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The Transportation of Wood in Chutes

Alexander M. Koroleff

Ralph Clement Bryant

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THE TRANSPORTATION OF WOOD IN CHUTES

BY

ALEXANDER M. KOROLEFF, M.F.
Forester, Canadian Pulp and Paper Association

AND

RALPH CLEMENT BRYANT, F.E., M.A., Sc.D.
Professor of Lumbering, Yale University

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A Note to Readers
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Saw logs moving down a V-chute and discharging into a pond along the logging railroad. St. Joe National Forest} Idaho. (Photo by courtesy U.S. Forest Service.)

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FOREWORD

ARTIFICIAL channels, known as chutes, in which logs and bolts may be transported down steep slopes by means of gravity, were devised several centuries ago in the mountainous regions of Europe[1] and later were used by North American loggers, especially in New England, New York, and Pennsylvania. They operate most advantageously on grades that are far in excess of those on which wheeled vehicles or sleds can be used safely, and they are most serviceable for moving timber on terrain which is so steep or broken that the construction cost of suitable roads is prohibitive.

Chutes vary greatly in type, ranging from crude earthen channels to highly perfected wooden and metal troughs supported on timber work designed to provide a solid bottom and to make sharp horizontal and vertical changes in the chute profile unnecessary.

For many years there was but little literature concerning chutes because forest managers in Europe and loggers on this continent left the design and construction of their transport devices chiefly to practical woodsmen whose knowledge of the physical laws involved in the movement of bodies on an inclined plane was wholly empirical. As a result many of the earlier chutes possessed faults, such as unsuitable grades and horizontal and vertical curves, which often caused them to function unsatisfactorily, especially in the case of long and large logs.

The first technical articles treating of chute construction and operation appeared about 1870 when foresters in the Salzkammergut region in Austria were becoming interested in road slides[2] as a means for transporting timber from the high mountain forests to roads in the valleys below. Among the technical writers about chutes of that period, all of whom were Austrians, were G. R. Förster, Steiner, and Petraschek, the latter in 1878 publishing an article entitled "Das Gefälle der Holzriesen," in which he included tables of coefficients of friction for given types and conditions of channels which are still considered as standard. The greater part of the chute literature, however, has been published since 1900 and has been pre-

[1] Chutes are reported to have been used in the Tirol district in Austria as early as the sixteenth century. See *Oesterreiches Vierteljahresschrift für Forstwesen,* p. 85, 1930.

[2] See p. 38.

pared chiefly by Austrian forest engineers actively engaged in the forest transportation field, among them Baltz, Hauska, Kubelka, Marchet, Micklitz, Schönweise, and v. Angerholzer, and by Miura of Japan. All of these writings have proved helpful to the authors of this bulletin, especially in the preparation of Part II.

The construction of chutes on this continent has followed different lines from those used in Europe where the major attention has been given to road slides, which, so far as known, have never been built on this continent. The common type of North American chute has been one with a V-shaped channel, and this may still be considered as the predominant one in use by American loggers, although several other forms of channels also have been employed.

The authors have been prompted to prepare this bulletin for the following reasons: (a) the inadequate knowledge possessed by loggers of the technical worth of chutes as a forest transport device; (b) the tendency of foresters to overestimate the destructiveness of chutes and to underestimate their value as a factor in the intensive management of extensive areas of mountain forests; (c) the wide adaptability of chutes to topographic conditions ranging from very rough mountain slopes to flat plains; (d) the advantage which gravity, a free motive force, offers as compared to forms of generated power which are required by other types of land transport; and (e) the lack of a comprehensive English treatise on the subject. An effort has been made to include a description of the various known types of chute channels which have been used and any new ones which, though untested, have qualities that justify a practical test. The section on the theoretical aspects of design has been confined to those simple principles and methods which it is believed can be applied readily by the practical logger.

Part I was prepared by A. M. Koroleff chiefly from field data collected by him in various regions of the United States, Canada, and Newfoundland. Part II was prepared by Ralph C. Bryant, who also was responsible for the editorial work and for the translation into English of numerous articles written in German by foreign forest engineers.

The authors here wish to express their appreciation of the interest shown in the preparation of this bulletin by the officials and members of the Woodlands Section of the Canadian Pulp and Paper Association whose support contributed much to the success of the field work. They also are indebted to the *Pulp and Paper Magazine of Canada* for the loan of several cuts and to those operators whose many courtesies aided in the collection of the field data.

THE TRANSPORTATION OF WOOD IN CHUTES

PART I

THE FORM, CONSTRUCTION, AND OPERATION OF CHUTES

THE CLASSIFICATION OF CHUTES

CHUTES may be classified under various headings depending on their gradient, the character of material to be chuted, the season of year in which used, the form of channel and method of its support, the length of use, and the degree of portability.

The most important classification factor is gradient, and we may distinguish (I) gravity or running chutes and (2) trailing chutes.

A *gravity* chute is one having grades which are steep enough to cause the wood to move down the channel by gravity, while a *trailing* chute has a profile the grades of which are so low that horses, a tractor, or a donkey engine and cable are required to keep the wood in motion. There are many chutes on which logs will move by gravity only for a portion of the distance, such channels being combination gravity and trailing chutes. Logs always will move by gravity on steep gradients regardless of weather; but often a chute having a low gradient may quickly change with weather conditions from a trailing to a gravity chute or *vice versa*. Chute resistance is at a minimum during the winter when the channel is wet, frosty, or coated with snow or ice. Hence, some chutes having relatively low gradients may be serviceable as gravity chutes during the winter only, while others having steep grades may be too fast for winter use and, therefore, can be used only during the summer. This leads to a general classification of chutes into *winter* and *summer* ones, respectively.

The kind and size of the material chuted usually determine the type, the size, and the general layout of the chute itself. Hence, they often are classified as *saw log, pulpwood,* or *cordwood* chutes.

The channel cross section may be *semicircular, U-shaped,* or *V-shaped,* with a great variation in width and depth as well as in the ratio between these two dimensions. Chute channels usually are *open* on top, but a channel may be completely *enclosed* at points where there is danger of wood leaving it.

The channel itself may be fashioned from *wood* in the form of logs, poles, planks, and slabs; it may be made from *sheet iron* or *steel* plates; it may be a groove in the *earth* which is iced; or it may be a so-called road slide, which is an *earth channel} floored witlt cross skids* at given intervals, and mayor may not be equipped with fender skids. The channel may be *imbedded* in the earth, laid directly on the ground surface or *on skids* or *crossties}* supported on *cribwork* or *trestle bents,* or *suspended from a cable.*

Chutes also may be *stationary* or *portable} temporary* or *permanent}* or comprise a *main* chute or a *branch* or *feeder.*

For convenience in the discussion of chutes the authors also have broadly grouped them into *customary forms}* or those best known and most frequently used, and *miscellaneous forms}* or those less well known and less frequently used.

CUSTOMARY FORMS

There are two general types included under this category; namely, *pole* chutes and *hewed log* V-chutes.

POLE CHUTES FOR SHORT TIMBER

This type is adapted chiefly for chuting pulpwood, firewood, crossties, and other relatively small-sized material by gravity, although if strongly enough constructed it may be used for small and medium-sized saw logs.

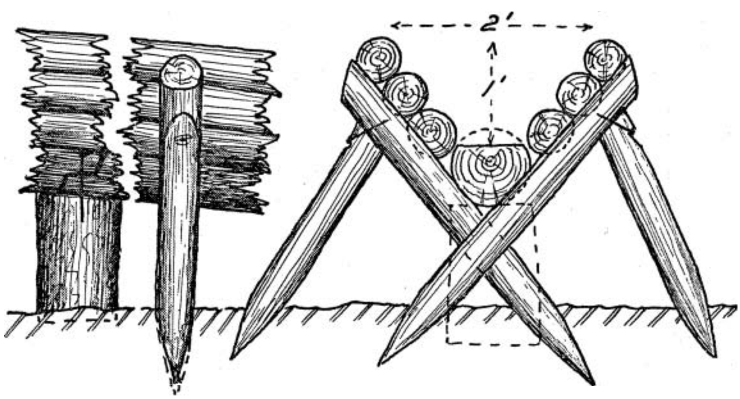

Fig. 1. A common type of pole chute. The supports are those used when the trough is not more than 5 feet above the ground level. Eastern Canada.

Pole chutes, generally speaking, are more widely known than any other type. They are in frequent use in the Appalachian section and fairly common in the mountainous portions of the Northeast and in the Rocky Mountain region, although in the latter district the V-chute predominates. In eastern Canada and Newfoundland 99 per cent of all chutes are of the

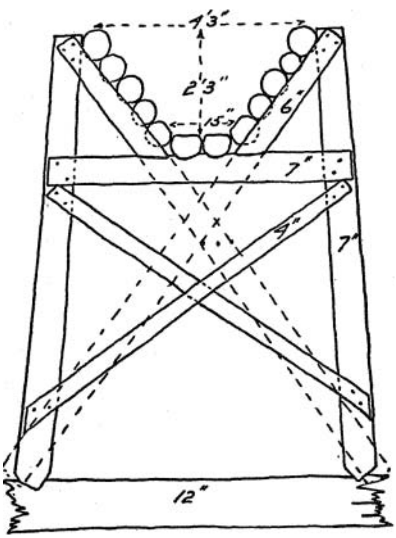

Fig. 2. A pulpwood pole chute. The channel is too wide for small wood, and the trestle bent bracing and the chute support are relatively weak. The strength of this form of trestle could be greatly increased by continuing the chute supports as shown by the dotted lines. Eastern Canada.

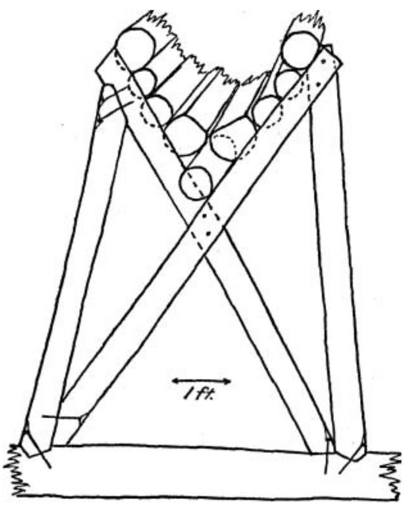

Fig. 3. A V-shaped pole chute. Both the trough and trestle bent represent a good type. Eastern Canada.

pole type, while in western Canada the pole and V-types both are used. In Europe and India pole chutes are the predominant type.

Pole chutes often are built very crudely and cheaply for moving a limited volume of wood down slopes which are too steep for horse logging. They usually are from a few hundred feet to a half mile in length. However, gravity pole chutes two miles in length have been used successfully in North America; in Europe greater lengths have been operated to advantage.

The chief function of a pole chute is to transport wood from plateaus or the upper reaches of steep mountain slopes to drivable streams or lakes in the valleys. In the North this work usually is done during the winter season, the wood being piled on the ice or stream banks ready for floating during the coming spring.

The channel. The typical pole chute has a U-shaped trough, made from five to twelve poles from 4 to 8 inches thick, which is supported at intervals of 10 or 15 feet on skids, cribwork, or trestle bents (Figs. 1, 2, and 3).

Sometimes the channel is made from two poles only, but such a trough is impractical, even on very short and straight sections, because of the tendency of the wood to leave it.

The 3-pole chute (Fig. 4) is rarely used and then only when the distance is short, the grades uniform, and the wood limited in quantity and of the same general size. It gives satisfactory results only on straight chutes on which the velocity is relatively low.

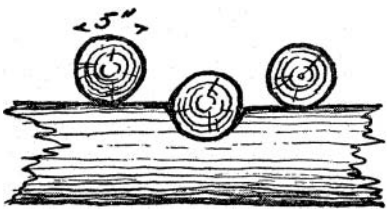

Fig. 4. A type of 3-pole chute occasionally used for pulpwood transport.

The shape and size of the channel of a pole chute are determined chiefly by the character of the material to be chuted, by the gradient, and by the constructor's ideas or by local custom. When the grade is steep, the profile irregular, or the chute of great length, the channel must be more strongly built and deeper than on short lengths or low grades.

The types of chutes shown in Figs. 1 to 3 and 5 and 6 are those used in eastern Canada for moving 4-foot pulpwood bolts having a diameter range of from 3 to 18 inches and an average of 6 inches. They represent the usual forms used throughout North America for moving small material.

The width of the trough at the bottom varies with the chute cross section, which may be semicircular, U-shaped, or V-shaped. The usual channel dimensions for depth and top width are from 12 to 30 inches and from 24 to 48 inches, respectively, on straight sections suitable for pulpwood of the sizes previously mentioned. These must be increased somewhat for curved sections.

The trough poles usually are made from conifers and should be as straight and sll100th as possible, from 3 to 5 inches in top diameter and from 12 to 30 feet in length. Straight hard\voods, such as birch, often are preferred by loggers for the bottom of the chute. The poles may be peeled

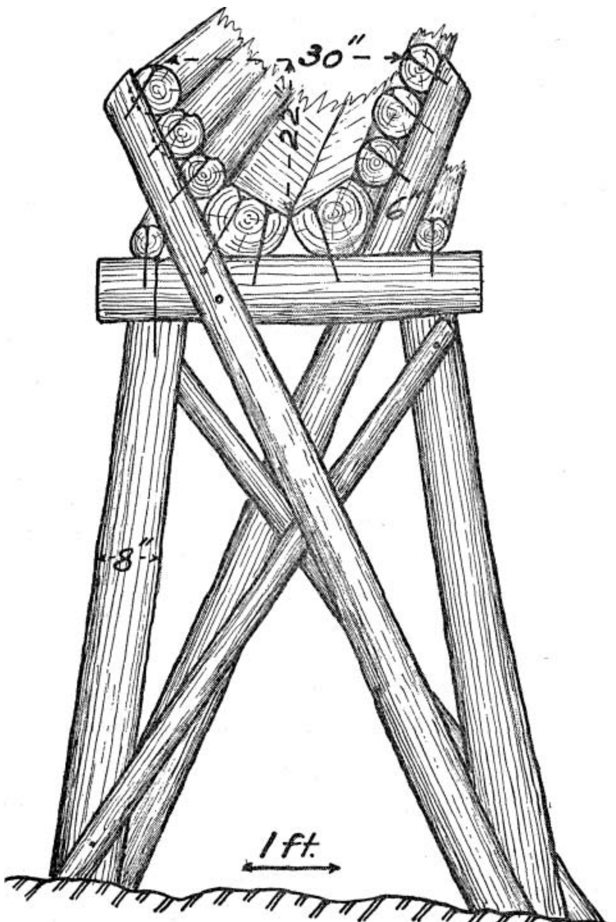

Fig. 5. AV..shaped pole chute of excellent design. Eastern Canada.

to make them smoother, although some ross only the bottom ones on low grades and leave them rough on steep grades in order to increase the frictional resistance. Poles which have swelled butts are "jump butted" and the lower ends are used in the substructure. Hewing of the poles is kept at a minimum and when done is restricted to the bottom logs and to the removal of any projections which would make the channel uneven and tend to interfere with its successful operation.

