REPORT OF PROGRESS IN PEAT DEVELOPMENT

By
CLAYTON E. PLUMMER

Published By
**OFFICE OF THE COMMISSIONER
of the
IRON RANGE RESOURCES AND REHABILITATION**
R. E. WILSON, ***Commissioner***
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FOREWORD

The Office of Commissioner of the Iron Range Resources and Rehabilitation is charged with the responsibility of full development of Minnesota's natural resources through scientific research.

In Minnesota the lack of natural fuel has always been a drawback in the field of industrial development. However, the state has the largest deposit of peat of any state in the union, in fact, with the exception of Russia, Minnesota has the largest deposit of peat in the world.

Since the utilization of the enormous potential peat resources has become a successful venture in Europe, it seems perfectly logical that here in Minnesota we could profit by the experience of our foreign neighbors. With this in mind, competent personnel was selected and a research laboratory established at Chisholm, Minnesota in 1946. The main objective being to obtain a low cost fuel for the production of electric power which in turn would be used in the development of "grass root" industries within the state. These industries to be developed through utilization of our other natural resources.

The following report sets forth determinations, based upon a careful examination of what has been done in foreign countries on "peat for heat" development, as well as what has been accomplished by actual research using Minnesota peat at the Chisholm laboratory. The report is not conclusive and considerable research is still necessary.

R. E. WILSON
Commissioner

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ACKNOWLEDGMENTS

In the preparation of this bulletin, the writer has used much information that has been obtained from a large number of publications written not only in the United States, but in Canada, Ireland, Sweden, Finland, and Russia.

Wholehearted cooperation has been received from technical men in foreign countries interested in development, production, and burning of peat fuel. We extend our appreciation to the following for their excellent cooperation: from Ireland, Mr. J. Martin, and Mr. H. M. S. Miller, Technical Development Director, both of the Bord Na Mona Experimental Station, and Mr. A. Harkin, Chief Engineer, Design Department, Electricity Supply Board; from England, Mr. E. L. Luly, Babcock and Wilcox, Ltd.; from Finland, Mr. Bengt Zimmermann, Kymene Aktiebolaget, and Mr. Jaakko Paalasmaa, Peat Instructor; from Sweden, Mr. S. M. Hjelte, Aktiebolaget S. M. Hjelte and Company; from Denmark, Mr. Jorgenson, Kaas Briquetting Factory; and from Russia, Dr. Ivan Pavlovich Bardin, Vice President, Academy of Sciences, USSR.

Kind and helpful criticism and suggestions in the writing of this report have been obtained from Mr. O. A. Sundness, General Manager, Snyder Mining Company; Mr. R. L. Fitzgerald, Vice President, Duluth Steam Corporation; Mr. H. Schlenk, Jr., Northwest Paper Company; Mr. W. S. Moore, W. S. Moore Company; and Dr. T. L. Joseph, Asst. Dean of the Institute of Technology, University of Minnesota.

The writer wishes to express his appreciation to those assisting in the writing of this report: Dmitri Pouchak, William A. Rodean, William F. McDermott, Mechanical Engineer; Mary G. Sterle, Secretary; and (former employees) Andrew J. Shine, Mechanical Engineer, and Guilford Congdon; and others working on the project.

The Office of the Iron Range Resources and Rehabilitation wish also to express their appreciation to Odin A. Sundness, General Manager of the Snyder Mining Company for the use of their sample house at Shenango; also to the State Division of Lands and Minerals for the use of their laboratory at Hibbing, Minnesota.

REPORT OF PROGRESS IN PEAT DEVELOPMENT

INTRODUCTION

The rapidity with which reserves of direct-shipping ores are vanishing spotlights the growing need for a cheap local fuel for the beneficiation of low-grade ore. It is generally recognized that low-cost fuel is of prime importance for sound industrial development.

The use of peat as a fuel in Minnesota dates back to the early 1870's, when a committee of the Legislature of Minnesota made an investigation on the use of peat as a fuel in locomotives. During the winter of 1919-1920, powdered peat was used as a fuel to heat the Phoenix Building in Minneapolis.[1]

In 1926, the United States Bureau of Mines published Bulletin No. 253, "Possibilities for the Commercial Utilization of Peat," by Odell and Hood. The bulletin clearly presents their study of the published work of other investigators, operating methods of companies successfully producing peat, available information and scientific cost data, small laboratory tests, relative commercial value of peat, and reasons for peat failures. The principal reasons for failures twenty-two years ago were that peat fuel could not compete with the cheap coal of that time and that there was a lack of information and development on excavating, macerating, and conveying equipment; and insufficient knowledge on the efficient drying of peat. Higher fuel prices and recent development in better excavating and drying methods have, to a great extent, removed the reasons for failures existing twenty-two years ago.

The potential fuel value of Minnesota's peat bogs has been fully recognized for years by the St. Louis County Board, the Duluth Engineers' Club, the Engineers' Club of Northern Minnesota, the Junior Chamber of Commerce, Mr. Odin A. Sundness, Mr. Robert L. Fitzgerald, and other engineers.

In September 1943, Robert L. Fitzgerald submitted a report entitled, "Report of the St. Louis County Sub-Committee on Peat," to Arthur G. Schadewald, Chairman of the County Commissioners of St. Louis County. The report covered the Committee's findings under the following subject headings: Previous Report; Value as Fuel; Handling Bulk Materials; the Developments in Recovering and Using Peat; Peat Products—Local, State, and National Interest; Conclusions; and Recommendations.

[1]Pulverized Peat Fuel a Success, by C. L. Bohannan, Journal of the American Peat Society, Vol. XIV, No. 3, July, 1921, pp. 19-20.

The report was clearly written and is an important step in the present "Peat for Heat" development in Minnesota.

The County Board of St. Louis County realized that a sufficient source of fuel for gas and electric power must always be available for treating our taconite ores. They accordingly made a request to the Duluth Engineers' Club and the Engineers' Club of Northern Minnesota to study the possibilities of the use of peat for fuel. Committees were appointed by each club which studied the subject constructively. These committees then met jointly, drafted and presented a report to the Governor and a group of legislators in St. Paul, requesting study and action by the State. This presentation was made at the Lowry Hotel by Mr. O. A. Sundness on March 26, 1945.

In April 1945, Robert L. Fitzgerald and Odin A. Sundness submitted a joint report to the Peat Committee on the subject, "Electric Power, Generated by Steam from Peat Fired Boilers." This report shows probable cost of peat fuel needed to operate a 45,000 kw plant at unit costs of peat fuel ranging from $0.50 to $1.10 a ton.

The Office of the Iron Range Resources and Rehabilitation Commission recognized that the development of peat for fuel necessitates the application of research and engineering. In April 1945, following the meeting at the Lowry Hotel on March 26, 1945, Robert E. Wilson, Commissioner of the Iron Range Resources and Rehabilitation Commission, authorized an investigation on "Peat for Heat" development; and in June 1946, established an office at Chisholm, Minnesota; and appointed Clayton E. Plummer, Chemical-Metallurgical Engineer, to evaluate present and proposed methods for making peat fuel and, if possible, to develop a more economical process.

The Iron Range Resources and Rehabilitation Commission has attacked the problem by making an exhaustive study of all literature pertaining to the subject. Correspondence with authorities in Russia, Ireland, Sweden, Denmark, Finland, Canada, and other countries in which peat is used commercially, has brought forth valuable information that would otherwise have to be obtained through expensive experimentation. In addition to these studies, many experiments have been conducted, results of which are incorporated in this report.

Part I
PEAT IN MINNESOTA

CHAPTER I

ORIGIN, NATURE, AND PROPERTIES OF PEAT

The peat of Minnesota owes its origin directly or indirectly to the influence of glaciation, which altered the surface of the land by forming basins and damming up drainage channels. Climatic, topographic, and geologic conditions are important factors in the origin of peat. Aquatic plants, upon decomposition in acid waters in the absence of sufficient air, leave their remains as peat. Where the depth of water is less than 10 feet, a deposit may represent a single type of plant. Sedges which grow near the water's surface also contribute to the formation of peat. Herbs may replace the sedges above the water level and the Sphagnum (moss) usually takes possession about 6 inches above the surface of a peat accumulation. Finally, trees become the dominant plants. Peat which has been formed in basins as a result of the decomposition of aquatic plants, sedges, herbs, and moss, is found in low, wet areas called bogs, swamps, and marshes. "Filled-in deposits" are formed by the filling of lakes or ponds with plant remains; and "built-up deposits" are formed as the result of the accumulation of partly decomposed plants on flat, wet, marsh surfaces.

Peat is an accumulation of partly decomposed plant life varying in consistency from a fibrous matted material to a highly decomposed mud, generally having a moisture content of 88 to 93 per cent.

Classification of Peat—According to the locality in which the bog occurs, peat may be classified into: 1. lake peat, 2. lowland peat, 3. upland peat, and 4. forest peat.

1. Lake peat is a sticky, plastic or pulpy, sedimentary material consisting of well decomposed aquatic plants mixed with some clay and sand occurring at the bottom of filled-in lake deposits.

2. Lowland peat is usually a second stage of marsh growth consisting of the partially decomposed remains of lake shore plants such as reeds, grasses, shrubs and small trees. Certain shallow bogs may consist wholly of grass remains.

3. Upland peat is composed largely of live and partially decomposed sphagnum mosses and heath. Such a deposit usually covers lowland or forest peat deposits.

4. Forest peat, as the name implies, consists of the accumulation of dead leaves, wood and trees, together with sphagnum mosses and heath. It is considered the final stage of filled-in lake deposits, the trees growing over the bog following the heath growth.

CHAPTER II

THE PEAT DEPOSITS OF MINNESOTA

E. K. Soper,[1] has so thoroughly discussed the peat deposits of Minnesota, that we shall quote him as follows:

> "**Depth of Accumulation**—The limitation in vertical thickness of all peat bogs is determined by the form of surface upon which the bog develops, as pointed out by Shaler. In Minnesota, deposits formed by the filling in of lake basins are deeper as a rule than those formed on low, flat, swampy surfaces. On the other hand, in many basins the deposition of vegetation has, for some cause, been arrested, and the process of peat accumulation stopped. Under such conditions, the peat in the built-up deposits might be of greater thickness than in lake basins.
>
> "There is a large variation in the thickness of the peat bogs throughout the state. Those in the southern portion are, in general, much more shallow than those in the north. In these southern deposits, the peat varies in thickness from merely a thick peaty sod of a few inches, up to 18 feet. Only two or three localities were found south of the Twin Cities, where the latter depth was obtained. The average thicknesses attain a depth of 20 to 25 feet in the center of the bog. The maximum thickness recorded is 63 feet in St. Louis County, near Central Lakes Station, on the Duluth, Winnipeg Railroad. This bog is crossed by the railroad and much trouble has been experienced in keeping the tracks in condition, where they overlie the deeper portions of the deposit.
>
> "At several other localities, notably the Corona Bog, at Corona, Carlton County, the deposits were so deep in the center that bottom was not reached with a 25-foot Davis sounding rod. These bogs are all of the filled-lake type.

[1] University of Minnesota Bulletin, No. 16.

"The average depth of peat over the great built-up deposits occupying portions of the bed of Lake Agassiz in north central Minnesota is about 7 to 9 feet. The thickness increases to 18 or 20 feet in many places, which apparently overlie depressions and hollows in the former lake bed.

"In northwestern Minnesota, in Marshall and Roseau Counties, some of the largest unbroken areas of peat in the state occur, but these are usually shallow. The average depth of peat over this region does not exceed 4 or 5 feet. Most of this region has been burned over, which probably accounts for the shallow depths.

"In northeastern Minnesota the peat bogs are chiefly of the filled-lake type. In St. Louis County and the western part of Lake County, the thickness is variable. The deepest portion of the deposit is usually near the center, and the thickness gradually diminishes as one approaches the edge of the bog, which corresponds with the rim of the basin in which the peat accumulated. The average depth attained in the center of these bogs is about 12 to 15 feet.

"Total Quantity of Peat in Minnesota—According to the report of the state engineer, Minnesota had originally about 10,000,000 acres of swamp lands, or lands too wet in their natural condition for agricultural purposes. This vast area comprises about one-fifth of the total area of the state. Not all of this swamp land was covered with peat, however, and millions of acres have been drained and converted into productive farms, while additional areas are being reclaimed each year. From the investigations made in the preparation of this report, it is estimated that about 7,000,000 acres, or approximately two-thirds of the original swamp area was originally covered with peat deposits, varying in thickness from a few inches to 30 feet or more. Of this peat land, it is estimated that about 5,217,000 acres are covered with peat at least 5 feet thick. Since this thickness (5 feet) is the minimum which can be profitably worked in the manufacture of machine peat fuel, only the deposits which attain a depth of 5 feet have been included in the estimate of the peat fuel resources of Minnesota. The average thickness of the peat in some counties in the state is greater than 5 feet, as in Beltrami, Koochiching, and St. Louis counties, where the average is 7 feet. The quantity of peat fuel (machine peat) available has been estimated separately for each county containing large peat deposits with an average thickness of 5 feet or more. The total quantity of machine peat fuel of good quality in Minnesota occurring in deposits 5 feet or more thick, estimated on a basis of 200 tons of air-dry machine peat per acre per foot of thickness of peat is approximately 6,835,300,000 tons.

"The estimates for the different counties containing important peat deposits are given below.

Table Showing Approximate Quantity of Peat Fuel of Good Quality Available in Minnesota, by Counties

County	Area of peat deposits, acres	Average thickness of peat, feet	Quantity of air-dried machine peat fuel available, tons
Aitkin	397,300	6	476,760,000
Anoka	30,000	7	42,000,000
Becker	12,800	5	12,800,000
Beltrami	1,299,200	7	1,818,880,000
Carlton	35,000	10	70,000,000
Cass	75,000	5	75,000,000
Clearwater	128,000	5	128,000,000
Crow Wing .	61,300	6	73,560,000
Douglas	5,000	6	6,000,000
Hubbard	10,000	6	12,000,000
Isanti	10,000	5	10,000,000
Itasca	250,000	6	300,000,000
Koochiching	1,000,000	7	1,400,000,000
Lake	150,000	6	180,000,000
Marshall	50,000	5	50,000,000
Mille Lacs	25,000	5	25,000,000
Morrison	10,000	5	10,000,000
Otter Tail	75,000	5	75,000,000
Pennington	10,000	5	10,000,000
Pine	75,000	5	75,000,000
Ramsey	1,500	5	1,500,000
Roseau	250,000	5	250,000,000
St. Louis	1,192,000	7	1,668,800,000
Todd	10,000	5	10,000,000
Wadena	5,000	5	5,000,000
All others	50,000	5	50,000,000
Total	5,217,100		6,835,300,000

"It is believed that the above estimates are conservative. Soundings in areas which on account of high water it was not possible to visit in preparing this report, will probably show that the average thickness of the peat in some counties is greater than the thickness given above.

"**Physical and Chemical Properties of Minnesota Peats**—The color of the peat in Minnesota bogs ranges from black to yellowish green, but by far the greatest part of it is dark brown. Next to dark brown, a light brown, or yellowish brown color is most common. All of the peat, regardless of the color when first dug, changes to a slightly darker shade within a few minutes after it is exposed to the air. As it dries, it gradually becomes lighter in shade until finally, when completely dried, the color is decidedly lighter than that of the freshly exposed material.

"The sphagnum peat in the big muskeg swamps of northern Minnesota is practically all of the same dark brown color. In the deeper portions of the bogs, where pond peat, or peat which has accumulated under water, is encountered, it is of a much lighter shade and frequently has the greenish color which is typical of peat formed from aquatic plants.

"The typical sedge-grass peat is yellowish brown, but this also often appears greenish in the lower levels of the deep bogs.

"Black peat has been found only in the bottom portions of the Minnesota bogs. It is usually structureless, and contains considerable soil or mineral matter. It represents the first layers of plant remains which accumulated, and which became mixed with the mud or soil on the original surface of the marsh, or on the bed of the lake in which the peat formed. Muck or very peaty soil, is black, but this material is not true peat, and occurs only in shallow 'sloughs' or meadows, and along some stream valleys.

"In texture, the Minnesota peats also vary greatly. The texture is dependent upon (1) the type of plants composing the peat, (2) the manner in which the deposit was formed, and (3) the state of decomposition. Most of the peat in Minnesota is fibrous or mossy. This is especially true of the sphagnum peat of the north, but the sedge-grass peat of the south is also fibrous except in the lower parts of the deeper bogs. The bottom portions of the deep filled-lake bogs usually consist of well decomposed material, in which the fibrous texture, if it ever were present, has been destroyed by disintegration. The upper 3 or 4 feet of the sphagnum bogs often consist of a dense mat of moss which shows scarcely any decomposition.

"Inspection of analyses shown in the appended table discloses the following facts. The peat containing the least ash was that in the sample from Koochiching County, Locality 202, analysis 128. This sample which is a composite of four samples collected at intervals of one-fourth of a mile along a line across the bog, contains only 4.15 per cent ash. Many contained less than 10 per cent of ash, while the average ash content of the peat of all the big muskegs of the northern counties is well under 15 per cent, the limit for good fuel.

"The peat in central and southern Minnesota contains much more ash than that of the north, and consequently most of these southern bogs are unsuited to the manufacture of peat fuel.

"The amount of fixed carbon in the peat of the big deposits in the northern part of the state is, on the average, about 20 per cent. The southern bogs contain a much smaller proportion of fixed carbon.

"One of the most noteworthy features of the peat of the state is its unusually high nitrogen content, which will average about 2.25 per cent. The proportions of nitrogen actually found in the 246 samples analyzed varied from .93 per cent at Locality 126a in Koochiching County (analysis 116), to 3.66 per cent at Locality 246 in Hennepin County (analysis 92). Only a few of the samples show a nitrogen content of less than 1.5 per cent.

ANALYSES OF PEAT SAMPLES FROM MINNESOTA
(Analyzed by U. S. Bureau of Mines)[1]

County	Analysis No.	Proximate Volatile Matter	Proximate Fixed Carbon	Proximate Ash	Ultimate S	Ultimate N	B.t.u. Value Moisture Free
Koochiching	128	74.54	21.31	4.15	.23	2.49	9,211
	116	42.25	11.27	46.48	....	.93	
Hennepin	92	62.00	17.66	20.34	.61	3.66	8,014
Crow Wing	79	61.23	17.51	21.26	.13	2.65	7,456
Marshall	140	67.73	18.18	14.09	2.55	2.81	8,153
St. Louis	186	64.87	24.19	10.94	.27	1.39	8,363
	188	59.82	26.66	13.52	.29	1.63	7,862
	206	74.17	22.60	13.23	.21	2.68	8,637
	218	69.94	21.88	8.18	.30	2.80	9,059
	225	62.36	24.49	13.15	.36	2.42	8,753

"The sulphur content of the Minnesota peats is more constant than that of any of the other constituents. The proportions of sulphur shown by analyses varies from .13 per cent at Locality 165 in Crow Wing County (analysis 79), to 2.55 per cent at Locality 135 in Marshall County (analysis 140). The amount of sulphur in the great majority of samples is very low. Out of the 246 samples analyzed, only 12 contained sulphur in excess of .99 per cent.

"No average analysis of Minnesota peats has been computed for the reason that the figures would be entirely misleading. A few samples of muck from southern Minnesota, with abnormally high ash content, would raise the average ash content to such a point as to con-

[1]The data included in this table has been selected from "Peat Deposits of Minnesota," by E. K. Soper, Bulletin No. 16, University of Minnesota, 1919.

vey an entirely erroneous impression as to the quality of the greater part of the peat of the state."

The results of peat taken from the Balkan bog near Chisholm, Minnesota, are similar to those reported on St. Louis County peat, and are presented in a later chapter.

Peat, a Potential Asset—Minnesota's 7,000,000 acres of peat lands representing approximately 50 per cent of the peat in the United States, is a potential asset provided an economical method can be developed for the winning of peat.

Part II

REVIEW OF PEAT WINNING METHODS

CHAPTER III

The production of a dense, cheap fuel from peat containing 85-90 per cent water has been a difficult problem confronting many peat investigators for a long time. Although millions of dollars have been spent in efforts to obtain an economical process, the goal of success has not been entirely realized. Although millions of tons of peat are burned in foreign countries where coal is scarce and labor is cheap, no appreciable amount of peat is burned in the United States, where coal is plentiful and the labor costs are high. In order to determine if the "Machine Peat," "Milled Peat," and "Hydro Peat," the three principal methods, now used in foreign countries, would be applicable and economical in the United States, a careful study has been made by the Office of the Iron Range Resources and Rehabilitation at Chisholm, Minnesota. Our review of peat winning methods includes a description and evaluation of the commonly used and also the new proposed methods.

LIMITING VALUES OF VARIOUS PEAT FUELS

In our review of peat winning methods, which follows, frequent references will be made to production costs by the various methods. In making an economic study on utilization of peat, consideration has been given to moisture content and net fuel value of each type of peat. The limiting cost of any fuel can be determined by calculating the cost of a competing fuel such as coal in cents per million Btu and using this figure to determine the limiting value of any type of peat. The following table gives the average moisture content, net Btu value and limiting economic value per ton of fuel based on steam coal selling for $11.36 a ton, equal to $0.45 a million net Btu.

TABLE I

Limiting Value of Various Peat Fuels for Steam Raising

Type of Fuel	%	Net Btu	Value Per Short Ton Based on $0.45 a Million Btu	Recommended[1] Max. Cost Per Short Ton
Milled Peat	55	3346	$3.00	$2.40
Machine Peat	30	5784	5.20	4.20
Briquettes	10	7732	6.96	5.60
Anhydrous Peat	0	8705	7.83	6.30

[1]Recommended maximum cost is 80% of fuel value to provide for possible reduction of coal price.

Milled Peat—The low cost of $1.84 a long ton for 55 per cent moisture peat in Ireland might be increased to $2.32 a long ton in this country due to higher labor costs. Corrected to a short ton basis, a cost figure of $2.10 is well below our limiting cost figure of $3.00 a ton and should place peat in a position to compete with coal for steam raising on the Range in northern Minnesota.

Machine and Hydro Peat—Cost figures on machine peat, as produced in Canada, Ireland, and Finland, range from about $8.00 to $10.00 a ton, figures considerably above our limiting cost of $5.20 a ton. Cost figures on the hydro process also seem to be too high to compete with coal in northern Minnesota.

Suggestions as to how the machine peat process might be modified so as to be more productive and economical are presented in a later chapter.

CHAPTER IV

MACHINE PEAT

The original method of producing peat was by means of a spade. This was called "Cut Peat." This primitive "Cut Peat" method of winning peat produces a light, friable product which requires an enormous amount of hand labor and, therefore, would not prove economical in the manufacture of peat for fuel on a large scale. Efforts were made to convert peat into a more compact and durable form. Processes attempting to produce these desirable qualities in a peat fuel have been known under terms such as "Machine Peat," "Machine Method," "Pressed Peat," "Press Peat," "Wet-Process Peat," and "Condensed Peat." Six fundamental operations are necessary in the production of machine peat: (1) excavation, (2) maceration, (3) forming, (4) transportation, (5) spreading, and (6) harvesting.

The various processes may be divided into two classes which differ mainly in order of the operations. In Class I, the peat is formed immediately after being macerated and is then transported to the drying field as blocks. In Class II, the peat, after being macerated, is transported to the drying field and then formed into blocks by a paving and cutting machine called a "Press." In Class I, methods are employed in the systems of Wielandt, Strenge, Dolberg-Strenge, Dolberg, Bauman-Schenck, and others.[1] In Class II, methods are employed by the systems of Ekelund-von Porat, Anrep-Moore, Anrep Plant No. 1, Moore Plant No. 2, and the Canadian Peat Committee's Plant No. 4.

The Canadian Peat Committee (1919-1922) adopted the belt conveyor scheme as designed by Moore. It is significant that after using a rectangular track and tip car plan in its Plant No. 1, the Committee adopted belt conveyors for the three subsequent plants. Plant No. 4 represents the final development of an all-out effort on the part of the Committee to design and actually operate a commercial plant. The machinery used in this plant was capable of spreading peat to a distance of 850 feet from the working face at a production rate of 10 tons of peat fuel per hour (70 tons of wet peat). In comparison, European practice (1919-1922) was confined to a spreading distance of about 350 feet with production at about 4 or 5 tons of peat fuel per hour.

B. F. Haanel[1] states:

> "Every element of the redesigned combination Anrep-Moore Plant, or Plant No. 4, has been tried out in actual operation over an extended period and defects observed. The construction of the entire redesigned machine is rugged and should stand up under continuous operation for many years. Practically all of the parts are standard and can be readily purchased. The plant resembles the ordinary machinery used by contractors for the moving and loading of such materials as earth with the exception that, on account of the low specific gravity of peat, the ease with which it is excavated and its freedom from hard lumps and abrasive matter, it can be made much lighter. The caterpillar aprons are of standard design and are larger in proportion to the weight carried than would be required for harder ground. The entire plant is portable and can be moved from one part of a bog to another under its own power, or from one bog to another by dismantling."

The operation of Plant No. 4 during 1922, was considered very excellent by the Canadian Committee. It is estimated that based on present prices, the cost to produce one ton of peat fuel would be in excess of $8.00 a ton, a figure higher than our limiting cost of $5.20 a ton for machine peat.[1]

Modern European machinery spreads only a distance of about 200 feet with a production of 10 tons of fuel per hour.

Machine Peat in Ireland—Bord Na Mona, a statutory corporation entrusted with the development of the Irish peat industry, has submitted data and answered our questions relative to labor and power requirements for peat processes.

A 25,000 kw power station, designed to burn machine peat, is now being erected adjacent to one of Ireland's large peat deposits.[2] The machine peat will be produced by methods similar to those developed by the Canadian Peat Committee between 1918 and 1925, and to those used in Germany, Sweden, Finland, and Russia. The dried blocks or sods are approximately 9 by 3

[1]Peat, Its Manufacture and Uses, by B. F. Haanel, Final Report of The Peat Committee, Canada, 1926, p. 181.
[1]See Table I, "Limiting Values of Various Peat Fuels for Steam Raising."
[2]Communication from H. M. S. Miller, Bord Na Mona, Dublin, Ireland, June 27, 1948.

by 2½ inches in size. It is estimated that the cost of the peat fuel laid down at the bunkers will be $9.00 to $10.00 per long ton.

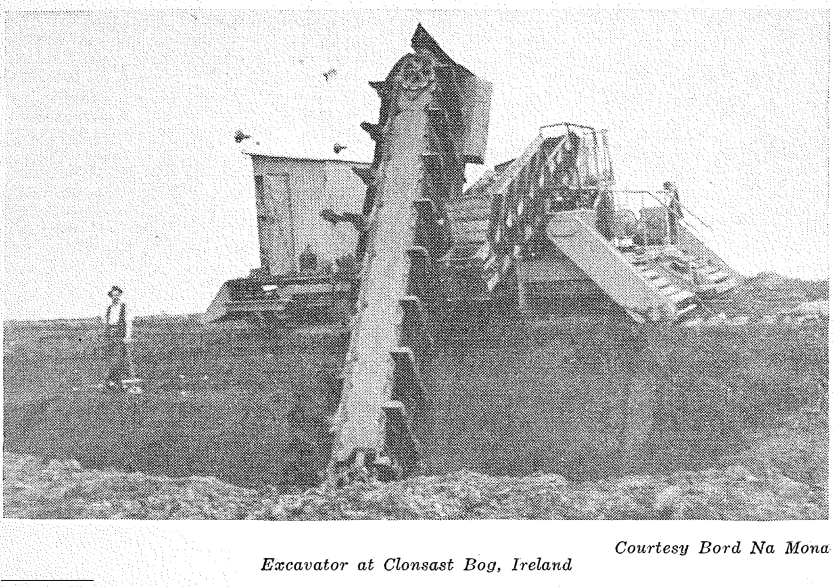
In a report of Bord Na Mona and Accounts for the Period, June 21, 1946 to March 31, 1947, it is stated:

> "The basic activity of the Board is concerned with the production of turf by mechanical processes and its sale at prices that enable it to compete effectively with other fuels. The total quantity of Machine-won Turf, including briquettes, produced in the year ended 31st March, 1947, was 113,985 tons, as compared with 92,097 in the previous year. The average cost of production of Machine-won Turf was 1 pound and 14 shillings per ton ($8.27 per ton),[3] and of briquettes, 3 pounds, 2 shillings, and 7 pence per ton ($15.23 per ton)."

In a communication from Bord Na Mona, dated December 14, 1948, Mr. H. M. S. Miller states:

> "Sod peat of about 30 per cent moisture content (6500 B.Th.U./Lb.) was sold ex-bog, this summer at 39 shillings and 6 pence per long ton ($9.60)."
>
> "—Household coal of between 10,000 and 12,000 B.Th.U./Lb. sold at 136 shillings per ton ($33.09) in the same period—."

A cost of $9.60 per ton for 6500 Btu machine peat would be prohibitive in the United States since labor costs are higher and coal is more plentiful.



Courtesy Bord Na Mona

Excavator at Clonsast Bog, Ireland

[3]U. S. equivalents in parenthesis have been inserted by the writer. We assume the ton referred to is the long ton.

The Report of Bord Na Mona and Accounts for the Year Ended 1st April, 1948, gives the following information.

> "Production and Disposal of Machine-Won Turf and Briquettes: The bogs at which machine-won turf was produced during the year covered by this Report were Clonsast, (Co. Offaly) Lyrecrumpane, (Co. Kerry) and Turraun, (Co. Offaly). Briquettes were manufactured at Lullymore Factory, (Co. Kildare). The total quantity of machine-won turf, including briquettes, produced in the period was 99,437 tons, as compared with 113,985 tons in the previous year. The average cost of machine-won turf, inclusive of interest, depreciation, and proportion of head office expenses, was 41 shillings and 3 pence ($10.00) per ton, and briquettes, 73 shillings ($17.76) per long ton.
>
> "The phenomenal and continuous snow falls and severe frosts during the first three months of 1947 prevented an early start to the production season and account for the reduced output shown above. This factor together with the increases in wages referred to in the Board's First Report resulted in an increase in the cost of production as compared with that of the previous year.
>
> "Kildare Emergency Scheme: The method by which this Scheme was operated and financed was set out in detail in the Board's First Report.
>
> "The Board produced 71,293 tons of hand-won turf on behalf of the Government under this Scheme during 1947. The total expenditure during the year was 288,156 pounds, 6 shillings, and 7 pence (about $19.00 a ton).
>
> "The number of employees maintained in Hostels at peak was 2,229. The cost of food, fuel for cooking, supervision, stores, transport and kitchen wages amounted to 29 shillings and 4½ pence per man per week. This figure does not include overhead expenses, depreciation and interest on capital. The charge made to workers for board and lodging was 1 pound per week.
>
> "The Board was instructed that production of hand-won turf under this Scheme would not be continued in 1948 and arrangements were, therefore, made to bring the Scheme to a close."

This recent information is interesting and shows the great difference in costs between machine and hand-won turf (peat) in Ireland.

Machine Peat in Finland—The State Central Committee of the Peat Industry, Helsingfors, Finland, is very active in peat development and have expressed a great interest in our peat development program.

In October 1947, Bengt Zimmermann, a Civil Engineer and a member of the State Central Committee, visited the Office of the Iron Range Resources and Rehabilitation at Chisholm, Minnesota, and discussed peat production in Finland. Mr. Zimmermann emphasized the fact that every bog presented its own problem and that peat varied to a great extent in the same bog, necessitating a careful study before the selection of a suitable method. The machine peat method is used by the paper company with which Mr. Zimmermann is connected. In Finland, peat is classified by numbers, 0 to 10; the live growing moss is "0" and the highly decomposed black peat near the bottom is "10." The peat at our pilot plant site on the Balkan Bog, located two miles north of Chisholm, was rated by Mr. Zimmermann about "5-7."

For successful operations for fuel, Mr. Zimmermann suggested that the quality of the peat should be 5-7 grade or higher. The bog should have only a thin surface of moss; be comparatively free from roots; have an excavating depth of at least 9 feet; be capable of complete drainage; have a regular bottom free from stones; and be accessible to transportation, cheap electric power, and sufficient drying fields. Mr. Zimmermann did not favor the milled peat process and stated that he had two factories equipped with Hesper Bagger Machines and two with Hydro Peat. Cost figures were indefinite and given in marks, without capital cost, as 1100 marks ($7.70) per long ton; better grade of coal sold for 3300 marks ($23.10) and low grade at 2300 marks ($16.10). Good dry peat in Finland contains only 4 to 5 per cent ash and has a Btu value of 9200 and a bulk density of 24 pounds per cubic foot.

In February 1948, as a result of Mr. Zimmermann's visit to the Chisholm Office, Leo Andersin, Helsinki, Finland, presented our peat library with 16 investigations on peat and peat production (No. 1-9, 1946 and No. 1-4 and 6-8, 1947). These are now being translated and this information will be presented in a later report.

Machine Peat in Russia—On June 16th, 1947, the Peat Library of the Iron Range Resources and Rehabilitation received from the Peat Institute Library in Russia, the following books:

Production of Peat Fuel, by Professor Goriachkin, Vol. 1, 1940.

Production of Peat Fuel, by Professor Goriachkin, Vol. 2, 1941.

A Resume of the Peat Industry of Capitalistic Countries During The War Years, by A. E. Probst, 1945.

A Directory or Consultant on Peat, N. N. Samsonov, M. A. Beller, and D. A. Begak, 1944.

Metallurgical Problems of the Northwest, by Professor I. P. Bardin, 1946.

These books are being translated; the following data on peat production in Russia was obtained from these translations.

The translation of Professor Goriachkin's article gives first-hand information relative to the production of peat fuel in Russia.

Following the revolutions in Russia, the greatest peat industry in the world was created. Both Lenin and Stalin emphasized the importance of peat fuel production in the State economy. As early as 1928, according to Professor Goriachkin, peat fuel production was 5,850,000 tons; by 1932, it was 15,000,000 tons, an increase of 257 per cent. Peat became one of the basic forms of fuel in Moscow, Lenningrad, and in the Gorky District.

Previous to the revolution, Russia obtained most of its peat by the elevator method, requiring hard manual labor. In the beginning of the Five Year Plan, only 18 per cent of all the peat was obtained by the hydraulic method. Four years later nearly 50 per cent of the peat was produced by mechanized methods.

The annual output of peat during the Second Five Year Plan reached approximately 32,000,000 tons.

A recent Russian article[1] describes the peat industry in Russia for the 30-year period from 1917 to 1947. The following tabulation shows approximate amounts of peat produced by the Machine, Hydro, and Milled Peat Methods and the total produced by all methods.

Year	Machine	Hydro	Milled	Total—All Methods
1931	2,500,000	2,500,000	5,000,000	12,500,000
1940	5,000,000	8,500,000	9,000,000	32,000,000
1942	3,000,000	5,000,000	3,000,000	14,800,000
1946	5,500,000	7,500,000	5,500,000	26,000,000
1947	7,000,000	8,000,000	8,000,000	31,140,000

The plan of developing the peat industry to its maximum during the Third Five Year Plan was visualized as the complete mechanization of both the hydraulic and milled peat methods. It is estimated that Russia now produces approximately 90 per cent of its peat by mechanized methods.

Machine Peat in Sweden—A new Swedish book[2] describes recent developments in peat processing in Sweden. There is a trend toward the use of shovels and draglines in the digging or excavating operations; also, an effort to increase the yield per square foot of drying area. This excellent book is being translated and copies of the translation will be available for distribution later.

1Torfyanaya Promyshlennost, by A. F. Bausen, November, 1947, pp. 4-5.
2Sveriges Branntorv Industri, 1940-46, Sweden.

A method developed in connection with peat production during the war, that differs from other methods used so far, is the Engineer S. M. Hjelte's Method.[3] This method has come to be used extensively at Tutaryd's Swamp. The following is an English translation of Major S. D. Ekelund's description of the process:

"To begin with, the slicing was done by manual labor. The peat was rolled down onto a belt conveyor located at the bottom of the slice; this facilitated the work so that a production of 5 m^3 (6 tons) per man-hour was not uncommon. At the side of the slice the conveyor went on a 30° angle up to a chute through which the peat was loaded into the cars standing on a Decauville-spur or rails. The conveyor, which was placed square to this spur, could be extended from 10-40 m (33-130 feet), depending on the number of workers to be served. The conveyor was moved sidewise as the slicing progressed. As the horizontal part could be lifted on beams (bearing beams) by blocks, the moving was done with practically no work stoppage.

