

1879

# Idea № 0001 – 0060

1879 – 1890 From refrigeration  
pioneer to international technology leader

## From the first refrigeration machine to an independent company

At a sometimes staggering pace and with a great love of experimentation, Carl von Linde created a new industry within just a few decades: refrigeration. His engineering company, the “*Gesellschaft für Linde’s Eismaschinen*,” was characterized from the very beginning by innovativeness and close customer relations.

Carl von Linde, a professor at the Technical University of Munich (see also page 12), had come upon refrigeration as an area of research by way of a contest for a cooling unit for the crystallization of paraffin. “The thought immediately struck me: here was an area of mechanical thermodynamics that had not yet been fully explored,” he said, describing his newly awakened curiosity in his 1916 memoir “*Aus meinem Leben und von meiner Arbeit*.”

Von Linde immediately set about laying the theoretical groundwork for an “improved ice and refrigeration machine.” In his calculations of caloric efficiency, he had come to the conclusion that the cold vapor machine promised the highest yield of cooling energy as compared to the absorption machine and the cold air machine. The method he conceived would work with the lowest possible temperature differences and use methyl ether as the refrigerant.

### Initial contacts with breweries

After von Linde had published his ideas in 1870 and 1871 in the Polytechnic Association’s “*Bavarian Industry and Trade Journal*,” which he also edited, a development was set in motion that would determine the direction of the entire rest of his life. His articles on refrigeration technology had aroused the interest of brewers who had been looking for a reliable year-round method of refrigeration for the fermentation and storage of their beer.

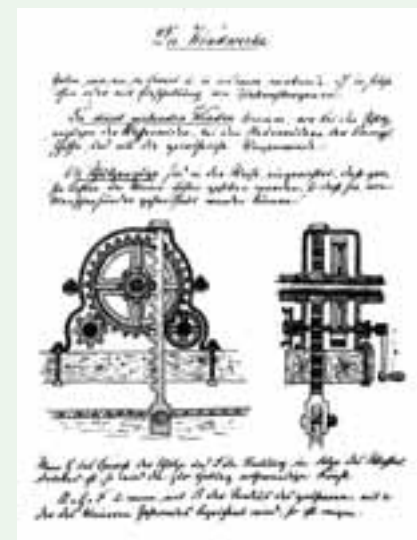
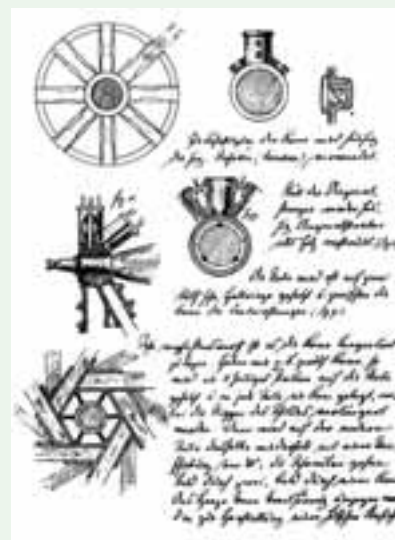
In the summer of 1871 an agreement was made between von Linde, Austrian brewer August Deiglmayr (Dreher Brewery) and Munich brewer Gabriel Sedlmayr to build a test machine according to Linde’s design at the Spaten Brewery. With their help,

Linde’s ideas would be put into practice, so that a refrigeration unit could then be installed at the Dreher Brewery, the largest brewery in Austria, in the hot, humid city of Trieste (now part of Italy).

### Building the first Linde ice machine

The construction plans were finally completed in January 1873 and the patent applied for. The Bavarian patent required, however, that the machine be in operation within one year. Therefore von Linde and Sedlmayr placed an order with *Maschinenfabrik Augsburg* that same month to build it. And with some effort they succeeded in starting operation by the important patent deadline in January 1874. Of course, the first machine did have its difficulties.

The main problem was that von Linde’s mercury seal did not work properly so that the methyl ether used as the refrigerant leaked out of the compressor. In Linde’s words, “This design was not a suitable solution for the requirements of practical use. So it seemed imperative to build a second machine.”



Sketches and notes from Carl von Linde’s early lecture drafts when he served as an instructor (1868-1879) at the Polytechnic School in Munich (today TU Munich).

# Nº 0001

The first refrigeration machine with methyl ether as the refrigerant.



The first Linde refrigeration machine ever sold, an improvement on the original model from 1873, started up in 1877 at the Dreher Brewery in Trieste (now Italy).

# Nº 0003

Refrigeration machine  
with horizontal ammonia compressor.

In order to finance it, von Linde assigned part of the patent rights to Sedlmayr, to locomotive builder Georg Krauss and to the director of *Maschinenfabrik Augsburg*, Heinrich von Buz. In return, they provided the funds needed for the development, building and testing of a new refrigeration machine.

## Building the second refrigeration machine

With his student and assistant Friedrich Schipper, von Linde designed a new compressor, which had a significantly simpler and more effective seal. The sealing material used in the newly designed gland construction was glycerin and the more efficient ammonia was used as the refrigerant. The new machine weighed and cost only half as much as its predecessor.

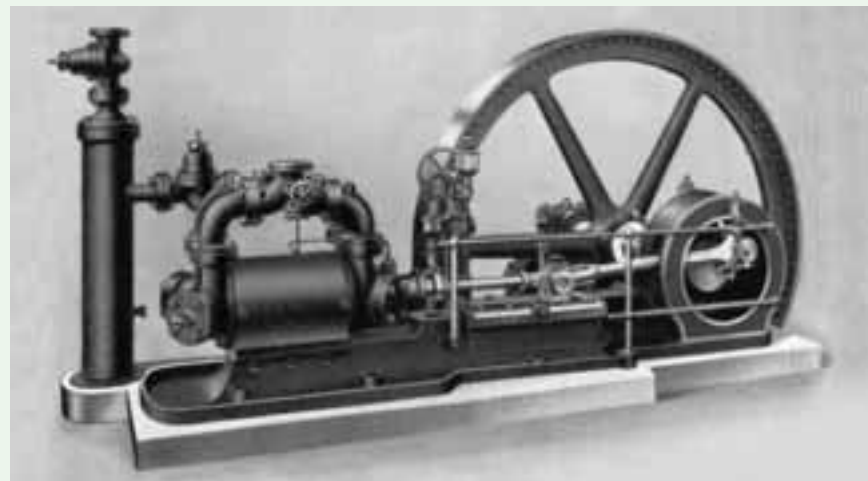
In the spring of 1875 Linde ordered the new compressor from *Maschinenfabrik Augsburg* and submitted it for a Bavarian patent, which was awarded on March 25, 1876 for ten years. He received the German *Reichspatent* in August 1877.