The channel members (at least the bottom ones) are laid with the butts pointing upgrade in order to decrease the wear on them by slivering. The individual poles should always be long enough to span at least two bents, and the joints should be staggered so that not more than one-half of them meet at one support, otherwise the trough will lack strength and will get out of alignment readily. An ideal support is one that possesses the requisite strength, requires only a limited amount of labor to frame it, and has its various parts so arranged that there is no possibility of any moving wood coming into contact with them.

The poles usually are fastened to the supports by nails, the heads of which are countersunk into notches cut with an ax. Wooden trenails, although formerly common, are now rarely used for this purpose.

The poles forming the channel must be placed close together when maximum strength is required. However, a spacing of about an inch often is left between the individual poles in order to economize on material and labor and also to permit bark, snow, and other débris to drop out of the channel.

The substructure. The type used to support the trough is governed chiefly by the height of the channel above the general ground level. When possible, the channel is supported on cross skids placed directly on the ground at intervals of from 8 to 15 feet or on crossed posts driven into the ground and braced as shown in Fig. 1. The latter type is also often used when the trough is not elevated more than 5 feet above the ground level, although cribwork is employed frequently under such conditions. When the channel is elevated more than 5 feet, pole trestles of several types are used. An important factor in the use of any of the above forms of support is to make certain that no part of the support projects above the trough or is located so that it can be hit by any piece of wood which may jump the channel.

A common type of chute and support used by those not familiar with the technique of chute construction is shown in Fig. 6. The trough is too shallow so that wood moving at a high velocity tends to leave the channel, and the excessive width of the latter permits the moving wood to attain a lateral motion which gradually will weaken the structure. The braces also are inadequate and cannot be made sufficiently rigid by nailing to maintain the chute in proper condition.

The type shown in Fig. 1 is much better than that in Fig. 6. The bottom log is preferably hewed flat or it may be left round, the chuted logs gradually wearing it down to a concave form. The bottom of the trough, at a point midway between the two supports, rests upon a block which adds much to the rigidity of the chute and also may serve as a point where two bottom logs may be spliced.

The chute shown in Fig. 2 has a cross section which is excessive for 6-inch pulpwood. In general the structure lacks stability, the supports being nailed only to the caps and side posts. The strength of this trestle could be greatly increased by continuing the supports to the ground sill, as shown by the dotted lines, or in the manner indicated in Fig. 5.

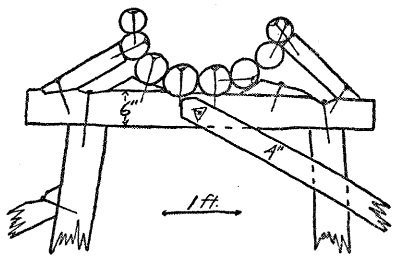

Fig. 6. A semicircular pole chute of a type sometimes constructed by operators who lack the necessary chute technique. This is an unsatisfactory form because the trough is too wide and the trestle bent bracing is inadequate. Eastern Canada.

The pole chutes shown in Figs. 3 and 5 represent satisfactory designs. The bottom logs of the trough are hewed V-shaped to reduce lateral motion and cause the wood to follow the center line; the walls also are sufficiently high and steep to reduce "jumping" to a minimum.

The method of joining the post and brace shown in the upper left corner of Fig. 3 provides a much stronger joint than that shown in the right-hand corner, but requires more labor to fashion it. The trestle in Fig. 5 is more substantial than that shown in Fig. 3, but it likewise requires more material and labor.

Trestles may be 50 feet or more in height when the chute crosses a deep depression, and in such cases they should be built in "stories" like railroad trestles, each story of every bent being braced diagonally and the various stories connected by longitudinal braces made from small poles (Fig. 7). When the bottom is soft or the trestle is more than 10 feet in height, each bent should rest on a mud sill.

The intake or head. The intake or head where the wood is put into the chute should be adapted for fast feeding. The funnel-like intake (Fig. 8) is a common and practical form for small material such as pulpwood and fuelwood bolts. It comprises a shallo\v trench which 'is' made in the ground surface below the point where wood is assembled for chuting, is lined with poles placed directly on the ground or on skids, and is contracted as it approaches the chute so that it forms a funnel that conducts the wood into the chute proper. Suchan intake should have a minimum grade of 35 per cent, a still greater slope being preferable.

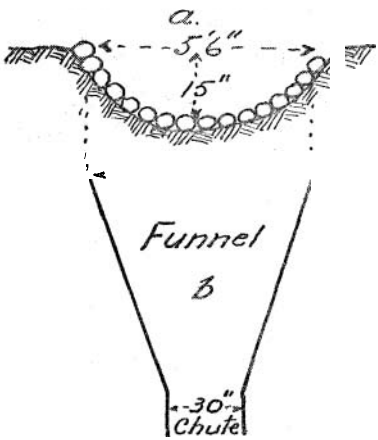

Fig. 8. The intake or head of a pole chute. *a*, cross section showing the funnel channel lined with poles; *b*, a top view of the funnel.

When the chute is very steep, a pole should be placed across the funnel top in order to prevent \vorkmen or horses from slipping into the channel. Wood may be "loaded" into the chute by a special crew, or the teamsters may unload their own sleds and feed the wood into the channel.

The lower terminal. Mnch thought and attention should be given both to the proper arrangement of the lo\ver end of the chute and to the landing or dump in order that excessive \vood breakage may be avoided and also that it may be possible to remove the chuted wood, cheaply and safely, by some other form of transport. The chief factors which must be taken into consideration are:

(I) The profile of the chute and the velocity of the logs as they leave it.

(2) The size, kind, and volulue of wood.

(3) The character of the landing and the amount of storage space available.

(4) The need for the immediate rehandling of the wood or for its temporary storage.

The wood may be discharged in ,vater, on the ice of frozen lakes or ri.vers, or on the ground, the preference being in the order named. When a deep-water landing on a swiftly flowing stream is available (which is rarely the case), wood may be discharged at a relatively high velocity without nn-

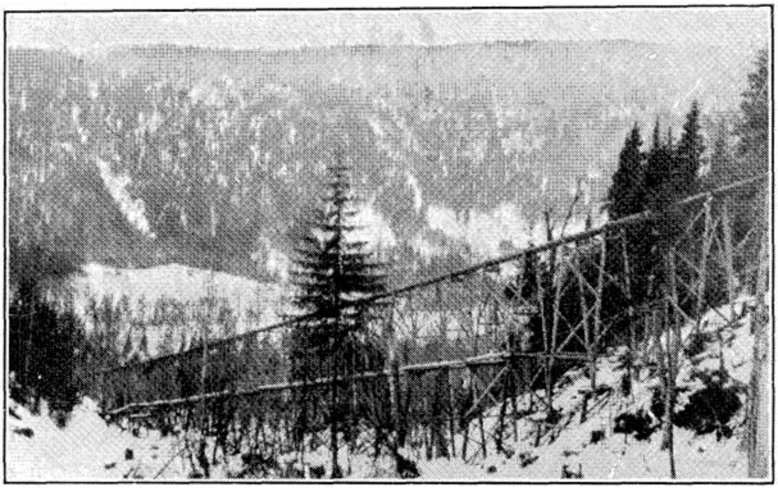

Fig. 7. The type of trestle support used on a high chute, The maximum elevation above ground was 45 feet. Eastern Canada.

Fig. 9. A typical pulpwood pole chute discharging wood from a trough elevated on a trestle bent. Eastern Canada.

due breakage. Ice landings predominate in the North, and the practice is to accumulate wood in relatively large piles in a stream channel down which it is moved by the spring freshets. Under such conditions it is essential that the wood leave the chute at a relatively low velocity, the maximum depending on the value of the \vood, its degree of brittleness, and the general character of the landing itself. Under favorable conditions the maximum for 4-foot wood rarely exceeds a velocity of from IS to 20 miles per hour.

The profile of a steep chute should be gradually flattened as the lower terminal is approached, the latter being horizontal or nearly so and, in some cases, having a counter grade. The breakage of wood is excessive and the end of the chute is soon clogged when \vood is discharged straight upon a landing ground or into a pile of wood previously accumulated.

It frequently is desirable to accumulate a relatively large quantity of wood in one pile at the end of a chute, and when this is the case the chute should, if possible, terminate at a point on a steep slope or high stream bank where the discharged wood drops naturally to a lower level. When the ground conditions do not make this possible, the end of the chute may be elevated by means of a trestle (Fig. 9). On some pulpwood operations in eastern Canada the wood is dropped for a distance as great as 100 feet, in which case breakage may be reduced by first dropping the wood upon a steep incline from ·which it ricochets or falls to the lower level.

When a large volume of wood is to be accumulated at the end of a chute, one of two methods usually is followed; namely, the formation of a high, compact pile of wood upon a stream landing of limited size or the rather wide distribution of the wood over the ice.

From 2,000 to 3,000 cords of wood may be stored in a single pile on the ice of a large, deep, and swift river having high banks, and ordinarily only a very limited amount of manual labor will be required to start it down stream the next spring. On the other hand, the placement of an excessive amount of wood on a small stream is usually accompanied by driving troubles. Often dynamite may be needed to break up the frozen mass and much hand labor required to loosen the wood so that it will float down the stream and also to salvage the wood on the banks .which the current cannot dislodge. On small streams, where the velocity of the current is rather slow and the volume of water is limited, a tunnel is sometimes built to provide a free channel for the \vater. A limited amount of wood is first chuted and used in making a small tunnel, on top of which the remainder of the wood is dumped, or an opening through the pile may be made by hand labor after all of the wood has been chuted. Ho,vever, the latter method requires too much labor to be profitable.

There are several methods which may be used to facilitate the drive and minimize the .breakage loss when large quantities of wood are stored in relatively small rivers.

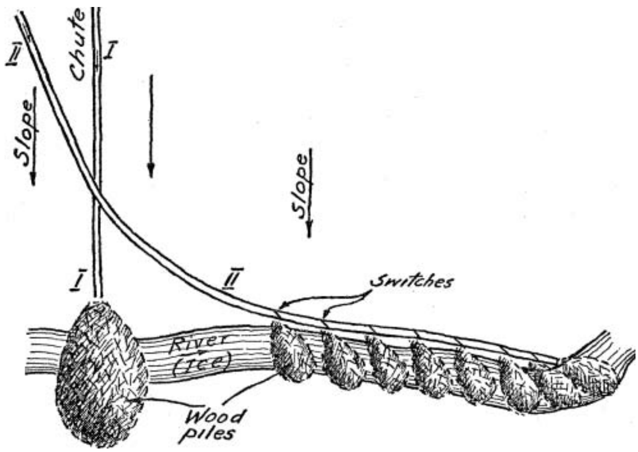

Fig. 10. A pole chute dump on a river. I, chuting ,vood down a steep slope into one large pile which is at right angles to the stream; II, discharging wood into several small piles directly in the stream bed. Wood thus distributed often can be driven at a lower labor cost than when discharged into one large pile.

Many an inexperienced logger runs his chute directly do\vn very steep slopes and discharges the wood in a large pile as shown in Fig. la, I. A better practice is to curve the lower end of the chute so that it parallels the stream channel, thus permitting the discharge of wood at a low velocity parallel to the stream and at various points along the channel as in Fig. la, II. The wood is deflected from the trough by impact against a plank or log switch fastened across the trough at a sharp angle and thus is diverted from the trough, the outer side of which is cut down at the switch point. When it is desired to close any-given switch, it is only necessary to remove the crossbar and insert it in the gap in the outer part of the trough timber, where it is held in position by trenails.

The chute also may have one or more forks at the bottom so that wood can be deposited in several places. Wood may be spread at the discharge point by one of several special types of deflectors. A rigid form which is simple and serviceable is shown in Fig. 11. A movable deflector by means of which wood may be chuted to the right or left is shown in Fig. 12. The latter comprises a deflector arm which may be bolted to the platform at various angles to the main axis of the chute. A hinged apron placed just below the platform will aid in scattering the wood, or an armored plate may be placed on the pile of wood in such a position that the discharged bolts strike it at a sharp angle and ricochet.

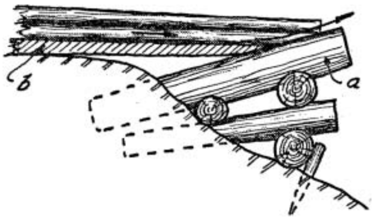

Fig. 11. A stationary deflector at the end of a pole chute which serves to distribute wood over a considerable area. *a*, the deflector; *b*, bottom pole of chute trough. (After Gayer.)

These methods are applicable when material such as pulpwood and cordwood are to be accumulated in large piles. When the chuted wood is to be rehandled at once, the chuting opera-

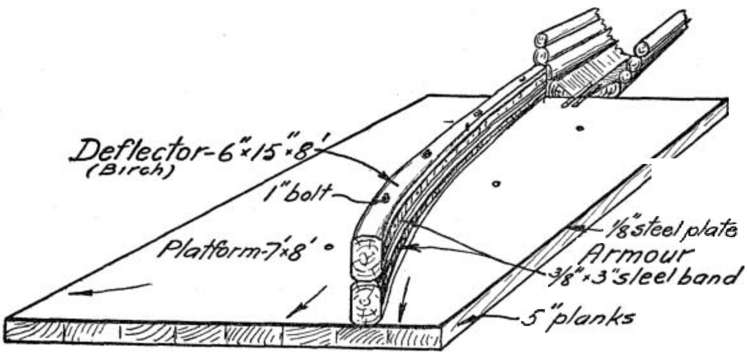

Fig. 12. A movable deflector at the end of a pole chute. The deflector arm may be moved and bolted at various angles to the end of the chute so that the wood may be widely distributed.

tion must be intermittent or the chute terminal forked so that workmen may remove wood from one branch while wood is being sent down the other.

Location problems. Two important factors in chute location are *grades* and *curves*, because it is essential that they correspond to the character of wood being chuted; otherwise serious operating troubles are certain to arise.

Grade.[3] The selection of the proper grade for any given section of chute is difficult and can only be done in an approximate manner because the velocity is affected by numerous factors, among the more important of which are the following:

(1) The natural gradient, which is not uniform throughout the length of the chute.

