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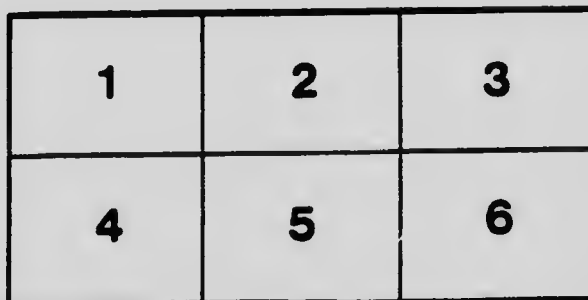
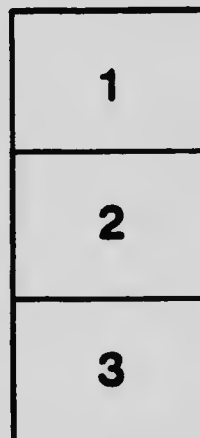
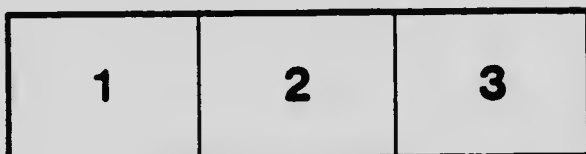
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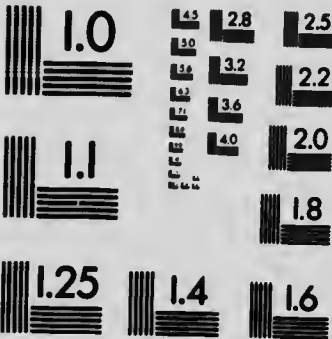
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REPORT ON THE
SOURCES OF HELIUM
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BULLETIN No. 31

Report
on
Some Sources of Helium
in the British Empire

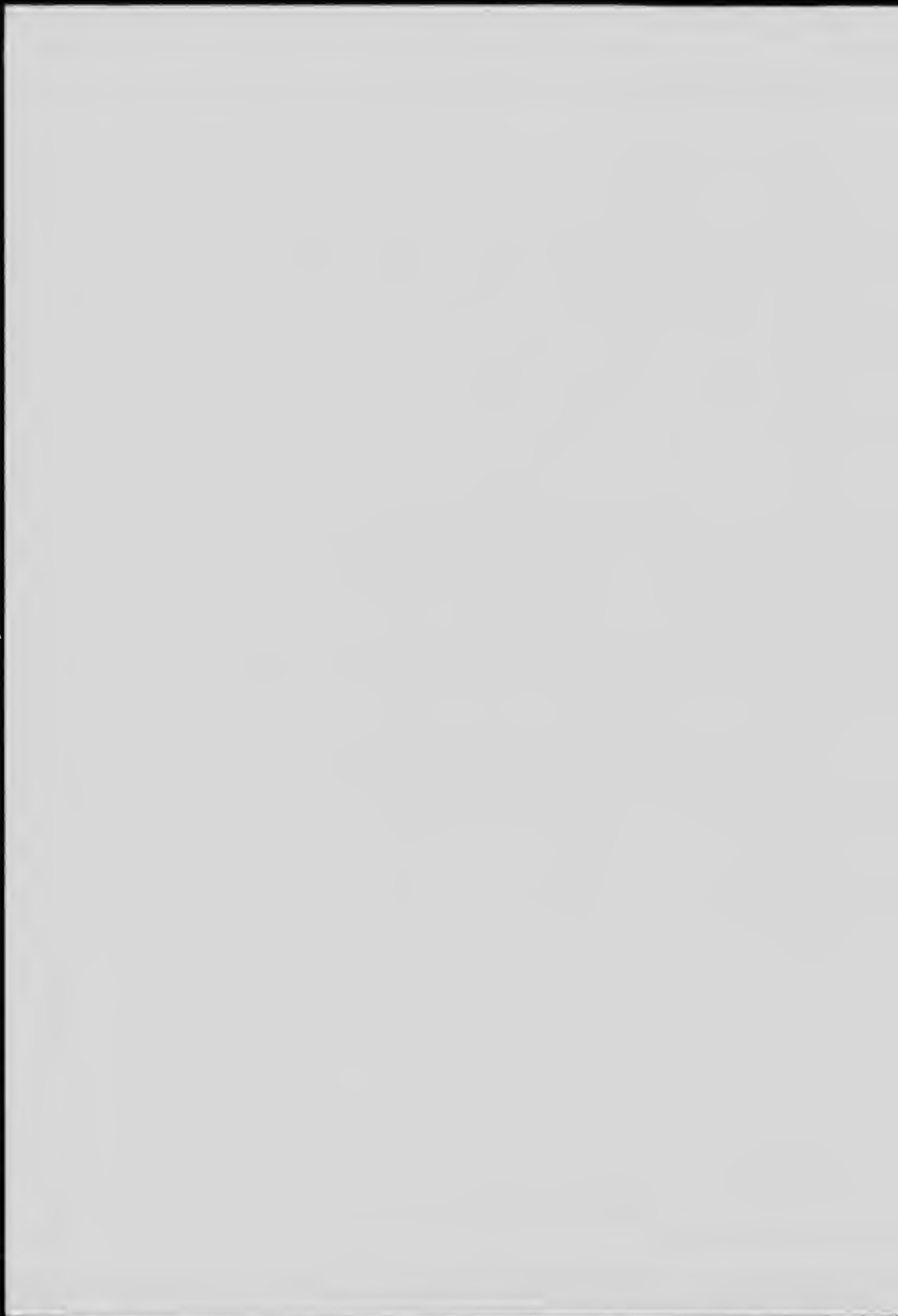
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J. C. McLennan, Ph.D., F.R.S.
and Associates.

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OTTAWA
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1920

No. 522



CANADA
DEPARTMENT OF MINES
HON. MARTIN BURRELL, MINISTER; R. G. MCCONNELL, DEPUTY MINISTER.

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OTTAWA
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PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1920

No. 522



LETTER OF TRANSMITTAL.

Dr. EUGENE HAANEL,
Director Mines Branch,
Department of Mines,
Ottawa.

SIR,—Early in 1915, Dr. J. C. McLennan, head of the Department of Physics in Toronto University, was requested by the Board of Invention and Research, London, England, to investigate the helium content of the various natural gas supplies within the Empire, it having been suggested that if a sufficient supply of helium gas could be secured, this gas would prove more suitable than hydrogen for use in aeronautics, owing to its inert character.

The results of this investigation are of interest not only to the scientist, but also to the practical aeronaut. It has been shown that the largest source of supply of helium at present known within the Empire is located in Canada. Commercial methods of separating Helium from the other gases with which it occurs have already been developed as a direct result of these preliminary investigations. The production of helium on a commercial scale, from certain natural gases in Canada, is almost certain to follow; and this production may become an important factor in the development of an aeronautical service in this country, and probably in other parts of the Empire.

The British Admiralty have authorized Dr. McLennan to make public the scientific results of this investigation. Dr. McLennan has very kindly offered the manuscript to the Mines Branch for publication, as one of the series of bulletins on technical subjects of special commercial importance now being issued.

The manuscript of this article is submitted herewith, and I recommend that it be published as a Bulletin by the Mines Branch.

I have the honour to be,
Sir,
Your obedient servant,

(Signed) **Alfred W. G. Wilson,**
*Engineer in charge of Investigation of
Chemical Industries.*

PREFACE.

Shortly after the commencement of the war, it became evident that, if Helium were available in sufficient quantities to replace Hydrogen in Naval or Military airships, the losses in life and equipment arising from the use of Hydrogen would be enormously lessened. Helium, as is known, is most suitable as a filling for airship envelopes, in that it is non-inflammable and non-explosive, and, if desired, the engines may be placed within the envelope. By its use, it is also possible to secure additional buoyancy by heating the gas (electrically or otherwise), and this fact might possibly lead to considerable modifications in the technique of airship manoeuvres and navigation. The loss of gas from diffusion through the envelope is also less with Helium than with Hydrogen, but, on the other hand, the lifting power of Helium is about ten per cent less than that of Hydrogen.

Proposals have been frequently put forward by scientists in the British Empire and in enemy countries regarding the development of supplies of Helium for airship purposes, but the first attempt to give practical effect to these proposals was initiated by Sir Richard Threlfall, who received strong support from the Admiralty through the Board of Invention and Research, under the Presidency of Admiral of the Fleet, Lord Fisher, O.M., G.C.B., etc.

It was known that supplies of natural gas containing Helium in varying amounts existed in America, and it became evident from the preliminary investigations made by Sir Richard Threlfall, and from calculations submitted by him as to cost of production, transportation, etc., that there was substantial ground for believing that Helium could be obtained in large quantities at a cost which would not be prohibitive.

The writer was invited by the Board of Invention and Research, London, England, in 1915, to determine the Helium content of the supplies of natural gas within the Empire, to carry out a series of experiments on a semi-commercial scale with the Helium supplies available, and also to work out all technical details in connexion with the large-scale production of Helium, and the large-scale purification of such supplies as might be delivered and become contaminated with air in service. In this work he received valuable assistance from his colleagues Professors John Satterly, E. F. Burton, and H. F. Dawes; Captain H. A. McTaggart; and Mr. John Patterson of the Meteorological Office, Toronto; also from Mr. R. T. Elworthy of the Mines Branch, Ottawa.

In the course of these investigations, which were carried out with the co-operation of L'Air Liquide C., it was found that large supplies of Helium were available in Canada; and from some rough preliminary experiments, on a small commercial scale, it was estimated that Helium could be produced at a cost of about 25 cents per cubic foot at normal pressure and temperature. Later work, however, has shown that the cost of production will be somewhat less than this amount.

In the preliminary work of development, an experimental station was established at Hamilton, Ontario, to treat the natural gases of western Ontario. This phase of the work was placed in charge of Professor Satterly, and with him were associated Mr. John Patterson, Professors E. F. Burton and H. F. Dawes and Mr. Lang. 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 Oxygen rectifying column, the problem of separating out the Helium which was present in the gas to the extent of only .35 per cent 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 way 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 per cent 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. The experimental station was removed in the autumn of 1918 to western Canada and placed in charge of Mr. Patterson. At this station a new type of rectification equipment was installed. No serious experimental difficulties were experienced, and the investigation is now well advanced on the road to production on a moderate scale. The Helium content of the richest gases in western Canada was found to be about .36 per cent.

In the summer of 1917, when the United States had decided to enter the war on the side of the Allies, and after the investigations referred to above were well under way, proposals were made to the Navy and Army, and to the National Research Council of the United States, to co-operate by developing the supplies of Helium available in their territory. These were made on behalf of the Admiralty, through the Board of Invention and Research, by Sir Ernest Rutherford, and a special Commission consisting of Commander Bridge, R.N., Lieut.-Commander Lowcock, and Professor John Satterly.

The authorities cited, agreed to co-operate with vigor in supporting these proposals, and large orders were at once placed by them with the Air Reduction Co., and the Linde Co. for plant, equipment, cylinders, etc. The Bureau of Mines, Washington, also co-operated by developing a new type of rectifying and purifying machine. By July, 1918, the production of Helium in moderate quantities was accomplished, and from that time onward, the possibility of securing large supplies of Helium was assured.

During the progress of the development and production stages in Canada and in the United States of America, steps were taken by the Admiralty to institute near London, England, an experimental station under the direction of the writer. This station was designed for purifying supplies of low percentage content Helium which might come forward from the base of supplies, or which might have become contaminated with air in service at the front.

Investigations were also 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 inflammability and explosibility of mixtures of Hydrogen and Helium; on the use of Helium for thermionic amplifying valves; on the stability 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; on the use of Helium for high electrical resistances; and 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 Professors Satterly and Burton, also Captain H. A. McTaggart, Mr. R. T. Elworthy, Mr. V. F. Murray, Mr. E. Edwards, Mr. J. T. F. Young, Mr. H. J. C. Ireton, and Mr. K. H. Kingdon—all, with one exception, members of the University of Toronto.

In the early stages of the investigation, 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 Gas Co. of Hamilton and those of the Canadian Western Natural Gas, Heat, Light and Power Co. of Calgary.

The solution of the problem of producing helium in large quantities was, before the beginning of the war, one which would have been considered by many visionary and chimerical, but through the enthusiastic support and financial aid received from the British Admiralty, London, and from the Bureau of Mines and the Naval and Air Boards, Washington, the possibility of the production on a large scale has been realized.

(Signed) **J. C. McLennan.**

LONDON, May 1, 1919.

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SECTION I.

THE HELIUM CONTENT OF THE NATURAL GASES OF CANADA.

REPORT BY PROFESSOR J. C. McLENNAN, F.R.S., AND PROFESSORS
E. F. BURTON, F.R.S.C., JOHN SATTERLY, F.R.S.C., AND
E. F. DAWES.

INTRODUCTORY.

HELIUM CONTENT AND RADIOACTIVITY.

In a paper by Professor J. C. McLennan* on the Radioactivity of the Natural Gases of Ontario, results of an investigation were given which showed that radium emanation was present in varying amounts in all the gases drawn from the wells situated in the different gas producing districts of the Province. In the same paper some considerations were presented which suggested that helium would probably be found as well to be one of the constituents of these natural gases. In the investigation referred to, however, no attempt was made to determine the emanation content of the different samples of gas in absolute measure. Indeed, that would have been impossible, for at the time the experiments were made sufficient data were not available to enable one to accurately ascertain the radioactive contents or fix the units for the different radioactive substances. The experiments did suffice, however, to show that wide variations existed in the emanation content of the gases taken from different geological horizons or selected from different localities. For example, in the case of one sample the electrical conductivity of the gas arising from the presence of radium emanation in it was found to be 145 units on an arbitrary scale, while the conductivity of a second sample when measured on the same scale turned out to be as high as 8,045 units.

Since the publication of this paper numerous communications† have appeared giving results of determinations of the helium and emanation content of the natural gases of the United States of America and of certain European countries, but up to the present, with the exception of the paper by Professor McLennan and one which has recently appeared on some physical tests made on a gas well in Alberta by Professors Boyle and Tory,‡ no determinations at all of this nature have been made in Canada.

Quite recently, however, some considerations of a practical as well as of a theoretical nature made it desirable to undertake an exhaustive examination of all the natural gases in Canada with a view to ascertaining their helium and emanation content, and also of establishing, if possible, some simple relation between the amount of the emanation present in a gas and the proportion of helium in it.

This survey has now been made by the writers, and the natural gases of Ontario, Alberta, and British Columbia have been systematically

* Proceedings of International Electrical Congress, St. Louis, 1904.

† Mache and Bamberger, Wien. Ber. 123, p. 325, 1914; Moureau and Lepape, Comptes Rendus, p. 598, 1914; Cady and McFarland, Jour. Amer. Chem. Soc., Vol. XXIX, p. 1523, 1907.

‡ Boyle and Tory, Trans. Roy. Soc. Can. 3, IX, p. 139, 1915.

examined. The present communication deals with the determinations of the helium content of the gases and the observations on the Radioactivity of the same gases are embodied in a second paper by Professor J. C. McLennan, F.R.S., and Professor John Satterly, F.R.S.C., which is given in Section II.

The general result of the investigation goes to show that it was found impossible to establish a direct proportionality between the helium and the emanation content of a gas.

DEVELOPING COMPANIES.

The wells in the various gas fields of Canada have been put down by various controlling or subsidiary companies. The following list of producers of Natural Gas in Canada was specially prepared for this report by the Division of Mineral Resources and Statistics, Mines Branch, Ottawa, in August 1919:—(See p. 3)

Producers of Natural Gas in Canada.

Operator.	Address.	Location of Wells.		No. of Producing Wells Dec. 31, 1918.	Representative, Superintendent, or Secretary.
		County.	Township.		
New Brunswick Gas & Oilfields, Ltd.	Edinburgh, Scotland. 46 Charlotte Sq.	Albert	New Brunswick. Stony Creek District	22	A. Crichton Moncton, Box 199.
*The Canadian Natural Gas Co.	Montreal, c/o Crown Trust Co. Bldg., Room 103.	St. Hyacinthe Richelieu	Quebec. (at St. Barnabe)	4 (2)	W. H. Jackson, Secy.- Treas.
*National Gas Co. of Canada, Ltd.	Ottawa, 54 Elgin	St. Hyacinthe	" "	2	J. D. Craig, Secy.- Treas.
Aldrich Gas & Oil Co., Ltd.	Hamilton, Merchants Bank Bldg.	Haldimand	Ontario. Rainham (at Selkirk)	7	J. L. Counsell, Pres.
Axon, Joseph	Middleport	Brant	Onondaga	1	
Azoff Natural Gas Co., Ltd.	Canfield	Haldimand	N. Cayuga	1	H. R. Laird, Secy.- Treas.
Barrick, Arthur	Marshville	Welland	Wainfleet 11 21	1	
Barrick, Oscar	"	"	" 1 22	1	
Barrick, R. & Stouth (Mrs.)	"	"	" 11 17	1	
Beaver Oil & Gas Co., Ltd.	Buffalo, 838 Marine Trust Co. Bldg.	Kent	Romney and Tillbury E.	23	J. A. Ritchie, Secy.
Bertie Natural Gas Co., Ltd.	Ridgeway	Welland	Bertie	8	M. H. Hibbard, Secy.- Treas.
Bresett, John E.	Middleport	Brant	Onondaga	1	
Brown, E. A.	Marshville	Welland	Wainfleet 11 21	1	
Battle Natural Gas Co., Ltd.	Hamilton, Sun Life Bldg.	Haldimand	Moulton 11, III.	8	Martin Battle.
Canadian Steel Foundries (see Indus- trial).					
Canada Cement Co., Ltd.	Montreal, Herald Bldg.	Welland	Wainfleet	7	H. L. Doble, Com- ptroller.
Canadian Gas Co., Ltd. (The)	Detroit, Mich., 1436 Dime Bank Bldg.	Kent	Romney, Ralsigh, Tillbury E.	43	W. H. Beamer, Pres. C. H. Smith, Secy.- Treas.
Canfield Natural Gas Co., Ltd.	Canfield	Haldimand	North Cayuga	3	W. M. Thompson, Secy.
Chippewa Development Co., Ltd.	Chippewa	Welland	Willoughby	8	C. E. Parce, Secy.

*DK not report, or reported no production in 1919.

†Well for private use only.

Producers of Natural Gas in Canada—Continued.

Operator.	Address.	Location of Wells.		No. of Producing Wells Dec. 31, 1918.	Representative, Superintendent, or Secretary.
		County.	Township.		
Ontario.—Continued.					
Chippewa Oil & Gas Co., Ltd.	Kitchener	Haldimand	Canboro	40	A. E. Rata, Secy., Tavistock.
Coleman, J. A.	Wellandport	Lincoln	Caistor	5	J. A. Colemaa.
*Commonwealth Oil & Gas Co., Ltd.	Hamilton, 240 King E.	Welland	Wainfleet	(3)	D. P. Campbell.
Cranston, Peter	Middleport	Brant	Onondaga	1	
Danski, David	Cainsville	"	"	1	D. Danakin.
Darling Road Co-operative Natural Gas Co.	Darling Road	Haldimand	Brantford	6	C. C. Miener, Secy.
*Deagle & Brown	Caledonia, R. R. 2	"	N. Cayuga (2), Canboro (4)	1	
Deagle, Chas.	Middleport	Brant	Seneca	1	Wm. Brown.
Deagle, John	"	"	Onondaga	1	
Deagle, Edwin	"	"	"	1	
*Delaware Development Co.	Sarnia, Drawer H.	Middlesex	Delaware	1	L. A. Wilson.
*Diener Gas & Manfg. Co., Ltd. (The)	Dunnville, R. R. 5	Haldimand	Canboro and Moulton	6	E. F. Diener, Pres.
Dominion Natural Gas Co., Ltd.	Buffalo, 838 Marine Trust Co. Bldg.	Elgin; Lincoln	Payham, Caistor	124	J. A. Ritchie, Secy.
Dougherty, Richard	Middleport	Wentworth	Binbrook and Glanford	512	
Douglas, W. A.	Caledonia, R. R. 2	Haldimand	Several	137	
Dunegan Oil & Gas Co.	Chatham	Norfolk Brant	" ; Onondaga	1	
Dunn Natural Gas Co., Ltd. (The)	Dunnville	Brant	" ; lot 76	1	
Dunsdon, W.	Middleport	Haldimand	Dunn and Sherbrooke	19	R. W. Smith.
Duxbury Wellington	Hagersville, R. R. 1	Brant	Onondaga	1	
Eastside Gas Co. (The)	Lowbanks, R. R. 2	Haldimand	Walpole, XIV, 8	1	
Empire Limestone Co.	Buffalo, 19 Hudson	"	Sherbrooke	6	Arch. McDonald, Secy.-Treas.
Emerson, Troughton & Laidlaw	Attercliffe Sta., R. R. 1	Welland	Humberstone	4	D. Hyman, V. Pres.
*Evans, Thomas	Glanford Sta., R. R. 1	Haldimand	Canboro	4	Wm. Troughton, Secy.
*Excelsior Gas & Oil Co., Ltd.	Hamilton, 602 Spectator Bldg.	Wentworth	Sherbrooke	1	
Fair, Geo. H.	Brantford, 15 Fair Ave.	Brant	Is Brantford	1	
Fairbank, J. H., Estate	Petrolia, R. R. 3	Lambton	Fanshillea (at Oil Springs)	1	I. Greenizen, Atty.
Fenton, James	Hannan, R. R. 3	Wentworth	Barton, VII 2	2	
Fisherville Gas Co.	Fisherville	Haldimand	Rainham	2	Chris. Held, Secy.

Fletcher, J. I.	Hannon, R. R. 1	Wentworth	Birchbrook, II	1	S. W. Winger, Pres.
Gas & Oil Co. of Springvale, Ltd.	Hagersville, R. R. 4	Haldimand	Walpole, XIII 9; XIV 6	2	J. A. Ritchie, Secy.
Glenwood Natural Gas Co., Ltd.	Buffalo, 838 Marine Trust Co., Bldg.	Kent	Romney, Raleigh, Tilbury E.	78	
and Maple City Oil & Gas Co., Ltd.	Caledonia, R. R. 2	Brant	Onondaga	1	J. V. Fradenburgh, Pres.
Gilmore, Melvin	Cayuga	Haldimand	North Cayuga	2	C. Harrington
*Grand, Ver Gas & Oil Co.	Astercliffe Sta.	Brant	Caaboro	1	Ilam, Hagar.
Hart, & C. Frirington	Middleport	Brant	Onondaga, River 63	1	
Hagar, Harry	Hamilton, 602 Spectator Bldg	Haldimand	Seneca	5	J. H. Brinkler, Secy.
Hagar, Calv	Fisherville	Haldimand	Rainham II 2	1	
Hamilton Gas & Oil, Ltd.	Cayuga	"	South Cayuga	1	J. V. Fradenburgh.
Helka, Fred	Chatham, 128 1/2 King	Elgin	Caaboro	6	R. L. Pattinson.
Hendee Natural Gas Co. (The)	Selkirk	Haldimand	"	14	A. E. Hoover.
*High Grade Natural Gas Co., Ltd.	Selkirk, R. R. 2	"	N. Cayuga and Seneca	4	
Hoover, Max, Kohler & McKillop	Selkirk, Box 18	"	Rainham	8	J. A. Norrington.
Hoover & May	Cainsville	"	Walpole	1	J. E. Hoover.
Hoover, David E.	Thorold	Brant	Onondaga	3	
Howell, Harold H	Attercliffe Sta.	Welland	Bertie, Crowland and Hum-	21	berstone.
Industrial Natural Gas Co., Ltd.	Port Maitland	Haldimand	Caaboro (I), Moulton (I)	2	Geo. H. Butcher,
and Canadian Steel Foundries.	Selkirk, R. R. 2	"	Dunn (at Port Maitland)	2	Secy. Treas.
Jones, Nelson	South Cayuga	"	Rainham, I 8, 9	3	N. Jones.
Kindy, D. & Sons	Sarnia	"	"	5	J. S. Jones.
Kindy Gas Company	Dunnville	"	Sarnia VII 5	3	O. A. Kindy, Mgr.
Kohl, Emily	"	"	Moulton (near Nanticoke)	6	Josiah Kindy, Mgr.
Lalor, F. R.	Strouness	Lambton	Walpole, I 23; II 23	1	
Lalor & Vokes	Buffalo, 697 Ellicott Sq	Haldimand	Seneca	5	H. E. Arderley, Secy.
Lamb, Alfred	Hamilton	Welland	Glandorf	10	H. E. Arderley, Secy.
*Lawson, J. J.	Port Maitland	Haldimand	Dunn	5	All. Lamb.
Liesinger-Lembke Co.	Chatbain, 128 1/2 King	Wentworth	Humberstone (at Sherksston)	3	A. C. Lembke.
Lime & Cement Works	Port Maitland	"	Seneca	1	James Marshall.
Maple City Oil & Gas Co. (see Glen-	Chatbain, 128 1/2 King	Haldimand	Dunn (at Port Maitland)	11	
wood Natural Gas Co.)	Hannon	Elgin	Bayham (at Vienna)	2	Ed. Martin.
Martin, Edward	Ridgectown	Wentworth	Barton	24	{K. H. Holmes, Secy.,
Medina Natural Gas Co., Ltd. (The)	Hamilton, 445 King F	Haldimand	Caaboro	1	{W. G. Ryan Mgr.
*Mickle, Geo. T., & S. McKechnie	Hamilton, 503 Bk. of Ilam	"	North Cayuga	5	Geo. T. Mickle.
Midfield Natural Gas Co., Ltd. (The)	Bldg.	"	Rainham and Seneca	7	Walter Anderson, V.
National Gas Co., Ltd.		"		72	Pres.
					R. F. Miller, Pres.
					Jas. Dixon, Sec.-Treas.

* Did not report, or reported no production in 1919.
 † Well for private use only.

Producers of Natural Gas in Canada—Continued.

Operator.	Address.	Location of Wells.		No. of Producing Wells Dec. 31, 1918.	Representative, Superintendent, or Secretary.
		County.	Township.		
North Shore Gas Co., Ltd.	Hamilton, Merchants Bank Bldg.	Haldimand	Ontario—Continued. Rainham, I 4, 5	8	J. L. Counsell, Pres.
Northern Gas & Gasoline Co., Ltd.	Hepworth	Bruce	Amabel	(1)	P. H. Forhan.
Oil Springs Oil & Gas Co., Ltd.	Oil Springs	Lambton	Feniskillen II 18, 19 (Oil Springs)	6	J. S. Monroe, Secy.-Treas.
Ontario Gypsum Co., Ltd. (The)	Paris	Haldimand	Seneca (at Caledonia)	4	R. E. Haire, Secy.-Treas.
Pilkington Bros., Ltd.	Thorold	Welland	Crowland	6	R. F. Taylor, Mgr.
Ponton, W. N.	Belleville	Hastings	Sidney		
Preston, S. R.	Port Colborne	Welland	Wainfleet, I 3, 5, 6, 8.	4	
Port Colborne-Welland Natural Gas & Oil Co., Ltd.	Port Colborne	Haldimand	Seneca, Oneida	24	Geo. H. Smith, Secy.-Treas.
*Pushinch Oil & Gas Co., Ltd.	Kitchener	Wellington	Onondaga	1	J. A. Good, Secy.
Progressive Gas & Oil Co., Ltd. (The)	Hamilton, 38 Sun Life Bldg.	Middlesex	Pushinch		F. L. Suively, Secy Treas.
Provincial Natural Gas & Fuel Co. of Ontario, Limited (The)	Niagara Falls, Box 55	Welland	Missouri (Saul farm)	215	D. A. Coste, Supt.
Producers Fuel & Light Co.	Sarnia, c/o	Lambton	Euphemia	1	R. T. Towers.
*Relief Gas Co., Ltd.	St. Catharines, Bk. of N.S. Bldg.	Lincoln	Gainsboro	(12)	A. Sylvain,
Richardson, J. W.	Caledonia	Welland	Wainfleet	‡ 1	and Man. Dir.
Richmond Gas & Oil Co., Ltd.	Chatham, 128 1/2 King	Haldimand	Seneca, lot 41	4	J. W. Richardson.
Robinson Road Gas Co.	Dunnville, R.R. 4	Elgin	Bayham	4	W. W. Sraue, Secy.
*Russell Natural Gas & Oil Co., Ltd.	Ottawa, 265 Queen St. Apartment No. 4.	Haldimand	Moulton (Robinson Road)	4	W. G. Houser, Secy.
Stevensville Natural Gas & Fuel Co.	Stevensville.	Russell	Canboro	2	O. R. Letts, Man. Dir.
Shurt, Wm.	Marshville	Welland	Clarence Creek (near Bourget)	3	(S. B. House, Pres.
Sparham, Andrew F.	Caledonia, R.R. 1	"	Bertie	‡ 2	(W. Robinson, Treas.
Sterling Gas Co., Ltd.	Port Colborne	Welland	Wainfleet, I 19	‡ 6	A. F. Sparham.
			Glanford, VII 12; VIII 11, 12	68	C. E. Steele, Secy. and Mgr.
Steele, Geo. G.	Sarnia, R.R. 1	Haldimand	Humberstone, Wainfleet	3	M. A. Reeb, Pres.
		Lambton	Moulton and Sherbrooke		G. Steele.

