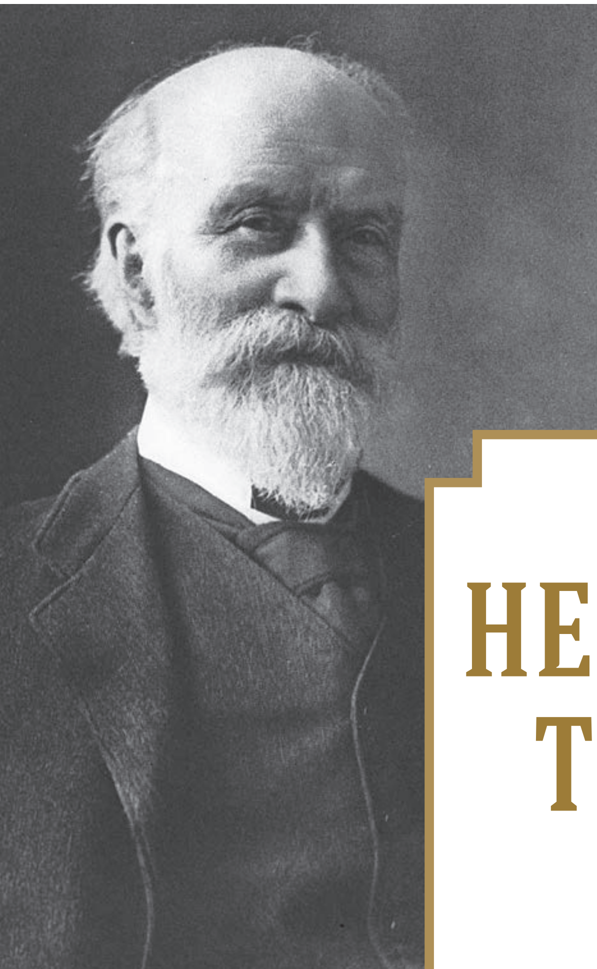
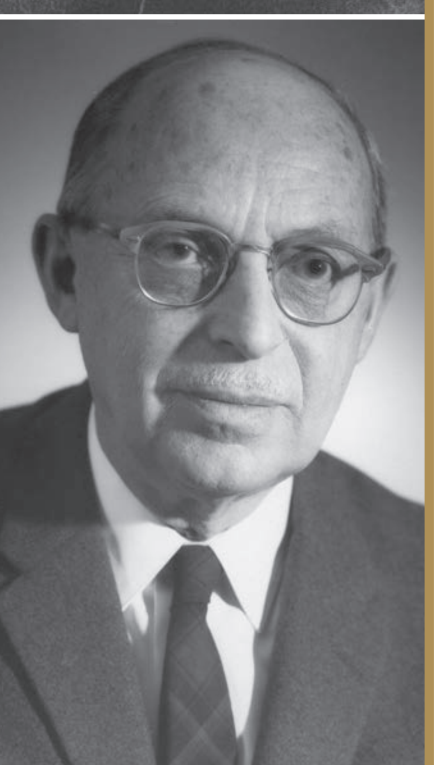


HEROES FOR THE AGES

Ten extraordinary engineers who have made their mark on history



BY
SHARON ASCHAIEK, NICOLE AXWORTHY, JENNIFER COOMBES & MICHAEL MASTROMATTEO

What makes a hero? The *Canadian Oxford Dictionary* defines a hero as "a person distinguished by courage, noble deeds and outstanding achievements, etc." We say a hero is also someone who has made life better for all. By these definitions, these engineers are heroes, and then some. These are people who have put their attention and extraordinary engineering skills to the task of finding a new way of doing things, often in the face of opposition. They have offered invaluable contributions to public works, health, transportation, scientific research, agriculture and the profession in general. Without even one of these great engineers, life would not be as we know it today.

Thomas Carroll

Thomas Carroll's invention of the No. 20 combine revolutionized agriculture worldwide, reducing a day's labour to just minutes.

PIONEER OF MODERN HARVESTING DESIGNED WORLD'S FIRST SELF-PROPELLED COMBINE THOMAS CARROLL, 1888–1968

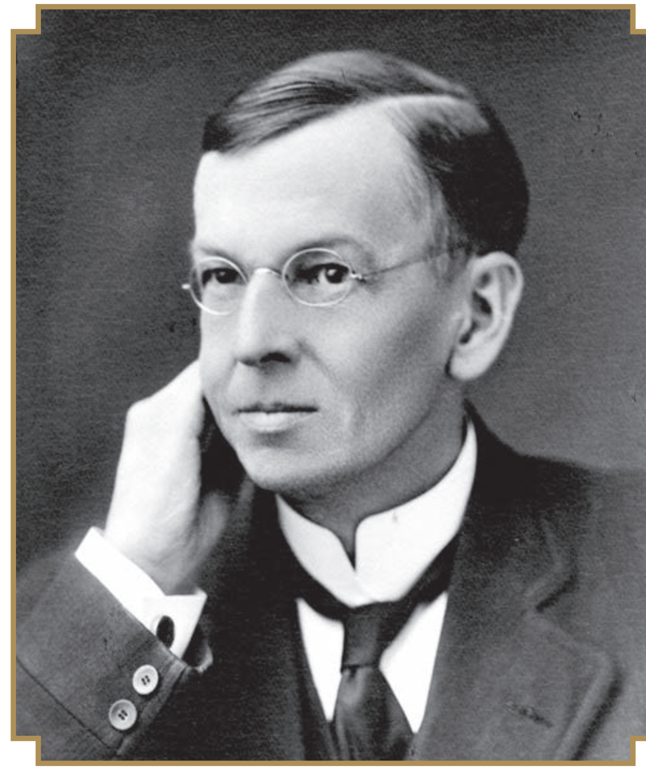
In 1937, Thomas Carroll, an Australian-born mechanical engineer working at Toronto's Massey Harris (M-H, now Massey Ferguson) factory, perfected the first commercially successful, self-propelled combine with its own engine and power train, used to harvest small grains under a wide variety of conditions. Engineered by Carroll and aided by Robert Ashton and Albert Luke, the No. 20 combine was first marketed in 1938. The combine ushered in a new era in farm mechanization, revolutionized the grain harvesting wheels of a row crop unit and set the standard for future self-propelled combine designs throughout the industry. Previously, combines were pulled by horses or tractors.

As it turned out, the No. 20 could go up to four miles an hour and wasted much less grain than previous combines while combining functions, like cutting wheat and separating it from the chaff. Only one person was needed to operate the No. 20 and it was far less destructive to fields. It now took mere minutes to do what had previously taken a full day of labour.

The success of Carroll's No. 20 was followed three years later by a version light and inexpensive enough to be sold widely. The No. 21 went into volume production in 1940, just in time to answer a wartime rural labour shortage. By 1955, when Carroll was promoted to chief combine engineer for the western hemisphere at M-H, self-propelled machines were working grain fields across the globe, and in 1963 the company held the largest share of the world combine market.

