CHARLES S LEOPOLD
1896-1960

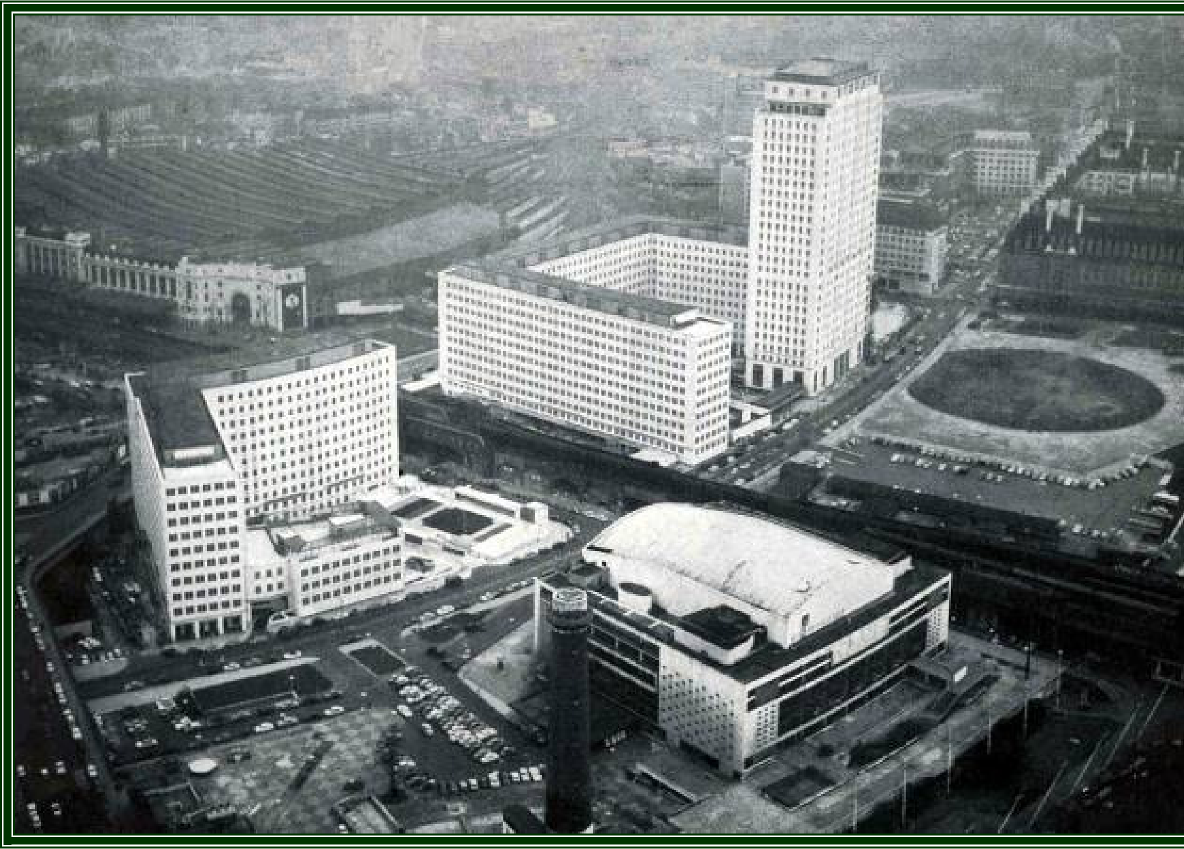
Pioneer of Panel Cooling

CHARLES S LEOPOLD **1896 – 1960**

Leopold graduated from the University of Pennsylvania and received a BS in electrical engineering in 1917 and EE in 1947. In 1923 he founded his own engineering firm and designed such projects as the Pentagon Building, New York Stock Exchange, Madison Square Gardens and the Philadelphia Convention Hall. In 1947 Leopold became active in the engineering and construction of the largest laboratory built by the Atomic Energy Commission at that time. The mechanical systems for this job were still operating in 1995 as proof of the efficiency of design. The largest panel cooling system to date, based upon his design, was installed in 1998 in a twelve-story office building in Canada. (However, in the 1950's he advised the British firm of Haden on the design of the panel cooling system at the Shell Centre* in London, then the largest air conditioned office block in Europe). In 1946 Leopold was President and Chairman of the Executive Committee of our predecessor Society, the American Society of Refrigerating Engineers. He was an ASHRAE Fellow, a Fellow of the Royal Society of Arts of Great Britain, and a recipient of the F. Paul Anderson Award in 1954. The University of Pennsylvania School of Engineering recognized him for his distinguished career as an engineer. Charles S. Leopold was inducted into the ASHRAE Hall of Fame in 2000.

**(The Mechanical Services at Shell Centre," H C Jamieson & J R Calland, JIHVE, April 1963)*

(Edited extract from "Hall of Fame" Citation)



Shell Centre, London: 600,000 sq ft offices (International Lighting Review, XIII, 6, 1962)

1946

ASRE

CHARLES S. LEOPOLD

1896-1960

PHILADELPHIA, PA

"The volunteer committees demand the greatest amount of work and offer the greatest opportunity to serve the Society." (p. 509, June 1946, *RE*)

(From "Proclaiming The Truth," ASHRAE, 1995)

SIR JOHN LESLIE
1766-1872

Figure 8-2 *John Leslie (1766-1872), professor of mathematics at Edinburgh, Scotland, experimented with absorption and vacuum refrigeration beginning about 1815 (from the Smithsonian Institution, Division of Engineering and Industry).*

Early experimenter into refrigeration

LESLIE John (1766-1832)

Born at Largo, Scotland.

Studied at the university of St Andrews. He undertook the translation of Buffon's 8-volume "Histoire des oiseaux" (history of birds), which he finished in 1793. During the 12 succeeding years he was devoted to philosophical research.

In 1804 he published his memoir "Experimental Enquiry into the Nature and Properties of Heat". In 1805 he was made professor of mathematics at the university of Edinburgh. In 1810, he described an apparatus for making ice by evaporation of water under vacuum and absorption of the water vapour in sulphuric acid (a system which Edmond Carré developed commercially in 1866). In 1819, he occupied the chair of natural philosophy in the university of Edinburgh, and in 1820 was elected a corresponding member of the French Académie des Sciences. He was knighted in 1832.