St. Luke's Oil & Gas Co., Ltd.	Niagara Falls	Kent	Dover	M. L. Quillina, Secy.
Sundy Gas Well Co.	Dunnville	Haldimand	Canboro	James Ralston
Symmes, H. D. & L. A. Wilson	Sarnia, Drawer H.	Middlesex	Caradoc, lot 29	L. A. Wilson
Tilbury Oil & Refining Co.	Utica, N. Y., 305 Arcade Bg.	Essex	S. Grosfield	S. Joseph, Secy.
Union National Gas Co. of Canada Limited (The)	Chatham	Kent	Dover, Raleigh, Tilbury E...	S. A. Morse, Secy.
United Gas Companies (The)	Buffalo, 838 Marine Trust Co. Bldg.	Welland	Wainfleet	J. A. Ritchie, Secy.
Vacuum Gas & Oil Co., Ltd. (The)	Toronto, 608 Lumsden Bldg.	Haldimand	Moulton	E. R. Rowe
Van Sickle, A. W.	Onondaga	Lincoln	Gainsboro	Wm. Alexander, Secy.
Vickers, Har. A.	Middleport	Norfolk	Middleton (Tilsenburg)	Treas.
Wainfleet & Moulton Gas Co.	Lowbanks, R. R. 1.	Brant	Onondaga	A. Van Sickle
Walker, Thomas	Caledonia, R. R. 2.	"	Moulton	E. F. Henderson,
Wedrick, M.	Nanticoke, R. R. 1.	Welland	Wainfleet	Secy.-Treas.
Wellandport Natural Gas Co. (J. A. Coleman, Lessee)	Wellandport	Brant	Onondaga	M. Wedrick
Wallace, Wm.	Stirling	Haldimand	Walpole, H. 5.	
Weylie, Wm. & Benjamin	Glanford, R. R. 2.	Lincoln	Gainsboro	
		Hastings	Stirling (town line)	
		Wentworth	Glanford, VII H.	Wm. Weylie.
Mr. Hastell	Treherne		Manitoba.	
			Treherne (Tp. 18, R. 10)	• 1
			Saskatchewan.	
Northern Commercial Co., Ltd.	Saskatoon and Edmonton		At Court	Jas. G. Morris, Secy.
Hanley Development Co., Ltd.	Hanley		At Hanley	Jas. L. Gessell, Pres.
Northern Saskatchewan Oil & Gas Co., Limited	Saskatoon, Box 320		Vicinity of Macklin	C. F. Graham, Man. Dir.
Saskatchewan General Development Co., Ltd.	Saskatoon, Box 320		"	John Laycock, Vice-Pres.
			"	Chas. G. Locke, Secy.
City of Medicine Hat	Medicine Hat		Alberta.	
			At Med. Hat	W. E. Porter, Gas Supl.
			"	G. R. Taylor, Sup. of Utilities.
			"	L. V. Birnie, V. Pres. and Mgr.
Gas City Brick Co., Ltd.	"	Purual	At Suffield	J. W. McArthur, Supl.
Canadian Pacific Railway Co.	"		At Alderson	

* Did not report, or reported no production in 1919
 † Well for private use only.

Producers of Natural Gas in Canada—Concluded.

Operator.	Address.	Location of Wells.		No. of Producing Wells Dec. 31, 1918.	Representative, Superintendent, or Secretary.
		County.	Township.		
Canadian Western Steel Co., Ltd.	Calgary	Powell Well	Alberta—Concluded.	1	A. MacWilliam, Secy.
The Alberta Clay Products Co., Ltd.	Medicine Hat, Box 672	Redcliff Well	At Med. Hat. (SE $\frac{1}{4}$ 20; 12-5-4)	1	R. P. Stewart, Gen. Mgr.
The Ogilvie Flour Mills Co.	" and Toronto	Big Chief	At Redcliff (NE $\frac{1}{4}$ 7; 13-6-4)	1	A. F. Andrews, Mgr.
Hedley Shaw Milling Co., Ltd.	Box 677	Marlboro.	At Med. Hat (NE $\frac{1}{4}$ 20; 12-5-4)	1	Wm. E. Bray, Mgr.
Southern Alberta Gas Co., Ltd.	"	Ogilvie	" (NE $\frac{1}{4}$ 30; 12-5-4)	1	C. F. Herbert, Secy.
Redcliff Brick & Coal Co., Ltd.	Redcliff	"	At Suffield. (NW 34; 14-9-4)	1	Treas.
Canada Western Power & Fuel Co., Ltd.	Calgary	"	At Redcliff. (NW $\frac{1}{4}$ 5; 13-6-4)	2	F. H. Sellhorn, Mgr.
Dominion Glass Co., Ltd.	Montreal, Que.	"	" (5, 8, 9; 13-6-4)	3	B. J. Bott, Mgr.
Canada Cement Co., Ltd.	Montreal, Que., Herald Bldg.	"	" (SW $\frac{1}{4}$ 17; 13-6-4)	1	Geo. Lydiatt, Mgr.
The Canadian Western Natural Gas, Light, Heat & Power Co., Ltd.	Calgary, 215 Sixth Ave. W.	"	At Med. Hat (NE $\frac{1}{4}$ 28; 12-6-4)	2	H. L. Doble, Comptroller.
Town of Bow Island	Bow Island	"	At Danstlem (NE $\frac{1}{4}$ 22; 12-6-4)	3	E. G. Coode, Pres. and Man. Dir.
*Canada Land & Irrigation Co., Ltd.	Medicine Hat	"	At Danstlem (NW 36; 11-6-4)	1	W. A. Bateman, Secy.
Town of Bassano	Bassano	"	At Brooks (32; 18-4-4)	2	Treas.
*Record Oil Co., Ltd.	Calgary, 307 McLean Bldg.	"	At Dunmore (2; 12-5-4)	1	J. W. McLean, Laed. Agent.
Calgary Petroleum Products Co., Ltd.	Calgary, 423 Lougheed Bldg.	"	At Bow Isld. (11; 11-12-4)	19	G. B. R. Bond, Secy.
Municipality of Town of Castor	Castor	"	At Chin Coulee (4; 11-11-4)	2	Treas.
*Provincial Government of Alberta	Edmonton	"	At Bow Isld. (NE 4; 11-11-4)	1	J. W. McLean, Laed. Agent.
		"	At Bassano. (8; 21-18-4)	1	G. B. R. Bond, Secy.
		"	At Black Diamond (4; 19-2-5)	1	Treas.
		"	" (6; 20-2-5)	2	A. M. McDermid, Sec.
		"	At Castor (NE $\frac{1}{4}$ 26; 37-14-4)	1	A. W. Dugman, Maa. Dir.
		"	At Posoka (NW $\frac{1}{4}$ 29; 42-25-4)	1	F. H. Tucker, Com'r. Deputy Minister Public Works.

*W. Gartin.....	Ridgecough.....	At Chauvin.....	12; 46-1-4)	9	Eugene Coste, Pres and Man. Dir.
North Alberta Natural Gas Develop- ment Co., Ltd.	Calgary, Box 2197.....	At Viking.....	—; 45, 12 13-4) —; 49-12-4)	1	Eugene Coste, Pres and Man. Dir.
*Alberta Volcanic Oil Co., Ltd. (The)	Calgary, Box 2197.....	At Viking.....	.....	2	Jas. S. Watson, Sept.
City of Wetaskiwin.....	Wetaskiwin.....	At Wetaski- win.....	14; 46-24-4)	1	J. W. McMillen, Secy. F. Wilson, Secy.-Treas
*Town of Tofield.....	Tofield.....	At Tofield (	1; 51-19-4)	1	L. M. Smart, Secy.
*Town of Vegreville.....	Vegreville.....	At Vegre- ville.....	19; 52-14-4)		
*United Oils of Alberta, Ltd.....	Calgary, 300 Burns Bldg.....	At Foremost(	31; 5-10-4)		

* Did not report, or reported no production, in 1919

Province of Ontario.

GAS BEARING FIELDS.

Natural gas has been developed in the Province, in what may be approximately defined as seven districts or fields, viz.:—

1. The Oil Springs-Petroleum Field.
2. The Tilbury Field.
3. The Selkirk-Rainham -Dunnville Field.
4. The Brant-Onondaga Field.
5. The Blackheath-Seneca Field.
6. The Welland Field.
7. The Toronto Field.

These districts are all indicated by circles in red on Map 523.

GAS PRODUCTION OF DIFFERENT FIELDS.

It is difficult to state exactly the available supply of gas from the various fields, but from an examination of all accessible Government Reports* and from information furnished to us privately by various developing companies, the following appears to us to be a fairly accurate estimate of the annual production of the different fields:—

	Amount of Supply Available in cubic feet per year.
1. Oil Springs, Petrolia Field.....	170 million
2. Tilbury, and other Kent fields.....	8,000 "
3. Selkirk, Rainham, Dunnville Field.....	2,100 "
4. Brant Onondaga Field.....	60 "
5. Blackheath-Seneca Field.....	500 "
6. Welland Field.....	3,000 "
7. Toronto Field.....	negligible.
Total.....	13,830 million.

PIPE LINES.

The gas from the different fields has been piped to different industrial centres. The largest and longest main goes from the Tilbury Field to Hamilton and on the way furnishes a supply of gas to such cities and towns as London, Ingersoll, Woodstock, Paris, Brantford, Galt.

A branch from this main runs from Chatham northwards and supplies the towns of Oil Springs and Petrolia. The wells in the Selkirk district are all linked up and fed into a main which runs from Simeoe through Cayuga and Canfield to Hamilton. The group of wells in the Rainham and the Dunnville district are also linked up and their output is sent into this main. A branch main runs from Dunnville to St. Catharines. The gas from a group of about 40 wells in the Blackheath-Seneca district is also led in a separate 6-inch main to the City of Hamilton. In Welland County

* Canada, Department of Mines, Petroleum and Natural Gas Resources of Canada, Clapp and others, 1915, No. 291; The Oil and Gas Field of Ontario and Quebec, Wyatt Malcolm, 1915, No. 1561; Chemical Composition of Natural Gas found in Ontario, Ontario Bureau of Mines, 1914.

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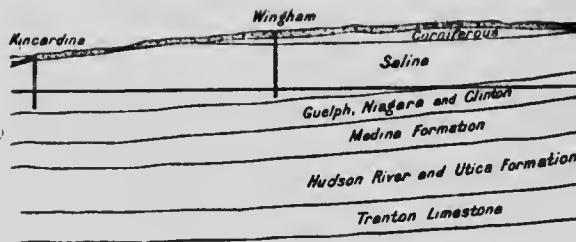


FIG. 1. Section

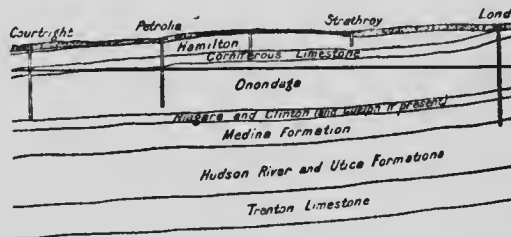


FIG. 2. S

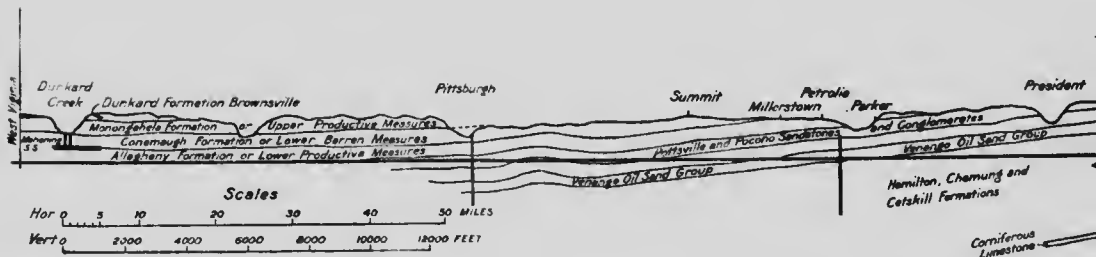
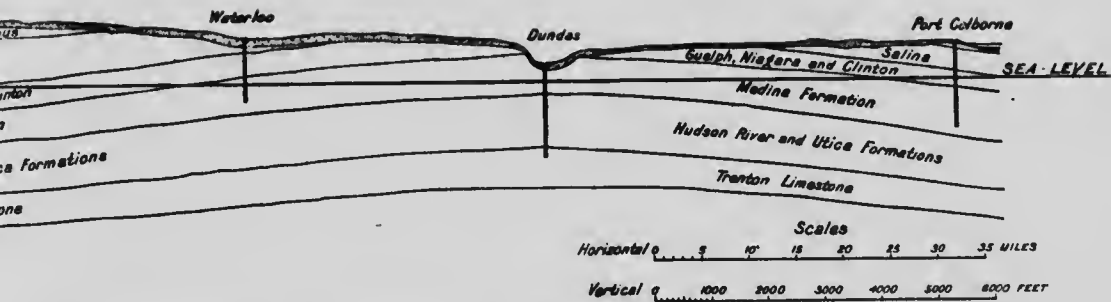


FIG. 3. Section, from Eastern Ontario, Canada



1. Section, from Port Colborne to Kincardine, Ont. (After Brumell.)

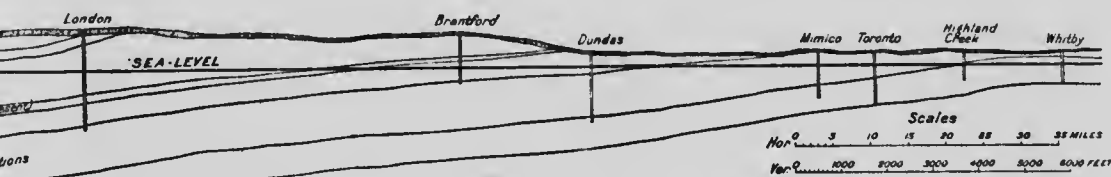
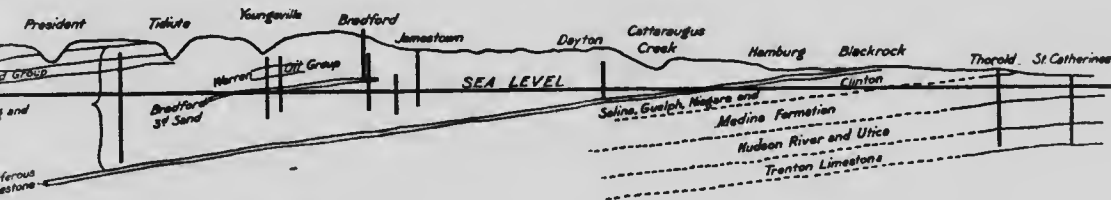


FIG. 2. Section, from Whitby to Courtright, Ont.



Section, from Toronto, Canada through Pennsylvania, U.S.A.

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the wells are largely under the control of the Provincial and Natural Gas Company. In all about 300 wells have been put down by this Company and at the present time the gas is largely consumed at Niagara Falls, Ontario. A small supply is furnished by the Company to the City of Welland.

These gas mains are indicated by circles in red on Map No. 523.

COLLECTION OF GASES.

In collecting the gases two methods were adopted. In most cases large glass bottles of about 5 gallons capacity were filled with water, and inverted over a vessel containing water. The gas was then led into these bottles and they were filled as the water was replaced. When a bottle was filled, and while the mouth and neck were still immersed in water, a close fitting rubber stopper was inserted in the mouth and securely fastened in position by a strong specially designed metal clamp. In other cases the gas was collected in large steel tanks of about a cubic foot capacity. These were used when the gas was collected directly from wells where the pressure was considerable. They were filled up to rock pressure and washed out from four to seven times according to the pressure of the well. By following this procedure it was considered that any of the original air remaining in the tanks at the final filling would not be more than one part in ten thousand. A trace of air of this amount being present would not affect to any extent the determination of the helium and emanation content.

GAS BEARING GEOLOGICAL HORIZONS.

In the oil springs, Petrolia field, a number of wells have been put down, but only a small and short-lived supply of gas has been found. The gas is found at a depth of between 330 and 515 feet and also at a depth of 1,900 feet.

In the Tilbury field the gas is found in dolomite of the Onondaga formation. The wells run from 1,200 feet to 1,450 feet in depth.

In the Selkirk field most of the gas is obtained from the Clinton limestone and from the White and Red Medina sandstone, particularly the latter. The wells run from 785 to 900 feet in depth. In Rainham township and in the neighbourhood of Dunnville the gas comes from the Clinton sandstone. The depths of the wells are between 600 and 800 feet.

In the township of Onondaga and in the Bow Park pool, White Medina is the principal producing formation at a depth of about 540 feet, but some gas is also found in the Clinton limestone at a depth of 430 feet.

In the Blackheath-Seneca field the gas is found in the Clinton limestone at 397 feet and in the White Medina sandstone at 497 feet.

In the Welland field the main supply of gas is obtained from the White Medina sand at a depth of 840 feet, although smaller quantities have been found in the Red Medina at 600 feet and in the Clinton formation at 500 feet. Showings also prevail in the Niagara at 490 feet. In addition a show of gas has been obtained in the Trenton limestone at a depth of about 3,000 feet.

In the York field a number of wells have been put down, but the supply is negligible. In the well at the St. Augustine Seminary gas was found in the Lorraine shale at a depth of 330 feet. Other wells have been put down to the pre-Cambrian limestone at a depth of 1,260 feet. Gas has

been found in the shales at 434 feet, in the Trenton limestone at 780, 885 and 1,089 feet.

The following table contains a summary of this information and appended is a chart (*see* Figs. 1, 2 and 3) showing the relative positions of the different geological formations. For this chart we are indebted to the Report on Petroleum and Natural Gas Resources of Canada, by F. G. Clapp and others, which was published in 1915 by the Mines Branch of the Department of Mines of Canada.

TABLE FOR ONTARIO.

Field.	Depth of Gas-bearing Strata.	Formation.
1. Oil Springs, Petrolia	330, 315, and 200 feet.....	Onondaga dolomite.
2. Tilbury.....	785 to 900 feet.....	Clinton limestone and White and Red Medina sandstone.
3. Rainham and Dunnville....	600 to 800 feet.....	Clinton and White Medina formation.
4. Brant, Onondaga.....	430 and 540 feet.....	Clinton limestone and White Medina.
5. Blackheath-Seneca.....	387 and 497 feet.....	Clinton limestone and White Medina.
6. Welland.....	500, 600, 840, and 3,000 feet..	Clinton, Red Medina, White Medina and Trenton limestone.
7. Toronto.....	330, 434, 780, 885, 1,089, and 1,260 feet.	Lorraine shale, Trenton limestone, pre-Cambrian formation.

Province of Alberta.

NATURAL GAS FIELDS.

In Alberta, natural gas has been developed in districts which may be roughly defined as follows:—

1. Medicine Hat Field.
2. Bow Island Field.
3. Sweet Grass Country.
Milk River Field.
4. Suffield, Brooks, Bassano.
Calgary Field.
5. Okotoks Field.
6. Wetaskiwin, Viking, Vegreville Field.
7. Athabaska Field.

These fields are indicated in red on Map 524.*

GAS SUPPLY.

In the Medicine Hat field there are in all some 28 wells located within an area of about 25 square miles, enclosing the city of Medicine Hat. The supply from this system was about 20,000,000 cubic feet daily in 1913. Since then it has slightly decreased.

At the present time there are in all 18 wells put down in the Bow Island Field. It is located to the north of the villages of Bow Island and Burdette, and covers an area of about 25 square miles.

The maximum capacity of this system is stated to be about 40,000,000 cubic feet per day. The actual amount of gas consumed per day, however,

*Department of Mines, Canada, Report on the Petroleum and Natural Gas Resources of Canada, No. 291, 1914, p. 233.

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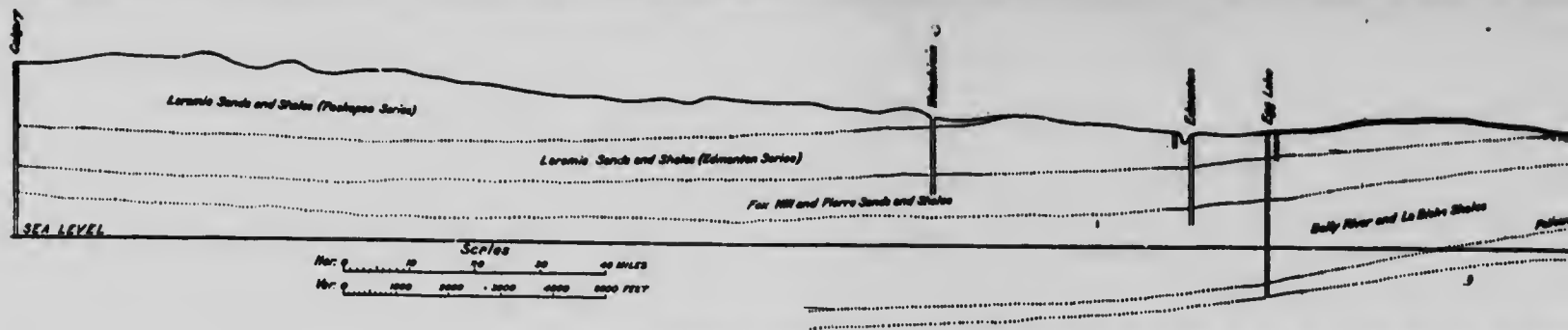


FIG. 4. Generalized geological section from Grand Rapids to Calgary: showing the "lay" of the strata, and also wells

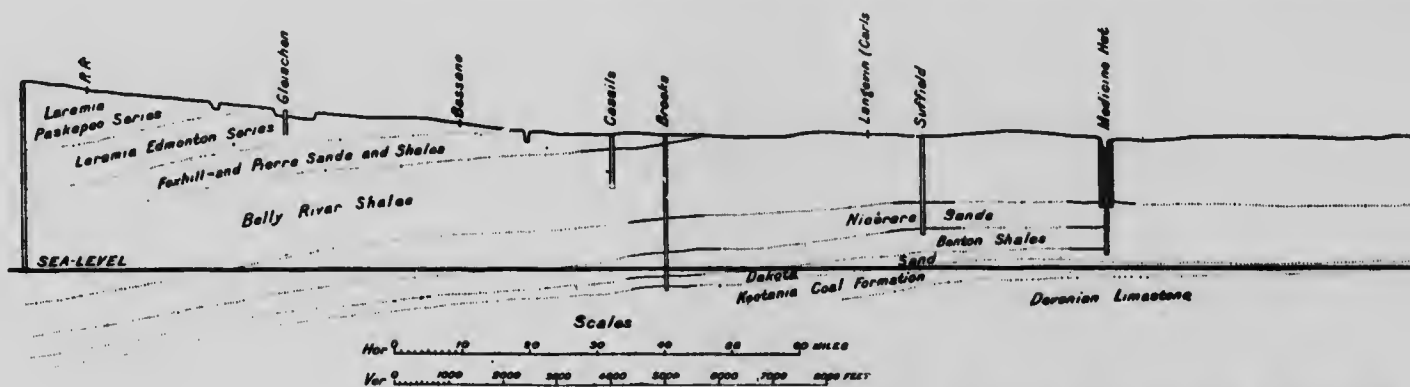


FIG. 5. Generalized geological section from Calgary to Regina:

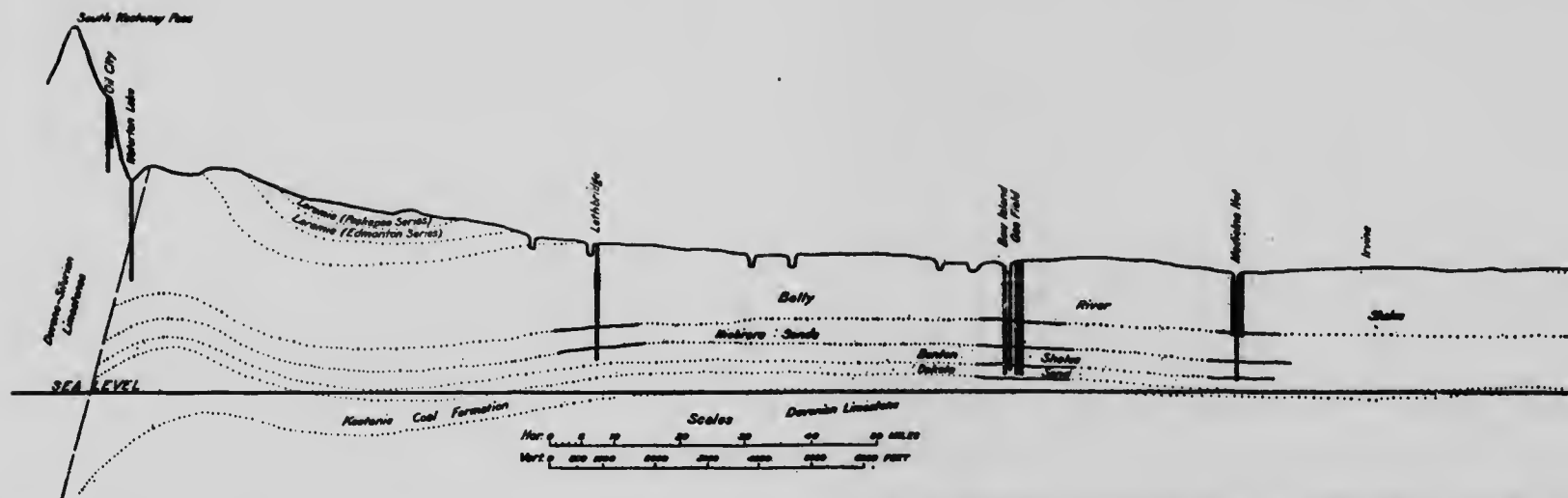
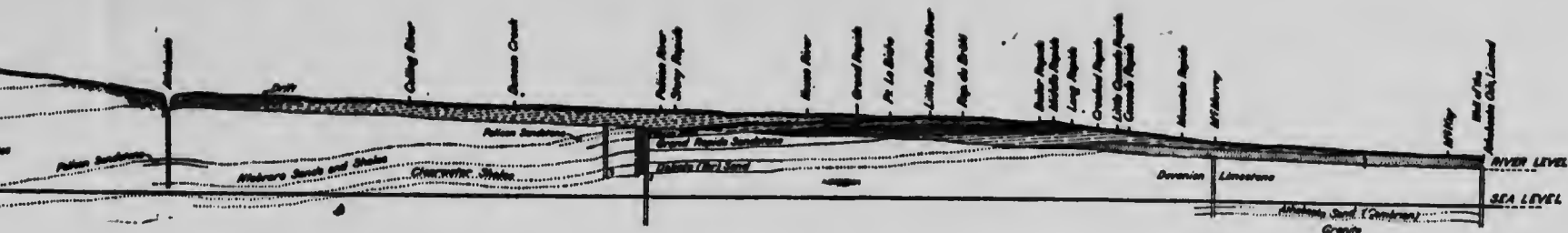
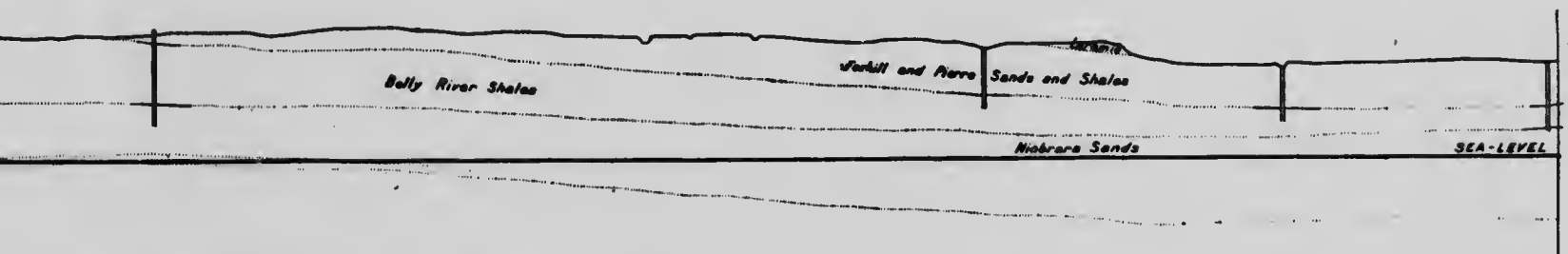


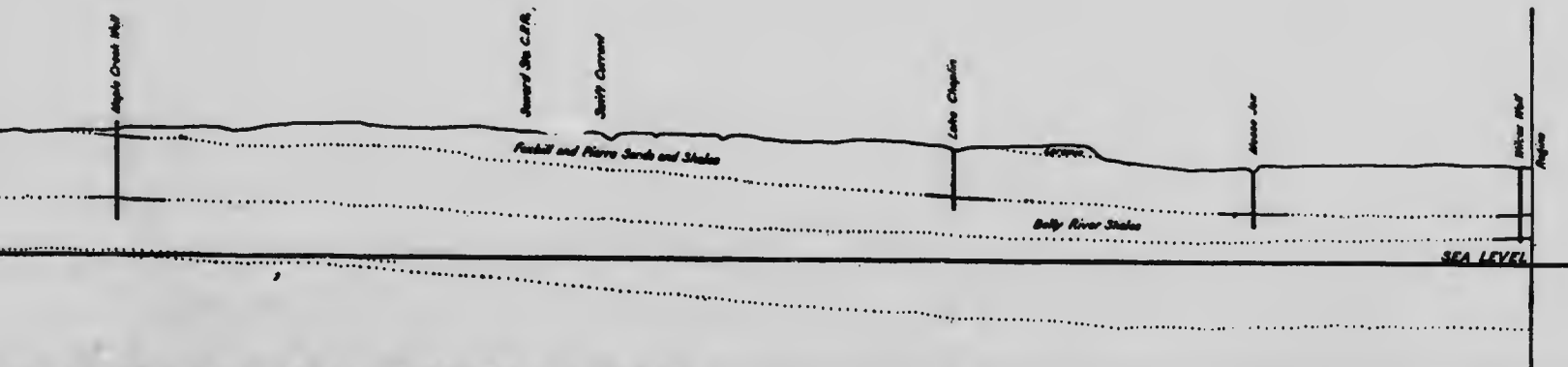
FIG. 6. Generalized geological section from South Kootenay Pass to Regina: showing



and also wells drilled at Pelican, Athabaska, Morinville, Edmonton, Wetaskiwin, and Calgary. (By F. G. Clapp and L. G. Huntley.)



to Regina: showing "lay" of strata and well borings. (By F. G. Clapp and L. G. Huntley.)



na: showing "lay" of strata and well borings. (By F. G. Clapp and L. G. Huntley.)



from the Bow Island system at the present time does not amount to as much as 20,000,000 cubic feet per day.

