SPECIAL COLLECTION FOR WORLD REFRIGERATION DAY, JUNE, 26 2021

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Refrigeration Applications

Heroes of Refrigeration History

An Andy Pearson Collection

Introduction to a Special Collection for World Refrigeration Day, June 26, 2021
Refrigeration Applications, Heroes of Refrigeration History: An Andy Pearson Collection

Honoring Heroes of Refrigeration History

By Andy Pearson, Ph.D., C.Eng., Fellow ASHRAE

Many great men and women of science and engineering have contributed to the development of refrigeration over the decades. Some of them, such as Lord Kelvin, are well known around the globe. Others, such as James Watt or Sadi Carnot, are still familiar names but their stories are less well known. Still others have passed into obscurity, and even their contribution to the world of cooling, as significant in their day as Otto Daimler or the Wright brothers, is now almost forgotten. Some of those, such as Thaddeus Lowe and Louis Sterne, led fantastically adventurous lives. Others, such as Milt Garland and Thomas Midgley, were apparently less wild, but perhaps more influential.

This collection of columns from the *ASHRAE Journal* celebrates the lives and work of these heroes. Their stories, battling against technical, financial and political challenges, can still inspire us today.

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Andy Pearson

Happy Birthday, Mr. Midgley

BY ANDY PEARSON, PH.D., C.ENG., FELLOW ASHRAE

This month marks the 125th anniversary of the birth of Thomas Midgley Jr., a man who transformed our lives in more ways than most of us know, and someone who, for several years now, has been something of a hero of mine.

Midgley was born in Beaver Falls, Pa., in May 1889 to Thomas and Hattie and was raised in Trenton, N.J., and Columbus, Ohio, where his father worked in the automobile industry, principally in the development of tires for motor cars—a fledgling industry in those days. Thomas Jr. had a quick mind and was good with his hands, so he studied mechanical engineering at Cornell University in Ithaca, N.Y., graduating in 1911. Through school and college he played baseball and football, and while at Cornell he founded a student aviation club, although the club had no aircraft, not even a glider.

Thomas Midgley Jr.

For a mechanical engineer, Midgley had a remarkable gift for chemistry, and became President of the American Chemical Society in 1944, the year of his death, having served on the Society's Board of Directors from 1930 onwards. He was responsible for four major developments in industrial chemistry, any one of which would have been a career-defining achievement. This unusual career path started in 1916 when he joined the Dayton Engineering Laboratories Company ("Delco") working with W.A. Chryst and C.F. Kettering.

As Kettering wrote in his biographical memoir of his younger colleague, "Midgley demonstrated unusual talents in all three of the important phases of industrial research; first in original investigation or invention; second, in development or in conversion to the stage of practical usefulness and, third, in selling the new thing to the public—or in some instances to management first."

I was impressed by the range of his interests beyond mechanical engineering and chemistry. He was deeply interested in history, zoology, writing poetry and recording music. He became an ardent golfer, with a handicap of five, and turned his experimental tendencies to the task of conducting trials of different grass types, becoming an expert adviser to all the greenkeepers around Columbus.

I learned key lessons from reading about Midgley's life and work. Always be dissatisfied with the current state of affairs and look for ways to make improvements. Draw on as broad a range of observation and experience as possible when considering a new problem. Talk to people who use the current technology in their everyday routine and seek to learn from their experiences. Be flexible and be willing to modify the approach to a problem if progress is not forthcoming. Midgley was very interested in the development of young people in industrial research and development—his presidential address to the American Chemical Society was titled "Accent on Youth" and emphasized the following message. Pass responsibility to the young people in your organization. Help them to network with people outside their normal circle of contacts. Let them exercise their curiosity and give them full credit for what they achieve.

Midgley was captivated by the thought that, in his lifetime, life expectancy of men in America had risen by more than 50%. He observed that this had never before happened in a single generation in the history of mankind and would likely never happen again. He was deeply concerned about the effect that all that extra manpower in middle management was having on the young engineers entering the profession. This is also a significant lesson that we should heed today.

Midgley is now harshly criticized for his lack of understanding of the environmental harm caused by two of his innovations, the tetraethyl lead additive in gasoline and the chlorine-containing refrigerants. However, I believe that within the constraints of the knowledge of his time he was seeking improvement in all aspects of quality of life. As we start to introduce new halogenated hydrocarbons to the world, we will do well to follow that example, but with the benefit of a far deeper appreciation of the possible effects of our actions on health, safety and the environment. We must seek to identify the correct level of caution in our developments to make sure that we repeat Midgley's successes, not his oversights. ■

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Andy Pearson

English, Irish and Scots

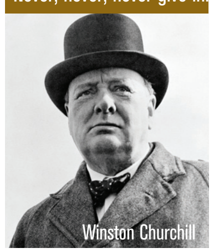
BY ANDY PEARSON, PH.D., C.ENG., FELLOW ASHRAE

Three pioneers of engineering science have been immortalized through the use of their names as units in the SI system, representing energy, temperature and power. They are James Joule, James Watt, and William Thomson (Lord Kelvin) and it is likely every practicing refrigeration engineer, designer, technician and mechanic uses at least one of their names every day of their working lives. They create an interesting weave in space-time.

Watt and Kelvin worked in the same cramped, old-fashioned and dingy university laboratories in Glasgow, Scotland, but were not contemporaries—Watt left Glasgow to settle in Birmingham, England, 50 years before Kelvin was born. Watt and Joule's lives overlap, but only by eight months, and Watt was nearly 83 when Joule was born. Kelvin and Joule, although separated by more than 200 miles, worked on the same mathematical and physical problems and had a strong friendship based on mutual respect and frequent letter writing.

James Joule, the Englishman in this trio of famous names, was born in Salford, just southwest of Manchester, England, in 1818. His father owned a brewery and Joule was raised and educated to take over the business, being tutored by John Dalton who is famous for creating Dalton's law of partial pressures (also widely used by refrigeration technicians, whether they realize it or not). Joule developed a passion for science, particularly topics that affected his working life such as electricity, heat and power. He was a businessman and industrialist who pursued science as a hobby, and his wealthy background and successful brewery business provided the means to follow his amateur enthusiasms.

