For Reference

NOT TO BE TAKEN FROM THIS ROOM

A FURTHER INVESTIGATION INTO
THE ENGINEERING PROPERTIES OF MUSKEG
by
Capt. R.C. Wyld, RCE

Ex LIBRIS
UNIVERSITATIS
ALBERTAENSIS

Digitized by the Internet Archive
in 2017 with funding from
University of Alberta Libraries

<https://archive.org/details/furtherinvestiga00wyld>

SYNOPSIS

The ever increasing demand for access by ground approach into Canada's north country and hitherto nearly inaccessible areas has made it essential that studies be carried out to increase the knowledge of the engineering properties of organic terrains, generally termed as muskeg.

This thesis is such a study, conducted by the author, under the direction of Dean R. M. Hardy of the Faculty of Engineering, University of Alberta.

The study consists of two parts. First is the development of a Vane Shear Test Apparatus employing the use of a Torque-wrench. Second is the collection of data on the measurement of in-situ shear strengths of different types of muskeg and its presentation showing the relationships between shearing strengths, depth, moisture content, ash content and angular deformation.

The Field Tests were conducted in the Pmbina Oil Fields which include large areas of different types of muskeg as classified by N. W. Radforth in his, " Suggested Classification of Muskeg for Engineers." (Bib #1.)

The results show that the maximum shearing strengths range from 115 to 850 pounds per square foot, that the shearing strengths increase, directly with depth, ash content and angular deformation and vary inversely with moisture content. The study shows that the Vane Shear Test Apparatus meets its design requirements.

Thesis
1958
34

THE UNIVERSITY OF ALBERTA

A FURTHER INVESTIGATION OF THE
ENGINEERING PROPERTIES OF MUSKEG.

A DISSERTATION
SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE
OF MASTER OF SCIENCE

FACULTY OF ENGINEERING
DEPARTMENT OF CIVIL ENGINEERING

BY
CAPTAIN RICHARD C. WYLD
ROYAL CANADIAN ENGINEERS.

EDMONTON, ALBERTA.

15 OCTOBER 1956

ACKNOWLEDGEMENTS

Acknowledgements are gratefully made to the Chief Engineer and to the Directorate of Military Training, Canadian Army, for the authorization of post graduate studies in the author's army career and for the provision of the necessary funds and time.

Acknowledgement is respectfully made to Dean R. M. Hardy and Associate Professor S. R. Sinclair whose personal interest and help enabled the author to complete the post graduate course.

Acknowledgement is made to the Research Department of Imperial Oil of Canada and to the Civil Engineering Department of Mobil Oil of Canada who gave valuable assistance in men, monies and materials thus providing field crews and transport for the collection of field data.

The author extends grateful thanks to Mr. I. C. MacFarlane of National Research Council for his continued help throughout the summer program of field work.

TABLE OF CONTENTS

	page
Introduction	1
Theory, Development and Description of Vane Tester Apparatus	3
Field Tests	8
Observations and Results	12
Discussion of	
a) Vane Shear Tester Apparatus	14
b) Results	15
Conclusions	25
Recommendations	26
Data Sheets	28
Computation Sheets	49
Plates	51
Bibliography	70
Appendices	
#1 Computation of Vane Sizes	71
#2 Radforth Classification Table	72
#3 Acker Drill Co. - Vane Tester Price list (1956)	73
#4 Theoretical Calculations of Angular Twist in Drill Stems	74

INTRODUCTION

Although organic terrain or muskeg has many undesirable properties, the available strength of such terrains must be taken into account in the economic study of the construction of roads both permanent and short term in such areas.

This need has been brought about by the rapid increase in development in such terrain by the Department of National Defence, the Pulp and Paper Industries, the Oil Industry and the large Ore Development Programs. These expansions, necessitating the construction of roads and railways are concurrent across Canada.

The specific problems studied in this report are those of determining the Shearing Strengths of organic terrains by means of a Vane Shear Tester and correlating the strengths to depth, muskeg classification, moisture content, ash content, angular deformation and to determine the Liquid, Plastic and Shrinkage Limits obtained by laboratory tests.

The preliminary study involved the production of a Vane Tester using a Torque-wrench to apply the required torque. The Vane Tester was to be designed so that it was portable by

a crew of two or three men yet sufficiently strong to endure the wear and usages of field tests.

The area chosen for the field work was the Pembina Oil Fields, an area of approximately one thousand square miles, the northeast corner of which is located sixty-five miles west and twenty-five miles south of Edmonton, Alberta. It is estimated, by the Oil Companies in this area, that about thirty percent of this large tract is muskeg.

It is of interest to note some of the difficulties that arose and delays that occurred during the field tests. These were the existence of ice conditions in the muskeg until the end of June, and the time required to become familiar with the Oil Companies Expansion Programs. Numerous delays were caused by roads made impassible from inclement weather. The trial testing of the Vane Shear Test Apparatus was delayed until the last of June pending the arrival of the required torque-wrenches from the factory.

THEORY, DEVELOPMENT AND DESCRIPTION

OF THE VANE TESTER APPARATUS

Essentially the Vane Test consists of pushing a vane, usually four bladed, into the ground and measuring the torque required to rotate the vane and thus shear a cylinder of soil. On rotation the vanes revolve a total cylindrical area equal to

$$2\pi r (h + r)$$

where h = length of vane

r = radius from centre line of shaft

The resisting moment to the torque applied is developed by the shearing strength of the soil acting on the revolved area of the vane. This can be stated as,

$$T = S \times A \times m$$

where T = Torque applied

S = Shearing strength of soil

A = revolved area of vane

m = moment arm. = radius of cylinder revolved.

Thus the necessary equation to compute the Shearing Strength of the soil from the torque applied may be stated as,

$$T = S \times A \times r \dots\dots\dots \text{Equation 1}$$

In order to make the vane penetrate to the required depth it is necessary to auger down to the desired depth less one half the length of the

THEORY OF THE EARTH'S CRUST

CHAPTER I. THE EARTH'S CRUST

The earth's crust is the outermost layer of the earth.

It is composed of the uppermost part of the lithosphere.

The lithosphere is the rigid upper part of the earth's crust.

It is composed of the uppermost part of the lithosphere.

The lithosphere is the rigid upper part of the earth's crust.

The lithosphere is the rigid upper part of the earth's crust.

The lithosphere is the rigid upper part of the earth's crust.

The lithosphere is the rigid upper part of the earth's crust.

The lithosphere is the rigid upper part of the earth's crust.

The lithosphere is the rigid upper part of the earth's crust.

The lithosphere is the rigid upper part of the earth's crust.

The lithosphere is the rigid upper part of the earth's crust.

The lithosphere is the rigid upper part of the earth's crust.

The lithosphere is the rigid upper part of the earth's crust.

The lithosphere is the rigid upper part of the earth's crust.

The lithosphere is the rigid upper part of the earth's crust.

The lithosphere is the rigid upper part of the earth's crust.

The lithosphere is the rigid upper part of the earth's crust.

The lithosphere is the rigid upper part of the earth's crust.

The lithosphere is the rigid upper part of the earth's crust.

The lithosphere is the rigid upper part of the earth's crust.

The lithosphere is the rigid upper part of the earth's crust.

The lithosphere is the rigid upper part of the earth's crust.

The lithosphere is the rigid upper part of the earth's crust.

The lithosphere is the rigid upper part of the earth's crust.

vane. Due to this, the area on which the shear strength acts is the cylindrical wall area plus one end area.

Expressing Equation 1 in terms of radius and length of vane,

$$T = S \left(2\pi r \times h \times r + \pi r^2 \times \frac{2}{3} r \right)$$

or
$$T = 2\pi r^2 \times S \left(h + \frac{r}{3} \right) \dots\dots \text{Equation 2}$$

where $T =$ torque in foot-pounds

$S =$ shearing strength in pounds per square foot

$r =$ radius in feet

$h =$ length of vane in feet.

To facilitate computations the height and radius of the vane were chosen such that the Shear Strength would be some whole integer times the torque applied. The radius of the vane was limited by the diameter of the portable field auger. After numerous trial computations the dimensions of the vane chosen were, diameter 4.5 inches and length 10.1 inches. Using a vane of these dimensions resulted in the shear strength being equal to the torque applied multiplied by five. Appendix number 1, page 70, shows the computations of Vane size.

From previous records of the shearing strengths of muskeg in Western Canada it was noted that in some instances strengths of over 1600 pounds per square foot were recorded. To ensure that the apparatus being developed would encompass such strengths, the torque

• 154 •

$$(\frac{1}{2} + \frac{1}{2}) = 1$$

wrenches used had a range from zero to three hundred foot-pounds and could be used with an extension arm so designed that the actual torque applied was equal to two times the torque reading on the wrench. The manufacturers of the wrenches used, specified that the wrenches should not be stressed beyond eighty percent of their scale reading, which set a limit of two hundred and forty foot-pounds on a wrench. This meant that the extension arm would have to be used if shearing strengths of more than twelve hundred pounds per square foot were encountered.

To eliminate friction between the vane shaft and the soil being tested, the drill stem used as the shaft was enclosed in a thin wall casing of sufficient inside diameter to clear the drill stem couplings. The drill stem turned through a bearing at the bottom of the casing which was two inches above the top of the vane. Plans of the Vane Tester designed are presented on Plates 14, 15, 16, 17 and 18, pages 64 to 68, of this report.

The Vane Tester Apparatus designed and used in the Field Tests consists of:

- 2 - 300' torque wrenches with 3/4" drive head
- 1 - extension arm, multiplication factor of 2
- 1 - Vane assembly, diameter 4.5", length 10.1",
complete with thrust bearing and casing,
overall length 2'-0" to centre of vanes.

- 2 - 5/8" pony drill rods, 2' long
- 4 - 5/8" pony drill rods, 4' long
- 2 - 2' lengths 1-3/4" casing complete with
couplings
- 4 - 4' lengths 1-3/4" casing complete with
couplings
- 1 - torque drive head fitted with 3/4" socket
- 1 - Casing Anchor complete with set screws
- 1 - Rotational strain gauge graduated to 1 degree
- 2 - Pipe wrenches 18"
- 2 - 5/8" pony drill stem coupling wrenches
- 1 - crescent wrench 6"
- 1 - Field auger kit, 6", complete with
extension rods
- 1 - Working Platform, 2 pieces 4' x 4', 3/4"
plywood
- 1 - Shovel LH
- 1 - Axe hand
- 1 - hammer sledge, 7 $\frac{1}{2}$ "

The Vane Shear Test Apparatus produced was jointly designed by Mr. J. P. Walsh of Pembina Branch, Mobil Oil of Canada and the author. Mobil Oil provided the materials, workshop and labor for the production of the apparatus and the manning of the field crew. Mr. Walsh gave freely of his time, advice and help throughout the time spent in the field.

The Vane Test Apparatus produced is a modified version of the Vane Tester developed by Captain S. Thomson which is described in his Thesis, Bibliography 2.

The primary modifications made to the Thomson apparatus are as follows:

In the Walsh-Wyld apparatus torque is applied directly to the vane shaft by means of a Torque-wrench from which the applied torque can be read. In the Thomson model torque was applied by means of tensioning a steel wire, by winding on a hand ratchet, through a mechanical system including a spring anchored pulley and the wire being wound around a 20 inch diameter disc which was clamped by set screws to the vane shaft. To determine the torque applied involved the computation of the extension of the spring anchoring the pulley and then reading the applied torque and the shearing strength from a graph giving the relationship between these. The Walsh-Wyld apparatus is so designed that the shearing strength is equal to five times the torque reading.

The physical differences between the two models is most apparent by a study of the plans included in this report and in Thomson's thesis.

FIELD TESTS

The field tests were conducted in the Pembina Oil Fields and with the exception of one site were all carried out within the leaseholds of Mobil Oil of Canada. A photographic copy of the site plan showing the test areas is included in this report as Plate No. 19, Page 69.

Trial Tests to establish procedure and to correct any flaws in the apparatus were conducted in Block 3 as this was the earliest accessible area.

