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Determination of the Viscosities and Specific Gravities of the Oils in Samples of Athabaska Bituminous Sand

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ATHABASKA BITUMINOUS SANDS

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Abstract

The difficulty of making viscosity and specific gravity determinations on the oil in Athabaska bituminous sand is that there is no method available for getting the oil out of the sand without altering it. A method of extracting the oil from the bituminous sand in a standardized, reproducible way and of correcting the viscosity and specific gravity measurements on the recovered oil for the alteration of it that has taken place has been devised. The viscosity-temperature relationships for the oils from several bituminous sands from locations widely separated over the bituminous sand area and from several beds at different elevations at Bitumount have been determined. Also, a relationship between the viscosity of a bituminous sand oil at 84.4°F. and its specific gravity at 77°F./77°F. has been established. Results show that at 50°F. which is about the temperature of bituminous sand beds at the fresh face of a quarry, the viscosity of the oil in the southern part of the bituminous sand area in the neighborhood of McMurray is 100 times that of the oil in the northern part around Bitumount. The viscosity varies considerably from bed to bed throughout the 60 foot thickness of bituminous sand exposed at Bitumount. The specific gravities, 77°F./77°F. of bituminous sand oils examined vary over the range 1.002 - 1.027.

METHOD OF APPROACH TO THE PROBLEM

The viscosity and the specific gravity of the oil in a sample of Athabaska bituminous sand are fundamental physical properties of that oil about which it is of interest and importance to have knowledge. It is known that the oils in bituminous sands from different locations and even from beds at different elevations at the same location are not identical. The determination of viscosity and specific gravity values provides a means for studying these variations. Any consideration of bituminous sand which involves flow of the oil through it necessitates knowledge of viscosity in specific terms. A method for making viscosity and specific gravity measurements on the oil in a bituminous sand sample is, consequently, of value.

The problem involved in determining the viscosity or specific gravity of the oil in a sample of Athabaska bituminous sand is how to get the oil in hand for measurement purposes. Given the oil, measurements can be made by well-known methods. But there is no method available for getting the oil out of a bituminous sand sample without altering it. The only line of approach seems to be to extract the oil from the sample by a standardized extraction procedure, to make measurements on the extracted, altered oil and then to correct the measurement for the alteration to the oil that has taken place.

Extraction of the oil from a bituminous sand sample with benzene and evaporation of the benzene for recovery of the oil is one way of getting the oil out of the sample for measurements. The recovered oil will not be the same as the oil in the sample. Some benzene will be left in it and some of the original oil will be carried away during the evaporation of the benzene. To be useful, the extracting and evaporating operations must be standardized so that the recovered oil from repeat applications of the method to any one bituminous sand sample will be identical ,or very nearly so.

Oil can be extracted from bituminous sand by the hot water separation process (1). The oil so obtained has a considerable mineral matter content and a very high water content. The water can be eliminated by evaporation. (3) However, about three percent of the light ends of the oil are carried out with the steam. Mineral matter can be reduced to two or three percent of fine clayey material by settling. The final oil is altered but, except for mineral matter, there is nothing in it that does not belong in the oil.

A system for correcting the viscosities of oils recovered by a standardized benzene extraction and evaporation method can be established by use of oil obtained by the hot water process and subsequently dried. The viscosity of the latter at some convenient temperature is measured. A sample of this same oil is dissolved in benzene and is recovered from the benzene solution by the standardized procedure. The viscosity of the recovered oil will differ from that of the original oil by some observed amount. The dry reference oil can be made more viscous by heating it at a moderate temperature for some time. The viscosity of the oil so heated is measured at the chosen temperature. It is dissolved in benzene and recovered again by the standardized procedure. The viscosity of this recovered oil will differ from the viscosity of its original oil by an observed amount which will not be the same as the former difference. By proceeding in this way with dry oils made more and more viscous by longer periods of heating, data are secured for plotting a curve relating the viscosities of benzene-recovered oils with the percents by which they differ from the viscosities of the original oils. With the correction curve established, benzene extractions of bituminous sand samples can be made, the viscosity determination can be made on the recovered oil and this viscosity can be corrected to that corresponding to the oil actually present in the bituminous sand.

This method of arriving at the viscosity of the oil in a bituminous sand sample involves two assumptions. One is that the dry oil obtained through hot water separation and made more viscous by heating is essentially identical with an oil of the same viscosity occurring in a bituminous sand. The other is that the oils in all bituminous sand samples are similar in that they are altered in the same way by recovery by the standardized benzene extraction method.

The specific gravities of oils in bituminous sand samples can be determined in a way analogous to that for determining viscosities. However, instead of setting up a curve for the percentage corrections to be applied to the specific gravity measurements on benzene-recovered oils it is advantageous to relate these specific gravities to the corresponding viscosities of recovered oils. A similar relationship is set up for the original oils. When an oil is extracted and recovered from a bituminous sand, its viscosity and its specific gravity are determined. These two values should plot to give a point on the established curve. If they do so it is assurance that the bituminous sand contains an oil to which the scheme of viscosity and specific gravity determinations has been fitted. The corrected viscosity is then determined by use of the correction curve and the correct specific gravity is obtained from the second specific gravity—viscosity curve.