Never, never, never give in.



He created sophisticated scientific experiments that were completely at odds with the received wisdom of the establishment at the time and he claimed, for example, to be able to measure temperature to within 0.005°F (0.0028°C), an accuracy that would not be out of place in a modern, digital, science laboratory. The main goal of all his experimentation was to demonstrate that mechanical work could be converted to heat and to establish the conversion factor; the so-called *mechanical equivalent of heat*. Although this seems normal to us, it was so far removed from scientific orthodoxy at the time that the first reading of his theories, at a meeting of the British Association for the Advancement of Science in 1843, was met with complete silence from the audience. He was 24 years old. Despite this setback he persevered with his experiments into electromagnetism and heat, presenting further papers to the British Association in 1845 and 1847. The latter meeting was attended by William Thomson, recently appointed as Professor of Natural Philosophy at Glasgow at the age of 23.

Thomson was initially skeptical because Joule's ideas were so unlike conventional thinking, but he noted that Joule's theory helped explain some shortcomings of traditional caloric theory and over the next four years he convinced himself that Joule's reasoning was correct. Joule and Thomson started a series of experiments to validate Joule's theory. Their correspondence extended from 1852 to 1856, and Joule continued stirring and measuring for a further 20 years.

Joule was not the only one to develop these ideas; similar thinking surfaced at about the same time in Germany and Denmark, but above all others Joule stuck to his task, even in the face of stony opposition. He continually refined his techniques and measurements, perfecting his craft and homing in on the elusive value of equivalence. The number he was seeking was the amount of mechanical work, measured in foot-pounds, that was required to heat one pound of water from 60°F to 61°F (15.56°C to 16.11°C). When he died in 1889 his tombstone was inscribed with the value "772.55," this being, in his opinion, his most accurate assessment, achieved in 1878 after 35 years of testing. The fact that this is within 1% of the true value of 778.17 ft·lb/Btu (4,187 Nm to raise 1 kg by 1 K) is testament to Joule's precision, his patience and his eyesight. ■

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Watt's the Big Occasion?

BY ANDY PEARSON, PH.D., C.ENG., FELLOW ASHRAE

James Watt, the Scotsman in the trio of famous names from April's column, was the oldest of the three, being born in 1736, over 80 years before Joule and Kelvin. He also lived the longest and arguably had more impact on the industrialization of society than any other. His life is a mixture of contradictions, and he is frequently misunderstood and misrepresented. Like James Joule, Watt had no formal university education but relied on personal contact with the leading academics of his day to formulate and develop his ideas.

Watt trained as an instrument maker, specializing in making laboratory instruments for Glasgow University and the shipping trade. His workshop was set up within the precincts of the university after Watt completed his craftsman's apprenticeship in one year rather than the usual seven years. Commissions included laboratory instruments and navigational aids such as quadrants, parallel rules, barometers and telescopes as well as musical instruments including wooden flutes, fifes and pipe organs. This led to a post of astronomical instrument maker for the university where he worked with Joseph Black and John Anderson.

One of his repair jobs for the university was reconditioning a model of a Newcomen steam engine, but even after repair he found it would barely work because the efficiency was so low. Watt's "big idea" came to him in an instant while strolling on Glasgow Green in May 1765. It took four years to get this idea—the separate condenser—designed, tested and patented. Watt partnered with Matthew Boulton who ran a factory in Birmingham, England, and their compact steam engines delivered up to five times more power than the previous design.

Although Watt is often credited with inventing the steam engine and many of its accessories, this is clearly not so. He took an existing poor design and transformed it into a practical and beneficial reality. However, it is also wrong to see him merely as a mechanic using his skill with machines and tools to effect improvements. Despite his lack of higher education, he absorbed knowledge from a wide range of fields and was instrumental in the development of many chemical advances in bleaching, dyeing and the separation of gases.

How to fund the R&D budget for next year.

PHOTO: BAROQUE FLUTE BY BOAZ BERNEY, AFTER AN ORIGINAL BY THOMAS LOT, 1740.

Sir Humphrey Davy, a colleague in many of these chemical experiments, said "he was equally distinguished as a natural philosopher and a chemist, and his inventions demonstrate his profound knowledge of those sciences," and that Watt had "that peculiar characteristic of genius, the union of them for practical application." However, Watt himself confessed that he was not a businessman, writing, "I would rather face a loaded cannon than settle an account." This is where Matthew Boulton played his part, managing the business side of Boulton & Watt, leaving his partner free from the financial worries that had filled his early career and allowing him to mix with the finest scientific minds in Britain and Europe. Watt more than held his own in such elevated company despite his humble origins.

A footnote to Watt's early career was found in the contents of his Birmingham workshop gifted to London's Science Museum over 100 years after his death. Among the wide range of woodworking tools were several specialist pieces required for the manufacture and repair of flutes, dating back to his early years in Glasgow. These tools include a manufacturer's stamp bearing the legend "*T LOT*," clearly intended to give the impression the instrument was made by leading French manufacturer, Thomas Lot, the "Stradivari of flutes." This adds an intriguing twist to young Watt's financial predicament. Fortunately, his association with Joseph Black's chemistry department and its needs for ingenious instrument repair kept him out of prison and enabled him to take that fateful, inspirational stroll on Glasgow Green exactly 250 years ago. ■

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Kelvin: An Irishman's Tale

BY ANDY PEARSON, PH.D., C.ENG., MEMBER ASHRAE

The most highly educated, well-respected and well-traveled of the three most famous names in refrigeration (Joule, Kelvin and Watt) is undoubtedly Prof. William Thomson, better known as Baron Kelvin of Largs, or simply Lord Kelvin. Unlike Joule, who was single-minded in his devotion to the study of one key topic, Thomson's interests were immensely varied, ranging from theoretical abstractions such as the theory of light or the nature of heat through practical applications such as calculating the tides around the coast of Britain or applying observations of ships' wakes to the design of the hull.

