JOHN C. MCLENNAN AND HIS PIONEERING RESEARCH ON SUPERFLUID HELIUM

by Allan Griffin, F.R.S.C.

This article briefly sketches the career of McLennan, putting special emphasis on his pioneering work in producing liquid Helium in 1923. Toronto was the second laboratory in the world to accomplish this feat, the first being in 1908 in the lab of Kamerlingh Onnes in Leiden. Over the next decade, McLennan and his students carried out pioneering research on both the superfluidity of liquid Helium and superconductivity in metals. I hope this article encourages interest in the history of physics in Canada.

> **In 1905 and for the next three decades, John Cunningham McLennan (1867-1935) dominated the development of physics at the University of Toronto. By 1930, Toronto's physics department was one of the leading research centres in North America, largely due to the heroic efforts of McLennan.**

The low temperature laboratory under McLennan attracted a large number of Canadian graduate students to the new world of low temperature physics. Two of these Toronto students, J.F. Allen and A.D. Misener, continued their research at the Cavendish Laboratory of the University of Cambridge, where they made the first observation of superfluid flow in thin capillaries. Their seminal discovery was published in Nature in early 1938 [1], along with the independent work of P. Kapitza [2]. These two short back-to-back papers ushered in the study of quantum fluids, a research field that has had an enormous effect on our modern understanding of condensed matter [3].

In this article, I will try to show how the discovery of superfluidity in 1938 was a direct outcome of the research at the low temperature laboratory that McLennan had set up at the University of Toronto in the period 1920-1930. Much of this story is little known in Canada, and even less so in other countries. Moreover, the few accounts that are available often contain serious errors.

The development of a first-class cryogenics laboratory at Toronto is also interesting as one of the first examples of "big physics" in Canada, involving a whole team of researchers. McLennan was also among the first physicists to push the Federal Government in Ottawa to set up programs to encourage as well as give financial support for fundamental research, including graduate fellowships to students. His pioneering efforts were very important in the eventual set-up of the NRC laboratories in Ottawa and the research grant committees run by NRC (which eventually became the present day NSERC).

I should briefly mention how I came to be writing historical articles. In my professional career as a theoretical condensed matter physicist, I have worked for over three decades on the microscopic theory of superfluid Helium, emphasizing the role of Bose-Einstein condensation (BEC). This latter phenomenon was first predicted to occur in a low temperature gas by Einstein in 1925; the relevance of BEC to superfluid Helium was first pointed out by Fritz London in 1938. When I joined the faculty in the Department of Physics at the University of Toronto in 1967, I was only vaguely aware of the pioneering work on both superfluid Helium and superconductivity done at Toronto in the period 1925-1935. It was only in the early 1990s, while I was writing a book on superfluid Helium [4], that I started to get interested in the work of McLennan and the low temperature laboratory that he had set up in the 1920s. In the last decade or so, I have made it a point to learn more about this history. I have written scientific obituaries [5,6] of J.F. Allen (1908-2001) as well as A.D. Misener (1911-1996), and have had access to their private papers and correspondence. I have read much about McLennan, but have yet to take advantage of the extensive documents available in the archives of the University of Toronto.

Ellizabeth Allin wrote a history of the physics department [7], one chapter giving an engaging account of her own days as a graduate student in the late 1920s. Allin was one of three woman students who received their Ph.D. working under McLennan . More detailed information about McLennan's family history and career is given in an article by the historian Craig Brown [8]. For a sense of the exciting atmosphere in the early 1900s, I strongly recommend a recent book on the history of the University of Toronto [9].

BUILDING A RESEARCH DEPARTMENT: 1900-1920

John McLennan was born on Oct. 14, 1867 near Woodstock, Ontario, and raised in the farming country of southwest Ontario. His father David, who had emigrated

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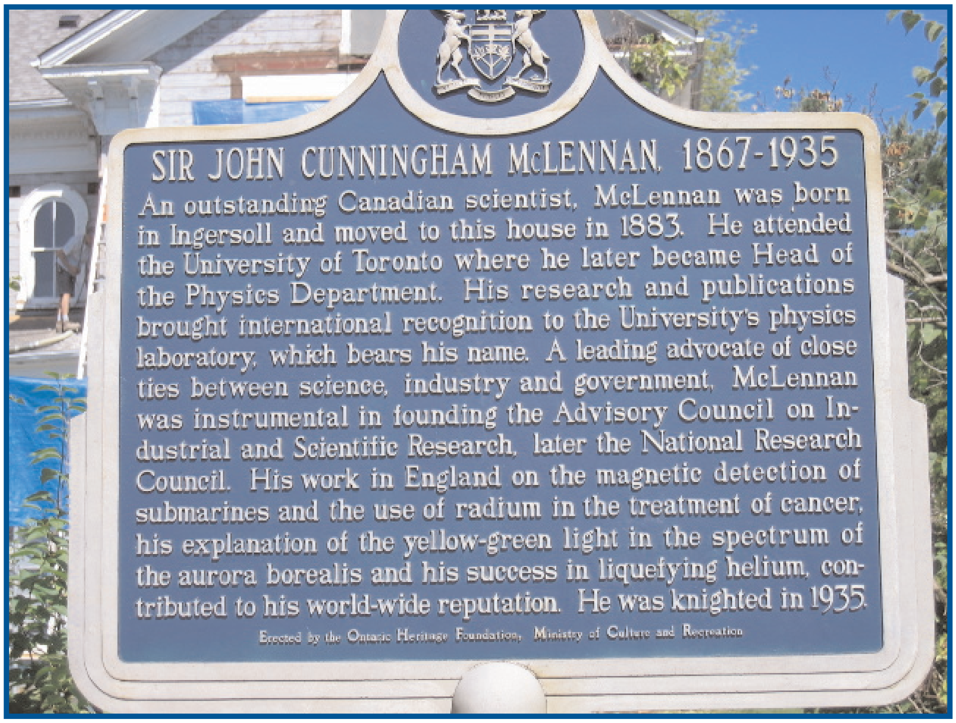