VISCOSITY DETERMINATION

VISCOMETER

The requirements for a viscometer that would be suitable for the study of the viscosities of Athabaska bituminous sand oils were that accurate measurements on a viscous oil over a wide range of viscosity could be made with it quickly on a small sample and that it should be easy and inexpensive to construct. A viscometer described by Traxler and Schweyer (4) was chosen. The instrument and assembly are indicated in Fig. 1. It is a pressure capillary tube viscometer. The theory of this viscometer is based on Poiseuille's Law for Newtonian fluids in viscous motion. Viscosity values are calculated by a modification of Poiseuille's Law

$$V = \frac{\pi P r^4 t}{8 L \eta}$$

consisting of substituting $\pi r^2 d$ for V

$$\pi r^2 d = \frac{\pi P r^4 t}{8 L \eta}$$

$$\eta = \frac{P r^2 t}{8 L d}$$

where V=volume of fluid in cubic centimeters
η=viscosity in poises,

P=pressure in dynes per square centimeter,

r=radius of the tube in centimeters,

t=time in seconds,

d=distance of advance of the oil in the tube during time t, in centimeters,

L—distance from the end of the tube where the oil enters to a point midway between the points at which the end of the oil column starts and to which it reaches during a determination, in centimeters.

The bore of a tube used for measurements must be calibrated carefully. Tubes of different bore are needed for different ranges of viscosity. The bore of some of these tubes may be too large to be properly described as capillary.

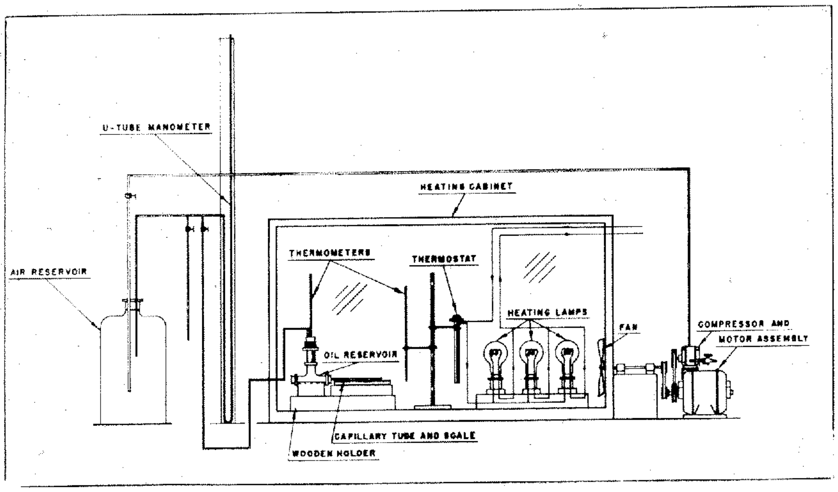

Fig. 1—Diagrammatic Sketch of Apparatus Used for Viscosity Measurements

Throughout the study a viscosity value for an oil at a particular temperature was determined by making observations at four or five pressure gradients and averaging results. It was found that viscosity values determined in this way on duplicate oil samples would check one another within ± 3.5% for the highest viscosities measured.

BITUMINOUS SAND OIL IS A NEWTONIAN FLUID

The viscosity values obtained by measurements with a viscometer such as that used in this study are true values provided that the substance under test is a Newtonian liquid in viscous or streamline motion. When a Newtonian liquid is in viscous flow the velocity gradient or rate of shear is directly proportional to the frictional force between adjacent liquid layers.

Several samples of dry oil obtained from bituminous sand by the hot water extraction method and thickened to varying degrees by heating were examined to see if they were Newtonian liquids. The tests were made using the capillary viscometer. Pressure gradients were varied within the range for viscous flow. The fluid flow of each sample, then, would be proportional to the pressure used to force the fluid through the tube if it were a Newtonian liquid, according to Poiseuille's Law. Results are plotted in Figs. 2 and 3. It is apparent from the straight line relationship passing through the origin that the oils were Newtonian liquids. From these results and from