It was found during the trial tests that it was not possible to push the vane through the surface mat due to its very fibrous and rooty nature. It became standard procedure to remove the top three or four inches of the mat and to take the initial reading for each test hole at a depth of one foot. The next reading was taken at a depth of two feet and consequent readings taken at two foot intervals to the bottom of the muskeg.

All holes were augered to such a depth that when the vane was inserted, the centre of the vane was at the required depth and the top of the vane was one inch below the bottom of the augered hole.

Torque was applied to the vane at a steady rate of approximately thirty degrees per minute. This rate of deformation was adopted after trial

tests showed that if torque was applied by hand at a slower rate its application became uneven and jerky. In order to maintain some consistency the torque was applied by the same person for all readings.

At any given location, tests were run to give data on virgin muskeg, muskeg affected by drainage and muskeg consolidating under the well site pads which were constructed for drilling operations. To ensure that fairly representative data were obtained three tests were run for each condition of muskeg at each site. Many test holes had to be abandoned because logs, large roots or boulders were encountered during augering.

Throughout the program difficulty was experienced in obtaining good samples for testing in the laboratory. Augering greatly disturbed the material and the removal and inserting of the auger caused a large amount of sloughing from the sides of the hole. To keep the samples as representative as possible they were taken from the bottom portion of the load in the auger. All attempts to obtain good Shelby Tube samples were failures and samples retained were greatly disturbed. The use of three and one half inch diameter tubes still resulted in very compressed samples with a large reduction in water content. For three feet of muskeg in-situ the

the samples obtained were about eleven inches in length. The samples retained were kept by Mr. I. C. MacFarlane for laboratory investigation at National Research Council, the results of which will not be available before the summer of 1957.

Muskeg Classification was done by the method as described by Dr. N. W. Radforth in his paper, "Suggested Classification of Muskeg for the Engineer." This system is based on the classification of the living organic material at or on the surface of the terrain under consideration. This living organic material, known as coverage, is the first thing noticed as an observer enters the muskeg area. No knowledge of the species of plants is necessary to classify by this method. The Classification is done by recognition of the physical aspects of the growth including such things as, the woody or non-woody characteristics, the approximate height of growth, whether the growth is young, old or dwarfed, if the coverage is of tree or scrub form or grass like, or if growth is in patches, mats or hummocks.

A table, giving the summary of properties designating nine pure coverage classes, is presented as Appendix Number 2, Page 71, to this report.

Vane Tests were conducted at Well Site No. 28-8, of Mobil Oil Block 4, as recorded on Data Sheet No. 8, Page 35. These tests were run on virgin mus-

keg. On the information from Mr. J. P. Walsh, that the construction pad of clay fill was to be built at this site within a few weeks, four settlement gauges of the Casagrande pattern were installed. These gauges were placed at the surface and bottom of the muskeg and at two intervening levels. Mr. Walsh, of Mobil Oil, kindly consented to keep the record of settlement of these gauges.

It is noted that about seventy percent of the time when the vane was withdrawn after a test, the revolved cylinder of soil adhered to the vane. It was noted by the author and Mr. I. C. MacFarlane that the diameter of the cylinder of soil as accurately as could be measured was the same as the diameter of the vane.

OBSERVATIONS AND RESULTS

The following Data Sheets, Computation Sheets, Tables and Plates are presented as part of this report. As all Data Sheets are straight forward no sample computations are included.

Data Sheets nos 1 to 9, pages 28 to 36, present the Field Data with accompanying remarks and field sketches.

Data Sheet no. 10, page 37, records the Moisture and Ash Content Determinations of twenty-three tests run in the Soils Laboratory, University of Alberta, on disturbed samples taken in the field.

Data Sheets nos. 11 to 19, pages 38 to 46, record the data for the Atterberg Limits determinations.

Data Sheet no. 20, page 47, lists the Angular Deformations recorded for torques varying from 40 to 160 foot-pounds on lengths of $5/8$ inch drill stem from 4 to 24 feet in length.

Data Sheet no. 21, page 48, is the summary of results of the Atterberg Limits Tests.

Computation Sheets nos. 1 and 2, pages 49 and 50, show the computation of the corrected angular deformations in the soil.

Plates nos. 1 to 4, pages 51 to 54, present graphs of shearing strength versus depth.

Plates nos. 5 to 8, pages 55 to 58, present the relationships between shearing strengths, moisture contents, ash contents and depths.

Plate no. 9, page 59, shows the position on the Plasticity Chart of some of the Muskegs tested.

Plates nos. 10 and 11, pages 60 and 61, present graphically the relationship between Angular Deformation and Depth for DFI and BDI Muskeg.

Plate no. 12, page 62, presents the relationship between Maximum shear strength versus Angular Deformation for BDI and DFI muskegs.

Plate no. 13, page 63, is the graphical presentation of Data Sheet no 20, page 47.

Plates nos. 14 to 18, pages 64 to 68, are the detailed drawings of the Walsh-Wyld model of the Vane Shear Test Apparatus.

Plate no. 19, page 69, is the Plan of the Areas within the Pembina Oil Fields where the tests included in this thesis were conducted.

DISCUSSION

The discussion is divided into two parts,

- a) Discussion of the Vane Shear Test Apparatus,
- b) Discussion of the results.

Discussion of the Vane Shear Test Apparatus

Mechanically the Vane Tester developed and used was found very satisfactory. The addition of guide bearings at regular intervals, say every second casing section, would eliminate the small transverse movement of the vane shaft within the casing. This could easily be done by use of tapered split bronze bushings, machined to fit between the vane shaft and the inside of the casing couplings. The weight of the tester, especially when assembled to a length of ten feet or over, made it quite awkward to handle. This could be remedied by the use of a smaller diameter high strength steel vane shaft and a lightweight metal for the casing. This would also reduce the overall weight of the tester which was not as easily portable as desired. To transport the apparatus from the vehicle to the test site required six well loaded trips by one man.

It is worthy of note, that just when the construction of the Vane Tester designed had been finished and the test trials and necessary adjustments made, that a commercial Vane Shear Kit was put on the market by Acker Drill Company Incorporated of Scranton, Pennsylvania.

The Acker kit includes three sizes of vanes, two torque wrenches of 150 and 600 inch-pounds capacities and guide bearing and couplings as required. The largest vane in the Acker Kit has a diameter of 3.63 inches as compared to the 4.5 inch diameter vane used in this project. The Acker Kit is practically the same as the apparatus developed by Mr. J. P. Walsh of Mobil Oil and the author. A summary of the component parts and the price list of the Acker Kit is included in this report as Appendix Number 3, page 72.

As a small sized vane was not used during any of the field tests, the author does not feel qualified to comment on any merits or demerits of smaller equipment. It is his opinion however that a Tester using small sized vanes would likely give comparable results. Smaller apparatus would also increase the portability of the equipment and greatly reduce the physical effort required during the operation of the field tests.

Discussion of Results

Perusal of plates numbers 1 to 8, which graphically present the correlation of some of the engineering properties of muskeg, shows the following characteristics.

a) For Muskeg of Radforth Classification DFI

- i Virgin muskeg shows an increase in strength with depth varying from 270 to 390 pounds per square foot and having a characteristic decrease in strength just below mid-depth with the minimum strength recorded at this point.
- ii Muskeg, which has been drained for 21 months, shows an increase in strength with depth, ranging from 285 to 475 pounds per square foot. The characteristic decrease in strength occurs between 0.2 and 0.4 of the total depth when the muskeg is on the virgin side of the drainage ditch. Where the tests were run between the overburden and the drainage ditch, the characteristic fall-off in strength occurs between 0.4 and 0.8 of the depth.
- iii The muskeg consolidated under 400 pounds per square foot for twenty-one months, shows no tendency to increase strength with depth, but it shows again the fall-off of strength at 0.4 to 0.6 of the depth with a minimum of 500 pounds per square foot, the maximum strength recorded for this condition being 700 pounds per square foot.

In summary DFI muskeg shows a general increase in shearing strength with depth, with a characteristic weak zone at 0.4 to 0.6 of the depth with minimum

values of 270 pounds per square foot in virgin muskeg to 500 pounds per square foot under consolidating conditions.

Plates, nos.5, 6 and 7, which present graphically the correlations from DFI muskeg, between shearing strength, depth and moisture and ash contents, show that the Shearing Strength increases,

- i with increase in depth
- ii with decrease in moisture content
- iii with increase in ash content.

Ash content was determined from weight of residue after 24 hours at 300°C divided by: dry weight of sample after 24 hours at 110°C .

The plates also indicate an increase in Ash content with depth and a decrease in Moisture content with depth. The consistency with which increase in the shearing strength is accompanied with a decrease in moisture content is clearly shown by graphs a and b on plate 5.

b) For muskeg of Radforth Classification BDI.

The following points are clearly depicted on plates 2, 3 and 8, which present the correlations of some of the engineering properties of BDI muskeg. It is noted at this point that some of the Field Data sheets show the classification as A to BDI, which is applying the Radforth classification beyond its intended degree.

In presenting the data in graph form the author has included all A to B DI classes as strictly BDI and feels justified in doing so as the A class growth tends to overshadow the B class growth in visual identification due to its height and more noticeable foliage during the summer season.

- i Virgin muskeg shows the shearing strength to increase directly with depth. BDI muskeg does not show the pronounced characteristic of having a zone from 0.4 to 0.8 of the depth which has a decrease in strength. Rather it shows a slight increase in strength through this zone and a marked increase in strength below this depth. Strengths vary from 175 to 525 pounds per square foot at one location and from 150 to 575 pounds per square foot at another location, both being in the same large BDI muskeg area.
- ii Muskeg affected by drainage increases in shearing strength directly with depth, with variations from 325 to 525 pounds per square foot from the surface to the bottom of the muskeg. Test run on the cleared Flowline right of way show strengths from 115 to 450 pounds per square foot which are a little lower than the strength ranges found in the virgin muskeg.

iii The plotted data from both locations show a slight decrease in strength with depth for BDI muskeg under an overburden of about 320 pounds per square foot for a period of ten months. One site shows a decrease from 550 to 500 pounds per square foot from surface to bottom and the second location shows a decrease from 600 at the surface to 375 at mid-depth increasing to 550 pounds per square foot at the bottom. In summary BDI muskeg, in the virgin and affected by drainage states, shows the shearing strength increases directly with depth, while under the overburden existing at the site, this type of muskeg shows a small decrease in shearing strength with increase in depth.

Plate 8, presenting the relationships between shearing strength, depth and ash and moisture content for virgin muskeg shows that moisture content decreases with an increase in shearing strength and depth. Ash content with depth remains nearly constant except for the bottom few inches of muskeg where the ash content shows a sharp increase. The data was not comprehensive enough to show any characteristic for shearing strength versus ash content.

c) For muskeg of Radforth Classification ADI and C

Plate 4 shows shearing strength versus depth for both ADI and C class virgin muskeg. As construction had not been started it was not possible to obtain further data at the sites.

The ADI muskeg shows minimum strengths varying from 275 to 475 pounds per square foot from the surface to the bottom. It is at this site that settlement gauges previously mentioned have been installed.

Data were obtained for the type C muskeg as it was the only area encountered where there was only a single descriptive type of muskeg. The surface mat was extremely tough and axe work was required before the vane could be pushed through to the one foot depth. After the bottom of the muskeg was reached at two and one half feet from the surface, augering continued as local lore had suggested the depth being somewhere between "very deep" and "bottomless". As data sheet number 9 records clay extended on down to a depth of eleven and a half feet, from the surface, at which point augering was stopped. Plate 4, graph (b) shows that for this type muskeg the shearing strength increases directly with depth over the range of 550 to 765 pounds per square foot for an increase in depth of one foot.

The data and computations recorded in the determination of moisture and ash contents for

twenty-three disturbed samples are presented on Data Sheet No 10, Page 37.

In an attempt to analyse the plasticity characteristics of muskeg, tests to determine the Atterberg Limits were conducted on nine disturbed samples. Data Sheets numbers 11 to 19, pages 61 to 69, record the test data and computations. A summary of the results is compiled as Data Sheet number 21, page 48. A study of this summary leads to the following discussion.