Fig. 1 Historical plaque commemorating McLennan, in front (or back!) of the McLennan family home in Stratford, Ontario (photo credit: A. Griffin).

from Scotland, was a successful grain merchant and had a large family. He finally settled in Stratford in 1882, where his son John graduated from high school in 1883. From 1887, the family occupied a beautiful home on the banks of the Avon River. This house is easily visited, since it sits on the far bank overlooking the Stratford Festival Theatre (more precisely, it is across from the Tom Patterson Theater). Fig. 1 shows the historical plaque on the public pathway along the river, in front of the impressive McLennan family home (see Fig. 2). It is probably the only historical marker in Canada that refers to liquid Helium!

Due to a depression in the grain markets around 1883, family finances were very tight. As a result, McLennan went to Normal School and taught in Perth County schools for several years. When the family circumstances improved, he entered University College at the University of Toronto (U of T), enrolling in 1888 at the age of 21. The Department of Physics at Toronto had just been set up in 1887, and thus McLennan was one of the Department's earliest undergraduates. He attended lectures by James Loudon, Head of the physics department as well as President of the University of Toronto (1892-1906). The University of Toronto was just coming of age [8, 9].

McLennan graduated at the top of his class in 1892 and was immediately appointed Assistant Demonstrator in the Department of Physics. Being ambitious, he visited physicists in Great Britain in 1895. He went back to do a research project for his Ph.D. at the Cavendish Laboratory during the period 1898-1899, under the supervision of J.J. Thomson (see Fig. 3). McLennan's fellow graduate students at Cambridge included many future leaders in physics, such as Paul Langevin and Ernest Rutherford. As discussed in another article in this special issue, Rutherford accepted a position at McGill University in 1898. In the next nine years, Rutherford did experiments at McGill that laid the foundation of our present understanding of the nucleus. Getting to know McLennan at Cambridge probably helped Rutherford see McGill and Canada as a more attractive place to do physics research.

Over the years, McLennan kept up his friendship with the physicists he met at Cambridge. Throughout his career at Toronto, he made annual summer visits to London, and other centres of research such as Paris and Berlin, finding out about the latest research as well as purchasing new equipment for his department in Toronto. He also arranged for many leading European physicists to visit Toronto and give lectures. On the other hand, my impression is that McLennan was not equally closely connected with the developing physics scene in the United States. This was due partly to the fact that in the period 1900-1930 both Canada and the U.S.A. were still very much backwaters as far as cutting-edge scientific research went. The real action was in Europe and McLennan knew this.

McLennan submitted his Cambridge research to the brand new Graduate School (1897) at U of T and received his Ph.D. in 1900. His thesis research and first paper was on "Electrical conductivity in gases traversed by cathode

Fig. 2 View of McLennan family home (on the right side) on the Avon river in Stratford , across from the Tom Patterson Theatre (photo credit: A. Griffin).

rays", published in the prestigious Transactions of the Royal Society (London) in 1900. This was the first doctoral degree in the physical sciences awarded by a Canadian university. In 1907, after President Loudon retired, McLennan was made Head of the Department of Physics. The Department moved into a brand new building in 1908, which McLennan had helped to plan and design. He remained Head until 1932, when he abruptly resigned (or "retired") as Dean of the Graduate School and from the University, over an argument about an increased role of the Graduate School. McLennan moved to England in 1932, where he was well known and appreciated, and was knighted in 1935. In his last years, he concentrated on the study of radioactivity and the use of radium therapy for the treatment of cancer. McLennan died of a heart attack on a boat crossing the English Channel in 1935, at age 68. His beloved wife of many years, Elsie Ramsay, had died two years earlier. They had married in 1910 and Elsie had played an important role in his world, as hostess to physics parties and receptions as well as being active in the Toronto scene.

Fig. 3 Graduate students and faculty of the Cavendish Laboratory at Cambridge University in the period 1898-1899. McLennan has the bow tie (photo credit: U of T Archives).

McLennan introduced the useful custom of binding together copies of all research papers by the physics faculty in a given year. These volumes go back to 1896, and provide a wealth of useful historical information about the research going on at the turn of the century and the decades following. Even a cursory look at these collected publications shows that up to 1930, McLennan and his students produced almost all the research publications of the Department. This was before the age of specialization and, as with most physicists of the time, McLennan did research on several different topics. Early on, he mainly studied natural radioactivity from rocks and the electrical conductivity of the atmosphere. McLennan was always keen on finding out about the latest research developments, such as atomic spectroscopy, and getting Toronto students involved. By 1930, with enormous energy and enthusiasm, McLennan had built up a research lab at U of T that was second to none in North America. I should note that in the British tradition, physics research at Toronto meant experimental research, with theoretical physics relegated to the Department of Mathematics. (This neglect of theoretical physics as an integral part of a physics department continued in both the U.S.A. and Canada until the mid 1930s. Indeed, at Toronto, this tradition lived on to the mid 1950s).