(2) The velocity of the chuted wood, which depends upon its size, weight, and degree of smoothness.

(3) The weather conditions, which may cause a rather rapid change in the frictional resistance between the chuted wood and the channel.

(4) The shape of the chute trough and the material from which it is made.

(5) The number and size of both horizontal and vertical curves and the technical skill displayed in locating and constructing such channel sections.

The angle of repose for an average softwood bolt 4 inches in diameter by 4 feet in length, moving in a typical pole chute, is about 14° (25 per cent) for dry summer conditions and somewhat less for winter conditions. A bolt of the above size, having attained a fair momentum, will continue to move on a grade of 11° or about 20 per cent. Larger bolts than the above will start to move on a somewhat lower grade and will attain a greater velocity, although the difference in speed of a 4-inch as contrasted with a 12-inch bolt, after having traversed several hundred feet of chute, often is not more than from 10 to 15 per cent. This difference, however, increases with the length of chute and is greater under summer than under winter conditions.

The optimum average speed for wood moving down a pole chute varies from 20 to 40 miles per hour (30 to 60 feet per second), and the optimum grade is between 14° and 22° (25 and 40 per cent). Wood may attain a velocity of 80 miles per hour (120 feet per second) or more on very steep chutes; however, even on straight sections, a velocity in excess of 50 or 60 miles per hour is very undesirable because excessive wood breakage and chute damage are likely to result from logs which leave the channel. Gradients of 35° (70 per cent) and, for short sections, of 45° (100 per cent) are found sometimes on pole chutes, but when they exceed 22°, and some-

3 See Part II, THEORETICAL CONSIDERATIONS IN GRAVITY CHUTE CONSTRUCTION AND OPERATION.

times even less, it becomes essential to install devices for the control and reduction of log velocity. Various devices used for this purpose are discussed in the section on DEVICES USED FOR CONTROL OF LOG VELOCITY. The most effective of these are the various forms of wolf brakes (Figs. 47 to 52 inclusive, and Fig. 59), which are discussed on pages 73 to 83.

Curves.[4] The chute constructor does not find it practicable to eliminate curves entirely because it is rarely the case that the alignment can be made straight and the gradient uniform at a reasonable construction cost. Horizontal curves should have a fairly long radius because the shorter the radius, the greater the braking effect of the curve on the velocity of the log and the more difficult it is to fashion the channel into a true curve, resulting in greater danger of logs leaving the chute at the curve and of the channel itself being damaged by impact. However, curves are more expensive to construct than straight sections, and since the curve length increases as the length of radius, a compromise usually is adopted by using the shortest radius that will provide satisfactory operating conditions. A chute channel for short bolts may have a curve with a radius as short as 50 feet, provided the trough is strongly constructed and the gradient is ample to overcome the resistance due to centrifugal force. A radius of 100 feet is preferable even for short wood, and, in general, one of 150 feet will be reasonably satisfactory for logs and bolts 8 feet and less in length.

The cross section of a chute channel must be altered on a curve because centrifugal force tends to cause logs to leave the trough. The latter is widened and its outer wall built higher than the inner one. The poles from which the trough is built should be larger, the trough should be more strongly braced on the outside, a heavier and more substantial substructure should be provided, and the distance between bents should be decreased as the radius becomes less in order that shorter poles may be used and the trough given a more circular form than would be possible with long poles.

The correlation between chute design and curvature is discussed in greater detail in Part II.

Construction work. The construction of a pole chute includes the following steps in the order of their performance: location; cutting and clearing the right of way; preparation and transportation of the construction material to the site; erection of the substructure, trough, chute intake, and lower terminal; and the final testing of the chute and adjustment of those

[4] See pp. 107 and 119.

portions which do not function satisfactorily. The right of way for a pole chute is seldom more than 8 feet wide, unless the trough is of large dimensions or the trestle bents of considerable height. Material suitable for construction purposes, which is cut during the process of clearing the right of way, is placed at one side within convenient reach.

Chute construction usually begins at the upper end, and the completed portions are used for bringing down the additional material required. This often proves the cheapest and most satisfactory method of transporting the construction timbers to the spot where they are desired.

Some loggers first complete and align the substructure and then build the trough (Fig. 13) ; while others complete the chute as they go and check it by the frequent chuting of timbers. The latter method of trial and error sometimes is permitted to supplant adequate computations and a careful location survey and may lead to serious operating troubles.

Construction cost. The cost of construction of a pole chute varies within wide limits, depending upon the type and dimensions, height and character of substructure, availability of suitable construction material, experience and cost of labor, and topography. The following data are an index, only, of the general range of costs. These usually vary from 20 to 45 cents per linear foot, with extremes of from 5 cents to $1. In eastern Canada and in the northeastern part of the United States the cost per linear foot is from 25 to 50 cents, while in the Inland Empire the range is from 15 to 30 cents per foot.

The average construction cost of twelve 3-pole chutes, ranging from 300 to 700 feet in length, which were made in Newfoundland for 4-foot pulpwood running 100 pieces per cord, was approximately 6 cents per linear foot, exclusive of the cost of the poles, the extremes varying from 3 to 12 cents. The poles used for the trough had a top diameter of 3 inches and were placed with the butts downhill, the tops and butts being fitted together so that very little hewing was required.

Capacity. Although the capacity of a pole chute may be influenced by numerous factors, it usually depends on the rate at which it is possible to feed wood into the trough, provided the latter has a gradient which is great enough to keep the feeding point open. An hourly maximum of from 15 to 20 cords of 4-foot pulpwood, averaging 100 pieces per cord, can be fed into a chute by two workmen. However, this speed will rarely be maintained for a long period. Taking into consideration lost time due to waiting for the

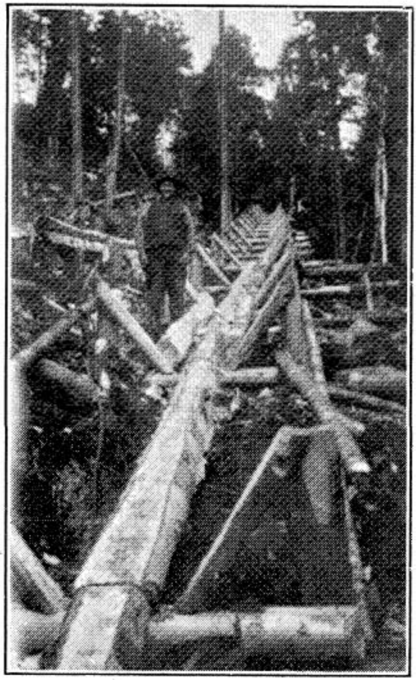

Fig. 13. A pole chute under construction. All of the substructure was erected previous to the installation of thetrough. Eastern Canada.

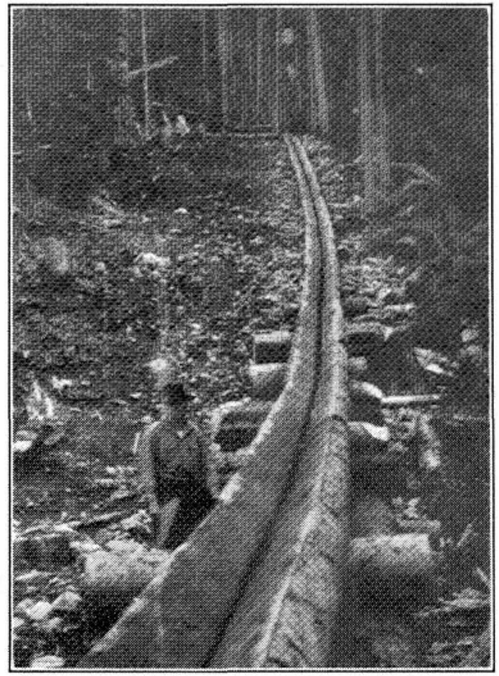

Fig. 17. General view of a "steep" gravity V-chute, British Columbia.

arrivai of loaded sleds, the average daily output on pulpwood and cordwood operations ranges from 30 to 80 cords or from 3,000 to 8,000 pieces.

Depreciation. The working life of a poorly constructed pole chute, subject to hard usage, often is only one season, while one constructed from heavy poles and carefully maintained will serve for six or more years, at the expiration of which the substructure begins to weaken from decay.

Steep chutes made from softwood poles and improperly constructed often are worn out after chuting 500 cords, while strong, well-designed ones will transport from 2,000 to 3,000 cords before extensive repairs are required.

Operating cost. The proper use of pole chutes usually proves a more economical method of handling wood on steep slopes than some form of horse operation. However, when serious errors have been made in location or construction or both, the logger may be confronted with extra costs or losses due to chute reconstruction, repairs, returning "jumped" wood to the channel, and excessive breakage.

The cost of chuting a cord of small-sized wood on northern operations approximates the cost per linear foot of a pole chute; that is, it varies from 15 cents to $1 per cord, averaging from 30 to 50 cents.

The following table gives a typical example of the costs incident to chuting pulpwood on small operations in eastern Canada. The data refer to a 1,000-foot pole chute, costing 30 cents per linear foot, which was designed to handle a total of 1,000 cords of wood at an average daily rate of 25 cords. The daily wage of the chute loader was $3 for a 40-day operating period.

Depreciation	$300
Loading	120
Repairs and miscellaneous	100
Total for 40-day period	$520, or 52 cents per cord

POLE CHUTES FOR SAW LOGS

Outside of North America there often is only a minor difference in type between chutes used for the transportation of small-sized material and of large logs. Although strongly constructed pole chutes sometimes are used in North America for the transport of large and long logs, the latter are more frequently moved in hewed log chutes of the type described in the following pages.

The usual form of European log chute as used in Austria[5] has a channel made from six logs, two of which form the bottom of the trough and the other four logs, the sides. The semicircular channel is from 42 to 48 inches in width at the top and is made in sections about 20 feet long, which are supported on cribwork or trestle bents. The channel members are fastened to each other and to the supports by means of trenails. The top ends of the chute timbers are usually placed pointing downhill, and these are mortised into the butts of the adjacent timbers. The cross section of the channel is modified on curves by raising the outer side and widening the channel.

HEWED LOG V-CHUTES

This type of chute is used frequently in North America for the transportation of saw logs and other medium to large-sized material, but it is little known in Europe and elsewhere. It is extensively employed in the Inland Empire region of the United States where, according to one authority,[6] approximately 250 miles of V-chute are constructed annually, and some companies are said to expend $100,000 or more per year on chute operations. Such chutes also are used in other mountainous regions of the far west including British Columbia, in the Appalachian region of eastern United States, and, to some extent, in other logging regions.

V-chutes are operated both as gravity and as trailing chutes. The chief difference between the two forms is that the trailing chute is located on level ground or on slopes of low gradient, the angle between the faces of the channel timbers is greater, and a trail is provided, parallel to the chute, as a runway for the horse team or the tractor used for dragging the logs.

Gravity chutes are the prevailing type in all regions except in the Inland Empire, where the use of the trailing type has increased greatly during the last fifteen years.

Gravity or running chutes. The following discussion of this type of chute is based chiefly on studies made by Koroleff in Idaho, Montana, and British Columbia, where the technique of construction and operation has been more highly developed than in most other regions. However, even here progress in the development of devices for the control of log velocity on steep grades has been slow and still leaves much to be desired.

A gravity chute, which may vary in length from a few hundred feet to

5 See *Das forstliche Transportwesen,* by G. R. Forster, pp. 47-49.

6 P. Neff of the U.S. Forest Service.

two or three miles, usually is located in the bottom of a gully or along the branch of some secondary stream, although it often is used on a side hilL The first location has the advantage that logs from both slopes maybe readily skidded to the chute.

The channel. This most frequently comprises two parallel logs placed close together, the inner faces of which are hewed to form a V-shaped cross section, as shown in Figs. 14 to 17 inclusive. The angle of slope of the hewed faces increases with the gradient of the chute. It is said to be flat when the angle of slope is from 8.5° to 17° (IS to 30 per cent) and steep when the angle is from 22° to 39° (40 to 80 per cent). Sometimes a third and smaller log forms the bottom of the chute, as shown in Fig. 16, C.

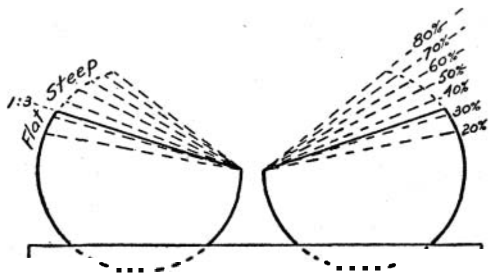

Fig. 14. Diagrammatic illustration of the "flat" and "steep" hewed faces used for V-chutes.

In the Inland Empire, Douglas fir, western hemlock, and western larch are preferred for the chute channel. Western yellow pine is considered only a fair material for this purpose because of its relative softness, while white fir is the least desirable.

A chute for transporting 16-foot logs, averaging from 8 to 10 logs per thousand board feet, should be built from straight, smooth sticks from 30 to 35 feet in length, having top diameters from 10 to 14 inches and butt diameters from 14 to 17 inches. The chute sticks or members forming the channel usually are spaced from 2 to 3 inches apart, but in channels designed for large logs this space may be as great as 6 or 8 inches. If small logs also are to be chuted, a pole is placed between the two chute sticks on which the small logs will ride, but with which the larger ones will not contact.

Some loggers favor the form of chute shown in Fig. 16, C, having a small bottom member hewed flat on top. Logs usually will slide in this type with somewhat less resistance than on a2-pole channel, but there is a tendency for lateral motion to develop when small logs are transported. In order to reduce hewing to a minimum some loggers use the type shown in Fig. 18, C, while others do away entirely with hewing, making the trough of 3 or 4 logs, the inside ones having a smaller diameter than the outer ones and being countersunk into the cross skids (Figs. 18, A and B). The non-hewed types are rarely used and actually represent a form of pole chute.