Two wells have been recently put down in the neighbourhood of the Sweet Grass hills near the Milk River close to the boundary between Alberta and Montana. But little gas has as yet been drawn from these wells and the available supply is estimated at about 3,000,000 cubic feet per day. A well just opened at Barnwell has an output of about 4,000,000 cubic feet per day.

There is one well at Suffield and one at the C.P.R. pumping station some 12 miles to the south of the town. Supply from these wells is approximately 250,000 cubic feet and 1,000,000 cubic feet respectively.

At Brooks two wells have been put down with a total daily output of 350,000 cubic feet.

The one well at Bassano has a daily capacity of 80,000 cubic feet.

At Calgary there is one well, namely, that put down on the Walker property. This well has a capacity of 80,000 cubic feet per day.

The gas wells in the Okotoks district are about 20 miles to the west of that town and are situated in the region in which exploratory work for oil is going on. At present gas is here produced by only two or three wells, with a daily output of about 2,000,000 cubic feet.

At Wetaskiwin there are three wells producing gas, and one each at Viking and Vegreville. At Viking, however, additional wells are being put down at the present time.

The supply at Wetaskiwin is about 600,000 cubic feet per day, and at Viking about 3,000,000 cubic feet daily.

In the Athabaska country the largest supply of natural gas has been developed at Pelican Rapids. There the available supply is about 860,000 cubic feet per day. At Fort McMurray and at Fort McKay only small showings have as yet been developed.

GAS MAINS.

Practically all the wells in the Medicine Hat field are linked up into one system and the supply is used entirely in the city of Medicine Hat for industrial and domestic purposes.

The gas from the Bow Island system is conveyed in a 16-inch main for over 160 miles and furnishes a supply to the towns of Lethbridge, McLeod, Claresholm, Okotoks and Calgary. This pipe line is shown on Map 525.

DEVELOPING COMPANIES.

For a list of the companies which control the supplies of gas from the different Alberta fields, see present report, pages 7-9.

GAS BEARING FORMATIONS.

In the Medicine Hat field the gas is largely drawn from the Niobrara formation at a depth of about 1,000 feet, though some is obtained at 600 feet in the Belly River shales and a small amount from the Dakota formation at about 1,800 feet.

In the Bow Island wells a small amount of gas is obtained at from 800 to 1,000 feet in the Belly River shales, but the principal supply comes from the Dakota sands at about 1,900 feet.

At Suffield the gas was obtained at a depth of 960 feet in the Belly River shales.

At the C.P.R. pumping station, 10 miles south of Suffield, a considerable supply of gas has been developed at a depth of 1,900 feet in the Niobrara and Benton shales.

At Brooks a well was put down to a depth of 2,795 feet passing entirely through the Dakota sand. A moderate supply of gas was obtained in this formation.

At Bassano the gas comes from the shales, but the wells were abandoned before the Niobrara or Dakota sands were reached.

At Calgary a well was put down to a depth of 3,414 feet, and a moderate supply of gas was obtained at 839 to 849 feet, at 1,440 to 1,445 feet, at 1,572 feet and at 2,760 feet, in the Belly River shales.

At Okotoks, one of the chief wells, the Dingman No. 1, has been put down to 3,900 feet where gas is obtained in considerable amount at the present time. Gas was also obtained in this well at 450 and 800 feet. The gas comes largely from the Belly River shales.

At Wetaskiwin the gas is obtained from the Pierre sands, at about 1,700 feet.

At Vegreville gas was obtained in moderate quantities in a sand stratum of the Niobrara formation at a depth of 1,360 feet, and at Viking the first sign of gas was obtained at 403 feet and later on at 2,180 feet and again at 2,202 feet close to the Dakota sands.

At Pelican Rapids in the Athabaska field a considerable supply of gas was obtained in the Dakota sands at 625 and 800 feet. At Fort McMurray wells have been put down to a depth of 1,405 feet running 266 feet in granite. Only a small supply of gas has yet been obtained. Several wells have been put down near Fort McKay in the granite, to a depth of about 1,200 feet. Here there is only a small showing of gas.

The following table shows a summary of this information, and charts which accompany it (*see* figs. 4, 5 and 6) give the relative position of the different geological horizons. These again were taken from the report by Mr. F. G. Clapp previously mentioned.

TABLE FOR ALBERTA.

Wells.	Depth at which Gas is obtained.	Formations from which Gas issues.
Medicine Hat.....	1,000 and 1,800 feet.....	Niobrara sands, Belly River shales and Dakota sands.
Bow Island.....	800 and 1,900 feet.....	Belly River shales, but chiefly Dakota sands.
Suffield.....	960 feet.....	Belly River shales.
C.P.R. Pumping Station.....	1,900 feet.....	Niobrara sands and Benton shales.
Brooks.....	1,450 feet.....	Dakota sands.
Bassano.....	1,500 feet.....	Shales.
Calgary.....	839 to 849 feet, 1,440 to 1,445 feet, 1,572 feet and at 2,760 feet.	Belly River shales.
Okotoks.....	450, 800, and 3,900 feet.....	Belly River shales.
Wetaskiwin.....	1,700 feet.....	Pierre sands.
Viking.....	403, 2,180 and 2,232 feet.....	Dakota sands.
Vegreville.....	1,360 feet.....	Niobrara sands.
Pelican Rapids.....	625 and 800 feet.....	Dakota sands.
Fort McMurray.....	Small supply.....	To granite.
Fort McKay.....	Small supply.....	To granite.

Province of British Columbia.

In British Columbia natural gas has been developed at Port Haney, Pitt Meadows on the mainland and at Pender island in the gulf of Georgia. (See Map 526.)

PORT HANEY GAS.

The well at Port Haney is about 4 miles to the northeast of the C.P.R. station of the same name.

As regards this well, the following information has been obtained from the Annual Report of the Minister of Mines of the Province of British Columbia* (see pages 392, 393) for the year ending 31st December, 1914:—

"The site of the drill-hole is in the bed of the Kanaka creek, a short distance above where it joins the Fraser river, and about 1 mile from the Dewdney Trunk road. The well is about 600 feet deep. Water is steadily flowing out of it, and a continuous stream of gas bubbles keeps rising to the surface of the water.

"An analysis of the gas, by G. S. Eldridge & Co., of Vancouver, gives the following:—

"Oxygen.....	7.5 per cent.
"Carbon dioxide.....	1.2 "
"Olefines.....	.15 "
"Paraffins.....	22.5 "
"Nitrogen.....	68.3 "

"The gas from this well, it will be seen, contains a considerable percentage of nitrogen, but it was found by our analysis to show a helium content of only .013 per cent."

PITT MEADOWS GAS.

At Pitt Meadows the Cossett Development Company, of which Mr. W. Innes Patterson, of Vancouver, is manager, is putting down a well in the hope of obtaining oil. It is now at a depth of 1,900 feet, and it is filled with exceedingly salt water which comes right up to the surface. Through this water gas is bubbling up in large quantities, but I could obtain no reliable information as to what the output of the gas was. By immersing a funnel in the water in the pipe, I readily filled, in about a minute, a bottle of 5 gallons by the displacement of water from it.

Our analysis of the gas showed that practically none of it was condensable at liquid air temperature. It showed about 99 per cent of nitrogen with .5 per cent of oxygen and .5 per cent of carbon dioxide. The helium content, which was only a trace, was found to be .003 per cent.

PENDER ISLAND GAS.

The third sample of gas investigated from British Columbia was obtained on Pender island. This island is in the Gulf of Georgia and is passed by the steamers on the way from Vancouver to Victoria. It can be reached by going by railroad from Victoria to Sidney on Vancouver Island and thence by motor launch for about 12 or 15 miles.

* Report of Minister of Mines, British Columbia, 1914.

The hole from which the gas comes on this island is on the farm of Mr. Davidson. I went down in seeking for coal to a depth of 1,200 feet but none being obtained, it was abandoned. The hole is only a small one and was made, I was informed, by a diamond drill. The mouth of the well, which is in a hollow of the ground about 2 feet deep, is about 30 feet above the level of the sea. Exceedingly salt water is continuously pouring out of the well, and a small quantity of gas is continuously bubbling through the salt water. Our analysis of this gas showed it to be practically all nitrogen with a helium content of only .028 per cent.

LOCATION OF NATURAL GAS WELLS IN BRITISH COLUMBIA.

As mentioned above, the only sources of natural gas in British Columbia regarding which I could get any information are—

Port Haney.....	Indication No. 11.
Pitt Meadows.....	" 12.
Pender Island.....	" 13.

These are indicated on the accompanying map (Map 526). I had learned before proceeding to British Columbia that nitrogen was one of the chief constituents of these gases, and knowing that the word "nitrogen" in the analyses of natural gases is frequently used to denote the non-combustible constituents, I thought, perhaps, the helium content might be considerable. The result of our analysis, however, is disappointing, for only small traces of helium were found. The percentages present, as already mentioned, are as follows:—

	Helium content.
Port Haney.....	.013 per cent.
Pitt Meadows.....	.003 "
Pender Island.....	.028 "

Summary of Wells and Gases.

We give here a few particulars about individual wells of the different fields from which samples of the gases investigated were obtained.

ONTARIO GAS FIELDS.

Oil Springs and Petrolia Field.

All in Lambton Co., Enniskillen Tp.

A.—No. 6 Oil Springs. Depth, 1,912 feet. Gas from the Dolomite at 1,898–1,912 feet. Rock pressure, 830 pounds per square inch. Output, 15,000,000 cubic feet per day.

B.—Oil Springs Co. Well.

C.—Bredger's Well. Rock pressure, 700 pounds; well connected up but never used.

D.—Park's Well. Rock pressure, 300 pounds per square inch. Well used continually.

Tilbury Field.

All in Kent Co., Tilbury Tp.

A.—Glenwood Station. Rock pressure, 420 pounds.

B.—Askew Well, Lake Shore Road, south of Glenwood. Depth, 1,300 feet. Gas from Onondaga Dolomites. Output, 2,000,000 cubic feet a day. Rock pressure, 552 pounds per square inch.

- C.—Glenwood Gas. Obtained at Hamilton Heights reducing station. Pressure, 65 pounds per square inch.
 D.—Tilbury, gauge line, northern pipe line, Canadian Gas Co. Pressure, 275 pounds per square inch.
 E.—Tilbury, Well 1., D. Brown's farm. Pressure, 280 pounds per square inch.

Selkirk, Raleigh, Dunnville Field.

All in Haldimand Co.

- A.—Dunnville.
 B.—Selkirk Mains. Taken at Hamilton from the 8-inch gas mains. Other side of valve, 40 pounds pressure per square inch.
 C.—Rainham Centre. Svent Well. 270 pounds pressure per square inch.
 D.—Rainham Centre Mains. Selkirk Field.
 E.—Dunnville. C. Ross's Well. A new well, opened a week before sampled. Four miles east of Dunnville and $\frac{1}{4}$ mile from Goderich and Buffalo Railway. Pressure, 240 pounds per square inch. Moderate supply.
 F.—Dunnville, a new well.
 G.—Dunnville, Munby's Well. Just opened. Depth, 793 feet. Output, 100,000 cubic feet a day.
 H.—Robbins' Well. Depth, 792 feet. Output, 60,000 cubic feet a day.

Brant-Onondaga Field.

In Brant Co., Onondaga Tp.

- A.—Onondaga Main. Taken at Brantford.
 B.—Van Sickle Farm Well.
 C.—Bow Park Well. Eight similar wells on the farm here, between 600 and 700 feet deep. The gas comes from the Clinton at 430 feet and the White Medina at 540 feet. One of these was tested in 1904 by Professor McLennan for radioactivity.*
 D.—Onondaga. Middleport main. Taken between Onondaga and Middleport.

Blackheath-Seneca Field.

All in Northern part of Haldimand Co.

- A.—Blackheath Gas. Dominion Gas Co.'s mains, the Selkirk feed being cut off.
 B.—Blackheath Gas. Main Line from South. National Gas Co.'s main fed by 40 wells. Taken at Mr. Fitzgreave's house. Pressure about 15 pounds per square inch.

* See Introductory.

C.—Blackheath Gas. National Gas Co.'s main fed by three wells through a 3-inch main. Pressure about 100 pounds per square inch

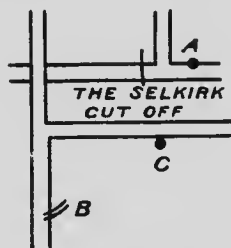


FIG. 7. Blackheath-Seneca field. Mains belonging to Dominion Gas Company, National Gas Company; and wells sampled.

D.—Blackheath Gas. Taken from mains of National Gas Co. Hamilton.

E.—Blackheath Main (National Gas Co.).

F.)
G.) Wells among the 40 supplying Blackheath.
H.)

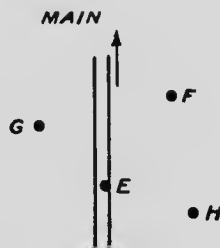


FIG. 8. Blackheath-Seneca field. Main belonging to National Gas Company; wells sampled.

Welland Field.

Well No. 382.

A.—Stevensville. Bertie Tp. Depth, 730 feet. Dug to White Medina. Rock pressure, 140 pounds. Output, 160,000 feet a day.

B.—Wainfleet and Bertie (Niagara Falls Main).

C.—Niagara Falls (Provincial Natural Gas and Fuel Co.).

D.—Stevensville. Well 382.

E.—Sherkstone. Well 318. Provincial Natural Gas and Fuel Co.

F.—Willoughby Tp. Very deep well. Depth, 3,030 feet. Gas at 2,000 feet in the Trenton limestone. Pressure, 100 pounds. Output moderate. One of those tested in 1904 by Prof. McLennan for radium emanation.*

G.—Point Abino. Bertie Tp. Depth, 910 feet. Gas at 500-580 feet from Onondaga and at 902 feet from White Medina. One of these tested in 1904 by Prof. McLennan for radium emanation.*

* See Introductory.

- H.—Stevensville. Bertie Tp. Three miles east of Ridgeway along Lake Shore. Well No. 436. A new sulphur well. Depth, 560 feet. Gas found in upper part of Niagara limestone. Rock pressure, 155 pounds per square inch. Output, 1,500,000 cubic feet a day.
- I.—Stevensville. Humberstone Tp. W. No. 437. Gas found in Red and in White Medina.

Toronto Field.

St. Augustine's, York Co., Scarboro Tp. Depth, 330 feet. Gas comes from Lorraine shale at 290 feet, which is about 11 feet above the surface of the water of Lake Ontario. Pressure only 8 inches of water.

THE ALBERTA GAS FIELDS.

Medicine Hat Field.

- A.—Cousins and Sissons Well. Two miles S. of centre of the city. Depth, 1,075 feet. Output, 3,000,000 feet a day.
- B.—Main behind the Methodist Church.
- C.—Old Well (Park Well). Seven or eight years old. Depth, 1,000 feet. Gas from 700 feet down. Rock pressure, 250 lbs. per square inch. Output, 3,000,000 feet a day.
- D.—C.P.R. Well. Depth, 1,020 feet.
- E.—Smith's Well. Three miles S. of centre of the city. Sunk in 1913. Rock pressure, 800 lbs. Large output.
- F.—Electric Park. Depth, 1,200 feet. Output, 3,000,000 cubic feet a day.
- G.—Central Park. Depth, 1,300 feet. Output, 3,000,000 cubic feet a day.
- H.—Low pressure. Top of hill.
- I.—C.P.R. Low pressure. Two years old. Depth, 1,020 feet.

Bow Island Field.

- A.—Well No. 4. Oldest and largest. Six miles north of Bow Island, 20 feet from River Saskatchewan. Rock pressure, 480 lbs. per square inch. Output, 20,000,000 cubic feet a day.
- B.—Wells Nos. 3, 11, 14. Main from these delivers 16,000,000 cubic feet a day.
- C.—Well No. 10. Burdette. Rock pressure, 480 lbs. per square inch. Output, 4,000,000 cubic feet a day.
- D.—Main. Filled at Calgary. Pressure here 100 lbs. per square inch.

Sweet Grass Country.

Suffield, Brooks, Bassano, Calgary Field.

- A.—Suffield. Town well. Depth, 960 feet. Rock pressure, 270 lbs. per square inch.
- B.—C.P.R. Pumping station. Agent, The S. Alberta Land Co.
- C.—Bassano. One mile south of C.P.R. track. Depth, 1,500 feet. Rock pressure, 115 lbs. Output, 80,000 cubic feet.
- D.—Brooks. West Well. Depth, 1,400 feet. Pressure, 270 lbs. per square inch. Output, 250,000 cubic feet a day.

- E.—Brooks. East Well. Depth, 2,795 feet. Plugged at 1,450 feet.
 F.—Calgary. Walker Well. Depth, 3,414 feet. Pressure, 280 lbs. per square inch. Output, 80,000 cubic feet a day.

Okotoks Field.

- A.—Dingman Well. Head casing gas from 400-800 feet. Output, 1,000,000 cubic feet a day.
 B.—Dingman Well. Gas from 3,900 feet. Output, 1,500,000 cubic feet a day. Gas from other horizons brings yield up to 3,200,000 cubic feet. Much gasoline vapour in gas.

6. Wetaskiwin, Viking and Vegreville Field.

- A and B.—Wetaskiwin Well. Depth, 3,800 feet. Gas from 1,700 feet. Yields 250,000 cubic feet at 20 lbs. per square inch pressure and 350,000 cubic feet at 90 lbs. per square inch pressure.
 C and D.—Viking Well. Depth, 2,300 feet. Gas from 2,300 feet. Reservoir pressure, 250 lbs. per square inch. Output, 3,000,000 cubic feet a day. Gas has the odour of garlic.

BRITISH COLUMBIA.

- A.—Pender Island. Flow less than a cubic foot a minute.
 B.—Port Haney. S.E. corner of North Westminster district. Depth, 200 feet. Gas from sandstone and shale at 193-200 feet.
 C.—Pitt meadows.

THE COMPOSITION OF NATURAL GAS.

It will be seen from the Table on pp. 49-51 that the percentage of helium ranges from .32 or .33 in the Blackheath and Bow Island regions down to very nearly zero in the Toronto and British Columbia regions.

The composition of natural gases varies widely often in the same field due to different geological horizons being tapped, and Cady and McFarlane found "that in general the helium content increases with the nitrogen content though a direct proportionality does not exist. Of course the percentage of both decreases as the percentage of hydrocarbons increases, although the ratio of helium to nitrogen may increase."

A few of their results for Kansas gases may be quoted in brief.

Locality of Well. State of Kansas.	Methane.	Ethane.	Helium.	Nitrogen.
Dexter.....	14.3	1.1	1.64	82.9
Elmdale.....	78.6	7.7	.56	12.1
Garnett.....	94.3	.0	.37	4.6
Augusta.....	79.1	7.4	.25	12.4
Arkansas City.....	81.1	12.0	.16	6.4
Bonner.....	97.2	.0	.10	2.4
Sheffield.....	92.9	.0	.04	5.4
Paola.....	98.0	.0	.009	.8

The traces of Oxygen, Carbon Dioxide, Olefines, Carbon Monoxide, Hydrogen, etc., are not entered in this table.

Chemical analyses of the gas wells sampled in the present research were not performed by us. Analyses have been published by Mickle and others* of some Ontario wells, by F. G. Clapp and others† of some Canadian wells in general, and in other cases by individual companies owning the wells. A list is given here of the best analyses we could find. The less important constituents have been omitted from the tables. In the case of the Ontario Field we have averaged up the samples according to the divisions into which we have divided the whole field.

From Report by G. R. Mickle on Ontario.

Name of District.	Methane.	Ethane.	Nitrogen.	Etc.
1. Oil Springs and Petrolia Field...	60	14	15	Propane 2½.
2. Tilbury Field.....	83	11½	5	Sulphuretted hydrogen ½.
3. Selkirk, Rainham, Dunnville Field.	78	13½	8½	—
4. Brant Onondaga Field.....	72	17	11	—
5. Blackheath-Seneca Field.....	79	13	8	—
6. Welland Field.....	82	12	6	—
7. Toronto Field.....	85	.....	13	Carbon dioxide 2.

From Report by F. G. Clapp and others.

In this Report the Ethane and other hydrocarbons are not separated from the Methane.

District or Locality of Well.	Methane.	Nitrogen.	Chief other Constituents.
Welland County*.....	96.6	2.7	Sulphuretted hydrogen .7.
New Tilbury and Romney*....	92.2	5.6	Carbon dioxide 1.4.
Medicine Hat*.....	99.5	.....	Sulphuretted hydrogen .5.
Central Alberta†.....	98.6	1.4	Oxygen .1.
Calgary (Walker Well)‡.....	86.7	6.0	Hydrogen 5.4 and heavy hydrocarbons 1.8.
Calgary, Alberta§.....	91.6	8.2	Oxygen .2.

* Page 62, Vol. I of the Report.
 † Page 340, Vol. II of the Report.

‡ Page 320, Vol. II of the Report.
 § Page 64, Vol. I of the Report.

The analyses for the following are various:—

Locality of Well.	Methane.	Ethane, etc.	Nitrogen.	Oxygen.	Carbon Dioxide.
Medicine Hat City, gas.....	90	3	5	.1	.8
Medicine Hat, Smith's well....	76.6	4.4	11	6	2
Calgary and Bow* Island Pipe Line.....	91.3	?	8.5	.2	.1
Okotoks Gas. Dingman well:—					
Casing head gas.....	66.1	34.1	.....	.49	.25
Bottom gas.....	99	?	.....	.2	.5
Viking†.....	64	?	5	.4	.6
Pender Island, B.C.....	.....	.....	99	?	?
Port Haney, B.C.‡.....	22.5	.....	68.3	7.5	1.2
Pitt Meadows§.....	.....	.....	99	.5	.5

The ? signifies that the ethane has not been separated from the methane.

* North Western Light, Heat and Power Co.
 † Dr. Kelso, University of Edmonton. (See Boyle and Tory's paper.)
 ‡ Annual Report of the Minister of Mines. British Columbia, 1914.
 § Satterly and Dawes.

Ordinary marsh gas has percentages of oxygen ranging from 3 to 5 per cent, while in natural gas the range is from .5 to .00 per cent. The oxygen content is usually a deciding factor as to whether the gas is of marsh gas or natural gas type. Marsh gas sometimes, but rarely, contains nitrogen up to 50 per cent.

Determination of the Helium Content.

Two methods were used for isolating the helium in a given sample of the natural gas* :—

- (1) Combustion of the gas with pure oxygen, removal of the resulting water and carbon dioxide by means of suitable reagents, and absorption of the nitrogen and remaining traces of other gases by means of coconut charcoal cooled in liquid air.
- (2) Condensation of those constituents of higher boiling points in a condenser immersed in liquid air, and purification of the residue by means of charcoal in liquid air.

THE COMBUSTION METHOD.

By burning electrolytic oxygen in the gas or the gas in oxygen, hydrocarbons and hydrogen present may be changed to water and carbon dioxide and the amounts of these constituents determined and removed in the manner commonly employed in gas analysis. The apparatus used is shown in Fig. 9. The gas was passed from the measuring tube B (1.5 c.c. at normal pressure and ordinary temperature) through the tap into the combustion bulb L, of about a litre capacity; electrolytic oxygen was passed from a second measuring tube through W into the same chamber L, this combustion vessel is similar to that used by Ellis, Bain and Ardagh in their gas analysis.† The mixture was ignited by an electrically heated platinum coil P, supported by a cork fitting tightly into the opening I at the top of L. Measured quantities of the natural gas and the oxygen were admitted into L, and the whole mixture caused to circulate several times past the incandescent platinum wire by alternately raising and lowering the mercury reservoirs attached to the "washers" M and N. Most of the water resulting from the burning gradually collected in the lower part of L, and could be run off at intervals through the small bulb G. When the appearance of the platinum coil showed that combustion was completed, the gaseous mixture was forced slowly through the three tubes K, which contain calcium chloride, potassium hydroxide, and phosphorus pentoxide, respectively; these reagents absorb the water vapour and carbon dioxide. The residue from the mixture is usually called nitrogen, although it may include rare gases, particularly helium. All constituents except helium are removed from

* For analysis of gases, both with and without fractional distillation, with special reference to natural gas, see:—

- (1) Ramsay and Travers.—Travers, the experimental study of gases, 1901.
- (2) Burrell and Seibert.—The sampling and examination of mine gases and natural gas. Bulletin 42, U.S. Bureau of Mines, also Journal of the American Chemical Society, XXXVI.
- (3) Lebeau and Damiens, C.R., T. CLVI, 1913, also Gas World, Vol. LIX, 1913.
- (4) Cady and McFarland.—Helium in natural gas and the composition of natural gas. Journal of the American Chemical Society, Vol. XXIX, II.

† Ellis, Bain and Ardagh. The Chemical Composition of Natural Gas found in Ontario, Report, Ontario Bureau of Mines, 1914.

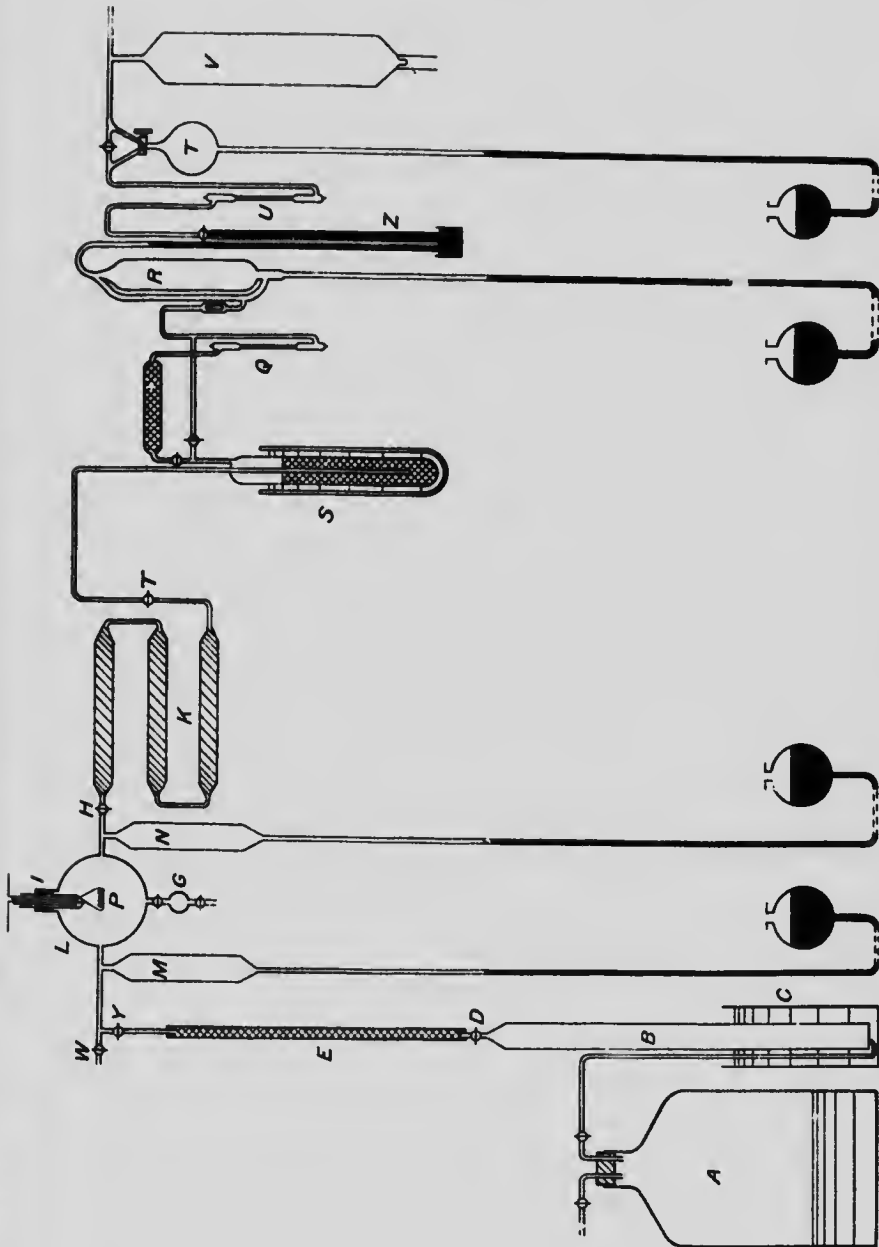


FIG. 9. Apparatus for determining the helium content of natural gas by combustion method.

