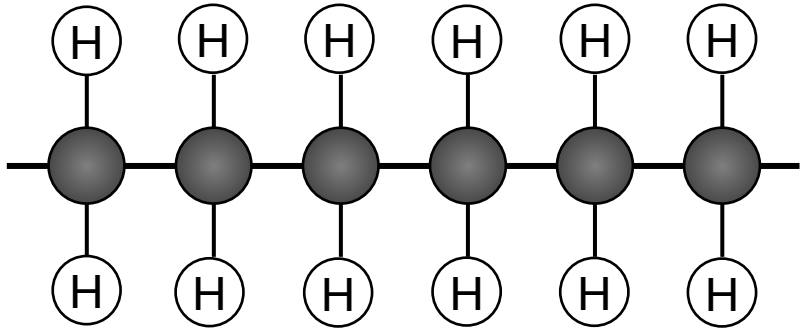
Fluorspar

Fluorination - one technology two technical application areas



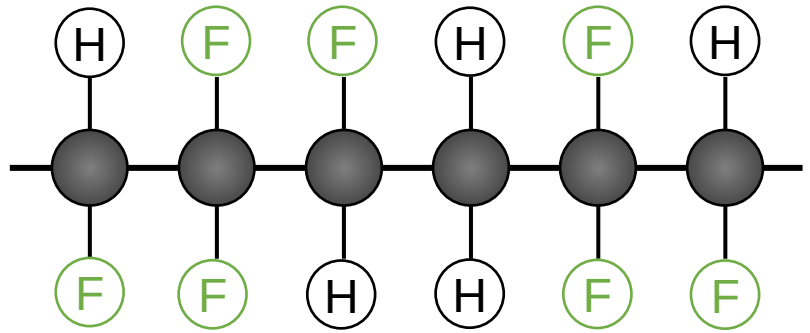
- Depending on the composition of the reaction gas, the properties of the plastic surface can be optimised in different ways by fluorination.
- Dehoust primarily uses barrier fluorination with a reaction gas consisting of an F_2-N_2 mixture.

View of the polymer structures



- Untreated polymer chains of carbon and hydrogen atoms
- Polymer molecules consist of multiple monomer structures

Supply of F_2-N_2



- Stepwise substitution of individual hydrogen atoms by fluorine atoms in the surface boundary layer

- Fluorination is a chemical reaction and not a surface coating technology.
- The reaction only takes place in the molecular surface edge layers (approx. 1µm) and thus fluorine atoms have a low penetration depth.

View of the reaction conditions

- The fluorination process is a form of halogenation.
- The reaction gas consists of a gas mixture of 10% fluorine gas (F2) in a nitrogen medium (N2).
- In a previously vacuumed chamber, the parts to be fluorinated are exposed to a fluorine atmosphere. The exposure time of the fluorine gas is only a few minutes.
- The residual product of fluorination is the toxic gas hydrogen fluoride (HF), which is neutralised by absorber systems.
- The fluorination process is defined by the following process parameters:
    - Fluorine partial pressure (fluorine gas concentration in the reaction gas).
    - Process temperature
    - Duration of fluorine gas exposure
- By varying the process parameters, different fluorination grades can be achieved.

Offline vs. Inline fluorination

Process parameters	Offline fluorination	Inline fluorination
Fluorination temperature	50°C – 75°C	100°C – 120°C
Fluorination pressure	200mbar – 650mbar	6bar – 8bar
Fluorination duration	60min – 120min	During blow moulding cycle
Fluorine concentration	10% - 20%	1% - 2%
Process profile	Discontinuous	Dynamic
Part geometry	Three-dimensional moulded parts	Sheet material
Process execution	External vacuum chamber	Inside blow moulding cycle

Advantages of offline fluorination:

- High flexibility regarding the shape of the plastic parts to be fluorinated
- High degree of optimisation of product properties
- Good reproducibility and controllability of the fluorination process