The 2-pole types are sometimes equipped with pole fenders (Fig. 16, B)

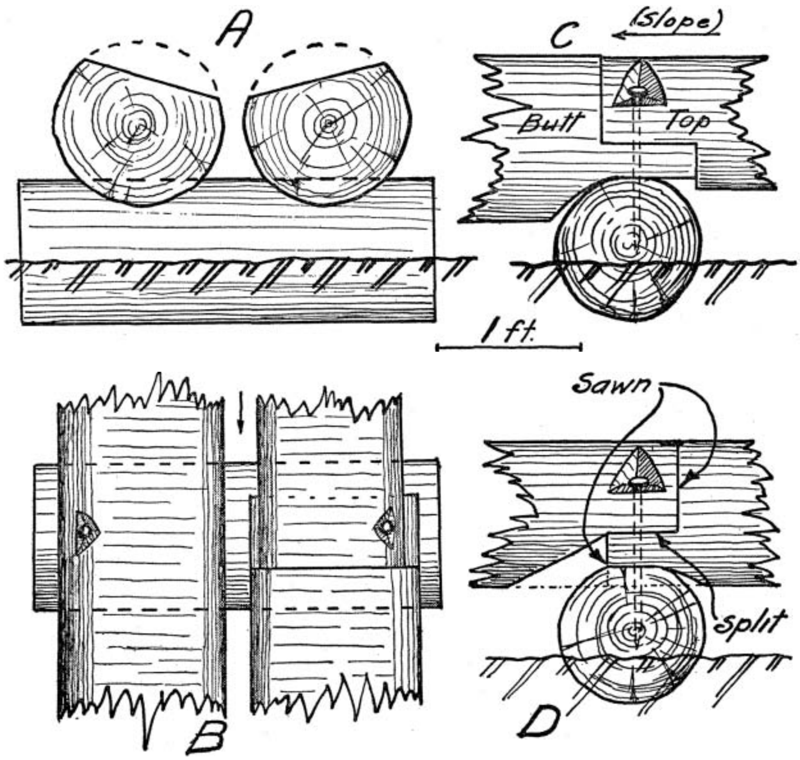

Fig. 15. A standard type of trailing V-chute. *A*, cross section; *B*, top vie"w; *C*, method of splicing the chute sticks; *D*, method of breaking and splicing a long or a bent chute stick in order to secure a better alignment. Montana.

which are spiked on the outer edge of chute sticks which have a very flat hewed face. The V-channel also may be built up by guard logs, as shown in Fig. 16, A.

The channel must be reinforced on sharp curves and frequently is modified to meet the more exacting conditions. The chute trough often is tilted, the "V" made deeper, and an outer log of a greater diameter provided, which sometimes has its surface hewed to a concave form (Fig. 19, B). The chute cross section shown in Fig. 19, A, is adapted for sharp curves around

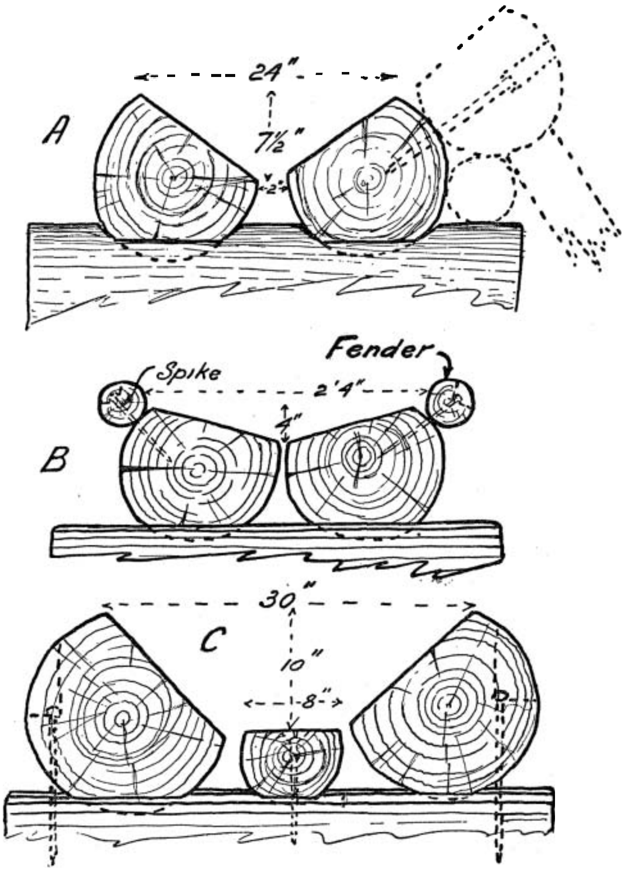

Fig. 16. J\1odifications of a standard V-chute. *A)* cross section of a "steep" gravity V-chute with a guard log indicated (Idaho); *B)* a "flat" hewed V-chute equipped with small pole fender skids (Idaho) ; *C)* a 3-log V-chute (British Columbia).

which logs pass at a relatively high velocity. The outer wall of the curve sometimes is made vertical or even overhanging and the trough armored with iron bands to reduce wear. The length of chute sticks also must be less on curves than on tangents in order to eliminate sharp angles in the trough.

The chute sticks or members forming the channel are placed with the butts uphill, their ends being spliced together as shown in Fig. 15, C, care being taken that the joints of both channel sticks are not spliced at the same point. They also are nailed to the substructure by square, iron drift-bolts either ½ by 12 inches or ⅝ by 14 inches in size. These spikes are

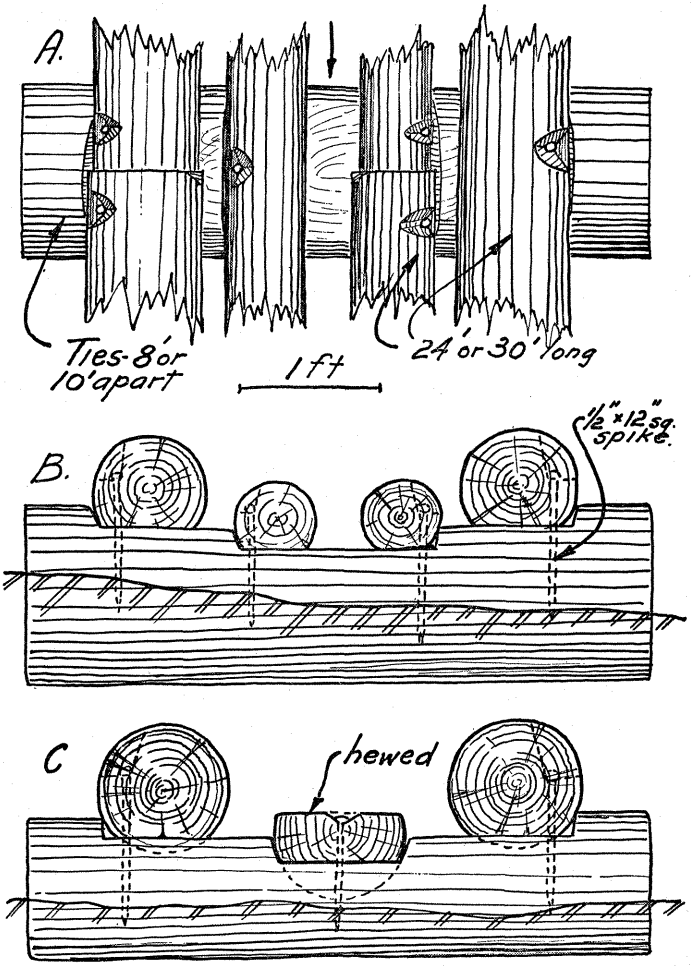

Fig. 18. Special saw log chute types. *A* and *B*, a 4-log unhewed trough; *C*, a 3-log trough with middle log only hewed. British Columbia.

pulled when the slide is dismantled or abandoned and used for other chute construction. Occasionally 1½ or 2-inch hardwood trenails are substituted for iron spikes.

The hewing of the faces follows the installation of the round timbers. The he\ving line is first marked with a chalk line, the surface is then scored, and later it is smoothed carefully by means of a broadax. The hewed faces

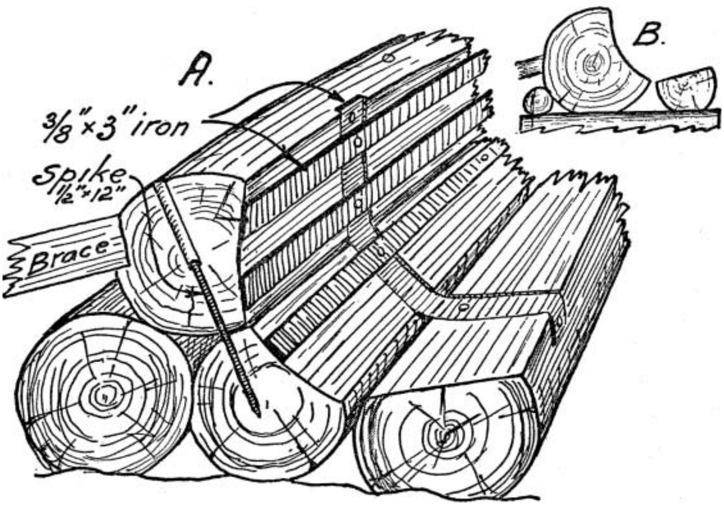

Fig. 19. The cross section of a V-chute on a sharp curve. *A,* a trough armored to prevent excessive wear; *B,* the face of the outer channel member hewed to a concave form.

often have a slope ratio of 2 to 1 (50 per cent), which gives a "V" from 5 to 7 inches deep and a width at the top of from 20 to 26 inches. The slope, however, may vary from 30 to 80 per cent, a deeper "V" being used at points where logs have a tendency to leave the channel.

The substructure. This requires a right of way 8 or 10 feet wide for a gravity chute. The channel usually is supported on short cross skids placed directly on the ground or sometimes imbedded. When the trough requires a slight elevation, it is supported on cribwork, and in the rare cases where a high support is required either cribwork or a standard fonn of trestle bent is used.

On permanent chutes the cross skids are 12 inches or more in diameter and from 3 to 3.5 feet long and often are secured in part by "butting" the chute timbers. If a chute is to be used for a short time only, saw log stock may be used in the construction of both the trough and the support. At the conclusion of the operation the chute is dismantled, starting at the top, and the saw logs are sent down to the lower terminal. Since a mile of V-chute often requires as much as 100,000 board feet of construction timber, it may be seen that the above salvage plan may prove desirable.

The usual spacing of the supports for a V-chute is from 12 to 16 feet, except on curves and very steep sections when an interval of 8 or 10 feet is used. A spacing of 16 feet makes possible the use of chute sticks which are 34 feet in length. This provides a 2-foot splicing length, and, if the logs are later salvaged, each stick may be cut into two 16-foot logs.

The general practice is to level the chute supports by eye, but this often results in irregularities which could be avoided by the use of an Abney or other form of level. Alignment on tangents also is usually done by eye, sighting over three existing supports to locate the position of the fourth.

The intake or head. The intake of a V-chute is located at some point at which it is easy to assemble the timber which is to be chuted. However, it also is a frequent practice to feed logs into a chute at several points along the route. In general, convenience in yarding logs and loading them into a chute is a very important factor in selecting the route.

The logs may be loaded directly into the trough as they are brought to the chute, or they may be decked and sent down later. When the latter practice is followed, the intake may be on fairly level ground with the skidways on a slightly higher level and parallel with the trough. The logs are rolled from the skidways to the chute, over skids which span the gap between the two. It always is desirable to have the intake grade great enough so that logs will run by gravity. However, if the intake is on flat ground and its grade is less than the angle of repose, "dead" rollers may be installed in the trough (Fig. 20) so that workmen can readily move the logs forward, or the logs may be trailed by a team until they reach a grade which is steep enough to cause them to move without towing.

The lower terminal. The character of a given chute landing is determined by local conditions and the subsequent form of transportation used. Water landings are the usual form when a log-drive is to follow chuting, and even when some other form of transport is to be employed a water landing will lead to less breakage. Also, if the timber is floatable, it can be handled to better advantage on water than on land. Frequently an artificial pond is created for this purpose on a small stream (see the frontis-

Fig. 20. The intake of a V-chute equipped with dead rollers.

Fig. 21. A trailing chute landing along a logging railroad. Montana.

piece), although a running stream always is preferable to dead water because the current will carry away the logs as they leave the chute, thus greatly reducing the loss from breakage. Although the damage to the logs usually is less when they are discharged at a low velocity and on the same general level as the banking ground, yet a fairly high velocity and a drop of from 50 to 100 feet may be used with only a limited breakage, provided the landing is a deep-water one. When logs are discharged into a shallow stream, the end of the chute should be flattened out gradually, until it is approximately horizontal, so that the logs will strike the water sideways and at a low velocity. They will then be less apt to strike the bottom and become shattered or badly broomed. The end of a chute having a ground landing may be on a side hill down which the logs will roll. Sometimes the lower terminal of a gravity chute has a grade which is so low that the logs stop before they reach the end. They must then be trailed by animals or a tractor to a landing which often is arranged in a form similar to that shown in Fig. 21.

Logs may be discharged parallel to the chute channel by building one side of the trough lower than the other or by inserting the "whippoorwill" switch shown in Fig. 22.

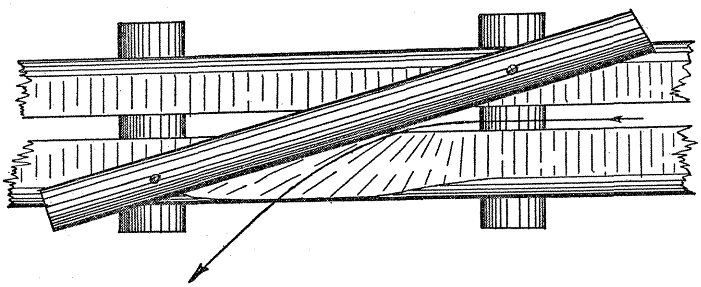

Fig. 22. A common form of switch used on V-chutes, known as a whippoorwill.

Grades. Greater care should be taken to avoid abrupt and irregular changes in the profile of a V-chute than in the pole type, because larger material usually is transported in them and operating troubles are more apt to result from improper design. In actual practice the grades of V-chutes vary from zero or slight counter grades to minus grades of 100 per cent. However, such extremes rarely occur and on short sections only. The best gradients for summer conditions are from 35 to 40 per cent and for winter conditions, from 5 to 10 per cent less.

Very flat sections of chutes may be traversed by logs, due to previously accumulated momentum, while on very steep sections some form of braking device may be required to keep the log velocity within safe limits. Logs usually stop when long low grade or counter grade sections occur, and some provision must be made for trailing the logs over them. On some chutes all or certain sections only may be operated intermittently as gravity and trailing chutes, depending on the season of the year or on weather conditions.

According to one authority,[7] softwood logs from 12 to 20 inches in diameter and from 12 to 18 feet in length have the accompanying angles of repose when transported in a V-chute.