The increases and decreases in the Liquid Limit parallel the natural moisture content and the highest values of moisture content and liquid limit occur at the lowest ash contents.

The Plastic Limits determined are in all but two cases higher than the liquid limits. In the two cases where the liquid limit is greater than the plastic limit the samples have a high ash content. From the tests run it is noted that when the ash content is over 50% the plasticity index can be computed. At an ash content of 37% the liquid and plastic limits are nearly equal giving a plasticity index of zero. Time did not permit but it might prove interesting to make a further study to see if 35% to 40% ash content is a limit below which the plasticity index can not be computed.

In performing the tests difficulties were

found in running the plastic and shrinkage limits. Due to the very fibrous organic nature of the samples the water content had to be very high in order to roll the soil into threads of approximately one-eighth inch in diameter. The few results obtained are plotted on the Plasticity Chart presented as Plate no. 9, page 59. The determination of the shrinkage limits was not continued throughout all the tests as measurement of the volume of the dry pats could not be done accurately.

During the field tests the total angular deformations for all torques were recorded on the applicable field data sheets. These angular deformations included the twist of the drill stem as well as the deformation of the soil. In order to know the deformation of the soil only, it was necessary to determine the amounts of twist in the drill stem for variations in lengths and applied torques.

By securing the blades of the vane in a vise and measuring the angular twist in the drill stem for applied torques of forty, eighty, one hundred and twenty and one hundred and sixty foot pounds the data as presented on Data Sheet no 20, page 47, were obtained. These data are presented graphically on Plate 13, page 63.

The determinations of the angular deformations

in the soil are shewn on Computation Sheets nos 1 and 2, pages 49 and 50, which are self-explanatory. For these computations the twist in the drill stems was determined from the graphs on Plate 13.

A brief discussion on the Theoretical Computations of twist in the drill stem is presented as Appendix no 4, page 73, to this study.

Plate no 10, page 60, shows the Angular Deformation versus Depth for DFI Muskeg in the three states of virgin, drained and drained and consolidated under a load of approximately 400 pounds per square foot for twenty-one months. In general there appears to be a decrease in angular deformation with increase in depth down to the six foot depth. The data presented are not conclusive.

Plate no 11, page 61, presents similar data for BDI Muskeg. Again there appears to be a decrease in angular deformation with increase in depth down to the six foot depth. BDI muskeg shows a tendency to increase in angular deformation between the six and eight foot depth zone. This may be due to the higher mineral content near the bottom of the muskeg.

From the data presented on Plates 10 and 11 both the DFI and BDI muskegs show a tendency to decrease in angular deformation with an increase in depth.

Plate no. 12 graphically presents maximum Shear Strength versus Angular Deformation for BDI and DFI muskegs. The data presented is not conclusive but show that both types tend to increase in shear strength with an increase in angular deformation as shewn by the sloped dashed lines. The slope of the lines as shewn indicate that BDI muskeg would increase about 7.5 psf and DFI muskeg about 8.5 psf per degree increase in angular deformation.

From a study of the Field Data Sheets and Computation Sheets it is seen that there is a definite difference in shear strengths for each state in which the muskeg was studied. For DFI Muskeg, as shewn on Computation Sheet No. 1, in the virgin state the average shear strength varies from 270 to 450 pounds per square foot. In the drained state the values varied from 300 to 650 psf and in the consolidated and drained state the shear strength varied from 625 to 850 psf. This indicates that DFI muskeg, under a consolidation load of approximately 400 psf for twenty-one months doubled in strength compared to the virgin state. The drained state shows a marked increase in strength compared to the virgin state.

The strengths recorded for the various states of BDI muskeg are from 150 to 500 psf for

the virgin state, from 325 to 650 for the drained state and from 400 to 700 psf for the consolidated state. Comparing the low values of shear strength obtained for each state shows that BDI muskeg drained gave twice the strength of virgin muskeg and that BDI consolidated shows nearly three times the strength of virgin muskeg. This type of muskeg was consolidated under a load of approximately 320 psf for ten months.

"C" class muskeg in the virgin state gave shear strengths from 550 to 765 psf. No consolidation or drainage had taken place in this tract of muskeg. The high strength in this virgin state is likely due partially to the root growth extending throughout the total depth of the muskeg which was just two and three quarter feet. Fine hair roots were encountered five feet below the bottom of the muskeg in a grey-blue sandy clay.

CONCLUSIONS

The vane shear test apparatus, designed for and used in the collection of data for this study, met the design requirements.

The maximum shear strengths for the types of muskeg tested varied over a wide range, from 115 to 850 psf, but indicate that the shear strength in muskeg is increased by drainage and when under consolidation. The shear strengths of

muskeg were found to vary directly with the depth, inversely with moisture content and appeared to vary directly with angular deformation and ash content.

The shear strengths of muskegs determined in this study are in agreement with those determined by Capt. S. Thomson, as presented in his Thesis on the same subject and with the values obtained by C. F. Ripley and Associates from investigations carried out in the Campbell River area on Vancouver Island. The following tables show the comparison of the values obtained from the three different sources.

COMPARISON BETWEEN RESULTS OF THOMSON AND WYLD

(tests done in virgin muskeg)

	THOMSON					WYLD						
Depth to bottom of muskeg (ft)	12	12	13	17½	!	10½	10½	9½	10	6½	2	3/4
Depth of Max. Shear Str.(ft)	10½	12	4	17½	!	10	8	9	9½	6½	2	
Max. Shear Strength (#/sft)	520	610	425	1090	!	480	600	525	600	500	765	
Radforth Classification	unknown				!	DEI	DFI	BDI	BDI	ADI	C	
Area Investigated	Alaska Highway				!	Pembina Oil Fields						

COMPARISON OF RESULTS OF RIPLEY & ASSOCIATES AND WYLD

	RIPLEY		WYLD
Undisturbed Strength (#/sq.ft)	150 to 300	!	175 to 600
Samples from Depth (ft)	0 to 7	!	1 to 10
Remolded Strength (#/sq/ft)	60 to 75	!	48 to 100
Water Content (%)	475 to 960	!	432 to 850
Under Consolidation		!	
a. Load	0.1 T/sq.ft	!	0.15 to 0.2 T/sq.ft
b. Increase in strength	25% to 100%	!	100% to 150%

RECOMMENDATIONS

It is felt that the following recommendations may be of some help in further investigations into

STATE OF NEW YORK

IN SENATE

1897

January

1897	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099	2100	2101	2102	2103	2104	2105	2106	2107	2108	2109	2110	2111	2112	2113	2114	2115	2116	2117	2118	2119	2120	2121	2122	2123	2124	2125	2126	2127	2128	2129	2130	2131	2132	2133	2134	2135	2136	2137	2138	2139	2140	2141	2142	2143	2144	2145	2146	2147	2148	2149	2150	2151	2152	2153	2154	2155	2156	2157	2158	2159	2160	2161	2162	2163	2164	2165	2166	2167	2168	2169	2170	2171	2172	2173	2174	2175	2176	2177	2178	2179	2180	2181	2182	2183	2184	2185	2186	2187	2188	2189	2190	2191	2192	2193	2194	2195	2196	2197	2198	2199	2200	2201	2202	2203	2204	2205	2206	2207	2208	2209	2210	2211	2212	2213	2214	2215	2216	2217	2218	2219	2220	2221	2222	2223	2224	2225	2226	2227	2228	2229	2230	2231	2232	2233	2234	2235	2236	2237	2238	2239	2240	2241	2242	2243	2244	2245	2246	2247	2248	2249	2250	2251	2252	2253	2254	2255	2256	2257	2258	2259	2260	2261	2262	2263	2264	2265	2266	2267	2268	2269	2270	2271	2272	2273	2274	2275	2276	2277	2278	2279	2280	2281	2282	2283	2284	2285	2286	2287	2288	2289	2290	2291	2292	2293	2294	2295	2296	2297	2298	2299	2300	2301	2302	2303	2304	2305	2306	2307	2308	2309	2310	2311	2312	2313	2314	2315	2316	2317	2318	2319	2320	2321	2322	2323	2324	2325	2326	2327	2328	2329	2330	2331	2332	2333	2334	2335	2336	2337	2338	2339	2340	2341	2342	2343	2344	2345	2346	2347	2348	2349	2350	2351	2352	2353	2354	2355	2356	2357	2358	2359	2360	2361	2362	2363	2364	2365	2366	2367	2368	2369	2370	2371	2372	2373	2374	2375	2376	2377	2378	2379	2380	2381	2382	2383	2384	2385	2386	2387	2388	2389	2390	2391	2392	2393	2394	2395	2396	2397	2398	2399	2400	2401	2402	2403	2404	2405	2406	2407	2408	2409	2410	2411	2412	2413	2414	2415	2416	2417	2418	2419	2420	2421	2422	2423	2424	2425	2426	2427	2428	2429	2430	2431	2432	2433	2434	2435	2436	2437	2438	2439	2440	2441	2442	2443	2444	2445	2446	2447	2448	2449	2450	2451	2452	2453	2454	2455	2456	2457	2458	2459	2460	2461	2462	2463	2464	2465	2466	2467	2468	2469	2470	2471	2472	2473	2474	2475	2476	2477	2478	2479	2480	2481	2482	2483	2484	2485	2486	2487	2488	2489	2490	2491	2492	2493	2494	2495	2496	2497	2498	2499	2500	2501	2502	2503	2504	2505	2506	2507	2508	2509	2510	2511	2512	2513	2514	2515	2516	2517	2518	2519	2520	2521	2522	2523	2524	2525	2526	2527	2528	2529	2530	2531	2532	2533	2534	2535	2536	2537	2538	2539	2540	2541	2542	2543	2544	2545	2546	2547	2548	2549	2550	2551	2552	2553	2554	2555	2556	2557	2558	2559	2560	2561	2562	2563	2564	2565	2566	2567	2568	2569	2570	2571	2572	2573	2574	2575	2576	2577	2578	2579	2580	2581	2582	2583	2584	2585	2586	2587	2588	2589	2590	2591	2592	2593	2594	2595	2596	2597	2598	2599	2600	2601	2602	2603	2604	2605	2606	2607	2608	2609	2610	2611	2612	2613	2614	2615	2616	2617	2618	2619	2620	2621	2622	2623	2624	2625	2626	2627	2628	2629	2630	2631	2632	2633	2634	2635	2636	2637	2638	2639	2640	2641	2642	2643	2644	2645	2646	2647	2648	2649	2650	2651	2652	2653	2654	2655	2656	2657	2658	2659	2660	2661	2662	2663	2664	2665	2666	2667	2668	2669	2670	2671	2672	2673	2674	2675	2676	2677	2678	2679	2680	2681	2682	2683	2684	2685	2686	2687	2688	2689	2690	2691	2692	2693	2694	2695	2696	2697	2698	2699	2700	2701	2702	2703	2704	2705	2706	2707	2708	2709	2710	2711	2712	2713	2714	2715	2716	2717	2718	2719	2720	2721	2722	2723	2724	2725	2726	2727	2728	2729	2730	2731	2732	2733	2734	2735	2736	2737	2738	2739	2740	2741	2742	2743	2744	2745	2746	2747	2748	2749	2750	2751	2752	2753	2754	2755	2756	2757	2758	2759	2760	2761	2762	2763	2764	2765	2766	2767	2768	2769	2770	2771	2772	2773	2774	2775	2776	2777	2778	2779	2780	2781	2782	2783	2784	2785	2786	2787	2788	2789	2790	2791	2792	2793	2794	2795	2796	2797	2798	2799	2800	2801	2802	2803	2804	2805	2806	2807	2808	2809	2810	2811	2812	2813	2814	2815	2816	2817	2818	2819	2820	2821	2822	2823	2824	2825	2826	2827	2828	2829	2830	2831	2832	2833	2834	2835	2836	2837	2838	2839	2840	2841	2842	2843	2844	2845	2846	2847	2848	2849	2850	2851	2852	2853	2854	2855	2856	2857	2858	2859	2860	2861	2862	2863	2864	2865	2866	2867	2868	2869	2870	2871	2872	2873	2874	2875	2876	2877	2878	2879	2880	2881	2882	2883	2884	2885	2886	2887	2888	2889	2890	2891	2892	2893	2894	2895	2896	2897	2898	2899	2900	2901	2902	2903	2904	2905	2906	2907	2908	2909	2910	2911	2912	2913	2914	2915	2916	2917	2918	2919	2920	2921	2922	2923	2924	2925	2926	2927	2928	2929	2930	2931	2932	2933	2934	2935	2936	2937	2938	2939	2940	2941	2942	2943	2944	2945	2946	2947	2948	2949	2950	2951	2952	2953	2954	2955	2956	2957	2958	2959	2960	2961	2962	2963	2964	2965	2966	2967	2968	2969	2970	2971	2972	2973	2974	2975	2976	2977	2978	2979	2980	2981	2982	2983	2984	2985	2986	2987	2988	2989	2990	2991	2992	2993	2994	2995	2996	2997	2998	2999	3000	3001	3002	3003	3004	3005	3006	3007	3008	3009	3010	3011	3012	3013	3014	3015	3016	3017	3018	3019	3020	3021	3022	3023	3024	3025	3026	3027	3028	3029	3030	3031	3032	3033	3034	3035	3036	3037	3038	3039	3040	3041	3042	3043	3044	3045	3046	3047	3048	3049	3050	3051	3052	3053	3054	3055	3056	3057	3058	3059	3060	3061	3062	3063	3064	3065	3066	3067	3068	3069	3070	3071	3072	3073	3074	3075	3076	3077	3078	3079	3080	3081	3082	3083	3084	3085	3086	3087	3088	3089	3090	3091	3092	3093	3094	3095	3096	3097	3098	3099	3100	3101	3102	3103	3104	3105	3106	3107	3108	3109	3110	3111	3112	3113	3114	3115	3116	3117	3118	3119	3120	3121	3122	3123	3124	3125	3126	3127	3128	3129	3130	3131	3132	3133	3134	3135	3136	3137	3138	3139	3140	3141	3142	3143	3144	3145	3146	3147	3148	3149	3150	3151	3152	3153	3154	3155	3156	3157	3158	3159	3160	3161	3162	3163	3164	3165	3166	3167	3168	3169	3170	3171	3172	3173	3174	3175	3176	3177	3178	3179	3180	3181	3182	3183	3184	3185	3186	3187	3188	3189	3190	3191	3192	3193	3194	3195	3196	3197	3198	3199	3200	3201	3202	3203	3204	3205	3206	3207	3208	3209	3210	3211	3212	3213	3214	3215	3216	3217	3218	3219	3220	3221	3222	3223	3224	3225	3226	3227	3228	3229	3230	3231	3232	3233	3234	3235	3236	3237	3238	3239	3240	3241	3242	3243	3244
------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------