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mixture by passing it into a tube containing cocoanut charcoal cooled in liquid air. The subsequent purification of the residue was carried out in the same manner as described under the condensation method.

Experiments were made with the combustion method on two gases only, those from Scarborough Tp., Toronto field, and Oil Springs, Oil Springs field, respectively. The results agreed fairly well with those obtained from the same wells by the condensation method.

See Table, pp. 49-51.

THE CONDENSATION METHOD.

As the specific purpose of the present gas-analysis investigation was to find the percentage content of helium and to obtain a working knowledge of the hydrocarbon content of the gas, the tedious combustion method was replaced by the simpler method* of liquefying all the constituents which have a boiling point above that of air by passing the gas through a condenser immersed in liquid air. All the hydrocarbons and the carbon dioxide and sulphuretted hydrogen are condensed in this way. The uncondensed portion which may contain oxygen, hydrogen, nitrogen and helium was then passed through charcoal immersed in liquid air. The helium alone is unabsorbed and can be pumped off and measured.

The following table gives the melting and boiling points of some of the gases likely to be met with in natural gas:—

Gas.	B.P. ° C.	M.P. ° C.	Gas.	B.P. ° C.	M.P. ° C.
Helium.....	- 269	- 271	Methane.....	- 164	- 185
Hydrogen.....	- 243	- 259	Ethane.....	- 93	- 195
Nitrogen.....	- 194.4	- 214	Carbon dioxide.....	- 80	- 65
Carbon monoxide.....	- 190	- 207	Sulphuretted hydrogen.....	- 62	- 86
Oxygen.....	- 181.4	- 227			

Fig. 10 represents the final form of apparatus.

A is a glass bottle in which the gas was brought from the field. The gas is forced from A into the glass tube B, where it collects by water displacement. The capacity of B was adjusted to be 1,200 c.c. under ordinary conditions of temperature and pressure. The gas was introduced into the apparatus in units of this volume. Before commencing the analysis the charcoal tubes were strongly heated by electric heaters to about 300° C. to expel absorbed gases, and the whole of the apparatus to the right of the tap was carefully exhausted. All the taps were then turned off. The charcoal on cooling absorbed the remainder of the gas in the apparatus and a good vacuum resulted.

On turning the taps D and Y the gas flowed from B through a drying tube E containing calcium chloride into the condenser F of about 400 c.c. capacity, which was immersed in liquid air kept in a Dewar's tube. Condensation of the hydrocarbons occurred at once, the liquid air boiling off rapidly. Comparison of the manometer G with the barometer J gave the pressure of the uncondensed gases in F plus the vapour pressure of the condensed gases.

Usually B was filled and emptied five times in quick succession so that the first charge in F was 6,000 c.c. of natural gas. After some minutes

* Cady and McFarland, Jour. Amer. Chem. Soc., Vol. XXIX, 1907, p. 1523.

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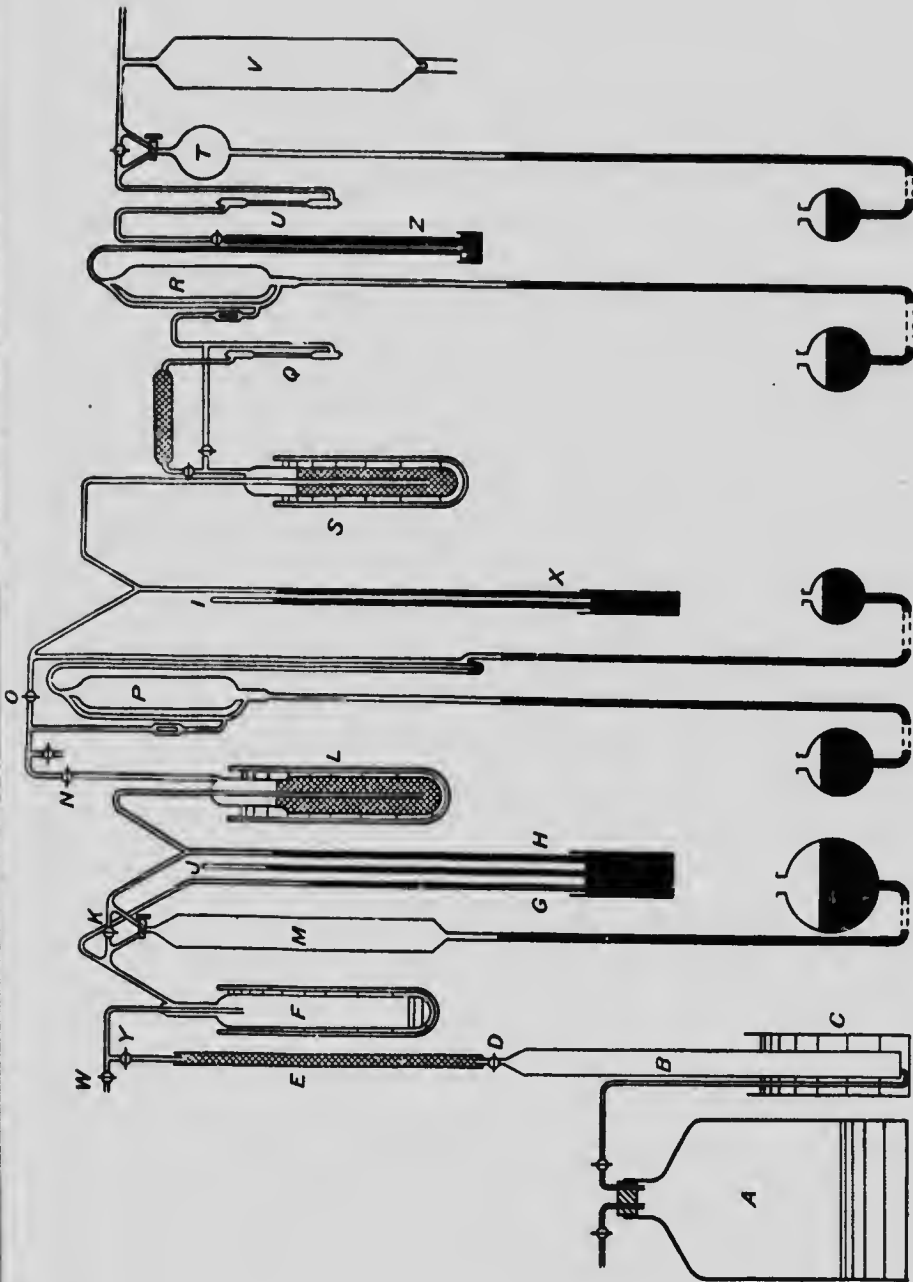


FIG. 10. Apparatus used for removing hydrocarbons, carbon dioxide, and sulphuretted hydrogen, by condensation with liquid air.

when the liquid air had ceased from boiling and the manometer was at rest the pressure in F was read. Subtracting from this reading the vapour pressure of methane at the temperature of liquid air we get the pressure of the uncondensable gases in F and knowing the volume of F it is an easy matter to find approximately the percentage of uncondensable gases in the sample of natural gas. This analysis, rough though it is, gives useful information as to the suitability of the natural gas for the manufacture of helium on a large scale.

Meanwhile the tube L, of about 300 c.c. capacity, which is full of finely broken cocoanut charcoal, had been immersed in liquid air.

The tap K was then opened and the uncondensed gas shared between F and L. The mercury in the gauge rose quickly and the liquid air surrounding L boiled vigorously, indicating a rapid evolution of heat when the gases are absorbed by charcoal. This is especially noticeable the first time the charcoal is used after being heated out. When the gauges were nearly at the same level, K was closed and the remainder of the uncondensed gas in F transferred to L by means of the large mercury pump M. This pump is simply a long wide tube with a two-way tap at the top and a flexible tube and mercury reservoir at the bottom. It was very efficient and after about 5 strokes practically all the gas had been transferred to L, the pressure in F falling to about 3 or 4 cms. The transfer of the gas was especially complete since at each expansion of the matter in F some of the liquid methane would evaporate and sweep out the gas; an excess of pumping is detrimental as it only transfers methane to L, thus tending to clog the charcoal. On standing the pressure in L slowly decreased as absorption reached its maximum amount. Usually very little except the helium was left unabsorbed in this tube.

When the reading of the gauge H was steady the taps N and O were opened and the unabsorbed gas was allowed to diffuse over to a second charcoal tube S of about 200 c.c. capacity, which was also cooled in liquid air. The tap O was then closed and complete transference of the gas was effected by a mercury pump P of special design. In the early days of the experiment the pump in this position was of the same type as M but the working and cleaning of the two-way tap proved inconvenient and it was replaced by the pump shown.

While these operations had been going on any gas left in the apparatus between taps above S and the delivery tube was completely pumped out by the pump R, exhaustion being carried to such an extent that the electric charge had great difficulty in passing through the tube Q.

The gas having stood in the second charcoal tube S for some time and the gauge X attached to this tube having become steady, the taps above S were opened and the gas pumped through the discharge tube and delivered to the collector Z, which was improvised from a graduated eudiometer by the placing of a tap at the closed end. The phosphorus pentoxide tube placed to the right of S was only required in the early stages of the experiment, when the charcoal gave off water on heating. A bye-pass was placed in between S and the pump R to facilitate the action of the pump.

Before the gas was pumped off its spectrum was carefully examined by a small direct vision spectroscope and if any but the lines of helium (and mercury) were found the gas was sent back into the charcoal tube or in the case of great impurity exhausted to the air and a fresh start made on a smaller quantity of the original gas. For example, if the natural gas

contained large quantities of nitrogen and hydrogen these may escape absorption and their presence would be detected at this stage.

The gas obtained in the collector Z was invariably pure helium and from the readings of its volume and pressure the volume at atmospheric pressure was calculated.

Tubes similar to V were used for storage and the pump T was designed to transfer the helium collected in Z over to V until the latter was filled at atmospheric pressure. The tube and pump had previously been exhausted by a mercury pump and a charcoal tube in liquid air (not shown in the figure) and then sealed off just to the right of V.

As a rule, for each sample of natural gas determinations of helium were made on three successive volumes of 6,000 c.c. each. It was always found that the value of the helium content for the first 6,000 c.c. is lower than that for the second and third. This is due to a slight absorption of the helium by the charcoal. The charcoal, however, very soon gets saturated with helium and the second and third determinations were usually in good agreement. The greatest discrepancies arose when the helium content was very low.

The following is a typical set of readings:—

Gas from Bow Island, Well 4, Alberta.

(Collected, April 1; tested, May 5th).

Volume of Natural Gas.	Pressure Readings.			Volume of Helium collected in Burette reduced to Atmospheric Pressure.	Percentage of Helium.
	Condenser Gauge. G.	First Charcoal Gauge. H.	Second Charcoal Gauge. X.		
c.c.	cms.	cms.	cms.	c.c.	
6,000	20.2 2.9	2.0 0	1.6	15.4	.26
6,000	21.8 4.0	1.8 0	1.7	16.4	.27
6,000	22.2 4.2	3.0 0	1.8	17.5	.29

Explanation.—The pressure in the condenser after the first 6,000 c.c. of gas had been passed in and allowed to stand for two or three minutes was 20.2 cms. After transference of the non-condensable gases to the second charcoal (this takes about 10 minutes) the pressure in the condenser had dropped to 2.9 cms., and that in the first charcoal tube had risen to 2.0 cms. After transference to the second charcoal tube the pressure in the first tube had fallen to zero and that in the second had risen to 1.6 cm. This pressure is due to the helium alone. The gas when pumped off had a volume, at atmospheric pressure, of 15.4 c.c. This coming from 6,000 c.c. of natural gas gives a helium content of .26 per cent. The other figures in the table give the pressure for the corresponding pressure for the second and third 6,000 c.c. of gas. It will be noticed that the percentage gradually increases as we go down the table. To show the variation obtained in these figures, when a gas of low helium content is analysed the following table is given:—

Natural Gas from Viking, Alberta.

(Collected, April 6th; tested April 10th.)

Volume of Gas.	Volume of Helium at Atmospheric Pressure.	Percentage of Helium.
First 6,000.	1.0	.017
Second 6,000	2.7	.045
Third 6,000	3.1	.052

From the results obtained with successive "fives" the best value of the helium content has been deduced. This is the value entered in the table (p. 30).

Remarks and Observations.

(a) *The Vapour Pressure of Methane.*

The vapour pressure of methane is about 6 to 7 cms. of mercury at liquid-air temperature, and it is surprising that the pressure in the condenser can be reduced by the pump to pressures much below this value. It is very likely that the act of pumping causes rapid evaporation of the condensed methane and a consequent drop of temperature and vapour pressure.

It was observed over and over again that if the condenser were allowed to remain undisturbed after pumping had ceased that the pressure in it would rise to about 6 or 7 cms. and then remain steady.

(b) *The Absorption of Gas by Charcoal.*

The rate of absorption of the gas by the charcoal depends to a marked degree on the state of saturation of the latter. For example, the smallest quantity of gas admitted to the charcoal tube after freshly heating out was quickly followed by a violent boiling of the liquid air, indicating the rapid evolution of heat accompanying the rapid absorption of the gas. With further admission of gas the boiling became less vigorous and soon became scarcely noticeable. Again, when a large quantity of gas had been admitted the rate of pressure-fall was slow though absorption still continued as shown by pressure readings extending over several hours.

(c) *The Condensate in F.*

At the conclusion of an experiment the liquid-air jackets were removed from the condenser and charcoal tubes and the appearance of these tubes noted. The deposit in the condenser was liquid in the case of nearly all the Ontario gases and solid in the case of those from Alberta. The melting point of methane lies between the boiling points of oxygen and nitrogen, and it was thought at first that the appearance of the condensate might depend on the newness or staleness of the liquid air, but repeated observations showed that this was not the case. Of course the condensate has not a simple chemical nature; in some cases the percentages of ethane and other hydrocarbons may be quite considerable, and these may have a considerable effect on the physical properties of the condensate, including that of lowering the vapour pressure. The liquid condensates were usually quite clear in appearance. When the liquid air was removed from the condenser the pressure within it gradually rose, and when it reached atmospheric the tap W was opened and the escaping gas burned. When

the condensate was solid the observations were more interesting. The solid, which appeared like white ice, was often on the sides of the condenser as well as on the bottom. The first effect of rising temperature was to melt the solid off the sides and to increase the vapour pressure of the condensate. As melting proceeded the gauge would keep fairly steady, but in many cases, however, the mercury rose a centimetre or so for a brief time, indicating either superheating or a lower vapour pressure for the newly formed liquid than for the solid; the pressure at which this upper movement occurred, as read with different samples of gas, varied between 14 and 18 cms.* As the liquid warmed up the gauge fell again, sometimes halting at intervals, indicating the boiling away of some constituent, finally when the pressure reached atmospheric the tap was opened as before. The appearance of the boiling methane varied but little. In one or two cases, however, there was a lot of froth, also possibly produced by other constituents.

(d) *The appearance of the Charcoal Tubes.*

The charcoal tubes often indicated a solid deposit, bluish white in colour and waxy in appearance, in the interstices of the charcoal. We could not fathom what this deposit was until one day one of the charcoal tubes broke immediately after the completion of an experiment. It was then seen that the so-called deposit was nothing more than a number of thin films on the wall of the charcoal tube occupying positions where the charcoal was not in contact with the glass. They appeared to be mercury, condensed from the vapour in the pumps.

(e) *Percentage of Uncondensable Gas.*

Attempts were made at various times to get the volumes of the gases condensed in the condenser, or absorbed in the charcoal tubes. The gases were pumped out by a little oil pump and delivered to a graduated jar inverted over water. The volume from the condenser gives us the total amount of condensable gas less what has been sent over to the charcoal tube. The volume from the charcoals gives us the quantity of uncondensable gas plus the methane sent over to them.

A better value of the uncondensable gas is found from the pressure readings in the condenser. For example, in the case quoted above, the total pressure in the condenser was 20.2 cms. Deducting about 4 cms. for the vapour pressure of methane under existing conditions, this leaves 16.2 cms. for the pressure of the non-condensable gas. The volume of the condenser being about 400 c.e., the volume of the non-condensable gas at 20° C. and standard pressure would be—

$$400 \times \frac{2938}{83} \times \frac{16}{75} \text{ or } 310 \text{ c.e.,}$$

which is about 5 per cent of the total volume, leaving 95 per cent for the condensable portion. The figures in Table on pp. 30-31, headed percentage of uncondensable gas, were obtained in this way.

The process used for extracting the helium was varied a trifle from time to time. In all cases, however, before beginning on a new sample

* In some subsidiary experiments the condensate was repeatedly melted and frozen by repeated removals and applications of liquid air. The first melting seems to liberate some uncondensable gas, nitrogen presumably, which evidently was absorbed by the methane when it was first frozen. When this gas also was pumped off and the liquid air withdrawn, the pressure gradually increased until the solid began to melt, when in some cases a decrease of pressure of as much as 6 cms. could be obtained.

the charcoal tubes were well heated and the gases given off withdrawn through the tap between N and O by means of a vacuum pump. A small motor-driven oil-pump proved very convenient for this purpose, as the operation of extracting *all* the gas from the charcoal tubes is by no means a short one. If plenty of natural gas was available, as, for example, when the gas was brought back under pressure in steel tanks, the process was not restricted to three volumes of 6,000 c.c. each, but was continued in many cases till the spectrum tube indicated signs of impurity in the helium. It was rare that more than 40,000 c.c. of gas could be safely attended to with the quantity of charcoal used. By so doing, however, much knowledge was obtained of the behaviour of the charcoal under different conditions of saturation.

The following extended run was made to get further knowledge of the pressure variations in the condenser and in the charcoal tubes. The first column gives the times of admission of the tubes of gas. The pressures in the third column were read after each admission, when the pressure had become practically steady. Of course there is latitude for error here. After each five, a longer wait was made and the pressure reading repeated. The "equalization" pressures which are read for the condenser and first charcoal when they are in communication through the tap K, and for the two charcoals when they are in communication between the taps N and O are noted in the table and linked up by the sign \equiv .

Natural Gas from Bow Island (Well No. 4).

Collected, April 1; Tested, June 10.

No. of Tube (each Tube =1,200 c.c.).	Time.	Pressure Readings.			Volume of Helium. c.c.	Percentage of Helium
		Con- denser.	First Charcoal.	Second Charcoal.		
		cms.	cms.	cms.		
1	1.43	0.2	0.0	0.0		
	.44		7.2			
2	.45	10.7				
3	.46}	14.0				
4	.48	16.8				
5	.48}	19.4				
	.53	19.4				
	.53}	4.5	\equiv 4.5			
		after pumping.				
	.58	2.4	2.2			
			1.1	\equiv 1.1		
			after pumping.			
			0.0	2.6		
				0.0	15.7	.262
1	2.1	8.2				
2	.2	12.0				
3	.3	15.2				
4	.4	17.6				
5	.5	20.2				
	—	19.8				
	—	3.5	\equiv 3.5			
		after pumping.				
	2.13	2.5	2.4			
	2.24		1.7			
			1.1	\equiv 1.1		
			after pumping.			
			0.0	1.9	17.2	.287
1	2.15	2.9				
2	2.16	9.0				
3	.17	12.2				
4	.18	15.2				
5	.19	17.6				
	.21	20.0				

No. of Tube (each Tube = 1,200 c.c.).	Time	Pressure Readings.			Volume of Helium.	Percentage of Helium.
		Con- denser	First Charcoal.	Second Charcoal.		
		em.	ems.	ems.	c.c.	
		19.7				
		after pumping.				
	2:38	2.7	2.6			
			1.9			
			0.0	0.0		
		after pumping.				
			0.0	1.9		
				0.0	17.3	.289
	2:42	3.3				
1	2:44	9.7				
2	2:46	11.1				
3	2:48	16.0				
4	2:49	18.6				
5	2:52	21.2				
		19.3				
		after pumping.				
	3:11	1	3.2			
			2.0			
			0.0	0.9		
		after pumping.				
			0.0	1.9		
				0.0	17.2	.287
1	3:15	10.1				
2	3:17	13.2				
3	3:19	16.0				
4	3:20	18.7				
5	3:21½	20.8				
		20.3				
		5.7	5.7			
		after pumping.				
		1.0	3.6			
			2.1			
			1.05	0.9		
		after pumping.				
			0.0	1.9		
				0.0	16.8	.280
	3:47	4.8				
1	3:48	11.7				
2	3:49	14.8				
3	3:51	17.5				
4	3:53	20.0				
5	3:56	22.1				
		19.9				
	1:9	6.0	6.0			
		after pumping.				
		3.8	4.9			
			2.5			
			1.05	1.0		
		after pumping.				
			0.0	1.9		
				0.0	17.2	.287
1	4:26	5.1				
2	4:27	11.1				
3	4:29	14.1				
4	4:31	17.0				
5	4:33	19.2				
	4:34	21.2				
		20.3				
		10.2	10.2			
		after pumping.				
	5:0	5.0	10.8			
	5:5	7.1	5.6			
		8.0	4.3			
			1.6	1.5		
		after pumping.				
			0.2*	2.2		
				0.0	17.9	.297

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Remarks.

1. It is interesting to plot the pressures in the condensers for the different runs and deduce results.

2. The condensate was solid. The gauge fell to a pressure of 18, then rose to 17 for a while, and afterwards fell continuously.

3. The pressure marked * could not be reduced to less than this. Is this the vapour pressure of methane in the charcoal?

4. The charcoals were heated and the gases cooled sent through a condenser immersed in liquid air. This throws out the methane and other hydrocarbons. The gas was then pumped off. Its volume was 2,170 c.c., representing on the total of $7 \times 6,000$ c.c. or 42,000 c.c., a percentage of 5.1. See also below.

It will be noted that the vapour pressure on the condensate gradually increased as the experiment went on, *e.g.*, 2.9, 3.3, —, 4.8, 5.1, 8.0. The steady pressures after successive "fives" (*i.e.*, pressure of uncondensed gas together with vapour pressure of condensate) are 19.4, 19.8, 19.7, 19.3, 20.3, 19.9, 20.3. Estimating as well as we can the pressure of the non-condensable gas at the various stages the following numbers are obtained:—

	cms.
19.4 — 2.5 =	16.9
19.8 — 2.9 =	16.9
19.7 — 3.3 =	16.4
19.3 — 3.9 =	15.4
20.3 — 4.8 =	15.5
19.9 — 5.1 =	14.8
20.3 — 5.1 =	15.2

Average 16.0 nearly.

These numbers gradually decreased. One would have expected them to increase on account of the space taken up in the condenser by the condensate.

It appears that on the average the pressure of the uncondensed gas in the condenser, after passing 6,000 c.c. of natural gas, is 16 cm. Hence this gas would have at atmospheric pressure and 20° C. a volume of

$$400 \times \frac{16}{75} \times \frac{293}{83} \text{ or } 300 \text{ c.c.},$$

which represents on the 6,000 c.c. a percentage of 5, agreeing fairly well with the value obtained by pumping out the charcoal.

Manufacture of Helium.

The natural gases with high helium content, such as those of the Blackheath (Ontario) and Bow Island (Alberta) regions provide a very convenient source for a supply of this gas.

If helium is required in moderate quantities for laboratory purposes the separation may be conveniently done in part at the source of supply. The hydrocarbons may be taken out of the gas by liquid air, and the uncondensable residue taken to the laboratory and purified by charcoal and liquid air.

For this purpose the gas may be passed straight from the main through a condenser B, Fig. 11, the inlet tube of which reaches nearly to the bottom of the interior. The outlet tube CD should be of greater height than the barometer, and its lower end should dip under a little mercury in a tray E, immersed in a larger dish of water H, over which a collector bottle G may be inverted. At the beginning gas is passed through the apparatus to sweep out all traces of air; then liquid air is applied to B and the collector bottle placed in position with, if necessary, a funnel F to guide the gas into the bottle. Condensation occurs in B; if the gas pressure is low it is likely that mercury will be sucked back into the tube DC, but no danger can result from this. The current of gas should be continued at a gentle rate until the condenser is practically full of condensed hydrocarbons. Using gas from the above wells, the uncondensed gases which

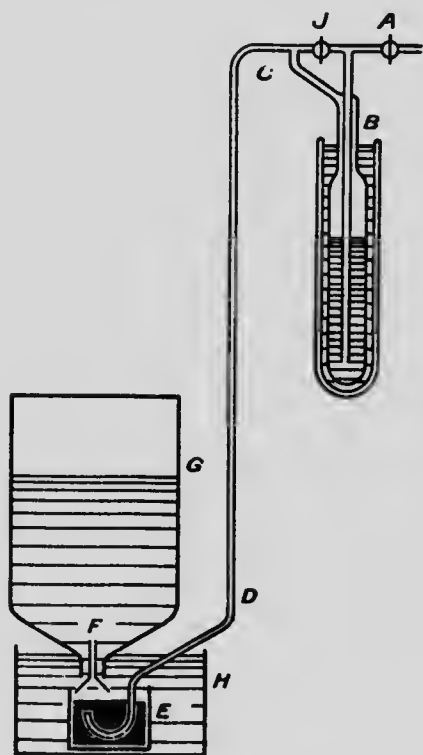


FIG. 11. Apparatus for collecting laboratory samples of helium, freed from hydrocarbons, at source of supply.

pass over into B will have a helium content of from 15 to 20 times that of the original gas. Using other sources the concentration will depend, of course, on the composition of the gas. We have found that a condenser of about 400 e.c. capacity, with about 2 litres of liquid air, is sufficient to treat 300 litres of gas at a time, giving 20 litres of uncondensable gases, of which about 1 litre is helium. If the process is carried on until the

condenser is full, little helium will be lost by being left in the condenser at the completion of the run. The liquid air can be removed and the condensate evaporated and returned through the taps J and A to the mains or burned. The residue obtained in this way can be taken to the laboratory and a separation effected by the charcoal method as described.

An alternate method might, however, be used to increase materially the concentration of the helium with the advantage of diminishing the tedious process of baking out the charcoal. This method is an extension of the condensation process as described above. In it the liquid air is made to boil in a partial vacuum instead of at atmospheric pressure, so that its temperature is sufficiently reduced to condense a large proportion of the nitrogen constituent of the above "non-condensable" gas. The charcoal process will then be applied to the re-concentrated helium.

Commercial Manufacture of Helium.

A very interesting problem is presented by the possibility of the separation of helium from natural gases on a large scale. It is obvious that any process for accomplishing this separation must take advantage of the fact that helium remains a gas long after all the other constituents of natural gas have been liquefied. Two methods of concentrating the helium suggest themselves. First, the combustion method in which all inflammable constituents are removed by burning and the products of combustion are absorbed. This method involves the problem of disposing of the large quantity of heat liberated. This difficulty might be met by burning the gas in an internal combustion engine, supplying at each explosion the oxygen necessary for the combustion of the gas. The energy thereby generated would be available for driving liquid air machines, dynamos for the production of oxygen by electrolysis, and other machinery required in the further processes. The products of combustion would be removed, the water by condensation and freezing and the carbon dioxide by chemical means or possibly also by freezing. The helium then remains mixed with small amounts of oxygen, hydrocarbons, and the original non-combustible gases. The further processes are suggested below.

The other method of concentrating the helium consists in applying a direct process of condensation. The gas is compressed and cooled as in the ordinary processes of liquefying air until all constituents whose boiling points are higher than that of helium are condensed. In order to do this economically it would probably be advisable to condense the gas by several stages—first to condense the hydrocarbons at as high a temperature as possible and then the nitrogen. Suitable temperature interchanges should be arranged so that the oncoming gas will be cooled on its way to the condenser by the evaporating condensate. The economy of the method depends largely on such an arrangement. In order to carry out the process advantageously the gas should be available at rock pressure, since thereby a large part of the cost of compression would be saved. The evaporating hydrocarbons could of course be returned to the mains so that waste of gas would be reduced to a minimum.

A rough estimate of the operating cost of separating helium in this manner may be made from the figures given by Claude* on the cost of liquefying air. According to Claude the energy required to produce

* Claude (Cottrell) *Liquid Air, Oxygen and Nitrogen* (Churchill, London), p. 173.

1 litre of liquid air is 1.41 h.p.-hours and the cost is therefore about one penny.

About 600 litres of natural gas are required to produce 1 litre of liquefied gas, and the helium content of this quantity in the best sample examined is about 2 litres. Assuming that the cost of producing 1 litre of liquefied natural gas is the same as that of producing 1 litre of liquid air, then the helium can be manufactured at the cost of one halfpenny per litre or a shilling per cubic foot.