He also was widely involved in industrial ventures, including the laying of the transatlantic telegraph cable, the development of the hydro power station at Niagara and the shipping of beef and lamb from Australia and New Zealand to Europe. Although he is assumed by many to be Scottish and, indeed, he spent over 50 years as professor of natural philosophy at Glasgow University, Thomson was born and raised in Belfast, Northern Ireland, and received his university education at Peterhouse College, Cambridge, England. His family moved to Glasgow when he was nine years old, and his father was appointed professor of mathematics at the university. William was a precocious child, learning French, German, Latin and Greek as well as showing a keen interest in natural philosophy. However he was not simply a bookworm; he enjoyed sports at Cambridge, particularly athletics and rowing, and he played the French horn in a chamber music group.

Hands up if you disagree with my momentum theory.

He undoubtedly was given great opportunities through his family connections (in addition to being personable and intelligent), but he also made the most of what he was given, working hard and investing time, talent and money in ventures that caught his imagination and offering unstinting support to friends and colleagues who needed his help. He was not always right, and was terrible at mental arithmetic, but he was always willing to listen to reason and evidence and was always willing to change his mind.

In 1870 the university moved from its city center location, which it had occupied for over 400 years, to a spacious new, custom-built facility on a hill overlooking the city. Professor Sir William Thomson, as he was known at this stage, moved out of the dingy, cramped cellars he had used as laboratories for 24 years through the most creative, productive period of his career. However, he remained professor in the department of Natural Philosophy for a further 30 years, bringing international recognition not only to himself but also to his colleagues, his department and his university.

Despite lucrative offers from around the world he refused to leave Glasgow. His devotion to his adopted home explains the famous name given to the absolute temperature scale; when citizens are granted the honor of a peerage, they can choose their title, usually adopting a place name that is particularly dear to them. Thomson selected the title Lord Kelvin when he became a baron in 1892, taking the name from the river that flows past his laboratory and the park in which the new university buildings were situated.

My great-grandfather, who trained as a doctor at Glasgow University, attended Kelvin's physics lectures in the 1870s. These were often deeply theoretical; one student is reported to have said, "I listened to the lectures on the pendulum for a month and all I know about the pendulum yet is that it wags."

However, Kelvin had a reputation for livening up the classes with hair-raising practical demonstrations. To illustrate the principle of conservation of momentum, Kelvin is said to have fired a blunderbuss-style elephant gun across the lecture hall at a steel plate hanging on the other side of the room. The reaction of the students is not recorded, but the lesson clearly made a big impression. ■

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Remembering Milt Garland

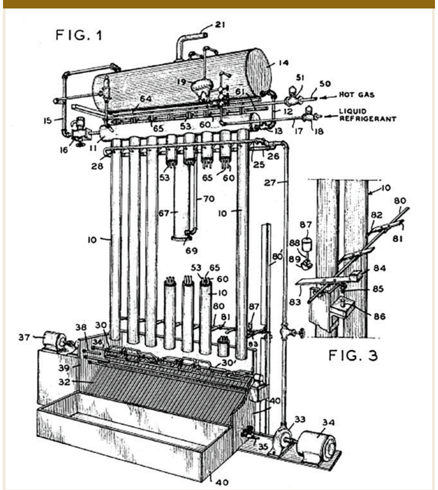
BY ANDY PEARSON, PH.D., C.ENG., FELLOW ASHRAE

Milton W. "Milt" Garland is fondly remembered by many coworkers and industry peers with whom he served in ASHRAE and the International Institute of Ammonia Refrigeration (IIAR) over many years.

He was in many ways a remarkable man, not least because he had the distinction of working for the same company for 80 years, from 1920 until two months before his death in July 2000. He died less than one month short of his 105th birthday. His length of service is all the more remarkable since his college education was interrupted by service in the U.S. Navy during World War I, so he was already 24 years old when he joined the Frick Company as a refrigeration erector.

Within three years of joining Frick, Milt was superintendent of field installation. By the time he retired in 1967, he was vice president for technical services, but he was rehired the next day and worked 20 hours a week as an engineering consultant to the company until May 2000.

Milt Garland's tube ice maker, from U.S. Patent 2,870,612.



Milt was the author or coauthor of 35 U.S. patents, with 16 in other countries, ranging from evaporator design, control valves, ice makers, compressors and a range of freezing techniques.

The length of his career is perhaps best illustrated by the subject of his first two patent applications in 1930. The first is for a thermostatic control arrangement for expansion valves using a temperature-activated switch and a solenoid valve. A few months later he patented a gravity-fed evaporator circuit, an arrangement most of us no doubt think had been around forever.

He worked on many major projects around the world, including cooling the Hoover Dam during its construction, chilling rubber to help wartime production, and aircraft engine environmental testing.

One of his most interesting ideas was for a tube ice maker that formed the ice on the outside of the tubes instead of the inside, as in most other tube ice machines. This was patented by Milt in 1955. Tube ice remains one of the most common methods of making bagged ice for supermarkets.

Milt's advice to younger colleagues was simple. "Don't answer a question if you don't know the answer. Don't worry; worry never solved a problem. Be professional." He also advised that the key to job satisfaction lies in learning to like what you are doing. "Go into something," he said, "and then stay with it, and then like it. You won't like it unless you have expertise, and once you are an expert it's a pleasure."

Milt is remembered in ASHRAE through the presentation by the Refrigeration Committee of the Milton W. Garland Commemorative Refrigeration Award for Project Excellence. The award recognizes the designer and owner of a project that features a non-comfort cooling refrigeration application that incorporates new technology in a unique manner. It is presented at the ASHRAE Winter Conference each year, provided a suitably qualified entry has been received.

Recent winning projects include a large-scale heat recovery system in Vancouver, the application of fuel-cells to supermarket systems in New York state, a solar-powered strawberry freezer in Southern California, the modernization of the San Fernando Brewery in California, and the air conditioning of the Penguin and Puffin Coast exhibit at the Saint Louis Zoo.

