temperature. This regenerative process goes on with continuous reduction of temperature until the air liquefies as it expands out of the motor. This method of producing liquid air seems to be the most successful of any for large installations.

4. The cooling of gases by the Joule-Kelvin effect.

If a gas be expanded from a high pressure to a lower pressure it suffers a slight change of temperature due to a readjustment of the internal energy. It is found that at ordinary temperature hydrogen and helium are slightly warmed, while all other gases are cooled slightly. The amount of the cooling or heating depends on the temperature at which the gas is taken for the experiment. If the experiment with air is carried out at a lower temperature, the cooling effect is greater. If we perform the experiment with hydrogen below about —90°, we find that the gas is cooled by this expansion just as in the case of air, while if we operate with air at a very high temperature it is heated. This is only another example of the law of corresponding states.

To liquefy air by utilizing the Joule-Kelvin effect, the air is first compressed as in the Claude process and expanded through a small opening, cooling itself as it expands. The same regenerative process is applied as in the Claude process and the temperature is finally lowered to the temperature at which air liquefies, viz., —190°.

In the early days of low temperature investigation freezing mixtures and boiling under reduced pressure were commonly used. So at Leiden we find a series of operations for production of low temperature. Methyl chloride will liquefy if compressed only a little—a few atmospheres suffices. It is then boiled under reduced pressure with the aid of a powerful vacuum pump, by which means the temperature is lowered to —90°. Then ethylene, which has a critical temperature of 10° and thus cannot be liquefied at ordinary temperature, is cooled in the cold of the methyl chloride chamber and liquefied under pressure. It then flows into a second vacuum chamber where the vacuum is maintained by another pump and temperature drops to —140°. Next, oxygen under pressure is cooled in this chamber, liquefied and poured into a third vacuum chamber