As a matter of fact it would likely be only a small fraction of this amount on account of the economy effected by the temperature inter-changers mentioned above. This estimate is for the energy change alone, but that will probably be the important item in applying the process on a large scale.

May 1, 1916.

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SECTION II.

THE RADIOACTIVITY OF THE NATURAL GASES OF CANADA.

REPORT BY PROFESSOR J. C. McLENNAN, F.R.S., AND PROFESSOR JOHN SATTERLY, F.R.S.C.

THE RADIOACTIVITY OF NATURAL GAS.

When a gas escapes from the soil it usually contains the emanations of radium and thorium. Thorium emanation has a very short life, one-half of it changing per minute into the next product; it therefore quickly decays into insignificance. The rate of change of radium emanation is much slower. It takes nearly four days to drop to half value and after 25 days there is still 1 per cent remaining. When therefore we speak of the radioactivity of a natural gas we usually mean that the gas contains radium-emanation, and the amount of this emanation in any given volume is taken as the measure of the radioactivity of the gas.

PRINCIPLE OF THE METHOD USED FOR MEASURING THE RADIOACTIVITY.

The amount of radium emanation in a gas is usually deduced from the increase of electrical conductivity which its presence imparts to the gas. The conductivity of the gas is measured in an ionisation vessel and then compared to the conductivity imparted to the same quantity of non-radioactive gas or air in the same vessel by the presence of a known amount of radium emanation. This radium emanation is usually obtained from a radium solution of known strength.

DESCRIPTION OF THE APPARATUS.

The natural gas was collected as described in the earlier part of the paper. It is, of course, essential for this part of the work that these vessels should be free from any radioactive contamination.

THE IONISATION VESSEL AND ELECTROSCOPE.

A diagram of the electrical apparatus is shown in Fig. 12. The ionisation vessel V is made of stout brass. Its dimensions are: height 53 cms., diameter 12 cms., and volume about 3,800 c.c. Fitting air-tight into the top of the vessel is an ebonite plug carried by a brass screw. Sealed into the ebonite is a quartz tube which carries a stout brass wire W. This wire reaches to within an inch of the bottom of the vessel. The upward prolongation of the wire is about 3 inches long and is enclosed by a little brass chamber E of about 6½ cm. side which is connected to V, and to the earth by a wire E. This part of the wire carries a gold leaf so that the little chamber with its contents constitutes an electroscope.

Opening into V are three tubes, one of which goes to a mercury manometer M, another P communicates, as required, to an exhaust pump,

the third one I is connected to a drying tube H containing calcium chloride. The gases were introduced through this tube to the testing vessel.

The gold leaf system was charged by means of a charged rod (the little apparatus made by Cossor, of London, is very convenient for this purpose) and its position observed by a "Pyc" telemicroscope. Sufficient potential was employed to saturate the vessel for all the leaks taken, and once the telemicroscope was fixed, all conductivities were taken by observing the movement of the gold leaf over the same position of the scale. The leaf was usually charged to a higher potential than that desired, and brought down to the correct position by touching it lightly with a match stick. The method of taking electrical conductivities is well known, and there is

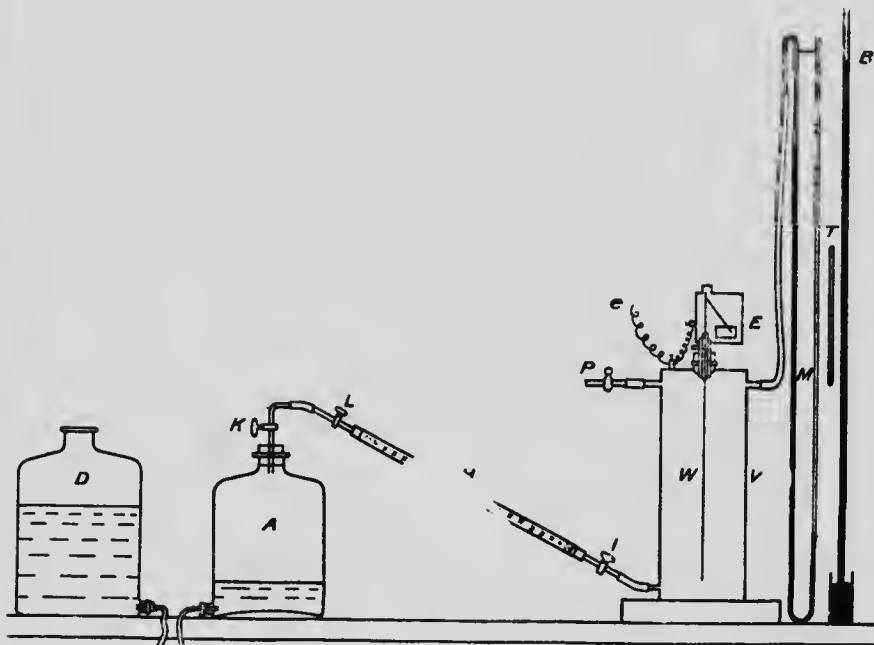


FIG. 12. Ionisation vessel and electroscopical.

no necessity for going into detail here. The air-leak is usually taken first. It is well not to attempt to read small leaks until about a quarter of an hour after charging the leaf system, or too high a result is obtained. After this interval, however, the leak is fairly constant. In the present case the leaf takes about a day to move from one end of the telemicroscope scale to the other. With one gold leaf used the air leak was .047 division per minute, with another about .07.

THE ASFIRATOR SYSTEM.

The natural gas was brought back from the field in two ways, either as high-pressure gas in large steel tanks or at atmospheric pressure in what are called 5-gallon "demijohns."

In the former case the nozzle of the tank was connected to the tap L, and V and H having been previously exhausted the taps were turned and the vessel filled with gas.

In the latter case a measured volume of gas is withdrawn from a demijohn by means of aspirators A and D. The volume of A is 2,830 c.c. After V was exhausted the aspirators were connected up to the apparatus as shown in the figure, and the gas passed into V. A was then disconnected from H and air was allowed to flow into V to bring the pressure up to atmospheric or rather to a pressure of 75 cms., this being the constant pressure at which all the readings were taken.

CHANGES WHICH OCCUR WITH RADIUM EMANATION.

The conductivity of a gas containing radioactive products is due to the ionisation of the gas by charged particles expelled from the atoms of radioactive matter when these change from one element to another. When air containing radium emanation is passed into a testing vessel the initial conductivity (normal air leak being deducted) is due to ionisation produced solely by the disintegration of radium emanation. As time goes on the successive products Radium A, Radium B, Radium C, etc., are generated and decay in turn, and the ionisation increases, reaching the maximum in about three hours, after which the activity slowly decreases. In order to get comparable results the leaks should therefore always be taken at the same interval after passing the gas into the vessel. Some observers always prefer to read the three-hour leak. It is a maximum value and fairly steady for some time. The objection to it is that by that time the excited activity which is due to radium A, B, C, etc., has been deposited on the walls of the vessel and the vessel cannot be used again on another sample of gas until these products have decayed into insignificance. It was found long ago* that a slight maximum occurs about 10-20 minutes after passing the radium emanation into the vessel. In order to save time this leak was usually taken, although in many cases when there was time to spare the gas was allowed to remain in the vessel, and the three-hour leak taken for the ratio of the two leaks (which is about 1.4) serves as a useful check on the accuracy of the work.

Also in cases where the radioactivity is very weak a better result can be obtained from reading the larger leak. Of course, it is the difference between the normal air leak and the leak observed with the radioactive gas that is a measure of the emanation in the gas.

THE RADIUM SOLUTIONS.

Standard radium solutions were obtained in 1914 from Professor Boltwood of Yale and the Bureau of Standards at Washington. Comparison between these solutions showed that Boltwood's solution was about 2 or 3 per cent weak.† After this a working standard solution was made from the Bureau of Standard's solution by dilution and the addition of redistilled water and hydrochloric acid. It contained 1.22×10^{-9} gm. radium.

This solution was placed in a glass flask R (Fig. 13) communicating by a wide tube O, through the inner tube of a long water-jacketed condenser C to the aspirator bottle A. To get the solution ready for use, it is boiled for an hour and then a stream of air is rapidly drawn through

* Satterly. *Phil. Mag.*, Oct., 1903.

† Cf. Moran, *Trans., Roy. Soc. Can.*, 1915.

it by means of the tube I and the aspirators. This removes all the emanation. The steam from the solution is condensed in the inner tube of C, and trickles back to the flask so that the concentration of the solution is unaltered. The solution is then sealed up and allowed to stand, say, for a week. In this time a definite quantity of emanation will have accumulated. The amount expressed as a fraction of the equilibrium

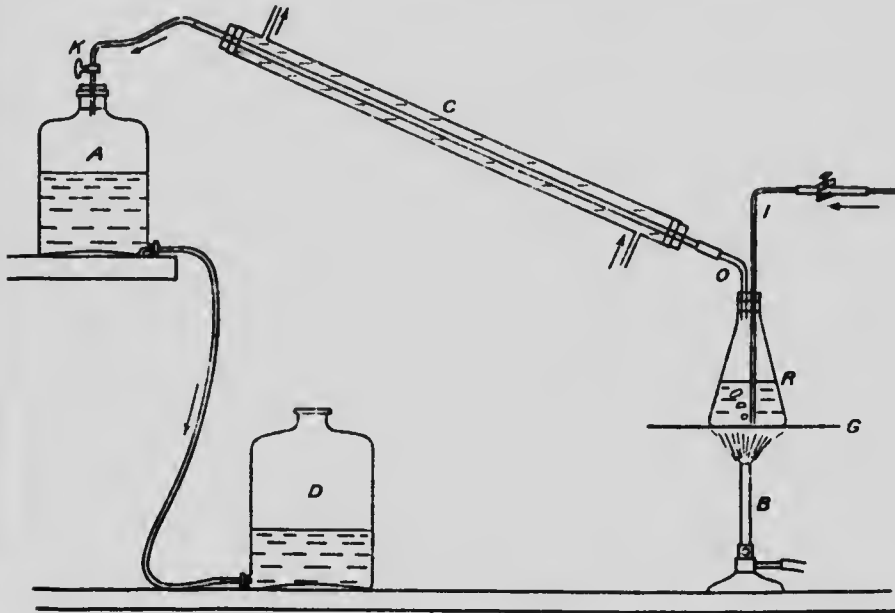


Fig. 13. Apparatus for preparing working radium solutions.

quantity can be obtained from Tables* drawn up for this purpose. Again the solution is boiled. The emanation is swept out as described above, and collected in aspirators similar to that shown at A in Fig. 13. Usually just sufficient air is drawn through the solution to fill the testing vessel. The air with the emanation is then transferred to the testing vessel and the leak read. Deducting the normal air leak we get the leak due to the emanation when the testing vessel contains air. From this we can calculate the amount of emanation which, when mixed with air, will give a leak of one division per minute. This amount is usually expressed as a fraction of a curie, the curie being that amount of emanation which is in equilibrium with one grain of radium.

In the case under consideration, this number is equal to—

$$\text{Fraction of growth of equilibrium amount of emanation} \times 1.22 \times 10^{-9} \\ \text{magnitude of leak.}$$

AIR FROM THE SOIL.

Some years ago experiments were made by one of us† on the radioactivity of air drawn from the soil at Cambridge, England. The experi-

* See Kolowrat, *Le Radium*, 1913.

† Satterly, *Proc. Camb. Phil. Soc.*, Vol. XVI, Part 4, 1911 and Part 6, 1912.

ments were repeated here, and a short description of the method and results is given below, showing how the radioactivity of a gas is measured.

By means of a narrow iron pipe, air was drawn from the soil about 5 feet away from the south wall of the Physics Building and from a depth of about 4 feet 6 inches. A volume of 2,830 c.c. was drawn up this pipe and immediately passed into the testing vessel. The vessel was filled up with normal air and the leak taken.

As an example of the work, the following readings of the normal air leak and the leaks from soil air, and the radium solutions are quoted, and the method of working out the emanation content of a gas given.

Sample of Readings.

(1) Volume of testing vessel = 3,800 c.c.

(2) Normal air leak = .05 division per minute.

(3) Leaks when 2,830 c.c. of soil air was passed in and the remainder filled up with normal air:—

(a) At the 10-minute interval = 17.3 divisions per minute.

(b) at the 3-hour interval = 24.7 “ “

Ratio $\frac{24.7}{17.3} = 1.43$.

(4) Keeping to the 10-minute leak and the leak per litre of soil air $\frac{17.3}{2.83} = 6.10$ divisions per minute.

(5) *Readings with Radium Solution.*—Strength = 1.22×10^{-9} gm. radium emanation swept out with air.

Date of Boiling.	Period of Accumulation.	Fractional Growth of Emanation in Solution.	Leaks.			Value of 1 Division per Minute expressed in Curies.
			Interval.	Total Leak.	Leak due to Emanation.	
April 26	4 days 23 hours	.591	10 min.	3.66	3.61	1.97×10^{-10} .
May 2	5 days 23 hours	.659	3 hr.	5.25	5.20	1.99×10^{-10} .
			10 min.	4.03	4.03	
			3 hr.	5.85	5.80	

Average... 1.98×10^{-10} .

The ratio $\frac{5.20}{3.61} = 1.44$

10-minute leak 3.61

3-hour leak 5.80

The ratio $\frac{5.80}{4.03} = 1.44$

10-minute leak 4.03

The agreement is a check on the accuracy of the work.

(6) From the above the

Radium emanation content of Soil Air—

= $6.10 \times 1.98 \times 10^{-10}$ curie per litre

= 12.1×10^{-10} curie per litre.

Small corrections should be made for the decay of the emanation both of the gas and the solution during the interval between their removal from their sources and their entrance into the testing vessel. The corrections are practically the same for both and as they are only of the order of $\frac{1}{10}$ of 1 per cent they have been neglected.

PROOF THAT THE INCREASED CONDUCTIVITY OBSERVED WITH THE GAS IS DUE TO THE PRESENCE OF RADIUM EMANATION.

The definite ratio between the 10-minute leak and the 3-hour leak is a proof that increased conductivity is due to radium emanation. Another proof is afforded by the decay of the conductivity with time after the three-hour interval has elapsed.

With passage of time radium emanation decays according to an exponential law. After 3.86 days only one-half the original amount is left, the rest being changed into Radium A, B, C, D, &c. After another 3.86 days only a quarter of the original remains, and so on.

One method of identification is to keep the gas in an ionisation chamber, seal it up and measure the conductivity every day for a number of days. By subtracting the normal air leak from the total leak that due to the emanation alone may be found. A curve may then be plotted and its agreement with the known curve for the decay of radium emanation tested. In our experiments this was done very carefully with the gas from St. Augustine's, Toronto Field, and the agreement was practically perfect.

Another method which must be used when the ionisation vessel is wanted for continual testing of gases is to pass into the vessel a definite volume of the sample and take the reading and after some days pass in the same volume and repeat the readings under the same conditions. From the ratio of the two leaks the identification can be thoroughly checked.

This method was used in several cases with the Alberta gases and good agreement found. Thus in the case of the gas from the Bow Island pipe line at Calgary the first test was made on May 8 at 4 p.m. and a leak of .47 obtained. The gas was again tested on May 24 at 11.30 a.m. and the leak was now .027. Assuming the activity of the gas to be due to radium emanation then the quantity which on the first occasion gave a leak of .47 should, by Kolowrat's tables for radium emanation, give 15 days 19½ hours afterwards a leak of $.47 \times .0576$. This is .027, hence strict confirmation is obtained.

EFFECT OF THE NATURE OF THE GAS ON THE AMOUNT OF LEAK PRODUCED BY A GIVEN QUANTITY OF RADIUM EMANATION.

During the experiments on the natural gases it was seen that in order to effect a strict comparison the nature of the gas used in the ionisation vessel must be considered. For example the normal air leak is taken of course in air, the leak in soil air is produced by radium emanation mixed with air. When testing the radium solutions air is used to sweep out the emanations. But when "natural" gases are under test the emanation is mixed with many gases the chief constituent being methane but nitrogen is always present in appreciable quantities. The question is "Will a given quantity of emanation produce the same leak in 3,800 c.c. of methane as it does in 3,800 c.c. of air?"

Metcalf* experimenting on the relative ionisations per unit volume by rays obtained the following results:—

Gas.	Ionisation.
Hydrogen.....	.23
Helium.....	.21
Air.....	1.00
Carbon Monoxide.....	1.00
Methane.....	1.10 to 1.105
Ethane.....	2.08
Propane.....	3.05
Butane.....	4.02

so that in methane the ionisation is 10 or 11 per cent greater than in air and in ethane over 100 per cent.

To test this point the radium solutions were used. The record given above gives the value of the microscope divisions when air was used to sweep out the emanation. Natural gas from the Bow Island Pipe Line at Calgary was now used for this purpose. The sample had been stored so long that its own radium emanation had practically vanished, the leak obtained when it was used to fill the testing vessel being just a little above the normal air leak. The results are shown in the next table.

READINGS WHEN THE EMANATION WAS SWEEPED OUT OF THE RADIUM SOLUTION WITH NATURAL GAS.

Date of boiling the solution.	Period of accumulation.	Fractional growth of emanation in solution.	Leaks.			Value of one division per minute expressed in curies.
			Interval.	Total leak.	Leak due to emanation.	
May 11	9 days 0 hour	.802	10 min. 3 hr. 10 min.	5.58	5.53	1.77×10^{-10}
May 17	6 days 5 hours	.673		8.15	8.10	
				4.66	4.61		$1.78 \times 10^{-10}$

Mean 1.77×10^{-10}

The ratio $\frac{3\text{hr. leak}}{10\text{ min. leak}} = \frac{8.10}{5.53} = 1.43$ very nearly the same as obtained before.

The value of 1 division per minute when the emanation is collected in Bow Island natural gas is 1.77×10^{-10} curie. When the emanation is in air it is 1.98×10^{-10} curie. The ratio $\frac{1.98}{1.77}$ is just a little less than 1.12.

The composition of the Bow Island Pipe Line gas is

Methane (including any ethane, &c.).....	91.3
Nitrogen.....	8.5
Carbon Dioxide.....	.1
Oxygen.....	.1
	100.0

* Metcalf, Phil. Mag., 1909.

so that if ethane were present to the extent of 2 per cent and we adopt Metcalfe's results the relative ionisation would be 1.12 times that of air and that agrees very well with the results of the radium solution.

A similar series of experiments was carried out with the gas from the Cousins and Sissons well at Medicine Hat and practically the same result was obtained.

CORRECTIONS TO BE APPLIED TO NATURAL GASES ON ACCOUNT OF THE COMPOSITIONS.

The correction to be applied is complicated in two ways.

(1) It is usually a mixture of gas and air that fills the testing vessel.

(2) The composition of the gas is not always known, and in cases where the gas has been analysed the methane percentage often includes the higher hydrocarbons.

The leak of 1 division per minute is equivalent to 1.98×10^{-10} curie when the emanation is in air and to 1.77×10^{-10} curie when the emanation is in natural gas of the Bow Island or Medicine Hat type.

If we adopt 1.77×10^{-10} curie as our standard and reduce all readings to what they would have been had the emanation been in air then all leaks in natural gas similar to those mentioned above must be reduced in the ratio of 1.98 to 1.77, *i.e.*, 1.11 to 1 or a deduction of 10 per cent must be made.

If the testing vessel were filled with a mixture of 2,830 c.e. natural gas and 970 c.e. air the leak should be reduced in the ratio

$$\frac{2,830 \times 1.11 + 970 \times 1}{3,800} = \frac{1.08}{1}$$

i.e., a deduction of 8 per cent, and so on.

Individual gases should be treated separately according to their composition. On account of our lack of definite analysis of the samples actually tested the percentage deductions given above will be applied to all the natural gases tested except those from British Columbia. In this case two of the gases, *i.e.*, those from Pender Island and Pitt Meadows, were practically nitrogen, while that from Port Haney was only 23 per cent methane, and the percentage deduction in this case is very small.

CALCULATION OF THE EMANATION CONTENT OF THE GAS.

The identity having been shown and the effect of the methane on the leak tested, the emanation content of the gas at the time of collection at the well may be calculated from the value of the conductivity of the gas, at the time of testing.

Take for example the case of the gas from the Bow Island Pipe Line at Calgary. This gas was collected in Calgary at 4.30 p.m. April 4, Mountain Time, and tested in the Laboratory in Toronto at 4.5 p.m. April 8, Eastern Time. Thus its age was 3 days 22 hours, and in that time the emanation had decayed to .49 of its original amount.* The observed leak for 3,800 c.e. of gas was .47 division per minute. Hence the leak per litre if taken immediately at collection would have been

$$\frac{.47}{.49} = .26.$$

$$3,800 = .49$$

* See Kolowrat's tables, *Le Radium*, 1913.
72333-4}

Correcting for the composition of the gas to get the leak the emanation would have given it had it been in air instead of in natural gas, the leak is reduced to .23 per litre, and hence the radium content of the gas is

$$.26 \times 1.98 \times 10^{-10} \text{ curie per litre.}$$

$$= .51 \times 10^{-10} \text{ curie per litre.}$$

The correction for decay was very important for the gas from the North-West as in some cases several days elapsed between collection and testing. The interval was as much as seven days for the British Columbia gases. In the case of the Ontario gases they were usually tested the day after collection and in some cases on the same day so that the correction for decay was much nearer unity.

The complete table of the emanation testing is shown here. The figures in the final column are repeated in the Table on pp. 49-51 for comparison with the helium content. When dealing with the radioactivity of a gas taken from pipe lines it must be considered that the age of this gas at the time of collection is unknown; there is also the possibility of contamination from bodies with which the gas has been brought into contact.

ONTARIO.

Field.	Gas Well.	When Collected.	When Tested.	Age at Time of Test.	Fraction of Emanation still in existence.	Quantity of Gas used.	Leak obtained.	Leak that would have been obtained per Litre of Gas at time of Collection.	Correction to "Emanation in Air" from "Emanation in Gas."	Radium Emanation Content of the Gas.
1916.										
1. Oil Springs-Petrolia.	C. Bredger's.....	2/5/5	3/8/5	3	.58	2830	.20	.12	.11	22
2. Tilbury	D. Park's.....	2/5/5	5/18/5	3	.57	2830	.04	.02	.02	4
	D. Tilbury Mains	1/3/5	11/16/5	3	.59	2830	.17	.10	.11	14
3. Selkirk, etc.	E. Brown's	2/3/5	12/16/5	2	.59	2830	.13	.08	.07	22
	G. Murby's	11/11/5	9/12/5	2	.85	2830	.67	.28	.25	30
4. Brant-Onondaga.	H. Robbin's.....	11/11/5	3/12/5	1	.81	2830	.45	.19	.17	34
	A. Onondaga	4/12/4	10/25/4	1	.878	2830	3.06	1.22	1.12	250
	B. Van Sickle.....	8/12/4	12/25/4	1	.888	2830	7.6	3.00	2.77	550
	C. Bow Park	5/23/4	7/25/4	2	.850	2830	10.6	4.40	4.05	800
	4. Onondaga-Middleton Main.	7/23/4	5/25/4	2	.840	2830	1.73	.72	.66	131
5. Blackheath-Seneca.	E. Blackheath Main	1/21/4	4/22/4	22	.848	2830	2.99	1.20	1.11	220
	F. Well.....	12/18/21/4	2/22/4	21	.830	2830	2.63	1.16	1.07	212
	G. Well.....	2/21/4	5/22/4	1	.818	2830	3.14	1.36	1.25	247
6. Welland.	H. Well.....	3/21/4	8/12/4	1	.804	2830	4.35	1.90	1.75	346
	D. Stevensville-382.	12/27/4	9/28/4	2	.830	3800	2.06	.84	.76	150
	E. Sherston.....	11/28/4	11/29/4	2	.851	2830	2.28	.95	.88	172
	F. Willoughby.....	3/27/4	5/29/4	2	.687	2830	.29	.15	.14	28
	G. P.L. Abino.....	9/28/4	11/29/4	3	.87	2830	.45	.28	.26	31
	H. Bertie.....	12/29/4	2/30/5	1	.82	2830	.41	.19	.17	34
	I. Humberstone	8/19/29/5	5/30/5	1	.75	2830	.81	.37	.34	67
	St. Augustine's.....	3/1/29/5	5/29/5	2	.75	2830	2.65	.95	.88	174

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ALBERTA.

Field.	Gas Well.	When Collected.	When Tested.	Age at Time of Test.	Fraction of Emanation still in existence.	Quantity of Gas used.	Leak obtained.	Leak that would have been obtained per Litre of Gas at time of Collection.	Correc-tion to "Ema-nation in Air" from "Ema-nation in Gas."	Radium Emanation Content of the Gas.
				d. h.		c. c.				×10 ⁻¹³ curie.
1. Medicine Hat.....	A. C.S.....	12 1/31/3 MT	7 1/3/4 ET	3 5	.56	2270	.39	.31	.29	57
	B. Main M.C.....	12 1/31/3 MT	11 1/4/4 ET	3 19	.50	2270	.37	.33	.31	61
	C. Park.....	4 1/31/3 MT	4 4/4 ET	3 22	.49	2830	.69	.50	.45	89
	D. C.P.R.....	4 1/31/3 MT	2 1/5/4 ET	4 20	.41	2830	.38	.33	.30	60
	E. Smith's.....	6 1/31/3 MT	9 1/4/4 ET	4 1	.48	2830	.36	.27	.24	48
	F. Electric Park.....	2/2/5 MT	10 1/9/5 ET	6 19	.29	2830	.31	.33	.35	69
	G. Central Park.....	3/2/5 MT	2 1/9/5 ET	6 22	.34	2830	.30	.37	.34	67
	H. L.P.....	11/27/5 MT	12/2/6 ET	5 23	.34	2830	.52	.54	.50	99
	I. C.P.R. L.P.....	11/27/5 MT	2 1/7/4 ET	6 14	.335	2830	.51	.54	.50	99
	A. Well 4.....	3 1/1/4 MT	4 1/6/4 ET	5 21	.35	3800	.12	.092	.083	16
	B. Wells 3, 11, 14.....	2 1/1/4 MT	4 1/6/4 ET	5 0	.41	3800	.60	.52	.47	93
	C. Well 16.....	3 1/1/4 MT	1 1/8/4 ET	6 18	.29	3800	.06	.055	.049	10
	D. Main at Calgary.....	4 1/4/4 MT	4 1/8/4 ET	3 22	.49	3800	.47	.26	.23	40
3. Sweet Grass Country.....	A. Suffield Town.....	9 1/3/4 MT	4 1/7/4 ET	3 18	.51	2830	.42	.29	.27	54
	B. Suffield C.P.R.....	10 1/6/5 MT	11/10/4 ET	3 22	.50	2830	.49	.35	.32	63
	C. Bassano.....	4/2/4 MT	9 1/6/4 ET	4 3	.47	2830	.85	.63	.57	113
	D. West Brooks.....	2 1/3/4 MT	11/8/4 ET	4 18	.42	2830	.46	.39	.36	71
4. Suffield-Calgary.....	E. East Brooks.....	2 1/3/4 MT	11/13/4 ET	9 19	.17	3800	.34	.08	.08	67
	F. Walker.....	4/4/4 MT	2 1/13/4 ET	8 20	.20	3800	.07	.39	.08	16
	B. Dingman.....	2 1/5/4 MT	10 1/11/4 ET	5 18	.35	2830	.14	.14	.13	26
	A. Wetaskiwin L.P.....	8 1/7/4 MT	10 1/12/4 ET	5 0	.41	2830	.90	.79	.73	145
5. Okotoks.....	B. Wetaskiwin H.P.....	8 1/7/4 MT	11/12/4 ET	5 3	.39	3800	1.68	1.15	1.03	205
	C. Viking.....	2/6/4 MT	12/10/4 ET	3 20	.50	3800	.17	.092	.083	16
	D. Viking.....	2 1/6/4 MT	2 1/11/4 ET	4 22	.41	2830	.20	.22	.20	40

BRITISH COLUMBIA.

A. Pender Isd.....	2 1/10/4 PT	5/17/4 ET	6 23	.285	2830	1.54	1.97	390
B. Pt. Haney.....	3/11/4 PT	12/17/4 ET	5 18	.355	2830	2.44	2.53	490
C. Pitt Meadows.....	7P/11/4 PT	12/18/4 ET	6 14	.394	2830	2.30	2.74	540

AND FOR COMPARISON.

	1916.		mins.		c.c.		$\times 10^{-12}$ curie.
Soil Air from behind Physics Building, University of Toronto.	10.20/18.5	10.30/18/5	10	.999	2830	17.5	6.2
	11.13/24/5	11.32/23/5	19	.999	2830	15.1	5.3
	4.33/2/6	4.48/2/6	15	.999	2830	10.9	3.85
	11.20-/5/6	12.36/5/6	35	.996	2830	12.9	4.52

RESULTS OF OTHER OBSERVERS ON THE RADIOACTIVITY OF NATURAL GAS.