Up to the 1930s, the majority of the Ph.D. degrees awarded at U. of T were to physics students under the supervision of McLennan. During this time, he also played a key role in U of T academic affairs and used his growing influence to encourage the Federal government to get involved in sponsoring research and helping graduate students in Canadian universities. In 1911, McLennan became president of the Royal Society of Canada. His tireless efforts to get better funding for research in Canada helped in the creation of the National Research Council in 1920s (which eventually spun off NSERC as a separate granting agency). By all accounts, McLennan "pursued his goals with an aggressive and ceaseless determination". Perhaps not surprisingly, these same features sometimes made enemies in the somewhat genteel academic world of the time.

In his time as Head of physics, McLennan tried to put Toronto and Canada on the map of world physics and he largely succeeded. However, McLennan failed to surround himself with a group of talented younger physicists who could push his legacy to new heights. This may be attributed to the fact that McLennan was very competitive by nature and did not like to share the spotlight with his Toronto colleagues. In any case, when McLennan abruptly left Toronto in 1932, the Department went into a slow decline, which was only reversed in the late 1950s.

THE LIQUID HELIUM YEARS: 1920-1930

In this section, I will discuss how McLennan got involved in low temperature research using liquid Helium and mention some of the major discoveries he and his students made in Toronto.

By the start of World War I, McLennan was already well known in the corridors of power in both Ottawa and London, England. It was thus natural for him to be involved when, in 1915, the Office of the Admiralty in London wished to have a survey of the available sources of Helium gas in the British Empire. The Admiralty's plan was to use He gas as a safe substitute for H gas in the airships then used by the military. Provided with ample funds, McLennan organized a world wide survey of gas wells, including those in New Zealand and Australia, with his usual energy and organization. (Prof. Archie Hollis Hallet, a former professor in the Department of Physics at Toronto (1951-1977), gave U of T an extensive file of original papers and government reports which give the details of the search for He in gas wells in Canada). Ultimately, McLennan arranged for facilities to be set up for He gas extraction and purification in Hamilton, Ontario as well as near Calgary, Alberta. The best sources the survey found were the Bow Island district wells near Calgary, which contained up to 0.36% He. By the end of WWI, most of the physics faculty at U of T were involved in one aspect or another of this He gas project.

Both before and after WWI, McLennan had been considered for very senior scientific positions in Great Britain, where he had become quite well known, but in the end, these possibilities did not come to fruition. In 1917, McLennan was involved in research for the Royal Navy in Britain and he received an O.B.E. in 1917. He returned to U of T in 1919 with considerable fame and influence, and eager to start a major new research effort. Figure 4 shows an imposing picture of McLennan in this period.

Fig. 4 **John Cunningham McLennan in September 1920 (photo credit: Bassano Ltd, Royal Photographers, from the National Portrait Gallery in London).**

McLennan and his associates had collected about 2000 m^3 of He gas (~90% pure), and stored it under pressure in cylinders just outside Toronto. However, with the rapid development of airplanes, the Office of the Admiralty in London lost interest in the military use of airships and hence in the He gas needed to fill them. At this point, one may assume that McLennan's Scottish and entrepreneurial family background came to the fore. Reckoning it would be silly not to make use of his large supply of fairly pure He gas, he quickly decided to develop a cryogenic laboratory to produce liquid Helium and initiated a research program to study this strange liquid and other phenomena at low temperatures.