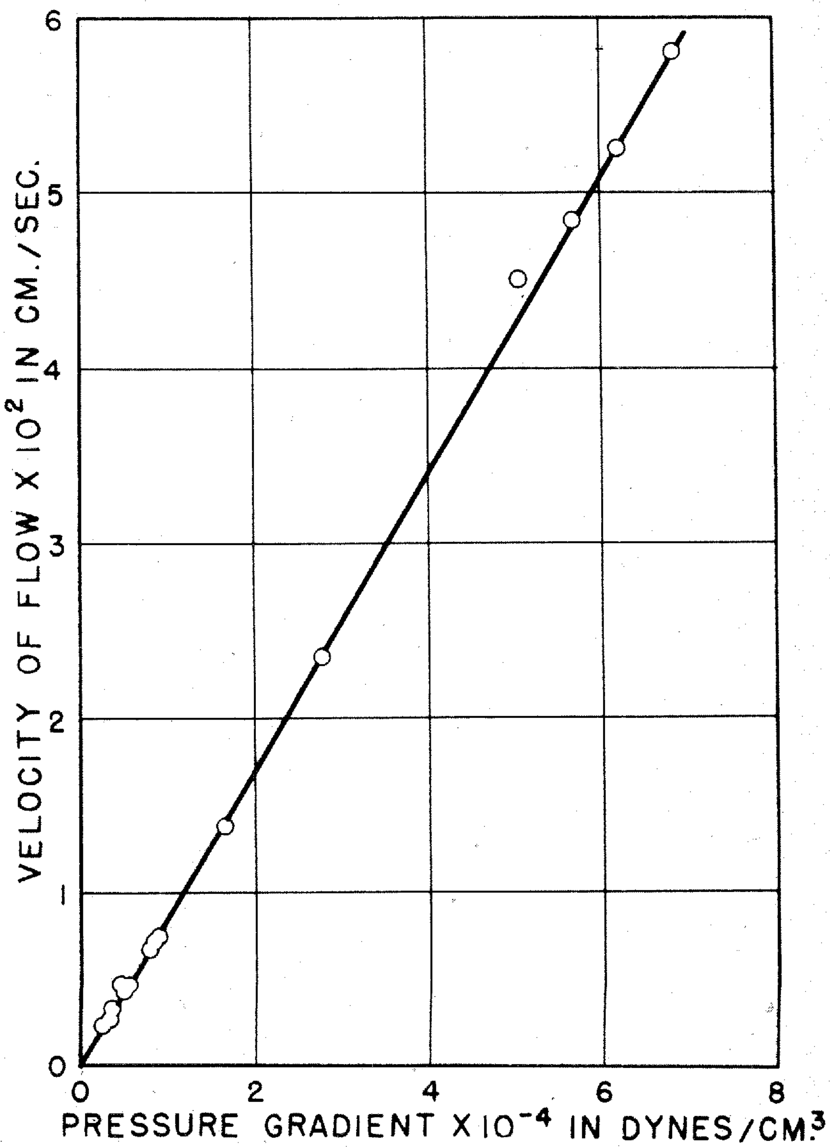

Fig. 2—Pressure Gradient—Velocity of Flow Relationship for a Bituminous Sand Oil of 875 Poises Viscosity at 84.4°F. Measurements were Made Using the Pressure Capillary Tube Viscometer.

the uniformity of the viscosity-temperature relationships presented later, it appears that Athabaska bituminous sand oils are essentially Newtonian in character. Since care was taken that all viscosity measurements were made with the oil sample in viscous motion, the determined viscosities are considered to be true values.

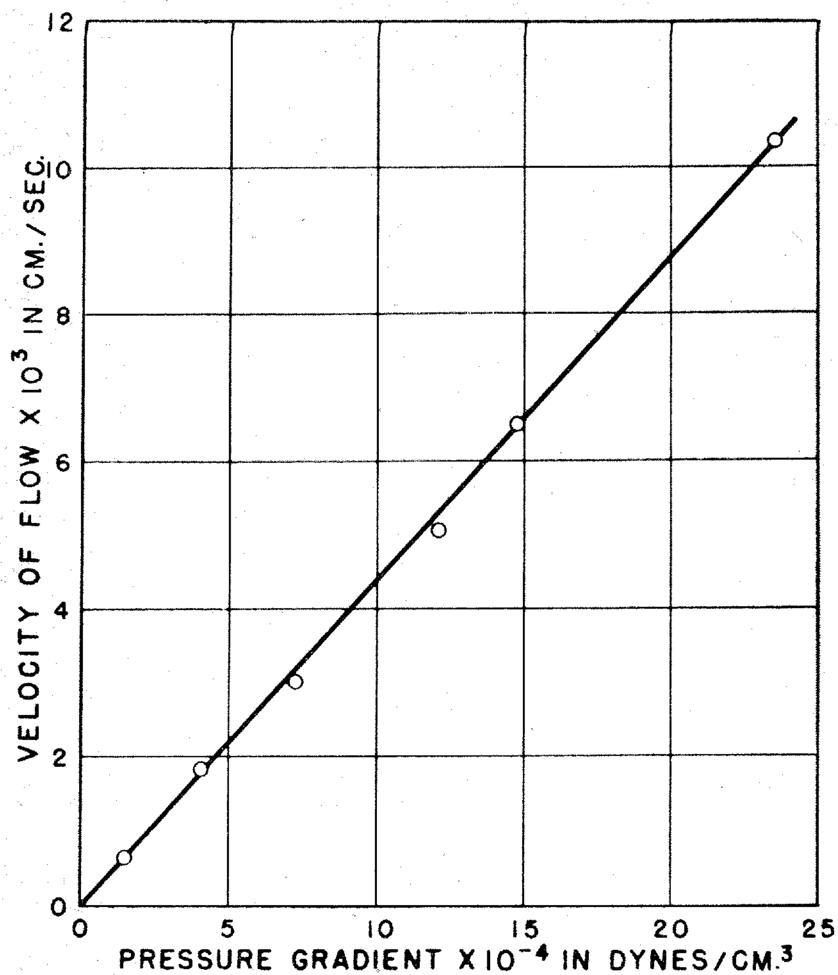

Fig. 3—Pressure Gradient—Velocity of Flow Relationship for a Bituminous Sand Oil Thickened by Evaporation to 16,000 Poises Viscosity at 84.4°F.

STANDARDIZED METHOD OF RECOVERING OIL FROM BITUMINOUS SAND FOR VISCOSITY MEASUREMENTS

The necessary requirement of a standardized method was that it would yield recovered oils from duplicate samples of the same supply of bituminous sand that had the same viscosities. Much work was expended in evolving a procedure that would satisfy these requirements. The method to be described gave recovered oils whose viscosities checked on duplicate determinations almost within the accuracy of the viscometer.

The fresh bituminous sand as received at the laboratory is mixed thoroughly and is stored in glass sealers. These sealers are turned upside down daily to prevent oil from draining from the top toward the bottom. The bituminous sand is analysed for content of water, mineral matter and oil. The water is determined by the A.S.T.M. (D 95-46) standard method of test for water in petroleum products and other bituminous materials. The mineral matter is determined by ignition of the bituminous sand. The oil is determined by difference. A quantity of the bituminous sand which contains about 90 gm. of oil is weighed in a beaker and is mixed with 250 cc. of benzene. The contents of the beaker are transferred to the bowl of a Dulin-Rotarex centrifugal filter and the benzene-oil solution is filtered off. The residue in the bowl is washed with 75 cc. of benzene followed by 90 cc. of benzene. The water, mineral matter and oil contents of the residue in the centrifuge bowl are determined after benzene has been allowed to evaporate. From the analytical data the concentration of oil in the filtered benzene-oil solution is calculated. Droplets of water settle from the benzene-oil solution during a settling period of 45 minutes or more. The solution is poured carefully from the settled water and is stirred thoroughly. Then a quantity of it calculated to contain 77.3 gm.* of oil is taken. This quantity is made up to a volume of 300 cc. by addition of benzene. The 300 cc. of solution are placed in a cupboard where the solution is allowed to evaporate at room temperature until a volume of 60 cc. of benzene remains in the solution.

