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CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS, OTTAWA

MINES BRANCH INFORMATION CIRCULAR

IC 105

PRICE 25 CENTS

THE STORY OF THE EARLY DAYS OF THE EXTRACTION OF HELIUM GAS FROM NATURAL GAS IN CANADA, 1915-1920

by

JOHN SATTERLY

UNIVERSITY OF TORONTO

APRIL 1959

THIS MEMOIR IS REPRODUCED AND DISTRIBUTED BY THE MINES BRANCH, OTTAWA, AS A CONTRIBUTION TO SCIENTIFIC KNOWLEDGE IN CANADA

FOREWORD

The following narrative by Prof. John Satterly gives a very interesting résumé of the details of the operation of the experimental helium extraction plant which Prof. (later Sir) J. C. McLennan, head of the Department of Physics of the University of Toronto, and his associates, constructed and operated near Hamilton, Ontario, in 1918 and later moved in the autumn of 1918 to Calgary where gas from the Bow Island (Alberta) field was processed. The plant was closed in April of 1920, having recovered, in all, about 60,000 cu.ft of helium of 60 to 90 percent purity.

Prior to, and in conjunction with, this pilot plant work, a survey of the helium content of Canadian natural gases was undertaken by Professor McLennan, and from early 1916 until 1918 numerous samples were analysed. Dr. R. T. Elworthy was associated with this work. The results of the survey showed that there were at that time two places in Canada where an experimental extraction plant might be established; namely, Hamilton in Ontario and Calgary in Alberta.

The above work was instigated and sponsored by the Board of Inventions and Research of the British Admiralty, in an effort to obtain supplies of helium for use in lighter-than-air ships.

Subsequent to this initial work in Canada, large helium reserves were developed in the United States, and, with the availability of helium assured, many commercial uses were found. The

Canadian Department of Mines, which is now part of the Department of Mines and Technical Surveys, has maintained a continuing interest in helium since the inception of this project, and regularly conducts analyses of natural gas, reporting the results periodically.

The publication of these notes has been undertaken by the Mines Branch in the interest of a historical record of an important activity in the Canadian mineral resources field. Inasmuch as no other account has ever been published, it was considered, in view of the passing of time, that it would be a pity not to take advantage of Professor Satterly's generous offer to describe in chronological order, some forty years later, the early attempts to recover the precious gas.

John Convey,
Director,
Mines Branch

Mines Branch Information Circular IC 105

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by

John Satterly*

ABSTRACT

A gap in the historical record of the early research on helium gas in Canada is filled by the author, who narrates from memory and from notes his recollections of the origin and progress of the 1915-1920 helium project sponsored in Canada by the British Admiralty in an effort to obtain helium for use in lighter-than-air ships. Details are given of the staff concerned; of the first experimental extraction plant at Hamilton; and of the second experimental extraction plant at Calgary, where, from early 1918 to April 1920, about 60,000 cu ft of helium of 60 to 90 percent purity was recovered from Canadian natural gas from the Bow Island (Alberta) field.

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AUTHOR'S PREFACE

As desired by Dr. C. W. Seibel, who is now in charge of the helium activity of the U. S. A. Bureau of Mines, I have written this story of the early history of the extraction of helium gas from the natural gases in Canada during the years 1915-1920. Those years are so long ago that it is hard to recall all the events, but I have done the best I can and have pieced my story together, partly from memory, partly from correspondence (fortunately kept), and partly from papers published just subsequent to more lively and interesting days. Correspondence with Prof. R. J. Lang of the University of Alberta, since the first draft of this article was made, has resulted in the addition of some of his reminiscences. I understand Doctor Seibel is engaged in a similar effort to recall the early days of the U. S. A. work on helium extraction, compared to which our Canadian effort was quite a small affair.

I wish to thank Dr. John Convey, Director of the Mines Branch at Ottawa, and Mr. A. Ignatieff, chief of his Fuels Division, for taking an interest in the Helium Story and having it published. I think there will be many interested readers.

JOHN SATTERLY
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Department of Physics,
University of Toronto,
April-May, 1959.

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(47 pages, 6 figures)

INTRODUCTORY

In 1914, at the beginning of World War I, observation balloons filled with hydrogen gas were used to observe the enemy's positions. These balloons were often set on fire by incendiary bullets, with consequent loss of life and material.

On February 28, 1915, Sir William Ramsay, the chemist, and co-discoverer of the rare gases in the atmosphere, wrote to his old pupil Richard B. Moore[1] (then chief chemist of the U. S. Bureau of Mines) in Washington, saying that he was looking for a supply of helium gas for the British Government (helium is non-inflammable and its lifting effort is about 93% of that of hydrogen). Ramsay wrote: "There does not appear to be any helium in England, but I am getting samples of natural gas from Canada and the U. S. A." He added that in his own opinion airplanes could operate successfully against dirigibles and he did not think that the need for helium was so important as the British Admiralty seemed to believe.

Moore was fully aware of the work of Cady and McFarland[2] on the helium content of the natural gases of Kansas, where some wells produced gas containing 1.8% of helium, but since at that time the United States was neutral in the war he did not inform Ramsay where to look for a supply of helium.

In England, Sir Richard Threlfall, formerly professor of Physics at the University of Sydney in Australia, an authority on phosphorus, and in 1915 a consultant on scientific matters for the

British government, strongly advocated the use of helium in observation balloons, and his calculations on the cost of production, transportation, etc., of helium gas to England, backed by the opinion of Sir Ernest Rutherford, convinced the Board of Inventions and Research, and the Admiralty (Sir John Fisher was First Lord), that if a sufficiently rich source of supply could be found the cost of extraction, etc., would not be prohibitive.

But the United States was not yet involved in the war.

Late in December, 1915, Professor J. C. McLennan, head of the Department of Physics in the University of Toronto, in Canada, and well known in England for his research in spectroscopy and radioactivity, received a letter from the Department of Inventions and Research, London, asking him to make a helium survey of the British Empire and consider where semi-commercial plants could be installed for the isolation of helium from natural gas, with a view to subsequent large scale production, and also to consider the feasibility of purifying helium after use in dirigibles and consequent contamination with air and other gases.

At the University of Toronto, two of the five permanent staff members of the Physics Department, Professors Gilchrist and McTaggart, had already left Canada for X-ray work with the Canadian contingent in England and the near East. The three professors remaining were J. C. McLennan, E. F. Burton, and the author. The University classes, though smaller than before the war, kept everyone busy.

McLennan, provided with a previous survey of the natural gases in the Ontario gas fields,[3] quickly visited the gas wells and collected samples of gas in 5-gallon glass bottles fitted with rubber stoppers and iron clips. These were sent back to Toronto for analysis. In the laboratory we received help from Professor H. F. Dawes of nearby McMaster University and, with the help of a glass blower, soon built a gas analysis apparatus similar to that used by Cady and McFarland. Between hours of teaching, and often until late at night, we tested about twenty wells.

McLennan thought that there might be a connection between the helium and radon (radium emanation) contents of the gas, and, as the gases came in, assigned the writer to examine their radioactivity. It was found that the richest Ontario gas had only 0.33% of helium and that there was little relation between helium content and radioactivity.[4]

McLennan then went farther afield, to Alberta and British Columbia, and collected another twenty samples. The richest gas was that from the Bow Island field in Alberta; it had 0.36% of helium and, as shown subsequently, was the richest gas in the British Empire. McLennan's surveys were completed in April and May of 1916.[5]

Natural gas was also collected from wells in New Brunswick (in eastern Canada), and from New Zealand, and sent to Toronto for analysis; the helium content was low.

Our experimental methods for testing for helium are fully described in McLennan's report. Briefly, the procedure was to use liquid air to freeze out all the hydrocarbon gases; then use coconut charcoal immersed in liquid air to absorb the nitrogen and hydrogen; and, finally, pump off the residue, i. e. the helium, to test it spectroscopically for purity and to measure its amount.

For the sake of secrecy, helium was also referred to as X-gas, or C-gas, or even as argon.

THE HAMILTON EXTRACTION PLANT

Not until the autumn of 1917 was a start made on the semi-commercial extraction of helium from natural gas. Professor McLennan was now in England with the Admiralty, and the writer was in charge of all monies. To operate the plant McLennan persuaded the Canadian Meteorological Department (Sir Frederick Stuart, director) to lend us the services of Mr. John Patterson. Mr. Patterson was a graduate in Engineering of the University of Toronto, second in command at the Meteorological office (Patterson's three-pronged anemometer is well known), and a most patient and versatile man. He took over all the engineering side of the project and was ably assisted by Mr. R. J. Lang (later professor of Physics at the University of Alberta).