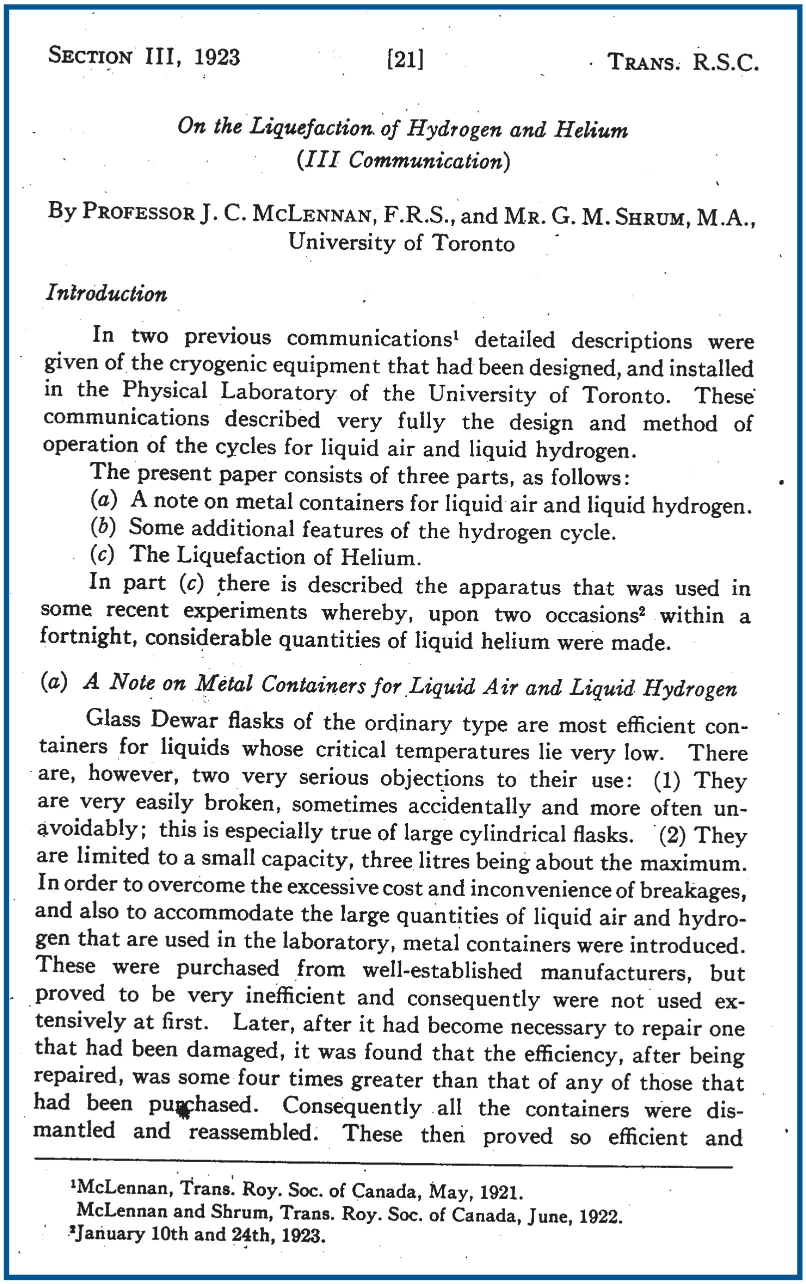
This quest to liquefy Helium gas at Toronto ushered in a new research direction, which in turn led to Canada developing a tradition for the study of liquid Helium. This tradition later reached its peak in the well-known work of the neutron-scattering group at the Chalk River Nuclear Laboratories of the AECL. Several of the key physicists at Chalk River who used neutrons to probe the static and dynamic properties of superfluid Helium in the period 1955-1970 had done their Ph.D. research at U. of T in the early 1950s, where a long research tradition of studying liquid Helium could be traced back to the work of McLennan. These physicists include B. Brockhouse (who helped initiate the liquid Helium research program at Chalk River) as well as A.D.B. Woods and D.G. Henshaw (who did the first accurate measurement of the phonon-roton spectrum).

The history of liquid Helium actually begins in Europe. Liquid Helium was first produced in Leiden in 1908 by Kamerlingh Onnes, after decades of work. In 1919, Leiden was still the only place in the world that could produce liquid Helium. When he began his own research program, McLennan asked for assistance from Onnes, who sent detailed drawings of the Leiden liquefier and gave advice. Perhaps the tradeoff for Onnes was that McLennan used his influence to make sure that Leiden obtained a supply of He gas after WWI. (Leiden's source had been stopped by Britain because of its potential military use). In view of later developments, it is interesting to note that McLennan also arranged for some He gas to be given to Cambridge University for future experiments.

With the hard work of a young graduate student, Gordon Shrum, and several excellent technicians, McLennan was able to liquefy Hydrogen on April 16, 1921. This was an important intermediary step in the design of the Leiden He cryostat. Finally, on January 10, 1923, about one litre of liquid Helium was produced at U. of T. The feat was repeated on January 24 and exhibited to the public, to great acclaim in the Toronto newspapers. McLennan, well ahead of his time, was always aware of the importance of publicity and the money for research that came with it. Figure 5 shows the first page of the paper (the last of three publications) announcing the liquefaction of Helium, published in the Transactions of the Royal Society of Canada, May, 1923 [10]. Figure 6 shows two photos of the Toronto Helium liquefier, taken from this article.

Occasionally, people belittle this major success of McLennan and Shrum by saying that the Toronto cryostat was just a "copy" of the one in Leiden. This ignores the fact that McLennan's group were new to this field and the He liquefier was a very complex piece of equipment, with many separate stages in the operation that had to work perfectly. Moreover, no other research group in the world had constructed a Helium liquefier to duplicate Leiden's success in 1908. Together, Toronto and Leiden dominated research on liquid Helium and superconductivity until about 1933. In the decade 1923-1933, Toronto became a centre for low temperature physics, producing a stream of well-trained young Canadian physicists who made several major discoveries about superfluids and superconductors.

As I have mentioned, a key person in the successful liquefaction of Helium was Gordon Shrum, who like McLennan grew up in the farming country in southwest Ontario, near Toronto. After completing his Ph.D. in 1923 on the energy levels of the Hydrogen atom, Shrum continued to do research with McLennan. In 1925, they solved a celebrated problem of the time, proving that the



SECTION III, 1923 [21] TRANS. R.S.C.

On the Liquefaction of Hydrogen and Helium
(III Communication)

By PROFESSOR J. C. MCLENNAN, F.R.S., and MR. G. M. SHRUM, M.A., University of Toronto

Introduction

In two previous communications[1] detailed descriptions were given of the cryogenic equipment that had been designed, and installed in the Physical Laboratory of the University of Toronto. These communications described very fully the design and method of operation of the cycles for liquid air and liquid hydrogen.

The present paper consists of three parts, as follows:
(*a*) A note on metal containers for liquid air and liquid hydrogen.
(*b*) Some additional features of the hydrogen cycle.
(*c*) The Liquefaction of Helium.