the engineering properties of muskeg.

A vane tester of similar design but of smaller dimensions and made of light weight materials will greatly reduce the work required in the field and will make the tester more portable. The Acker Vane Shear Test Kit, mentioned previously is suggested as a standard kit for such further investigations.

A suggested alteration to the Vane tester used by the author, to enable the application of torque at any desired rate is as follows.

Axially fix the Torque wrench on to a cogged wheel of radius equal to the length of the Torque wrench and motivate the assembly by means of a hand operated worm screw.

Continued investigation is required to broaden and substantiate any conclusions indicated by this report. Such investigations should be conducted over divers and well dispersed muskeg areas. All data should be centrally collected thus allowing the best interpretation, and correlation of properties and classification.

FIELD DATA SHEET NO.!!

VANE: height...4.71"
diameter...6.0"

TEXAS

Radforth
Classification
DEI..
•DFI..

Weather Warm a.m. Cloudy, rain p.m.

317

Date: 2 / .8. / 56

Mobil Oil	Block	1	USD	6	Sec	15	Tp	48	Pg	8	W5
-----------	-------	---	-----	---	-----	----	----	----	----	---	----

PLA

MacFarlane

Kjorlien

$$\begin{array}{r} +12 \\ +11 \\ +10 \end{array}$$
$$5 + 4 + 4$$

rmd				remd			
Depth	T	Strain	T	Depth	T	Strain	T
Hole # 1	(DEI)	#		Hole # 4	(DFI)		
1	45	70	8	1	65	50	12
2	55	50	12	2	88	80	12
4	63	60	15	4	50	55	10
6	50	50	15	6	53	60	17
8	72	80	20	8	82	70	22
10	80	60	20	10	80	70	5
							480

101-611 may

grey clay

[illegible]

Hole # 3	(DEI)	Hole # 6	(DFI)
1	55	1	55
2	70	2	90
4	75	4	55
6	45	6	60
8	75	8	98
10	65	10	90
			100
			8
			27
			15
			10
			15
			90
			55
			60
			55
			90
			12
			360
			540
			300
			330
			588
			540

10'-3" marl

means, Samples Taken

See Field Data Sheet No. 2. for completion of
Field Sketch Detail

REFERENCES

Hole # 2	-	trace of marl at 10'
Hole # 4	-	surface of marl at 10'
Hole # 5	-	" " " " 10'
Hole # 6	-	" " " " 10'

Legal Sub-Divisions in a Section →

13	14	15	16
12	11	10	9
5	6	7	8
4	3	2	1

Date 2... / 3... / 56

Mobil Oil.....	Block ..	LSD ..	6 Sec ..	15 "p ..	.48 Rg ..	8 W5 ..
----------------	----------	--------	----------	----------	-----------	---------

Drilling Island constructed
in November 1954.
Contour levels run over an
Wald MacFarlane
Kjorlien
Erickson

with island at centre
showed a fall of only
0.2' to the north.

REMARKS	Depth	Sample No.	
Hole # 7	1	12	Hole # 10 - trace of blue clay at 3'
	2	13	Hole # 11 - probably encountered log at 4'; 1 st layer of blue clay at 8'
	4	14	
	6	15	
	8	16	

Depth	T	Strain	T	S	Depth	T	Strain	T	S
Hole # 7 (S = 6 x T)									
1	117	100	25	702	1	30	30	13	400
2	117	80	25	702	2	100	90	25	500
4	105	70	28	630	4	105	85	20	525
6	110	115	30	660	6	80	55	20	400
8	149	120	35	700	8	100	90	27	500
started use of vane					10	grey blue clay			
with S = 5 x T									
9	blue grey clay no marl present				Hole # 11				
Hole # 8 (S = 5 x T)									
1	75	65	15	375	1	75	65	15	375
2	85	55	20	425	2	85	55	20	425
4	130	120	28	650	4	130	120	28	650
6	80	60	20	400	6	80	60	20	400
8	85	80	20	425	8	85	80	20	425
9	105	90	22	525	9	105	90	22	525
4.5' of fill - island for holes # 7, 8, 9, 13 and 14					9'-6" very organic silty blue clay				
2	160	180	40	800	Hole # 12				
4	170	100	30	850	1	75	70	15	375
6	125	120	35	625	2	85	65	20	425
8	155	125	50	775	4	95	85	20	475
9	clay as in hole # 7				6	75	65	20	375
1	no rdg due to roots at surface of muskeg under 4.5' fill				8	60	65	10	300
					9	95	75	20	475
					9'-6"	clay as in hole # 11			
Hole # 9									
1	205	230	40						
damaged vane - do not use values									

FIELD DATA SHEET NO. 3.

VANE: height ... 10.1".....
 diameter ... 4.5".....

S = .5. x T

Padforth
 Classification

Weather ... Hot.....
 ... 80.....

Date 22. / .8. / 56

D.F.

Mobil Oil... Block ... 1 ISD .6. Sec .15 Tp 48. Rg .8. W5

Wylde
 MacFarlane
 Erickson

See Data Sheets Nos. 1. & 2. for Field
 Sketches.

Depth	T	Strain	re mld	T	S
Hole # 13	4.5'	clay fill			
# 1	145	100	32	1030	
2	encountered	log			
2'-6"	155	140	35	775	
4	160	115	35	800	
6	100	80	28	500	
# 8	145	130	45	805	
# - see remarks					

Hole 14 4.5' clay fill

1	encountered	roots			
1'-6"	160	115	35	800	
2'-6"	170	140	38	850	
4	160	115	35	800	
6	130	105	35	650	
# 8	135	130	40	750	
8'-9"	clay				

- see remarks

REMARKS

Hole # 13 at 1' depth only 7" of vane in muskeg
 at 8' " " 9" " " " "
 Hole # 14 at 8' " " 9" " " " "
 a ir escaped as fill was punctured at
 muskeg surface, samples in auger
 appeared lighter brown in color and
 somewhat drier than normally.

VANE: height....10.1"....
diameter...4.5"....

S = .5. x T
Radforth
Classification

Weather.....hot.....
.....

Date .13 / .8. / 56

Mobil Oil... Block .3. LSD .2. Sec .5. Tp .49 Rg .8. W5
Wyd
MacFarlane
Erickson

Depth	T	Strain	remld	T	S	Depth	T	Strain	remld	T	S
-------	---	--------	-------	---	---	-------	---	--------	-------	---	---

Hole # 1											
Hole # 4						3.5' fill-is land					
1	65	60	10	325	1'	115	90	35	575		
2	65	70	12	325	2'-6"	130	80	28	650		
4	80	80	22	400	4'	120	100	30	600		
6	70	75	13	350	6'	100	75	25	500		
8	85	80	20	425	8'	highly organic clay					
9	highly organic clay										

Hole # 2												
Hole # 5 3.5' fill- island												
1	40	70	8	200	2'-6"	1	112	80	25	560		
2	37	55	10	185		4	175	120	28	875		
4	68	60	20	340		6	110	100	28	550		
6	70	75	15	350		8	100	80	23	500		
8	75	90	22	375			highly organic clay					
9	105	90	20	525			water 8' below fill @ 1600 hr					
9'-6"	highly organic clay											
							"	6"	"	"	@ 0800 "	

Hole # 3											
1	35	65	8	175	1	12	5	120	25	780	
2	60	70	12	300	2'-6"	135	75	35	675		
4	75	60	15	375	4	120	100	25	600		
6	75	60	20	375	6	115	85	28	575		
8	85	90	20	425	8	highly organic clay					
9	115	100	15	575							
9'-3"	highly organic clay

Hole # 3		Depth	Sample No.
		1	17
		2	18
		4	19
		6	20
		8	21
		9	22
		9'-3"	23

REMARKS

Hole #3 augered through rotten log at 7'-8"
Hole #4 first try abandoned- log at 1'-6"
Hole #6 depth 1' - used only 8" of vane
Hole #5 at 2'-6" rdg, felt root snap
rdg will be high.

FIELD DATA SHEET NO. 5.

VANE: height.....10.1"
diameter.....4.5"

S = .5 x T
Radforth
Classification

Weather
Hot
.....

Date 15 / 8 / 56

Mobil Oil.. Block 3. LSD 2. Sec 5. Tp 49 Rg 8.. W5

..01..

Depth	T	Strian	remld	T	S	De pth	T	Stria	T	Remld	S
-------	---	--------	-------	---	---	--------	---	-------	---	-------	---

Hole # 7

1	65	65	15	325
2	75	60	20	375
4	155	120	25	775
6	80	55	20	400
8	105	90	27	525
8'-3"	clay as in hole # 6			

Hole # 8

1	35	65	17	425
2	75	55	18	375
4	110	90	18	550
6	80	55	20	400
8	110	100	20	550
8'-4"	clay as in hole # 7			

Hole # 9

1	82	75	18	410
2	encountered log			
4	75	75	20	375
6	85	60	20	425
8	105	105	60	660
8'-4"	clay as in hole # 8

See Data Sheet # 4. for other Field Sketch Detail

REMARKS

Hole # 9 - 8' depth only 8" of vane used
Hole # 7 - vane for high rdg at 4' depth possible root

VANE: height ..10.1"
diameter..4.5"

S = ..5. x T

Radforth
Classification

Weather ..Hot.....
..85.....