The M-H harvester sales success was due largely to the skill of Carroll, who joined M-H in 1917 as a combine specialist and played a leading role in maintaining the company's world leadership in harvesting technology until he retired in 1961. The M-H No. 21 combine was commemorated with a Canada Post stamp on June 8, 1996.

In 1958, Carroll became the first non-American to be awarded the American Society of Agricultural Engineers' Cyrus Hall McCormick Medal for his outstanding contribution to world agriculture.



Willis Chipman, P.Eng., a pioneering consulting engineer, is best known as the originator of separate systems for sanitary and storm sewers.

PIONEER CONSULTING ENGINEER CONCENTRATED ON SAFE WATER SYSTEMS
WILLIS CHIPMAN, P.ENG., 1855–1929

The name Willis Chipman gained fresh attention in 2003 when Consulting Engineers of Ontario (CEO) chose to name an annual award in his honour. CEO's Willis Chipman Award recognizes the knowledge, skill and expertise of consulting engineering firms and showcases the importance of engineering projects to the economic, social and environmental well-being of Ontario.

CEO says the award is a fitting way to acknowledge consulting engineers for excellence and to pay tribute to one of the great leaders and innovators of the engineering profession.

Chipman's name and work might have lost some lustre in recent decades due to the quiet efficiency and steadfast operation of his major engineering projects in the late 1800s. But for a profession that prides itself on being the custodian of critical infrastructure, it's fitting that Chipman's name and achievement come back into the spotlight.

Chipman was at his engineering zenith in the late 19th and early 20th centuries, particularly for his work with sewage and water systems, primarily in Ontario. In a career that thrived for 50 years, Chipman worked on 54 waterworks projects in Ontario, seven in the Maritimes, two in Quebec and 27 in the western provinces.

Although he made his name with water- and sewage-related projects, Chipman is also considered to be one of Ontario's first consulting engineers, and it is in this capacity that he brought significant prestige and acclaim to a fledgling engineering profession.

The pioneering consulting engineer is also regarded as the originator of separate systems for sanitary and stormwater sewers. At a time when typhoid and other water-borne diseases exacted a sombre toll on many communities, any effort to safeguard drinking water was to be celebrated and made the standard for future works.

But as admirable as Chipman's water system work came to be, he also exhibited a flair for administration and support of associations and professional groups that would serve to strengthen the overall practice of engineering.

After graduating from McGill University in 1876 with a degree in civil and mechanical engineering, Chipman became active with the Geological Survey of Canada, where he eventually earned designations as a dominion land surveyor (now called Canada lands surveyor) and an Ontario land surveyor. He was a key player in the founding of the Association of Ontario Land Surveyors, and served as its first secretary treasurer from 1886 to 1890.

Chipman went on to establish a private engineering practice in Brockville before moving the operation (Chipman and Power) to Toronto in 1901. A 1923 newspaper advertisement taken out by the firm reads as follows: "Chipman & Power, Civil Engineers, Water Supply, Sewerage, Sewage Disposal, Pavements and Other Municipal Works, Reports & Estimates, Supervisor of Construction, Appraisals of Works and Utilities."

Prior to devoting more of his time to his consulting work, Chipman served three terms on the council of the Canadian Society of Civil Engineers, which later became the Engineering Institute of Canada.

Having done so much to support civil engineering and its related associations, it was no surprise that Chipman would be active in the founding of the Association of Professional Engineers of Ontario in 1922. He served as the second-ever PEO president the following year.

It's said that Chipman's firm popularized the term "sanitary engineering" as it sought to eliminate contaminants in drinking water and to provide a more robust system for disposing of sewage.

Although chlorination of Ontario's drinking water would not be introduced until 1910, and further improvements would not come until the 1920s, Chipman can rightly be credited with laying the foundation for a new standard in drinking water quality and waste water treatment in Canada.

A booklet from the Petrolia (Ontario) Public Utilities Commission (1966) outlines the care and meticulousness with which Chipman went to work: "In 1895, town council, having launched a further unsuccessful well drilling experiment, called in Willis Chipman of Toronto, one of the most brilliant civil engineers of his day…On the 11 mile conduit, Chipman had installed seven gate valves, four automatic air valves and four blow-off valves. These protected the line and provided for maintenance and repair...Chipman credited this excellent showing to the care in manufacture of the pipe and careful inspection and workmanship at the joints. A piece of this pipe was excavated in 1962 and pronounced 'as good as new.'…Of the quality of water, [Chipman] wrote, 'except for an occasional turbidity, the water supplied your citizens is a perfect water for all purposes. In my opinion, it will be found superior to the water furnished the majority of the cities and towns extending along the Great Lakes and it can never be contaminated by sewage.'"

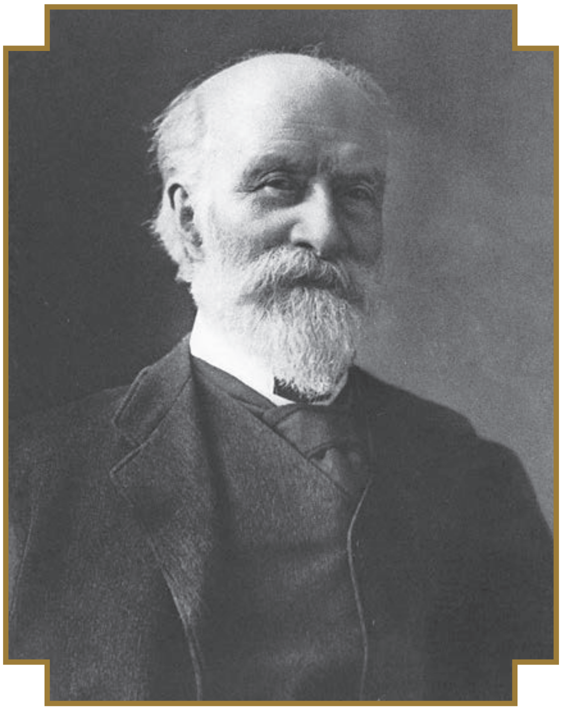
Some engineers today have suggested that engineering was as important as medical science in the late 19th and early 20th centuries with its emphasis on hygiene, disease prevention and water purity. Although modest by nature, Chipman might have supported that view. And given today's concerns about the health and robustness of community infrastructure, buried or otherwise, Chipman, with his attention to detail and awareness of the constraints faced by consulting engineers, might well be considered to be prescient.

RAILWAY ENGINEER KNOWN AS THE FATHER OF STANDARD TIME SIR SANDFORD FLEMING, 1827–1915

The story of Sir Sandford Fleming is one of initiative, innovation and intrepidness. Canada's premier railway engineer and inventor of standard time ushered in an effective system of transportation by train that helped unite the country's widespread provinces.

In 1845, Canada's entire railway ran just 16 miles and train transport was disorganized and inefficient. The arrival that year of 18-year-old Fleming, an engineering apprentice from Scotland who had emigrated with his brother, would change all that. Settling in

Crowds gathered in 1885 to witness the first train on the completed Canadian Pacific Railway (CPR). In 1871, as chief engineer of the CPR, Sir Sandford Fleming embarked on the challenging project of linking the Atlantic and Pacific oceans by rail.