In part (*c*) there is described the apparatus that was used in some recent experiments whereby, upon two occasions[2] within a fortnight, considerable quantities of liquid helium were made.

(*a*) *A Note on Metal Containers for Liquid Air and Liquid Hydrogen*

Glass Dewar flasks of the ordinary type are most efficient containers for liquids whose critical temperatures lie very low. There are, however, two very serious objections to their use: (1) They are very easily broken, sometimes accidentally and more often unavoidably; this is especially true of large cylindrical flasks. (2) They are limited to a small capacity, three litres being about the maximum. In order to overcome the excessive cost and inconvenience of breakages, and also to accommodate the large quantities of liquid air and hydrogen that are used in the laboratory, metal containers were introduced. These were purchased from well-established manufacturers, but proved to be very inefficient and consequently were not used extensively at first. Later, after it had become necessary to repair one that had been damaged, it was found that the efficiency, after being repaired, was some four times greater than that of any of those that had been purchased. Consequently all the containers were dismantled and reassembled. These then proved so efficient and

[1]McLennan, Trans. Roy. Soc. of Canada, May, 1921.
McLennan and Shrum, Trans. Roy. Soc. of Canada, June, 1922.
[2]January 10th and 24th, 1923.

Fig. 5 First page of the 1923 paper by McLennan and Shrum [10] reporting on their successful liquefaction of He.

auroral green line was due to Oxygen atoms in the upper atmosphere. In 1925, Shrum moved to the University of British Columbia (UBC). He was Head of the Department of Physics at UBC from 1938-1961, as well as the founder and first president of Simon Fraser University. After retirement, Shrum became a dominant figure in British Columbia, running many large public enterprises.

In an autobiography published in 1986 [11], Gordon Shrum paints a vivid picture of his exciting years at U of T as an undergraduate and graduate physics student in the period 1915-1925. In particular, Shrum affectionately describes the impact that McLennan had on him and his fellow physics students. Here are some quotes from Shrum's book:

> "McLennan was a man with tremendous ambition: a great worker, a marvelous lecturer and altogether a very strong personality."

> "McLennan was the best dressed man on campus, always wearing the most stylish suits."

> "He would rivet you with his great eyes as he talked of physics."

It is clear from this account that Shrum tremendously admired McLennan and in his later career strove to be like him. He succeeded!

Shrum's autobiography is highly recommended as a day-by-day account of the work at U of T which led to the successful production of liquid Helium in 1923. I cannot resist telling one delightful story. Shrum's undergraduate studies in physics were interrupted by the First World War, during which he was in the Canadian Army artillery. After the war, Shrum completed his B.A. degree and took a job in business. While he was visiting some friends in the Physics Department in 1920, McLennan saw him and asked Shrum to drop by at his office. The conversation went as follows:

McLennan: Shrum, during the war, you were in the artillery, weren't you?
Shrum: Yes.
McLennan: Shrum, you are not afraid of explosions, are you?
Shrum: No
McLennan: Shrum, you are just the man I need to help me liquefy Helium!

McLennan encouraged Shrum to enter graduate school for his Ph.D. It was only later that Shrum realized what this "Helium project" entailed, and that the initial liquefaction of Hydrogen was a very "explosive" aspect of the research. There are many other amusing stories in Shrum's book, including McLennan's determination to "beat the Americans." The National Bureau of Standards (now NIST) in Washington, D.C. had launched a major effort to try and liquefy He but only achieved this in 1926, and never contributed much to liquid Helium research.

McLennan is given credit for the first explicit observation in 1932 that superfluid Helium exhibited very strange fluid behaviour. Thermodynamic measurements carried out in Leiden by Keesom and coworkers in the 1920s had shown that there was some sort of phase transition at 2.17 K. What this transition involved or what were its implications was not clear at the time. In their 1932 paper [12] on the scattering of light (see Fig. 7), McLennan and his coworkers noted that the rapid bubbling which occurs just above the transition temperature Tc = 2.17 K abruptly disappears just below Tc. While he did not ask why this occurred (and neither did anyone else), it was the first evidence that the "macroscopic" features of liquid Helium

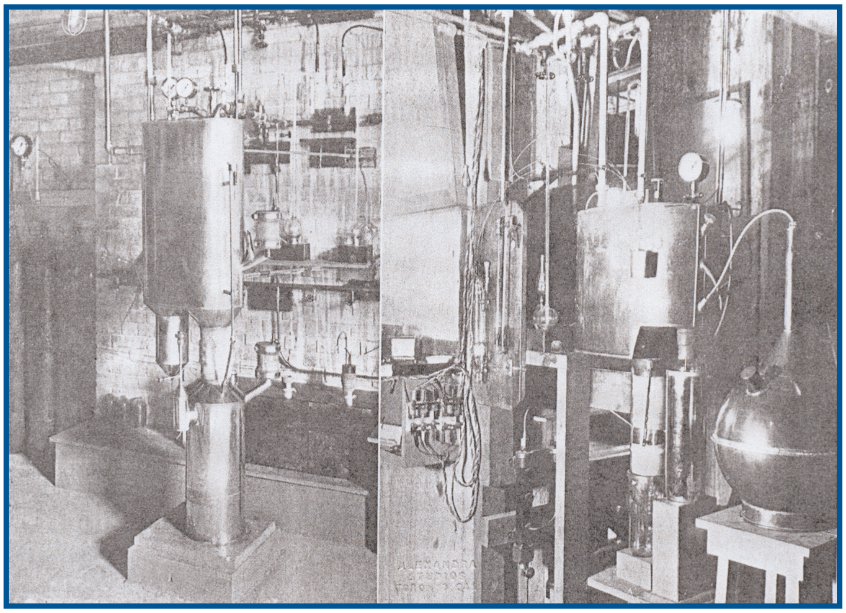


Fig. 6 **Two views of the original Toronto Helium liquefier (photo credit: Ref.10)**