The first Canadian plant was established towards the end of 1917 near Hamilton, Ontario, 40 miles west of Toronto. It used gas from the "Blackheath" system of southwestern Ontario. The composition of this gas was: methane, 80 percent; ethane, 12 percent;

and nitrogen, 8 percent. Permission to use the gas was obtained from the National Natural Gas Company, of Hamilton, the agreement being that after we had extracted the helium the remainder of the gas was to be sent back into the pipeline for consumption in Hamilton.

Patterson and Lang were now in charge of the engineering side of the project; we in Toronto gave what advice we could. A large gable-roof building, 20 feet in height, was built near the pipeline and the reducing valve. It was not far from the brow of the Hamilton "mountain", just above the Barton Street reservoir and the Barton Street station on the Hamilton-Grimsby electric radial line. A tall wire fence was erected to keep out prying intruders, so secret was this work considered in those days. A power line was built up the hill, but the Hydro-Electric Commission of Ontario could not spare any men to wire the building; so we had to do it ourselves, including the circuit and starting control for a 100-hp motor to drive the big compressor. The starting controls were put in a separate annex to avoid the danger of sparking. Of course, our work was carefully inspected.

L'Air Liquide Co. of Toronto lent us, free of charge, a Claude oxygen column and necessary auxiliary equipment, and Mr. Jordan of that company gave us all the advice he could. McLennan sent out from England a large compressor made by Reavell of Ipswich. I now quote from McLennan:[6]

> In treating the gas, considerable difficulty was experienced at first in getting rid of the heavier hydrocarbons, but by making suitable modifications in, and additions to, the ordinary type of L'Air Liquide Co. oxygen rectifying column,

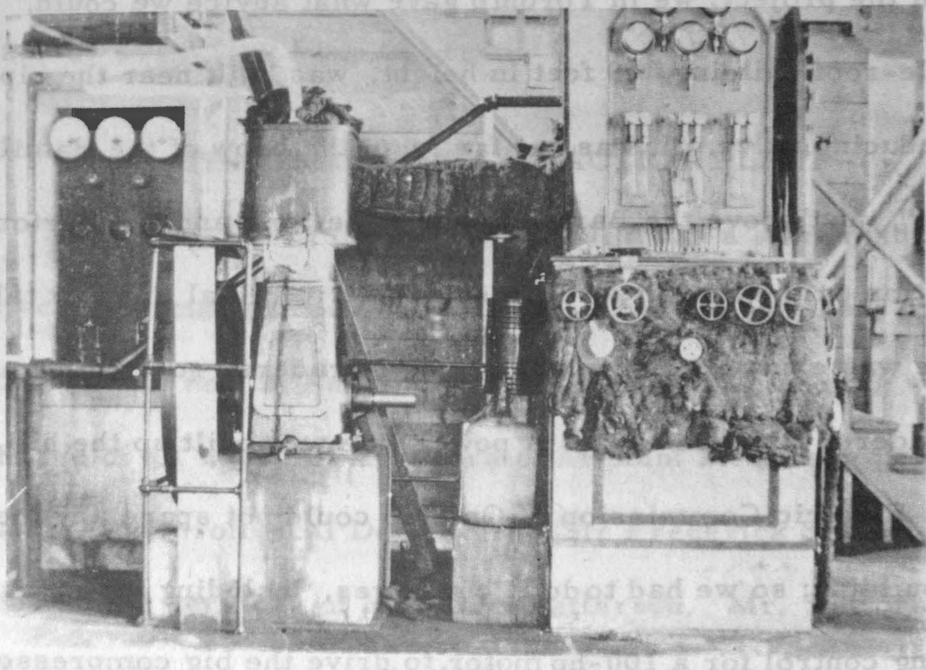

Figure 1 - The only photograph taken of the Hamilton machinery. The machine shown at left centre is the well-drilling apparatus.

the problem of separating out the helium which was present in the gas to the extent of only 0.33 percent was solved. In February, 1918, it was found possible to raise the percentage of helium in the gas by passing it through the rectifying column once only. As the gas obtained in this consisted of nitrogen and helium with a small percentage of methane, the problem of obtaining helium with a high degree of purity was a comparatively simple one.

In one particular set of experiments on this final rectification, helium of 87 percent purity was obtained. For the actual running of the station and for the technical modifications in, and additions to, the rectifying column, Mr. John Patterson was largely responsible.

Burton, the writer and Dawes helped with advice, with analysis of products, and occasionally worked in the plant at week-ends and whenever time could be spared from teaching duties in Toronto.

INCIDENTS IN TORONTO AND HAMILTON

One day, in the laboratory in Toronto, we had just finished a long innings of analysing natural gas for helium and we collected all our liquid air (now chiefly liquid oxygen) in a large spherical Dewar flask. To help insulation, I put this in a large carton and packed cotton wool around it. Unfortunately, the flask broke and its contents saturated the cotton wool. The glass blower said: "Put a match to it and see what happens." Unthinkingly, I applied a match. A sudden uprush of fire and burnt wool followed which hurt me horribly about the face and hands. The hot blast ruckled the skin on the back of my hand, burnt my face, and removed the hair at the front of my head. Luckily I had closed my eyes in time. Dawes immediately ran to the teaching laboratory where we kept olive oil for specific gravity and surface tension experiments, got some, and dabbed me with it. He then applied fresh cotton wool to keep the oil there and led me home, about a mile away. My wife was astounded at my appearance. Luckily I heal well, but the scars remained for a long time, especially the wrinkles around my eyes. Experientia docet!

Later, in my lecture on liquid air I repeated the experiment, taking care to use less liquid air and wool and to replace the match by a candle wired to the end of a metre stick.

The Hamilton building was about 4 miles from that town. It was situated on high ground just behind the brow of the so-called Hamilton mountain (which is really a continuation of the Niagara escarpment), and was approachable by a dirt road from the plateau plain behind. A trolley line ran along the base of the mountain, as mentioned earlier. As funds were never very plentiful and secrecy was desirable, those who worked in the plant took the trolley to the Barton Street stop and climbed steep winding paths up the hillside with the aid of the bushes. In winter snow and ice, this was hard going and the descent at midnight was even worse, for then we slithered down in the dark.

Lang came to the project from the Royal Flying Corps. His chief duties there had been to pick up bits of scrap paper, etc., from the ground with a stick furnished with an iron spike. This dissatisfied him and he applied to us (and to Professor McLennan) for a shift to our gas work. His desire was granted and he came to us wearing the uniform of the Royal Flying Corps. The Flying Corps only allowed him $3.00 to buy civilian clothes. So much for secrecy!

A young workman, Barker by name, was also engaged. He proved very good and stayed with the project to the end of the Calgary days.

Patterson and Lang sometimes slept in a Hamilton hotel and occasionally when we were helping we all slept in the building. On these occasions, when the frost was keen, our cold pork at supper had to be sliced with an axe.

In a recent letter dealing with this period, Lang remarks:

It was late in the autumn of 1917 before the compressor and liquefying column could be installed. L'Air Liquide Co. had had some mysterious explosions in the bottom of the column, so for safety's sake it was decided to place this part in a pit. When we had the pit dug in the rock, at considerable cost, it promptly filled with water. A caulked wooden box was then made to occupy the pit but the water caused the box to heave and eventually a pipe had to be used to take the water away.

We also needed water to cool the compressor, so that a well was required. The driller came and used the forked branch of the water diviner. He found water underneath the building, just where we required it. We all tried the twig and located the same spot -- such are the powers of suggestion! The well did not flow sufficiently to be used directly, so a large wooden reservoir was built underneath the floor; from it the water was pumped to the compressor and then returned. Even then the supply had to be augmented from a nearby pond formed by the melting snow and ice.

L'Air Liquide Co. sent us an elderly employee to supervise the assembly of the liquefying column. He turned up in carpet slippers because "his feet hurt". It used to take two of us 10 or 15 minutes each morning to get him up the steep path from the radial station. When the installation was finished we asked him to stay and supervise the operation of the first run of gas, but he said: "Non, non! I work on gas for Claude in Paris and a man just fall down and they carry him away." A reference to Claude's book on "Liquid Air, Nitrogen, Oxygen" told of Claude's attempt to liquefy the poisonous carbon monoxide, and perhaps the accident happened then. To the elderly Frenchman all gases were alike so he would not stay, and the first run was carried out by Patterson and Lang, the latter having taken the precaution of spending a night at L'Air Liquide Co's oxygen plant in Toronto.