“The very first trials with this second compressor yielded fully satisfactory results,” said von Linde, not without pride. The machine was sold to the Dreher Brewery in September 1876, erected under Schipper’s supervision and started up in spring 1877. It ran until 1908, providing refrigeration and dehumidification.

## Technical breakthrough

But despite this success, Linde created a third design immediately after the second machine was installed at Dreher, turning his attention to gas pumps, which were already widely used. This third, horizontal design proved to be the best cold vapor machine on the market in terms of its price/performance ratio and became the standard type of Linde compressor for decades to come.

During the more than six-year development and experimentation phase, a reliable solution also had to be found for distributing the generated cold. After long trials, in executing an order for the Heineken Brewery in Rotterdam, von Linde developed a method of circulating cold saltwater brine in a pipe cooling system (natural convection cooling), which was installed on the ceiling of the refrigeration rooms.



Horizontal two-stage ammonia compressor by Carl von Linde, the traditional design for major refrigeration units (approx. 1900).

## Entering the refrigeration market

After Linde and his friends in the breweries had developed a reliable functioning and economic refrigeration system, it was time for him, together with his licensees, *Maschinenfabrik Augsburg* and the Swiss company *Gebrüder Sulzer*, as well as sales representatives Satre & Averly in Lyon, Carels Frères in Ghent and Morton in Great Britain, to pursue a larger customer group.

They found open doors with many European brewers: Because not enough ice was available in warm winters for fermentation and cooling the cellars, Linde’s powerful refrigeration machines quickly found strong interest. In addition to the ice machines, von Linde soon also supplied equipment to automate the cooling process and make it more efficient, thus saving strenuous manual labor. Finally, he was able to produce the crystal-clear artificial ice preferred by his customers.

1882  
First electric streetlights in Berlin.

Nº 0006  
Improved gland design.

Nº 0010 Circulation of cold saltwater brine in cooling tubes for direct cooling of fermentation and storage cellars, known as natural convection cooling.

## First customers and partners: brewers

In 1840, many continental European breweries switched to bottom-fermented lager production (in contrast to the “English” top-fermented brown beers or ales) because the beer remained fresh longer and customers preferred the taste. The ice machine described by von Linde seemed ideal for achieving the required lower temperatures and to ensure precise cooling control. So it is no wonder that some major brewers showed great interest in this invention.

Gabriel Sedlmayr of the Munich Spaten Brewery was willing to let von Linde experiment with an early refrigeration machine in his brewery in the early 1870s. The first unit functioned passably well, but was too large and had numerous flaws. The drawings submitted for the patent showed that Sedlmayr himself had a hand in the second version, which was significantly smaller in size and worked well. This unit was sold to the Trieste Dreher Brewery for air cooling.

With Sedlmayr as an intermediary, the Rotterdam Heineken Brewery under its director Feldmann ordered an ice machine in 1877 for ice production. In his collaboration with the Heineken Brewery, Linde developed “natural convection cooling” with a system of cooling pipes under the

ceiling of the cellar. Feldmann in turn put von Linde in contact with J. C. Jacobsen, head of the Carlsberg Brewery in Copenhagen, who ordered a large refrigeration unit in 1878.

Karl Lang, technical adviser and supervisory board member of several Rhineland breweries, also played a significant role during the founding period of the “*Gesellschaft für Linde’s Eismaschinen*.” He introduced Linde to brewery director Gustav Jung, who not only ordered a refrigeration unit but also became, with Lang and banker Moritz von Hirsch, a shareholder and Supervisory Board member of the Linde Company.

The connection between the Linde Company and brewery directors was maintained to some extent over several generations. After the death of Karl Lang in 1894 his position as chairman of the Supervisory Board was taken over by Gustav Jung, followed by his son Adolf Jung in 1886. Carl Sedlmayr took over for his father Gabriel on the Supervisory Board and in 1915, the third generation of this family followed with Anton Sedlmayr. The Jung and Sedlmayr families held their Supervisory Board seats until after the Second World War.

Even before the founding of the “*Gesellschaft für Linde’s Eismaschinen Aktiengesellschaft*,” von Linde had already delivered 20 refrigeration systems in Europe. In 1878 already, the professor decided to bundle his activities into a company and concentrate on refining and marketing his refrigeration machines. In order to do so, he had to leave his stable job in the civil service.

His negotiations with Karl Lang, the technical adviser and supervisory board member of many Rhineland breweries, were a decisive factor in this decision. In 1878 he advised Carl von Linde to give up teaching and take up a position as head of his own company.

## Going into business

After thinking it over for some time, von Linde decided to give up his secure civil service position as a university instructor and jump into the risky world of business. With Lang and banker Moritz von Hirsch, who wanted to help finance the young company, von Linde came to an agreement on pension and disability pay, in exchange for which he granted them patent rights. In addition to Lang and von Hirsch, Linde’s previous partners Gabriel and Johann Sedlmayr, locomotive manufacturer Georg Krauss and Heinrich von Buz, Director of *Maschinenfabrik Augsburg* subscribed for shares in the recently-founded “*Gesellschaft für Linde’s Eismaschinen*.” Finally in May 1879, Gustav Jung, owner of the *Aktienbrauerei* in Mainz, also became a shareholder in the company, which made Wiesbaden its main location.

At first the young company’s purse strings were tight. Against von Linde’s calls to fund the company with 400,000 marks starting capital, Hirsch and Lang insisted on investing only 200,000 marks – and not even in cash, but by contributing the patents. The original supervisory board at the company’s founding on June 21, 1879 included Lang (chairman), Sedlmayr, Krauss, Buz and Jung.