"On cars pulled by cable, the peat was moved to a pre-working machine in the feed-sump and from there to a Svedala 1:18 peat mill to be re-worked. A conveyor then loaded the peat onto cars on a cable-track to be taken to the drying field and there dumped on each side of the track.

"During 1946, instead of the aggregator, a "Ruston Bucyrus 10" excavating machine was used to remove the peat. This machine loads the peat into a gathering trough provided with a feeding arrangement from which a conveyor takes it to a Eurika Mill. From this mill the ready-worked peat is loaded into cars on the cable-track and taken directly to the drying field.

"By this method, a very important saving of manpower was made, since a normal shift formerly consisting of 20.7 men has now been reduced to 9.4 men. Furthermore, by this mechanization, with all its growing pains, an increase in production of 10 per cent over anything accomplished before was made during the last four weeks of the season. The 300 liter (.4 cu. yd.) dipper of the excavating machine was replaced by a 750 liter (1 cu. yd.) dipper. The result was 60-70 m^3 of peat per hour, which is considered very satisfactory.

"It should be pointed out that the machine digs by the overhead system and, thus, moves on the bottom of the cut. But it cannot move on its caterpillars alone, so

[3]Sveriges Branntorv Industri, 1940-46, Sweden, pp. 102-107.

special timber mats were made for it to run on. These mats are moved ahead by the machine itself.

"When the cars have been emptied on the drying field, they are again hooked onto the cable and returned to be reloaded. They have then completed a trip on the closed circuit. This circuit is of a rectangular form with one movable side, namely the side where the dumping is done. When the movable side has been filled with peat, there is already a new track built 10 m (33 feet) from the old one and the cable is then moved to this one. The cars will then be running on the new track. A machine goes then to the last filled track to turn and spread out this peat. The spreading is done by rotating steel spirals which level out the dump piles to a layer about 10 cm (4 inches) thick and 5 m (16 feet) wide. The cutting is done by rotating discs both lengthwise and crosswise. This machine moves on its own track about 20 m (66 feet) long and after both spreading and cutting is successively done, the track is moved ahead by a movable arm mounted on the machine.

"The peat is turned and stacked (made into small heaps) in the usual manner.

"The special advantages with the 'Hjelte System' are that the stumps are removed successively in the course of slicing and cause no further trouble; that as the cable drawn cars take the peat to the drying field, the slicing area becomes independent of the size of the drying field and, consequently, 100 per cent of it is taken out (mined) ; and that the slicing, dumping, and spreading of the peat flow smoothly. The moving of the cable to the new movable side takes about two hours.

"The moving of the track is a continuous work at Tutaryd. For this reason the Decauville rails have been provided with extra ties and some of them with welded splice bars at one end to facilitate the work and make for smoother riding.

"The main contract, at the beginning, was figured on the basis of using 20.7 men to a shift. This includes slicing, transporting, macerating, and dumping the peat on the drying field. During the first three years, a slightly falling scale was used, which was afterward changed to a fixed price of 93 ore ($0.23) per m^3. Later when an excavating machine contract was made, the price was fixed at 58 ore ($0.15) per m^3 for corresponding work. Although this contract, on paper, carried with it an increase in the per-hour earning, it should be pointed out that the work stoppage has shown a decided increase with the use of the excavating machine, because any breakdown of any part of the system necessarily means a stoppage in all parts of the work. Cave-ins have also caused a lowering of production and earnings as well.

"The Hjelte method at Tutaryd's Swamp with one peat mill produced in 1944, 8000 tons; in 1945, 11,700 tons; and in 1946, 8000 tons.

"The effective production those years started April 15, April 8, and May 1, respectively."

From direct communication with Mr. Hjelte, we have obtained a description of his new method; this is described later under, "New Proposed Methods."

CHAPTER V

MILLED PEAT

The Freztorf or Milled Peat Method differs from the other processes in that all operations are fully mechanized. A layer of peat about one-half inch is cut from the surface of the bog in a finely divided condition and dried on the bog near where it was cut. In this process there is no maceration. The Milled Peat Method is used extensively in Europe, especially in Ireland, Denmark, Russia, and Sweden.

Milled Peat in Ireland—Since milled peat is used extensively in Ireland in the form of briquettes for use as domestic fuel, and consideration is being given to the possible use for large-scale power generation without combined briquetting, attention is drawn to two recent Irish publications[1&2]. Mr. Martin, in his introduction, states:

> "Winning of Milled Peat—The term 'milled' is applied to peat in a finely divided form. To win milled peat, it is first necessary to divide the bog surface up into a large number of narrow sections or 'fields,' divided from each other by a ditch about 4 to 5 feet deep. The top heather and grasses are then completely removed. During the dry months of the year, machines called 'Millers' (somewhat like outsize lawn-mowers) cut off the top one-half inch of the bog and spread it out for drying. Some time afterwards, when the peat has had time to dry a little, fast tractor-drawn Harrows ruffle the peat several times until it is dry enough. Then the peat is pushed to the center of each field in a long ridge

[1]The Winning and Utilization of Milled Peat for Briquetting and Power Generation, by J. Martin, B.E., 1946, p. 197.
[2]Report of Bord Na Mona and Accounts for Period from 21st June, 1946, to 31st March, 1947, Dublin, 1948.

by a 'Ridger' machine, thereafter being removed to beside the nearest railway line by a transporter or 'Harvester' machine. When required at the briquetting factory, the peat is loaded mechanically into wagons and drawn thereto by Diesel Loco.

"Briquetting Factory—On arrival at the factory, the peat is emptied into a storage bunker from which it is removed as required to disintegrating and screening processes. The coarse material is not used for briquetting but is instead used as boiler feed—being first dried by the hot flue gases. Steam is generated, and after some electric power is obtained from it in a turbo-alternator, it is used for drying the fine peat which has passed through the screens. After drying, this peat is fed to a briquetting press and then conveyed to the nearby canal for transport.

"The amount of milled peat required to make one ton of briquettes is referred to as the input to output ratio, and varies from 2.2:I, to as high as 5.0:I, depending on the quality and moisture content of the peat being processed.

"The final detailed bog production costs for the season 1944-45 at Lullymore are given in their Table 5. It will be seen that the final cost (less interest and depreciation) of milled peat per ton in the factory bunker is 8 shillings and 9 pence ($2.10) and that cost of production only on the bog is 7 shillings and 5 pence ($1.78). Loading and transport is 1 shilling ($0.24) per ton. Production of milled peat is 51,500 tons (weighed) and from this 16,400 tons of briquettes have been manufactured, giving an average input/output ratio of 3.14:I."

"Table 5. — BOG AND FACTORY COSTS 1944-45 SEASON

	Cost per ton pence	
BOG.—51,404 tons of milled peat produced and transported to factory		
Drainage Maintenance and Bog Preparation	12.00	
Bog Power	9.91	
Milling	3.94	
Ridging	0.91	
Harvesting	3.86	
Bog Transport	12.13	($0.24)
Repairs to Bog Machines and Equipment	38.80	
Repairs to Workshop Machines and Equipment	0.18	
Miscellaneous	7.48	
	89.21	($1.78)
OVERHEAD EXPENSES:		
General Expenses	14.36	
Maintenance and Repairs to Land and Buildings	1.21	
	104.78	($2.10)

CAPITAL CHARGES:		
Interest	8.40	
Depreciation	6.44	
	119.62	($2.39)
FACTORY.—16,400 tons of briquettes manufactured and sold		
Factory Process	75.65	
Factory Power	28.61	
Repairs to Factory Machines and Equipment	53.57	
Repairs to Workshop Machines and Equipment	0.92	
Miscellaneous	18.75	
	177.50	($3.55)
OVERHEAD EXPENSES:		
General Expenses	45.00	
Maintenance and Repairs to Land and Buildings	3.78	
	226.28	($4.53)
CAPITAL CHARGES:		
Interest	26.34	
Depreciation	30.61	
	283.23	($5.66)

FINAL COST OF BRIQUETTES:

51,404 X 119.62 plus 283.23 = 54s. 9d." (Equivalent to $13.18 per ton)

16,400

In a recent letter, dated December 14, 1948, Mr. H. M. S. Miller[1] quotes Mr. Martin as follows:

> "Lullymore milled peat cost on bog this year to 31st March 1949, is estimated at 5 shillings and 4 pence ($1.28) exclusive of capital and depreciation. Cost of loading and transport to factory (8 pence) ($0.16) will bring this to 6 shillings ($1.44) a ton. At present, capital and other charges aggregate about 1 shilling and 8 pence ($0.40) per ton, but for a new plant, 2 shillings to 2 shillings and 6 pence ($0.48 to $0.60) a ton should be allowed.
>
> "The briquette production will be approximately 18,000-20,000 tons in the financial year and this will give a cost of production figure per ton of about 16 shillings ($3.84) per ton (at 31st March 1949) to which must be added overheads, capital and depreciation amounting to some 5 shillings ($1.20) per ton, giving 21 shillings ($5.04) a ton total. Adding the cost of peat at 7 shillings and 8 pence ($1.84) a ton and input/output ratio of 3.1/1, we get—
>
> 7 shillings and 8 pence x 3.1 plus 21 shillings = 45 shillings ($10.80) a ton
>
> cost of briquettes ex factory.

[1]H. M. S. Miller, Technical Development Supervisor, Bord Na Mona, Ireland.

"The drop in estimated cost as compared with last year is due to increased production. We hope to increase the production by another 50 per cent in 1949-50. This will give a further downward trend to cost of production per ton."

These recent figures show that the cost of milled peat at the bunkers has been reduced from $2.39 a long ton to $1.84; and that the cost of peat briquettes has been reduced from $13.18 a long ton to $10.80.

Mr. Martin's figure of 7 shillings and 8 pence ($1.84) as the cost of a long ton of 55 per cent moisture milled peat delivered at the bunkers, appears low enough to be worthy of further study.

His estimated cost figure of $1.48 a long ton of 55 per cent moisture peat, for larger productions, is below the present 1948-49 cost figure of $1.84 and well below our limiting cost figure of $3.35 a long ton. Since the cost of labor in the United States is approximately three or four times that in Ireland, we have added $0.52 a ton to Martin's estimated cost of $1.48, thus placing a corrected U. S. cost at $2.00 a long ton. Based on an annual production of 322,000 tons, this corresponds to an estimated cost of about $0.27 per million Btu, compared to steam coal now selling in northern Minnesota for $0.45 per million Btu. This figure suggests that peat produced by the milled peat process might compete in Minnesota as a power fuel, provided bog characteristics and weather conditions correspond to that at Lullymore, Ireland, where about 20 harvestings are made per season. It is believed that our weather conditions might permit 24 harvestings.

Milled Peat in Denmark—Mr. E. L. Luly, who discussed our Minnesota peat problems with Mr. Jorgensen, of the Kaas Briquetting Factory in Denmark, states:

> "The average cost of 1 ton of milled solids (i.e. 2 tons of raw material) to the Factory Bunker is 24 Kroner ($6.43) for labor, maintenance, petrol and oil, but does not include capital charges. With a production of 250,000 tons of solids a year and with modern machinery, it should be possible to reduce the cost below 24 Kroner per ton. Labor per ton of solids is 6 man-hours. In Denmark, wages are from 3 to 3½ Kroner ($0.80 to $0.94) per hour. It should be understood, however, that one cannot generalize about the cost of producing peat, since bogs can vary so much in character, and climatic conditions are also very important."[1]

By raw peat, it is assumed to be the milled peat as harvested; and by milled solids, the calculated dry peat. If this is the

[1]Correspondence from Mr. E. L. Luly, Winchester House, Victoria Square, Birmingham, England, August 22, 1947.

case, then 1 ton of raw material costs about 12 Kroner, equivalent to approximately $3.20 a ton (not including capital costs).

Milled Peat in Russia—The milled peat process is used extensively in Russia. According to Professor Goriachkin, 330,000 tons of milled peat was consumed by the large electric stations at Briansk in 1940; he places milled peat first over other processes from a standpoint of mechanization and economy. Professor I. P. Bardin[2] recognizes the necessity to reduce labor costs and employ more mechanized methods of peat winning, and he mentions that labor costs in Denmark, Sweden, and Ireland are one-third to one-half less than that reported in Russia. Apparently from the translation of this Russian article, milled peat is not used as extensively as in other countries to produce briquettes.

Cost figures are given in rubles. The total cost of a million calories in rubles is: Hydro Peat, 18.8; Milled Peat, 18; and coal, 18.9. Since we have no definite value of the ruble, it is difficult to show cost figures in dollars. However, the figures show that milled peat costs less than hydro peat and competes with coal.

Milled Peat in Sweden—An excellent description of the milled peat process as practiced in Sweden is found in a recent Swedish book.[1] The article compares the various types of milling machines, scrapers, and harvesters used in Sweden, Ireland, and Denmark.

According to information available, the milled peat as harvested contains about 50 per cent moisture and costs $1.20 a ton laid down at the factory ($1.20 does not include overhead, depreciation, and capital costs).

Allowing 30 per cent of this figure to cover other costs, we estimate a total cost in Sweden of about $1.60 a ton, equivalent to about $0.21 a million Btu. (Steam coal now sells on the Range in northern Minnesota for about $0.45 a million Btu).

This is extremely interesting since the Swedish cost of living is almost as high as in the United States.

[2] Problems of Northwest Metallurgy, by Prof. I. P. Bardin, Prof. A. E. Probst, and V. V. Rikman, 1946.
[1] Sveriges Branntorv Industri, 1940-46, Sweden.

CHAPTER VI

HYDRO PEAT

If water and electricity are available and the bog contains a large proportion of timber and roots, a method known as the "Hydro Peat Method" is extensively used in foreign countries. In this method, the peat is cut by a stream of water, pumped to drying fields, and later cut into blocks. In order to obtain a knowledge of present practices and cost figures, we contacted peat producers and engineers in foreign countries.

Hydro Peat in Denmark—Mr. E. L. Luly,[2] who is familiar with the peat situation in Denmark writes:

> "Another system is also used at Kaas, Denmark. This is called the 'Hydro Peat' system in which jets of high pressure water (about 130 to 150 p.s.i.) are directed against the vertical face of the peat, thereby making a slurry which washes down into the lake thus formed. From here it is pumped a distance of 2 to 3 Kilometres to a relatively small reservoir which acts as a 'break.' From here it is pumped to the drying field, (essentially sandy or porous and covered with grass) which is covered by this slurry to a depth of about 20 cms. After some two or three days draining, it is cut into blocks by a horse-drawn cutter and then allowed to dry for a further period which may be up to six weeks when it is ready for use with a moisture content of 25% to 30%. During this drying period, the blocks will have been turned over by hand and will have shrunk from 20 cms (8 inches) to about 4 cms (1.6 inches).
>
> "The normal output of hydro peat is about 15,000 tons in 3½ months, 17 hours a day. Last year, however, was a very wet season, and production was only 10,000 tons of peat.
>
> "It is important to note, however, that the drying field is 200 acres in area and is quite flat. It is the considered opinion that without this facility, the system could not be successful.
>
> "On this site, the labour is divided as follows:
>
> **At the 'lake.'**
>
> 5 men. 2 men directing the jets against the peat face,
>
> 3 men for relief work and odd jobs.

[2]Mr. E. L. Luly, Winchester House, Victoria Square, Birmingham, England.

At the drying field.

3 men to control pumping and leveling. Turning of the blocks is usually done by female labour.

"Each hydro plant consists of 4 jets (2 working) and is capable of producing 200 cubic metres of slurry per hour. Slurry contains 96 per cent water, but here again one must be careful. Poor quality peat may, due to the increased resistance, set up by fibres to pumping, require 97 per cent water and good quality peat may require only 94 per cent water.

"The cost of dried peat on the drying field ready for transport is normally 16 Kroner per ton; this includes labour, repairs, and maintenance, and electric current, but does not include capital charges."

The operating season is short and a wet season resulted in only two-thirds of normal production.

The cost of dried peat on the field ready for transport is quoted at 16 Kroner per ton ($4.30) ; this does not include capital charges and transportation costs, which might raise the cost figure to $5.50.

Hydro Peat in Russia—The Russians produce a great deal of peat fuel for power by the hydro peat method. They apparently have gone further than other countries in the development of this process. For a more detailed description of their operations, reference is made to a Russian article by Professor Goriachkin. He describes a hydro scraper method, in which the very wet peat is conveyed through pipes to a reservoir where the mass gradually thickens and part of the water removed by syphoning. The settled peat is removed by scrapers having a capacity of about 13 cubic yards and conveyed to the drying field where it is spread uniformly to a thickness 12 to 14 inches. The peat is cut into blocks and after about 6 weeks the dried peat is removed by a special 8-cubic yard scoop and conveyed to the stockpile by movable platform.

Although approximately one-fourth of the peat in Russia is produced by the "Hydro Peat" method, the method could not be considered practical in the United States, since peat fuel produced by the "Hydro Peat" method would cost more than our limiting cost figure of $5.20 a ton.

CHAPTER VII

NEW AND PROPOSED METHODS

Many attempts have been made to develop new methods that would produce a better peat fuel at lower costs. Several of these new methods, still in the development stage, are discussed in order to show the great interest that still exists in the use of peat for fuel.

Hydro Peat—Screen Tank Method—As a result of certain studies and experiments,[1] a possible method was visualized in which the peat bog would be torn down with hydraulic giants at 150-200 pounds pressure per square inch, and the resultant sludge or slurry (containing approximately 95 per cent water) pumped to the preparation ground where the sludge would be discharged onto vibrating screens to eliminate sticks and green peat. The waste material, composed of the sticks and green peat, might be used in agriculture or horticulture. The peat sludge passing through the vibrating screens would be caught in huge tanks containing 8-mesh screen trays and permitted to drain to 90 per cent water, after which it would be discharged onto presses or rolls to reduce, if possible, the water to 80 per cent. In reducing the water content from 95 to 80 per cent, 79 per cent of the original water would be removed. The 80 per cent moisture peat would again be transferred to screen trays in which the peat would be mechanically stirred during air drying to a moisture content of about 30 per cent. It would then be conveyed to the power plant, located near the bog, and burned under boilers for steam raising in the generation of electric power.

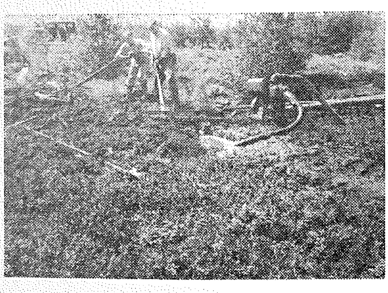
Early Studies—Previous to the summer of 1946,[1] several small experiments were made in which the peat was diluted with water to produce a peat slurry containing about 95 per cent water, thoroughly mixed, permitted to drain in 8-mesh screen trays or boxes, and then placed out to dry in the sun and wind. The largest test was one in which 127.6 pounds of 94.8 per cent moisture peat slurry was drained and dried in an 8-mesh screen tray or box, 14.5 by 14.5 by 11.5 inches, in 20 days. The screen mesh tray (box) and contents were set out to dry in the sun and wind on supports 4 feet above the ground. The sample was stirred every hour to expose fresh surface to the atmosphere and weighed every hour from 8:00 a.m. to 11:00 p.m. Moisture determinations were taken at various periods to show the effect of time on water removal. The moisture content after one day was 87.3 per cent; 4 days, 84.7 per cent; 8 days, 80.6 per cent; 11 days, 79.7 per cent; 14 days, 75.6 per cent; 16 days, 66.3 per cent; 18 days, 57.2 per cent; 19 days, 49.5 per cent; 20 days, 34.8 per cent, and 12 hours later at 8:00 p.m. on the 20th day, 22 per cent. The initial weight

[1]Early studies by Odin A. Sundness.

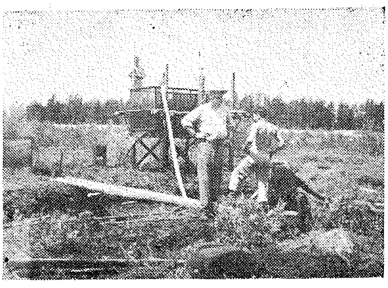
was 127.6 pounds and the final weight was 8.3 pounds, showing a loss in weight due to water of 94 per cent.

If instead of plotting per cent water, the ratio of water to dry peat substance is used, then the curve will show a steep slope during the draining period (plus 88 per cent water) and a uniform flatter slope during the drying period. A sample having a moisture content of 95 per cent will have a ratio of water to dry peat substance of 19 to 1, but a sample containing 30 per cent moisture will have a water ratio of only 0.43 to 1. Certain conclusions were drawn from this test. Although it was originally thought that peat could be dried in beds 3½ feet to a moisture content of 30 per cent in less than 10 days with stirring, this test and those made by this office in 1946, showed that 90 per cent peat spread only 8 inches deep and periodically stirred required 20 days drying time, aided by edge or scale effect. If 6 pounds of dried peat could have been obtained from 1 square foot of screen in 5 days, the method would require considerably less drying area than any other known method. Although peat dries faster when spread in thin layers, the amount recovered per unit of drying area is so small that it does not warrant the higher plant costs and higher material handling charges.

Hydro Peat—Screen Tank Test (1947)—During the summer of 1947, the Office of the Iron Range Resources and Rehabilitation made a large-scale test in which about 8000 pounds of peat slurry was pumped into a screen box, 8 by 8 by 4 feet, and stirred over a period of 34 days. The single screen tank served as a drainage tank and a drying tank. It would have been better had the screen tank been sectioned so that the top 3 feet could have been removed to permit a better circulation of air over the surface of the peat bed. If the peat is to be stirred, some screen would have to extend above the bed to retain the peat in the tray during stirring. Even a small amount of screen extending above the peat will reduce the wind velocity a great deal, in some instances, 50 per cent. The details of Hydro Peat Screen Tank Test are given in the Appendix. The test showed that pumping macerates the peat and reduces the rate of draining—4 days was required for the



Hydraulic Excavation of Peat at Balkan Bog at Chisholm, Minnesota



Pumping of Peat Slurry into a Screen Draining Tank peat to drain to 88 per cent moisture; stirring resulted in a loss of 71 per cent of the peat through the screen and did not reduce the drying time as was expected; the time required for the peat to dry to a moisture content of 31 per cent was 34 days.

Evaluations—In evaluating the data, we assumed that the 90 per cent moisture peat spread 1 foot thick weighs 62.4 pounds; that 9.93 pounds of 30 per cent moisture peat would be recovered from 1 square foot of screen in 1 harvesting or 31.2 pounds in 3½ harvestings; that 16 screen trays 1000 feet long, 10 feet wide, and 1 foot deep would be loaded and unloaded daily in a drying season of 140 days.

Calculations show that if 8.93 pounds of 30 per cent moisture peat is harvested from 1 square foot, then 3½ harvestings would produce 31.2 pounds per season from 1 square foot of screen. If 1 square foot of drying area is required to produce 31.2 pounds of 30 per cent moisture peat, then 64 square feet of drying area will be required to produce 2000 pounds, or 1 ton. If 100,000 tons is the desired production, then 100,000 tons would require a drying area of 6,400,000 square feet. If the system is 10 feet wide, the length would be 640,000 feet, equal to 121 miles. If 16 tanks are loaded each day, then at the end of 40 days all the tanks have been filled. On the 40th day, the last unit of 16 tanks would be filled as the first unit of 16 tanks was being emptied, ready for second filling on the 41st day.

It was found that the cutting action of the pump made the peat more collodial, resulting in an increase from the estimated draining time of 8 hours to 48 hours. This would increase the number of receiving tanks from 2 to 12. Since the peat after draining has a depth of 12 inches, additional screen on the sides would be necessary to retain the peat in the system during stirring. This would increase the amount required from 64 square feet per ton to 80 square feet per ton.

Stirring is advantageous as evidenced in the Milled Peat process. If thinner beds are used, the drying cycles will be shorter and more cycles will result. This should permit longer drying seasons with less harmful effect from rains. Nevertheless, the amount of screen required would be large and the cost prohibitive. The finely divided peat has a bulk density of only about 20 pounds per cubic foot and could not be classed as a domestic fuel. In our opinion, peat made by this method, could not compete as an industrial fuel with lignite or coal.

The Hjelte Method—A modified machine peat method that is receiving a great deal of attention in Sweden is one developed by Mr. S. M. Hjelte, Norrtullsgatan 43, Stockholm, Sweden. Before communicating with Mr. Hjelte, we were informed by a reliable source that 35 per cent moisture peat could be produced by a new machine peat method in Sweden at a cost of 25-30

Swedish Kroner ($7.00 to $8.00 a long ton). In April of 1948, we started to communicate with Mr. S. M. Hjelte and have, since that time, received a great deal of information from him regarding his new method for producing peat fuel.

According to Mr. Hjelte, his process has been in operation since 1942, at bogs producing 18,000 tons of peat fuel annually in a working season of 100 days.

The Hjelte method differs in several ways from the usual machine peat methods. In the Hjelte method, 90 per cent moisture peat is spread about 63 pounds per square foot instead of about 21 pounds as in the older methods; after spreading, the peat is cut into blocks about 12 by 4 by 4 inches and dried on end instead of 14 by 5 by 4 inches and dried on the side. During the cutting, the sides are pressed together somewhat to form a truncated pyramid 12 inches high with a 4 by 4 inch base. Only about 7 per cent of the total area of the block is in contact with the surface of the bog compared to 24 per cent in the usual method. The purpose of the Hjelte method of spreading is to obtain at least three times more peat per square foot of drying surface and thus reduce transportation costs. It is claimed that the shape of the sod is more suitable for shedding water and that the dried sod is more dense. The method and the machinery are, to a large extent, protected by patents.

Drainage—The peat in the bog is drained to give a moisture content of about 90 per cent; it is recommended that the bog be drained as much as possible.

Excavation—The raw peat containing about 90 per cent water is dug from the bog by a mechanical excavator using steel buckets mounted on an endless chain; the peat is scraped from the sloping wall of a trench from bottom to top, delivered to a transverse conveyor, and then discharged into cars and transported by cableway system to a pug mill where the peat is ground or macerated.

Maceration—The macerator is so located between the peat pit (place of excavation) and drying field as to give the shortest distance possible for transportation. The raw peat is dumped into a spacious hopper and fed into the macerator below, where it is ground and then loaded into cars and transported by a cableway system out to the drying ground.

At the Drying Ground—Mr. Hjelte, in his communication of January 14, 1949, described the operation of his spreading and cutting machine as follows:

> "The machine consists of a right-hand and left-hand spiral worm rotating in vertically adjustable bearings, driven and hauled by a special caterpillar tractor fitted with devices for both longitudinal and transverse

cutting of the peat mass spread. Either worm is 5 m long, the working width of the machine being about 11 m. The working speed is max. 3 m/minute. The peat mass is spread in a layer about 0.3 m thick, which is cut into about 0.1 m x 0.1 m squares, obtaining thus truncated pyramids with a base of 0.1 m x 0.1 m. Shortly after the spreading and cutting of the peat mass a rather waterproof film is formed on its faces which along with the shape of the peat-pieces affords good protection against damage by rain. In the usual production of piece-peat the pieces bend during drying and get a more or less defined curve form in which the water remains after a rain shower.

"The manner described gives a 3-4 times larger production per surface unit of the drying ground than what is the case with piece-peat produced in the ordinary way, where spreading as a rule is not more than 0.1 m thick and the drying ground seldom fully utilized. Drying is more rapid since the base in contact with moisture is considerably less and the air-touched face giving off moisture is many times larger than what is usually the case. The open cutting enables air circulation around the peat-pieces and thus increased loss of water."

Turning—Exposing fresh surfaces after about 3 weeks by turning over the peat results in a lower moisture product. The peat is removed from the original location and carried sideways behind the moving machine to a dryer base by means of a tractor-driven turning machine. Claim is made that less fines are obtained and that the dry peat has a higher bulk density than is the case using the older methods.

Harvesting—Further information on the harvesting operation is being obtained. The author includes a sketch showing a harvesting machine working in conjunction with a tractor pulling 3 wagons or trailers. A worm conveyor apparently picks up the peat sods, deposits them onto an elevator from which the peat is carried to the wagons or trailers onto a belt conveyor. From the sketch, it appears that the width of the peat harvested corresponds to the width of the peat spread on each side of the track, that is, about 16 feet.

Estimated Costs Per Long Ton—Although single operations have produced only about 18,000 long tons of dried peat annually, the total produced by this method since 1942, is claimed to be about 90,000 tons. In the smaller operations, costs are estimated at $5.30 a ton. According to Mr. Hjelte, rather detailed cost estimates are made based on a proposed annual output of 75,000 tons. We have, in quoting Mr. Hjelte, used only his summary figures.

Summary

Capital expenditure	Sw. Cr. 4:40	per ton peat	$1.19
Wages for employees	Sw. Cr. 1:62	per ton peat	0.44
Wages for workers	Sw. Cr. 3:50	per ton peat	0.94
Fuel, etc.	Sw. Cr. 1:33	per ton peat	0.36
Office expenses, etc.	Sw. Cr. 0:67	per ton peat	0.18
Licenses and unforeseen	Sw. Cr. 1:48	per ton peat	0.40
Sum Total	13:—	per ton peat with 30% water	$3.51

Evaluation of Hjelte Method—Information as to the exact moisture contents of the dried peat, the length of the drying period, and the number of cycles or harvestings per season are indefinite. From what can be gathered from the various communications with Mr. Hjelte, we have concluded that a process that is claimed to produce three times more peat per unit is worthy of further investigation.

If 23 men are employed on a year around basis, as we understand would be the case in Sweden, a correction would have to be made for our higher labor costs. According to our calculations, this correction might add $1.38 a ton to Mr. Hjelte's estimated cost of $3.51, making our total of $4.89 a long ton, or $4.37 a short ton,[1] only slightly below our limiting cost figure.

Since estimated costs, based on a proposed annual production of 75,000 tons, have not been verified by actual production figures, no definite conclusions can be made. The method, however, should be more carefully studied since it appears to have merit based on information now available.

The Paalasmaa Method—In May 1948, the Office of the Iron Range Resources and Rehabilitation received from the Office of International Trade Department of Congress, Washington, D. C., a Foreign Service Report prepared by the American Legation at Helsinki, Finland, on the subject of "Improved Method for Peat Fuel Production."

> "A new integrated system for producing peat fuel which speeds drying time, extends the period during which peat may be dug, saves labor and is not limited to ideally situated peat bogs has been recently patented by Mr. Jaakko Paalasmaa, Finnish peat-bog supervisor at Paavola, Finland.
>
> "The system involves the use of automatic machinery for digging, reducing the peat to small pieces, spreading it on framework four to five meters above the ground for drying and for other handling. Mr. Paalasmaa claims that with his method raw bog peat (85-90% wet) becomes air dry (20-35%) in 3 to 5 days compared to the present drying time of 40 to 50 days,

[1]Costs do not include cost of bog.

and that the digging season may be extended 75 to 80%. Loading time of prepared peat is reduced to one-third of the time required by present automatic machinery.

"The Central Meteorological Station has certified that in experiments conducted between August 20th and October 20th, 1947, it was shown that under the new method, peat could be dug during the entire period when the ground remained unfrozen and that the moisture content of the entire production averaged under 20%.

"Due to difficulties in obtaining machinery for utilization of his method in Finland, Mr. Paalasmaa would be pleased to offer his method to appropriate parties, public or private, in the United States for investigation and development."

In August 1948, correspondence began between this office and Mr. Jaakko Paalasmaa;[1] in January 1949, Mr. Paalasmaa sent us a description of his method, which we will try to describe and evaluate.

The tests, started in March 1948 and continued through September, were conducted by the firm Palalurveyhlyma with state subsidies, under the direction of Mr. Paalasmaa, assisted by Mr. Bey Heng, Architect, and Mr. Veikko Rossi, special lecturer on meteorology at a university in Helsinki.

Mr. Paalasmaa's method differs from the original machine method in that the peat pieces are small and drying takes place either on boards placed on special stands or on racks on the ground in thin consecutive layers. The equipment used to excavate and macerate the raw peat is apparently similar to that used in other machine peat methods.

Drying on Boards—After digging, the peat is moved by an aerial cableway system to a field railway along which tipping carts carry the peat to an intermediate storage house and return along a parallel railway. From the storage house, the peat sods are transferred by means of an elevator to a stationary sod dressing machine or macerator. From the dressing machine, the peat is elevated and transported into 4 feeding drums from which it is extruded and cut into 40 sausage-like rolls, 1 by 6 inches. Peat pieces are spread 5.3 pounds per square foot of board surface and then transferred to an aerial cableway. From the aerial cableway, the boards, together with the peat, are transferred from the hoist onto a framework where the peat dries to about 60 per cent moisture and is then shaken onto the ground to be further dried.

Evaluation—Drying on Boards to 60 Per Cent Moisture—From what can be gathered from various communications with

[1]Mr. Jaakko Paalasmaa, Peat Instructor, Paavola, Finland.

Mr. Paalasmaa, we have arbitrarily made certain assumptions in order to calculate the drying area needed and to evaluate the method as it might apply in the United States.

In drying on boards, 5.3 pounds of 87 per cent moisture extruded peat is spread per square foot of board area. This is dried to a 60 per cent moisture peat in about 2.4 days. Claim is made that there are about 70 harvestings in an average season. This would produce 1.7 pounds of 60 per cent moisture peat per square foot per cycle, or 119 pounds per square foot per season. Using the above figures, we find that 18.8 square feet of board area is required per long ton of 60 per cent moisture peat. A board area of 3,055,000 square feet would be needed to harvest 162,500 tons of 60 per cent moisture peat (the amount needed to produce 100,000 tons of 35 per cent moisture peat).

In order to dry the 60 per cent moisture peat to 35 per cent moisture on the ground, additional drying area would be required, probably at least two times the board area required to dry to 60 per cent moisture.

Drying on the Ground—Instead of drying peat particles on boards placed on a frame, the peat may be spread as a continuous sausage-like mass on a special rack on the ground. Limiting the diameter of the pieces to about 1 inch and spreading in a single layer seems to be the inventor's explanation for quick drying.

The macerated peat is transferred to a field railway outside the bog, extruded and spread (3.5 pounds per square foot) along side the railway in a single layer; after several days, another layer is spread and so on until the end of the drying season, when all the dried peat is harvested and removed over the same railway that brought the wet peat to the bog.

Evaluation—In drying on the ground, 3.5 pounds of 87 per cent moisture peat pieces are spread per square foot of drying area. According to the data available, this should produce 0.7 pounds of 35 per cent moisture peat per square foot per cycle of 3.3 days. If 50 spreading cycles are possible during an average season, the output per square foot per season would be 35 pounds. A drying area of 64 square feet would be required to produce one long ton per season, or 6,400,000 square feet to produce 100,000 tons of 35 per cent moisture peat. The figure of 64 square feet is very low compared to 300 square feet generally accepted as the area in the usual machine peat method.

Mr. Paalasmaa states that he considers drying on the ground to be, in most cases, more economical than drying on boards.

This method evidently permits the use of a longer drying season, increases the number of spreadings per season, and produces a dense, compact fuel suitable for domestic use. The method is still in the development stage and further work will have to be done before a definite conclusion can be drawn; reliable cost figures are not available.

The Klint Ball Peat Method—Early Experiment—Since 1940, Mr. Hjalmar Klint of Sweden has been investigating the possibilities of a ball peat method of drying peat. In the early experiments,[1] peat was pre-dried on the ground to 75 per cent moisture content, after which it was macerated, extruded, formed into balls, and later dried by hot air or flue gases. Since artificial drying proved too expensive to be practical, experiments were continued in which air drying was used exclusively.

Final Experimental Plant—A ball making and drying plant was installed on a bog at Vislanda in 1946, and experiments on the drying of peat balls were conducted in July and August of 1947. A complete report of these experiments has been prepared by Mr. Torsten Widell.[1] This office has been instrumental in securing a printed English translation of this study which will soon be available.