Sir Sandford Fleming

Sir Sandford Fleming's proposal of a single 24-hour clock for the world eventually became known as Universal Standard Time, cementing his status as the "Father of Standard Time." Photo: McCord Museum

Peterborough, he became an Ontario land surveyor in 1849, and his first accomplishment was creating the first map of the city. He started his career with the Grand Trunk Railway, which operated in Quebec, Ontario and some northeastern US states, and his achievements there helped him become, in 1857, chief engineer of the Ontario-based Northern Railway of Canada, the predecessor to the modern Canadian National Railway. In 1867, as engineer-in-chief of the Intercolonial Railway, he led efforts to connect New Brunswick and Nova Scotia to Upper and Lower Canada by rail as part of a Confederation pact.

In 1871, as chief engineer of the Canadian Pacific Railway (CPR), Fleming embarked on perhaps his most challenging project: building a rail link from the Atlantic Ocean to the Pacific Ocean. In a grueling expedition, 800 men surveyed 74,000 km of line, including through the perilous Rocky Mountains, where Fleming and his team discovered a workable route through Yellowhead Pass. In 1885, Fleming, by then retired from surveying but a consultant on the project and a director of the CPR, was present as the last spike was driven in the line.

Developing cross-country rail systems was only one part of Fleming's plan to enhance rail transport in Canada; the other involved fixing the approach to scheduling trains, which was unreliable, because every city, town and village told time by the rising of the sun. Fleming, himself, had once missed a train in Ireland because its printed schedule listed p.m. instead of a.m. as the departure time. This incident sparked his efforts to develop a solution, which led to his development of 24 standardized time zones spanning the Earth. His Universal Standard Time system was adopted in 1885 and came into use worldwide by 1929.

Fleming is also known for linking communications among all nations within the British Empire. He was the chief proponent of the All Red Line, a system of undersea telegraph cables completed in 1902. He also designed Canada's first postage stamp, the Threepenny Beaver, which was issued in 1851.

Fleming's involvement in business and public life lasted for decades after his retirement from the Canadian public service. In 1880, he was appointed chancellor of Queen's University, to which he donated generously and used his influence to raise funds to bolster the university's programs in the sciences, eventually establishing a chair in physics. A popular figure at Queen's, Fleming was continuously re-elected as chancellor, serving for 35 years until his death in 1915. He also became a founding owner of the Nova Scotia Cotton Manufacturing Company in Halifax, which was formed as part of an effort to industrialize Canada's Maritime provinces.

Fleming was recognized widely for his achievements by his peers and by public institutions. He received honorary degrees from Queen's, the University of Toronto (U of T), Columbia University and St. Andrew's University in Scotland. He was made a companion of the Order of St. Michael and St. George, and knighted by Queen Victoria in 1897. His name is borne by a town in Saskatchewan, a college and high school in Ontario, the main building of U of T's faculty of applied science and engineering, and a park in Halifax situated on 95 acres of land where Fleming spent many of his final years before deeding it to the city.

Late in his life, reflecting on the thousands of miles of train track he facilitated and his other accomplishments, he wrote: "I have always felt that the humblest among us has it in his power to do something for his country by doing his duty, and that there is no better inheritance to leave his children than the knowledge that he has done so to the utmost of his ability."

A LEGACY OF OCCUPATIONAL HEALTH AND SAFETY FOR ONTARIO JAMES M. HAM, SCD, P.ENG., 1920–1997

To say that James M. Ham, ScD, P.Eng., was a dedicated Canadian engineer would be an understatement. After earning an electrical engineering degree from U of T in 1943, Ham served with the Royal Canadian Naval Volunteer Reserve from 1944 to 1945 as an electrical officer.

Following World War II, Ham received master's and doctorate degrees from MIT and, following brief stints as a research associate and associate professor there, returned to his alma mater in 1953 as a professor. Later he became head of the department of electrical engineering, then dean of the faculty of applied science and engineering, chair of the research board and, finally, 10th president of the university. He was appointed professor emeritus in 1988.

In addition to his legacy at U of T, Ham was honoured many times for his work in education, training, the health and safety sector, and automatic control, his area of research. Among the awards he received were the Centennial Medal of Canada, Officer of the Order of Canada, Order of Ontario, IEEE McHaughton Medal, the Ontario Professional Engineers Gold Medal, U of T's Alumni Medal, and the Engineering Institute of Canada's Sir John Kennedy Medal. He was also awarded honorary doctorates by one Korean and 12 Canadian universities.

Yet, despite a lifetime of extraordinary service, it is likely not an exaggeration to call Ham's role in developing the *Occupational Health and Safety Act* (OHSA) the most important of his accomplishments.

In 1974, a wildcat strike by uranium miners in Elliot Lake over concerns that mine workers were developing lung cancer and silicosis at abnormal rates prompted the Ontario government to appoint the Royal Commission on Health and Safety of Workers in Mines. Ham chaired the commission, which came to be known as the Ham Commission. When the investigation concluded in 1976, the resulting report contained over 100 recommendations aimed at increasing workers' knowledge and experience of workplace health and safety. Those recommendations led to

James Ham

Among many honours and accomplishments, James Ham, ScD, P.Eng., is best known for his role in the development of the *Occupational Health and Safety Act*. Here, Ham (left) with R. F. Moore, takes part in the demolition ceremony of the School of Practical Science (engineering) at U of T in 1966. Photo: University of Toronto archives

James Ham, ScD, P.Eng., (second from right) helps to celebrate the 50th anniversary of U of T's Ajax campus in October 1994 with the unveiling of a commemorative plaque.

the creation and passage of the OHSA in 1979, resulting in a giant leap forward in protecting the health and safety of Ontario's workers.

The Ham Commission report established three basic rights for workers–the right to participate in occupational health and safety by helping to identify, assess and control workplace hazards; the right to know about any on-the-job hazards presented by people, equipment, materials, processes or the environment; and the right to refuse work that they believe to be unsafe without fear of retaliation by employers.

At the heart of the OHSA is the Internal Responsibility System (IRS), which is based on the idea that everyone in a workplace–workers and employers–is responsible for their own safety and the safety of those around them. To implement the system, Ham advocated creating joint labour-management health and safety committees with worker members.

"Whether they call it the IRS or not, the best performers have found that a system of universal, but personal, responsibility is the most effective way to drive risk down. The power of the IRS is that it captures the creativity, leadership, experience and knowledge of everyone in the organization. The person in the best position to see how the work can be improved on an on-going basis is the person who is doing the work, at whatever level in the organization. Everyone does health and safety as an intrinsic and essential part of his or her job," wrote Peter Strahlendorf, PhD, in "The Internal Responsibility System" published in *OHS Canada*, March 1, 2001.

To inspire engineering students to incorporate safety into their designs and to honour Ham, Minerva Canada Safety Management Education Inc. has awarded the James Ham Safe Design Awards each year since 2006. Students who "make an original and unique contribution to integrating safety into engineering design" are eligible to win a first prize of $3,500 or a second prize of $1,500.