Date .17 / .8. / 56

..BDI...

Mobil.Oil.. Block .3. ISD .8. Sec .5. Tp 49. Pg .8. W5

Wylde
MacFarlane
Erickson

Depth T Strain remld
T T

Hole # 1 Hole #4 3'-6" fill; island

1	30	50	10	150	6"	120	30	28	600
2	55	55	12	275	2'-6"	112	75	25	560
4	65	70	15	325	4'-6"	95	90	2 5	475
6	65	60	18	325	6'-6"	85	80	23	425
8	100	100	20	500	8	120	120	30	600
9'-8"	120	100	20	600	8'-8"	115	120	27	575
10	2" light marl then grey clay				9'-3"	dark organic clay			

Hole # 2

Hole # 5 3'-6" fill; island

1	30	60	7	150	1	125	100	25	625
2	70	70	15	350	2	135	30	28	675
4	65	75	15	325	4	75	70	20	375
6	55	55	15	275	6	85	75	22	425
8	80	85	20	400	8	110	115	30	550
9'-6"	115	90	20	575	9'-6"	clay-soft plastic			
10	clay - no marl					trace of marl			

Hole #3

Hole # 6 3'-6" fill; island

20.8.56

1	30	60	7	150	encountered log at 3'-3"				
2	50	50	15	250	in fill				
4	60	60	17	300	1 no rdg - roots				
6	70	65	17	350	2 120 80 15				
8	100	100	25	500	-5" of vane				1450
9'-6"	135	110	20	675	snap of root felt on				
10	clay as in hole # 2				vane				
					3'-6" log-abandoned hole				

#3+
#2+
#1+

456
+7
+8
+9
+10

Δ well head + test hole + drainage

REMARKS

Hole #4 - 1'-6" disturbed muskeg + 2' fill
Hole #6 - at 2' rdg minus 5" of vane

VALE: height ..10.1".
diameter...4.5".

S = ..5. x T

FIELD DATA SHEET NO. 7.
Weather ..Feb.....
.....

Date .21 / .8. / 56

..BDI....

Mobil Oil.. Block .3. LSD .8. Sec .5. Tp 49. Pg .8. W5
Wyd
MacFarlane
Erickson

See Data Sheet # 6 for Field Sketch.

Depth	T	Strain	remld	S	Depth	T	remld	S
Hole # 7 3'-6" fill; island Hole # 10								
1	135	95	25	675	1	encountered root		
2	110	70	28	550	2	55	60	8
5	90	95	23	450	4	55	75	12
6	85	75	20	425	6	95	100	16
8	120	130	33	600	8	65	85	15
9'-6"	Clay as in Hole # 5			5	9'-9"	90	75	20
					10'-3"	Clay as in hole # 9		

Hole # 8

1	28	60	5	140
2	55	70	12	275
4	130	95	15	650
6	70	75	13	350
8	80	85	22	400
9'-6"	93	80	28	465
10'-6"	Silty clay highly organic			

Hole # 9

1	23	55	5	115
2	40	55	8	200
4	75	105	12	375
7	70	90	15	350
8	55	65	12	275
9'-6"	100	90	25	500
10'-6"	Clay as in hole # 8			

REMARKS

Hole # 7 - pushed vane past 4' rdg at 5'
Hole # 8 - at 4' watch for high rdg as
vane appeared to contact root
during rotation

FIELD DATA SHEET NO. 8.

VANE: height 10.1"
diameter 4.5"

S = 5. x T Radforth
Classification

Date 24 / 8. / 56

Weather rainy...
sunny...
fog...

Mobil Oil... Block 4. LSD ... Sec. 28 Tp 49. Pg. 8. W5
Site of Battery # N. P. 28

Depth	T	Strain	T	remld	S
Hole # 1					
1	55	70	12	275	
2	65	55	15	325	
4	110	35	12	550	
5'-9"	90	65	20	500	
6'-3"	grey clay				

Radforth Classification

A - dense over 15'

B-D - dense 2'-15'

I - surface mat of moss
With some Grass

Hole # 2

1	85	70	18	425
2	70	50	13	350
4	95	80	12	475
5'-6"	100	75	20	500
6'-3"	grey clay			

Hole # 3

1	80	65	20	400
2	70	65	13	350
4	83	75	12	415
5'-6"	95	75	13	475
6'-3"	grey clay

REMARKS

Test Holes in virgin muskeg as shown,
pad to be constructed approx 3'-6" thick.
Hole # 1 - at 5'-9" used only 9" of vane
Four settlement gauges installed as
indicated.

FIELD DATA SHEET NO. 8.

VANE : height10.1".....
diameter4.5".....

S = .5. x T Radforth
Classification

WeatherCloudy....
...Cool.....

Date 30. / .8. / 56

Trans. Canada Block ... LSD 15. Sec. 19. Tp. 47. Rg. 7. W5

Depth	T	Strain	T	S	remld
Hole # 1					
1	110	90	12	550	
2	130	65	12	765	
2'-9"	clay - heavy organic				
	dark grey well				
	mixed with roots				

11'-6" clay - blue grey with
trace of fine grained
sand.

Hole # 2

5'-3"	clay - soft blue grey	1	110	80	12	550
	silty with very	2	130	70	10	765
	fine sand, a few	2'-9"	clay as in hole # 1			
	grains of white					
	sand visible					

7'-6"	clay - high sand					
	content, with the					
	appearance of					
	" SNAP " cleanser					
	fine hair like					
	roots apparent					

9'-3"	clay - blue grey,					
	silt and sand both					
	noticeably less					
	than at 7'-6"					
	no hair roots					
	visible					

10'-3"	clay - blue grey with					
	high fine sand					
	content and trace					
	of silt					

Note:

This area pointed out by Mobil Oil and Road
Construction personnel as a very difficult
area, suggestion that the muskeg was very
deep.

The area was solely Class "C" by Radforth
Classification - grass 3'-6" high with no
presence of moss or woody growth.

Muskeg Area
1/2 mi x 1/3 mi.

Test holes
approx 60' S
of Road A/lwce.

Surface Mat very tough

REMARKS

Hole # 1 at 2' - used 8 1/2" 68 vane
Hole # 2 at 2' - " 8 1/2" of "
Water table approx 2" above ground level

MOISTURE AND ASH CONTENTS - DATA SHEET											NO 10.
Sample Cont. No.	Wt. Sample Wet + Tare	Wt. Sample Dry	Wt. Sample Tare	Weight of Water	Tare Container	Wt. of Dry Soil	w %	Wt. Ash + Tare	Weight of Ash	Ash Content %	
1	A1	103.97	68.73	40.24	63.64	5.09	791	64.13	0.49	9.6	
2	A2	102.29	68.43	33.86	62.91	5.52	613	63.52	0.61	11.0	
3	A3	105.00	72.48	32.52	67.93	4.55	715	68.33	0.40	8.8	
4	A21	115.47	81.50	33.97	75.57	5.93	573	76.56	0.99	16.7	
5	A22	106.47	76.10	30.37	69.75	6.35	473	73.38	3.63	57.2	
6	A23	130.02	99.66	30.36	71.67	27.99	109	98.81	27.14	96.9	
7	A24	127.71	79.53	48.18	72.43	7.10	679	73.13	0.70	9.3	
8	V11	119.40	82.28	37.12	76.33	5.40	687	77.45	0.57	10.6	
9	V13	123.57	76.57	47.00	71.03	5.54	850	71.46	0.43	7.8	
10	V16	102.66	66.48	36.18	60.62	5.86	617	61.40	0.78	13.3	
11	V23	110.68	74.40	36.28	65.99	8.41	482	69.13	3.14	37.3	
12	V28	103.65	72.96	30.69	65.61	7.35	418	67.72	2.11	28.7	
13	V40	123.84	78.80	44.04	70.95	8.85	498	73.11	2.16	24.4	
14	V41	101.20	70.49	30.71	64.78	5.71	538	65.67	0.39	15.6	
15	V42	117.48	74.12	43.36	65.55	8.57	505	67.49	1.94	22.7	
16	V45	104.80	76.16	28.64	69.70	6.46	443	70.82	1.12	17.3	
17	V47	107.28	67.08	40.20	64.02	3.06	1315	64.37	0.35	11.4	
18	V48	113.64	78.06	35.58	74.10	3.96	900	74.63	0.58	14.6	
19	V49	128.00	78.67	49.33	71.56	7.11	694	72.23	0.67	9.4	
20	V50	147.53	94.98	52.55	87.64	7.34	717	88.50	0.86	11.7	
21	V51	122.40	73.75	58.65	67.13	6.57	895	67.80	0.62	9.4	
22	V52	128.00	77.30	50.70	70.71	6.59	770	71.41	0.70	10.6	
23	V53	128.54	84.32	43.72	61.61	23.21	188	80.72	19.11	82.4	

UNIVERSITY of ALBERTA
DEPT. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
ATTERBERG LIMITS

PROJECT MUSKEG RESEARCH
SITE Pembina Oil Fields
SAMPLE # 2
LOCATION
HOLE #1 DEPTH 41
TECHNICIAN RW DATE Oct 56

Liquid Limit

Trial No.	1	2	3	4	5	6
No. of Blows	7	8	7	28	29	28
Container No.	V49	V50	V51	A21	A22	A23
Wt. Sample Wet + Tare	83.6949	101.7980	82.0661	90.2250	81.1243	91.4276
Wt. Sample Dry + Tare	73.2304	89.5545	69.2220	73.2422	71.8130	75.2613
Wt. Water	10.4645	12.2435	12.8441	11.9828	9.3113	16.1658
Tare Container	71.5841	87.6574	67.1820	75.5734	69.7503	71.6690
Wt. of Dry Soil	1.6463	1.7981	2.0400	2.6688	2.0627	3.5928
Moisture Content $w\%$	635	645	640	449	450	450

Average Values

$w_L = 470$
 $w_p = 619$
 $w_s = 219$
 $I_p =$
 $I_f = 322$
 $I_t =$

Plastic Limit

Trial No.	1	2	3
Container No.	AV	BI	AJ
Wt. Sample Wet + Tare	57.1623	57.3863	56.9883
Wt. Sample Dry + Tare	54.8189	55.3193	54.3079
Wt. Water	2.3434	2.0670	2.6804
Tare Container	54.4458	54.9808	53.9948
Wt. of Dry Soil	0.3731	0.3385	0.3127
Moisture Content %	628	611	8509

Shrinkage Limit

 $w_p = 619$

Trial No.	1	2	3
Container No.	15	16	17
Wt. Sample Wet + Tare	132.471	130.930	123.347
Wt. Sample Dry + Tare	121.175	119.364	112.074
Wt. Water	11.297	11.566	11.273
Tare Container	119.660	117.812	110.550
Wt. of Dry Soil W_o	1.515	1.551	0.313
Moisture Content $w\%$	746	745	740
Vol. Container V	12.10	12.35	12.00
Vol. Dry Soil Pat V_o	4.15	4.30	3.90
Shrinkage Vol. $V - V_o$	7.95	8.05	8.10
Shrinkage Limit w_s	221	227	209

$$w_s = w \left(\frac{V - V_o}{W_o} \times 100 \right) \quad w_s = 219$$

Description of Sample: _____

Remarks: _____

UNIVERSITY of ALBERTA
 DEP'T. of CIVIL ENGINEERING
 SOIL MECHANICS LABORATORY
ATTERBERG LIMITS

PROJECT Muskeg Research
 SITE Pembina Oil Fields
 SAMPLE #3
 LOCATION
 HOLE #1 DEPTH 6'
 TECHNICIAN RW DATE Oct 56