ANGLES OF REPOSE FOR A V-CHUTE

	Types of V-chute		
	2-log hewed steep	*2-log hewed flat*	*3-log hewed*
Chute condition	*Angle of repose*		
Dry (summer)	14°–16°40′	11°20′–14°	10°10′–14°
Wet (summer)	11°20′–16°40′	10°10′–11°20′	8°30′–14°
Greased (summer)	11°20′–16°40′	8°30′–11°20′	8°–14°
Wet (winter)	10°10′–14°	8°30′–11°20′	8°–11°20′
Iced (winter)	5°40′–8°30′	4°–6°50′	4°–8°30′

These figures check within reasonable limits with data collected by the authors from experienced chute loggers and those obtained by direct observations. However, they must be accepted only as indicators of the approximate angles of repose, because the latter are affected by so many factors that their values usually cannot be established in advance. Thus, the angle of repose may increase several degrees during the course of a few hours and then again decrease, due to weather conditions; large, smooth logs will start to move on a lower angle than small, rough wood, and all logs will run on certain classes of chute timbers at a lower angle of repose than on some other kinds. Thus, the angle of repose when the chute timbers

[7] P. Neff, U.S. Forest Service; also see Petraschek's data for pole chutes, p. 140, which coincide approximately with those of Neff.

are made of western larch is from 3 to 5 per cent less than when white pine timbers are used.

Curves. It is essential to exercise greater care in the construction of curves on V-chutes than on the pole type because of the longer log lengths which usually are chuted. A radius less than 200 feet should not be used for logs from 16 to 20 feet long, moving at a moderate speed, and when the velocity exceeds 40 feet per second the radius should not be less than 500 feet. Unfavorable topography often leads chute operators to violate this rule in order to save construction expense. When this is done it is essential to make the chute channel on sharp curves much stronger than on the straight sections.

Construction cost. This varies from 20 to 70 cents per linear foot, depending on topography, bottom, chute profile, accessibility of construction timber, amount of cribwork or other substructure required, and the skill and cost of labor. When experienced labor is available at 40 cents per hour, a V-chute often can be built for from 30 to 50 cents per linear foot.

The costs in the Inland Empire vary greatly by sections. They are considerably lower in the western yellow pine than in the white pine section because of the character of the topography and the available lumber. The costs in British Columbia are approximately the same as in the Inland Empire, while in the Appalachian region they are somewhat less, due to cheaper labor and the use of a lighter form of construction. In other regions the costs usually are higher because of the lack of labor trained in chute construction work.

Capacity. The daily saw log capacity of gravity chutes operated in the Inland Empire is governed more by the number than by the size of logs and, measured in terms of log scale, is much greater when the logs are large than when they are small. The daily average output is approximately 500 logs, with a total log scale of from 40,000 to 100,000 board feet.[8]

Depreciation. A well-constructed and properly maintained V-chute usually will be serviceable for a period of from six to eight years, although if it is used very intensively the trough may be worn out in one or two seasons. A poorly constructed chute will seldom transport more than from 1 to 2 million board feet of timber, while a well-built one on which logs travel only at medium speeds may serve to transport 10 million board feet or more.

[8] Scribner "Decimal C" log rule.

Operation. The method of operation varies with the logging policy. The logger may conduct a "hot logging" job in which the logs are chuted as they are skidded, while another logger, because of chute grade conditions or for other reasons, may "cold-deck" or store the logs on skidways near the chute and await suitable operation conditions several months later. In both cases the logs may be "chuted in trails" or "wildcatted," the former being a method of sending down, at one time, a turn of from 10 to 20 logs, while the latter method is one in which the logs are chuted singly.

"Chuting in trails" is the customary method for long chutes on which logs would tend to collide because of their difference in size and velocity, unless they were fed slowly enough to ensure an adequate time interval between each log. The usual practice is to put the small and slow logs in the front of the trail and the large and faster ones at the rear. The tendency then is for the larger logs to have their velocity reduced and the smaller logs to have theirs accelerated, the result being that all travel together to the lower terminal. This method of operation is found only in those regions in North America where long V-chutes are in use for saw log transport. It requires a larger operating crew than the single log method because of the added labor involved in making up the trails, a procedure known as "jigging." Two cant-hook men roll the logs into the chute, one tong slinger adjusts the tongs on the rear of the trail, and a teamster with a single horse or a team moves the trail forward to make room for the next logs. Animal power also may be required to start the trail down the chute, provided the grade at the head is less than the angle of repose.

"Wildcatting" or the chuting of single logs is practiced in the same regions as the method just described when the chute length is short and a good water landing is available. It is the common method in all other regions. The procedure is for cant-hook men to roll single logs into the chute at proper time intervals and permit them to travel to the landing. Chute tenders may be required if there are certain sections which have grades so steep that devices must be installed to check the log velocity, for these are rarely wholly dependable and automatic, and where the grades are so low that the channel must be greased. A telephone line or signal men stationed within communicating distance of each other are essential for the proper control of the operation on fast and long chutes, because the feeding of logs must be stopped immediately when there is an interruption at an intermediate point.

Minor repairs to a chute are made by the chute tenders as a part of their daily work. "Rearing" or replacing in the chute logs which have jumped out may be an easy or difficult task, depending on the elevation of the trough at the loading point, the general character of the terrain, and the size of the timber. "Rearing" usually is done by the crew after chuting proper has ceased. A large number of logs requiring replacement is an indication of some serious error in location or construction or both.

Although there is a wide range in operating costs, they should not exceed from 10 to 20 cents per thousand board feet on short, well-designed and well-constructed chutes over which medium-sized timber is being transported to a favorable water landing. The usual cost on long chutes is from $1 to $1.25 per thousand board feet, although under unfavorable conditions it may exceed $3.

Trailing chutes. The practice of "trailing" logs in chutes probably originated in Pennsylvania and from there spread to the Appalachian Mountain region and the western part of the United States. To-day trailing chutes are used chiefly in the Inland Empire and to a limited extent on the Pacific Coast. They are occasionally found in British Columbia and in the eastern part of North America, but are not employed elsewhere on this continent or in other countries.

The popularity of the trailing chute in the Inland Empire, especially in Montana, seems to be due to the fact that loggers have not been very successful in devising methods for the control of log velocity and the elimination of log breakage on steep gravity chutes, and for these reasons, even on grades as high as 40 per cent, they often seek to increase the sliding resistance by various means in order to convert what would normally be a gravity chute into a trailing one.

The channel. The trough of a trailing chute is similar to that of a gravity chute and usually is made from two logs only (Fig. 15). However, a pole may be placed between the chute sticks to close a gap which is too wide, or small pole fenders (Fig. 16, B) may be fastened to the outer edge of the channel when such a precaution is necessary to prevent logs from leaving it.

The slope of the hewed faces of a trailing chute usually ranges from 20 to 25 per cent, although it may vary from 10 to 40 per cent (Fig. 14). Logs drag easier in a flat trough than in one having a steep face, and greasing also is more efficient because the lubricant does not run off as readily. The chief disadvantages of a flat face are that more hewing labor is required because of the awkward position in which the work must be done and there is a tendency for the logs to leave the channel.

The trough is made from sticks which are of the same approximate size as those used for a gravity chute (page 17). These are placed about 3 inches apart with the top ends pointing towards the landing, and, for transporting 16-foot logs averaging 10 pieces per thousand board feet, the channel is hewed so that the "V" has a depth of about 4 inches and a top width of 24 inches.

Branch chutes often are used as feeders for the main line, to which they are joined as shown in Fig. 23.

A good alignment is essential, and when the sticks are not straight or the chute is being constructed on a curve the channel members are cut into shorter lengths and spliced, either with broken or even joints, as shown in Fig. 15, D. Iron driftbolts ½ by 12 inches in size or hardwood trenails are used to fasten the chute sticks to the substructure, the heads being countersunk into notches cut with an ax.

The substructure. The supports for the channel are crossties which are placed either directly on the ground or on low cribwork, usually at 16-foot intervals, especially when it is feasible to secure and to use 34-foot chute sticks. However, the spacing may vary from 12 to 18 feet on straight sections and from 8 to 12 feet on curves. The trough may be partly imbedded, but more often it is slightly above the ground surface. However, for horse trailing it should not be elevated more than 3 or 4 feet, otherwise the towline may choke the animals by pulling up the harness collar.

The lower terminal. Many trailing chutes, especially in the Inland Empire, serve as feeders for a logging railroad, and the predominating type of lower terminal is that shown in Fig. 21. A "trail" of logs on arriving at such a terminal is rolled from the chute upon the double skids by workmen using cant hooks, or a portable steel deflector similar to a "whippoorwill" switch (Fig. 22) is inserted in the channel to deflect the logs from it.

Grades. The optimum grade varies with the season of the year and the condition of the channel. The most desirable slope for summer conditions is from 10 to 15 per cent, because logs often will move by gravity on gradients of from 15 to 30 per cent, depending on whether the channel is dry, wet, or greased. The best grade for a channel covered with frost is from 5 to 12 per cent. Steeper grades than the above may be used when the topography requires it, provided an angle of repose may be secured by the use of sand,

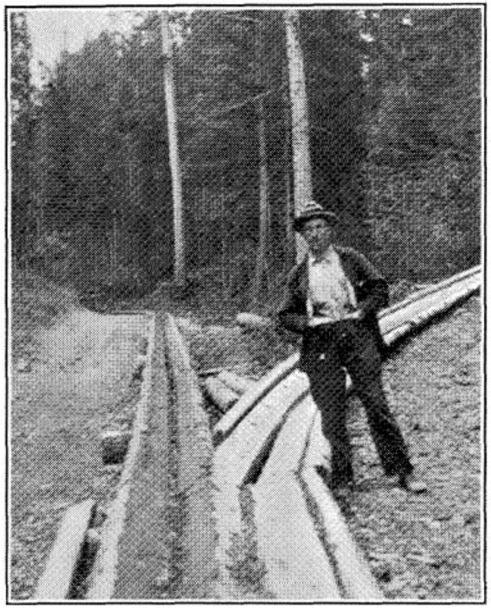

Fig. 23. The method of joining a branch feeder to a main trailing chute. l\lontana.

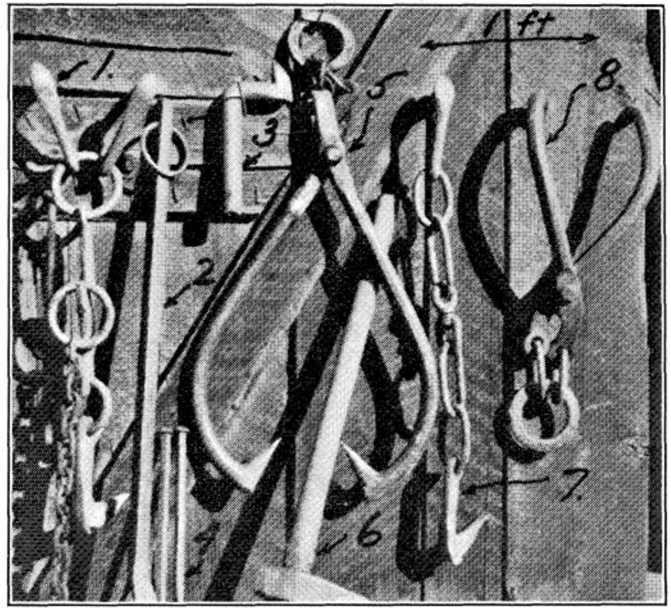

Fig. 24. Tools and equipment used with trailing chutes. 1, double dogs with skidding chain hooked onto the "J" hook; 2, crowbar used for separating .10gs of a trail; 3, gooseneck; 4, chute spikes used to fasten together the various parts of the channel and substructure; 5, skidding tongs; 6, skipper for driving and releasing dogs; 7, single dogs; 8, trailing tongs.

goosenecks, or other means, which is great enough to prevent the logs from moving by gravity.

Although loggers prefer a continuous trailing chute, many are combinations of both trailing and gravity. In some cases a given chute may be operated by gravity in cold or rainy weather and by trailing during dry, summer weather.

Curves. Although logs travel only from 2 to 5 miles per hour, they are liable to leave the chute channel when a long tow is passing around a sharp curve. This tendency increases with the force of the motive power, the length of the tow, and also with the length of logs. Even when horses or small tractors are used for motive power, the minimum chute radius should not be less than 200 feet and, when possible, a greater radius should be employed. Sharp curves are impractical on a combined trailing-gravity chute, especially when the tow is hauled by a cable actuated by a donkey engine.

Construction. The usual width of a right of way is from 20 to 24 feet, of which from 8 to 10 feet is represented by the tow trail.

A typical construction crew employed by a Montana firm, which constructs 20 miles of trailing chute annually, comprises 13 men, of whom the head builder receives 60 cents per hour, the teamster and horse team, $8.50 per day, and the remaining labor, 40 cents per hour.

The following crew will construct approximately 20 linear feet of chute per one-man day:

Construction	1 head builder 3 helpers 2 sawyers 1 swamper 1 teamster and team
Hewing	1 broadax man (foreman) 1 pinner 3 scorers

Construction cost. The cost of constructing a trailing chute in the Inland Empire, including the towing trail, ranges from 25 to 65 cents per linear foot, with an average cost of 40 cents at the labor rates previously mentioned.

The usual cost of an 8-foot towing trail, when the ground conditions are favorable, is from 7 to 10 cents per linear foot, but may greatly exceed this when the bottom is very rough or swampy, thus requiring some blasting or a relatively large amount of corduroy.

The accompanying itemized statement represents average construction costs incurred under favorable conditions.

AVERAGE CONSTRUCTION COSTS—TRAILING CHUTE

Construction items	*Per linear foot*
Right of way, 24 feet; horse trail, 8 feet	13.4 cents
Constructing chute and pinning	13.9
Scoring (2-log trough; the "V" 4 or 5 inches deep and 24 inches wide at the top)	2.9
Hewing	1.6
Construction of landings	2.5
Horse labor	1.5
Spikes	0.5
Powder and miscellaneous	0.6
Total	36.9

Capacity. The trailing capacity of a team may vary from 500 board feet or less to 3,000 board feet or more per tow, depending upon chute conditions. A tow of 1,000 board feet should be handled readily under summer conditions when the chute profile is favorable and the logs of fair size.

One outstanding record made on an iced chute in Montana which was 3 miles in length and had an average grade of 12 per cent was 110 logs or 12,000 board feet trailed by one team.

Operators formerly moistened dry trailing chutes with water to decrease the frictional resistance, but this practice has now been supplanted by greasing, which provides a smoother and more efficient surface and often increases the capacity of a flat trailing chute from 50 to 100 per cent.

The average daily output of a trailing chute in the Inland Empire is approximately the same as for a gravity chute; namely, about 500 logs scaling from 50,000 to 100,000 board feet.