Says Vic Pakalnis, P.Eng., president and CEO, MIRARCO Mining Innovation: "I had the pleasure of escorting Ham around northern Ontario 10 years after the Ham Commission report was delivered. He met with miners in Elliot Lake and Sudbury and I remember the expressions on their faces. He asked them whether things had improved and they said emphatically, yes, they had. They also thanked him. It was quite amazing to have seen the changes that his work produced over my career at the Ministry of Labour. It was indeed an honour. Dr. James Ham, P.Eng., is truly an engineering hero."

CANADA'S FATHER OF BIOMEDICAL ENGINEERING INVENTS EXTERNAL PACEMAKER JOHN "JACK" ALEXANDER HOPPS, P.ENG., 1919–1998

As a pioneer of biomedical engineering best known for inventing the world's first artificial pacemaker, John Hopps, P.Eng., has been instrumental in advancing an innovation that has helped millions of people with cardiac conditions worldwide.

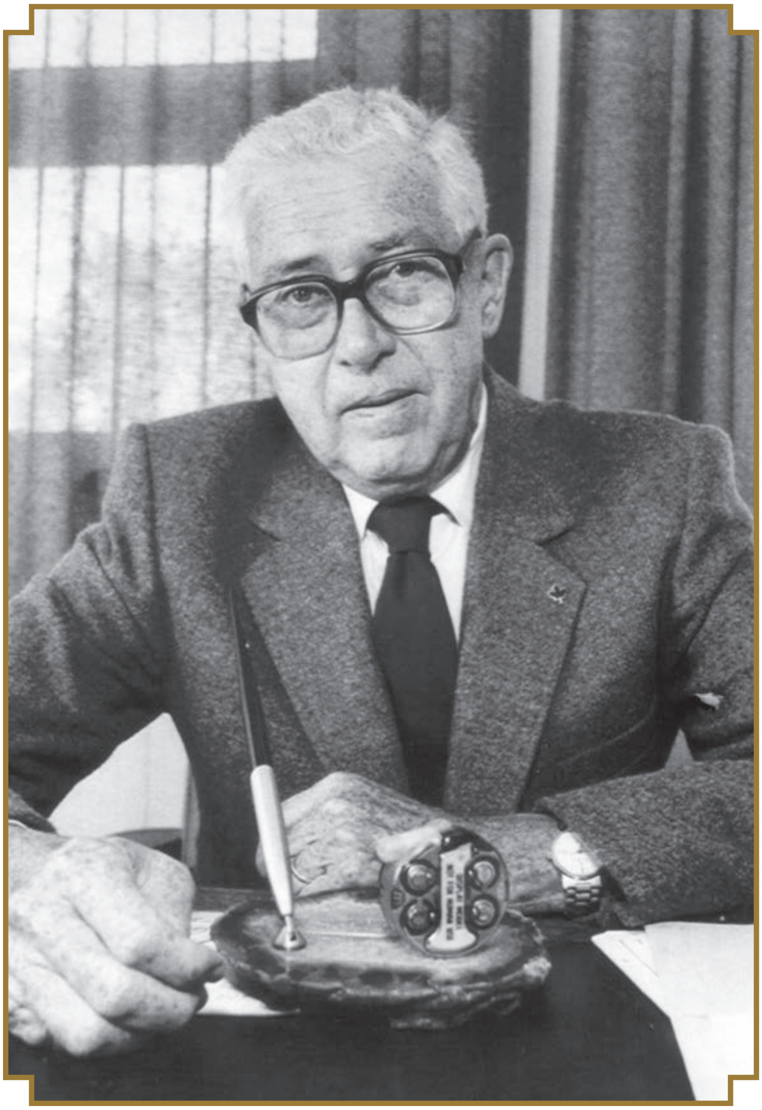
It wasn't heart health that originally prompted the research efforts of the electrical engineer from Winnipeg–it was beer. In the 1940s, the University of Manitoba graduate was working at the National Research Council Canada (NRC) in Ottawa, studying the pasteurization of the beverage using radio-frequency, or microwave, re-warming. While at the NRC, he also worked on a variety of other electrical and radio projects, including wartime radar development. In 1950, Hopps' expertise in radio frequency heating found practical use in the medical sphere when he joined a research initiative at the Banting Institute at U of T. Researchers Wilfred Bigelow and John Callaghan were studying how hypothermia slows the human heart rate, and they invited Hopps to help them find a mechanical or electrical approach to restart a stopped heart.

Drawing on his expertise in radio frequency heating, Hopps created a bipolar catheter electrode that could stimulate a heart's lining without the need to open the patient's chest. The device used vacuum tubes to generate 60 Hz of electrical current that were delivered to the heart through an insulated wire inserted through the jugular vein. Hopps' invention was about 30 cm long and several centimetres high and wide, so it worked strictly as an external device. However, it was the precursor to smaller pacemakers that emerged with the advent of transistors and more reliable batteries. In 1957, the first pacemaker was implanted in the chest of a Swedish man and, since then, has evolved into a common medical device that has had a profound impact on the quality and longevity of life for many people, including Hopps himself, who received two such implants, one in 1984 and one in 1997.

In 1957, Hopps took a one-year leave of absence from the NRC to pursue a professional opportunity as a consultant for Columbo Plan, an organization that promotes economic and social development of countries in the Asia-Pacific Region. Working in Sri Lanka, he helped establish an electromedical division for the country's government health service. Upon returning to NRC, he became involved in enhancing hospital care and safety in Canada, and helped design the first integrated electronic hospital operating room in Canada and an intensive care ward monitoring system.

In 1973, Hopps became head of NRC's medical engineering section, and from then until his retirement in 1979, his team conducted further cardiovascular research, and also invented assistive medical devices to help the blind, enhance the diagnostic uses of ultrasound, and support people with muscular disabilities.

Hopps was a champion of biomedical engineering, who helped promote its growth in Canada. In 1965, he founded and became the first presi-



John Hopps, P.Eng., helped millions of cardiac patients, including himself, with his invention of the world's first pacemaker. Photo: *Ottawa Citizen*–Wayne Cuddington/The Canadian Press dent of the Canadian Medical and Biological Engineering Society. He also helped lead the International Federation for Medical and Biological Engineering, serving as its president in 1971 and as its secretary general from 1976 to 1985. As well, Hopps was president of the Ottawa Chapter of the Ontario Heart Foundation, and chaired the Canadian Standards Association's Committee on Patient Care Safety.

Hopps' contributions to biomedical engineering and to human health earned him several distinctions. In 1986, he was made an officer of the Order of Canada; in 2005, he was inducted into the Canadian Science and Engineering Hall of Fame. In June 2008, his invention of the pacemaker was recognized by IEEE Canada with a Milestone in Electrical Engineering and Computing, which honours significant technical achievements in all areas associated with IEEE.

In 1995, Hopps published his autobiography, *Passing Pulses–the Pacemaker and Medical Engineering: A Canadian Story*. About a year before his death on November 24, 1998, he commented about his enthusiasm about the evolution of the pacemaker, saying that he was "constantly amazed at how technology" had refined the device he helped to create so many years ago.

