Part One
Introduction

Industrial High Pressure Applications: Processes, Equipment and Safety, First Edition. Edited by Rudolf Eggers.

1
Historical Retrospect on High-Pressure Processes

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The historical development of high-pressure processes since the beginning of the industrial period is based on two concepts: first, the transfer of the inner energy of water vapor at elevated pressures into kinetic energy by the invention of the steam engine; second, the movement of gas-phase reaction equilibrium at high pressures enabling the production of synthetic products like ammonia. Thus, the industrial use of high-pressure processes goes back to both mechanical and chemical engineering. Beginning in the second half of the eighteenth century, the need of safe and gas-tight steam vessels up to few megapascals became essential because that time many accidents happened by bursting of pressure vessels. Chemical industry started high-pressure synthesis processes in the early twentieth century. Compared to moderate working pressures of steam engines, the pressure range now was extremely high between 10 and 70 MPa. As a consequence, a fast growing requirement for high-pressure components like high-pressure pumps, compressors, heat transfer devices, tubes and fittings, reliable sealing systems, and in particular new pressure vessel constructions developed.

Besides, mechanical and chemical engineering material science has promoted the development of new high-pressure processes by creating high ductile steels with suitable strength parameter.

Finally, the safety of high-pressure plants is of outstanding importance. Thus, in the course of development, national safety rules for vessels, pipes, and valves have been introduced by special organizations. For example, in 1884, the American Society of Mechanical Engineering (ASME) launched its first standard for the uniformity of testing methods of boilers. The German society TÜV was founded in 1869 in order to avoid the devastating explosions of steam vessels.

The following list of year dates shows essential milestones of high-pressure processes concerning their development and technical design:

1680: Papins construction of the first autoclave for evaporating water. The design shows the idea of an early safety valve working on an adjustable counterbalance.
1769: James Watt introduced the steam engine transferring thermal energy in motive power.

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1826: Jacob Perkins demonstrated the compressibility of water by experiments above 10 Mpa. Caused by the increasing application of steam engines, the boiling curve of different media became of interest. It was observed that boiling temperatures increase with rising pressure. That time one assumes a remaining coexistence of liquid and gas phase up to any high pressure. It was the Irish physicist and chemist Thomas Andrews who in 1860 disproved this assumption. On the basis of experiments with carbon dioxide, he was able to demonstrate a thermodynamic state with no difference between liquid and gas phase characterized by a distinct value of temperature, pressure, and density. This point has been called the "critical point."
1852: J.P. Joule and W. Thompson discovered the cooling effect caused by the expansion of gases during pressure release.
1873: J.D. van der Waals gives a plausible explanation for the behavior of fluids at supercritical condition.
1900: W. Ostwald claimed a patent on the generation of ammonia by the combination of free nitrogen and hydrogen in the presence of contacting substances.
1913: F. Haber and C. Bosch: First commercial plant synthesizing ammonia from nitrogen and hydrogen at 20 Mpa and 550 °C. The reactors were sized at an inner diameter of 300 mm and a length of 8 m. The productivity of one reactor was 5 ton/day [1]. The pressure vessel was equipped with an in-line tube made from soft iron and degassing holes in order to protect the pressure-resistant walls against hydrogen embrittlement. This process was the forerunner of many others that have been developed into commercial processes [2].
1920: First application of methanol synthesis as a conversion of carbon monoxide and hydrogen at a pressure of 31 MPa and temperatures between 300 and 340 °C.

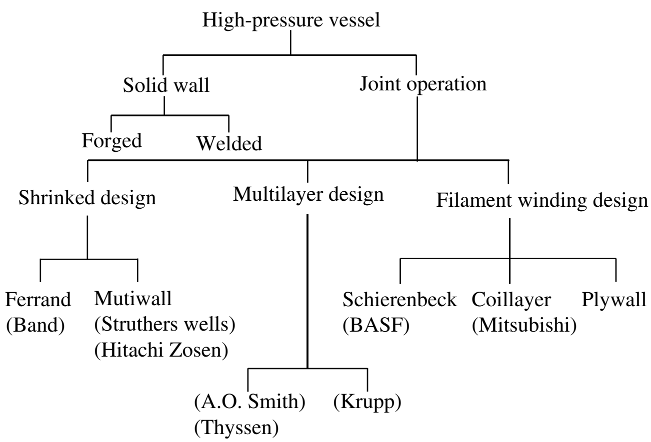

Figure 1.1 Survey on high-pressure vessel design [3].

1924: First industrial plant for direct hydrolysis of fuel from coal at 70 MPa based on the Bergius process, which was claimed at 1913.
1953: Initiation of a polyethylene production at about 250 MPa.
1978: First commercial decaffeination plant using supercritical carbon dioxide as a solvent.