Fermentation cellar of a brewery with natural convection cooling.

The company had humble beginnings in terms of personnel as well: Its entire staff consisted of one board member and one designer. And business was extremely slow in the beginning. Linde wrote in his memoirs, "Our quiet beginning was answered during the initial months by an almost oppressive silence in the progress of negotiations and orders for refrigeration systems so as to give the impression that the initially urgent demand had already been satisfied."

But of course that was quick to change. The small engineering office was at the leading edge of a turbulent development, which would soon make it the main supplier of refrigeration equipment even beyond the German border.

### A successful start in a difficult environment

The overall economic conditions in Germany in the 1870s and 1880s did not look especially rosy. After the short boom from 1871 to 1873, which in Germany is known as the *Gründerzeit* or founders' era, the German economy crashed dramatically. While the "Great Depression" of the Bismarck era had already reached its lowest point in 1879, the slow economy continued in a less severe form in the course of 1894.

Only the German compressor and refrigeration machine company survived an industry-specific boom and quickly captured a leading international position. The "*Gesellschaft für Linde's Eismaschinen*" benefited especially from this dynamic development because it was represented in all of the important markets early on and could offer the most efficient products.

### Weather as an ally

The most important customers of the refrigeration machine builders remained the breweries through the turn of the 20th century. The fast penetration of cooling fermentation cellars and fermentation vats with manufactured ice was assisted by the weather to bring direct cooling into the storage cellar.



The first supervisory board of the *Gesellschaft für Linde's Eismaschinen*  
Top: Chairman Karl Lang; below from left: Carl Sedlmayr, Georg Krauss,  
Heinrich von Buz and Gustav Jung.

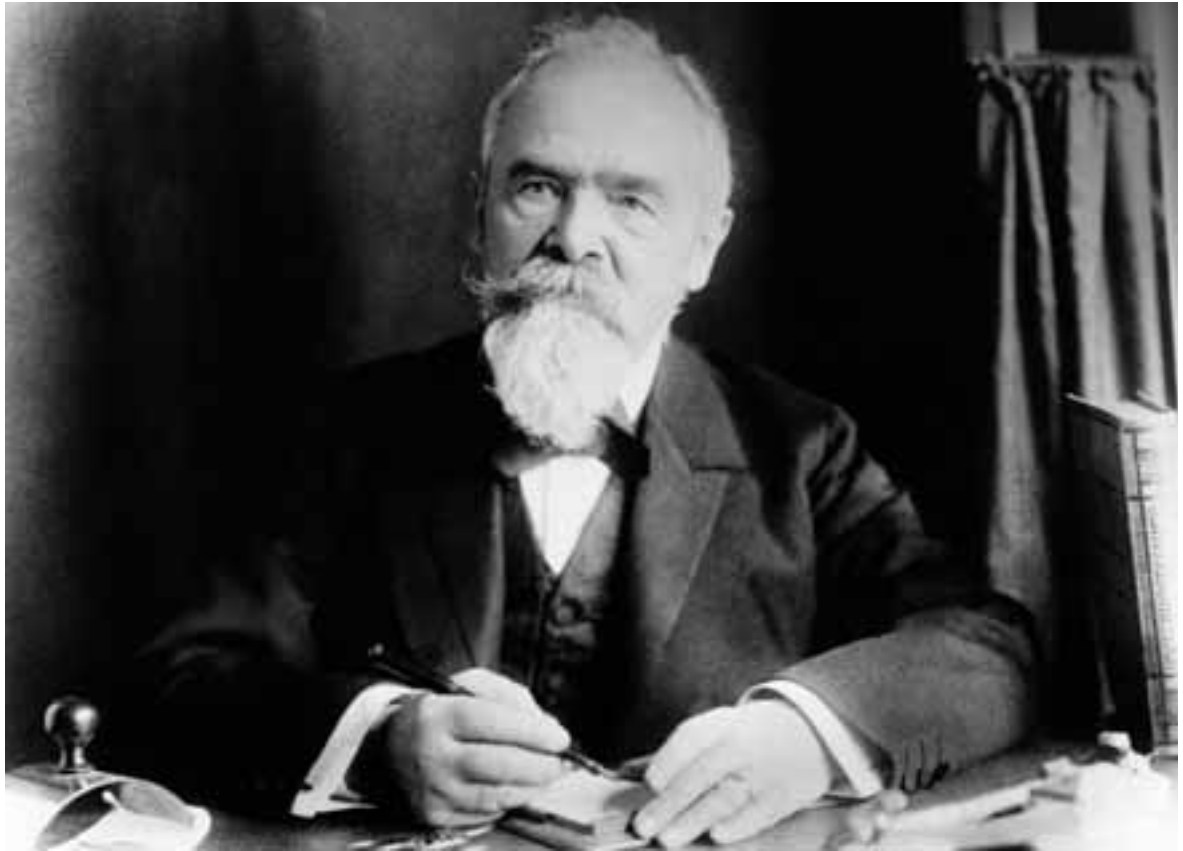
## Carl von Linde – gifted engineer and entrepreneur

When Carl von Linde was born on June 11, 1842 in the Lutheran parsonage of Berndorf in the Oberfranken district of Bavaria, he was never expected to forge a career as a distinguished scientist, gifted inventor and successful entrepreneur. His father Friedrich would have liked to have seen the third of his nine children follow in his footsteps as minister.

However, the family's move to Kempten, where his father was assigned a parish, and his later attendance at the local high school put Carl von Linde in close contact with the family of the director of the Kempten cotton spinning mill. His frequent visits to the factory, with its impressive power machines stimulated in the youth an interest in technology and a desire to study engineering.

Despite the tight financial situation in the parson's large household, von Linde was able to convince his father to allow him to study mechanical engineering at the leading technical university of the time, the Polytechnikum in Zurich, Switzerland. There, his most important teachers were Dr. Zeuner (mechanics and theoretical machine studies), Dr. Reuleaux (mechanical engineering) and Dr. Clausius (physics), he reported in his memoir *"Aus meinem Leben und von meiner Arbeit"* (My Life and Work). It was also Zeuner and Reuleaux who wrote personal letters of recommendation for Linde when he had to leave the Polytechnikum without officially graduating as a result of a student protest.

