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The Transportation of Logs on Sleds

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YALE UNIVERSITY · SCHOOL OF FORESTRY

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THE TRANSPORTATION OF LOGS ON SLEDS

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NEW HAVEN

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A Note to Readers
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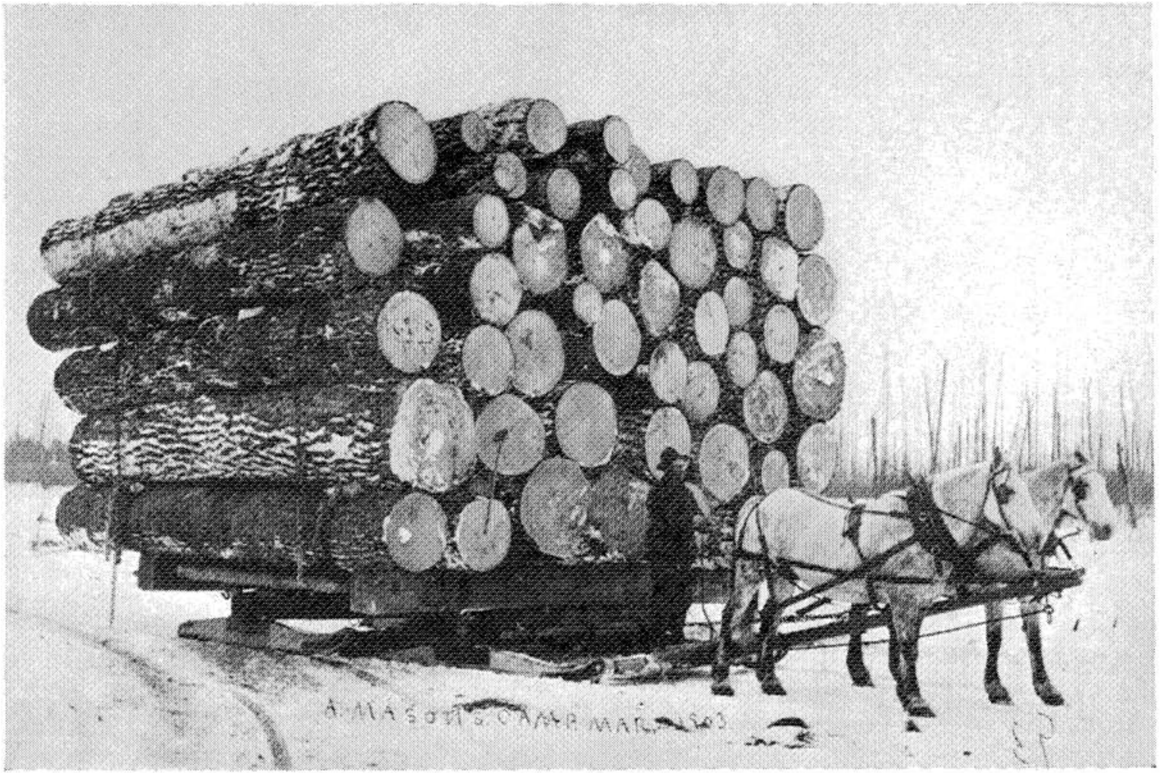

Fig. 1. A Two-sled loaded with White Pine Logs. The total weight of the sled and load hauled by the team over an iced road was approximately 70 tons. Lake States.

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THE TRANSPORTATION OF LOGS ON SLEDS

INTRODUCTION

HEAVY sleds, designed to transport timber from the forest to water courses down which it is floated or to haul it to mill or market, have been perfected chiefly in the United States and Canada. The importance of this method is indicated by the fact that it is used in transporting approximately 90 per cent of the annual log input of New England and New York, 80 per cent of that of the Lake States, and 100 per cent of that of Alaska and of Canada, exclusive of British Columbia.

The credit for the development of sled-hauling methods in the logging industry is due chiefly to practical woodsmen. Technical road engineers have not given much thought to this form of transportation, in fact they seem to regard a snow or an iced bottom from one point of view only, namely, as a nuisance interfering with the operation of wheeled vehicles.

There is very little literature available, in any language, on the use of sleds for log-hauling purposes even though it is a form of transport of great commercial importance in some regions. Further, there has been no standardization of methods or equipment even in the United States and, consequently, there are many different forms of sleds and sled roads used in given localities, some differing greatly, others only slightly, from each other, notwithstanding the conditions of operation are often so closely allied that some common method is desirable. In order to determine, if possible, what is the best form of road and equipment for heavy-duty sled transportation, a study of the subject was undertaken by Alexander M. Koroleff during the collegiate year 1922-1923 while a student in the Yale School of Forestry. He is well qualified for this work, for in addition to his technical training he has worked as a laborer in logging camps in the Far West, Inland Empire, Lake States, and Northeast, where he has had an opportunity to observe and study in detail the log transportation methods in use. As a result of his preliminary study it became evident that a more intensive investigation of the problem was desirable and he spent the collegiate year 1923-1924 in a further field study of the subject in the territory extending from the Lake States to eastern Canada and the northeastern United States. The results of his investigation are submitted in this bulletin in which there has been brought together, for the first time, much valuable data relating to the transportation of logs on sleds.

LOGGING METHODS IN THE NORTHERN UNITED STATES[1]

LOGGING operations in those regions of the United States and Canada where the winter is long and steadily cold have been carried on chiefly during the fall and winter seasons because skidding is more easily done on frozen ground and on shallow snow; hauling on sled roads is easier and cheaper than on earth roads; and woods labor is more abundant and cheaper during these portions of the year. However, the use of logging railroads for timber transportation has greatly increased in the Lake States and in the Inland Empire in recent years because it enables loggers to operate continuously.

Sled hauling may be eliminated and the timber skidded[2] directly from the stump to railroad spurs built a comparatively short distance apart, provided the stand of timber per acre is heavy and the conditions are favorable for the cheap construction of logging railroads.

Chutes, flumes, and other similar improvements for timber transportation are rarely used in northern logging regions, except in the Inland Empire.

The unit of logging operations is the camp, which has a crew of from 25 to 100 men under the supervision of a foreman.

Winter logging may be subdivided into the following typical phases:

1. Construction of camps and roads.
2. Felling and log-making.
3. Transporting the logs to the skidways located along the sled roads.
4. Decking (piling) logs at skidways (if they are not hauled at once).
5. Loading on sleds.
6. Sled hauling to the landings at railroad or waterway.[3]
7. Unloading sleds at landing.
8. Scaling and stamping logs.[4]

[1] Only a general summary is here attempted.

[2] Especially in summer time.

[3] When the distance is short, timber may be hauled directly to the sawmill or market.

[4] Often done at a skidway in the forest.

9. Decking or piling logs at the landing (when required).
10. Loading on cars and railroad transportation, or river driving in the spring.

Felling and log-making begin in the fall as soon as the logging camp is established, and may continue until deep snowfall only, or throughout the entire winter, depending upon local conditions and methods of logging. Trees are felled with an ax and a crosscut saw and the boles are cut into logs ranging in length from 12 to 20 feet, although the greater part of them are made 16 feet long. Two men usually work together, but three-man crews, two sawyers and an undercutter, are not uncommon. Men usually work singly in cutting pulpwood and other small-sized products. Swamping may be done by the sawyers or by special swampers. Two sawyers can fell and make into logs from 3500 to 5000 board feet of timber per day when it averages from 5000 to 10,000 board feet per acre, and the logs run from 10 to 18 per 1000 board feet.

Skidding frequently begins in September or early October and ceases in December or January simultaneously with or soon after the beginning of the hauling operations. However, if the snow is not too deep, skidding may be carried on throughout the latter part of the winter, in conjunction with sled hauling. When this is done, the method is called "hot-logging" and the logs are not decked on the skidways along the sled roads, but are loaded on sleds and hauled directly to the landing.

Skidding in the United States usually is done with two-horse teams and only rarely with single horses,[1] or with four-horse teams.

There are two forms of skidding; namely, snaking, when the timber is dragged on the ground, and yarding or draying, when some form of sled is used and only the rear end of the log is dragged. Sometimes, however, the sled supports the entire load.

Snaking is done with a skidding chain[2] or a pair of skidding tongs. The skidding chain is placed around the forward end of one large or of several small logs in the form of a noose. When tongs are used only one log is dragged at a time, but the labor required to attach and detach the tongs is less than that required to adjust the skidding chain and the logs are less liable to hang upon obstacles. Tongs are preferable for snaking medium and fairly large logs of uniform size. A two-horse team may snake 500 board feet of large logs, when skidding conditions are favorable, but an average

[1] In Canada single-horse skidding often is practiced.

[2] Called a choker. It is usually ⅜-inch thick, and from 12 to 16 feet long.

load is from one to three logs, the total scale of which ranges from 100 to 200 board feet. Snaking, although the most common method of skidding logs in the North, is practical for short distances only, generally for not more than 600 feet.

Various types of vehicles are used by northern loggers for yarding or draying logs over distances too long for profitable snaking and too short for hauling on heavy-duty sleds, chiefly between 500 and 4000 feet. Hauling logs on yarding sleds, as compared to snaking, reduces the tractive resistance, but more time is required for loading and unloading and, in addition, an effort is required on the part of the animals to pull the empty sleds back.

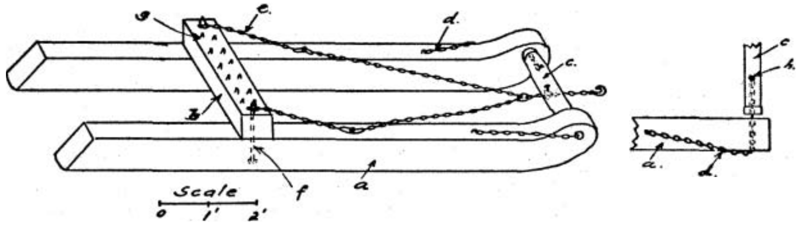


Fig. 2. A Large Dray or Skidding Sled. a. A dray runner 8 by 8 inches by 11 feet. b. A bunk 6 by 8 inches by 5 feet. c. A roller 5 inches in diameter. d. A 3/8-inch chain connecting the roller "c" with the runner noses. e. A 1/2-inch draft chain. f. A 1 1/4-inch bolt fastening the bunk to the runner. g. Bunk spikes. The insert is a top view of a portion of one runner, showing the method of attaching the roller to the runner by means of chain "d." The key "h" passing through the runner prevents the chain "d" from pulling out.

The yarding sleds[1] which are most commonly used in winter logging are:

1. Small dray, or go-devil. This is a crude sled made by the camp blacksmith, which has hardwood runners from 4 to 6 feet long, from 4 to 6 inches wide, and from 3 to 5 inches in thickness. The width or gauge usually is from 3 to 4 1/2 feet. The front ends of the runners are slightly upturned and are connected, by means of chains, to a hardwood roller. The chains pass from the ends of the roller through holes in the front ends of the runners to which they are then fastened. A bunk, from 4 to 6 inches in width and thickness, is bolted to the runners at a point about two-thirds of the distance

1 Two-wheeled yarding vehicles, such as big wheels and bummers, are used by a few loggers in the Inland Empire and in the Lake States in summer operations, but are rarely used in winter.

from the forward end. Thus the runners are connected so that each one of them has a limited amount of play which permits them to slide over obstacles. One end of a log is placed on the bunk of the go-devil and fastened with chains. An ordinary load is from 300 to 600 board feet and the average yarding distance is between 500 and 1000 feet.

2. A large dray or yarding sled, Fig. 2, is of the same type of construction as the go-devil, but it is of larger size and capacity. In the Lake States, it is made with runners from 9 to 12 feet long, from 7 to 9 inches wide and thick, and with a gauge of 5½ or 6 feet. A two-horse team can haul from 500 to 1500 board feet of timber on such a dray. A go-devil supports only the front ends of the logs, but a large dray is so loaded that the logs[1] are nearly balanced on the bunk and the dragging of the rear ends of the logs is

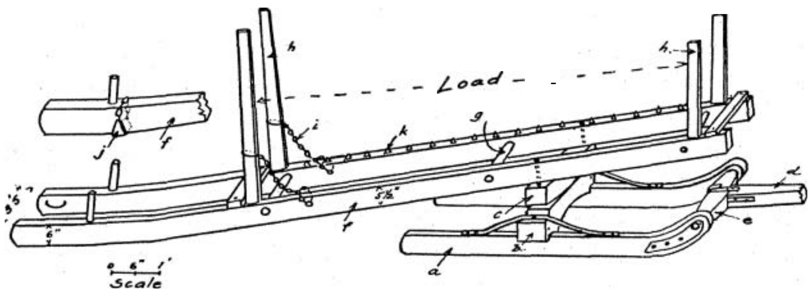


Fig. 3. A Swing-dingle for use in skidding Small-sized Forest Products. a. Runner 5 by 5 inches by 6½ feet. b. Sled beam 6 by 8 by 48 inches. c. Sled bunk 6 by 7 by 48 inches. d. Sled tongue with a 4 by 6-inch base and a length of 12 feet. e. Roller 4 by 6 by 42 inches. f. Rack frame timber 5½ by 60 inches by 15 feet. g. Rack frame brace. h. Rack stakes. i. Chain supporting the rack stake. j. Bridle chain placed around the rear ends of the rack frame timbers to check the speed of the sled on steep descending grades.

nearly eliminated. Logs may be yarded with a large dray for distances ranging from 1000 feet to 1 mile. The front set of runners of a hauling sled may be substituted for a large dray[2] for long distance skidding in some of the northern regions.

3. A dray for skidding small-sized timber cut into short pulp wood, cross ties, and fence posts, resembles a go-devil but its runners are connected by two bunks instead of one and often both ends of the runners are upturned

1 Standard, 16 feet in length.

2 A detailed description of logging sleds is given on pages 43 to 58.

so that the dray can be hauled in either direction without turning it around. Very short wood, such as 4-foot pulp sticks, is loaded crosswise on the dray, and longer wood lengthwise, but wholly supported on the bunks. Chains may be used to hold the load but wooden stakes usually suffice for this purpose. The capacity of such a dray is from ¼ to ½ of a cord. The average skidding distance is between 200 and 300 feet. A dray is drawn either by a two-horse team, or by a single horse, usually the former.

Small-sized forest products, 8 feet or more in length, may be skidded in small bundles for short distances, the pieces being dragged on a go-devil or snaked with a skidding chain.

4. The "swing-dingle,"[1] having an average load capacity of one cord, is used for skidding small-sized forest products for distances ranging from 500 to 4000 feet. It is a type of sled adapted to crooked skidding roads, especially when the grades in the loaded direction are steep.

Snaking or draying timber may be done on bare ground, but better results are secured on a snow bottom. Drays used for skidding on snow sometimes have the runners shod with steel or cast iron.

Logs may be loaded on drays by hand methods, but when the logs are large and the loads are big, they are rolled upon the dray by means of a crosshaul and animal power. Large drays are sometimes loaded by horse jammers in the Lake States.[2] Small-sized forest products always are loaded by hand.

It is often practical to skid timber for short distances without any preparation of the skidding trails, provided the stand is open and free from underbrush and the bottom is smooth and solid. However, such conditions rarely occur in northern forests. Preparation, in the case of secondary skidding trails, may comprise only the removal of underbrush on a strip wide enough to enable a horse or team to pass. However, skidding roads over which much timber is to be moved, such as long roads for large drays, may require as much labor for their construction as a main sled road. The chief skidding trails and draying roads are often made in advance of actual use, while small and secondary trails are cut by swampers when skidding is in progress. A typical layout of skidding trails is diagramatically shown in Fig.

1 See Fig. 3.

2 A logger usually considers the "average skidding distance" to be one-half of the distance from one sled road to another, such as A-B, Fig. 4. However, this is greater than the average for which the logs are actually skidded because only those logs on the back end of the strip will be transported for a distance as great as A-B.

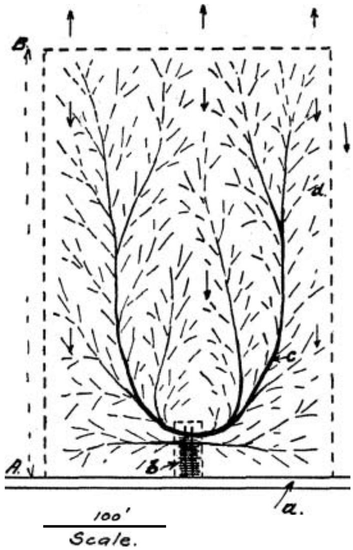


Fig. 4. A Typical Scheme of Skidding Trail Location. a. Main sled road. b. Skidway. c. Main skidding trail. d. Secondary skidding trails. The arrows indicate the direction of slope.

4. The chief consideration in locating such trails is to secure a favorable down grade from the stump to the skidway by the shortest route.

Two or three skidding teams usually work on an area tributary to a given skidway. In addition to a teamster for each skidding team the services of swampers are required for making skidding trails and for swamping limbs which may have been left on logs by the log-makers.[1] One swamper may accompany the teamster on his trips to the skidway and aid him in handling the load and in overcoming obstacles encountered during the trip. The daily output per team for an average skidding distance of 500 feet is usually between 5000 and 10,000 board feet for logs running from 12 to 15 per thousand board feet.

When small-sized timber is cut into short lengths, each sawyer usually works on a strip, about as wide as the height of the trees, which runs at

[1] The amount of swamping labor, per team, varies with the underbrush on the area. One man may be able to swamp for two teams when the work is light but, in a brushy region, two or three swampers per team are not unusual.

right angles to the sled road. The trees are felled so that their tops come near the edges of the strip and the branches as they are trimmed are thrown to one side so that a clear passage is left along the middle of the strip, between two windrows of brush, which is used later as a skidding trail. The sawyer cuts the tree boles into short lengths and carries them to the middle of the strip, for distances of 50 feet or less, where he places them in small piles along the edge of the skidding trail from which point they are later drayed to the sled road. Thus, skidding trails for hauling out small-sized products usually run parallel to each other and are from 40 to 100 feet apart.

A skidway or yard, which is a cleared area along a sled road or a railroad where a skidding trail terminates, may serve for the storage of logs or merely as a place where logs are assembled for immediate loading upon sleds or cars. Logs are stored on skidways if they are skidded to the sled roads before sled hauling begins. This practice is followed when deep snow at hauling time makes skidding impractical. All logs may be decked, or all may be hot-logged; when skidding and hauling periods overlap each other, some of the logs may be decked and others hot-logged, depending upon local conditions and practice.

Logs may be decked one or a few tiers high by hand labor, but high log decking is done with a team and crosshaul. The volume of timber placed on one skidway varies with the area tributary to it and the stand of timber per acre, but frequently from 20,000 to 60,000 board feet of logs are stored at one place.

Sleds may be loaded by hand with canthooks, by team power and crosshaul, or by "jammers."[1] Handloading is practiced chiefly in New England and Eastern Canada when small logs are being hauled and when skidways are made on sidehills so that it is not necessary to elevate logs to any extent when rolling them upon a sled.

The loading of logs upon sleds is done with horse jammers in the Lake States. Small-sized forest products usually are loaded by hand.

SLED ROADS

THERE is no standard type of road used in a given region because the choice for a given operation is based upon traffic requirements and construction and maintenance costs. However, some types are preferred in

1 See pages 62 to 69.

certain sections, due to the greater familiarity of the logger with the methods of constructing and operating them.

The efficiency of a sled road depends upon the following factors:

1. The profile.
2. The cross section of the roadbed, which may be (a) flat, (b) "trough" shaped, (c) with two wide grooves cut in the roadbed for the sled runner tracks and animal tread, or (d) two narrow ruts for the sled runners, alone.
3. The road foundation, which may be (a) a thick layer of snow, (b) a thin layer of compacted snow, (c) an ice covering on an earth foundation[1] or (d) layers of snow alternating with ice.[2]

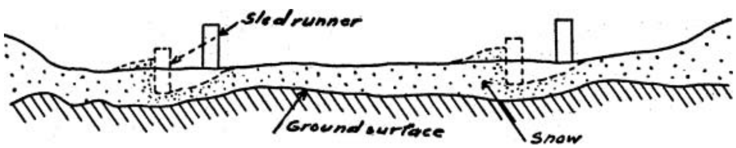


Fig. 5. A Cross Section of an Unimproved Snow Road. The dotted line indicates the manner in which sled runners cut into the roadbed, permitting them to slue.

TYPES OF SLED ROADS

Snow Roads, Unimproved.[3]—This road is the simplest and cheapest of all types to construct and is, therefore, frequently used on small operations and for very short hauls. The construction work is confined chiefly to clearing the roadbed and roughly grading it. When the snow on the roadbed is from 6 to 12 inches deep, a track is broken out with a sled and the loose

1 Solid ice is the best foundation for a heavy-duty sled road, but it requires a carefully graded roadbed in order that a smooth ice surface can be secured without making the ice cover thick and expensive. The reverse is true in the case of a thick layer of snow.

2 This is brought about by sprinkling the road after snowstorms without the complete removal of snow from the roadbed.

3 See Fig. 5.

snow thus compacted.[1] A snowplow may be used to clear the road previous to hauling if the snow fall has been heavy, but such work often is not necessary.

The general procedure is to haul a few sled loads of logs over the road in order to form ruts. The latter, however, are often irregular in alignment and form, due to the uneven character of the roadbed and the variation in the depth and compactness of the snow bottom. This type of road is difficult and often unprofitable to maintain in suitable condition for the efficient and safe hauling of heavy loads because ruts made on such a bottom are not solid enough to prevent the sled runners from sluing and, therefore, crooks and depressions rapidly increase in size and number under heavy traffic.

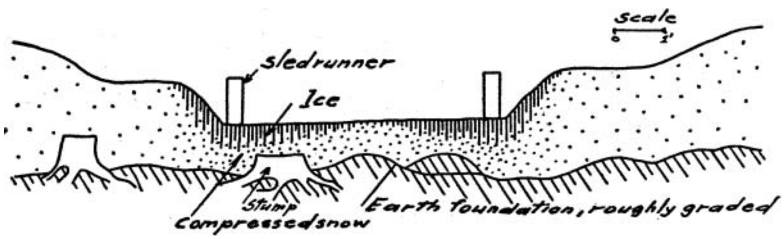


Fig. 6. An Iced Trough Road with a Snow Base.

Much tractive power is wasted in overcoming the resistance due to the inequalities of the road surface and the consequent sluing of the sled runners and, therefore, comparatively small loads must be hauled. Nevertheless, unimproved Snow roads are frequently used on logging operations because of the simplicity of their construction and the low initial cost.

Snow Roads, Improved.-The snow road may be improved by sprinkling water on the snow foundation. The entire road foundation may be iced but more often only that portion on which the sled runners travel is so prepared. This improvement is not costly when an ample water supply is available and it is superior to the unimproved snow road because the frictional resistance of the sled runners is decreased and the strength of the road foundation is increased. However, such a road has a relatively low efficiency because the

1 The depth of snow may vary within rather wide limits, depending on the time at which snow fall begins and the amount of precipitation during the early part of the winter season. The figures given represent a general average only.

sled runners will slue since there is no definite track in which they are forced to travel. The movement of heavily loaded sleds over such a bottom is, therefore, somewhat difficult and unsafe.

Trough Roads.[1]-This road usually, though not necessarily, has a thick snow foundation covered with ice. In preparing such a roadbed a snow-plow is first run over the road and a portion of the snow cover removed. This leaves a flat bottom of compressed snow with a bank or shoulder of snow on each side. The roadbed and shoulders are then sprinkled with water in order to form a coating of ice on them. The width of the roadbed

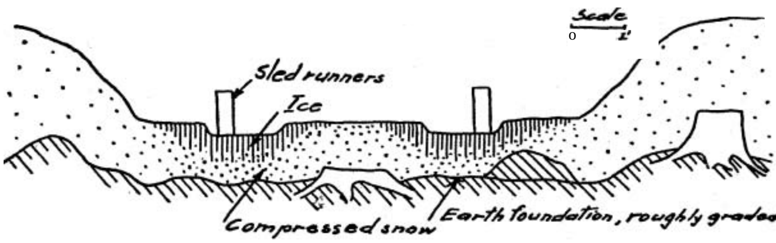


Fig. 7. An Iced Road with Wide Ruts which serve both as a Track for the Sled Runners and for the Horses or the Traction Drivers of a Tractor. The iced road surface rests on a snow base.

is only slightly greater than the gauge of the sled runners. The shoulders reduce the tendency of sled runners to slue, and at the same time the runners have enough side play so that they will not jam. Trough roads have been superseded by rut roads in the Lake States, but they are still used in the northeastern part of the United States and in eastern Canada.

Wide Rut Roads.[2]-This type has a wide traction groove cut on each side of the roadbed, which serves as a base both for sled runners and for the draft power, either animal or mechanical. Such roads are common both in the northeastern part of the United States and in Canada. They are built on a snow foundation and represent a type intermediate between the trough road and the rut road which is subsequently described. The ice cover is confined to the traction ruts and to the shoulders, the outer shoulders being the sole means used to prevent the runners from sluing.

1 See Fig. 6.
2 See Fig. 7.

;Less water is required for icing this type of road than for the trough road, hence, the cost of maintenance is less. However, the use of a wide groove for the traction base as well as for the sled runners, makes it difficult to maintain a smooth and clean surface on which the frictional resistance of the sled runners will be at a minimum. This is especially true when horses furnish the traction force, because the sharp shoes cut up the surface of traction grooves and the horses foul them with manure.

Narrow Rut Roads.-This type of road may have either a snow or an earth foundation which mayor may not be iced. The ruts are cut by a machine, called a rutter or rut cutter, and usually have a width about twice that of the thickness of the sled runner. Ruts properly made provide

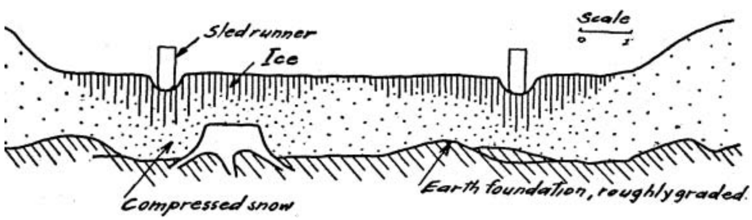


Fig. 8. An Iced Rut Road with a Snow Base.

a smooth and level track for runners and confine them to a definite narrow channel which prevents sluing and wabbling, and when made with a concave base for convex runners, reduces the side friction to a minimum. The ruts must be kept free from manure and other debris and a correct profile maintained, hence wide-gauge sleds should be used in order that the animal or power tread may be between the ruts and far enough removed to prevent injury to them.

The efficiency of rut roads in preventing sleds from sluing and in providing a snlooth, even, and hard track for the runners was recognized by Lake States operators more than forty years ago, but loggers in other regions have not used this type of road extensively and it is unknown in Europe.

1. Snow rut road, snow base. This type is constructed in the same manner as an unimproved snow road[1] with the exception that the sled ruts are formed by rutters. The cross section of a snow rut road does not remain

1 See page 13.

uniform in shape for long because ruts made in compact snow are not strong enough to prevent heavily-loaded sleds from sluing. and breaking them down. Roads of this character are found chiefly in the Lake States, but even there they are seldom used.

2. Iced rut road, snow base.[1] This type of road requires a foundation of well-compacted snow which is deep enough to cover all of the inequalities of the roadbed, including stumps and rocks. It can be used, therefore, only in regions which have a heavy snowfall.

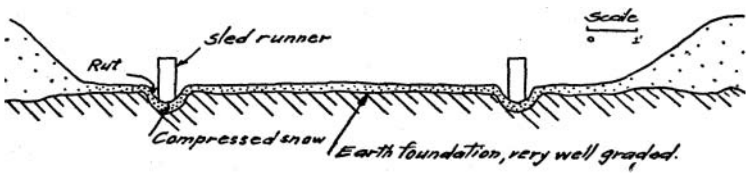


Fig. 9. ·A Snow Rut Road with an Earth Base.

The roadbed is roughly graded and no further work is done until all inequalities are covered with snow, when the latter is compacted and levelled. The ruts are then cut in the snow foundation, following which the road is sprinkled until the ice covering is a few inches thick and strong enough to bear up the loads. This type of road, when properly constructed, is more efficient than any of those previously described.

3. Snow rut road, earth base.[2] These are very durable and serviceable if properly constructed and well maintained, but much labor is required to build and maintain them. The roadbed must be carefully cleared and graded, all stumps, roots, and stones being removed from the portion in which ruts are to be cut. When the ground begins to freeze, a rutter is drawn over the road, and ruts, straight and regular in shape, are cut in the earth's surface. There should be only a very thin layer of clean, well-pressed snow on the road, since the strength of the ruts is derived from the frozen earth underlying their sides and bottom. Such a road may be very efficient and durable provided a thin, uniformly compressed snow cover, about 2 inches inside the ruts, is constantly maintained.[3] The accumu-

1 See Fig. 8.

2 See Fig. 9.

3 The pressure of the runners of a heavily loaded sled may convert the snow lining of the ruts into ice, but this ice will not be as compact and smooth as that formed by the freezing of water.

lation of snow is prevented by the use of a snowplow and by carefully cleaning out the ruts with a rutter after snowstorms. Occasionally it may be necessary to place snow on the road to maintain an adequate snow cover in the ruts so that the sled runners will not come into direct contact with the ground. Snow roads with ruts cut in the earth are used only when a large amount of heavy traffic is expected and when water for icing the road is not available because maintaining them in good condition is costly. A period of prolonged cold weather is essential for the successful operation of such roads, since they are very sensitive to thaws. A heavy snowfall also is a hindrance to their maintenance. Only a few main logging roads in the Lake States are built in the above manner.

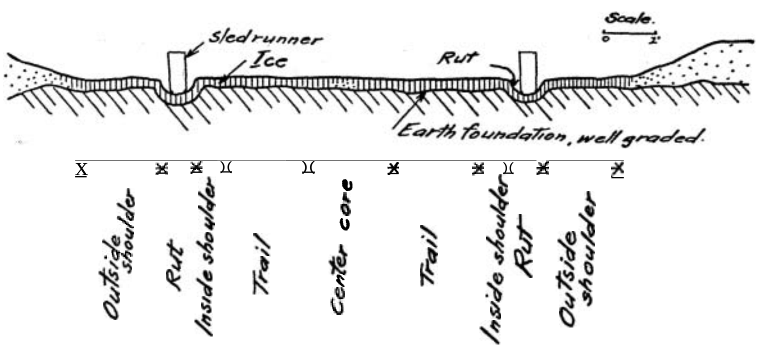


Fig. 10. An Iced Rut Road with an Earth Base.