Natural Gas radioactivity was tested by Professor J. C. McLennan in 1904. He compared the radioactivity of the gas from several wells and found that the gas at Bow Park, Ontario, was very active. This is confirmed by the figures quoted in this paper. There was not the means at the time to estimate the activity in standard measure. Boyle and Tory found that the gas from the well at Viking was not radioactive. A distinct radioactivity has been found in both our samples and the gas from the well, which was stored in a steel tank, was tested twice, on April 10 and April 20, respectively, and the law of decay found to be that of radium emanation so that the activity could not be ascribed to contamination from the tank.

Satterly and Elworthy working in 1914 on the radioactivity of mineral springs of Eastern Ontario and Southern Quebec tested in many cases the radioactivity of the gas which bubbles up through the water. They found values of emanation content ranging from 120 to 750×10^{-12} curie per litre.

The following table gives a few of the results obtained by the above and other workers.

TABLE OF THE RADIUM EMANATION CONTENT OF SOME AIRS AND GASES.

	X 10^{-12} curie per litre.
Atmospheric Air:	
At Cambridge, England, Satterly*	.635—350
At Montreal, Canada, Evef.....	.060
At Manila, Philippines, Wright and Smith‡	.071
Air from the Soil:	
At Cambridge, England, Satterly§	70—230
At Dublin, Ireland, Joly and Smith ||	200
At Newhaven, Conn., U.S.A., Sanderson¶	240
At Manila, Philippines, Wright and Smith‡	305
At Toronto, Canada, Satterly.....	760—1,210
Marsh Gas:	
At Cambridge, England, Satterly**	150—360
At Caledonia Springs, Ontario, Satterly.....	1130
Natural Gas in some Saline Waters of Canada:	
At Carlsbad Springs, Ontario, Satterly.....	250
At Bourget (Russel Lithia), Ontario, Satterly.....	590
At Victoria Springs, Ontario, Satterly.....	870
At Caledonia Springs, Ontario, Satterly.....	200—300
At Varennes, Quebec, Satterly.....	880
At St. Leon (Lami), Quebec, Satterly.....	140
At St. Leon (Lupien), Quebec, Satterly.....	500
At St. Hyacinthe (Leitatairic), Quebec, Satterly.....	590
At Berthier (River Bayonne), Quebec, Satterly.....	480
At Maskinonge (Lernyre), Quebec, Satterly.....	250
At Banff, Alberta, Elworthy.....	2,500—3,000
Natural Gas in Saline Waters in England:	
At Bath, Ramsay††	33,700
At Buxton, Makower‡‡	8,000

* Phil. Mag., 1910.

† Phil. Mag., 1908.

‡ Phys. Rev., 1915.

§ Proc. Camb. Phil. Soc., Vol. XVI, Parts IV and VI.

|| Sci. Proc. Roy. Soc., Dublin, Vol. XIII, 1911.

¶ Amer. Jour. Sci., 1911.

** Proc. Camb. Phil. Soc., Vol. XVI, Part IV.

†† Chem. News, pp. 105-134, 1912.

‡‡ Chem. News, pp. 105-135, 1912.

Summary of Results.

ONTARIO GAS FIELDS.

Date of Collection.	Name of Well.	Percentage of Helium.	Amount of Radium Emanation in Units of 10^{-12} Curie per Litre of Gas.	Percentage of Uncondensable Gas at Temperature of Liquid Air.
<i>1.—Oil Springs—Petrolia Field.</i>				
Jan. 7	A. No. 6 Oil Springs, Fairbanks, combustion method.	.15	—	—
" 7	B. Oil Springs Co. (combustion).....	.15	—	—
	B. Oil Springs Co. (condensation).....	.15	—	—
May 5	C. Brodger's Well.....	.14	22	3.5
" 5	D. Park's Well.....	.14	4	3.8
<i>2.—Tilbury Field.</i>				
Jan. 21	A. Glenwood Station.....	.11	—	—
" 22-4	B. Askew Well.....	.18	—	—
" 29	C. Glenwood Gas (at Hamilton from Tilbury Line).	.13	—	—
May 3	D. Tilbury (at Glenwood from Northern Pipe Line).	.14	18	2.9
" 3	E. Tilbury, Brown's Farm.....	.13	14	3.1
<i>3.—Selkirk-Rainham-Dunnville Field.</i>				
Jan. 25	A. Dunnville.....	.19	—	—
Feb. 8	B. Selkirk Mains (at Hamilton).....	.30	—	—
" 8	C. Rainham Centre (Svent Well).....	.22	—	—
" 11	D. Rainham Centre Mains (Selkirk Field)	.30	—	—
Mar. 18	E. Dunnville (C. Ross's Well).....	.27	—	—
" 18	F. Dunnville (a new well).....	.27	—	—
May 11	G. Dunnville (Mumby Well).....	.24	50	6.5
" 11	H. Dunnville (Robbins' Well).....	.27	34	6.7
<i>4.—Brant-Onondaga Field.</i>				
April 24	A. Onondaga Main (taken at Brantford)....	.25	226	5.5
" 24	B. Van Sickle Farm Well.....	.29	550	4.5
" 24	C. Bow Park Well.....	.33	800	5.7
" 24	D. Onondaga-Middleport Main (between O. and M.).	.32	131	5.7
<i>5.—Blackheath-Seneca Field.</i>				
Feb. 3	A. Blackheath Gas (Dom. Gas Co., Selkirk) (cut off).	.29	—	—
" 5	B. Blackheath (main line from S. Nat. Gas Co.).	.34	—	—
" 5	C. Blackheath (National Gas Co. Main).	.28	—	—
" 15	D. Hamilton (National Gas Co. Main)....	.29	—	—
April 21	E. Blackheath Main (National Gas Co.).	.32	220	3.8
" 21	F. A Well)	.32	212	3.0
" 21	G. A Well, Out of the 40 supplying the main	.32	247	6.0
" 21	H. A Well) E.	.32	346	4.0
<i>6.—Welland Field.</i>				
Jan. 25-26	A. Stevensville (Well No. 382).....	.21	—	—
" 31	B. Wainleet and Bertie (Niagara Falls Mains).	.30	—	—
Feb. 7	C. Niagara Falls (National Gas Co.).....	.24	—	—
April 27	D. Stevensville (Well No. 382).....	.28	150	3.1
" 28	E. Sherkston (Well No. 318).....	.28	172	3.5
" 27	F. Willoughby (Well No. 61).....	.11	28	1.7
" 28	G. Pt. Abino.....	.26	51	5.0
May 29	H. Stevensville (Bertie Tp. Well No. 436)	.22	34	5.5
" 29	I. Stevensville (Humberstone Tp. Well No. 437).	.26	67	4.1

ONTARIO GAS FIELDS—Continued.

Date of Collection.	Name of Well.	Percentage of Helium.	Amount of Radium Emanation in Units of 10^{-12} Curie per Litre of Gas.	Percentage of Uncondensable Gas at Temperature of Liquid Air.
<i>7.—Toronto Field.</i>				
Jan. 3	A. St. Augustine (combustion method).....	.013 (first result obtained).	—	—
May 29	A. St. Augustine (condensation method)....	.009	174	10.0

THE ALBERTA GAS FIELDS.

<i>1.—Medicine Hat Field.</i>				
Mar. 31	A. Cousins and Sissons Well.....	.13	57	2.1
" 31	B. Main behind Methodist Church.....	—	61	—
" 31	C. Old Well (Park Well).....	—	89	—
" 31	D. C.P.R.....	—	60	—
" 31	E. Smith's Well.....	—	48	—
May 2	F. Electric Park.....	.12	69	3.5
" 2	G. Central Park.....	.11	67	3.1
" 2	H. Low Pressure. Top of Hill.....	.11	—	3.7
" 2	I. C.P.R. Low Pressure. Same as D.....	.11	—	3.5
<i>2.—Bow Island Field.</i>				
April 1	A. Well No. 4. Old and largest.....	.29	16	5.2
" 1	B. Wells 3, 11, 14, pipe.....	.29	93	7.3
" 1	C. Well 16, Burdette (Latest Well).....	.34	10	7.3
" 4	D. Bow Island Pipe at Calgary.....	.33	46	6.3
<i>3.—Sweet Grass Country.</i>				
No results.				
<i>4.—Suffield-Brooks-Bassano-Calgary Field.</i>				
April 3	A. Suffield (Town Well).....	.10	54	< 9.0
May 6	B. Suffield (C.P.R. pumping station).....	.12	63	4.2
April 3	C. Bassano (S. of C.P.R. track).....	.06	113	< 12.0
" 3	D. Brooks (West Well).....	.09	71	—
" 3	E. Brooks (East Well).....	.08	67	3.8
" 4	F. Calgary (Walker Well).....	.15	16	2.7
<i>5.—Okotoks Field.</i>				
April 5	A. Dingman Well, head casing gas from 400 feet to 800 feet down.....	.03	—	—
" 5	B. Dingman Well, 3900 feet down.....	.01	26	.9
<i>6.—Wetaskiwin-Viking-Vegreville Field.</i>				
April 7	A. Wetaskiwin Well, 20 lb. per square inch..	.05	145	2.0
" 7	B. Wetaskiwin Well, 90 lb. per square inch..	.06	205	2.0
<i>Viking Well.</i>				
April 6	C. At well.....	.05	16	—
" 6	D. Pipe Line—mile away.....	.05	40	4.0
<i>7.—Athabaska Field.</i>				
July	Pelican Well.....	.002	—	80.0
<i>8.—Peace River Field.</i>				
July	Tar Island Spring.....	.010	—	—

BRITISH COLUMBIA.

Date of Collection.	Name of Well.	Percentage of Helium.	Amount of Radium Emanation in Units of 10^{-18} Curie per Litre of Gas.	Percentage of Uncondensable Gas at Temperature of Liquid Air.
April 10	A. Pender Island.....	.028	390	99.0
" 11	B. Port Haney.....	.013	490	—
" 11	C. Pitt Meadows.....	.003	540	99.0

UNIVERSITY OF TORONTO.

Soil Air from 4½ feet down near Physics Building.

May 18	A. Pipe at S. end of building.....	—	1,210	—
" 24	A. " " ".....	—	1,050	—
June 2	A. " " ".....	—	760	—
" 5	B. Pipe at N. end of building.....	—	895	—

May 1, 1916.

SECTION III.

DETERMINATION OF THE HELIUM CONTENT OF A NATURAL GAS FROM NEW BRUNSWICK, CANADA.

A DETERMINATION BY MR. R. T. ELWORTHY, B.Sc., A.I.C.

A detailed examination, comprising chemical analysis, density, measurements, analysis for Helium, and spectroscopic examination of the Helium isolated, has been made on a sample of natural gas from Moncton, New Brunswick.

The labels on the two 5-gallon bottles, containing the sample, read as follows:—

“Sample of natural gas from Stony Creek field near Moncton, New Brunswick. Collected from a tap on the premises of the Moncton Tramways, Electricity, and Gas Co., at Moncton, by S. Lister James, instructed by the Anglo-Persian Oil Co., Ltd., and by courtesy of the Moncton Tramways Co., Ltd.

Jan. 5, 1918.”

Both bottles were in good condition and had not leaked. The gas in each was under slight pressure.

DENSITY.

The density of the gas was determined using a quartz density balance, described in the appendix to this report. The value was found to be $\cdot 820$ gram per litre (air $1\cdot 293$ grms. per litre, methane $\cdot 716$ grms. per litre).

CHEMICAL ANALYSIS.

A chemical analysis of the sample was carried out with the gas analysis apparatus described in Section VI of this report, “The Investigation of Natural Gases from New Zealand, Heathfield, Bath, and Pisa.”

The following results were obtained:—

	Per cent.
Methane CH_4	80.0
Ethane C_2H_6	7.2
Carbon dioxide CO_2	None
Oxygen O_2	None
Nitrogen and rare gases N_2	12.8

HELIUM CONTENT.

The Helium content of the New Brunswick gas was found, using the analysis apparatus described in Section VI of this report. The only departure from the procedure there described was that liquid oxygen was substituted for liquid air, used to cool the cocoanut charcoal and to condense the hydrocarbon gases.

As the temperature of the liquid oxygen (-183°C .) is a few degrees above the freezing point of methane, and especially of the freezing point of the methane-ether mixture that is obtained in this case, the hydrocarbons do not solidify as they do when condensed at liquid air temperature,

but remain liquid. The liquid mixture obtained was found to have a vapour pressure of 100 mm.

Duplicate analyses were made on the gas in each sample bottle with the following results:—

	Initial Volume.	Final Volume.	Helium.
	c.c.		Per cent.
Bottle A—1.....	4,000	2.30	.058
2.....	6,000	3.61	.060
Bottle B—1.....	6,000	4.75	.079
2.....	6,000	3.50	.058
		Mean.....	.064

SPECTROSCOPIC EXAMINATION.

The Helium obtained from the analyses of the gas sample in bottle A and in bottle B was passed through a second charcoal absorption apparatus and led into a discharge tube.

By means of a small Hilger spectroscope the spectrogram shown in Plate I was obtained.

For purposes of comparison spectrograms of pure Helium, mercury, neon and argon are added.

February 7, 1919.

SECTION IV. ON THE HELIUM FIELD IN ALBERTA.

REPORT BY JOHN PATTERSON, M.A.

INTRODUCTION.

The following report on the Helium Field in Alberta is submitted for information. Table II is specially informing. From it it will be seen that the minimum average consumption of gas at Calgary, where our experimental plant is located, is about 5,000,000 cubic feet per day. The maximum consumption is about 15,000,000 cubic feet per day. As the Helium content is about $\frac{1}{3}$ per cent, this would mean that at Calgary the available supply of Helium would range from about 500,000 to 1,500,000 cubic feet per month.

REPORT.

The main Helium Field in Alberta is operated by the Canadian Western Natural Gas, Heat, Light and Power Company, and it is in the Bow Island district near the junction of the Bow River and the South Saskatchewan. The latter flows about five miles per hour between high and, in many places, cut banks, while the surrounding country is undulating prairie. There are now about 25 wells in the Bow Island field proper and their location is given on the accompanying field map Fig. 14. Wells Nos. 5, 2, 1, 6, 3, 13, 4, 7, 23, 12 and 8 are situated on C.P.R. lands, and the company have to pay a royalty on the gas obtained from these wells; this gas is measured at the Coste measuring station and after being metred it passes into the main trunk line to Calgary. The company have drilled a new well No. 25 at Chin Coolie, near Barnwell; its position is marked in red on the map of the Gas Trunk line. This well has a capacity of about 4,000,000 feet per day, and it is evident that there is an important gas field there which the company intends to develop. The company turns a sufficient number of wells into the pipe line to maintain the pressure at the field end of the pipe line at about 160 lbs. and at the reducing station at Calgary at about 100 lbs. This reducing station is near Ogden, and there the pressure is reduced from 100 lbs. to 35 lbs. The intermediate pressure lines are then distributed to various parts of the city, where there are stations to reduce from 35 lbs. to 4 ozs.

As shown in the accompanying trunk line map (Map 523.) there are a number of cities and towns supplied along the way, the chief of which are Lethbridge and Macleod. Table I gives the total monthly consumption of gas at the different places supplied, and Table II the total monthly and daily average amounts for each month drawn from the field, the average daily amount for Calgary and its percentage of the total supply.

On December 23 and 24, 1918, I visited the well at Barnwell and those at Bow Island and obtained samples from No. 25 at Barnwell; one sample at the Coste measuring station containing gas from wells Nos. 5, 2, 1, 6, 3, 13, 4, 7, 23, 12 and 8, one sample from wells Nos. 9, 10, and southern Alberta, and one from well No. 22. An analysis of these samples gave the following:—

—	Barnwell, Well No. 25.			C.P.R. Gas.	No. 22.	Nos. 9 and 10 and Southern Alberta.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Helium.....		.36 (3 tests)		.30	.33	.30
CH ₄	(1) 86.2	(2) 81.6	(3) 87.0	87.0	90.1	89.2
C ₂ H ₆	4.3	1.9	5.0	.9	2.6	.9
N ₂	9.14	6.11	7.64	11.2	6.97	11.2

The analysis shows that the well at Barnwell is the richest in Helium and that it contains more ethane; this may not be a detriment to the production of Helium, but Mr. Coste has agreed to shut off the Barnwell well if necessary when the tests are being made.

On analysing the gas for hydrocarbons, the tests all showed a negative value for the ethane in the samples from the Bow Island Field. This suggested hydrogen in the oxygen used in the analysis, and on testing for hydrogen it was found that there was .55 per cent hydrogen in the oxygen. The results were then corrected and positive values were obtained for the ethane as given in the Table. As regards the nitrogen content, sample No. 2 from well No. 25 was taken from a fresh bottle that had no water in it, and the sample was drawn off immediately after the bottle was opened under water. It gave the nitrogen and Helium at 6.5 per cent, and the sample that was drawn off about half an hour later, during which time the gas was exposed to some water in the bottle, gave the content as 8 per cent, while the first sample was taken from gas that had been standing over water for some days, and the nitrogen and Helium content was 9.5 per cent. This sample was analysed for oxygen and found to contain .93 per cent oxygen. This shows that the air dissolved in the Toronto water had contaminated the gas, and as all the samples tested had been standing over water they are probably 3 or 4 per cent too high in their nitrogen content.

TABLE I.

THE CANADIAN WESTERN NATURAL GAS, LIGHT, HEAT, AND POWER
COMPANY, LIMITED.

Consumption of Natural Gas in Thousand Cubic Feet.

—	Calgary Gas Co., Ltd.	Bow- ness.	Clare- holm.	Field.	Gra- num.	Leth- bridge.	Mac- leod.	Main Line.	Nan- ton.	Okot- toks.	Sand- stone.
1917.											
October..	266,326	1,189	3,673	5,711	1,601	13,326	9,640	312	1,968	1,016	17
November	313,958	798	3,286	4,002	1,527	17,865	9,734	511	2,417	1,606	24
December	464,292	1,468	9,438	1,917	4,497	37,502	13,765	965	5,492	3,357	55
1918.											
January..	407,033	1,223	9,195	1,760	3,717	38,152	12,656	722	5,088	3,197	48
February..	382,972	1,032	8,528	1,042	3,464	36,618	12,740	910	5,584	2,637	61
March.....	328,132	895	6,871	2,614	2,750	31,083	10,626	626	3,566	1,866	36
April.....	265,588	877	3,668	5,155	1,901	17,881	8,417	479	2,440	1,423	31
May.....	242,003	931	2,910	1,589	1,458	13,066	8,665	416	1,680	1,038	2
June.....	168,967	829	1,362	1,456	806	9,730	9,940	406	1,025	586	5
July.....	141,058	930	951	1,605	781	7,044	8,238	562	822	476	5
August.....	135,703	878	1,029	1,405	732	6,396	8,573	362	902	481	7
September.	151,866	1,024	1,715	672	974	8,992	9,219	598	1,149	705	1
Total....	3,270,829	12,074	52,629	28,958	24,211	237,655	122,213	6,869	32,163	18,388	292

TABLE II.
THE CANADIAN WESTERN NATURAL GAS, LIGHT, HEAT, AND POWER
COMPANY, LIMITED.

Yield of Natural Gas in Thousand Cubic Feet.

	Total Yield of Field.		Daily Average Consumption at Calgary.	Percentage of Total Yield used in Calgary.
	Monthly Total.	Daily Average.		
1917.				
October.....	304,812	9,833	8,590	87.4
November.....	355,738	11,836	10,465	88.2
December.....	542,718	17,507	14,972	85.5
1918.				
January.....	482,791	15,574	13,130	84.3
February.....	455,588	16,271	13,678	84.1
March.....	389,069	12,551	10,586	84.4
April.....	307,840	10,261	8,852	86.3
May.....	273,758	8,831	7,807	88.4
June.....	195,112	6,504	5,632	86.6
July.....	162,472	5,241	4,550	86.8
August.....	156,468	5,047	4,377	86.7
September.....	179,915	5,997	4,995	83.3

March 10, 1919.



POWER

Percentage of
Yield
Calgary.

87.4
85.2
85.5

84.3
84.1
84.4
86.3
88.4
86.6
86.8
86.7
83.3

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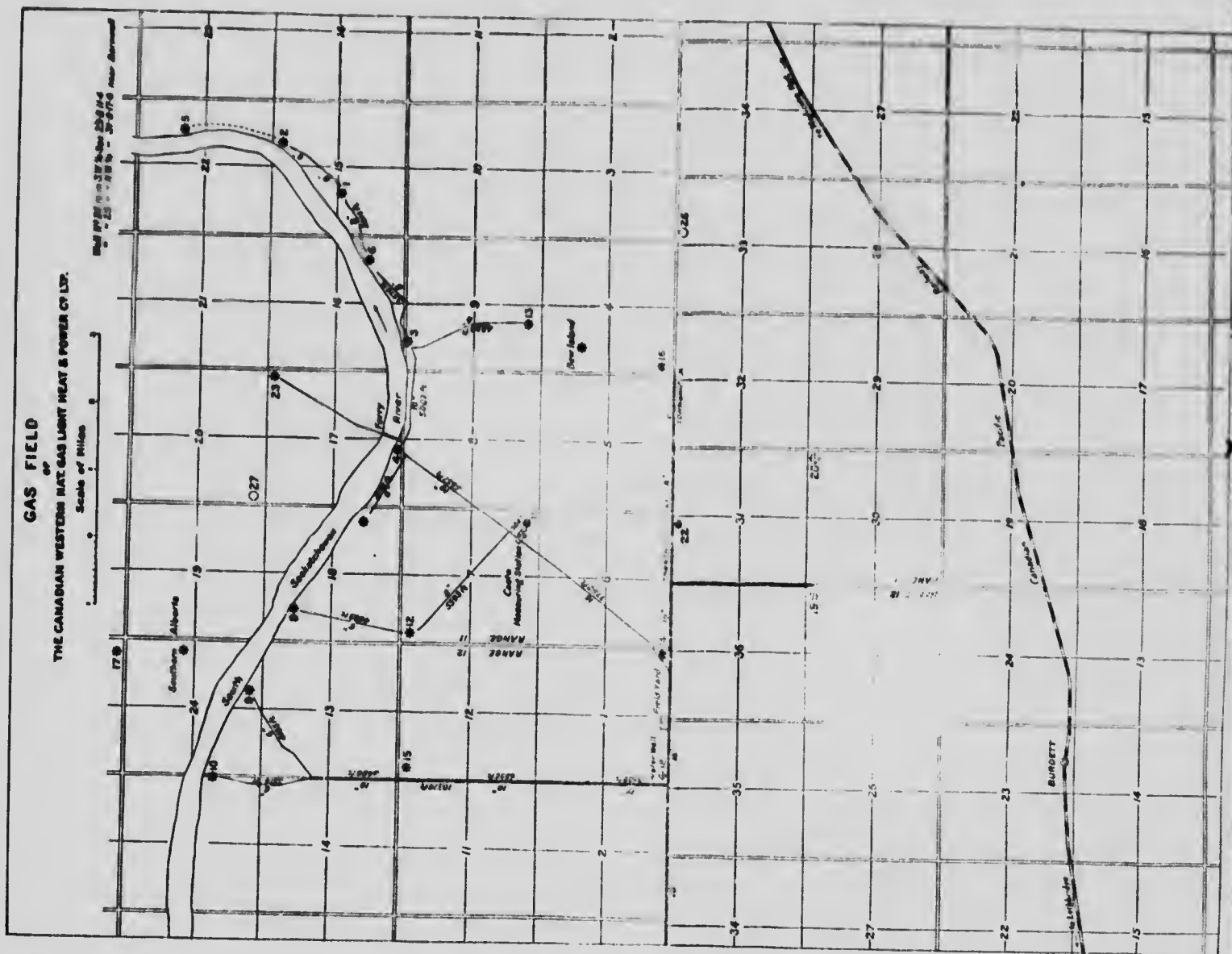


TABLE II.

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SECTION V.

THE HELIUM CONTENT OF NEW ZEALAND NATURAL GASES.

I.—REPORT BY PROFESSOR J. C. McLENNAN, F.R.S., AND CAPTAIN H. A. McTAGGART.

Introduction.

The following report contains an account of an investigation on the Helium content of a number of samples of the Natural Gases of New Zealand. These samples of gases, which were handed over by the Admiralty to the Board of Invention and Research for examination, were collected, treated, and sent forward by Mr. J. S. McLaurin, Dominion Analyst (Department of Internal Affairs), Wellington, New Zealand.

The gases were transported in hermetically sealed glass flasks. Regarding the flasks, Mr. McLaurin stated that "they contain residual gas after removal of carbon dioxide, hydrogen, hydrocarbons, and the greater part of the nitrogen." The original volumes of the gases from which these residual samples were obtained were marked on the flasks. The gases were obtained from seven different sources in New Zealand, and as the residues from four of the sources were in duplicate, there were therefore eleven samples in all to be tested.

Information about the Gas Samples.

The following information regarding the different samples was sent forward by Mr. McLaurin along with them:—

No. 1 is from Hanmer, 24 miles from Culverden, which is connected by railway to Christchurch.

No. 2 is from Kotuku, on the Grey-Brunner Railway, three miles from the station.

No. 3 is from Weber, 20 miles east of Dannevirke (Wellington-Napier Railway).

No. 4 is from Blairlogie, 20 miles east of Masterton (Wellington-Napier Railway).

No. 5 is from Grooby's, seven miles from New Plymouth.

No. 6 is from Rotorua, from a spring in Lake Rotorua, one mile from the railway station.

No. 7 is from No. 3 Bore, New Plymouth, near wharf and railway station.

No. 1 Hanmer contains approximately—

Methane.....96.1 per cent.

Inert gas.....3.5 "

The rate of flow is about 330 cubic feet per hour.

No. 2 Koiuku contains approximately—

Carbon dioxide.....57 per cent.

Methane.....11 "

Oxygen.....6.5 "

Inert gas.....25.5 "

100.0

Apparently a considerable amount of air had leaked into this cylinder.

Rate of flow 400 to 500 cubic feet per hour.

No. 3 *Weber* contains approximately—

Methane.....	95.0 per cent.
Carbon dioxide.....	2.8 “
Inert gas.....	2.2 “
	<hr/>
	100.0

Rate of flow 1,000 to 1,200 cubic feet per hour.

No. 4 *Blairlogie* contains approximately—

Methane.....	96.1 per cent.
Inert gas.....	3.5 “

Rate of flow 12 to 14 cubic feet per hour.

No. 5 *Grooby's* contains approximately—

Methane, &c.....	95.8 per cent.
Inert gas.....	3.4 “

Rate of flow 6 to 7 cubic feet per hour.

No. 6 *Rotorua* contains approximately—

Hydrogen and methane.....	17.4 per cent.
Carbon dioxide.....	79.9 “
Inert gas.....	2.7 “

Rate of flow, approximately 200 cubic feet per hour.

No. 7, No. 3 *Bore, New Plymouth.* contains approximately—

Methane, etc.....	15.1 per cent.
Carbon dioxide.....	81.7 “
Oxygen.....	0.5 “
Inert gas.....	2.7 “

Rate of flow, 100 cubic feet per hour.

Method of determining Helium Content.

The method of determining the Helium content can be seen from the diagrammatic sketch of the apparatus used, shown in Fig. 15.

The flask A containing the residual gas was connected by rubber tubing to the apparatus, which was then thoroughly evacuated first of all by means of a mechanical air pump connected at Y, and afterwards by means of the pumps D, Q, R, and S. The residual gases were then introduced into the apparatus by breaking off the point of the side tube of the flask which was connected to the rubber tubing.

Liquid air surrounding B condensed out any residual CO₂, methane, or water vapour present and cocoanut charcoal in C and D, cooled to the temperature of liquid air, absorbed all the oxygen and nitrogen present.

The residual inert gas in the apparatus was finally pumped over to X, where it was measured, and then from X it was passed over in the manner indicated in the diagram into the flask T for storage.