The drying plant consisted of a structure supporting twelve screens set at a 30° incline, each 3 meters (9.8 feet) wide and 8 meters (26 feet) long, and having a total area of 288 m^2 (3100 square feet). The drier was provided with a movable roof so that tests could be performed with or without roof. One test was made to determine the effect produced by forced air circulation. For this purpose, a fan was placed below the drying screens.

Operations—Bog peat containing 85-90 per cent moisture was transported in ordinary dump trucks to the experimental plant, where it was macerated and carried by a band conveyor to the top level of the drier. The peat was then formed into balls, which were allowed to fall on the screens and roll to the first stop board placed across the screen. As drying proceeded, the balls were let roll further down the screen until finally they reached the bottom where they were harvested.

Continuous recording of humidity and temperatures were made on a thermo-hydrograph. Attempts were made to predict drying rates in the air by determining effective drying time based on temperature differences of wet and dry thermometers, rainfall, and other weather factors. Some interesting relationships have been formulated.

The peat was made into balls about 2.3 inches to 2.5 inches in diameter and spread at the rate of about 5 pounds per square foot of screen. The raw peat had about 85 per cent moisture content which was dried to a moisture content of about 35 per cent in 13 days.

[1] Widell, Torsten, Peat Balls, IVA, 1941:1, pp. 22-25.

[1] Widell, Torsten, The Drying of Peat Balls, IVA, 1941.

Widell gives the following summary:

"In the summer of 1947, a number of drying trials were made with peat balls on the Klint Method. In the months of July and August the production of the plant, if fully utilized, would have been between 0.3 and 0.6 kg dry substance per m^2 of screen surface per day, the moisture content of the peat used varying between 81.2 and 87.2 per cent. The drying speed, particularly during the first part of the drying, may be considerably accelerated by blowing air through the screens with a fan. The weight per hectolitre of the finished peat balls was 40-55 kg and the average moisture content was approximately 35 per cent. The drying process in its relation to weather conditions was closely investigated."

Our Evaluation of Klint Method:

An analysis of the data shows:

1. Five pounds of 85 per cent moisture peat balls 2.3 to 2.5 inches spread on 1 square foot of screen.

2. Fifty-one days included in the study.

3. Thirteen days, average drying time per harvest or cycle.

4. Four harvestings or cycles included in the test.

5. An amount of 1.15 pounds of 35 per cent moisture peat harvested per square foot per cycle, equivalent by calculation, to 0.089 pounds per square foot per day for the 51 day test.

6. Eleven harvestings instead of 14 are assumed per season of 180 days, allowing for about 21 per cent safety factor to correct for possible unfavorable drying weather at beginning and end of season.

7. An amount of 12.7 pounds of 35 per cent moisture peat assumed as harvested per 180 day season per 1 square foot of screen.

8. A screen drying area of 176 square feet required per long ton (2240 pounds) of product per season.

9. A screen drying area of 17,600,000 square feet required to produce 100,000 long tons of 35 per cent moisture peat per season.

10. Based on the above data, their pilot plant of 3100 square feet would have an annual drying capacity of 17.6 long tons, equivalent to 1.76 per cent of the proposed figure of 100,000 long tons.

In our opinion, peat fuel made by the Klint Ball Peat Method could not compete with coal in northern Minnesota, where steam coal is now selling for $11.36 a ton.

CHAPTER VIII

THE IRRR PELLETIZING METHOD

Early Developments—The Pelletizing Method studied and developed by the Office of the Iron Range Resources and Rehabilitation is essentially as follows:

Excavation—The raw peat containing 85 to 90 per cent water would be excavated and stockpiled. In 1946 thought was given by this office to the use of a slackline cableway excavator, with head and tail towers mounted on crawlers, capable of digging and moving 250 tons an hour, as the most logical and efficient method for digging peat; by using an eight-yard Crescent Scraper, stumps and roots would offer no problem.

Maceration—Peat from the stockpile would be removed with scrapers and macerated in a movable breaker plate hammermill of sufficient size to handle 250 tons to become, later, a part of the peat fuel. Maceration may take place at the time of excavation or pelletization.

Pelletization—The macerated peat would be rolled in long drums 7 feet in diameter and at least 35 feet in length. The peat, as it is fed into the drum should be cut or stirred in such a manner that the peat pieces fed into the drum are less than 2 inches; a trommel or shaker screen might be beneficial; in controlling feed size, a screw feeder has been found to give fairly satisfactory results. The drum revolves at a speed of approximately 12 rpm and the peat forms into pellets or balls without any appreciable sticking to the drum.

Pellet Size Control—The discharge end of the drum is a trommel screen which controls the size of the pellets or balls. Two sizes, $-1\frac{1}{2}+1$ inch and $-1+\frac{1}{2}$ inch, have been found to be most satisfactory. The under- and over-size is recycled, in a closed circuit, to the macerator or piece-cutting machine from which the material again enters the drum. Classification has been found to be an important step in the pelletizing method, since the thickness to be spread depends on the size of the pellets; the larger size is spread in thicker layers and the smaller in thinner layers in order to obtain optimum drying.

Drying—The classified pellets are spread in a multiple screen shelf system 8 to 10 feet wide and 12 to 20 feet high with shelves spaced 12 to 18 inches apart, with the lower shelf 18 inches above the surface of the bog. The mechanics of loading and unloading such a system is a problem still to be solved. Since classified peat pellets spread 5 pounds per square foot will dry to an average of 30 to 35 per cent in 5 to 6 days on 3-mesh screen, the pellets should air dry in consecutive layers on the surface of the bog. If screen prove to be uneconomical, drying in consecutive layers were spread; screen doors were used for drying shelves and these were so arranged as to give varying areas and distances between shelves.

Information Gained From Tests—Although these tests were too small to give accurate information as to drying rates under varying conditions, they showed certain trends that were of value in designing the 1948 drying system.

Among the factors affecting drying, it was observed that in a multi-shelf system, the top layer dried the fastest, due to greater exposure to the sun and wind. The middle layers dried the slowest, due to surrounding layers of wet peat and less edge or scale effect. Shelves 4 inches apart showed a drying rate considerably lower than shelves 12 inches apart, a condition which would probably be more pronounced in a larger system with less edge drying effect. Pellets were spread with different layer thicknesses, ranging from 3.3 pounds to 13.4 pounds per square foot. Because of the lateness of the season, it was impossible to get any appreciable drying in thick layers, indicating the desirability of spreading thin layers late in the season when drying of a thick layer would be impossible. These small experiments did indicate, however, that peat pellets spread 3 to 6 pounds per square foot, equivalent to 1 to 2 inches thick, might air dry to 30 per cent in 2 to 6 days.

The raw peat used in these experiments was unmacerated or only partially macerated by extruding through one-inch mesh screen. No provision was made to classify the pellets produced. These conditions made it impossible to secure a product of high bulk density, so desirable in a domestic fuel.

Results of these preliminary outdoor experiments showed the need of designing a more permanent drying system, improving the pelletizer so as to form a more uniform classified pellet, and providing for more complete maceration. Larger drying tests were needed to simulate more nearly conditions that would occur in a large drying system.

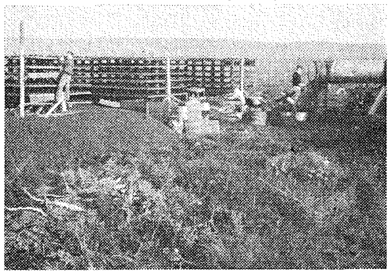
Pelletizing Method Studies for 1948 on Balkan Bog

Plans were made during the winter of 1947-48 to continue and expand the experimental study of water removal of peat by the pelletizing method.

These plans included the designing and building of a multiple shelf drying unit; increasing the length of the pelletizer with provision for classifying the pellets produced; moving the equipment onto the bog for more efficient operation; excavating and stockpiling peat for the drying tests (using a dragshovel); purchasing a suitable macerator; and making continuous drying tests on a larger scale than that used before.

Plan and Design of Multiple-Shelf Drying Unit—The drying unit, designed to furnish a screen drying area of 4608 square feet, consists of three unit sections, each having a drying area of 1536 square feet. Each section consists of 6 horizontal 3-mesh screen shelves, each 8 feet by 32 feet (256 square feet) spaced one foot apart. Shelf I is one foot above the bog and the top shelf, No. VI, is 6 feet above the bog. The shelves are supported by a central framework consisting of columns spaced two feet apart with arms extending four feet to either side of the central framework.[1]

Clayton E. Plummer, Technical Director of Peat Development, and Robert E. Wilson, Commissioner of Iron Range Resources and Rehabilitation, at the Screen Shelf Drying System



Peat Pellet Pilot Plant in Full Operation. Dried Pellet Stockpile is in Left Center

The three sections were built parallel to each other and spaced 18 feet apart from center to center. They were built with their longitudinal axis extending in approximately a NE-SW direction so that the prevailing SE-NW winds would blow across the shelves.

Excavation of Peat—Excavation for the 1948 drying experiments started May 4, and was completed May 9, 1948. Approximately 1200 square yards of 89 per cent moisture peat was dug from the bog with a B-10 Dragshovel (3/8 yard capacity). The peat was excavated from three parallel trenches each about 10 feet wide, 7 to 14 feet deep, and 150 feet long. Approximately three feet of surface peat was first removed to one side of the trench and the deeper, more humified peat was stockpiled on the other side.

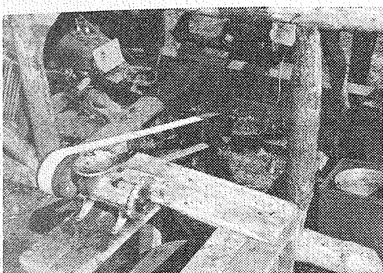
It was interesting to note that the stockpile peat sank into the bog somewhat and lost part of its moisture by pressure. Water was pumped from the ditch to determine drainage of bog under pressure.

Maceration—Early experiments showed the need of better maceration to secure a more dense and compact fuel. An oppor-

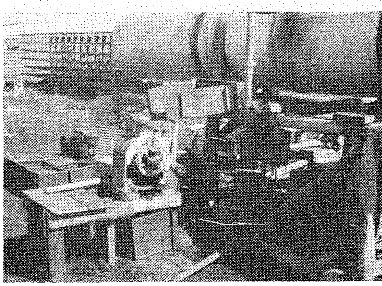
[1]Designed by Mr. Andrew Shine, Mechanical Engineer, Iron Range Resources and Rehabilitation.

tunity presented itself to purchase a Canadian macerator of the screw or meat grinder principle, having a capacity of 7 tons of 90 per cent moisture peat per hour. This machine was ordered May 18, 1948, but was not received until August 23, 1948.

Meat Grinder Maceration—Pending the arrival of the Canadian macerator, the peat used in the early experiments was macerated using a large meat grinder, operated at first by hand, but later by power. It was rather surprising the amount of peat that could be macerated with an ordinary household meat grinder. In a trial test, 40 pounds of peat was macerated in 10 minutes, equivalent to 240 pounds an hour. The extruded peat formed into comparatively uniform pieces which, after rolling, formed dense pellets of uniform size. Such a macerating device seems ideal for small scale laboratory tests.



Power Driven Meat Grinder Used in Early Maceration Tests



Small Hammermill Tested as a Peat Macerator

Hammermill Maceration—On August 18, a small hammermill was secured from the Northwest Paper Company at Cloquet, Minnesota, to replace the meat grinder. This machine mixed the peat as the rotating hammers forced it through the machine. Unlike the uniform pieces extruded from the meat grinder, the product was a fluffy mass. Trial tests showed the mill to have a capacity of 40 pounds a minute, or 2400 pounds an hour.

The Canadian Macerator—The new Canadian macerator, after its arrival, was installed adjacent to the pelletizer and was powered by the same engine that was used to operate the drum pelletizer.

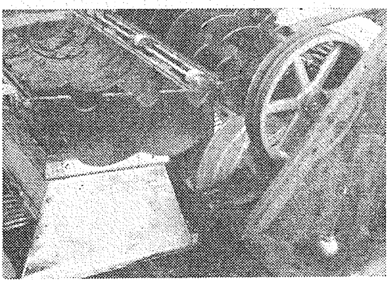
A description, with photographs, of the machine are found in Bulletin No. 1, Maine Geological Survey.[1]

> "A third type is constructed on the screw or meat grinder principle. A machine of this type has been developed by the Canadian Bureau of Mines. This machine consists of a hopper through which the peat is fed to

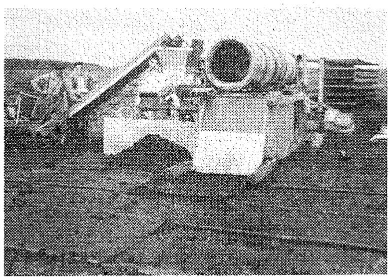
[1]Domestic Fuel Possibilities of Main Peat, by J. M. Trefethen and R. B. Bradford, Bull. No. 1, Maine Geological Survey, p. 28.

two intermeshing screws. The section of the screws directly under the hopper serves as cutters and feeds the peat along the screws which force the pulp through three openings, each about three inches square, thus combining macerating and molding.

"The Canadian machine is so constructed as to be mounted on the chassis of a used car or truck which serves to move the machine when necessary, and also furnishes power for its operation. The capacity of this machine is about one ton of air dry fuel per hour. A machine of this type and capacity can be constructed for approximately one thousand dollars, including the reconditioned automobile on which it is mounted."



Top Half of Macerator Opened to Show the Macerating Blades



Elevator, Macerator, and Pelletizer in Foreground, Driven by One Power Engine. Drying Section is in Background.

Peat from the stockpile, containing approximately 82 per cent moisture, was shoveled onto a flight elevator from which it discharged into the hopper. The inter-meshing screws, each 12 inches in diameter and 40 inches long, produced the mixing and kneading action for the proper maceration of peat. The screws were operated at a speed of 200 rpm when using peat containing more than 85 per cent moisture; and at less than 100 rpm when using peat containing less than 85 per cent moisture. Small roots passed through the screws without trouble; however, larger ones clogged the extruder. Peat containing over 82 per cent moisture was macerated fairly easily; however, with peat containing less than 80 per cent moisture, the power consumption increased and stoppages were more frequent. When extruded through a nozzle 10 inches in length and having a cross section 3 by 9 inches, the peat received additional maceration, but the power required was greater. Attempts were made to extrude the peat through 1½ inch square openings, but the dividing wires clogged with roots, necessitating frequent cleaning. The extruded peat, after being chopped with a shovel, was ready to feed into the pelletizing drum.

Pelletization—The drum pelletizer, together with the original log framework, used in the fall of 1947, was moved onto the bog on May 8, 1948. In order to permit a longer rolling action and thus a denser product, the length was increased to 16 feet by adding a four foot length of galvanized sheet iron to the discharge end. Later in the season, 3 feet of screen (1½ feet with ⅝ inch openings and 1½ feet with 1 inch openings) was added to the discharge end to serve as a trommel screen for classifying the pellets into the desired sizes. A new frame for the drum was built with 4 by 4 inch lumber and installed in September.

Operation of the Drum—Attached to the drum were two steel bands on which the drum revolved on 4 steel rollers. A Model A engine powered either the pelletizing drum or the macerator.

Several factors affect the kind of pellets produced: type, moisture content, degree of maceration of peat; depth of bed in drum; and speed and slope of the drum.

Fibrous peats, even though highly macerated and containing as much as 84 per cent water, can be pelletized without sticking to the drum. Even growing moss that is highly macerated will form into pellets and when dry would be suitable for litter in pellet form; ideal for brooder houses.

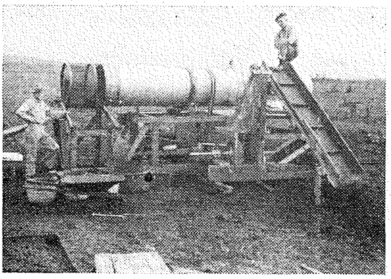
For the more humified peat, the amount of water and maceration should be carefully controlled. The drier, humified peat, containing 78-80 per cent moisture, permits more maceration with the same pelletizing results. Peat with a moisture content ranging between 78 and 82, generally causes no appreciable sticking to the drum during pelletization; due consideration should be given to the type of peat treated. In tests described later, the macerated peat was stirred or chopped previous to charging it into the drum.

The depth of peat in the drum should be such that there is no avalanching; otherwise, the peat drops onto the pellets being formed, resulting in large balls. As the drum revolves counterclockwise (facing the feed end), the highest position attained by the pellets corresponds to about 20 minutes after the hour. Even with this thick bed of peat, the pellets do not stick together if the proper moisture is maintained.

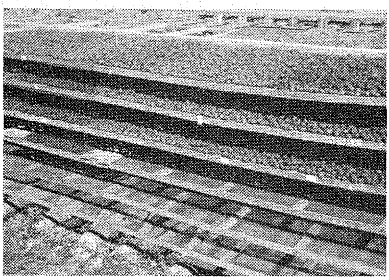
A speed of 250 feet per minute corresponds to about 32 rpm for a 2½ foot diameter drum, or 11½ rpm for a 7 foot diameter drum; 250 rpm appears to be the proper speed for most types of peat. The slope may vary, but a 2 per cent slope has given good results. The length of the drum controls the time the peat is subjected to rolling; the capacity varies approximately as the square of the diameter.

Pellet Size Control—Two methods were tried to control the size of the finished product; by controlling the size of the particle fed into the pelletizing drum and by classifying the pellets on the discharge end.

The control of the size of the peat pieces fed into the drum can be accomplished by extruding root-free macerated peat through a die. Unless the peat has been previously freed from roots, or finely ground, clogging of the openings will result. Peat charged onto a punched steel plate and subjected to rolling will sometimes produce a uniform product. In our experiment, we attempted to feed the drum with a particle size that would produce pellets less than 2 inches in diameter.



View of Peat Pelletizer Showing Trommel Screen Classifier



Peat Pellets Drying on a Screen Shelf Section

Using a trommel at the discharge end of the drum makes it possible to get a better size control and results in classified products. A trommel screen arrangement was connected at the discharge end of the pelletizer. The screen was 1 inch and discharged a plus 1 inch product and passed a minus 1 inch product to a $5/8$ inch screen set under the trommel at an incline; this screen, when tapped, served to give a classified product, —1+½ inch. The undersize was recycled to the macerator. Later, a new trommel screen made it possible to produce the desired sizes without using the sloping screen under the trommel.

Spreading, Sampling and Harvesting

After pelletization, the classified pellets were spread uniformly on screen shelves with a specified bed thickness or weight per square foot.

Spreading—A steel tray was used to spread the pellets on the screen shelves. A 4 by 4 foot wooden frame was first placed on the shelf and a definite amount of peat was spread in the frame, the amount depending on the bed thickness desired; when spreading 5 pounds per square foot, 80 pounds would be spread in the 16 square foot area. The frame was then moved along the shelf and the process was repeated until the entire shelf was spread.

Sampling—The peat, in the various stages of processing, was carefully sampled and tested for moisture and other properties, especially bulk density.

Standard methods of sampling were used; grab samples were taken of the pellets as spread; both grab and cut samples were taken of the dried pellets. Large samples, 500 and 1000 grams, were used for moisture determinations; larger samples were used on wet peat. Bulk densities were obtained by using one cubic foot samples. In determining the percentage of moisture in the samples, the peat was dried in a large oven at about 212° F. to constant weight. This method was chosen, since it is the one used by most peat investigators and permits the use of large, more representative samples.[1] In most cases, checks were obtained by comparing the weight of the pellets as spread and the weight of the pellets as harvested.

Harvesting—A special scraper was used to pull the dried pellets off the shelves into a sheet metal trough from which the pellets were transferred to baskets, weighed and stockpiled.

SUMMARY OF OPERATIONS

The complete peat pelletizing experimental plant, as set up at the Balkan bog in 1948, was arranged so as to permit a batch flow of material rather than a continuous flow. Raw peat was transported by wheelbarrow from the stockpile to the flight elevator of the macerator onto which it was shoveled. The macerated chunks of peat were extruded near the feeding end of the pelletizing drum. When the desired amount of macerated peat had been formed, the engine was belted to the pelletizer and the speed adjusted to about 35 rpm. The extruded peat was then chopped into small pieces and fed into the pelletizing drum where it was rolled into pellets of various sizes. At the discharge end of the drum, the pellets were classified into the two sizes, —1+½ and —1½ +1. These were then spread on the screen shelves and air dried, after which they were harvested, weighed, and sampled; the finished product was stockpiled.

ABSTRACT OF 1948 TESTS

Early Summer Tests—During the period from May 10 to July 7, twenty-two small-scale experiments were made in which 4500 pounds of pellets were spread. These tests were made to determine the extent to which different factors affected the drying of pellets on screen shelves, and also to develop sampling methods. Due to the limited facilities available during these experiments, peat was only partially macerated by stamping it

[1]Moisture can be determined by a direct method in which the sample is digested with an organic solvent and the water measured · described in the Final Report of the Peat Committee, by B. F. Haanel, 1926, p. 263.

on a metal plate and then extruding it through screen mesh with 1 by 2 inch openings.

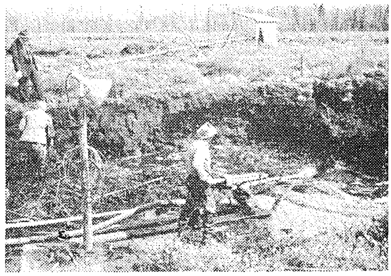
Mid-summer Tests—Later in the summer, a larger production of pellets was made possible by using as macerators, a power driven meat grinder and a small hammermill. During the period from July 8 to August 19, thirty-one runs consisting of 116 tests were completed in which 9,420 pounds of pellets were spread. The total weight of product harvested was 3,051 pounds. The average moisture content of the pellets spread was 80.4 per cent, and of the pellets harvested, 36.5 per cent. In these tests, two sizes (—1¾+1 inch and —1+½ inch) were spread 6⅔ pounds per square foot. The average drying time for the tests was 5.4 days.

During the period from August 11 to September 2, fifteen runs, consisting of 135 tests, were completed in which 8,100 pounds of pellets were spread. The total weight of product harvested was 2,092 pounds. The average moisture content of the pellets spread was 80 per cent and of the pellets harvested, 32 per cent. Two sizes were spread as in the preceding tests; however, the quantity spread was reduced to 5 pounds per square foot. The average drying time for the tests was 5.2 days. Although the amount spread per square foot in these tests was 75 per cent the amount spread in earlier tests, the average final moisture content was only 4.5 per cent lower. It is believed that in order to receive the maximum benefit of the drying weather, the amount spread per square foot would vary throughout the season; in the early summer and during dry periods, the thickness would be greater than during the fall and rainy seasons.

Continuous Tests During September and October—After the arrival of the Canadian macerator on August 23, sufficient quantities of pellets were made daily to keep two sections of the drying unit filled in continuous spreading and harvesting cycles. The center section, No. II, having an area of 1536 square feet, was used to carry on a continuous flow series of experiments. Section III, of the same area was kept filled with —1¾+1 inch pellets for another series of experiments and Section I was kept filled with 3 by 3 by 4 inch blocks of extruded macerated peat. The two outside sections (Nos. I and III) were used primarily to surround the middle section with wet peat and to obtain data on the drying of balls 1 to 3 inches in diameter. The results obtained from Section II would thus be more comparable to those obtained from a larger system. Preliminary tests revealed that best results were obtained with pellets cassified into two sizes, —2+1 inch and —1+½ inch. A size intermediate between the lower and upper limits would probably be ideal. Classification is recommended for drying pellets. The bed depth found most favorable for drying was 1½ inches, equivalent in weight to 5 pounds per square foot.

During a one-month test period, from September 9 to October 9, thirty-five runs were made in which 47,760 pounds of pellets were spread on Section II of the drying unit. In the first 25 runs, two sizes of pellets (—2+1 inch and —1+½ inch) were spread, and in the remaining 10 runs, only the smaller size was spread. The pellets averaged 79 per cent moisture content and were spread 5 pounds per square foot. The total weight harvested in these tests was 14,330 pounds of pellets averaging 35 per cent moisture content; the average drying period or cycle being 4.7 days. A detailed analysis of the 35 runs appears in the appendix. A similar series of runs was continued on Section II until November 4; the final harvest being on November 22; the average drying time of the final spreading was 18 days. As a result of freezing, the dried pellets harvested during the month of November averaged about 20 pounds per cubic foot, compared to an average of 24 pounds per cubic foot for pellets not frozen during drying.

Stockpile of Dried Peat Pellets



Hydraulic Excavation of Peat Moss for Litter and Horticultural Purposes at the Floodwood Plant, Floodwood, Minnesota

Beginning September 29, and ending November 5, a series of 23 runs was spread and harvested on Section III of the drying unit. The pellets spread in these runs were all of the larger size, the —2+1 inch. A total of 27,800 pounds of wet pellets averaging 78.5 per cent moisture content were spread 5 pounds per square foot of screen. The total weight of the harvested product averaging 33 per cent moisture content was 8,486 pounds. The average drying time of 17 runs spread between October 1 and October 23 was 7.4 days and the average of all 23 runs was 8.1 days.

Conclusions—From the analysis of the above runs, several conclusions may be made, keeping in mind, also, the results of preliminary experiments. The average drying time for the smaller size pellets, when spread 5 pounds per square foot, was approximately 5 days; however, it is estimated that a seasonal average would be approximately 6 days. The limits of the spreading season are April 1 and October 31; however, this does not mean that seven months is the average total drying season. The length of the average season is between 5 and 6 months. Ten runs were selected from those made on Section II to determine the difference in drying of the large and the small pellets. From data on these runs, it was found that with the time constant the small pellets dried to an average moisture content of 33.5 per cent compared with 42.9 per cent for the large pellets. The small pellets had a final moisture content 10 per cent lower than the large pellets. Since the length of the drying section was in a northeast-southwest direction, and since approximately 15 per cent of the total area of the southern half of the shelves was exposed to direct sunlight, it was expected that the final moisture content of the harvested product would be less on the south than on the north side of the shelves. Results of the eight runs analyzed showed an average moisture content of 36.7 per cent for large pellets harvested from the south side and 49.5 per cent for pellets harvested from the north side. This is a difference of approximately 13 per cent. Results of eight corresponding runs of small pellets showed that the average moisture content of pellets harvested from the south side was 31.6 per cent and of the pellets from the north side, 43.6 per cent. The difference in this case is 12 per cent, which is almost the same as in the case of the large pellets. Winds have a decided effect on the drying rate of pellets on screen shelves. The wind direction varies considerably and often changes several times during a drying cycle. The upper shelves receive greater benefit of the wind since the wind velocity is greater at that height. A strong wind during a period of low relative humidity greatly increased the drying rate. The upper shelves have as advantages, higher wind velocity and lower relative humidity. It was found that 1½ times as much peat could be spread per square foot on the top shelf as on the lower shelves with the same drying results; this is due chiefly to the total exposure of the top shelf to the direct sunlight. In a small drying system, there is the possibility of edge effect which would make results appear more favorable than in a large system.

Comparison of Two Ball Peat Methods—A comparison can now be made between the Swedish Klint Ball Method and the Pelletizing Method, as developed by the Office of the Iron Range Resources and Rehabilitation. These two methods were developed independently; only recently was it learned that the Swedish method existed.

In both methods, the peat is dried in small balls on screen shelves. The balls in the Klint Method were approximately 2½ inches in diameter; the balls or pellets in the Iron Range Resources and Rehabilitation Method were classified so as to keep the maximum size under 1½ inches. In the Klint Method, the screens are arranged in a slanting position to facilitate loading and unloading. This is a possible advantage over our method in which the screen shelves are arranged horizontally; it is hoped that an economical method can be developed for the loading and unloading of the pellets.

A comparison of the Klint Ball Peat Method with the Iron Range Resources and Rehabilitation Pelletizing Method shows that the Klint Method would require about 2½ times more screen than the Pelletizing Method, a figure similar to the ratio of drying times and the peat ball sizes.

Peat Fuel Analysis Report[1]

At the end of the season, a large representative sample was taken from the stockpile where the pellets had been placed after being removed from the screen shelves. This sample represents the dry pellets made during the summer of 1948.

	Peat (As Received)	Peat (Moisture Free)	Peat (Moisture and Ash Free)
Proximate Analysis			
Moisture	12.9	....	....
Volatile Matter	51.5	59.1	67.0
Fixed Carbon	25.4	29.2	33.0
Ash	10.2	11.7	....
	100.0	100.0	100.0
Ultimate Analysis			
Hydrogen	5.8	5.0	5.7
Carbon	45.0	51.6	58.5
Nitrogen	1.4	1.6	1.8
Oxygen	37.4	29.9	33.8
Sulphur	.2	.2	.2
Ash	10.2	11.7	....
	100.0	100.0	100.0
British Thermal Units	7720	8850	10030

Fusibility of Ash, °F	
Initial deformation temperature	2030
Softening temperature	2080
Fluid temperature	2470

PRODUCTION AND EQUIPMENT DATA FOR PROPOSED 50,000 SHORT TON PLANT

50,000 tons of 30 per cent moisture peat fuel
50,000 × 0.70 = 35,000 tons of solids

$\frac{35,000}{0.10}$ = 350,000 tons of 90 per cent raw peat to excavate

$\frac{35,000}{0.20}$ = 175,000 tons of 80 per cent moisture pellets

Excavation — Slackline Cableway. (Head and Tail Towers Mounted on Crawlers)
200 days per year, 20 hr. per day
$\frac{350,000}{200}$ = 1,750 tons/day; $\frac{1,750}{20}$ = 87.5 tons/hr.

[1]Analysis made by the U. S. Bureau of Mines, Golden, Colorado, under the direction of V. F. Parry.

might prove to be a better method. From a few tests, made in the summer of 1948, it was observed that the pellets could be dried in consecutive thin layers on the bog; however, the drying time would be somewhat longer than when dried on the screens.

EARLY DEVELOPMENTS — 1946-1947

Studies in 1946 at Chisholm, Minn.—In developing the peat pellet scheme, this Office visualized the reduction of spreading areas by increasing the effective drying area in the layer itself. The first pellets were made in July 1946, by C. E. Plummer[1] in the Office of the Iron Range Resources and Rehabilitation at Chisholm, by stirring unmacerated peat and then rolling it in a wastepaper basket. The peat formed into pellets readily. These were then spread in thin layers on paper placed on the lawn and on the metal roof of the Memorial Building at Chisholm, Minnesota. These early experiments showed that 85 per cent moisture unmacerated peat could readily be formed into pellets and air dried in a few days.

Further experimentation with the pelletizing method was made, in 1946, at Shenango, near Chisholm, where a study of the hydro peat-screen box tests was also progressing. In these experiments, pellets were formed by rolling both hydro and macerated peat in a steel tub by hand. Among other things, these early experiments showed that the degree of decomposition of the peat influenced the moisture content at which pellets formed most readily. Fibrous peat could be pelletized at a higher moisture content than the more humified peat. It was found that even hydro peat, after drying to 80 per cent moisture, could be pelletized but since the pellet size was difficult to control, the need of devising a method of controlling particle size was evident.

Experiments in the State Laboratory at Hibbing, Minn.—During the first-half of 1947, tests were made in the laboratory of the State Division of Lands and Minerals at Hibbing, Minnesota. The peat was pelletized by rolling in a small drum about 12 inches in diameter and 8 feet long, powered by a small variable speed motor. The effect of slope, speed and load variations were studied. It was found that too high a speed or too high a moisture content caused sticking. Due to the shortness of the drum, it was found advisable to pass the product through the drum several times in order to produce a denser pellet.

Drying Peat Pellets in Screen Boxes—One of the important experiments made in June 1947, at the laboratory of the State Division of Lands and Minerals at Hibbing, compared the drying rates of four different sizes of classified pellets when dried in 8-mesh screen boxes in layers 12 inches and 4 inches deep. The four sizes tested were —2+1 inch, —1+5/8 inch, —5/8+1/2 inch,

[1]Technical Director of Peat Development, Iron Range Resources Rehabilitation, Chisholm, Minn.

and $-\frac{1}{2}+\frac{1}{4}$ inch. The samples were placed on the roof of the building and were not disturbed until the 11th day when they were examined and weighed.

In samples 12 inches deep, the results showed that as the size of the pellets decreased, the per cent of moisture increased; that is, the $-2+1$ inch pellets had a final moisture of 14 per cent and the $-\frac{1}{2}+\frac{1}{4}$ inch pellets had a 50 per cent moisture content.

In samples 4 inches deep, the general trend was the same with the exception that the two largest sizes had similar moisture contents, the $-1+\frac{5}{8}$ inch pellets being slightly lower than the $-2+1$ inch pellets. These results suggested that smaller pellets would probably dry more satisfactorily in thinner layers and that larger pellets could be dried in thicker layers.

Early Experiments at Balkan Bog Near Chisholm, Minn., 1947

Preparations for Outdoor Testing — The results obtained from using the small drum at Hibbing were sufficiently encouraging to warrant building, in the late summer of 1947, a larger drum, 30 inches in diameter and 12 feet in length. This drum was powered by a Model A Ford engine, driving a flat belt connected directly to the periphery of the drum.

On August 7, 1947, pellets were spread in single layers on screens protected from the sun to determine if peat could be dried in single layers in a multiple screen shelf drying system. Dmitri Pouchak and Andrew Shine of this office suggested the possibility of the quick drying of pellets by such a method, thus avoiding the necessity of using shallow screen boxes. Since the early tests were near the bog surface, plans were to make further drying tests on screen shelves placed on the bog.

On September 16 and 17, approximately 60 yards (45 tons) of peat containing about 86 per cent moisture was dug, with a 10-B Dragshovel, from a small area located about 150 feet east of the west shoreline of the Balkan bog where the peat had a depth of about 7½ feet and was rated as 6-7. The peat was hauled about 100 yards and dumped onto the gravel shore of the bog into a pile about 4 feet high.

The peat on the top one foot of the pile had, in two weeks' time, dried down to about 81 per cent moisture; no difficulty was had in maintaining this moisture in all the experiments.

Drying Peat Pellets On Screen Shelves—Preliminary experiments started September 5, but actual outdoor testing was started October 3, 1947 and was discontinued October 23, 1947. During this period of 20 days, 20 experiments were started, but because of undesirable weather conditions at the end of the period, complete data was obtained on only 12 of the tests. During the tests, 3,880 pounds of approximately 80 per cent moisture peat pellets

Using a density of raw peat as 62.4 lb./cu. ft. or 1,680 lb./cu. yd. equivalent to .84 tons/cu. yd.

$$\frac{1{,}750}{.84} = 2{,}080 \text{ cu. yd./day}$$

$$\frac{2{,}080}{20} = 104 \text{ cu. yd./hr., quantity excavated}$$

Estimated cost is placed at $0.10 a ton, based on using a slack-line cableway excavator digging 250 tons of raw peat per hour.

Maceration — Movable Breaker Plate Hammermill.

175,000 tons/year (180 day season, 20 hr. day)

$$\frac{175{,}000}{180 \times 20} = 48.6 \text{ tons/hr. to macerate}$$

Pelletization.

175,000 tons/year (180 day season, 20 hr. day)

$$\frac{175{,}000}{180} = 972 \text{ tons/day}$$

$$\frac{972}{20} = 48.6 \text{ tons/hr.}$$

30 in. = 2.5 ft. dia. drum, capacity = 1 ton/hr.

$$7 \text{ ft. drum capacity} = 1 \times \left(\frac{7}{2.5}\right)^2 = 7.84 \text{ tons/hr.}$$

$$\frac{48.6}{7.84} = 6.2\text{; use 6 machines}$$

Drying System.

180 days at 6 days per cycle = 30 cycles per season

5 lb./sq. ft. of 80 per cent pellets = 1.43 lb./sq. ft. of 30 per cent moisture fuel

$$\frac{1.43}{6} = .238 \text{ lb./sq. ft. per day of 30 per cent moisture fuel}$$

$$\frac{2{,}000}{.238} = 8{,}400 \text{ sq. ft. of screen required per ton per day}$$

$$\frac{50{,}000 \times 8{,}400}{180} = 2{,}335{,}000 \text{ sq. ft. of galvanized 3 mesh screen required}$$

Screen cost—$0.10 to $0.15 per square foot.

Method A. Using 6 units 8 feet wide and 12 or 18 shelves high; each supplying an 8 foot section.