4. Iced rut road, earth base.[1] The roadbed must be cleared and graded in the manner described for the snow rut road with an earth base, and the ruts are cut in the same manner. Sprinkling follows the rut cutting, forming at first a thin ice coating which grows in thickness as the road is watered during the hauling season. The ruts towards the close of the season may be entirely above the ground level owing to the thick ice cover which has been built up.

The iced road is kept free from snow by plowing after each snowstorm and by cutting out the ruts.

This is the most efficient and durable type of heavy-duty sled road and is used extensively in the Lake States and occasionally in other regions.

1 See Fig. 10.

TRANSPORTATION OF LOGS ON SLEDS

COMPARATIVE MERITS OF ICED ROADS AND SNOW ROADS

Ice forms a more efficient road surface than snow for sled hauling, although its use is not always practicable.

The Advantages of Iced Roads.-Among the chief advantages which iced roads possess, as compared to snow roads, are the following:

1. The tractive force required to draw sleds over iced roads is about one-half that required for snow roads because, (a) the frictional resistance is much less and, (b) sleds slue and wabble less because the iced banks of trough roads and grooves of rut roads hold the runners to the road and not only reduce the tractive force needed but also keep sled depreciation at a minimum.
2. The roadbed can be maintained in a more efficient operating condition.
3. The iced track provides a better footing both for shod horses and for traction machinery.
4. Greater draft power may be used with a lesser amount of manual labor on iced roads than on snow roads because an iced base will support heavier loads and stand up under more traffic than a snow base. Iced roads, therefore, are better adapted to hauling with high-powered machinery when sleds are coupled in trains, since on a snow road the sleds of a train tend to "jack-knife" and to leave the road on curves, and also when braking, stopping, or backing the train. A greater hauling speed is practicable on iced roads than on snow roads. This increases the efficiency of operation, especially when high-speed mechanical draft is used.
5. Iced roads may be made and successfully operated when the snowfall is not deep enough for the construction of good snow roads, and also during snowless winters, provided the temperature is low enough. The thick ice cover which is accumulated on an iced road during the winter, makes it possible to use the road for two or three weeks after snow roads have been ruined by spring thaws, thus providing a longer period for sled hauling.

The Disadvantages of Iced Roads.-The chief disadvantages of iced roads are:

1. A greater initial financial outlay is necess.ary for building iced roads than for snow roads, therefore it may not be profitable to use theIll when a road is of minor importance.

2. The cost of water for road-sprinkling purposes may be excessive, provided an adequate water supply is not within easy access of the road.

The Conditions Required for Iced Roads.-Amongthe major considerations that are essential to the successful construction of iced roads are:

1. Climate. Cold and steady winter weather is necessary to build up an iced road, but very low temperatures increase the sliding resistance. Light thaws of short duration do not affect iced roads appreciably although it sometimes maybe necessary to stop hauling, temporarily. Long continuous thaws seriously damage iced roads and considerable time and money may have to be expended to restore them to an operating condition. Snow is not essential for the construction or maintenance of an iced road; in fact, deep snow is a detriment because its removal increases the maintenance cost. High winds may cause drifting snow or sand to cover up an iced road at exposed places, thus decreasing its efficiency and in some extreme cases making its use impractical.
2. Water. A large amount of water is required for the construction and maintenance of iced roads and therefore sources of water must be available which are so located that they can be reached by the sprinklers on an easy and short haul.
3. Topography. The ideal profile for an iced logging road is one with a gentle down grade in the direction of loaded traffic. This grade should be a mean between dead level and a down grade on which a loaded sled would require braking. The advantages of iced over snow roads are greatest in a flat country, because descending grades and light ascending grades in the loaded direction greatly reduce their efficiency. Roads with a rough profile are not iced on steep down grades.
4. Traffic. There must be a large tonnage to haul to warrant their construction.

THE CONSTRUCTION OF SLED ROADS

THE construction of the various types of sled roads have many features in common and therefore no attempt is made to describe in detail the different methods of road building for each type of sled road which has been mentioned. The following description refers chiefly to iced roads with ruts cut in a snow or in an earth foundation. Some data are given, however, to show the difference in construction between these and other types of sled roads.

The steps in the construction of an iced road are as follows:

1. Location of the road.
2. Cutting the right-of-way.
3. Grading the roadbed.
4. Snow removal or compression.
5. Rutting.
6. Icing.

LOCATION

The sled road must be located so that the cost of road construction and road maintenance, plus the cost of transportation, will represent the minimum possible expense. A thorough knowledge, not only of road construction, but also of logging in all its aspects, is essential because the location of a logging sled road will determine, to a large extent, the plan of the whole operation and its success. Consequently, the location of sled roads is done by a practical logger, usually the foreman of the camp. Topographic maps are sometimes used, if available, but usually the locator learns the topography of the country and the character of the earth bottom by tramping over it. In most cases location work is done without the aid of surveying instruments, although a compass is sometimes used and, more rarely, a hand level. Many woodsmen are expert in measuring the grade by eye, yet the use of a simple hand level is always desirable, and the extra expense put into careful work is justified because a difference of 1 per cent in the maximum grade may, in the case of an iced road with a flat profile, increase or decrease the efficiency of hauling as much as 30 per cent, measured in terms of the maximum weight of load.[1]

The following points require consideration when locating a heavy-duty logging sled road.

1. The efficiency of transportation. This is determined chiefly by those factors which affect the costs of hauling over the road.

a. The profile. The most favorable profile is one which has a gentle down slope in the direction of loaded traffic. Steep descending grades and slight ascending grades increase the operating costs and therefore are avoided when practicable. The route for a heavy-duty sled usually follows natural drainage.

b. The location of main and branch roads with reference to the log supply. These must be located so that the relation which exists between the cost of skidding trails and roads, the cost of skidding on

[1] See page 92.

them, the cost of construction and maintenartce of main and branch sled roads, and the cost of transportation over them is such that the minimum total transportation expense, per unit of product, is secured. Therefore, the entire system of transportation ffom stump to mill or market must receive consideration.

2. The cost of road construction. This will be determined chiefly by the physical features present along the route.

a. l'opography. Cuts, fills, bridges, and similar improvements may be necessary to secure the required profile. The amount of such work which has to be done is usually greatest in a rough country, and those sites should be chosen which demand the minimum amount of these forms of construction work.

b. The character of the bottom. The cost of grading increases rapidly as the bottom changes from earth to rock, hence, as far as practicable, routes should be avoided on which rock removal is necessary. A rock bottom also is detrimental when an iced rut road is contemplated. The location of a road across a swamp necessitates the use of corduroy or other construction which will provide a firm bottom, hence such areas should be avoided.

c. The mileage of the road system.

3. The cost of road maintenance. The amount of work required for road maintenance will depend chiefly upon the following factors.

a. The quality of initial road construction work.

b. The character of bottom on which the road has been constructed.

c. l'he profile of the road.

d. The liability of snow drifting upon portions of the road.

e. The accessibility of an adequate water supply, when iced rut roads are used.

f. The climatic conditions during the hauling period.

CUTTING THE RIGHT-OF-WAY AND GRADING

Cutting the right-of-way and grading the roadbed are done simultaneously or nearly so. Both kinds of work are often performed by the same men, either working by the day, or by contract, at a stated price per unit of surface or per Ioo-foot section. The right-oI-way should be cut early in the fall so that the roadbed can be graded before the ground freezes. It is usually cut about 20 feet wide for main sled roads, though it may vary in width from 10 to 30 feet. The graded roadbed varies from 5 to 15 feet for

Fig. 11. The Roadbed for an Iced Road which is to be built upon a Deep Snow Foundation.

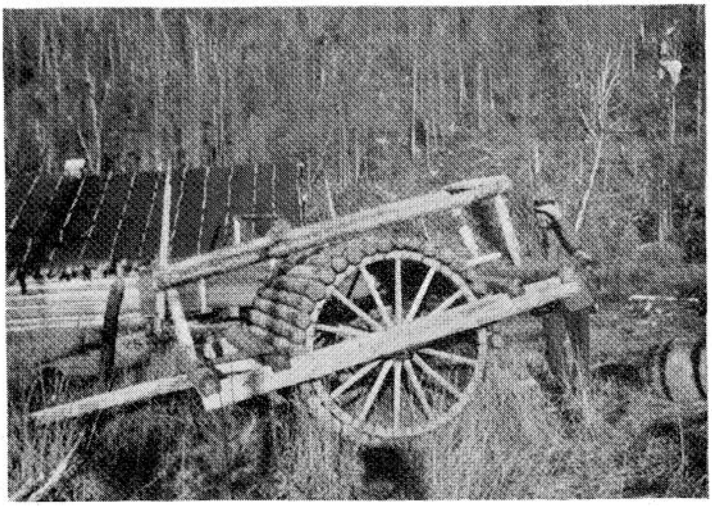


Fig. 13. A Roller for Compacting the Snow on a Sled Road.

sleds having a gauge of from 4 to 8 feet. The trees on the right-of-way are cut with low stumps, sawed level with the ground, or felled by chopping off at the roots, depending on local practice and the type of the road to be built. Merchantable timber is cut into logs or other products, and all felled timber is removed by hand or with teams. A sufficient number of "turn-outs" are made so that empty sleds returning to the woods will not interfere with loaded traffic; or less frequently a special narrow road is made for returning sleds.[1]

A very rough preparation of the roadbed will suffice when a deep foundation of snow is to be used as a road base. The stumps are cut low and left to be covered with snow, and large humps and boulders are removed only if they cannot be avoided by a detour, or if chunks of wood cannot be placed near them and the road level raised so that the sled can pass over them. Holes are filled with non-merchantable timber and debris or covered with skids, laid across the road at intervals of 1 or 2 feet, to support the sled runners.[2] Earth work is avoided whenever possible on account of expense. When a side slope is not too steep, logs are placed along the lower side of the road and short skids which slope towards the center of the road are placed crosswise in notches on these logs, and serve to prevent sleds from running over the edge of the road. When a road traverses a steep side slope, the lower side is built up with rough cribwork covered with cross-skids or "corduroy" instead of excavating the higher side. Corduroy is made by placing poles close together across the road, and in contrast to cross-skids, supports both the horses and the runners of the sleds. Corduroying is necessary when the road passes over marshes and swamps with live springs, when winters are not cold enough to keep swamps frozen solid during the hauling period. A roadbed may be so rough that it is difficult to walk over it before it is covered with deep snow and yet occasionally loggers prepare a foundation of compressed snow on such a bottom and sometimes ice it. Such rigid economy in roadbed construction is rarely justified, because the higher the surface of a sled road is raised above the earth bottom, by snow and cross-skids, the less efficient it will be for transportation and the more difficult it will be to maintain it in good condition. Loggers usually lose more by grading their sled roads roughly than they do by going to the other extreme.

1 Special roads are seldom made except on steep grades.

2 A rough preparation of a roadbed for an iced road on a deep snow foundation is shown in Fig. 11.

Clearing and grading must be carefully done when ruts are to be cut in the earth. All obstacles such as stumps, protruding boulders and large roots on a central strip from 2 to 8 feet wider than the sled gauge are removed by hand labor and the use of animal power or dynamite. Outside of this central strip the road is graded and obstacles removed only to the extent necessary to permit snow-plowing and the passage of overhanging loads. Grading is done chiefly by pick and shovel, although wheelbarrows and occasionally teams with scrapers are used when there is a large volume of earth to be moved.

The amount of labor required for clearing and grading varies from 30 to 150 one-man working days per mile of road and represents from one-fourth to three-fourths of the total cost. The average width of the sled road right-of-way is 20 feet, and the roadbed is graded from 8 to 12 feet wide for sleds from 4 to 8 feet between the runners. The average labor expenditure in clearing and grading a road of this character in the Lake States is from 100 to 120 one-man working days per mile for a first-class sled road built close to the ground. The expenditure necessary for a road of the same size cut in small or scattered timber and roughly graded, as is frequently the case in eastern Canada and New England, would be about one-half as much.

PREPARATION OF THE ROADBED FOR HAULING

Snow Removal and Compression.-The compression or removal of the snow on the sled road may be necessary during the period of road construction in order to provide a solid foundation previous to rutting, icing, or hauling. This work is done in most cases with a homemade V-plow which may be made of two logs about 20 inches thick and from 25 to 30 feet long, hewed either on the outer side or on both sides and slightly flattened on the bottom. A steel plate may be bolted on each lower edge of the V-plow to provide a more effective scraping action. The front ends of the logs are held togetherby a ½-inch draft chain to which from one to five teams are attached. The rear ends of the plow are spread as far apart as desired by a "spreading pole" fitted into notches in the center of the logs and by a "cross log" held by pins at the rear end. The V-plow is longer than the width of the road and it would be difficult, and in some places impossible, to turn it around. Hence, instead of turning, the V-plow is reversed by moving the chain and cross log to the opposite end and by drawing together the ends of the logs which previously were in the rear. The ratio between the length and the spread of the V-plow often is 1½ to

1. A V-plow weighs from 1 to 3 tons and when increased weight is desired, extra logs are placed on top of the frame.[1]

A V-plow may be used for the following purposes when roads are under construction.

1. The partial or total removal of the snow when the road is built directly on an earth foundation, or to the extent desired when other types of sled roads are in the process of construction.

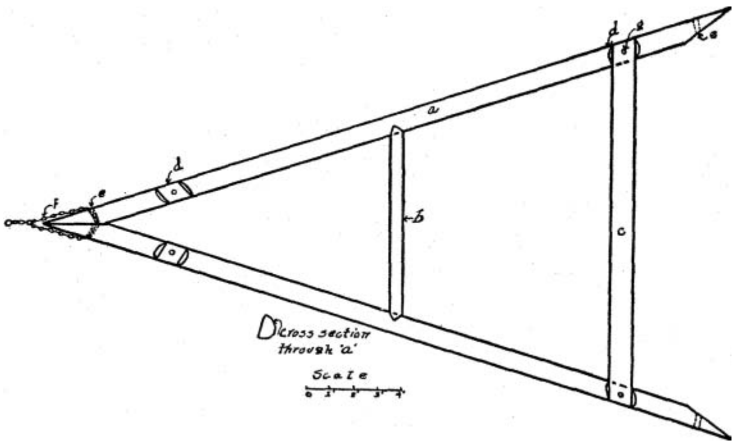


Fig. 12. A V-plow used in the Construction and Maintenance of a Sled Road. a. Side log. b. Spreading pole or "dutchman." c. Cross log. d. Notch cut in the side logs and in which the cross log rests. e. Holes through which the draft chain passes. f. Draft chain made from ½-inch iron. g. Pin for holding the cross log on the side logs.

2. The removal of the loose snow cover on boggy and swampy sections of the road in order to hasten the freezing process.

3. The compression of the snow in order to make a solid and smooth foundation for a road. A V-plow made of round logs is preferred for this purpose. A heavy V-plow is advantageous in preparing a roadbed in which ruts are to be cut directly in the ground because it compacts those sections where the ground surface is loose, due to a cover of thick moss or to a swampy condition. The scraping and levelling action of a V-plow also aids in grading the roadbed.

The crew required to operate a V-plow comprises from 1 to 3 teamsters,

[1] See Fig. 12.

1 helper, and from 4 to 8 horses. This crew will plow daily in both directions from 6 to 8 miles of road if the conditions of work are not too adverse.

Roads built on a deep snow foundation may be broken out previous to hauling by methods other than the use of the V-plow. Among these are dragging or rolling a heavy log crosswise to the road; hauling a sled with a small load of logs, the rear ends of which drag; or dragging an unswamped tree top along the road to "disturb" the snow, so that soft spots will freeze more readily. Men may be used to tramp down the snow cover where horses cannot be used. Crawler tractors also are very efficient in compacting the snow cover both on wet and dry bottom.

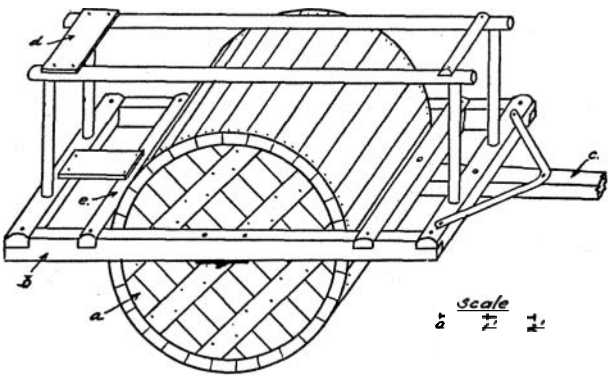


Fig. 14. A Roller for CQmpacting Snow on a Sled Road. a. Drum, diameter 58 inches, width 96 inches, made from 2-inch plank. b. Roller frame. c. Tongue, 12 feet long. d. Driver's seat. e. Beam for scraping snow from the drum. Ontario, Canada.

Rollers from 5 to 8 feet in diameter made as shown in Fig. 13, or more frequently made of planks as shown in Fig. 14, are sometimes used to compact the snow foundation on a roughly prepared roadbed. The roller is drawn by a 4-horse team, the creW comprising two teamsters and one assistant. It requires from one-half to one day to roll 1 mile of sled road, back and forth four times, when the snow is from 18 to 24 inches deep. A V-plow usually is more satisfactory than a roller, since the former tends to fill the holes in the road with snow or dirt carried from the knolls, while the latter compacts the snow. Rough grading of the kind just mentioned can be best done, however, by a simple handmade scraper or leveller such as is shown in Fig. 15, which is often used in the construction and maintenance of trough roads. The material scraped from the road surface is either dragged until it is deposited in depressions and holes, or is pushed from the road by the V-shaped wings of the scraper. This scraper does not slue as much as the V-plow but it is more difficult to pull it over obstacles such as stumps, boulders, and cross-skids. It is used, therefore, only when deep snow covers a road which has been "broken out" previously. The width of the scraper is from 2 to 6 inches greater than the gauge of the sleds.

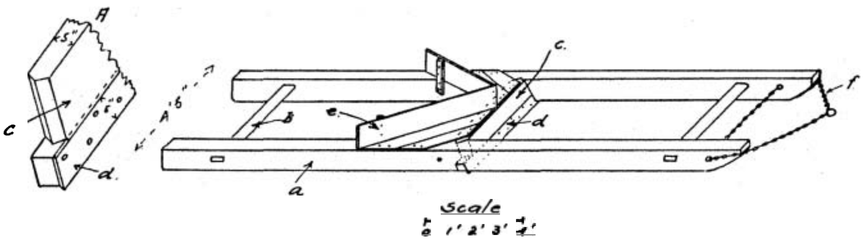


Fig. 15. A Scraper or Leveller used to grade roughly a Sled Road after the First Snowfall. a. Runner 5½ by 9 inches by 24 feet. b. Brace 6 by 58 inches. c. Scraper plank 5 inches thick. d. Steel scraper knife ½ by 5 by S8 inches. e. V-shaped wing for crowding the snow off the road. f. Draft chain. The details of the scraper plank are shown in "A." Maine.

Rut-cutting.-The width between the ruts which are cut in a road corresponds to the width between sled runners and is from 4 to 8½ feet, center to center. A gauge of from 4 to 5 feet is suitable only for a single horse, although some loggers occasionally use teams on roads of this width. The trail required by a horse is from 18 to 24 inches wide and the space between the trails of two horses abreast is about 2 feet. A gauge of from 4 to 6 feet for rutted roads, therefore, is too narrow for team hauling, because it provides a poor footing for the horses, which step in the ruts, break them down with their shoes, and foul them with manure. It is necessary, therefore, to have a margin or "inside shoulder" from 6 to 12 inches wide between the rut and the path of a horse, in order to keep ruts clean and in good condition. Consequently, in the Lake States, where rut roads are highly developed, the ruts on roads where animal draft is used are made from 7 to 8 feet apart. For mechanical draft, such as crawler tractors or steam log haulers, the margin should be frbm 12 to 18 inches on each side of the traction members in order to enable the driver to keep the machine on its path between the ruts, which usually are from 8 to 8½ feet apart, center to center. The depth of ruts is from 3 to 6 inches. A depth of 3 or 4 inches is sufficient if the ruts are properly cut and have solid and strong banks. Ruts should be deeper on curves than on straight stretches, especially when mechanical power is used. Very sharp curves should be avoided because they increase road resistance, and add to the danger of hauling on steep down grades. The width of the ruts is normally about twice that of sled runners, usually from 7 to 9 inches. Ruts must be widened a few inches on curves to prevent the sled runners from jamming. This work usually is done with an axe. Ruts are rounded[1] to prevent the side friction of the runners,

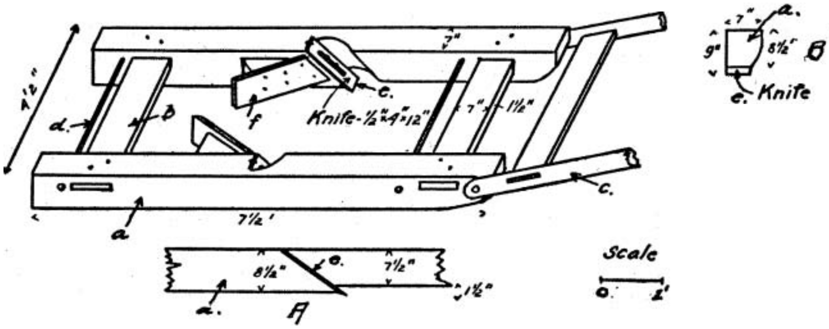


Fig. 16. A Rutter for a Single-horse Sled Road. a. Runner 7 by 7½ or 8½ by 90 inches. b. Brace 1½ by 7 by 50 inches. c. Shafts. d. Iron brace rod. e. Flat rutter knife ½ by 4 by 12 inches, projecting 1½ inches below the front part of the runner. f. Wings which throw the material cut from the ruts into the center of the road. A. A side view of a runner and position of runner knife. B. Front view of runner and knife.

which are usually shod with rounded steel shoes. Ruts with a flat bottom are less practical.

Ruts were first cut in the iced surface of the road or in the ground with axes or special mattocks, which was a slow and expensive method. The first device built for rut cutting by animal power had two crude heavy runners, connected by braces, the squared front ends of which cut grooves in the road surface as the rutter was pulled over the road. Steel knives were later fitted into the runners of the rutter and provision made for the regulation of the depth of cut. Several types of rutters are now in use, some home-

[1] See Fig. 28, a.

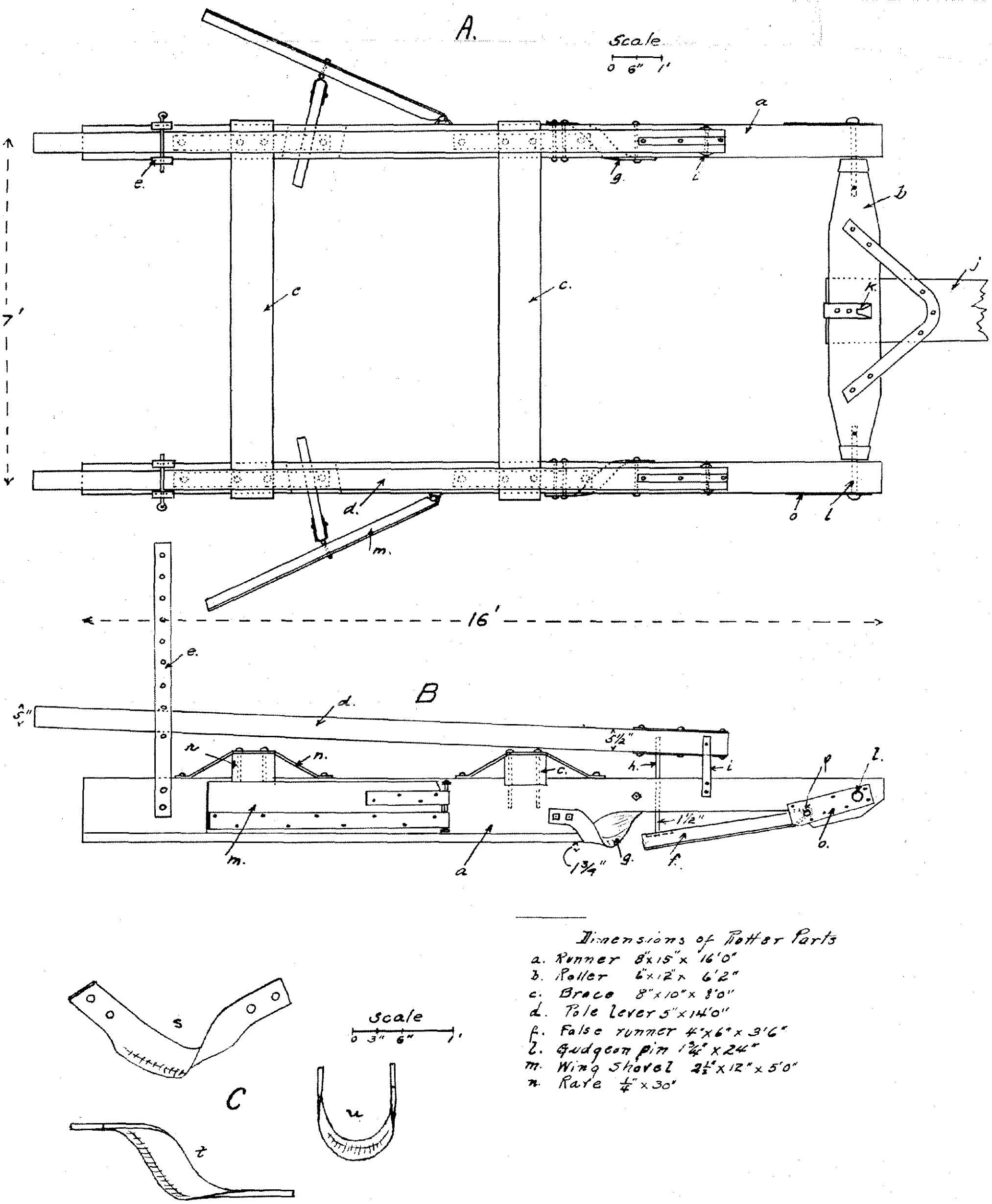


Fig. 17. A Homemade Rut Cutter. A. Top view. a. Runner. b. Roller. c. Brace. d. Pole lever for regulating the depth of cut. e. Double standards which support the pole lever "d." g. Rutter knife which projects 1¾ inches below the runner. i. Yoke supporting the forward end of pole lever "d." j. Tongue. k. Draft hook. l. Gudgeon pin. m. Wing shovel for crowding snow or ice, cut by the rutter knives, off the road. o. Steel plate. B. Side view of rutter. f. Steel-shod false runner for regulating the depth of cut. h. Bolt for raising or lowering the false runner "f." n. Rave. p. Hinge of false runner. r. Rave pins. C. Rutter knives. s. Side view. t. Top view. u. Front view.

made, others offered by the manufacturers of logging equipment, practically all of which are horse-drawn.

The rut cutting usually is done with one machine, but a few loggers use two rutters, a crude and very strong "bull-rutter" for the rough work of cutting ruts in the ground and another lighter and more elaborate machine for maintaining the road. Bull-rutters have two flat steel knives, fitted into slots made in the heavy runners, which protrude from 1 to 3 inches under the runners. No attempt is made to regulate the exact depth of cut. The machine shown in Fig. 16, drawn by one or two horses, is a small machine of the bull-rutter type and is used for a single-horse sled road. It is not adapted to cutting ruts in the earth, but fairly good ones can be made and maintained on an iced road by the use of this device.

One of the best and simplest homemade rutters, frequently used in the Lake States, but little known elsewhere, is shown in Fig. 17. The knives, made of tool-steel plates ¾ by 4 inches, are bent and fitted so that they cut the rounded ruts at an angle. The material removed from the ruts is pushed outside of them and then is carried to the edge of the roadbed by "wings" or side boards hinged on the rutter runners. The depth of cut for each knife can be quickly and easily regulated by the false runner, pivoted to the nose of each rutter. runner,[1] the rear end of which can be raised or lowered by means of the pole lever,[2] thereby decreasing or increasing the depth of the cut made by the rutter knife. This rutter is serviceable both for earth rutting and for sled road maintenance. The wings, m,[3] attached to the outer sides of the runners, may serve for lightly plowing the outside shoulders of the road or they can be folded, when not required, so that the machine can be used solely for rutting or for snowplowing, or for both operations simultaneously. The runners of rut cutters are from 6 to 8 inches thick, from 14 to 20 inches high, and from 12 to 20 feet in length. They are usually hewed and have a rounded bottom. Long runners make more regular ruts than short ones, but they do not work well on sharp curves.

The runners of the "Badger" rutter are made in two sections.[4] The rear section of each runner, to which a steel "scoop pattern" knife is fastened, may be raised or lowered by a screw actuated by a hand wheel, the depth of cut being regulated in this manner. This rutter may be combined with a snowplow, in which case an adjustable center V-plow is fitted between the

1 See Fig. 17, f.
2 See Fig. 17, d.
3 See Fig. 17.
4 See Fig. 18.

forward skeleton runners. This plow can be raised or lowered by means of screw bolts operated by hand wheels. The snow is forced to the edge of the road by wings, hinged to the outside of the runners by means of four rings and a pin. The wings are held to the road by gravity, and automatically move up or down in a vertical plane when variations in the depth of the ruts occur. The V-plow and wings have steel plates on the lower edge which scrape the road surface. The Badgerrutter and rutter-snowplow is an effective device for use in the maintenance of sled roads, but it is more expensive and not as strong as the homemade rutter previously described. It is, therefore, not well adapted to the first rutting of roads where obstacles are numerous.

Intermediate between trough roads with their flat cross section and those with narrow ruts are sled roads with wide flat grooves cut on each side of the roadbed.[1] These serve as a track for the sled runners as well as for a team or for the drivers of a traction machine. These flat grooves are usually 18 inches wide and from 2 to 5 inches deep and are separated by a "center core" which is from 1 to 5 inches above the base of the runner beds; and approximately 40 inches wide for a 48-inch gauge sled. The grooves are made correspondingly farther apart for wider gauges. Such grooves will keep a sled in the road but will only partially prevent side sluing and side friction of the runners. They make a better track than a trough road but they are inferior to a rut road. Economy in the use of water for icing purposes is one of the reasons for making roads of this type, since sprinkling is confined solely to the runner beds. Flat-shoe runners are used commonly on such roads.[2] The outside banks of the runner beds, when high enough and solid, will prevent a sled from leaving the road, but runner sluing and side friction are much greater on this type of road than on one which has rounded ruts. The travel of horses or of the traction members of a tractor makes it rather difficult to maintain such roads in the smooth and clean condition which is necessary for the best results. In so far as sliding resistance is concerned, this type of road is inferior to rutted roads on which horses travel between the ruts. However, narrow-gauge sled roads of this type are popular with loggers in eastern Canada and in New England.