The gas supply at Hamilton was small, so no attempt was made to obtain helium in quantity, but efforts were made to modify and test the column for future work. The operations were carried on at night when the Hamilton demand was small; and the gas was not returned to the mains, but discharged to the air through a long vertical pipe through the roof. The gas supply, of course, was metered.

After each short test run the products were analysed in Toronto. Patterson made many journeys to the University by cliff, radial, train, and streetcar, carrying two 5-gallon glass bottles. Fellow passengers wondered where he was getting them filled!

One cold and frosty night, when the liquefier had been in operation for some time, the gauges began to show excessive accumulation of liquid in different parts of the column. So, to avoid shutting down, Patterson drew off some liquid ethane in a pail and gave it to Satterly and Dawes to dispose of outside. Close at hand there was a large frozen puddle on the dirt road. They therefore poured the ethane upon the ice and put a match to it. A tremendous blaze rose house-high and must have startled anyone in the vicinity. It certainly did startle Patterson and myself, for the bright salmon-coloured flash came in through the upper windows and for a moment we thought the whole place was on fire with us to be victims. Luckily, on account of the absence of wind the gas from the tall exhaust pipe did not ignite.

The building was in a lonely spot in the woods and, usually, to guard against any sabotage, one of the party spent the night there. Occasionally one would be awakened by a sudden bang that sounded like a rifle shot. It was very disturbing. Investigation showed that the noise was caused by the inner thin cardboard lining of the building tearing itself away from the main structure as a result of temperature changes.

At another time, an accident happened at night to a little gasometer, 3 feet in diameter and 6 feet high, which was made of galvanized heavy sheet-iron and was used for collecting samples. It had the usual two components: the outer bottom half, filled with water; and the inner portion, which rose and fell with the gas supply, supported by rope and counterpoise attached to its conical roof. There was a small tap at the bottom of the inner portion for drainage purposes. One evening I opened this tap, preparatory to some repairs in the morning, and left without telling Barker. During the night Barker heard a tremendous row from the gasometer and thought some one must be inside. What had happened was that as the upper part descended, its fall was arrested by catching on a bolt-head in the outer portion, and a partial vacuum was produced by the issuing water. Then the atmospheric pressure took the upper hand and crushed in the roof, making a great dent and a very loud noise.

Patterson often reported to the writer by telephone the result of the latest run. Late, one winter night, the telephone rang and Patterson said in his sepulchral voice: "Satterly, worse and worse!" I comforted him as best I could.

While the Hamilton work was in progress, we made some subsidiary experiments in Toronto. One was on the behaviour of the condensate obtained by cooling the gas in liquid air.[7] With the liquid methane and ethane obtained in Hamilton, we measured "the latent heats of vaporization" of methane and ethane.[8] With the helium obtained in our analyses we measured the combustibility of mixtures of helium and hydrogen.[9] These results were communicated to the British Admiralty in December, 1917.

THE MOVE TO CALGARY

In the autumn of 1918 the gas supply at Hamilton decreased, and in October it was decided to shift operations to Calgary, Alberta. Gas arrived in Calgary from the Bow Island field in large quantity and at moderately high pressures. The large quantity, however, was not so large as first thought, being about 6 and 18 million cubic feet a day in summer and winter, respectively. The pipeline pressure was 100 psi, and this was reduced in two stages, to 35 psi and finally to 6 ounces per square inch, for household use. The composition of the gas was: methane, 86-91 percent; nitrogen, 6-9 percent; ethane, 2-3 percent; oxygen, 0.1 percent; and helium, 0.36 percent. The gas contained less ethane than the Hamilton gas and was cheaper.

Mr. John Patterson now took full charge of the Canadian operations, and we in Toronto gave full time to our academic work except when called in for discussion, advice, and to do a few analytical tests.

There were now long distances between Patterson in Alberta, us in Toronto and McLennan in London, and from the many cables and letters, which often crossed on their journey, it is not easy at the present time, 1959, to make a connected story. McLennan had to persuade the Admiralty to sanction all expenditures and Patterson had to send over all vouchers.

In October, 1918, McLennan reported to the Admiralty that the expenses up to the present were £ 2,100 for work done in

Canada (L'Air Liquide Co. had lent us the Claude column), and he estimated that buildings, equipment and running expenses at Calgary would cost £6,400. He also required £5,000 for a plant at Wormwood Scrubbs, just west of London, where he proposed to erect a liquid-air machine and other equipment to purify and enrich the helium to be sent over; 4,000 cubic feet of 70 percent purity had already been sent over from Texas. The liquid-air machine was on loan from the British Oxygen Company.

McLennan also established a laboratory in the City and Guilds College building in South Kensington, London, S. W., where arrangements were made for purifying any small quantities of helium sent over from Canada and for further scientific work on helium (see later). In November, 1918, McLennan reported that he estimated the expenses at Hamilton and London were now about £ 7,500, and that £ 10,000 was required for the Calgary operations. The Calgary plant would include some of the apparatus used at Hamilton, a compressing and expanding air pump, a newly designed rectifying machine, and three storage balloons. He estimated that Calgary might supply 30,000 cubic feet a month and that the Wormwood Scrubbs plant would raise this from a 70 percent content to a 99 percent purity. He also emphasized to the Admiralty the many advantages of using helium in dirigibles, suggested the possible uses of helium in many branches of scientific activity, and stressed that it was up to England to carry on the low temperature work to which British scientists, such as Faraday, Andrews and Dewar, had contributed so much.

<u>Figure 2</u> - The building at Calgary, Alberta, which housed the plant. It fronted on the street.

In December, 1918, McLennan reported to the Admiralty details of the work carried out in the London laboratory on the purification and enriching of helium gas mixtures by absorption and continuous flow methods, and on the use of the Aston gas-density balance (in the U.S.A., called the "Edwards" balance).

About that time Patterson went to Calgary. There he interviewed Sir Clifford Sifton of the Canadian Western Natural Gas, Light, Heat and Power Co. and Mr. Coste, manager of the company, and rented a two-storey brick warehouse on the pipeline. This building measured 50 feet by 30 feet and was for the installation of the machinery. It was estimated that it would cost $2,500 to build a shed (30 x 10 x 10) for housing the balloons, and $1,400 to build a heating plant (Calgary is cold in winter). He also bought a transformer and other machinery and awaited the coming of the new rectifying column.

This new column was sketched by Patterson, argued over with Jordan of L'Air Liquide Co., Toronto, and then modified until the two of them agreed it would do the job. Jordan estimated it would cost $20,000, but said his company would make it for the cost of the material and labour, plus 30 percent for the overhead charges for power, heat, and tools. It would take two months to build. McLennan squirmed at the cost and delay and had difficulty in persuading the Admiralty to sanction it, but eventually it went through -- the Admiralty to own the machine and exchangers, and L'Air Liquide Co. to hold patents on anything new inserted in it.