The procedure for recovering dry oil from benzene solution is the same as that described except that 90 gm. of dry oil instead of bituminous sand containing 90 gm. of oil are stirred and dissolved in the 250 cc. of benzene. It is necessary to analyse the dry oil for mineral content so that the concentration of oil in the filtered benzene-oil solution can be determined. This solution, of course, does not deposit droplets of water on settling.

The final evaporation of the benzene from the solution is done in a special way. About 12 cc. of it are poured into an aluminum tray. This tray is 14 in. long, 10 in. wide with sides ¾ in. high and sloping at an angle of approximately 15° from the perpendicular. The solution is distributed evenly over the bottom of the tray by tipping it about. Excess solution is allowed to drain out of the tray. The tray is then placed in the cabinet in which the viscometer is housed. It is set against the end of the cabinet opposite the fan and is tipped away from the fan at an angle of 10° from the vertical. Five trays are needed for the total volume of solution. These are all put in the

*The reader will probably wonder why this value, and others that will be met further along in the text, were chosen. The explanation is, simply, that these values became established more or less fortuitously while doing exploratory research. If the work were repeated somewhat different values would be used. However, 77.3 gm. is as good a weight as, and no more difficult to attain than 77.0 gm., for instance.

cabinet one in front of the other with a sixth empty tray at the front. The arrangement is shown in Fig. 4. Nails placed in the back of the cabinet fix the location and position of each tray. The door of the cabinet is left open and the temperature inside the cabinet is maintained at an average of 79°F by means of the fan, thermoregulator and heating lamps. A period of 1½ min. is taken to pour the solution into the tray, distribute it, drain off the excess solution and place the tray in the cabinet. *Each tray is removed from the cabinet at exactly one hour after* starting its preparation. The film of oil on it is scraped off with a wooden scraper and is placed in a 25 cc. beaker. About 20 cc. of oil are recovered from the five trays. The recovered oil is stirred thoroughly before placing it in the viscometer for measurements.

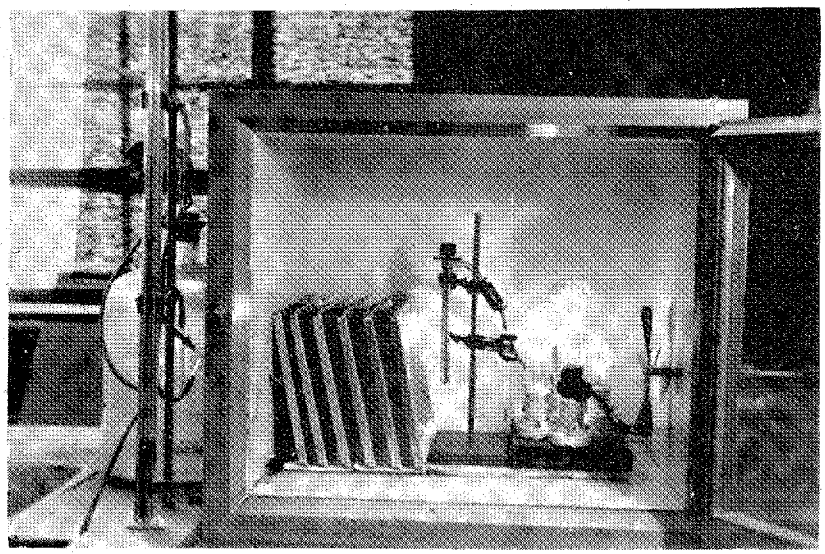

Fig. 4—A View of the Cabinet with the Trays Arranged in It for Evaporation of Benzene from Recovered Oil.

The procedure described, along with the particular cabinet, fan, trays, etc., used yielded recovered oils from the same supply of oil sand which had practically identical viscosities. Another investigator with his particular cabinet, accessories and technique would probably recover oils which checked with each other but not with those produced in this laboratory. Consequently it would be necessary for him to develop his own set of the correction curves which will be discussed in sections to follow.

CORRECTION OF VISCOSITY OF OIL SAMPLES FOR MINERAL MATTER CONTENT

All oil samples recovered from Athabaska bituminous sand contain mineral matter. Even when the sample is obtained by extraction with benzene by use of the Dulin-Rotarex centrifuge, some very fine mineral matter passes through the filter ring and gives a mineral matter content of from 0.1% to 0.5% to the recovered oil. When the sample is obtained by the hot water separation method, the mineral matter content is much higher. A supply of such oil was used in this study. After having been settled at 185°F for 24 hrs. and then dried, its mineral content was 3%. The viscosity of an oil is increased by the presence in it of mineral matter.

A curve showing the corrections to be applied to the observed viscosity of an Athabaska bituminous sand oil because of its mineral content was established. A quantity of the water-separated, settled and dried oil was heated at 266°F. for 30 hrs. During this heating period the viscosity was increased. But, also, considerable mineral matter settled. A series of oil samples of varying mineral contents was prepared for viscosity measurements. This was done by mixing different amounts of the oily settlings into samples of the settled oil. The mineral content of each sample was determined by igniting a portion of it and weighing the ash. Viscosity measurements were made at 84.4°F. The viscosity of the mineral-free oil was obtained by extrapolation of the plot of viscosities against percentage ash content. This viscosity was 23,600 poises. A plot of the increase in viscosity against ash content was then prepared. This plot is shown in Fig. 5.