(From "A History of Refrigeration," Roger Thevenot International Institute of Refrigeration, Paris, 1979)

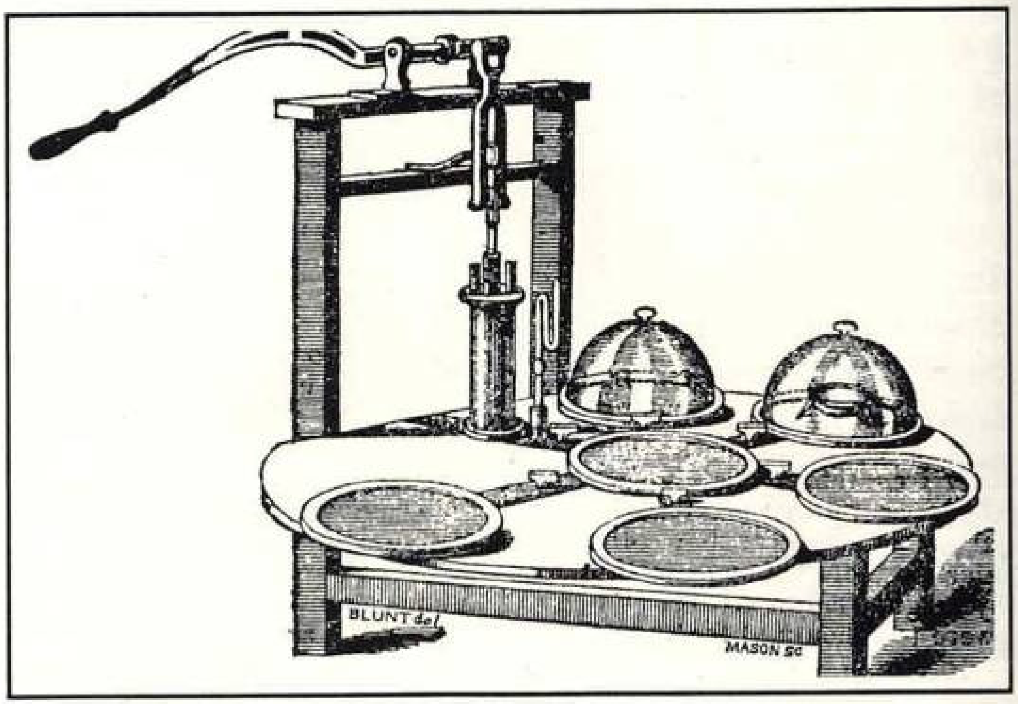


Figure 8-4 *John Leslie's freezing table of 1823. This modification to the device shown in Figure 8-3 allowed successive bell jars to be evacuated by one pump. As each jar was evacuated, the valve on the evacuation line was shut off and the sulfuric acid was allowed to absorb the water vapor until the water was frozen (from* Mechanic's Magazine, *1823, p. 312).*

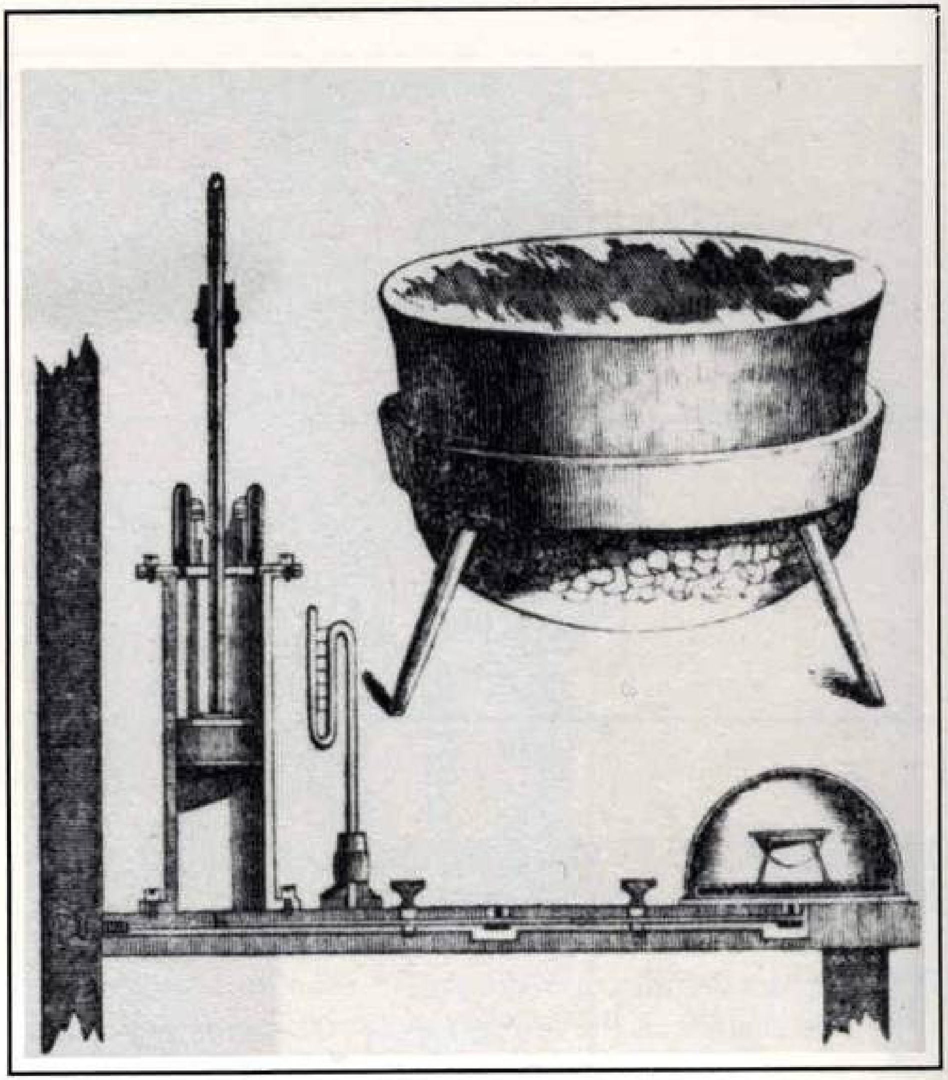


Figure 8-3 *John Leslie's absorption and vacuum freezing device, 1823. A dish of water is suspended above a flat tray of sulfuric acid under a sealed glass bell jar. The air pump at left is used to draw a vacuum on the jar. The water boils at a temperature below freezing, not only due to the action of the air pump, but also due to the absorbing effect of the acid, which absorbs water vapor, permitting an even greater vacuum. Leslie later discovered that parched oatmeal was a better absorber than sulfuric acid. The oatmeal had an added advantage of being reusable—it could be regenerated by heating on a stove or in the sun (from* Mechanic's Magazine, *1823, p. 313).*

