INVESTIGATIONS

OF

MINERAL RESOURCES AND THE MINING INDUSTRY, 1927

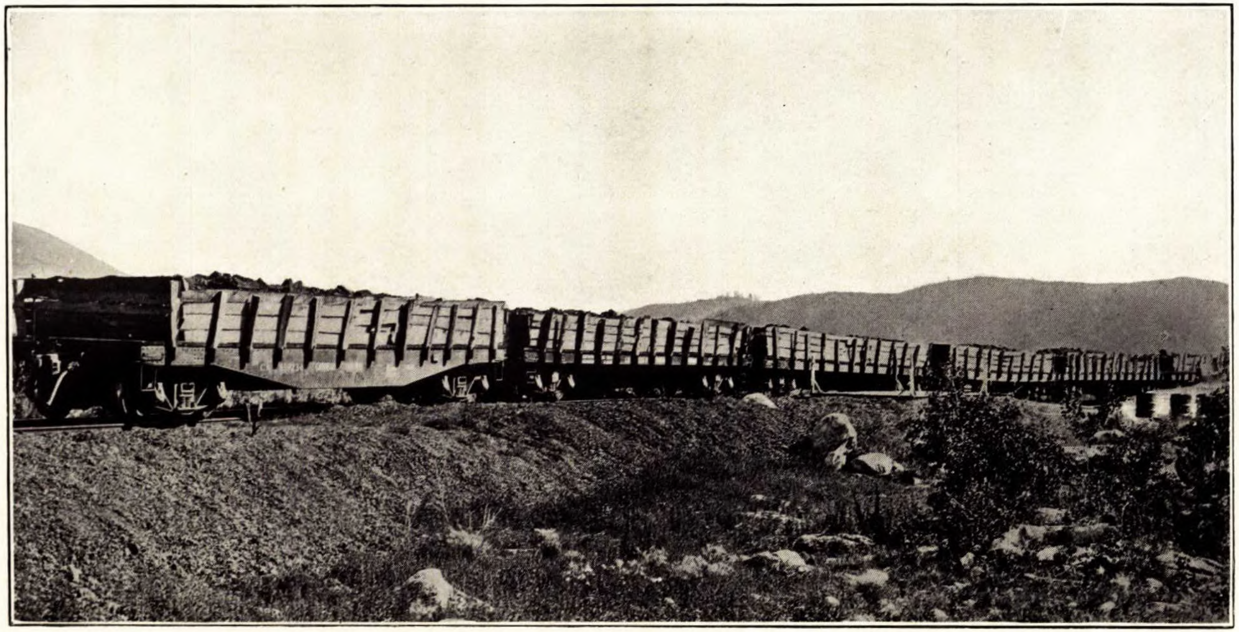
MINES BRANCH

DEPARTMENT OF MINES

OTTAWA

1928

No. 694



Cars of bituminous sand arriving at mixing plant, Jasper, Alberta.

CANADA
DEPARTMENT OF MINES
HON. CHARLES STEWART, MINISTER; CHARLES CAMSELL, DEPUTY MINISTER

MINES BRANCH
JOHN MCLEISH, DIRECTOR

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OTTAWA
F. A. ACLAND
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INTRODUCTION

The Mines Branch investigation of the bituminous sands of northern Alberta was continued by the writer during the field season of 1927. Paul Schmidt acted as field assistant in charge of drilling, and references to drilling operations during 1926 and 1927 are based, to a large extent, on his report. Benson H. Bell was in charge of mining operations and supervised all shipments of bituminous sand. G. P. Connell was in charge of laboratory analyses and physical determinations in connexion with paving work at Jasper, and also supervised the examination of 267 core samples secured during drilling operations in the McMurray field in 1925, 1926, and 1927. Each of the above assistants discharged his duties in an efficient and satisfactory manner. The writer also wishes to express his sincere appreciation for many helpful and practical suggestions and for the continued co-operation of Mr. A. W. Haddow, City Engineer, Edmonton, and of various members of his staff.

Work undertaken during 1927 constituted a logical sequence in the program planned some years ago when the investigation of the McMurray deposit was initiated, and included core-drilling and paving.

DRILLING

In a preliminary report on the bituminous sands of northern Alberta, issued by the Mines Branch in 1914, it was indicated that only after detailed exploration by means of adequate equipment could the true commercial value of any part of the area be determined. Subsequent investigation has amply confirmed this conclusion, and it is consequently of practical interest to consider methods best adapted to prospecting this type of deposit.

In various reports (issued by the Mines Branch subsequent to 1914 on the Bituminous Sands of Northern Alberta), the writer has indicated that, having due regard to recognized factors, more than 95 per cent of the area represented by outcrops may, at present, be disregarded from the standpoint of commercial development. Banding by unimpregnated materials, such as clays, silts, and lignitic particles[1], constitutes one of the more important factors. (Plates IIA, IIB, IIIA, IIIB.)

Conditions[2] which affected the deposition of the McMurray formation[3] on the Devonian floor have not, as yet, been studied in detail.

[1] Lignitic particles are usually free from impregnation owing to overlying and underlying partings of clay or silt.

[2] The writer considers that important paleographical studies may be taken up in the McMurray area by those who seriously desire to carry out original work. Among such studies may be mentioned:—

(a) Determination of the shore-line of Glacial Lake Athabaska.

(b) Determination of Glacial and post-Glacial drainage between the modern Athabaska valley and Glacial Lake Agassiz.

(c) Study of conditions which governed deposition of the McMurray formation.

[3] It is considered by Dr. F. H. McLearn that the bituminous sands may belong to a period earlier than the Dakota and consequently in the McMurray field the use of the name Dakota has been discontinued. Provisionally, the bituminous sands are here referred to as the "McMurray formation."

However, it is clear that the origin of the bulk of the sediments from which this formation has been built up, may be traced to the main body of Pre-cambrian rocks (and its outliers[1]), lying well to the east of the present Athabaska valley. Rocks of this type would be reduced chiefly to silica sand, silt (finely divided silica and argillaceous materials), and micaceous particles. During later Mesozoic times (including lower Cretaceous) extensive water areas submerged parts of the peneplains of northwestern America. It is also probable that this period was marked by the elevation and subsidence of land areas, accompanied by corresponding variation in depth of water. Such conditions would also be favourable to the formation of extensive deltas, somewhat similar to those now forming at the mouths of the Nile, Mississippi, and other rivers.

In interpreting the sequence of the sediments, the McMurray formation, which unconformably overlies the Devonian, should probably be regarded as a delta deposit, evidence of which is seen in the prevalence of typical false-bedding throughout much of the area. This assumption would imply change in strength and direction of water currents and the occurrence of local swamps and lagoons. Prior to the Mesozoic era, seasonal changes in temperature, accompanied by flood phenomena, had become an established condition and had introduced a new factor affecting seasonal sedimentation. These and other conditions, varying from time to time over a long period of years, must be reckoned with in explaining the building up of the McMurray formation.

As a whole, the lower part of the McMurray formation apparently consisted originally of fairly homogeneous, uncompacted sands relatively free from partings of silt, clay, and lignitic particles. Such a condition would imply stable off-shore conditions and depth of water. On the other hand, the upper part of the McMurray formation is to a large extent marked by banding. This reflects quite different conditions of deposition —varying depth of water, changing currents and distributary channels, and the effect of seasonal changes. Certain interbedded partings of sand (or silt) are entirely free from bitumen, and this is apparently due chiefly to diminished total pore spaces, and size and shape of grains. It is interesting to note that in certain areas of townships 94 and 95, where the sand aggregate is unusually coarse and has a greater flow capacity[2], tar springs are of common occurrence. In those townships in which the finer grained aggregates predominate, such springs are rarely seen. (*See* Plates IVA and IVB.)

Overburden Proper. Throughout the McMurray area the bituminous sand is covered with overburden varying in thickness up to several hundreds of feet. This overburden consists largely of softer sediments, such as boulder clay, clay shales, and sand; although, in places, boulders, gravel and thin partings of quartzite, clay ironstone and sandstone may be encountered.

Intermediate Zone. Between the overburden proper and the homogeneous bed of bituminous sand, an intermediate zone is usually encountered[3]. This is chiefly made up of a large number of alternating bands of clay (or other impurities) and bituminous sand, individual bands vary-

[1] Notably in tps. 99, 100, and 101, Rs. 3 and 4, W. of 4th.
[2] Flow capacity increases in proportion to the square of the diameter of the grains. "The Capillary Concentration of Gas and Oil." C. W. Washburn, Trans. A. I. M. and M., vol. L (1914).
[3] "Bituminous Sands of Northern Alberta," Mines Branch, Dept. of Mines, Canada, Rept. No. 632, p. 46 (1926).

ing in thickness from one-half inch to possibly three feet or more. This class of material may be readily drilled and under-reamed by standard cable tools, or, if core samples are required, by the use of special boring equipment referred to under "Drilling Equipment."

Bituminous Sand Proper. Below the intermediate zone a workable bed of fairly homogeneous bituminous sand, with a content of from 10 to 20 per cent bitumen, and lying almost immediately above well-bedded Devonian limestone[1], is usually encountered.

A variety of methods[2], depending on widely different local conditions encountered in various parts of the McMurray field, may be resorted to in prospecting a bituminous sand area. It should be borne in mind, however, that sampling by means of shallow trenches should be avoided since it is quite obvious that such sampling can only prove misleading. Evidence available indicates that throughout the greater part of the field drilling will prove most economical and will ultimately give the most satisfactory results. Consequently it has appeared desirable to develop and demonstrate a suitable type of efficient drilling equipment[3].

DRILLING EQUIPMENT

For Passing Through Overburden

Types of relatively light portable drills, suitable for passing through the above class of material, are well known and require no comment. Large hollow augers, usually operated by horsepower, and capable of drilling from 50 to 100 feet per ten hours, are also used to some extent where conditions are favourable. In drilling over a wide area, however, within which variation in character of overburden must be expected, it is probable that standard cable tools will be found best adapted to general requirements. Moreover, it appears desirable that the power plant consist of a separate unit, such as a gasoline tractor. The use of a tractor will not only materially reduce the weight of the drilling unit itself, but will also render available a power plant which is better suited than horses to intermittent transportation requirements.

Preliminary work in 1925 was in the nature of an experiment and a minimum of new equipment was purchased. Thus, bull wheels and draw-works of a standard Canadian cable tool rig were kindly loaned by the Northern Alberta Exploration Company, Ltd., and a three-pole derrick erected. (Plate VB.) Power for operating this equipment was supplied by a Fordson tractor. Cable tools comprised one 6-inch bit, one $4\frac{5}{8}$-inch bit, and one 3-inch bit—together with necessary jars and stems—and standard collapsible under-reamers for $4\frac{5}{8}$-inch and 3-inch casing. Other equipment comprised heavy wrenches, cables, blocks, blacksmith outfit, chain block, and a variety of small tools.

In order to simplify transportation, much of the cumbersome standard equipment used in 1925 was discarded in 1926 and replaced by a second-hand, portable, No. 4-C well drill manufactured by the Ontario Wind

[1] Usually a bed of residual clay of variable thickness immediately overlies the limestone. Representative samples of this residual clay examined by J. F. McMahon of the Ceramic Division, Mines Branch, indicate that it is of only fair quality and, unless better material is not available, cannot be recommended for commercial enterprise. (*See* Plate VA.)

[2] Mines Branch, Dept. of Mines, Canada, Rept. No. 632, pp. 43, 53-57, 150-152 (1926).

[3] Comments by Paul Schmidt are placed in quotation marks.

Engine and Pump Company. The hinged mast was, however, dismantled and, in order to secure greater head room for rotary drill rods, the three-pole derrick was again erected.

In passing through overburden at Wells Nos. 1, 2, and 3, progress was rapid and no serious difficulties were encountered. Since the presence of bituminous sand was at once indicated by a film of bitumen on water brought up by the bailer, the driller quickly learned to interpret such an indication and to determine when coring tools should be substituted for cable tools. A heavy type of clay auger would have drilled at least 50 feet per day in material actually encountered in Wells Nos. 1, 2, and 3, but for general use throughout the McMurray area cable tools are probably preferable.

For Passing Through Bituminized Strata

In securing core samples of bituminized strata, water must be excluded from the well since the associated bitumen readily separates in situ under the action of even cold water. Consequently standard core-drilling equipment involving the use of water cannot be used. Abrasive action of the sand is also severe, and heavy stellite studs, set in a standard coring bit rotated at 300 r.p.m., were worn completely in three minutes. Unlike conditions usually encountered in diamond-drilling, grinding or abrasive action is not necessary, while the silica sand not only heats but very quickly wears away the hardest steel if rotated rapidly. Slow speed and moderate constant pressure are therefore desirable.

At the outset in 1925, a "BD" type of core drill, manufactured by the E. J. Longyear Company, of Minneapolis, and formerly operated by the Mines Branch in Saskatchewan, was used in passing through bituminized strata. Instead of the customary power drive, however, rods were rotated by hand by means of a chain and sprocket attachment. In 1926 the above drill head was replaced by a small No. 1 rotary table (Plate VIB) supplied by the American Well Works, Aurora, Ill., and designed to rotate a pipe 3 inches or less in diameter. This table was also operated by hand, since the possibility of unexpected strains practically precludes the use of power with such light equipment.

"E" diamond drill rods, $1\frac{5}{8}$-inches in diameter, and "N" diamond drill rods, $2\frac{7}{8}$-inches in diameter, each equipped with a ball-bearing swivel, were used, but the smaller and lighter rods were found to be sufficiently strong. These 10-foot rods were coupled in 20-foot lengths, but height of the crown block was such that three lengths, or 30 feet, together with a cutting tool, 18 inches long, could be raised just clear of the rotary table. Advantages that might be derived by increasing height of derrick would probably not be sufficient in the case of wells 200-250 feet deep to compensate for the disadvantages which such increase would imply.

"In addition to its proper function, the sand line was also used for handling casing and drill rods. Consequently, on account of the speed of the sand-line drum, and the weight of casing and rods, a double line was used in handling this equipment. Since changing from single to double line was sometimes necessary several times during a single day, a considerable loss of time was involved. The use of a third line, operated by winch belted to a pulley secured to an extension of the bull wheel shaft, is suggested.

"The use of the rotary equipment required the services of three men. Two men on the upper platform (Plate VIA) coupled and uncoupled rods and also operated the chain and sprocket attachment (Plate VIB) connected with the rotary table. The third man attended to controls on the drilling rig and supervised operations. In withdrawing rods and coring tool from the well, the double line usually proved adequate, but when jerking

was resorted to, a part of the core was frequently dislodged from the auger. Consequently in starting the auger loose from the bituminous sand, a chain block was used. If the united efforts of three men did not move the auger at once, a few minutes' steady strain usually proved effective."

The design of satisfactory coring tools presents difficulty, and it is doubtful whether the most suitable type has even yet been determined. Such tools should possess sufficient strength to push aside or fracture small, thin fragments of hard shale or sandstone. They should also be of the heaviest construction compatible with size since they are the weakest point in the system. Certain tools which have been used, or suggested, are illustrated in Figure 1. A, B, and C illustrate augers which have been used.

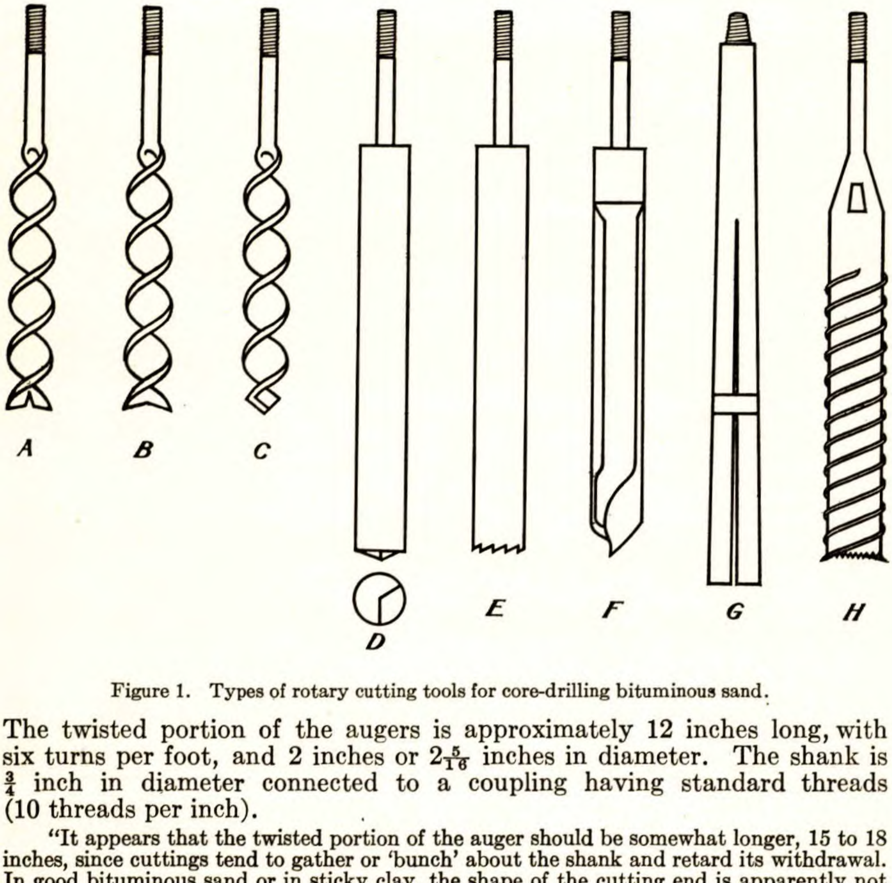

Figure 1. Types of rotary cutting tools for core-drilling bituminous sand.

The twisted portion of the augers is approximately 12 inches long, with six turns per foot, and 2 inches or $2\frac{5}{16}$ inches in diameter. The shank is $\frac{3}{4}$ inch in diameter connected to a coupling having standard threads (10 threads per inch).

"It appears that the twisted portion of the auger should be somewhat longer, 15 to 18 inches, since cuttings tend to gather or 'bunch' about the shank and retard its withdrawal. In good bituminous sand or in sticky clay, the shape of the cutting end is apparently not of great importance. In somewhat hard material that shown as (C) gave best results and has the further advantage that it can be easily sharpened on a grindstone without the use of fire. The cutting edge, illustrated in Figure 1A, worked satisfactorily in clay and mixed material, while that illustrated as Figure 1B, was generally used in rich bituminous sand. If surplus metal at the cutting end is turned up—as on a carpenter's auger—material at the tip adheres more securely. Apparently, increased diameter at cutting end is of no advantage and merely increases difficulty of withdrawing the auger. Holes drilled with the auger[1] show no tendency to cave, and at one time, in Well No. 2, the auger was 134 feet below bottom of casing. If even a small amount of water is present, samples do not adhere securely to augers or tubes."

[1] **In June, 1913, a hole 12 feet deep was drilled by the writer with a 2-inch auger in a bituminous sand outcrop on Clearwater river (sec. 14, tp. 89, R. 9). In 1923 the hole showed no indication of caving.**

Other types of coring tools are illustrated in Figure 1, D and E. Tool "D" consists of a plain tube connected to the drill rods by means of a coupling. The lower, or cutting, end is partially closed but has a cutting edge projecting downward. Tool "E" is merely a plain piece of $2\frac{1}{2}$-inch pipe, welded to a $\frac{3}{4}$-inch shank and provided with teeth at the lower or cutting end. Neither of these proved a success since, after penetrating approximately 2 inches, plugs formed and completely closed the tubes. They did prove useful, however, in cleaning out wet material after under-reaming with cable tools. Another type of coring tool suggested is illustrated in Figure 1 F.