ASHRAE's Refrigeration Committee also presents a comfort cooling award. Details of both can be found on the Refrigeration Committee's page (www.ashrae.org/refrigeration) under Awards. Entries must be approved by the submitting chapter and received by May 1. ■

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Thaddeus Lowe: Refrigeration Pioneer

BY ANDY PEARSON, PH.D., C.ENG., FELLOW ASHRAE

He has been described as "the most famous American you've never heard of" and "the most shot-at man in the Civil War." As a teenager he ran away from the family farm to join the circus, and he went from rags to riches several times in a long career in science and engineering. At the age of 23 he met a 19-year-old Parisian actress, fell madly in love and a week later they were married, on Valentine's Day, 1855. Despite this whirlwind romance they raised a family of three sons and seven daughters, and when she died on May 16, 1912, after 57 years of marriage, he was heartbroken and only survived a further eight months.

His main passion was the science of manned flight. The circus act that enticed him from the farm was a traveling show that filled soap bubbles with hydrogen and floated them across the audience. This led him in turn to develop interests in the new sciences of aeronautics, climatology and astronomy, and then to him competing (unsuccessfully) to be the first person to cross the Atlantic by balloon. Although he often used the title "Professor Lowe," he had no formal education and was largely self-taught. However, this did not prevent him from achieving several successful balloon flights in 1860 and 1861 and coming to the attention of President Lincoln.

Reach for the skies.

At a demonstration to Lincoln of his ballooning capability on the Mall in Washington, D.C., in 1861, Lowe showed how a balloon observation post could be deployed in a short time, giving unrivaled intelligence of enemy troop positions. As a result Lincoln invited him to form the U.S. Army Observation Corps, and despite being a civilian, he went on to serve in numerous battles as a "spotter" for the Union Army artillery. His equipment was mounted on two gun carriages for portability and used a mixture of zinc, iron and sulphuric acid to create hydrogen gas, which was then pumped into the balloon fabric. Within a couple hours of establishing camp, he could be in the air, using a telegraph wire to signal to the gunners below.

After the war his interest turned, among other things, to the preservation of meat. He adapted his hydrogen pump to work with carbon dioxide and created a system to condense

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and evaporate the working fluid in a closed loop. Although vapor compression had been described by several people including Jacob Perkins, Alexander Twining and James Harrison, Lowe was the first to use carbon dioxide, predating the first closed-loop ammonia system by about six years.

While it was technically successful, with three patents granted in 1867, his ice-making machine was not sufficiently attractive commercially, so Lowe returned to the Northeast and developed interests in the production of gas. In 1875, he patented a process for the production of "carburetted water gas," a mixture of carbon monoxide and hydrogen produced by passing superheated steam over hot charcoal while injecting oil. This was highly successful and enabled him to retire to Pasadena, Calif., on the proceeds.

Once there he indulged his passion for astronomy, building an observatory on a peak in the San Gabriel Mountains and constructing a gas works, hotel, electricity generating station, and funicular railroad (to the observatory on "Mount Lowe") in the city.

A theme recurs throughout this story. There are numerous sharp changes of direction in Lowe's career. It seems that he not only had a quick brain, but a quick temper, too. He left New York, the Army and the refrigeration business after failing to see eye to eye with people and falling out with them. Yet he was also faithful to his wife, his family, his business partners and his ideals. This brought him into contact with presidents, generals and the leading scientists of the day.

If his life had been scripted in Hollywood, it would be dismissed as "too unbelievable." Indeed, it has the air of Forrest Gump about it, being edited into the major moments and inventions of his century. However, he was someone who appeared at just the right time with just the right mix of inventiveness, adventure and charm to succeed. ■

Andy Pearson

Godfather of Thermodynamics

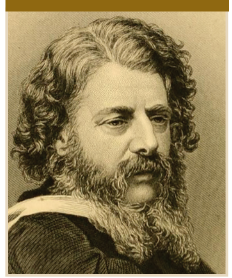
BY ANDY PEARSON, PH.D., C.ENG., FELLOW ASHRAE

Anyone who struggles with ill health through their school years is largely self-taught as a result, yet creates a career for themselves in industry and then transitions to the top flight of academia deserves our respect. When this person works alongside far more famous colleagues, but has his career cut short by ill health and dies at the age of 52, it would seem likely they would fade into obscurity. Not so for Professor William John Macquorn Rankine, engineer, scientist, educator, communicator, and much more.

As a teenager, Rankine attended the University of Edinburgh for two years, leaving at 18 (without a degree) to join a railroad construction company. He worked in Scotland and Ireland during the early 1840s in the first wave of rapid growth of the railroads and also worked on the construction of harbors and waterworks.

He made one of his first engineering breakthroughs with an article called "The Fracture of Axles." This article was the first description of the phenomenon that we now call "metal fatigue" and correctly identified it as the cause of several serious railway accidents. It explained the mechanism that caused cracks to form and then grow near square-cut shoulders in the axles. Rankine showed that the form and structure of the metal were significant (as every engineering student now knows). The article also disproved the prevailing theory of the time, that these accidents had been inexplicable and unpredictable because the metal just crystallized spontaneously.

William J.M. Rankine.



In the early 1850s, he worked as civil engineer on the construction of the main water supply from Loch Katrine to Glasgow, a distance of over 40 miles (64 km). This water supply is credited with driving typhoid and cholera out of the city and is still in use today.

In the late 1840s while still developing his career as a young civil engineer, he started making some groundbreaking advances in thermodynamics, approaching the science of heat from the atomic level. Several novel publications resulted in his election to the Fellowship of the Royal Society in 1853, and two years later he accepted the chair of Civil Engineering and Mechanics at Glasgow University in the company of Professor William Thomson (later Lord Kelvin).

Thomson later wrote of Rankine's contribution to the dynamical theory of heat that "even the mere title of his earliest paper on this subject, 'Molecular Vortices,' is an important contribution to physical science." He is credited with writing the first treatise on thermodynamics in the English language and for naming the equivalence of heat and the increase of entropy as the "first and second laws of thermodynamics," although he wasn't the first to describe them.

As an educator, it was said that "all his writings are marked by a power of statement so clear and logical that the reader, even should he fail entirely to follow the demonstrations, cannot but be benefitted in the attempt to master them." I think this was a compliment.