(From "Heat & Cold: Mastering the Great Indoors," Barry Donaldson & Bernard Nagengast, ASHRAE, 1994)

LEE LOGAN LEWIS
1885-1965

Developed the return air bypass and downward air distribution for the air conditioning of movie theatres

[103] L. Logan LEWIS

American air conditioning engineer. One of the founders of Carrier Engineering Corp. (1915). Early cinema air conditioning included two Balaban & Katz theatres, the Central Park (1919) and the Riviera (1920), both in Chicago, probably designed by Frederick Wittenmeier [209]. These systems both used *up-systems* of supply air distribution from floor outlets and caused the audience to complain of cold feet. Lewis decided to reverse the air circulation in his design (1922) for Graumans Metropolitan, Los Angeles, an arrangement termed the *upside-down* system of air distribution. The installation used an air washer and CO_2 refrigerating plant by the Carbondale Machine Co. He also devised a return-air bypass arrangement* to improve humidity control (USP 1,583,060: 1926). Lewis was ASRE President (1941).

(Mini-biography from "The Comfort Makers," Brian Roberts, ASHRAE, 2000)

The founders of Carrier Engineering Corporation, now Carrier Corporation. They are, standing, from the left, Edmund P. Heckel (Superintendent of Erection), Ernest T. Lyle (Boston Office), and Alfred E. Stacey, Jr. (Western Manager and Engineer). Seated are L. Logan Lewis (Chief Application Engineer), Willis H. Carrier (President, Chief Engineer), J. Irvine Lyle (Treasurer, General Manager) and Edward T. Murphy (Secretary, Manager, Philadelphia District).

The Founders of Carrier Engineering Corporation, USA, 1915
L Logan Lewis, Chief Application Engineer, is seated front row left

WILLIS HAVILAND CARRIER

Father of Air Conditioning

by Margaret Ingels

1952 • COUNTRY LIFE PRESS • GARDEN CITY

(CIBSE Heritage Group Collection)

So, with Carrier and Lyle encouraging them, the company's sales engineers began concentrating on theater owners. The engineers not only had Carrier's new, safe, and simple refrigerating system, but also a method for introducing cleaned, cooled, and dehumidified air into a theater, without causing drafts or cold feet. This no-draft feature was achieved through a system of by-pass down-draft air distribution which Logan Lewis had designed in 1922 for Grauman's Metropolitan Theater in Los Angeles. Designed, sold, and installed before Carrier's centrifugal refrigerating machine was available, this installation used a carbon dioxide refrigerating system to cool the air. The air flowed through outlets located in the ceiling, diffused slowly downward, then entered return grilles located in the floor. Thus, Lewis accomplished the seemingly impossible feat of circulating a large volume of cooled and dehumidified air without the audience being aware of any air movement. This has caused many persons to refer to Grauman's Metropolitan Theater as "the birthplace of theater air conditioning." However, the crucial test of theater

(Text extract from "Father of Air Conditioning")

Carrier

THE ROMANCE OF AIR CONDITIONING

By LOGAN LEWIS

Vice President and one of the founders of Carrier Corporation, Syracuse, New York

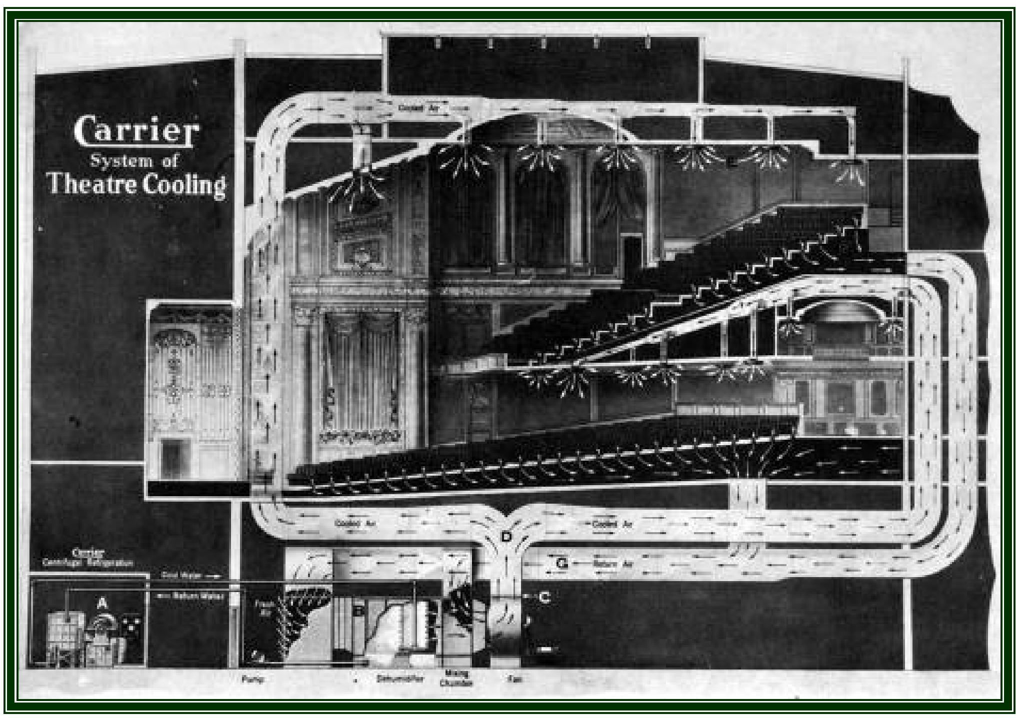
Booklet c.1950 (CIBSE Heritage Group Collection)

We tried, time and again, to sell systems that met our own standards of quality but always lost out on prohibitive price – until two radical concepts in engineering practice were developed. The newly invented "bypass" made it possible not only to maintain low humidities with less refrigeration but also practical to control humidity and temperature independently of each other. The trick was to cool only one third of the air about twice as much and then to mix it with warm bypass air coming back from the theater.

Experience in the suppression of dust in a tobacco stemery, prompted a reversal of air circulation – so shockingly different that it was, until proven, widely ridiculed in theater circles as "the upside-down system." With it, tempered air of much lower dewpoint was delivered through overhead outlets and taken out through mushrooms at the floor level.