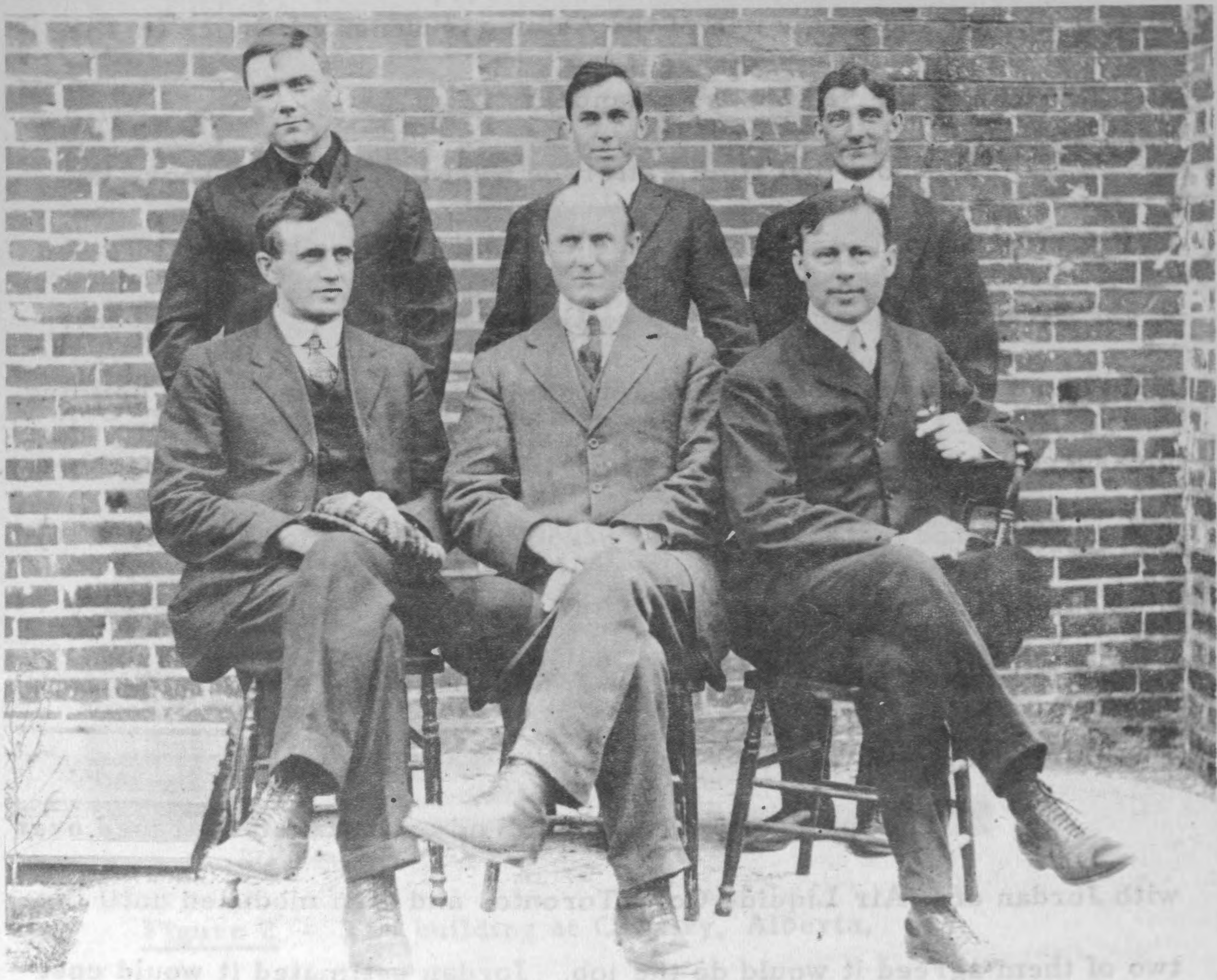

Figure 3 - The staff at Calgary, September 1919.

Front row, (left to right): R. J. Lang, John Patterson, H. F. Dawes.

Back row, workmen (left to right): Percy Blackman, Basil Cody, James Barker.

Shortly thereafter, Patterson and Dawes left for Toronto, leaving Lang in full charge.

The Admiralty was now prepared to resume the work, although the war was over; and McLennan was insistent in his demands for Patterson to send over some Canadian helium, even if only of 70 percent purity. McLennan was now becoming convinced that all bulk supplies of the gas would come from the U.S.A., and that Calgary and Wormwood Scrubbs would be experimental plants only.

About this time, Patterson communicated with F. C. Cottrell (U. S. director of helium activity at the time) about a visit that our Professor McTaggart wished to make to Texas to see how things were done on the grand scale. In his reply, Cottrell mentioned the hundreds of thousands of dollars the U.S. Army, Navy, Air Force and Bureau of Mines were spending on the project, and stated that all was doing well.

So Patterson and his men dismantled the Hamilton building, took what they wanted to Calgary, and engaged more manpower, including Messrs. Dawes, Ainslie, Cody and Blackman -- all from the University of Toronto.

On November 17, 1918, Patterson wired to McLennan: "Machinery shipped. Balloon shed nearly ready. Column progressing. Money arrived." A month later, in a cable dated December 15, 1918, he reported: "Calgary plant probably running by beginning of February 1919."

However, many delaying difficulties arose, but they were gradually overcome, and late in the summer of 1919 things really got started.

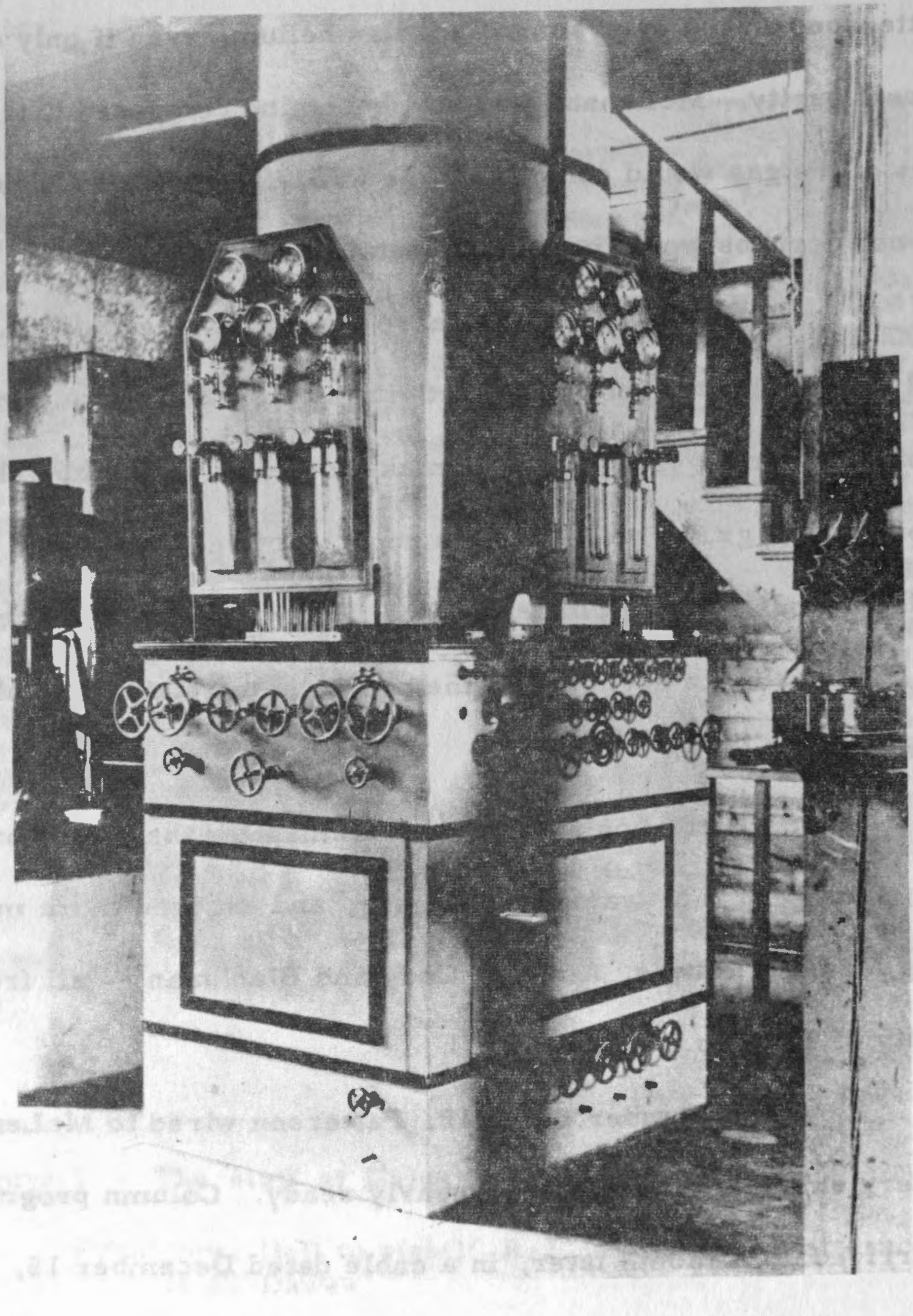

Figure 4 - The two-stage liquefier column used at Calgary. The valves and gauges on the left were used during the first stage and those on the right for producing the final product. The galvanometer on the post was used to control the temperatures at various places in the column by means of thermocouples.

In a Chemical Society lecture in 1920,[12] McLennan said:

> The experimental station at Calgary consisted of a brick building of moderate dimensions, a small brick hut, and a galvanized iron balloon shed located on the property of the gas company. The equipment in these buildings included that necessary to furnish an adequate supply of gas, which consisted of the requisite piping, gate valves, pressure reducing valves, etc., a gasometer and two balloons, a number of gas cylinders and the rectifying column with its expansion engine, together with the necessary compressors and complete gas testing outfit.