As opposed to the tools noted above, all of which are rotated, Mr. Schmidt suggests:—

. . . . "the use of a special bit (Figure 1G) somewhat similar to an 'earth socket.' This would consist of a piece of split pipe slightly enlarged at the lower end, bevelled to cutting edge, secured to the drill stem and operated by cable. Apparently the use of such a tool would represent a saving in time, since it could be raised and lowered much more rapidly than the augers now in use, while the drop of the tool, length of stroke and drilling speed could be controlled to a nicety with the rig now in use. A further advantage would be that the original hole would probably be large enough to receive the casing, thus obviating present delays due to under-reaming. Time now lost in changing from cable to rotary tools would also be saved, while the use of the mast attached to the portable rig would obviate the necessity of erecting a derrick. Operation would require the services of but two men and, under favourable conditions, one man would be sufficient. The average depth for each run would probably be not less than that of an auger run, and the sample would be equally representative of material passed through."

"Another type of suggested coring tool is illustrated in Figure 1H. This consists of a core barrel so designed as to cut the bituminous sand around a central core, and rotated at a speed sufficient to heat the sample slightly. This would not appreciably alter the bituminous sand but would facilitate its entry into the core barrel. By installing a power drive it might also be possible to develop an under-reamer in connexion with a circulating pump and settling tank, thus eliminating the cable tools to a large extent.

"In order to keep the well dry, some simple type of pump should be available. A length of pipe 10 feet long, fitted with a valve at the bottom and a bail at the top, would probably answer requirements."

GENERAL METHOD OF DRILLING

The general method of operation was to drill through the overburden by the use of standard cable tools, after which augers or other rotated coring tools were used until water appeared. Since no rotary under-reamer suitable for use in bituminous sand has yet been developed, drill rods were then withdrawn, the timber frame carrying the rotary table pushed aside on rollers, the hole under-reamed by the use of cable tools, and the casing lowered. This procedure involved the introduction of water into the well and its subsequent complete removal before core drilling could be resumed. Owing to the difficulty of withdrawing rotary tools from the bituminous sand, individual "lifts" in this material rarely exceeded six inches. General arrangement of cable and rotary equipment is illustrated in Plates VIA and VIB. Core samples, as soon as secured, were placed in tight, friction-top tins having a capacity of about two pounds each, the sample number stamped on the lid, and the necessary notation made in the log book.

Casing

Wells were drilled with the 6-inch bit as far as possible, or until showings of bitumen made the use of coring tools advisable, and cased with 6-inch (outside diameter) I. J. casing. In bituminous sand, $3\frac{3}{4}$-inch (outside diameter) I. J. casing was used. At times, $4\frac{5}{8}$-inch casing was used prior to inserting the smallest size. The use of inserted joint casing is recommended in preference to drive pipe. The use of drive shoes increases the amount of under-reaming required and, in the class of material under consideration, does not give a compensating advantage.

CONDITIONS AFFECTING DRILLING

Water Seepages

Water seeps in overburden are of common occurrence. Even in the richest beds of bituminous sand, partings of fine gravel, clay, or other materials[1] occur, and these also act either as water carriers or as sills.

Frequently such seepages may be plainly seen at partings in adjacent exposures, as, for example, on Wood creek and on Athabaska river in township 91. At times in Well No. 2, traces of water were noted but later disappeared. These may have been due, in part, to condensation in the casing, while minor seepages may have been sealed off by the repeated passage of the auger carrying rich bituminous sand.

As noted above, and owing to relatively low surface tension, bitumen associated with unaltered bituminous sand separates readily in situ under the action of cold water. Consequently casing must follow drilling tools as closely as possible in order to prevent deterioration of cores. This implies that casing must be kept loose at all times.

Apparently effectiveness of such water separation varies somewhat with grading of aggregate, degree of enrichment, and character of the bitumen itself. Further evidence of low surface tension is seen in the fact that bitumen is frequently brushed from core samples brought up by the auger, particularly after a hard pull, leaving the outer surface almost white. When exposed to the air, however, grains of sand again quickly become coated with bitumen exuding from the remainder of the sample, a feature that was also noted during shaft sinking[2] in 1924. Moreover, it appears that colour of the original bituminous sand is not necessarily governed altogether by the degree of enrichment, but may vary from brown to black according to the character of associated bitumen or oil. As pointed out in previous reports, freshly mined sand of apparent low bitumen content rapidly becomes black or brown when exposed to the atmosphere. Such conditions indicate the ease with which the separation of bitumen from freshly mined sand may be effected, and confirm the writer's observations during the past fourteen years.

At times pockets of practically clean sand are encountered, or a band of clean sand may follow the turns of the auger from top to bottom.

[1] Mines Branch, Dept. of Mines, Canada, Rept. No. 632, pp. 46 and 55.
[2] Mines Branch, Dept. of Mines, Canada, Rept. No. 632, p. 56, section *g*.

If for any reason, as a temporary measure, it becomes necessary to introduce water into the well (as during progress of under-reaming), this must be removed before core sampling is resumed. A standard type of flat-valve sand pump has been used to remove the greater part of the water, final traces being removed by the use of sponges. These were secured to the drill rods by means of a simple basket attachment. Should tools become stuck in the bituminous sand, heated water—or in extreme cases, kerosene—may be introduced into the well, and as a solvent, each has been used by the writer with satisfactory results.

Transportation

In areas where gradients are frequently abrupt, where roads are practically non-existent, and where drilling is undertaken at elevations of 200 to 250 feet above river level, weight and mobility of equipment constitutes an important factor. Indeed, during 1927, it is probable that at least 40 per cent of the total field season was devoted to road building and transportation. Consequently, if an extensive drilling program were contemplated, such preliminary work should be carried out in advance by a separate working party.

As noted elsewhere, power for operating drilling equipment was delivered by a Fordson tractor. This tractor was also used for moving equipment and supplies from point to point and, on the level, would haul a load of approximately 5,700 pounds. In wet weather, tractor haulage was both difficult and dangerous and the use of block and tackle was resorted to freely.

Grades should not exceed 15 per cent as a maximum in order that the tractor may pull at least 1,000 pounds under all weather conditions.

Water Supply

Well sites and camp sites may, at times, be located at points somewhat remote from adequate water supply. Thus, during a part of the field season of 1925, it was necessary to haul water for camp and drill a distance of $1\frac{3}{4}$ miles, while in 1927 the maximum haul was upwards of $1\frac{1}{4}$ miles. Consequently the installation of a gasoline-driven pump, capable of delivering water at a maximum elevation of 200 feet and at a distance of 1,500 feet, will in certain parts of the McMurray area justify the necessary expenditure.

RATE OF DRILLING

As noted elsewhere, and in order to secure satisfactory samples, much of the footage recorded in logs was drilled three times, first with coring tools, then with cable tools, and finally with the under-reamer. Time required to secure an individual core sample varied with depth. In good material only a few turns of the rotary table were necessary to penetrate the bituminous sand from 4 to 6 inches, and rarely required more than $1\frac{1}{2}$ minutes. Approximate periods of time required at various depths, including lowering and raising rods, may be stated as follows: 50 to 75 feet, 10 minutes; 75 to 100 feet, 15 minutes; 100 to 125 feet, 20 minutes; 125 to 150 feet, 25 minutes; 150 to 175 feet, 30 minutes; 175 to 200 feet, 45 minutes. The following records are from the log of Well No. 2, and in point of speed, represent the best results secured during 1927.

Date	Position of core		Total depth
	' "	' "	' "
1927			
May 25	76 2	79 8	3 6
" 26	79 8	84 11	5 3
June 1	84 11	90 7	5 8
" 2	90 7	97 4	6 9
" 3	97 4	102 5	5 1
" 4	102 5	110 0	7 7
" 6	110 0	112 0	2 0 (half day)
" 7	112 0	121 4	9 4
" 8	121 4	129 0	7 8
" 9	129 0	136 6	7 6
" 10	136 6	146 2	9 8
" 11	146 2	154 6	8 4
" 13	154 6	166 1	11 7
" 14	166 1	174 3	8 2
" 15	174 3	180 0	5 9
14½ days			103 10
Average per day	....		7 2

The effect of water seeps on rate of core-drilling is well illustrated by the following comparison. In Well No. 2, no water was encountered between 76 feet 2 inches and 180 feet and, as noted above, 103 feet 10 inches of core were secured in 14½ days. On the other hand, in Well No. 3 when drilling at shallower depths but with numerous seepages, 56 feet were cored in 13 days. During this period it was necessary to change 16 times from cable tools to rotary tools and vice versa.

WELLS DRILLED

Well No. 1

In 1925 an experimental drilling unit was assembled (Plate VB) and a well drilled[1] in an attempt to determine the class of equipment best suited to stratigraphical and other conditions in the McMurray area.

Drilling was commenced on August 17, but at a depth of 44 feet the well was abandoned as a result of caving. On August 28 a second well, referred to as Well No. 1, was commenced immediately adjacent to the first and carried to a depth of 232 feet. The casing was then removed from the well.

Drilling was seriously delayed, chiefly owing to lack of an under-reamer, and the well was not completed until October 21. A summary of strata passed through is shown in Table I and is based on analyses of 90 core samples. It may be noted that in drilling through fairly rich bituminous sand (10 per cent or more bitumen content) strings or ropes of almost

[1] The site of this well is at a point in River Lot 13, McMurray settlement, 204 feet from the southwest corner of the lot and 5 feet north of the southwesterly boundary of McMurray settlement. Elevation of casing head is 1,041 feet above sea-level datum.

pure separated bitumen, depending on thickness and degree of enrichment of bituminous sand drilled through, adhered to the drilling tools. While cable tools were being used, only a faint film of bitumen appeared on the surface of the water, indicating that no bituminous sand of commercial value was being encountered. Drilling was discontinued in typical calcareous clay such as is usually encountered immediately above the Devonian limestone. The elevation (804 feet) at the bottom of the well agrees closely with elevation of limestone 3,600 feet distant on Hangingstone river.

TABLE I

Log of Well No. 1

Depth from surface	Bitumen content (per cent)		Remarks
feet	min.	max.	
0–111.............	0·0	0·9	Drilling chiefly by cable tools; augers or coring tools used whenever traces of bitumen appeared on water; material chiefly clay and sandy clay with thin, hard, siliceous partings.
111–125...........	2·5	5·4	All drilling by use of augers and coring tools; only occasional bands of bituminous sand show evidence of stickiness.
125–139...........	8·3	9·2	All drilling by use of augers and coring tools; bituminous sand with thin partings of clay and sandy clay.
139–189...........	11·2	17·8	5 feet drilled by use of cable tools owing to caving; remainder drilled with auger.
189–237...........	0·4	2·7	Auger used to depth of 200 feet; beyond this cable tools used.

Well No. 2

(See Plates VIA and VIB)

In 1926 a site for No. 2 well was selected in L.S. 16, sec. 32, tp. 89, R. 9, at an elevation of 1,037 feet. To reach this location it was necessary to clear and partly grade nearly one mile of an old logging road, and to cut a new road for a further distance of one mile. Drilling and camp equipment was moved by scow and tractor.

During the early part of the season, preliminary stripping in connexion with proposed quarrying operations occupied the attention of Mr. Schmidt and his field party, and it was not until August 14 that drilling was begun. On August 30, after approximately 50 hours' actual drilling, operations were discontinued and shipments of bituminous sand to Jasper commenced. Drilling was resumed on May 19, 1927, and completed on June 25. A detailed log of this well is given in Table II.

TABLE II

Detailed Log of Well No. 2

Sample No.	Depth	Moisture in sample as received	Bitumen content: (dry-sand basis)	Sulphur content of (water-free) bitumen	Screen analyses of dry extracted sand							
					Held on 10 mesh	Passing mesh						
						10	20	30	40	80	100	200
	′ ″ ′ ″	%	%	%	%	%	%	%	%	%	%	%
Samples 1-4 through clay (0′—43′ 6″).												
5................	43 6 — 44 6	low-grade	bituminous sand									
6................	44 6 — 46 6	19·1	2·1									
7................	46 6 — 47 9	6·0	3·5									
8................	47 9 — 49 0	7·1	5·0									
9................	49 0 — 50 2	10·2	4·1									
10................	50 2 — 51 3	3·8	6·3									
11................	51 3 — 51 7	2·4	10·8									
12................	51 7 — 52 9	2·8	11·8									
13................	52 9 — 54 3	15·4	7·8									
No samples taken between 54′ 3″ and 57′ 2″.												
14................	57 2 — 58 7	14·4	10·9									
15................	58 7 — 60 3	13·2	11·9									
16................	60 3 — 61 0	11·8	12·2									
17................	61 0 — 62 1	13·3	12·2									
No samples taken from 62′ 3″ to 65′ 3″.												
18................	65 3 — 66 5	8·7	11·5		0·0	1·4	3·2	1·4	28·4	25·5	25·4	14·7
19................	66 5 — 67 0	6·6	13·7	5·2	0·5	0·4	0·9	0·7	47·5	26·2	14·7	9·1
20................	67 0 — 68 2	7·8	13·9		0·1	0·1	0·3	0·3	32·1	30·6	25·0	11·5
21*................	68. 2 — 69 0	9·6	13·1	5·1	0·1	0·5	0·6	0·9	50·2	7·2	31·9	8·6
22................	69 0 — 70 4	15·4	12·7		0·0	0·2	0·5	0·4	24·0	34·0	24·2	16 7
23*................	70 4 — 71 5	6·7	13·1		0·0	0·1	0·2	1·6	57·9	8·2	26·3	5·7
24................	71 5 — 72 10	5·3	12·4	5·1	0·1	0·5	0·5	0·3	36·3	22·9	24·3	15·1
25*................	72 10 — 73 8	4·2	11·8		0·3	0·8	0·8	0·9	12·0	3·0	68·6	13·6
26................	73 8 — 74 5	4·1	13·4	5·0	0·0	0·1	0·1	0·1	1·1	1·2	52·7	44·7

* Screened with Eimer and Amend screens.

TABLE II—continued

Detailed Log of Well No. 2—continued

Sample No.	Depth	Moisture in sample as received	Bitumen content: (dry-sand basis)	Sulphur content of (water-free) bitumen	Screen analyses of dry extracted sand: Held on 10 mesh	Passing mesh 10	20	30	40	80	100	200
	' " ' "	%	%	%	%	%	%	%	%	%	%	%
27*................	74 5 — 75 6	5·0	12·1	5·0	0·2	1·0	1·8	1·8	3·8	0·8	74·7	15·9
	75 6 — 76 2	No sample taken.										
28................	76 2 — 77 4	4·7	11·8		0·0	0·1	0·4	0·4	1·4	0·9	51·7	45·1
29*................	77 4 — 78 6	5·6	12·7	4·6	0·0	0·5	0·6	0·5	1·5	0·4	77·6	18·9
30................	78 6 — 79 8	3·9	13·0		0·3	0·5	0·6	0·3	0·8	0·5	49·5	47·5
31*................	79 8 — 80 9	3·4	12·8		0·0	0·1	0·1	0·2	1·7	0·2	77·6	20·1
32................	80 9 — 81 7	2·9	12·4	4·6	0·0	0·1	0·4	0·2	0·8	0·6	57·3	40·6
33*................	81 7 — 82 10	2·8	12·1		0·0	0·5	0·7	1·0	7·5	0·8	76·5	13·0
34................	82 10 — 83 8	3·4	11·6		0·0	0·1	0·2	0·2	0·6	0·5	66·9	31·5
35................	83 8 — 84 3	4·4	9·0		0·0	2·0	3·3	1·8	4·7	1·6	47·1	39·5
36................	84 3 — 84 11	5·7	8·3		0·0	2·5	4·3	2·5	6·7	1·7	27·9	54·4
37*................	84 11 — 85 8	6·3	9·6	4·4	0·0	1·4	1·3	2·8	6·4	0·7	58·2	29·2
38................	85 8 — 86 8	4·2	12·0		0·4	0·1	0·4	0·4	1·3	0·6	46·8	50·0
39*................	86 8 — 87 3	5·5	9·0		0·0	2·7	3·1	2·8	5·7	1·4	65·8	18·5
40................	87 3 — 88 1	5·6	8·4		0·0	0·7	1·4	1·3	7·0	5·5	60·3	23·8
41*................	88 1 — 89 2	9·7	9·4		0·0	1·4	2·7	3·4	15·2	2·6	65·0	9·7
42................	89 2 — 90 7	5·4	7·1	4·8	0·3	1·4	2·9	2·4	9·7	6·7	49·2	27·4
43*................	90 7 — 91 4	6·1	5·3		0·1	3·4	4·7	4·6	17·2	3·0	56·4	10·6
44................	91 4 — 92 0	4·9	5·3		0·0	4·5	6·6	3·5	10·0	7·8	39·6	28·0
45*................	92 0 — 92 9	5·2	5·9		0·0	3·2	4·0	3·1	7·0	2·3	63·8	16·6
46................	92 9 — 94 2	3·1	11·0	4·9	0·0	0·6	1·0	0·5	1·5	5·4	66·1	24·9
47*................	94 2 — 95 3	3·7	9·7		0·0	3·1	3·1	2·5	6·3	1·9	67·8	15·3
48................	95 3 — 96 1	2·9	11·4		0·0	0·8	1·2	0·7	1·7	2·5	68·5	24·6
49*................	96 1 — 97 4	3·2	12·3	4·4	0·0	0·6	0·8	1·0	5·1	1·7	81·0	9·8
50................	97 4 — 98 3	3·5	11·6		0·0	0·7	1·1	0·9	3·9	5·6	55·9	31·9