Offline fluorination at Dehoust GmbH

2. Construction of offline fluorination plant

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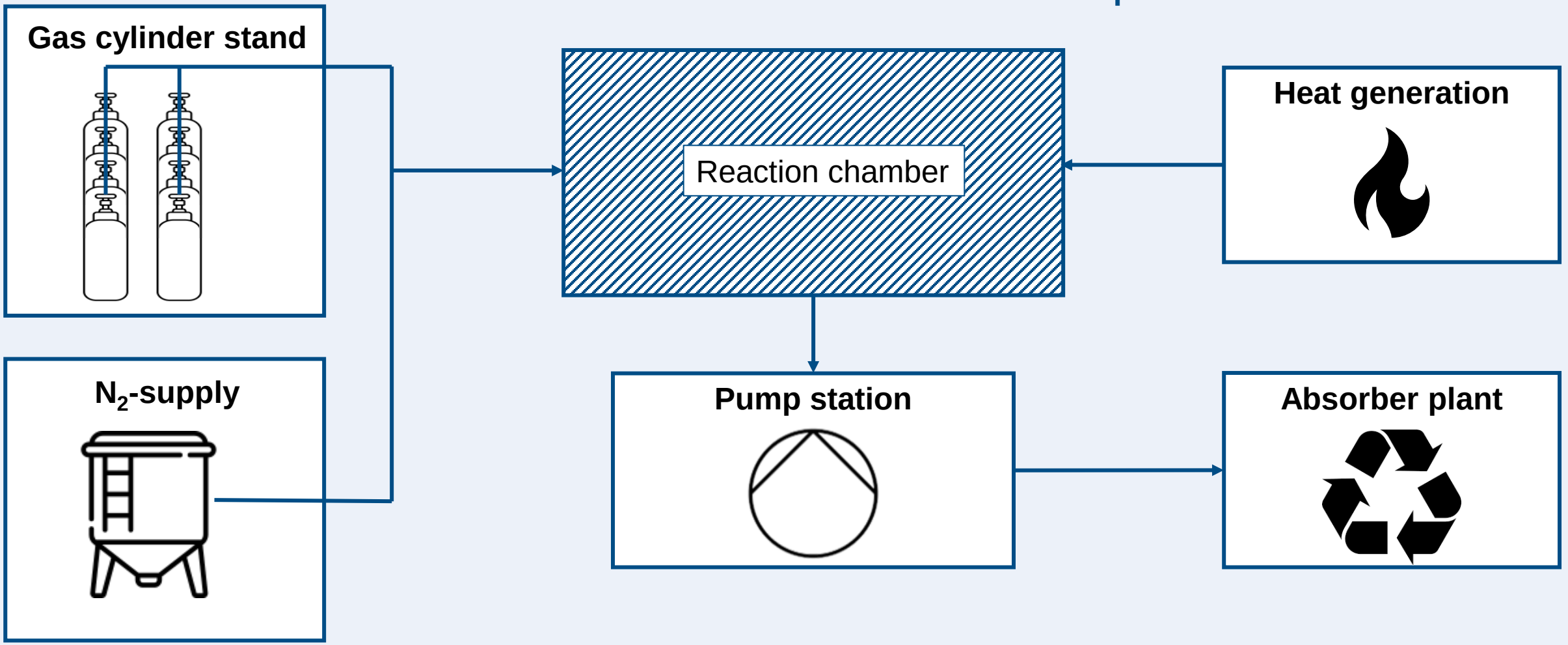
Schematic structure of an offline fluorination plant



Technical plant components

Gas cylinder stand

- The fluorine bundle station supplies the reaction chamber with the reaction gas. (10% F_2).
- The gas supply is controlled automatically via remote-controlled valves.
- The fluorine bundle station is used as the gas transfer station and thus represents the system interface.
- The fluorine bundle station is protected against gas leakage by redundant safety systems and is continuously monitored by several measuring devices.
- The fluorine bundle station may only be entered and equipped by instructed and specially trained personnel.

Technical plant components

Reaction chamber

- The reaction chamber is often also called a vacuum or fluorination chamber.
- The reaction chambers of the Dehoust plants have a volume of 20m^3 and are closed hydraulically.
- The fluorination reaction takes place inside the reaction chamber. For this purpose, the chamber is first vacuumed and then filled with the reaction gas.
- The reaction gas circulates continuously inside the chamber to obtain a uniform fluorination result.
- The reaction chamber is loaded and unloaded unmanned by an automated scale system.

Technical plant components

Pump station

- The pump station is the interface between the reaction chamber, the fluorine bundle station and the absorber systems.
- The pump system consists of a double-stage combination of a vacuum pump and a circulation pump.
- The pumping system is able to vacuum the chamber in less than 10 minutes.
- To reduce the pump system's susceptibility to failure, pumps with few rotating mechanical parts are used.

Technical plant components

Absorber plant

- The absorber plants bind and neutralise the toxic hydrogen fluoride and the excess reaction gas from the reaction chamber via a double-stage system.
- Used absorber technologies:
  - Calcium carbonate absorber ($CaCO_3$)
  - Aluminium oxide absorber (Al_2O_3)
- Residual products of the absorption process are non-toxic and can be recycled in cement production.
- The exhaust air from the absorber system is continuously checked for pollutants.