He then gave details and diagrams of the developed rectification column -- these are omitted from this story, but are contained in R. T. Elworthy's 1926 report, "Helium in Canada".[10]

In September, 1919, Patterson and Dawes were called back to their respective duties in Toronto. Lang, who had been away ill for some time, now went to Calgary and had sole charge of the project there. His assistants were Ainslie, foreman Barker, Blackman, and two workmen from Calgary.

Lang's Calgary period, which was the "production" period, extended through the winter months from October 1919 to April 1920. I now quote from Lang:

> The Calgary extraction plant was installed in the summer of 1919. It used a new liquefying column designed to operate on the Bow Island gas. It was necessary to operate in two stages, for the temperature which would be obtained by the vaporization of the liquefied hydrocarbons present was not low enough to liquefy the 10 to 11 percent of nitrogen. The first stage, therefore, removed as much as possible of the 87 percent methane and 1 percent ethane, and the product was stored in a large balloon in a wooden shed built for that purpose. (In this stage, the helium percentage was raised from 0.36 to about 5.)

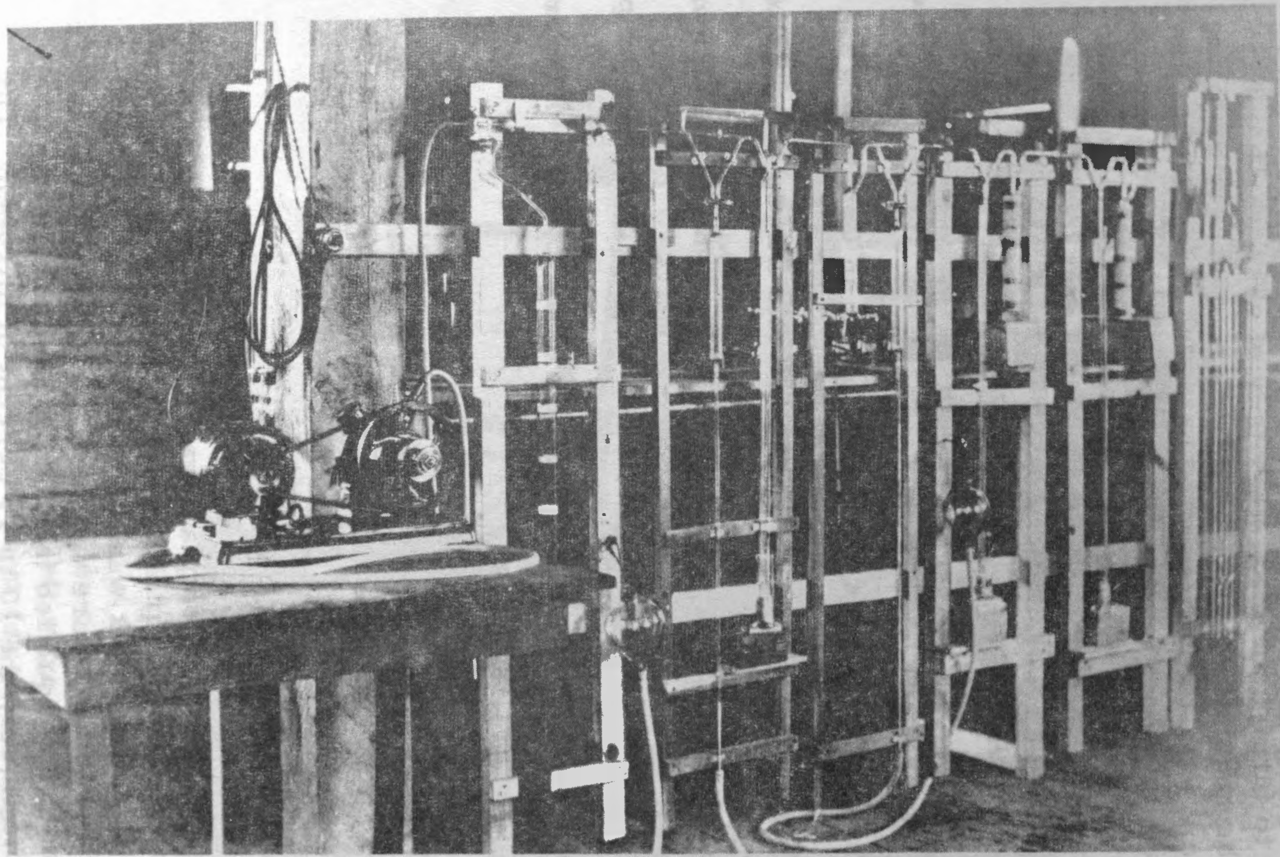

Figure 5 - The glass apparatus for testing the purity of the interim and final products. It was set up in the upper part of the Calgary building.

When this large balloon was filled after some 80 hours of steady night and day operation, this product was passed through a separate small liquefier. This required only three or four hours and gave a final product of 85 to 90 percent. About 500 cubic feet was obtained each time. (This product was stored upstairs in a small balloon of heavy rubber until it could be compressed into the large steel cylinders.)

The first stage took up Monday to Thursday, day and night; the second stage occupied Friday; and on Saturday there came the most disagreeable task of all--cleaning out the used caustic from the large steel tanks and refilling them with fresh.

In the previously mentioned Chemical Society lecture,[12] McLennan presented graphs (on page 930) showing the results of twenty-six weekly runs made by Lang at Calgary from 1919 to 1920. They indicate a gradual increase in the amount of helium per run and in the percentage purity of the product. He said: "In the first stage 500,000 cubic feet of natural gas yielded 20,000 cubic feet of interim product; in the second stage, this yielded 300 cubic feet of helium in the early days and 700 cubic feet in the later days, with an average of 500 cubic feet of nearly pure helium as stated above."

The plant tests for purity were: (1) for the first stage non-inflammability of the product, a sample was collected in a small balloon and tested outside the building; and (2) for the second stage a Shakespeare katharometer was used (this instrument was designed for testing for hydrogen, but Patterson adapted it to testing for helium). Back in the laboratory, an Aston micro-balance was used.