(a) 12 shelves high

$$\frac{2{,}335{,}000}{12 \times 8 \times 6} = 4{,}050 \text{ ft. length of each of 6 sections}$$

(b) 18 shelves high

$$\frac{2{,}335{,}000}{18 \times 8 \times 6} = 2{,}702 \text{ ft. length of each of 6 sections}$$

Method B. Using one long unit 18 shelves high and 20 feet wide.

$$\frac{2{,}355{,}000}{18 \times 20} = 6{,}480 \text{ ft. total length of the section}$$

Suggested Spreading Method[1]

Conveyor 20 inches wide to handle 50 tons per hour at 150 feet per minute requires a spreading rate of 48.6 tons per hour or 97,200 pounds per hour.

Method I. Single shelf, spreading 5 pounds per square foot

(a) 8 foot wide sections

$$\frac{97{,}200}{5 \times 8} = 2{,}430 \text{ ft./hr.} = 40.5 \text{ ft./min. forward travel of spreader}$$

(b) 20 foot wide sections

$$\frac{97{,}200}{5 \times 20} = 972 \text{ ft./hr.} = 16.2 \text{ ft./min. forward travel of spreader}$$

Method II. Simultaneous spreading of a number of shelves 5 pounds per square foot.

(a) 8 foot wide sections, 12 or 18 shelves high
6 shelves spread simultaneously

$$\frac{97{,}200}{5 \times 8 \times 6} = 405 \text{ ft./hr.} = 6.75 \text{ ft./min., forward travel of the 6 shelf spreader}$$

(b) 20 foot wide sections, 18 shelves high
6 shelves spread simultaneously

$$\frac{97{,}200}{5 \times 20 \times 6} = 162 \text{ ft./hr.} = 2.7 \text{ ft./min., forward travel of 6 shelf spreader}$$

Estimated Costs—

Before reliable cost figures can be given, larger pilot plant operations would be necessary. Excavation, maceration, pelletization and drying system costs can be estimated rather closely. The method of loading and unloading pellets is still unsolved and cost figures are not available.

It was believed that our investigation should include the development of both a domestic and industrial peat fuel. To compete with domestic coal, peat pellets would have to be produced to sell for less than $0.80 a million Btu. The present cost of coal selling for $21.50 a ton. Thirty per cent moisture peat having a heating value of 6,000 Btu could not then sell for more than $9.60.

Excavation.

Tower scraper 3 cu. yd.—estimated cost.................................$100,000.00
100 hp motor or a diesel engine
Power consumption, ¼ kw per 100 ft. haul
Maintenance for replacement of expendable parts at $0.09 a ton
Net peat, 90% moisture; dried pellets, 30% moisture

[1]Andrew Shine, Mechanical Engineer, Iron Range Resources and Rehabilitation.

Conversion factor, 7

	Estimated cost per ton New	Dry
Ammortization	$0.043	$0.301
Maintenance	0.009	0.063
Power	0.010	0.070
Labor	0.054	0.378
Total	$0.116	$0.812
Maceration. (80% moisture) Est. cost	$0.04	$0.135
Pelletization (80% moisture) Est. Cost	0.04	0.135

Drying System
Screen—2,335,000 sq. ft., costing $233.500
Structure estimated cost $250,000

15% annual charge

Screen	$ 35,025	$0.70
Structure	$ 37,500	$0.75

Spreading and Harvesting
(Not sufficient data)

Total (not including spreading and harvesting, etc.) $2.53
(To compete with steam coal the total cost cannot exceed $5.20; domestic coal, $9.60).

PART III

IMPORTANT OPERATIONS IN PEAT PROCESSING

CHAPTER IX

EXCAVATION

Excavation, maceration, transportation, and water removal are important operations in peat processing.

Any method for producing peat fuel at a price competitive coal must be highly mechanized. The high moisture content of peat bogs limits the use of heavy equipment on the bogs unless the bog is well drained or means are taken to provide the large bearing surface necessary for operation on the bog. The surface of a drained bog will generally bear weights of from 200 to 800 pounds per square foot, the exact amount depending upon the kind of surface and the season. Equipment is often supported on wide timber sleepers or, in undrained bogs, on mats. Present practice is to mount the excavating equipment on a caterpillar tractor with wide treads.

Chain bucket types of peat digging machines of the endless chain type are designed for excavation with the idea in mind to keep the process automatic and continuous. The elevator operates in a system with the macerator and was first driven by steam and later by electric power. Some of them have operated efficiently in root-free deposits but are unsuitable for bogs containing roots and stumps. The majority of excavators, supported on rails or caterpillars, travel on the surface of the bog or the bottom of the working trench; others are floating dredges and pump the wet peat through pipe lines. Recently, there has been a trend towards the use of shelves and dragline systems.

The use of the mechanical excavators results in a thorough mixing of all layers from top to bottom, a condition that does not exist when the milled peat process is employed. As previously the hydro peat process uses water for cutting, mixing, and transportation, thus eliminating maceration as a step in the production of peat fuel.

Use of Draglines—Draglines have been used for excavating in Florida.[1]

"Using a one cubic yard dragline and four trucks about 450 cubic yards of wet peat can be dug and hauled

[1]The Peat Deposits of Florida, by J. H. Davis, Jr., Geological Bulletin No. 30, Tallahasse, Florida, 1946, pp. 210-12.

about a quarter of a mile in an eight hour day at a total cost of about $90 or about 20 cents per cubic yard."

"A report from one of the peat producers in Florida of operations during 1944 indicated that: about 15,000 cubic yards of wet peat was excavated using a dragline dredge; the peat was dried by gravity and air in stockpiles about 10 feet high, then shredded in a Cylandar shredder run by a gasoline engine; the 15,000 cubic yards dried to about 8,000 cubic yards; the cost of operation was 25 cents a cubic yard to excavate and pile wet peat, and 25 cents a cubic yard to shred and pulverize dried peat; most of the peat was sold at $2.00 per cubic yard at the plant; overhead and other operating costs were probably 50 cents a cubic yard for the final air dried shredded peat; and the total costs may be estimated at $10,500 and sale price $16,000 showing a good profit for the entire operation."

"One acre of a deposit 3 feet deep yields nearly 5,000 cubic yards of excavated wet peat, which wet peat usually weighs 1,500 pounds per cubic yard and contains about 80 to 90 per cent water. After air drying in the pile to about 60 per cent water this 5,000 cubic yards shrinks to about 3,500 cubic yards and weighs less than 1,000 pounds per cubic yard. After shredding or pulverizing and more air drying, the peat may lose no or very little volume but does lose moisture and weight, a cubic yard at 50 per cent water usually weighing 600 to 900 pounds.

"Consequently, if a five acre deposit is excavated 9 feet deep 75,000 cubic yards or 56,250 tons of wet peat will be obtained. After the usual shrinkage, and drying to 50 per cent moisture have taken place, and the peat shredded approximately 52,500 cubic yards weighing from 15,750 tons to 23,645 tons will be recovered."

Possible Application of a Slackline Cableway Excavator for Digging Peat—The frequent presence in the bogs of undecomposed roots or trees seriously interferes with the operation of most excavators of the chain bucket type. Using a slackline cableway excavator for digging, with an eight-yard bucket, should solve the root problem. The bog should not have an irregular bottom, otherwise contamination could result.

Peat, before it is macerated, must be dug, elevated, conveyed, and dumped. Any excavating methods should attempt to save labor; be simple in construction and operation; be rapid in operation; dump clean; require small power consumption; require a low maintenance cost; be properly designed for maximum service; be capable of working over a large area; and be adapted to varying peat conditions. Since a slackline cableway excavator appears to meet the above requirements, cost figures were obtained from a leading manufacturer of such equipment.[1]

The machine under consideration is one costing approximately $175,000 and consisting of a self-supporting and self-propelled head and tail tower, each mounted on a crawler, with a 600 foot span between the towers. The crawler machine with 350 hp would be capable of motivating an 8-cubic yard Crescent Scraper Bucket and produce 250 tons of 90 per cent moisture peat per hour, when operating on average haul of 300 feet.

The crew of four would be small and consist of an operator at the head tower and one at the tail tower and two helpers to oil and grease the machines and do general labor work. Power consumption is given as 1 kwhr per ton per 100 feet of haul. Maintenance for replacing expendable parts of equipment such as cable, sheaves, and brake lining, is estimated at about $0.01 per ton of material handled.

Peat as dug and conveyed to a stockpile will contain about 90 per cent water. By drying in the stockpile from 90 to 80 per cent water, the peat loses half its original weight, equivalent to about 55 per cent of its water; such a process appears to be an economical way of removing half of the water.

Only actual digging data will give true cost figures, but from figures given by the manufacturers, the cost of excavation by this method should not exceed $0.10 a ton, equivalent, we estimate, to $0.45 a ton of 55 per cent moisture peat fuel, or $0.70 a ton of 30 per cent moisture peat.

CHAPTER X

MACERATION

Maceration, pulping, or grinding are terms applied to peat when it is mixed, kneaded, or cut. Wet peat can be macerated by passing it between rotating, cutting, and shredding rolls, or hammermills with the screen removed. Macerated peat, when dried, is denser, more brittle, and more water repellent than unmacerated peat. A small amount of the well decomposed colloidal peat serves as a binder for the less decomposed fibrous peat. Maceration is an important step in producing domestic peat fuel, since a high bulk density is required.

The first mixing machine, or macerator, on record is that of Hasselgren in Sweden in 1845.

[1]Sauerman Bros., Inc., 522 S. Clinton St., Chicago 7, Illinois.

The early macerators were of the meat grinder type. The Anrep macerator was one of the popular machines and depended on the action of a series of rotating knives intermeshed with stationary knives. Roots and fibrous materials caused clogging and often breakages. The hammermill was found to possess outstanding advantages over the screw type machine, since it was able to clear itself of roots, stones, etc. without breakage and resulted in greater efficiency through its ability to shred pieces of wood and thus increase the amount of fuel from the material handled.

Non-Clog Hammermill With Moving Breaker Plates—Since hammermills with stationary breaker plates have proven satisfactory for macerating peat in Canada,[1] further study has been made into the possible application of a non-clog hammermill with movable breaker plates for macerating peat.

Manufacturer Cost Data—In answer to our questions relative to the use and cost of such a machine, the manufacturer[1] writes as follows:

> "As your crushing problem up there will require large capacities, we will base our estimate on your outside figure of 250 tons per hour and estimate that the 3650 Dixie Non Clog Hammermill when operating on wet peat and having only the No. 1 section of grate bar installed should approximate that capacity.
>
> "We would recommend that this 3650 Hammermill be driven with not less than a 150 hp, 1200 rpm motor, being provided with three rows of cutting hammers in order to macerate the sticks and roots of the unrotted vegetation in the peat deposits.
>
> "The idle or no load horsepower required to turn the 3650 Dixie Non Clog Hammermill up to 1200 rpm with the standard 1500 lb. flywheel will average approximately 150 hp required for a capacity of 250 tons per hour."
>
> "The power or kilowatt hours energy required for an output of 150 hp per hour would require approximately 120 kilowatt hours for the crushing of 250 tons of peat basing your cost per kilowatt hour at 1½c and then dividing by 250 tons per hour should give you a net cost of energy per ton of approximately ¾c."
>
> "From information which we have on the crushing of wet clay, coal, limestone and other material, we cannot possibly conceive how the grate bar and hammer

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[1]Peat, Its Manufacture and Uses, by B. F. Haanel, Final Report of the Peat Committee, Canada, 1926, pp. 137-138.
[1]Dixie Machinery Mfg. Co., 4200 Goodfellow Blvd., St. Louis 20, Missouri.

wear would exceed ½c per ton, this including maintenance in changing hammers and grate bars when required, and summing up the figures given above, it is our estimate that the actual crushing cost for macerating your peat, including electrical energy, hammer and grate bar wear, should not exceed 1¼c per ton.

"We further wish to advise that these figures will vary, depending on the variation in the cost of electrical energy due to the amount of energy consumed and also the hammer wear may vary with a change in the character of the peat deposit being crushed, however, we feel that this will be a reasonably safe figure on which to base your estimates.

"In order that you may complete your estimate as to the cost of this crushing equipment, we wish to advise that the present day price of the 3650 Dixie Non Clog Moving Breaker Plate Hammermill is $11,600.00 without motors and also that the cost of the Dixie 30" x 8' Apron Feeder which you would require for handling volume of material will be approximately $3450.00, including the motor and speed reducer driving the feeder unit. The cost of a 150 hp, 1200 rpm motor, standard open type is approximately $1,830 and should you desire splash proof construction, it will be necessary to add approximately 10% to that figure. Starter for the above motor, being of the full automatic compensator type, arranged for operation on 440 volts, will cost approximately $2000.00."

Only actual maceration data will give true cost figures, but figures available place the cost of maceration by this method at approximately $0.02 a ton, equivalent to $0.14 a ton of 30 per cent moisture peat, provided 90 per cent moisture peat is macerated. If 80 per cent moisture peat can be macerated at $0.02 a ton, then the cost for maceration charged against the 30 per cent moisture fuel is estimated at about $0.07 a ton.

CHAPTER XI

REMOVAL OF WATER FROM PEAT

The Effect of Water on the Value of Peat—The removal of water is generally considered the most difficult and also the most important factor to consider in setting up an economical peat winning process. For general economic discussion, it is suggested that the net heating value of peat be used. In our calculations on fuel value, we have based them on the net heating value in order to avoid great discrepancies in comparing with other fuels.

The peat under consideration is a sample taken from the pilot plant site at the Balkan bog, located about 2 miles north of Chisholm, Minnesota. On a Moisture-Free Basis, the sample contains 11 per cent ash, has a gross heating value of 9,170 Btu per pound, and a net heating value of 8,712 Btu per pound; on a Moisture-And-Ash-Free Basis, the sample contains 5.6 per cent hydrogen, has a gross heating value of 10,300 Btu per pound and a net heating value of 9,794 Btu per pound.

According to the U. S. Bureau of Mines:[1]

> "In order to calculate the net heating value of the above sample of Minnesota peat, it is necessary to correct for the latent heat of hydrogen. In the bomb calorimeter, the latent heat of water is 1030 Btu per pound at 68° F. The latent heat of hydrogen is, therefore, $1030 \times \frac{18.016}{2.016} = 9{,}204.6$ Btu/lb.

The net heating value of peat substance is calculated as follows:

$$10{,}300-(9{,}205 \times 0.056) = 9{,}794 \text{ Btu, net heating value on the moisture-and-ash-free basis.}$$

To determine the net heating value of peat on the As-Received Basis, the following formula is used:

$$N(1\text{-}W\text{-}A)-(W \times 1030) = \text{net Btu}$$

N = net heating value, moisture-and-ash-free = 9,794

W = moisture in 1 pound of peat = 55%

A = ash in 1 pound of peat = 5%

1030 = latent heat of water, using 68° F base used in calorimetry

$9{,}794(1-.55-.05)-(.55 \times 1030) = 3{,}918 - 568 = 3{,}350$ Btu, net heating value theoretically available."

The net heating values shown in the following tabulation were obtained by using the formula:

$$9{,}794(1\text{-}W\text{-}A) - (W \times 1030) = \text{net Btu}$$

[1]Reviewed by V. F. Parry, Supervising Engineer, Sub-bituminous & Rocky Mtn. Coals Division. U. S. Bureau of Mines, Golden, Colorado.

TABLE II

Effect of Moisture on the Net Heating and Dollar Value of Heat

Analysis of Peat As Rec'd. %		Heating Value Btu Per Pound		Water Ratio Lbs. Water Per Lb. of Peat	Dollar Value[1] Per Short Ton
Moisture	Ash	Gross	Net		
95	0.6	459	—538	19.0	0
92	0.9	734	—262	11.5	0
90	1.1	917	— 55	9.0	0
89	1.2	1009	+42	8.1	$0.04
80	2.2	1835	919	4.0	$0.80
70	3.3	2760	1894	2.33	$1.70
55	5.0	4130	3352	1.22	$3.00
40	6.6	5500	4818	0.67	$4.30
35	7.2	5960	5300	0.54	$4.75
30	7.7	6420	5793	0.43	$5.20
10	9.9	8250	7839	0.11	$7.00
0	11.0	9170	8712	0	$7.80

The water content is expressed in both per cent and "water ratio." It has been found more useful in certain cases to express water contents in terms of water ratio instead of the usual percentage method. The water ratio of any sample may be defined as the number of units of water associated with one unit of dry peat substance in the sample. Bog peat containing 90 per cent moisture, having a water ratio of 9:1, has 9 units of water for every unit of dry peat substance. Peat with 80 per cent moisture has 4 units of water to one of dry peat substance. This means 90 per cent bog peat, dried to 80 per cent moisture, has lost 5 units of water for each unit of dry peat substance or 55.6 per cent of its original water.

Peat of the analysis shown in the preceding table, with 89.4 per cent moisture has no net calorific value. The heating value increases as more and more water is removed. Peat in bogs containing less than 89 per cent moisture has a net heating fuel value, which explains why bogs burn.

It is apparent that a peat winning process, to be successful, must remove the bulk of the water by methods involving a very small outlay of capital and labor per unit of raw material. This is perhaps the reason air drying is the only successful method of water removal in use today.

Much research has been undertaken to determine the practicability of removing water from peat by draining, pressing, artificial heating, and finally, by air drying. A discussion and evaluation of these processes of moisture removal follows.

Removal of Water from Bogs by Draining—It is a common occurrence for competent engineers to suggest drainage as a method for removing most of the water from peat. Observation

[1]Based on present value of steam coal at $11.36 a short ton, equal to $0.45 a million net Btu; for domestic fuel this price is nearly doubled, ($0.85 a million net Btu).

and experimentation show that it is impossible to reduce the moisture content much below 87 per cent by drainage methods.

The capacity for retaining water is one of the most remarkable properties of peat. Non-macerated, highly humified peat, diluted with an excess of water to form a thin slurry containing 5 per cent solids will, when placed in a small screen box, drain in a few hours to about 89 per cent water. Peat bogs containing about 87 per cent water are found on the sides of mountains; the water is held so tenaciously in the pores or cells of the peat that the natural forces of gravitation fail to separate the water from the peat. Tests have been made in which a large block of peat was cut out of the bog and the water did not flow from the sides. A deep hole can be dug beside a drainage ditch without the water immediately flowing into the hole. Reducing the water level will reduce the water content in some peats to 86 per cent after years of standing. We have found this to be true near the north shore of the Balkan bog where peat was excavated for the 1947 experiments.

Drainage is necessary for the milled peat process. The ditches 4 to 5 feet deep are generally spaced 50 feet apart. By proper draining, it is possible to reduce the water in the upper surface from 92 to 88 per cent.

Reducing the water content of peat from 92 per cent to 88 per cent, changes the water ratio from 11.5 to 7.3. In other words, 4.2 units of water have been removed for each unit of dry peat substance or equivalent to a loss of about 36.5 per cent of the original water.

Although the draining of peat bogs seems to be a practical and convenient method of removing a high percentage of the original water in peat, still, after draining, the peat may contain 88 per cent water. In the milled peat process, draining not only removes a large percentage of the water, but it also provides a suitable drying area and makes the surface of the bog sufficiently firm for working. It would not be advisable to attempt to reduce the water content of peat much below 88 per cent by draining a bog, especially in a short time.

Removal of Water from Bogs by Pressing—Experience in Canada goes to confirm the general conclusion that it is not economical to remove water from peat by pressing. B. F. Haanel[1] discusses the removal of water in pressing thus:

> "The idea that the process of manufacture of fuel from raw peat could be greatly hastened by the expulsion of a large proportion of the contained water by mechanical pressure has been widely popular and has led to thousands of experimental efforts and to the establishment of numerous large-scale plants relying upon

[1]Final Report of the Peat Committee, B. F. Haanel, Mines Branch, Dept. of Mines, Ottawa, Canada, 1926, p. 63.

such means to avoid the delays incidental to air-drying. Although apparently promising results have been obtained in laboratory experiments, no success in commercial production has been achieved.

"Every form of press has been tried—rollers, filter presses, hydraulic piston presses of various types; and pressure has been applied in every conceivable way—low pressures gradually increasing, intermittent pressures, and extremely high pressures continued for short or long periods of time.

"The net result of all such efforts has been to demonstrate that the water content of raw peat cannot be economically reduced by pressure alone to less than 75 per cent, and that the application of pressure in any form whatever to further reduce the water content requires so long a time, and the use of so much power that the process cannot be commercially employed.

"The great difficulty which is experienced in removing the water content of peat by mechanical means is due to the colloidal character of the peat humus that it contains.

"Those substances known as colloids are distinguished by the extremely minute subdivision of the particles of which they are composed, and, therefore, in contact with liquids or gases, present an exceptionally large surface of contact in relation to their mass. Not only the contents of the cells in peat-forming plants, but also the structureless materials produced by humification or decomposition of the organized structure are colloids. The products of humification, which may be designated peat humus resemble in certain respects such substances as glue, gelatin, starch, paste, and soap. Peat humus has in common with them the property of abording very large quantities of water, and of shrinking very greatly in drying. Water is held in colloids in such a manner as to render its expulsion by mechanical pressure a physical impossibility, since the particles of which they are composed are so minute and have so strong an attraction for the molecules of water, that the pressure exerted to expel the molecules of water will also carry off the particles associated with them. In direct proportion to its value as a source of fuel, the amount of the contained water which can be removed by pressure decreases."

The Ekenberg Process—The Ekenberg Process, in which the raw peat was heated in a closed vessel at 180° C. and then subjected to pressure was carefully investigated for 20 years (1900-

1920). Since more calories were consumed than produced, naturally, the process was reported as not economical. The idea to destroy the colloidal properties by strongly heating the raw peat under pressure in a closed vessel has often been tried, but here again, the favorable results obtained in the laboratory were not duplicated in actual plant operations, although some improvement could possibly be made by output-input heat interchange or otherwise.

Removal of Water by Artificial Heat—A study of Table II shows that it is not practical to use artificial heat for removing the major part of the water. Peat with more than 89 per cent water has no net heating value and is, therefore, worthless as a fuel. Milled peat containing 55 per cent moisture and having a net calorific value of 3352 Btu per pound, should not be dried in a rotary drier of 60 per cent efficiency.

Recent engineering developments indicate that it might be possible to use 50 to 55 per cent moisture peat as a fuel for steam raising by using part of the furnace gases to dry the peat down to 40 per cent moisture, at which moisture content the ground powder would ignite and burn satisfactorily in suspension. This is discussed in more detail in that part of the report dealing with fuels. If peat is to be used as a fuel for steam raising, it appears to be good economy to burn the more bulky 55 per cent moisture peat in a properly designed plant located at the bog where the cost of handling the larger amount of fuel would be reduced.

Removal of Water by Air Drying—Processes that actually produce peat fuel on a commercial scale utilize the heat of the sun for evaporating the water from raw peat. The removal of water is not only the most important, but also the most difficult factor, in most peat winning processes. Since air drying is the basic method of water removal, this office has, during the past two years, made an extensive and intensive study of the factors that control and influence the rate of air drying.

Air drying depends on the utilization of solar energy both as direct radiant heat and through convection currents in the air. Variations in solar energy produce changing weather conditions. Experimental evidence shows that the amount of direct sunshine, temperature, humidity, wind velocity, and rain are weather factors that affect air drying. Weather data, taken several times daily, is carefully considered in the proper evaluation of results obtained by experimentation.

Peat exposed to the direct rays of the sun dries faster than peat not exposed but becomes less compact and develops cracks—properties considered undesirable for a domestic fuel but not objectionable for industrial fuel.

The effect of rain and other forms of precipitation on air drying of peat depends on several factors, such as quantity of rain, time of rain, wind condition accompanying rain; size and shape of peat particles; quality of peat; moisture of peat at time of rain; and degree of maceration.

Machine peat dried in the form of blocks on the surface of the bog or on the ground adjacent to the bog is not seriously affected by rain since a protective film forms on the surface of the peat. Such peat is usually dried on the bog to a 30 per cent moisture content. Milled peat, which is unmacerated and finely divided, absorbs moisture more readily. It is, therefore, necessary to harvest milled peat as soon as possible at 50 to 55 per cent moisture content so as to avoid delays due to rain.

Peat reduced to an anhydrous state is found to reabsorb moisture from the air until a certain condition of equilibrium is reached. The actual amount of hygroscopic moisture in peat varies slightly with relative humidity and usually contains 16 per cent water.

Comparison of Area Requirements for Machine, Hydro, Milled, and Pelletizing Processes—A study of the various methods used to produce peat fuel shows that large drying areas are required in all processes, and that the drying area required per ton of dried peat varies. In order to evaluate the various methods, a formula can be used. Areas are often reported in square meters or acres.

$P_h = A_h \text{ x } (P_{sf}) \text{ x } (N_h)$, where P_h is the number of pounds of peat harvested per season, A_h is the number of square feet needed, P_{sf} is the number of pounds per square foot harvested, and N_h is the number of harvestings per season.

Machine-Hydro Peat—Assuming that 90 per cent moisture peat is spread 4½ inches thick and this substance has the density of water (62.5 lb./sq. ft.), the weight of peat spread per square foot is 23.3 pounds. This is equivalent to 2.33 pounds of dry peat substance or 3.33 pounds of 30 per cent moisture peat.[1]

Drying time is approximately six weeks, which limits the number of harvestings to two or three.

Applying the formula with the above values to find area needed per ton, we get,

$$1(A_h) \text{ x } 3.33(P_{sf}) \text{ x } 2(N_h) = 6.66 \text{ pounds} = P_h$$

$$\frac{6.66 \text{ (lb.)}}{1 \text{ (sq. ft.)}} = \frac{2000 \text{ (lb.)}}{X} \qquad x = 300 \text{ square feet per ton}$$

If 12.5 per cent is allowed for loss, etc., then a drying area of 375 square feet will be required per ton of 30 per cent moisture fuel produced by the machine peat process.

[1]Dry peat substance in 90% moisture peat = 10% of 23.3 lb. = 2.33 lb. $\frac{2.33}{.70}$ = 3.33 lb. 30% moisture peat.

This figure is an agreement with the 372 square feet per ton calculated by the Canadian Peat Committee.[1]

To produce 100,000 tons of fuel by either the machine or hydro peat methods would require a drying area of about 37,500,000 square feet, approximately 860 acres.

Drying experiments made in Canada have shown that 90 per cent moisture machine peat will dry to 55 per cent moisture on the average in 3.6 weeks. It should be possible to increase the output of machine peat per season by increasing the number of harvestings to four by harvesting 55 per cent moisture peat instead of 30 per cent moisture peat.

Milled Peat—In the milled peat process, only about one-half inch of 88 per cent moisture peat is cut from the surface of the drained bog and immediately spread in a finely divided condition on the surface of the bog adjacent to where it was cut. After drying for 5 to 6 days, the peat containing approximately 55 per cent moisture will now probably weigh about .3 pounds per square foot and is ready to be harvested.

Applying the formula to milled peat we get:

$$1(A_h) \times .3(P_{sf}) \times 20(N_h) - 6(P_h)$$

$$\frac{6}{1} = \frac{2000}{X} \qquad X = 333.3 \text{ square feet per ton of 55\% moisture peat}$$

Since one ton of 55 per cent moisture peat is equivalent to .643 of 30 per cent moisture peat, then by calculation, 518 square feet would be the area required for the equivalent one ton of 30 per cent moisture peat.

J. Martin[2] states that at the Lullymore bog in Ireland, about 59,775 tons were harvested from 500 working acres in the summer of 1945. The actual area needed here to harvest one ton of 55 per cent fuel is 363 square feet, slightly more than that calculated in the formula. Mr. Martin adds that an output of 90,000 tons of milled peat per annum from 500 working acres is possible. This would be an actual area of 242 square feet per ton of 55 per cent moisture peat. The number of harvestings in Ireland range between 16 and 24; 20 is a fair average; and 120 tons per acre per season is possible in Ireland, according to Mr. Martin.

Pelletizing Process—It appears that at least 30 harvestings of 30 per cent moisture pellets should be possible each year. Apply the formula to determine area needed for a ton of fuel we get:

$$1(A_h) \times 1.43(P_{sf}) \times 30(N_h) = 42.9(P_h)$$

$$\frac{42.9}{1} = \frac{2000}{X} \qquad X = 46.6 \text{ square feet per ton of 30\% moisture pellets}$$

[1]Final Report of the Peat Committee, B. F. Haanel, 1926, p. 152.
[2]Winning and Utilization of Peat, J. Martin, Ireland, p. 209.

Table III give comparative drying areas for machine-hydro, milled peat, and pelletized peat as calculated by the writer. The results are in close agreement with actual bog outputs.

TABLE III

Comparative Drying Area Data

	Machine-Hydro	Milled		Pelletized
			(Equiv.)	
Moisture	30	55	30	30
Sq. ft./ton/year	300	333	518	46.6
Lb./sq. ft./year	6.7	6	3	43

It appears from these calculations that milled peat needs a larger drying area than either of the other processes.

Since the only methods used for producing peat for fuel use solar energy, it is evident that the only methods which can be economically employed for the manufacture of peat fuel are those employing air drying.

Part IV
PEAT AS A FUEL

CHAPTER XII

INTRODUCTION

Peat is not usually considered as a fuel in the United States, in spite of the fact that it was well known and used as a fuel by many American citizens before they moved to this country. As can be seen from the coal energy table below, showing the reserves in the United States, peat is not even listed as a possible fuel.

TABLE IV

Distribution of Coal Energy[1]

Material	Per Cent
Anthracite	0.5
Bituminous Coal	57.5
Sub-bituminous Coal	23.0
Lignite	19.0

The reason peat is not recognized as a fuel here is quite obvious and easily explained. The United States has always had unlimited reserves of natural coal, with coal appearing in 37 of the states; this accounts for the almost complete neglect of peat as a fuel.

Minnesota represents one of the 11 states that does not have coal deposits or any fuel deposits within its boundaries. Northeastern Minnesota, along with Florida, are the two places in the country which are most remote from any natural coal reserves. The Northeastern corner of Minnesota is within 500 miles of the North Dakota lignite deposits, but because of the high freight rate ($3 a ton) and low heating value of lignite, this source of fuel has not been able to compete with coal from West Virginia, even though these West Virginia deposits are 1200 to 1400 miles away. When this normal fuel deficiency and the remoteness from coal deposits is realized, it can easily be understood why Minnesota has a primary interest in finding ways to make its vast peat deposits a source of fuel economically available to its people and industry.[2]

It has long been recognized that the development of low-cost power fuel is a vital step forward in the utilization of Minnesota's

[1]Coal Research in the U. S. A. Today, Bengt Christiansson, Sweden.
[2]The Potential Industrial Fuel Value of the Peat Deposits of Northern Minnesota, by R. L. Fitzgerald, July 17, 1947.

low-grade iron ore and, therefore, it is important that the use of peat as a power fuel be considered. It is also important that we do not only look on the uses of peat as a power fuel from an economic viewpoint alone, but also from the necessity viewpoint. With the realization that at present, approximately 75 kwhr is needed to produce one ton of concentrates from taconite (low-grade ore), it can be seen that the existing power supply might become inadequate. During 1948, and the spring of 1949, we have experienced in northern Minnesota, an extreme shortage of electrical power due to very dry weather. It is during times likes these that the necessity value of peat becomes of prime importance.

Peat, as it comes from the bog, has no net heating value because all of the heat available by burning the peat is consumed in evaporating the moisture contained in the peat. Dried peat, however, does have a heating value of about 8850 Btu per pound. This compares favorably with lignite, but its heating value is far below that of the better grade coals which have heating values of 13,500 to 14,800 Btu per pound. A typical analysis for peat, lignite, and coal found in the U. S. A. is given below.

TABLE V

Average Analysis of Peat, Lignite, and Coal Fuel

	Air-Dried Peat	Lignite	Coal
PROXIMATE ANALYSIS (Moisture Free)			
Ave. Moisture % (As Received)	30.0	35.2	4.5
Fixed Carbon %	29.2	48.6	54.19
Volatile Matter	59.1	43.1	35.26
Ash	11.7	8.3	6.05
ULTIMATE ANALYSIS (Moisture Free)			
Hydrogen	5.0	4.5	4.9
Carbon	51.6	65.7	78.7
Nitrogen	1.6	.8	1.58
Oxygen	29.9	19.6	7.45
Sulphur	.2	1.1	1.15
Ash	11.7	8.3	6.05
Fusion Temp. of Ash	2,100	2,470	2,303
Btu/lb. (Dry)	8,850	11,070	14,140

The essential difference between coal and peat are: (1) peat with 25 per cent moisture has about half the heating value and twice the volume of the same weight of coal; (2) peat has nearly twice the volatile content of average coal, i.e., 55 to 65 per cent as against about 35 per cent for ordinary bituminous coal; and (3) peat has about half the fixed carbon of coal.[1] As a result of the high per cent of volatile matter, the flame produced when peat is burned is much longer than that from coal. As can be seen from the foregoing statements, a furnace to burn peat would be required to handle 4 times the volume of coal necessary to produce the same heat liberation. This can be taken care of in several

[1]Turf as Fuel for Steam Boiler—Industrial Research Council, Dublin, Ireland, 1946.

ways: a greater grate area can be provided; a larger amount of forced draft introduced; or a pre-combustion chamber or furnace where the peat is only partially burned can be installed. In burning peat in a finely divided state or using a spreader type stoker, it is necessary to increase the forced draft a great deal due to the light weight of the peat particle.

CHAPTER XIII

PEAT AS A DOMESTIC FUEL

Early Uses—Developments of peat for domestic fuel have been taking place for a great number of years. These activities have varied from individuals digging and drying their own peat to the large briquetting factories of Ireland and Sweden, producing 30,000 tons a year.

Early developments in this continent were made in Canada by the Canadian Peat Committee and Department of Mines from 1915 to 1925. Peat fuel was tried out in several installations in Minnesota from 1920 to 1930. The Phoenix Building in Minneapolis used peat in their furnaces in 1920 with good results. The American Peat Society was then very active and their reports indicate that following World War 1, a great deal of both time and money was spent on the development of peat for fuel.

Requirements of a Peat Burning Furnace—Peat can be burned in an ordinary home or office building furnace. As a household fuel, it presents no appreciable clinker problem when properly fired, due to the low heat liberation necessary in a small furnace. The ash is very light in weight and easy to remove. Since peat fuel is more bulky than coal, more frequent firing is necessary or a larger fire box must be installed. When burning peat fuel, it has been generally found that a greater amount of air has to be provided for combustion which means a change in the damper arrangement. Damper control also becomes very important due to the large percentage of volatile matter in peat which could form an explosive mixture if the combustion is not properly controlled.

Peat fuel (30 per cent moisture) ignites slowly due to the large percentage of moisture present. Firing with peat fuel, especially wet peat, which produces great quantities of gas, points to the fact that a furnace should have a more convectional character than those fired with coal. When burning peat fuel, the combustion temperature is lower, gas velocity higher, over heating somewhat greater, but efficiency poorer (installations adopted from coal burning). It should be emphasized that due to the difference in combustion properties of coal and peat, a coal furnace burning peat cannot give as good results as can a furnace especially designed to burn peat.

Peat Burning Methods—There are several ways of firing peat fuel for domestic use. Hand firing can be used on small installations but neither the type of firing or installation is considered as the best way to utilize peat fuel for domestic heating. The most modern and efficient method of firing is the spreader and plunger type feeding stoker, using a traveling or slanting grate. In the larger installations, due to the slow ignition of peat, it is considered better to use the traveling grate to insure as rapid combustion as possible. It is believed (and proven by small tests) that the screw type of feeding stoker is not always a satisfactory means of firing peat. This is due to the fact that the peat between the flights of the screw cakes and forms a solid mass which stops the screw and the feeding operation.

Pellets and Briquettes as Household Fuels—The possibility of using peat fuel in the form of pellets or briquettes for small heating installations should not be overlooked.

Machine peat as used in Europe as a household fuel would probably not be accepted by the average American consumer who is accustomed to burning high grade coal. The production of peat pellets, which form a more dense and clean fuel, would be more satisfactory as a household fuel, provided it can be produced at a cost competitive with coal. It possesses properties intermediate between machine peat and briquettes.