Absorber plant

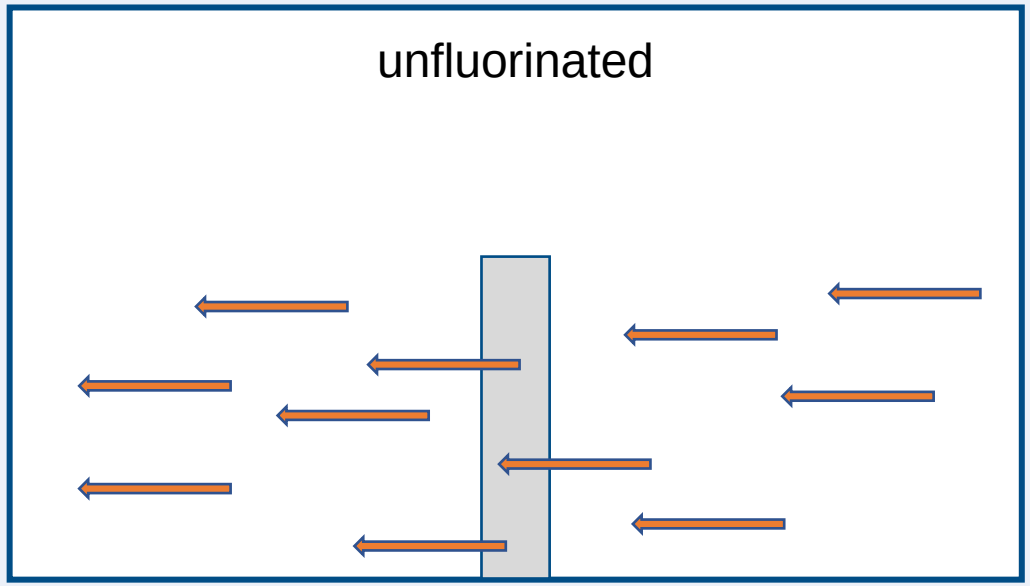
Residual product absorber

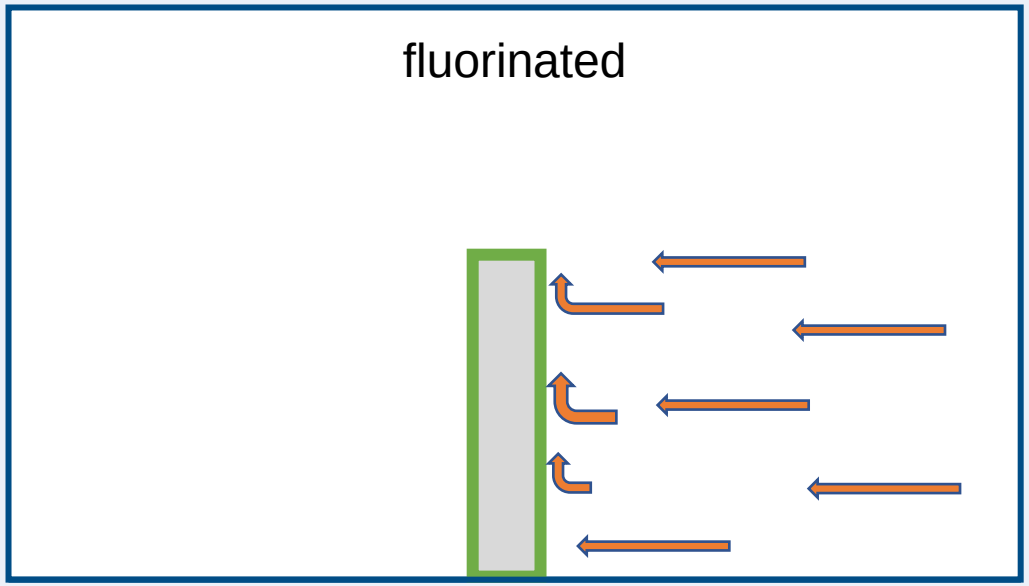
Fluorination plants at Dehoust GmbH

Fluorination plant 1

Fluorination plant 2

Surface activation through offline fluorination
Permeation





- Non-polar media (e.g. fuel oil, aromatics, AdBlue©) permeate over time through untreated plastic containers.
- The fluoroplastic layer provides a low-energy surface which prevents or significantly slows down the penetration and thus permeation.

Surface activation through offline fluorination

- Long-term stable optimisation of the surface properties
- Reproducible reaction process through standardisation of the reaction parameters
- No damage (mechanical and thermal) to the plastic surfaces and structures
- Applicable for almost all types of plastics as well as part sizes and part geometries
- Consistent treatment qualities throughout the product

Offline fluorination at Dehoust GmbH

4. Application examples Dehoust

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Double-walled Triosafe plastic tanks

Triosafe 750l

Triosafe 1000l

Triosafe 1100l

Triosafe 1500l

Offline fluorination at Dehoust GmbH

4. Application examples Dehoust

Combi tank inner shells 720l and 1000l