Von Linde received his first practical training as an intern in the mechanical workshop of the Kottner cotton spinning plant near Kempten, then at Borsig in Berlin. He started work as an engineer in the Borsig drawing office in August 1865.



Carl von Linde at the age of 83 (1925).

At the end of 1865, Carl von Linde applied to become the head of the technical office upon the founding of the Krauss & Co. locomotive factory in Munich. On February 20 or the following year he received this position and celebrated by becoming engaged to Helene Grimm on February 26 before leaving Berlin. The wedding was held September 17 in Kempten. During their 53-year marriage, the Lindes had six children: Maria (1867-1954), Franziska (1868-1966), Friedrich

(1870-1965), Anna (1873-1949), Richard (1876-1961) and Elisabeth (1880-1959).

Still, the young Linde, not yet 25 years old, had aspirations beyond the drawing office into science and teaching. On the recommendation of the founding rector of the Polytechnic School in Munich (later Technical University) he was hired as an associate professor on August 24, 1868 and on December 24, 1872 was promoted to full professor of mechanical engineering. He included the theory of refrigeration

machines in his teaching syllabus.

So that he could also give his students practical instruction, the Bavarian government approved 70,000 florins to set up a machine laboratory – the first of its kind in Germany. It would become the starting point for his groundbreaking developments in refrigeration technology.

During his first teaching period from 1868 to 1879, the restless von Linde was already involved in various technical associations – an activity that would take a

# N<sup>o</sup> 0016

Device for the evaporation and direct exchange of heat between a liquid forming drops and a gas.

considerable amount of his time during his term as head of the “*Gesellschaft für Linde’s Eismaschinen*” in 1890 after his return to Munich.

Professor von Linde is thus one of the founding fathers of the Bavarian Boiler Review Association and the Munich Thermal Testing Station. In the Polytechnic Association he examined applications for a Bavarian patent and served as part of the Berlin commission that reformed German patent law.

Back in Munich and armed with an honorary professorship (it was converted into a full professorship without teaching duties in 1900), von Linde took the position of Bavarian district chairman of the Association of German Engineers (VDI) in 1892 and was elected chairman of the Bavarian Boiler Association. In 1895 he was appointed to the board of trustees at the German Physical-Technical Institute, one year later to the Bavarian Academy of Science. In 1898 he joined the Göttingen Association for Applied Physics and Mathematics, from which the Kaiser Wilhelm Society and ultimately the Max Planck Society emerged.

In 1904 and 1905 he served as president of the VDI, and in 1903 he immersed himself with Oskar von Miller in the founding of the Deutsches Museum in Munich. Carl von Linde remained on the museum’s board until he was 80 years old.

As always, however, his main attention was focused on the Linde Company and its subsidiaries. His practical work in the area of refrigeration and later in air liquefaction and air separation shows the entrepreneur-engineer side of von Linde – and thus his true calling.

His entrepreneurial side was often in demand on many supervisory boards – of a few subsidiaries as well as of the locomotive manufacturer Krauss & Co., the *Mainz Aktienbrauerei*, the Trierberg Electricity Company, The Güldner engine company and *Maschinenfabrik Sürth*. This multifaceted and diverse range of commitments required an active travel schedule. Since his head engineers were very often also on the road starting up equipment at customer facilities, a unique correspondence culture developed within the Linde Company. A total of 3,010 business letters written personally by Linde alone during the years 1876 to 1929 are preserved in eleven copy books.

Although von Linde withdrew more and more from his active working life starting in 1910, he held on to some of his supervisory and advisory activities until the end of his life. His two sons Friedrich and Richard and his son-in-law Rudolf Wucherer (who was married to Linde’s youngest daughter Elisabeth) carried on his life’s work. Two of his four daughters married pastors and the eldest married psychiatrist Dr. Karl Ranke, who also sometimes served on the company’s Supervisory Board.

Carl von Linde died in 1934 at the age of 92. Over the course of his life he was awarded three honorary Doctorates, the Bavarian crown achievement medal, and was honored with elevation to personal nobility status among many other distinguishing honors.



Carl von Linde (front left) appraises the building site for the *Deutsches Museum* in Munich together with the architects and the members of the building committee (ca. 1910).



Carl von Linde (seated, 2<sup>nd</sup> from right) with his sons and daughters and their spouses.



# Nº 0023

Device for the production of block ice.



In 1892 the *Gesellschaft für Linde's Eismaschinen* opened a large plant for chilling food and producing ice in Hamburg.

When the warm winter of 1883/84 failed to yield a sufficient supply of natural ice, the last reservations as far as the reliability of artificial refrigeration were removed. And so a "veritable torrent" (Linde) of orders broke over the Linde Company and the machinery builders working with it. Happily, Carl von Linde had had sufficient ice machines in standard sizes produced for stock so that the demand could be met quickly with reliable quality.

By the end of the 1880s, the "*Gesellschaft für Linde's Eismaschinen*" had equipped 445 breweries with 747 refrigeration machines. With year-round refrigeration ensured, the breweries could now brew bottom-fermented beer in summer as well as winter and thus considerably increase their profitability.

## Ice factories under own control

During the first several months after the official founding of the company when no refrigeration machine orders were coming in, von Linde felt forced to build ice factories at his own expense.

The purpose of these sample plants was to demonstrate their efficiency and cost effectiveness. His first own ice factory was built in Elberfeld-Barmen between two breweries that had agreed to take on greater quantities of the manmade ice. At the same time, financier von Hirsch, who had acquired Linde's patent rights for France, built an ice factory in Paris. And finally, parallel to this, von Linde designed a smaller ice factory for an exhibition taking place in Düsseldorf in 1880.

In addition to Elberfeld-Barmen, the Linde Company had opened other ice factories in Stuttgart, Munich and Strasbourg by 1881. Each one produced up to 50,000 kilograms of ice per day – and at the very competitive price of 70 pfennigs per 100 kilograms. Once the ice plants had proven their profitability, they were sold by 1890 "with considerable surpluses over their book value" (von Linde). It was not until after 1896 that the "*Gesellschaft für Linde's Eismaschinen*" – certainly due to the decline in machine sales and as capital investments – again decided to build its own ice factories and cold storage facilities in Nuremberg (1896), Leipzig (1910), Königsberg (1914) and Magdeburg (1937).