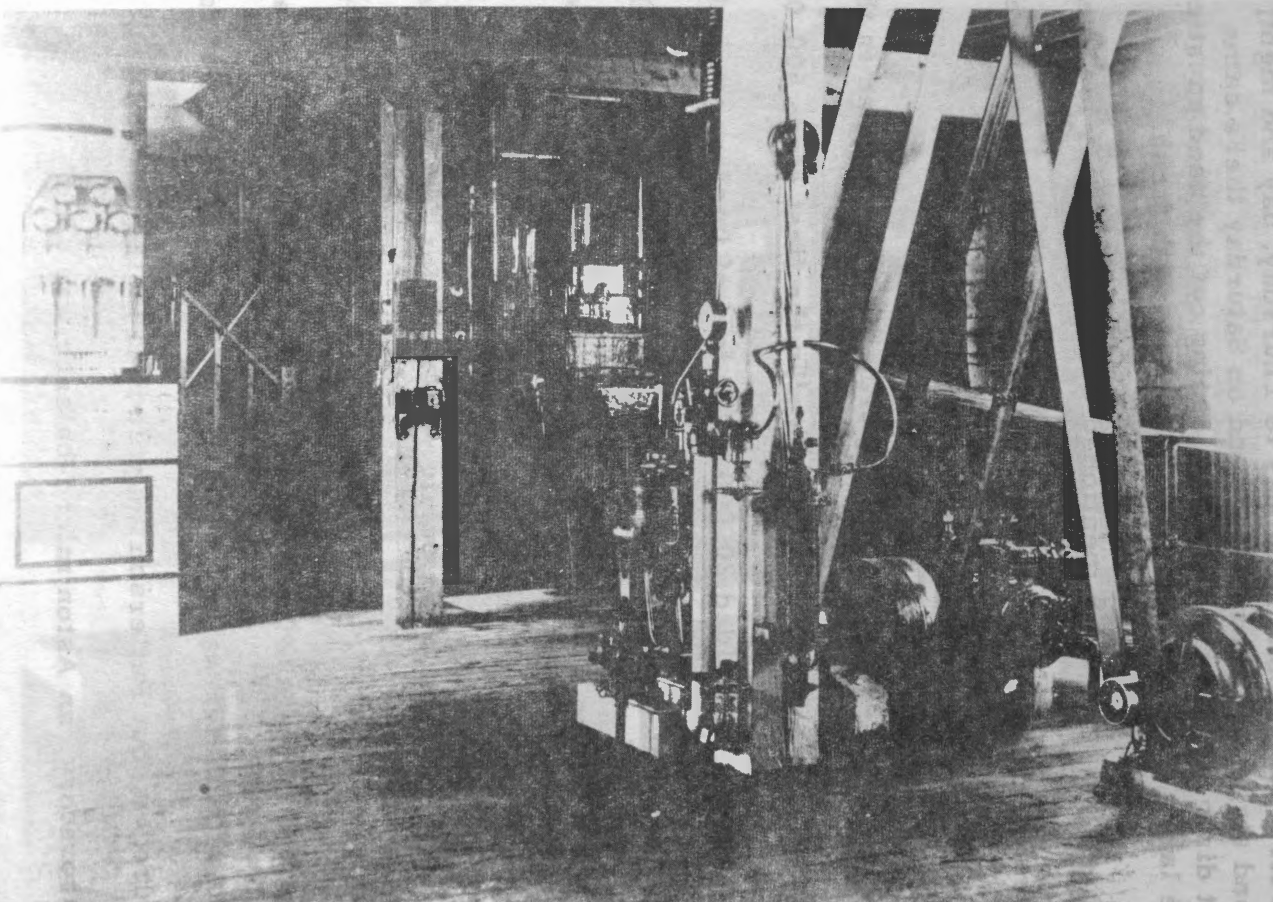

Figure 6. - The interior of the Calgary warehouse. (The compressor in the corner is too dark to show.)

INCIDENTS AT CALGARY

Of his Calgary period, Lang says:

The caustic (sodium hydroxide) came sealed in large black sheet metal drums of 500 pounds each. We had to use an axe to open the drums and the workmen got burned about the face and hands with the stuff, not to mention the wear and tear on their clothing. We supplied them with high rubber boots, rubber coats, rubber gloves, and goggles. Then while the rest of us hid somewhere, the axe was applied and the chips flew. We wanted dry chunks of caustic in the first steel tank, and water solution in the second; otherwise, we could have dissolved the stuff direct from the drums.

It was one of my duties to impress on the staff, especially any newcomers, the highly dangerous business we were in. Smoking was strictly forbidden. Besides precautions against any accidents with bursting pipes or breaking belts, we had to make sure that the big caustic tanks, whose tops had to be removed and replaced weekly, did not leak.

The big compressor, being an air compressor, was not really adapted to the work and was very temperamental. The gas from the mains entered the crank case, which was closed by a sheet-iron door about 3 feet in diameter, so the gas had to enter close to atmospheric pressure or else the door would be blown out or sucked in. Hence, the regulator on the main valve had to be watched and adjusted carefully for changes in gas pressure (for example, between night and day).

Then, in the dry climate of Calgary, winter static electricity was an ever-present hazard in case of a leak. One amusing thing used to happen in this connection. We kept the long, empty steel cylinders lying on the wooden floor, ready for filling, and it happened that the ends of these extended near the big 18-inch drive belt of the compressor. When a workman went to get one of these cylinders he would get a terrific shock. When he put on rubber gloves the shock went through them also. We quickly cured this evil by running a ground wire across the floor and down the basement to a water pipe.

Finally, to be as safe as we could, we operated with a large door, used as a truck door, wide-open close beside the column, even though the temperature outside often fell to 20 or 30 degrees below zero F. Of course, we wore all the clothes we had, with gloves and caps over the ears.

About once a week, however, one of Calgary's famous Chinooks came in with a warm south-west wind. The temperature would rise perhaps 50 degrees in half a day. It never lasted more than a day or so, and the cold returned as quickly as it left.

The sudden rise in temperature was a nuisance. The colder the weather the easier it was to remove the hydrocarbons in the first stage, and of course that meant a high purity for the final product. When the Chinook hit us, the liquefier filled up with liquid hydrocarbons so rapidly that we had to drain off some and throw it away to keep the machine going reasonably well. I concluded that, somewhere nearby, the gas main was on top of the ground and that in the very cold weather some component, probably the ethane, liquefied in the main and was kept back until the Chinook came, when it vaporised and came on with the rest to flood our machine. But for that, I think we could have held the purity to 90 percent all the time.

R. T. Elworthy states, on page 7 in his 1926 report,[10] that, after the Armistice, Calgary operated from December 1, 1919, to April 17, 1920, and produced, in all, about 60,000 cubic feet of helium of 60-90 percent purity. The Admiralty then closed its purse and the plant was shut down. It was estimated that it could produce 30,000 cubic feet a month.

ACKNOWLEDGMENTS

At the conclusion of the Canadian work, McLennan[6] stated:

In the early stages of the extraction of helium from natural gas in Canada, valuable help was secured from Lord Shaughnessy and the members of his staff on the Canadian Pacific Railway, from the President and Board of Governors of the University of Toronto, from the Director of the Meteorological Office, Toronto, and from the Directors of the various natural gas producing companies in Canada, in particular from those of the National Natural Gas Co., of Hamilton, and those of the Canadian Western Natural Gas, Light, Heat and Power Co., of Calgary. (To which I add L'Air Liquide Co. of Toronto, and, in particular, its manager, Mr. Jordan, for continuous advice and help. -- J. S.)

MCLENNAN IN ENGLAND

While the work of helium extraction was in progress, Professor McLennan was in England as Scientific Advisor to the Admiralty. His chief work was on submarine and mine detection and destruction. However, he contined to direct the Canadian helium work, as is evidenced by the number of cables and letters to and from Canada, and by the many official secret reports he gave the Admiralty.

McLennan also established a laboratory at the rear of the City and Guilds College in South Kensington, London, and collected there for helium research many of his old students; no matter what they were doing, he enlisted their services and got them -- he had "a way with him" and would override the objections of the Services. He says:[6 (11)]

> Investigations were set in train to develop industrial and scientific uses for helium, and to work out experimental details of the technical use of helium in aircraft. Among others, investigations were begun on the use of helium for thermionic amplifying valves, on the suitability of helium for gas-filled incandescent lamps and gas arc lamps, on the permeability of balloon fabrics for hydrogen and helium, on large-scale charcoal absorption methods of purifying the gas, and on the use of helium for high electrical resistances. Progress was made in the installation of equipment for the production of liquid helium for low-temperature research. Steps were also taken to examine spectroscopically all samples which came forward, with the object of ascertaining whether any indication could be obtained of the existence of any new and hitherto unobserved gaseous elements.

Those who participated in these investigations were Captain H. A. McTaggart, R. T. Elworthy, V. R. Murray, E. Edwards, J. T. F. Young, H. J. C. Ireton, W. W. Shaver, A. C. Lewis, and K. H. Kingdon. With one exception, all were members of the University of Toronto.

Before returning to Canada from England, McLennan lectured and wrote papers on the extraction of helium from natural gas, and on its properties and uses.[12]

PROCESS SUMMARIES FROM ELWORTHY

I quote now from Elworthy's report,[10] written in 1926; it conveniently summarizes the processes of extraction, purification, storage, transportation and costs:

Extraction Processes

Although at least four experimental plants and one large-scale plant in the United States, and one experimental installation in Canada, have been operated for the extraction of helium from natural gas, the same general principles have been employed in each. It is not proposed to enter into details here but only to indicate briefly the main operations followed in the general process. More detailed descriptions of the extraction processes, illustrated by diagrams and photographs, are to be found in several papers and reports which have been published.

Methods Employed

The methods used depend on the fact that the main constituents of natural gas--methane, ethane, and nitrogen--can be liquefied at much higher temperatures than helium. Ethane becomes liquid at -86°C, methane at -164°C, and nitrogen at -196°C. Consequently, the helium, which is only liquefied at -269°C, can be pumped off in a gaseous state after the other gases have been liquefied.

An analogous process is the separation of argon and neon from the air, which is sometimes carried out in conjunction with the preparation of oxygen from the air. This latter process, the recovery of oxygen from the air, is now in common use in all parts of the world and plants are established in almost every large manufacturing centre. The general types of apparatus that might be used and the main lines to be followed were therefore worked out when the first experimental plants for the separation of helium were planned.

Outline of Processes

The processes may be divided into five series of operations: compression, purification, liquefaction, rectification, and final purification of the helium.