51*................	98 3 — 99 5	4·9	9·0	4·0	0·0	1·0	1·5	2·5	9·8	4·1	61·3	19·8
52.................	99 5 —100 0	4·0	8·5		0·0	0·5	0·8	0·9	6·1	8·5	58·7	24·5
53.................	100 0 —100 9	4·5	7·2	4·5	0·0	1·0	2·6	2·3	9·2	12·2	49·8	22·9
54.................	100 9 —101 5	3·6	7·1		0·3	2·7	4·2	2·4	6·3	5·6	58·0	20·5
55.................	101 5 —102 5	5·9	6·4		0·3	1·6	3·7	2·5	7·9	8·8	52·5	22·7
56.................	102 5 —102 10	3·9	7·4		0·0	3·2	4·6	2·5	5·5	3·9	57·7	22·6
57.................	102 10 —104 0	4·0	8·9		0·0	2·7	3·1	1·6	4·5	3·0	55·4	29·7
58.................	104 0 —105 0	3·6	9·2	4·2	0·0	1·7	2·7	1·5	4·7	6·0	59·7	23·7
59.................	105 0 —106 2	2·5	11·2		0·5	2·0	1·8	0·8	2·7	4·4	62·9	24·9
60.................	106 2 —107 0	2·0	12·2		0·0	0·9	1·1	0·5	1·2	2·5	65·1	28·7
61.................	107 0 —108 4	1·9	11·8		0·6	1·2	1·8	1·1	2·6	2·5	66·0	24·2
62.................	108 4 —109 5	4·6	5·8	4·5	0·0	3·1	4·1	2·5	6·5	5·6	57·7	20·5
63.................	109 5 —110 0	6·5	6·1		0·0	4·2	5·7	2·6	6·6	5·8	50·1	25·0
64.................	110 0 —110 10	4·2	8·3		0·0	0·9	2·5	1·6	6·0	12·1	60·5	16·4
65.................	110 10 —112 0	3·2	10·6	4·5	0·0	0·2	0·9	0·8	3·5	10·0	69·8	14·8
66.................	112 0 —113 2	3·4	10·1		0·0	2·0	3·4	1·9	6·8	9·6	56·9	19·4
67.................	113 2 —114 3	3·8	7·4		0·0	1·6	3·4	2·1	8·0	12·6	57·4	14·9
68.................	114 3 —115 8	3·8	7·2		0·0	1·0	2·5	1·8	7·8	16·1	56·3	14·5
69.................	115 8 —117 3	5·3	6·8	4·7	0·0	2·1	5·2	3·0	10·9	12·9	50·0	15·9
70.................	117 3 —118 5	5·3	6·2		0·0	1·5	3·5	2·3	10·5	22·5	44·8	14·9
71.................	118 5 —119 3	4·5	5·6		0·0	3·1	5·1	2·5	11·3	22·7	44·9	10·4
72.................	119 3 —120 2	3·5	7·0		0·0	1·1	2·6	1·9	7·4	10·2	47·5	29·3
73.................	120 2 —121 4	3·7	7·3		0·0	0·4	0·9	0·8	4·4	16·7	60·5	16·3
74.................	121 4 —122 4	3·6	10·0	4·8	0·0	0·7	1·2	0·9	4·0	13·9	62·8	16·5
75.................	122 4 —123 6	3·4	9·2		0·0	0·8	1·7	1·2	5·9	20·0	48·4	22·0
76.................	123 6 —124 9	3·2	6·9		0·0	0·1	1·0	0·9	6·0	27·2	52·5	12·3
77.................	124 9 —125 11	3·4	7·4		0·0	0·5	1·4	1·5	7·6	20·7	56·3	12·0
78.................	125 11 —126 10	2·7	8·4	4·5	0·0	0·1	0·2	0·2	2·3	20·4	64·9	11·9
79.................	126 10 —128 0	2·6	9·2		0·0	0·1	0·3	0·2	3·4	22·0	61·7	12·3
80.................	128 0 —129 0	2·4	13·4		0·0	0·3	0·6	0·3	2·5	21·3	61·3	13·7
81.................	129 0 —130 0	2·6	14·3		0·2	0·3	0·6	0·4	2·3	24·5	56·1	15·6
82.................	130 0 —131 3	3·5	12·0	4·9	0·0	0·3	1·0	0·8	3·9	10·9	53·9	29·2
83.................	131 3 —132 3	3·1	9·9		0·0	0·3	0·8	0·5	4·4	30·2	51·0	12·8
84.................	132 3 —133 6	1·4	12·0		0·0	1·6	2·2	0·8	3·3	21·7	52·6	17·8
85.................	133 6 —134 3	2·1	14·5		0·0	1·2	1·3	0·5	3·4	24·7	57·3	11·6

* Screened with Eimer and Amend screens.

TABLE II—continued

Detailed Log of Well No. 2—continued

Sample No.	Depth	Moisture in sample as received	Bitumen content: (dry-sand basis)	Sulphur content of (water-free) bitumen	Screen analyses of dry extracted sand: Held on 10 mesh	Passing mesh 10	20	30	40	80	100	200
	′ ″ ′ ″	%	%	%	%	%	%	%	%	%	%	%
86	134 3 —135 8	3·8	10·7	4·9	0·0	3·3	3·0	1·3	6·3	24·1	50·1	11·9
87	135 8 —136 6	2·8	12·4		0·0	2·8	3·3	1·6	5·3	15·9	50·7	20·4
88	136 6 —137 9	2·5	9·6		0·0	1·0	1·5	0·7	2·6	12·1	63·6	18·5
89	137 9 —139 3	1·7	14·1		0·0	0·9	1·0	0·5	3·6	19·0	60·9	14·1
90	139 3 —141 4	1·7	14·4	4·8	0·0	0·5	0·7	0·4	2·2	15·9	65·0	15·3
91	141 4 —142 0	2·3	12·9		0·2	2·0	2·1	0·9	4·4	22·1	52·4	15·9
92	142 0 —143 3	1·7	15·2		0·0	0·1	0·3	0·2	1·3	12·4	67·8	17·9
93	143 3 —144 10	1·7	14·6	4·3	0·0	0·3	0·6	0·3	2·4	21·8	57·1	17·5
94	144 10 —146 2	2·2	14·0		0·2	0·8	1·3	0·6	2·4	15·2	60·5	19·0
95	146 2 —147 6	1·6	14·6		0·0	0·9	0·7	0·4	3·3	14·4	63·1	17·2
96	147 6 —148 11	2·2	12·1		0·0	0·9	1·3	0·7	5·5	28·0	48·6	15·0
97	148 11 —150 5	1·7	12·9	4·7	0·0	0·2	0·6	0·4	2·2	14·4	67·8	14·4
98	150 5 —152 0	2·0	13·4		0·0	0·8	1·2	0·7	2·7	13·5	64·3	16·8
99	152 0 —153 5	2·3	12·6		0·0	0·8	1·0	1·0	3·5	16·0	61·7	16·0
100	153 5 —154 6	2·4	12·2	4·9	0·0	1·1	1·6	0·8	3·4	20·9	56·3	15·9
101	154 6 —156 3	2·6	13·3		0·0	0·3	0·9	0·8	5·0	26·3	53·6	13·1
102	156 3 —157 6	2·1	13·7		0·0	0·8	1·6	0·7	4·4	29·3	49·2	14·0
103	157 6 —158 6	3·0	13·6	4·9	0·0	0·2	0·5	0·3	7·4	41·9	34·9	14·8
104	158 6 —159 6	4·2	8·7		0·0	3·8	4·2	1·8	24·0	30·6	22·2	13·4
105	159 6 —160 8	5·2	12·0		0·0	0·1	0·2	0·1	5·0	26·9	58·5	9·2
106	160 8 —162 1	4·0	13·4		0·0	0·3	0·6	0·4	9·0	33·3	45·0	11·4
107	162 1 —163 0	2·3	14·1	4·9	0·0	0·3	0·7	0·4	16·2	49·4	23·0	10·0
108	163 0 —164 1	2·9	14·1		0·3	0·5	1·1	0·6	19·0	41·6	26·4	10·5
109	164 1 —165 0	1·7	16·4		0·0	0·2	0·3	0·2	8·6	42·8	38·8	9·1
110	165 0 —166 1	4·1	13·1		1·4	3·9	3·2	1·1	7·8	31·9	40·4	10·3
111	166 1 —166 11	1·8	15·6		0·0	2·4	1·5	0·7	6·5	31·3	50·4	7·2
112	166 11 —168 2	1·1	16·3		0·0	0·2	0·5	0·2	5·2	35·2	51·6	7·1

67531—2¼

113................	168 2 —169 1	1·7	16·0	5·0	0·0	1·1	1·0	0·4	6·1	36·8	45·2	9·4
114................	169 1 —170 3	2·4	13·9		0·9	2·4	2·3	1·0	8·6	34·0	39·9	10·9
115................	170 3 —171 3	2·0	14·3		0·0	0·6	1·0	0·4	17·1	43·9	25·6	11·4
116................	171 3 —172 3	2·5	15·7		0·1	0·7	0·9	0·4	37·3	35·9	15·9	8·8
117................	172 3 —173 3	1·8	14·7	4·7	0·0	0·5	0·8	0·5	32·6	31·0	24·5	10·1
118................	173 3 —174 3	1·5	16·8		0·0	0·1	0·6	0·7	32·3	35·1	20·8	10·4
119................	174 3 —175 6	2·8	13·7		0·0	1·9	2·8	1·6	14·0	22·9	41·7	15·1
120................	175 6 —186 1	14·3	1·7	6·7	0·0	0·0	0·3	0·7	0·7	1·2	25·0	72·1
121................	186 1 —187 10	9·6	1·0		0·0	0·0	0·4	1·3	0·6	1·5	34·3	61·9
122................	187 10 —188 11	6·8	1·2		0·0	0·0	0·3	0·1	0·5	1·2	43·4	54·5
123................	188 11 —190 0	7·8	2·3	5·1	0·0	0·0	0·2	0·3	1·3	1·3	32·2	64·7
124................	190 0 —191 1	8·2	4·4		0·0	0·0	0·1	0·7	0·9	1·0	31·0	66·3
125................	191 1 —192 3	8·1	3·1		0·0	0·0	0·1	0·6	0·4	1·5	26·7	70·7
126................	192 3 —193 5	8·4	0·2	5·9	0·2	0·1	0·3	0·4	18·2	12·5	36·2	32·1
127................	193 5 —194 9	4·5	11·4		0·0	0·0	0·2	0·3	25·1	26·4	36·1	11·9
128................	194 9 —196 0	4·0	12·3		0·0	0·1	0·3	0·3	37·0	15·9	16·5	29·0
129................	196 0 —197 8	2·7	15·9	5·1	0·0	0·3	0·7	0·2	16·7	18·1	49·2	14·8
130................	197 8 —199 1	0·3	14·2		0·0	0·3	0·6	0·4	32·6	19·9	30·6	15·6
131................	199 1 —200 6	2·3	14·8		0·1	0·3	0·8	0·3	38·1	15·9	28·3	16·2
132................	200 6 —201 7	8·1	6·5	5·1	0·0	0·0	0·4	0·5	40·7	14·1	23·0	21·3
133................	201 7 —202 10	1·5	12·3		0·0	0·2	1·0	0·4	59·7	13·8	13·3	11·6
134................	202 10 —204 11	3·0	9·3		0·0	0·1	1·2	0·7	35·3	12·3	30·4	20·0
135................	204 11 —206 3	2·5	10·0	5·4	0·0	1·4	5·0	3·0	45·5	9·8	23·8	11·5
136................	206 3 —207 7	3·9	7·4		0·2	5·9	11·7	4·6	31·6	6·4	20·9	18·7

* Screened with Eimer and Amend screens.

The above well is of particular interest since it probably represents fairly well the very large tonnage of bituminous sand exposed in the imposing cliffs on the east side of Athabaska river, in sec. 33, tp. 89, R. 9 and in sec. 5, tp. 90, R. 9. (Plate VIIA). This important tonnage had not been previously sampled although the surface of the cliffs appeared to indicate highly banded material of doubtful commercial value[1]. Apart from the character of the bituminous sand, however, conditions which would govern development are not favourable. The disposal of a large yardage of overburden would present difficulties, while the necessary acreage for town site and plant site is not available. Rail transportation along the river front is not practicable.

Well No. 3

A site for well No. 3 was selected in L.S. 11, sec. 20, tp. 91, R. 9, at a point approximately 10 miles north of Well No. 2. Clearing and grading roads, overhauling barges, and moving equipment occupied approximately five weeks. Continued wet weather seriously hampered operations.

The site of this well is on a terrace or river bench[2], 600 to 1,200 feet in width and 3,000 feet in length. Extensive exposures of what appear to be good quality bituminous sand occur in the immediate vicinity and along both sides of Wood Creek valley. It was therefore considered that results of drilling within the area indicated, would represent a very large tonnage of bituminous sand.

Drilling of this well was commenced on July 30 and discontinued on September 26. A detailed log of the well is given in Table III.

The following comment on conditions encountered in Well No. 3 is submitted by Mr. Schmidt.

"Drilling was commenced on what appeared to be a low sandy ridge[3] and, considering local topography and drainage, it was hoped that the well would be relatively free from water seeps. Almost at the surface, however, 14 feet of clay were encountered, and this was followed by silt and fine sand showing merely a trace of bitumen. At a depth of 27½ feet coring was commenced with augers and core barrels, and continued to a depth of 84 feet. Much of the bituminous sand passed through appeared to be banded, varying in hardness and in colour from brown to black. Progress was seriously handicapped by numerous water seeps.

"At 77½ feet, coring tools again encountered hard, brownish grey clay and some silt, which continued, with merely a trace of bitumen, to a depth of 84 feet. At this point, however, a 6-inch stratum of hard shale necessitated a resort to cable tools, the use of which was continued to a depth of 123 feet. Strata passed through constituted alternating beds of clay and hard shale with numerous water seeps. The presence of more than 45 feet of clay and shale would condemn this area from the standpoint of immediate commercial development, and drilling operations were therefore discontinued at a depth of 123 feet.

"Following the coring tools, cable tools—and water—were used for enlarging or underreaming the bore. On being withdrawn, stem and jars were partly covered with almost pure bitumen[4] which had obviously separated under the action of water in the well. In connexion with drilling operations in the McMurray area during the last twenty years, 'pools of bitumen' have been reported at various depths[5]. Since practically all previous wells have been drilled with cable tools, involving the use of water, it appears that the reported 'pools of bitumen' in bituminous sand strata, may be the result of water separation. The origin of such pools in underlying Devonian strata may probably be traced to interbedded shales."

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[1] In 1913 the writer cored four complete sections of these cliffs at intervals of approximately one-third mile. These samples were, however, taken at a maximum of 4 feet from the surface and had probably been subject to alteration.
[2] Mines Branch Map Sheet No. 635.
[3] Mines Branch, Dept. of Mines, Canada, Rept. No. 632, p. 5, par. 4.
[4] See Table III, sample No. 25.
[5] Mines Branch, Dept. of Mines, Canada, Rept. No. 632, *see* "Well Records," p. 21 *et seq.*

TABLE III

Detailed Log of Well No. 3

Sample No.	Depth	Moisture in sample as received,	Bitumen content: (dry-sand basis)	Sulphur content of (water-free) bitumen	Screen analyses of dry extracted sand: Held on 10 mesh	Passing mesh 10	20	30	40	80	100	200
	′ ″ ′ ″	%	%	%	%	%	%	%	%	%	%	%
	0 — 15	Chiefly clay shading into low-grade bituminous sand with traces of bitumen at depth of 14 feet.										
1..........	15 0 — 28 0	22·0	1·8	5·6	0·0	0·4	2·6	2·7	7·1	4·0	34·8	48·4
2..........	28 0 — 28 10	12·7	3·9		0·0	0·0	0·2	0·6	2·8	1·4	44·4	50·6
3..........	28 10 — 30 4	11·9	3·1	5·3	0·0	0·0	0·2	0·4	3·6	3·4	66·7	25·7
4..........	30 4 — 33 6	14·4	3·5		0·0	0·0	0·5	0·2	1·2	2·8	67·2	28·1
5..........	33 6 — 35 0	12·5	6·5		0·0	0·0	0·0	0·2	1·3	6·1	68·4	24·0
6..........	35 0 — 36 5	11·5	6·3	4·9	0·0	0·0	0·0	0·5	2·0	10·5	68·8	18·2
7..........	36 5 — 39 8	12·1	8·0		0·0	0·0	0·3	0·1	1·5	8·1	73·8	16·2
8..........	39 8 — 41 4	9·3	9·7	5·2	0·0	0·3	0·8	0·3	2·3	7·8	70·1	18·4
9..........	41 4 — 42 7	12·8	5·9		0·0	0·0	0·4	0·5	2·3	9·8	64·7	22·3
10..........	42 7 — 45 6	11·3	8·5		0·0	0·2	0·1	0·3	1·3	7·8	77·2	13·1
11..........	45 6 — 47 6	12·4	12·0	4·8	0·0	0·0	0·1	0·1	1·6	24·8	65·4	8·0
12..........	47 6 — 49 0	13·0	9·5		0·1	0·1	0·4	0·3	6·1	25·8	53·8	13·4
13..........	49 0 — 49 6	12·1	8·8		0·0	0·0	0·1	0·2	19·4	34·8	33·9	11·6
14..........	49 6 — 51 9	11·0	9·4	4·6	0·0	0·0	0·3	0·4	16·6	37·8	33·2	11·7
15..........	51 9 — 53 6	12·9	8·3		0·0	0·0	0·4	0·3	20·9	25·6	38·7	14·1
16..........	53 6 — 56 6	13·5	9·1		0·0	0·0	0·2	0·3	16·0	23·5	43·0	17·0
17..........	56 6 — 56 9	12·9	3·7		0·0	0·1	0·2	0·7	18·4	15·5	30·6	34·5
18..........	56 9 — 70 0	14·6	7·9	5·0	0·0	0·0	0·5	0·3	13·7	30·1	41·3	14·1
19..........	70 0 — 70 5	16·5	11·0		0·2	0·1	0·3	0·2	6·9	30·9	51·9	9·5
20..........	70 5 — 71 9	6·1	14·2		0·0	0·0	0·1	0·1	3·4	34·1	54·9	7·4
21..........	71 9 — 72 6	15·0	4·5	5·1	0·0	0·1	0·2	0·1	6·6	27·6	54·9	10·5
22..........	72 6 — 73 3	12·9	12·5		0·0	0·0	0·1	0·1	4·0	37·0	50·2	8·6
23..........	73 3 — 74 7	9·6	13·9	4·8	0·0	0·1	0·1	0·1	2·3	35·0	54·2	8·2
24..........	74 7 — 77 9	6·7	13·9		0·0	0·0	0·0	0·2	5·8	25·5	59·0	9·5
25..........	77 9	9·4	85·1	5·6								
		(Sample taken from bottom of hole. Bitumen probably separated from formation above.)										
	77 9 —117	(Clay and shale.)										

NOTE.—Apparently the heavy bed of clay and shale between 77 feet 9 inches and 117 feet will prevent development of underlying bituminous sand. Drilling was, therefore, discontinued at 117 feet.

Well No. 4

In order to further explore the extensive terrace in sec. 20 referred to above, the site of a second well (Well No. 4) was selected at a point approximately 300 feet west of the ¼ mound in the north boundary of sec. 20, tp. 91, R. 9, or 1,820 feet N. 10 degrees E. from No. 3 well, and at an elevation of 1,004 feet. It had been anticipated that the upper limit of the bituminous sand would lie at a lower elevation than in Well No. 3, and this was confirmed by actual results.

Reference to so-called residual beds of bituminous sand on certain smaller streams tributary to Athabaska river, will be found in previous reports[1] issued by the Mines Branch. On these smaller streams residual beds, from which the original overburden and much of the low-grade banded material have been eroded, are especially adaptable to commercial development. The writer has always maintained that within the Athabaska valley itself similar conditions will be encountered, though on a correspondingly larger scale, and that residual beds will be found where, as in secs. 13 and 24, tp. 97, R. 11, pronounced bends occurred in the pre-glacial channel. On the smaller streams, the maximum thickness of residual beds of bituminous sand is usually found in an upstream direction, eroded bituminous sand in the downstream direction being replaced by river wash. Logs of Wells Nos. 3 and 4 have confirmed the writer's theory that similar conditions prevail along Athabaska valley.

Drilling of Well No. 4 was commenced on September 1, but, owing to difficulties encountered, was discontinued at a depth of 30 feet, without reaching bituminous sand.

The log is summarized in Table IV.

TABLE IV

Log of Well No. 4

Depth from surface	Bitumen content (per cent)		Remarks
feet	max.	min.	
0–5	0	0	Sand containing rounded gravel and small boulders.
5–12	0	0	Same with thin, secondary (marginal) deposits of bituminous sand.
12–24	0	0	Coarse gravel and small boulders.
24–30	0	0	Same, but boulders larger and more numerous.