## Cold storage facilities market

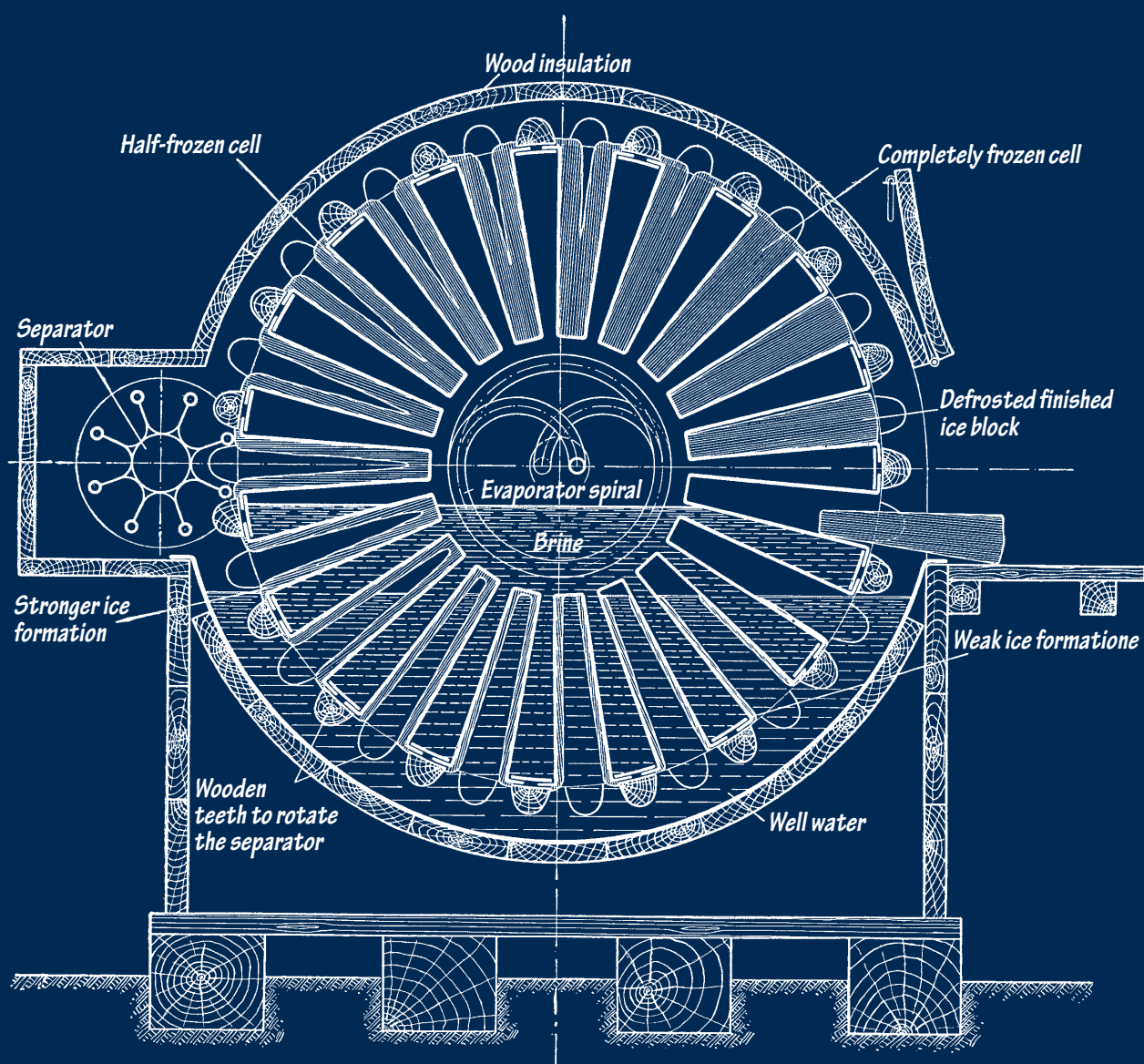
With the building of city slaughterhouses initiated by new legislation during the last third of the 19th century, the demand for cold storage houses for meat and other food products rose – another driving force for sales of refrigeration machines. The first cold storage facility for meat was built in Bremen in 1882 with von Linde called in as an adviser.

One year later von Linde supplied the equipment for the city slaughterhouse in Wiesbaden, solving the complex problem not only of generating refrigeration but at the same time dehumidifying and purifying the air.

When, at the beginning of the 1890s, nearly all larger communities in Germany built their slaughterhouses with cold rooms and cold storage houses as a result of changed legislation, this industry quickly became the second largest market for refrigeration systems.

# No 0028

Processes and devices for the preparation of distilled and air-free water for crystal ice production in compression refrigeration machines.



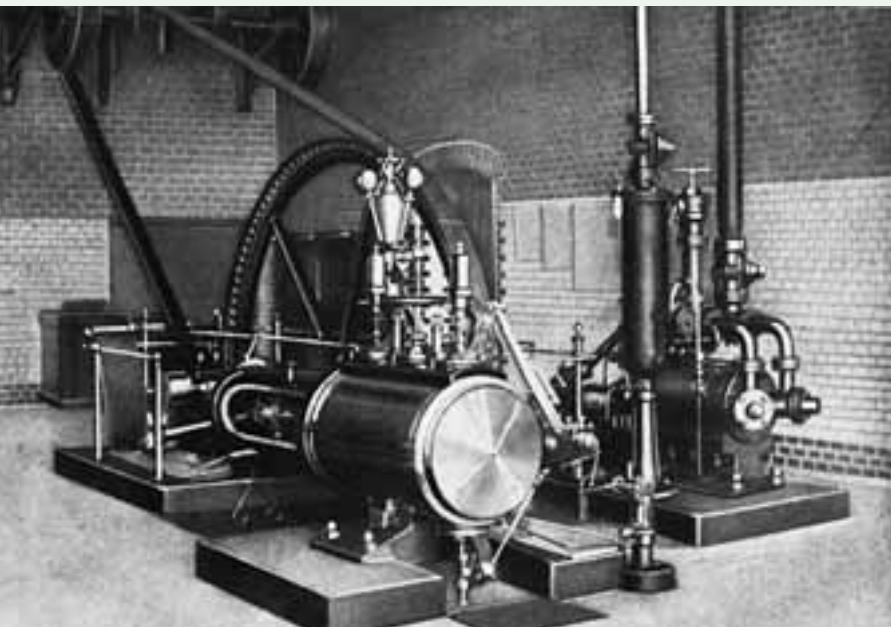
The first device for producing clear ice.