Liquid Limit

Trial No.	1	2	3	4	5	6
No. of Blows	9	9	10	21	22	21
Container No.	V40	V41	V42	V52	V53	A1
Wt. Sample Wet + Tare	89.3537	77.1006	80.5735	82.8280	77.3092	78.2966
Wt. Sample Dry + Tare	73.1061	66.1797	67.3084	72.5590	63.9635	65.8112
Wt. Water	16.2476	10.9209	13.2701	10.2690	13.3457	12.4854
Tare Container	70.9537	64.7806	65.5493	70.7273	61.6410	63.6375
Wt. of Dry Soil	2.1524	1.3991	1.7586	1.8217	2.3235	2.1737
Moisture Content $w\%$	755	780	755	564	571	573

Average Values

$w_L = 532$
 $w_p = 691$
 $w_s = 268$
 $I_p = -$
 $I_f = 553$
 $I_t = -$

Plastic Limit

Trial No.	1	2	3
Container No.	W1	W2	W3
Wt. Sample Wet + Tare	41.045	38.567	39.060
Wt. Sample Dry + Tare	39.343	36.425	37.052
Wt. Water	1.702	2.141	2.008
Tare Container	39.098	36.120	36.756
Wt. of Dry Soil	0.245	0.305	0.296
Moisture Content %	694	703	677

Shrinkage Limit

Trial No.	1	2	3
Container No.	19	23	25
Wt. Sample Wet + Tare	128.029	141.032	136.996
Wt. Sample Dry + Tare	116.555	129.576	125.146
Wt. Water	11.474	11.455	11.851
Tare Container	115.477	128.622	124.031
Wt. of Dry Soil W_o	1.078	0.954	1.113
Moisture Content $w\%$	1065	1200	1065
Vol. Container V	12.70	12.25	12.75
Vol. Dry Soil Pat V_o	3.65	3.55	3.95
Shrinkage Vol. $V-V_o$	9.05	8.70	8.60
Shrinkage Limit w_s	224	288	294

$$w_s = w \left(\frac{V - V_o}{W_o} \times 100 \right)$$

Description of Sample: _____

Remarks: _____

UNIVERSITY of ALBERTA
DEPT. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
ATTERBERG LIMITS

PROJECT Muskeg Research
SITE Pembina Oil Fields
SAMPLE #4
LOCATION
HOLE #1 DEPTH 8'
TECHNICIAN RW DATE Oct 56

Liquid Limit

Trial No.	1	2	3	4	5	6
No. of Blows	9	8	9	28	29	29
Container No.	V16	V23	V28	V45	V47	V48
Wt. Sample Wet + Tare	71.5682	77.2462	79.8327	81.6400	77.4276	88.1462
Wt. Sample Dry + Tare	62.2023	67.5860	68.8933	71.8983	66.4293	76.7023
Wt. Water	9.3659	9.6602	10.9394	9.7417	10.9483	11.4439
Tare Container	60.6227	65.9928	67.0405	69.7035	64.0160	74.0950
Wt. of Dry Soil	1.5796	1.5932	1.8528	2.1948	2.4633	2.6073
Moisture Content $w\%$	592	605	590	443	444	439

Average Values

$w_L = 460$
 $w_p = 688$
 $w_s = 213$
 $I_p = -$
 $I_f = 289$
 $I_t = -$

Plastic Limit

Trial No.	1	2	3
Container No.	W4	W5	W6
Wt. Sample Wet + Tare	37.859	38.365	40.254
Wt. Sample Dry + Tare	35.656	36.130	37.970
Wt. Water	2.203	2.235	2.286
Tare Container	35.338	35.811	37.631
Wt. of Dry Soil	0.318	0.319	0.339
Moisture Content %	692	692	680

Shrinkage Limit

Trial No.	1	2	3
Container No.	8	9	10
Wt. Sample Wet + Tare	134.046	129.664	124.648
Wt. Sample Dry + Tare	122.573	118.399	113.210
Wt. Water	11.473	11.275	11.438
Tare Container	121.033	116.890	111.689
Wt. of Dry Soil W_o	1.540	1.500	1.521
Moisture Content $w\%$	745	750	750
Vol. Container V	12.35	12.25	12.90
Vol. Dry Soil Pat V_o	4.30	4.70	4.10
Shrinkage Vol. $V - V_o$	8.05	7.55	8.80
Shrinkage Limit w_s	222	247	172

$$w_s = w \left(\frac{V - V_o}{W_o} \times 100 \right)$$

Description of Sample: _____

Remarks: _____

UNIVERSITY of ALBERTA
 DEP'T. of CIVIL ENGINEERING
 SOIL MECHANICS LABORATORY
ATTERBERG LIMITS

PROJECT Muskeg Research
 SITE Pembina Oil Fields
 SAMPLE #5
 LOCATION
 HOLE #1 DEPTH 10'
 TECHNICIAN RW DATE Oct 56

Liquid Limit

Trial No.	1	2	3	4	5	6
No. of Blows	9	8	9	32	33	34
Container No.	A1	A2	A3	A21	A22	A23
Wt. Sample Wet + Tare	74.6605	75.2400	80.0045	90.4646	82.6371	82.3553
Wt. Sample Dry + Tare	65.1817	64.6355	69.6190	78.3379	72.1508	73.6586
Wt. Water	9.4788	10.6045	10.3853	12.1267	10.4863	8.6967
Tare Container	63.6375	62.9115	67.9254	75.5734	69.7503	71.6690
Wt. of Dry Soil	1.5442	1.7240	1.6936	2.7645	2.4005	1.9896
Moisture Content w%	614	616	614	438	437	437

Average Values

$w_L = 473$
 $w_p = 429$
 $w_s = 98$
 $I_p = 44$
 $I_f = 306$
 $I_t = 0.144$

Plastic Limit

Trial No.	1	2	3
Container No.	W1	W2	W3
Wt. Sample Wet + Tare	41.391	38.162	38.734
Wt. Sample Dry + Tare	39.532	36.506	37.229
Wt. Water	1.859	1.656	1.605
Tare Container	39.098	36.120	36.756
Wt. of Dry Soil	0.434	0.386	0.373
Moisture Content %	429	429	430

Shrinkage Limit

Trial No.	1	2	3
Container No.	8	9	10
Wt. Sample Wet + Tare	133.741	129.247	124.414
Wt. Sample Dry + Tare	122.947	118.627	113.508
Wt. Water	10.795	10.620	10.906
Tare Container	121.033	116.890	111.689
Wt. of Dry Soil W _o	1.914	1.737	1.819
Moisture Content w%	563	611	600
Vol. Container V	12.35	12.25	12.90
Vol. Dry Soil Pat V _o	3.65	3.35	3.55
Shrinkage Vol. V - V _o	8.70	8.90	9.35
Shrinkage Limit w _s	108	100	87

$$w_s = w \left(\frac{V - V_o}{W_o} \times 100 \right)$$

Description of Sample: _____

Remarks: _____

UNIVERSITY of ALBERTA
 DEP'T of CIVIL ENGINEERING
 SOIL MECHANICS LABORATORY
ATTERBERG LIMITS

PROJECT Muskog^{re} research
 SITE Pembina Oil Fields
 SAMPLE #8
 LOCATION
 HOLE #5 DEPTH 4'
 TECHNICIAN RW DATE Oct 56

Liquid Limit

Trial No.	1	2	3	4	5	6
No. of Blows	7	7	8	33	35	34
Container No.	A2	A3	V28	A1	A21	A22
Wt. Sample Wet + Tare	79.5448	85.6793	84.3957	79.7466	89.5723	83.9398
Wt. Sample Dry + Tare	64.9910	70.1503	69.1940	66.3430	77.9387	72.1180
Wt. Water	14.5538	15.5290	15.2017	13.4036	11.6336	11.8218
Tare Container	62.9115	67.9254	67.0405	63.6375	75.5734	69.7503
Wt. of Dry Soil	2.0795	2.2249	2.1535	2.7055	2.3653	2.3677
Moisture Content w%	700	701	707	495	493	499

Average Values

$w_L = 538$
 $w_p = 641$
 $w_s = -$
 $I_p = -$
 $I_f = 311$
 $I_t = -$

Plastic Limit

Trial No.	1	2	3
Container No.	AV	BK	AD
Wt. Sample Wet + Tare	55.649	54.394	54.502
Wt. Sample Dry + Tare	54.609	53.420	52.621
Wt. Water	1.040	0.974	1.881
Tare Container	54.446	53.267	52.331
Wt. of Dry Soil	0.163	0.153	0.290
Moisture Content %	638	636	648

Shrinkage Limit

Trial No.			
Container No.			
Wt. Sample Wet + Tare			
Wt. Sample Dry + Tare			
Wt. Water			
Tare Container			
Wt. of Dry Soil W _o			
Moisture Content w%			
Vol. Container V			
Vol. Dry Soil Pat V _o			
Shrinkage Vol. V - V _o			
Shrinkage Limit w _s			

$$w_s = w \left(\frac{V - V_o}{W_o} \times 100 \right)$$

Description of Sample: _____

Remarks: _____

UNIVERSITY of ALBERTA
DEPT. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
ATTERBERG LIMITS

PROJECT Muskeg Research
SITE Pembina Oil Fields
SAMPLE # 9
LOCATION
HOLE # 5 DEPTH 61
TECHNICIAN: RW DATE Oct. 56

Liquid Limit

Trial No.	1	2	3	4	5	6
No. of Blows	10	9	8	32	31	32
Container No.	V42	V49	V50	V40	V41	V45
Wt. Sample Wet + Tare	80.7254	87.0705	104.3886	83.0025	80.6164	86.1328
Wt. Sample Dry + Tare	67.3290	73.3330	89.5015	72.6546	67.0334	72.0320
Wt. Water	13.3964	13.7375	14.8871	10.3479	13.5830	14.1008
Tare Container	65.5498	71.5841	87.6574	70.9537	64.7806	69.7035
Wt. of Dry Soil	1.7792	1.7489	1.8441	1.7009	2.2528	2.3285
Moisture Content $w\%$	752	785	805	603	603	603

Average Values

$w_L = 638$
 $w_p = 670$
 $w_s = -$
 $I_p = -$
 $I_f = 324$
 $I_t = -$

Plastic Limit

Trial No.	1	2	3
Container No.	BW	AJ	BI
Wt. Sample Wet + Tare	56.281	55.346	56.357
Wt. Sample Dry + Tare	54.938	54.173	55.158
Wt. Water	1.343	1.173	1.199
Tare Container	54.738	53.996	54.981
Wt. of Dry Soil	0.200	0.177	0.177
Moisture Content %	671	663	676

Shrinkage Limit

Trial No.			
Container No.			
Wt. Sample Wet + Tare			
Wt. Sample Dry + Tare			
Wt. Water			
Tare Container			
Wt. of Dry Soil W_o			
Moisture Content $w\%$			
Vol. Container V			
Vol. Dry Soil $Pat V_o$			
Shrinkage Vol. $V - V_o$			
Shrinkage Limit w_s			

$$w_s = w \left(\frac{V - V_o}{W_o} \times 100 \right)$$

Description of Sample: _____

Remarks: _____

UNIVERSITY of ALBERTA
DEPT. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
ATTERBERG LIMITS

PROJECT Muskeg Research
SITE Pembina Oil Fields
SAMPLE # 10
LOCATION
HOLE #5 DEPTH 8'
TECHNICIAN RW DATE Oct. 56

Liquid Limit

Trial No.	1	2	3	4	5	6
No. of Blows	10	10	9	30	30	29
Container No.	V51	V52	V53	V47	V48	A24
Wt. Sample Wet + Tare	82.3613	87.0347	79.7150	76.1806	87.0453	86.0236
Wt. Sample Dry + Tare	69.2925	72.9738	64.1382	66.0113	76.2300	74.6794
Wt. Water	13.0688	14.0609	15.6568	10.1693	10.8153	11.3442
Tare Container	67.1820	70.7273	61.6410	64.0160	74.0950	72.4316
Wt. of Dry Soil	2.1105	2.2465	2.4972	1.9953	2.1350	2.2478
Moisture Content $w\%$	619	624	626	510	507	505