Our first quotation was accepted and our first installation was made in 1921 in Graumans Metropolitan Theater at 6th and Hill Streets in down-town Los Angeles – now known as the Paramount.

(Text extract from "The Romance of Air Conditioning")



Lewis's "Upside-down" system of air distribution

The Metropolitan Theatre, Los Angeles in the 1920's

The Metropolitan Theatre, Los Angeles, 1925

THE INVENTION OF

THE CENTRIFUGAL REFRIGERATING MACHINE

"PROPOSED" SCRIPT FOR A TAPE RECORDING

FOR THE SMITHSONIAN INSTITUTION

PLUS A COMPLETE HISTORICAL SKETCH

When the Smithsonian decided to display the compressor of the Original Centrifugal Machine, it requested a tape recording for the Archives. This type of description would institute a new practice, and consequently, there were no definite ideas about what it should be. To write the script was the original objective--but, as the story was developed by research and thought, it became increasingly evident that a complete coverage would be too long for an oral presentation.

There was entirely too much substance to the story for it to be left half told: The invention had projected a revolutionary development into the art of refrigeration; it had given a tremendous impetus to the development of air conditioning. The story had to depend too much upon memories that were fading rapidly with age; and it had to draw a clear distinction between the Centrifugal Compressor that would constitute the sole exhibit and an entirely new method of refrigeration in which the compressor was only one of numerous functional elements.

This led to a plan by which one document could be made to serve two purposes: One was to provide an abridged version for the oral presentation, and the other was to provide a complete and well-rounded Historical Sketch for the studious reader and the Archives.

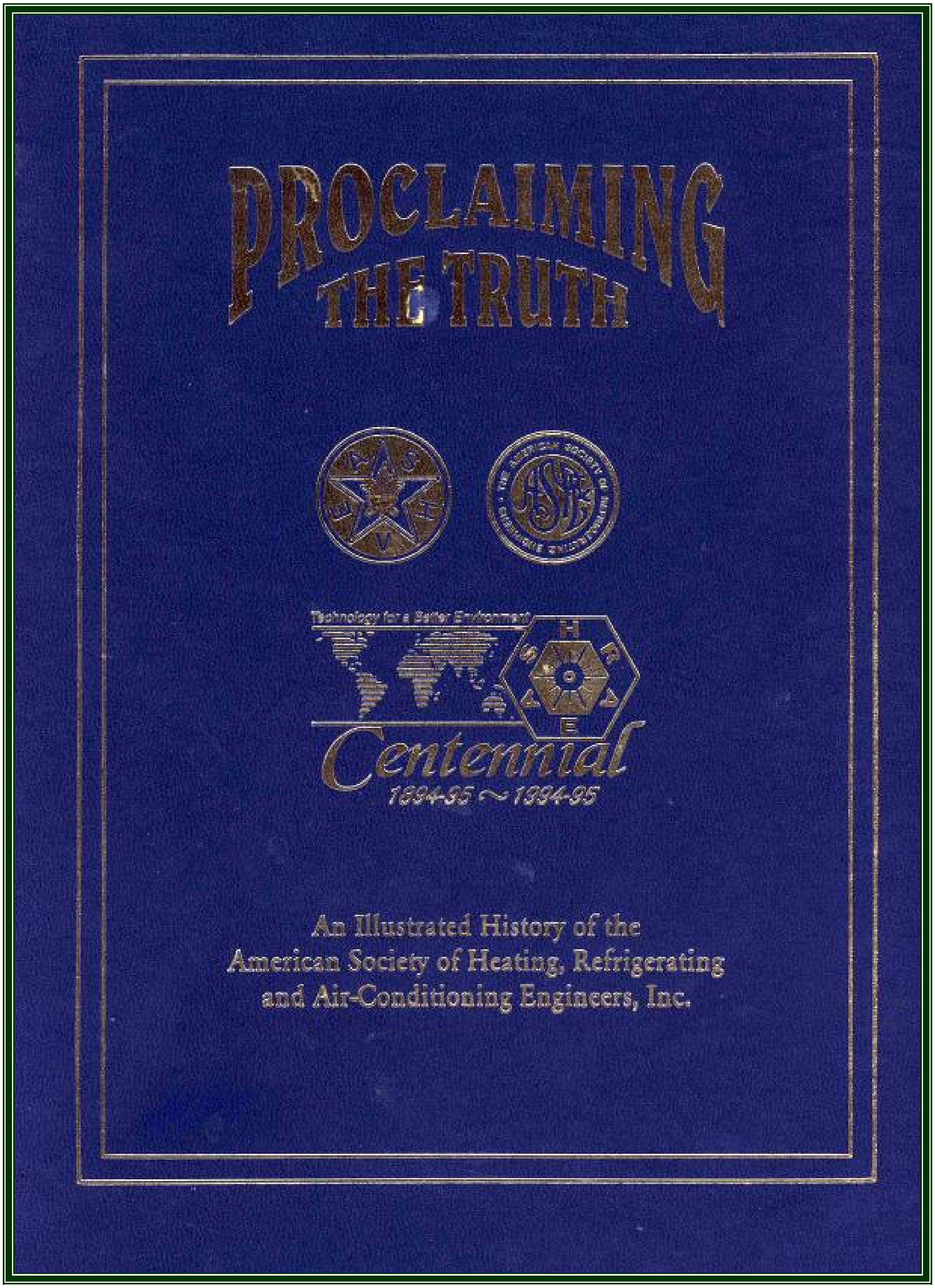
The division between short and long could be shown by the style of typing. The short would be double-spaced in full-length lines; and the long would consist of the short plus all that was single-spaced and indented. With a little extra effort, good contunity could be maintained and the reader could be given a free choice according to time and interest.

The idea may have had some merit; but as research brought more and more facts to light, length got more and more out of hand. The upshot was a complete change of plan: An appropriate history would be written in the original short-long style, divided into chapters, and reinforced with some last minute illustrations--and the script for the tape could come later.

The author is not too happy about the length of the current edition (about 7500 words for the short, and 10,000 for the long); but he does feel that justice to the story has been reasonably well done.