# Nº 0032

First man-made  
ice rink with Linde refrigeration in Nuremberg.



A manmade ice rink with Linde cooling was displayed at the Bavarian Industry and Trade Exhibition in Nuremberg in 1896.



In 1883 the “Gesellschaft für Linde’s Eismaschinen” equipped the Wiesbaden slaughterhouse with a refrigeration machine.

## Additional sales markets

In order to further reduce dependency on business with breweries, von Linde and his top engineers sought other application areas for the new refrigeration technology: ice skating rinks, refrigerator and freezer units for ships and railroad cars and even cooling systems for living spaces. For example, Carl von Linde prepared the complete building plans, including “installations for the dehumidification and temperature control of the air in the living and sleeping areas” of a planned hotel in Calcutta, India. Nothing ever came of this, however, because the financing for the project fell through.

Far greater economic importance came to methods of extracting sugar from sugar beets, refrigerating milk in dairies and refrigeration in chocolate factories. There was also a cooling process for aniline production, refrigeration systems for crystallization from brines and for benzene extraction and refrigeration machines for the liquefaction of carbon dioxide and chlorine – even a method of freezing asparagus. The many new markets for refrigeration technology ensured increasing order receipts when the sales boom in the brewery industry flattened out after 1890 due to market saturation.

By its 50-year anniversary, the company had thus struck a balance: By the end of 1929, the “Gesellschaft für Linde’s Eismaschinen” had sold 6,599 large refrigeration machines, with 2,057 to breweries, 1,865 for food refrigeration, 727 to ice factories, as well as 14 to mines for sinking shafts in the frozen subsoil and three for cooling furs, to name just a few. All in all, the 50-year anniversary chronicle lists 17 countries and regions where refrigeration machines were sold – ranging from Argentina and Central America to China, Japan and Russia.



Imperial patent for Carl von Linde for his first refrigeration machine (1877).

# N<sup>o</sup> 0037

Process and  
device for defrosting air cooling tubes.

## Business model and early internationalization: factors for success

A number of factors underlie Carl von Linde's success in developing his young business into Germany's leading international supplier of refrigeration machines within just ten years:

*The business model.* As an entrepreneur, Carl von Linde relied from the very start on close cooperation with potential users of his technology, above all beer brewers. In production he relied in turn on a few machinery manufacturing companies. But von Linde insisted that only his engineers, assemblers and installers would install and start up the machines at the customers' facilities, thus ensuring direct and exclusive contact with the customers.

*Loyalty.* One of von Linde's closest confidants was Heinrich von Buz, the director of *Maschinenfabrik Augsburg* (later MAN). Over their entire business relationship of 50 years or so, von Buz sat on the Linde Supervisory Board for 39 years. In the Sulzer brothers von Linde found highly competent people to turn to for technical problem-solving. Von Linde also had the Sulzer connection to thank for the fact that his company became the largest supplier of refrigeration machines for the meat industry in Argentina.

*Personnel policies.* Over the years, von Linde preferred to hire graduates of the Technical University of Munich whom he knew personally or who were recommended to him by his teaching successor at the university, Moritz Schröter. Friedrich Schipper, Robert Banfield, Rudolf Diesel (see also page 38), Karl Heimpel, Hermann Reuther, August Krebs and Alexius Negele, among others were all alumni of TC Munich. Von Linde also relied on family members. During the early years, two of his brothers and a brother-in-law worked for Linde's company. They were followed by two nephews, two sons-in-law and two of his own sons, physicist Friedrich and engineer Richard Linde, who, together

with their brother-in-law Rudolf Wucherer largely determined the fortunes of the company through the middle of the 20th Century (see also page 45).