The above well was drilled with cable tools, and at a depth of 23 feet further progress was stopped by large boulders. A shaft was sunk which made it possible to continue drilling to a depth of 30 feet, but at this point boulders effectually prevented further progress.

The presence of secondary deposits of bituminous sand indicated marginal[2] beds similar to those observed in township 98, and elsewhere.

[1] Mines Branch, Dept. of Mines, Canada, Rept. No. 281, p. 16.
Mines Branch, Dept. of Mines, Canada, Summary Reports, 1914-26.
Mines Branch, Dept. of Mines, Canada, Rept. No. 632, p. 31.
[2] Mines Branch, Dept. of Mines, Canada, Rept. No. 632, p. 17.

CONCLUSION

Results of drilling operations referred to above have amply confirmed the writer's previous contention that only after detailed exploration by means of adequate equipment, can the true economic importance of any bituminous sand area be determined. It is realized that the most efficient drilling equipment for core sampling has not, as yet, been developed. It is considered, however, that the experience already acquired will prove of practical value to any who may contemplate extensive core sampling.

PAVING

INTRODUCTION

During July and August, 1926, an internally heated mixing plant for the manipulation of bituminous sand was designed and built by the writer at Edmonton, Alberta. During parts of September and October of that year this plant was operated for a short period at Jasper, but, owing to unseasonable weather, the area surfaced at that time did not exceed 5,000 square yards. Paving work was, therefore, again resumed on May 25, 1927. Since equipment used and methods adopted in 1926 are described in Mines Branch Report No. 684, the following statements should be regarded merely as supplementary to that report. As in 1926, work was interrupted by unusually wet weather.

EXTENT OF OPERATIONS

Wearing surface laid between May 25 and September 7, 1927, comprised approximately 12,100 lineal feet of highway (Plate VIIB) varying in width from 15 to 18 feet—adequately widened at curves—and equivalent to approximately 23,000 square yards; 3,200 square yards of roadway and parking area adjacent to Jasper Lodge, and 2,100 square yards of walks within Jasper Lodge grounds (Plate VIIIA and Figure 2). During the period noted, 1,130 two-drum batches of mixture (approximately 3,160 tons) were prepared at the plant (VIIIB). This should be equivalent to rather more than 31,000 square yards of 2-inch compacted surface, but, owing to unavoidable unevenness in the original gravel surface, actual thickness of compacted bituminous sand mixture was frequently materially greater than 2 inches. The quantity of bituminous sand shipped from Waterways (McMurray) during 1927 was 2,373 tons.

Mining Operations

As in 1926, operations at McMurray (Plates IXA and IXB) were handicapped by inadequate transportation facilities. Following the removal of overburden, the bituminous sand was drilled and blasted, and wheeled in hand-barrows to a steel chute. This chute discharged directly onto decked barges, which were pushed one mile up Clearwater river to Waterways landing. Here the material was again loaded by hand into small mine cars which were hauled by cable and winch up a trestle, 160 feet long, and discharged onto flat cars. Quite apart from the cost involved, the tonnage which could be handled by such methods would be entirely inadequate should important commercial development be undertaken.

Plant and Road Operations

As in 1926, neither the personnel at the mixing plant nor on the road operated to capacity. Moreover, mechanical appliances were not available for unloading cars, crushing bituminous sand, and elevating materials. With adequate labour-saving devices, the same plant and road personnel could have handled a much larger tonnage of materials.

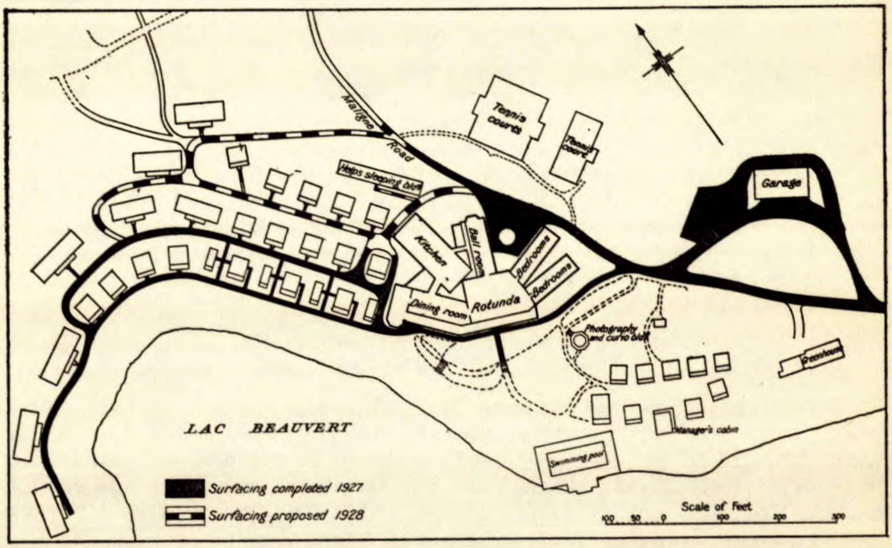


Figure 2. Plan of Jasper Lodge grounds, Canadian National Railways, Jasper, Alberta, showing walks and roads surfaced with Alberta bituminous sand. (September, 1927.)

COSTS OF DEMONSTRATION PAVING AT JASPER

In view of the above factors, operating costs were unduly high and, with improved transportation facilities at McMurray and perfected plant equipment, can be materially reduced.

Mining Costs

Owing to variation in thickness of overburden, cost of bituminous sand delivered on cars at Waterways ranged from \$3.50 to \$5.00 per ton. It is considered that with rail transportation immediately adjacent to the quarry, this cost should not exceed \$1.00 per ton. Freight charges from Waterways to Edmonton—a distance of 300 miles— were \$3.50 per ton. Large and assured tonnage should be reflected in a freight rate of possibly

$2.50. Since paving at Jasper was considered as beneficial to Jasper Lodge—a tourist resort operated by the Canadian National Railways—freight charges between Edmonton and Jasper were waived by that company.

Plant and Road Costs

Conditions under which operations were conducted at the quarry, mixing plant, and on the road, must be considered in interpreting costs. Moreover, roller, trucks, and other standard equipment were furnished by the Parks Branch. Consequently, other charges must be added to costs indicated below if work is to be done by private contractors. Similarly, allowance must be made for variation in wages and costs of materials[1] at various points.

Actual out-of-pocket plant and road costs at Jasper, apart from supervision by the Mines Branch and Canadian National Parks, may be summarized as follows:—

Mixing Plant

Wages—		
1 drier man at 45 cents per hour	$ 4 50	
5 men unloading cars at 45 cents per hour	22 50	
3 men breaking lumps of bituminous sand at 45 cents per hour	13 50	
1 engineer at 60 cents per hour	6 60	
1 man tending discharge chutes at 45 cents per hour	4 50	
		$ 51 60
Fuel—		
70 gallons fuel oil (for combustion chamber)	12 60	
½ ton coal for boiler	2 00	
		$ 14 60

Road Costs

Spreading, raking, and rolling—		
1 foreman at 50 cents per hour	$ 5 00	
6 labourers at 45 cents per hour	27 00	
1 roller man at 60 cents per hour	7 20	
Gasoline, oil, etc	3 00	
		$ 42 20
Transport—		
1 truck driver at 50 cents per hour	$ 5 00	
Gasoline and oil	2 50	
		$ 7 50
Materials—		
7 cubic yards gravel	$ 12 25	
11 cubic yards silt (filler)	5 50	
33 tons bituminous sand	146 85	
Freight on bituminous sand	115 50	
		$ 280 10
		$ 396 00
Supervision, depreciation, and contingencies (10 per cent of above)		39 60
		$ 435 60

or $9.90 per ton of paving mixture laid on road.

COMMENTS ON PLANT AND ROAD COSTS

Plant costs per ton of mixture will obviously be affected by the size and frequency of batches passed through the mixing-drums, that is, by drum capacity and heating efficiency. In 1926, weight of a two-drum batch was approximately 5,800 pounds. In 1927, however, in order to

[1] Mines Branch, Dept. of Mines, Canada, Rept. No. 632, p. 83.

prevent spilling from drum openings, this was reduced to approximately 5,600 pounds. Actual working time per day was approximately 9½ hours and, during this period, 16 batches or 45 tons of mixture were sent to the road. Toward the end of the season a slight change in design of combustion chamber increased the plant capacity to 19 batches per day or 53 tons of mixture. In the above estimated costs indicated capacity is, however, assumed as 45 tons per day.

In Texas[1], drums 8 feet in diameter and 6 feet long are commonly, though not always, used. With such drums, and assuming 19 batches per 10 hours, daily capacity would be equivalent to 133 tons of mixture.

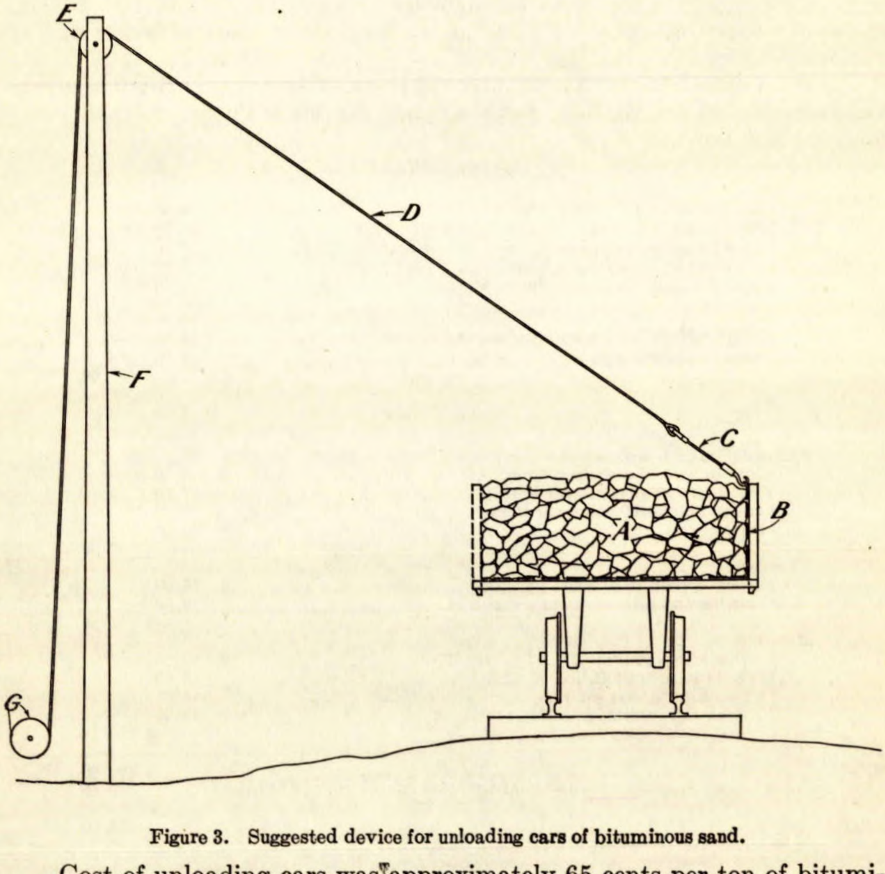


Figure 3. Suggested device for unloading cars of bituminous sand.

Cost of unloading cars was approximately 65 cents per ton of bituminous sand. A simple unloading device, such as that illustrated in Figure 3, would probably reduce this cost to not more than 25 cents per ton.

This device provides for the use of net B, fabricated with wire cable. Meshes might be 10 to 12 inches square, stiffened at one or more points by light iron channels.

On arrival at the plant a cable D, operated by a light donkey engine and drum G, and passing over sheave E, at top of temporary, guyed mast F, would be secured by one or more attachments C, to channel at end of net B.

[1] Mines Branch, Dept. of Mines, Canada, Rept. No. 684.

Stakes and boards along one side of load A would then be removed, and net and bituminous sand rolled clear of the deck of the car. The number of nets required per car can be determined only by actual experiment but three would be a maximum. When a car was unloaded the nets could be rolled up and shipped back to the quarry. Such a device would be much

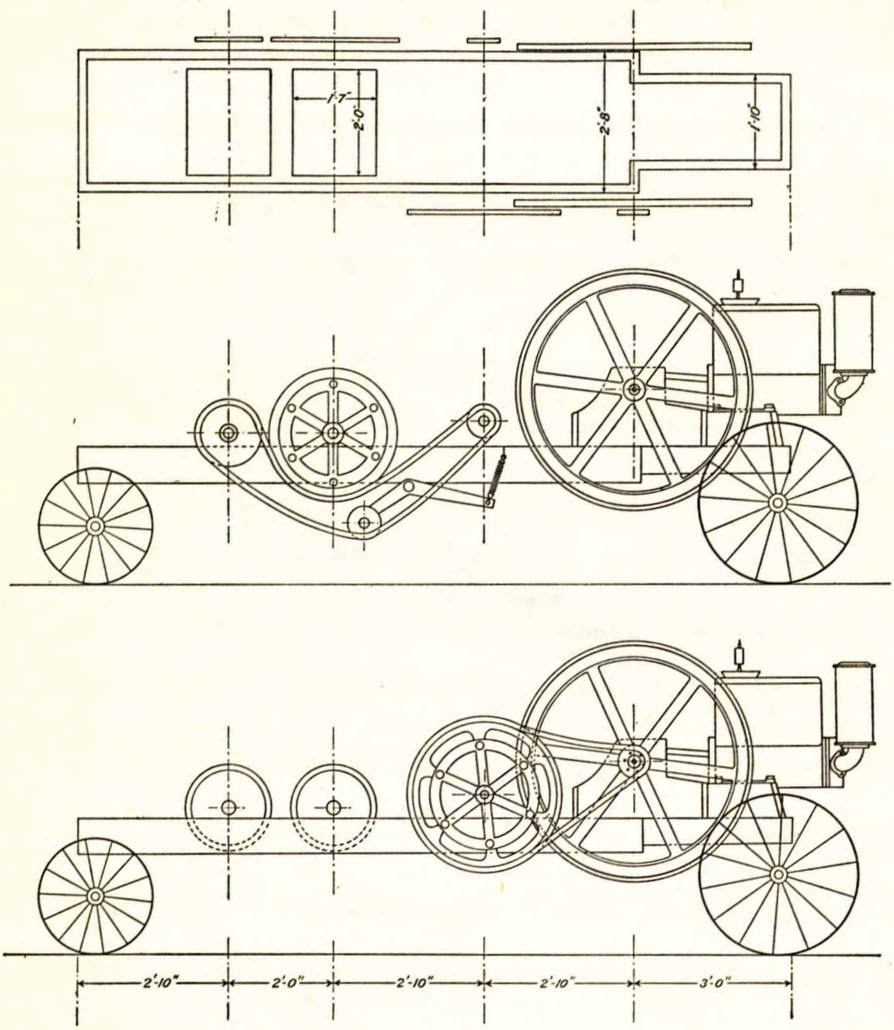


Figure 4. Crushing rolls for breaking lumps of bituminous sand.

less cumbersome than the wooden trays[1] used at one time by the City Street Improvement Company of San Francisco. Sledging lumps of bituminous sand cost 40 cents per ton. The use of a toothed roll crusher, such as that illustrated in Figure 4 and Plate XA, would reduce this cost

[1] Mines Branch, Dept. of Mines, Canada, Rept. No. 632, p. 161.

to not more than 20 cents per ton. Duties of the engineer were limited to furnishing steam for atomizing the fuel oil. With a small compressor, this item of $6.60 could be reduced or done away with.

Fuel oil used was a distillate costing 18 cents per gallon. Using a heavier oil, this cost could be reduced to 12 cents per gallon.

Assuming 45 tons of mixture or 450 square yards of 2-inch compacted surface per 10 hours, it is clear that the road crew—particularly the roller man—did not work to capacity. The same crew, with two additional labourers, could spread, rake, and roll 133 tons or 1,330 square yards. The larger capacity—133 tons— would also imply the use of two additional trucks.

Assuming a plant capacity of 133 tons per day and a mixture consisting of 30 parts added clean aggregate and 70 parts of 16 per cent bituminous sand, quantities noted in the above estimate would be increased to 7 tons filler, 33 tons crushed rock or gravel, and 93 tons bituminous sand. With a plant of such capacity (Figures 5 and 6) equipped with car unloader, crusher, elevator, etc., the cost estimate on paving operations, if conducted under conditions such as prevailed at Jasper in 1927 could apparently be modified as follows:—

Mixing Plant Costs

Wages—		
1 drier man at 45 cents per hour	$ 4 50	
6 men unloading cars, feeding, elevator, etc	27 00	
1 man on crusher at 45 cents per hour	4 50	
1 man tending discharge chutes at 45 cents per hour	4 50	
1 engineer at 60 cents per hour	6 60	
		$ 47 10
Fuel—		
150 gallons fuel oil for combustion chamber at 12 cents	$ 18 00	
75 gallons fuel oil for 100 h.p. steam boiler at 12 cents	9 00	
		$ 27 00

Street (or Road) Costs

Spreading, raking, and rolling—		
1 foreman at 65 cents per hour	$ 6 50	
4 rakers at 65 cents per hour	26 00	
8 labourers at 45 cents per hour	36 00	
1 roller man at 60 cents per hour	7 20	
Gasoline and oil	4 00	
		$ 79 70
Transport—		
3 truck drivers at 50 cents per hour	15 00	
Gasoline and oil	6 00	
		$ 21 00
Materials—		
7 tons silt at $2 per ton	$ 14 00	
33 tons outer clean aggregate at $2.20	72 60	
93 tons bituminous sand at $1	93 00	
Freight on same at $2.50 (Waterways to Edmonton)	232 50	
		$ 412 10
		$ 586 90
Profit, interest, depreciation, etc. (33 per cent of above)		195 63
		$ 782 53

or $5.80 per ton of mixture laid on road.

The above estimates assume that working conditions are similar to those which prevailed at Jasper in 1927. Although 33 per cent has been allowed for profit, interest, and depreciation, other recognized cost items should obviously be added at the discretion of private contractors.

In considering the above data the following costs, which have been furnished through the kindness of Mr. A. W. Haddow, City Engineer, Edmonton, will be of interest.

"1927.

"Our contract price was $1.60 and $1.65 per square yard for 2-inch surfacing. Our own paving plant costs were $1.32½ per square yard for an output of 31,889 square yards. For billing purposes, local improvement work was charged $1.50 per square yard, and small jobs, sundry debtor work, $1.75 per square yard. Even in the makeup of our $1.32½ price, we have not included such items as Workmen's Compensation Board, interest and sinking fund on the capital investment, fire insurance premium, engineering supervision, and profit, which I calculate would bring our price to $1.59, which is in close agreement with the $1.60 price of the contractor. In 1927, the following rates of wages were in effect:—

"Team and teamster	95c. per hour
Common plant labour	52c. "
Plant foreman	$175 per month
Street gang foreman	$144 "
Street rakers	57c. per hour
Street labourers	52c. "

"1926.

"In 1926 our contract price was $1.54 per square yard for street work and for lanes $3.52 per square yard for base and surface. Putting the base at $2 per square yard would leave $1.52 for surface.

"In 1925 the 101st Street subway contract price was $1.75 per square yard of 2-inch surfacing. Other prices in this case were $1.80, $1.86, and $2.09 per square yard.