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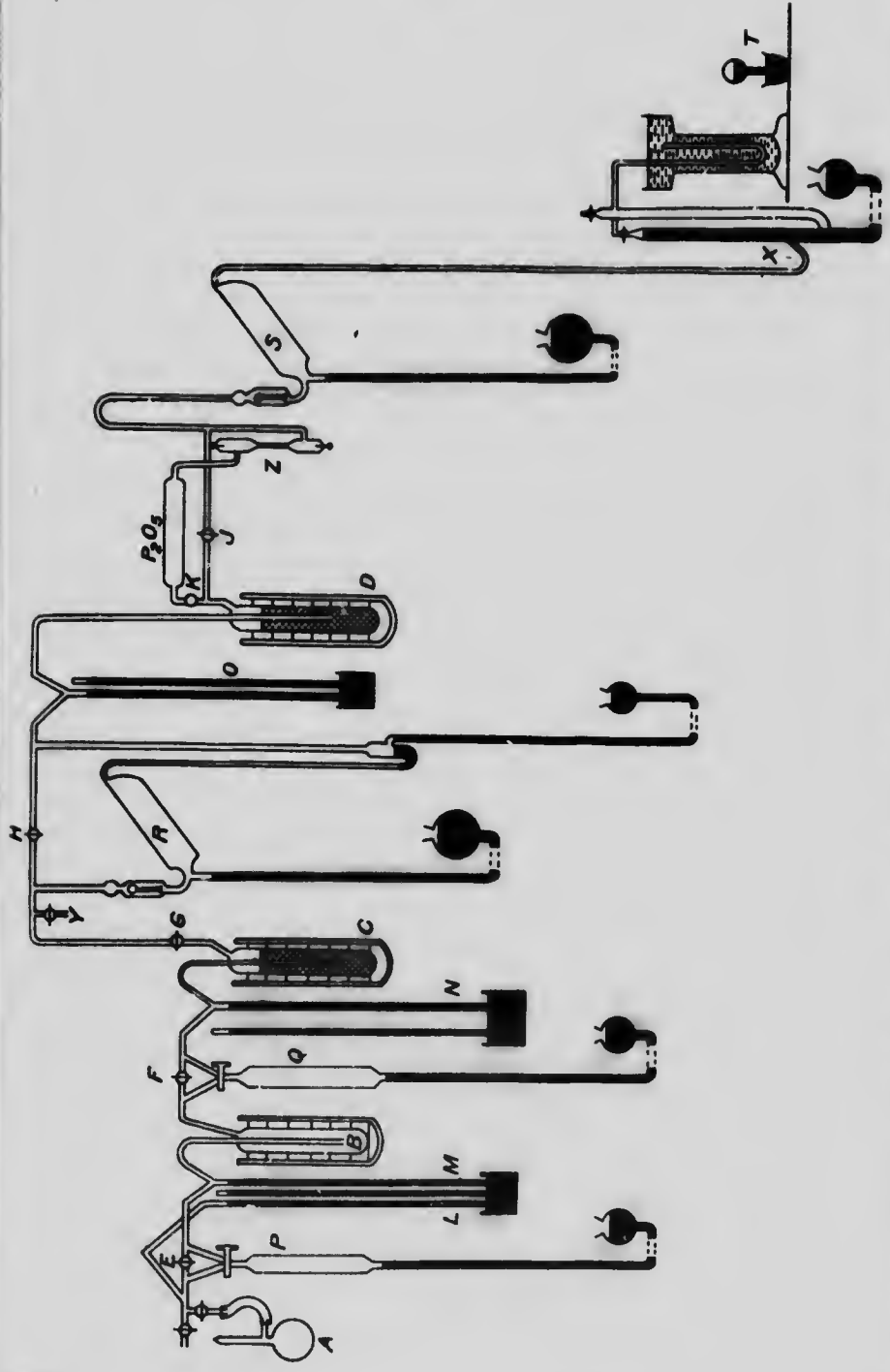


FIG. 15. Apparatus for determining the helium content of natural gas by condensation method. (Special container with partially treated gas).

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Results.

The results of the investigation are shown in Table I. In the first column the source of the sample is given, in Column II the original volume, as furnished by Mr. McLaurin, in Column III the volume of the final residual gas, as measured by us, and in Column IV the deduced percentage of rare gases present in the sample. The table contains as well the Helium content of the gases from three other sources which have been recently investigated.

TABLE I.

Column I.	Column II.	Column III.	Column IV.
Source of Gas.	Original Volume	Volume of Final Residual.	Percentage of Rare Gases in Samples.
	Litres.	c.c.	
1a	7½	4.4	.6
1b	12	.2	.7
2	50	.8	.001
3a	16	.0	Bulb cracked
3b	20	.9	.004
4a	25	3.2	.012
4b	20	2.9	.014
5a	12½	.3	.002
5b	14	.4	.003
6	70	3.7	.005
7	45	1.1	.002
Fort Worth and Petrolia, Texas.	—	—	.94 per cent to .98 per cent
Blackheath District, Ontario....	—	—	.32 "
Bow Island, Alberta, Canada....	—	—	.30 "

From the results given in Table I it will be seen that the "rare gas" content of the New Zealand samples has turned out to be insignificant. From the information given by Mr. McLaurin, moreover, it will be seen that the gas flow at the sources corresponding to the samples investigated is extremely meagre.

Spectroscopic Examination of Residues.

By means of the apparatus shown in diagram in Figure 16 known amounts of the rare gas residues collected from each of the samples and stored in the tubes T, Fig. 15, were in turn introduced into the spectrum tube E. The discharge from a small transformer, run by a small rotary converted set, was then passed through the gas introduced into E, and the spectrum of the light emitted by the gas of each sample was photographed with a small Hilger spectrograph. Spectrograms obtained in this way of the different samples are illustrated by the one in Plate I. For the purpose of comparison, spectrograms of the discharges in Helium, Neon, Argon and Mercury Vapour are also included in the table.

In every case it will be seen that the spectrum of the residues include the more prominent lines of helium, and also those of mercury as well. No spectroscopic evidence of the presence of neon or of argon in any of the residues was obtained.

Density Determinations.

An Aston balance had been constructed for the purpose of making density determinations, but on account of the extremely small amount of

final residual gas obtained with each of the samples, it was not thought that any useful purpose would be served by attempting to make density measurements on them.

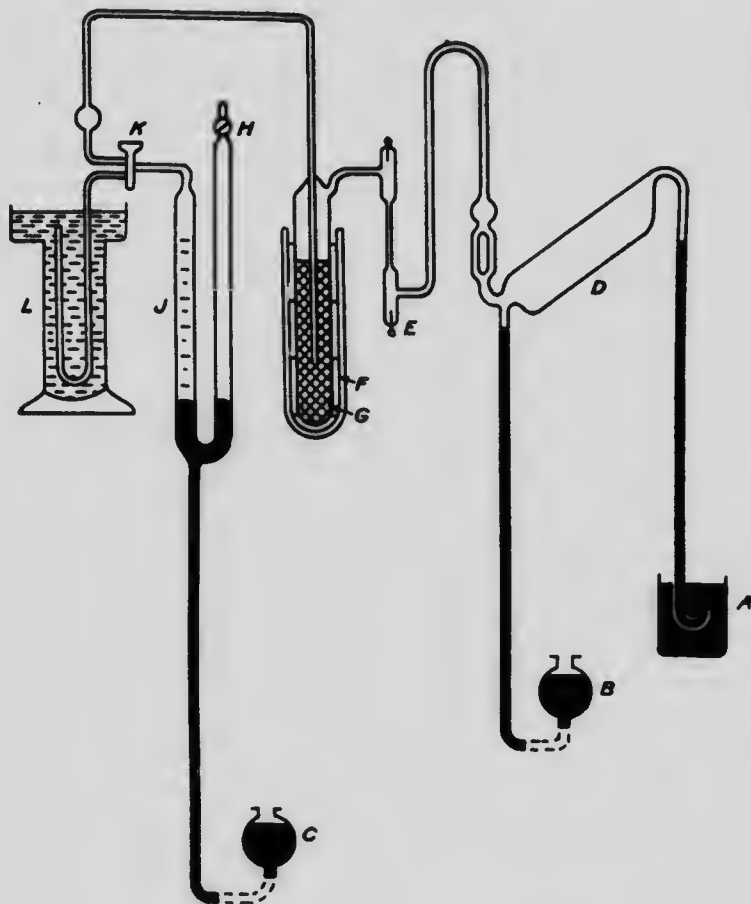


Fig. 16. Apparatus for the spectroscopic examination of rare gas residues.

We desire to acknowledge our indebtedness to Sir Charles Parsons for the loan of a mechanical air pump and motor, and to the University of Toronto for the loan of a Gaede mercury pump and a Gaede rotary mechanical pump and motor.

January 28, 1918.

Report by Professor John Satterly, F.R.S.C.

Samples of natural gas from New Zealand were sent forward to Toronto and their helium content was carefully determined with the following results:—

	Helium content.
Sample No. 1, Hanmer .....	.077 per cent.
No. 2, Kotuku .....	.002 "
No. 3, Weber .....	.004 "
No. 4, Blairlogie .....	.016 "
No. 5, Rotorua .....	.0072 "

These results, together with the determinations made by Professor J. C. McLennan and Captain H. A. McTaggart, for the samples of the same gases, are given in Table I. The agreement in the analyses it will be seen is satisfactory.

TABLE I.

New Zealand Gases.	Helium Content.		
	A. Satterly.	B. McLennan and McTaggart.	Ratio. A.B.
Origin of Sample.	Per cent.	Per cent.	
No. 1, Hanmer .....	.077	.065	1.18
No. 2, Kotuku .....	.002	.001	2.00
No. 3, Weber004	.004	1.00
No. 4, Blairlogie016	.013	1.23
No. 5, Rotorua072	.005	1.44
No. 6, Rotorua	—	.025	—

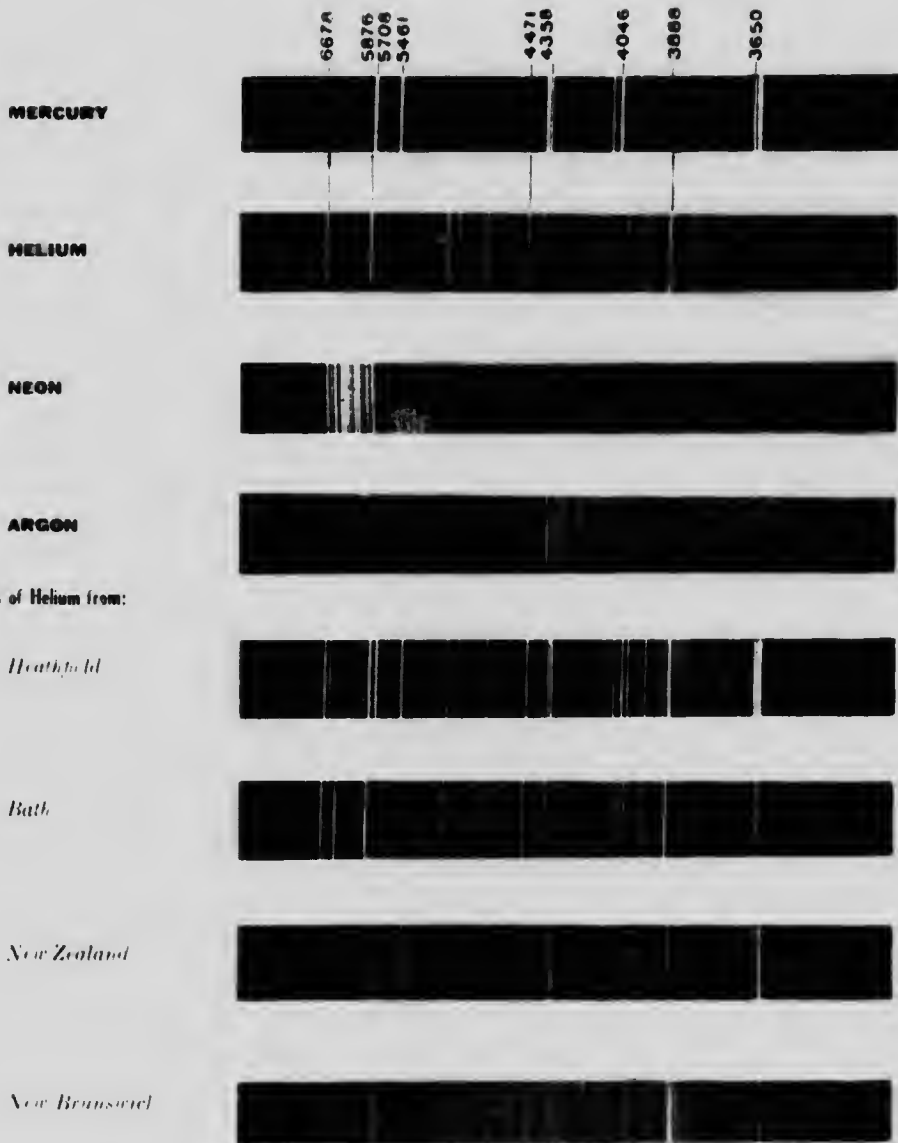
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SECTION VI.

**REPORT ON THE HELIUM CONTENT OF NATURAL GAS FROM
HEATHFIELD (SUSSEX), BATH (KING SPRING)
(SOMERSET), AND PISA (ITALY).**

REPORT BY CAPTAIN H. A. McTAGGART AND
R. T. ELWORTHY, B.Sc., A.I.C.

The gases were collected over water in glass bottles of 25 litres capacity approximately, closed by rubber stoppers. When these reached the laboratory they were inverted over water and the gas taken out by allowing water from the tap to run into the bottle through a tube in the cork, while the gas was driven out through another as in the diagram, Fig. 17.

The apparatus used for the examination is also shown. On the left is the bottle holding the gas. As the water ran into it the gas was forced into the graduated tube A filled with water and by upward displacement forced the water downward, the flow of gas being stopped when the water level was the same inside and out. The reading thus gave the volume at atmospheric pressure of the gas taken.

The gas then passed through CaCl in V and over P₂O₅ in U and entered the condensation tube B quite dry. Liquid air surrounding B condensed any constituents in the gas that would liquefy at that temperature. When this was complete, as shown by the manometer M, the tap F was opened and the gas entered the tube C filled with cocoanut charcoal, where all absorbable gases were taken up by the charcoal. When no more was absorbed, as shown by the manometer N, the taps G and H were opened and the residue entered a second charcoal tube E, where any remaining absorbable gas not taken up by C was absorbed.

R was a pump for completing the exhaustion of C.

The gas could be examined visually in Z with a spectroscope to see that the absorption was complete. The lines of Hg were always present, the remaining lines being those of helium and traces possibly of some other rare gases.

The pump S was used to transfer the residue from D to the gas burette X, where its volume was measured at atmospheric pressure, after which it was collected over mercury in the usual way in small bulbs as at T.

The pump P could be used to exhaust U and V of the sample admitted there, and Q to exhaust B, but when a run was made in which A was filled several times in succession it was found easier to make no use of P and Q until the run was finished, when they were used to make a final exhaustion only.

When the gas examined contained volatile constituents like methane these condensed in B, and on attempting to exhaust the residual gas it was found impossible to make it complete at one trial because of the existence of a vapour pressure of 6 cms. or more, depending on the freshness of the liquid air used. The usual practice was to close F, remove the liquid air for a moment or two and allow the liquid to boil out any rare gas dissolved in it; then replace the liquid air again and exhaust once more to the vapour pressure of the condensate. This repeated two or three times washed all the rare gas over into C.

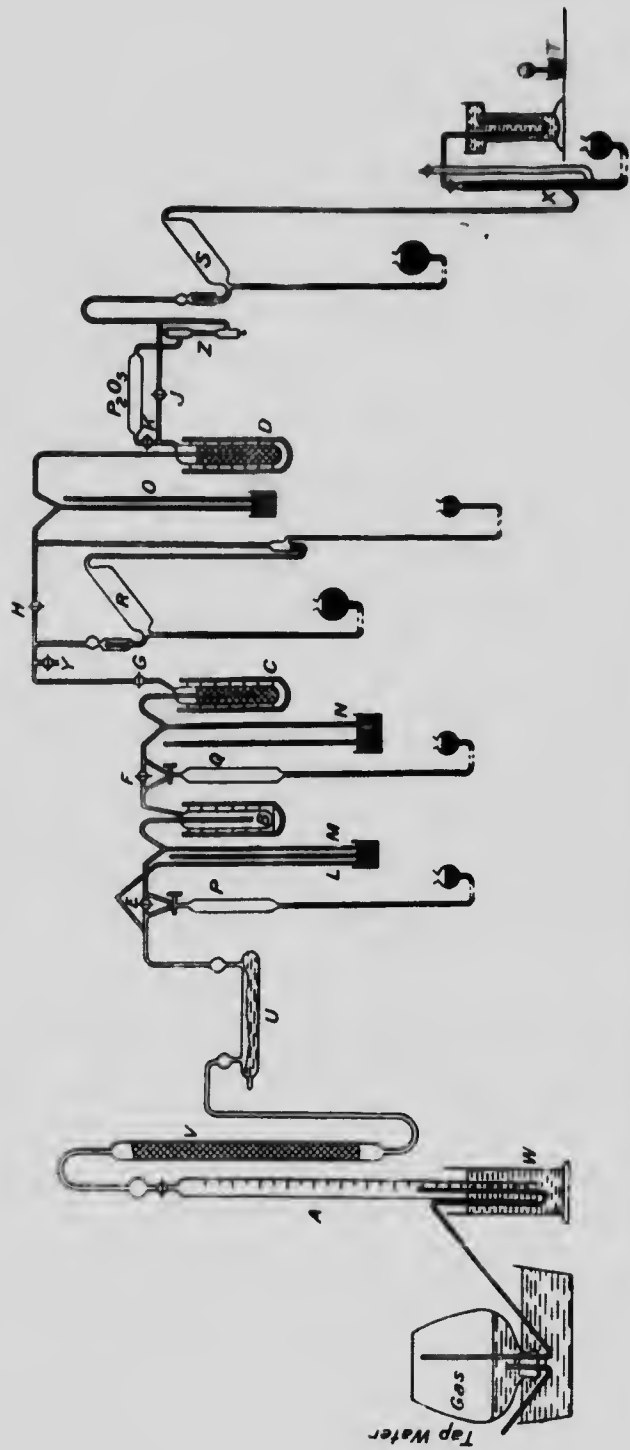


FIG. 17. Apparatus for the determination of helium in gases by condensation method. (Bottle container.)

When the charcoal in C and D became saturated during a run, F was kept closed and all the residue to the right of it was pumped into X. The liquid air around C and D was removed and the tubes allowed to warm up. The absorbed gas came out fairly rapidly and was pumped off at Y by a Fleuss pump. When this was completed Y was closed, the liquid air was replaced and the run continued.

The following tables give the results in the cases of the three gases mentioned:—

HEATHFIELD NATURAL GAS.

Volume admitted to Apparatus.	Temperature of Room.	Volume of Residue.	Per cent of Rare Gas.
Litres.	C.	c.c.	
4	14°	7.8	
2	14°	4.3	
2	14°	3.6	
2	15°	4.4	
2	15°	4.3	
2	15°	4.9	
Total 14		29.3	.21

BATH GAS (KING SPRING).

Volume admitted to Apparatus.	Temperature of Room.	Volume of Residue.	Per cent of Rare Gas.
Litres.	C.	c.c.	
2	15°	3.1	
2	17°	3.3	
2	16°	3.2	
Total 6		9.6	.16

PISA NATURAL GAS.

Volume admitted to Apparatus.	Temperature of Room.	Volume of Residue.	Per cent of Rare Gas.
Litres.	C.		
4	14°	None.	
2	14°	None.	

The Bath gas was examined in 1895 by Rayleigh, who found 12 per cent helium, in 1897 by Dewar, who found 1.4 per cent argon and some helium, in 1912 by Ramsay, who found .73 per cent argon, .23 per cent neon, and .03 per cent helium. (See Notes on Therapeutics of Radium in Bath Water, by John Hatton.)

It is not known whether the gases from Heathfield or Pisa have been examined for rare gas before.

The residue from the gases at Heathfield and Bath were examined spectrographically in the apparatus illustrated in Fig. 16.

The rare gas was introduced at L into the pipette J and then passed into G, where it was allowed to stand for 20 minutes or half-an-hour over cold charcoal, as in the previous apparatus. An electric current was then passed through the discharge tube E and the spectrogram taken with a Hilger glass prism spectrograph, using panchromatic plates.

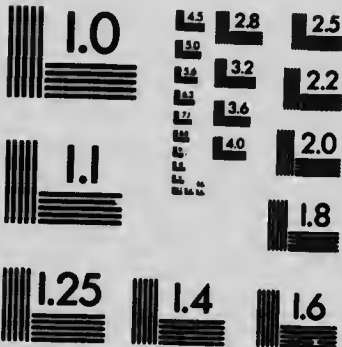
Prints of these are shown on Plate I, accompanied by comparison spectra of Hg. A. Ne. and H., taken with the same spectrograph.

A chemical analysis of these gases was also made as described below:—



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Analyses of Samples of Gases from Pisa (Italy), Bath in Somerset, Heathfield in Sussex.

R. T. ELWORTHY, B. Sc., A.I.C.

For the analyses of the common constituents a modified Burrell gas analysis apparatus was constructed. This apparatus consisted essentially of a burette, a compensation tube, and four pipettes connected together as shown in Fig. 18.

The compensation tube and capillary had the same volume as the burette and capillary "Leader" and taps, and was connected with it through the potash pipette. Before every burette reading the potash pipette was opened to the burette and the solution in it adjusted to the index marks on the capillary of the pipette, and on the capillary side tube by raising or lowering the potash reservoir and the mercury reservoir of the burette. This adjustment automatically compensated for all changes of temperature and pressure occurring during the analyses.

Carbon dioxide was determined by measuring the absorption in the potassium hydroxide solution, oxygen by absorption in the alkaline pyrogallol solution, and unsaturated hydrocarbons, such as acetylene, ethylene and benzene, by absorption in fuming sulphuric acid. Paraffin hydrocarbons were estimated from the data obtained by measuring the contraction caused by combustion and the volume of carbon dioxide formed.

Pisa Gas.

Methane was the chief constituent, occurring to the extent of 80 per cent.

Analysis gave—

	Per cent.
Carbon dioxide. CO ₂	3.5
Methane CH ₄	80.0
Ethane. C ₂ H ₆	4.0
Oxygen. O ₂.....	.6
Nitrogen. N ₂	11.9

An analysis by Gigli in 1912 gave (Chem. Zeit. 1912-36-511)—

	Per cent.
Carbon dioxide.....	3.8
Methane.....	80.7
Ethane.....	6.0
Carbon monoxide }.....	Traces
Oxygen }	
Heavier hydrocarbons.	

Bath Gas.

The gas consisted almost entirely of nitrogen. Its origin is probably dissolved air in the waters, which percolating through the ground finally issue as the hot springs. The oxygen of the air would be used up during the underground passage, leaving the nitrogen and argon to bubble out with the water.

An analysis by Sir William Ramsay in 1912 is given for comparison (Chem. News, Vol. 105, p. 134, 1912). The carbon dioxide in the present

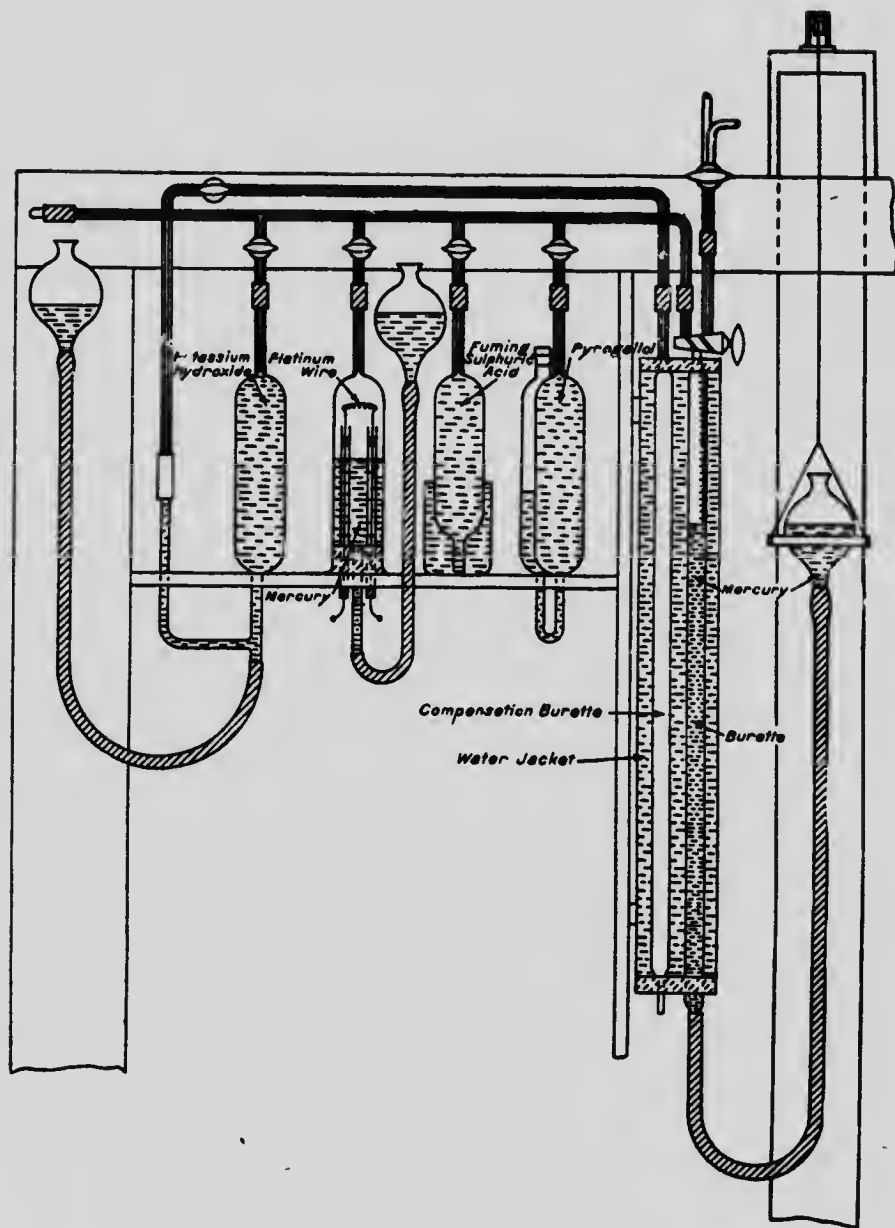


FIG. 18. Burrell gas analysis apparatus.

analysis is low on account of the sample having been kept over water which was several times changed and in which the carbon dioxide would dissolve.

	Present analysis.	Ramsay.
	Per cent.	Per cent.
Carbon dioxide. CO_2	2.4	3.6
Oxygen. O_2.....	.5	—
Methane CH_4	—	—
Nitrogen. N_2	97.1	96.4

Heathfield, Sussex.

The sample was taken from a boring situated close to the L.B. & S.C. Railway Station. The boring was drilled in 1896 and is 300 feet deep. It is said at that time the gas issued at a pressure of 140-200 lbs. per square inch, though when the sample was collected on March 14, 1918, the pressure was only equal to about 3 inches of water.

At present the gas is piped into a small gasometer and used to light the railway station.

Analysis gave the following results:—

	Per cent.
Carbon dioxide. CO_2	None
Oxygen. O_2.....	.5
Methane. CH_4	80.0
Ethane. C_2H_6	1.1
Nitrogen. N_2	18.4

An analysis of a natural gas at Heathfield was made by H. B. Dixon and W. A. Bone in 1902 (Proc. J. C. S. 1903, p. 63) with the following results:—

	Per cent.
Carbon dioxide. CO_2	None
Oxygen. O_2	None
Methane. CH_4	93.16
Ethane. C_2H_6	2.94
Carbon monoxide. CO	1.0
Nitrogen. N_2	2.9

March 18, 1918.

APPENDIX.

GAS DENSITY BALANCE.

PRINCIPLE OF METHOD.

The gas density balance consists essentially of a bulb, beam and counterpoise, adjusted to balance when the buoyancy of the gas displaced by the bulb compensates for the difference in weight of the bulb and counterpoise. If equilibrium is obtained in each of two gases by adjusting the pressure of the gas surrounding the balance the ratio of these pressures is of the inverse ratio of the densities of the gases.

Let a = density of air at p_0 mm. pressure.

Let g = density of gas at p_0 mm. pressure.

Let p_1 = pressure at which beam balances in air.

Let p_2 = pressure at which beam balances in the gas for the same scale reading.

The buoyant effect of the air displaced

$$= K a \frac{p_1}{p_0} \text{ where } K \text{ is equal to a constant depending on the difference in the volume of bulb and counterpoise.}$$

The buoyant effect of the gas displaced

$$= K g \frac{p_2}{p_0}$$

$$\text{then } a \frac{p_1}{p_0} = g \frac{p_2}{p_0}$$

$$\therefore \frac{g}{a} = \frac{p_1}{p_2} \text{ or } g = a \frac{p_1}{p_2}$$

DESCRIPTION OF APPARATUS.

The Balance.

The balance consists of a Silica bulb about $\frac{3}{4}$ inch diameter fused to a beam of the same material about $\frac{1}{32}$ inch diameter. The beam carries a screw thread and aluminium adjusting nut and a fixed iron counterweight at the opposite end, together with a small mirror (see Fig. 19). The beam

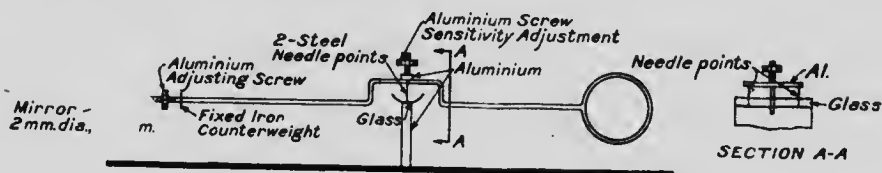


FIG. 19. Silica balance.

is mounted on an aluminium bridge carrying two needle points which have for their bearing surface a shallow glass trough. A small aluminium nut, screwed on an upright from the upper side of the bridge, serves to

adjust the sensitivity of the balance. The section AA, Fig. 19, shows the arrangement of the bridge and support.

The support is fixed on a base which slides into a glass tube 1.2 inch diameter which constitutes the balance case. This case is closed at one end by a glass plate and is connected at the other end to a gas burette, mercury pump and manometer.

Magnetic release.

To avoid displacement of the balance on its points of support during the transference of gases into or out of the apparatus the beam is held in position by the attraction of the iron counterweight to a bar magnet hung just below it, underneath the case.