Logan Lewis
March 1, 1962

Title page of a Logan Lewis Typescript from 1962
(CIBSE Heritage Group Collection)



ASHRAE Centennial Handbook 1994 (CIBSE Heritage Group Collection)

1941

ASRE

L. LOGAN LEWIS

1887-1965

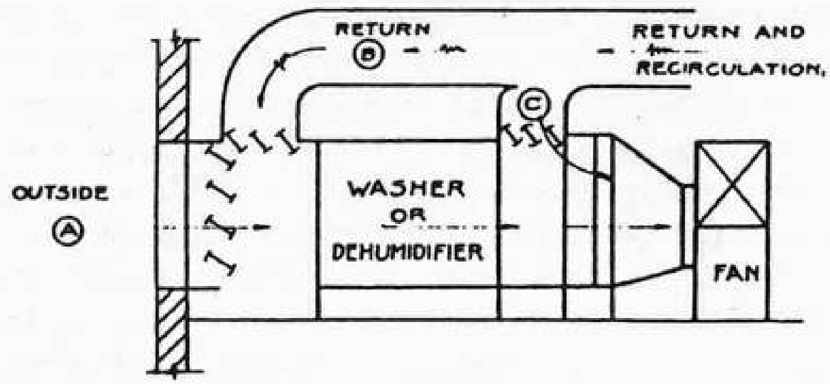
SYRACUSE, NY

"Just one thing – the hearty, intelligent and unselfish cooperation of national and sections officers, of committee chairmen and members, of individual members and of the staff at headquarters – has made [a successful Society] possible." (p. 395, Dec. 1941, *RE*)

(From "Proclaiming the Truth")

However, Carrier's commitment to humidity control eliminated this type of recirculation as a viable option for CEC. Instead, the firm proposed a little-used type of recirculation, which it eventually called a "by-pass system." The bypass system appears in the company's plans for the Balaban and Katz theater. Unlike Wittenmeier's design, this system would not send the return air through the air washer and recool it, but would mix it with the cold air that came out of the air washer in order to raise its temperature and lower the relative humidity before the conditioned air entered the theater. In effect, the company eliminated the heater of industrial practice and instead raised the temperature of the conditioned air with warmer air from the theater. This technique of recycling the air of the theater and mixing it with the treated air before returning it to the auditorium received its name because the recirculated air bypassed the air washer. As early as 1919 CEC identified this as a possible method of achieving economical comfort air conditioning. The bypass technique preserved humidity control as an important part of comfort air conditioning and thus linked the company's existing expertise to a growing new field.

Despite this early recognition of its potential, CEC's first bypass system was not installed until 1921, in Sid Grauman's Metropolitan Theatre in Los Angeles. L. L. Lewis sketched out his ideas for the system in a company memo of 9



Bypass. As depicted here, in bypass circulation, air is returned from the air-conditioned room and bypassed around the air washer at C. *This warmer, recirculated air raises the temperature of the treated air to bring it up to a proper level of humidity and comfort before it is reintroduced into the room. Bypass circulation proved to be the most economical way to achieve humidity control in comfort air conditioning, and consequently the patent holders captured an estimated 90 percent of the comfort air-conditioning market.* (*Refrigeration Engineering* 15 [May 1928]: 122)

September 1921 to E. P. Heckel, who went to Los Angeles to estimate the job.[79] Then, on 22 December 1924, Lewis filed a patent application on his ideas.[80] Essentially, the system supplied the full 30 cfm per person mandated by law, yet only 25 percent of that air was outside air that had been washed and cooled, while 75 percent was air recirculated from the theater auditorium that bypassed the air washer. The reduction in the volume of air sent through the air washer meant that the refrigeration machinery, an expensive part of the installation, could be greatly reduced in size.

The Metropolitan Theatre epitomized the combination of innovative mechanical systems and extravagant architecture. It was Grauman's third large Los Angeles theater, built after the Chinese Theatre and the Million Dollar Theatre (1919). Designed by architect William Lee Woollett, it has been described as an "exotic jumble of Middle Eastern ornament and geometric patterning."[81] Three years in the planning, it was part of Grauman's ambitious plans for a theater–office tower complex on Pershing Square that were never entirely realized, despite the formation of a partnership with Paramount Publix to give him greater financial resources.[82] Nevertheless, the house that opened in January 1923 was spectacular for its size (3,500 seats), its lavish decoration, and not least, its air-conditioning system.

The Metropolitan was expensive, reputedly costing $3 million, and one newspaper reported that the air-conditioning system accounted for $115,000 of that total.[83] Construction costs were only part of the expense of air-conditioning the theater. Operating costs for the installation ran $500 per month during the winter and rose to $2,200 in the summer, even with bypass recirculation.[84] To some such an expenditure was an essential part of a new theater, for as one engineer noted, "builders of new theatres would no more leave out cooling than they would neglect heating, for the public demands it and experience has demonstrated that it pays."[85] But for Grauman in 1920, when planning for the theater began, including air conditioning was an innovative step.

(Text extract from "Air Conditioning America," Gail Cooper, 1995)
To put costs in context the currency exchange rate in the early 1920's was $4.5=£1

Lee Logan Lewis

Born in Clark County, Ky., on April 16, 1887. Air-Conditioning Engineer. Business Executive. University of Kentucky, B.S., 1907; M.E., 1909. Died, March 8, 1965.

He was a pioneer in the air-conditioning industry, one of the seven founders of the Carrier Corporation, Syracuse, New York.

A design engineer, he developed the downward flow method for cooling large auditoriums. Prior to entering the air-conditioning field, he was an instructor at the University for two years, 1908-09, while he was pursuing a graduate degree.

His career with Carrier Air-Conditioning Company began in 1909 and continued until 1915, when he became a founding member of Carrier Engineering Corporation, an association that was to continue for the rest of his life. In 1921, he organized a school for the training of engineering graduates in the air-conditioning field, and he served as Director until 1936. He became Vice-President of the Carrier Corporation in 1936.

During World War II, he served the government as an adviser on armored vehicles. He was a Fellow and President of the American Society of Refrigeration Engineers; a member of the American Society of Heating and Air-Conditioning Engineers; a member of Sigma Alpha Epsilon, and the author of numerous articles on the subject of air-conditioning and heating.

Following his retirement in 1957 and until his death in 1965, he began an extensive historical collection of records for the air-conditioning industry.

Lee Logan Lewis was named to the Hall of Distinguished Alumni in February, 1965.