Briquettes are a compact, clean fuel having a Btu value of 7700. At present, peat briquettes are being produced at the Lullymore Plant in Ireland for $10.40 a ton, f.o.b. Lullymore. The limiting selling price on peat briquettes, in order that they can compete with coal in the U. S. A., is $12.30. The briquettes produced at Lullymore are made using a 55 per cent moisture peat dried down to 9 to 11 per cent by use of extracted steam from the turbines before briquetting. The steam for the turbo-electrical system is produced by burning the waste peat substance. This is a very economical means of drying peat due to the fact that by extraction a gain in steam economy is made. This also applies to the combination of electrical generation and central steam heating, where the extracted steam goes into a city heating system.

There is a press in use in the United States at present that is used for briquetting wood waste. On small tests, this press has performed very well on 30 per cent moisture peat. The estimated cost to produce a ton of peat briquettes using this machine is $10.70, which is under the limiting price of $12.30 for peat briquettes of 7700 Btu, but does not leave much for profit. The product is extremely clean and excellent for stoker fuel.

Central Heating System—All tests and actual operational data available indicates that the most efficient and economical way to utilize peat fuel for domestic use is the central steam heating system. There are in existence at present, peat burning furnaces that are producing steam efficiently and economically. Swedish engineers have perfected several ways to effectively produce steam with peat. Efficiencies as high as 89 per cent with a steam production of over 57,000 pounds per hour have been attained.

The operational data, taken from four types of furnaces burning peat in Sweden, is listed in Table IV. The figures in Column 1 are those for a Swedish furnace originally designed to burn coal. Column 2 shows data for a furnace designed to use only peat. Column 3 gives data for a furnace using a Swedish stoker called the Ell-Stoker. The figures in Column 4 are for a furnace using a stoker and slanting grate. It should be noted that a great improvement was made when peat was burned in a furnace designed for peat burning. The steam production listed in Column 2 was greatly improved when a slightly drier peat was used. With a more firm and dried peat, the steam production was raised to 52,800 pounds per hour. It can be seen from these figures that small communities if located near a peat bog could utilize peat fuel to their advantage; the limiting factor being the cost of the peat fuel (3346 net Btu per pound) which could not be above $2.40 a short ton to compete with coal.

TABLE VI[1]

Type of Boiler	Plutostoker[1] (for coal)	Stoker (for peat)	Ell-Stoker	Comb Stoker (slanting grate)
Boiler fire area—ft.^{2}	2180	7450	3850	3430
Heating area of superheater—ft.^{2}	387.0	2570	2140	1860
Heating area of economizer—ft.^{2}	....	3810	8820	1870
Heating area of secondary air preheater—ft.^{2}	....	....	10320	4250
Heating area of primary air preheater—ft.^{2}	....	....	....	4250
Grate area—ft.^{2}	109.7	339	226	150
Combustion chamber—ft.^{3}	....	....	3880	2120
Moisture content of peat—%	45.2	42.5	23.5	38.5
Effective heating value of peat—Btu/lb.	4360	4480	6700	5120
Steam pressure—psi	175	269	366	379
Steam temperature—°F.	477	580	750	770
Feed water temperature—°F.	135	70	201	147
Flue gas—°F.	424	257[2]	306[3]	241
CO_2—%	13.3	....	14.3	13.3
Primary air temperature—°F.	....	....	324	234
Secondary air temperature—°F.	....	....	602	234
Steam production—lbs./hr.	5080	37,300	57,500	14,450
Steam production psf of combustion area—lbs./hr.	2.32	5.02	15.0	4.2
Amount of fuel used—lbs./hr.	1850	12,430	12,700	4310
Amount of fuel used psf of grate area—lbs./hr.	16.9	36.7	56.2	28.7
Efficiency—%	73	84	89	84
Steam produced/lb. of peat—lb.	2.75	3.00	4.53	3.35

[1]Originally designed for coal.
[2]After economizer.
[3]After primary air preheater.

[1]Sveriges Branntorv Industri, 1940-46, Olle Uddgren, p. 235.

General Summary—At present the use of peat fuel for domestic purposes in Minnesota is quite possible due to the high selling price of coal. At first thought, it would seem that a drop in the selling price of domestic coal would result in a drop in the economic possibilities of peat fuel, but when one realizes that both the selling price of coal and peat fuel is made up of the same elements of cost (e.g. labor costs, power cost, overhead, and taxes) it is evident that the cost of peat fuel would also drop with domestic coal prices.

The market for peat fuel is an item that should be given serious consideration. A. Dachnowski[1] has made the following comments in regard to this problem.

> "At first thought, any desirable type of fuel would seemingly find a ready market at good prices, but more careful consideration will raise the question as to whether a substance like peat, which is quite unknown and untried in most American fuel markets, will be accepted by any number of buyers until they have learned by experience that it may be depended upon. Experience shows that most people are conservative in adopting new materials in place of those which they have long known and have found satisfactory. The conclusion may be drawn, therefore, that the market for any form of peat, as for other new materials, must generally be won by slow and persistant effort, in which a first-rate product, skillful manufacture, careful advertising, and constant demonstration must be combined. It must also be remembered that the fuel trade is thoroughly and closely organized, and therefore, opposition must be expected to any new and independent product. This opposition, if effective will result in reduced sales, in lower prices, and obviously in smaller profits during the stage when competition from these agencies is active."

These facts point out another definite advantage to the central heating system because it would be easier to prove the worth of peat to a technical man in the heating plant than to an average home owner. Steam, an accepted heating medium, would then be the product sold to the people.

Peat fuel is being effectively and economically burned for steam raising in foreign countries and if peat fuel can be produced in Minnesota to compete with coal, there is no reason why communities near peat deposits could not be provided with cheap steam heat. For example, a combination power and heating plant located in northern Minnesota, in 1947, burned over 45,000 tons of coal, costing about $407,000.[2] This represented 37 per cent of

[1] Geological Survey of Ohio, Bulletin No. 16, by A. Dachnowski, p. 147.

[2] Taken from the Annual Report of the Hibbing, Water, Light, Power, and Building Commission of 1947.

the cost of a kwhr and 57 per cent of the cost of a pound of steam for heating. Today the same amount of coal would cost approximately 29 per cent more due to an increase in coal prices from $0.367 a million Btu in 1947 to $0.473 in 1948. This increase would then make the cost of 45,000 tons of coal, $525,000. If peat fuel of 3346 Btu can be produced today for $2.40 a ton and was used in the same size plant as mentioned above, the fuel cost would then become $398,000, a saving to the community of $127,000 or if passed on to the plant's customers, would result in the reduction of a customer's electrical bill, 9.0 per cent and of the heat bill, 13.8 per cent, assuming that the ratio between fuel and other costs remained the same for 1947 to 1948. Again, it should be pointed out that to use peat fuel, as well as any fuel, for steam heating economically, the combination of an electrical and heating plant should be strived for.

CHAPTER XIV

PEAT AS A POWER FUEL

The use of peat as a power fuel can be applied to prime movers in three general ways: (1) through a peat fired steam boiler to a steam turbine; (2) through a gas producer to a gas engine; and (3) through a gas producer to a gas turbine. At present, number 1 is in use; number 2 has been successfully tried in the United States on pilot plant scale only; and number 3 is a very probable operation and is now being tried with pulverized coal by the Locomotive Development Committee at Baltimore, Maryland. The following discussion will be accomplished by first treating peat as a power fuel through a peat fired boiler and then as a power fuel through the gas producer.

Peat Fired Steam Boilers—The use of peat fuel in a boiler furnace has been successfully carried out by Russia, where it is claimed that peat fuel is used to generate 30 per cent of all the electrical energy produced. In Ireland, the waste peat substance from a briquetting plant is used to produce steam, which in conjunction with a steam turbine, produces about 750 kw, which is sufficient to drive all their briquetting equipment. Sweden also uses large peat burning furnaces to generate steam.

Russian Developments—The Russians, in 1914, at the Klasson power station, 70 miles east of Moscow, were the first to burn peat in a boiler furnace on a large scale. The boiler efficiency was very low and it was not until the Makarev shaft-chain grates were tried at the Shatura station in 1921, that the efficiency of coal-fired boilers was reached. This station had a capacity of 136,000 kw and claimed a boiler efficiency of 83 per cent. This station, on a test over a period of a month as reported by Monkhouse,[1] used 26,700 tons of 31.14 per cent moisture peat to produce 111,829,000 kg of steam with an evaporation rate of 48.6 kg/m^2. This corresponds to 4.6 pounds of steam per pound of peat (coal is usually considered capable of producing about 9 pounds of steam per pound) and an evaporation of 10 pounds per square foot per hour of heating surface.

Makarev Grate—The Makarev grate, as reported by Monkhouse, is a combination of a gas producer and a chain grate. The peat is fed down from the bunkers and while in the upper part of the furnace "shaft," heated air is forced through it and the peat becomes incandescent. At this stage, its more volatile constituents pass through the openings in the rear arch into the main combustion chamber; moisture in the peat is converted into water gas and also passes through with the volatile constituents into the main chamber. The final burning of the peat then takes place on the chain grate. It was found that 32 per cent moisture peat gave the best results in the boiler and too dry peat was moistened to 32 per cent. These original plants used machine-formed, air-dried peat. The largest known plant capacity where machine peat was used is that of 204,000 kw at the Gorgress station.

The Russians, in their extensive use of peat fuel, have found that with dry machine formed peat, furnace water walls increase boiler capacity without danger of slagging, but with high moisture peat, water walls seriously affect the combustion. With 35 per cent moisture peat, water walls increase generating capacity by 15 per cent. At 50 per cent moisture, water walls show a 15 per cent decrease in capacity. They also found that mixing the lumps (machine peat) and milled peat lowered the efficiency because of incomplete combustion.[1]

Shirshnev Furnace—Since about 1930, the production of milled peat in Russia rose steadily because of cheaper extraction by the milled process. Milled peat portrays combustion properties quite different from those of machine-formed peat; therefore, new burning problems were manifested. Attempts to adopt the Makarev furnace failed. The Russians found that milled peat could not be used in the shaft furnace because the fine milled peat became caked and chared in the shaft and hot air would not pass through. The difficulty was finally overcome by the development of the Shirshnev furnace, a suspension burning furnace, introduced at the Briansk and Klasson power stations in the early 1930's. The principles used are very similar to those employed in the burning of pulverized coal. In order to maintain the furnace contents in a state of high turbulence required for successful combustion of milled peat, high velocity air is injected from horizontal ports. The furnace was designed for continuous slag tap operation to eliminate furnace slagging and fly-ash emission. The furnace bottom is of the conventional slag tap design. To keep

[1]Electrical Developments in the U.S.S.R., by Allen Monkhouse, 1933.

the slag in a liquid state, a high degree of air pre-heat is an important pre-requisite. In addition, a constant stream of flue gas is withdrawn through the slag taps. As a standby measure, electrical heating units are also installed to protect against solid slag formation. The peat used has the following characteristics and analysis.[1]

Moisture	52%
Heating Value (Higher) Moisture Free	10,435 Btu
Ash Fusion Temperature	2,152° F
Carbon	60.1 %
Hydrogen	6.1 %
Oxygen	30.4 %
Sulphur	0.78%
Ash	9.07%

The Kalinin station was also equipped with the Shirshnev furnace, but was originally built with dry hopper ash removal which gave considerable slagging trouble. Therefore, the furnace was rebuilt for continuous slag tap operation. The Kalinin station uses milled peat of 22 to 25 per cent moisture. The plant has an evaporation of 66,000 pounds of steam per hour with 10 to 12 metric tons of 22 per cent moisture peat. This is equivalent to 2.75 pounds of steam for 1 pound of peat. Slag tap operation could not be maintained at heat releases below 7,800 Btu per cubic foot per hour. As there are no other arrangements for preparatory treatment of the peat before it enters the furnace, its own power consumption is lower than for other types of furnaces and reaches about 1 kwhr per ton.

In the use of the Shirshnev furnace, it was found that a drop in efficiency occurred when firing exceeded 10 pounds per square foot of grate surface per hour. Heat releases of 15,000 to 17,000 Btu per cubic foot per hour do not require water walls, but higher heat releases do. The plant had an overall boiler efficiency of 86 per cent at a steam output of 62,000 pounds per hour.[1]

Th. T. I. Mosenergos Furnace—In burning of milled peat in furnaces of the Th. T. I. Mosenergos construction, it must first be ground up and dried. The peat is fed from a bunker to a magnetic separator and then to a mill where the peat is ground. After grinding, the peat passes, by means of a wave arrangement, through a tube type torch. A fan is located at the upper end of the torch to transport the peat from the torch to the precombustion chamber. According to Russian report, the furnace will burn milled peat moisture up to 55-58 per cent. If the moisture content exceeds 55 per cent, the boiler load will be somewhat lower. The load on the precombustion chamber is about 18,000 kcal/m^3/hr. The power consumption in pulverizing, drying, and pneumatic transportation is about 6 kwhr per ton.[2]

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[1] Peat As A Fuel, Frederick Alton. Boiler House Review, March, 1942.

[1] Peat As A Fuel, Frederick Alton.

[2] Sveriges Branntorv Industri, 1940-46, Olle Uddgren.

Irish Developments—The Irish at present have in operation a small power plant in conjunction with a briquetting plant at Lullymore bog. The size of this power plant is not large, being only 750 kw, but the plant is using methods of drying which are noteworthy and could be applied to larger plant operation. The total cost per kw generated is estimated to be 1.84 cents. If the heat in the steam used for the drying of the material to be briquetted is credited to power generation, the total cost per kwhr becomes 0.65 cents.

Two systems of driers are being used. The flue gas drier is used in conjunction with the power plant for the waste substance not suitable for briquetting. The other drying system is that one used to dry the briquetting material from a 55 per cent moisture content to 10 per cent moisture content by use of exhaust steam at 40 psig and 370° F. from the pass out turbine. The flue gas drier as described by Mr. Martin[1] is a three foot duct some 100 feet long, in which the boiler flue gases at 550° F. entrain the peat and dry it to about 20-25 per cent moisture content. The peat is removed from the gases by a suitable cyclone and fed through an airlock to the boiler step grate and then to the traveling grate. The flue gas velocity (under suction of the induced draft fan) is about 70-90 fps so that drying time of the peat from a 55 per cent moisture content to a 25 per cent moisture content takes about 1¼ seconds, if no allowance is made for slip. The driers handle from 3 to 4 tons of 55 per cent moisture peat an hour at full load. The gas temperature at the chimney stack base averages about 300° F.

Two new installations are being erected at present in Ireland. These are the Portarlington and Allenwood power stations. The Portarlington station will consist of two 15.6 MW (15,600 kw) turbo-alternator sets with condensers and 3 boiler units, each with a maximum continuous rating of 150,000 pounds per hour. The plant will operate at steam condition of 425 psig pressure and 825° F. temperature. The furnace used is a standard Babcock and Wilcox type such as is used with a coal boiler. The chain grate used is a B. & W., Style 28. The furnace has a volume of about 6000 cubic feet. It is estimated that at an output of 150,000 pounds of steam per hour, the feed rate will be 16.8 long tons per hour. This is equivalent to about 4.00 pounds of steam per pound of peat. The fuel to be used will be machine peat in blocks 19 by 3 by 2½ inches and will contain about 30 per cent moisture with a cost of $9.12 a ton. The Allenwood station will consist of two 20,000 kw steam turbo-alternator sets with 4 boilers, each of 150,000 pounds of steam per hour capacity.[2]

The flue gas drier, such as was previously described, will not be used but instead, a vertical drying shaft will be provided be-

[1]The Winning and Utilization of Milled Peat for Briquetting and Power Generation, by J. Martin, Dublin, Ireland.
[2]Correspondence with Electricity Supply Board, Dublin, Ireland, Jan. 1949.

tween the bunker and stoker. The peat on entering the shaft is subjected to a strong cross-current of preheated air (300° F.) which is admitted through a series of ports in the front of the vertical drying shaft and passes through the rear of the shaft into the furnace. Secondary air nozzles in the front and rear furnace walls. The primary air is provided by a separate forced draft fan and is fed through the compartment type stoker.

The estimated total cost per kwhr at the Portarlington station is 2.00 cents, of which 1.22 cents is for fuel. Cost figures for the Allenwood station are not known. The output per year for the Portarlington station is 90 million kwhr and for the Allenwood, 135 million kwhr, making a total of 225 million kwhr. This means a peat supply to feed these two stations of 300,000 tons per year. The costs of the Portarlington and Allenwood stations are approximately 1.1 million pounds ($5,010,000) and 2 million pounds ($9,100,000) respectively. These costs correspond to about $160 per kw and $227 per kw respectively, the latter being considerably over the installation cost of about $165 per kw for coal burning boilers in this country.

It should be noted that these two new power plants as well as the others in operation at present in Ireland use a machine peat costing $9.12 a ton and that at the Lullymore bog, milled peat is being produced at $1.84 a ton. Comparable costs per million Btu are $0.63 for the machine peat and $0.24 for the milled peat. It appears that the Irish are making the same discoveries that the Russians made years ago, namely that milled peat can be produced at a far lower price than machine peat. Drawing from the Russians' experience, it is very probable that the Irish will go to the suspension type burning with the introduction of milled peat as was done in Russia. It should be brought out at this time that the reason why Ireland has not produced milled peat until the Lullymore plant was completed is that when the development of the peat industry was undertaken by the Bord Na Mona, it was thought safer, in view of Ireland's wet climate, to concentrate on methods of production and harvesting which had been proved successful in countries with comparable climates. Furthermore, the harvesting of peat cut by hand in the traditional manner had, of course, been carried out annually for countless generations in Ireland and the same method of harvesting is employed, for all practical purposes, with machine peat.

Swedish Development—The use of peat as a fuel in Sweden had developed from small hand-fired furnaces using machine peat to present day automatic furnaces using finely ground milled peat as a pulverized fuel.[1] Methods similar to those used in both Ireland and Russia are employed by the Swedes to effectively burn peat. Some of the important developments that have been made and used in Sweden are the use of the Whirl and Tornado Burn-

[1]Sveriges Branntorv Industri, 1940-46, Olle Uddgren, page 248.

ers. These are quite similar to those burners used in America for the burning of pulverized coal. The tendency has been away from the Tornado Burner because even feeding of the fuel to the furnace cannot be made. The Whirl Burner was found to be more dependable and, therefore, it is less difficult to regulate the steam production to suit the requirements. The Whirl Burner has been used with good results at several establishments in Sweden with overall boiler efficiencies of 85 per cent. Experience has shown that pulverized peat with a moisture content of up to 35 per cent can be used with these burners without help of a support fire. However, as a precautionary measure, arrangements have been made to have a small gas flame continually burning from a tube in the furnace. The Swedes have also found that by mixing in correct amounts of a better fuel (coal or oil) a higher efficiency, along with better regulation of boiler output, is attainable.

At the Sosdala Peat Briquette Factory, a furnace is being used that incorporates a slanting grate, a Kramer Mill, and a flue gas drier. The Kramer Mill is a device that grinds and propels the peat into the combustion chamber. With this type of arrangement at Sosdala, a 70 per cent moisture content peat has been fed to the drier, dried in a manner similar to the previously described Lullymore drier, and burned without the aid of a support fire.

Experiments have also been conducted in Russia using the Kramer Mill. The experiments conducted by the Thermo-Technical Institute at Moscow showed that by using the Kramer Mill with a preheating of the air (about 250° C.) that it was possible to burn milled peat with a moisture content of 55-58 per cen without difficulty. About 70 per cent of the air was supplied by the mill; the remainder entered the furnace via the grate in the lower part of the pre-burning chamber.

General Conclusion—Peat as a power fuel presents one major problem in the efficient burning of it. This is the slag problem which seems to appear in the larger installations. The other problem of securing higher heat releases and more efficient combustion depend a great deal on the solution of the slag problem. Due to a rather low heat of fusion (2150° F.), peat has a tendency to form a slag that presents a problem of removal. Along the same line is the fly ash loss in the suspension burning furnace combined with the slag problem. The Russians, with a continuous slag tap operation, have solved this problem in their Makarev furnace, but with the introduction of milled peat and the Shirshnev suspension burning furnace the problem presents itself again. In this type of furnace there is not only a slag problem, but also a very complicated ash removal system. As a result of the slag problems, the Russians have encountered in the desired suspension burning furnace, they have made the following recommendations:

> "A complete combustion in a suspended stream should not be an object to strive for because the intensity of burning diminishes at the end of the process.

Therefore, it is advantageous to combine a preliminary furnace intended for burning of coarse particles in a suspended state (for instance, the furnace of the jet type) with an ordinary furnace for burning pulverized fuel. Combustion gases and fines from the preliminary furnace complete their combustion in the second furnace. Only in such a combination of a preliminary furnace and an ordinary furnace—using the second for the ash removal—can a correct and easy solution to the problem of ash removal and the problem of the proper temperature condition in the preliminary furnace be found."[1]

In Sweden, the Whirl Burner is considered the most efficient and to our knowledge does not present a slag problem. In Ireland, as well as existing station, machine peat in block form is used on chain grates without any difficulties in ash removal. It is significant to note that in both Russia and Sweden the development of peat firing has lead to some form of suspension burning. This follows along the same line in the development of coal burning boiler furnaces in this country.

The utilization of waste heat is an important step in the efficient burning of peat. Modern peat burning furnaces in Russia, Ireland, and Sweden use some form of a waste heat or flue gas drier. In modern coal boilers with economizer and air preheater, the loss up the stack in the form of flue gases amounts to about 6-10 per cent of the total heat input to the furnace. It is the utilization of 25 to 50 per cent of this waste heat to dry the incoming fuel that helps to raise the efficiency of peat burning to that of coal burning.

Mention should be made of a plan concerning a flue gas drier presented by J. Martin in his paper on The Winning and Utilization of Milled Peat for Briquetting and Power Generation. This idea was pioneered by Gramin and Testrup at the 1928 World Power Conference. Mr. Martin proposes a power plant of 20,000 kw capacity using a flue gas drier patterned after the one at Lullymore. The driers would have to handle 45 tons an hour of 55 per cent moisture peat. The plant would require three boilers (100,000 lb. per hr.) each with a drier 400 feet long and 4 feet in diameter equipped with 2 cyclones and special damper arrangement at the back of each boiler. The cost of this equipment per boiler is estimated at 3,500 pounds ($16,000). Using 322,000 tons of peat per 300 day operational year would give a fuel cost of 0.167 pence (0.334 cents) which is far below the 0.61 pence (1.22 cents) fuel cost anticipated at the new plant at Portarlington. The total cost per kw is estimated to be 1.48 cents. If the heat in the steam used for drying the material to be briquetted is credited to power generation, the total cost per kwhr becomes about 1.00 cents.

[1]From a paper presented at the Second World Power Conference, Prof. L. K. Ranzin, Russia, 1935.

CHAPTER XV

PEAT FIRED GAS PRODUCERS

A peat fired gas producer is not a new application of peat. In 1914, a plant in Germany and one in Italy, were operating by-product gas producers using peat for the fuel. These plants were then producing gas for power and recovering ammonia sulfate as the by-product. The Canadian government studied the possibilities of the peat fired gas producer and published a report in 1914, through the Department of Mines, written by B. F. Haanel. In that report, the author reported not only the possibilities of the peat fired gas producer, but also gave first-hand accounts of the operation and construction data of the gas producer plants in existence at that time. Haanel reports that at the time of his report, both Sweden and Germany were using producer gas made from peat fuel for both power and metallurgical fuel. Dachnowski reports:

> "New plants for utilizing peat fuel in the form of producer gas are annually added to those already at work, and in 1912, it was reported that large electric power plants using peat for fuel in gas producers were running in Sweden, Germany, Italy, England, Ireland, and Russia."[1]

The peat fired gas producer is in use in several foreign countries. Limited information from Russia indicates that the peat fired gas producer is used quite extensively in conjunction with annealing furnaces and other metallurgical equipment.[2] In Sweden, the peat fired gas producer has been experimented with for porcelain burning, but was not found satisfactory; however, further experiments were conducted for the burning of other ceramics. These tests were very encouraging.[3]

The Gas Producer—The gas producer differs from a common furnace in several ways. In the gas producer, less oxygen is admitted to the combustion chamber and the fuel bed is thicker. In an ordinary furnace, complete combustion is strived for and, therefore, excess air is fed to the burning fuel in order that the energy of the fuel can be converted rapidly into heat. In the gas producer, enough air is supplied for complete combustion of only part of the fuel. The heat generated is then used to convert the remaining carbon and hydrogen units to a permanent fuel. Under the ordinary type of furnace, therefore, the objective is formation of carbon dioxide, but in the gas gas producer, formation of carbon monoxide is sought.

The gas produced from a peat fired gas producer has a calorific value of about 145 Btu per cubic foot. The gasification rate is

[1]Geological Survey of Ohio, Bulletin No. 16, by Dachnowski, p. 185.
[2]Problems of Northwest Metallurgy, by Bardin, Probst, and Rickman, p. 76.
[3]Sveriges Branntorv Industri, by Olle Uddgren, p. 252.

less with peat than coal, but the gas produced with peat has a higher calorific value than that produced with coal.[1] Therefore, by using peat fuel, more Btu can be generated per day than with coal; this being due to a much greater liberation of volatiles and because peat yields twice the amount of tar that coal does.

Types of Gas Producers—There are two general methods of gasification of peat fuel employed at the present:

(1) Gasification in a producer designed for the recovery of by-products which in some instances, the gas produced becomes the by-product.

(2) Gasification in a producer not constructed for recovery of by-products. A producer designed to convert the fuel into gas with the highest possible thermal efficiency.

By-Product Recovery Producer—A producer designed for the recovery of by-products is usually referred to as the updraft producer. Operating conditions are adjusted to get maximum yields of tar and ammonia. In order to secure the most favorable results in the use of peat fuel in a gas producer for the recovery of by-products, it is necessary that the peat fuel have the proper characteristics for burning. Machine peat with a moisture content of 30 to 35 per cent has been found to give the best results.[1] Moisture in the peat fuel can be utilized to replace some of the steam in an updraft producer.[2] Character of ash is also very important in determining the gas production efficiency of a fuel. Proper and uniform size of the fuel is also important.[3] The updraft producer produces a richer gas than does the downdraft, because richer gases distilling off first are not decomposed into leaner gases on passage through the incandescent fuel.[4] However, the gas that is produced must be burned hot so as not to deposit tar.

Ammonia, being the chief by-product, necessitates that the peat fuel should be high in nitrogen content (2.0 per cent or better) so that the quantity of ammonia sulfate produced will more than exceed the cost of manufacture. Tar is also a possible by-product, but recovery equipment is very costly.

The by-product recovery producer is not feasible in small installations due to the high cost of by-product recovery equipment, operational costs, maintenance cost, and supervisory costs being higher for small installations than they are for large installations. Also a small gas producer cannot produce enough gas to keep the recovery equipment working full time.

1Problem of Northwest Metallurgy, by Bardin, Probst, and Rickman.

1Final Report of the Peat Committee, by B. F. Haanel, 1926, p. 184.

2Producer Gas from Peat, by G. W. Semmes.

3Possibilities for the Commercial Utilization of Peat, Bulletin No. 253, by Odell and Hood, U. S. Dept. of Commerce, Bureau of Mines, 1926.

4Producer Gas From Peat, by Semmes.

The six factors that should be considered for the successful operation of a by-product recovery gas producer are:[5]

1. Availability of a sufficient supply of suitable peat fuel.
2. Cost of peat supplied to the producer and its nitrogen content.
3. Labor costs.
4. Cost of sulfuric acid at the plant.
5. Plant costs.
6. Market for power and by-products produced.

Non-By-Product Gas Producer—The non-by-product gas producer (downdraft producer) produces a leaner gas, but generates more gas than does the updraft. In the downdraft producer, the tars are cracked to gases so there is not a tar deposition problem. The downdraft producer gas is as suitable for power as updraft because it uses less air for combustion, thus making the final mixture the same in both cases. The peat fuel burns with a fine ash and forms a compact fire bed in the producer.

Developments in the Gas Producer and Gas Engine—The gas producers that Haanel, Semmes, and Odell and Hood described and proposed in their reports have undergone a number of changes in both construction and operational efficiency and economy. As in any equipment that has been in use for a great number of years, the gas producer of today is an improved piece of machinery. Thermal efficiencies have been increased from 60 to 65 per cent for the gas producer of 1920 to 75 to 85 per cent for the gas producer of today. The capacity of yesterday's producer has also been changed. The trend has been from large single units to a number of small units of about 3,000 pounds per hour of 30 per cent moisture content peat fuel. The gasification rate for the modern producer is about 37 cubic feet per pound of 30 per cent moisture content peat. With experience gained by operation of the gas producer for the past 50 years, the gas producer in use today is operated more efficiently and has less maintenance and supervisory cost.

The improvements made in the gas producer were closely associated with improvements in the gas engines. The gas engine of 1920 was considered efficient if a brake horsepower hour was produced with 10,000 Btu. Today the gas engine can do the same thing with about 8,000 Btu. The improved gas engines, with their fine machined parts and close operational control, brought about the requirement that the gas burned must be clean. This required scrubbers, tar removers, and other gas purifying equipment. Today the gas producer needs these pieces of equipment to make its product usable. A typical analysis of producer gas from 30 per cent moisture content peat fuel is as follows:

[5]Final Report of the Peat Committee, by B. F. Haanel, p. 198.

Carbon Dioxide	12.4%
Oxygen	0.0
Carbon Monoxide	21.0
Hydrogen	18.5
Methane	2.2
Ethylene	0.4
Nitrogen	45.5

Power Generation—The peat fired gas producer in the era of the steam engine was considered a vastly superior means of utilizing the Btu in a fuel. Haanel reports:[1]

> "The general practice of converting the energy stored up in fuel into useful work by burning it under a boiler and utilizing the expansive power of the resulting steam is a wasteful and inefficient method."

Today the picture has changed because the high pressure, high temperature steam boiler and turbine have been introduced. However, the peat fired gas producer with by-product recovery still holds forth the opportunity to obtain cheap power. It is doubtful if a peat fired gas producer of the non by-product recovery type should compete with the steam boiler and turbine. The Wellman Engineering Company, manufacturers of gas producers, have submitted the following data dealing with the cost of gasification of peat:[2]

1. Cost of eight 10 foot, 35 tons per hour of 6750 Btu peat fuel, gas producers, complete with scrubbers, pumps, building, conveying equipment, spray pond, etc. Erected and ready to operate—$100,000.00 each $800,000.00
2. Three laborers to operate a battery of 8 producers .... $ 96.00
3. Peat fuel required—275 tons per day for 8 producers at $5.00 a ton $1,375.00
4. Water required—3 million gallons per day for 8 producers .... $ 150.00
5. Power required to operate 8 producers—20,000 kwhr per day .... $ 200.00
6. Maintenance for 8 machines per day .... $ 30.00

The 8 producers at 85 per cent conversion would produce 126,000,000 Btu per hour in the form of gas which at 8000 Btu per brake horsepower would produce about 15,750 shaft horsepower. The 15,750 horsepower, if converted into electricity would mean that about 11,000 kwhr would be produced. This corresponds to about 2.1 pounds of 30 per cent moisture content peat per kwhr, which is below the value for a kw produced through a peat fired steam boiler and turbine.

[1]Final Report of the Peat Committee, by B. F. Haanel, 1926, p. 184.
[2]Taken from a letter dated Jan. 7, 1949, from the Wellman Engineering Company of Cleveland, Ohio.

The above figures give a cost per million Btu in gas (taking into consideration amortization and all other costs) of $0.68 which is above the cost per million Btu of steam produced by a coal or peat fired boiler. The cost to gasify one ton of 30 per cent moisture peat for the above proposed plant is $2.53 a ton. The cost to gasify a ton of coal is about $2.00. Both these costs are for hot raw gas, the cheapest to manufacture. The cost of gasification of any fuel is a function of the amount of fuel that can be handled by the producer. The cost varies almost inversely with the amount of fuel that can be handled. The efficiency with which the gas is used in the gas engine and the steam in the turbine becomes of importance when the gas and steam Btu production costs approach each other. A typical efficiency for the gas engine is 27 per cent and for the steam turbine, 30 per cent.

The installation cost per kw for a combination of gas producer and gas engine is considerably above the installation cost of about $165 per kw for a steam boiler and turbine power plant. However, for the same capacity plant, the operational, maintenance, and supervisory costs are lower. This tends to equalize the two over a number of years.

Waste Heat—It is estimated that about 25 per cent of the Btu delivered to a gas engine is lost in the exhaust gases. Here again, as in the steam boiler, utilization of a portion of these lost Btu will increase the efficiences and economy of the gas engine. The Brue McBeth Engine Company reports in their bulletin on gas engines:

> "An added feature of importance with gas engine power is that much valuable heat from the exhaust may be utilized for producing hot water or low pressure steam. An approved form of heat transfer equipment will recover a good proportion of the heat of the exhaust gases, which have a temperature of about 900° F., and produce hot water or steam up to 100 pounds pressure with no added expense for fuel."

The waste heat dryer idea could be employed with the gas engine as well as the steam boiler. There would be more waste heat available with the gas engine with which the peat feeding into the gas producer could be dried. This would result in an overall economy for the plant. A peat of 55 per cent moisture content produced at a cost of less than $2.50 could be fed to the exhaust gas dryer, dried to 30 per cent moisture, and then fed into the gas producer at a total cost below the $5.00 a ton cited for a bog-produced 30 per cent moisture peat.

Summary—Peat fuel can be used as a gas producer fuel. With modern gas producers, operating at efficiencies of 75 to 85 per cent, and a gas engine driving electrical generating equipment, it is quite possible that electricity can be produced at a cost competitive to, or below the cost of electricity generated with coal as a fuel. The use of exhaust gas driers would be a requisite to this proposed plant because of the reason mentioned before. This type of plant set up could apply to small installations as well as the larger ones.

The by-product recovery gas producer plant incorporates large initial cost for equipment and only in large efficiently operated and managed plants could electricity be produced at a cost below existing electrical costs. Bogs that have high nitrogen content would be a prerequisite for location of a by-product recovery plant.

Either of the two types of gas producer plants should be located in close proximity to the bog with adequate peat supply for a great number of years. The by-products and electricity would then be transported to the users.

It is well to remember when considering the use of peat fuel for gas producer fuel that a cheap fuel may sometimes be more expensive than a costly fuel in gas production when unloading, storing, handling, charging, and removal are considered.

Part V

PEAT IN THE IRON ORE INDUSTRY

CHAPTER XVI

EARLY PROPOSALS AND EXPERIMENTS

Since large peat bogs lie in close proximity to the iron ore deposits on the Mesabi Range, consideration has been given to the possible uses of peat in the iron ore industry.

Early Proposals and Experiments—Peter Christianson, former professor of metallurgy at the University of Minnesota, was interested in the possibilities of using peat in connection with the iron ore industry. E. K. Soper[1] quotes Christianson as follows:

> "Christianson suggests the following possibilities of using peat in connection with the iron ore industry:
>
> "1. The use of peat for power—A large amount of low-grade iron ore as mined on the Mesabi Range is now being concentrated. All ore concentrating processes require power, which in Minnesota, at present, is usually obtained from coal. It is possible to generate this power cheaply from peat, as has been demonstrated at numerous localities in Europe. A peat power plant should be located on the bog and should consist of a plant for the manufacture of machine peat; a gas-producer plant for converting this machine peat into producer gas; and gas engines coupled to electric generators for generating electric power. The power thus obtained could be cheaply transmitted from the bog to the mines, whereas the transportation of machine peat in large quantities would be more expensive because of its bulk.
>
> "2. The use of peat for heating operations—(a) By burning machine peat directly; (b) by burning peat powder; (c) by burning producer gas derived from machine peat.
>
> "In the processes for the beneficiation of iron ores, drying, roasting, calcining, and sintering are often important steps. In all of these operations peat could be used as a source of heat to take the place of coal. The simplest method of burning peat is to use it in the form of machine peat. In Sweden, where peat powder has been

[1]The Peat Deposits of Minnesota, by E. K. Soper, 1919, p. 92-93.

successfully used in boiler firing, it is claimed that this form of peat fuel is more economical and higher temperatures are obtained than are possible when machine peat is used. To offset any such advantages, however, the cost of manufacturing peat powder is considerably above the cost of machine peat. Where the ore is treated in gas-burning furnaces, peat producer gas would make an excellent fuel.