C. D. Howe, P.Eng., lived up to his nickname of the "Minister of Everything." His hand was in almost every facet of life in his era–the St. Lawrence Seaway, the Trans Canada Pipeline, the Trans Canada Highway, the Canadian National Railway and the CBC. Photo: University of Toronto archives

MINISTER OF EVERYTHING RESPONSIBLE FOR MANY TRANSPORTATION MEGAPROJECTS C. D. HOWE, P.ENG., 1886–1960

In 1947, PEO presented its first Professional Engineers Gold Medal to the Rt. Hon. Clarence Decatur (C. D.) Howe, P.Eng., dubbed by historians as the "minister of everything." Instrumental in organizing Canada's production effort for the war, Howe's era in the federal government also saw the birth of megaprojects like the St. Lawrence Seaway, the Trans Canada Pipeline, the Trans Canada Highway and the precursor to Air Canada.

Howe was considered the most successful businessman-politician of his day, and provided a link between the Liberal Party and Canadian industry. With an engineering degree from the Massachusetts Institute of Technology, Massachusetts-born Howe first came to Canada to teach engineering at Dalhousie University in Halifax. His years there (1908 to 1913) were successful, but he readily abandoned academe in 1913 to work with the Canadian Board of Grain Commissioners designing wheat elevators across the Prairies. In 1916, Howe formed his own engineering firm, specializing in the design of grain elevators.

Between 1916 and 1935, the C. D. Howe Company Ltd. built elevators in Vancouver, Saskatoon, Churchill, Port Arthur, Toronto and Prescott, as well as Buenos Aires, Argentina. World War I drove demand for wheat and Canada became a major supplier, with a system of storage sites and transportation links that efficiently moved grain to eastern ports for shipment to Europe.

The Depression in the 1930s, though, forced the company to drastically reduce its activities and, in 1935, Howe entered politics and parliament as a Liberal, representing Port Arthur (now Thunder Bay). He was promptly made a member of Mackenzie King's cabinet, chosen by King for the double portfolio of shipping and railways–to be amalgamated into the transportation department in 1936. In that capacity, Howe helped create Trans-Canada Airlines (later Air Canada).

On June 30, 1937, Howe flew from Montreal to Vancouver on a Lockheed 14H of the department of transportation. The 17.5-hour flight was the first transcontinental connection in Canadian history and the first flight of the new Crown corporation, Trans-Canada Airlines.

Applying his keen business sense to political issues, Howe launched a reorganization of the Canadian harbour system and a restructuring of the Canadian National Railway to help them regain profitability. He also ensured Canadian control over the airwaves by creating the Canadian Broadcasting Corporation (CBC).

In 1939, the department of transportation was preparing for the upcoming war. On April 9, 1940, the department of munitions and supplies (DMS) was created, with Howe at the helm. The engineer-turned-politician was facing a major challenge: to lead the Canadian war production effort.

"Since the beginning of the war, it has not been my practice to take part in the debates of the house, apart from giving certain information about my department, which seemed to be required in order to allow of decisions being reached," said Howe. "I have been entrusted with the task of mobilizing the activities of industry for war production, and I have concentrated all my time and thought on that particular problem."

Through the *War Measures Act*, the DMS enjoyed far-reaching powers, controlling markets, the allotment of natural resources, production volumes, and the use of specialized manpower. To run this war production, Howe relied on the patriotism of Canada's leading businessmen, asking them to provide their services to the DMS for the duration of the war without compensation. He also surrounded himself with an outstanding management team, which included men such as E. P. Taylor and W. C. Woodward.

In 1944, Howe was asked to run the new department of reconstruction. In this role, he worked on reconverting the Canadian economy to a free-enterprise system, with minimal government controls. During the 1950s, Howe was concerned with developing certain sectors of the economy, such as steel, and as minister of trade and commerce, with expanding Canada's trade. In that capacity, in 1956, he sponsored a trans-Canada pipeline, with government aid to a private firm. The move stirred up a parliamentary storm and, in 1957, the Liberals were defeated and Howe lost his seat. After 22 years of uninterrupted, good and faithful service, Howe, then 70 years old, retired from political life.

INVENTOR NOTED AS ALL-AROUND SOLUTION FINDER GEORGE KLEIN, 1904–1992

Some have postulated that the Canadian engineering and science community has yet to produce a character in the mould of American inventing icon Thomas Edison.

Described by some as the "inventor of the 20th century," Edison's name and reputation continue to inspire generations of students, dreamers, would-be entrepreneurs and even basement workshop tinkerers.

If any Canadian engineer could approach Edison's inventive accomplishment, however, it might be George Johann Klein, a 1928 graduate of U of T's practical science program, and a long-time researcher and inventor with the NRC in Ottawa.

But unlike Edison, who hoarded his many patents and became adept at self-promotion–despite the homespun image as a trial and error man, Klein was more inclined to eschew patents and share his inventions widely.

A native of Hamilton, Klein was inducted posthumously into the Canadian Science and Engineering Hall of Fame in 1995. The museum's virtual hall of fame roster features a well-chosen Klein axiom: "No one really taught me anything like that [inventing]. I was given a problem and thought of about 15 different ways of getting at it."