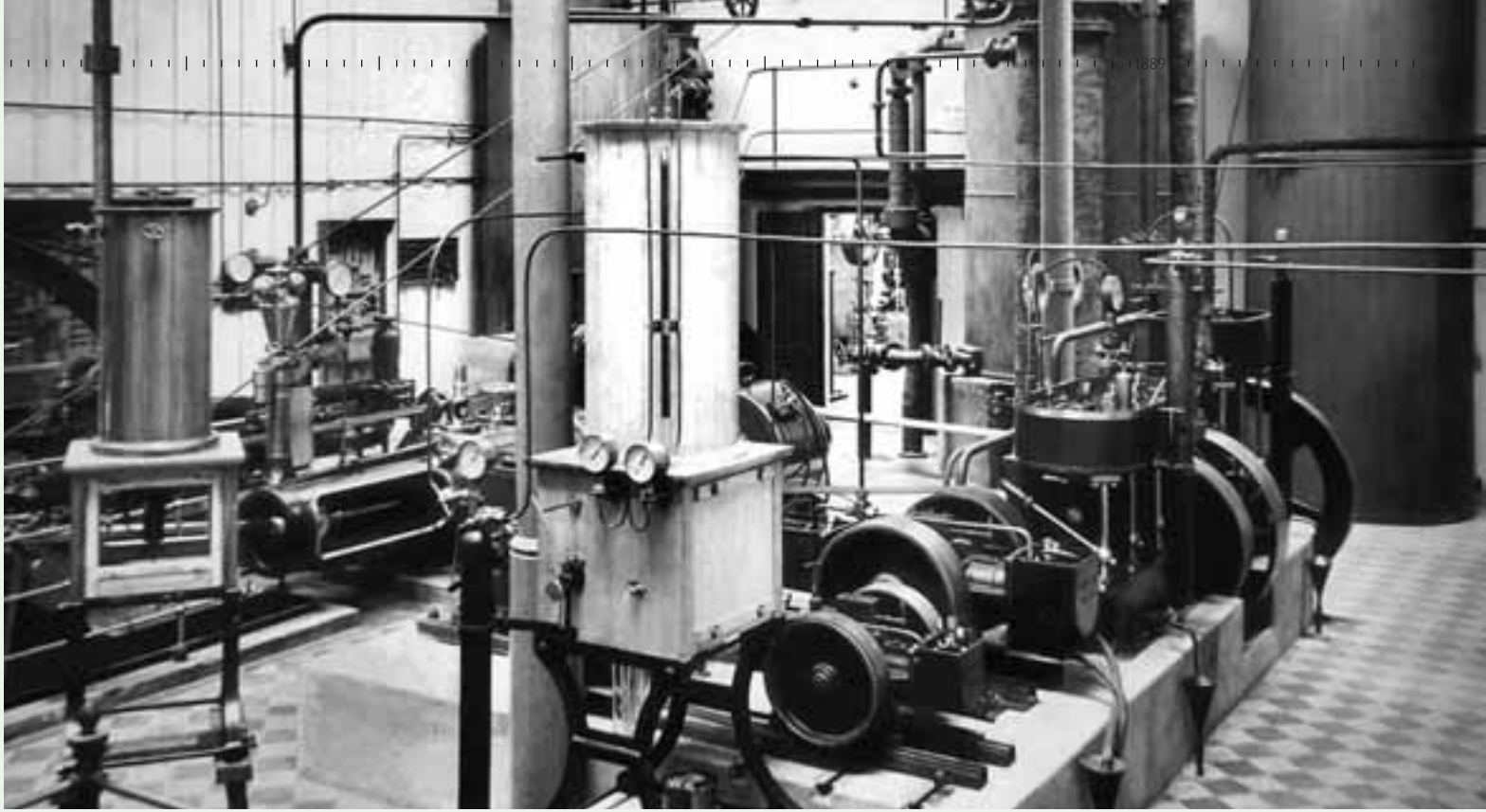
*Compensation.* In order to create the strongest possible ties between his key people and the company, von Linde paid above-average salaries. Head engineers could earn between 15,000 and 20,000 marks per year including profit sharing during the 1890s. Unlike the engineers, for a long time the commercial employees in the company did not play an especially major role. It is a telling fact that prior to the Second World War no commercial employee was ever appointed to the company's Executive Board.

## Early internationalization

For decades Linde's first production partners remained his most important ones, such as *Maschinenfabrik Augsburg* and *Gebrüder Sulzer* in Winterthur, Switzerland. However, because of differing patent regulations in each country, the size of the markets and for reasons of caution, the number of license partners within and outside Germany quickly rose, which didn't always appeal to the company's most important business colleagues.

### France

In France, after a few detours and false starts, von Linde established a relationship with Satre & Averly of Lyon in 1877. This company also built the first machine in order to secure the French patent. But after the founding of the Linde Company, shareholder Moritz von Hirsch took over Linde's patents in France and founded the "*Société pour la production de glace et d'air froid d'après le système Linde.*" Business, however, was unsatisfactory, so von Linde bought the license rights back from this major shareholder in 1890 and awarded them to the CAIL company.



The testing station for refrigeration machines built in Munich in 1888. It was also the site of the first trials in air liquefaction. In the foreground: Two small air liquefiers.

#### Great Britain

In England von Linde began a cooperation with brewery equipment manufacturer Robert Morton in 1876, but the latter soon switched to a rival product. After fruitless agreements with other partners, a joint venture was finally established in London, the "Linde British Refrigeration Corp." in London, whose shareholders included the Austro-Bavarian Lagerbeer Brewery, the Atlas Engine Works and the "*Gesellschaft für Linde's Eismaschinen*." The company, which began building Linde machines in England in 1892, was headed by English refrigeration pioneer T. B. Lightfoot.

#### Belgium/the Netherlands

The entry into the Belgian/Dutch market was not without its problems. Finally in 1886 the Linde Company founded the cold storage company "*Société Anonyme des Frigorifères d'Anvers*" in Antwerp with some Dutch and Belgian business associates, which at the same time served as the "base for the increasingly important supplier business to Belgium and Holland" (Linde).

#### Austria-Hungary

The licensing process in Austria-Hungary looked like a relay race until in 1881 Linde's employee Karl Heimpel established himself as an independent representative in Vienna. After 1890, four

machinery factories in Austria-Hungary began production of Linde machines within a short time of one another. (In 1913 the competition among the Austrian machine builders was ended by a cartel-like division of the market.)

#### United States

Carl von Linde started out well in the United States: His collaboration with the German-speaking brewery equipment manufacturer Fred Wolf from Chicago, which began in 1879, developed smoothly. Wolf first imported refrigeration and vapor machines from Sulzer and in the mid-1880s began his own production of refrigeration machines (see also page 35).

#### Competition in refrigeration

Carl von Linde's quick success naturally attracted competitors to the field who wanted a piece of the booming refrigeration market. Traditional machine builders rose to become the most serious competition. They were able to benefit from their know-how in building vapor machines, pumps and gas engines as well as from their sales networks.

## Dr.-Ing. E.h. Friedrich Schipper (1849–1929)



Dr.-Ing. E.h. Friedrich Schipper, Chairman of the Executive Board from 1890 to 1924.

The son of a pharmacist, Schipper was already one of Carl von Linde's closest associates and confidants even before the founding of the "*Gesellschaft für Linde's Eismaschinen*." As early as 1873 he was involved in his teacher von Linde's development and testing work in refrigeration. He succeeded him in 1890 as head of the company and worked for Carl von Linde and/or the Linde Company for 56 years until 1929.

After his university studies at TC Munich from 1870 to 1874, Friedrich Schipper first worked as Carl von Linde's assistant and helped build the first three versions of the refrigeration machines. For example, in 1877 he was in charge of the installation of the refrigeration unit for one of the Anton Dreher breweries in Trieste.

Between 1878 and 1880 Schipper gained practical experience in the workshops of *Maschinenfabrik Augsburg* and in 1879 helped von Linde in the start-up of an ice machine in the Munich Spaten Brewery.