Average Values

$w_L = 524$
 $w_p = 561$
 $w_s = -$
 $I_p = -$
 $I_f = 241$
 $I_t = -$

Plastic Limit

Trial No.	1	2	3
Container No.	1	2	3
Wt. Sample Wet + Tare	37.624	38.418	33.826
Wt. Sample Dry + Tare	35.972	36.677	36.793
Wt. Water	1.652	1.741	2.033
Tare Container	35.682	36.367	36.425
Wt. of Dry Soil	0.290	0.310	0.368
Moisture Content %	570	562	553

Shrinkage Limit

Trial No.			
Container No.			
Wt. Sample Wet + Tare			
Wt. Sample Dry + Tare			
Wt. Water			
Tare Container			
Wt. of Dry Soil W_o			
Moisture Content $w\%$			
Vol. Container V			
Vol. Dry Soil Pat V_o			
Shrinkage Vol. $V - V_o$			
Shrinkage Limit w_s			

$$w_s = w \left(\frac{V - V_o}{W_o} \times 100 \right)$$

Description of Sample: _____

Remarks: _____

UNIVERSITY of ALBERTA
 DEP'T. of CIVIL ENGINEERING
 SOIL MECHANICS LABORATORY
ATTERBERG LIMITS

PROJECT Muskeg Research
 SITE Pembina Oil Fields
 SAMPLE # 11
 LOCATION
 HOLE #5 DEPTH 9'-6"
 TECHNICIAN RW DATE Oct 56

Liquid Limit

Trial No.	1	2	3	4	5	6
No. of Blows	9	11	9½	37	38	40
Container No.	V13	V16	V23	A23	A24	V11
Wt. Sample Wet + Tare	84.5195	74.5690	81.8060	83.8463	82.7528	88.7239
Wt. Sample Dry + Tare	73.7168	63.5094	69.0758	75.2318	74.3767	79.7759
Wt. Water	10.8027	11.0596	12.7302	8.6145	8.3761	8.9480
Tare Container	71.0344	60.6227	65.9928	72.4316	71.6690	76.876
Wt. of Dry Soil	2.6824	2.8867	3.0830	2.8002	2.7077	2.8943
Moisture Content w%	402	383	412	307	310	309

Average Values

$$w_L = 337$$

$$w_p = 345$$

$$w_s = -$$

$$I_p = -$$

$$I_f = 166$$

$$I_t = -$$

Plastic Limit

Trial No.	1	2	3
Container No.	4	5	6
Wt. Sample Wet + Tare	39.405	40.395	39.142
Wt. Sample Dry + Tare	37.698	38.533	37.441
Wt. Water	1.707	1.862	1.701
Tare Container	37.214	37.999	36.935
Wt. of Dry Soil	0.484	0.534	0.506
Moisture Content %	353	349	336

Shrinkage Limit

Trial No.			
Container No.			
Wt. Sample Wet + Tare			
Wt. Sample Dry + Tare			
Wt. Water			
Tare Container			
Wt. of Dry Soil W _o			
Moisture Content w%			
Vol. Container V			
Vol. Dry Soil Pat V _o			
Shrinkage Vol. V - V _o			
Shrinkage Limit w _s			

$$w_s = w \left(\frac{V - V_o}{W_o} \times 100 \right)$$

Description of Sample: _____

Remarks: _____

UNIVERSITY of ALBERTA
DEP'T of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
ATTERBERG LIMITS

PROJECT Muskeg Research
SITE Pembina Oil Fields
SAMPLE # 23
LOCATION
HOLE #7 DEPTH 9'-3"
TECHNICIAN RW DATE Oct 56

Liquid Limit

Trial No.	1	2	3	4	5	6
No. of Blows	7	8	7½	24	25	23
Container No.	V49	V52	V45	A1	V13	V28
Wt. Sample Wet + Tare	87.1683	83.3134	84.8627	80.6365	85.5609	82.6576
Wt. Sample Dry + Tare	76.4324	74.9183	74.6190	70.4730	76.9571	73.2026
Wt. Water	10.7359	8.3951	10.2437	10.1635	8.6038	9.4550
Tare Container	71.5341	70.7273	69.7035	63.6375	71.0344	67.0405
Wt. of Dry Soil	4.8483	4.1910	4.9155	6.8355	5.9227	6.1621
Moisture Content w%	222	200	209	149	145	153

Average Values

$w_L = 147$
 $w_p = 121$
 $w_s = -$
 $I_p = 26$
 $I_f = 121$
 $I_t = 0.215$

Plastic Limit

Trial No.	1	2	3
Container No.	BK	AD	AV
Wt. Sample Wet + Tare	56.080	55.547	56.701
Wt. Sample Dry + Tare	54.524	53.768	55.501
Wt. Water	1.556	1.779	1.200
Tare Container	53.267	52.331	54.446
Wt. of Dry Soil	1.257	1.437	1.055
Moisture Content %	124	124	114

Shrinkage Limit

Trial No.			
Container No.			
Wt. Sample Wet + Tare			
Wt. Sample Dry + Tare			
Wt. Water			
Tare Container			
Wt. of Dry Soil W _o			
Moisture Content w%			
Vol. Container V			
Vol. Dry Soil Pat V _o			
Shrinkage Vol. V - V _o			
Shrinkage Limit w _s			

$$w_s = w \left(\frac{V - V_o}{W_o} \times 100 \right)$$

Description of Sample: _____

Remarks: _____

DATA SHEET No. 20.

ANGULAR DEFORMATION IN $\frac{5}{8}$ " DRILL STEMS

TORQUE- Ft-lbs				
	40	80	120	160
LENGTH Ft				
4	5	12	20	30
6	10	20	25	35
8	12	28	42	58
10	14	30	45	58
12	15	34	55	75
14	18	37	60	85
16	19	42	70	105
18	20	47	75	110
20	25	64	95	130
22	30	65	100	142
24	35	75	115	155

TABLE NO. 1

SUMMARY OF RESULTS OF A THERMOGRAVIMETRIC ANALYSIS
 RUN ON SAMPLES OF DISPERSED ASKING FROM PEMBINA OIL FIELDS

Sample No.	Depth (feet)	w%	Ash Content	Shear (#/sq.ft)	w ₁ %	w ₂ %	w ₃ %	I _p	I _f	I _t
2	4	613	11	378	468	619	219	-	322	-
3	6	715	9	300	532	691	268	-	553	-
4	8	573	17	432	460	688	213	-	289	-
5	10	478	37	480	473	429	98	44	306	0.144
8	4	687	11	288	538	641	-	-	311	-
9	6	850	8	330	638	670	-	-	324	-
10	8	617	13	600	524	561	-	-	241	-
11	9'-6"	432	37	528	337	345	-	0	166	-
23	9'-3"	188	82	575	147	121	-	26	121	0.215

Hole No.	Depth	Torque	Length of Drill Stem	Angular Deformation	Twist in Drill Stem	Angular Deformation in Soil	Shear Strength	Hole No.	Depth	Torque	Length of Drill Stem	Angular Deformation	Twist in Drill Stem	Angular Deformation in Soil	Shear Strength
1 (DEI) V								3 (DEI) C							
1 45	2	70	4	66	270			2 160	2	160	12	160	160	100	
2 55	2	50	4	46	330			4 170	6	100	39	61	850		
4 63	6	60	11	46	378			6 125	6	120	28	92	625		
6 50	6	50	11	39	300			8 155	10	125	53	67	775		
8 72	10	80	27	53	432										
10 80	10	60	30	30	480			10 (DEI) D							
2 (DEI) V								1 80	2	80	6	74	100		
1 45	2	50	4	46	270			2 100	2	90	8	82	500		
2 45	2	50	4	46	270			4 105	6	85	24	61	520		
4 68	6	70	15	55	408			6 80	6	55	18	37	400		
6 55	6	60	12	48	330			8 100	10	90	37	53	500		
8 65	10	65	24	41	390			11 (DEI) D							
10 70	10	70	26	44	420			1 75	2	65	6	59	375		
3 (DEI) V								2 85	2	55	7	48	425		
1 55	2	60	4	56	330			4 130	6	120	29	91	650		
2 70	2	70	5	65	420			6 80	6	60	10	42	400		
4 75	6	60	17	43	450			8 85	10	80	32	48	425		
6 45	6	60	10	50	270			9 105	10	90	39	51	525		
8 75	10	70	28	42	450			12 (DEI) D							
10 65	10	55	24	31	390			1 75	2	70	6	64	375		
4 (DEI) D								2 85	2	65	7	53	425		
1 65	2	50	5	45	390			4 95	6	85	21	64	475		
2 88	2	80	7	73	528			6 75	6	65	17	48	375		
4 50	6	55	11	44	300			8 60	10	65	22	43	300		
6 53	6	60	12	48	318			9 95	10	75	35	40	475		
8 82	10	70	31	39	492			13 (DEI) C							
10 80	10	70	30	40	480			1 145	2	100	11	89	1030		
5 (DEI) D								2 155	6	110	35	105	775		
1 67	2	65	5	60	402			4 160	6	115	36	79	800		
2 67	2	70	5	65	402			6 100	6	80	22	58	500		
4 43	6	55	11	44	286			8 145	10	130	54	76	805		
6 55	6	60	12	48	330			14 (DEI) C							
8 100	10	80	37	43	600			1 160	2	115	12	103	800		
10 90	10	100	33	67	540			2 170	6	140	39	101	850		
6 (DEI) D								4 160	6	115	36	79	300		
1 60	2	55	5	50	360			6 130	6	105	27	76	650		
2 90	2	90	7	83	540			8 135	10	130	50	80	750		
4 50	6	55	11	44	300										
6 55	6	60	12	48	330										
8 98	10	70	36	34	588										
10 90	10	100	33	67	540										
7 (DEI) C															
1 117	2	100	9	91	702										
2 117	2	80	9	71	702										
4 105	6	70	24	46	630										
6 110	6	115	25	90	660										
8 110	10	120	52	63	700										

Block 1, TSD 6, SNO 15-42-8-15

Hole No.	Depth	Torque	Length of Drill Stem	Angular Deformation	Twist in Drill Stem	Angular Deformation in Soil	Shear Strength	Hole No.	Depth	Torque	Length of Drill Stem	Angular Deformation	Twist in Drill Stem	Angular Deformation in Soil	Shear Strength
1 (BDI) V								1 (BDI) V							
1	65	2	60	5	55	325		1	30	2	50	2	48	150	
2	35	2	70	5	65	325		2	75	2	55	4	50	275	
4	80	6	80	13	62	400		4	65	6	70	15	55	325	
6	70	6	75	16	59	350		6	55	6	60	15	45	325	
8	85	10	80	32	42	425		8	100	10	100	37	53	500	
2 (BDI) V								10	120	10	100	45	55	600	
1	40	2	70	3	67	200		2 (BDI) V							
2	37	2	55	3	52	185		1	20	2	60	2	50	150	
4	63	6	60	15	45	340		2	70	2	70	5	65	350	
6	70	6	75	16	59	350		4	65	6	75	15	60	325	
8	75	10	90	28	62	375		6	55	6	55	12	43	275	
9	105	10	90	38	51	525		8	80	10	85	30	55	400	
3 (BDI) V								9	115	10	90	43	47	575	
1	35	2	65	3	62	175		3 (BDI) V							
2	60	2	70	5	65	300		1	30	2	60	2	50	150	
4	75	6	60	17	43	375		2	50	2	50	4	46	250	
6	75	6	60	17	43	375		4	60	6	60	13	47	300	
8	85	10	90	32	58	425		6	70	6	65	16	42	350	
9	115	10	100	43	57	575		8	100	10	100	37	63	500	
4 (BDI) C								9	135	10	110	50	60	675	
1	115	2	90	9	81	575		4 (BDI) C							
2	130	6	80	29	51	650		1	120	2	80	9	71	600	
4	120	6	100	27	73	600		2	112	6	75	25	50	560	
6	100	10	75	37	38	500		4	95	6	90	21	69	475	
5 (BDI) C								6	85	10	80	32	48	425	
1	112	2	80	9	71	560		8	120	10	120	45	75	600	
2	175	6	120	40	80	875		8-10	115	10	120	43	77	575	
4	110	6	100	25	75	550		5 (BDI) C							
6	100	10	80	37	43	500		1	125	2	100	10	90	625	
6 (BDI) C								2	135	2	80	11	69	675	
1	125	2	120	10	110	780		4	75	6	70	17	53	375	
2	135	6	75	30	45	675		6	85	6	75	19	56	425	
4	120	6	100	27	73	600		8	110	10	115	41	74	550	
6	115	10	85	43	42	575		7 (BDI) C							
7 (BDI) D								1	135	2	95	11	84	675	
1	65	2	65	5	60	325		2	110	2	70	8	62	540	
2	75	2	60	6	54	375		4	90	6	95	20	75	450	
4	155	6	120	35	85	775		6	85	6	75	19	56	425	
6	80	6	55	18	37	400		8	120	10	130	45	85	600	
8	105	10	90	39	51	525		8 (BDI) V - cleared							
8 (BDI) D								1	28	2	60	2	58	140	
1	85	2	65	7	58	425		2	55	2	70	4	60	275	
2	75	2	55	6	49	375		4	130	6	95	20	80	650	
4	110	6	90	25	65	550		6	70	6	75	18	53	350	
6	30	6	55	10	37	400		8	80	10	85	30	52	440	
8	110	10	100	41	59	550		9	93	10	85	35	45	465	
9 (BDI) D								9 (BDI) V - cleared							
1	82	2	75	6	69	410		1	40	2	55	2	53	115	
4	75	6	75	17	56	375		2	75	6	105	17	86	375	
6	85	6	60	19	41	425		4	70	6	90	16	74	350	
8	105	10	105	39	66	600		6	55	10	65	20	45	275	
								8	160	10	90	37	55	500	
								10 (BDI) V - cleared							
								1	55	2	60	4	54	275	
								2	55	2	75	14	63	375	
								4	95	10	120	35	85	600	
								6	85	10	85	35	61	440	
								8	160	10	90	37	55	500