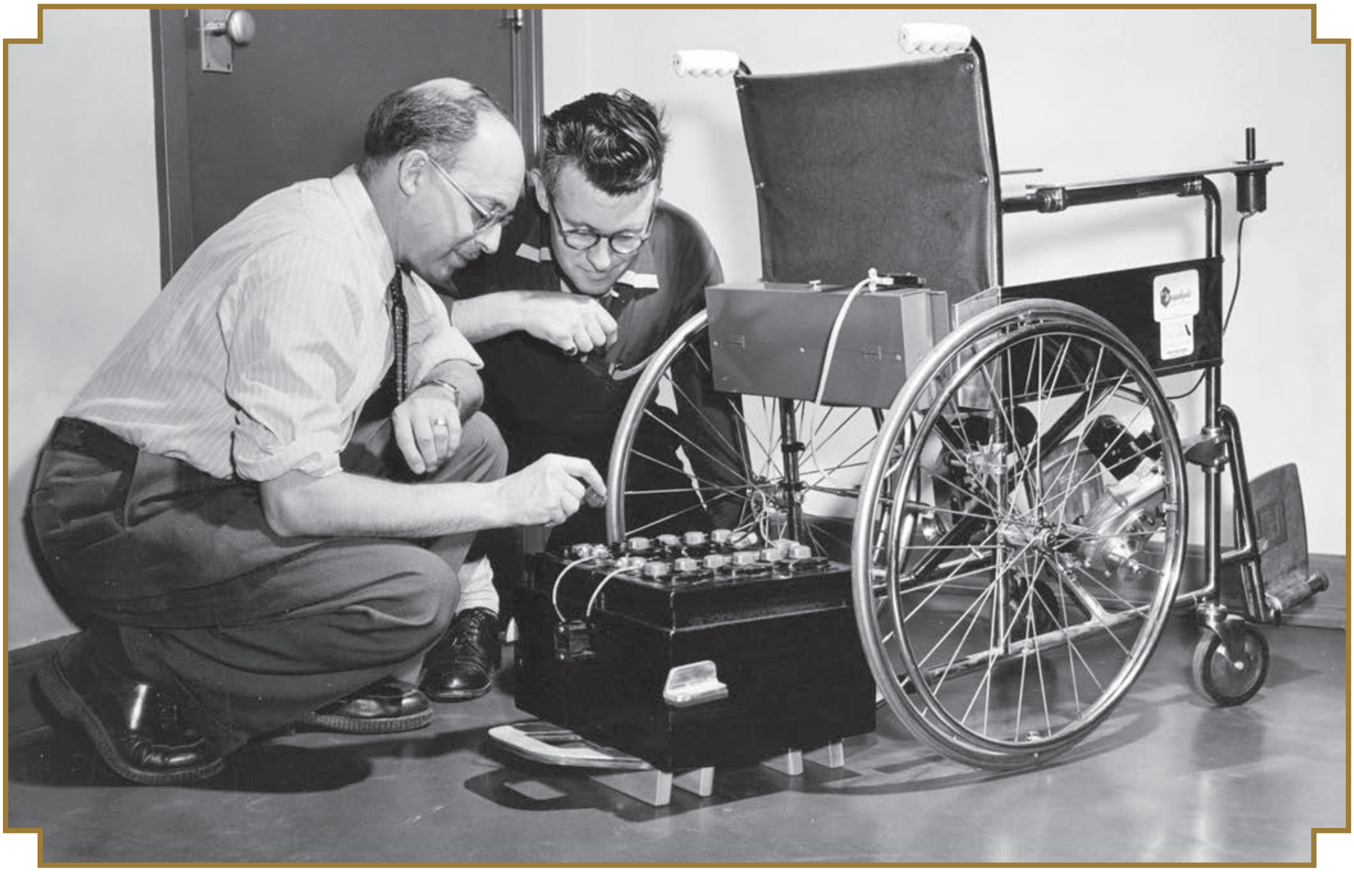
Klein joined the NRC staff in 1929 with the title of junior research physicist. According to biographies, he had already impressed NRC directors with his research into wind tunnel and aviation dynamics as a student at U of T. As the country and, in fact, all the world looked to advance in aviation technology, air freight and eventually airline travel, Klein's work with wind effects would prove especially useful in the coming decades.

Klein is best remembered for his work on airplane skis, the dynamics of snow, locomotive streamlining, and his efforts toward the design of the zero energy experimental pile (ZEEP) at Chalk River, the first nuclear reactor outside the US to sustain critical nuclear fission.

But it is his later work on an electric-powered wheelchair, which came to be known as the "Klein chair," that in many ways characterizes his most significant engineering triumph. The design incorporated an early version of the now popular "joystick" to enable ease of movement, steering, acceleration of over 2 miles an hour, and smooth braking.

Richard Bourgeois-Doyle, author of the NRC publication *George J. Klein: The Great Inventor* (2004), suggests Klein's painstaking work to perfect a practical, inexpensive and long-lasting wheelchair paved the way for the development of "rehabilitation engineering" and the human-centred approach to design for people with disabilities.

"It is now well accepted in the field known as rehabilitation engineering that a very special combination of scientific, technical, and personal skills is required and that the patient is at the very centre of



George Klein

George Klein (left) described as the "Inventor of the 20th Century," is best known for his work with airplane skis, locomotive streamlining and designing the first nuclear reactor outside the US. His invention of the first electric wheelchair was inspired by the desire to give more mobility and dignity to wounded World War II soldiers and opened the door to the field of "rehabilitation engineering." Photo: National Research Council

the process," Bourgeois-Doyle writes. "Klein in many ways broke new ground and helped define the field…Years later, Klein's work continues to stand up, even in the midst of subsequent developments, as a major turning point in the engineering profession."

The author is equally impressed with Klein's work on the characteristics of snow, which led to a huge increase in the store of knowledge about the movement through snow by ski-mounted land vehicles and bush-piloted planes, on takeoff and landing.

Klein eventually established an international snow classification system, which has special resonance for engineers in northern climes.

"Only the imagination could ever capture the impact that this work has had internationally," Doyle notes in the biography. "Even if the snow classification system had only been used by Klein's immediate colleagues in the international bodies he served, it would have most certainly affected industry, public safety, and societies in many countries. Engineers, geophysicists, and hydrologists over the decades will have consciously or unknowingly used the system, or at least the data and discoveries of others who did, to design most of the transportation systems, buildings, and consumer products that serve the snow-covered world."

Klein's most productive period was from the late 1930s until the mid-1950s. But even as he neared retirement in 1969, the engineer-inventor kept at it. He developed a suturing tool that helped doctors connect severed arteries, and was later named a lecturer at Ottawa's Carleton University.

In the early 1970s, Klein came out of retirement to help the Canadian Space Agency with the initial design work on a project that ultimately led to the development of the Storable Tubular Extendible Member (STEM), used with satellites, and as the basis for the more high-profile Canadarm.

Bourgeois-Doyle suggests that Klein was most successful in finding practical design solutions around "major public concerns." Certainly his work with the electric wheelchair, inspired as it was by a desire to give more mobility and dignity to injured soldiers returning from World War II, lent poignancy to his engineering design work.

Loren Gold, P.Eng., researcher emeritus at the NRC, worked briefly with Klein in the snow classification project. He told *Engineering Dimensions* Klein would probably be embarrassed to be considered in a list of engineering heroes. Nonetheless, he believes the title is not unwarranted for this prolific but modest poet of an inventor.

"You might call him a hero but otherwise an individual who was very generous with his time," Gold said. "In addition to his own research areas, he was always willing to help others find solutions to their particular problems."

CONSERVATION AND FLOOD CONTROL ENGINEER DESIGNED FOR NATURE AND PUBLIC PROTECTION
G. ROSS LORD, P.ENG., 1906–1986

There is parkland located in the northwest sector of Toronto named for an engineer whose life and work likely mean very little to the outdoor enthusiasts who picnic, ski or kick a soccer ball on the park's 136 hectares.

The G. Ross Lord Park was opened in 1972 to commemorate engineer George Ross Lord, P.Eng., one-time head of mechanical engineering at U of T, and the 25th president of PEO.

Lord served as PEO president in 1946, but was active with the association for several years before and after that date.

Here is what the *Professional Engineer*, the PEO publication of the time, said of Lord on his election as president in January 1946: "In 1939 [Lord] was awarded the PhD degree by the U of T for his original research in cavitation in hydraulic turbines. Dr. Lord has been employed on consulting work for mine ventilation for several gold mines in northern Ontario. His specialty is hydraulics and water power. He has over several years been associated with the Hydro Electric Power Commission of Ontario, on hydraulic studies. At the present time, he is hydraulic consultant to the Department of Planning and Development of the Ontario government."