In 1880 he joined the Linde Company as its first engineer and moved to Wiesbaden. Here he became manager of the design office and assisted von Linde in the responsibilities of running the company. In 1888 he became Carl von Linde's deputy and in 1890 his successor as chief executive.

Schipper served in this office until 1924, after which he moved to the Supervisory Board. For the company's 50th anniversary, the 80-year-old man left the firm, ending more than 50 years working for Carl von Linde and the Linde Company. He died on November 13, 1929 in Wiesbaden.

In the intensifying battle for customers and market share, some competitors resorted to means which clearly angered Carl von Linde as he recalled them. The arguments – mainly between the Swiss-French Dr. Raoul Pictet and German licensee Rudolf Grübs & Co. – became a contentious "battle of systems" over which refrigeration method was best thermodynamically.

At Linde's urging, the Polytechnic Association in Munich set up a testing station (financed by the Linde Company) in 1887 and invited the competing refrigeration equipment manufacturers to perform comparison tests.

This step proved to be doubly successful: The Linde concept came out the winner of this battle of systems and the testing station, after the Linde Company took it over, became the seed from which new groundbreaking inventions grew.

### Linde's move to the Supervisory Board

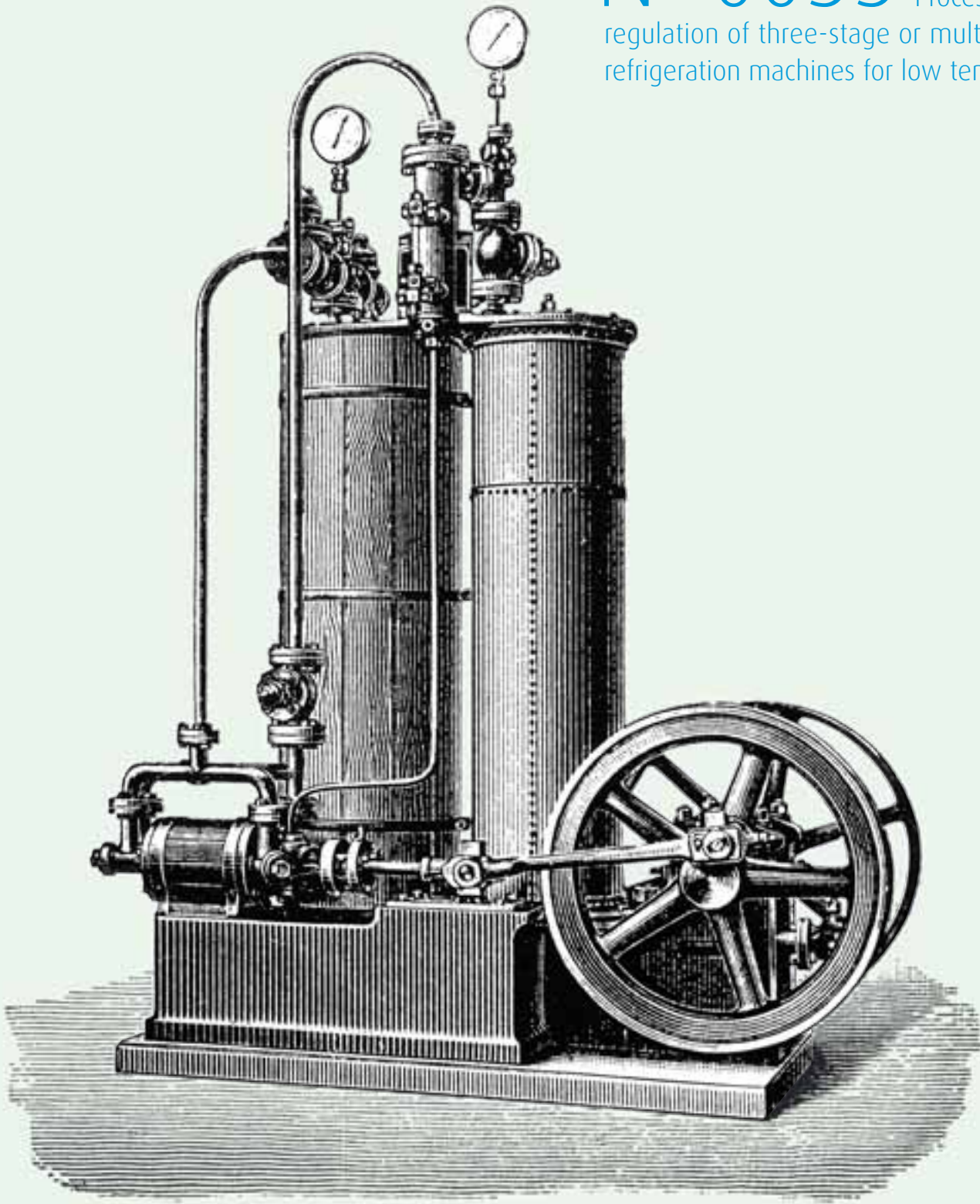
Spring of 1889 marked the end of the ten years to which Carl von Linde had committed himself as head of the company. In that time the company had established itself as the market leader in refrigeration and attracted first-class employees. Linde, the wanderer between theory and practice, was drawn back to science and research. Although he was not yet 50 years old, the demands of his position had taken their toll on his health, and so he decided to return to Munich and the Technical University.

However, in order to set newly undertaken enterprises, such as the founding of the "*Gesellschaft für Markt- und Kühlhallen*" in 1890 in Hamburg, on a secure path and to help break in his successor Friedrich Schipper, von Linde put off his return to Munich. The family finally moved in May 1891 first to their summer home on the Obersalzberg near Berchtesgaden and ultimately to Munich.

He did not, however, launch himself with all his energies into his teaching duties, but rather created the completely new low temperature technology – required for the liquefaction of air and to produce pure oxygen and other gases.

1890  
German physician Emil von Behring develops  
serums against diphtheria and tetanus.

Nº 0055 Process for the  
regulation of three-stage or multi-stage  
refrigeration machines for low temperatures.



Ongoing technical improvement of the Linde refrigeration machines.  
The photo shows a model from approx. 1900.