The wide grooves on a sled road are usually cut by a "Brazel" machine.[3] A reach connects the steering sled with the main body of the machine, which has a wooden frame mounted on runners. The front part of the frame is

1 See Fig. 7.
2 See Fig. 28, b.
3 See Fig. 19.

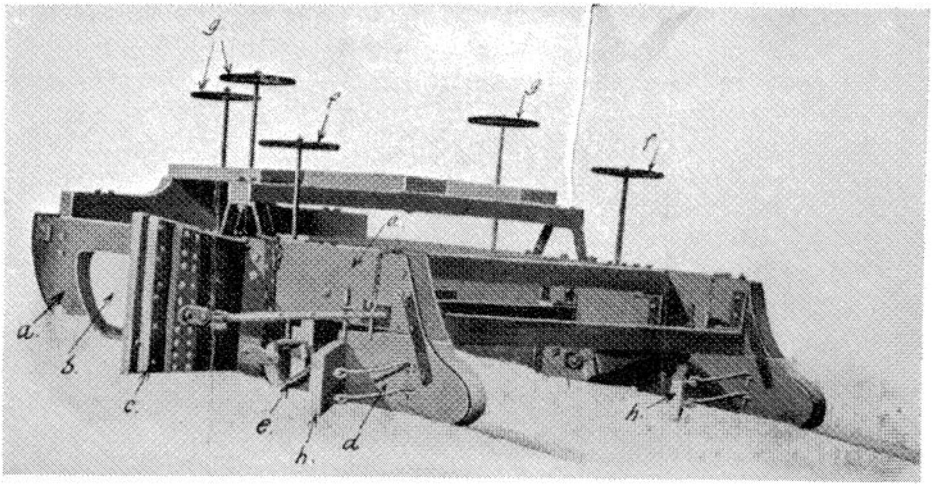


Fig. 18. The Badger Conlbined Snowplow and Rutter (Rear View). a. Front section of runner. b., Opening in runner which serves as an outlet for snow. c. Wing for snow plowing. d. Rear portion of runner. e. "Scoop" pattern rutter knife. f. Hand wheels for regulating the height of the rutter knife "e." g. Hand wheels for raising or 10'wering the center V-sno,vplow. h. Small wing for removing earth and snow cut from the ruts by the futter knives "e."

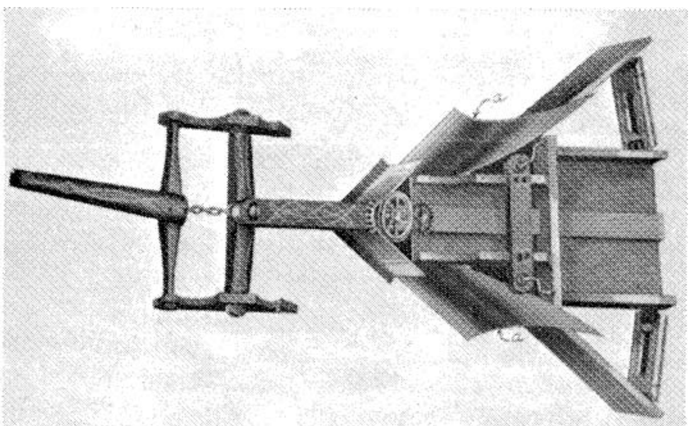


Fig. 19. A Top Vie'w of the Brazel COlnbined Snowplow and **Rut-**cutting Machine. The wide, fiat grooves are cut by shares on the bottom of the mold boards, "a."

fitted with a V-plow with cutting edges which are adjustable by means of hand screws or screw bolts and hand wheels. The flat grooves are cut in the road surface by sharp ¾-inch steel shares, which are fastened to the bottom edges of ¼-inch cast-iron mold-boards. The depth of the cut is regulated through the vertical adjustment of the mold-boards, by means of hand screws or screw bolts and hand wheels operated by the conductor. There is a hinged wing, on each side of the body of the machine, behind the mold-boards, for plowing snow from the "wing bed" or "outside shoulder" of the sled road, in order to provide room for the free passage of loads, which generally overhang the sled bunks.

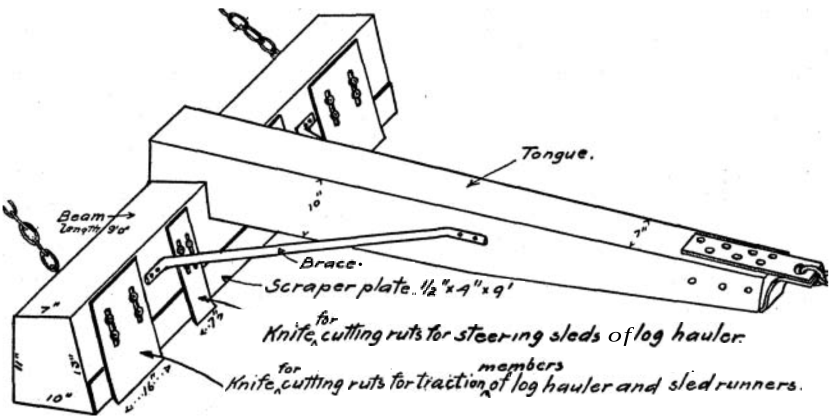


Fig. 20. A Rutter and Scraper drawn by a Steam Log Hauler. Maine.

A homemade machine for doing this work has wide heavy planks with steel blades set at an angle to the road surface instead of the mold-boards. The cutters are raised and lowered by means of levers and ratchets.

The mold-boards on a Brazel machine may be set at the same level as the center plow in order to make a wide, fiat surface for a road of the trough type. They also may be equipped with rounded or fiat futter knives for cutting narrow ruts.

A convenient homemade device[1] for the construction and maintenance of an iced sled road is sometimes used in northern Maine when the draft power is a steam log hauler. It has a tongue mortised into a heavy beam,

1 See Fig. 20.

as wide as the roadbed, to which a steel plate for scraping and levelling the road surface, and two pairs of steel knives are attached. The inner pair of knives cuts two grooves in the roadbed for the steering sled of the log hauler while the outer knives make broader beds for the drivers of the machine and for the sled runners. The knives may be set to cut grooves to the required depth or the device can be used as a scraper and leveller only. It is suspended, by three chains, under the body of the log hauler behind the steering sled and in front of the drivers. The length of the two rear chains, by which the beam of the scraper issuspended from the body of the hauler, is so adjusted that the scraper is prevented from cutting too deep.

Ruts made in the earth are first cut when the ground begins to freeze, because rut cutting in frozen ground is difficult unless the soil is loose, due to the presence of humus or moss.[1] The proper rut shape is secured later by the combined work of the rutter and water tank. When rut cutting first begins, the rutter, drawn by from two to five teams, is run once or twice back and forth over the road, the chief object being to secure straight and well-formed channels. On the first run, the rutter knives are set so as to make a very shallow cut and on each successive trip the depth of the cut is increased until the maximum depth desired is reached.[2] A crew for operating a rut cutter includes one driver for the first two- or four-horse team, and one driver for each additional team, and one or two men on the rutter to regulate the depth of cut by means of levers or hand wheels. Two or more men with axes and mattocks follow and remove obstacles from the ruts, such as large roots and stones. The above crew is required for the proper rutting of a roadbed; however, when rutting is done rather carelessly, the rutter may be operated without conductors and without men for clearing the ruts behind the machine. The knives will cut roots and remove small stones, but large obstructions often cause crooks in the ruts or stop the machine instantly. Rutter knives, when dull, are removed from the rutter, heated to a cherry-red color and hammered sharp by the camp blacksmith. They should not be sharpened with a file because it is difficult to retain the proper shape.

A rutter, under favorable conditions, can cover from 4 to 5 miles[3] of road in a day when cutting ruts in the earth. When it is difficult or impossible to

1 See Fig. 21.

2 See Fig. 22.

3 This includes rutting both on the outward and returning trip, a total daily distance of 8 or 10 miles.

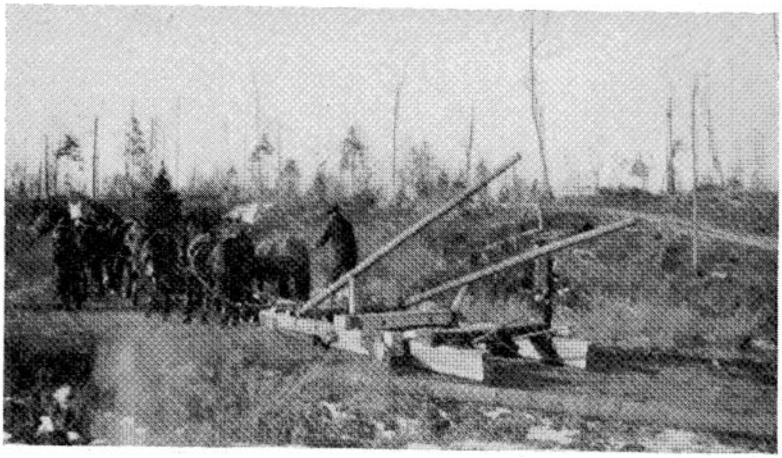


Fig. 21. Cutting Ruts in Frozen Earth with a I-Iomemade Rut Cutter. IVfinnesota.

Fig. 22. The appearance of a Rut Road before it has been used for the first tilne. The ruts have been cut in the earth follo\ving a light snowfall. l\1innesota.

cut ruts in the earth because of rocks the roadbed is sprinkled and shallow ruts are then cut in the ice.

Narrow ruts can be cut much easier and quicker in compressed snow than

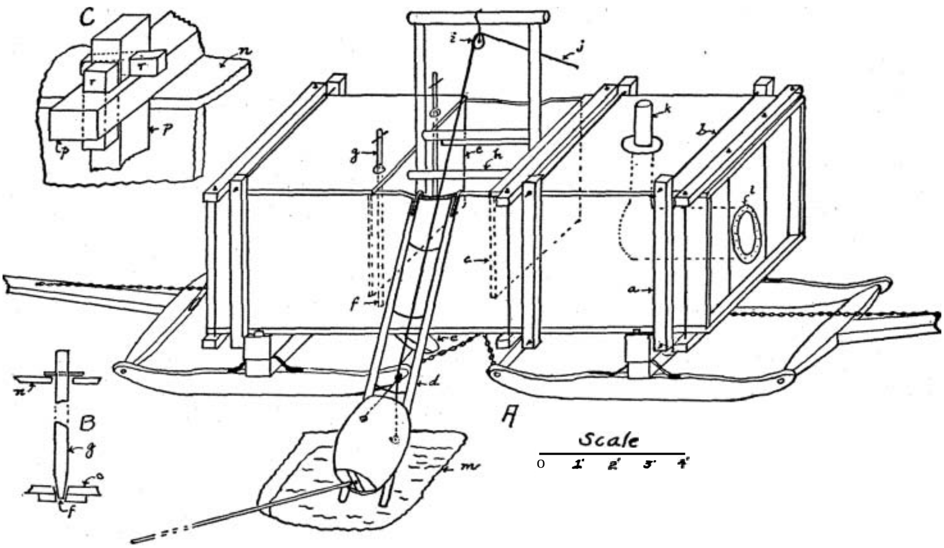


Fig. 23. A. A Water Tank used to Sprinkle Iced Sled Roads. This tank is 4 feet high, 7 feet wide and 14 feet long and has a capacity of 390 cubic feet of water. The tank is made from 1 ½-inch plank. a. Frame timber 4 by 4 inches in cross section. b. A ¾-inch brace rod. c. Interior partition to prevent the splashing of the water. d. Barrel ladder. e. Sheet iron trough for deflecting the water to the ruts. f. Holes in the bottom of the tank just over the trough "e." g. Plugs by means of which the holes "f" may be opened and closed. h. A bumper which prevents the barrel from falling into the tank. i. Hoisting block. j. Hoisting cable, ⅜-inch. k. Stack of tank heater. l. Fuel door for tank heater. m. Water hole in a stream. B. Details of the water plug "g." n. Roof of water tank. o. Floor of water tank. C. Details of a wooden frame for a water tank which is sometimes used instead of that shown in "A." p. Frame timbers. r. Wooden wedges.

in the earth. Two teams of horses are usually sufficient to pull a rutter on snow, and a rut-cutting crew of one or two teamsters and a conductor can cover, daily, on a good snow bottom free from obstacles, from 7 to 8 miles of road going over it once in each direction.[1] Cross-skids which have been

[1] This includes rutting both on the outward and return trip, a total of 14 or 16 miles.

laid across holes and around obstacles and which have been used in side-bridging a roughly prepared roadbed, are a hindrance in rutting when they are not well covered with compressed snow.

Sprinkling or Icing.-A sprinkler or water tank for icing logging sled roads has an approximate capacity of from 200 to 500 cubic feet of water.[1] The tank is mounted on a sled and drawn by from 1 to 3 teams of horses, the number depending upon the profile and quality of road, and on the size of the tank. The usual dimensions of a sprinkler drawn by four horses are 4 by 14 by 8 feet with an approximate maximum water capacity of 450 cubic feet.[2] A smaller tank holding from 200 to 300 cubic feet and drawn by a single team is used in the Northeast. When sprinkling first starts and tank hauling is most difficult because of poor road conditions, an additional team may be necessary. Sprinklers are made box shape from 1½- or 2-inch square-edged or matched planks which are held together by 6 or 8 frames, each having 2 beams, which are placed around the body of the tank with their ends joined by iron rods which are threaded on the ends. The beams are drawn together by the use of nuts, thus tightening the walls of the tank as much as is necessary to prevent leakage. The front and back walls of a tank are fitted into slots cut in the sides, top, and bottom. The sled sets upon which the sprinkler is mounted are so constructed that they can be drawn in either direction because it is impossible to turn a sprinkler around on a logging road.

A water-tight cylindrical heater made from ¼-inch wrought steel and burning 36-inch wood fuel may be installed in the sprinkler to prevent the water from freezing when low temperatures prevail.

A common method for filling a sprinkler with water is by the use of a barrel drawn up an inclined ladder.[1] A block is fixed on a framework above an opening in the top of the sprinkler tank, and through this block a ⅜-inch steel cable is passed, one end of which is fastened to a bail on a barrel and the other end to a singletree. The sprinkler tank is drawn up near a water hole, the team unhitched and one of the animals or a team is hitched to the singletree. The ladder is placed in position between the water hole and the top of the tank and the barrel lowered into the water. A pole attached to the bottom of the barrel enables the workman to submerge it. When the barrel is filled, it is drawn up the ladder by the horse and dumped

1 See Fig. 23.

2 This is a common type in the Lake States.

into the tank. It requires about 30 minutes to fill a tank holding 300 cubic feet of water. Suitable water holes which are sufficiently deep toftll a barrel can be made in small and shallow streams or in swamps by dynamite, provided there is enough flow to prevent the stream from freezing solid. Sprinklers are filled by gravity from brooks, springs, or a dam on a higher level when local conditions make it practical. Pumps sometimes are used, but chiefly when water for filling a sprinkler must be taken from wells.

The water is released from the sprinkler through two or four holes in the bottom of the tank between the front and rear runners. These holes, shaped like the frustum of a cone, are closed by long wooden plugs, tapered on the lower end to fit the holes. Small sheet-iron troughs attached to the underside of the tank spray the water over the runner tracks or any other part of the road desired. The volume of water released is regulated either by opening the sprinkling holes wholly or partially by raising the plugs, or by varying the speed at which the tank is hauled, or both. Two men are required to fill the sprinkler and to ice a road, namely, a teamster and a conductor.

Road sprinkling, which usually begins in December, is started on sections of the road nearest the water supply, and at first only the runner tracks are iced in order to facilitate the hauling of the sprinkler. Then, according to the type of the road, water may be sprinkled between the runner tracks to make an ice bottom for the team or traction machine and to build up outside shoulders or, in case of a trough road, banks also may be sprinkled to strengthen the roadbed, and to prevent the sleds from leaving it.[1]

Heavy-duty iced rut roads must have outside shoulders, at least 1 foot wide, which are composed of solid ice. Rut shoulders should be wider and stronger for long and heavy sled trains hauled by mechanical power than for single sleds hauled by animals since it is more difficult to make the sleds remain on the roadbed.

The ruts, only, may be iced, when a comparatively small amount of timber is to come out over the road but, when the traffic is heavy, better results are obtained by icing the entire roadbed, with the possible exception of a narrow strip in the center. The ice cover on a heavy-duty road with a 7-foot gauge should be 8 feet wide, that is, 10 feet less 2 feet for the center core, which is only slightly sprinkled. Approximately 3800 cubic feet of water, from 12 to IS tanks, are required to make an ice cover 8 feet wide and 1

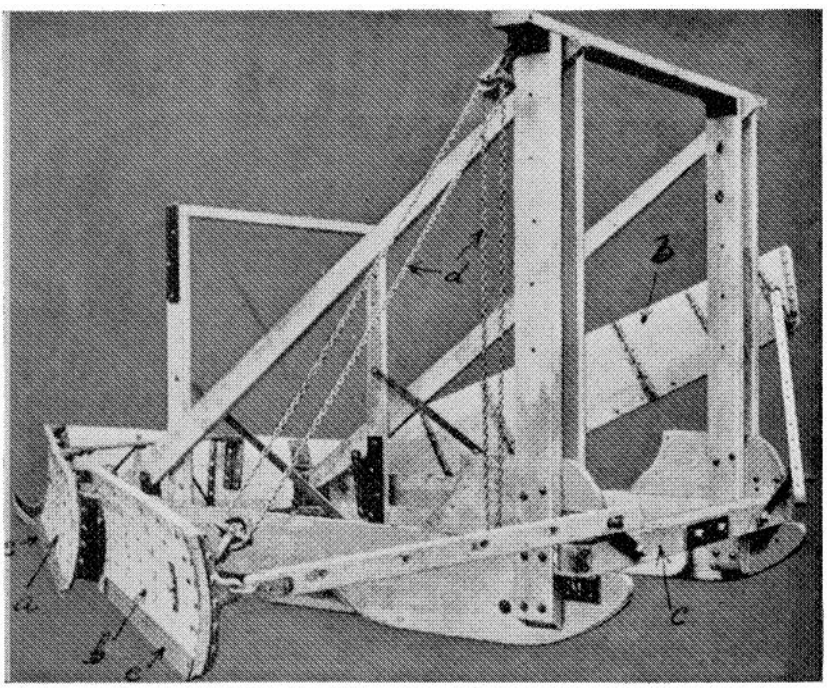
1 See Fig. 24.

inch thick on a mile of road, assuming that water, transformed into ice, increases 8½ per cent in volume. A sprinkler crew of two men with a four-horse team will fill and sprinkle, daily, about 8 tanks of 300 cubic feet capacity each, provided the sources of water are not far from the road to be iced. The average cost of this work is from ½ to ¾ cent per cubic foot of ice coating on the road. However, the cost varies greatly with the conditions of work and the manner in which sprinkling is done. When sprinkling first begins the chief object may be to make the road more level by filling the small depressions with water which later freezes. A tank containing about 300 cubic feet of water may then suffice for only 1320 feet of road. Later, when the road is in good condition, the same amount of water may suffice for 1 mile or more of road, since only a clean thin ice coating is desired. Some loggers prefer to have about 2 inches of ice on the road before they start hauling, while others may begin to move small loads as soon as icing begins, provided the road has a compact snow foundation. At the opening of the season, sprinkling may proceed both day and night in two shifts in order to obtain a suitable ice cover in the shortest possible time, but when the road is in shape, it is usually iced only at night in order not to interfere with log hauling. A rutter having knives set for a very shallow cut maybe run over the road during the first icing period to secure the proper shape of ruts or a Brazel machine or a scraper may be used to level and smooth down a track for the runners and for animals or traction machinery. Some handwork usually is necessary in order to widen and deepen the ruts on sharp curves and to fix the road in bad places.

Unsuccessful experiments were undertaken some years ago to make an ice coating on sled roads by melting the snow by means of steam generated in a boiler hauled over the road on a sled. In one case steam was discharged directly on the road surface, and in the other the snow was melted by contact with hollow iron runners heated with steam.

Iced Roads on Bridges, Rocky Sections, and on Water Basins.-Bridges for iced roads must be built so that they will not sag under heavy loads, otherwise the ice cover will disintegrate. The stringers of the bridge are usually supported by cribwork piers and the floor of the bridge is made of crosswise poles laid close together and covered with bark and a few inches of earth, or if the traffic is light, well compacted snow may be substituted for the earth. The rut cutter makes very shallow grooves on the bridge which are later deepened by frequent sprinkling of the road surface and by careful

Fig. 24. A Rut Road on an Earth Foundation which has been sprinkled a Few Times Only.



By pern1ission Union Iron Works; Inc.

Fig. 25. A Sargent Snowplow for Use "with a Crawler-type Tractor. a. Plow nose. b. Wing. c. Drawbar. d. Chain for raising the wing. e. Cutting edge of the wing. A plow designed for a la-ton tractor has the following dilnensions: Length over all 24 feet; height of nose 42 inches; width of plow, wings closed, 13 feet; width of plow, wings open, 28 feet; height of wings 32 inches; cutting edge "e," ¾ by 8 inches; drawbar 8 by 10 inches. Total weight 6500 pounds.

rutting in the ice cover so formed. Special attention is given to building up broad and strong outside shoulders. A down grade of 1 or 2 per cent in the loaded direction is desirable on a bridge.

The roadbed may be smoothed down by blasting and the rock surface covered with enough earth to make very shallow ruts possible when a short rocky section is encountered along the route of a proposed iced road in which the ruts are to be cut in the earth. It is often cheaper to cover a rocky section of the road with twigs and skids instead of earth so that the sprinkler can pass over that section of the road and build up a solid ice foundation in which ruts may be cut later. If rocky sections are frequent both of these methods may be too expensive. In such cases the road is iced after a compressed snow foundation has been formed. Ruts may be cut either before or after a road is iced, but when the latter procedure is followed it is rather difficult to make straight ruts because the rutter will slue on the road.

Loggers usually prefer to avoid the level surfaces of frozen lakes, ponds, and rivers because valuable hauling time may be lost, due to the necessity of having to wait until the ice is thick enough to start hauling and also on account of the danger of breaking through when the ice becomes rotten in the spring.[1] The formation of thick and strong ice on lakes and rivers may be hastened by plowing the snow off the ice, or by making holes in the ice and flooding the roadbed. The strength of such a roadbed also may be increased by laying long cross-skids on the ice and then sprinkling over them. Ruts cut in the ice of water basins are comparatively shallow, usually from 2 to 3 inches in depth. A clean ice cover is maintained by sprinkling. Hauling heavy loads on lakes or rivers is not only dangerous but difficult unless the ice is thick because it sags down while the load is passing and thus creates a constant uphill grade.

Steep down grades are kept free from snow and ice, and frequently other means must be used to check the speed of sleds.

MAINTENANCE OF SLED ROADS

SNOW plowing, scraping or levelling, rutting, sprinkling, removing dirt from the road surface, and hand repairing work in weak spots comprise the chief forms of sled road maintenance.

PLOWING SNOW

The snowfall in most of the logging regions of the United States during the two or three months of the sled hauling period varies from 12 to 48

[1] Ice 12 inches in thickness is scarcely strong enough for hauling with horses and 24 inches of good ice may not be safe for heavy loads or traction machinery.

inches in depth. When it is moderate and the snow accumulates slowly, it may be gradually tramped down in the process of hauling, but usually at least a portion of the snow is removed from the road, especially after heavy snowstorms. Loggers who have heavy-duty iced roads made on an earth foundation and who desire to maintain them in perfect condition remove all of the snow after each storm. Loggers often use a V-plow made of hewed logs or heavy planks in sled road maintenance. If the road is rutted, the V-plow may be mounted on runners which follow the ruts, while the plow drags over the roadbed. This reduces the tendency of the snowplow to slue. It is customary, when plowing deep snow from a wide road, first to run the V-plow with a spread which will make a passage for the horses only, and later to run it spread out so that the entire width of the road is plowed. Light plows are weighted with logs when used for removing deep snow. Combined rutter-snowplows, and also Brazel machines, are frequently used for plowing snow in road maintenance, removing it by the center V-plow and then by the wings. After each snowstorm these machines are run over the road first as a snowplow only, and later they clean the snow from the ruts by means of the rut cutter. Snowplows similar to these combinedmachines, but without a rutting device, are also in use.

Three teams of horses with two or three drivers and a conductor can plow 8 miles of road daily, clearing a strip 10 feet wide and 6 inches deep when the snow is loose. Animals pulling in deep snow cannot work to advantage because of the bad footing and the difficulty in moving. It is impracticable to push a plow from behind with animals because it is impossible to steer it. However, in deep snow it is practical to have one team push'ing the plow from behind and other teams pulling in front. The rear team is hitched to a long tongue loosely pivoted to the rear of the snowplow, so that the tongue will not injure the team by swinging. Loggers usually do not wait until a heavy snowstorm is over before plo,ving begins, because an excessive depth of snow may accumulate, which can be more easily moved in several plowings than in one.

Snow plowing with heavy crawler tractors is a very efficient method when the plow is pushed and steered by a tractor travelling inside of the plow frame. A snowplow of this type[1] is moved forward by means of a pushbar attached to the forward part of the tractor. Chain connections to the tractor prevent excessive side play and also allow a vertical movement independent of the tractor. The plow travels on runners and is steered by turning the tractor. The nose or "V" may be raised or lowered by means of levers. The

1 See Fig. 25.

wings of the snowplow widen the path made by the V and when plowing deep snow they may be raised by chains so as to deposit the loosened snow on the top of the banks.

Rotary snowplows have been designed during the last few years, and may prove suitable for maintenance work on logging sled roads in regions where the snowfall is heavy. The latest model of a rotary snowplow, pushed by a crawler tractor, has a rotor or propeller mounted on the lower end of a vertical shaft which is driven by a 60 horse-power gasoline engine at 1000 R.P.M. It can throw snow, by means of deflectors, far enough from the road so that side banks are not formed. The front part of this machine is supported by a pair of steering wheels for which sled runners may be substituted, and the rear end is attached to a crawler tractor which propels the snowplow by pushing it forward. The rotor is protected from striking any obstacle on the road and, as the machine advances, the snow is guided to the rotor by two steel intake blades or wings. This snowplow can clear a strip 14 feet in width.

Other schemes for snow removal such as a steel blade set at an angle to push the snow to one side, a rotary brush, melting, and removal by a power conveyor, are not adapted to logging sled road maintenance.

The drifting of snow may be prevented or greatly reduced by leaving protective strips of green timber along main sled roads, by placing coniferous tree tops along the windward side of the road or by plowing furrows in the deep snow which act as snow traps.

Snowsheds, with a pole framework covered with coniferous brush and completely enclosing the road, are sometimes made to keep the road bare on steep down grades where the snow tends to accumulate in drifts.

RUT CLEANING AND SPRINKLING

A rutter is generally used about once a week during the hauling period to keep the ruts clean and uniform in shape. They are also used after every snowstorm to remove the snow from the ruts before sprinkling. The rutter and sprinkler are used jointly in making a smooth track for the runners, the sprinkler filling small depressions, and the rutter working as a planer, keeping the ruts the proper depth. The sprinkler is used every night on iced roads which carry heavy traffic, while those of lesser importance and which are not maintained so carefully are sprinkled once or twice a week, only. A crew of two men with a tank of 250 or 300 cubic feet capacity can maintain about 4 miles of wide iced road. If the water supply is readily accessible such a crew will sprinkle 8 tankfuls per day, icing with each

TABLE I

THE AVERAGE COSTS OF CONSTRUCTION AND MAINTENANCE OF SLED ROADS[1]

Construction and Maintenance Items	Type of Sled Road: *Iced road with ruts, earth foundation. Lake States type. Right-of-way 20 feet. Roadbed 10 feet, well graded. For wide-gauge sleds.*						*Snow road. Lake States type. Right-of-way 20 feet. Roadbed 10 feet, roughly prepared. For wide-gauge sleds.*						*Snow foundation, wide iced grooves. Northeastern type. Right-of-way 15 feet. For narrow-gauge sleds.*					
	Per mile of road																	
	Unskilled Labor	*Skilled Labor*	*Total Labor*	*Horse Labor*	*Cost*	*Per cent of cost*	*Unskilled Labor*	*Skilled Labor*	*Total Labor*	*Horse Labor*	*Cost*	*Per cent of cost*	*Unskilled Labor*	*Skilled Labor*	*Total Labor*	*Horse Labor*	*Cost*	*Per cent of cost*
	one-man days	one-man days	one-man days	one-horse days	Dollars		one-man days	one-man days	one-man days	one-horse days	Dollars		one-man days	one-man days	one-man days	one-horse days	Dollars	
Location and blazing	...	2.0	2.0	...	10.00	2.5	...	1.5	1.5	...	7.50	2.8	...	1.0	1.0	...	5.00	2.5
Clearing right-of-way	45.0	7.5	52.5	5.0	155.50	39.5	40.0	7.5	47.5	5.0	142.00	54.0	25.0	5.0	30.0	...	83.50	41.1
Grading	45.0	7.5	52.5	5.0	155.50	39.5	20.0	7.5	27.5	5.0	88.00	33.4	16.0	6.0	22.0	4.0	70.40	34.7
Plowing or tramping snow	0.5	0.5	1.0	2.0	6.95	1.7	0.75	0.5	1.25	2.25	7.62	2.9	0.5	0.5	1.0	2.0	6.95	3.4
Rutting	2.0	1.0	3.0	2.5	13.60	3.5	...	...	...	...	...	...	0.75	0.5	1.25	1.25	6.12	3.0
Icing, 1-inch cover	2.0	2.0	4.0	8.0	27.80	7.0	...	...	...	...	...	...	1.0	1.0	2.0	4.0	13.90	6.8
Road improvement, hand work	2.0	...	2.0	...	5.40	1.3	3.0	...	3.0	...	8.10	3.1	2.0	...	2.0	...	5.40	2.6
Other expense[2]	...	...	...	...	20.00	5.0	...	...	...	...	10.00	3.8	...	...	...	...	12.00	5.9
Total Construction	96.5	20.5	117.0	22.5	394.75	100.0	63.75	17.0	80.75	12.25	263.22	100.0	45.25	14.0	59.25	11.25	203.27	100.0

THE AVERAGE COSTS OF CONSTRUCTION AND MAINTENANCE OF SLED ROADS[1] (cont.)