"3. Peat as a binder for ore briquets—In some of the deposits of soft hematite ore a large amount of fines must be agglomerated before smelting. Since iron oxide has no plasticity or binding properties, it is necessary to add some binder in order to agglomerate the fine ore. It is suggested that peat may be used as a binder in briqueting these finely divided iron ores. Christianson conducted a series of experiments using 12½, 12¾, and 15 per cent of dry peat with finely divided iron ore, and made the mixture into briquets of the usual type. All the briquets showed remarkable toughness, and retained their shape in a reducing atmosphere similar to that of a blast furnace. In an oxidizing atmosphere, however, the briquets soon crumbled because of the small amount of peat used as a binder with the ore. Because of the low ash content in Minnesota peat, only a very small amount of impurities would be introduced into the ore by this process. Assuming a mixture of 85 per cent ore, 15 per cent dry peat containing 10 per cent ash, the total foreign slag-making matter thus introduced into the charge would be only 1.5 per cent.

"4. Possibilities of peat for smelting—(a) The use of peat charcoal: (b) the use of peat coke.

"The use of peat charcoal to take the place of wood charcoal in the smelting of iron ores does not seem practicable under the present conditions. However, in the electric smelting of iron ore, peat charcoal may be used, when the supply of wood charcoal becomes diminished.

"Peat coke would be satisfactory in the smelting industry if it could be produced in a suitable form. At present, peat coke is too soft to compete with coal coke for use in iron ore smelting."

The question that has often been asked is, "Why is pig iron not produced on the Range using peat or peat char as the reductant or fuel." Peat char is a good reducing agent, but is not strong enough to support the burden in the furnace.

CHAPTER XVII

THE PRODUCTION OF SPONGE IRON

Another question that has often been asked is, "Can peat be used in making sponge iron and would the production of sponge iron create further industries on the Range?" Peat can be used as the reductant either directly or by using the gases, carbon monoxide and hydrogen, derived from it.

Many patents have been granted between 1876 and 1947, which show the continued efforts on the part of many investigators to produce iron direct from ore at temperatures lower than the melting point of iron. The reducing gases in most cases have been carbon monoxide, hydrogen, or mixtures of these gases. The temperatures have ranged between 550 and 1100° C. Since both carbon monoxide and hydrogen can be produced from peat and since peat occurs close to the ore, consideration should be given to the possible use of peat in the production of sponge iron.

TYPES OF FURNACES USED TO PRODUCE SPONGE IRON

Various furnaces have been used in the production of sponge iron: shaft, rotary kiln, multiple hearth, tunnel kiln, endless conveyor, movable grate, multiple bubble hearth, multiple hearth, porous lower hearth, etc. Although no process has operated commercially in the United States, the Norsk-Staal plant at Bochum, Germany, and the Wiberg Process at Soderfors, Sweden have produced sponge iron.[1]

The Wiberg Process—The Wiberg Process has been under development for the past 25 years and according to data available, production of melting stock averages 22 tons a day; plans have been completed for a 60 ton a day unit. Since the Wiberg Process is dependent on the use of charcoal or coke for the production of the reducing gases, carbon monoxide and hydrogen, we quote Mr. Edward P. Barrett[1] as follows:

> "In 1941, a Wiberg furnace of 10,000 metric tons annual capacity was put into operation at Soderfors Works, Sweden. The operation at present is satisfactory, with production about 22 net tons of sponge-iron daily. Sintered Vintjarn ore is used largely, and the average reduction is about 85 per cent. No really satisfactory lump ore has been available. Most of the ores available at a reasonable price disintegrate, gradually choking the shaft with fines, or soften and stick in the furnace, forming large lumps, which will not discharge. The maximum diameter of furnace feed is 2½ inches.

[1]Bureau of Mines Report of Investigations 4402.
[1]Reprinted from Bureau of Mines Report of Investigations 4402. E. P. Barrett, Chief, Minneapolis Branch Office, Metallurgical Division, Bureau of Mines.

It is more economical to use sizes smaller than 2½ inch, as rates of reduction are much slower for pieces larger than 2½ inches in diameter."

"A schematic drawing of a larger plant for producing 60 tons of sponge iron daily is shown in figure 23.

"A sealed hopper on the top of the furnace holds about 15 tons of feed. A valve between this hopper and the furnace is opened periodically to fill the shaft.

"The upper zone of the shaft furnace is a preheater, in which about 25 per cent of the spent reducing gas is burned with air to heat the ore to 955° C. to 980° C. Only 25 per cent of the reducing gas is passed through the prereduction zone.

"The temperature increases in the reduction zone, when the reduction of FeO to Fe takes place. The sponge-iron enters the cooling zone at 955° C. to 1,010° C. If the temperature increases to more than this, sticking and hanging of the charge occurs with most ores.

"The sponge iron is cooled to between 95° and 150° C. in the water-jacketed cooling chamber. A conical, water-cooled, eccentric, rotating table will crush agglomerated lumps of sponge-iron, provided they are not too large and tough. The discharged sponge-iron is received in an air-tight steel can holding about 4 tons. When the can is filled, it is removed and sealed. The cans are used for storage and transportation of the sponge-iron to the electric-arc smelting furnace.

"The quantity and analyses of the gas used in the Wiberg furnace are shown in the following tabulation:

Gas, to—	Cubic feet/ ton of sponge	Temperature, °C.	Analysis, per cent CO_2	CO	H_2	N_2	H_2O
Shaft	42,000	980	2.0	75.2	21.5	1.0	0.5
Circulating fan	33,000	650	23.9	59.4	11.2	1.0	5.0
Pre-reduction zone	9,000	1,010	51.2	33.0	7.2	1.0	9.0

"The efficiency of the Wiberg process is dependent on withdrawing and regenerating the partly spent reducing gas. By withdrawing three-fourths of the reducing gas below the pre-reduction zone, the gas volume in the upper part of the shaft is only slightly greater than that needed for pre-reduction. The portion of gas withdrawn from the shaft is passed through the electrically heated carburetor, where the CO_2 is converted to CO and the water vapor reacts to form H_2.

"Experiments to use coke and coke-charcoal mixtures in the carburetor instead of charcoal indicate that charcoal yields the best results. A newly designed carburetor has been perfected for using coke.

Analyses of Various Ores Used and of the Sponge-Iron Produced in the Wiberg Furnace, Soderfors Works, Sweden

Product	Total Fe	Metallic Fe	Per Cent Reduction to metal	SiO_2	S	P	C	Moist.
Kiruna lump	68.8	......	......	4.5	0.042	0.019	....	8.0
Vintjarn sinter	62.6	......	......	10.5	.010	......	....	....
Steep Rock	59.3	......	......	6.0	.028	0.020	....	6.2
Kiruna sponge	92.6	83.6	90.3	3.8	.008	.018	1.22	....
Vintjarn sponge	82.0	71.5	87.0	10.0	.005	.015	0.70	....
Steep Rock sponge	90.7	85.5	94.0	9.0	.008	.020	.70	....

"Sponge iron, produced in the Wiberg furnace is used to make electric furnace steel."

Sponge iron, if made from a good grade of concentrated ore, makes a satisfactory material for making high quality alloy steels. In times of war, when steel scrap is scarce and the price is high, interest in sponge iron increases, since sponge iron becomes competitive with steel scrap. Since peat is a source of carbon monoxide and hydrogen, needed in the production of sponge iron, it is recommended that further studies be made as to its use in this field.

CHAPTER XVIII

GAS FROM PEAT FOR THE AURORA POWDERED IRON PLANT

The pure iron oxide made at the powdered iron plant at Aurora from the iron carbonate slates is fed through a furnace in which the iron oxide is reduced to pure iron by contact with gas made in a gas producer plant from coke. A gas producer using peat char could be operated in conjunction with the present Aurora plant, eliminating the need of importing coke, provided there would be no clinker problem.

CHAPTER XIX

GERMAN AND RUSSIAN INTEREST

During the war, the Germans were interested in producing producer coke and foundry coke from peat. The peat was briquetted and subjected to low temperature carbonization. It is possible that carbon electrodes low in silica can be produced from peat char and used where electrodes are required in electric furnace operations. Mr. I. P. Bardin[1] states that even taking into consideration the fact that the heat of combustion of coal is twice as great as peat, the use of peat for the metallurgical plant is

CHAPTER XX

PEAT AS A REDUCTANT IN TESTS AT CHISHOLM

The main purpose of the work at Chisholm, Minnesota, is to determine if an economical method of converting peat into fuel can be developed. However, some thought has been given to the possibility of peat as a reductant for ore, and a few preliminary experiments have been made.

Experiments were started on December 4, 1946, in which peat and iron ore were mixed together and pelletized. The intimate contact of the peat with the ore results in a rapid conversion of the ore to iron or magnetite, depending upon the amount of peat and temperature.

Under proper conditions, the use of less than 5 per cent peat will convert hematite to magnetite, thus permitting the separation of the iron magnetically. These early experments showed that low grade ores mixed with less than 5 per cent peat, heated to 1200° F. for 20 minutes resulted in a satisfactory recovery of the iron as magnetite. At higher temperatures, the reaction is more rapid and a shorter time is required for the reduction.

CHAPTER XXI

SUMMARY

Since peat char does not have the properties of coke, it is not a satisfactory substitute for coke in the blast furnace; the bulk of the iron ore will continue to be shipped to the Pittsburgh and Wheeling Districts.

Peat char is a source of reducing gases, carbon monoxide and hydrogen, for the production of sponge iron. The production of sponge iron could develop into an industry in case of an emergency.

Peat is a good reductant which could be used to convert the non-magnetic low-grade ores to magnetite, which would then make them amenable to magnetic separation.

The main value of peat is its use in large generating stations to supply a sufficient amount of cheap electric power for the beneficiation of low grade ores.

Provided an economical method can be developed for the production of peat fuel, peat would then have an important place in the iron ore industry.

[1]Ivan P. Bardin, Vice President, Academy of Sciences, USSR.

Part VI
OTHER USES OF PEAT

CHAPTER XXII

PEAT AND PEAT LANDS IN AGRICULTURE

The major uses of peat lands in Minnesota have been in connection with agriculture. Peat lands can be reclaimed, and converted into meadow and pasture land; or soil for the growth of crops such as blueberries, gooseberries, cranberries, onions, lettuce, celery, and other plants requiring an acid or humus soil. Peat contained in the bogs can also be used for the manufacture of litter, filler for fertilizers, or humus.

RECLAMATION OF LAND FOR AGRICULTURAL USE

What Has Been Done in Minnesota—Some of the peat lands in Minnesota are natural meadows which are overgrown with the wild wire grass used in carpet making; other grass covered areas have been partially drained and used for the production of hay. Most of the peat bogs in northern Minnesota contain tamarack and spruce, but in general, the timber is too dwarfed to be of much economic value. According to Mr. F. J. Alway, only a few thousand acres have been brought under the plow, and from most of this the results have been disappointing.

Considerable ditching has been done in Minnesota with the purpose of making large areas of peat soil productive. The results have, in most cases, been unsatisfactory. Mr. Alway explains the results as follows:[1]

> "Extensive ditching projects far in advance of reclamation which have been common in northern Minnesota, are to be attributed to the prevailing erroneous belief that drainage alone will make the peat lands productive.
>
> "When immediate reclamation is not purposed, the grass covered bogs had better be left to serve as wire-grass meadows, or drained just enough to allow the cutting of wild hay, while the bogs with merchantable timber should be kept under proper forest management and all others left undisturbed until the would-be developers have satisfied themselves by systematic investiga-

[1]Agricultural Value and Reclamation of Minnesota Peat Soils, by F. J. Alway, University of Minnesota Bulletin No. 188, 1920, p. 10.

tions and small-scale trials that reclamation will prove profitable."

What Has Been Done in European Countries—In Germany, about 10 per cent of the 5,000,000 acres of peat was reclaimed before World War I. Sweden, Denmark, Holland, Great Britain, and other European countries have reclaimed vast areas and carried on extensive experimental work on the reclamation of peat lands. England claims some of its best potato land is reclaimed peat land. Denmark reclaimed 195,000 acres in forest plantations.

Mr. Alway, in discussing future possibilities, has this to say about European experiences:

> "The future possibilities of these lands lie in their use for agriculture, forestry, and industrial purposes. European experience has shown peat lands to be eminently adapted for tame meadows and pastures, but unpromising for forestry purposes. They also have been shown to be able to produce good crops of vegetables, forage crops, and grains, in so far as the climate permits. The use of the bogs for agriculture would tend to hasten rather than retard their development for any industrial purposes for which the peat in them may be suitable."

METHODS USED IN RECLAMATION

Drainage—In the reclamation of peat soils, drainage is the first essential step. The amount of drainage needed depends on the type of crops grown; meadows need the highest water level, pastures a little lower, and cultivated crops the lowest.

By means of a system of water level control, it should be possible to have good yields even during years when yields on upland soils are light due to insufficient water. The cost of draining would probably be a major factor in determining the possibility of reclaiming a given bog economically.

Preparing the Soil—The cost of preparing the ground for cultivated crops varies greatly, being low for grass-covered bogs, but much higher for bogs with roots and logs. In preparing the land for clover or tame grasses, it is sometimes feasible to plant without plowing or removing the woody fragments.

Chemical Requirements—Peat soils, in general, differ from mineral soils in the marked deficiency of certain plant nutrients which necessitates the use of commercial applications of phospate or potash, and in some cases, lime and nitrates. The chemical treatment required to make peat land productive varies widely. Before spending much money on improving a tract of peat land, a systematic field and laboratory investigation of the chemical requirements should be made. Many of the disappointments encountered in peat reclamation are probably due to the mistaken notion that all peat soils would respond to the same treatment.

Peat soils usually contain a comparatively larger amount of nitrogen which would become available as needed if the soil contained sufficient lime or bacteria. On Minnesota bogs, the application of phosphate is generally most important; the application of barnyard manure often helps condition the soil by introducing bacteria of decomposition.

Combatting Summer Frosts—Peat soils are very susceptible to summer frosts. Observations in Grand Rapids, Minnesota, in 1914, showed the minimum temperature on a cultivated peat bog to be from 3 to 19 degrees lower than the temperature recorded on adjacent mineral lands.[1] Studies made in Wisconsin showed that the temperature two inches above bogs covered with grass and cranberry vines is frequently 8 to 12 degrees lower than that over a well-drained sanded bog.[2]

A compact peat soil will not frost as readily as one that is loose. Rolling is, therefore, a desirable operation in preparing peat soil. A coating of sand or clay will also greatly lessen the danger of frost.

Surface Burning—The surface layer of peat has sometimes been burned to increase the fertility of the land. The crops produced the next year are usually excellent but the beneficial effects decrease rapidly, probably after the first year. Burning might ruin the drainage system, produce an alkali soil, and often will be difficult to control. It may be a source of a great fire danger, such as occurred in 1918 at Moose Lake. Peat ash, a by-product from power plants using peat, could profitably be added to peat soil to increase its mineral content.

SOME SUGGESTED CROPS SUITABLE FOR PEAT LAND

Cranberry Raising—Cranberry culture on peat bogs has been very successful in New Jersey, where nearly 12,000 acres of peat bog was planted into cranberries in 1932 and yielded 145,000 barrels or about 12 barrels per acre. Several thousand acres of peat soil in Wisconsin are available for cranberry culture.

Blueberries and Other Berries—Wild blueberries which also thrive on acid soil, should be an ideal crop to grow in northern Minnesota. B. F. Haanel[1] has this to say about blueberry growing on peat soil.

> "Only a beginning has been made in the improvement of the blueberry, but by selection of superior wild

[1]Some Limitations on the Cultivation of Peat Lands in Minnesota, by F. J. Alway, Journal of American Peat Society, Vol. VIII, No. 2.
[2]The Development of Marsh Soils in Wisconsin, by A. R. Whitson, Journal of American Peat Society, Vol. XIII, No. 3.
[1]Final Report of the Peat Committee, by B. F. Haanel, Canada, 1926, p. 238.

strains and hybridization, berries, seven-eights of an inch in diameter have been produced. Blueberry culture, when improved strains have been developed, may become a profitable industry, and lead to the utilization of lands otherwise almost valueless."

Truck Farming—Concerning the use of peat for truck farming, Mr. Haanel says,

"Intensive farming of peat soils has been carried on successfully for a number of years in some districts of the United States. In southern and western Michigan, in the vicinity of Kalamazoo, Grand Haven, Muskegon, and other centres of population, numerous small farms of one to fifty acres are devoted to vegetable culture, the main crops being celery and onions. Lettuce and cabbage are also extensively grown. Onions are a standard and reliable crop on peat soils. Celery probably gives the greatest returns per acre but is an expensive crop to produce, requiring more expert labour and heavier fertilizing than any of the other crops commonly grown on peat soils.

"In addition to celery and onions, lettuce, cabbage, spinach, kale, cauliflower, sweet corn, and peppermint, are among the most important crops now grown with success on peat soils.

"Restrictions imposed by the markets available, cost of fertilizers, etc., strictly limit the aggregate area of peat lands which can be profitably employed in intensive farming for the production of vegetables.

"The efforts of plant breeders have hitherto been almost entirely directed towards the production of varieties and strains which would yield the best results when grown on ordinary mineral soils. The breeding and development of strains best adapted to the special conditions of growth on peat and muck soils is a promising field for experiment, and may, eventually, materially affect the productive capacity and value of such soils."

Mushrooms—Dr. B. B. Stoller[1] of Duluth has performed a series of experiments for the Iron Range Resources and Rehabilitation with peat from the Balkan bog for casing mushroom beds. He found that mushrooms grew abundantly in black decomposed peat which had been neutralized with calcium carbonate to a Ph of 7.5. Calcium sulfate was added to some samples and slag was added to others. The results indicated that peat mixed with slag will result in a satisfactory yield of mushrooms. Dr. Stoller reports:

[1]Dr. B. B. Stoller, Duluth Mushroom Farm, Lester River Road, Duluth, Minnesota.

"To summarize this use of peat: Nitrogren is present in peat in large quantities. It has been shown by repeated experiments that the nitrogen as it occurs naturally in peat is almost completely unavailable for the nutrition of the mushroom. By splitting or hydrolyzing the peat, a highly concentrated nitrogen-humus complex is derived, which may be a satisfactory source of nitrogen for the mushroom. The lignin solution remaining after the removal by precipitation of the nitrogen, may have many uses.

"A use of peat for mushroom growing has already been tried, found satisfactory, and is now practiced in Duluth. The peat is used as a casing for mushroom beds. A characteristic of mushroom culture is that the mushrooms do not mature unless the mushroom beds are cased with a loamy soil. The mushroom bed is made up of 6 to 8 inches of compost as described above, but a layer of an inch of loam must be covered over the 6 to 8 inch bed of compost before the mushrooms will mature. Now the procurement of a loamy soil in the vicinity of Duluth is difficult. Most of the soils around Duluth are a heavy red clay which is unsuitable for mushroom culture.

"After hearing a talk by Mr. Clayton Plummer, who is in charge of the peat project in Chisholm, the idea occurred to the writer to use peat for casing the mushroom beds. Arrangements were made with Mr. R. E. Wilson, commissioner, of the Iron Range Resources and Rehabilitation, to obtain peat for this purpose. The pH value of the peat as dug from the bog was about 5.0. This range of acidity is unsuitable, so the peat was neutralized with calcium carbonate; the pH adjusted in this way, was then 7.5. An inch layer of the neutralized peat was placed over the mushroom beds. It was, indeed, pleasant to discover that the mushrooms grew more abundantly in the peat casing than in the loam. The mushrooms were whiter and free of any blemishes, so that a better price was commanded.

"Another advantage of using peat as a casing instead of soil, was that the spent compost was more valuable as a fertilizer for other plants. By spent compost is meant the compost remaining after the mushrooms no longer will grow in it, so that it is removed and replaced with fresh compost. The addition of peat to the spent compost increased the water-holding capacity and the soil crumb structure of soils to which it was added for the growth of various plants. Those who used this spent compost-peat mixture found that it increased measurably the growth of berries, potatoes and grass.

"Another plan to try in growing mushrooms in St. Louis County is to grow the mushrooms in trays instead of long, immovable beds. These trays are built with a surface area of 8 to 10 square feet, so that they are easily transported. The plan is to prepare the compost, fill the trays, and innoculate them with spawn or mushroom seed in one central plant. Then the trays may be distributed to farmers and other individuals before the mushrooms appear. The farmers and others would harvest the mushrooms and deliver them to a central cannery in Duluth."

SUMMARY

Mr. F. J. Alway summarized the possibilities of peat land reclamation as follows:

"It appears that at present in the case of the greater proportion of our immense peat acreage, the profit of reclamation is to be regarded as extremely doubtful, even under the most skilled supervision and with every resource and facility for conducting the work economically, while many extensive tracts could be improved only at a loss. There is, however, much peat land that might at once be profitably reclaimed, especially where the owners already live upon it or where it forms parts of farms consisting largely of mineral soil. In general, the wise method of procedure appears to be for those men already living upon farms which have more or less peat land, either already provided with, or convenient to outlets, to try out at once the complete reclamation of a few of these unprofitable acres, making use of modern methods."

For further information relative to the value and use of peat lands in agriculture, communications should be addressed to the Division of Soils, University Farm, St. Paul, Minnesota.

OTHER USES OF PEAT IN AGRICULTURE

Peat as a Fertilizer and Soil Improver—Impoverished mineral soil may be improved in fertility, texture, and moisture-holding capacity by the application of peat.

In general, peat as a fertilizer cannot compare in effectiveness on plant growth with manure or inorganic fertilizers. As the nitrogen of peat is only slowly available, its value as a source of plant food is limited.

In recent years, more emphasis has been placed on using peat as a soil improver. Sedge and reed peats were found to improve the physical properties of the soil for plant growth far better than could be accomplished with stable manure. Treatment of peat on sandy soil increased its moisture content and gave considerable increase in yield. In an experiment with tobacco it was found that peat decreased the leaching of nutrients 50 per cent.[1]

Peat for Composts—With the realization of the need humus in the soil and the decrease of availability in horse manure the use of peat either directly or as a compost with manure soil has received attention. Perhaps the most convenient way of using peat moss litter is to form a compost heap alternating layers of peat, soil, and manure, frequently with the addition of commercial fertilizer. Such peat moss manure has been used successfully on golf courses and other grass land.

Use of Peat as an Absorbent—The use of peat as a litter barns is recognized as superior to straw or other absorbents. absorbing power of a good peat litter is over 800 per cent often ranges from 1200 to 1500 per cent, cereal straw capacity of only 200 to 350 per cent and sawdust, 360 to 500 per cent.

The importance of peat as a litter is stated very clearly S. A. Waksman.[1]

> "The litter is spread in the stables to a depth of 10 to 20 cm. (4 to 8 inches) and, until the animals have become accustomed to it, covered with some straw. For every square meter of the stable floor 9 kilograms (20 pounds) of peat are required. The manure is removed from the stables once or twice a day; the fully saturated litter is also removed and replaced by 1 to 2 kilos (2 to 4.5 pounds) of fresh litter per animal. The full bedding should be removed when the air of the stable has become saturated with smells, when the animals show a disinclination to lie down, or when they wet their coats in doing so. A bed thus prepared lasts 2 to 4 weeks. Urine channels in the stalls are filled with peat litter to prevent the liquid from flowing away; when absorbed by the peat, this makes an excellent manure.
>
> "It has been said that the hoofs of the animals standing in this bedding attain a high degree of flexibility and soundness, which can only be compared with the condition of pasturing animals. Their stamping in the stalls is noiseless, because of the softness and resiliency of the moss as a litter. The temperature in the stables is somewhat lower than that in stables where straw or other forms of litter are used, since the peat litter prevents the rapid heating of the manure due to decomposition. Peat litter tends to keep the atmosphere

[1] Hyper-Humus, by T. R. Swanback, Conn. Agr. Exp. Station 53rd Report 24, 1929, pp. 220-227.

[1] The Peats of New Jersey and Their Utilization, Bulletin No. 55, by S. A. Waksman, 1942, pp. 124-125.

of the stables odorless by preventing the formation of ammonia. By keeping down unpleasant gases, peat litter is said to reduce the susceptibility of animals to diseases of the eyes, lungs, and hoofs. It also adds to the value of the stable manure, by preventing its rapid decomposition.

"In poultry houses where the peat moss is placed on the floors, diseases are said to be far less frequent. The birds scatch the material searching for food, thereby keeping themselves clean. The droppings are soon worked up into the litter and the resultant chicken manure become enriched in available nitrogenous materials.

"Fresh peat manure has found favor with market gardeners, since it is very similar in action to straw manure. It is even claimed that better crops of beets and other vegetables were obtained on land treated with peat manure than on land receiving straw manure. Peat manure was believed to be especially beneficial for rapid-growing crops. Favorable results were reported from Russia, where an increase of 8 per cent in the yield in cereals and 25 per cent in root crops resulted from applications of peat manure.

"Peat moss was found to be a very effective material for the conservation of the nutrient elements in the animal excreta and urine. There is also said to be less loss by composting of peat-manure mixtures than of straw-manures, thereby making peat manure richer in fertilizer elements.

"Not only peat moss but also certain other forms of fibrous peat may be used as stable litter; they absorb the nitrogen-rich urine, most of which is ordinarily wasted. As an effective deodorizer and disinfectant, peats are usually superior to lime and ashes, and even to some of the more expensive disinfectants. They are a nearly ideal material for use in earth closets and other receptacles which receive moist waste organic matter. As early as 1867, every farmer in this country knew the efficacy of peat as a disinfectant and deodorizer.

"Certain types of peat may be used in the construction of filters to purify sewage effluent. Small peat filters were found to be good in conjunction with the usual household septic tanks where an effluent is desirably free from objectionable smells. Larger plants are used together with screens and sandtraps. The final product may be used as fertilizer. One of the special properties of peat which recommend it for this purpose is the lack of odor and flies."

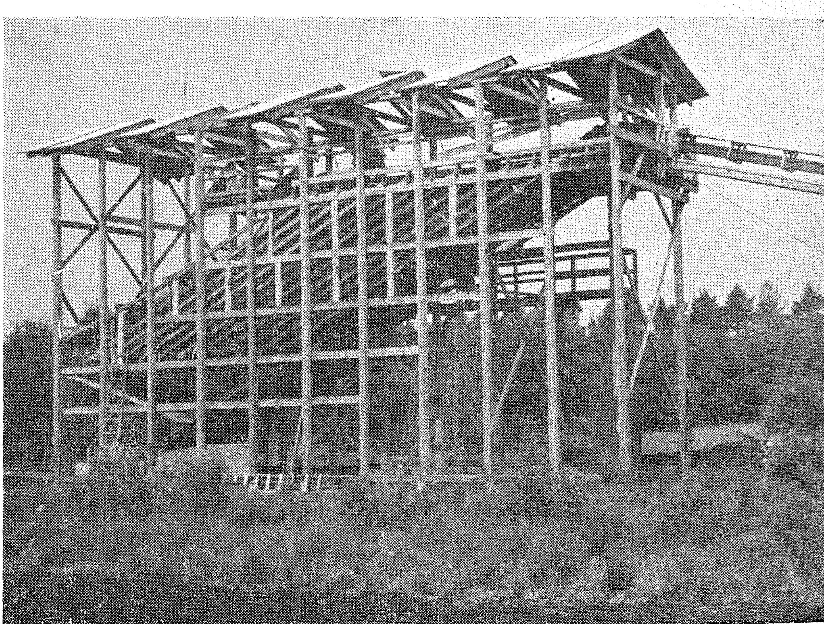
CHAPTER XXIII

PRODUCING LITTER AND HORTICULTURAL PEAT AT THE FLOODWOOD PLANT

Large quantities of peat are imported from Canada or other countries annually. Commissioner Wilson, realizing the presence of huge peat deposits in Minnesota, undertook to build an experimental pilot plant at Floodwood, Minnesota, to process sphagnum moss into poultry litter for poultry farms as well as for horticultural purposes.

A description of the plant is as follows:[1]

> "The plant is 252 feet long and 50 feet wide. The moss is removed from a nearby bog by means of hydraulic pressure, is floated through small trenches to a pump which forces it through a two-block long pipe into the washroom adjoining the plant. There it is washed and cleaned thoroughly and leaves this room free from all foreign material. It then enters the main plant, going first through the fordinear. It is carried by conveyor belt into the 135-foot tunnel oven where it is dried to about 25 per cent moisture, thence to the hammer-mill room and finally to the baler.



Courtesy T. Widell

The Klint Screen Shelf Peat Ball Drier in Sweden

[1]Developing the Resources of Minnesota, Biennial Report, 1945-47, Iron Range Resources and Rehabilitation, p. 33.

"The pilot plant has a production capacity of 750 bales a day weighing 80 to 100 pounds per bale. Present plans call for around-the-clock operation to meet the demand for peat moss in the field of horticulture and for poultry and stable litter. The new plant will provide year-around employment for approximately 40 persons residing in the Floodwood vicinity."

The Floodwood plant was operating to capacity last fall, processing peat both for litter and for horticultural purposes. Ready sale was found for all peat processed.

CHAPTER XXIV

THE USE OF PEAT FOR HORTICULTURAL PURPOSES

Peat has found numerous applications in horticulture. Some of these uses are as a medium for germinating seeds, to transplant and grow evergreens and shrubs, to start cuttings, and to propagate orchids. Peat is also used as a mulch to protect plants and soils against alternate freezing and thawing and to keep down weeds. Its use in the preparation of top-dressings for lawns has grown in favor. For many plants, peat was found to be favorable for root formation of tree seedlings and strawberries. The texture of peat and its ability to maintain a uniform moisture makes it very useful for horitcultural purposes.

Florida, having peat bogs totalling 3,500 square miles, has excavated peat for horticultural purposes since 1917. During 1945, nearly 30,000 tons were processed, having a total value of $150,000.[1]

Imports—The U. S. Bureau of Mines gives the following information on imports:

> "Imports in 1945, all from Canada, totaled 77,673 short tons valued at $2,393,214. Before 1939, most of the peat imported came from Germany. In 1938, Germany supplied 36,381 tons valued at $525,564; in the same year, the Netherlands and Sweden together supplied 36,381 tons valued at $348,252."[2]

Minnesota in a Position to Meet Demand—Since the United States imports peat valued at over $2,000,000 annually, largely for horticultural and soil improvement purposes, the demand for this product is evident.

The new modern peat processing plant at Floodwood, Minnesota, has demonstrated that Minnesota, with its vast peat resources, can supply the market with a uniform and superior

[1]The Peat Deposits of Florida, Geol. Bull. No. 30, by J. H. Davis, 1946, pp. 4 and 202.
[2]U. S. Bureau of Mines Minerals Yearbook, 1945.

product for litter and horticultural purposes, at a cost that would compete with imported peat.

The demand for litter will probably increase when the superior absorbing qualities of peat become more generally known. With increased production, costs would decrease and a larger market would develop.

CHAPTER XXV

UTILIZATION OF PEAT FIBER IN INDUSTRY

The Germans were active during the war in developing methods of utilizing peat fibers. The following simplified flow diagram shows what might be accomplished by further research on peat fibers.

The Floodwood peat processing plant should be in a position to carry on research on the utilization of peat fibers in industry.

CHAPTER XXVI

CARBONIZATION OF PEAT

Peat heated in ovens or retorts in the absence of air results in a modification of its physical structure and the production of char; uncondensable gases; pyroligenous acid liquid, containing ammonium acetate; methyl alcohol compounds; and tar oils. Temperatures may range between 400° F. and 1650° F., depending on the yield of products desired; at the higher temperatures, the amount of char is less but the amount of gas is more. The uncondensed gases are generally returned to the combustion chambers to serve as fuel.

HALF COKING (450° F.)

This is a term given to the process when the peat is heated to about 450° F. in order to produce a product that is not as hygroscopic as ordinary peat; the product still retains tar and makes a good generator fuel. A typical analysis of ordinary peat and half-coked peat is as follows:[1]

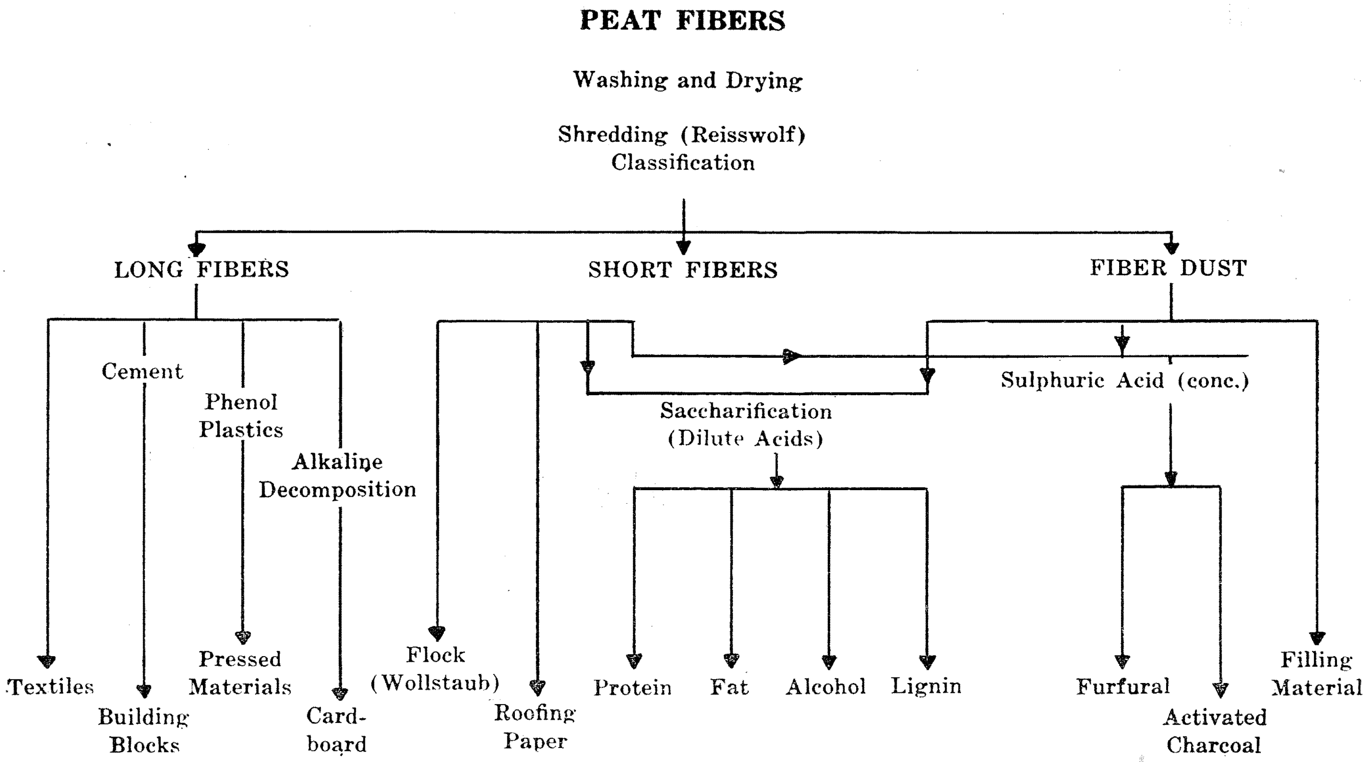
Analysis of Peat and Half-Coked Peat

	Ordinary Peat	Half-Coked Peat
Carbon	56.0	63.6
Hydrogen	5.6	4.8
Sulphur	0.2	0.1
Nitrogen	1.2	26.0 (Nitrogen and Oxygen)
Oxygen	33.5	
Ashes	3.5	5.5
	100.0	100.0

[1] Sveriges Branntorv Industri, 1940-46, by Olle Uddgren, page 256.

SIMPLIFIED FLOW DIAGRAM[1]

UTILIZATION OF PEAT FIBER



[1]Interrogation of Dr. Gunter Spengler, Munich, formerly of Institute for Coal Research, German Technical High School, Prague, prepared by direction of Field Information Agency, Technical (U. S.), Office of the Director of Intelligence, U. S. Control Council, Germany.

The results show that peat loses approximately 30 per cent of its weight during the heat treatment, resulting in a product containing more carbon and less oxygen and having a heating value of about 10,500 Btu.