The following data will serve as an illustration of the general capacity of a well-constructed and operated flat, greased V-chute, 6,000 feet in length, which was built by a Montana operator. The upper half of the chute with an average grade of 10 per cent was operated by teams, each of which trailed about 1,100 board feet of 16-foot logs, averaging 9 logs per thousand board feet, over a "beat" 600 feet in length. The lower half of the chute had an average grade of 5 per cent, and the trailing over this portion was done by two 5-ton Caterpillar tractors, each of which averaged two and one-half trips per hour. Each tractor moved two horse "trails" or an average of 2,200 board feet at one time, the total daily output of the chute being about 80,000 board feet. Although the 5-ton "Caterpillar" had the tractive power of 6 horses only, its greater speed enabled it to perform the \vork of 8 animals; a Io-ton "Caterpillar" should do the work of from 14 to 16 animals.

The saving over horse hire is very appreciable because the daily cost of operating a 5-ton tractor is from $20 to $25 and that for a Io-ton, about $35, as contrasted to a cost of $34 per day for four teams and $59.50 for seven teams and teamsters at $8.50 per day each.

The capacity of a chute in which logs are trailed by donkey engines varies with the distance and the size of logs chuted. On one operation in Idaho, on a haul of 4,000 feet, ten round trips were made daily, the average trail being from 30 to 35 logs, or 325 logs daily. The average log scale was 60,000 board feet. On another 7,000-foot haul which required one hour for the round trip, the average tow was 10,000 board feet and the daily average 80,000.

Depreciation. A well-built and properly maintained trailing chute may last for eight or more years and serve for the transport of from Iota 20 million board feet of timher with one rehewing.

Operation. Horses are the chief motive po\ver used on trailing chutes; donkey engines also are employed to some extent, but hath have been steadily giving way during the last decade to crawler tractors. Both horses and tractors pull the "trail" of logs by traveling along a tow path which parallels the chute channel, while a donkey engine is stationed at one of the terminals and llloves the tow of logs by means of a cable which is returned for a new tow by means of a messenger line. The use of "donkeys" is restricted chiefly to moving large logs.

(A) Trailing \vith horses and tractors.-About 80 per cent of all logs "trailed" in the Inland Empire are moved by horses, and the remainder are towed chiefly by 5 or la-ton tractors, although some 2-ton machines also are in use. Donkey engines are seldom used in this region.

The various operations incident to chute trailing are rolling the logs into the channel and making up the trails, known as "jigging"; trailing proper; greasing and sanding the chute; rolling logs from the channel at the lower terminal; and tailing down. Logs may be loaded into a chute at any point along its course where it is convenient to assemble them and practicable to roll them into the channel.

"Jigging" or making up the trail requires the services of two cant-hook men, a tong slinger, and a teamster with a single horse or a team. The usual tow comprises from five to twenty-five r6-foot logs, depending on their size and character, the gradient and frictional resistance of the chute, and the motive power employed. The practice is to place the smaller logs in the front of the trail and the larger ones in the rear in order to prevent the middle of the to\V from "jackknifing." The last log to which the draft power is attached always is one of the largest ones because a relatively light log could be pulled readily from the channel.

A trail usually is made up in the following manner. A log is rolled into the chute channel and a pair of trailing tongs (Fig. 24, 8), equipped with a 6-foot chain, is attached to it. A hook on the free end of the chain is caught on a ½-inch jig chain, about 80 feet long, which passes over a block fastened belo\v the loading point, and the team pulls the tow forward until there is room in the chute for another lqg to which the trailing tongs are attached, and the process of moving the tow forward is repeated. Several logs may thus be moved before the tow team must return to the loading point and repeat the procedure.

When a trail is ready the tag line, made from a ⅝-inch chain from 25 to 50 feet in length, is attached to a pair of trailing tongs which are fastened 2 or 3 feet back of the front end of the rear log of the trail. The team pulls the log to which the tongs are attached, and it in turn pushes all of the logs which are in front of it. When the tow is a long one a crowbar (Fig. 24, 2) is used to separate the ends of the logs so that when the rear logs contact as the tow is started, the momentum they acquire will aid in overcoming the inertia of the forward ones. One or two large logs often are placed behind the one to which the tag chain is attached in order to keep that log from being pulled out of the channel. The rear logs usually are

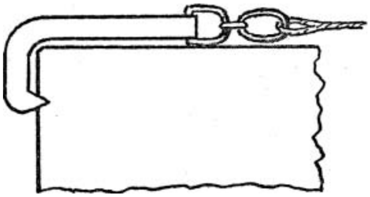

Fig. 25. An "L"-hook for attaching the tow line to the last log of a trail.

fastened to the tow log by means of a grab similar to that shown in Fig. 24, 7.

At one time it was customary to connect all of the logs in a trail by means of dogs, the larger logs being placed in front and one horse traveling on each side of the channel. This plan is practicable only when the chute gradient is so low that the logs will not run by gravity, otherwise the team would be endangered. A far safer method, and the usual one, is that shown in Fig. 26, II, because in this method the trailing tongs may be readily pulled out of the tow log if the trail starts to move by gravity.

An "L" hook (Fig. 25) may be substituted for trailing tongs, or grabs equipped with a "J" hook (Fig. 24, I) may be attached to the rear log and a ring or the tag line caught on the hook. These two methods provide a ready means of disengaging the tow team provided the logs start to move by gravity, but they are considered to be less efficient than trailing tongs and do more damage to the logs.

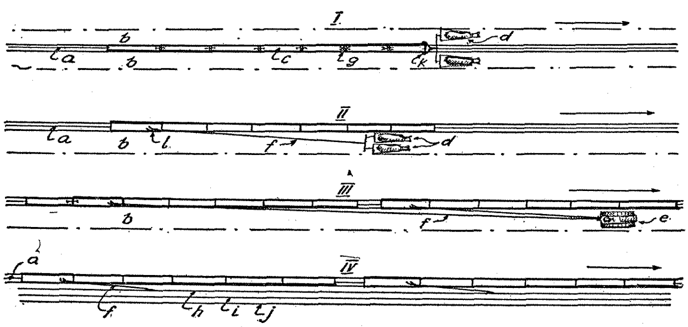

Fig. 26. Chute trailing methods. I, team hitched to the forward log; II, the customary method of attaching the draft; III, tractor towing a trail in two sections; IV, method of trailing by cables actuated by a donkey engine. *a,* chute channel; *b,* horse or tractor trail; *c,* a "trail" of logs; *d,* horse; *e,* tractor; *f,* tow line; *g,* "dogs"; *h,* main cable; *i,* haul-back or messenger line; *j,* signal wire; *k,* skidding tongs; *l,* trailing tongs.

Horses usually are used in relays, each being assigned to a given "beat," varying from 300 to 1,000 feet in length and averaging usually from 500 to 600 feet. The logs are then picked up by another teamster and team which, in turn, later delivers the tow to others.

When tractors are used to furnish motive power for trailing, the tow often is broken into two or more sections, each containing eight or ten logs

(Fig. 26, III). These sections are spaced several feet apart, each one being pulled by a separate tag line made from ¾-inch steel cable usually in lengths ranging from 50 to 100 feet. The advantage of this is that the several sections are less apt to buckle or "jackknife" than a single tow comprising the same number of logs.

(B) Trailing with donkey engines.—Chutes, also known as fore-and-aft roads, were formerly used extensively in the western part of the United States in connection with power logging. They served chiefly as a roadbed over which logs were dragged by a road engine, several of which, arranged in a series, served as a connecting link between the yarding engine and tidewater or some navigable stream. They were supplanted gradually by logging railroad spurs, which proved a more efficient transport method. It is probable that this method of chute trailing will soon become obsolete.

The channel used for trailing large logs on the Pacific Coast is made of from two to five logs, placed either directly on the ground or on cross skids. When crossing a depression they usually are supported on heavy cribwork. The amount of timber required to build a chute of this character is 100,000 feet or more per mile, depending upon the amount of cribwork required (Fig. 27). The timber, in the form of long logs or tree lengths, is transported for distances usually of from 1,300 to 2,600 feet by means of a cable operated by a donkey engine located at the landing, the hauling line being later returned to the chute-feeding point bya smaller cable. A signal wire usually runs parallel to the chute (Fig. 28, c) and makes it possible for the "chaser" to signal to the engineer from any point along the line.

The following brief description of a western Idaho operation illustrates the combined use of trailing, gravity, and cable chutes and flumes to move timber from a stand which ran in size from 5 to 61qgs per 1,000 board feet.

The chief transport system was the flume which followed the main valley and into which ten chutes emptied, some of them being operated by gravity, others as trailing chutes in which the motive power was horses, and still others, up to a mile in length, which were operated by cables actuated by a donkey engine located at the chute terminus along the flume. The two logs forming the chute channel were from 12 to 18 inches in diameter, the faces being hewed at a slope of from 25 to 30 per cent. On curves the outer log was of greater size than the inner one, and its face was hewed somewhat steeper. The power for operating the chute was provided by an II by 13 Willamette road engine having two drums, one carrying the 1⅛-inch main

Fig. 27. A "fore-and-aft" road under construction. The heavy cribwork in the foreground serves to carry the channel over a deep depression. The construction timber is brought into place by the donkey engine shown in the background. Oregon.

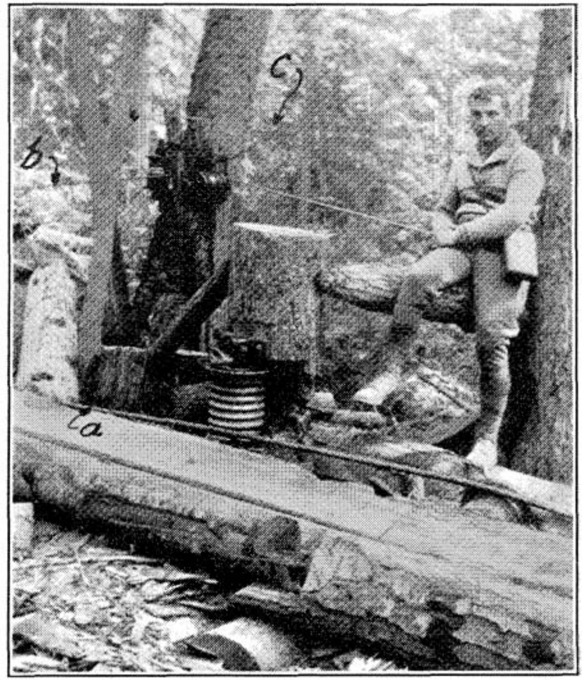

Fig. 28. The general arrangement of the cables used for trailing logs by donkey engine power. *a*, main cable; *b*, haul-back or messenger line; *c*, signal "wire. The spools serve chiefly to hold the cable close to the chute so that logs cannot be pulled out of it.

cable. The logs were brought down the chute in tows of from 30 to 35 pieces, which were divided into sections containing 4 or 5 logs each. The last log in each section was attached to the main cable by a 5/8-inch chain 8 feet long, to one end of which a pair of trailing tongs was fastened.

A round trip was made in 40 minutes, of which 4 minutes was required for hooking the load to the main cable, 20 minutes for drawing it to the flume, and 8 minutes each for unhooking at the flume and returning the cable to the chute head. The usual practice was to make up the trails with the aid of horses, although the main cable also was used occasionally for this purpose. The daily capacity of one chute was about 325 logs or 60,000 board feet.

The crew comprised eleven men and one team: four were employed at the road engine, two at rolling logs into the channel, one as a tong hooker, one teamster and team at "jigging," one man at attaching the "trail" to the cable, one as a "chaser" who rode in a "pig" or small boat attached to the rear log and followed each trail to the landing, and one as a greaser who oiled certain sections of the chute.

MISCELLANEOUS FORMS

Miscellaneous chutes represent a wide variety of types, some of which have been in use in Europe, others employed to some extent on this continent, while certain ones, especially suspension chutes, still await a thorough test to prove their true worth.

EARTH CHUTE

This form of chute, used to some extent in all forested mountain regions, in its simplest form (Fig. 29) comprises a natural depression or an artificial furrow having a grade steep enough so that logs may be moved by gravity. Trailing earth chutes also are used in some regions.

Although gravity is the usual motive power used on earth chutes, hand labor may be required to move the logs at certain points, and sometimes animals also are employed when the grade of the chute is less than the angle of repose. In the latter case the chute becomes a trailing one in which several logs are drawn in a tow, the animal or animals traveling on a path alongside the chute.

Gravity earth chutes are most efficient when the ground is frozen and the furrow covered with a thin layer of snow or ice. European practice indicates that the most suitable grade for a winter gravity chute is approximately 20°. A much steeper grade is necessary for summer conditions.

When a chute passes diagonally down a slope, a fender skid or guard rail often is placed on the lower side of the channel. Such skids also are

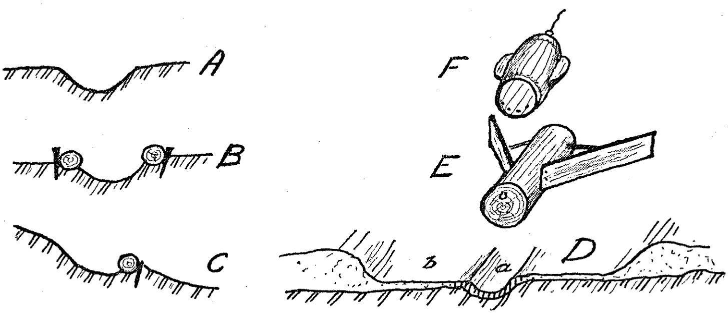

Fig. 29. An earthen chute, Pennsylvania type. *A*, an unimproved channel; *B* and *C*, channels reinforced with fender skids; *D*, an iced channel, *a*, with a tow path, *b*; *E*, a snow plow made from a log equipped with board "wings"; *F*, a barrel sprinkler for use in icing an earthen chute.

frequently installed along one or both sides of the chute at points where the logs may tend to leave it. Occasionally operators on this continent line the bed of the channel with small poles, thus giving it some semblance to a crude pole chute.

Earth chutes having a natural or artificial channel from 5 to 20 feet wide, passing down slopes having grades of from 20 to 60 degrees, were formerly in use in India.[9] Gravity was the chief motive power, but the chuted logs were kept under constant control so that they could not attain a high velocity. On slopes ranging from 20° to 25° it was possible for workmen to regulate the speed of logs weighing as much as one ton, but on higher gradients it was necessary to install "check walls" at varying intervals of from 50 to 500 feet, against which the chuted logs would impact and come to a stop.