The same commenter, W.J. Millar, a student of Rankine's, also wrote "Rankine's lectures, although simpler than his textbooks, were marked by the same clearness of arrangement and were enforced by his distinct and vigorous enunciation, and admirably illustrated by carefully prepared diagrams." He was responsible for introducing a degree qualification in engineering at Glasgow University, creating the first engineering graduates in the United Kingdom.

Kelvin and Rankine, who worked at the same university at the same time, have given their names to the two scales of absolute temperature (SI and IP, respectively). Rankine is also now widely remembered for first describing the Rankine power cycle, which is known as the organic Rankine cycle system when it uses HFCs.

Spare a thought for Professor Rankine and his legacy on Christmas Eve this year. William J.M. Rankine: born July 5, 1820, died Dec. 24, 1872. ■

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Andy Pearson

Louis Sterne
International Man of Mystery

BY ANDY PEARSON, PH.D., C.ENG., FELLOW ASHRAE

I was recently asked why I chose a career in refrigeration and why it was that Glasgow, my hometown in Scotland, was the place to follow that path. Strange as it may seem, it is all the result of the shocking events of April 14, 1865, when John Wilkes Booth shot the 16th President of the United States in Ford's Theatre, in Washington, D.C.

At the start of the Civil War a young railroad engineer from Philadelphia volunteered with the 7th Regiment of the New York State Militia. The engineer, Louis Sterne, first came to Abraham Lincoln's attention when he sailed a steamboat up the Potomac River to the Washington Navy Yard with 170 troops and supplies for the regiment on board. Sterne had cleverly disguised the boat as a gunship by installing half kegs down both sides, painted to look like gun barrels. This "sham gunboat" appealed to Lincoln's sense of humor and he remembered Sterne two years later when the engineer sought a position on the President's diplomatic staff, having been wounded at the Battle of Gettysburg.

Louis Sterne: shaken, not stirred.

SOURCE: SEVENTY YEARS OF AN ACTIVE LIFE BY LOUIS STERNE

Sterne was sent to Europe as a Secret Service agent in Sweden and Denmark to prevent ships being equipped as blockade runners for the Confederate army. As the war drew to a close in 1865, Lincoln invited Sterne to return to America, with the offer of a "more profitable but perhaps not so agreeable" appointment. Sterne was in London on his journey home when he received news of the assassination. As Lincoln had never disclosed the details of his proposal, Sterne had no job of which to return. He was fortunate to meet Cyrus Field in London, and Field arranged for Sterne to be employed in his endeavor to lay the transatlantic telegraph cable. This high-profile project enabled him to establish himself in London as an enterprising and resourceful engineer. His early experience on American railroads led him in 1874 into a business venture with William Sparks Thomson who had a business in Great Britain manufacturing spiral springs for railroad bumpers. The business was called Thomson, Sterne and Co. and the headquarters were in London, but the manufacturing plant was the Crown Iron Works on the northwest side of Glasgow, center of the railroad locomotive manufacturing business in Britain. When Thomson retired in 1882, James Beale was appointed as chairman and the company was renamed "L Sterne and Co." To augment the spring manufacture, Sterne introduced a line of emery grinding wheels and he made frequent trips back to the U.S. looking for other business opportunities. This resulted, in 1887, in an agreement between L Sterne and Co. and the De La Vergne Co. of New York City, manufacturer of a steam-powered ammonia compressor. Within three years the sales figures for ammonia compressors exceeded those of emery wheels and springs combined, and L Sterne and Co. was established as one of the leading refrigeration firms in Great Britain.

Sterne described himself as an inventive engineer with a string of patented inventions to his credit. However Sir Samuel Beale, James' son who served as managing director and chairman of L Sterne and Co. from 1905 to 1936, wrote that Sterne's "geese were always swans," meaning that he tended to over-sell his accomplishments, and added of Sterne's long list of patents "I am afraid that none of these ever left any great mark on the world." In 1925 Sir Samuel's nephew, Peter Brown, was appointed general manager, and in 1936 Steve Pearson joined the company as assistant works manager. In time their sons, Anthony and Forbes, also joined Sterne's, leaving in 1970 to form their own company, Star Refrigeration Ltd. It was Anthony, the great-grandson of James Beale, who offered me my job with Star in 1986, and that is how I came to be doing refrigeration in Glasgow. ■

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Richard Mollier

King of the Charts

BY ANDY PEARSON, PH.D., C.ENG., FELLOW ASHRAE

Richard Mollier, born in Trieste, Italy, in 1863, was professor of mechanical engineering in Dresden, Germany, from 1897 until his retirement in 1931. He was one of a group of scientists and engineers in Southern Germany in the late 19th century including Clausius, Linde and Zeuner who did much to advance the understanding of the science of refrigeration, but Mollier's contribution was uniquely practical and is still widely used by designers.

At the beginning of the 20th century, engineers had been building and operating vapor compression refrigeration systems for nearly 50 years but had a very sketchy idea of what was actually happening. Mollier undertook the meticulous task of tabulating the thermal properties of various fluids including ammonia, carbon dioxide, steam and moist air, enabling more accurate computation of system performance, and in 1904 took the radical step of plotting this information in easy-to-use charts. The two most commonly used charts are the temperature-entropy diagram and the pressure-enthalpy chart. The former tends to be favored by academics in thermodynamics because the area under any process traced on the chart is proportional to the work done, whereas the latter form is more useful to practical engineers because the enthalpy difference multiplied by mass flow gives the heat transferred in the evaporator or condenser and the work done in the compressor. To make the scale more useful the pressure is often plotted on a logarithmic axis up the side of the chart, and enthalpy is plotted on a linear scale along the bottom of the chart.

Richard Mollier, King of the Charts.