CHARCOAL FROM PEAT BY WOOD DISTILLATION PRACTICE (572° F.)

The Canadian Bureau of Mines, in 1922, made carbonization runs in hardwood distillation ovens. Those interested in a full report of these large-scale experiments are referred to the Summary Report on Mines Branch Investigations for 1922, pages 194 to 209. Haanel summarizes as follows:

> "In this investigation a carload of air-dried peat with slightly over 25 per cent moisture content was carbonized in plant-size hardwood distillation ovens, under low temperature conditions. The rate of reaction was controlled at about 300° C. and the yields of the commercial products were measured, a preliminary examination of which has been made.
>
> "Air-dried peat bricks when handled and carbonized in the same manner as hardwoods responded to the same method of oven firing, but required slightly more fuel to carry on the carbonization during the later half of the run, which extra fuel was supplied by the oven gases produced. Although the oven firing did not require special attention to avoid a too rapid increase of the internal temperature of the ovens, there were indications of exothermic reaction, but not to the same extent as with hardwood. The moisture in the peat, however, apparently masked any appreciable outward signs of such reaction. The commercial products obtained were peat charcoal, peat tar oils, crude alcohol, and ammonia, of value in the order given. The alcohol when blended with certain light oils may be considered as a crude motor spirits product.
>
> "Peat charcoal in many respects resembles hardwood charcoal and as a special fuel for quick, hot and short-lived fires may be considered a substitute. The quality of the alcohol from peat, the yield of which is disappointingly low in comparison with hardwoods, has not as yet been thoroughly examined.
>
> "The weight per bushel of peat charcoal averaged 35 pounds as compared with 21 pounds per bushel for hardwood charcoal, and the yields per ton of raw material carbonized was roughly 21 bushels from peat and 26 bushels from hardwoods. At the same price per bushel to be marketed in bulk similar to the hardwood

product, the value of the peat charcoal is, therefore, only about 0.8 of the value of the charcoal from an equal weight of hardwood.

"The lumps of peat charcoal produced by carbonizing air-dried peat were irregular in shape and not so black as wood charcoal. Although apparently more friable than charcoal from hardwoods, the handling properties of the peat charcoal are such, that it can be used as a fuel in the condition produced and does not need to be briquetted.

"The value of the products from air-dried peat is estimated as three-quarters of the value of the products from equal weight of hardwoods, and for peat the value of the charcoal as a percentage of the value of the total products is much higher than for hardwoods.

"Once the cost of air-dried peat in large quantities is known, the yield figures given in this report may be used for determining the economic feasibility of carbonizing peat similar to the low temperature process as used for hardwoods. Until such a time, however, as the production of air-dried peat more than meets the demands as a household fuel, it is doubtful if the price of the raw material will allow the carbonization of peat to develop into an industry either to supplement a successful peat-harvesting enterprise, or in conjunction with the already established hardwood distillation industry."

LOW TEMPERATURE CARBONIZATION (932° F.)

Experiments in Sweden—Mr. B. Christiansson, a Swedish chemist, has been active in the study of new methods for the chemical utilization of peat. On the subject of low carbonization, Christiansson states:

"When peat is carbonized, i.e. heated to about 500° C. without admission of air, 30-40% coke, 10-15% tar, including volatile matters, 20-30% water and about 20% gas can be obtained with a suitable kind of peat and good carbonization conditions. The coke is, therefore, the main product. It is a good fuel with a heating value of about 6000-7000 kcal/kg and might be used for different technical processes, especially metallurgical, where a low sulphur and phosphorus content is required. It can be converted to further advantage to activated carbon, a process which has also been carried out in industrial scale—in other countries.

"The tar products can be utilized in many ways. For instance, phenols, fatty acids, solid paraffins, solvents, liquid fuels, greases and pitch may be obtained. Certain groups of components in the tar might be used as starting material for chemical synthesis; by cracking the tar, gasoline, pitch and a gas with a high heating value can be obtained. Finally, it may be subjected to hydrogenation in order to produce gasoline and different kinds of oils.

"During the last years extensive experiments have been going on in Sweden with carbonization of peat. The purpose of this activity has been partly to obtain better knowledge of the utilization of our different kinds of peat for carbonization and the character of obtained products, partly to bring forth constructions of apparatus suitable for the carbonization, especially such as permit continual processing of powdered material. For economic reasons carbonization must be carried out in plants of a certain minimum size, and the working of the tar in larger centers."

Peat Research in Germany—Germany, during the war, did research on peat processing, and the carbonization of low ash peat briquets for the manufacture of coke and the recovery of phenolic tar, which can be converted into wax, are phenols, plastics, glues and other products.

Dr. Gunter Spengler, a German chemist, was active during the war in pure research on peat. A government report shows that the Germans were active in research on the by-products obtained by the low temperature carbonization of peat. We quote from this report:[1]

"At present a plant is being constructed near Munich by Torfveredlungswerke G.m.b.H., Munich, which is headed by Dr. Spengler. Present plans are to have a production of 20 T/D briquets by Dec. 1, 1945, after which Dr. Spengler hopes to expand production to 100 T/D briquets and to recover by-products as well. This plant has been approved by military authorities concerned. It is recommended that further details on the operation of this plant be secured after it starts operations."

The report gives data on the utilization of peat tar and composition of peat tar, products of methanol extraction and products of naptha carbonization as follows:

[1]U. S. Group Control Council, Germany, Office of the Director of Intelligence.

ANALYSIS OF PEAT TAR AND EXTRACTION PRODUCTS

Product	Per Cent	
Peat Tar		
Bases	3.0	
Lower Fatty Acids	12.0	
Olefins	36.5	
Aromatics	6.5	
Paraffines, hydrocarbons	22.0	
Phenols	30.0	
Methanol Extraction Products		
Diesel Oil		35
Condensible Phenols		10
Acid Resin		5
Wax		30
Bitumin Pitch		20
Naptha Extraction Products		
Heating oil or impregnating oil		50
Wax		30
Asphalt		20

The market demand for phenols places peat in a favorable position as a source of raw material for the phenol-aldehyde plastics, now being widely used in the United States.

It is apparent from research being conducted on peat in Germany that there is a growing interest in developing new methods for the chemical utilization of peat. This suggests that further investigation and research should be undertaken on uses of peat for purposes other than fuel, when an economic method has been developed for producing dry peat.

PROPOSED HIGH TEMPERATURE CARBONIZATION RESEARCH

More high temperature carbonization experiments should be made to determine the effect of coking, specially prepared peat in a continuous chamber at temperatures above 1200° F. The distillation products, such as tar, gases, and water should move concurrent to the charge, and thus become cracked with the deposition of carbon and the liberation of hydrogen and carbon monoxide as gases. Such a carbonization treatment could result in a strong peat coke and a gas high in hydrogen and carbon monoxide.

LOW AND HIGH TEMPERATURE CARBONIZATION

As previously stated, high temperature carbonization results in a lower yield of char but a higher recovery of gas. Haanel[1] shows in table form a comparison of commercial products in hardwood ovens and in vertical gas retorts:

[1]Final Report of The Peat Committee by B. F. Haanel, Department of Mines, Ottawa 1926, p. 224.

Comparisons of Commercial Products in Hardwood Ovens and in Vertical Gas Retorts

Products	Low temperature carbonization in wood ovens	High temperature carbonization in gas retorts
Peat charcoal		
Per cent of air-dried peat charged	37.2	25.1
Pounds per ton	745	503
Per cent ash (dry basis)	12.7	9.9
Per cent volatile matter (dry basis)	28.7	3.9
Calorific value B.T.U. per lb.	11,940	12,650
Peat tar oils—Imp. gals. per ton		
Total produced	14.1 gals.	14.2 gals.
Specific gravity at 60° F.	0.968	0.992
Fraction to 170° C. (dry basis)	6.7% weight	2.5% weight
Fraction 170° to 230° C.	25.8% weight	13.9% weight
Fraction 230° to 270° C.	17.5% weight	15.4% weight
Fraction 270° to 335° C.	24.0% weight	34.7% weight
Pitch and loss (by difference)	26.0% weight	33.5% weight
Aqueous liquor products per ton		
Total liquor (Imp.) gallons	86.0	87.0
Ammonium sulphate, lbs.	15.1	22.6
Crude alcohol, (Imp.) gallons	1.08	0.34
Gas—cu. ft. per ton	less than 4,000	about 12,000
Crude motor spirits, (Imp.) gallons Alcohol—plus oils below 170° C.	2.10	0.75

CONCLUSION

Our survey shows that many unsuccessful attempts have been made to operate peat carbonization plants economically. Present research should be carefully watched and evaluated. In our opinion the investment in a plant to produce and refine the by-products would not be justified until there existed an ample supply of dry cheap peat, and a ready market for the charcoal, ammonimum sulphate, phenols, etc. Our first problem is the development of a method for the economical production of peat fuel; a market survey may then show the feasibility of producing chemical products by the carbonization of peat.

Part VII
CONCLUSIONS

1. A peat winning method, to be successful in northern Minnesota, must be able to produce a fuel at a cost competitive with coal. An analysis of the machine and hydro peat methods, as practiced in Europe, indicates that a peat fuel, produced by these methods in Minnesota, would prove too expensive to compete with coal and other fuels. Cost figures of machine peat in Ireland are calculated at $8.60 a short ton, equivalent to $0.70 a million Btu.

2. The Milled Peat Method, to be economically successful, must be applied to bogs comparatively free from roots and stumps. Since many of our bogs in northern Minnesota have this disadvantage, the use of the milled peat process is limited to only a small portion of our potential peat fuel.

Milled peat in Ireland (Peco Method) is actually produced at $1.64 a short ton, equivalent to $0.25 a million Btu. With large production, it is estimated that the cost delivered to the bunker will be about $0.20 a million Btu. The probable cost in Minnesota is placed at $0.30 a million Btu. (Present cost of power coal is $0.45 a million Btu, equivalent to coal costing $11.50 a ton.)

3. Milled peat production is less dependable than machine peat during unfavorable weather conditions since the product is fluffy and absorbs water readily. In our opinion, to be economically successful, at least 24 harvestings should be obtained per season; a 7-day drying period and 168-day drying season will result in 24 harvestings.

4. If economically feasible, a modified milled peat method might be used in which the raw peat would be excavated, macerated, and stockpiled. The milled peat method or some special cutting and harvesting procedure would then be applied on the top and sides of the stockpile. Drying on the stockpile would be more rapid than on the bogs. Excavation and maceration would solve the root problem and produce a more dense and uniform product.

5. We recommend the use of large material handling equipment for economy.

> A slackline cableway system with head and tail towers mounted on crawlers appears to meet the requirements of a desirable excavator.
>
> A non-clog movable breaker plate hammermill, capable of grinding up roots and stumps, should solve the macerating problem.

The use of conveyor belts and stackers, such as are used in the iron ore industry suggests their possible use with peat.

6. More economical machine or hydro peat methods might be developed to produce fuel competitive with power coal.

Harvesting machine peat at 50 to 55 per cent moisture content instead of 30 per cent would increase the number of harvestings per season and should reduce the production cost of power fuel.

Using large and improved material handling equipment should eliminate root and stump difficulties and reduce labor costs by increasing output per manhour.

Modified machine peat methods have been tried which claim more efficient drying and greater production than is produced by the ordinary machine peat process. Drying on bog or stockpile of particles different in size and shape than those ordinarily used might increase production sufficiently to make the method economically satisfactory.

7. Peat briquettes are considered a very desirable domestic fuel in countries where such fuel is produced. Peat pellets such as have been produced in our research program have some properties comparable to peat briquettes and should find a ready market as a domestic fuel.

Although the cost of producing peat pellets appears to exceed our limiting value of $5.20 a ton as a power fuel, it is very probable that as a domestic fuel, it could be produced at a cost low enough to compete with domestic coal, now selling for $0.80 a million Btu. Estimates place the cost of peat pellets at approximately $8.00 a ton, equivalent to $0.60 a million Btu.

8. Peat is a good reductant which could be used to convert low-grade, non-magnetic iron ores to magnetite which would make them amenable to magnetic separation.

9. Peat can be used as a fuel in a gas producer for the generation of power or the production of gas and ammonium sulfate. The results to date have not been sufficiently favorable to recommend the former practice. Many attempts have been made to use high moisture peat as fuel in the gas producer without the desired results. Peat fuel, containing 30 to 35 per cent moisture, is satisfactory and has been burned to give a gas containing 145 Btu per cubic foot, results comparable using coal, coke, etc.

Conversion efficiencies are higher now than 25 years ago when the use of peat as a fuel in gas producers was being highly advocated. Conversion efficiencies were given then as 60 to 75 per cent, while now 75 to 85 per cent are figures often used. If the cost of heat per million Btu can be limited to $0.45 (55 per cent milled peat costing $2.00), the writer will then recommend peat fuel for gas producers, provided a satisfactory method is available for burning finely divided peat. Peat containing 25 per cent moisture, costing $5.00 a ton would give a producer gas costing $0.68 per million Btu. Replacing air with oxygen has been suggested as a means of producing a gas low in nitrogen and high in hydrogen and carbon monoxide.

A peat containing 2 to 3 per cent nitrogen, naturally, would permit a higher peat fuel cost, due to credit for the ammonium sulfate obtained as a by-product.

10. If produced economically, peat fuel could be used in large generating stations located near the bog site to supply a sufficient amount of cheap electric power for the beneficiation of taconite ores.

11. In our opinion, a 25,000 kw power plant, equipped with waste heat driers and designed to use 55 per cent moisture milled peat will produce electricity in Minnesota at about 11 mills a kwhr; 50 per cent of this estimated cost figure is charged to fuel.[1]

Since Minnesota possesses over one-half the potential peat fuel available in the United States, the importance of further research in the utilization of this resource is self-evident.

In our "Recommended Peat Development Program for 1949-1950," we suggest a program which should inform us whether peat can be produced economically as a power fuel; what other uses of peat might be developed successfully in northern Minnesota; and in what ways, besides the supply of needed power, might peat be used in beneficiating the low-grade taconite ores of northern Minnesota.

If a thorough study of possibilities indicates that peat for fuel cannot compete with coal and other imported fuels, this office hopes to point the way to other uses of peat that would be economically possible.

[1]This estimate has been calculated by studying the cost figures worked out by R. L. Fitzgerald in "Electric Power, Generated by Steam from Peat Fired Boilers," April, 1945; and the cost estimates made by A. H. Harkin and J. Martin of Ireland.

Part VIII

APPENDIX

SUMMARY OF EXPERIMENTAL PROGRAM[1]
1946-1948

Preliminary to development work on any method or process, it is necessary to become familiar with the behavior of the material under consideration. This office has performed many experiments on the properties of peat in order to determine methods of overcoming its peculiar characteristics.

EFFECT OF WATER ON THE PROPERTIES OF PEAT

The physical properties of peat vary considerably at different moisture contents. As it occurs in the bog at 90 to 92 per cent water, well decomposed peat is a solid gel-like material. The loose chunks will retain their shape as dug; however, in a large pile where it is under pressure, raw peat has a tendency to flow. When macerated at the above moisture content, peat becomes very sticky and plastic and flows like a viscous mud. When stirred with water, raw peat becomes a slurry above 93 per cent water; above 95 per cent water, it becomes a thin slurry which may be pumped easily.

A bog, during draining, slowly reduces to a moisture content of about 87 per cent, and gradually increases in firmness. Stockpiled peat containing 82 to 86 per cent moisture is firm, but when macerated, the resulting material has the proper consistency for pelletizing without sticking to the equipment. The pellets retain their shape in a pile 3 feet deep without appreciable deformation. Below a moisture content of 79 per cent the power required for maceration of raw peat increases rapidly. Peat starts becoming granular when stirred at a moisture content of less than 75 per cent and the particles will not stick together unless pressure is applied. Raw peat dried in block form to less than 30 per cent moisture retains its shape but is not as hard, strong, and dense as macerated peat.

Dried peat has interesting moisture reabsorbing properties. The less decomposed, or moss peat, has greater absorption powers than the highly decomposed peat. Moss peat should not be dried below 30 per cent moisture if it is to be used as litter. Fuel peat which has been dried below 30 per cent will absorb water until it reaches the moisture content of approximately 65 per cent.

DENSITY

Density is an important property of peat to be used for fuel. Raw peat taken from a point near the shore of the Balkan bog

[1]Compiled by Dimitri Pouchak.

weighed about 64.2 pounds per cubic foot in place, while peat taken from the center of the bog weighed 63.3 pounds per cubic foot. One cubic yard of wet peat weighs approximately 1700 pounds. J. H. Davis[1] gives the density of excavated Florida saw grass peat as 1400 to 1600 pounds per cubic yard when wet, and 600 to 675 pounds per cubic yard when dried to 15 per cent moisture.

The density of dried peat depends upon the amount of shrinkage, which is affected by the degree of decomposition, amount of maceration, and the rate of drying. Moss peat, because of its porous, fibrous structure, shrinks very little during drying and is very light in weight even if the material has been macerated. Well decomposed peat, when highly macerated and air-dried has a density of approximately 1 and is as firm as hardwood. The volume shrinkage of peat during drying varies from 50 to 75 per cent. The rate of drying has an important effect on the shrinkage of peat. Slow drying results in a denser product than rapid drying. Cracking is caused by the rapid shrinkage due to fast drying of the outer shell while the wet inside remains the same volume.

MACERATION

Maceration was considered to be an essential step in early peat processes. Peat fuel produced from macerated peat is more dense than cut peat and easier to handle without waste.

Laboratory tests were made by this office to study the maceration of different types of peat. Fibrous peat is difficult to macerate in a screw type machine unless the peat is saturated with water or a sufficient amount of well decomposed peat is present to act as a lubricant. Well decomposed raw peat containing over 87 per cent moisture can be macerated very easily. With a moisture content between 82 to 87 per cent, maceration may still be accomplished by a screw type machine; however, the power consumption increases rapidly with a further decrease in moisture content of the peat.

FREEZING

The physical properties of wet peat are changed by freezing, but little attention has been given to this fact by most investigators. If advantage could be taken of the cold winters of northern Minnesota, a year-round utilization of energy from natural sources would be possible. About 30 small experiments were made by this office to determine the effects of freezing on peat. It has been observed that the greatest changes, resulting from freezing, occur in wet macerated peat, and that little or no changes occur in air-dried peat. It is not definitely known what happens, but the change in physical structure appears similar to that in peat which has been heated in an autoclave. After freezing and

[1]The Peat Deposits of Florida, by J. H. Davis, Geological Bulletin No. 30, 1946.

thawing, the contained water is freer and can be more easily pressed from the peat which seems less colloidal and sticky. If the peat is allowed to thaw and dry rapidly after freezing, it shrinks very little and the product has a pulpy or corky structure without cracks. The dry material has a remarkable property of powdering easily; if such peat is used for powdered fuel, grinding costs will be reduced.

CHEMICAL COMPOSITION OF PEAT

Raw peat consists of accumulated organic residues and partly decomposed products of many species of plants. The mixtures of very complex organic constituents occurring in peat are difficult to analyze. The different compounds are often separated into groups according to their general chemical nature and their solubility in various solvents. The constituents of peat may be classified into either, alcohol, and water soluble portions; and hemicellulose, cellulose, lignin, protein, and ash portions. Cellulose or vegetable fiber ($C_6H_{10}O_5$) and lignin or woody fiber ($C_{35}H_{24}O_{20}$) are the two principal constituents. Typical chemical composition analyses of various peats are listed in the following table, which was extracted from information compiled by S. A. Waksman[1].

CHEMICAL COMPOSITION OF VARIOUS PEATS
(Percentages of Dry Peat)

TYPE OF PEAT	pH	Ether-Soluble	Alcohol-Soluble	Water-Soluble	Hemi-Cellulose	Cellulose	Lignin	Protein	Ash
Sphagnum									
Live	....	1.47	....	3.86	30.8	21.1	6.97	5.88	3.18
Dead	....	1.60	....	1.56	24.5	15.9	19.15	1.86	19.92
Finland	....	3.53	4.56	7.82	18.15	16.55	38.53	3.81	1.48
Woody Sedge Peat									
Washington	....	1.86	5.65	7.59	7.0	2.9	41.4	20.3	9.61
Sedimentary									
New Jersey	8.0	0.36	....	1.24	5.92	....	15.62	9.81	59.55
Florida	....	.59	2.16	3.80	3.9	1.8	48.43	23.94	26.92
Lake Peat									
New Jersey	6.8	0.67	....	0.81	12.14	....	33.25	19.38	24.87
High Moor									
0-15 ft.	3.7—	2.35—	1.45—	....	26.45—	16.86—	27.18—	4.08—	2.00—
Missouri	4.7	4.89	4.29	....	12.69	11.85	44.83	5.24	0.90
Low Moor									
0-5 ft.	5.9—	0.66—	....	3.08—	10.31—	....	38.35—	22.48—	13.22—
New Jersey	6.7	1.10	....	1.14	7.02	....	57.83	14.81	10.15

ELECTRON MICROSCOPE STUDIES

Recently, six samples of peat taken at one foot depth intervals from the Balkan bog were sent to Northwestern University, where their Chemical Engineering Department will examine the peat with an electron microscope. Such an investigation may reveal some important observations of the physical structure of peat, and should be of great interest to all peat investigators, since no similar work has yet been done. Little is definitely known at present about the colloidal and water retaining characteristics of peat.

[1]S. A. Waksman, The Peats of New Jersey and Their Utilization, Geological Bulletin No. 55, 1942, Vol. I, pp. 77-79.

GENERAL INTRODUCTION

During the 1946-1947 season, 89 experiments were made on peat; 37 of these were performed on peat pellets, 9 on balls, 6 on blocks, 4 on hydropeat, 9 on stirred peat, and 24 on other tests.

During the 1947-1948 season, 77 small experiments were performed on peat; 38 of these being made with wet peat pellets, 30 with frozen peat pellets, and 9 on other tests. Two larger scale tests were made during the fall of 1947, and a small pilot plant test during the summer of 1948, which accounts for the fewer number of small experiments performed during that period. The pilot plant tests were made during two periods. The first period was devoted to studying the variables affecting the drying of pellets in layers on screen shelves, and the second period to the continuous drying of pellets on the shelves.

The majority of the experiments described in this section were made to study the air-drying properties of peat. Other tests were made to determine draining, mixing, macerating, pelletizing, and shrinking properties of peat.

LABORATORY EXPERIMENTS

Hydro Peat Screen Box Tests—1946—To investigate the possibilities of drying hydro peat in screen tanks, several experiments were undertaken in which peat slurry was poured into screen boxes.

Group I—Tests were made to determine the relative time to air dry drained hydro peat in four forms: small particles; a block perforated by a few large holes; a block perforated by many small holes; and in the form of balls of uniform size.

Four boxes, each 14.5 by 14.5 by 11.5 inches in size and made from 8-mesh screen, were filled with 88 pounds of peat sluge containing 94.5 per cent water. The 4 samples were closely consistent in their draining rates. During 16 hours of draining, the water content was reduced to 89 per cent and the bed depth decreased to 5.8 inches. After 25 hours, dripping ceased at a moisture content of 87.5 per cent.

After drainage, Sample (A) was perforated by nine 2 inch holes; Sample (B) was perforated by about 18 holes 7/8 inches in diameter; Sample (C) was stirred at intervals; and Sample (D) was formed into balls 3.2 inches in diameter.

After 14 days of drying outdoors, the perforated blocks (A and B) were reduced to a moisture content of approximately 68 per cent, whereas the stirred peat and balls were reduced to 34 per cent moisture content. The drying rate curves of the perforated blocks were almost identical. The curve of the pellets showed only a slightly more favorable drying rate than that of the stirred peat. After 27 days of outdoor exposure, seven of which were rainy or unfavorable, the final moistures were as follows: blocks with the large holes, 63 per cent; blocks with the small holes, 66 per cent; stirred peat, 42 per cent; and the balls, 23 per cent.

Group II—The purpose of this experiment was to compare the draining and drying rates of hydro peat and non-hydro peat in screen boxes.

Two 5000 gram samples of 88 per cent moisture raw peat were carefully weighed. One sample was placed into an 8-mesh screen box (9.75 by 9.75 by 6.5 inches) ; the other sample was mixed with an equal weight of water and poured into a similar container.

After 2 days the hydro peat drained to a moisture content of 87 per cent, the same moisture content as the raw peat. The drying rate was similar for both samples, with the hydro peat slightly more favorable. The final difference in moisture after 13 days of drying was 5.5 per cent; the non-hydro containing 51 per cent moisture and the hydro peat containing 45 per cent moisture.

Group III—In October 1946, 100 pounds of 93 per cent moisture hydro peat drained in 24 hours to 88 per cent moisture. With periodic stirring, the peat dried to 62 per cent moisture content in 21 days.

Conclusions—These early tests brought forth the following conclusions;

1. Peat in the form of balls 3 inches in diameter dried faster than stirred peat and considerably faster than the perforated blocks.

2. Hydro peat drained and dried to a lower moisture content than raw peat in the same period.

3. Raw peat diluted with water to a consistency corresponding to hydro peat, drained to 88 per cent moisture in 24 hours. (Peat containing 95 per cent moisture and stirred does not correspond to peat cut with a stream of water and pumped).

Pellet Drying Tests—Early conclusions from preliminary tests showed that the form and size of the peat particle has an important effect on the drying rate. In a peat particle of spherical shape, there is less tendency for the outer shell to crack since the shrinking forces are equalized toward the center. Since the outer surface shrinks more rapidly than the inner wet peat, a pressure is exerted which tends to force part of the water towards the surface and results in faster drying. Drying tests were made on different forms such as solid blocks, perforated blocks, granular peat, solid and perforated thin layers, pellets, balls, and clyinders. The most rapid drying occurred in the thin layers of pellets.

Since promising results were obtained with pellets in these early laboratory tests, it was thought advisable to continue our studies on a larger scale. Many experiments were made to determine the properties of pellets. It was found that the chief requirement for proper pelletization was that the peat should contain 79 to 82 per cent moisture. If the peat is more fibrous or given less maceration, satisfactory pelletization can be obtained with a moisture content of 82 to 86 per cent. However, if the peat is well decomposed or highly macerated, better pelletization would result with a moisture content of 78 to 80 per cent. (Spherical particles of peat larger than two inches in diameter are usually referred to as balls and those less than two inches in diameter as pellets.)

Early tests, made with cubic foot screen boxes proved that, even in the form of pellets, peat could not be dried rapidly in a one-foot thick layer. It was learned that to increase the drying rate, there should be more surface area in direct contact with free flowing air. In layers of less than two inches in depth, pellets fulfilled this important requirement. Factors affecting the drying rate of pellets are size, uniformity of size, area and depth of layers, and distance between layers. In full cubic foot screen boxes, it was found that pellets 2 inches in diameter dried more quickly than those less than one inch in diameter. This was believed due to better circulation of air among the larger pellets in such a larger mass.

Test 1—In this test made between August 9 and August 25, 1946, a sample of peat from the Balkan bog was macerated and then pelletized by rolling in an oil drum. Fifteen and five-tenths pounds of pellets, ranging in size from ½ to 1½ inches in diameter, were placed in a screen box, 9¾ inches by 11½ inches by 6 inches, and placed out of doors on a rack 4 feet above the surface of the ground. During the first three days of drying the weight had decreased to 10.19 pounds and the bed depth to 4.5 inches. On the tenth day the weight was 5.82 pounds and bed depth 3 inches. A drying time of 11 days was required to reduce the moisture content from 81.2 to 30 per cent. Eight of the 11 days were favorable for drying. Since the depth was 6 inches, the results were regarded as favorable.

Test 2—In this test made between August 20 and August 28, 1946, 13 pounds of pellets containing 85 per cent water were placed on 2.4 square feet of screen area to 5.4 pounds per square foot. After 6 days of favorable drying weather, the pellets weighed 2.45 pounds, and contained 27.5 per cent moisture.

Test 3—In Test 3, made between September 12 and September 26, 1946, pellets were dried in two boxes, one placed above the other. Twenty-five pounds of 86.15 per cent moisture pellets were placed into each of 2 screen boxes (10 inches by 10 inches by 10 inches). The bed depth was approximately 7.5 inches.

With excellent drying weather during the first 6 days, volume was reduced to 50 per cent and moisture content to 35.5 per cent in the top basket and 47 per cent in the bottom. Rain occurred after the sixth day; however, the top basket of peat absorbed most of the rain and protected the peat layer underneath. The peat in the bottom basket contained less moisture than that in the top throughout the remainder of the experiment. After 13 days the pellets of both samples had dried to approximately 30 per cent moisture, a condition regarded as favorable considering the thickness of the bed.

In evaluating the data, consideration was given to scale or side effect due to the small size of the sample. In cubic foot screen boxes, at least 50 per cent of the peat is favorably exposed to drying due to scale effect.

Test 4—In Test 4, made between April 29 and May 14, 1947, a sample of pellets weighing 44.1 pounds and containing 81 per cent moisture was placed into each of two 8-mesh screen boxes, 14.5 by 14.5 by 9.75 inches, and placed out-of-doors for drying. One sample was stirred and the other not, to determine the effect of stirring on the drying rate.

The drying rate curves show that on the 13th day, the pellets not stirred contained 27.45 per cent moisture and the pellets stirred contained 16.2 per cent moisture, or a difference of 11 per cent. To drop to the same moisture as the stirred pellets, the non-stirred pellets required a day longer. This test shows that a day was gained in drying time by stirring. However, consideration must be given to the cost of power required for stirring, since it is possible that such a cost might not compensate for the extra day gained.

This small test was only indicative; it did show, however, that peat pellets spread 9 inches deep did not dry quickly even when stirred and that stirring peat in screen tanks might not be economical. (As shown later, for quick drying, a bed less than 2 inches deep, is recommended).

Test 5—To stimulate drying in a large system, an interesting test was made in which 18 pounds of 79.9 per cent moisture peat pellets were placed in each of two boxes. One box had solid sides with a screen bottom, which would correspond to a center section taken from a large bed; the other box had both screen sides and bottom. After seven days of drying, the enclosed pellets contained 66.7 per cent moisture and the exposed pellets contained 48.3 per cent moisture, a difference of 18.4 per cent. From the seventh through the eleventh day, the pellets in both boxes were stirred after which the pellets contained 37 per cent and 14.8 per cent moisture, respectively; a difference of 22.2

per cent. Air circulated through the bed in both cases, but more scale effect resulted in the box with screen sides.

PEAT AS A BINDER

Peat has remarkable binding properties which may be utilized in agglomerating various materials for different purposes. Many materials in powder or granular form, which at present are industrial wastes, might be converted into useful briquetted products. To determine the drying properties of various mixtures, more experiments should be made in which peat is mixed with different substances such as iron ore concentrates, low-grade iron ore, powdered coal, dry peat powder, and sawdust. From such laboratory data, one may determine the possibility of developing an economical process using peat as a binder.

Peat-Iron Ore Mixtures—A test was made in which macerated raw peat was mixed with iron ore concentrates in various ratios. In each sample 100 grams of 84.2 per cent moisture peat was used. The amount of ore introduced ranged from 0 to 100 grams in 20 gram intervals. After thorough mixing, each sample was formed into pellets and dried indoors. Although the drying rates were not uniform, the trend was for the drying time to decrease with an increase in the percentage of ore used. After four full days of drying, the content of all of the samples had dropped to less than 50 per cent, the range being 24 to 47 per cent. After five days, the moisture contents were all less than 40 per cent. From then on, the drying proceeded very slowly. Pellets containing over 75 per cent dry ore resulted in a product with a weak physical structure and tendency to crumble. Some of the material was lost as dust. Those containing less than 55 per cent ore were firm and showed no crumbling. The following table gives the ratio of ore to dry peat substance, per cent of ore, and nature of the pellet formed.

TABLE 1
Results Of Iron Ore-Peat Mixture Pellets

Ratio Ore-Peat (Dry Basis)	% Ore	Structure of Pellet
6.35 :1	86.4	Poor
5 :1	83.5	Poor
3.8 :1	79.2	Weak
3 :1	75	Some crumbling
2.5 :1	71.5	Fair
1.25 :1	55.7	Good
.95 :1	48.7	Very Good
.316:1	24.1	Very Good

A second drying test, similar to that above, was made with the exception that the peat was pressed into cylinders. The amount of ore concentrates ranged from 0 to 60 grams per 100 grams of wet peat. These samples dried to less than 38 per cent after four days and less than 30 per cent moisture after five days of indoor drying. The variation in moisture contents of the different samples during drying was less than in the preceding test.

In the third test, a comparison was made in the drying rate of two peat cylinders; one consisted of 200 grams of 84.2 per cent moisture peat and the other 200 grams of wet peat plus 20 grams of -100 mesh iron ore concentrate. It was interesting to note that the weights of the peat alone in each sample were consistent throughout the drying period. In this test, the drying rate, apparently, was not affected by the presence of the iron ore.

In a fourth test, a mixture consisting of 1430 grams of 84.2 per cent moisture peat (containing 226 grams of dry peat), 100 grams iron ore concentrates, and 3 grams of lime was made into cylinders and then formed into pellets approximately 50 grams each. On a percentage basis, these proportions amount to 68.7 per cent dry peat, 30.4 per cent iron ore, and .9 per cent lime. A similar batch of material was compounded and poured into a drum. It showed excellent pelletizing properties and dried to a very hard, brittle product. The separate tests varied only slightly in their drying rates, being reduced to 19.3 per cent and 14.4 per cent moisture content respectively during four and one-half days of indoor drying.

This test was made to give, after carbonization, a mixture of iron, charcoal, silica, and lime. Peat ash is high in lime and additional lime was added for fluxing purposes. Plans were to reduce the ore to metal in a small laboratory electric furnace. The test was not completed.

Peat As A Reductant for Iron Ore—Preliminary experiments showed that peat is an excellent reducing agent for iron ore. Low grade ores mixed with 20 per cent peat and heated become amenable to magnetic concentration. Final results will be given in a later report.

Wet Peat, Peat Char, and Dry Peat Mixtures—Several experiments were made to determine the effect of coating peat pellets with ground peat char. Mixtures of wet peat and char or dry peat were made to determine drying rates. The object of these experiments was to produce pellets which would not be too sticky to handle and which would still dry to a hard, dense product.

Test 1—Wet peat containing 85 per cent moisture was formed into twelve 125 gram pellets; these were rolled in 15 grams of ground peat char to produce a non-sticky coating. Four of the pellets were placed outdoors under a shelter to dry; a second group of four was allowed to dry indoors; and a third group was first partially roasted in a pan and then set under the outdoor shelter to dry. The partial roasting reduced the moisture content from 85 to 81.4 per cent and slightly hardened the surfaces of the pellets making them easier to handle in the wet stage. After eight days of outdoor drying, the roasted and unroasted pellets contained 34.6 per cent and 35.3 per cent respectively. Even with the lower starting moisture, the roasted pellets did not dry to a correspondingly lower final moisture content.

Test 2—In another experiment, the wet peat was mixed with the ground peat char and then formed into pellets. One group of four 130 gram pellets was made from 500 grams of wet peat to which had been added 20 grams of ground char. A second group of four pellets was made from 500 grams of wet peat plus 5 grams of char. In the first group, the ratio of dry peat to ground char was 3.5 to 1 and in the second group, 15 to 1. The pellets containing the greater proportion of char had a slightly faster drying rate than the pellets coated with char in previous tests. During the first eight days, the moisture content, based on the amount of wet peat, was reduced to 32.5 per cent and during the five additional days to 15.7 per cent. The pellets containing only 5 grams of char were reduced to only 40.3 per cent moisture during 8 days. The pellets containing the greater proportion of peat char dried slightly faster than those containing less char.

Test 3—Partially dried peat was mixed with wet raw peat in different proportions to determine the possibility of decreasing the drying time. The 60 per cent moisture peat was macerated in rolls and passed through ½-inch mesh screen. Wet peat containing 86.6 per cent moisture was mixed with partially dried peat containing 60 per cent moisture, in the following ratios: 2 to 1, 3 to 1, 4 to 1, and a blank consisting of only the wet peat. During 64 hours of drying, the greatest water ratio loss occurred in the 86.6 per cent moisture peat, or blank sample; however, the final moisture content was 74.5 per cent. The greatest loss in the peat mixtures occurred in the 2 to 1 wet to dry ratio. This material was reduced from 77.8 per cent to 36.4 per cent moisture content. Although the drying appeared favorable, in actual practice, the amount of material which would have to be recycled would be 33 per cent.