"In 1923 the contract price for 5-inch bituminous slab was $2.57 and $2.65 per square yard, and for 2-inch surfacing on concrete base $3.30 per square yard. At that time, concrete base was bid at $1.96, leaving $1.34 for surfacing.

"In 1916 on Portage Avenue, we paid $2.20 per square yard for base and surface, and in 1915, $2.10 per square yard for base and surface. In 1914 we paid $2.28 for 2-inch surfacing and 6-inch concrete base, and in 1913 we paid $1.30, $1.32, and $1.38 per square yard for surfacing only."

PAVING MIXTURES

Bituminous Sand

Each car of bituminous sand as it arrived at the paving plant (Plate VIIIB) was sampled; and moisture, bitumen content, and grading of sand aggregate determined in a field laboratory, the whole operation taking approximately three hours. From results obtained the paving mixture was set. While the above method proved fairly satisfactory, sampling of the bituminous sand in situ at the quarry is suggested as an alternative. With the stripped surface of the bituminous sand laid out in rectangles, analyses of material underlying each rectangle could be determined in advance. This method has been found satisfactory at certain of the rock asphalt quarries in Texas, although composition of mixtures is also checked by analyses of batch samples at mixing plants. Unless a deposit definitely comprises a large tonnage of proved uniform bituminous sand, adequate supervision of all shipments should also be maintained at the quarry, since, otherwise, quarrymen will inevitably at times supply unsuitable material. It must, however, be recognized that some variation in the quality of bituminous sand will be met with. Consequently, it is desirable, if possible, that both drums at the mixing plant be charged with bituminous sand from the same car; otherwise it may be necessary to charge a different proportion of clean aggregate and bituminous sand into each drum.

Analyses of representative samples of bituminous sand shipped to Jasper during the past season (1927) are summarized in Table V. The marked variation of bitumen content indicated by these results is largely due to severe slipping followed by infiltration of water[1] along a great number of slip-planes. Such a condition would probably be less marked—or non-existent altogether—in the richer residual beds[2] such as are found on Horse river and elsewhere in the McMurray area[3].

Clean Aggregate

Owing to the somewhat low bitumen content in material shipped from McMurray during 1927, added clean aggregate was equivalent to from 15 to 22 per cent of the bituminous sand mixture. Clean aggregate consisted of gravel screened to pass a 1-inch ring, and approximately 5 per cent of filler.

TABLE V

Analyses of Car Samples[4]

Held on 10 mesh	Passing mesh								Water, per cent	Associated bitumen, per cent
	10	20	30	40	60	80	100	200		
Trace	0·2	1·2	0·9	56·9	......	18·8	20·9	1·1	0·7	15·1
"	0·6	3·1	2·0	9·6	35·0	25·1	23·2	1·4	0·4	14·5
"	0·5	2·7	2·0	77·5	......	8·5	7·9	0·9	1·2	14·1
"	0·3	2·5	2·0	61·2	......	14·7	17·9	1·4	1·1	13·7
"	0·5	3·2	2·1	10·6	41·2	24·5	16·9	1·0	1·5	13·3
"	0·8	4·3	2·9	11·4	40·3	23·1	16·3	0·9	0·8	13·0
"	0·6	3·2	2·2	11·0	39·2	25·7	17·2	0·9	1·6	12·8
"	1·1	5·0	3·3	12·8	43·8	17·6	15·4	1·0	0·7	13·3
"	0·9	5·4	4·1	18·3	40·9	15·7	13·5	1·2	0·6	13·6
"	1·0	7·5	5·3	23·4	35·5	15·5	10·9	0·9	0·5	14·2
"	0·7	4·7	3·5	17·7	46·6	14·8	10·9	1·1	0·8	13·8
"	0·9	5·7	4·7	21·7	35·7	15·9	13·6	1·8	0·3	13·7
"	1·1	5·7	4·4	21·6	38·6	15·7	11·3	1·6	0·5	13·9
"	0·4	3·9	2·6	18·5	38·0	21·1	14·0	1·5	0·8	14·3
"	0·2	4·0	5·0	27·4	35·6	15·4	10·6	1·8	1·0	13·4
"	1·5	8·1	6·1	22·8	31·0	15·6	13·4	1·5	0·8	13·9
"	0·6	5·3	4·8	26·4	34·0	15·7	11·8	1·4	0·2	13·9
"	0·5	4·0	3·6	18·5	42·0	15·6	14·4	1·4	1·4	13·0
"	0·9	7·1	5·2	24·7	38·0	11·8	11·0	1·3	1·3	13·1
"	0·6	6·5	8·0	24·9	35·2	11·1	12·0	1·7	1·2	13·5
"	0·8	8·4	6·3	27·3	34·2	10·9	10·5	1·6	0·7	13·8
"	0·3	3·6	3·6	32·7	25·3	18·1	14·7	1·7	0·7	14·1
"	0·6	3·8	3·2	23·3	40·1	13·8	13·8	1·4	0·7	13·5
"	0·6	5·5	4·2	17·6	37·1	17·2	16·2	1·6	0·7	14·1
"	1·5	9·4	6·9	21·7	31·0	14·4	13·5	1·6	0·6	13·8
None	0·4	4·4	3·4	26·7	34·7	15·7	13·2	1·5	1·4	13·5
"	0·	3·7	4·6	19·2	40·6	14·5	15·3	1·6	0·6	13·9
Trace	0·3	2·9	3·4	30·0	35·2	14·3	12·5	1·4	0·8	13·2
"	1·5	6·4	4·4	21·1	36·6	15·4	13·0	1·6	0·6	14·2
None	0·1	1·3	2·0	33·6	39·2	11·8	10·7	1·3	0·7	12·7
Trace	0·5	4·6	4·8	32·3	30·5	13·2	12·7	1·4	0·5	13·8
"	1·3	8·2	5·8	23·7	31·1	16·3	12·3	1·3	0·2	13·3
"	0·4	4·8	5·2	39·2	25·4	13·2	10·1	1·7	0·2	13·3
"	1·3	7·5	4·8	21·2	30·5	16·5	16·5	1·7	1·8	12·5
"	1·5	11·2	7·8	22·8	24·3	12·2	18·0	2·2	2·6	12·3
"	1·6	11·3	7·5	21·0	28·9	15·2	12·4	2·1	2·8	12·3
"	1·4	5·4	3·9	33·7	28·8	13·5	11·7	1·6	2·5	11·3
None	2·1	8·9	5·6	19·1	32·0	16·3	14·0	2·0	2·2	13·0
Trace	2·5	12·5	5·8	21·8	28·9	13·7	12·9	1·9	2·3	12·7
0·1	2·1	12·3	7·7	26·7	27·2	10·9	10·8	2·2	2·2	12·2

[1] Mines Branch, Dept. of Mines, Rept. No. 684, pp. 53-57.

[2] Mines Branch, Dept. of Mines, Canada, Rept. No. 632, p. 73.

[3] Bituminous sand excavated by the writer prior to 1927 (notably on Horse river) contained nodules of iron pyrite up to five pounds in weight. At the Clearwater pit very few nodules of pyrite were encountered, but nodules of clay ironstone, up to five pounds in weight, were of fairly common occurrence.

[4] Variation in samples is due in part to occasional difficulty in sampling cars, but chiefly to the extent to which infiltration of water along slip-planes had leached out associated bitumen. Moreover, the amount of bituminous sand required at Jasper was greater than originally estimated, and rather than undertake new stripping, somewhat low-grade material was shipped from McMurray.

During 1926 an appreciable amount of moisture present in the gravel was driven off in the mixing-drums, and this tended to prolong periods of heating. As a result, capacity of plant did not exceed an average of 13 batches per day. In 1927, two corrugated galvanized iron pipes, placed side by side—each 12 feet long and 24 inches in diameter—were used as driers (Plate VIIIB), and as a result gravel was introduced into the mixing-drums practically free from moisture and at a temperature of not less than 250° F. Partly rotted ties from an abandoned railway grade nearby were used as fuel in the pipes and proved satisfactory. These ties burned slowly and an average of nine per day furnished sufficient heat. Truckloads of gravel were dumped directly onto the pipes, thus reducing shovelling to a minimum.

As will be seen from analyses indicated in Table V, bituminous sand received at Jasper was deficient in –200 material. During paving operations in the fall of 1926, no attempt was made to correct this deficiency, but during initial operations in 1927 Portland cement was introduced with the clean aggregate. Subsequently—on June 18—river silt, of which approximately 76 per cent passed a 200-mesh screen, was substituted for the Portland cement with apparently satisfactory results. The relation of variable percentages of mineral filler to the stability of wearing surfaces need not here be discussed. An unduly high, though not definitely determined percentage of filler with resulting increase of density does, however, seriously affect the rate at which batches, even when heated to 400° F, are discharged from mixing-drums.

Representative analyses of batches sent to the road are shown in Table VI, and indicate variation in bitumen content. This was chiefly due to the fact that, at times, difficulty was experienced in securing accurate samples from cars of bituminous sand.

TABLE VI

Analyses of Mixer Batches

Batch No.	Held on mesh ½	Passing mesh										Bitumen, per cent
		½	¼	10	20	30	40	60	80	100	200	
152.......	1·6	3·4	5·2	5·1	7·0	3·4	11·1	35·0	14·3	9·8	4·1	10·2
156.......	1·0	1·8	4·5	4·7	6·3	3·3	13·3	39·7	12·9	8·6	3·9	10·1
185.......	0·3	2·5	4·7	4·8	6·6	4·5	19·0	28·6	14·5	10·2	4·3	10·4
196.......	2·1	2·7	4·4	4·0	5·9	3·7	13·4	31·7	16·4	11·0	4·7	9·9
202.......	1·1	1·9	5·2	5·4	7·1	4·1	16·2	29·7	13·8	10·9	4·6	9·7
206.......	1·3	2·2	4·6	4·5	6·7	3·8	13·5	30·3	17·5	11·9	3·7	10·2
208.......	2·2	3·8	5·3	5·6	7·2	4·3	15·6	26·8	14·1	10·5	4·6	9·7
214.......	1·1	2·4	4·9	5·7	8·0	4·7	19·3	31·0	10·7	8·4	3·8	9·7
222.......	1·2	2·8	5·1	4·7	7·3	5·3	18·7	28·9	12·5	9·8	3·7	10·1
230.......	0·8	3·8	4·2	5·7	5·2	3·9	17·7	32·3	13·2	9·7	3·6	10·4
237.......	1·5	2·1	4·5	4·4	6·9	4·4	16·2	31·5	13·0	10·6	4·9	10·1
249.......	0·2	2·3	4·5	4·6	6·4	3·2	14·2	39·5	13·1	8·4	3·6	10·8
256.......	0·0	2·6	3·7	4·4	6·5	4·7	16·7	29·7	16·1	11·6	3·9	10·2
266.......	0·0	2·2	3·9	3·7	6·6	5·7	23·0	27·6	12·3	11·3	3·7	10·4
271.......	0·4	1·9	4·5	4·9	8·3	6·1	21·5	25·3	11·9	11·8	3·4	9·6
275.......	0·4	2·0	3·9	4·1	6·4	6·6	18·2	29·3	15·1	10·5	3·5	10·1
277.......	0·0	3·6	6·1	5·2	8·4	5·1	20·3	24·8	11·5	11·3	3·7	9·9
285.......	2·3	1·5	3·8	4·2	6·4	4·6	22·4	28·2	11·8	10·6	4·2	10·2
288.......	0·4	2·4	3·6	4·8	8·6	5·5	20·2	26·5	12·8	11·1	4·1	10·2
294.......	0·0	2·4	5·5	5·2	8·6	5·4	19·9	27·8	9·9	10·9	4·4	10·1
300.......	0·0	1·9	3·9	4·0	6·0	4·0	21·6	30·1	14·1	10·5	3·9	10·0
303.......	0·8	1·6	4·8	5·4	8·1	5·5	19·2	26·4	12·5	11·0	4·7	10·2
316.......	0·6	1·8	4·5	5·3	9·1	5·0	16·2	26·9	14·2	11·8	4·6	10·0
319.......	0·6	3·4	4·7	5·1	9·5	5·5	18·1	24·8	12·7	10·9	4·7	10·1
323.......	0·1	1·3	3·9	4·7	7·3	4·1	17·1	30·5	13·8	12·7	4·5	9·8
325.......	0·0	1·7	3·4	5·2	9·0	5·0	16·0	31·7	11·7	11·6	4·7	10·4
331.......	0·5	2·5	3·3	4·1	7·2	4·0	15·4	33·0	14·1	11·3	4·6	9·7
343.......	1·1	2·4	3·8	4·3	8·6	4·8	19·0	28·0	12·8	10·4	4·8	10·4
346.......	0·0	1·0	3·6	4·4	7·2	5·1	21·1	30·7	11·9	10·5	4·5	10·3
349.......	1·5	2·2	3·8	4·2	8·1	4·9	17·0	29·6	12·6	11·1	5·0	10·7
356.......	0·0	1·3	3·6	4·4	7·2	4·5	19·5	32·1	12·1	11·0	4·3	10·3
371.......	0·0	2·2	3·3	3·4	6·6	4·9	23·1	26·3	14·4	11·4	4·4	10·4
378.......	1·9	2·0	3·3	5·6	10·8	5·9	15·1	25·4	14·6	10·9	4·5	9·6
381.......	1·7	2·3	4·2	4·7	6·2	4·4	14·8	26·4	16·4	13·8	5·1	10·0
387.......	1·0	2·0	4·5	4·9	7·7	5·0	18·7	26·9	12·8	12·2	4·3	10·3
410.......	3·0	1·6	3·2	3·9	6·1	3·6	26·5	22·8	13·8	11·6	3·9	10·0
431.......	0·8	1·8	3·2	4·0	6·6	5·2	21·7	30·3	11·0	10·9	4·5	10·1
454.......	0·7	2·7	4·5	4·6	5·1	3·2	13·0	26·5	18·9	16·3	4·5	9·9
469.......	1·8	1·3	3·5	4·3	5·5	3·5	17·0	35·7	10·3	13·2	3·9	9·5
485.......	0·6	1·7	3·8	5·2	8·6	5·9	24·0	30·1	7·5	8·6	4·0	10·4
489.......	1·3	3·3	4·4	5·6	9·6	5·9	18·4	25·2	11·6	10·1	4·6	9·7
494.......	0·8	1·5	4·6	5·8	9·9	6·1	19·0	25·1	12·5	10·6	4·1	10·0
502.......	2·2	1·4	3·8	4·9	9·1	6·2	18·2	26·1	12·6	11·1	4·3	9·9
510.......	0·0	2·1	3·3	4·1	6·3	3·9	22·8	24·0	17·0	12·7	3·8	9·6
518.......	0·3	1·5	3·2	4·1	6·4	4·5	20·1	31·0	13·6	11·4	3·9	9·9

Temperatures

At Jasper, in 1926, average batch temperatures did not exceed 275° F. Even so, the wearing surface did not mark unduly, and after one winter and one summer, appeared to be in satisfactory condition. In 1927, however, average batch temperatures were increased to approximately 320° F. In spite of this higher temperature—owing to the use of the gravel drier and to certain minor changes in the combustion chamber—it was possible to materially increase the number of batches per day.

67531—3

TABLE VII

Results of Analyses of Samples from Paving Plant

Sample No.	Time in mixer (minutes)	Temperature °F.	Composition of sample, percentage of: Bitumen	Mineral matter	Water	Screen analyses of mineral matter, percentage of: Retained on mesh 14	28	48	100	200	Passing mesh 200	Specific gravity 25°/25°C	Penetration 100 grms., 5 secs. 25° C.
Stock bit. sand..	....	....	11·9	86·0	2·1	......	......	14	70	14	3	1·016	Too soft.
			11·6	86·3	2·1	......	......	13	71	13	3	1·019	
1...............	10	260	12·1	87·8	0·1	5	4	19	57	12	3	1·032	110
			12·2	87·8	0·0	3	4	20	58	12	3	1·033	
2...............	17	300	10·0	90·0	0·0	11	7	18	48	11	5	1·031	129
			10·1	89·9	0·0	16	7	17	45	10	5	1·031	
3...............	22	328	9·6	90·4	0·0	......	......	......	......	......	....	1·029	85
			9·9	90·1	0·0	13	7	17	47	11	5	1·022	
			9·8	90·2	0·0	14	7	17	47	10	5	1·030	
4...............	24	350	9·8	90·2	0·0	10	7	18	49	11	5	1·040	48
			9·5	90·5	0·0	13	7	17	47	11	5	1·038	
5...............	27	400	9·3	90·7	0·0	14	6	17	47	11	5	1·031	Too soft.
			9·5	90·5	0·0	12	7	17	48	11	5	1·023	

On July 21, 1927, Dr. K. A. Clark, Research Engineer, Industrial Research Department, University of Alberta, secured a progressive series of samples heated under average working conditions in one of the mixing-drums of the paving plant at Jasper. The charge weighed approximately 2,700 pounds and consisted of bituminous sand and screened gravel. Subsequently, these samples were studied under Dr. Clark's supervision in the laboratory of the Industrial Research Department at Edmonton. Through the courtesy of Dr. Clark the results summarized in Table VII have been placed at the disposal of the Mines Branch. From these results it appears that at some temperature between 350° F and 400° F breaking down of the bitumen has taken place, since the fifth sample—heated to 400° F—was much softer than the fourth sample—heated to about 350°F. This result is of practical value and emphasizes the importance of accurate heat control in connexion with the manipulation of bituminous sand for paving purposes.

In order to determine heating losses and changes in character of bitumen due to heating, a further series of samples was taken by the writer on August 20, 1927, from a standard batch, heated under normal working conditions. The drum was charged with 2,200 pounds of bituminous sand, but no clean aggregate was added. Subsequently these samples were studied under G. P. Connell's supervision in the Mines Branch laboratory and the results compiled in Table VIII. Separation of bitumen from 1,000-gramme samples was effected by the use of a Rotarex Dulin centrifuge using benzol as a solvent. A complete description of methods adopted in making the determinations referred to in this report will be found in Mines Branch report "Investigations of Fuels and Fuel Testing, 1927".

TABLE VIII

Losses and Changes in Bitumen Due to Heating

Sample	Time in mixer, mins.	Temperature of sample ° F.	Bitumen, per cent	Loss on heating, per cent	Penetration		Ductility
					77° F.	32° F.	77° F.
					100 grms.	100 grms.	
1..........	6½	170	11·96	0·0	Too soft	163	100+
2..........	15½	223	12·75	0·0	"	134	100+
3..........	20	265	12·54	0·15	"	180	100+
4..........	24	300	12·31	0·24	"	67	100+
5..........	26	320	12·25	0·065	"	42	52
6..........	28	333	12·06	0·175	"	140	65
7..........	32	360	11·98	0·09	"	141	64
8..........	34½	392	11·86	0·115	118	22	....
Total loss..	....	....	....	0·835	....	....	....

It appears desirable that a series of trial runs be conducted, followed by laboratory determinations in order to ascertain the effect of (a) slow heating of batches at temperatures[1] not exceeding 500° F, (b) slow initial heating of batches at low temperatures (max. 500° F), (c) rapid heating of batches at constant temperatures of 800° F to 850° F.

[1] Temperatures indicated are those which prevail in drums immediately adjacent to end of flues.