The pressure-enthalpy chart for a refrigerant contains a couple of boundary lines, representing the heat content of the fluid when it is liquid on the point of boiling (the saturated liquid line) and when it is gas on the point of condensing (the saturated vapor line). The horizontal distance between these two lines at any point is the latent heat of the fluid—the amount of energy that needs to be added to turn it from liquid to gas, or conversely the amount of heat to be removed to turn the gas to liquid. The saturated liquid line has a positive gradient on the pressure-enthalpy chart, but the gradient reduces until the line is horizontal. The saturated vapor line at high pressure has a negative gradient and there may be a pressure at which the heat content is maximal; below this pressure the vapor line gradient becomes positive. Thus, the two lines form a dome, meeting at a pressure maximum where their gradients are horizontal.

When working with these charts we routinely talk about points between these two lines as if a homogeneous fluid exists at these points. To fully understand what's happening inside a refrigeration system, however, it is necessary to appreciate that this is a hypothetical construct; in reality for any point under the dome some of the fluid is liquid and some is gas. From a mathematical point of view this doesn't matter and the mixture can be treated as a single fluid with enthalpy being the aggregate of the liquid and gas phases. The percentage of gas in the mixture is known as the "quality"—a mixture that is 10% quality means that 90% of the fluid is liquid. This concept is helpful for the math, but it is always important to recognize the practical implications of the two phases when designing systems, especially pipes and heat exchangers. In this sense, high quality means less useful for refrigeration purposes.

Mollier's charts were of such immense practical value that they quickly became widely used by scientists and engineers around the world as the standard way of calculating system performance. In 1923 at the World Congress of Thermodynamics in Los Angeles it was agreed that any graph with enthalpy as one of its axes would be known as a Mollier Diagram. ■

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Andy Pearson

'Where No Man Has Gone Before'

BY ANDY PEARSON, PH.D., C.ENG., FELLOW ASHRAE

For people, like me, of a certain age the phrase "To boldly go where no man has gone before," conjures up a level of excitement and anticipation of the adventures of the starship Enterprise and its intrepid commander, James Tiberius Kirk. In the refrigeration world, however, we ought to celebrate another Kirk with a funny middle name, Alexander Carnegie Kirk.

Like his 24th century namesake, Kirk boldly did things that had never been done before but he seems to have been modest in his achievements and happy for others to take the limelight. His early career was spent as an apprentice in a Glasgow shipyard's foundry with a reputation for building high-powered marine engines and in 1854 he moved to London as chief draftsman for the company who had made the engines for Brunel's SS Great Western. After five years in London Kirk's career took a sharp tack to starboard when he moved back to Scotland and joined chemist James Young at his shale oil works in the industrial area halfway between Glasgow and Edinburgh. Young was one of the first to synthesize kerosene by the dry distillation of shale and Kirk developed an improved design of retort, which made the process commercially viable. At its peak the Scottish shale oil industry produced 90% of the world's kerosene (known as paraffin in Britain) and substantially replaced whale oil as the preferred fuel for indoor lamps before electric light was introduced.

I need more power, Scotty.

©CBS PHOTOS

While working on the shale oil process Kirk found he had a need for an artificial cooling system to maintain process efficiency in summer. The refinery had already installed an early ethyl ether machine developed by William Harrison in Geelong, Australia, five years earlier, but Kirk was inspired to use air as the means to scale up the cooling capacity. Kirk's machine worked on the same principle as Robert Stirling's heat engine, but with the focus on driving the pistons to make a stream of air cold.

With a pressure ratio of 2 in his early machine, he was able to achieve a temperature of 9°F (–13°C) and his first prototype ran for 10 years at the plant. For later models he increased the pressure ratio and was able to achieve –40°F (–40°C). This air cycle quickly became the preferred method of cooling, and 15 years later, one of Kirk's colleagues at the refinery, James Coleman, produced an improved machine in collaboration with Sir William Thomson (*ASHRAE Journal*, June 2015). The Bell-Coleman machine was more compact and led the effort to ship refrigerated meats from Australia, New Zealand and South America.

Kirk didn't stay at the refinery long enough to see this development. In 1865 he returned to marine engine manufacture in Glasgow, with succession of famous Clydeside shipyards, eventually returning to Napier's where he served his apprenticeship almost 30 years earlier. At Napier's he made perhaps his most notable development; the invention of the triple expansion marine engine that made steamships up to 25% more efficient and revolutionized marine engineering throughout the world for the next 75 years.

Kirk's early efforts were not promising and the Royal Navy was not keen to try this crazy new invention. However, despite his shy manner, Kirk showed a remarkable flair for marketing; telling the men from the British Admiralty that the Imperial Russian Navy had already ordered over 12,000 hp (8948 kW) of engines for its fleet. The Admiralty quickly placed an order for two, which exceeded its expectations in sea trials and so the future of the innovative technology was ensured. ■

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Andy Pearson

From Journalist to Ice Maker

BY ANDY PEARSON, PH.D., C.ENG., FELLOW ASHRAE

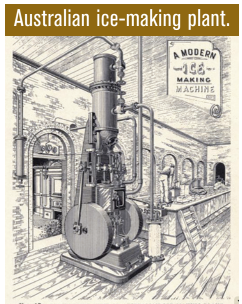
I made a terrible blunder in a recent column (June 2018) when I referred to the Scots-born refrigeration pioneer James Harrison as "William." There's really no excuse and I should know better. Harrison was born in Scotland in 1816, in the village of Bonhill, which is about 20 miles from my home, although he emigrated to Australia at the age of 21 and carved out three careers there in journalism, local politics and the development of mechanical refrigeration.

Bonhill sits on the east bank of the River Leven, which connects Loch Lomond with the River Clyde. The Leven is only 6 miles (10 km) long but it is one of the fastest flowing rivers in Scotland with a mean flow rate of about 700,000 gpm (44 000 L/s). The village has existed since at least 1225 when it was a fording point on the cattle drovers' road from Dumbarton to Stirling. In the late 18th century, in the early days of the industrial revolution, it became a center for textile finishing including bleaching, dyeing and printing, no doubt helped by the plentiful supply of clean, fast-flowing water.