The development of high-pressure vessel design is characterized by the initiation of seamless and forged cylindrical components. The two versions are the forged solid wall construction and a group of different layered wall constructions. Among these, the BASF Schierenbeck vessel plays an important role, because these vessels are manufactured without welding joints. Figure 1.1 presents an overview.

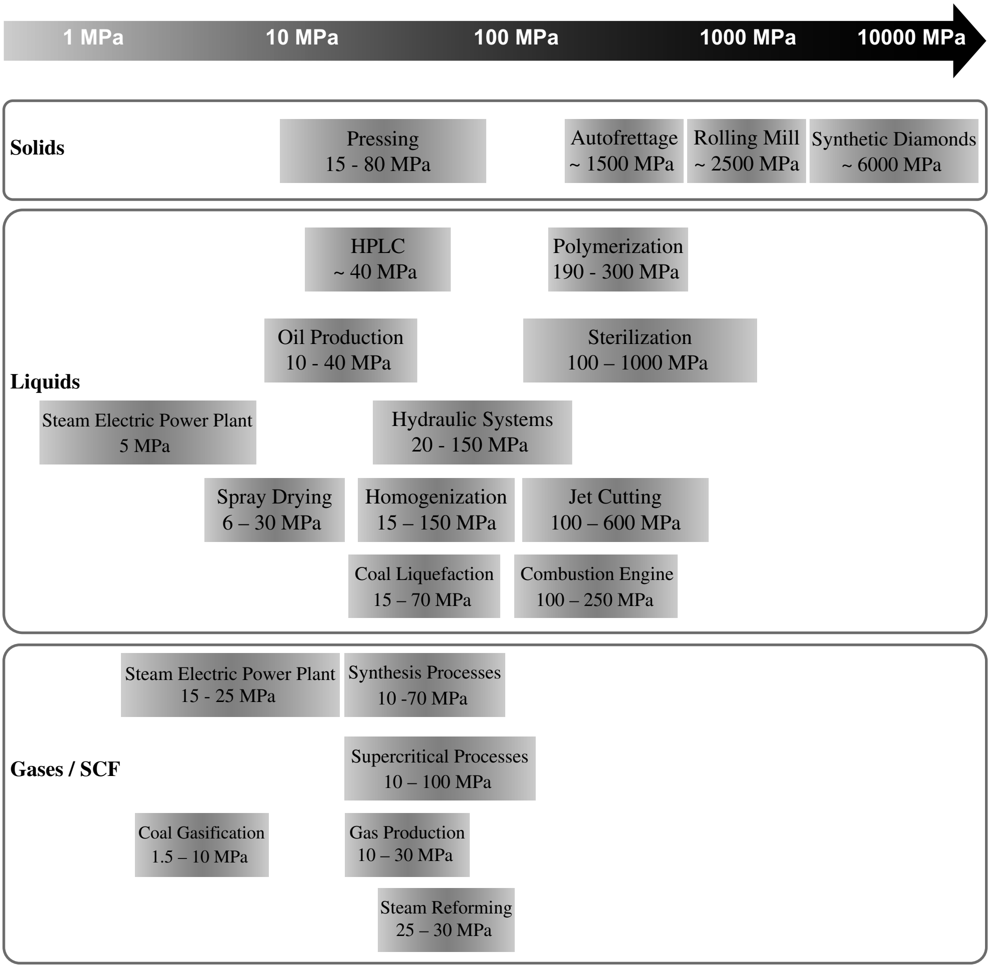

Figure 1.2 Working pressures of currently used high-pressure processes.

Special high-pressure closures have been developed equipped with single or double tapered sealing areas. A breakthrough toward leak-tight high-pressure devices was without doubt the “principle of the unsupported area” from Bridgman [2]. His idea extended the accessibility of pressures up to 10 000 MPa. Another concept is that the metallic lens ring enabled safe connections of high-pressure tubes and fittings.

Up to now new high-pressure processes have been introduced constantly. Materials like ceramics, polymers, or crystals having special properties are generated and formed in high-pressure processes. The current increase in liquid natural gas (LNG) plants is not possible with safe high-pressure systems. Also, the enhanced recovery of oil and gas by fluid injection at very high pressures requires qualified compressors, tubes, and safety valves. High-pressure fuel injection decreases the efficiency of combustion engines.

An example of current development is the investigation of processes aiming homogenization and even sterilization in industrial scale at high pressures up to 1000 MPa. Figure 1.2 illustrates the pressure regimes of currently operated high-pressure processes.

References

1 Witschakowski, W. (1974) Hochdrucktechnik, Schriftenreihe des Archivs der BASF AG, Nr. 12.

2 Spain, I.L. and Paauwe, J. (eds.) (1977) *High Pressure Technology*, vol. I, Marcel Dekker Inc., New York.

3 Tschiersch, R. (1976) Der Mehrlagenbehälter. *Der Stahlbau*, **45**, 108–119.