Construction and Maintenance Items	Type of Sled Road																	
	Iced road with ruts, earth foundation. Lake States type. Right-of-way 20 feet. Roadbed 10 feet, well graded. For wide-gauge sleds.						*Snow road. Lake States type. Right-of-way 20 feet. Roadbed 10 feet, roughly prepared. For wide-gauge sleds.*						*Snow foundation, wide iced grooves. Northeastern type. Right-of-way 15 feet. For narrow-gauge sleds.*					
	Per mile of road																	
	Unskilled Labor	*Skilled Labor*	*Total Labor*	*Horse Labor*	*Cost*	*Per cent of cost*	*Unskilled Labor*	*Skilled Labor*	*Total Labor*	*Horse Labor*	*Cost*	*Per cent of cost*	*Unskilled Labor*	*Skilled Labor*	*Total Labor*	*Horse Labor*	*Cost*	*Per cent of cost*
	one-man days	one-man days	one-man days	one-horse days	Dollars		one man days	one man days	one man days	one-horse days	Dollars		one-man days	one-man days	one-man days	one-horse days	Dollars	
Snow plowing	2.0	3.0	5.0	10	35.00	13.6	2	2	4	6	23.80	11.1	1.0	2.0	3.0	6	21.10	11.5
Rutting or scraping	1.5	1.5	3.0	6	20.85	8.1	..	..	..	..	...	...	1.0	1.5	2.5	3	13.50	7.3
Icing	6.0	6.0	12.0	24	83.40	32.5	..	..	..	..	...	...	3.0	3.0	6.0	12	41.70	22.6
Road-monkey work	32.5	...	32.5	..	87.75	34.2	65	..	65	..	175.00	81.9	32.5	...	32.5	..	87.75	47.7
Other expense[2]	...	...	...	..	30.00	11.6	..	..	..	..	15.00	7.0	...	...	...	..	20.00	10.9
Total maintenance[3]	42.0	10.5	52.5	40	257.00	100.0	67	2	69	6	213.80	100.0	37.5	6.5	44	21	184.05	100.0

[1] This table is based on the approximate daily cost of labor on northern logging operations in January and February, 1924, namely, unskilled labor $2.70, skilled labor $3.20, specialists $5, and horses $2 each. These prices include board.

[2] Includes supervision, depreciation, and like expense.

[3] Per season of 65 working days.

tankful from ½ to 1 mile of road and making an ice coating from ⅛ to ¼ inch in thickness on an 8-foot roadbed. The thickness of ice accumulated on a road during the hauling period usually is from 4 to 12 inches. Sprinkling, snowplowing, and rutting are often done by the same crew, which is reenforced when necessary. This crew rarely is assigned to any other kind of work unless the weather is too warm for sprinkling. The maintenance[1] in good condition of 1 mile of broad iced road during the 60 to 75 hauling days, requires an average of 20 one-man working days and 40 one-horse working days, exclusive of the work performed by road monkeys. Less than one-third as much labor is expended by those loggers who maintain their roads in proper condition.

CLEANING AND REPAIR OF ROADBED

A certain amount of hand work is required on any sled road throughout the entire hauling period. This is done by men called road monkeys, who repair the road in weak places by shovelling snow on or off of it, as required, improve the form of the ruts by the use of axes when necessary, and remove the horse manure from the road. The latter is very important because if manure is left on the road for some time it becomes scattered over the track and kicked into the ruts by the horses, thus making hauling more difficult. One road monkey will keep 2 miles of first-class iced road in good order, and 1 mile of snow road on which there is heavy traffic. The expense connected with icing heavy-duty sled roads may be more than offset both by the greatly increased efficiency of hauling and the economy effected in the wages paid to road monkeys. The proper maintenance of a heavy-duty snow road requires about twice as much hand labor as for an iced road, in spite of the fact that some loggers neglect the condition of their snow roads and have an inadequate number of road monkeys. Extra road monkeys are stationed on very steep grades to keep the road free from snow and to place hay or to scatter sand in the runner tracks.

Table I, based on field data collected during the winter of 1923-1924, at thirteen large logging operations in the Lake States, New England, and Canada, gives typical examples of the amount of labor and expense required for each step of construction and maintenance in the case of three types of sled roads. This table is made for average conditions and for medium-quality roads. In extreme cases the amount of work and the expenses may be double or treble that given.

1 Lake States practice.

LOGGING SLEDS

CHARACTER

THE heavy-duty logging sleds used in the United States and Canada are characterized by (a) ease of hauling, (b) maximum loading capacity and strength of sled with minimum weight and (c) efficient devices for the safe and rapid loading and unloading of heavy and bulky loads.

In all of these respects they are superior to the sleds used in other countries. They can carry a load of logs as heavy as that ordinarily placed on railroad flat cars[1] and loads several times larger than this are on record.[2] The dead weight of the logging sled is usually less than 10 per cent of the net weight of the load, and in this respect a logging sled is superior to other log carriers, either wagons or railroad equipment. When a powerful traction machine is used for draft power as many as 20 sleds may be coupled together, making a train up to 500 feet in length which can negotiate fairly sharp curves, and may be subject to a tractive force as high as 100 horsepower.

A sled having only one set of long runners is inefficient for long-distance log hauling, and many years ago was superseded, in the United States, by the two-sled. Sleds with a single pair of long runners are sometimes used for toting supplies, or for hauling logs on small operations. Sleds for skidding timber are always made with only one pair of comparatively short runners.

The principles of construction are practically the same in all types of two-sleds but there is a wide variation in dimensions, patterns, and efficiency. All types of sleds have a front and a rear set of runners, which support the front end and the rear end of the load, respectively. Both sets of runners are alike, or differ in a few minor particuiars only, and they are connected crosswise by chains or poles so that on curves the rear runners follow the forward ones with a minimum of side friction. The possibility of carrying a long and heavy load on sets of comparatively short runners is most important for efficient hauling.

The two runners of each set of sleds are connected by a cross-beam. The connection between the runners and the cross-beam is either wood or steel,

1 From 4000 to 9000 feet, log scale.

2 The largest load of logs hauled on a sled in the United States by a 4-horse team was about twice as great as that shown in Fig. 1. The latter load weighed approximately 70 tons net.

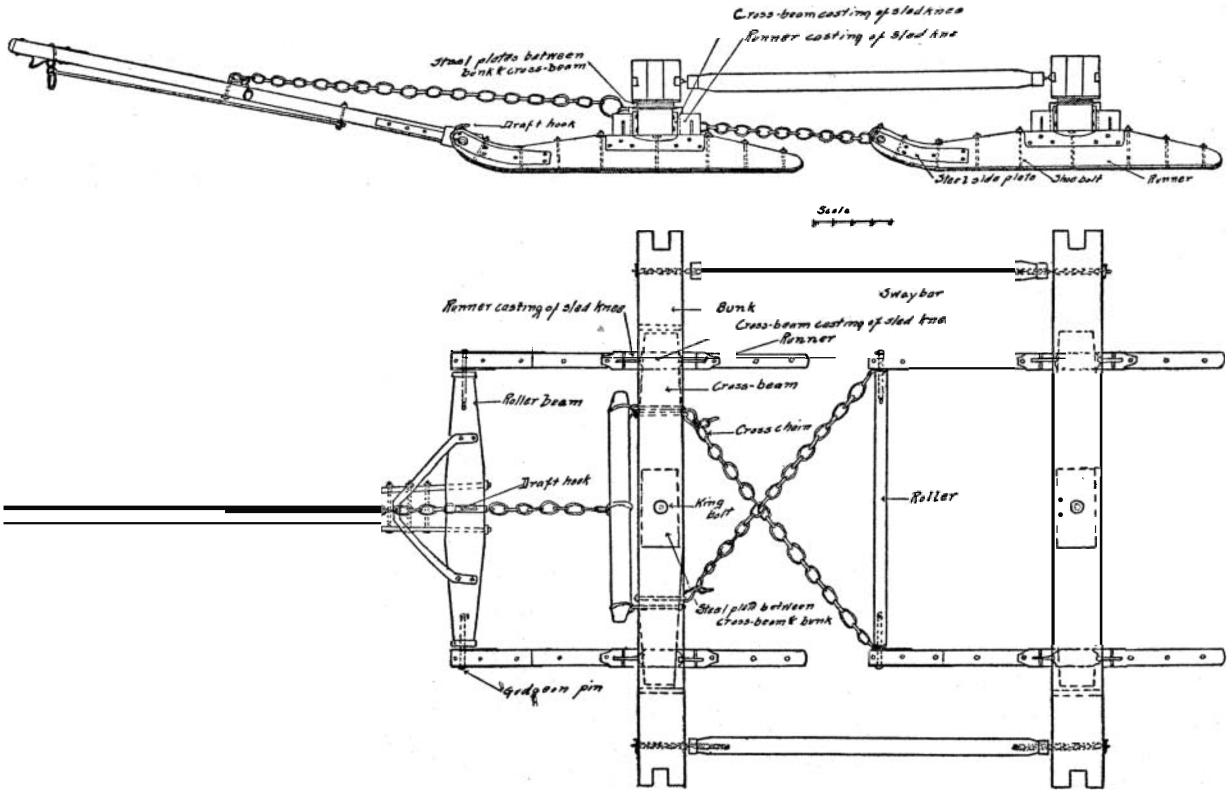


Fig. 26. A Side and Top View of a Heavy-duty Logging Sled for Animal Draft. Lake States type.

and is called a sled knee.[1] The bunk or racker, a beam directly supporting the load, is fastened over the center of each cross-beam by a vertical steel king bolt so that each set of runners can be turned independently without turning the bunk and the load. The front ends or noses of the runners are joined by rollers. Sleds for team hauling have the roller on the front set of runners stronger than on the rear set because the pole or tongue is attached to it.

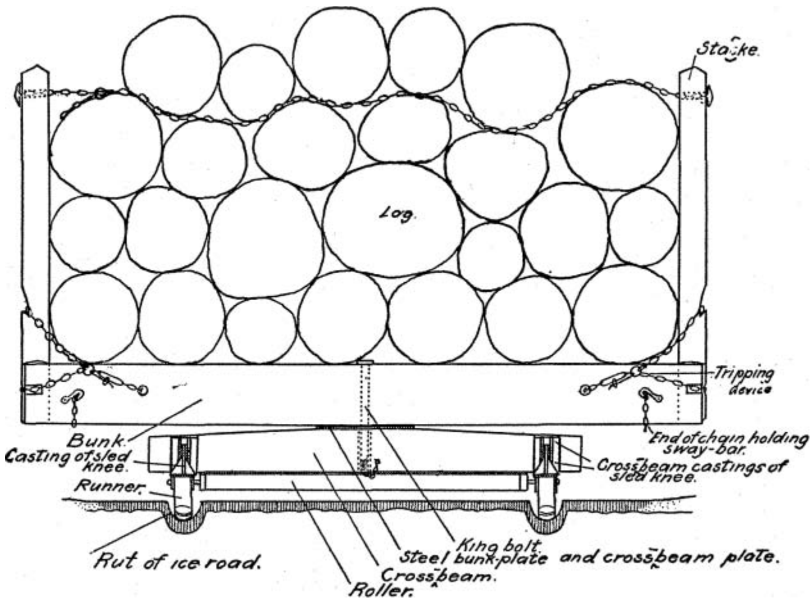


Fig. 27. Rear View of The Heavy-duty Logging Sled shown in Fig. 26.

Runners.-Sled runners must be made from a strong and durable wood and white oak is often used for the best grades of sleds, especially in the Lake States. In the northeastern United States and in eastern Canada runners are made chiefly of birch. A piece of timber with a natural bend or crook which conforms to the curve required for the nose of the runner is preferred. The shape of runners shown in Fig. 26 is characteristic of logging sleds used in the United States. The noses of runners are elevated

1 Typical logging sleds are shown in Figures 26 and 27 and specifications for them are given in Table II.

TABLE II

SPECIFICATIONS FOR HEAVY-DUTY SLEDS

Type of Sled		*Unit of measure*	*Single-horse*[1]	*Single team*[2]	*Light 4-horse or single team*[3]	*Four-horse team and small tractors*[4]	*Powerful traction machinery*[4]	*Traction machinery*[5]
Region			Eastern Canada	Eastern Canada and Northeastern U.S.	Lake States	Lake States	Lake States	New England and Eastern Canada
Gauge[6]		feet	3½ to 4	3½ to 5½	6 to 8	6 to 8½	7 to 9	4 to 6½
Runners	Length	feet	5	6 to 10	8 to 10	8 to 11	9 to 12	8 to 12
	Thickness	inches	2½ to 3	3 to 4	3 to 4	3½ to 4	4 to 4½	4[7]
	Height at Knee	inches	5 to 6	6 to 7	8 to 10	8 to 11	8 to 11	8 to 10
Shoes	Width	inches	2½ to 3	3 to 3½	3 to 4	3½ to 4	4 to 4½	4-inch shoe 2-inch keel
	Thickness	inches	⅜	⅜ to ½	⅜ to ½	½	½ to ⅝	½
	Type		flat	flat	rounded	rounded	rounded	flat, with keel
Knee Type			Wooden blocks or rave and starts		McLaren; sometimes a rave and starts		McLaren	Lombard
Cross-beam	Length	feet			According to the gauge of the sled			
	Thickness at middle	inches	4 by 6	6 by 8½	8 by 11	9 by 12	10 by 14	9 by 10
Bunks	Length	feet	4 to 7	4 to 10	8 to 11	10 to 18	11 to 18	7 to 12
	Thickness	inches	5 to 6	6 to 9	10 to 11	12 to 13	14 to 15	9 by 10 or 10 by 12
Tongue	Length	feet	([8])	11 to 12	11½ to 12	12	....	....
	Thickness at base	inches	([8])	2½ by 6	3 or 3½ by 10	3½ by 12	....	....
Front Roller	Length				According to the gauge of the sled			
	Thickness at middle	inches	2	4 by 5	4 by 10	4½ by 12	4½ to 5	4 to 4½
Rollers	Length				According to the gauge of the sled			
	Thickness	inches	2	2½	4	4¼ to 4½	4½ to 5	4 to 4½
Gudgeon Pins	Length	inches	9	10	10	12	12	10
	Thickness	inches	¾	1 to 1⅛	1¼	1¼ to 1½	1½ to 1¾	1⅜ to 1⅝

SPECIFICATIONS FOR HEAVY-DUTY SLEDS (cont.)

Type of Sled		*Unit of measure*	*Single-horse*[1]	*Single team*[2]	*Light 4-horse or single team*[3]	*Four-horse team and small tractors*[4]	*Powerful traction machinery*[4]	*Traction machinery*[5]
Region			Eastern Canada	Eastern Canada and Northeastern U.S.	Lake States	Lake States	Lake States	New England and Eastern Canada
King Bolt	Length	inches	9 to 12	12	18	20	24	20
	Thickness	inches	1¼	1¼ to 1½	1½	1½ to 2	2	1½ to 2
Cross Chains	Length				According to the length of the load			
	Thickness	inches	⅜	⅜	⅜	½	½ to ⅝	....
Cross Reach	Length				According to the length of the load			
	Thickness	inches						4 to 6
Weight, Approximate		tons	⅓ to ½	¾	1	1¼ to 1½	1½ to 1¾	1¼ to 1½
Normal Capacity		tons	8	14	20 to 25	25 to 30	35	25
Crown of Runners		inches	none	seldom any	⅜- to ⅝-inch crown in 6 to 7½ feet of the bearing line			none

[1] The horse travels between the runner tracks.

[2] The horses travel in the runner tracks.

[1] and [2] Sleds of these two types may have the front runners from 1½ to 2 feet shorter than the rear runners. Both the forward and rear or the rear runners only may be of the moccasin type. See Fig. 28.

[3] Horses travel inside of the runner tracks when the gauge is 6 feet or more.

[4] The tractor or log hauler travels inside of the sled runner tracks.

[5] The drivers of the machine usually travel in the sled runner track.

[6] Width between the center of the runners.

[7] From 5 to 8 inches when moccasin runners are used.

[8] Ten-foot shafts are used.

and the bearing surface in contact with the ground is from three-fourths to four-fifths of the total runner length. This "bearing line" may be straight or slightly curved, with a crown of from ¼ to ½ inch and a bearing line of from 6½ to 7 feet for g-foot runners. Sleds having runners with a crown are easier to start, to turn, and to haul, provided the road surface is hard. A crown on runners also is advantageous in hauling long sled trains with mechanical draft on high-grade iced rut roads. Many Lake States loggers also prefer crowned runners for horse hauling. Runners of logging sleds usually are shod with hard steel, rarely with cast-iron, shoes. The latter offer greater resistance than steel in hauling on ice or snow and are brittle, but

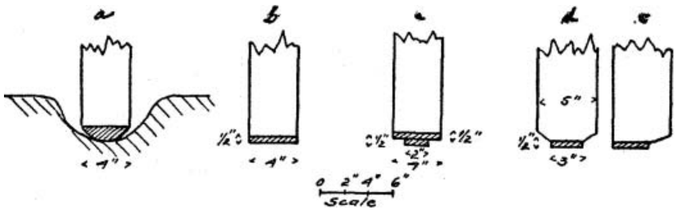


Fig. 28. Types of Sled Runner Shoes. a. Round. b. Flat. c. Flat with a "keel." d and e. "Moccasin."

they slide easier than steel on roads which have more or less sand or horse manure on them. Runner shoes may be rounded, fiat, flat with a "keel," or "moccasin" type.[1] Rounded or narrow flat shoes offer less resistance than the others ana hard surface because they encounter fewer of the numerous minute obstacles on the road and can better avoid them than wide shoes. However, on soft roads, a wide-bearing runner surface is necessary to support the sled and therefore broad, wide, fIat shoes are preferred under these conditions. Rounded shoes slue less than flat shoes on solid ice and on well-compacted snow roads because fiat shoes do not cut into the road surface. The result is the opposite on snow roads where the snow is so loose that both types of shoes cut deeply. Tractive resistance is the least when runners have rounded shoes and travel in concave iced ruts because side friction is reduced to the minimum, and the iced rut shoulders prevent the sled from leaving the proper track. This is true even in the case of long trains, hauled by powerful mechanical draft, in which the middle sleds of the train are subjected to a strong side-pull at the center of a curve. Rounded shoes are

1 See Fig. 28.

quite universally used in the Lake States, even on snow roads without artificial ruts and they have been successfully introduced into some other regions. The sleds used by eastern loggers, for hauling in trains by mechanical draft, have a 2-inch flat "keel" on a 4-inch flat shoe. Logging roads in that region, even if iced, are seldom rutted and keels on the sled shoes prevent the side-dragging of the runners and thus overcome the tendency of the sleds in a train to crowd to the inner side of a curve. The inner sides of such roads on curves are also made higher to lessen side-crowding. Although sled runners with a keel pull and steer with difficulty, they are adapted to some extent for both a hard and a soft bottom. Although eastern loggers prefer flat runner shoes for horse hauling, they sometimes use those of the moccasin type. Runners with the latter kind of shoes travel on the flat portion of them when on hard surfaces and, when in loose snow, the

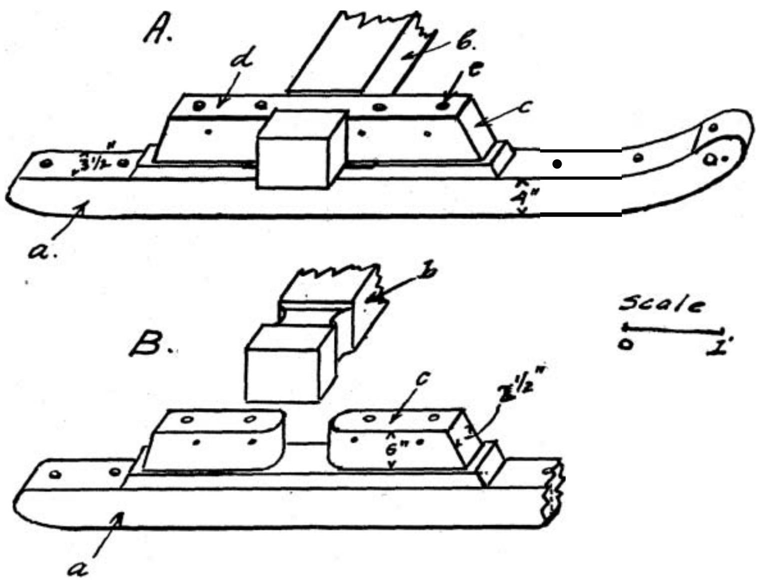


Fig. 29. A Sled Runner equipped with Wooden Block Knees. A. General view. a. Sled runner. b. Cross beam. c. Wooden block 2½ inches thick by 6 inches high. d. A ⅜-inch steel strap. e. Bolts holding a, c, and d together. B. Bunk with top strap "d" and beam "b" removed. The grooves in the beam "b" are cut with a 3-inch radius, and the rounded ends of the block "c" are cut on a 2⅝-inch radius, thus providing for the desired play. Province of Quebec, Canada.

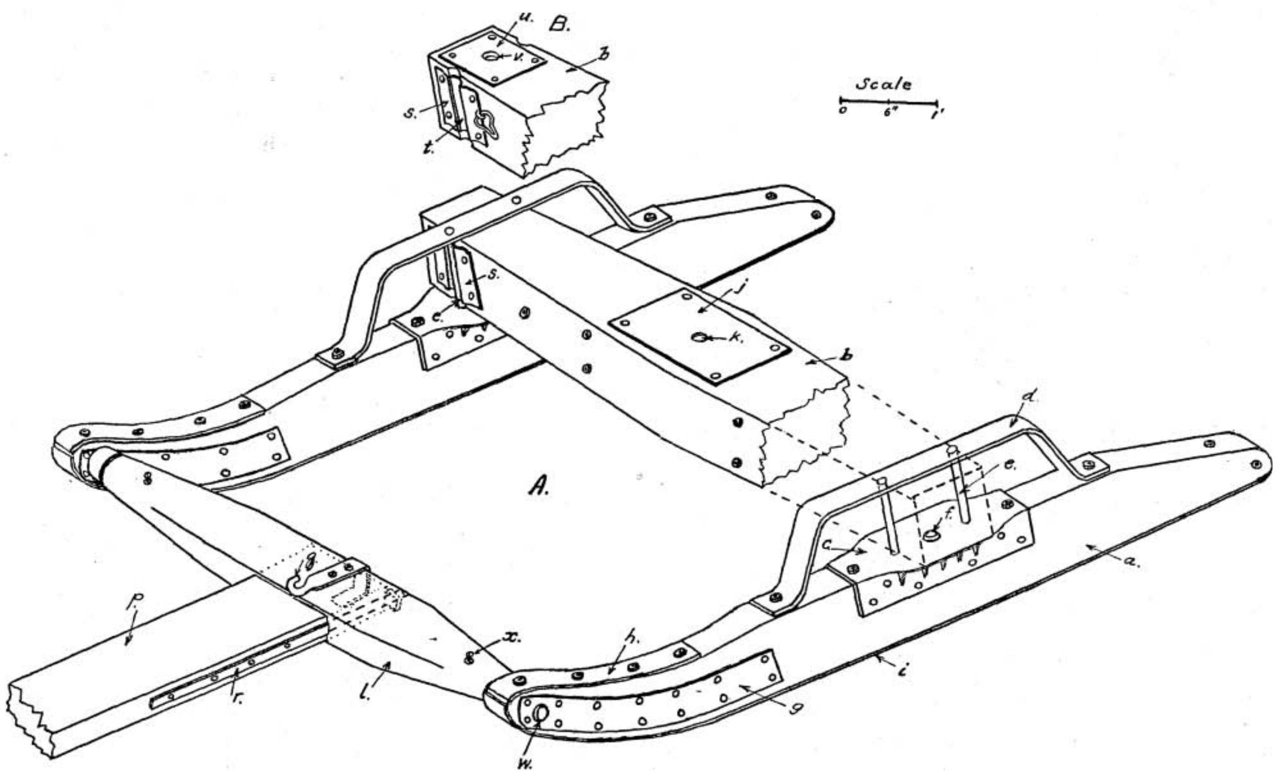


Fig. 30. The Front Set of Runners of a Heavy-duty Sled, equipped with "Rave Knees," for Animal Draft. Michigan type. A. a. Runner. b. Cross beam. c. Runner casting of sled knee. d. Rave. e. Start, 1¼ inches in diameter. f. Knob of the runner casting. g. Steel side plate on runner nose. h. Top plate of the runner nose. i. Steel shoe, ½-inch in thickness. j. Cross beam steel plate. k. Hole for kingbolt, 2-inch. l. Roller. p. Tongue. q. Draft hook. r. Bolt fastening tongue to the roller. s. Steel plate with a groove "t," for the start. w. Gudgeon pin. B. One end of a cross beam turned upside down. s. Steel plate as in "A." t. Groove in "s" for a start. u. Bottom plate of a cross beam with a depression, "v," which fits over the knob "f" on the knee casting.

sidewise bearing surface prevents them from sinking too deeply into the road.

The runners of the front and rear sets of sleds usually are identical in form and both sets carry an equal part of the load. However, eastern loggers load the rear set of sled runners heavier and therefore make the rear runners 2 or 3 feet longer or of the moccasin type to provide a correspondingly larger carrying surface. Loading the front set of runners lighter than the rear one facilitates the starting and especially the steering of the sled when a single team or a single horse is used, since it has to steer the sled by a direct pull applied to the end of the tongue.

Knees.-The cross-beam of a set of runners is attached to them at a point approximately above the center of their bearing surface, by "sled knees," which must be very strong without being perfectly rigid, so as to give a certain amount of play to the runners. This slight flexibility is absolutely necessary for the efficiency of a heavy-duty sled because it makes hauling easier, increases the strength and durability of the sled, and saves the road. The desirable amount of play is small and a sled knee must be so designed that it will not increase to any appreciable extent with use.

The construction of a "wooden block" knee, which is favored by many loggers on account of the ease with which it can be made and repaired in the woods, is shown in Fig. 29.

Another type of sled knee in common use, especially on lighter sleds, is the "rave knee."[1] The end of the cross-beam has two grooves cut in it or else a steel plate or casting with a groove is bolted to the beam. The beam is fitted between two steel pins or "starts," which are fastened in the sled runners and reinforced by a steel "rave." This holds the cross-beam securely and allows only the required amount of play.

The McLaren patent knee,[2] which is more serviceable than previously mentioned types, is quite universally used in the Lake States for heavy-duty sleds and is popular with many loggers in other regions, except in the Eastern States. It has an annealed steel casting which is bolted to the sled runner, and into which another casting is fitted which is bolted to the end of the cross-beam. The merits of the McLaren sled knee are its strength and nearly constant play within a desirable limit of from 1/8 to 1/4 inch, and the fact that the cross-beam and runner are reenforced rather than weakened by it. This knee is adapted both to small sleds drawn by animals and to heavy-duty sleds drawn by the most powerful mechanical draft.

1 See Fig. 30.
2 See Fig. 31.

Loggers in the eastern parts of the United States and Canada often equip heavy-duty sleds with the Lombard kneel when the sleds are to be hauled in trains by log haulers or tractors. The casting bolted to the beam has two ears which span the runner to which it is fastened by means of a

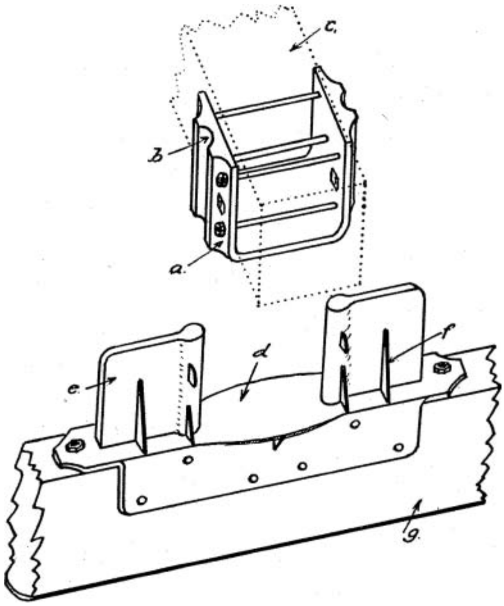


Fig. 31. The McLaren Patent Sled Knee. a. Cross beam casting. b. Groove in cross beam casting. d. Runner casting. e. Knee blocks. f. Flanges which brace the knee blocks.

steel bolt. This bolt fits tightly in the hole in the runner and its side plates, but the hole for the bolt in the ears of the beam casting is made oblong to provide for the required play between the cross-beam and the runners.

Cross-beams.-A cross-beam made of oak, rock elm, or birch connects the runners on each set of sleds. It tapers slightly from the center to each end, which is connected to a runner by means of a sled knee.

Bunks.-The bunk or rocker which carries the load is supported by the cross-beam.[2] It is made from seasoned softwood and tapers slightly from

1 See Fig. 33.
2 See Fig. 26.

the center to each end and is connected to the cross-beam by a steel king bolt which passes through a hole in the center of the beam and the bunk, so that it can revolve in a horizontal plane, independently of the sled. Sleds carrying long loads can easily take very sharp turns without the side-dragging of the runners. Steel plates are placed between the bunk and the cross-beam at the king bolt to minimize friction. Poles called sway-bars are

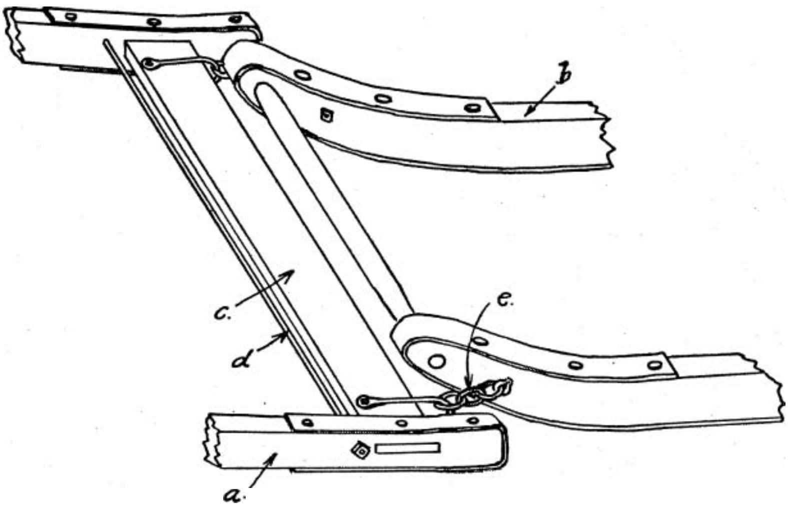


Fig. 32. A Flexible Shaft Connection 'which Serves as a Braking Device on a One-horse Sled. a. Rear end of shaft. b. Forward part of sled runner. c. Cross bar connecting the two shafts. d. Iron brace rod. e. Chain connecting the cross bar with the nose of the sled runner.