As notable as his teaching and consulting was, it was primarily for his conservation and flood control work that city fathers chose to name a park for him. In addition to his work at U of T and PEO, Lord chaired the Metropolitan Toronto and Region Conservation Authority (MTRCA, now the Toronto Region Conservation Authority), from 1958 until 1972. He stayed on as a provincially appointed trustee of the authority until 1978.

The parkland, through which runs the West Don River, was developed largely for flood control purposes. It was envisioned shortly after city authorities planned for the recovery from the devastating flood caused by Hurricane Hazel in October 1954, which claimed over 80 lives.

In a bid to prevent a similar calamity, city officials and conservation authorities looked to Lord and other engineers to plan the elaborate flood plains, reservoirs, dams and water catchment areas that became the legacy of Hurricane Hazel. In fact, the conservation authority system in southern and central Ontario owes its existence in some measure to Ross' prescience in putting in measures to mitigate the effects of similar disasters.

G. Ross Lord, P.Eng., is responsible for Toronto's flood plains, reservoirs, dams and water cachement areas that ensured the devastation left in the wake of Hurricane Hazel would never occur again.

In his brief history of the Toronto Conservation Authority, author Bill McLean made note of some of Lord's bona fides. "Dr. G. Ross Lord was an astute choice to follow A.H. Richardson (another P.Eng.) as chair of MTRCA," McLean noted. "The recognition that he had received as chair of the department of mechanical engineering at the University of Toronto assured acceptance on technical issues related to water management, as his experience as a member of North York planning board paved the way for his acceptance in the political community. His appointment to chair in 1958 had the full backing of the Ontario government and the Metropolitan Toronto chairman, Frederick G. Gardiner. These qualifications in its leadership were essential to the authority's being accepted by the community. Technical and political credibility was an invaluable asset."

McLean also describes Lord as a "thoroughly decent man" who combined technical abilities with tact and diplomacy in winning over political leaders to his engineering solutions.

With typical understatement, Lord described his vision for conservation and flood control in an October 1959 item in the *Professional Engineer*.

"In order to prevent the recurrence of the flood dangers and losses of life, the [conservation authority] has planned a comprehensive, integrated program of flood control measures based on a rational conservation policy. The authority's land and water conservation policy is founded on the principle that the social needs of the locality, as well as the needs of the streams for passing their waters, must be reasonably satisfied."

He went on to list construction of multi-purpose dams and reservoirs, key channel improvements, public acquisition of vulnerable flood prone lands, the extension of stream gauging and food warning systems, and zoning and bylaw changes to restrict residential encroachment on flood plains, as major components of the new way to go.

"It is the authority's view that some of the national wealth produced by the region should be reinvested in the area in the form of land and water conservation measures," said Lord. "The authority hopes to salvage the region's remaining potential water resources from the spoil of an industrial community before it is too late."

In declining health, Lord retired from the conservation authority in 1972 and died in January 1986. He no doubt would have taken solace in the knowledge that Toronto Conservation Authority, in its efforts to preserve a bit of nature while providing flood protection in a densely populated urban area, would become a model for other communities.

"QUEEN OF THE HURRICANES" WAS THE ULTIMATE ENGINEERING TRAILBLAZER

ELSIE MACGILL, P.ENG., 1905–1980

Elizabeth "Elsie" MacGill, P.Eng., accumulated a unique list of firsts during her career. She was the first Canadian woman to obtain an electrical engineering degree, the first woman in North America to earn a master's degree in aeronautical engineering and the world's first female chief aeronautical engineer. She was also PEO's first female member. Most of all, she was an inspiration to all women who followed in her footsteps on the path to their careers in engineering.

The woman who became known as the "Queen of the Hurricanes" not only had a comic book written about her exploits, she went on to challenge the traditional roles for women, play a leading role in the war effort and establish many other firsts in engineering and aviation. She was the first and only woman in engineering classes at four different universities. She was the first female electrical engineer in Canada upon her graduation from U of T in 1927 and, within a decade, she became the first woman admitted to the Engineering Institute of Canada.

While studying at the University of Michigan, MacGill was diagnosed with acute infectious myelitis, a form of polio, and was told she would spend the rest of her life in a wheelchair. She refused to accept that limitation and learned to walk with two metal canes.

MacGill returned to Canada in 1934 to work as an assistant engineer at the new Fairchild Aircraft plant in Longueuil, Quebec, arriving in time to contribute to the refinement and further development of the Fairchild Super 71, a streamlined and innovative monocoque monoplane and the first aircraft with an all-metal fuselage to be both designed and built in Canada. According to MacGill's biographer, Richard Bourgeois-Doyle, the Super 71 and its successor, the Super 71P (redesigned for photographic survey work), were challenging and exciting learning experiences for MacGill and her colleagues that highlighted the era of growth and innovation in the industry.

Before leaving the firm in May 1938, MacGill also designed wings and other components, as well as contributing to the development of the highly popular Fairchild 82 bushplane series and taking a more senior role in the design and refinement of the less popular and problematic 45-80 Sekani. MacGill's disability had forced her to shelve her ambition to be a pilot, but she always insisted, whenever possible, on riding along as the official observer in all test flights.

MacGill moved on to become chief aeronautical engineer at Canadian Car & Foundry (CCF) in Fort William (now Thunder Bay), where she designed and tested a basic aircraft to train pilots. The Maple Leaf II–the only plane at the time completely designed by a woman–first flew in 1939, with MacGill as a passenger. Although CCF's desire to sell the aircraft to the Royal Canadian Air Force (RCAF) didn't materialize, a number of Maple Leafs were sold to Mexico.

Although MacGill held many important positions in the aeronautics industry, she is perhaps best known for her work during World War II. As chief aeronautical engineer, she was put in charge of all engineering work in connection with the production of the famous Hawker Hurricane fighter aircraft for the British government. She was also responsible for developing fitting skis for landing on snow and de-icing controls for winter operation. All test flights were carried out under her direction. When production ended in mid-1943, the "Queen of the Hurricanes" had supervised production of about 1450 of the fighter craft.

In 1943, MacGill set up her own business in Toronto, opening a consulting office in aeronautical engineering and in that year also marrying an aircraft associate, E. J. (Bill) Soulsby, assistant general manager of Victory Aircraft Ltd. By this time, she had established her skill and reputation as an expert in stress analysis, laying the foundation for her seminal role in establishing the International Civil Aviation Organization (ICAO). In the post-war period, she served as a technical advisor and chair

Elsie MacGill

In addition to being the first Canadian woman to earn an electrical engineering degree and a number of other firsts, during World War II, Elsie MacGill, P.Eng., was in charge of all engineering related to the famous Hawker Hurricane fighter plane. Photo: Canada Aviation and Space Museum

Above: The Maple Leaf II Trainer was the only airplane at the time to be entirely designed by a woman.

to the ICAO's inaugural technical committees, laying the foundation for innovation, aircraft design and safety regulations around the world. She was the first and only woman at that time to have chaired such a committee.