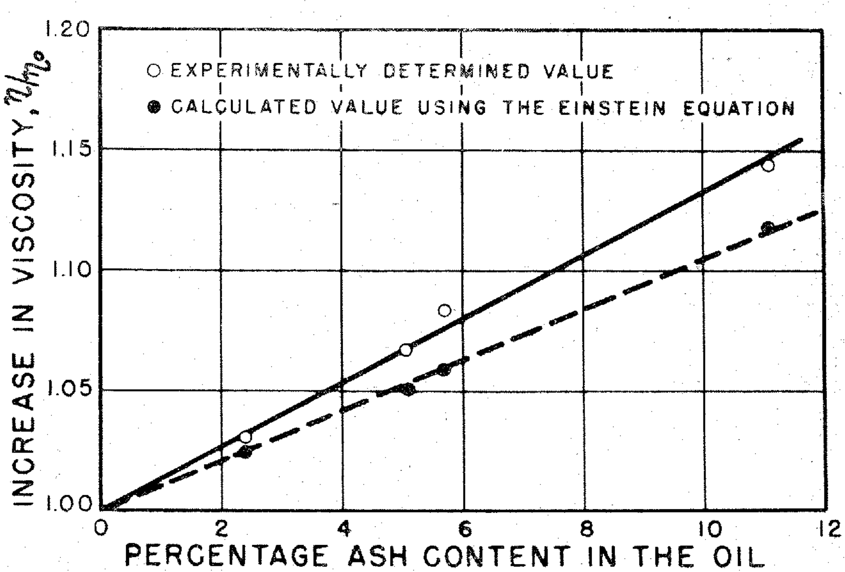

Fig. 5—Increase in Viscosity of Oil from Bituminous Sand Due to the Mineral Matter Content as Determined by Ignition.

The increase in the viscosity of a liquid due to the presence of non-solvated particles is given by the theoretical Einstein equation

$$\eta = \eta_0 (1 + Kc_v)$$

where η=viscosity of the suspension,

η_0=viscosity of the liquid,

c_v=volume of particles in 1 cc. of suspension,

K=constant.

The increase in viscosity according to the Einstein equation using the value of 2.5 for *K* (spherical particles) is shown by the broken line in Fig. 5. If 3.2 is used as the value for K, the equation fits the experimental data.

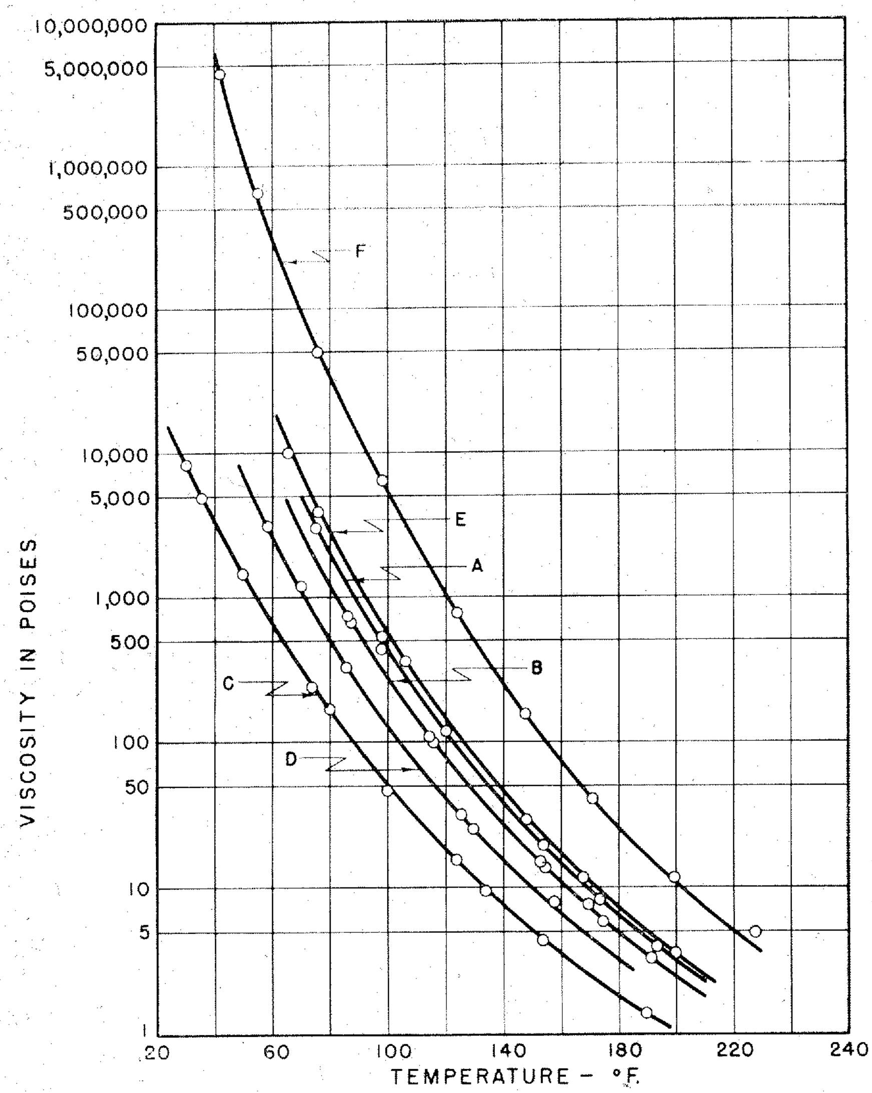

Fig. 6—Viscosity-Temperature Relationship for Six Altered Bituminous Sand Oils.

VISCOSITY—TEMPERATURE RELATIONSHIP FOR BITUMINOUS SAND OILS

The viscosities at various temperatures between 30°F. and 230°F. were measured for a number of altered bituminous sand oils. Although none of these oils was the actual oil in a bituminous sand, it was thought likely that the way in which their viscosities changed with temperature would be similar and that the viscosities of actual oil contents of bituminous sands would change in the same way. The viscosity-temperature relationships for the oils are shown in Fig. 6. The oils used were:

Oil A—From the supply of oil prepared by settling and drying oil obtained by the hot water separation of bituminous sand from Bitumount.