RELATIONSHIPS BETWEEN SHEARING STRENGTHS, ASH & MOISTURE CONTENTS & DEPTH
VIRGIN MUSKEG.

MOBILE OIL, BLOCK No 1, WELL No 15-6. MOLE No 1, RAPPORT CLASSIFICATION DFI JULY 1936. RYND

RELATIONSHIPS BETWEEN SHEARING STRENGTHS, ASH & MOISTURE CONTENTS & DEPTH

MUSKEG 30' FROM DRAINAGE DITCH

MOBIL OIL, BLOCK NO. 1, WELL 15.6, MOLE NO. 5, RAPFORTH CLASSIFICATION DFI July 56 R34d

MUSKEG CONSOLIDATED UNDER 400 #/sq FOR 21 MONTHS

RELATIONSHIPS BETWEEN SHEARING STRENGTHS, ASH & MOISTURE CONTENTS & DEPTH
VIRGIN MUSKEG

MOBILE OIL, BLOCK 3, WELL NO. 5-2, HOLE NO. 3, RADFORTH CLASSIFICATION B.D.1 AUG 56 RYLD

PLASTICITY CHART

ANGULAR DEFORMATION VS. DEPTH
FOR DEI MURKES-FLMUNA

Angular Deformation (Degrees)

Consolidated & Drained

#7-0 #8-B #13-B #14-1

Drained

#4-0 #5-B #6-A #10-X #11-1 #12-X

Virgin

Hole #1-0 #2-B #3-A

CHART FOR DETERMINATION OF ANGULAR DEFORMATION
IN DRILL STEMS FROM 2" TO 24" IN LENGTH AND
FOR APPLIED TORQUES FROM 0 TO 160 FT LBS

SCALE 1 1/2" = 1'-0"

RN56

SCALE 1/2 FULL SIZE

R.V.
55

1 1/2"

4' LENGTHS AS REQ'D

4' LENGTHS AS REQ'D

COUPLING

- MACHINED TO 1 3/32"

- BRONZE BUSHING

- I.D. BUSHING 39/64"

- O.D. BUSHING 1 7/8"

- INSIDE OF PIPE SCHEDULES REBROD
TO 1 3/8" DIA.

SCALE 1/2 FULL SIZE

R-56

SCALE 1/2 FULL SIZE

BIBLIOGRAPHY

1. N. W. Radforth, " Suggested Classification of Muskeg for the Engineer," Engineering Journal November, 1952.
2. Captain S. Thomson, R.C.E., " An Investigation into the Engineering Properties of Muskeg, " Thesis, Department of Civil Engineering, University of Alberta.

Additional Reference Material for Background and Current Information;

3. Lea and Benedict, " Foundation Vane Tester," N.R.C. Tech Memo No. 27.
4. Fenske, "Deep Vane Tests in the Gulf of Mexico, " A.S.T.M. Pam 90 b.
5. Hvorslev, " Subsurface Exploration and Sampling of Soils, " Rotary Vane Tests, page 475.
6. Vey and Schlesinger, " Soil Shear Tests by Means of Rotating Vanes," Proceedings of Highway Research Board, Vol 29 (1949).
7. Hamilton Gray, " Vane Shear Tests of Sensitive Cohesive Soils," Proceedings ASCE July 1955, Vol 81, Paper No. 755.

Appendix No. 1

COMPUTATION OF VANE SIZE

In computing the size of the vane the following points are to be considered.

- a) Shearing strength = Torque applied X 5
- b) The ratio of height to diameter to be 2 or more.
- c) Area upon which the shearing strength acts is side area plus one end area.

From Equation No. 2

$$T = S \times 2\pi r^2 (h + r/3)$$

$$\text{and as } S = 5 T$$

$$1 = 10 \pi r^2 (h + r/3)$$

Trial # 1.

$$\text{Letting } r = 0.25 \text{ feet then } h = 0.425'$$

$$h/D = 0.85$$

Trial # 2.

$$\text{Letting } r = 2 \frac{1}{4}'' \text{ then } h = 10.1''$$

$$h/D = 2.25$$

USE VANE WITH Diameter = 4.5 " and Height = 10.1 "

THEORY OF THE

THEORY OF THE

THEORY OF THE

$$\begin{aligned} & \frac{1}{2} \left(\frac{1}{2} + \frac{1}{2} \right) = 1 \\ & \frac{1}{2} \left(\frac{1}{2} + \frac{1}{2} \right) = 1 \\ & \frac{1}{2} \left(\frac{1}{2} + \frac{1}{2} \right) = 1 \end{aligned}$$

THEORY OF THE

$$\begin{aligned} & \frac{1}{2} \left(\frac{1}{2} + \frac{1}{2} \right) = 1 \\ & \frac{1}{2} \left(\frac{1}{2} + \frac{1}{2} \right) = 1 \end{aligned}$$

THEORY OF THE

$$\begin{aligned} & \frac{1}{2} \left(\frac{1}{2} + \frac{1}{2} \right) = 1 \\ & \frac{1}{2} \left(\frac{1}{2} + \frac{1}{2} \right) = 1 \end{aligned}$$

$$\begin{aligned} & \frac{1}{2} \left(\frac{1}{2} + \frac{1}{2} \right) = 1 \\ & \frac{1}{2} \left(\frac{1}{2} + \frac{1}{2} \right) = 1 \end{aligned}$$

SUGGESTED CLASSIFICATION OF MUSKEG FOR THE ENGINEER

by Norman W. Radforth

Coverage Type (Class)	Woodiness vs Non-Woodiness	Stature (approx height)	Texture (where required)	Growth Habit	Example
A	Woody	15 ft. or over		Tree form	Spruce, Larch
B	Woody	5 to 15 ft.		Young or dwarfed tree or bush	Spruce, Larch Willow, Birch
C	Non-woody	2 to 5 ft.		Tall grass like	Grasses
D	Woody	2 to 5 ft.		Tall shrub or very dwarfed tree	Willow, Birch Labrador Tea
E	Woody	0 to 2 ft.		Low shrub	Blueberry Laurel
F	Non-woody	0 to 2 ft.		Mats, clumps or patches sometimes touching	Sedges Grasses
G	Non-woody	0 to 2 ft.		Singly or loose association	Orchid or pitcher plant
H	Non-woody	0 to 4 in.	leathery to crisp	mostly continuous mats	Lichens
I	Non-woody	0 to 4 in.	soft or velvety	often continuous mats sometimes in hummocks	Mosses

APPENDIX NO. 3COMPONENT PARTS AND PRICE LIST FOR THE ACKER DRILL
COMPANY INCORPORATED VANE SHEAR TEST KIT.

Acker Drill Co. Inc., 725 West Lackawanna Avenue,
Scranton 3, Pennsylvania.

Item		Price
1.	1 - 2" Vane - use with 2½" drive pipe	25.00
2.	1 - 2½" Vane - use with 3" drive pipe	28.50
3.	1 - 3 5/8" Vane - use with 4" drive pipe	31.00
4.	4 - Ball bearing guides - 1 for each 25' depth	
	for 2½" drive pipe @ 14.50 ea	58.00
5.	for 3" drive pipe @ 14.50 ea	58.00
6.	for 4" drive pipe @ 18.00 ea	72.00
7.	1 - Thrust bearing guide for use with E or A Drill rods	36.50
8.	1 - Collar with set screws for E or A rods	5.25
9.	1 - Adapter E or A rod to Torque Wrench	8.50
10.	1 - Torque Wrench - 0 to 150 inch-pounds	46.75
11.	1 - Torque Wrench - 0 to 600 inch-pounds	35.75
12.	1 - Coupling for 2½" drive pipe (2½ x 3)	2.50
13.	1 - Coupling for 3" drive pipe (3 x 3)	3.00
14.	1 - Coupling for 4" drive pipe (4 x 3)	3.85
15.	1 - Carrying Case	24.75
	TOTAL	\$ 439.35
	Price when complete kit is ordered	\$ 396.00

For export add 8% to the above prices.
All prices F.O.B. Scranton, Pa. 1956.

Gross weight 150 lbs. Volume 3 cu.ft.

THEORETICAL CALCULATIONS OF ANGULAR TWIST IN DRILL STEMS.

From the theory of torsion,

$$\theta = \frac{M_t}{G \cdot I_p}$$

where θ = twist in radians per unit length

M_t = torque

G = Modulus of Rigidity

$$I_p = \frac{\pi d^4}{32}$$

To express twist as degrees per foot of length using torque in foot-pounds and assuming $G = 12 \times 10^6$ psi, this equation becomes,

$$\theta \left(\frac{\text{radians}}{\text{foot}} \right) = \frac{M_t \text{ (foot-pounds)}}{144(12 \times 10^6) \times \frac{\pi}{32} \times \frac{5^4}{8^4} \times \frac{1}{(12)^4}}$$

which reduces to,

$$\theta = 0.046 (M_t) \text{ degrees/foot.}$$

The following table is produced using this formula.

M_t	θ	Total angle of twist in degrees for lengths in feet					
ft.lbs.	$\frac{\text{degrees}}{\text{foot}}$	2	4	6	8	10	12
40	1.84	3.68	7.36	11.04	14.72	18.40	22.08
80	3.68	7.36	14.72	22.08	29.44	36.80	44.16
120	5.52	11.04	22.08	33.12	44.16	55.20	66.24
160	7.36	14.72	29.44	44.16	55.88	73.60	88.32

Plate no. 1 to Appendix 4 presents the above table in graphical form on page 76.

 

Comparison to the values obtained by measurement of the angular twist in the drill stem is shown by the dashed lines.

The discrepancies are due to,

a. assumptions in theory of torsion

b. assuming G as 12×10^6 psi

c. the theoretical values do not take into account the enlarged cross-sectional areas at all couplings of the drill stem, which occurred at the 2, 6 and 10 foot lengths and gave a total length of drill stem with increased cross-sectional area of about 27 inches in a ten foot length.

Due to these discrepancies, corrections for angular deformation were taken from the graph as shown on plate no. 13 page 63, which is plotted from direct measurements.

DETERMINATION OF TWIST IN DRILL STEM

FOR LENGTHS OF 2', 10', 12' AND

FOR TORQUES UP TO 100 FT.

Theoretical ———

Measured - - - -