OPERATION OF MIXING PLANT

Construction and operation of the mixing plant installed at Jasper (Plate VIIIB) in 1926 is described in Mines Branch Report No. 684. The following supplementary notes are based on observations made during 1927.

An outstanding feature of the plant is simplicity of operation. Moreover, when preparing for a day's run, little preliminary preparation—as compared with standard pug-mill plants equipped with kettles—is necessary. Indeed, firing the boiler—involving the services of one man—is practically all that is required.

Continuous feed and discharge of drums—rather than having advantages over intermittent operation—appear to have real disadvantages. A definite weight of charged materials must be raised to a more or less definite temperature, and with efficient facilities for charging and discharging, drums are rarely free of incoming or outgoing batches for more than one-half minute. Assuming a day's run of 20 batches, the total time thus lost would probably not exceed 10 minutes. Such a loss is more than offset by the advantage of definite control of mixtures and temperatures.

Mixing-drums

Mixing-drums installed at Jasper were such as could be secured without delay when required in June, 1926. Each drum was 6 feet in diameter but only 39 inches in length. Thus, apart from the fact that cubic capacity was not adequate for large-scale operations, relation between diameter and length was not such as to ensure maximum heating efficiency.

Drums should be designed to distribute charged materials as much as possible over the inner surface, to reduce (to a minimum) thickness of mixture on the lower circumference, and to expose cascading materials to the action of the hot blast for a maximum aggregate period of time. Consequently, limiting length of drums will be that which will enable the discharge chute—when inclined at an adequate angle—to rapidly and efficiently remove the heated batch. Lifting-plates and buckets should be designed to lift a maximum amount of mixture to the top of the drum.

Rigidity of drum supports is essential if excessive wear of rollers and drive gears is to be avoided. This implies concrete foundations in a stationary plant or heavy channels in a railroad type plant. All boxings and grease cups should be protected from the heat from the combustion chamber, and all rollers and other moving parts from materials which may fall from drum openings. An inclined metal plate placed transversly 15 inches below the discharge opening will be found satisfactory. The desirability of an inexpensive type of roller bearing is suggested.

It is unnecessary to add that all possible safety devices should be provided, even to the extent of partially housing, by the use of sheet metal, the lower portions of the drums.

Caking of asphaltic materials on the inner surface of the drum shell presents no difficulty and in 1927 required no attention during a period of three months' operation. A barrow of gravel or crushed rock introduced into a drum while still warm, will remove all adhering material and leave the surface bright and clean.

The use of elevators discharging directly into the drums will be practicable only if weighing or adequate measuring devices are provided. Measuring by the use of barrows is not altogether satisfactory and may at times result in errors and incorrect proportions of charged materials.

Operations during the past season indicate clearly that, when heating McMurray bituminous sand, flues should be provided above drum hoppers to carry away smoke. On quiet days the smoke is not a serious inconvenience, but when a wind is blowing the men are frequently seriously affected. Installation of flues, provided with openings at the base for introduction of materials to be heated, presents no difficulty.

Owing to the volatile nature of bitumen associated with bituminous sand, ventilation of drums should be as complete as possible, in order that gases may be removed immediately they are formed. The tendency for batches to 'flash'" and become ignited increases with the percentage of bitumen in the mixture. At Jasper, mixtures containing not more than 9·5 per cent bitumen have never taken fire at temperatures up to 350°F, but with richer mixtures batches may, at rare intervals, become ignited. Freshly mined bituminous sand will also "flash" more readily than material which has been excavated for some days. Similarly, unaltered bituminous sand excavated at a point somewhat removed from an outcrop will "flash" more readily than material mined at or near the outcrop itself. Ignition of batches is not, however, a source of serious danger. Fire may be quickly suppressed by the introduction of a few hundred pounds of clean aggregate, by the use of steam, or by discharging the drum itself. In view of the above, the use of wood should be eliminated from plant construction.

In order to ensure uniformity in periods of heating and in batch temperatures, openings at flue and at discharge ends of drums must be protected from the effect of wind. At Jasper, the use of canvas curtains proved fairly satisfactory.

As illustrated in Figure 6, Mines Branch Report No. 684, discharge chutes at the Jasper plant were withdrawn clear of the drum openings during periods of heating. Consequently, these metal chutes became cold, a condition which somewhat retarded the flow of the heated batch being discharged, and probably involved a loss in time of at least 30 minutes per day. If, however, masses of bituminous sand are reduced by means of a crusher to lumps that do not exceed five pounds in weight, ends of chutes should remain within the drums at all times.

Capacity of trucks should be adequate to receive an entire batch from one drum; otherwise sufficient leverage should be provided to reverse inclination of chutes during discharge.

Flues and Combustion Chambers

In lining combustion chambers, the use of firebrick should be avoided, and some fireclay compound—such as Plibrico—used. Flues leading from combustion chamber to mixing-drums should also be constructed of similar material, since at the point where the flue enters the combustion chamber metal pipe is entirely inadequate to withstand the high temperatures. The end of the flue projecting into the drum should also be protected so that cascading materials will not lodge in the end and "build up". This result can be attained by securing an inclined metal lip or flange to the end of the drum and concentric with the flue itself. This lip should extend at least one inch beyond the inner end of the flue.

Pronounced angles in interior faces of combustion chambers should be avoided, in order that flame or hot blast may follow an uninterrupted course, free from pockets. Total length of chamber and flue should be such as to furnish adequate heat and yet prevent flame from actually entering mixing-drums. In a two-drum plant design and heating capacity of chambers should be the same in order that progress of heating in both drums may be uniform.

It appears that heating efficiency is somewhat increased if the roof of the combustion chamber slopes slightly downward—as 1 inch in 12 inches—toward the flue opening. It also appears desirable that the flues themselves be given a downward pitch of 1½ to 2 inches in 24 inches, in order that the considerable mass of material on the lower, and cooler, circumference of the drum may acquire the maximum amount of heat. It is important that the roof of the combustion chamber and the top of the flue should lie in the same horizontal plane. Bottoms of combustion chambers—especially if adjacent to timber supports—should be well insulated.

PORTABLE MIXING PLANTS

As previously noted, portable (railway type) and stationary mixing plants are in use in Texas and other southern states, an example of the former being illustrated in Plates XB, XIA, and XIB. In Figures 5, 6, and 7, the general arrangement of a railway type plant is diagrammatically

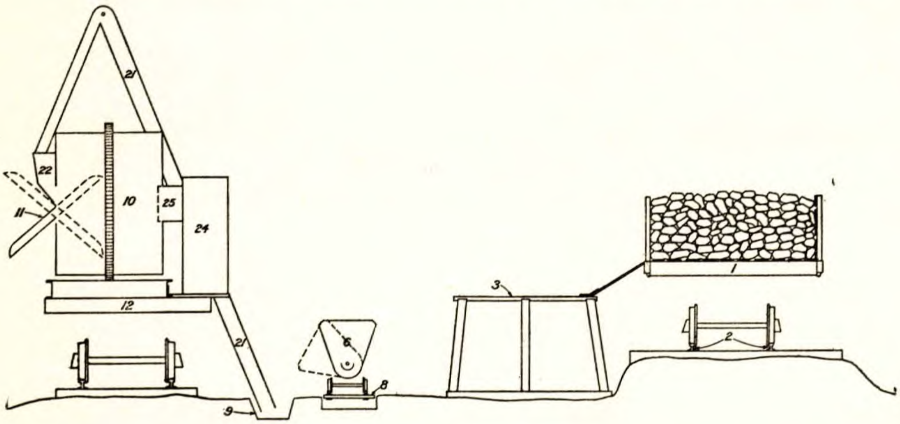


Figure 5. General section of proposed mixing plant (railroad type).

indicated. Light construction, such as metal frame work for supporting hoppers, chutes, etc., is not indicated. If second-hand equipment of serviceable quality, such as mixing-drums, engines, boiler, etc., is secured the cost of such a plant should not exceed $5,000. On May 25, 1926, the San Antonio Machine and Supply Company, San Antonio, Texas, quoted the writer a price of $2,433 on the following equipment, f.o.b. San Antonio, Texas.

Two mixer-drums, 6 ft. by 6 ft. by ¼-inch, mounted on 10-inch I-beam end channel frame, complete with heating chambers, bearings, shafting, gears and drive shaft with 38-inch driven sprocket for No. 1030 steel roller chain, and two Gem oil burners.
Drive chain and engine drive sprocket not included.
Heating chambers to be unlined.
No pipes for burners included.
Approximate horsepower required at pinion shaft of this equipment, 40.

The total weight of this equipment was estimated at 22,000 pounds. The freight rate to Calgary, Alberta, was $2·675 per hundred pounds based on a minimum of 24,000 pounds or $6·165 per hundred pounds L.C.L. Subsequently, the San Antonio Machine and Supply Company furnished the General Construction Company of Fort Worth, Texas, with a two-drum mixing plant at a cost of approximately $4,870. This plant included (in addition to equipment itemized above) an elevator complete with buckets, chains, chutes, and two weighing hoppers. The plant was equipped with ball bearings on trunnion shafts and the total weight was 41,700 pounds.

In considering the construction of a portable railroad paving plant such as is referred to above, the following railway line clearances are of interest.

Railway Line Clearances (February, 1928)
Canadian National Railways

	Width of load ′ ″	Height above rail ′ ″
Brandon to Regina—		
Brandon to Kipling / Kipling to Regina	11 6	22 0
Regina to Saskatoon	7 0	21 6
	11 6	19 0
Saskatoon to Prince Albert	11 6	22 0
Regina to Moose Jaw—		
Regina to Riverhurst	11 6	22 0
Saskatoon to Wainwright—		
Rivers to Biggar	7 0	21 3
	11 6	19 0
Biggar to Wainwright	7 0	21 6
	11 6	19 0
Wainwright to Edmonton	11 6	22 0
Edmonton to Jasper—		
Edmonton to Edson	11 6	19 0
Edson to Jasper	3 0	21 6
	11 6	19 0
Edmonton to Calgary—		
Edmonton to Wainwright (Tofield)	11 6	22 0
Tofield to Calgary	7 0	21 6
Calgary to Biggar—		
Kindersley to Calgary	7 0	21 6
	11 6	19 0
Kindersley to Saskatoon	11 6	22 0
Saskatoon to Biggar	7 0	21 3
Rivers to Biggar	11 6	19 0
Biggar to Sibbald—		
Biggar to Rivers	7 0	21 3
	11 6	19 0
Kindersley to Saskatoon	11 6	22 0
Kindersley to Calgary	7 0	21 6
	11 6	19 0
Sibbald to Saskatoon—		
Kindersley to Saskatoon	11 6	22 0
Kindersley to Sibbald	7 0	21 6
(Calgary)	11 6	19 0

Canadian Pacific Railway

	Width of load ' "	Height above rail ' "
Winnipeg to Brandon Brandon to Regina Regina to Moose Jaw Regina to Saskatoon Saskatoon to Edmonton Edmonton to Red Deer	11 6 10 8	21 0 4 0
Red Deer to Calgary	3 0 11 6 10 8	20 0 19 6 4 0
Calgary to Moose Jaw—		
Calgary to Shepard	5 0 11 6 10 8	20 2 19 0 4 0
Shepard to Suffield	11 6 10 8	21 0 4 0
Suffield to Java	11 6 10 8	21 0 4 0
Java to Moose Jaw	11 6 10 8	21 0 4 0
Calgary to Banff	6 0 11 6 10 8	21 0 15 6 4 0

As indicated diagrammatically in Figures 6 and 7, the portable mixing plant consists essentially of a flat car (12) on which is a heavy channel frame (31), 12 inches high and with 4-inch flanges. Mixing-drums (10–10) are 8 feet in diameter and 6 feet long and are equipped with a single gear band. Power is furnished by a 50 h.p. engine—of which the cylinder head (13) is shown, with fly wheel (14), and is transmitted to the drums through speed reduction gear box (15) by roller chains (16), sprockets (17), and gears (18). Power for blower (19) is transmitted from pulley (20), and power for elevator from a sprocket. Heat is supplied to mixing-drums (10–10) from oil-fired combustion chambers of which (23) is the horizontal section, (24) the vertical section, and (25) the flues. These combustion chambers when in operation are supported by adjustable extensions from deck of car. When car is being moved, the chambers are withdrawn against channel frame (31), the flues passing into the drum openings. Air is delivered through 6-inch pipes (26) equipped with dampers, and fuel oil supplied from storage tank (27) which is equipped with steam coil. Principal shafting is 3 inches in diameter, equipped with roller bearings and provided with clutches (28). Steam is generated in boiler (29). A light collapsible mast and derrick on the floor of the car is suggested to expedite dismantling and reassembling of certain parts of the plant before and after shipment. The installation of bins immediately above the mixing-drums is also suggested since there is a very considerable amount of heat radiation. In these, bituminous sand might be somewhat preheated and clean aggregate dried.

As indicated diagrammatically in Figure 5, crude bituminous sand (in lumps up to 100 pounds in weight) is unloaded by special device (Figure 3) from flat car (1) on track (2) onto temporary plank platform (3). From this platform the bituminous sand is shovelled direct into crusher hopper (4) and discharged from crushing rolls (Figure 4) to temporary storage-pile (5). This crushed material is then shovelled into a V-dump car (6), trammed on light 24-inch gauge tracks (7) to weighing platform (8) and

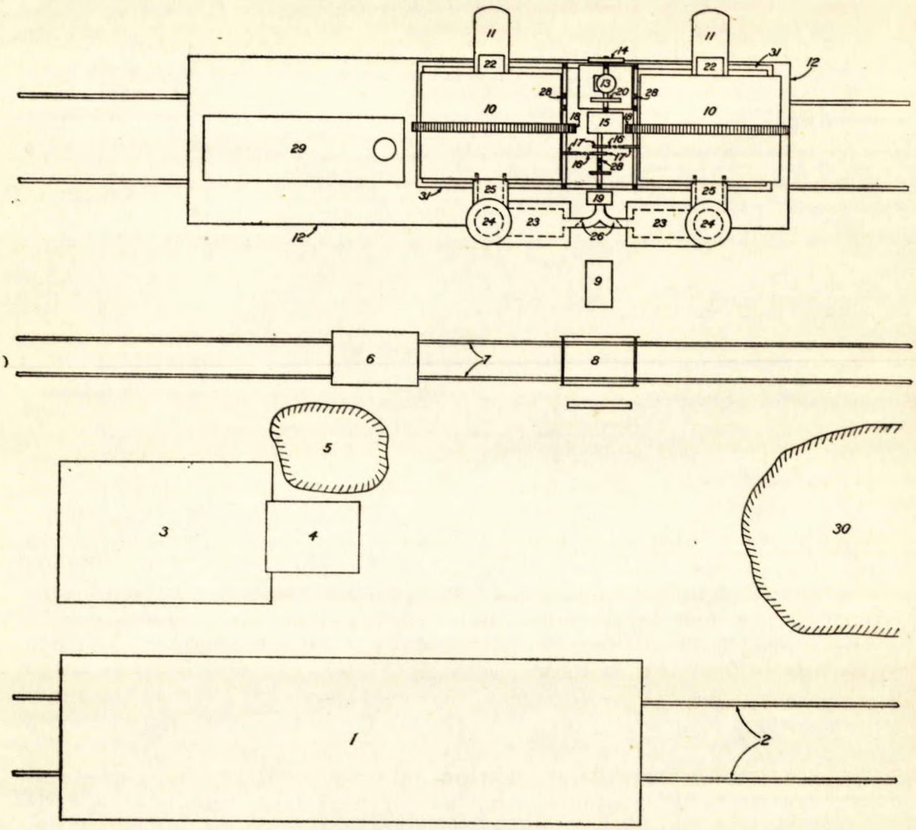


Figure 6. General plan of proposed mixing plant (railroad type).

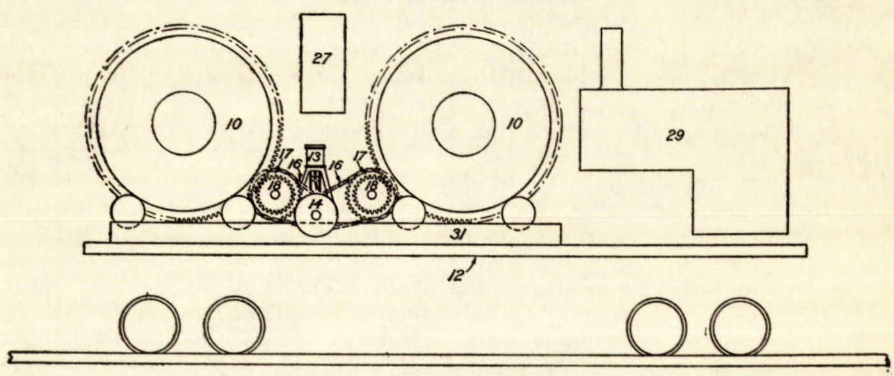


Figure 7. General elevation of proposed mixing plant (railroad type).

transferred to elevator boat (9). The upper end of the elevator discharges by metal chutes, alternately to hoppers (22) of either of the two mixing-drums (10–10). The heated mixture is discharged to trucks or wagons by reversible chutes (11–11). Material from stock-pile of clean aggregate (30) is also loaded into a V-dump car, weighed, and elevated to the drums. It is anticipated that scouring action of alternating charges of clean aggregate will prove effective in keeping elevator buckets and chutes clean.

CONDITION AND QUALITY OF PAVEMENT

With reference to the wearing surface completed at Jasper the following comment, under date of July, 1928, has been received from J. B. Snape, Resident Engineer at Jasper Park:—

> "The road from Jasper to the Lodge, which was paved with McMurray bituminous sand last year, has come through the winter in splendid shape and, in fact, the general appearance is better than last fall. It is quite dustless; gives excellent trackage normally, and also during wet weather, and there is no fear of skidding or side-slipping.
>
> "In fact it seems to be the ideal road surfacing material."

In addition to its excellent wearing qualities the attention of the writer has been called to the unusual non-skid properties of this wearing surface by drivers of various types of motor vehicles, including trucks and motor cycles.

CONCLUSION

Results of the past season's paving operations appear to indicate that, granted reasonable and assured freight rates, and markets which will justify adequate capital expenditure, the commercial use of Alberta bituminous sand for road surfacing is worthy of serious consideration. Under such conditions cost of finished wearing surface should be materially less than where oil asphalt (petroleum residuum) mixtures are used. Since bituminous sand cannot be stock-piled without very materially increasing costs, prompt delivery of shipments as required from quarry to paving plant is essential. Small-scale, intermittent operations cannot succeed, and organization and financial ability of paving companies should be adequate for securing and carrying out large contracts. Movement of large tonnage will also be reflected in more efficient and dependable freight service. Should a satisfactory process be developed for separation of bitumen from bituminous sand, a drum plant, such as is referred to in the preceding pages, could with minor additions be adapted to the manipulation of synthetic mixtures.

APPENDIX

ASPHALT EMULSIONS

During recent years the question of asphalt emulsions for the treatment of road surfaces has attracted not a little attention. The writer has had no practical experience in the use of such emulsions. Moreover, it would appear that many others who have given the matter some thought do not appreciate the relative value of such emulsions as compared with present accepted standards of asphalt paving.

The preparation of asphalt emulsions from bitumen separated from Alberta bituminous sand has, however, been repeatedly suggested, and it appears pertinent to quote current opinion on the general question of such emulsions. The following statements by representative highway engineers and others are therefore submitted without comment.