Kentucky University Record for Lee Logan Lewis

CARL VON LINDE
1842-1934

Pioneer of thermodynamic analyses of refrigeration

[90] Carl von LINDE **1842-1934**

German scientist, professor, engineer, and industrialist. Studied under Clausius [167]. Wrote his classic paper *The Extraction of Heat at Low Temperature by Mechanical Methods* (1870), in which he compared the efficiency of cold air, compression, and absorption machines. Linde was possibly the first to use a rigorous thermodynamic approach to refrigeration design. Built a methyl ether compressor (1875), following with ammonia compressors (1876) and his successful double-acting design (1877). He established commercial production of the latter by forming his own company at Weisbaden (1879). The Chicago engineer, Fred W. Wolf, secured the rights (USP 228,364: 1880) to manufacture and sell Linde's machines in the USA (1881). The Linde ammonia compressor and refrigerating system was widely used throughout the world.

(Mini-biography from "The Comfort Makers," Brian Roberts, ASHRAE 2000)

von LINDE Carl (1842-1934)

Born at Berndorf, Upper Franconia, Germany. Died in Munich.

He studied for four years at the Zurich Polytechnicum, where his notable teachers included Clausius, Zeuner, Dedihind, and Reuleaux, and where he developed a passion for thermodynamics. From 1864 to 1868, he worked in various industries, in particular in the locomotive factory in Munich. In 1868 he was put in charge of a course of mechanics at the Munich technical university, which had just opened. He was a regular professor in 1872 and remained in this post until 1879.

In 1870, Linde produced an important paper on "mechanical methods of extracting heat at low temperatures", in which he compared the efficiency of air cycle refrigerating machines, absorption machines and compressors of liquefiable vapours. In 1873, at the international brewery congress in Vienna, his lecture on compressors was much commented on.

In 1875, Linde made his first compression refrigerating machine, using methyl ether (as Charles Tellier had done, and taking note of the difficulties which he had encountered), in which gas-tighness was achieved by a mercury joint. In 1876, he made his first ammonia compressor (two vertical cylinders) and in 1877 a second type (double acting horizontal) which was quickly taken up all over the world, with almost immediate manufacture in five countries.

In 1879, Linde gave up teaching, to devote himself entirely to the company which he had just formed, in Wiesbaden, to manufacture refrigeration equipment of his design, and which he directed until 1890.

From 1894, Linde worked in the field of very low temperatures. In May, 1895, he became the first to liquefy air in appreciable quantities (3 l/h) and in 1898 he built an air liquefier of 50 l/h, for the chemical industry.

Carl von Linde shone at one and the same time as a scientist, professor, engineer and industrialist, qualities rarely united in one man.

(From "A History of Refrigeration," Roger Thevenot, International Institute of Refrigeration, 1979)

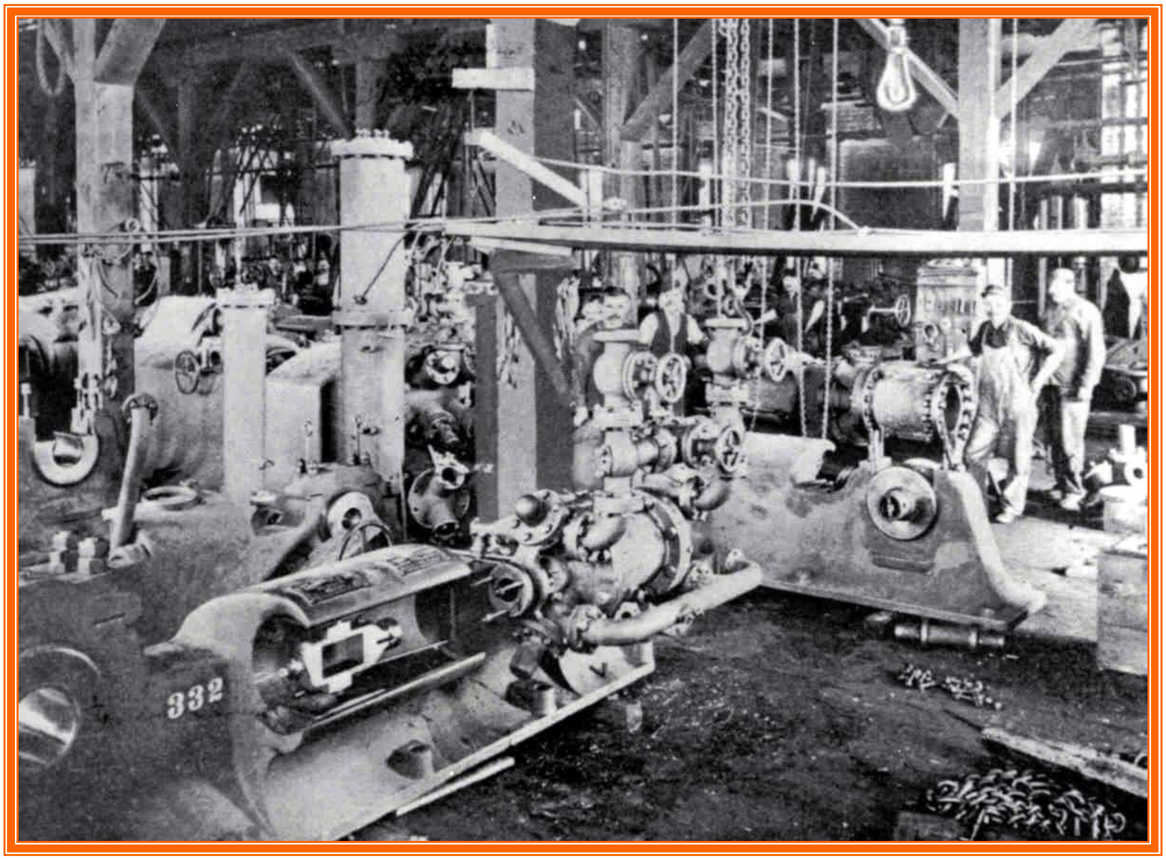
Carl Linde and the Thermodynamic Approach

Attempts at mechanical refrigeration before 1870 had yielded results that could hardly be termed efficient in energy use. These early attempts were lucky to achieve even a 20% efficiency.[53] It appears that the first rigorous thermodynamic approach to refrigeration was taken before 1870 by Carl Linde in Germany (Figure 8-24). Linde's 1870 paper, "The Extraction of Heat at Low Temperature by Mechanical Means," was the beginning of what was possibly the earliest attempt to approach the design of refrigerating systems by considering scientific theory first. The next stop was to design the equipment, which Linde addressed the next year in his paper "Improved Ice and Refrigerating Machines."