Her many honours include: Order of Canada in 1971, the Ontario Professional Engineers Gold Medal in 1979, the Julian C. Smith Memorial Medal in 1973, the 99s International Amelia Earhart Medal in 1975, four honorary doctorates (Toronto in 1973, Windsor in 1976, and Queen's and York in 1978), and induction into Canada's Aviation Hall of Fame in 1983.

BIOMEDICAL ENGINEER'S INVENTIONS INCREASED SURVIVAL OF PREMATURE BABIES
JOHN M. SMITH, PHD, P.ENG., 1942–

For John M. Smith, PhD, P.Eng., a lifetime devoted to tinkering has meant the world to countless premature babies and their parents. Smith, the recipient of the Ontario Professional Engineers Gold Medal in 1988, held various engineering positions at the Hospital for Sick Children (Sick Kids) in Toronto from 1972 until his retirement in 2005, initially heading up a staff of engineers, technologists, technicians and instrument makers as director of medical engineering and, finally, as director of technology planning.

During his years at Sick Kids, Smith puzzled out solutions to some of the trickiest medical engineering problems, among them, how to adapt adult-sized equipment to deal with the specialized needs of premature infants weighing as little as 500 grams at birth.

One of the devices he developed was a blood vessel detection system used to reduce the risk of locating tiny arteries in babies undergoing surgery. The system was based on a conventional ultrasonic probe redesigned by Smith to use a narrow sound beam to find the arteries.

He also designed a computer-based system to measure the CO_2 expired versus O_2 inhaled by infants, which allowed neonatologists to calculate the most effective nutrition requirements for them. Another device monitored air pressure to ensure that artificial ventilation applied to premature babies during surgery was not overpressurizing their delicate lungs.

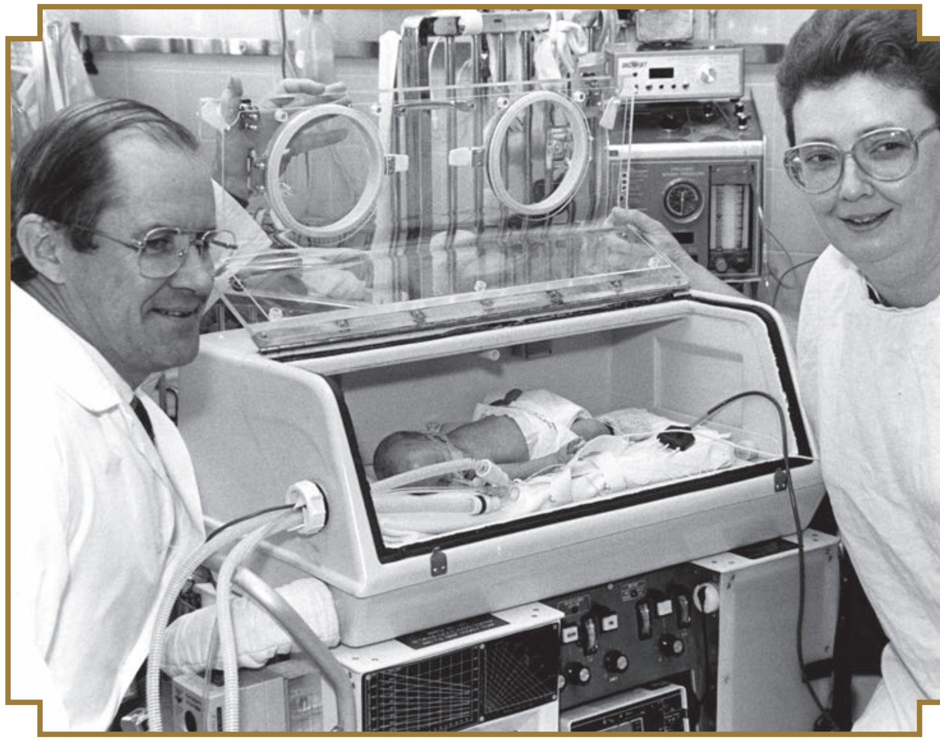
But perhaps his greatest invention was the HSC infant transport incubator, developed in the mid-1980s. At the time, there was no transport network or even a transport concept for premature babies and, Smith says, "in the early days, babies were often brought through the tunnel from Toronto Hospital to Sick Kids wrapped in blankets or brought in by ambulance or aircraft the same way." The HSC transport incubator revolutionized the way premature babies were brought to Sick Kids from hospitals near and far.

Smith redesigned the infant compartment of a commercial incubator to maintain an easily adjusted thermal-neutral environment, so babies did not expend energy to maintain their body temperatures. The incubator also prevented the babies' evaporative heat loss by keeping the air still, and provided reliable monitoring of blood pressure, heart rate, inspired gas concentrations and blood gas levels.

Says Paul R. Swyer, MD, FRCPC, FRCP(L), DCH, former chief of the Division for Newborn Medicine at Sick Kids and professor emeritus, pediatrics, U of T:

John Smith

Above, John Smith, PhD, P.Eng., today. Photo: Nicole Axworthy Right, Smith with the HSC transport incubator he designed. As director of medical engineering at the Hospital for Sick Children, Smith invented this device and many others for the treatment of premature infants that resulted in an 80 per cent decrease in their mortality.



"Babies transported by a specialized team and equipment had a much better survival rate and arrived in much better condition than if they were transported the old way. It was a different concept to bring intensive care to babies outside the hospital and transport them under the best conditions. And John was really instrumental in getting us the equipment to do that."

Swyer adds: "It's standard equipment now. The transport incubator John built was the foundation for how all transport incubators are now developed. We had reps from commercial outfits who would take away our lessons and apply them to the commercialization of the equipment."

Smith, a native Australian, says, "wanderlust" originally brought him to Canada. Once here, he earned an MASc in 1967 from U of T to add to his electrical engineering degree earned from the University of Sydney in 1963. He then went on to earn his PhD in biomedical engineering, graduating in 1970. He was licensed in 1972.

Smith says his interest in biomedical engineering stemmed from an early interest in wanting to apply electrical engineering to something different. "I came to the University of Toronto and went to a few lectures there. I just got interested in biomedical, pursued it and the rest, as they say, is history." It most certainly is.

Smith's work literally became part of the text book for engineering as it applies to neonatology, especially in the area of transport. Says Swyer in his book, *Babies: The fight for intact survival at The Hospital for Sick Children,* which was published privately by the hospital: "It is emphatically no exaggeration to say that without John Smith's engineering expertise and interest well beyond the call of duty, the 12-year series of papers, which emanated from our Clinical Investigation Unit from 1976, would not have been possible. These have been accepted as basic in the field."

Later in his career, Smith chose to move more into technology acquisition and management. "With the advent of more computer-based devices and applications available in the marketplace, I chose in the latter part of my career to move into the management of medical technology as this would have a more significant impact in the hospital environment," he says.

Nevertheless, it's clear that Smith's legacy as a pioneer in the field of infant transport was already cemented. "It is obvious that his expertise and willingness to help beyond the call of duty was a major component of our service and research, which I personally valued most highly and which resulted in an 80 per cent reduction in the mortality rate for our highest-risk newborns over the years," says Swyer. Σ