James Harrison's father (who was a William) was a fisherman in Bonhill but moved his family to Glasgow, the industrial center of the region and James attended the local Mechanics' Institute there to train as a print compositor. Once qualified he moved to London at the age of 19 and a short time later, in 1837, he emigrated and found work with JP Fawkner at the offices of the Melbourne Advertiser. Fawkner instructed Harrison to set up a sister paper, the *Geelong Advertiser*. Geelong was a port about 47 miles (75 km) southwest of Melbourne and in 1840, when Harrison arrived there, the town had a population of 400 people, similar in size to Bonhill in those days. It is now known as the City of Greater Geelong and has over 230,000 inhabitants (Bonhill has about 9,000).

It is said that his observation of the cooling effect of diethyl ether on the plates of the printing presses inspired Harrison to develop his ice-making machinery. Whatever the starting point, he remained an enthusiast for ether, despite its disadvantages, for the rest of his life.

Australian ice-making plant.



He was not the first person to propose a closed-cycle ice-making system but he has a strong claim to be the first to be commercially successful and was most probably not aware of the previous ideas of Oliver Evans and Jacob Perkins or the concurrent work of John Gorrie and Alexander Twining in the U.S. Harrison developed his machine in the early 1850s and brought his ideas back to London in 1856 where he attracted much attention from the scientific community, including Michael Faraday at the Royal Institution.

He linked with Daniel Siebe of London to commercialize his ideas, which included a high-pressure float valve as the expansion device, a shell-and-tube condenser and an air purge mechanism, which presumably was essential due to the operation of the system below atmospheric pressure and the extreme flammability of ether. He also proposed using his system as a heat pump for the distillation of essential oils—one of the first applications of heat pump technology.

After two years in London promoting his ice-making ideas Harrison returned to Australia and founded the Victoria Ice Works in Geelong in 1859. He continued as editor of the *Geelong Advertiser* until 1866 when the mounting costs of his technical developments pushed him into bankruptcy. From this point on, while others profited from his initial ideas and the refrigeration market blossomed, he took virtually no further part in it. He died, in poverty, in 1893, and his gravestone in Geelong carries the epitaph "One soweth—another reapeth." ■

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Andy Pearson

Born With a Silver Spanner in Her Hand

BY ANDY PEARSON, PH.D., C.ENG., FELLOW ASHRAE

I am writing this column on the birthday of one of the most unusual and inspiring characters in engineering history. She was born in a Scottish castle near Perth into a family of the landed gentry and was named after her godmother who was Queen of the United Kingdom of Great Britain and Ireland.

Despite her noble beginnings Victoria Drummond clearly had an aptitude for hands-on engineering. As a young girl she enjoyed making wooden toys and models and is said to have won prizes for them. Aged 21 she started an apprenticeship in a garage in Perth and two years later transferred her training to the Caledon Shipbuilding yard in Dundee, where she served her time in the pattern shop for the foundry and in the finishing shop. After two more years she completed her apprenticeship and spent further time as a journeyman engine builder and then in the drawing office at Caledon. When the yard hit hard times a couple of years later she was laid off, but managed to get a place with the Blue Funnel line in Liverpool and after a short trial voyage she was signed on as tenth engineer (the bottom rung of the ladder) on a passenger liner sailing between England and Australia.

After completing two years' service with Blue Funnel she passed her second engineer's ticket, but could only find work as a fifth engineer sailing on a cargo ship between England, East Africa and India. She sat the Chief Engineer's examination in England 37 times over a 10-year period—eventually the Board of Trade representatives admitted that they always failed her because she was a woman, but in order to avoid accusations of bias they failed all the other candidates who sat the exam at the same time as her.

One month before her 45th birthday war was declared. Despite her excellent qualifications,


Victoria Drummond, MBE, Oct. 14, 1894, to Dec. 25, 1978.

CREDIT: IMAREST

experience and record, Victoria could not get a berth in the British Merchant Navy, so she signed on with a Palestinian cargo and passenger ship and then with a Panamanian freighter. While sailing to the United States the freighter was attacked by enemy aircraft. Despite some damage to the boiler feed water pipes

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due to several near misses she managed to raise the output of the engines, enabling the ship to reach 12.5 knots, nearly 40% faster than it had ever gone before. This was done single-handed, as she had ordered the engine-room crew to go up on deck in case they had to abandon ship. The ship survived the half-hour bombardment and docked in Norfolk, Virginia, on Sept. 8, 1940. For her part in this remarkable escape, Victoria Drummond was awarded the MBE and the Lloyd's War Medal for Bravery at Sea, although her diary for the day of the attack simply says "Three great explosions on the port side when bombs fell….made temporary repairs."

For the rest of the war Victoria continued to sail with a variety of cargo ships, including as refrigeration engineer on a voyage from Liverpool to New York, Panama, Australia South Africa, Sierra Leone and Gibraltar, returning to Liverpool eight months after setting off. She also sailed on the brutal Arctic convoys to Northern Russia and after D-Day she spent several months on supply ships in the English Channel. After the war she worked for Blue Funnel and Cunard-White Star, supervising construction of new ships back at the Caledon yard in Dundee and sailing as Chief Engineer for a variety of companies. She celebrated her 59th birthday as Chief Engineer on a freighter sailing from England to Belgium (via Suez, Japan, Hong Kong, Singapore, the Black Sea, the USA, the Caribbean, Argentina and Brazil). She continued to sail the world for a further eight years and finally signed off in Hong Kong on March 30, 1962—at the age of 67-and-a-half.

Throughout her long career as a marine engineer Victoria Drummond battled and overcame bias, prejudice and red tape, principally by being exceptionally good at what she did. She was not afraid to stand up for herself and spoke out against low standards wherever she found them. She won the respect of the majority of the crews who served with her and she was said to have an "uncanny power over engines." She died on Christmas Day 40 years ago. Remember her example and pass on her legacy this Christmas. ■

Andy Pearson

Happy Birthday, Mr. Rankine

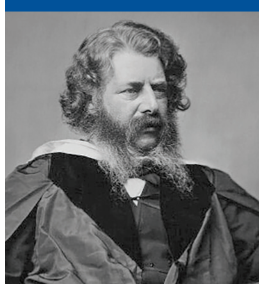
BY ANDY PEARSON, PH.D., C.ENG., FELLOW ASHRAE

When the Fourth of July celebrations are fading into the morning after the night before, please take a moment to raise a glass to Professor William Rankine on the occasion of his 200th birthday. I had hoped to be leading the celebrations with a paper on Rankine's legacy regarding thermodynamics at the Purdue Conference the week after his birthday, but sadly that fell victim to the pandemic and has been postponed until next year.