Oil B—Oil obtained by benzene extraction of bituminous sand from Bitumount.

Oil C—Oil A to which 8.5% of light ends obtained during the drying operation were added.

Oil D—Oil A to which 4% of light ends were added.

Oil E—Oil A made more viscous by heating at 266°F. for 28 hrs.

Oil F—Oil A made more viscous by heating at 266°F. for 30 hrs.

Examination of Fig. 6 shows that any of the curves can be superimposed on any other by shifting the curve along the horizontal axis. This means that the viscosity-temperature curve for any bituminous sand oil can be drawn if one accurate viscosity value for it is available.

VISCOSITY CORRECTION CURVE

An ample supply of dry bituminous sand oil was on hand. This supply had been prepared from wet oil produced by the Oil Sands Ltd. hot water separation plant in 1944, operating on bituminous sand at Bitumount. In the laboratory a barrel of this oil was settled at 185°F. for 24 hrs. eliminating sand and coarse silt. The wet, settled oil was pumped through a heater which raised its temperature to 315°F. and converted it into an oil-steam foam. The steam escaped from the foam in a separator. Dry oil was drawn from the separator. About 3% of light ends of the oil were carried out by the steam. This light oil was condensed with the steam and was recovered from it. The dry oil contained about 3% of clayey mineral matter. The loss of light ends increased the viscosity of the dry oil. But since the oil in Bitumount bituminous sand is among the least viscous of the oils in Athabaska bituminous sands, the viscosity of the dry oil supply was well within the range of viscosity for bituminous sand oils in general.

A series of oils of varying viscosity was prepared by heating quantities of the dry oil at 266°F. for varying lengths of time. The viscosities of these oils at 84.4°F. were determined. Then these oils were dissolved in and recovered from benzene using the standardized method that has been described. The viscosities of the recovered oils at 84.4°F. were determined. All viscosity values were corrected for content of mineral matter. From the data thus accumulated a curve was plotted showing the percentage correction necessary for correcting the viscosity of a recovered oil to that of the oil which was dissolved in benzene for recovery. This curve is shown in Fig. 7.

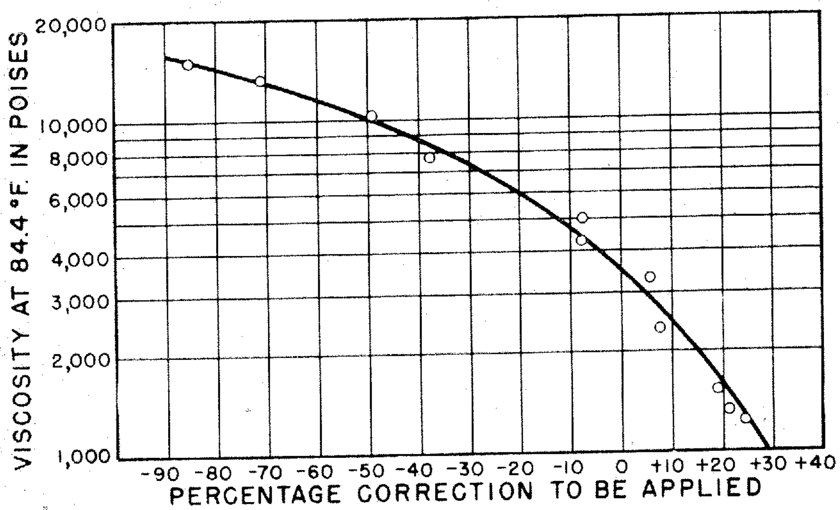

Fig. 7—Correction Curve Showing the Percentage Correction that Must Be Applied to the Measured Viscosity of a Sample of Bituminous Sand Oil Recovered from Solution in Benzene by the Standardized Method in Order to Obtain the Viscosity of the Original Oil. A Positive Percentage Correction Means that the Measured Viscosity is too Great and is to be Reduced.

SPECIFIC GRAVITY DETERMINATIONS

The specific gravities at 77°F./77°F. were determined for all the oils used in establishing the viscosity correction curve, Fig. 7. The observed values were corrected for content of mineral matter. Using these data a correction curve for the specific gravities of oils recovered from benzene solution could have been constructed. Instead of doing this, however, the specific gravities of recovered oils at 77°F./77°F. were plotted against their viscosities at 84.4°F. A similar plot was made for the specific gravities and viscosities of the oils before being dissolved in and recovered from benzene. These curves are shown in Fig. 8.

These curves provide a test for the applicability of the viscosity correction curve for correcting the viscosity of an oil recovered from a sample of bituminous sand by the standardized procedure to its true value. Both the viscosity and the specific gravity of a recovered oil are determined. If these values are represented by a point falling on or close to curve B of Fig. 7 the oil under examination is assumed to belong to the family to which the correction method applies. The viscosity of the recovered oil can then be corrected to that of the original oil. The specific gravity of the original oil can be found by use of curve A, Fig. 8. In doing this the corrected viscosity is used to find the true specific gravity of the original oil. It is believed that the more closely the determined viscosity and specific gravity values of a recovered oil fall on curve B the greater will be the precision of the corrected values. Two points are shown in the figure which do not fall closely to curve B. They were for oils recovered from duplicate samples of an oil sand from the Ruth-Mildred Lake region of the Athabaska bituminous sand area, Fig. 9. They were taken from a core sample cut during the drilling operations of the Department of Mines and Resources and obtained through the courtesy of Abasand Oils Ltd. The viscosities and specific gravities of recovered oils from all other oil sands examined gave points which fell near curve B.