The figure shows the position of the shafts when the draft power is applied. On descending grades the sled tends to move faster than the horse which slackens the chains "e" and the runners, crowding on top of the cross beam "c," cause the ends of the shafts to drag on the road. Province of Quebec, Canada.

often hung between the ends of the bunks of the forward and rear sets of runners to prevent the sleds from jack-knifing when empty and to keep the bunks parallel to each other.

Draft Attachment and Steering Mechanism.-The use of a single horse for sled hauling is common in eastern Canada only. The shafts are fastened either to the gudgeon pins on the front pair of runners or there is a flexible chain connection[1] which is adapted to roads with a rough profile, because it

1 See Fig. 32.

provides an automatic braking device on descending grades. The sled ends of the shafts of the latter type are connected by a crossbar which is attached to the noses of the runners or to the front roller by two short chains. When the sled tends to move faster than the horse, the noses of the runners press down on the shaft crossbar and cause the rear ends of the shafts to drag on the road just outside of the runners, thus checking the speed of the sled. This type of draft attachment makes steering more difficult than when the shafts are attached to the gudgeon pins of the runners, and the dragging ends also tend to tear up the road.

Four-horse teams are most frequently used for sled hauling in the Lake States, but in other parts of the United States horses are used chiefly or exclusively in single teams. The doubletree of the butt team is attached to a hook on the front roller and the sled is steered by a side pull or a push on the sled tongue. Steering is much easier when a 4-horse team is used instead of a 2-horse one, because the leaders are hitched to a chain that passes through the ring near the front end of the tongue and then is hooked to the front roller. When the leaders apply a pull to the front end of the tongue, the force is applied at the end of a longer lever arm and steering, therefore, is much easier.

Traction machinery is attached to the front set of a sled or a sled train by means of a V-pole,[1] or by two chains connecting the drawbar with the noses of the forward runners. In the latter case a pole, hung with some slack between the drawbar and the bealll of the front set of runners, prevents the sled bumping against the tractor and makes it possible to back, though not as easily as when the V-pole is used.

Formerly the two sets of runners for a horse sled, and all sets for a sled train, were coupled together with wooden tongues mortised into rollers and hooked to the cross-beam of the front set of runners. This method of coupling is now rarely used for logging sleds, having been superseded either by cross chains, or by cross poles or reaches.[2] The latter are used less frequently than cross chains; however, they are preferred by eastern loggers for coupling trains of long logs or pulp wood when powerful mechanical draft is used on roads which are not properly rutted. Sleds used by eastern loggers with mechanical draft have castings bolted to the beams and to the noses of runners so that sleds may be coupled with reaches and bolts, allow-

1 See Fig. 33.

2 A reach is a pole about 6 inches in diameter, the length of which varies with the length of logs. It is about 24 feet long when 40-foot logs are hauled.

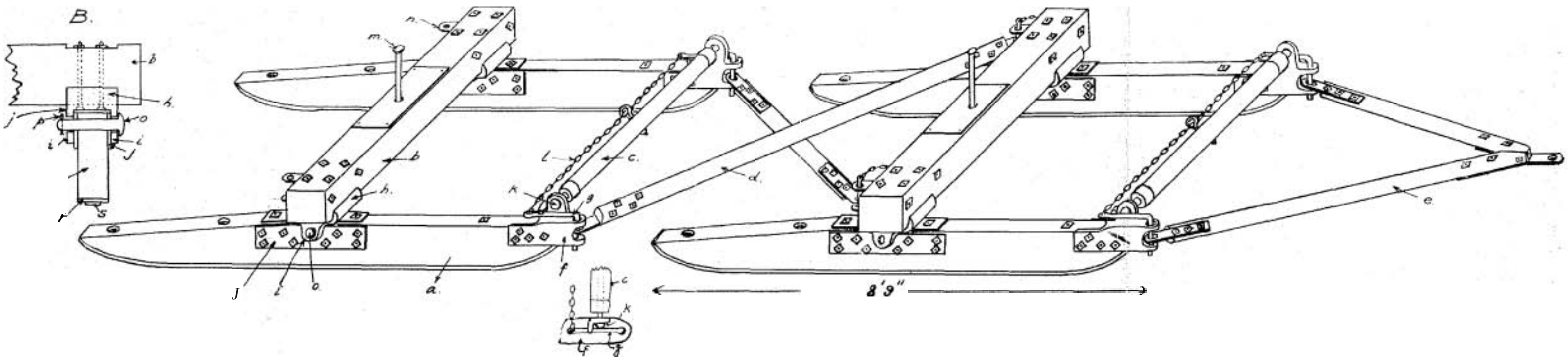


Fig. 33. A Lombard Patent Logging Sled for Mechanical Draft (the bunks arc not shown). a. Runner. b. Cross-beam. c. Front roller. d. Cross-pole or reach. e. V-pole to which the draft power is attached. f. Runner nose casting. g. Bolt which fastens the cross-pole to "f." h. Knee casting. i. One of the two ears of the knee casting which fit over "j," the side plate of the runner. j. Side plate of the runner. k. Gudgeon pin, which is prevented from slipping out of the roller "c" by the bolt "g." 1. Chain 'which holds the bolts "g" in place. m. Kingbolt. n. Ear of the casting to which the cross-poles "d" are attached. o. Pin holding the sled knee on the runner. p. Cotter pin for "0." r. Sled shoe. s. Keel on the sled shoe.

ing about ¾-inch play at each end of the reach.[1] This method of coupling sleds, which is more rigid than when cross chains are used, is convenient for niaking sleds into trains with mechanical draft, because a pull or a push can be applied to one runner only until the sled is turned and placed in proper position.

The front and rear sets of runners of a horse-drawn sled are usually coupled with two chains which run crosswise from the gudgeon pins of the rear set of sled runners to grab links bolted to the cross-beam of the front

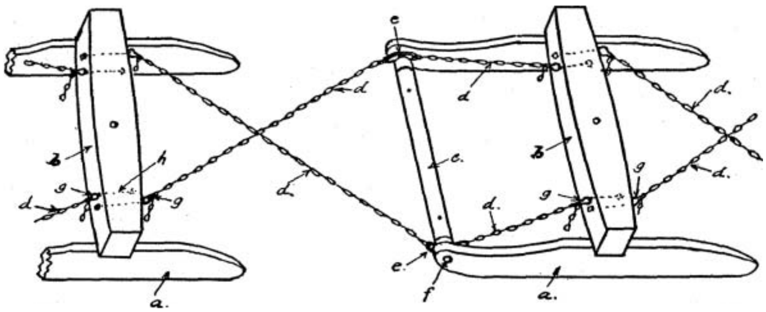


Fig. 34. Coupling IIeavy-duty Logging Sleds by Cross-chains into Trains for Hauling with Tractionl\1achinery. a. Sled runner. b. Cross-beam. c. Roller. d. Cross-chain. e. Long link of cross-chain, which prevents a direct pull on the gudgeon pin. f. Gudgeon pin. g. Bitch link bolted to cross-beam, which securely holds the cross-chain and also provides a ready means for regulating the chain length. h. Bolt holding the bitch link. This method of coupling sleds transfers the draft pull directly from one cross-beam to the next one throughout the whole train.

set. The traction pull is transferred, through the runners and other parts of the sled, to the bunks that carry the load. This method is satisfactory for horse-drawn sleds because the load and the strain on the sled runners is relatively small, but it is not suitable for use when sleds are coupled in trains. Some types of sleds used with log haulers have runners strong enough to withstand the pull necessary to move the whole train, but it is desirable to relieve the runners and other parts of the sled from that pUll. The system of coupling sleds preferred by most loggers when hauling with mechanical draft transfers the pull throughout the train directly from the beam of the first bunk to the beams of each succeeding one, as shown in Figs. 34 and 35. rrhus the gudgeon pins, rollers, runners, and sled knees

[1] See Fig. 33.

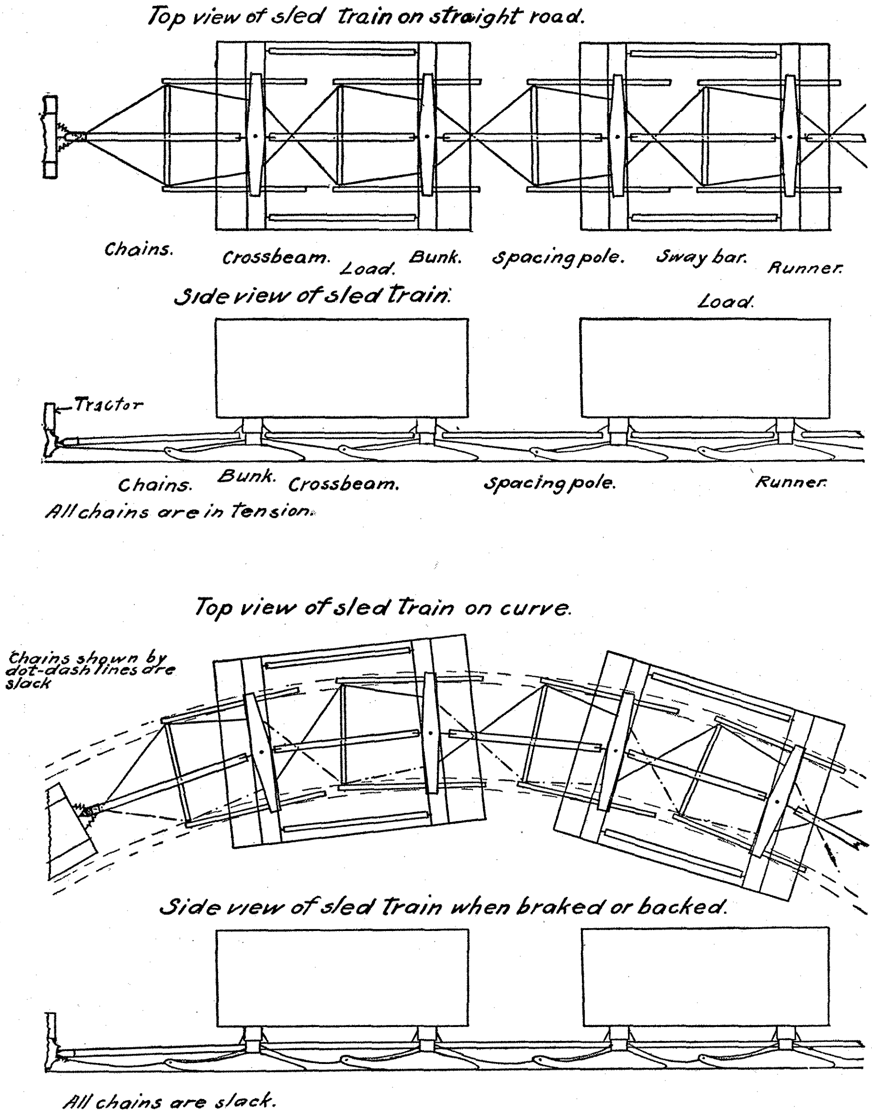


Fig. 35. A Method of Coupling and Steering a Train of Sleds drawn by a Tractor.

are relieved of the very severe strain caused by the tractive resistance of the whole train, and the steering of the sled train is made easier. This method of coupling also facilitates hauling, since the extra pull, when starting or when meeting an obstacle on the road, tends to elevate the noses of the runners.

Bumping poles are hung between the centers of each two cross-beams throughout the entire train when cross chains are used for coupling sleds. When the train is moving forward the poles hang slack with their ends a few inches from the sled cross-beams but when braking, stopping, or backing the train, the cross chains become slack and the bumping poles strike against the cross-beams and serve to transfer the push, directly from one cross-beam to the succeeding one throughout the train" thus preventing a jack-knife action. The length of the cross chains and bumping poles is such that from 3 to 7 inches of slack is provided between any two sleds in the train. This slack enables the draft power when starting a load to overcome gradually the inertia of the sled train and also serves gradually to absorb the momentum of the whole train when braking or decreasing the speed. Therefore, the power required for hauling the train, as well as the strain on the sleds, is much less than in the case of rigid coupling devices. From 10 to 20 sleds may be coupled together forming a train up to 500 feet long, which will still negotiate rather sharp curves. Although sleds are guided to some extent by the ruts of the road and the sled train is prevented from crowding inside the curve by the keel on the runners and by the superelevation of the inner side of the road on curves when there are no ruts; yet the steering of the runners of a single sled or of those of an entire sled train is due chiefly to the cross chain or cross reach connection. When a curve is reached and the front set of runners on a sled is turned by a tractor or by horses, one of the cross chains or reaches is slackened and all of the pull is transferred to the next set by another cross chain or reach which turns that set so that it follows the route of the first one.

Depreciation.-The life of a logging sled is from four to seven years, depending upon the construction and the material of the sled, the working conditions, and the care received. When good steel parts are used, they may last twice as long as the wooden parts of the sled, especially if a nondurable wood like birch is used in construction. The initial cost of good heavy-duty logging sleds ranges from $90 to $200 per set. Sleds made by the manufacturers of logging equipment are expensive and most loggers make their sleds at the logging camps, buying only the necessary steel parts and castings. The depreciation and maintenance expense of a heavy-duty sled that costs $150 and which requires about $50 for maintenance and repairs during a 6-year period or approximately 400 working days, is about 60 cents per working day. This expense is about 0.4 cents per ton-mile, assuming that the sled averages 10 miles daily, with a load weighing 15 tons net.[1]

Sleds should be kept well painted and between hauling seasons should be taken apart and stored under cover.

DEVICES FOR HOLDING LOGS ON A SLED

Pulpwood, cordwood, ties, posts, and other short wood, usually from 4 to 9 feet long, are loaded crosswise on racks bolted to the bunks of the sled. These racks or pole frames are from 20 to 30 feet long, with a width corresponding to the length of the wood carried. The load is held only by stakes set in the rack frame.[2]

Logs, poles, and other long material are placed directly upon bunks of the sled and parallel to the road. It is necessary to build a high load, especiallywhen short- or standard-length logs are being handled, if a heavy logging sled is loaded to capacity. Long bunks make a wide and comparatively low load possible but, even so, the height is often from 5 to 7 feet and sometimes higher when hauling conditions are favorable. The efficiency and safety of loading, hauling, and unloading sleds depends chiefly upon the devices, chains, or stakes, used to hold the logs on the bunks of the sled.

Chains.-Steel chains which are used to hold logs on sleds are from 3/8 to 5/8 inch thick and of the following kinds: 4 corner-bind chains, 2 or 4 deck chains, and 1 or 2 wrapper chains.[3] A corner-bind chain, used to fasten the outside logs of the lower tier to one of the bunks of the sled, is passed through an eyelet in the bunk, then around the log, and then fastened to itself on the outside of the log by means of a grabhook and a fid hook.[4] Each deck chain is in two sections. The short one, 3 or 4 feet long, is attached to the end of the bunk and has a ring or a grabhook at the free end. The other part of the deck chain is fastened to the opposite end of the bunk and, after being passed over and above two or three tiers of logs, it is locked to the short chain by a fid hook.- High loads require two pairs of deck chains, the second pair being above several tiers of logs which have

1 One-way loaded traffic.

2 See Fig. 36.

3 Wrapper chains are not always used.

4 See Fig. 37.

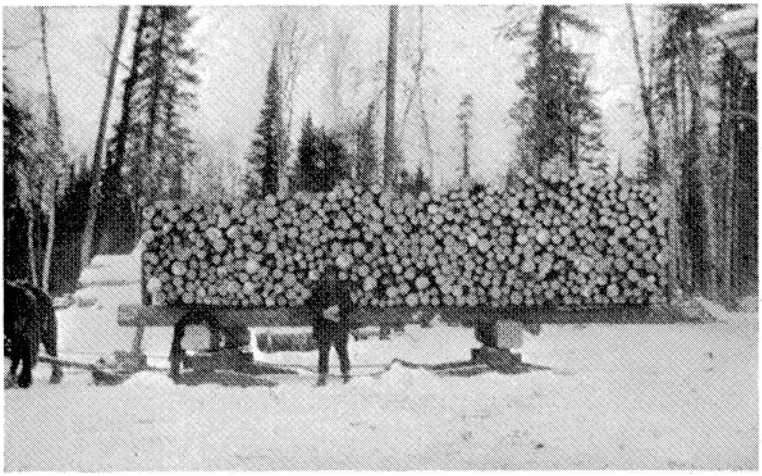


Fig. 36. A Logging Sled equipped with Racks for carrying 8-foot Pulpwood. Minnesota.

been placed on top of the first pair of deck chains. Deck chains cannot be drawn tight by hand, hence some logs are placed on top of them so that their weight will press down on the chains and draw them taut. One or two wrapper chains are bound around the entire load when it is large or is composed of long logs. They are not attached to the sled and are intended only to hold the load in a solid body.

Formerly, sleds were loaded to a triangular peak, but now a compact rectangular shape is preferred. The sides of the load are made as nearly

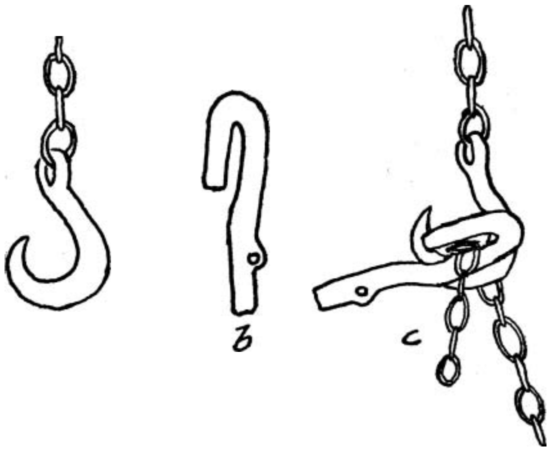


Fig. 37. Types of Hooks used in binding Chains on Loaded Sleds. a. Grabhook. b. Fid hook. c. Method of locking a binding chain by means of a grabhook and a fid hook.

vertical as possible, then the deck chains are put in position and fastened rather loosely, so that the top layers of logs may be spread out by cant hooks, until the sides of the load are verticaL The logs laid on top of the chains take up any slack that may still remain in them.

When sleds, which have been bound with chains as described, are unloaded, the fid hooks are released by striking them with a hammer. As soon as the chains are free, most of the logs will roll off by gravity, and the remainder are rolled from the sled with cant hooks. Logs are prevented from rolling off on the wrong side of the sled by fastening an upright pole in a vertical position to the framework of the sled on the side opposite the landing.

Stakes.—Another method of holding logs on a sled is by means of stakes or poles 4 or 5 inches in diameter and from 4 to 6 feet long. These are fitted into slots or pockets in the ends of the bunks and are held in position by some form of a tripping device, by means of which the stakes may

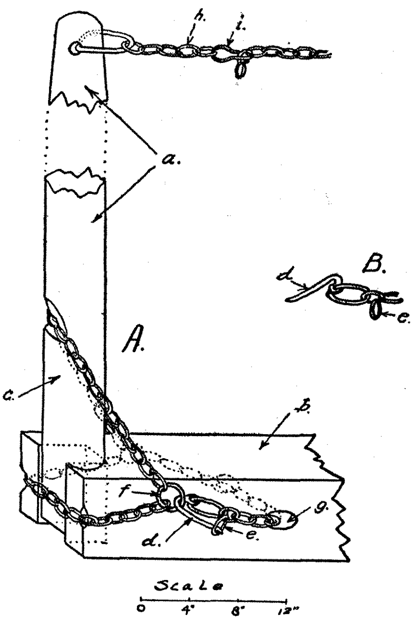


Fig. 38. A. Stake with a Tripping Device used for Holding Logs on a Sled. (Lake States). a. Stake, 5 inches in diameter and 5 feet long. b. Bunk. c. ⅜-inch chain. d. Hook of the clasp. e. Key ring of the clasp. f. Ring connecting two loops of chain "c." g. Hole in the bunk. h. Top chain (unnecessary on low loads). i. Bitch link of top chain. B. Tripping clasp opened.

be quickly released. One of the best of the numerous tripping devices[1] is shown in Figs. 27 and 38. It has a ⅜- or ½-inch chain which passes through an eyelet in the bunk and then branches in two loops, one of which holds the base of the stake in the slot of the bunk while the other chain, tightened by the pressure of the corner log, resists the side pressure of the load on the

[1] A common type in the Lake States.

stake. One man stands at the front and one at the rear of the sled, when unloading, and releases the stakes on both bunks on the unloading side by sliding a key ring off the hook of the clasp. Unloading is less dangerous when stakes are used instead of binder chains because the unloaders must often use considerable time and effort to release the fid hooks holding the chains, meanwhile standing on the unloading side of the sled, from which place they must quickly jump to avoid danger when the logs start to roll.

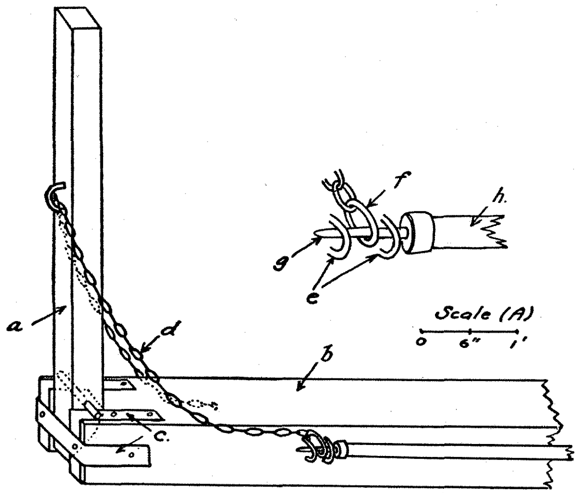


Fig. 39. Safety Tripping Device for Logging Sled Bunk Stakes. a. Stake 4 by 4 by 56 inches. b. Sled bunk 8 by 9 by 144 inches. c. Steel plates 3/16 by 2 inches. d. Stake chains made from 7/16-inch material. e. Staples, 5/8-inch material with a 2-inch spread, placed 1½ inches apart. f. Ring on the end of chain "d." g. Steel pin ¾ by 5 inches. h. Rod 2 inches in diameter for releasing chain "d." i. Key holding rod "h" in place.

Another type of tripping device for sled stakes which is simple and serviceable although but little known among loggers is shown in Fig. 39. The chain holding the stake in a vertical position may be quickly released when two rods, one on each bunk, are pulled by unloaders standing in safety on the opposite side of the sled.

Stakes usually are so fitted that they drop from the bunks when released by the tripping device. Some loggers, however, prefer to hang the stakes on hinges in the slot of the bunks. The chains of the tripping device will hold the stakes in a vertical position unless the stakes are long and the loads are large and high, in which case chains are fastened near the tops of the stakes and are hooked together above the load by a grab link. A few logs are then laid on the top chains to draw them tight. When the tripping device releases the stakes from the bunks on the unloading side, the logs roll from under the stakes, except those which served as binders on top of the chains.

Loading with stakes equipped with a good tripping device has the following advantages over the use of corner-bind and deck chains:

1. It is simpler and, therefore, does not require the same degree of skill that is necessary to build up a large load with chains.

2. Loading and unloading are much quicker.

3. Loading, hauling, and especially unloading, are safer.

4. Stakes are cheaper and, in the case of large loads, weigh less than chains.

LOADING SLEDS

LOADING sleds with logs which are stored on skidways is done chiefly by hand or by horse power. Power machinery is used for this purpose only in a very few instances.

Hand Loading.-Loading logs on sleds by hand methods is still quite frequently practiced in the eastern parts of the United States and Canada. Cant-hook men roll the logs from the skidway to the sled over two poles or skids which span the intervaL These skids are sometimes spiked when logs must be rolled up-grade. Hand loading is a satisfactory method for small-sized logs and for small loads, when the skidways are so located on a sidehill that thelogs can be rolled upon the sled on a level or a slightly downhill grade. Hand loading is inefficient when logs have to be elevated even a few feet.

CrosshauL-The greater part of the sled-loading work is done with a crosshaul and team, or with a "jammer." Loading with the crosshaul, known also as a parbuckle, is done with a single line, either chain or cable, or with a crotch line. When a single line is used, one end has a sharp hook which is put around and under the center of a log on the skidway which is to be' loaded, and the hook is then caught on the sled frame or on a log at the spot where the log is to be placed. The free end of the line passes over the sled, and serves as the point of attachment for the draft power which is used to roll the log upon the sled over two skids, which span the gap between the skidway and sled. The loading line is attached to the doubletree of the loading team, by means of a triphook,[1] which enables the teamster to release instantly the loading line when the log is in the proper position on the sled. Two ground loaders guide the ends of the log with cant hooks so that it will roll straight up the skids.

A crotch line simplifies loading, since the logs are dragged and not rolled over the loading skids. The ends of the crotch line carry loading hooks which are caught in the ends of the log and grip it when the loading team is started. Each of the two ground loaders has a light hemp rope which is attached to the hook on the end of the crotch line, and by means of these ropes the hookers guide the log up the skids until it is loaded and then, by jerking the rope, they release the hooks and pull them back for the next log. Several small logs may be loaded at one time, by making them into bundles around which the crotch line is thrown in a loop. Very little skill is required from the men who guide the logs, but it is harder for the loading team when large logs are dragged instead of rolled. The loading line passes through a lead block at one side of the road, so that the loading team can travel along the sled road. Loading horses must be active and usually work without reins, being guided by the verbal commands of the teamster.

A loading crew usually comprises 6 men, namely, a top loader who is in charge and who, working from the top of the load on the sled, directs each log to its proper position in order to make a compact and well-balanced load; two ground loaders or hookers, who hook the logs and guide them upon the sled; two "tailing-down" men, who roll logs along the skidway within convenient reach of the hookers; and a teamster, who drives the loading team.

Jammers.-Loading by hand and by crosshaul has been replaced to a large extent by loading with horse jammers, except where the timber is scattered so that the frequent moving of the jammer from one small skidway to another consumes an undue proportion of the working time.

1. The most common and simple of these devices is a side-jammer, the construction and dimensions of which are shown in Figs. 40 and 41. A team can easily move this jammer on its runners from one skidway to another. A side-jammer, when loading a sled, is stationed directly opposite the skidway on the far side of the road and the sled to be loaded is drawn up between the skidway and the jammer. A hemp guy-rope, attached to the top of the jammer, is then secured to a stump or a tree in the rear and opposite the

1 See Fig. 40, d.

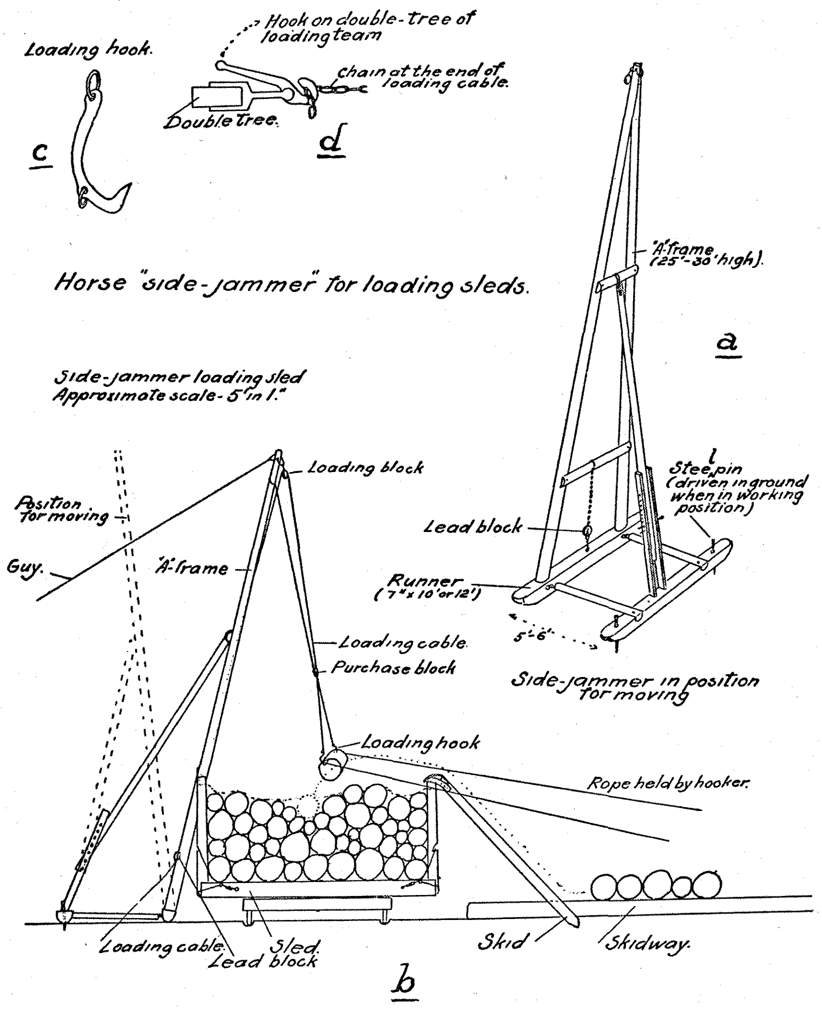


Fig. 40. A Side-jammer operated by Horse Power, which is used for Loading Sleds. a. Jammer ready to move to a new loading point. b. Loading a sled by means of a side-jammer. c. A common type of loading hook. d. The trip-hook, attached to the double-tree of the loading team, by means of which the loading line may be released instantly.

skidway. The A-frame of the jammer, supported only by the guy-rope, is placed in position so that the loading block hangs directly over the sled at a height of 25 or 30 feet above the ground. The loading line passes through a lead block near the base of the jammer, then upward to the loading block and down to the crotch line, which may be fastened directly to the loading

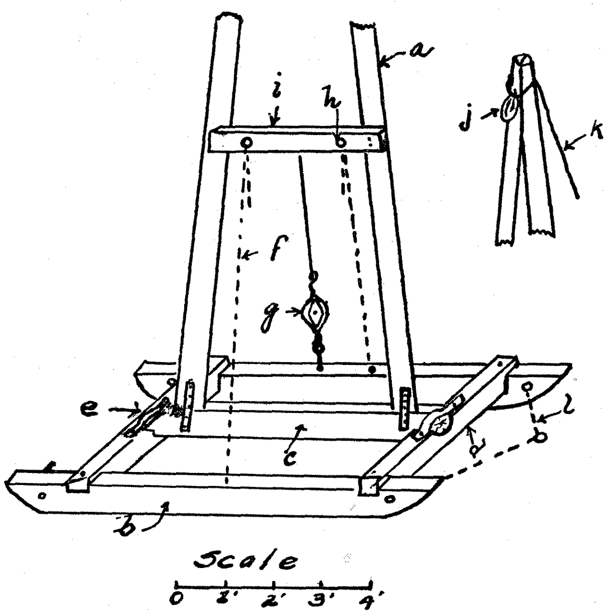


Fig. 41. A Side-jammer, operated by Horse Power, in position to move to a New Loading Point. a. A pole with an 8-inch base, a 6-inch top, and a length of 25 feet. b. Runner 6 by 7 by 108 inches. c. Rocking beam 7 by 8 by 72 inches to which the bases of the boom poles "a" are fastened. d. Runner brace which also serves as a bearing for the rocking beam "c." e. Steel strap holding the rocking beam shaft on to the brace "d." f. Chain which serves as a brace for the boom when the jammer is being moved from one loading point to another. g. Lead block for the ⅜-inch loading cable. h. Fid hook locking the chain "f" after it has been passed through a hole in the cross-brace "i." i. Boom cross-brace. j. Loading block. k. Hemp guy rope supporting the boom when the jammer is ready for loading.

cable or, as is usually the case, to a block in the bight of the loading line.[1] The crew required and the process of loading is much the same as that described for loading with a crosshaul and crotch line, but the efficiency of loading with a jammer is much greater. The position of the loading block high above the sled makes it easier for the horses to elevate the logs and provides a perfect control of the log during the loading process, since it may be suspended in the air and then placed on any desired spot on the load. A crew of men and a team will load from 30,000 to 50,000 board feet of medium-sized logs, daily.[2]

2. An end-jammer, so called because it operates from the road at the rear end of the sled to be loaded, has a swinging boom and is mounted either on a logging sled or on two long runners.[3] When in working position, the side of the jammer next to the skidway is slightly elevated by wedges and the swinging boom tends to move in the opposite direction, but is prevented from doing so by a guy-rope which permits the boom to swing only between the skidway and the sled. The loading crew is the same as that for a side-jammer. The hookers swing the jammer boom over the skidway by means of the hemp ropes fastened to the loading hooks. When a log is hooked and the loading team pulls the cable the log slides along the skidway and is then drawn up the skids to the sled, the boom meanwhile swinging automatically to the center of the load.

