SuperCritical Fluid Technology

Minimising emissions
for a better world

Supercritical fluid (SCF) technologies have the capability to significantly reduce emissions of harmful substances by the use of environmentally friendly solvents such as carbon dioxide. The main advantages are easier and quicker to operate processes without having harmful or flammable solvents on site.

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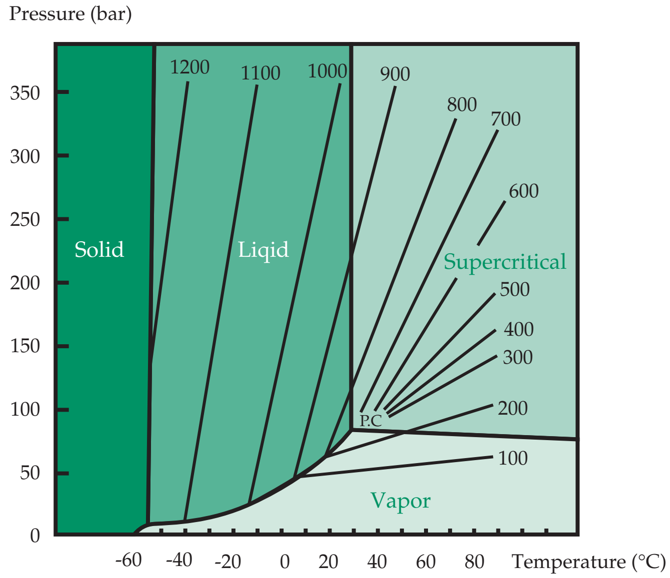
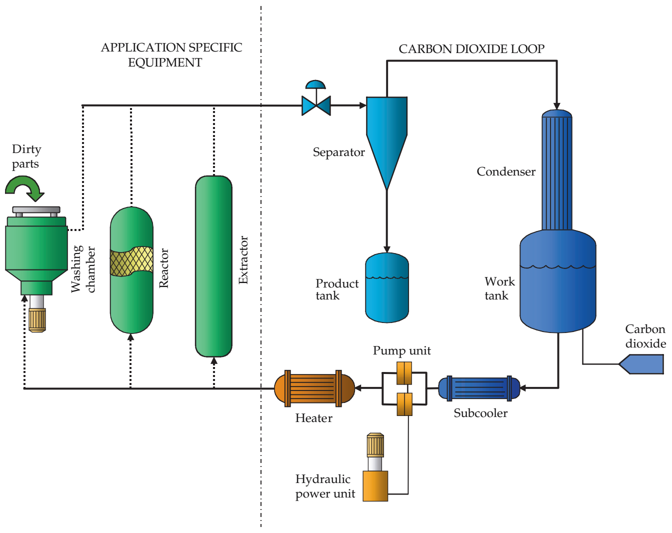


Phase diagram for carbon dioxide. Constant density lines g/L.

Why go Supercritical?

The diagram shows the different phases of a typical fluid (in this case carbon dioxide). The critical point for a fluid is defined by the maximum temperature (critical temperature) at which a gaseous substance can be liquefied and by the pressure (critical pressure) needed to do this. A substance below the critical temperature is either a vapour or a liquid while one above is either gaseous or supercritical depending on the pressure. The critical point is characterised by a liquid like density and a gaseous like diffusion and viscosity. As a result, sometimes supercritical fluids are referred to as dense gases. The variation in density of carbon dioxide as a function of temperature and pressure can be seen in the diagram. Small changes in temperature and pressure produce significant changes in density and solvating power. An example of this is naphthalene which is practically insoluble in low pressure carbon dioxide. At 100 bar the solubility is 10 g/L and at 200 bar it is 50 g/L. It is this impact on the solvating power and the ability to tune the solubility that enables the supercritical processes to have improved characteristics compared to traditional processes. In the case of carbon dioxide there are many significant advantages as it is naturally occurring, inexpensive, colourless, odourless, tasteless, non-flammable, non-ozone depleting and non-toxic. In addition it has gaseous like diffusivity and viscosity and complete miscibility with gases. It is also one of few solvents that can be unrestrictedly used for food processing.



General flow sheet for a SCF process

The Process

The fluid is stored in the work tank, as a liquid at high pressure from where it is sub-cooled before being fed to the pump. The pump increases the pressure of the fluid which is then heated to the desired temperature. The operating conditions vary between processes, so the standard pumping loop has a maximum pressure of 500 bar and a maximum temperature of 200 °C. The fluid then enters the application dependant part of the process, extractor, reactor or washing chamber, to e.g. extract an oil or convert reactants to products.

The fluid then passes through a pressure control valve, which reduces the pressure of the product mixture to subcritical conditions.

The product mixture enters the separators where heat can be added, to assist in the separation of the product and gaseous fluid. The liquid product will stay in the separator vessel and is periodically drained away to an atmospheric product storage vessel.

The gas phase from the separator enters the condenser where the fluid is condensed and returned to the work tank.

Typical applications of the SCF process technologies:

Extraction

Supercritical fluid extraction technology has been developing since the early seventies. Large scale applications are found in the field of natural products such as extraction of hops for beer manufacturing and decaffeination of coffee beans. When used in the supercritical state, the fluid can achieve similar solvating power to their organic competitors, such as hydrocarbons and chlorinated solvents. With the ever tightening environmental legislation, companies are looking for extraction processes with flexibility that do not use harmful solvents. Supercritical extractions certainly fit these advanced processing requirements.

Reaction

SCF Reactions have been proven in numerous fields to offer an alternative method of producing chemicals without the need for hazardous solvents. The supercritical reaction processes have shown that over a fixed bed catalyst, quantitative conversion can be achieved, and even pure isomers can be selectively produced. The ability to tune the pressure and temperature enables this to be optimised. SCF reactions in the fields of hydrogenation, Friedel-Crafts acylation and alkylation, etherification and hydroformylation have been proven by Chematur's partners Thomas Swan & Co and Nottingham University, to be economic and to enable quantitative conversions.

SuperDebind™

In the manufacturing of Powder Injection Moulding (PIM) components, binders such as waxes and polymers must be removed before the final sintering. This step is often the bottleneck as it ties up the expensive oven for many hours. By using $scCO_2$ for part of the debinding to remove waxes, valuable capacity increase in the sintering oven can be gained, often together with improved quality.

Other SCFT processes available

- Particle formation
- Textile dying
- SCF Chromatography
- Polymerisation reactions

Facts about SCF processes

- Integrated solvent recovery
- Integrated product separation
- Temperature and pressure can be “tuned” to modify the process performance
- Addition of co-solvents increases the range for SCF processes
- SCFs are miscible with gases giving quick processing
- Commonly used SCFs are environmentally friendly solvents that are non-toxic or non-flammable
- No liquid wastes are produced
- Processes are simple and safe

Typical SCF pumping loop specification

Flowrate	40 to 20 000 kg/h
Pressure	500 bar
Temperature	100 to 200 °C

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