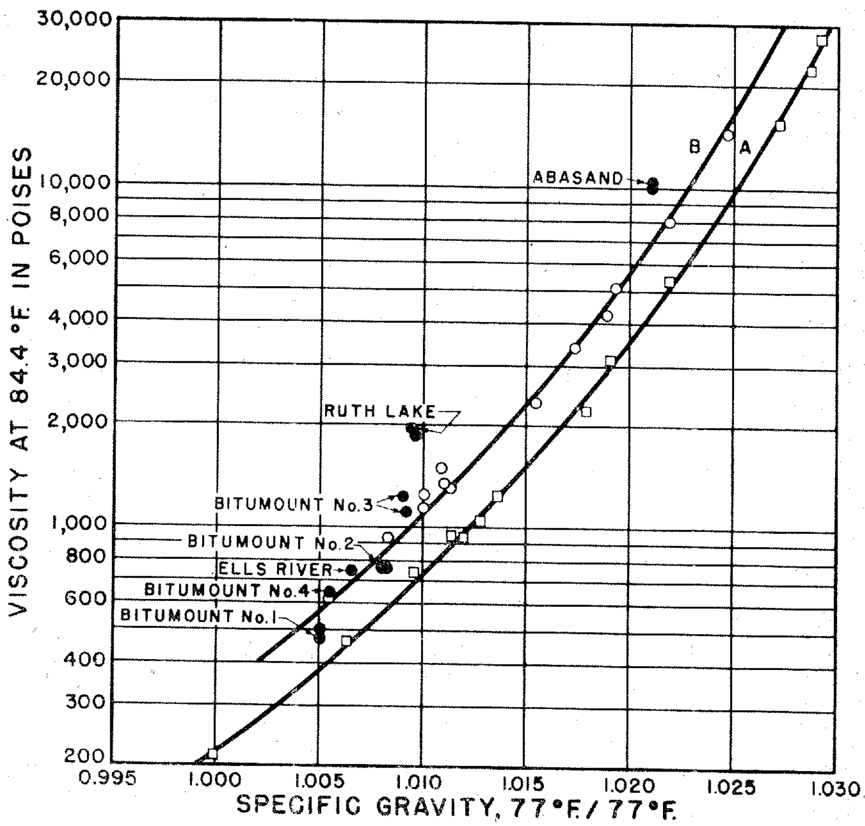

Fig. 8—Viscosity-Specific Gravity Relationship for Bituminous Sand Oils. Curve A is Derived from Measurements on Oil Obtained from Bituminous Sand by Hot Water Extraction and Then Thickened by Varying Degrees of Heating. Curve B is Derived from Measurements on These Same Oils after Solution in Benzene and Recovery from Solution by the Standardized Method. Points for Measurements on Oils Obtained by Extracting Bituminous Sand Samples with Benzene and then Recovering the Extracted Oil by the Standardized Method Are Shown Also.

cans with good lids at the time of collecting. On arrival at Edmonton three weeks later, a supply from each sand was taken from the cans and put in half gallon glass sealers fitted with rubber rings. The Ells River sand was brought from the north in glass sealers. A sample of bituminous sand core from the Ruth-Mildred Lake area was received from Abasand Oils Ltd. This material was in the closed, waxed cardboard container in which it was put after removal from the core-barrel. The Bitumount samples were numbered starting with the sample taken at the highest elevation and numbering downwards.

Oil was extracted and recovered from each bituminous sand using the standardized procedure that has been described. The viscosity at 84.4°F. and the specific gravity at 77°F./77°F. were determined for each recovered oil. Duplicate extractions and determinations were made for each sand and the averages of the pairs of viscosity and specific gravity values were taken as final values. These values were plotted on Fig. 7 to see that the point representing them fell on or near curve B. If this was the case, the viscosity value was corrected to the value for the original oil by use of Fig. 6. The curve for the viscosity-temperature relationship for the oil was then obtained by plotting the viscosity against the temperature at which it was measured and drawing a curve through this point which was parallel to the curves of Fig. 5. The viscosity-temperature curves for the oils in the various bituminous sands are shown in Fig. 10. A curve for the Ruth-Mildred Lake bituminous sand does not appear because of the failure of the points for the viscosities and specific gravities of the recovered oils to fall near curve B of Fig. 8. Confidence could not be placed in the corrected viscosity values from these determinations.

GENERAL OBSERVATIONS

One of the most interesting findings of the study is the remarkable difference in the viscosity of the oil in the Abasand bituminous sand as compared to that of Bitumount and Ells River bituminous sands. At 50°F., which is probably close to the temperature of bituminous sand beds at a fresh quarry face the Abasand oil has a viscosity of about 600,000 poises whereas the viscosities of the oils in Bitumount and Ells River sands are in the range of 6,000 to 9,000 poises. This difference in viscosity explains why the bituminous sand in the McMurray region is so much more firmly cemented than down river toward the north of the bituminous sand area. Abasand Oils Ltd. found it necessary to loosen the beds in its quarry with explosives before excavating with a power shovel and the feed to its plant was lumpy. At the old plant at Bitumount, bituminous sand was pushed to a dragline with a bulldozer. At the new plant, foundations for buildings were excavated in the bituminous sand with a power shovel without difficulty. Bituminous sand, on removal from the beds, collapsed into a disintegrated mass. The data available indicates that there is a gradation in the viscosity of the oil in the sand from the south to the north part of the area. Although the viscosity measurement on the oil in the bituminous sand from the Ruth-Mildred Lake location is unreliable, it is clear that it is intermediate between that of oils from Abasand and Bitumount.