In general, the addition of most powdered aggregates to raw peat results in a dried product of less strength than that to which no aggregate has been added. However, if the raw peat is well decomposed and very wet when the drier components are added, the binding properties are improved. The addition of sawdust produced a very light-weight product; although less desirable than coal, due to its low bulk density, the mixture in the form of pellets, is a better domestic fuel than ordinary sawdust. The addition of coal dust to peat increases both the density and the fuel value of the dried product.

EFFECT OF FREEZING ON THE PROPERTIES OF PEAT

During the winters of 1947 and 1948, about 30 experiments were performed by this office on the freezing of peat. Interesting changes occur in the physical properties of wet peat that has been subjected to freezing. The effect of freezing varies greatly with different types of peat. Some observations and general trends obtained from the results of the experiments will be discussed.

The most important factor in determining the freezing effects on peat is the degree of decomposition of the peat. Little or no changes occur in green peat moss and slightly decomposed peat; slightly greater changes are noticeable in very highly decomposed peat; and the greatest changes occur in the range of moderate degrees of decomposition.

Wet peat expands during freezing because of the large amount of water it contains. During this expansion of the water while freezing, it is believed that the cell structure of the peat bursts, thus releasing some of the water. If this is true, the water might be partially released; however, due to capillary action of the broken cells, much of the water is still retained in the peat and cannot be completely removed even with mechanical pressure.

If the peat dries while in the frozen state, it retains its open structure as expanded by the water during freezing. It is very light and fluffy, and loses its plastic and sticky properties. Frozen peat shrinks to its original volume during thawing.

Freezing appears to have a coagulating effect on wet peat. According to Professor V. G. Goriachkin[1], the highly dispersed particles of peat combine to form coarse particles as in coagulation. The per cent of coagulation increases as the freezing time increases. Professor Goriachkin gives the following tables on the effect of freezing peat:

TABLE 2
"Effect Of Freezing Peat On Its Coagulation"

Length of Freezing Time In Hours	0	5	12	18	48	72	96
Quantity of Non-Coagulated Peat in % of Total Quantity	100	31	14	11	11	9	9

TABLE 3
"The Change in Physical Properties of Surface Peat of 25% Degree of Decomposition Produced by the Effect of Freezing"

	Non Macerated Peat		Macerated Peat	
	Non Frozen	Frozen	Non Frozen	Frozen
Shrinkage in %	55	40	74	61
Volumetric weight	0.44	0.34	0.76	0.53
Moisture capacity in %	279	303	129	214
Mechanical stability in kg–cm²	....	....	38	6

[1]Proisvodstovo Torfyanoho Topliva (Production of Peat Fuel), by Prof. V. G. Goriachkin, 1940, Part I, pp. 59-60. (Russian Peat Institute Library.)

Results in the above tables show that frozen peat shrinks less than non-frozen peat during drying and consequently has a lower density. Frozen peat, because of its porosity after drying, has a higher water absorption capacity than non-frozen peat. An interesting property of frozen peat after drying is its poor strength; it is very easily powdered.

During November, 1948, a pile amounting to 7 tons of wet pellets was built up by spreading a four inch thick layer of pellets on the bog, allowing it to freeze one day, and then spreading another layer over the one previously frozen. Another pile of approximately 18 tons of 3 by 3 by 4 inch blocks of macerated peat was built up by spreading a 16 by 16 foot single layer base, allowing it to freeze and then spreading another layer. The pile was built up in this manner in two foot steps so that one end of the pile was two feet deep and the other end 8 feet deep. Since the tests are still in progress, data is not complete, and, therefore, results will be given in a later report.

SUN RADIATION-REFLECTOR TEST

In studying the drying rate of wet peat, is was necessary to determine the effect of direct sunlight. It was suggested that a reflector might be used to concentrate the sun's radiation and, by this means, raise the temperature of a wet peat bed to increase the drying rate[1]. In the experiments performed, comparisons were made by observing the temperature rise, temperature differences, and moisture loss of peat pellets, solid bed of wet peat, and powdered oven-dry peat. The solar radiation was not determined as heat units of energy absorbed and lost.

Two stands or tables, each 3 feet high, were used in the tests; one with a vertical corrugated aluminum reflector extending 3 feet above the table and facing south, the other openly exposed. For comparative purposes, two sets of peat samples were used in each test, one set being placed in front of the reflector and the other on the open table.

In Test I, 90 per cent moisture peat was prepared by adding 6 pounds of water to 10 pounds of 84 per cent moisture stockpile peat. Six pounds of this material was placed into a pan (9 by 13 by 2 inches) forming a bed 9 by 13 by 1.3 inches. A layer of oven-dry peat was placed in another pan. A thermometer was inserted just beneath the surface and in the center of each peat bed. One group of pans was set on the table one foot in front of the reflector; a duplicate group was set on the open table.

Data from the results of Test I showed that the peat beds in front of the reflector increased in temperature rapidly at 10:00 a. m. and decreased in temperature rapidly at 2:00 p. m. The approximate effective time of the reflector was found to be 4 to 6 hours. The difference of the averages of the wet bed

[1]Odin A. Sundness.

temperatures from 9:45 a. m. to 3:30 p. m. on the first day was 5.7 degrees. This increase in temperature should result in an increase in evaporation by the reflector pan of 31.7 per cent over the openly exposed pan. During the above time, the open air pan lost 1 pound-1 ounce of water, while the reflector pan lost 1 pound-2 ounces of water. On the second day, the difference of the temperature averages of the reflector wet peat bed and the open air wet peat bed was 5.4 degrees. Average weather conditions during the test were approximately as follows: air temperature, 76.5 degrees; wind velocity, 551 feet per minute from a S. E. direction; humidity, 64 per cent; sky, clear the first day and partly cloudy the second.

Test II consisted of a solid wet peat bed and pellets both containing 84 per cent moisture, and oven dry peat powder. One pan (6 pounds net) each of 1 inch pellets, solid wet peat, and powdered dry peat was set one foot in front of a corrugated aluminum reflector facing south. For comparison, the above group was duplicated simultaneously on a stand without a reflector.

The difference in temperature between the wet pellets in front of the reflector and those in the open was greater than the difference between the solid wet peat beds in the corresponding positions. The greater loss of water from pellets is probably due to the greater surface area and better circulation of the air through the peat pellet bed. Since the starting moisture of the wet peat was approximately 84 per cent, six pounds of it would contain .96 pounds of oven-dry peat. From the final weights, the calculated final moisture contents were:

	Wet Pellets	Solid Wet Bed
Reflector	79.0%	81.3%
Open	79.8%	81.6%

Average weather conditions during this test were: air temperature, dry bulb-76.1 degrees, wet bulb-62.9 degrees; humidity, 48 per cent; wind velocity, 838 feet per minute from a westerly direction; sky, partly cloudy. These are excellent drying conditions.

From this data, it appears that a reflector does not increase the drying rate greatly.

Test III was made to determine the effective range of a reflector. Pans containing six pounds of 90 per cent moisture peat were placed at one, two, and three foot distances from the reflector. Pans of oven dry peat were placed beside the wet ones at the same distances. One wet and one dry peat pan were placed on the open table. Thermometers were placed just beneath the surface of the peat beds as in the previous tests.

During this test, a partly cloudy sky and great variations in the wind resulted in non-uniform changes in temperature.

The average temperature differences, during the 6 hour mid-day period, between the wet peat beds exposed to the reflector and those openly exposed are as follows:

Distance	Temp. Difference	Theoretical Increase in Drying
1 ft. mark	5.7°	31.7
2 ft. mark	4.8°	26.7
3 ft. mark	3.8°	21.1

Average weather conditions during this test were: air temperature, dry bulb-77.3°, wet bulb-63°; humidity, 44 per cent; wind velocity, 237 feet per minute; sky, partly cloudy.

A. F. Meyer[1] states that:

"Water temperature is the most significant single factor in determining evaporation loss. For every 18 degrees F. increase in temperature, the elastic pressure of water vapor practically doubles. Evaporation varies with temperature at substantially the same rate."

In all the tests performed, the maximum average increase in temperature produced by the effect of a reflector on a wet peat bed was 13.3 degrees. This was one foot from the reflector where conditions are most favorable. In Tests I, II, and III, the maximum average increases in temperature were less than the above figure.

The effective range and time of the reflector are small. The appreciable increase in temperature is within 1 foot of the reflector which is only one third of its effective range. The maximum increase in drying which can be produced by the effect of a flat vertical reflector and with 100 per cent efficiency is a doubling of the drying rate. This is because a flat reflector serves the purpose of concentrating the sun's radiation from two unit horizontal areas to one. This would amount to a maximum decrease in drying area of 50 per cent. The effective time of a reflector is roughly six hours. The early morning and later afternoon sun is lower and rays are parallel to the reflector, which results in greatly diffused or no radiation. After 4:00 p. m., the reflector shades the peat layer and, therefore, detracts from the amount of radiation the peat could receive.

From the experiments, it is estimated that the efficiency of a reflector system in increasing the drying rate of peat would be much less than 50 per cent. From the resulting data, it appears that the average increase in temperature over the whole bed would not exceed 7 degrees. Theoretically, this should amount to a 39 per cent increase in evaporation. From the weights of water lost from the 90 per cent moisture peat in Test I, it is calculated that the reflector increased the evaporation 8.6 per

[1]Evaporation From Lakes and Reservoirs, by A. F. Meyer, 1942, published by Minnesota Resources Commission, St. Paul, Minnesota.

cent over the open air drying. In Test II, the reflector increased evaporation of water from the solid wet bed of 84 per cent moisture peat by 7.7 per cent, and from the pellets of the same moisture content by 15 per cent. The above information is the result of tests performed during excellent weather conditions; therefore, it may be assumed that with average weather conditions, the percentages given above would be lower.

It appears unlikely that such a small increase in the drying rate by the use of reflectors would economically reduce the cost of producing large quantities of dry peat.

PEAT AIR DRYING EXPERIMENTS

EXPERIMENT AT BALKAN BOG—1947

Hydro Peat—Screen Tank Test—In small experiments, made previous to July, 1947, the size of the samples ranged between 30 and 127 pounds of 95 per cent moisture peat, equivalent to only 1.5 pounds to 6.3 pounds of dry peat substance. It was thought advisable, before building a small pilot plant, to make a larger drying experiment using an 8000-pound sample of 95 per cent moisture peat slurry, having a volume of 128 cu. ft.

The purpose of the larger experiment was to determine the length of time required to dry hydro peat in a screen tank (1/8 inch openings) using periodic stirring as a possible aid to drying.

The experiment was made between July 25th and August 28th, 1947, at a small bog on State property located about 1 mile north of Chisholm and about 1/2 mile east of the Balkan Garage. (SE1/4 of the SW1/4 of Sec. 9, T58N-B20W). The peat was of fair quality (Grade 5-7) and was taken near the shore of the bog where the depth was 9 feet and the moisture content approximately 85 per cent. It was probably due to this low moisture and fibrous condition that necessitated the use of an excessive amount of water during cutting.

The procedure followed was to cut the peat with a stream of water, pass the resulting slurry through a screen strainer and then pump the peat slurry into the screen tank in which draining and drying took place, aided by periodic stirring.

Previous to making the actual test, the surface at the place of excavation was removed to a depth of approximately 6 inches. A sump was dug by the side of a ditch near the working area to furnish water for cutting. A second hole was dug to the bottom of the bog to give a working face for cutting and a sump for storage of the peat slurry. A screen strainer, with 1 inch openings was placed in the hole between the slurry reservoir and the cutting face to separate out the roots during the pumping of the slurry.

Two Gorman-Rupp pumps were used, one a model 5303, 15 to 20 h.p., with 3 inch intake and 3 inch discharge, and a double inlet enclosed impeller; the second, model W 13X, with a 3 inch inlet and 3 inch discharge, and a three-vane semi-open impeller. (The fire hose and nozzles were loaned to us by the Fire Department, and the suction hose by Warren S. Moore). The screen tank, 4 by 4 by 8 feet made by the Davis Engineering Company was supported on a wooden framework about 4½ feet above the surface of the bog at a distance of about 30 feet from the cutting face.

The test showed that 8000 pounds of 97.3 per cent moisture peat slurry, pumped into a screen tank 4 by 4 by 8 feet, drained to a moisture content of 88 per cent in 4 days and dried during stirring to a moisture content of 31 per cent in 34 days. The peat showed certain physical properties at various moisture contents. It settled after 24 hours to form a pulp containing 93.3 per cent moisture; it was necessary to draw off the clear water from the surface by unplugging the screen above the settled peat. The peat became highly macerated during the pumping operation, which made it more colloidal and resulted in slower draining. As the peat lost water, it underwent definite changes in properties. At 93 per cent water, it stirred easily. At 90 per cent water, the peat started to take the form of the shovel but there was still evidence of draining; the depth of the slurry had decreased from the original depth of four feet to one foot. At 86 per cent water, the peat stuck to the shovel during stirring; at 82 per cent moisture, the peat stirred easily and showed a tendency to form pellets; at 73 per cent moisture, on the 23rd day, the peat began to pass through the screen during stirring.

During August 1947, (at the Balkan bog) the weather conditions during the test were equal to or better than normal. The weather data given here is based on readings taken at 8:00 a. m., noon, and 4.00 p. m. The average mean temperature was 73.3° F; average per cent relative humidity, 73.6 per cent; average wind velocity, 509 feet per minute; prevailing wind direction, South; total precipitation, 4.4 inches; and the number of clear days, 13; partly cloudy, 11; cloudy, 6.

Seventy-one per cent of the peat was lost through the screen during stirring while drying. Had the peat that passed through the screen been returned to the tank, the drying time would probably have exceeded 34 days. The screen sides of the tank extending three feet above the peat bed, interferred considerably with the free flow of wind over the peat surface. As a typical example, a wind velocity taken outside the tank was 1188 feet per minute, while inside the tank it was 516 feet per minute on the peat surface.

The peat used in the earlier experiments came from the top four feet of the bog where the peat was more fibrous and each winter often froze to a depth of one to two feet. This type of peat drained, without maceration, to 89 per cent water content in four hours.

The unfavorable results obtained in the larger experiment can be partly attributed to a difference in the type of peat originally used and the effect of maceration during the pumping operation.

Summary—

1. Pumping macerates the peat and reduces the rate of draining; 4 days were required for the peat to drain to 88 per cent moisture.

2. Stirring resulted in a loss of 71 per cent of the peat through the screen and did not reduce the drying time as much as was expected.

3. The time required for the peat to dry to a moisture content of 31 per cent was 34 days.

4. To obtain one ton of air-dried peat would require a spreading or harvesting area of 64 square feet per season (Based on three harvestings).

If $6.00 is used as the value for 1 ton of dry peat substance, 1 ton of 97.3 per cent moisture peat is worth less than 17 cents. It is doubtful if a material of such low value can be processed economically by the above method.

Early Pellet Drying Tests—From results of general experiments, it was learned that peat dried more rapidly in pellet or ball form, and in thin layers rather than in block form or thick layers. Larger tests were recommended and carried out during the month of October 1947.

During the period October 3 through October 6, four tests were made on a single screen shelf one foot above the ground level and exposed to the sun. The results from these tests showed that a cubic foot of 81 per cent moisture unclassified pellets, spread on 12 square feet of screen (3.33 pounds per square foot, 1 inch layer) dried to 20 per cent moisture in 2 days during good weather. Macerating the peat before pelletizing resulted in faster drying and a more dense product.

During the period October 8 through October 12, four more tests were made to study the drying of layers of peat pellets on shelves spaced four inches apart vertically. Four shelves, each 48 square feet in area, were loaded with 3.33 pounds per square foot of 80.6 per cent moisture pellets. These pellets froze the first night after spreading. After drying during 1½ clear days and three cloudy days with ½ inch rainfall, the top shelf recovery was 42.2 pounds of 30.1 per cent moisture pellets. The average recovery from each of the three lower shelves was 43 pounds of 35.6 per cent moisture pellets. These tests showed that pellet layers could dry rapidly even on shelves not exposed to the sun. An identical set of runs was made during the same period of time except with one foot instead of four inches spacing between the shelves. The average moisture was 10.4 per cent lower than that obtained with the four inch spacings.

A slightly larger run was made during the period October 13 through October 17, in which three shelves each 8 by 12 feet in area were set up four inches apart, the lower shelf being one foot above the ground. The shelves were loaded with 3⅓ pounds per square foot of 80.6 per cent moisture pellets. The average moisture content of pellets on the two lower shelves after three days of drying was 38.4 per cent and after 4 days, 18.1 per cent. Those on the top shelf were reduced to 27 per cent moisture content in 3 days and 14 per cent in 4 days. The average mid-day weather readings during this period were as follows: temperature, 73° F; humidity, 48 per cent; wind velocity, 760 feet per minute; sunshine, 80 per cent. Since this run produced good drying results, larger tests were proposed.

The next run, made from October 20 through October 23, on a narrower section, consisted of six shelves (each 4 by 6 feet), vertically spaced 4 inches apart, the bottom shelf being 1 foot above the ground. Pellets containing 80.5 per cent moisture were spread 6.67 pounds per square foot of screen. The pellets on the top shelf were reduced in moisture content to 52.6 per cent in two days and to 46.1 per cent in three days. The moisture of those on the bottom five shelves was reduced to 63.9 per cent in two days and to 63.5 per cent in three days. The third day was cloudy, temperature low, and humidity high, which accounts for the small drop in moisture of the lower shelf pellets. Because rain and colder weather set in, tests were discontinued.

The results obtained from these preliminary tests indicated that peat pellets could be dried on screen shelves in about 2 to 4 days when spread 3⅓ pounds per square foot. Since these tests were made late in the season, it seemed that during mid-summer, a faster drying rate would be obtained. Further tests were proposed to determine the optimum pellet layer thickness which would dry in the minimum time on a multi-shelf unit. In order to completely understand the drying characteristics of pellets on a screen shelf system, only larger scale tests would reveal their behavior in simulated large scale production.

EXPERIMENTS AT BALKAN BOG—1948

Pellet Drying on Screen Shelves, 1948—

Treatment of Raw Peat—In the production of peat pellets, moisture content of the peat at various stages in the method is very important. The purpose of moisture control is to use peat which will form easily into pellets without sticking together or to the machinery.

In preparation for the pellet drying tests of 1948, peat was excavated and dumped into stockpiles as explained earlier in the report. The purpose of the stockpiles was to allow the peat to drain and dry to a moisture content suitable for pelletizing. Samples of a stockpile taken three months after excavation showed a range in moisture of 82 to 85 per cent with an average of 84 per cent; the original moisture content was 89 per cent. Since the desired moisture content of the peat for pelletizing is 78 to 82 per cent, the moisture content of the peat in the stockpile had to be reduced further. This was satisfactorily accomplished by mixing the dryer surface of the pile with enough of the wetter inner material to produce a product which, after thorough mixing in a macerator, averaged between 80 and 82 per cent moisture. By the time the first layer was completely removed from the long stockpile, a second layer had dried to the desired moisture content and was ready for removal. Moisture was also lost during the pelletizing of peat. Averages of a group of samples showed a moisture content of 81.6 per cent immediately after maceration and 79.4 per cent at the time of spreading, the difference being 2.2 per cent. Based on the original water content, this amounts to a water loss of 13.1 per cent. Average weather conditions during the sampling periods were: air temperature, 76° F; relative humidity, 55 per cent; wind velocity, 775 feet per minute; sky, clear.

Mid-summer Tests — Tests on pellet drying in the early summer of 1948, were made primarily to study the various factors involved in the production of air dried peat pellets, and were a continuation of the fall tests of 1947. As a result of the early tests, a weight of 6⅔ pounds per square foot was chosen as the amount to be spread in one group of larger tests. The following table summarizes the results of 31 runs; each test consisted of two cubic feet or approximately 80 pounds of 1¾ + 1 inch pellets spread on a 3 by 4 foot area on the screen shelves of Section II. The average moisture percentages given are the results obtained from actual sampling data.

TABLE 4
Pellet Drying on Screen Shelves (6⅔ lbs. sq. ft.)

Shelf	No. of Tests	Wt. Spread 7/8-8/10/48	Wt. Harvested 7/10-8/19/48	Ave. Moisture %		Cycle Ave.	
				On	Off	Hrs.	Days
3	16	1280 lb.	428.3 lb.	80.4	42.4	159	6.6
4	29	2320	685.1	80.4	36.5	145	6.0
5	30	2400	707.9	80.4	35.8	142	5.9
6	41	3280	974.4	80.4	34.8	100	4.2
Total	116	9280	2795.7	80.4	36.5	130	5.4

In another group, 15 runs were made in which the individual tests consisted of 1½ cubic feet or approximately 60 pounds of 1¾ + 1 inch pellets spread on a 3 by 4 foot area which amounts to about 5 pounds per square foot; since the pellets were measured by volume, the figures given as weight spread, are only approximate. These tests were made on both north and south sides of Section I. The following table gives the amounts and average moisture contents of the spread and harvested pellets, and the average time required for drying on the different shelves.

TABLE 5
Pellet Drying on Screen Shelves (5 lbs. sq. ft.)

Shelf	No. of Tests	Wt. Spread 8/11-8/28/48	Wt. Harvested 8/16-9/2/48	Ave. Moisture %		Cycle Ave.	
				On	Off	Hrs.	Days
2	40	2400 lb.	677 lb.	80.1	38.9	130	5.4
3	44	2640	705	80.1	34.9	125	5.2
4	42	2520	572	80.1	22.8	125	5.2
5	2	120	32	80.1	25.4	144	6.0
6	7	420	116	80.1	32.6	84	3.5
Total	135	8100	2092	80.1	32.1	125	5.2

Evaluation — In the series of tests spread 6⅔ pounds a square foot, peat was dried from 80 to 36 per cent in about 5½ days; in the second series spread 5 pounds a square foot, the peat dried from 80 to 32 per cent moisture content in about 5 days.

Since the second group of tests was spread later in the season, the weather conditions were not as good as during the earlier tests. This may explain why there was little difference in the drying time and the final moisture contents even though the amount spread was less in the second group. It is believed that the bed thickness should be varied throughout the season to obtain the greatest benefit of weather conditions.

One Month Continuous Test Period—Late in the summer of 1948, sufficient quantities of pellets were produced to allow continuous tests to be made on a full drying section. The knowledge gained from all of the preliminary tests was applied in planning the larger tests.

During a one month test period in September and October, 36 runs were made on Section II of the drying unit. Six complete cycles of spreading, drying, and harvesting were made on each of the six shelves of the section. The pellets were all weighed and sampled before spreading and after harvesting. The manual spreading of the pellets onto the shelves was facilitated by the use of metal trays. Various methods of harvesting and sampling were employed so that a number of different comparisons could be made between the shelves.

Accurate weather data was kept throughout the test period. The spreading period took place between September 9 and October 7 and the harvesting between September 13th and October 13.

In the first 25 runs two sizes (— 2 + 1 inch and — 1 + ½ inch) of pellets were spread, and in the remaining 11, only the smaller size was spread.

Pellets were spread 5 pounds per square foot on shelves 2, 3, 4, and 5; however, on shelves 1 and 6, the amount spread per square foot was varied. It was found that a thicker bed of pellets could be spread on shelf 6 (top shelf) and dried in the same time as lower shelves. In four of the six runs on the top shelf, pellets were spread 7½ pounds per square foot, which is 50 per cent more than the amount spread on lower shelves. In one of the six runs on shelf 1 (bottom shelf), pellets were spread 2½ pounds per square foot which was only half the normal amount.

Table 6 is a summary of the results obtained in the 36 runs.

TABLE 6
Pellet Drying On Screen Shelves

Shelf	No. of Runs	Wt. Spread 9/9-10/7/48	Wt. Harvested 9/13-10/13/48	Ave. Moisture %		Cycle Ave.	
				On	Off	Hrs.	Days
1	6	7040 lb.	2646 lb.	78.6	44.1	117	4.9
2	6	7680	2556	79.2	41.7	118	4.9
3	6	7680	2213	79.8	35.0	112	4.7
4	6	7680	2147	78.4	30.7	111	4.6
5	6	7680	2225	78.5	30.6	108	4.5
6	6	10000	2546	79.0	24.5	108	4.5
Total	36	47,760	14,333	79.0	34.7[1]	112	4.7

During the one month test period, the time required to dry a spreading of pellets from 79 to 34.7 per cent moisture content averaged 4.7 days and ranged from 3 to 6 days. Factors which are important in the drying of pellets on screen shelves are: effect of pellet size, effect of elevation above the bog, effect of wind, effect of north and south sides of shelves, and scale effect in a small system. An evaluation of these factors follows.

Effect of Pellet Size—To determine the effect of pellet size on the drying rate of peat pellets, ten of the 36 runs made during the one month test period were selected for comparative purposes. Each of the runs analyzed consisted of equal areas of large and small pellets (— 2 + 1 inches and — 1 + ½ inches). In five of the runs, the large pellets were spread on the east half of each shelf and the small ones on the west half. The remaining five shelves were selected from those in which the pellet sizes were spread in the opposite order to neutralize the possible directional effect due to winds. After drying the same length of time, the small pellets, in most cases, contained a lower

[1]This figure is the average moisture of samples; the calculated moisture is 30 per cent.

percentage of moisture than the large pellets. The small pellets dried to an average moisture content of 33.5 per cent compared to 42.9 per cent for the large. The actual resulting moisture contents of the individual runs are listed in Table 7.

TABLE 7
Moisture Content of Small and Large Pellets in 10 Runs
(Drying Time, 5 Days)

Run No.	Shelf No.	Large Pellets		Small Pellets	
		Moisture	Shelf Pos.	Moisture	Shelf Pos.
2	5	35.7	East half	22.9	West half
3	4	39.6	"	28.8	"
4	3	38.7	"	32.8	"
5	2	48.3	"	50.2	"
6	1	40.6	"	29.2	"
11	2	51.0	West half	39.2	East half
12	1	56.2	"	46.4	"
13	6	27.3	"	16.6	"
14	5	43.2	"	26.2	"
16	3	48.4	"	42.8	"
Average	....	42.9	....	33.5	....

Effect of Sunlight and Wind—Since the south side of the shelves receive a greater amount of direct radiation from the sun than the north side, one would expect peat pellets to dry more rapidly on the south side. During the time of the sun's greatest effect, about 10 to 20 per cent of the south side of the shelves is exposed to direct sunlight; this would not apply to the top shelf, since it is totally exposed to the sun.

Nine runs made during the period, 9/19/48 to 10/2/48, were selected to compare the drying rates between the north and south sides of the shelves. The average moisture content of the large pellets harvested from the south side of the shelves was 36.7 per cent and from the north side, 49.5 per cent, the difference being 12.8 per cent in favor of the south side. In the same runs, the average moisture content of the small pellets was 31.6 per cent on the south side and 43.6 per cent on the north side, a difference of 12.0 per cent in favor of the south side. Table 8 shows the moisture contents of the pellets in the individual runs.

TABLE 8
Drying Rate On North and South Side Of Shelves

Run No.	Shelf No.	PELLET SIZE				Drying Time Days
		(—2+1		(—1+½)		
		S.	N.	S.	N.	
15	4	29.6	38.8	16.4	36.6	5.0
16	3	46.1	57.4	35.2	46.8	5.0
17	2	....	....	31.0	50.9	5.0
18	1	29.0	57.2	....	....	5.4
20	5	35.7	49.2	21.4	27.6	4.8
21	4	20.8	31.1	22.9	41.5	5.0
22	3	33.0	46.0	34.0	52.0	5.0
23	2	48.0	58.8	31.6	30.0	4.4
24	1	51.5	57.8	60.6	63.4	5.0
Average	....	36.7	49.5	31.6	43.6	5.0
Difference	....	12.8		12.0		....

Weather data taken during these runs showed clear skies during the entire period with eleven days of prevailing wind from the south and two days from the northwest. Since wind is an important factor affecting drying, and since it was almost totally from the south during the listed runs, one might conclude that the differences between the north and south sides are not entirely due to sunshine.

During nine runs following those analyzed above, the wind direction was evenly divided between the north and south. Half of the number of days were cloudy and half clear. In these runs, only the small size was spread. The average moisture content of the pellets harvested from the south side was 28.2 per cent and from the north side, 30.3 per cent, a difference of 2.1 per cent in favor of the south side.

To determine the drying differences during cloudy weather, four runs, completely of small pellets, were selected in which the drying was done entirely during cloudy weather. The results, given in Table 9, showed a negligible difference of 0.8 per cent in favor of the south side. During these runs which took place between October 4 and October 12, 1948, the wind occurred from all directions.

TABLE 9
Drying Rate During Cloudy Weather

Run No.	Shelf No.	% Moisture		Wind	Sky
		South	North		
32	5	16.6	17.3	S-SE	3 days cloudy
33	4	22.4	21.9	S-SE—W-NW	4 days cloudy
34	3	31.7	34.0	S-SE—N-NW	Cloudy
35	2	49.8	48.6	N	Cloudy
Average	....	30.1	30.9	....	....

Results of these tests show that when the sky is clear, pellets on the south side of the shelves dry to a lower final moisture content during the same time than those on the north side. It was possible to dry 50 per cent more peat on the top shelf than on the lower shelves; this was due mainly to the exposure of the whole shelf to direct sunlight and to the freer flow of air over the pellets. During cloudy weather, with the wind varying from all directions, no difference in the drying rate was found between the north and south sides of the shelves.

Erkki Suksi[1] made extensive tests at Kihnio, Finland, to determine the effect of sun radiation on the evaporation of water from peat containing 89 per cent moisture. His studies showed that evaporation of water from peat, caused by direct sun radiation is about 62 per cent. This figure closely corresponds to the figure obtained in our studies on the amount of peat dried on the top shelf compared with lower shaded shelves.

[1]Erkki Suksi, "State Peat Industry Committee's Fuel Peat Tests," Test No. 2/1947, p. 15.

Winds have the greatest effect on the rate of drying of pellets on screen shelves. The results of these tests indicated that prevailing winds from the west and southwest had a greater effect on drying than winds from the east. This was probably due to the high average velocity and lower relative humidity of westerly winds, since these factors determine the ability of the air to take up water. Wind direction usually changes several times during a drying cycle and, therefore, a directional effect on the drying of pellets on shelves is not great.

Effect of Elevation Above the Bog—A study of the effect of elevation above the bog on the drying rate of pellets may be made from the results of runs listed in Table 7. The numbers of the shelves correspond to their respective height in feet above the bog surface; shelf No. 1 being one foot and shelf No. 6, six feet above the bog. The difference in drying rates on the shelves is attributed chiefly to different wind velocity and relative humidity of the air at the various heights. Upon rising from a point two feet above the bog, the wind velocity gradually increases and the relative humidity of the air gradually decreases. Receding from the two foot mark and approaching the bog surface, the wind velocity diminishes and the relative humidity of the air decreases. One may observe from the drying results of pellets on shelves 1 and 2, which are less than two feet above the bog surface, that the drying time was greater and the harvested moisture content much higher than that of pellets on the upper shelves.

From the results of these studies, it seems probable that more favorable drying rates would be obtained on a higher drying system with a greater number of shelves. The disadvantage of such a system would perhaps be the difficulty in loading and harvesting at greater heights.

Scale Effect in a Small System—Another factor which affects the rate of drying on a screen shelf system is the size of the shelves. If pellets on the central part of a shelf dry slower than those on the ends, the difference in drying would be more pronounced in a larger system. In several runs, special sampling methods were employed to obtain the moisture content of the pellets at different positions on the shelves. Each shelf was divided into eight sampling areas each 4 by 8 feet. It was found that in drying tests made during a period when the wind was entirely from a southern direction, the difference in final moisture content of pellets between the north and south sides was about 10 per cent or less. The difference in final moisture contents of pellets on the center and those on the ends was about 5 to 15 per cent. The central positions showed higher moisture contents in each run tested; however, in all cases, the extent of difference depended on the wind velocity and direction of the wind. End effect was more pronounced during periods when wind velocity was low and relative humidity high.

Rate of Drying—In a drying system such as the screen shelf method, the total seasonal production is dependent on the drying rate. The purpose of pelletization is to increase the drying rate by increasing the drying surface. Since drying conditions are chiefly dependent on relative humidity of the air and wind velocity, it was believed that peat could be dried on screen shelves, thus increasing the drying area without increasing the bog area. Since the weather conditions during the test period were better than normal, it is estimated that the average drying cycle during an entire season would be between 5 and 6 days, instead of the figure 4.7 days obtained in the tests.

Section II of the drying unit had six shelves, each 8 by 32 feet. The total shelf area, 1536 square feet, when loaded 5 pounds per square foot, would hold a total of 7,680 pounds of 80 per cent moisture peat pellets. The quantity of 30 per cent moisture pellets harvested from this section in one cycle would be 2,194 pounds. Using six days as the average drying cycle, the amount harvested daily would be 366 pounds. Assuming a 180 day season or 30 cycles, the annual production from one section would be 65,820 pounds or 32.9 tons. The amount of screen surface required per ton of product per season would be 46.7 square feet.

Summary—Previous to the continuous tests, doubts existed concerning the various factors affecting the drying of peat pellets on screen shelves. The larger scale tests were performed with the intention of studying these factors and determining their effects on drying. From observations during the tests and from an analysis of data obtained from the tests, several outstanding trends were noticed from which the following conclusions were derived.

1. Moisture control is important throughout the peat pellet processing method. Little difficulty was encountered in maintaining the proper moisture content of the peat in the various stages of the method. Bog peat containing 87 to 92 per cent water was excavated and dumped into a stockpile where it drained and dried to a moisture content of 82 to 85 per cent. The peat taken selectively from the stockpile was macerated at 79 to 82 per cent moisture content, and then pelletized. During pelletization, the moisture content of the peat was reduced to a range of 77 to 80 per cent. The pellets were then spread 5 to 7½ pounds per square foot on screen shelves and dried to a moisture content of 25 to 45 per cent during a period of 3 to 6 days.

2. Pellet size control is recommended in the drying of peat pellets. In the larger scale tests, two sizes of pellets (— 2 + 1 inch and — 1 + ½ inch) were spread five pounds per square foot of screen. In almost all cases, the small pellets dried to a final moisture content of approximately 10 per cent less than the large pellets during the same period of time and with the same weather conditions.

3. Direct sun radiation has a decided effect on the drying rate of peat pellets on screen shelves. Excluding the top shelf, the pellets on the south side of the lower shelves dried to an average moisture content of approximately 10 per cent less than those on the north side. This may be attributed to the exposure of 10 to 20 per cent of the southside of the shelves to direct sunlight. Since the top shelf was totally exposed to direct sunlight, it was found that 50 per cent more pellets could be dried to the same moisture content during the same period of time than on the lower shelves.

4. Wind is the greatest single factor contributing directly to the drying of pellets on shelves. Wind with a high velocity and low relative humidity produces the most favorable drying results. A high wind results in more uniform drying, whereas a low wind from one direction results in uneven drying of the pellets on the shelves.

5. The effect of elevation above the bog on the drying rate of pellets is attributed chiefly to the increase in wind velocity and decrease in relative humidity upon rising from the bog surface. A higher drying system might decrease the average drying time of pellets but greater difficulties would be encountered in loading and unloading such a system.

6. Scale effect was noticeable in the screen shelf system when the wind velocity was low; this would correspond to a higher wind velocity in a wider and longer system. By the time the wind traverses a wide system, it decreases in velocity and increases in relative humidity and, therefore, loses the greater part of its drying power. In one long shelf system, it might be possible to use a shelf width of about 16 feet. However, in a system where the sections are placed in parallel rows, it is doubtful that a shelf width of greater than 10 feet could be used without too great a variation in drying.

7. The rate of drying peat pellets on screen shelves is dependent upon all the above factors, and varies throughout the drying season. The amount of pellets spread per square foot of screen should also be varied throughout the season to obtain best drying results. The proper amount would range from 4 to 8 pounds per square foot of screen, depending upon the height of the shelf and also the expected weather. An averaging drying cycle based on seasonal production would probably be about 6 days.