I gave a short description of Rankine's career and contribution to refrigeration in a previous column (December 2016). Since then, in preparing for the Purdue paper and for a conference planned for the end of July in Glasgow,* I have come to an even greater respect and admiration for the man and his legacy, particularly in engineering education and thermodynamics.

He was highly regarded as an educator not only for the clarity of his lecture courses, but also for the five major textbooks he produced over a period of about 10 years. These became popular throughout the world and were revised and reissued for many decades after his death. As a result, he was far better known in the early 20th century in the United States and Japan than he was in his home country. His books can be found in electronic form on web sites such as archive.org and are still models of clarity, brevity and simplicity that should serve as the blueprint for any aspiring author of a scientific text.

WJM Rankine, born July 5, 1820.



In stark contrast, his work on thermodynamics was highly complex and, as one biographer said, he was "*profuse in his use of algebraic symbols and profound in all kinds of equations and analysis*."† Inspired by the writings of Carnot and Clapeyron, he started work on the theory of heat and work in 1842 while still a trainee civil engineer constructing railroads and waterways in Ireland. Using an entirely innovative thought experiment on the nature of heat, he generated a complete set of mathematical models to predict fluid properties and power cycle performance but was unable to take his work further at that time because empirical data on the properties of steam and other gases did not exist. However, when Victor Regnault of the Collège de France in Paris published his measurements of steam properties in 1848 Rankine was quick to return to the development of his theory, despite the fact that by that time he was a practicing Consulting Engineer earning his living in the design of infrastructure projects. By this time Thomson in Glasgow, Joule in Manchester, Clausius in Zurich and many others around Europe were agreeing that the old theory of heat as a weightless fluid (also called *caloric*) was deeply flawed and the science of thermodynamics was born. Rankine's paper "On the Mechanical Action of Heat" was presented to the Royal Society of Edinburgh in February 1850 and runs to 63 pages of densely packed logic and complex calculations. One striking feature of the paper is the extent to which he name-checks and hat-tips all those who came before him, some of them still household names and others lost in the mist of time.

His sense of humour shines through his technical writing, too. In a paper titled, "On the Want of Popular Illustrations of the Second law of Thermodynamics," in 1867 he wrote "*The second law….has been much neglected by the authors of popular (as distinguished from elementary) works*" and added a footnote: "*The explanation of the second law of thermodynamics in Dr Balfour Stewart's excellent treatise on heat is elementary, but it is not, nor does it profess to be, popular.*"

Happy birthday, sir! We salute you. ■

https://bit.ly/2YUre1I
Rate this Column

* The Rankine 2020 Conference will go ahead at the end of this month, but as an online event.

† Hedderwick, J., "Backward Glances," p. 223, published by Wm Blackwood & Sons, Edinburgh, 1891.

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Andy Pearson

Celebrating Sadi Carnot

BY ANDY PEARSON, PH.D., C.ENG., FELLOW ASHRAE

June 1, 2021, is the 225th birthday of Sadi Carnot, an original thinker who was not afraid to ask the questions that nobody else had thought. His attempts to answer them were hampered by deficiencies in the scientific theory of the day, and sadly he died in a cholera outbreak at the age of 36 before he had managed to untangle himself from the contemporary understanding of the nature of heat that was holding him back.

Carnot is often portrayed as a maverick loner, working outside the establishment, whose ideas about heat popped out of nowhere and failed to make an impact at the time because of his isolation from mainstream scientific thought. Like most of history this is partly true, but misses a lot of the detail that helps to put his work in context.

Carnot trained for three years from the age of 16 at the École Polytechnique in Paris, where the staff at that time included Ampère, Gay-Lussac, Arago and Poisson and their international contacts included Biot, von Humboldt, Foucault and Faraday. However, he had the misfortune to graduate in 1814 as a second lieutenant in the Corps of Engineers in Napoleon's army the year before the Battle of Waterloo.

At last, a picture of the Carnot cycle that I understand.

Carnot's father, who had been Minister of the Interior in Napoleon's government, was exiled and shortly afterwards Carnot left active military service and transferred to the General Staff in Paris. This gave him the opportunity to reconnect with scientific thinking and he furthered his education by attending lectures in industrial chemistry by Professor Clément, striking up a friendship with the Professor in 1819 and working with him on the improvement of steam engine efficiency. Clément was also responsible for defining the calorie as a unit of heat—the amount of heat required to heat one kilogram of water by one degree Celsius.

Rather than popping out of nowhere, Carnot's now famous publication "*Réflexions sur la Puissance Motrice du Feu*" ("*Reflections on the Motive Power of Fire*") was the result of five years of intense study with Clément and his colleagues, probing the shortcomings of existing theory. Carnot's major significant breakthrough was the observation that "The motive power of a waterfall depends on its height and on the quantity of liquid; the motive power of heat depends also on the quantity of caloric used, and on what may be termed, on what in fact we will call, the height of its fall. (The matter here dealt with being entirely new, we are obliged to employ expressions not in use as yet, and which are perhaps less clear than is desirable.)" His insight that the "height of the fall" of heat set limits on the process took another quarter-century to travel from the fringes of scientific thought to the mainstream. His big idea was almost lost to posterity because most of his papers were burned after his death due to fear of cholera infection and it was a descriptive interpretation of *Réflexions* by Clapeyron, published two years after Carnot's death, that provided a picture signpost to the next generation of heat investigators by plotting Carnot's ideal cycle on a graph of pressure against volume.

I am indebted to *ASHRAE Journal* reader Bob Hanlon who has produced an excellent (and very accessible) textbook called *Block by Block: The Historical and Theoretical Foundations of Thermodynamics*. The extract from *Réflexions* quoted above and much of the historical context comes from Bob's book, which he says took 20 years to write. It should be on every refrigeration engineer's bookshelf. ■

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