A more complicated type of end-jammer has a rotating vertical shaft to which an inclined boom is rigidly fixed.[4] A plank equipped with two lead blocks, is fitted to the base of the vertical shaft directly opposite the boom. During the loading operation, the vertical shaft on which the boom is fastened is turned so that the boom is brought over the skidway. This throws the plank and loading cable out of line with the stationary lead blocks on the jammer and when the team pulls on the loading cable the latter tends to return the plank to its normal position, thus automatically turning the vertical shaft and swinging the boom over the sled. The chief advantages of a swinging boom on a jammer are that the distance which the team has to travel for loading each log is reduced and, therefore, less slack-pulling is necessary.

The "Forest Loader,"[5] a patented machine, has three drums which are

1 See Fig. 40, b.
2 Two extra men may be needed for tailing-down on a long skidway.
3 See Fig. 42.
4 See Fig. 43.
5 See Fig. 44.

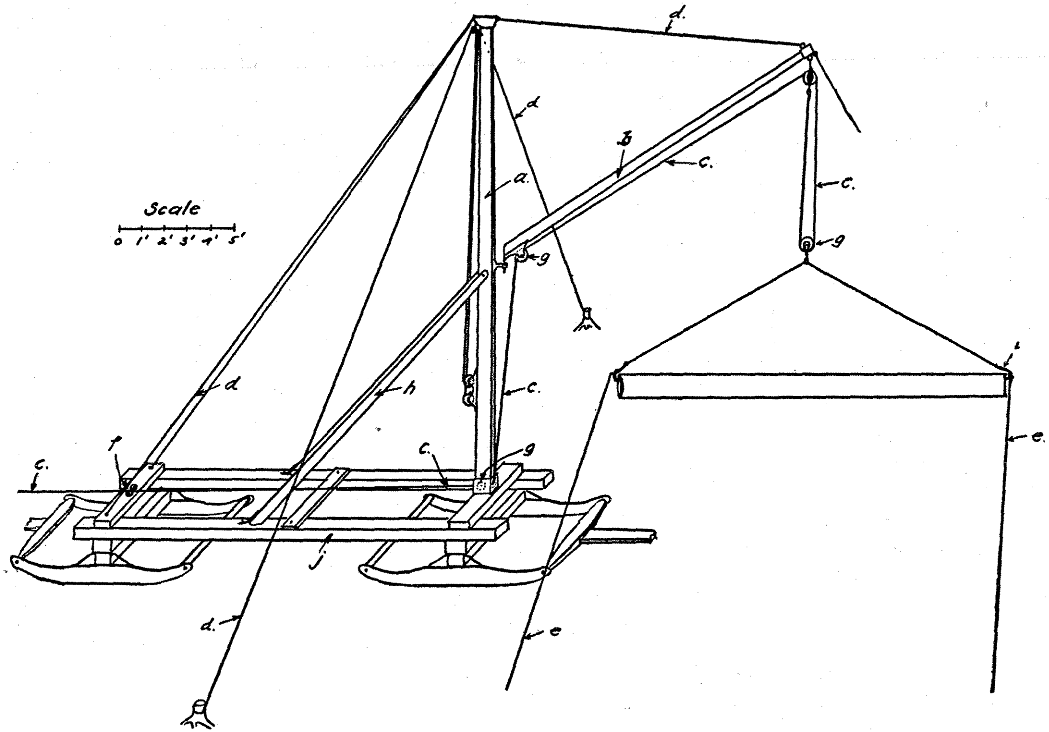


Fig. 42. An End-jammer for Loading Logs on Sleds, operated by Horse Power. a. Spar 7 by 7 by 240 inches. b. Swinging boom, 4½ by 4½ by 144 inches. c. Loading cable, ⅜-inch. d. Guy lines. e. Hemp rope attached to the loading hooks. f. Lead block for the loading cable. g. Lead blocks for the loading cable placed in a hollow steel casting which serves as a base for the spar "a." h. Brace supporting the spar. i. Loading hook. j. Framework of loader made from timbers 6 by 8 inches by 18 feet. Lake States.

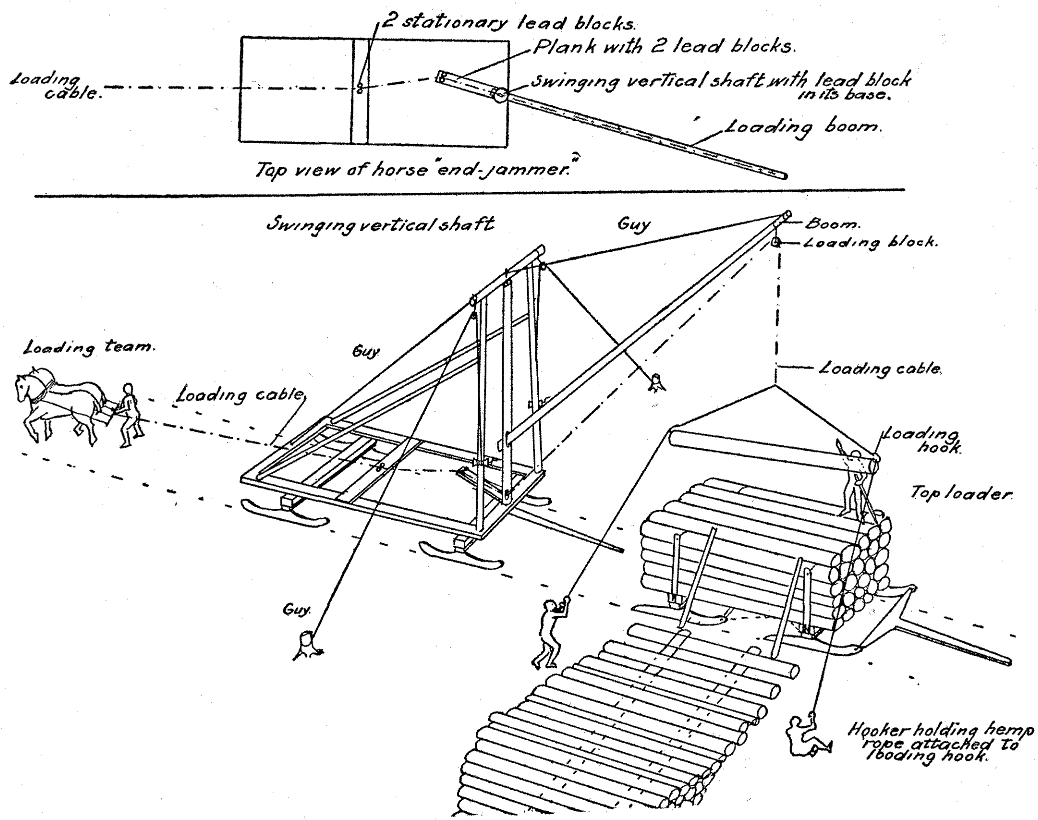
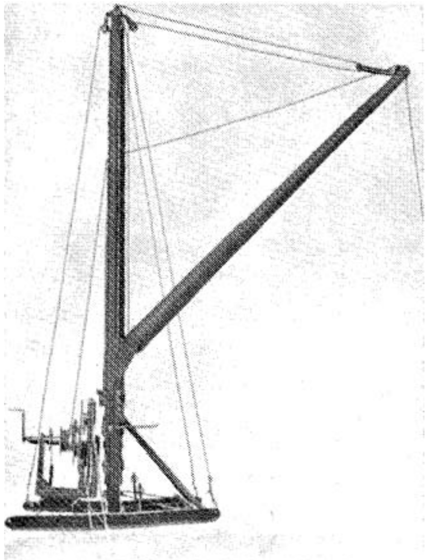


Fig. 43. An End-jammer, operated by Horse Power, used for loading Logging Sleds. Wisconsin.



By permission, National Iron Co.

Fig. 44. The "Forest Loader" used for loading Logging Sleds by Aninlal Power. The mast has a length of 18 feet, and the swinging boom 22 feet.

Fig. 45. A Power Conveyor driven by a Gasoline Motor used for loading Logs on Sleds. Eastern Canada.

5, 10, and 15 inches in diameter respectively, the loading cable being fastened to the 10-inch one. The cable may be instantly shifted from one drum to the other, thus exchanging power for speed or vice versa, according to the weight of the load. A friction device operated by a hand lever interlocks the loading drums with the drive wheel. The power of the loading team is transmitted to the drive wheel through an endless chain which passes around that wheel and through a block 100 feet or more from the loader. The loading team may pull in either direction, the draft power being attached to the lower part of the endless chain when the animals are pulling in a direction away from the loader and to the upper part when they are pulling towards the loader. The machine requires one more man in the crew than the swinging-boom jammers; it is his duty to operate the friction lever.

Jammers driven by gasoline motors have not proved satisfactory because a team is a more reliable and cheaper source of power for this work.

Jammers usually are made in the logging camp blacksmith shop, although there are some which are offered for sale by manufacturers of logging equipment.

An attempt has recently been made in eastern Canada to apply the power conveyor principle to loading logging sleds.[1] The logs are elevated from the skidway and dropped upon the sled by two endless chains equipped with dogs fastened at intervals of 4½ feet. Power is furnished by a 3 horsepower gasoline engine. A maximum of six logs per minute can be loaded. This device is mounted on runners and drawn about by a single horse. A crew of eight men is required to operate it, namely, two top loaders, one in charge of the machine and crew, two ground loaders, and four tailing-down men.

Methods of Loading Short Wood.-Pulpwood cut in 4-foot lengths and other wood cut in short pieces is usnally piled along the sides of a sled road and loaded by hand crosswise on the sled racks. Loaders work singly or in pairs, often using a hay hook or a pickaroon to aid them. Hand loading is difficult when the blocks are large, but no mechanical device has been perfected which is as satisfactory as this method. A hand loader may average 12 cords of 4-foot wood, daily, but the efficiency of this method varies widely with the conditions. Pulpwood cut in 8-foot lengths, cross-ties, and posts usually are loaded on sleds by hand but sometimes, especially in the

[1] See Fig. 45. This device was patented in 1923 by L. Gosselin of River Manie, Quebec, Canada.

Lake States, they are loaded in bunches with side-jammers having a swinging boom.

DRAFT POWER USED IN SLED TRANSPORTATION

ANIMAL POWER

TRACTORS have been used for sled transportation in the United States and in Canada much less extensively than animals, although the use of them has been constantly increasing during the last two decades, especially since the World War.

Efficiency of Animals.—Pioneer loggers in the northern regions used oxen for sled hauling, but many years ago these were superseded by horses weighing from 1300 to 1800 pounds, the average weight being 1500 pounds. The speed of a horse on a fairly level road is approximately 2½ miles per hour when pulling a loaded sled, and 3 miles per hour when pulling an empty one. Formerly, when working hours on logging operations were longer than they are to-day, horses often made from 25 to 30 miles per day on long-distance hauls. The present normal daily mileage is about 20 miles on long trips, but on short hauls this total is much less, because considerable time is spent at the loading and unloading points. The relation between the length of the haul and the normal daily mileage of horses in sled hauling is approximately as follows:[1]

Length of haul	*Number of round trips*	*Mileage*
Miles	Daily	Daily
5-6	2	20-24
4	2-3	16-24
3	3	18
2	4-5	16-20
1	6-8	12-16

A horse in good physical condition, when hauling at a speed of 2½ miles per hour, can exert a continuous pull equal approximately to one-tenth of its weight.[2] The same horse, in emergencies and for very brief periods only, can increase its pulling ability to three or four times the normal. Thus a horse

[1] From *Logging* by R. C. Bryant. John Wiley & Sons, Inc., New York.

[2] Based on a 10-hour working day.

weighing 1500 pounds normally develops work approximately equal to one mechanical horse power[1] and in emergencies may develop three or four horse power.

Logging sleds usually are so loaded that horses are not required to exert an effort above their normal and they may, therefore, haul loads for several miles without stops for rest, unless the road conditions are very adverse.

When several horses work in one draft unit, a part of their energy often is wasted, due to a lack of coördinated effort. Some authorities state that the loss of energy by each horse in a 2-horse team is about 5 per cent, and in

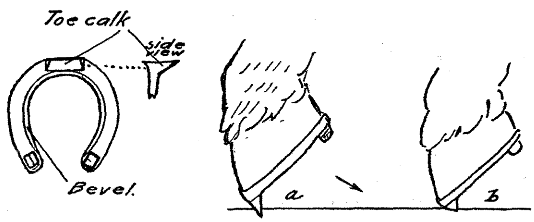


Fig. 46. Horse Shoes adapted to Use on Iced Sled Roads. a. Proper angle for a toe calk. b. The usual angle for a toe calk which does not provide a good grip.

a 4-horse team about 20 per cent. This, however, depends on working conditions, and in sled hauling the loss of energy for 2- and 4-horse teams, is very small when horses are accustomed to work together.

In the United States sled hauling is done with 2-horse or 4-horse teams driven by one man. Single teams are common in New England, while in the Lake States 4-horse teams predominate. Six-horse teams, which require a second driver for the lead team, as a rule, are impractical and are only occasionally used for hauling logging sleds. In the Province of Ontario, Canada, 4-horse teams are chiefly used for hauling, while in Quebec and other eastern Canadian provinces, horses are used singly or in 2-horse teams.

It is very important when hauling on sled roads, especially on iced roads, to have the horses shod properly. The shoe best adapted for an iced road has a wide and sharp toe calk slightly inclined towards the forward end

[1] The normal pull of such a horse is $\frac{1500}{10}$ or 150 pounds at 2½ miles per hour, which is equal to a pull of 375 pounds at 1 mile per hour, or a pull of 33,000 pounds at 1 foot per minute, or 1 horse power.

of the hoof.[1] The shape of toe calks and the angle at which they are set is important because the horse is in most need of a good grip at the time when its hoof first strikes the road surface and not when it is set flat on the ground. The inside edge of the shoe should be bevelled so as to prevent the collection of compacted snow on the hoofs.

Labor Cost.—The comparative cost of labor in the northern part of the United States and eastern Canada when horses were used singly and in teams with one driver, was approximately as follows during the winter of 1923-1924.

TABLE III

COMPARATIVE LABOR COST IN HAULING WITH 1, 2, AND 4 HORSES

Number of animals	*Cost of labor per working day*			*Cost of labor per one-horse working day*	
	Horse	*Driver*	*Horses and Driver*	*Horses and Driver*	
	Dollars	Dollars	Dollars	Dollars	Per Cent
Single horse	2.00	2.80	4.80	4.80	100
2-horse team	2.00	3.00	7.00	3.50	73
4-horse team	2.00	3.20	11.20	2.80	58

Local logging methods and conditions on specific operations determine whether it is most practical to use a single horse or 2- or 4-horse teams for sled hauling. Four-horse teams, however, are preferable when it is profitable to have wide, well-built roads and when skilled teamsters are available at moderate wages.

Animal Cost.—Loggers generally buy four-year-old horses, work them for four or five years and then sell them for about one-third of the initial cost. The number of horses annually lost or disabled on logging operations, due to accidents or sickness, is from 5 to 10 per cent.

Logging companies in the North either own horses or hire them for the winter season from farmers or contractors who have need for them only

[1] See Fig. 46.

TABLE IV

COST OF HORSE LABOR

Item of Cost	*Cost of horse per working day* Dollars	Per Cent
1. Depreciation.		
Purchase cost of horse $250. Period of work, 4½ years. Salvage 25 per cent, or $56 per horse.		
Annual loss due to accidents or sickness, 5 per cent or $13 per horse. 200 actual working days per year. Horse depreciation, per working day		
$\dfrac{\dfrac{250 - 56 + 13}{4.5}}{200} = 28$ cents	.28	14.4
2. Interest on investment.		
Investment per horse (at middle period of its working life), $125. Simple interest, 6 per cent, = 4 cents per working day.	.04	2.1
3. Feed.		
a. Daily ration, 20 pounds of oats and 25 pounds of hay. Cost of oats, 2.4 cents, hay 1.5 cents per pound, including toting expenses. Cost of horse feed per day, 85.5 cents, and for 8 months, $208.62.		
b. Daily rations, 2 months' idle time in spring; oats 10 pounds at 2 cents and hay 20 pounds at 1 cent per pound. Cost of horse feed = 40 cents per day, or $24 for 2 months.		
c. Pasture, 2 months at $4 per horse. Total cost of horse feed per working day =		
$\dfrac{208.62 + 24 + 4}{200} = \$1.18$	1.18	60.8
4. Care and housing.		
Barn boss, 8 months, at $80 per month, $640 for 24 horses, or $26.67 per horse.		
Barn boss for 2 idle spring months, $160 for 40 horses or $4 per horse.		
Man caring for 40 horses, 2 months of pasture, $160 or $4 per horse.		
Care of horses per working day,		
$\dfrac{26.67 + 4 + 4}{200} = 17.3$ cents		
Depreciation of stables and stable equipment per horse, per working day = 3.5 cents.		
Total, care and housing, per working day = 20.8 cents	.21	10.8

COST OF HORSE LABOR (cont.)

Item of Cost	*Cost of horse per working day* Dollars	Per Cent
5. Depreciation of harness.		
Initial cost of harness per team, $90.		
Repairs for 6 years, $50.		
Harness depreciation and repairs per horse, per working day, 5.8 cents.	.06	3.1
6. Shoeing.		
Blacksmith's labor, depreciation of shop and equipment, cost of materials (4 sets of shoes per horse, annually), per horse, per working day = 12 cents.	.12	6.2
7. Other expenses.		
Transportation of horses, veterinary, etc.	.05	2.6
Total cost, per horse, per working day.	1.94	100.0

during the warmer months of the year. Such coöperation in the use of horses is common in the Lake States where, during the winter of 1923-1924, the rental price of horses was $30 per month plus transportation charges to and from the logging job. The cost of horse labor, per working day, varies with the number of working days per year and the cost of forage delivered at the logging camp. The average winter ration for a logging horse is 20 pounds of oats and from 25 to 30 pounds of hay. The total cost of horse work on logging operations in the Lake States, New England, and in eastern Canada, during the winter of 1923-1924, ranged from $1.70 to $2.30 per working day per horse, with an average of about $2.[1] There is a widespread tendency among loggers to underestimate the actual cost of horse labor, due to the failure to charge to this cost all items of actual expense incurred.

Cost of Animal Draft.—The itemized cost of horse labor at a northern logging camp during the winter of 1923-1924 is shown in Table IV.

[1] The total average cost of a horse, per working day, in the Lake States during the winter of 1923-1924 was approximately $2.15.

MECHANICAL POWER

Character.-The types of mechanical power used in the United States for sled transportation may be divided into three groups, namely, (a) steam log haulers, (b) tractors, with an internal combustion motor, mounted on two "crawler" members and with a steering sled in front, (c) "full-crawler" tractors with an internal combustion motor. Wheeled tractors are not adapted to sled transportation because the wheels dig into snow and slip on ice. These difficulties cannot be overcome by lugs or grousers on the wheels because of the small area of contact between the wheels and the road surface.

The successful application of mechanical draft to sled transportation was due to the invention of the "chain-track" or "crawler" type of traction machinery.[1] The first successful tractors of the crawler type were built in the United States about 25 years ago, although the principle of the crawler or chain-track device had been known since 1870.

The traction device of a modern type of crawler tractor has an endless "chain-track" or belt composed of a number of steel links or shoes pivoted together by steel pins. This chain-track rotates around an idler, rollers, and a sprocket driven by the engine. The chain-track of a crawler traction member corresponds to the rim of a wheel, but its inner side serves as a track over which the tractor travels in the same manner as a locomotive on a rack-and-pinion railroad. A direct drive is provided by the contact of the driving sprocket teeth with the pins, a,[2] of the track. The weight of the tractor is carried on the flanged rollers. A crawler tractor has the following characteristics which are not found in other types.

1. Large area of ground contact. A modern 5- or 10-ton "full-crawler" tractor, which does not have a steering wheel or sled, has traction members from 10 to 12 inches wide, and a track length in contact with the ground of from 5 to 8 feet. The total area of the two traction members in contact with the ground, therefore, may be 16 square feet for a track of standard width.

2. Slight ground pressure. The ground pressure of a crawler tractor is slight and consequently it can work, without miring, on a loose bottom where wheeled tractors or animals could not be used. The approximate pres-

[1] Such tractors are known also under the names of "caterpillars" or "track-layers." These names, however, are misleading since "Caterpillar" is an exclusive trade name for tractors built by the Holt Manufacturing Company and "track-layer" is often used to designate a machine used for laying railroad track.

[2] See Fig. 47.

sure, in pounds per square inch, exerted on a moderately hard road surface is as follows:

Wheeled tractors	50 to 100
Horses	20 to 25
Men	6 to 8
Full-crawler tractors, 5- to 10-ton, with standard width track	4 to 9

3. Ability to span uneven spots on a road surface. The long traction members make it possible for the tractor to span uneven spots, which reduces the motive power which would otherwise be required to move the tractor and pull the load over an uneven road. It also makes it possible to run a full-crawler tractor over broken ground and even over ditches and deep holes, where wheeled tractors could not travel.

4. Maximum transmission of power to drawbar. A crawler tractor transmits a much greater proportion of the engine power to the drawbar than does a wheeled tractor because of the better ground contact. This difference in favor of crawler tractors is more marked on a snow or iced bottom than on an earth one.

5. Ease in turning. A full-crawler tractor may be turned around easily almost within its own length and can take very sharp curves, because steering is done by releasing, braking, or stopping one traction member and applying the entire driving power to the other.

Steam Log Hauler.—Steam log haulers have been built in the United States chiefly for hauling logging sleds over snow or iced roads. The first practical machine of this type was built in 1904 in accordance with patents granted to A. O. Lombard, of Waterville, Maine. The steam log hauler is a geared locomotive, mounted on a framework which has a steering sled in front and two crawler traction members or "chain-tracks" in the rear.[1] A number of steam log haulers, built by two plants in the United States, have been successfully used by loggers, but they are now considered less suitable for log-hauling purposes than the lighter motor tractors which use liquid fuel.

These machines require three men to operate them, namely, a pilot, who rides at the handwheel on the front of the machine, an engineer, and a fireman.

The steering sled may be replaced by steering wheels, but this makes the hauler heavy and clumsy; therefore wheels are seldom used and then only on sled roads which have a smooth and hard bottom.

[1] See Fig. 48.

TABLE V

SPECIFICATIONS OF STEAM LOG HAULERS

	Phoenix Steam Hauler	*Lombard Steam Hauler*
Rated Drawbar H.P.	100 H.P. with working boiler pressure of 200 lbs. per sq. in.	
Boiler	Horizontal multi-tubular locomotive type; fire box equipped for wood or coal fuel; length 15 feet; diameter 3 feet.	
Engines; No. of cylinders	4 vertical	2 horizontal
Size of cylinder	6¼″ x 8″	9″ x 10″
Revolutions per minute	336	250
Gear ratio	7.6 : 1	5.92 : 1
Transmission	Gear	Gear and sprocket chain
Speed, miles per hour[1]	0-5	0-5
Normal working speed, miles per hour	4½	4½
Width of "chain-track"	12″	16″
Length of "chain-track" in contact with ground	60″	53″
Bearing surface of both "chain-tracks"	1440 sq. in.	1696 sq. in.
Approximate ground pressure	21 lbs. per sq. in.	18 lbs. per sq. in.
Length of the machine	27′ 6″	30′
Width	5′ 4″	6′ 4″
Weight	18 tons	18 tons

The water tank carries 400 gallons of water, which is adequate for about one hour of continuous operation. Steam haulers ordinarily consume 1¾ tons of coal or 3½ cords of wood during a 10-hour working period. They remain serviceable for about 10 seasons.

Few fundamental changes have been made in steam log haulers during the past 15 years, consequently they lack some of the modern improvements found on recently developed logging equipment. They still have some advantages, however, over gasoline tractors for remote logging operations, due to their simplicity and durability of construction, and to the fact that wood fuel can be used where other kinds of fuel are unavailable or too expensive.

[1] Steam log haulers can be and sometimes are run at a speed of from 6 to 6½ miles per hour. Speeds in excess of 5 miles per hour are destructive to a machine and are considered unsafe.

TABLE VI

SPECIFICATIONS OF GAS LOG HAULERS

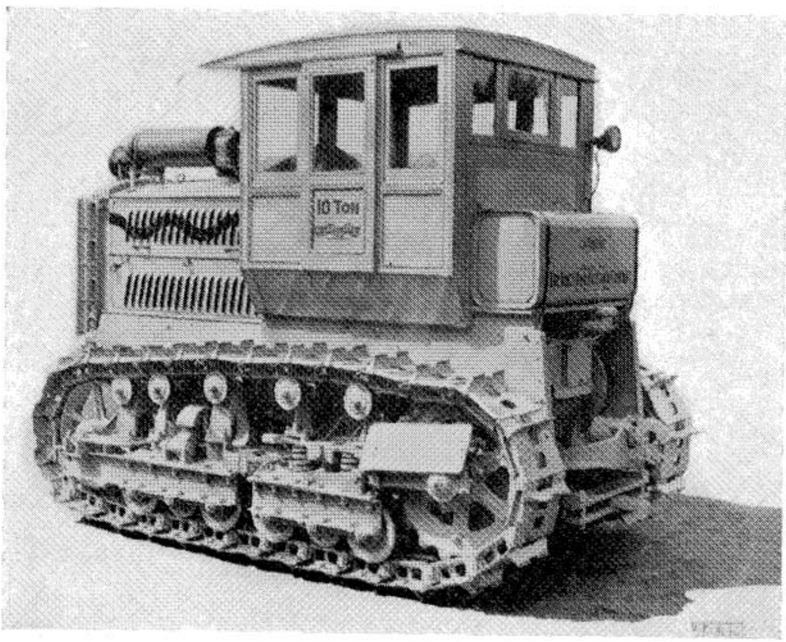
		Lombard 60 tractor-truck	*Lombard 100 tractor-truck*
Manufactured by	The Linn Mfg. Co., Morris, N.Y.	Lombard Tractor Engine Company, Waterville, Maine	
Rated belt H.P.	40	60	100
Rated drawbar H.P.	25[1]	32	50
No. of cylinders	4	4	6
Bore, cylinder, inches	5	5½	5¾
Stroke, inches	6¼	6½	7
Normal motor speed, R.P.M.	1000	1050	1050
Low speed, miles per hour	1	2	1¾
Medium speed, miles per hour	2 and 4	4	3½
High speed, miles per hour[2]	6	6	7
Reverse speed, miles per hour	2	2	2
Crawler traction members, width, inches	14	12	12
Crawler traction members. Length in contact with ground, inches	40	86	84
Ground pressure, lbs. per sq. inch (with empty platform)	5½	4½	6¾[3]
Maximum capacity of platform, tons	5	5	5
Length of tractor, inches	228	175	255
Width of tractor, inches	79	52	77
Height of tractor, inches	96[4]	72	78
Weight (empty platform), lbs.	10,000	12,000	19,000
Weight per 1 drawbar H.P., lbs. (empty platform)	400	375	380

[1] Twenty-five drawbar horse power for the Linn Tractor is a rough approximation, because no exact data are available.

[2] Six miles per hour is the normal maximum speed of a gas log hauler. However, the "Lombard 60" tractor-truck may be geared to a high speed of 8 miles per hour, and the "Lombard 100" to 10 miles per hour. Such high speeds are rarely practical and safe under average log-hauling conditions. The coasting speed of a gas log hauler is determined chiefly by considerations of safety. In rare cases on straight down grades, the coasting speed may attain a maximum of from 15 to 20 miles per hour, but such high speed with a train of loaded sleds is unsafe.

[3] On hard ground, the ground pressure is 10.8 pounds.

[4] To top of cab.



By permission of the Holt Mfg. Co.

Fig. 47. Ten-ton Holt "Caterpillar" Tractor. A type used on logging operations.

By permission of Lombard Auto T'ractor-Truck Co.

Fig. 48. Lombard Steam Log I-Iauler.