The natural gas is compressed to pressures, which vary in the different processes, between 500 and 3,000 pounds per square inch; the impurities, such as carbon dioxide, water, and traces of heavy oils, are removed by treatment with caustic soda solution, calcium chloride, silica gel, or by refrigeration. As the liquefaction and rectification apparatus, and particularly the heat exchangers, contain many copper tubes of small diameter, subjected to low temperatures, it is essential that every trace of these impurities should be removed to ensure continuous operation of the plant, otherwise they will solidify in these tubes and prevent free passage of the gases. Many improvements in the extraction processes have been mainly concerned with the more efficient removal of impurities.

The compressed, purified gases are then passed through the heat exchangers. These in principle resemble water-tube boilers, being formed of numerous copper tubes concentric with wider tubes, and have as their object the cooling-down of the incoming raw gases by heat exchange with the outgoing cold-treated gases coming from the liquefaction and rectification apparatus. The purified natural gas, now at a comparatively low temperature, requires only abstraction of a little more heat to have its temperature reduced below the liquefaction point. It is in the means adopted to secure this end that the two main processes differ, for the preparation of oxygen from the air as well as the liquefaction of natural gas for the recovery of helium.

Costs of Extraction

Until the development of the production of helium from natural gas, the only method for its production was by the treatment of certain rare minerals containing uranium, the cost being about $1,500 per cubic foot.

In 1926 the lowest cost per thousand cubic feet that was obtained in the United States helium extraction plant at Fort Worth, Texas, was $24.00, or 2.4 cents per cubic foot.

A most interesting and valuable account of the operation of the Fort Worth plant, and the detailed figures showing the progressive reduction in costs from the initial figure of $500 per thousand cubic feet in May, 1921, down to $65 in January, 1924, followed by gradual improvement in operation and the development of more efficient methods during 1925 until the low figure quoted above was obtained, was given by Lieut. Commander Wicks,[14] and is a great tribute to the value of co-operation between the scientist and the engineer, and to the ability of the staff which directed and operated the plant.

No plant has been operated in Canada on a sufficiently large scale or for a sufficiently long period to obtain actual costs of production from the natural gases available in Canada. However, from the operations of the small-scale experimental plant in Calgary, under the direction of Messrs. J. Patterson and R. J. Lang, 1919-1920, Prof. J. C. McLennan estimated that helium could be produced on a commercial scale in the Bow Island field for $100 per thousand cubic feet.

The cost of extraction depends on a number of factors, the chief of which is the helium content of the gas under treatment. Unfortunately, with one exception, there are no large supplies of natural gas available in Canada with as high a helium content as the United States commercial sources possess. Also, there are no centres of population, near the richest Canadian helium-bearing gases, that could consume the large quantities of natural gas that would have to be treated to secure the minimum of operation costs.

The Canadian gases differ in composition from the United States gases that are at present treated, as they contain a much larger proportion of methane and much less nitrogen. What effect this would have on the processes of extraction, particularly on the costs of operation, is not known*.

In the Linde process, advantage is taken of the Joule-Thomson effect, the fact that if gas at a high pressure is allowed to expand to a lower pressure through an orifice, it loses heat. In the Linde process, therefore, the natural gas, compressed to a pressure of 2,000 to 3,000 pounds per square inch and already cold because of its passage through heat exchangers, is allowed to expand through a valve to a lower pressure and in consequence has its temperature so reduced that much of it liquefies.

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*In the Proceedings of the Royal Society of Canada, 1956, in an obituary notice of John Patterson, Dr. Andrew Thomson, his successor at the Meteorological Office, states that Patterson succeeded in perfecting a process for the separation of helium from natural gas at a cost of about $50.00 per thousand cubic feet. Presumably this came from Patterson's notes.

In the Claude process, which does not require such a high initial pressure, the gases are cooled to the liquefaction point by allowing a certain proportion to do work in an expansion engine. In either case the desired result is obtained; that is, the greater part of the hydrocarbon gases liquefy in the lowest compartment of the liquefaction and rectification column (as the apparatus, usually built in one unit together with the heat exchangers, is commonly called).

The column is divided into several sections, each compartment of which is fitted with a series of vertical tubes which the unliquefied gases from the lower section ascend. Arrangement is made for surrounding these tubes with the various liquid fractions of the condensed gases, mostly liquid methane and liquid nitrogen, so that a progressively lower temperature is attained and finally only a certain amount of nitrogen and the helium remain in the gaseous state. The cold gases evaporating from the baths of liquid methane and liquid nitrogen pass out through the heat exchangers, cooling the incoming gases and themselves being warmed to atmospheric temperature. The final helium-nitrogen mixture is subjected to a further cooling by a bath of liquid nitrogen under reduced pressure or by some other means. Finally, helium can be obtained from 70 to 95 percent pure, depending on the efficiency of the process.

Practically no natural gas is used up in the process, and it is returned to gas mains for subsequent industrial or domestic use, entirely unchanged except for the removal of the small content of helium and the nitrogen.

Research on Helium Extraction Processes

Although the helium extraction processes closely resemble the well known methods for the liquefaction and separation of oxygen from the air, the conditions of temperature and pressure to be employed, the solubility of helium in the various liquid hydrocarbon and nitrogen mixtures, and the best design of apparatus, have all required much research in order that the highest efficiency of extraction might be obtained. Many scientific investigations of fundamental importance have been carried out by the United States Bureau of Mines and the United States Bureau of Standards, few of which have been made public.

Purification Processes

Owing to the leakage of air through the material of the gas bags in an airship, it becomes necessary, after a time, to renew the gas. In the case of hydrogen it is discarded and replaced by a new supply. Helium, however, is too valuable to be lost in this way, and methods for repurifying it have been developed by the United States Bureau of Mines in co-operation with the Army and Navy authorities. Two methods have been adopted. In the first, activated charcoal has been used which, when cooled to a low temperature, absorbs all the impurities (chiefly oxygen and nitrogen) but does not retain the helium. The second method is based on the fact that if the impure helium at a high pressure, say 1,800 psi, is cooled to the temperature of liquid air, the oxygen and nitrogen in it will liquefy out and pure helium passes on. The cost of this operation can be made as low as $3.00 per 1,000 cubic feet. All the machinery is on railway cars for ease of transportation.

Storage and Transportation

In Canada, the helium was stored in small steel cylinders at a pressure of 1,800 psi; but the U.S.A. used large steel cylinders 160 feet long and 4 feet in diameter, each holding 65,000 cubic feet at 2,500 psi. A railway car carrying three of these thus transports 200,000 cubic feet at a pressure of 170 atmospheres.

OUR VISITS TO THE UNITED STATES RE HELIUM

The Cunard liner Lusitania was sunk by a German submarine on May 7, 1915, and the U.S.A. declared war on Germany on April 6, 1917.

During that summer we in Canada were making plans for the erection of the helium extraction plant at Hamilton. In October, I received a request from the British Admiralty and the British Department of Invention and Research to join an English mission, consisting of Commander C. D. C. Bridge, R.N., and Lieut-Commander L. C. Lowcock, in New York. The purpose of this mission was to put the

British proposals on helium before the appropriate departments in the U.S.A. and to enlist their support. As far as my memory goes the British were asking the U.S.A. to set up plants for the extraction of helium in the American gas fields (which had much richer natural gas, particularly in Texas, than any we had in Canada) and proposed that, if the U.S.A. would deliver the cylinders of helium to a Gulf port (Galveston or New Orleans), the Royal Navy would transport them to Europe.

Having met in New York and established our credentials, we then went to Washington on October 9, 1917. In the next few days we met with officials from the Bureau of Mines, Bureau of Standards, National Defence, and Army, Navy and Air Forces, and put our case before them. I gathered that on our party Commander Bridge represented the Navy, Lowcock the engineering profession, and I, as a physicist, was expected to know the laws of the thermodynamics of gases.

The American response was most gratifying, and the money it proposed to allocate to the problem was enormous compared with that which the British could afford (the British had already been at war for over three years).

My diary, which is very fragmentary, indicates that on different days we met a Mr. Taylor (Hoover's second in command), Professor Millikan, Professor Cady, Admiral Taylor, and Messrs. Narramore, Norton and Walker and Dr. Stratton of the Bureau of Standards. At one meeting (according to my diary) there were eighteen important men (see Van H. Manning's report[20] on the production of helium; U. S. Bureau of Mines Bulletin 178c, page 80). For the sake of secrecy it was decided to refer to helium gas as X-gas, or C-gas, or argon. We were also hospitably entertained at the Cosmos Club and taken on a Navy ship, the "Tecumseh", down the Potomac river, to see experiments on smoke-screening at sea.

On October 16, Bridge, Lowcock and I left Washington for Fort Worth, Texas. We spent October 18 in Chattanooga, where we were entertained to lunch at the Rotary Club and taken around Camp Oglethorpe and the nearby battlefield.