below Tc were very different from those above (where He behaved like an ordinary fluid). We now know [3,4] that this abrupt cessation of bubbling is a consequence of the formation of a Bose-Einstein condensate. Such a BEC gives rise to a new collective degree of freedom (the superfluid component) and a two-fluid hydrodynamics, which in turn allows for a very efficient heat transfer mechanism (related to second sound).

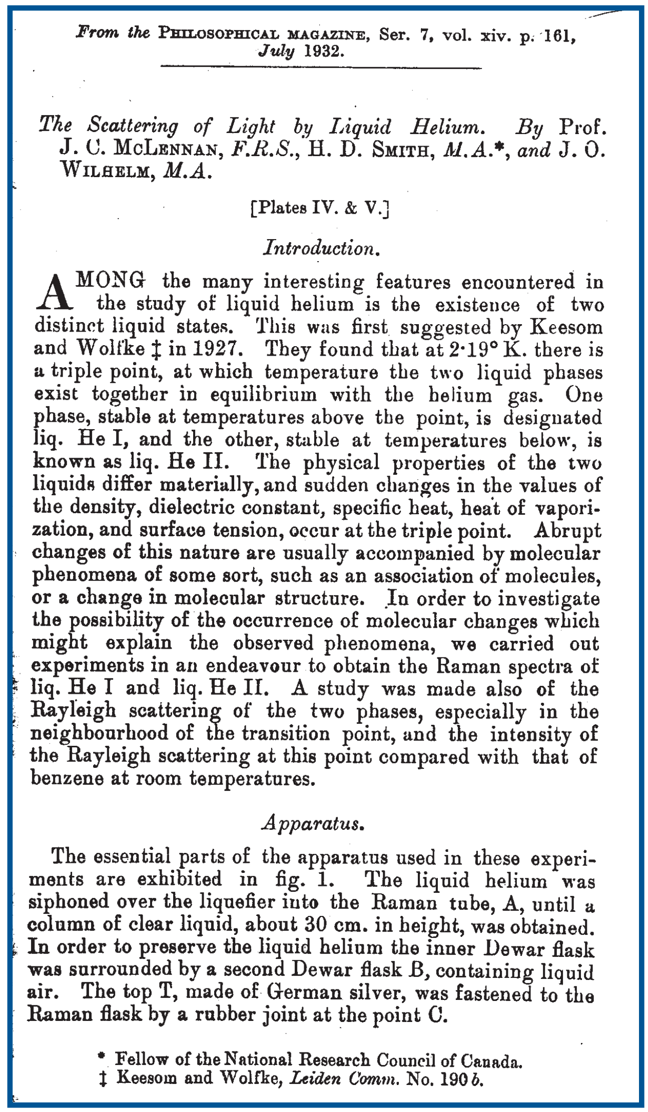
In June of 1932, at the height of his career in physics, McLennan was invited to give a public lecture, at the Royal Institution in London, England, on superfluid Helium and the superconductors that one could study with it. With typical flair, McLennan had one of his Toronto graduate students, Jack Allen, construct a small glass-walled cryostat. On the day of his lecture in London, McLennan had the cryostat flown to Leiden from London to be filled with liquid Helium (and liquid Nitrogen in an outer Dewar flask) and then flown back across the English Channel in a small open cockpit airplane. The precious cargo was held in the lap of the Leiden cryogenics technician. The pilot and technician arrived by taxi just before McLennan's lecture started, enabling him to show a floating superconducting lead ring with a persistent current, to great acclaim. This was the first time superfluid Helium and superconductivity had been exhibited in the U.K. and the demonstration was widely reported in the press. Unfortunately, the small cryostat remains in the Royal Institution Museum in London. Perhaps some day it will be returned to Canada, as part of our intellectual and scientific heritage.

ALLEN AND MISENER AT TORONTO: 1930-1936

In concluding this article, I want to briefly discuss the work of J.F. (Jack) Allen and A.D. Misener, two of the most talented of the top-notch group of graduate students attracted to McLennan's cryogenic laboratory in the early 1930s.

Jack Allen was born in Winnipeg in 1908 (the year that Helium gas was liquefied in Leiden). His father Frank was the first (and long serving: 1904-1944) Head of the Department of Physics at the University of Manitoba, where Allen did his undergraduate studies in physics. In 1929, Jack Allen began his Ph.D. studies under McLennan, supported by a 3 year NRC scholarship. Allen has fondly discussed his days at U of T [13], with the dry humor that he was known for. By then, McLennan was spending little time in the lab. Indeed, although Allen published 10 papers with McLennan on superconductors and their alloys at U of T, he later commented that he could not remember ever sitting down with McLennan once to discuss his thesis research. In fact, this lack of detailed supervision suited Allen fine, since he was a very independent-minded, take-charge sort of person (just like McLennan in his youth). Allen became the main user of liquid Helium in the Department.