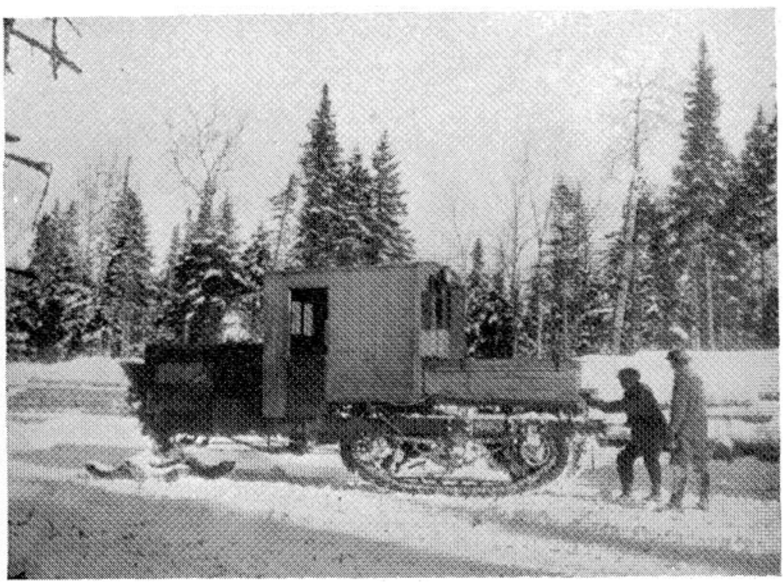


Fig. 49. The Linn Gas Log Hauler.

Gasoline tractors are now preferred by loggers to the steam log haulers because they are more independent in the matter of fuel and water supply and require less labor to operate them.[1] They may be safely and efficiently operated on cheaper roads than those required for steam log haulers because they weigh less, have a lower ground pressure, are more flexible, steer more readily, are more difficult to upset due to lower center of gravity, and can be used throughout the year.

Gas Log Hauler.[2]—A tractor with an internal combustion motor, mounted on two crawler members and with a steering sled, is known among loggers as a gas log hauler or tractor truck because it can carry a portion of the load on its platform. Loggers use this machine chiefly during the winter season for sled hauling, but it may be used during other periods of the year by substituting steering wheels for the sled. Gas log haulers are used in New England, New York, and in eastern Canada, where to a large extent they have superseded steam log haulers and are gradually though slowly replacing horses in sled transportation.

A gas log hauler has heavy gear differentials. A steering sled pivoted at the front end of the tractor carries from one-fourth to one-third of its weight. A certain degree of flexibility is provided in mounting the body of these machines and in the construction of their traction members so that they adhere to the road even on an uneven ground surface.

The consumption, per 10-hour working day, of gasoline and lubricants by gas log haulers, under ordinary sled-hauling conditions, is approximately as follows:

TABLE VII

CONSUMPTION OF GASOLINE AND LUBRICANTS, GAS LOG HAULERS

Type	*Gasoline*	*Lubricating Oil*	*Cup Grease*
	Gallons	Gallons	Pounds
Linn tractor	27	1.00	0.50
Lombard 60, tractor-truck	35	1.25	0.75
Lombard 100, tractor-truck	50	1.50	1.00

[1] Gasoline tractors require a driver only, while steam log haulers require three men.

[2] See Fig. 49.

Full-crawler Tractor.-A full-crawler tractor is mounted on two traction members only, which are approximately as long as the body of the machine. It does not have a steering sled or wheels and is adapted to logging because it can be used not only for hauling on roads, but also for skidding timber in the forest.

Nearly all full-crawler tractors have been developed during the last 15 years and the earlier models have been greatly changed and improved.

All full-crawler tractors manufactured in the United States are driven by internal combustion motors which, with one exception, have four 4-cycle vertical cylinders. These machines have three speeds, namely, low, from 1¼ to 2, medium, from 2¼ to 3½, and high, from 3½ to 5¾ miles per hour. Changes in speed are accomplished by sliding gears. The control of each traction member is effected by the steering clutch, usually of the multiple disc, dry plate type. Steering is accomplished by releasing, braking, or stopping one of the traction members, while the other may be driven forward or backw.ard under the full power of the motor. These machines are extremely flexible, due to the independent vertical oscillation of each traction member and to the "three-point" suspension of the body, that is, the front part of the tractor is pivoted to the center of an equalizing crossbar, the ends of which rest on the frames of each crawler member. Spiral springs are usually provided for shock absorption.

The traction member may be flexible or rigid. In the first type, the frame is made in two sections pivoted together, which, toa certain extent, permits it to adjust its shape to any unevennesses on the road surface. Crawler tractors with rigid traction members are satisfactory for logging purposes but they are not as effective on an uneven road surface as the·'flexible type and they tend to dig up roads that are not smooth.

Full-crawler tractors may be divided into three groups according to their approximate ,veight, namely, 2-ton, 5-ton, and Io-ton. The approximate ratio between the weight of such machines and their rated horsepower is from 400 to 500 pounds per drawbar horse power. The cost varies according to the type and make, but ranges from $150 to $170 for each drawbar horse power.

Brief specifications are given in the following table for twelve models of full-crawler tractors which are used by loggers.

TABLE VIII

SPECIFICATIONS FOR FULL-CRAWLER TRACTORS

Manufacturer	*Model*	*Rated brake h.p.*	*Rated drawbar h.p.*	*No. of cylinders*	*Bore, inches*	*Stroke, inches*	*Normal motor speed, r.p.m.*	*Low speed, miles per hour*	*Medium speed, miles per hour*	*High speed, miles per hour*	*Reverse speed, miles per hour*	*Standard width of track, inches*	*Length of track on ground, inches*	*Approximate ground pressure, pounds per square inch*	*Ground clearance, inches*	*Length of tractor, inches*	*Width of tractor, inches*	*Height of tractor, inches*	*Weight of tractor, lbs.*	*Weight per drawbar h.p., lbs.*
Cleveland Tractor Company	"Cletrac"	20	12	4	4	5½	1265	...	3½	...	...	8	50	4½	12	96	50	52	3300	275
Holt Mfg. Co.	"Caterpillar T-35"	35	15	4	4	5½	1000	2⅛	3	5¼	2⅖	10	51	5	11	103	48	55	4000	200
J. T. Tractor Co.	"J.T."	30	16	4	4¾	6	900	1¾	2½	5	1¼	11	74	4	15	137	60	68	7300	451
Monarch Tractors, Inc.	"E. 4-40"	40	25	4	4¾	6	1200	2¼	3¼	5	...	12	67	7.5	..	134	83	79	12000	480
Monarch Tractors, Inc.	Industrial C. 18-30	30	18	4	4¾	6	950	1½	2¼	3½	...	12	66	4	16	126	66	75	8100	450
C. L. Best Tractor Co.	"30"	30	20	4	4¾	6½	800	2	...	3 1/16	2½	11½	60	5	11½	112	53	59	6700	335
Bear Tractors, Inc.	"Bear"	40	25	4	4¾	6½	...	2.1	3.4	5.9	2	12	64	3.9	11	118	55	54	5500	220
Holt Mfg. Co.	"5-ton Caterpillar"	40	25	4	4¾	6	1050	1½	3	5.7	1	11	84	5	12	124	63	64	9400	376
Monarch Tractors, Inc.	"D. 6-60"	60	35	6	4¾	6	1200	2	3	5	...	12	89	7.3	..	140	84	79	15500	430
C. L. Best Tractor Co.	Cruiser	60	35	4	6½	8½	650	2	2⅜	4.2	1.3	12	88	8½	14½	141	84	76	17500	500
Holt Mfg. Co.	"Northern Logger"	60	40	4	6½	7	700	1.67	3	4.78	1¼	11	96	9.4	17	143	81	108	21000	525
Holt Mfg. Co.	"10-ton Caterpillar"	60	40	4	6½	7	700	1.67	3	4.78	1¼	11	96	8.5	17	146	80	81	19000	475

TABLE IX

DRAWBAR HORSE POWER TESTS, FULL-CRAWLER TRACTORS[1]

Model	*Horse power developed*	*Drawbar pull*	*Speed*	*Crankshaft speed*	*Fuel*	*Amount of fuel used, per hour*	*Hours per gallon, per horse power*	*Horse power developed*	*Drawbar pull*	*Speed*
		Pounds	m.p.h.	r.p.m.		Gallons			Pounds	m.p.h.
Cletrac W 12-20	13.47	1395	3.62	1386	Kerosene	2.67	5.04	15.52	1734	3.36
Monarch C 18-30	19.28	3443	2.10	946	Kerosene	3.72	5.18	21.03	4670	1.69
Holt 5-ton Caterpillar (T-11 25-40)	26.54	3336	2.98	1050	Gasoline	4.15	6.39	33.34	3546	3.53
Holt 10-ton Caterpillar (T-16 40-60)	42.76	4963	3.23	779	Gasoline	8.70	4.91	51.59	5250	3.69

[1] Data in this table are taken from tests made by the University of Nebraska Experiment Station.

The fuel most commonly used is gasoline, but some tractors are run on kerosene or heavier oils, after being started on gasoline. A cheap heavy liquid fuel usually is not fully satisfactory because it entails the use of larger quantities of cylinder oil and may decrease the life of the motor by 25 per cent. The gasoline consumption of a motor doing continuous work at the rated load, under experimental conditions, is about 2¾ gallons per hour for 2-ton, 4 gallons per hour for 5-ton, and 8 gallons per hour for 10-ton tractors. When tractors are used for sled hauling, the average consumption of gasoline, per 10-hour working day, is approximately as follows:

2-ton crawler tractor	15 gallons
5-ton crawler tractor	25 gallons
10-ton crawler tractor	40 gallons

Tractors are lubricated usually by a force feed system adapted to operations on steep grades and at low temperatures. The amount of lubricating oil required for a 5- or 10-ton crawler tractor is from one to two gallons of oil and one pound of cup grease per 10-hour working day. Antifriction bearings are used extensively in these machines. Kerosene instead of water often is used in the radiator in very cold weather to prevent freezing. The use of a proper type of grouser on the shoes of the traction members is fully as important as the proper shoeing of a horse. Sharp or very long spikes on the track shoes are impractical, because they tear up the roadbed. Grousers should be from 1 to 2 inches high for a snow road and from ¾ to 1 inch for an iced road[1] in order to obtain a good grip on the road surface without spoiling it. They have rectangular holes cut in their surface to prevent sluing on iced side-hills. The holes in the shoes of the track serve as openings through which snow or ice is forced out by the teeth of the driving sprocket, thus preventing the traction member from becoming clogged. Even the heaviest models of crawler tractors, when equipped with the proper form of grousers, do not chop an iced sled road as much as the calks of horseshoes.

One driver is required to operate a crawler tractor, but when hauling sled trains, it is customary to employ a second man to couple and uncouple the train and to travel with it. When only one or two machines are used, the necessary minor repair work on the tractors is done at the camp garage by the drivers, provided they are competent mechanics. When three or more tractors are in use on the same operation it is better to have an expert

1 See Fig. 47 for a practical type of grouser.

mechanic do the repair work. The cost of repairs usually does not exceed $4 per working day when tractors are handled properly.

. The construction of a modern crawler tractor is intricate but under proper treatnlent it will do extremely heavy work. Most breakdowns are due to the employment of incompetent drivers in an effort to economize. The working time lost, due to the breakdowns, can be decreased appreciably by making the drivers financially interested in the continuous productive operation of the tractors by a bonus or other means.

There are no reliable data available regarding the average working life of crawler traction machinery because it has been used in logging for a few years only. Loggers, however, estimate a total depreciation of full-crawler tractors in from 3 to 5 years without allowing any wrecking value.[1] Depreciation costs are becoming less,. however, with more intelligent handling of the machinery, and improvements which are adding to the durability of the tractors.

Most of the full-crawler tractors used by northern loggers for sled transportation are Holt Caterpillar Tractors of the la-ton, rather than the s-ton model. Next in point of numbers CaIne the "Monarch," "Cletrac," and the "Best." Ten-ton machines as a rule are more economical than 5-ton, especially on long hauls, \vhile 2-ton tractors are too small for average logging conditions.

There have been attempts to use tractors with wheels of the "girdle" form, both 4-wheel drive and 2-wheel drive, with a front steering sled. Such tractors work better than ordinary wheeled tractors on sled roads, but they are much less satisfactory than the crawler type machines. They are used in logging only by farmers and small operators. Some manufacturers offer "full-crawler tracks" or "track pull" which, when adjusted to a Fordson wheeled tractor, convert it into a full-crawler tractor. These tractors, when so equipped, are better for sled roads than a wheeled machine, but arenot'suitable for ordinary logging conditions.

Gas Log Haulers versus Full-crawler Tractors.-There is a marked difference in steering methods between a gas log hauler and a full-crawler tractor. A gas log hauler is steered in the same manner both when pulling and when being pushed down grade by a load, while the controls of a full-crawler tractor, which is backing or is being pushed by a load, are operated in a manner which is the reverse of that used when a load is being pulled. For example, a full-crawler tractor will turn to the left when pull-

1 See Table X and footnote I, page 86.

ing a load, when the left traction member is permitted to run free, while it will turn to the right when the load is pushing it. When hauling down a rolling grade, the load rapidly changes from a pull to a push and vice versa, and the driver must each time quickly reverse his method of steering the tractor in order to prevent it from leaving the road and to keep the load from jack-knifing. Thus a full-crawler tractor requires a more skilled driver and is more difficult to operate than a gas log hauler, especially if the road has steep grades. Due to this consideration, the efficiency of hauling over roads with a rough profile may be less with full-crawler tractors than with gas log haulers of equal drawbar horse power.

When a full-crawler tractor, pulling a load, has to make a sharp turn, the total power is applied to one traction member only; thus its effective bearing on the road surface is reduced one-half and the machine tends to stall with a maximum load which it could pull in a straight direction. However, the absence of a steering sled or wheels, and the comparatively short length of the tractor, enable full-crawler tractors to turn practically within their own length, to work on a soft bottom where a steering sled or wheels would mire and would make work impossible, to work among the trees away from the road and also to move easily over rocks, windfalls, and other obstacles, which cannot be done with a tractor having a steering sled or wheels. These advantages are of slight importance in sled hauling although they are very important in some other kinds of work.

A gas log hauler has its center of gravity in front of the traction members and is about twice as long as a full-crawler tractor of the same weight and capacity; therefore it does not have the tendency common to some of the full-crawler tractors of decreasing the area of contact with the ground under a heavy drawbar pull, especially on uphill work when the torque lifts a full-crawler tractor in front and causes it to ride only upon the rear part of the traction members. However, most of the full-crawler tractors are so constructed as to height of drawbar and distribution of weight that they do not have the disadvantage mentioned. Although a full-crawler tractor carries its entire weight on the traction members and, therefore, under ordinary conditions, gains some in traction as compared to a gas log hauler having steering sleds, yet the weight and the traction of the latter machine may be greatly increased by loading a part of the pay load on the platform, which will carry as much as 750 board feet, weighing 3½ or 4 tons.

A gas log hauler has four forward speeds, while a full-crawler tractor has only three, and the high speed of a gas log hauler is greater than that of a full-crawler tractor.

Most of the tractors used by loggers for sled hauling in New York State, New England, and in eastern Canada are gas log haulers, but they are rarely, if ever, used in the Lake States. Full-crawler tractors are more widely distributed over the regions where sled hauling is practiced and are

TABLE X

THE COST OF CRAWLER TRACTION MACHINERY, SLED HAULING, PER 10-HOUR WORKING DAY

Items of expense	*Full-crawler tractor*		*Log hauler*		
			Gas		*Steam*
	5-ton	*10-ton*	*5-ton*	*10-ton*	*18-ton*
	Dollars	Dollars	Dollars	Dollars	Dollars
Depreciation[1]	5.40	8.80	7.20	9.90	12.50
Interest[2]	.65	1.05	1.90	2.60	3.80
Fuel[3]	6.25	10.00	6.75	12.50	19.25
Lubricants	1.50	2.00	1.50	2.00	2.00
Repairs	3.00	4.00	2.50	3.50	4.00
Labor[4]	9.25	9.25	9.25	9.25	17.25
Other expenses	2.00	3.00	2.00	3.00	5.00
Total	28.05	38.10	31.10	42.75	63.80

[1] The working life of a full-crawler tractor is assumed to be 4 years of 200 working days each, one shift; for a gas log hauler, 9 years of 90 working days each; and for a steam log hauler, 10 years of 80 working days each. The average sled hauling season is from 60 to 70 working days, but crawler traction machinery often is used in two 10-hour shifts, both day and night. In addition, full-crawler tractors are often used by loggers for various purposes at other seasons, which is seldom true with gas log haulers. The salvage value of crawler traction machinery at the end of its working life is approximately 10 per cent of its purchase price.

[2] Simple interest at 6 per cent is calculated for the average cost of traction machinery at the middle period of its working life.

[3] The assumed cost of gasoline delivered at the logging camp is 25 cents per gallon. The consumption of fuel, per 10-hour working day, is given on page 83. The assumed cost of coal delivered at the logging camp is $11 per ton.

[4] Based on the following rates of wage: Driver $6 and conductor $3.25 per working day, for full-crawler tractors and gas log haulers. Engineer $6, pilot and fireman $4 each, and conductor $3.25 per working day, one shift, for a steam log hauler.

more common on logging operations in the Lake States region than in the northeastern part of America. Loggers, as a rule, are not very familiar with the various models of tractors and they often prefer machinery manufactured in their vicinity, even though it may not always best meet their local conditions.

Tractor Cost.-Although the cost of crawler traction machinery used in sled hauling is subject to wide variations, an approximate average cost on logging operations is given in Table X.

The cost of operating crawler traction machinery in Canada is about 25 per cent greater than in the United States, because interest and depreciation charges are much greater, due to the high customs duties on American-made tractors and also to the fact that gasoline is about one-third higher in Canadian logging camps than it is in those in the United States.

FACTORS CONTROLLING THE SIZE OF SLED LOADS

IT is often desirable to know in advance both the maximum load that can be hauled over a road with a given amount of animal or mechanical draft power, and the amount of power that will be required to haul a given load under specified conditions. Loggers usually solve such problems in an empirical manner. Since the relation between the power used in hauling and its maximum load capacity varies widely with the conditions in each individual case, a logger of wide experience may make serious errors if there is some phase of the problem which he has not previously encountered. Hence, a simple, though approximate, theoretical basis for determining such relations is of aid when planning and organizing or analyzing hauling operations.

TRACTIVE RESISTANCE

The energy required to move a sled over a roadbed must be sufficient to, overcome resistance[1] due both to sliding and to grade. The sliding resistance of a sled on a level road depends chiefly on the nature of the road surface, but it is also influenced by the type and condition of the road, and the construction of the sled.[2]

1 The coefficient of sliding resistance is expressed in per cent of the gross weight of the load, or in pounds per ton of the load hauled.

2 The sliding resistance of snow and iced roads, based chiefly on data collected by the junior author in northern logging operations, and the rolling resistance of logging railroads, based on the average results obtained from several reliable investigations, are shown in Table XI.

TABLE XI

THE ROLLING AND SLIDING RESISTANCE OF LOGGING ROADS (approximate)

Character of road		*Type of Carrier*	*Resistance*	*Coefficient of rolling or sliding road resistance (on level)* *Per cent of gross load*	*Pounds per ton of gross load*	*Comparative efficiency of road as measured by rolling or sliding resistance*
Logging railroad		Flat car	Rolling	1.75 (1 to 2.25)[1]	35 (20 to 45)	Per Cent 100.0
Sled Road	Iced	Logging sled	Sliding	1.75 (1 to 2.25)	35 (20 to 45)	100.0
	Snow	Logging sled	Sliding	3.25 (2.5 to 4)	65 (50 to 80)	53.8
Wagon Road	Earth	Logging wagon	Rolling	7.50 (6 to 9)	150 (120 to 180)	23.4
	loose sand or wet clay	Logging wagon	Rolling	17.50 (12.5 to 22.5)	350 (250 to 450)	10.0

The rolling resistance incident to moving a load on a logging railroad is approximately the same as the sliding resistance of the same load hauled on a heavy-duty sled over an iced road. Twice as much force is required to move the same weight on a sled on a snow road and four times as much force to move the same weight on a wagon hauled on an earth road.

The sliding resistance during very cold weather (—30° F. to —40° F.) is about 20 per cent greater on an iced road and about 30 per cent greater on a snow road than when the temperature is just below the freezing point.

The resistance offered by grade is independent of the rolling or sliding resistance of a road and is equal to 1 per cent of the gross weight or 20 pounds per ton of load for each per cent of the grade.[2]

[1] The rolling resistance of logging railroads, especially on spur lines, is caused chiefly by the poor construction and maintenance of the track and is much greater than it is for trunk-line railroads. The figures in parenthesis represent the range in resistance.

[2] This is correct for grades up to 15 per cent for which the actual distance of

THE INFLUENCE OF GRADE

The efficiency of sled transportation on a given road is determined chiefly by those portions, often short in length, where hauling is most difficult. These generally are steep ascending grades in the loaded direction, but there may be portions of a level road which are not in good condition or a steep down grade where the hauling of a very heavy load is attended with danger. An extra effort is required to start a loaded sled, and even when hauling on a well-made level road, the start may require a greater force than is needed to pull the load over any other part of the road. In such cases the weight of load that can be hauled may be limited by the difficulty of starting and, therefore, all measures should be taken to reduce this to the minimum. Sleds should not be loaded on even a slight adverse grade and the teamster should avoid stopping on an ascending one. The difficulty attendant on starting a sled is due, not only to the inertia of the load, but also to the fact that the sled shoes become heated by friction while hauling and when the sled stops they cool off very quickly and freeze to the road surface. A sled thus frozen to the road may be started much more easily by a slight sidewise swinging motion than by a straight forward pull and, therefore, a heavy load is first drawn far enough to one side to move the sled from the dead point, or else the runners are struck by a wooden maul to release them. The crown of the sled runners, the construction of sleds and the method of coupling them into trains also provide a slight amount of play which makes starting much easier.

Bark and dirt accumulating on the road at the loading points make it difficult to start sleds and hence such places must be cleaned at frequent intervals.

An additional team or the one used for loading the sleds may sometimes be used to aid in starting.

Speed Control on Descending Grades.-Although slight down-hill grades in the loaded direction greatly facilitate sled transportation, steep grades present serious obstacles, especially when they occur on curved portions of the road. The grade on which a loaded sled once started will just move by its own momentum, varies with conditions, but it is usually between 2 and

hauling along the slope may be taken as equal to its horizontal projection and where the tangent of an angle forming the grade is practically equal to its sine. For steeper grades, the grade resistance is equal to the weight elevated multiplied by the tangent of the grade angle, which is equal to the height of the grade divided by its length along the slope.

5 per cent. Loads may be hauled down grades steeper than this, without braking the sled, provided such grades are short and straight, or the weight of the load is reduced. Among the various methods of controlling the speed of sleds on down grades, the following are the most effective.[1]

1. Slight grades on iced roads may be left with a snow bottom only, since the sliding resistance is greater on snow than on ice.

2. Hay or straw placed on iced or snow roads is effective in checking the speed of sleds on descending grades of 10 per cent or less. Small bunches of hay should be placed in holes cut across the ruts at intervals of from 2 to 10 feet, depending upon the steepness of the grade, because when it is scattered broadcast over the road the sleds will drag it away. The sliding resistance of a sled road is influenced by weather changes and, therefore, the checking of the speed of sleds on a descending grade must be regulated accordingly. This is done by placing more hay on the road or removing some or all of it, as conditions require. Horse manure may be substituted for hay or straw, but usually this is not practicable.

3. Descending grades which exceed 10 per cent are kept free from ice and snow so that the sled runners travel on the bare ground.

4. Steel bridle chains may be fastened around the sled runners to serve as a brake. This method lacks flexibility and rapidly depreciates both the sled and the road.

5. A heavy hardwood log may be fastened to one end of a lowering rope which, after passing through a block at the top of the grade, is fastened to the sled. A trough is made along one side of the road in which the log slides as the sleds ascend or descend. The speed of the descending sled is checked by the resistance of the log acting as a counterweight. The same log sliding down the trough may assist in hauling empties uphill. This scheme is seldom used because, when weather conditions make the road slippery, the counterweight also slides easier, hence its effectiveness is decreased at a time when it is most urgently needed.

6. Hot sand, scattered on steep pitches, is a very effective method of braking sleds on grades ranging from 15 to 25 per cent. The continuous attendance of road monkeys is required on steep and long grades. Their duty is to heat the sand in buckets over near-by fires and throw it, by handfuls, in front of the runners of the descending sleds in whatever quantity is required. This is a popular method of sled speed control, but it wears down the runner shoes very quickly.

[1] See Fig. 32 for a device used on single-horse sleds.

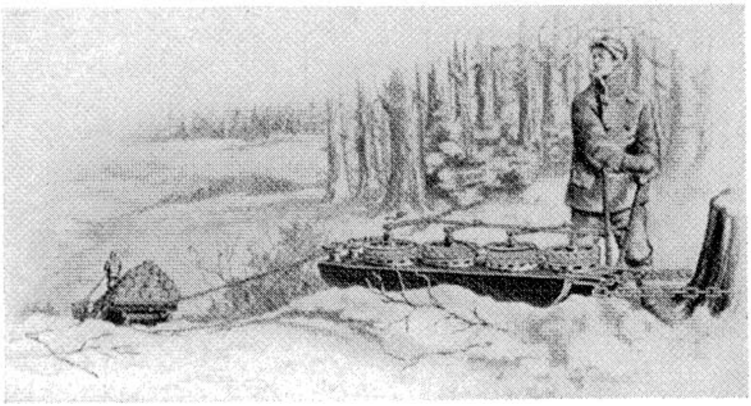


Fig. 51. The Barienger Brake used for lowering Loaded Sleds on Steep Grades.

When too much sand has been thrown under the runners of a descending sled it may stop but it will start as soon as the runner shoes, heated by friction, have cooled. This will not happen when hay or straw has been used, because the cooling of the runner shoes causes them to freeze to the hay and makes it more difficult to again start the sled.

Hay or sand, when used on steep grades for checking the speed of descending sleds, may make it more difficult to haul the empty sleds uphill. This objection may be overcome by confining the hay or sand to the ruts in

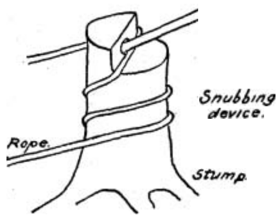


Fig. 50. A Snub Line for lowering Sleds on Steep Grades.

which the runners of the descending sleds travel and using other unsanded ruts for the ascending sleds.

7. A strong cable called a snub-line may be used for lowering sleds down steep grades. One end of the cable is fastened by a noose around the loaded sled and the cable is then passed three or four times around a stump located near the road at the top of the incline.[1] A man at the stump allows the line to run out as the sled descends, the speed being controlled by hand or by a lever.

8. A patented device known as the Barienger brake is sometimes used to lower heavily loaded sleds on long steep grades. It has four or six cast-iron grooved sheaves which are mounted horizontally on a frame fitted with two runners.[2] A steel cable, from 3/8 to 3/4 inch thick and about 100 feet longer than the length of the hill, is wound on the grooved sheaves in such a manner that, due to friction, it cannot slide and moves only when the sheaves are allowed to revolve. The speed of the descending load is controlled by hand levers which bring the lower surface of the sheaves into contact with hardwood friction blocks secured to the frame of the machine, thus making

1 See Fig. 50.
2 See Fig. 51.

a friction brake for regulating the speed at which the cable is unwound. The Barienger brake is anchored by chains to a stump at the top of the grade, and one end of the cable is fastened around the load and the sled. When a sled has been lowered down the grade, the next sled is attached to the opposite end of the cable. Cast-iron rollers are installed on stumps or short posts to guide the cable around turns on roads which are not straight. On a long and rolling grade when the brakeman cannot see the progress of the descending sleds, the cable is marked in certain places, and these marks enable a brakeman to know the location of a descending sled at any given moment.

Movement of Loaded Sleds on Ascending Grades.-The following measures may be taken, in lieu of decreasing the load, in order to overcome ascending grades, especially when they occur only on very short sections of a long and otherwise easy road.

1. The use of tow teams to assist in pulling the sleds up the hill.

2. The division of a sled train, hauled by mechanical draft, into two or more sections, each of which is separately pulled up the grade.

3. The use of a steam hoisting engine, placed at the top of the hill, which pulls the loaded sleds up the grade by a cable.

4. When sled trains are hauled by mechanical draft over a road which has short but steep pitches, the load may be placed on light capacity sleds, thus making the train longer, so that only a part of the sleds are ascending the adverse grade at one time.

Some sled-hauling tractors which are equipped with a low-geared winch may leave the sled train at the base of a steep grade and after climbing to its top and being anchored, pull the train up by means of a cable.

Calculation of Hauling Ability.-The approximate relation between the power used in hauling, the road conditions, and the corresponding maximum load may be expressed by the following formula:

$$\text{Maximum gross load} \quad \frac{\text{Drawbar pull on level (pounds)} \qquad \text{Grade resistance for tractor or animals (pounds)}}{\text{Total resistance, in pounds per ton, of load hauled}}$$

Let L = Maximum net weight of load hauled (tons)

L_1 = Maximum weight of carriers on which load is hauled (tons)

P = Drawbar horse-power of machine or corresponding work of animals, on level

S = Speed, miles per hour

W = Weight of machine, or animals hauling the load (tons)

Q = Maximum adverse grade; *i.e.*, the grade on which the maximum of pulling force is required, expressed in per cent

R = Sliding or rolling resistance of road, in pounds per ton of gross load hauled[1]

R_1 = Grade resistance of road, equal to 20 pounds per ton of gross load hauled for each 1 per cent of ascending grade

R_2 = Axle resistance of carriers, in pounds per ton of load carried on the axles[2]

375 = Pulling force, in pounds, corresponding to the work of 1 horse power at a speed of 1 mile per hour

Then from formula (1)

$$L + L_1 = \frac{\frac{P \times 375}{S} - WQR}{R + R_1 Q + R_2}$$

The following examples demonstrate some of the possible uses of this formula.

Example I.

Given: A crawler tractor, 40 drawbar horse power. Weight 10 tons. Low speed, 2 miles per hour. Ordinary snow road. Maximum adverse grade, 5 per cent.

Find: The maximum load that the tractor can haul at low speed.
By formula (1)

$$L + L_1 = \frac{\frac{40 \times 375}{2} - (10 \times 5 \times 20)}{65 + (5 \times 20) + 0}$$

$\therefore L + L_1$, the gross weight of load, equals 39.3 tons.