The reason for the failure of the oil from the Ruth-Mildred Lake bituminous sand to fit into the system which held for oils from locations as far apart as Abasand and Bitumount is not apparent. The simplest explanation is that the Ruth-Mildred Lake sample was contaminated in some way. If the difference in this oil is real, something of interest may be uncovered by further studies.

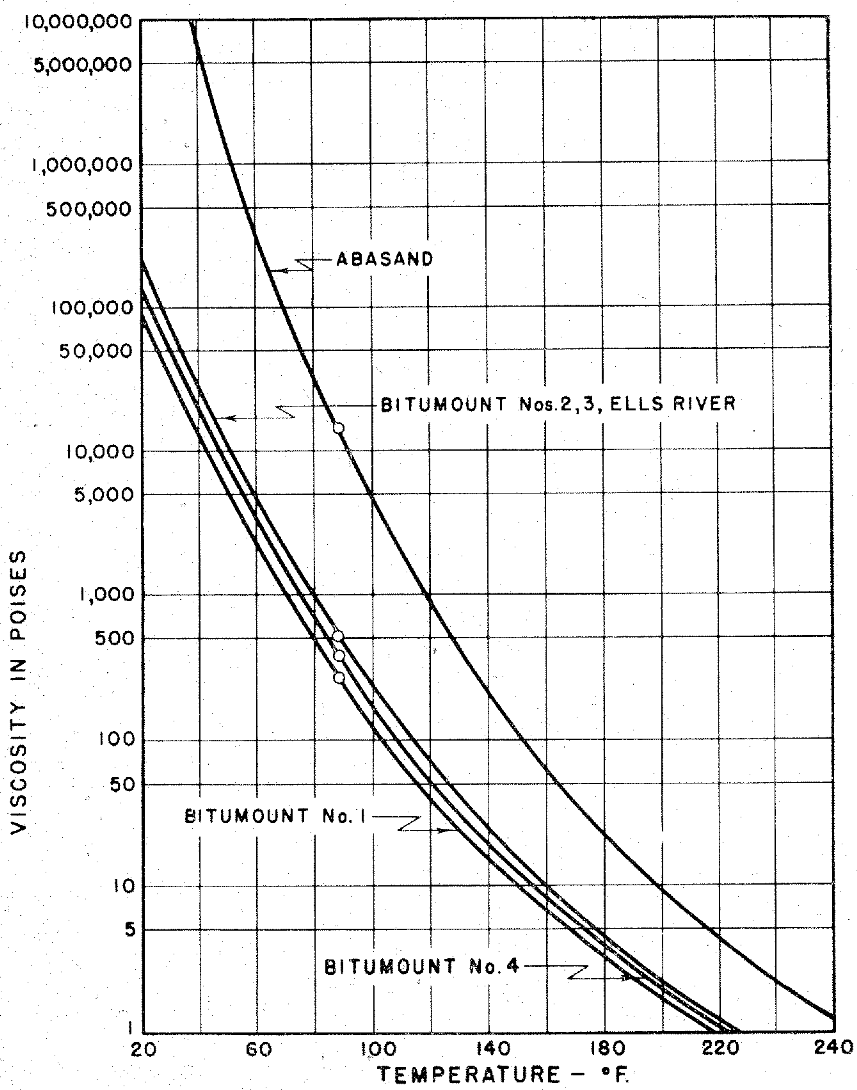

Fig. 10—Viscosity-Temperature Relationship for the Oils occurring in Bituminous Sand Beds at Various Locations and in Beds at Different Elevations of the Same Location.

The spread in the viscosities of the oils from Bitumount oil sands show that the oils in the bituminous sands beds at a given location are not identical throughout the thickness of the deposit. The vertical variation in the oil is small compared to the lateral variation but it is appreciable.

The viscosity-temperature curves for the oils examined give little encouragement to thoughts that, possibly, oil might be won from the Athabaska bituminous sand deposit by such recovery methods as water floodings. At the formation temperature of about 36°F. the viscosity of even the Bitumount oils is too great for flow through the sand at rates of practical significance. It would be necessary to heat the bituminous sand in place to reduce the viscosity of the oil sufficiently for useful flow rates. How this could be done is far from being apparent.

Specific gravities of the oils in bituminous sand samples collected during examination by the Research Council in 1924 of exposures throughout the bituminous sand area were determined and reported (2). The method of determination was to extract the oil from a bituminous sand sample with benzene in a Dulin-Rotarex centrifugal filter, to distil most of the benzene from the filtered benzene-oil solution in a 300 cc. flask fitted with a small column filled with glass beads, to transfer the concentrated solution to an evaporating dish and to heat it with stirring on a water-bath until no odor of benzene could be detected, to measure the specific gravity with a picnometer and to correct the obtained value for mineral matter content. Since the bituminous sand samples examined were collected from trenches cut down the faces of exposures, many of them were of weathered material. But it is interesting to note that the specific gravities of samples taken from a shaft sunk into the bituminous sand beds in the valley of Horse River close to where the Abasand quarry was opened were reported as 1.020 at 77°F./77°F. and that oil from some samples of bituminous sand collected from Ells River exposures were reported as having specific gravities as low as 1.005. The specific gravities found in the present study for the oils from Abasand and Ells River bituminous sands are 1.027 and 1.008 respectively. While it must be admitted that the method of specific gravity determination used in the early work was open to criticism, the results obtained were near enough to being correct to lead to valid deductions. It was concluded, for instance, that the oil in the bituminous deposit, exclusive of weathered material, did not exceed 1.025 and that there was an area in the neighborhood of Ells River where the specific gravity of the oil was as low as 1.005. The main modification of that conclusion that seems in order now is that the area of low specific gravity oils extends farther than was suspected. A specific gravity of 1.002 has been observed at Bitumount.

ACKNOWLEDGEMENTS

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