> This paper clearly disclosed the involved theoretical and thermodynamic considerations. It provided a real scientific basis, and as such became immensely valuable in the further technical development of refrigerating machinery . . . which in a short time led to such improvements in general design that practical efficiencies were boosted to fifty percent of the possible thermodynamic maximum. Dr. Linde himself, was the first to make use of his theoretical deductions in the design and construction of refrigerating equipment.[54]

Linde was convinced that the vapor-compression system offered the best possibilities. Persuaded that the brewing industry was the area most in need of mechanical refrigeration, Linde delivered a paper at the Vienna brewers' conference in 1873. This attracted the financial backing of Munich brewer Gabriel Sedlmayr, who allowed him to experiment with refrigerating machinery at the Spaten Brewery. His first machine, using methyl ether as a refrigerant, was completed in 1874, and tests proved that its efficiency was double that of other existing equipment.[55] Still, this first machine was not considered satisfactory in its construction, and Linde proceeded to construct an improved design using ammonia as a refrigerant in 1877. These first two machines were vertical, two-cylinder compressors. The second system employed a brine chiller, the brine being used in a spray-type device to refrigerate the air. The vertical cylinder compressor, which used a complicated glycerine sealing system for the pistons and shaft, was considered unsuitable for commercial production and was abandoned in favor of a horizontal, double-acting type (Figures 8-25 and 8-26). This approach produced a lower cost compressor by combining the two single-acting cylinders into a double-acting one. The glycerine sealing system was eliminated in favor of an oil-sealed stuffing box at the shaft, as well as the use of mineral oil as a lubricant and piston seal.[56] This new design was considered suitable for production, and commercialization began in 1879 with the establishment of Gesellschaft für Linde's Eismaschinen in Weisbaden, Germany.[57] The Chicago engineer Fred W. Wolf was one of Linde's early advocates and secured rights to manufacture and sell Linde's refrigerating systems in the U.S. in 1881. The Linde machine and refrigerating systems became popular throughout the world.

(From "Heat & Cold: Mastering the Great Indoors," Barry Donaldson & Bernard Nagengast, ASHRAE, 1994)



Linde horizontal compressors being manufactured in the workshops of Fred W Wolf Co in Chicago (Catalogue No. 4, Linde Ice & Refrigerating Machines, Chicago, c.1891)

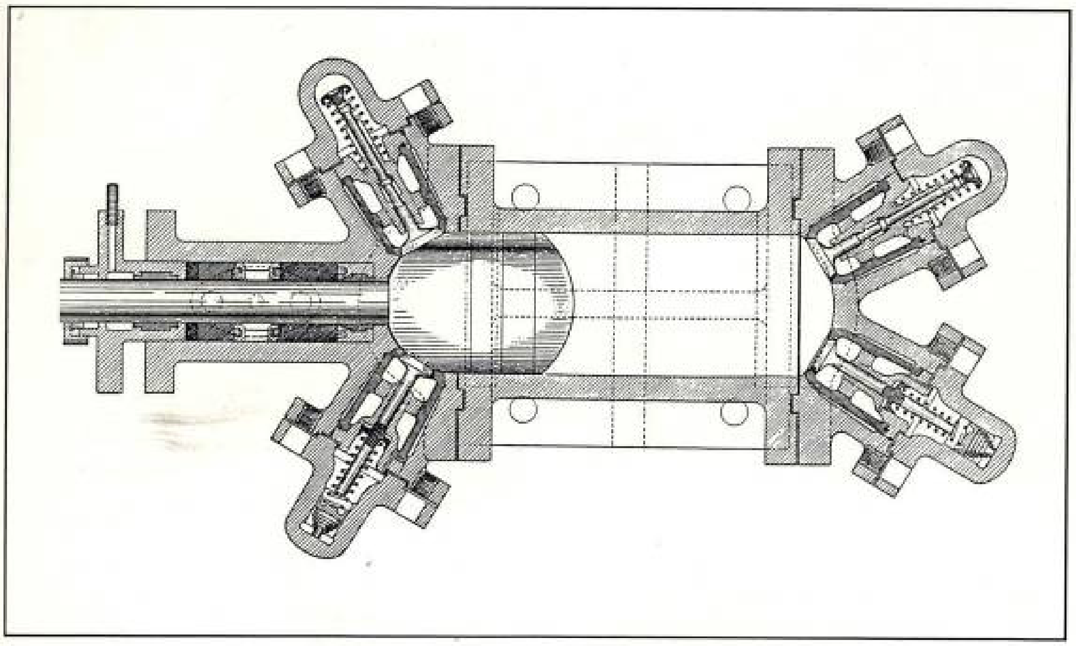


Figure 8-26 *Linde's improved horizontal ammonia compressor. Although Linde was not the first to use ammonia as a refrigerant, his double-acting design was more efficient than others of the 1870s, and was widely used for many years (from J.A. Ewing, 1908,* The Mechanical Production of Cold, *p. 87).*

In 1870 C. V. Linde wrote his first important paper "Über die Wärmeentziehung bei niedrigen Temperaturen durch mechanische Mittel" in which he calculated the efficiency of cold-air, compression and absorption machines. He showed that none of the existing machines had more than about 1/5 of the possible efficiency and he demonstrated how improvements might be made. In 1874, Linde in conjunction with his pupil Schipper prepared the drawings for his first refrigerating machine, and in 1875 it was built (Fig. 5.5). Linde chose methyl ether as the refrigerant, overcoming the difficulties which beset Tellier by using a sealing fluid. The specific capacity of this machine was much greater than the measured values for previous machines, although the movement of the sealing fluid enforced slow-speed running.[33]

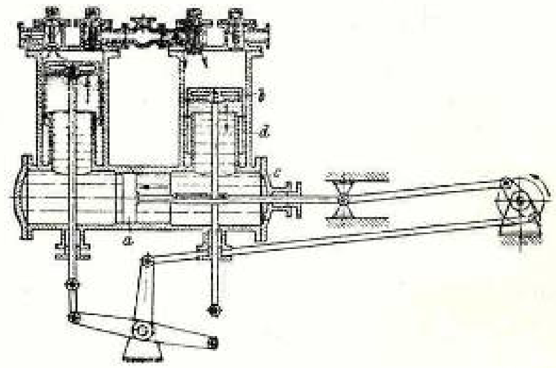


Fig. 5.5. Linde's methyl ether compressor *ca.* 1875.