[1] See Table XI.

[2] The axle resistance for heavy-duty wagons used in logging is usually from 4 to 5 pounds per ton of load.

Example II.

Given: The maximum gross load which a 5-ton, 25 drawbar horse-power tractor can haul on sleds, at a speed of 2 miles per hour, over a given road with 6 per cent adverse grades, is 20 tons.

Find: How much can the load be increased if the road is rebuilt so that the maximum adverse grade is 4 per cent.

The sliding resistance per ton, X, for this road will be:

$$20 = \frac{\frac{25 \times 375}{2} - (5 \times 6 \times 20)}{X + (20 \times 6) + 0}, \text{ or } 84.4$$

Therefore, the gross load, $L + L_1$, which can be hauled on a 4 per cent adverse grade with a speed of 2 miles per hour equals

$$\frac{\frac{25 \times 375}{2} - (5 \times 4 \times 20)}{84.4 + (20 \times 4)}, \text{ or 26 tons,}$$

which is 7 tons, or 35 per cent greater than the load which can be hauled under the same conditions on a 6 per cent adverse grade.

Example III.

Find: What drawbar horse-power must a 5-ton tractor exert to haul on a wagon over an ordinary dirt road a load of 10 tons gross weight up a 5 per cent adverse grade at a speed of 2 miles per hour.[1]

By formula (1)

$$10 = \frac{\frac{X \times 375}{2} - (5 \times 5 \times 20)}{150 + (5 \times 20) + 4}$$

∴ X, or the required drawbar horse-power of the tractor is equal to 16.2

[1] The rolling resistance of the road is assumed to be 150 pounds per ton.

Example IV.

Given: A snow road with an ascending grade of 2 per cent for distances not exceeding 200 feet.

Find: What is the average gross load, in tons, that can be hauled on a sled by two horses, each of which weighs 1500 pounds.[1]

By formula (1)

$$L + L_1 = \frac{\dfrac{5 \times 375}{2.5} - (1.5 \times 2 \times 20)}{65 + (2 \times 20)} = 6.6$$

$\therefore L + L_1$, the gross weight of the load, is approximately 6.6 tons.

Computations of the above character, if intelligently applied to the analysis of a logging operation, often show clearly where and how improvements may be made which will increase the efficiency of transportation when either mechanical or animal draft is used.[2]

Judgment must be exercised in determining the condition of the road, when using the data in Table XI to calculate its sliding resistance.

The comparative efficiency of logging roads, shown in Fig. 52, indicates the maximum load which can be hauled on a level road and on an adverse grade by a given traction force and also shows that the efficiency of an iced road as compared to a snow road decreases rapidly as the adverse grade increases.

The relation between the various factors which affect the hauling ability of a given kind of traction power under various road conditions is shown in Fig. 53.[3]

The following example will demonstrate the use of the chart, Fig. 53.

Find the maximum load a 10-ton Caterpillar can pull on a wagon at low speed[4] over an earth road with 4 per cent ascending grade.

[1] It is assumed that each horse will develop 2½ horse-power when ascending the grade at a rate of 2.5 miles per hour. Since this is two and one-half times the normal power of the animal, it can put forth this exertion only for short distances and at occasional intervals.

[2] When calculations are made for animal draft, it must be remembered that the work exerted by a horse when hauling is not constant but may decrease or increase greatly below or above its normal work according to conditions.

[3] This chart, which is for a 10-ton Holt Caterpillar tractor, was prepared by the Research Department of the Holt Manufacturing Co., with the exception of the values for the coefficient of traction resistance, which were inserted by the junior author.

[4] 1.65 miles per hour.

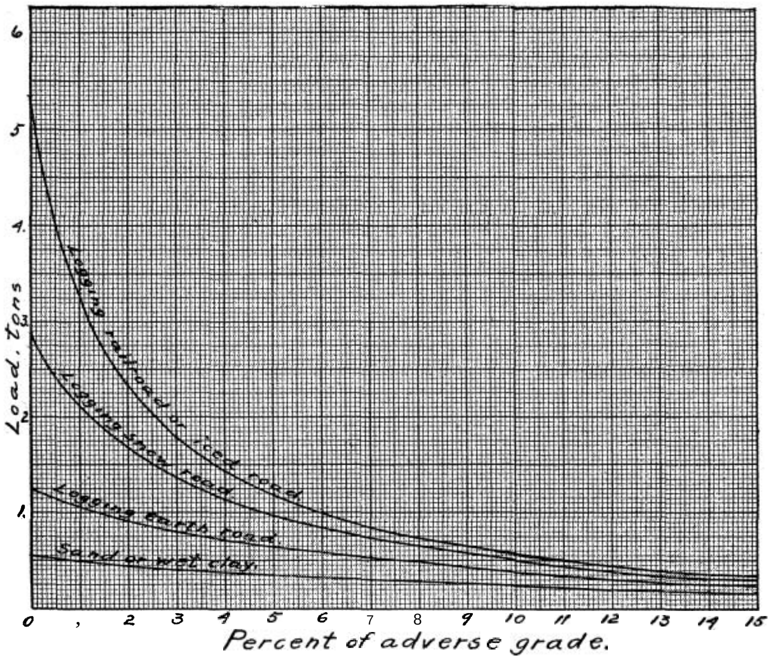


Fig. 52. The Weight of Load which can be hauled, per 1 Horse Power, with a speed of 2 Miles per Hour, on Level or Adverse Grades. It is assumed that the tractive power weighs 500 pounds for each horse power of its drawbar pull.

Locate the point on the ordinate \vhich represents a 4 per cent grade and follow this line diagonally to the right to its intersection with the vertical line representing a coefficient of rolling resistance equalto 7.5, which is the resistance for an earth road.[1] From this point move horizontally to the left to the point of intersection with the curve which represents .grade resistance. Then drop a perpendicular to the line representing the desired speed. The hauling capacity, that is, the maximum load, which is 38 tons, can be read from the .figures ·at the lower end of the radiating lines. The drawbar pull, 8400 pounds, is found by following to the left the horizontal line which is at the point of intersection of the vertical and the lo\v speed curve.

1 See Table XI.

This chart may be used in many ways, such as to determine approximately what a tractor can do under specified road conditions or what conditions are requisite when a certain amount of work must be accomplished by a tractor. A similar chart may be made for any kind of tractive power.

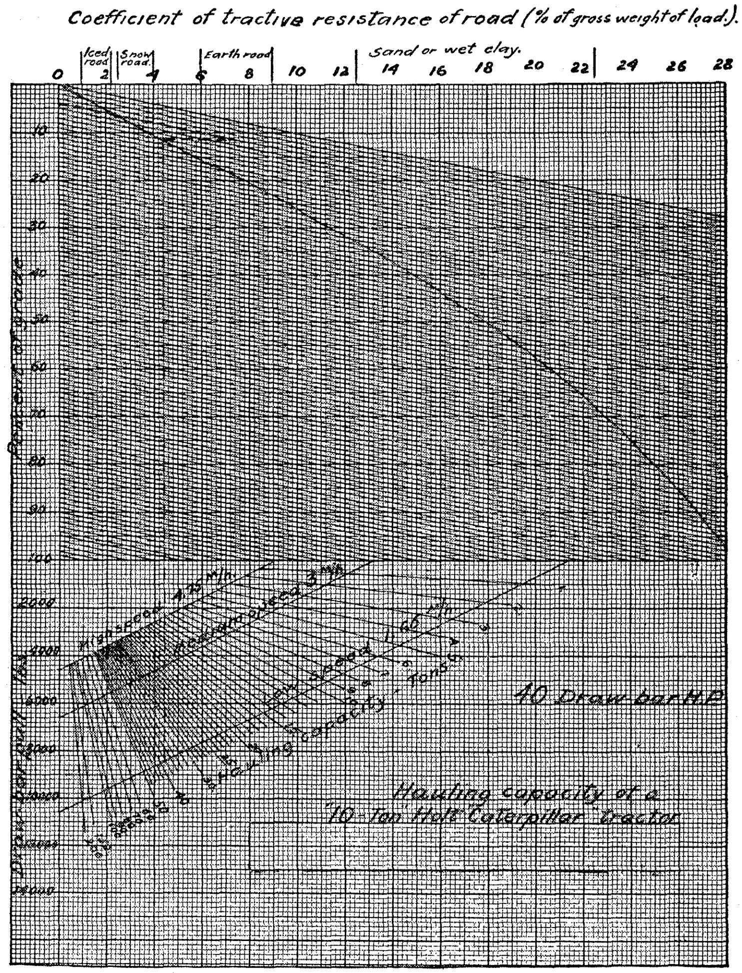


Fig. 53. Chart showing the Hauling capacity of a 10-ton Holt "Caterpillar" Tractor (40 drawbar horse power) on various road surfaces.

TRANSPORTATION OF LOGS ON SLEDS

ANIMAL VERSUS MECHANICAL DRAFT

FACTORS INFLUENCING THE CHOICE

ALTHOUGH horses constitute the chief draft power used for sled hauling in the United States and in Canada, there is a growing tendency to substitute tractors for them. Which of these forms of draft is the more practical and economical can be determined only after considering the specific conditions found on each operation. Some of the factors which have a bearing on the choice of method are:

1. Period of work. A horse, over a period of several weeks, cannot work longer than ten hours per day and remain in good physical condition. On the other hand, tractors may be worked continuously, day and night, by using two drivers.[1] A much greater amount of power is concentrated in the hands of one tractor driver than in the hands of a teamster, hence there is economy in wages as compared to horse draft.
2. Expense during idle periods. The care and feeding of draft animals, when idle, may represent a rather high cost against a logging operation. Tractor expense ceases when the machine is not in operation.
3. Trained drivers. It is easier to secure expert teamsters than it is to get tractor drivers who are competent to keep their machine in repair. When tractors break down, it is often difficult or impossible to replace them immediately with animal draft, whereas on operations where animals are used, replacements can usually be made in a short time. The incapacitation of one or two teams represents a much lower power loss than that represented by a single tractor.
4. Maximum power. A working horse in good condition can increase its normal tractive force from 300 to 400 per cent for a brief period if necessary, such as may occur in starting a load, pulling it over an obstacle or overcoming short adverse grades. Tractors cannot increase their tractive power much in excess of their normal or rated drawbar horse power.

Horses have an advantage over tractors when hauling on a road that is fairly level and in good condition, except possibly for a few bad places. On such roads a sled may be loaded to capacity, and, on reaching the bad sec-

[1] Working tractors in two shifts may effect some economy in overhead, but the chief advantage is the ability to get logs out of the forest in a short time. It is the usual practice to load and unload sleds for night hauling during the daytime, hence twice as many sleds are needed as are necessary for operating a day shift only.

tions of the road, the load is dra\vn over them by the extra exertion of the draft animals.

The hauling capacity of a tractor on such a road is limited to the load which can be hauled over the poorest sections, hence, the load is below normal for the major part of the distance.

If, however, the road is of such a character that the animals are frequently and for comparatively long periods of time called upon to exert a force above their normal, then the conditions are reversed, and tractors have the greater advantage, since the animals become fatigued and are unable to exert their normal effort.

Little is kno\vn about the comparative efficiency of horses and crawler tractors when used for drawing sleds. Data collected by the authors at logging operations on which horses and tractors were used for sled transportation, under the same or identical working conditions, indicate that a horse weighing 1500 pounds can exert a normal tractive force equivalent to from 2 to 3 mechanical drawbar horse power of a crawler tractor. For example, a la-ton tractor actually developing 40 horse power on the drawbar will haul, at the same speed as horses,[1] a load usually requiring 16 horses, while a 5-ton, 25-drawbar horse-power tractor will haul a load which would require 10 horses.

If a road throughout its entire length presented a uniform resistance to the load being hauled, an increase in hauling speed would cause a proportional decrease in pulling power and therefore in the weight of the capacity load, provided the amount of the tractive energy developed remained unchanged. Thus, a gain in speed and in working time would result in a loss of pulling power and in weight of load, and the hauling efficiency would not be directly affected by the change in speed. Such conditions, however, do not usually occur in actual hauling practice. The tractive resistance of the various parts of a logging road usually is not the same, because the profile is not uniform, and there are variations in the character and condition of the surface on various sections of the road. The possibility of exchanging speed for pulling power and vice versa, according to the tractive resistance of the road, increases the hauling efficiency.

The low speed with which it is most practical to overcome the sections of the road which offer maximum tractive resistance is approximately the same for horses and tractors, but most tractors can interchange speed and pulling power without much loss of energy and within much wider limits

1 About 2½ miles per hour.

than is possible with horses. Tractors hauling on a road of variable tractive resistance can maintain a higher average speed than horses and without a loss of load capacity. Tractors gain in productive working time as compared with horses because they can return empty sleds at a higher speed.

The average speeds of horses and tractors in sled hauling under average hauling conditions is shown in Table XII.

TABLE XII

SPEEDS OF HORSES AND TRACTORS IN SLED HAULING

	Horses	*Full-crawler tractors*	*Gas log haulers*	*Steam log haulers*
Mean speed, loaded, miles per hour	2.5[1]	3.0	3.5	3.75
Mean returning speed with empties, miles per hour	3.0	4.25	5.25	5.0
Mean speed, round trip, miles per hour	2.73[2]	3.52	4.2	4.3[3]
Miles covered with load per running hour[3]	1.36	1.76	2.1	2.15[3]
Gain in per cent of traction machinery over horses in mileage covered with load per running hour	....	29	54	58[3]

[1] This speed corresponds to a typical case. On logging roads with long and steep descending grades in the direction of the haul, the speed of the loaded sleds may be the same or even greater than on the return journey with empties.

[2] The mean speed for a round trip is not equal to the average of the hauling and returning speed. For example, if the hauling speed is 1 m.p.h. and the returning speed is 9 m.p.h., the mean speed per round trip will be only 1.8 miles per hour, and not 5.

[3] Steam log haulers usually carry a supply of water and fuel sufficient for a 3- to 5-mile run. Thus, they have to stop about once an hour for a period of 15 or 20 minutes to refill the water tank and fuel box. When an extra water tank is hauled with the sled train and the steam log hauler is equipped with an extension fuel box for coal, the delays may be less than given above; but when cordwood is used for fuel the delays may be greater. On an average, the delays due to taking on coal and water are about 20 minutes per running hour and the actual mean speed is thus decreased from 4.3 to 3.3 miles per hour. The mileage covered per hour with a load is thus decreased from 2.15 to 1.65 and the gain in mileage per hour of a steam log hauler over horses is decreased from 58 to 22 per cent.

This table is based on running time only, therefore the actual gain in hauling efficiency for traction machinery, due to the higher speed, does not necessarily correspond to the data given in Table XII even though the gain in speed, of tractors over horses does not cause any loss in their load capacity. The actual gain or loss of tractors in hauling efficiency as compared with horses, due to the difference in speed, is proportional to the gain or loss in the mileage covered with a pay load per working hour, not per funning hour. Thus, the amount of working time which generally elapses, due to delays in hauling by horses and traction machinery should be considered, although an accurate estimate of it cannot be made, since it depends not only on the source of power used in hauling, but on the individual conditions of work in each case.

Delays in loading sleds in the woods and unloading them at the landing decrease the efficiency of hauling much more \vhen the haul is short than when it is long. Such delays are usually longer and more costly when traction machinery is used, because larger loads are hauled than with horses. However, on efficiently organized operations there should be a sufficient number of sleds to allow their use in a single or double relay. In the first case, teams or tractors wait while the sleds are unloaded at the landing, but an arrival at the other end of the road they leave the empty sleds and are immediately coupled to loaded ones. The double relay requires more equipment, but it eliminates delays at the unloading point. A team hauls only one sled at a time, while tractors, according to their power and to road conditions, haul a train of from 2 to 10 sleds and occasionally from 15 to 20 sleds. The assembling of long sled trains is a slow process, because the sleds cannot be conveniently coupled by teams. Sometimes an extra tractor is used for bringing loaded sleds from branch roads and coupling them in a train for a machine which operates only on the main road. The more common pra.ctice, however, is for tractors and log haulers to make up their own trains, which occasions a delay ranging from 5 or 10 minutes t02 or 3 hours per trip, depending on the size of the train and on working conditions.

Delays at the loading and unloading points are frequently as great and often much greater for tractors than for teams, especially when large tractors assemble their own trains. The longer the delays, the more rapidly the efficiency of hauling decreases with the shortening of the hauling distance.

The manner in which the actual productive speed of haulingpy horses and by tractors depends on the time elapsed per trip and on the length of the haul is shown in the following table.

TABLE XIII

MILEAGE COVERED PER HOUR BY HORSES OR TRACTION MACHINERY WITH A NORMAL LOAD[1]

Assumed elapsed working time, per round trip	*Length of haul (single trip)*	*Unit of measure*	*Horses*	*Full-crawler tractors* 5-ton	*Full-crawler tractors* 10-ton	*Gas haulers* 5-ton	*Gas haulers* 10-ton	*Steam log haulers*[2]
Minutes	Miles		m.p.h.	m.p.h.	m.p.h.	m.p.h.	m.p.h.	m.p.h.
0 Running time only, *i.e.*, time when tractors or horses are hauling loaded or empty sleds	....	Miles per running hour (loaded)	1.36	1.76	1.76	2.10	2.10	1.65
30 Same for horses and traction machinery	10	Miles per working hour (loaded)	1.27	1.62	1.62	1.91	1.91	1.53
	5		1.21	1.50	1.50	1.73	1.73	1.42
	2½		1.07	1.30	1.30	1.48	1.48	1.24
	1¼		.88	1.03	1.03	1.14	1.14	1.00
30, for horses; 60, for 5-ton traction machinery; 90, for 10-ton traction machinery; 120, for steam log haulers	10	Miles per working hour (loaded)	1.27	1.49	1.39	1.74	1.60	1.46
	5		1.21	1.30	1.15	1.48	1.29	.91
	2½		1.07	1.03	.86	1.14	.93	.62
	1¼		.88	.73	.57	.78	.59	.38

[1] It is assumed that the pay load is hauled in one direction only and that the empty sleds are returned each time.

[2] The time necessary to load with water and fuel is considered for steam log haulers, only. See footnote 3, page 100.

TABLE XIV

NORMAL HAULING CAPACITY OF HORSES AND CRAWLER TRACTION EQUIPMENT[1]

Draft Power	Pulling Power: Normal	Pulling Power: Maximum	Pulling Power: Comparative load capacity	Normal Load Capacity: Iced road, favorable profile		Normal Load Capacity: Average road conditions		Normal Load Capacity: Poor road conditions, snow bottom, unfavorable profile	
	H.P.	H.P.		Tons	1000 ft.b.m.[3]	Tons	1000 ft.b.m.[3]	Tons	1000 ft.b.m.[3]
Horse (1500 lbs.)	1	3 to 4	1	9	1.8	4.5	0.9	2.25	0.45
Full-Crawler Tractor 5-ton	25	....	10[1]	90	18	45	9	22.5	4.5
Full-Crawler Tractor 10-ton	40	....	16[2]	144	28.8	72	14.4	31	7.2
Gas Log Hauler 5-ton	25	....	10	90	18	45	9	22.5	4.5
Gas Log Hauler 10-ton	50	....	20	180	36	90	18	45	9
Steam Log Hauler	100	....	40	360	72	180	36	90	18

[1] It is considered that the tractive force exerted by a horse under ordinary conditions of sled transportation is equivalent to 2½ drawbar horse-power of a crawler tractor.

[2] Some loggers believe that the actual load capacity of a full-crawler tractor, especially on hilly roads, is from 30 to 40 per cent less than for gas log haulers of equal power, due to the considerations of safety and other factors mentioned on pages 84 and 85.

[3] It is assumed that logs weigh 5 tons per 1000 feet, log scale, and that the weight of the sleds is 10 per cent of the gross load, and that the ratio between the load capacity of horses and tractors when hauling under good or bad road conditions, is the same as for average road conditions. This is not always true (see page 99), but the assumption is made because otherwise it would not be possible to arrive at a general, although approximate, conclusion in regard to the comparative merits of horses and tractors in hauling.

The capacity load of a horse or tractor may vary from zero, under the most adverse conditions, to an enormous weight on a good road with a favorable down-hill grade. Loggers, in the Lake States, using teams and taking advantage of a very favorable road profile, have hauled loads of logs as great as 8000 board feet or 40 tons net per horse, over iced roads several miles in length. However, such large loads are notpracticaJ, even on the best sled roads, and they have been hauled chiefly with the desire to establish a record.

The approximate capacity load for a horse or a tractor hauling under specified sled road conditions may be calculated from the data on pages 92 to 95.

The actual average sled load hauled over main roads is approximately 900 board feet of logs, or about 4.5 tons net per horse,[1] for average road conditions. The normal capacity load on a poor snow road with an unfavorable profile is approximately one-half of the above, while for excellent road conditions, such as a good iced road with a favorable profile, it may be twice as great.

The efficiency of horses or tractors in hauling; measured in ton-miles per hour, is equal to the average weight of the load, in tons per trip, times the distance, in miles, which the load is hauled per hour.

The comparative efficiency of sled hauling with horses and crawler tractors, under average road conditions, is shown in Table XV, which has been based on Tables XIII and XIV.

The higher mean speed of tractors as compared to that of horses usually increases the efficiency of hauling with tractors, because,as a rule, the resistance on various sections of a sled road is variable.[2] The data presented in Tables XIV and XV on comparative load capacity and on comparative efficiency of sled hauling with horses and tractive machinery are based on this assumption. The result of this comparison would be less favorable to tractors on a logging road that offered a uniform resistance to hauling, because the higher speed of hauling, even without a loss in energy development, would necessarily cause a corresponding decrease in the capacity load and, therefore, would add nothing to the efficiency of hauling.[2] Thus, if the resistance of the road was uniform throughout, the comparative efficiency of

1 It is assumed that the sled weighs 10 per cent of the gross load, and that logs weigh 5 tons per thousand board feet.

2 See page 99.

TABLE XV

COMPARATIVE EFFICIENCY OF HORSES AND CRAWLER TRACTION EQUIPMENT

Assumed elapsed time per round trip	*Length of haul (single trip)*	*Net load hauled in ton-miles per hour under average road conditions*						*Number of horses which crawler traction machinery will replace*					
			Full-crawler tractor		*Gas log hauler*		*Steam log hauler*	*Horse (1500 lbs.)*	*Full-crawler tractor*		*Gas log hauler*		*Steam log hauler*
		Horse	*5-ton*	*10-ton*	*5-ton*	*10-ton*			*5-ton*	*10-ton*	*5-ton*	*10-ton*	
Minutes	Miles												
0[1, 2]	Any distance	6.1	79	127	95	189	298	1	13	21	15½	31	49
30[3]	10	5.7	73	117	86	172	276	1	13	20½	15	30	48½
	5	5.4	67	108	77	156	256	1	12½	20	14½	29	47½
	2.5	4.8	58	93	67	133	224	1	12	19½	14	28	46½
	1.25	4.0	46	74	51	103	180	1	11½	18½	13	25½	45
30 for horses	10	5.7	67	100	78	144	263	1	11½	17½	13½	25½	46
60 for 5-ton traction machinery	5	5.4	58	83	67	116	164	1	11	15½	12½	21½	30½
90 for 10-ton traction machinery	2.5	4.8	46	62	51	84	113	1	9½	13	10½	17½	23½
150 for steam log haulers	1.25	4.0	33	41	35	53	68	1	8	10	9	13	17

[1] The time necessary for taking on water and fuel for steam log haulers is included. See page 100, footnote 3.

[2] Only running time, *i.e.,* time spent for actual hauling of load and empty sleds is considered.

[3] The same time is allotted both for horses and for traction machinery.

hauling a load with horses and tractors would be proportional to their tractive energy or their load capacity.

TABLE XVI

TRACTOR EQUIVALENTS IN HORSES[1]

Type	*Weight* *Tons*	*Horses* *Number*
Full-	5	10
Crawler	10	16
Gas Log	5	10
Hauler	10	20
Steam Log Hauler	18	40[2]

COMPARATIVE COST OF HAULING WITH HORSES AND WITH MECHANICAL DRAFT

The comparative costs of hauling with horses and with tractors, shown in Table XVII, are deduced from previously given approximate average data on the cost of using horses and operating crawler tractors[3] and on the number of horses which would be required to do an amount of productive work equivalent to the work of one crawler tractor. It should be borne in mind that this table gives the comparative costs of horse and tractor hauling under the assumption that they are used in an equally efficient manner and, therefore, does not represent total hauling expenses. It is helpful, however, in determining whether horse or tractor hauling is the more economical.

Table XVII shows that hauling with a 2-horse team is usually more expensive than with a 4-horse one and that large capacity traction machinery is less expensive than horses, especially on long hauls. This is true in so far as concerns those expenses which are directly involved in the process of hauling by horses or tractors, and in this table only those factors which can be generalized and readily expressed in figures have been considered.

[1] Based on hauling on a sled road which has a uniform resistance throughout. Running time, only, considered.

[2] This should be reduced to 30 horses, provided the time covered by delays incident to loading fuel and water are added.

[3] See Tables III and X.

TABLE XVII

COMPARATIVE COST OF SLED HAULING WITH HORSES AND WITH CRAWLER TRACTORS[1]

Road conditions	*Elapsed time, per round trip*	*Length of haul (single trip)*	*Horse* *4-horse team*	*Horse* *2-horse team*	*Full-crawler Tractor* *5-ton*	*Full-crawler Tractor* *10-ton*	*Log Hauler* *Gas* *5-ton*	*Log Hauler* *Gas* *10-ton*	*Log Hauler* *Steam* *18-ton*[3]
		Miles	per cent	per cent	per cent	per cent	per cent	per cent	per cent
Road resistance uniform throughout its length[2]	None—running time, only, considered	..	100	125	100	85	111	77	77
Road resistance variable[2]	None—running time, only, considered	..	100	125	77	65	72	49	47
	30 minutes—for horses	10	100	125	87	78	82	60	49
	60 minutes for a 5-ton tractor	5	100	125	91	88	90	72	75
	90 minutes for a 10-ton tractor	2½	100	125	105	104	105	74	98
	150 minutes for a steam log hauler	1¼	100	125	125	136	123	117	134

[1] The data in this table are based on the assumption that the cost of a horse operated in a 4-horse team is equal to 100 per cent.

[2] See page 99.

[3] The data for steam log haulers includes the time necessary to take water and fuel.

The total cost of sled hauling by horses or tractors includes:

1. The cost of teamster labor and horses or tractor operation.[1]
2. The cost of sled depreciation and maintenance.[2]
3. The cost of construction and maintenance of sled roads.[3]

Although the cost of sled hauling with a 2-horse team is generally higher than for a 4-horse team because of the driver's wages, yet the cost of hauling with a 4-horse team maybe higher because the load is much heavier and it may require a stronger road, which, under certain conditions, might be much more expensive to construct and to maintain than a sled road which would be suitable for hauling with a 2-horse team.

Some sled roads built for team hauling may be suitable for a heavy tractor, but usually this is not the case.[4] There may be a great difference between the cost of a sled road for horses and one for tractors, particularly when steam log haulers are used, because of their heavy weight and great hauling capacity.

Traction machinery is often handicapped by the conditions under which it must work, due to the fact that horse draft has been used by loggers for generations and is thoroughly understood, while crawler tractors are of comparatively recent origin and many loggers have little or no knowledge about their proper care and use. Usually when sled hauling with crawler tractors has been a financial failure, it has been due to frequent breakdowns which have resulted from improper handling. This is particularly true in so far as full-crawler tractors are concerned, in the use of which the working time lost on account of breakdowns is often from 10 to 25 per cent of the total and in some cases much greater. Tractors, when out of order, usually cannot be readily replaced and, therefore, in addition to a heavy expense for repairs a great loss may result from the forced cessation of hauling, which causes labor directly or indirectly dependent on hauling to remain idle until the tractor is again ready for use.[5] Delays may also occur because of the sickness at injury of some of the horses, but the latter are more easily replaced than tractors and it is rarely the case that many horses are disabled at one time. The financial risk of the logger, due to the possi-

1 See Tables III, IV, X, XV.

2 See page 57.

3 See Table I.

4 The road and bridges must be much stronger, the curves less sharp and the down-grades less steep than when hauling single sleds with teams.

5 Some loggers who use full-crawler tractors for sled hauling have an extra machine which may be substituted for one which is temporarily laid up for repairs.

bility of equipment breakdowns, is greatest when traction machinery of large capacity is used and when unexpected climatic conditions reduce the length of the sled hauling season.

Tractors may be handicapped by road conditions to a greater extent than teams, in so far as capacity loads are concerned, because loggers often do not spend enough money on the road to make the movement of large loads possible. Thus, tractors often work underloaded while horses haul their capacity loads on hilly roads which were built cheaply for the transportation of limited quantities of timber.

When considering the replacement of horses by large-capacity traction machinery, it is well to remember that different sleds must be used; stronger and better roads may be required; and that some changes in the method of sled loading and unloading may be desirable or necessary. The most practical distance between sled roads and the most practical skidding distance may vary considerably, depending on whether hauling is done with teams or with large-capacity tractors. Therefore, the choice between animal and mechanical draft for sled hauling may affect the cost of other phases of logging and this possible difference in cost must be taken into account when considering whether horse or mechanical hauling would prove most economical.

There may be cases in which the total cost of sled hauling with crawler tractors is less than it would be with horses and in which mechanical hauling would not increase the cost of any other phase of logging, yet the use of mechanical draft would be less economical than animal draft. For example, a logging company may own many horses which are used for skidding timber and which, after the completion of this part of the logging work, cannot be used during the remainder of the winter for any purpose other than for hauling. Under such circumstances, even though hauling would be cheaper with tractors, economy in that one phase of logging might be more than offset by the expense incident to feeding and caring for horses that are idle during the hauling season.

Although it is difficult to make positive general statements of fact with reference to when animals or tractors are the more profitable, yet it can be safely said that powerful crawler tractors are preferable to horses, when a large volume of timber[1] must be hauled for a relatively long distance,[2] provided the tractor is kept running steadily and hauls capacity loads.

1 The volume of timber should be great enough to keep one or more tractors continually employed.

2 Four miles or more.

Thirty years ago, a logger, impressed by the performance of one of the first crawler traction machines made for log hauling, remarked, "She'd revolutionize the business if she'd only go." Such machines have now reached a point of mechanical perfection where they do "go" and the peaceful revolution predicted by the logger is rapidly taking place. There is every indication that the number in use will gro\v greater each year.

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