On October 20, at Fort Worth, we interviewed Messrs. Biddison and Chase of the Lone Star Gas Co. This company was taking about twenty million cubic feet a day of natural gas (of nearly 1% helium) from the adjacent gas fields and burning it in Fort Worth, Dallas, and nearby towns. Again we were hospitably entertained and our mission heartily approved. On Sunday, October 21, we looked over Camp Bowie and celebrated Trafalgar Day at a club dinner.

One day we were taken to the Fort Worth gas-reducing station, to Wichita Falls, and to the Petrolia gas fields. I collected five-gallon samples of gases from both fields, for transport to Toronto and for our own analysis. On minor excursions we visited the Fort Worth golf course, a pig (U.S.A. "hog") farm, the stockyards, and, in the countryside, picked cotton off the plant, also pecan nuts and Ozark oranges.

As described by Dr. R. B. Moore, plants were later established near Fort Worth by the Air Reduction Company and the

Linde Products Company, and at Petrolia (Texas) by the Norton-Jeffreys Company; all under the general supervision of the U. S. Bureau of Mines.

On Friday, October 26, I left for the University of Kansas at Lawrence, where again I met Professor H. P. Cady and Dr. C. W. Seibel. They dined me at their club, where we talked over helium matters for some hours before I left for Chicago en route to Toronto. Later, Dr. Seibel kindly sent me an electric discharge tube (Goetze pattern) containing helium and neon gases from the Petrolia gas extracted on 1-5-13 (per date plate).

On April 7, 1918, our own plant at Hamilton being now in operation, although not yet very efficiently, John Patterson and I visited Worcester, Mass., to discuss gas affairs with Messrs. Cottrell, Norton and Jeffrey, and especially to learn more of the Norton-Jeffrey process. Norton very kindly gave us blueprints of his helium extraction plant.

On May 6, 1918, Mr. Patterson and I went to New York, where we interviewed Messrs. Barrett, Berge and Lacey, and on to Washington where we discussed helium with Messrs. Cottrell, Norton, Millikan and Narramore, and others. On May 11 we visited Fort Worth, where we spent three days looking over the now established Air Reduction Company (Claude process) and the Linde Products Co. plants, and met Roberts, Seibel, Hoffman, Czarnecki, and several other chemists. On page 81 of his report [20], Manning states that "we were highly pleased with what we saw".

From May 27 to June 2, 1918, I was again in New York to meet Sir Richard Paget, now Secretary of the British Board of Inventions and Research, who had been sent out from England to study the helium situation in the U. S. A. In New York we discussed helium with Professor Birge, Commander Spence-Eddy, Lieut. Irving and the U.S. Naval Intelligence, and finance with Mr. Pierpont Morgan. In Washington we had conferences with Admiral Griffin, Dr. Van H. Manning, Professor (now Colonel) Millikan, and Professors Marks, Davis, and Buckingham.

From June 19 to 23, Patterson and I were again called to Washington, to meet Sir Richard Paget and the Naval Attache of the British Embassy. My diary tells me that we discussed helium matters with Admiral Griffin, Messrs. Cottrell, Millikan, Carter, Bancroft, Barrett, Buckingham and Knox, and Mr. Fowle of the Smithsonian Institution. We were taken out to see the poison gas experiments at Washington University. Our conferences over, Patterson left for New York and London, to report progress to McLennan and the Admiralty, and I returned to Toronto.

On December 15, 1918, Professor McTaggert of the University of Toronto, who had been with the University hospital in Saloniki and had been called back to help McLennan in his South Kensington experiments, and who later (Oct. 31) had returned to Toronto and gone to Calgary, was sent by McLennan to Fort Worth to see again, with Canadian eyes, how much the Americans were doing. No doubt he was much impressed; I have, however, no report on his findings.

Professor J. C. McLennan returned to Toronto in April, 1919, and set himself to establish a cryogenic laboratory in the Physics Department at the University of Toronto. In doing this he was much helped by Professor H. Karnerlingh Onnes, of the world famous cryogenic laboratory at Leiden, the Netherlands, who gave him generous advice, full information on details of working, and blueprints of the liquefaction apparatus required.

On April 16, 1921, McLennan liquefied hydrogen; the next step was to liquefy helium. He says:(15, 16, 17)

> The helium was obtained from the natural gas of the Bow Island district near Calgary in the years 1919-1920 and has been kept, since then, stored in 8-foot-long steel cylinders at about 150 atmospheres pressure. Analysis showed it was about 90 to 95 percent helium, the impurities consisting chiefly of methane and nitrogen. The impurities were removed by cooling the gas to the temperature of liquid air, boiling under reduced pressure, and absorption in charcoal cooled in liquid air. Traces of hydrogen were removed by copper oxide-palladiumized asbestos.
>
> On January 10, 1923, with the assistance of G. M. Shrum (now head of the Department of Physics in the University of British Columbia), 100 litres of liquid air was prepared, and by its use 10 litres of liquid hydrogen, and finally 1 litre of liquid helium.

This was the first time that helium had been liquefied on this continent. Two weeks later helium was again liquefied and exhibited to a public audience. The cryogenic laboratory in the University of Toronto was formally opened on January 24, 1923.[18] Since then, researches on liquid helium and the properties of bodies at liquid helium temperatures have been actively pursued in the University of Toronto.

Professor McLennan retired from the University of

Toronto in 1932 and died in 1935.[19]

In the process of writing this story I have made reference to many of the published American papers, in addition to (1) and (2) mentioned earlier. They are listed as (20) to (25) in the complete list which follows.

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JS:(DS:PES)EJA.

APPENDIX

Copies of Three Acknowledgment Letters from the British Admiralty, June 12, 1916, March 2, 1918, and December 27, 1918.

Letter 1 (Copy):

Admiralty, S. W.

12th June, 1916

C. E.

Sir,

I am commanded by My Lords Commissioners of the Admiralty to state that they have had before them the valuable reports prepared by you and your colleagues, Professor Dawes, Dr. Burton and Dr. Satterly, in regard to the Helium content of the natural gas wells of Canada, which have been of the greatest assistance to the Board of Invention and Research in an important investigation undertaken on behalf of the Admiralty.

Their Lordships desire me to convey to you and your colleagues an expression of their thanks for your valuable co-operation in this investigation, and to state that, although they do not propose at the present time to proceed further with the subject of enquiry, the information which you have obtained and furnished will be of the greatest value, should future developments lead to the matter being reopened.

I am,

Yours obedient servant,

(Signed) W. Graham Greene

Professor J. C. McLennan,

Physics Department,

The University,

Toronto, Canada

(APPENDIX, continued) -

Letter 2 (Copy):

B. I. R. 4397/18.

A D M I R A L T Y,
S. W. 1.

2nd March, 1918.

PERSONAL & CONFIDENTIAL.

Sir,

I am commanded by My Lords Commissioners of the Admiralty to acquaint you that their attention has been called by the Board of Invention and Research to the valuable assistance received from you by the Officers who were deputed by Their Lordships last year to visit America to report upon the "C" Gas investigation in progress there.

I am to convey to you an expression of Their Lordships' thanks for and appreciation of the services kindly rendered by you in connexion with this work.

The help given by your Assistants in this matter is also highly appreciated, and I am to ask if you will be so good as to convey to these gentlemen the thanks of Their Lordships.

I am, Sir,

Your obedient Servant,

(signed) O. Murray

Professor John Satterly,
University of Toronto,
Canada.

(APPENDIX, concluded) -

Letter 3 (Copy):

Communications should be addressed to: The Secretary of the Admiralty, Great George Street, London, S. W. 1. Quote: C/E 52631/18 Telegraphic Address: Armageddon, London.

Admiralty,
Great George Street,
London,
S. W. 1.

Call "Admiralty Control,
LONDON."

27th December 1918.

DW

Sir,

I am commanded by My Lords Commissioners of the Admiralty to convey to you the thanks of Their Lordships for the valuable assistance you have rendered the Admiralty in the experimental work in connection with rectification, testing and purification of "C" gas in Canada, and for the liaison work with the United States of America which you have carried out in connection with the experimental investigations in that country.

Their Lordships trust that you will be able to help the Admiralty in the future should the occasion arise.

I am, Sir,

Your obedient Servant,

(sgd) R. R. Sim

Professor John Satterley,
University of Toronto,
TORONTO, ONTARIO,
CANADA.