The counterweight and magnet serve another purpose. During measurements the balance can be given a slight oscillation by bringing the magnet above or below the iron rider.

Index scale and pressure readings.

A beam of light reflected on to a scale one metre distance from the small mirror fastened to the counterpoise end of the beam serves as an index to determine the position of equilibrium on the balance. The mirror is 2 mm. in diameter and weight 12 mg. Corresponding readings agreeing to less than 1 mm are obtained. The pressure, corresponding to the scale reading is read with an accuracy of half a millimetre on the manometer scale. Small changes of pressure, sometimes required to bring the spot on the scale to a desired reading, can readily be obtained by unscrewing the clip on the rubber-tubing of the mercury reservoir attached to the manometer and thereby altering the level of the mercury in the pressure gauge and by that means the pressure of the gas in the balance case.

Apparatus for transferring gases.

Fig. 20 shows the arrangement of burette mercury reservoir and gas sample tube from which gas is passed into the balance case. The volume used can be measured in the burette and the gas let into the case, after drying in the P_2O_5 tube, as required. After a series of readings have been made the gas is pumped out back into the gas sample tube with the Töpler mercury pump.

Manipulation.

The balance case and drying tube are exhausted and the gas burette filled with mercury. A gas sample is passed into the burette from the gas tube in the mercury reservoir and after drying some gas is allowed to pass into the balance case until the beam is balancing in a horizontal position, the magnetic control having been removed. Several readings of the scale division corresponding to that particular pressure are taken after oscillations of the balance. The pressure of the gas is altered by a few mms. and the corresponding scale readings are determined. After having obtained a series of such readings the magnetic control is replaced and the gas pumped out. Dry air is passed in and the pressures corresponding to the same scale readings previously obtained for the gas are obtained.

The ratio of the pressures for corresponding readings with the balance in equilibrium in air and in the gas give the density of the gas relative to that of air or by a simple calculation the absolute density of the gas taking the density of air to be 1.293 gms. per litre at normal temperature and pressure.

Sensitivity.

When the balance is in equilibrium in air a change of 1 mm. pressure causes a change in scale reading of 3 mms. One mm. change in pressure alters the density of air by .0017 mg. per c.c., therefore a change in density of .0006 mg. per c.c. can be detected. The manometer used, however, cannot be read to less than .5 mm., therefore .00085 mg. per c.c. change of density is the limit of accuracy. One per cent of air or nitrogen alters the density of pure C gas by .01 mg. per c.c., therefore the presence of at least 1/10 per cent of either of these impurities is readily determined.

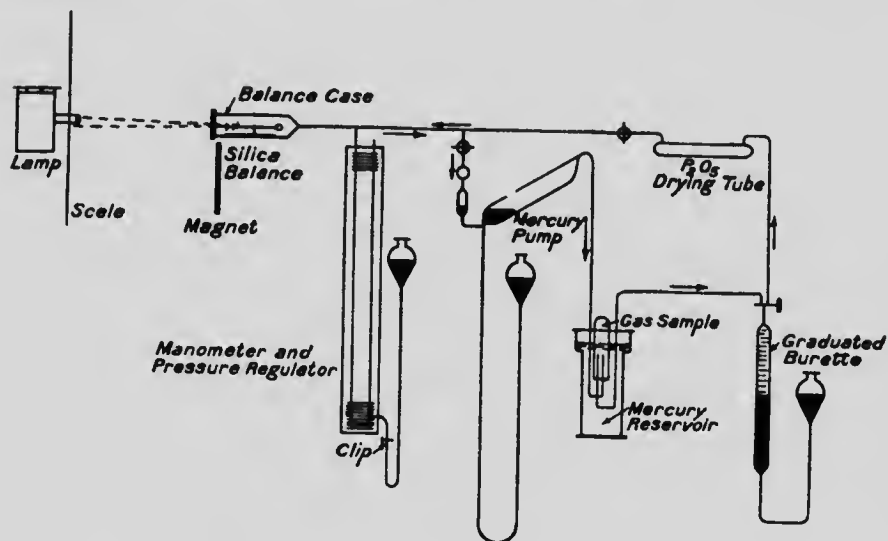


FIG. 20. Gas density balance. (Diagrammatic Sketch.)

Example of method of calculation.

Density of sample of C gas, purified by passage through cocoanut charcoal cooled in liquid air.

Scale reading.	Corresponding pressure of C gas.	Corresponding pressure of air.	Ratio.	Density of sample gm. per litre N.T.P.
25.0.....	mm. 346	mm. 48	.1385	.1792
22.6.....	386	53.5	.1383	.1791
20.0.....	428	59.5	.1387	.1795
			Mean ..	.1794

The density of pure C gas, according to the latest determination* is .1785 gm. per litre. One per cent of nitrogen or of air in C gas increases its density by .01 gm. per litre, therefore the purified sample of density .1794 gm. per litre contains less than 1/10 per cent impurity, assuming the impurity to be nitrogen or air.

* The Density of Helium. T. S. Taylor. Phys. Rev., Vol. 10, pp. 653-60. 1917.

Analysis of mixtures of gases by means of the density balance.

The balance is intended to measure the density of pure C gas or of mixtures containing a high proportion of C gas. If the mixture consists of C gas and another constituent, the nature of which is known, the percentage composition can be calculated from the found value of the density of the mixture and the respective densities of the constituents.

For a mixture of three gases the density of the mixture and the percentage of one of them must be known to determine the percentage of each—assuming the qualitative composition is known of course. This can readily be carried out with mixtures of C gas, nitrogen, and oxygen, methane or hydrogen for example as either of the latter gases can be determined by analysis in the usual way. The mixture C gas, nitrogen, argon, could be analysed by determining the density and the percentage of nitrogen by absorbing it by hot calcium metal.*

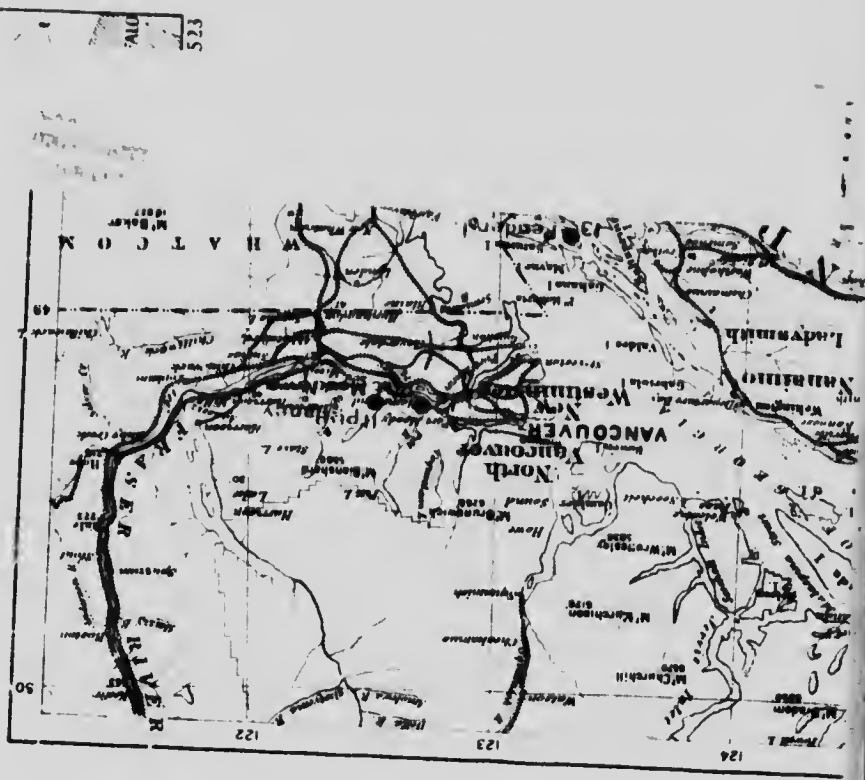
* Sieverts and Brandt. *Zeit angew Cham.*, 1916, pp. 207-402. Soddy. *Proc. Roy. Soc.* 1906. 78 A. 429.



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Map showing location of Natural Resources
Scale: 35 miles

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Map of Natural Gas wells in British Columbia
Scale: 35 miles to 1 inch

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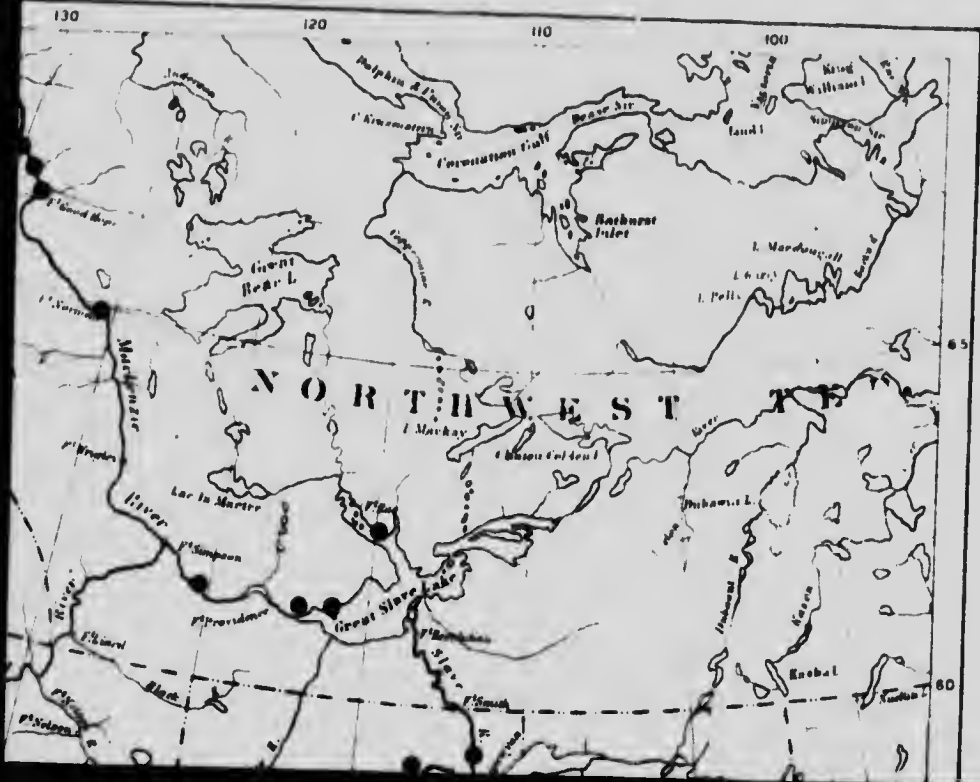
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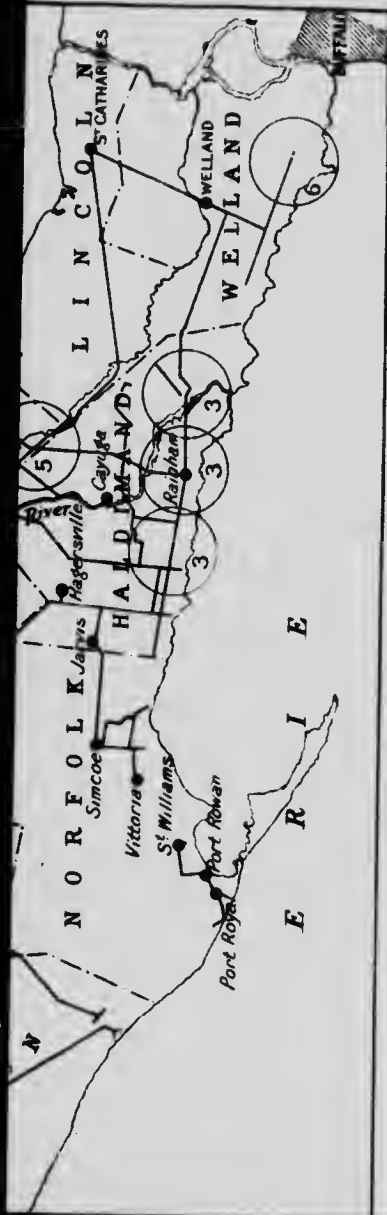


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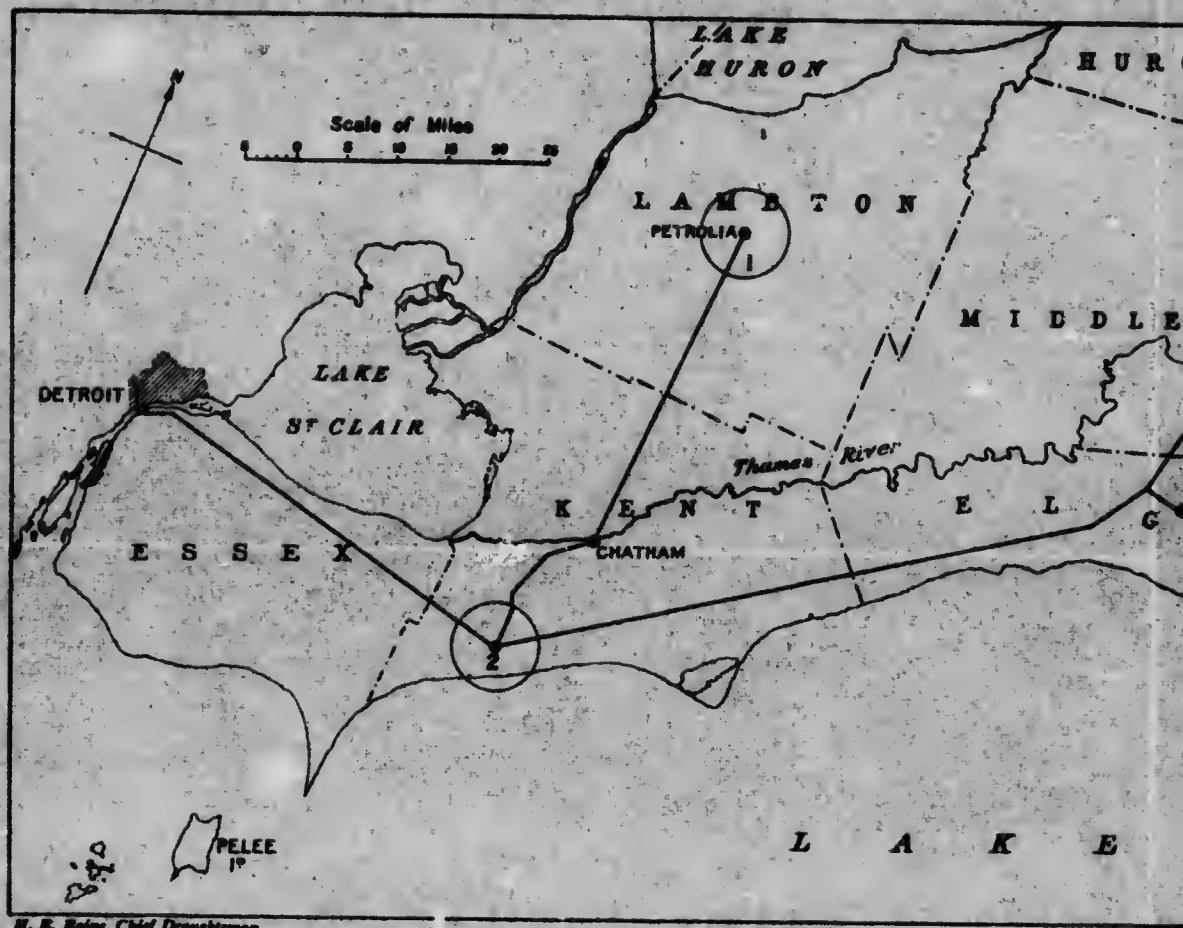




Gas and Pipe Lines in Southwestern Ontario

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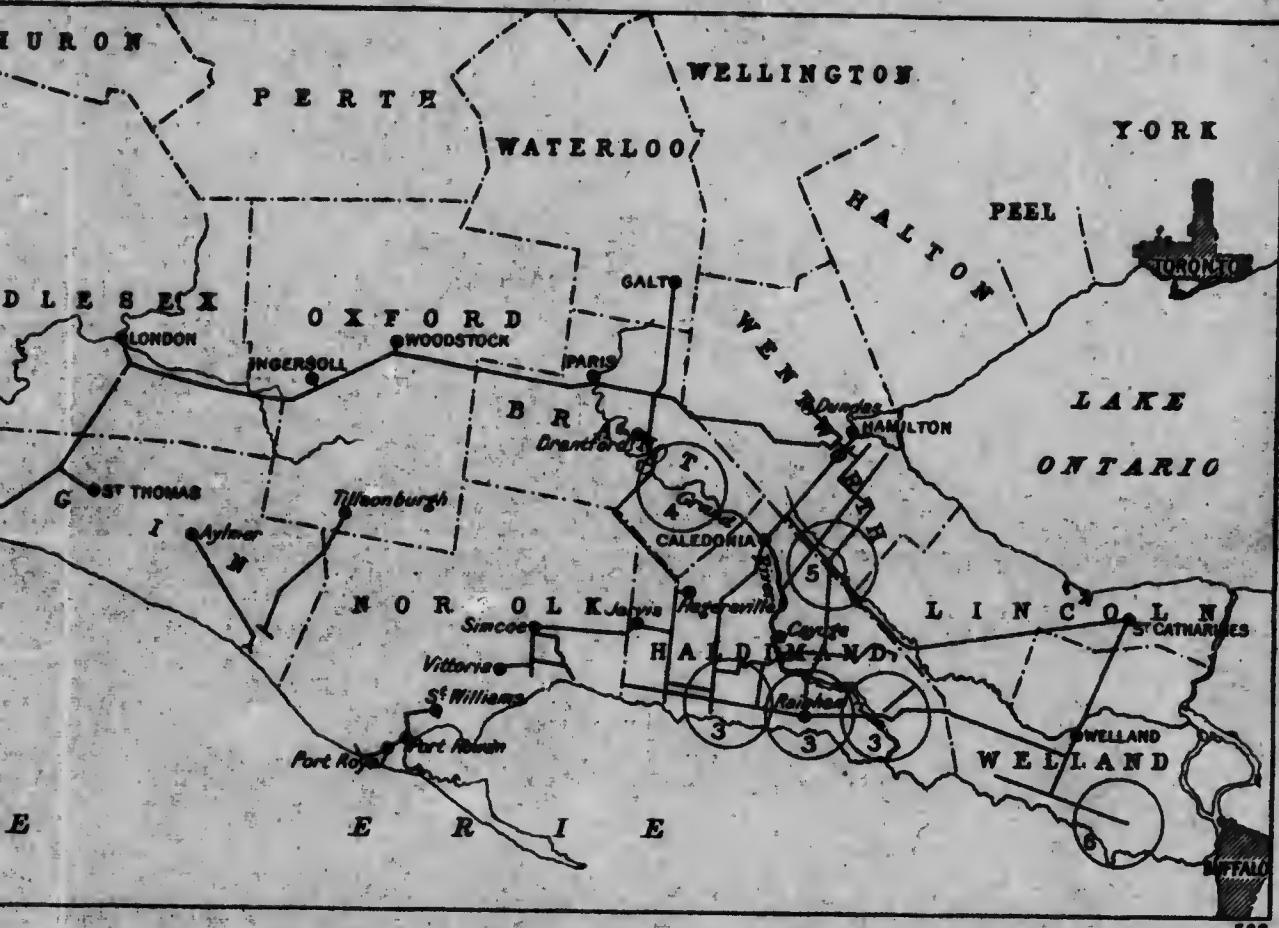
H. E. Bolser, Chief Draughtsman

Map showing Gas and Oil Fields and

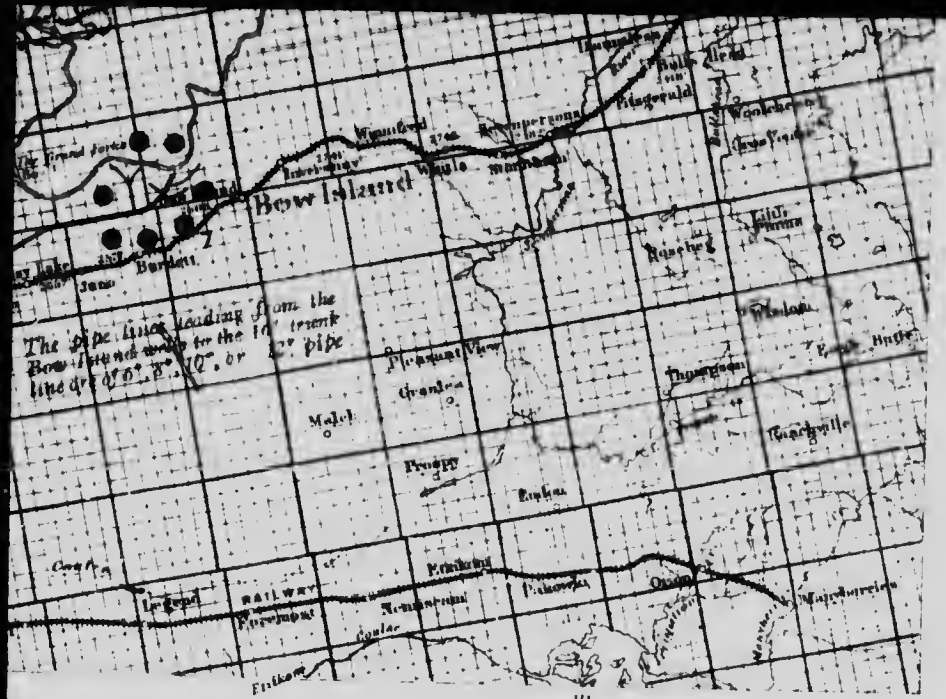
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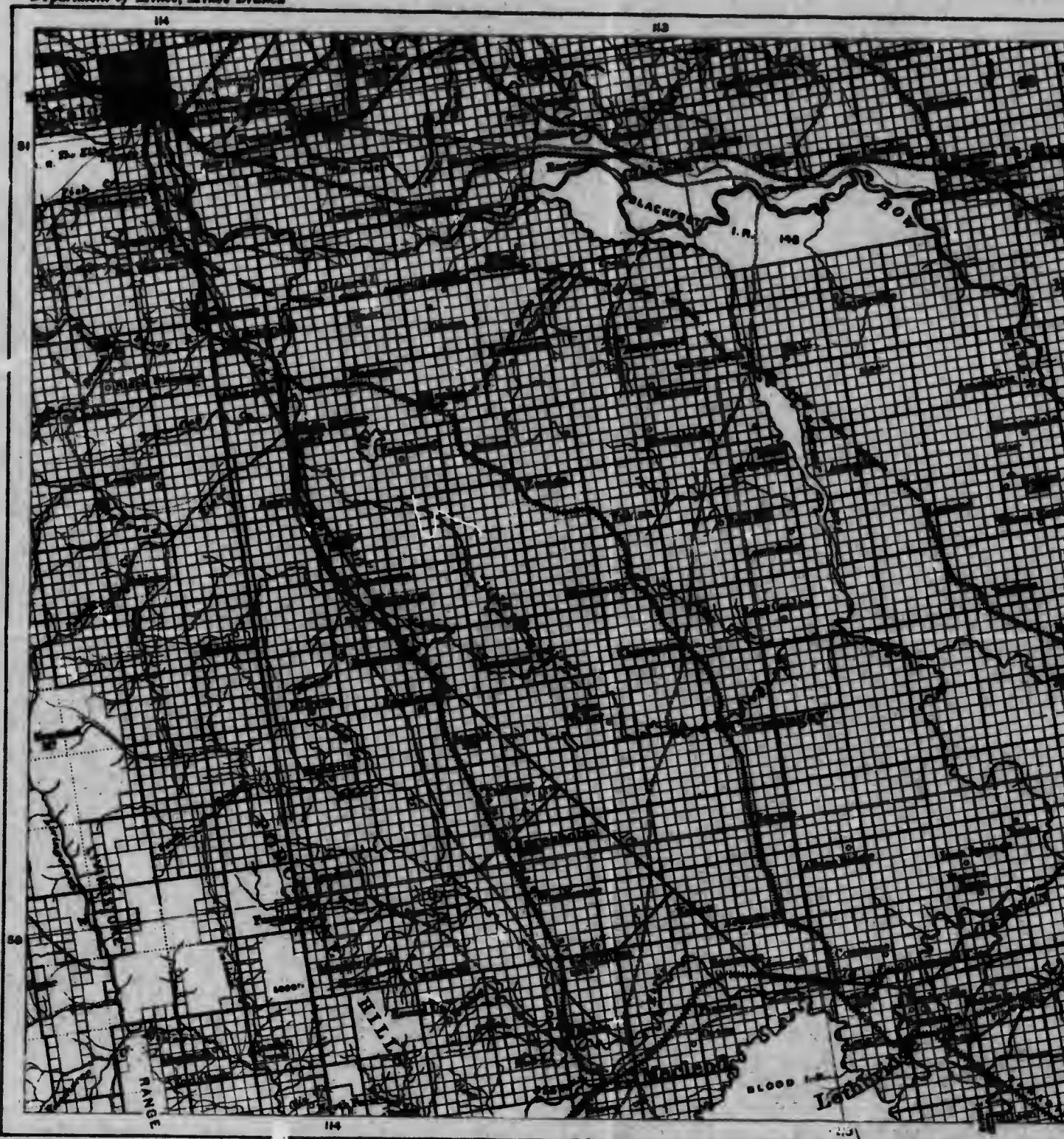
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Fields and Pipe Lines in Southwestern Ontario



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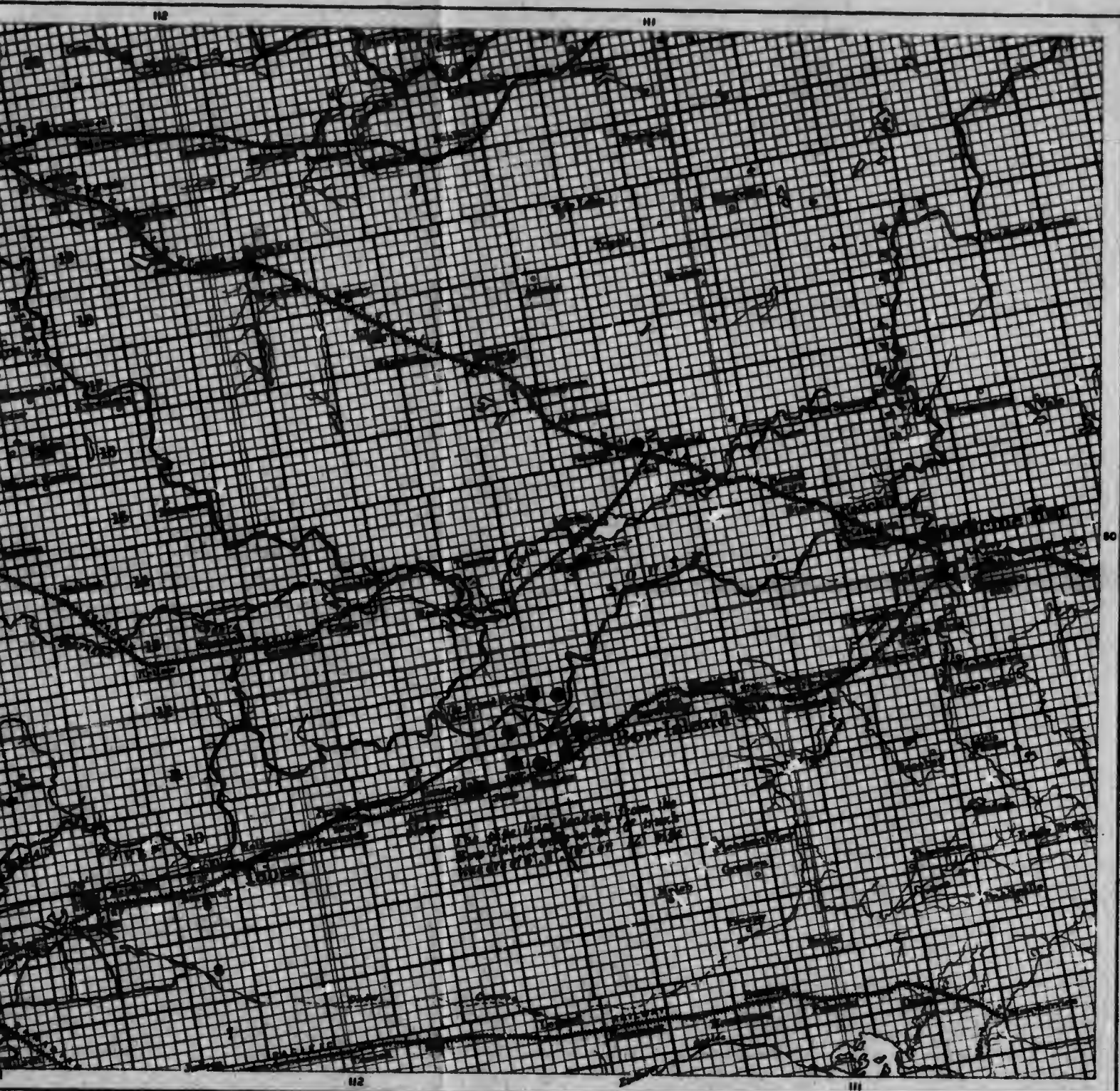
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