ASPHALT EMULSIONS IN THE CONSTRUCTION AND MAINTENANCE OF HIGHWAYS

C. M. Baskin

Asphalt Technologist,

Imperial Oil Refineries, Montreal, Canada

The use of asphalt emulsions, although still somewhat of a novelty in Canada, has become fairly well established in connexion with road work in Europe. The theory of emulsions is, however, by no means new. It is based on the fact that certain oils will mix with water in various proportions if treated, either with special agents that aid this mixing, or by employing some special mechanical treatment. These mixtures or emulsions were originally used for medicinal or cosmetic purposes. The oils emulsified or mixed with water were mainly vegetable or animal, and in most cases emulsification was effected by vigorous stirring without the use of an external agent, or as it is commonly known, an emulsifier.

An emulsion is, therefore, a mechanical mixture of water and oil, and is neither a solution nor a chemical combination. The only possible chemical action involved is where external agents are used, and this chemical action depends on the agent, some—such as soap—being purely mechanical in nature.

That emulsions are neither solutions nor chemical combinations is easily proved by examining a drop under a microscope. When so examined, the emulsion is revealed as an aggregate of minute particles within other globules. Usually the whole is in constant motion and may at times be confused with the so-called Brownian movement; but it always appears as two distinct entities. These distinct entities, noticeable only under the microscope, are known as the external and internal phases.

Emulsions being composed of water and oil, with the possible exception of the stabilizing agent, the phases, internal or external, are made up of either water or oil. The nature of the emulsion in respect to its physical and chemical properties, such as fluidity, colour, solubility, etc., is determined by the material which constitutes the external phase, water; the emulsion will to all intents and purposes be as fluid as water and very light in colour. If a thick emulsion is desired similar to a paste, it is necessary to have the oil as the external phase.

Thus, for years, oils have been emulsified in the above described manner. While restricted mainly to the preparation of medicines and cosmetics, the use of emulsions was very limited. Even the advent of the so-called cutting oils used in the manufacture of machinery, both as a lubricant and cooler, and which are mainly emulsions, did not give the emulsions any outstanding importance. The development of road construction, however, is what really turned the attention of some technicians to the possibility of making asphalts (both solid and semi-solid) liquid at ordinary temperatures by emulsifying with water.

Road construction, being such a broad field, naturally implies widely varying conditions. The requirements are general, but conditions and resources vary from one part of the country to the other, even within comparatively narrow limits. While the thickly populated and prosperous sections may be able to afford high-grade, stable pavements, the sparsely populated districts have to content themselves with less expensive types of surfacing. Furthermore, even in the construction of the high-grade roads, there have been constant attempts to devise ways and means that would lower costs of construction and yet give good and serviceable results. It is in these attempts to secure lower construction costs in the building of secondary grade roads and in their maintenance, that emulsified asphalts find an ever-increasing field.

As is known to everyone familiar with modern highway construction, the outstanding method in the construction of bituminous highways is to mix paving asphalt with graded mineral aggregate. This mixture is spread on the road-bed or prepared base and rolled down, that is, compacted by means of heavy rollers. The operation has to be carried out with hot materials from start to finish, from the mixing which is possible only when the solid paving asphalt is fluid, down to the grading and rolling. This "hot mix" operation is naturally costly, and a method that would enable the mixing and laying to be undertaken with cold materials would materially reduce costs. Furthermore, the preparation of hot mixes requires a specially designed and expensive plant. Such plants are within reach of only certain localities, but are necessarily remote from other localities. Cold mix work, however, does not require such expensive equipment, a factor which extends its field of application.

The secondary types of roads are constructed in many ways, the most popular being the so-called asphaltic macadam. This process involves the spreading of layers of stone, spraying the stone with molten asphalt binder, and compacting the whole by rolling. The operation is much simpler and less expensive than the usual hot mix methods. Here, also the paving asphalt has to be sprayed on hot, and if the asphalt could be in liquid form, without the necessity of preheating, there would be a decided advantage.

Maintenance, the repairing of small breaks in pavements by cold patching which require mixtures of asphalt and mineral matter, and the sealing and waterproofing of road surfaces called for bituminous materials that were liquid or semi-liquid at ordinary temperatures. The attempt at the production of such materials took two distinct forms. In the United States and Canada they turned to solvents, that is, the use of petroleum distillates to dissolve the solid asphalt and render it liquid at ordinary temperatures. The underlying idea is that a solution of asphalt and a volatile oil, when spread on the road or when mixed with mineral aggregate, will leave the asphalt to do the binding after the solvent has evaporated.

In Europe, where petroleum distillates were not so plentiful as on this continent, they have turned to emulsions. In this case it is the water that evaporates and the asphalt is left to do the sealing and binding. The field being wide and the demand varied, the emulsification of asphalt became a rather widespread business. Numerous methods were developed and though they were similar in their basic aims, in practice they differed materially. At the present stage in the development of emulsions, it is difficult to express an opinion as to their actual importance and to what extent they may figure in future road construction. So far they have made themselves felt only in the secondary part of the highway field, in surface treating and maintenance. The failures have in many cases been counterbalanced by successful applications. Careful review, however, shows a distinct improvement in the emulsions now appearing on the market.

Comment by David Noonan, Maintenance Deputy, Department of Public Works, Division of Highways, State of New York.

The state of New York, during the past fifteen years, has continuously used in the maintenance and repair of its improved highway system a gallonage of asphaltic emulsion of one million gallons or more per annum. We have developed two specifications, one covering asphaltic emulsion which is classified under standard specifications adopted by this Department on January 2, 1928, as "bituminous material A, emulsion type 1." This is a material which must not be subjected to freezing temperature, as freezing will cause separation and render the same unfit for use.

We have a second specification known as "bituminous material A, emulsion type 2," which is an emulsion which will withstand freezing temperature without separation and, therefore, can be stored upon the roadside during the winter months without damage. We find that for patching macadam pavements there is no bituminous material of superior quality for binding purposes in the above class of work and we anticipate the continued use of a large gallonage of the above in the immediate future, particularly during the present season.

In our adjacent state of New Jersey there has been developed the use of bituminous material asphalt emulsion such as the above, as a surface treatment using a vaporized spray of the material upon the surface of newly laid Portland cement concrete pavements. The purpose of this surface treatment is to properly protect the concrete during the curing state. The material is applied to freshly finished concrete in the form of a fine spray and unlike other methods of curing, such as ponding, puddling, or hay-curing, requires no further attention after this application. The use of this material is based on the theory that the concrete mixture will be made with the correct and usual amount of water, which is adequate for complete hydration of the Portland cement and that the adherent continuous film of asphalt left by the surface application prevents the evaporation of water from the concrete mixture.

We are using emulsion during the present season in a small way, experimentally, as a surface treatment in the curing of concrete operations similar to the above.

In this connexion and in reference to your study of the possible use of bituminous material which may be extracted from the bituminous sand deposits in your Dominion, we would call your attention to our cold patch asphaltic material, classified as "bituminous material A, cutback," according to detailed specifications,* indicating the "asphaltic material A, cutback" for surface treatment. This Department uses upwards of one million gallons of this "bituminous material A, cutback" annually and we have secured very excellent results.

*Note.—Specifications referred to above are as follows:—

SPECIFICATIONS FOR BITUMINOUS MATERIAL A

Cutback

This material shall have the following characteristics:—

1. It shall be free from water.
2. The various hydrocarbons composing it shall be present in a homogeneous solution.
3. When distilled (A. S. T. M. Standard Method) up to a temperature of 400° F., the total distillate shall not be less than 22 nor more than 28 per cent by weight. The residue, poured from the flask immediately after the distillation, shall have the following characteristics:—

(*a*) It shall have a specific gravity at 77° F. of not less than 0·99.
(*b*) It shall have a penetration (77° F., 100 g., 5 sec.) of not less than 100 nor more than 150.
(*c*) Its solubility at air temperature in carbon disulphide shall be at least 99·5 per cent.
(*d*) Its solubility at air temperature in 76° Bé. paraffin petroleum naphtha distilling between 140° and 190° F. shall be between 75 and 88 per cent.
(*e*) It shall show between 8 and 16 per cent fixed carbon.
(*f*) It shall not contain more than 4·7 per cent paraffin scale.
(*g*) It shall have a ductility at 77° F. of not less than 40 cm. (Dow mold).

Emulsion (Type 1)

The emulsion shall meet the following requirements:—

The emulsion shall be homogeneous.
It shall mix with water in all proportions.
It shall be of such fluidity as to readily flow from the bung hole of a barrel.
The emulsion must be of such stability that it will remain constant and uniform while being combined and mixed with clean wet crushed stone sufficiently to thoroughly and uniformly coat the entire surface of each fragment of crushed stone, and while being manipulated and incorporated into the work. A test to determine the stability of the emulsion shall be made as follows:—

A 500-gramme mixture composed of 93 per cent of clean, drenched, No. 1 stone (½-in. to ⅞-in.) and 7 per cent emulsion by weight, shall show no appreciable separation of the asphalt contained in the emulsion after a vigorous mixing of three minutes. Emulsion shall be of such consistency as to leave a satisfactory coating of bitumen on the stone.

When distilled up to a temperature of 500° F., the total distillate shall not be less than 26 nor more than 32 per cent. Not over 2 per cent of this distillate shall be oil. The residue from the foregoing distillation shall have the following characteristics:—

1. It shall have a specific gravity at 77° F. of not less than 0·99.
2. It shall have a penetration (77° F., 100 g. 5 sec.) of not less than 100 nor more than 150.
3. Its solubility at air temperature in carbon disulphide shall be at least 95·0 per cent.
4. The solubility of the bitumen at air temperature in 76° Bé. paraffin petroleum naphtha distilling between 140° and 190° F. shall be between 72 and 92 per cent.
5. The bitumen shall show between 6 and 16 per cent fixed carbon.
6. It shall contain not more than 1·5 per cent of ash.
7. It shall not contain more than 4·7 per cent paraffin scale.
8. It shall have a ductility at 77° F. of not less than 40 cm. (Dow mold).

Comment by H. P. Haydon, Technical Bureau, Barber Asphalt Co., Philadelphia, Pa.:

Supplementing the information given in the booklet, "Barber Brand Cold Repair Cement", we believe we should state that the use of asphaltic emulsions is growing very rapidly, not only as highway repair materials, but also as a binder in new construction of bituminous wearing surfaces. Some of the states have specifications for the use of emulsion in new construction.

Asphaltic emulsions are now widely used as a paint coat for the protection of metal and for general waterproofing purposes and relatively large quantities of this material are being used in the waterproofing and plying of paper and in other industrial operations.

One of the most recent uses for asphaltic emulsion is in the curing of concrete. The emulsion is applied by means of a sprayer to the surface of freshly laid concrete prior to the initial set thereof and effectually prevents the evaporation of the water used in the mix which is always sufficient in quantity to completely hydrate the Portland cement. This method relieves the contractor of the necessity of keeping the surface of the concrete wet during the curing period. We enclose herewith a copy of our Curcrete booklet describing fully this utilization of an asphaltic emulsion.

In your discussion of the use of asphaltic emulsions as "Cold Repair Cement" you will no doubt, stress the peculiar advantages of an emulsion for this class of work which are, briefly, as follows:

An asphaltic emulsion may be applied without the use of heat.

An asphaltic emulsion may be successfully applied to wet stone or wet road surfaces.

It is non-inflammable and has no objectionable odour.

It results in a tougher and more durable patch than can be obtained by the use of cutback asphalts.

The scope of asphaltic emulsions has been broadened by the production of emulsions of such stability as to withstand freezing without damage to the emulsion. It is, however, undesirable to attempt to do repair work with emulsions or other patching materials at temperatures below 40°F, as patches made at lower temperatures are not likely to develop the same strength as repairs made at higher temperatures, in that the water or solvent in the case of cutback, does not completely evaporate before traffic is permitted to pass over the repaired area.

Comment by W. J. Emmons, Director of Michigan State Highway Laboratory, University of Michigan, Ann Arbor, Michigan.:

My own experience has been confined to the observation of the use of this material in the construction of small areas of asphaltic concrete, at the time I was connected with the Bureau of Public Roads, at Washington. In that vicinity, several small jobs were laid, using a mixture composed of $\frac{3}{4}$-inch limestone and concrete sand, with the asphalt emulsion as a binder. The aggregates were mixed in the proportions of two parts of crushed stone and one part of sand. The mixing was accomplished in a small concrete mixer. This work has turned out very well indeed, and could not be distinguished from similar mixtures prepared by the usual hot mixed methods.

The State Highway Department of Pennsylvania has laid a mile or more of asphaltic concrete, using an emulsion which was, in general, similar to the work referred to in the preceding paragraph. On this work a specially designed plant was employed. I understand that this work was done under the supervision of Mr. H. S. Mattimore, Engineer of Tests and Materials, Pennsylvania State Highway Department, Harrisburg, Pennsylvania.

PRIOR USE OF ASPHALT EMULSIONS IN CANADA

Charles A. Mullen

Director of Paving Department,

Milton Hersey Company, Limited

Asphalt emulsions are not new in the paving business. However, a recent impetus in that direction, which comes from Europe, and more particularly from England, calls for a revaluation of these materials.

The "Westrumite" pavement, laid quite extensively in Ontario about fifteen years ago, is, so far as I am aware, the only commercial use of emulsions for bituminous concrete work in Canada. Some of these pavements are still in existence; the best of them, I believe, at Stratford, Ontario.

Not many years ago, I went over these Stratford "Westrumite" pavements with Mr. Manson, the City Engineer. They were a "hungry" looking lot; and he told me that every few years they required a surface treatment of bituminous oil to keep them going. I think a little heavy traffic would have made short work of any of them.

But the main point now to be considered is, does the asphalt emulsion method promise sufficient advantages to road making to justify its further extensive study. Except in the field of surface treatments, and some repair work, I think not. However, the field is certainly open for those who wish to try.

Before much thought is put upon this subject by any Canadian engineer, and by way of knowing the worst first, I would recommend his reading and considering Chapter XVIII, entitled: "Bituminous Emulsions", in P. J. M. Larranaga's "Successful Asphalt Paving". Mr. Larranaga, who was many years ago in Canada, is writing from England, which seems to be the home of asphalt emulsions for road making.

Mr. Larranaga's position is strongly anti-emulsions, even to the point of levity in some passages; but his views are well worth considering. The book "Successful Asphalt Paving" is published by Richard Clay and Sons, Limited, Blackfriar's House, Newbridge Street, London E.C. 4, England. One passage reads as follows:

"Not everybody, not even some of the chief actors themselves, is always able to visualize the perplexing conflict of goals and viewpoints attending the preparation of emulsions. This is due to the fact that chemists, in their own peculiar indoor cosmos, are wholly absorbed with the problem of making them, while the road contractors in their own practical outdoor sphere, are particularly concerned with the problem of unmaking them, in order that the coagulated residue will again acquire the properties of the original bitumen."

Mr. Baskin's remarks under the title of "Asphalt Emulsions in the Construction and Maintenance of Highways" cover the technical side of emulsions very well; and I need further to say again only that this field of research does not look very promising to me, except as regards surface treatments and small areas. Maybe I am mistaken.

VALUE OF ASPHALTIC EMULSIONS ON HIGHWAY WORK

Samuel Eccles, Chief Engineer, Department of Highways, Harrisburg, Pennsylvania.

Asphaltic emulsions as manufactured in United States consist of approximately seventy (70) per cent asphalt, twenty-nine (29) per cent water, and one (1) per cent of emulsifying agents (such as soaps, oils, etc.). The materials of this class which had been received in the United States from England contain only about fifty (50) per cent asphalt. The process of manufacture is held a secret by all companies producing it, but from the different classes of emulsions on the market, it seems as though it is possible to emulsify asphalts from the hardest to the softest grades of penetration on a commercial basis. The extensive use for emulsified asphalt has been in the patching of bituminous roads. It is more desirable for this purpose than bituminous materials which require heating, and very efficient results were obtained with its use. The development of cutback bituminous materials for cold patching work is a serious competitor of asphalt emulsions, in that, usually they are sold at the same price or slightly less, and they have an advantage over the emulsion, that is, they can be stored and remain efficient in low temperatures, while temperatures below the freezing point of water will cause the asphalt emulsion to separate, which is detrimental to its quality.

Some experiments have been tried within the past few years in using emulsified asphalt in bituminous concrete construction, replacing the hot asphalt mixture customarily used. In this class of work the per cent of asphalt in the mix is retained the same as in the hot mixture, that is, about five (5) per cent. This, in consideration of the water content, requires about eight and one-half (8½) per cent of the emulsion. The stone aggregate is added in the same percentage, that is about seventy-four (74) per cent of the total, and on the same grading as used in the standard bituminous concrete. At first the usual bituminous sand grading was used, but reports indicate that better success was secured with a coarser graded material, and some places where this type of road is being constructed sand of the usual concrete grading is used.

One feature of this construction which differs considerably on bituminous concrete hot mix is in the application of seal coat. It has been found necessary to broom into the surface a covering of sand before the seal coat is applied; otherwise the seal coat is added in excessive quantities and is likely to cause a pushing.

Roads which were constructed of this type seven years ago are giving efficient service, and compare favourably with hot mix bituminous concrete. The asphalt emulsion is more expensive than the usual grade of asphalt used on this work, but the expense on the plant work can be considerably reduced, due to the fact that no heating of the bituminous material and drying of the aggregates are required. On some sections of work, probably along from about one-half to one mile in length, it may prove an economic type of construction, due to the reduction on plant cost, but on greater limits of road the probabilities are that the costs of the emulsified mixture would be greater.

Attempts have been made to use this material for the penetration of macadam surfacing and in surface treatment, but the results obtained so far as reported were unsatisfactory.

The conclusion which might be stated is that asphaltic emulsion is an efficient patching material, and also gives efficient service in bituminous concrete, and in the latter use would probably be more economic than the usual hot mix, when small sections are constructed. So far as patching of bituminous road surfaces is concerned, it seems that highway engineers are greatly favouring the use of a cold patch material, rather than to use a material requiring heating, which may be ruined by improper handling by unskilled workmen.

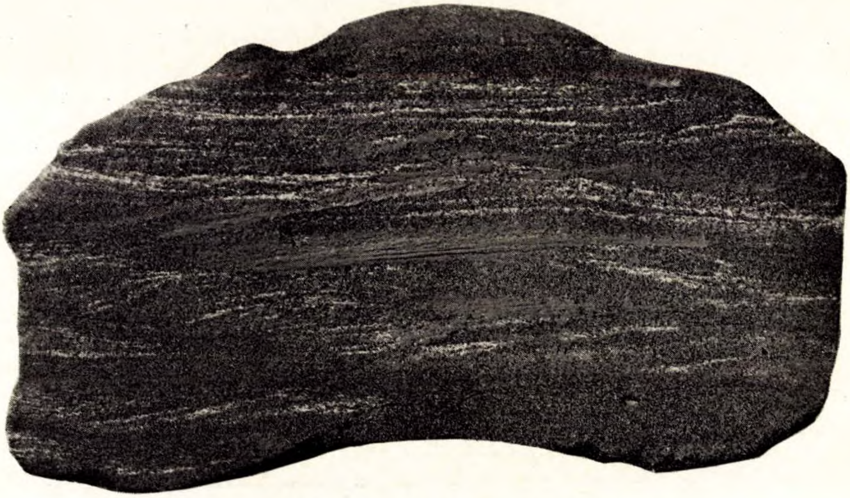
In certain European countries, there is a large mileage of well compacted macadam on an adequate base. Such surfaces are particularly adaptable to treatment by asphalt emulsions. Consequently, the use of such emulsions is well established and is rapidly increasing. A comprehensive reference to current practice will be found in "Impressions on Road Building in Europe", a paper presented at a meeting of the Western Association of State Highway Officials at Los Angeles on March 10, 1928, by C. L. McKesson, Division of Highways, Department of Public Works, Sacramento, California.