5.6 AMMONIA MACHINES

Even in 1873, Linde was thinking of a new design using ammonia. During the next seventy years ammonia became one of the most widely used of all refrigerants, particularly for large industrial applications where its suitability outweighed any risks associated with its high toxicity and flammability. It has been much less used since World War II.

Although both Harrison and Tellier had suggested its use, and David Boyle in the USA had obtained a patent in 1872, Linde is generally credited with being responsible for the first large practical ammonia machine built on truly scientific lines.

Linde's first machine of 1873 and a second of 1875 were installed in the Spaten Brewery of Munich. In 1877, Linde erected a 100-tr (350 kW heat extraction) plant in England. Linde obtained British Patent No. 1458 in 1876, and a U.S. Patent in 1880 (Fig. 5.6).

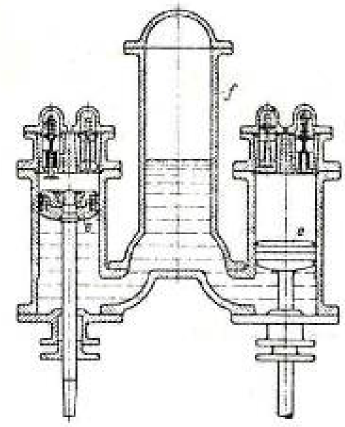
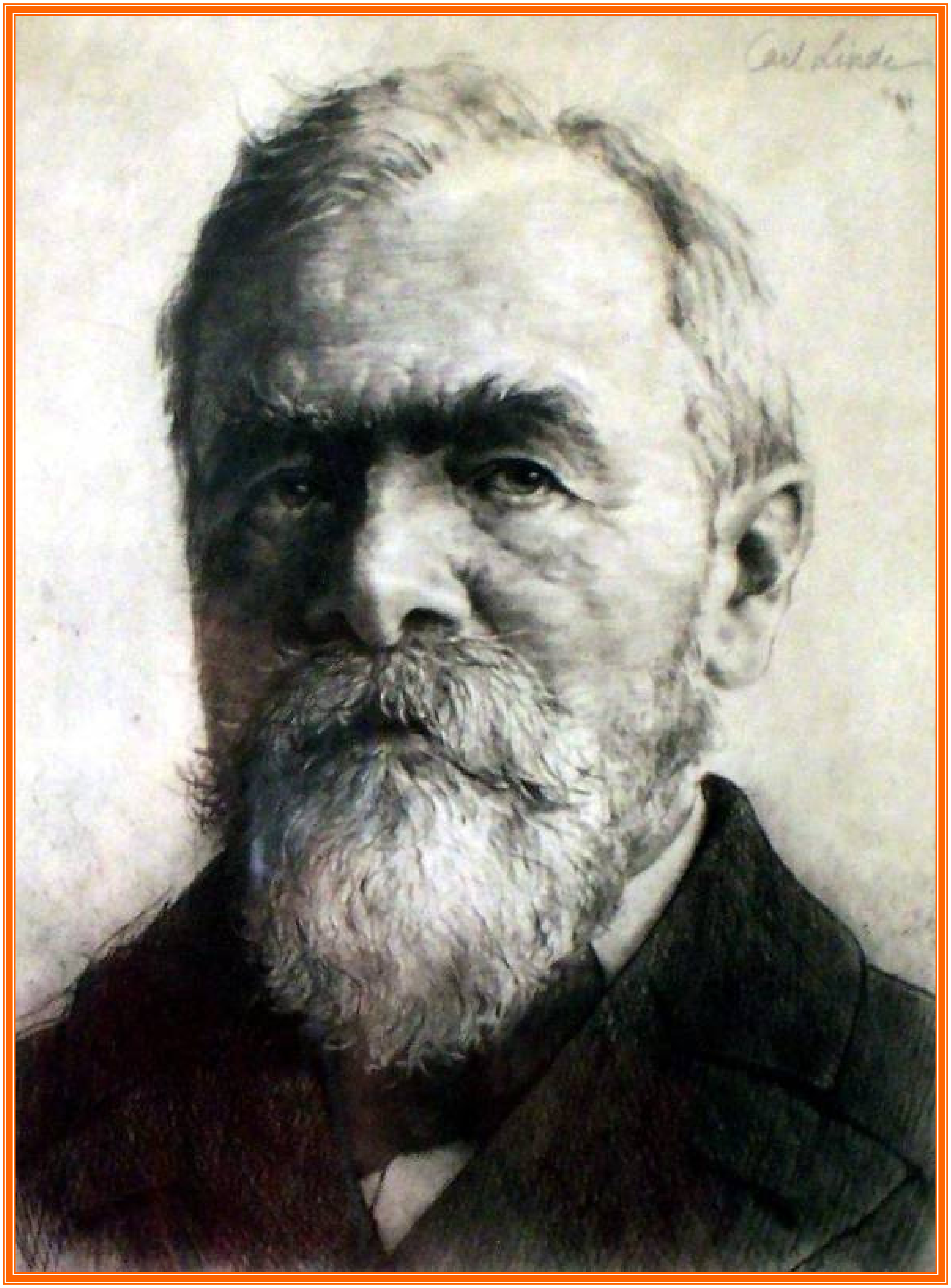


Fig. 5.6. Linde's first vertical ammonia compressor (*ca.* 1876).

The piston used in earlier (ether) machines was abandoned, so that the two vertical cylinders were in direct communication, so far as the space beneath the pistons *e* were concerned. This space also communicated with the vessel *f*. It was largely filled with a liquid seal which also served for lubrication, the liquid moving to and fro with the motion of the pistons. The stuffing boxes were thus not in contact with ammonia, but only sealing fluid which was maintained at a slightly higher pressure than the maximum ammonia pressure.[33]

Ammonia was not then available as an article of commerce. To fill the machine, Linde provided a still to generate ammonia from sal ammoniac. By 1889, ammonia, sulphur dioxide and carbon dioxide were all available in cylinders. Ammonia then cost 3.2 DM/kg, but fell to 1.5 DM/kg by 1896.

(From "Building Services Engineering,"
Neville S Billington & Brian M Roberts, 1982)



Professor Carl von Linde