Trailing earth chutes were frequently iced in the colder regions of the North American continent because an ice cover often increased the hauling capacity of a tow horse tenfold as compared to non-frozen ground. The

[9] See *A Manual of Forest Engineering for India*, Vol. III, pp. 110–116, by C. G. Rogers, Calcutta, India, 1902.

average tow per horse on an iced chute was 1,000 feet, log scale, and, under very favorable conditions, reached a maximum of 30 logs.

A type of iced earthen chute, frequently used in Pennsylvania,[10] had a channel from 15 to 20 inches wide and from 6 to 10 inches deep which was made in the ground, before freezing weather, either by dragging a large log over the route or by turning a furrow with a plow when the character of bottom permitted. When necessary, the channel was improved by hand work. Small depressions were spanned by a wooden chute and a rather crude tow path was made alongside the channel. The total cost of the initial work was from 3 to 5 cents per linear foot.

The preparation of the ice cover on an earthen chute was started as soon as there were a few inches of snow on the ground. A water tank made from a 50-gallon barrel (Fig. 29, F), with wooden guides attached to each side to hold it in position, was dragged along the chute, and water was sprinkled on the channel through holes bored in the rear end of the barrel. A horse snowplow (Fig. 29, E) was frequently used to keep the channel free from snow, although this work was sometimes done with a shovel and a broom. A thick layer of ice was not essential, but due to repeated sprinklings it often became 6 or more inches thick by the end of the season.

Trapholes usually were installed at occasional intervals in the bottom of the chute in order that the dirt and snow which the logs brought into the channel could be disposed of readily. Excess log velocity on steep grades was reduced by throwing sand into the channel.

Iced earthen chutes have never been used extensively by loggers in New England and eastern Canada, and, when installed, they seldom have been carefully constructed and properly operated. In view of the fact that they formerly were used with a high degree of satisfaction in Pennsylvania where the winters are of moderate length only and subject to occasional thaws, it may be assumed that they would be serviceable in the colder portions of this continent where the snowfall is not excessive.

One Canadian firm[11] experimented in the Lake Saint John District of Quebec with earth gravity chutes of various lengths up to 800 feet and found them cheaper and as satisfactory as the conventional wooden chute. The channel was cut into the ground for a depth of about 6 inches and lined on both sides by fender skids which were required to keep the logs

10 As described by C. Sykes, a former logger in that region.

11 Price Brothers and Company.

within the channel which ran directly do,vn a steep slope. The trough was iced over a thin snow cover by using buckets to throw water on it from an adjacent stream. These chutes worked satisfactorily in cold weather, buton mild and stormy days the accumulation of slush and snow in the channel necessitated frequent cleaning, and the iced surface depreciated rapidly. The bed of the chute was later lined \vith poles placed longitudinally, which proved to be an improvement for mild weather operation.

ROAD SLIDE

This is a form of gravity chute unknown on this continent but rather extensively used in the mountainous parts of Europe, chiefly in Austria and Germany, for the transport of long logs and entire tree boles. They are called road slides because formerly they also were used as sled roads for bringing out firewood after the long timber had been chuted. This dual use has now been abandoned in most cases because grades suitable for gravity chuting of logs are too steep for sled hauling.

A road slide is intermediate in type between an earthen and a wooden chute and in some particulars resembles the skid or skipper road formerly in common use in various parts of the United States, differing from it in that it uses gravity as a motive force and is much more carefully designed and constructed. The cost and maintenance of a road slide is considered by European operators to be less than that for a wooden chute, and its advantages are often greater because of the lesser amount of wood required in construction (about one-sixth that of a wooden chute), the greater log lengths that can be transported, the lower maintenance cost, and the reduced breakage and depreciation of the chuted timber. One of the disadvantages of a road slide is that it is not adapted for transporting short or small logs, and the channel may be subject to severe erosion, especially on loose soils.

One author,[12] in comparing the merits of road slides and aerial trams as methods of transporting timber from mountainous forests in western Europe, states that the cost of installing road slides is about one-fourth that of aerial trams, the maintenance cost is much less, and they are much better adapted to the selection system of cutting because of the longer period during which amortization of the investment can take place.

The following description of the general methods of constructing a road

12 See "Riesbahnen, Anlagen für die Holzbringung über steile Gebirgslehnen," by Karl Koneczni. *Celttralblatt für das gesamte Forstwesen*, Vienna, Sept., 1931.

slide is based chiefly on data contained in the article on road slides previously cited.

The construction work, usually performed by a crew composed of an equal number of graders and ax men, follows the survey and clearing of the right of way. The grading work includes the leveling of the ground surface for a width of 3 or 4 feet on tangents and a somewhat greater width on curves. On this leveled surface 5-inch by 6-foot transverse skids are laid at intervals of approximately 3 feet. These skids, which are placed at an angle of from 60° to 70° to the main axis of the chute, have their ends firmly anchored to the ground by strong stakes. The walls of the channel usually are formed by guard rails which rest upon the outer ends of the cross skids. However, cross skids arranged herringbone fashion are sometimes substituted for them on tangents, thus forming a concave cross section. It is very important that the upper face of all cross skids shall be carefully leveled, otherwise they will be displaced by the impact of descending logs.

The wall of the chute on the outer side of curves is built up sometimes for a height of 3 or 4 feet in order that logs may not leave the channel. This elevated wall must be strongly constructed and braced in order to resist the heavy impact caused by centrifugal force.

The minimum radius for a horizontal curve should not be less than 150 feet and that for a vertical curve not less than 600 feet. In addition, the bed of the slide where a vertical concave curve occurs should be lined with planks instead of cross skids because chuted logs will tear up the latter.

Proper drainage is very important because road slide channels are subject to erosion. Culverts similar to the type shown in Fig. 30, D and E, are installed at frequent intervals and suitable side ditches must be provided to carry away the water. An important feature of maintenance work is cleaning the drainage equipment so that it will function satisfactorily.

The usual method of carrying a road slide across a gully is to erect a trestle on which cross skids are mounted herringbone fashion on the stringers. Cuts are sometimes necessary, but fills are rarely used because of the expense of construction and also because of the fact that it requires a rather long period before the material settles and the slide bed becomes stable, the slide in the meantime being more or less inefficient because the cross skids do not maintain their level position.

Road slides with very steep grades (80 to 100 per cent) are serviceable only in a dry condition, while those having grades as low as from 5 to 15 per cent can be used only during the winter. Small logs 8 inches and less in

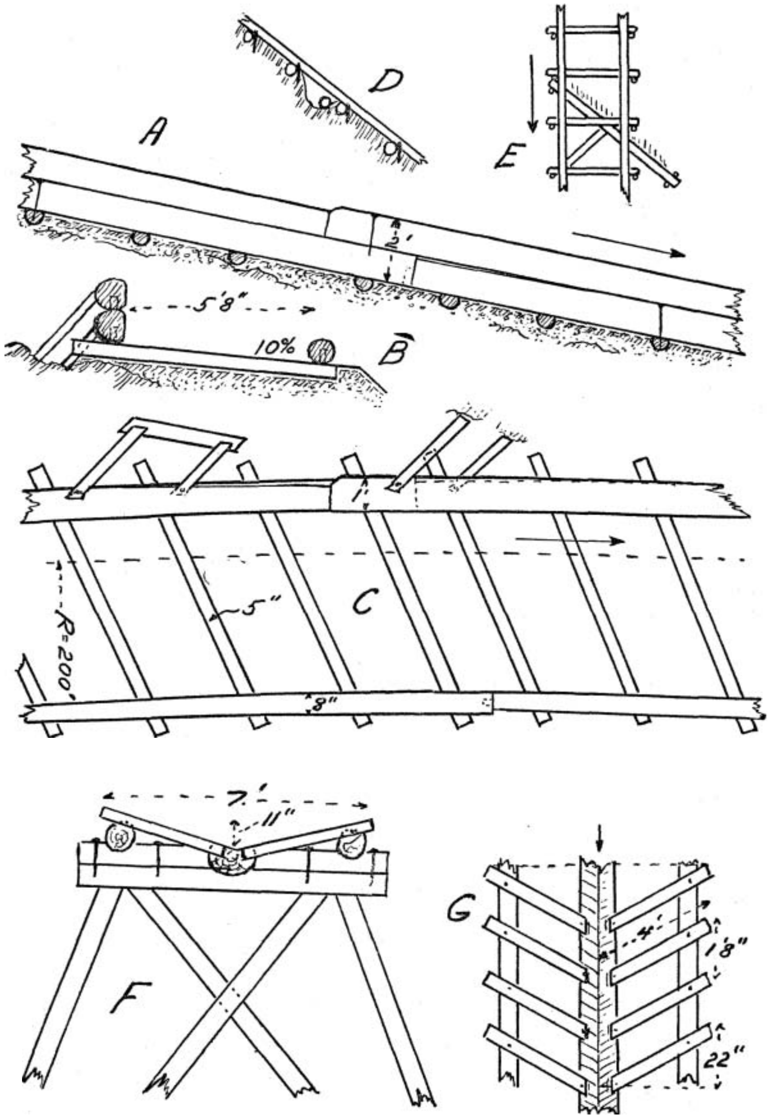

Fig. 30. Details of a road slide. *A) B}* and *C* represent a side, end, and top view, respectively, of a road slide in Austria; *D* and *E)* details of a drainage culvert; *F* and *G,* details of a bridge across a deep depression. (*A* to C after Glatz; *D* and '*E* after Koneczni; and *F* and *G* after Kubelka.)

diameter and 20 feet and less in length can be chuted only on grades exceeding 20 per cent. Large logs are best transported, unrossed, in full tree lengths with the butt ends sniped.

According to Koneczni[13] logs may safely attain a maximum speed of 120 miles per hour on well-constructed and properly designed road slides. As a rule, however, the maximum is much below this figure. Excessive velocities are checked by various devices for speed retardation, among the m.ore important of which are wolf brakes.[14] The lower end of a road slide ends in a horizontal section or a counter grade, usually located on a side slope so that logs can be rolled to a storage point at a lower level.

PLANK CHUTE

Chutes having a channel made from sawed material are more frequently used in Europe than on this continent, although they are occasionally employed here when sawed material may be readily secured or when it is de-

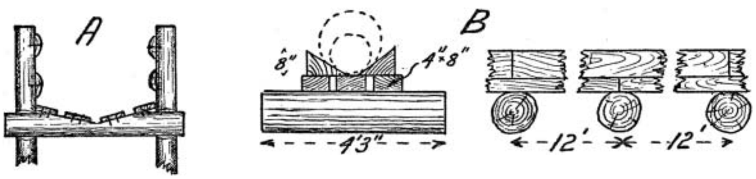

Fig. 31. Plank chutes. *A*, a gravity chute in Switzerland; *B*, a trailing chute, United States.

sirable to have a chute which may be dismantled and moved from one site to another. They are seldom installed unless there is a relatively large volume of wood to be moved.

A Swiss log chute made from 2-inch sawed material is sho\vn in Fig. 31, A, and that for a trailing saw log V-chute, used on this continent, in Fig. 31, B.

WET CHUTE

A wet chute, sometimes termed a chute-flume, is a type intermediate between a chute on which the log slides and a flume in which the log floats. A chute trough may be made sufficiently tight to hold water, thus facilitating

13 See "Riesbahnen, Anlagen für die I-Iolzbringung über steile Gebirgslehnen," by Karl Koneczni. *Centralblatt für das gesamte Forstwesen*, p. 266, Vienna, Sept., 1931.

14 See pp. 73 to 83.

the sliding of the log, and a flume may have a grade so steep that it closely approaches a chute both in construction and performance. Wet chutes, although seldom used, may be very serviceable when the gradient is insufficient to operate a dry chute by gravity and also where a flume is impractical due to expense or to a lack of water or both. A gravity chute may be made dry on very steep sections, and it may be converted into a wet chute on very low grades.

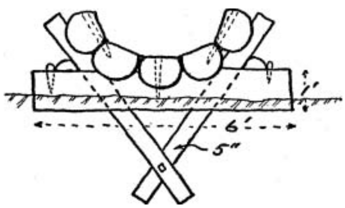

Fig. 32. A "wet" chute. Tyrol district, Austria.

A wet chute is made from hewed logs or from planks in a variety of designs which are similar to dry chutes except that they are water-tight. An Austrian wet chute made from five smooth straight logs, hewed on one or more faces, is shown in Fig. 32. The logs are closely fitted to form a semicircular channel, the chinks of which are caulked with moss or oakum. The dirt and bark carried by the water also serve to keep the cracks filled and fairly tight.

Deota timber slide.[15] This slide or wet chute was built about 55 years ago for the transportation of crossties in India. The channel had inside cross-sectional dimensions of 8 by 13 inches, being made from three planks 5 by 13 inches in cross section by 12 feet in length, which were supported at 6-foot intervals on trestle caps or on crossties laid on the ground and held tightly together by wedges, as shown in Fig. 33. Its length was 12,200 feet, the difference in elevation of the head and the lower terminal was 1,300 feet, and the gradient ranged from 5 to 22°, the optimum being 15°.

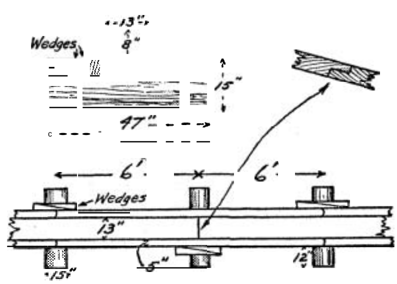

Fig. 33. The Deota wet chute. India. (After C. G. Rogers.)

A good flow of water was required on sections under 18°, but at 22° the crossties moved readily by gravity, although some water was required to

15 See *A Manual of Forest Engineering for India*, Vol. III, pp. 110-116, by C. G. Rogers, Calcutta, India, 1902.

prevent the ignition of the chute by friction. The water for operation was conveyed by feeders from mountain streams, some of which were ¼-mile distant. Owing to the scarcity of water the chute was operated only during the rainy season, at which time a crosstie would cover the distance of 2¼ miles in ten minutes. The average daily output was 2 crossties per minute or 1,200 per working day.

This chute was used for about 4 years, when it was destroyed by a severe flood. During this period 500,000 crossties were transported at a net saving over cartage of 20,000 rupees. The operating crew comprised 11 men, including one carpenter who was engaged in tightening wedges and making other repairs.

Pierson wet flume. This was designed by an Inland Empire operator[16] and represents a type used to a limited extent in the Rocky Mountain region (Fig. 34). It will move saw logs on grades as low as 15 per cent with a limited quantity of water and also may be used to advantage on grades as steep as 60 per cent. Primarily, this type is designed for a trailing chute on low gradients, under which conditions it has a high daily capacity.