After receiving his Ph.D. in 1933, and spending an unproductive year at Caltech in California, Allen



From the PHILOSOPHICAL MAGAZINE, Ser. 7, vol. xiv. p. 161, *July* 1932.

The Scattering of Light by Liquid Helium. By Prof. J. C. MCLENNAN, *F.R.S.*, H. D. SMITH, *M.A.**, *and* J. O. WILHELM, *M.A.*

[Plates IV. & V.]

Introduction.

AMONG the many interesting features encountered in the study of liquid helium is the existence of two distinct liquid states. This was first suggested by Keesom and Wolfke ‡ in 1927. They found that at 2·19° K. there is a triple point, at which temperature the two liquid phases exist together in equilibrium with the helium gas. One phase, stable at temperatures above the point, is designated liq. He I, and the other, stable at temperatures below, is known as liq. He II. The physical properties of the two liquids differ materially, and sudden changes in the values of the density, dielectric constant, specific heat, heat of vaporization, and surface tension, occur at the triple point. Abrupt changes of this nature are usually accompanied by molecular phenomena of some sort, such as an association of molecules, or a change in molecular structure. In order to investigate the possibility of the occurrence of molecular changes which might explain the observed phenomena, we carried out experiments in an endeavour to obtain the Raman spectra of liq. He I and liq. He II. A study was made also of the Rayleigh scattering of the two phases, especially in the neighbourhood of the transition point, and the intensity of the Rayleigh scattering at this point compared with that of benzene at room temperatures.

Apparatus.

The essential parts of the apparatus used in these experiments are exhibited in fig. 1. The liquid helium was siphoned over the liquefier into the Raman tube, A, until a column of clear liquid, about 30 cm. in height, was obtained. In order to preserve the liquid helium the inner Dewar flask was surrounded by a second Dewar flask B, containing liquid air. The top T, made of German silver, was fastened to the Raman flask by a rubber joint at the point C.

* Fellow of the National Research Council of Canada.
‡ Keesom and Wolfke, *Leiden Comm.* No. 190 *b*.

Fig. 7 **Article in 1932 on the scattering of light by liquid Helium near T = 2.18 K**

applied to go to Cambridge to work with the brilliant Russian physicist, Peter Kapitza. Kapitza was a protégé of Rutherford and, in 1934, had just constructed a new simpler kind of liquid Helium cryostat. Fig. 8 shows a letter from Rutherford discussing the somewhat forbidding terms of Allen's appointment (note the opening reference to McLennan). By the time Allen arrived at Cambridge in the fall of 1935, Kapitza was under house arrest in the Soviet Union, with instructions (and generous funds) to build a new low temperature laboratory in Moscow. This was to become the famous Institute for Physical Problems.

With Prof. John Cockcroft as Acting Head, Allen started work in low temperature research in the Royal Society Mond Laboratory, again without any real supervisor or guidance. Allen effectively took charge of the research using liquid Helium and within a few months impressed everyone enough to be offered a salary. Later, he referred to the Cavendish Laboratory at that time as a "civilized jungle", but he clearly loved it.

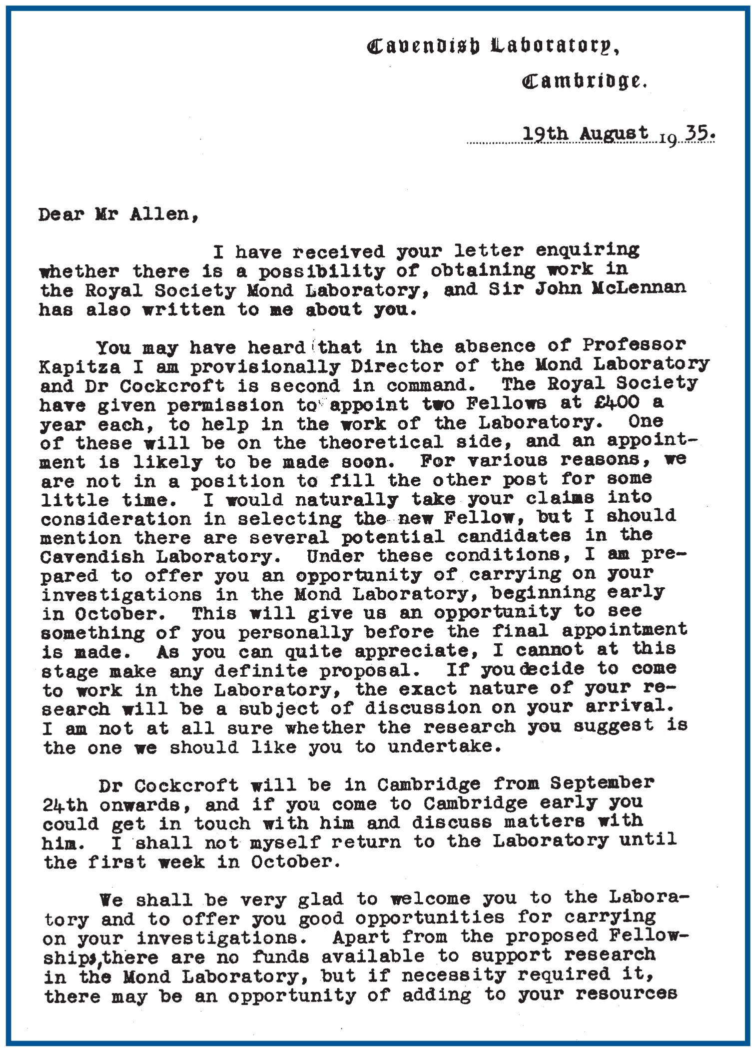
Allen's fellow graduate student, Donald Misener, is perhaps less well known but equally deserving of recognition [6]. Misener's ancestors were United Empire Loyalists who moved to Ontario in 1785. He was brought up in Kobe, Japan by his widowed mother, a missionary and distinguished educator. Misener entered U of T in 1929 and graduated with his B.A. in 1933, receiving the Silver Medal for mathematics and physics. His future wife, Agnes Crutcher, received the Gold Medal in the same year, also in mathematics and physics.