The paper is of present interest in view of the fact that a considerable mileage of gravel roads has already been constructed in western Canada. Maintenance charges on this class of construction are high, and it would appear that this type of road offers a wide field for the use of emulsions.

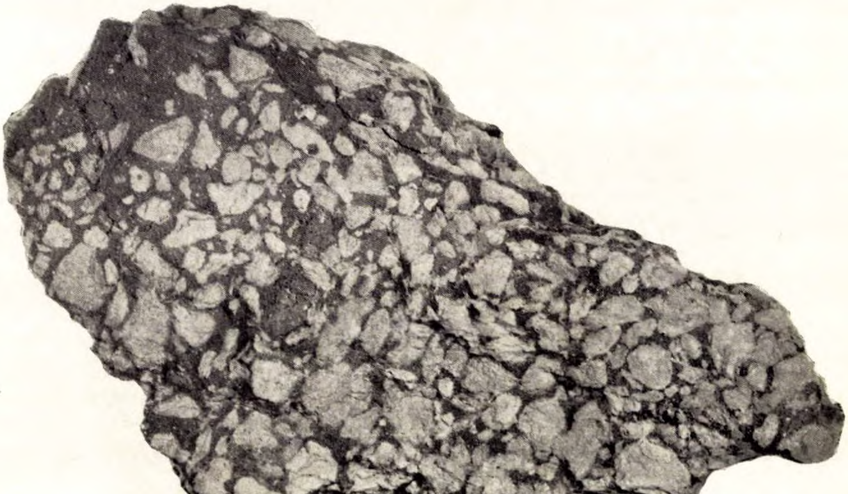
PLATE II

A. Homogeneous bituminous sand.

B. Variety of low-grade bituminous sand.

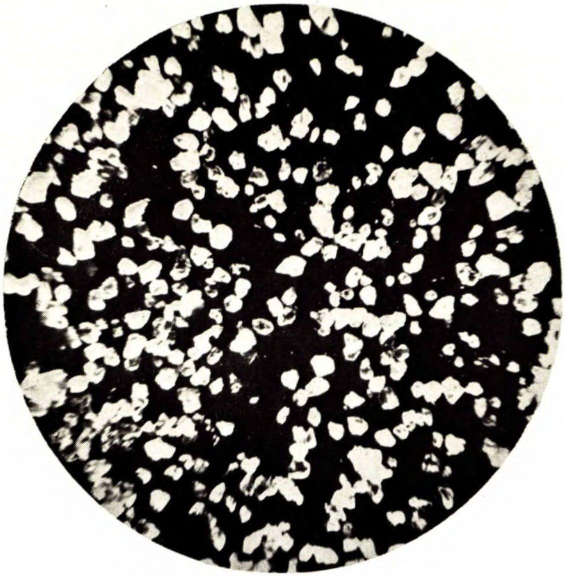


A. Variety of low-grade bituminous sand.



B. Variety of low-grade bituminous sand.

PLATE IV



A. Photomicrograph of finer grained aggregate from Alberta bituminous sand.
(Magnification: x 22.)

B. Photomicrograph of coarser grained aggregate from Alberta bituminous sand.
(Magnification: x 22.)

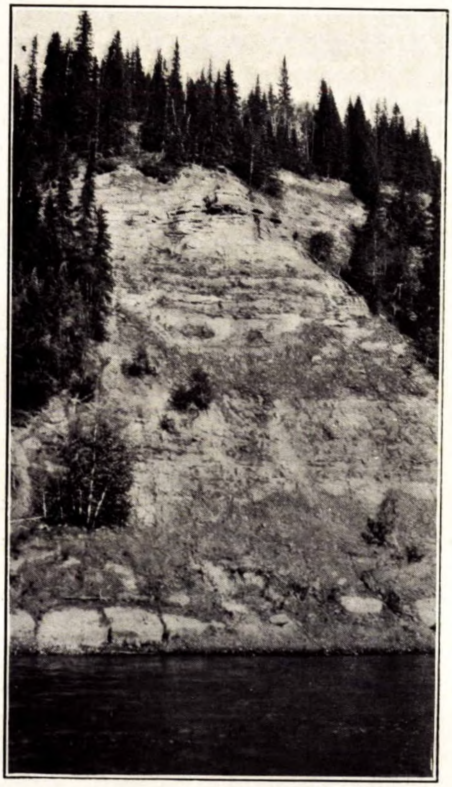
A. Residual calcareous clay usually found at contact between bituminous sand and Devonian limestone.

B. Equipment for core-drilling Alberta bituminous sand: A, Fordson tractor; B, draw-works; C, bull wheel; D, platform for connecting and disconnecting drill rods.

A. Equipment for core-drilling Alberta bituminous sand: A, belt to tractor; B, portable well drilling rig; C, rotary table; D, drill rod; E, drill rods not in use; F, platform for connecting and disconnecting drill rods.

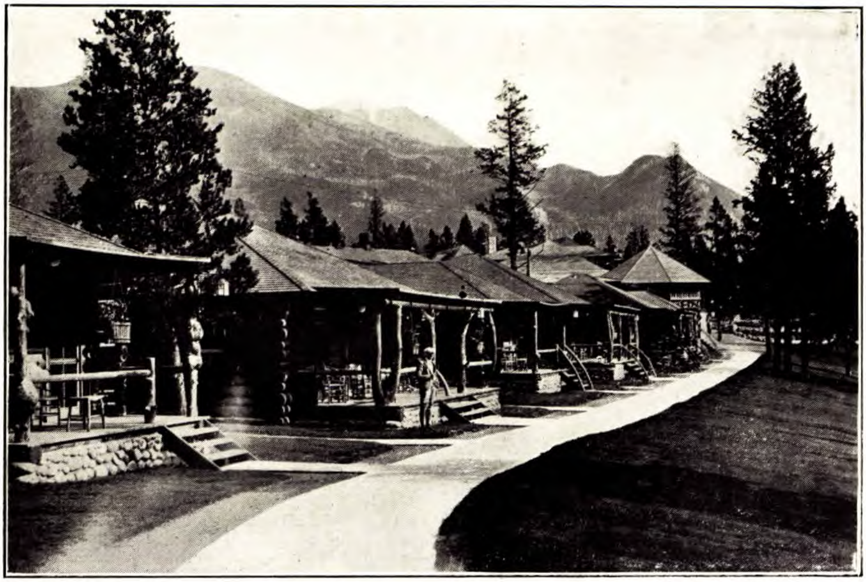
B. Rotary equipment for core-drilling Alberta bituminous sand: A, drill rod; B, rotary table; C, chain and sprocket for operating table; D, chain block; E, timber supports on which rotary table is moved aside; F, disconnected drill rods resting in cellar.

PLATE VII

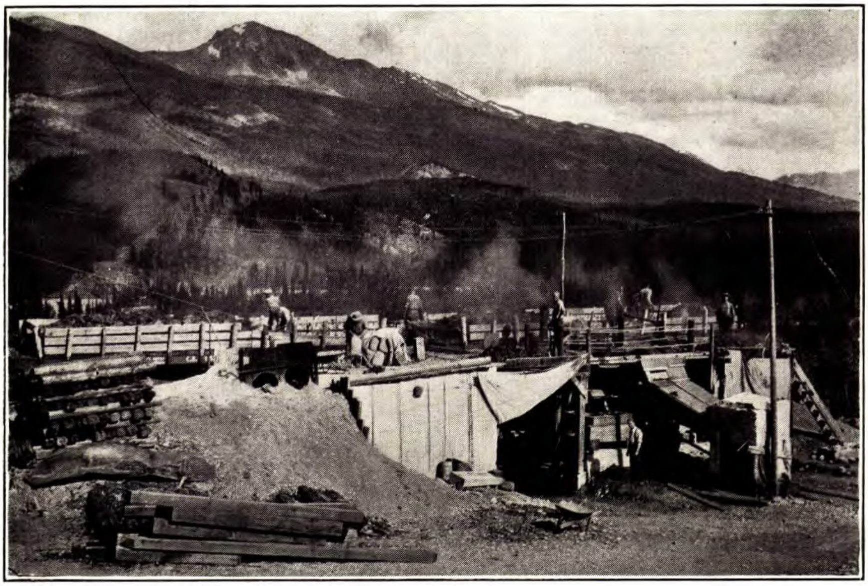


A. Banded appearance of exposure 150 feet west of Well No. 2. This exposure is typical of much of the bituminous sand along Athabaska river, immediately north of McMurray.

B. Typical example of bituminous sand surfacing, Jasper, Alberta (1927).



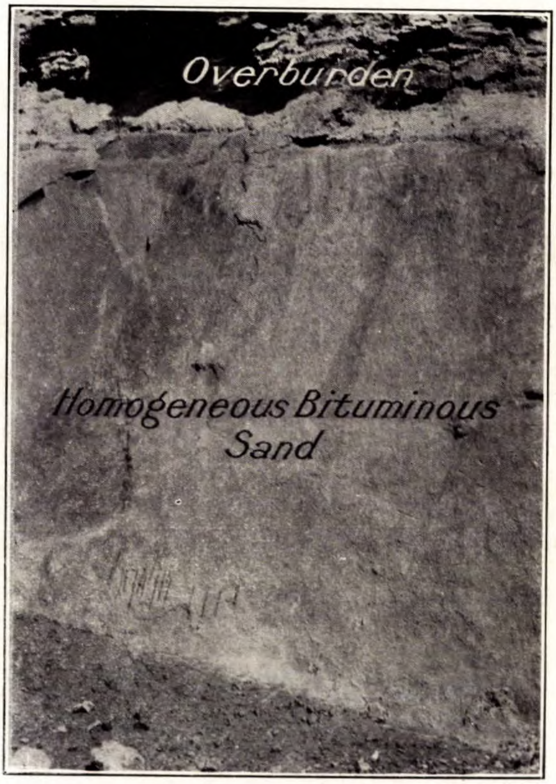
A. Walks at Jasper Lodge, Jasper, Alberta, surfaced with bituminous sand.



B. Plant for manipulation of bituminous sand at Jasper, Alberta. Gravel drier and old railway ties used for fuel seen at left.

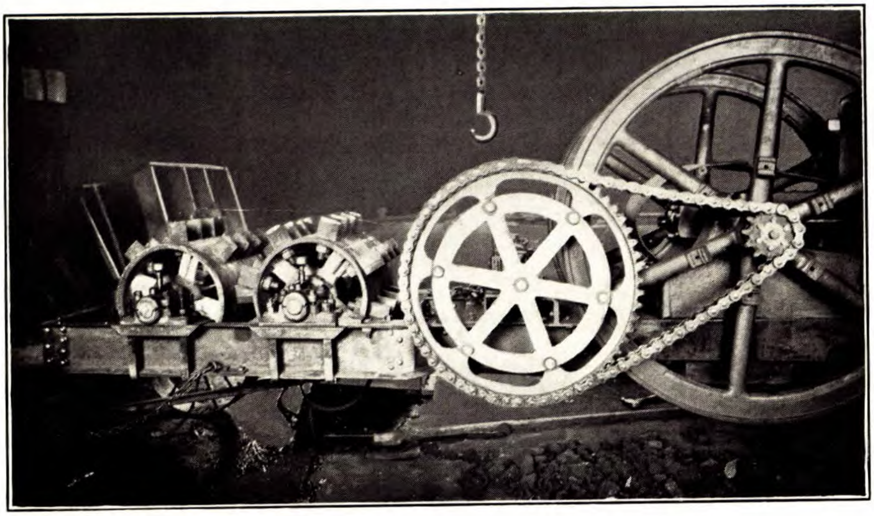
PLATE IX

A. North end of bituminous sand quarry on Clearwater river, McMurray, Alberta, showing typical structure due to slipping.



B. Typical face of homogeneous bituminous sand at Clearwater quarry, showing absence of impure partings, and also small seepages of bitumen.

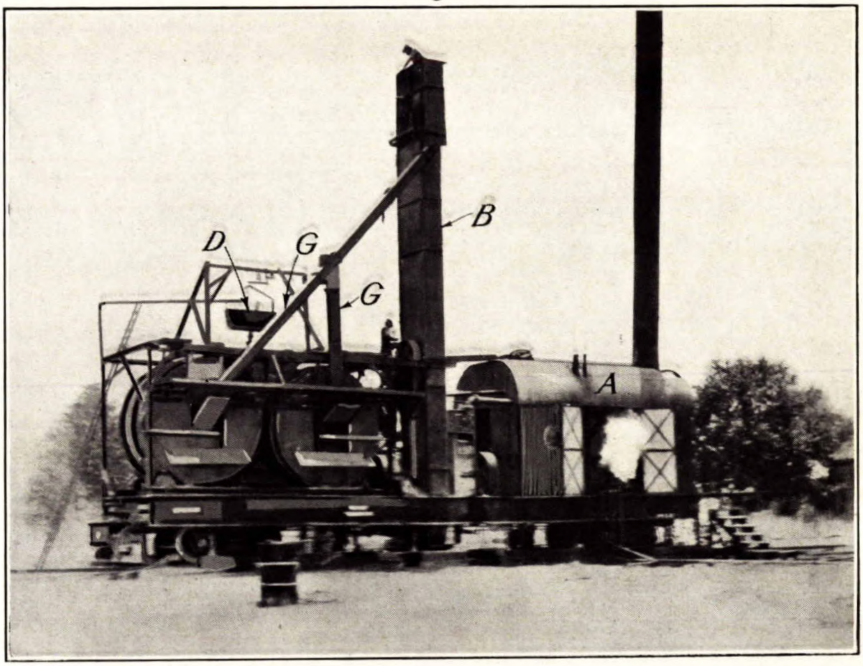
PLATE X



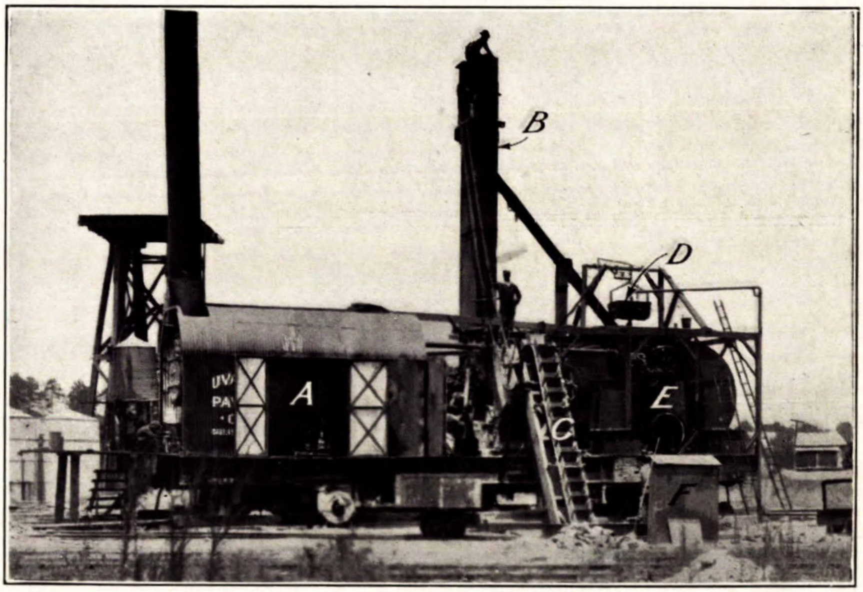
A. Crushing rolls for disintegrating lumps of bituminous sand.

B. Typical railway plant for manipulation of Texas rock asphalt (Uvalde Rock Asphalt Co., San Antonio, Texas): A, drum hoppers; B, mixing drums; C, steam engine.

PLATE XI



A



B

Typical railway plant for manipulation of Texas rock asphalt (Uvalde Rock Asphalt Co., San Antonio, Texas): A, 125 h.p. boiler; B, hinged elevator; C, elevator; D, bucket for flux (suspended on weigh scales); E, 50 h.p. engine; F, weigh scales; G, chutes from elevator to mixing-drums.

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The following reports on bituminous sands have been published by the Mines Branch, Department of Mines, Ottawa:—

Special Reports

Report No.

*281. Preliminary report on the bituminous sands of northern Alberta (1915); 92 pages, 55 plates, 5 figures, 1 map (No. 284) showing outcrops of bituminous sands.

625. Bituminous sands of northern Alberta (1924); 35 pages, 6 plates.

632. Bituminous sands of northern Alberta (1926); 244 pages, 53 plates, 46 figures, 8 maps, 4 sections.

684. Use of Alberta bituminous sands for surfacing of highways (1927); 31 pages, 5 plates, 10 figures.

693. Bituminous sands of northern Alberta—drilling and paving operations, 1927 (1928); 48 pages, 11 plates, 7 figures.

Annual Reports

Report No.

285. Summary report of the Mines Branch for 1913.
Report on the bituminous sands of northern Alberta; pages 54-62, 9 plates, 1 map (No. 284) showing outcrops of bituminous sands.

346. Summary report of the Mines Branch for 1914.
Report on the bituminous sands of northern Alberta; pages 60-73.

421. Summary report of the Mines Branch for 1915.
Report on the bituminous sands of northern Alberta; pages 67-76, 2 plates, 1 figure.

454. Summary report of the Mines Branch for 1916.
Report on the bituminous sands of northern Alberta; pages 56-58.

*509. Summary report of the Mines Branch for 1918.
Alberta bituminous sands for rural roads, by G. C. Parker; pages 194-200.

574. Summary report of the Mines Branch for 1920.
Report on the bituminous sands of northern Alberta; pages 19-22, 1 figure.

605. Summary report of investigations made by the Mines Branch during the calendar year ending December 31, 1922.
Report on the bituminous sands of northern Alberta; pages 44-46. (Separate: Report No. 607, pages 44-46.)

Report No.

616. Investigations of mineral resources and the mining industry, 1923.

Report on the bituminous sands of northern Alberta; pages 4-11.

689. Investigations of fuels and fuel testing, 1926.

Report of experiments on the dehydration of bitumen emulsion from Alberta bituminous sands, by P. V. Rosewarne and G. P. Connell; pp. 96-103, 1 plate, 1 figure. (Separate: Report No. 689-2, pp. 96-103.)

Canadian shale oil, and bitumen from bituminous sands as sources of gasoline and fuel oil by pressure cracking, by R. E. Gilmore, P. V. Rosewarne, and A. A. Swinnerton; pp. 121-132, 2 figures. (Separate: Report No. 689-2, pp. 121-132.)

NOTE.—The geology of the McMurray area is described by F. H. McLearn, in Geological Survey Summary Report 1916, pp. 145-151.

The above reports which are marked * are out of print, but may be consulted at many of the public libraries throughout the country.

Any of the above reports in print may be obtained on application to the Director of the Mines Branch, Department of Mines.

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