Misener joined McLennan's low temperature group in 1933 (just after McLennan had resigned) and did his M.Sc. (1934) working on superconducting thin films as well as on liquid Helium. In 1935, Misener carried out what would prove to be one of the most important experiments in the history of physics: he measured the shear viscosity of liquid Helium just below the transition temperature Tc = 2.18 K by studying the decay of the torsional oscillations of a rotating cylinder immersed in the liquid. He found that the viscosity appeared to decrease sharply just below Tc. The short letter published in Nature announcing these results [14] had a huge impact on the growing low temperature community (by this time, many laboratories could produce liquid Helium). In particular, Kapitza, then working in Moscow, was galvanized by it [2].

Unfortunately, this Nature article [14] was published under the sole name of E.F. Burton, the new head of the Department of Physics at U of T and a long-time colleague of McLennan. This attribution of authorship later led to considerable controversy in connection with Misener's role in the discovery of superfluidity. At the end of the Nature letter, Burton did give complete credit to Misener, Wilhelm and Clark (Wilhelm and Clark, at the time, were senior technical staff in the Toronto cryogenics lab) for carrying out the experiment. Clearly, however, something was amiss. Later in 1935, a longer paper on these results was published [in the Proceedings of the Royal Society (London)] by Wilhelm, Misener and Clark, without a single mention of Burton's short letter in Nature! In his Ph.D. thesis submitted to Cambridge in 1938, Misener discusses the rotating cylinder data as his own experiment.

It only became clear in the 1960s that Misener had in fact measured the decrease in the "normal fluid" density just below Tc, rather than the viscosity of the superfluid. Today, the response of a Bose superfluid to a rotation is viewed as a more fundamental signature of superfluidity than zero viscosity. However, the correct interpretation of Misener's data required a theory of superfluidity. This did not exist in the 1930s, even though the key idea of BEC had been suggested by Einstein in 1925 [3,4].

When Don Misener arrived in Cambridge 1936 to do his doctorate, Allen quickly teamed up with him to study the flow of liquid Helium in thin capillaries. This led to their discovery of superfluidity in liquid Helium [1]. The young Canadians are both shown in Fig. 9 in a group



Cavendish Laboratory,
Cambridge.

19th August 19 35.

Dear Mr Allen,

I have received your letter enquiring whether there is a possibility of obtaining work in the Royal Society Mond Laboratory, and Sir John McLennan has also written to me about you.

You may have heard that in the absence of Professor Kapitza I am provisionally Director of the Mond Laboratory and Dr Cockcroft is second in command. The Royal Society have given permission to appoint two Fellows at £400 a year each, to help in the work of the Laboratory. One of these will be on the theoretical side, and an appointment is likely to be made soon. For various reasons, we are not in a position to fill the other post for some little time. I would naturally take your claims into consideration in selecting the new Fellow, but I should mention there are several potential candidates in the Cavendish Laboratory. Under these conditions, I am prepared to offer you an opportunity of carrying on your investigations in the Mond Laboratory, beginning early in October. This will give us an opportunity to see something of you personally before the final appointment is made. As you can quite appreciate, I cannot at this stage make any definite proposal. If you decide to come to work in the Laboratory, the exact nature of your research will be a subject of discussion on your arrival. I am not at all sure whether the research you suggest is the one we should like you to undertake.

Dr Cockcroft will be in Cambridge from September 24th onwards, and if you come to Cambridge early you could get in touch with him and discuss matters with him. I shall not myself return to the Laboratory until the first week in October.

We shall be very glad to welcome you to the Laboratory and to offer you good opportunities for carrying on your investigations. Apart from the proposed Fellowships, there are no funds available to support research in the Mond Laboratory, but if necessity required it, there may be an opportunity of adding to your resources

Fig. 8 First page of a letter to Jack Allen from Ernest Rutherford in 1935, discussing his terms of appointment (from personal papers of J.F. Allen, University of St. Andrews).

Fig. 9 Faculty and graduate students of the Cavendish and Royal Society Mond Labs in 1936 . J.J. Thomson is to the left of Rutherford in the centre of the front row. Misener is in the fourth row, third from right. R.E Peierls is just behind Rutherford, and Allen is to the right of Peierls. (From personal papers of J.F. Allen, University of St. Andrews.)

photo of the faculty and students of the Cavendish Lab, taken in 1936. The detailed series of events that led to this discovery [15] is another story, which will be treated elsewhere. However, I hope I have convinced you that their success at Cambridge had its roots back in Toronto, and that it would not have happened without McLennan.

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