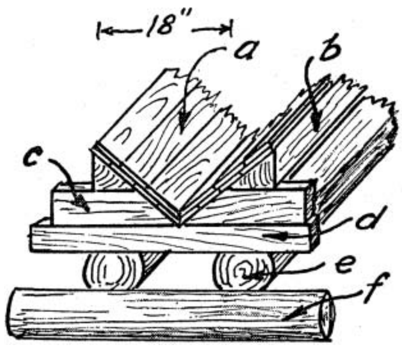

Fig. 34. Pierson's chute flume. Idaho. (After 1. V. Anderson.)

The trough of the Pierson chute forms a V-channel, having a 90-degree angle at the apex and is made from 1¼-inch sawed material, doubled. The box is braced by longitudinal triangular pieces "b" which are made by sawing, diagonally, an 8 by 10-inch timber. Each brace rests ana 6 by 8-inch by 4 feet 2-inch cap which overlays a lower cap "d," 4 by 6 inches by 4 feet 8 inches in size. The caps are supported on two round stringers "e" which reston mud sills or cribbing "f" of sufficient height to maintain the desired grade.

ARMORED WOODEN CHUTE.

Wooden chutes, especially those made from poles, wear out rapidly.

16 V. Pierson, Idaho.

Sheet iron sometimes is used to cover the channel members at points where the wear is greatest; in rare cases the chute may be armored for its entire length. Some loggers also use sheet iron to reduce the frictional resistance on the flat sections of a wooden chute, but the effectiveness of this measure is limited.

A new chute is seldom armored when it is built, but rather the lining is added to reinforce weak places as they develop. The entire inside surface may be covered; the bottom only; or merely narrow strips of iron placed longitudinally with a slight space between them. It is essential that the sheets be nailed so that the passing logs will not tear them loose which, however, frequently happens within a short time. Some operators prefer to use round iron bars, the upset ends of which are barbed and driven into the logs forming the channel, because they are more durable and lasting than sheet iron strips. They are preferred as a reinforcement on sharp, horizontal curves; at the angle of a concave vertical curve; and at points where wolf brakes are installed.

PORTABLE CHUTE

These represent types which are built so that they may be moved from one site to another and thus used for bringing timber out of different areas. They may have a wooden or a metal channel, and the latter may have a ground support or be suspended on cables without intermediate supports.

Wooden trough. There are several portable wooden chutes in use, among which the following are the more important.

Turner chute.[17] This type (Fig. 35), designed for transporting 4-foot pulpwood, has a trough made from sawed birch lumber and a framing made from any suitable softwood. The channel is in 12-foot sections for convenience in assembling, dismounting, and transportation from one site to another. Experience indicates that two men can construct, daily, ten sections or 120 linear feet of this chute.

Experiments made during clear, cold weather with a 400-foot chute of this type, having a 12 per cent grade, showed that pulpwood bolts as small as 3 inches developed sufficient momentum to move by gravity to the landing. Based on results secured from chuting several thousand cords of pulpwood, it is believed that the Turner chute is well adapted for moving pulpwood on grades that are too low for pole gravity chutes. The channel

[17] Designed by Jack Turner of Quebec for use in Newfoundland.

members become very smooth with use and are superior in this respect to a pole chute shod with sheet iron.

The working life of a well-constructed Turner chute is longer than that of one having a channel made from poles. One chute, moved twice to new locations, was in excellent condition after having transported more than 2,000 cords of wood. Light chutes of this type used for feeders to the main line were satisfactory as a channel, but were not strong enough to stand rough and hard usage.

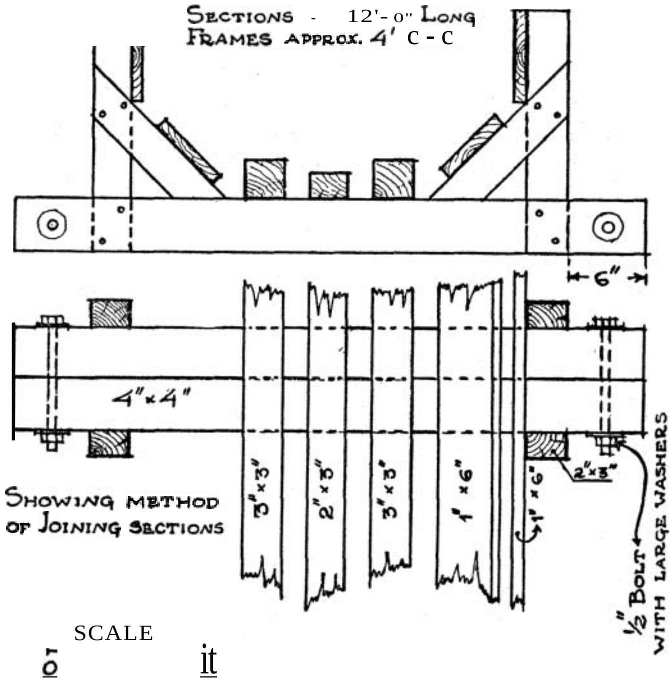

Fig. 35. The Turner portable plank chute. Newfoundland.

Miller chute. This type (Fig. 36) for trailing saw logs was designed by a Montana logging operator[18] and used on the Absaroka NationalForest. The trough comprises two beveled sticks made by sawing a 6 by 8-inch by 16-£00t sawed timber at the proper bevel. The channel members are laid on crossties spaced 8 feet c. to c. and braced by two round side rails which

18 1. Miller, Gray Cliff, Mont.

are spiked to the crossties. This chute is satisfactory for trailing operations and can be readily dismantled and moved to another location.

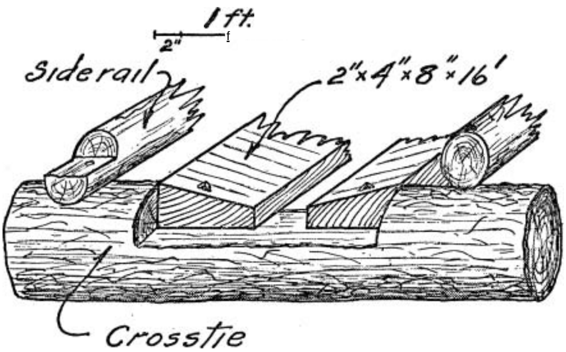

Fig. 36. The Miller portable saw log chute. Montana.

Sykes chute. This was invented and patented by an operator[19] in northern New York and is designed for trailing logs, although it sometimes is operated as a gravity chute for short distances and for rather low grades. A schematic layout for a combined railroad and chute operation is shown in Fig. 37.

The channel members, in 8-foot lengths, are three in number and are made from birch or hard maple, preferably the latter (Figs. 38 and 39). The ends of these pieces rest without nailing on a "shoe" or "chair" which is placed directly on the ground, if topography permits, or on a cribwork of sufficient height to maintain the desired slope to the channel. This type is best adapted to a comparatively flat region, although it is possible to operate it on grades somewhat above the angle of repose, provided the "chairs" are so braced by wooden stakes that they cannot move down grade.

It has been used successfully for trailing logs for distances as great as one mile. On a greased chute, the average trailing capacity of a team towing hardwood logs averaging from 10 to 15 per thousand feet, log scale, is about 1,000 feet per tow or a volume approximately four times greater than the same team could drag over unfrozen ground. An example of daily capacity is indicated by the following: One team averaged seven round trips on a chute ¾ mile in length which had a few down grades of from 3 to 5 per cent and occasional upgrades of from 1 to 2 per cent.

19 F. Sykes, Cranberry Lake, N.Y.

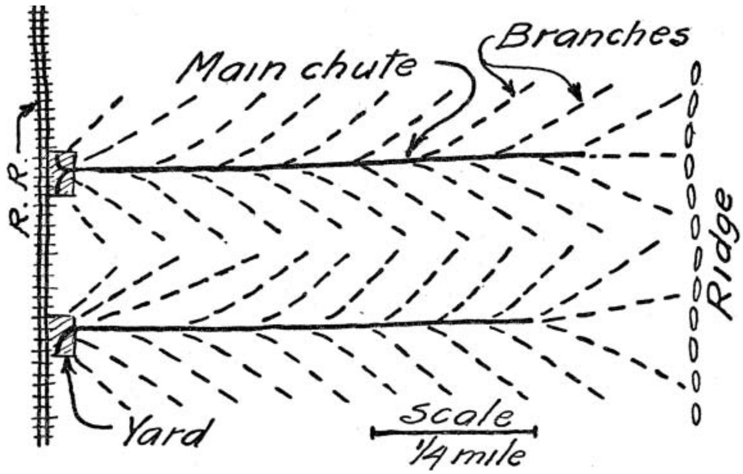

Fig. 37. A typical arrangement of a Sykes portable chute serving as a feeder for a logging railroad. New York.

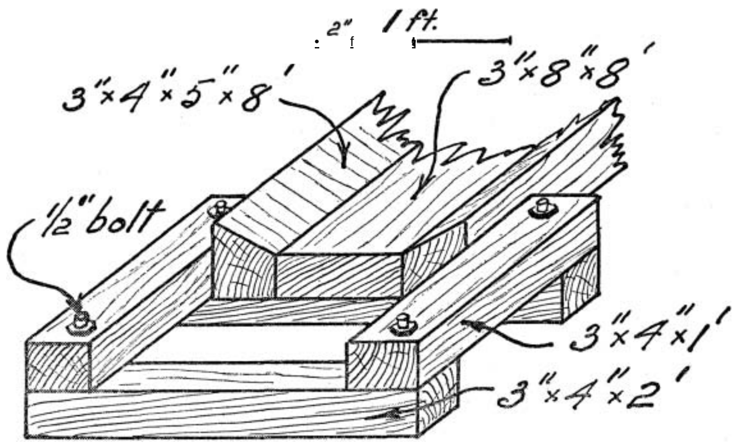

Fig. 38. The details of construction of one section of a Sykes portable saw log chute. New York.

When the topography is such that only a very limited amount of cribbing is required, one man can install daily about 500 feet of this chute. One teamster and a team with a trailing rack can dismantle, daily, approximately 1,000 feet of chute and move it to a new location from ¼ to ½-mile distant.

The average life of this type based on 200 days' annual use is from 5 to 7 years. The sales price per linear foot as given by the inventor is 23 cents. The ease with which this chute can be moved from one set-up to another and the large size of logs it will handle warrant a more extensive use than it now has. It should be well adapted to Lake States and Appalachian conditions.

Metal trough. Experiments have been made in recent years with various forms of metal channels, both sheet iron and steel plates being used for this purpose. The usual method of support has been on some form of ground structure, but during the last few years several types suspended from cables have been suggested, although they have not yet been tested.

Ground-supported channel. The following types represent those that have been developed with more or less success.

(A) Sheet iron.—Plates of sheet iron are neither sufficiently strong nor durable for use in constructing channels for large logs, but short sections made from corrugated iron sheets have been used in Newfoundland for lowering limited quantities of pulpwood bolts down steep river banks. Experience with all types, including the *Dutcher* chute described below, has been too limited to draw accurate conclusions concerning their efficiency and life.

Three designs of demountable and reversible sheet iron chutes (Fig. 40, A, B, and C) have been patented by H. K. Dutcher, who states they have been used successfully in British Columbia for transporting shingle bolts. However, more extensive experimental data concerning their durability are desirable. They are offered for sale by a Canadian firm.[20]

The *Dutcher* chute is built in sections 8 and 10 feet in length. In types *A* and *B* the sheets overlap about one-third, which permits four reversals of the bottom where the wear is greatest. Such an arrangement increases greatly the life of the chute as compared to one in which the trough is made from a single sheet only. The sections are bolted to iron bands[21] which support the trough and which, in turn, are fastened to the longitudinal stringers at 8 or 10-foot intervals. This method is simple and makes

[20] The Pedlar People Ltd., Montreal, Canada.

[21] These bands are 3 inches wide and are made from sheets from 6 to 10 gage (3/16 to 1/8 inch) in thickness.

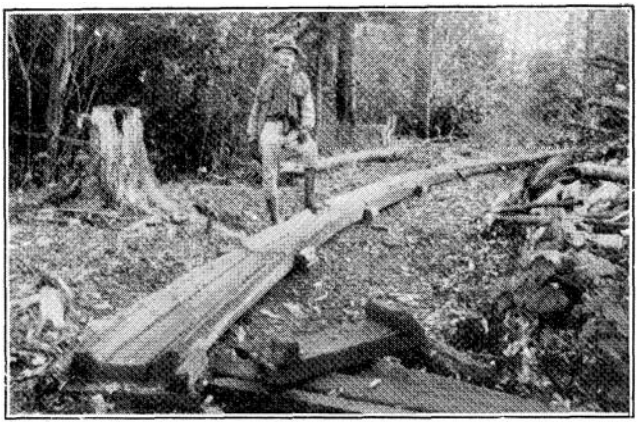

Fig. 39. View of several sections of a Sykes portable chute on a curve.

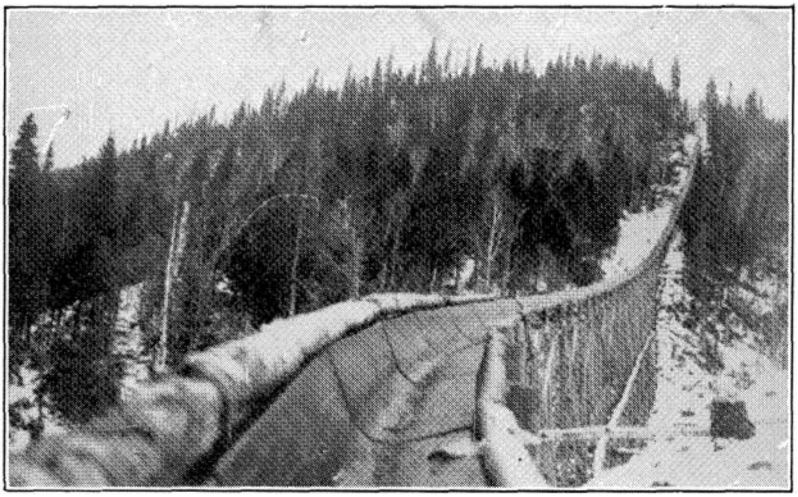

Fig. 43. General view of a Saint Anne chute showing the metal channel bordered by birch fender skids. Quebec.

assembly and dismantling easy_ The size of the trough may be varied by changing the amount of overlap on the bottom, extra holes being provided for this purpose in the trough-support bands.

Type C of the *Dutcher* chutes is more simple in design than the first two mentioned. Supporting bands are not used since each Io-foot section, comprising two iron sheets, has flanges 2 inches wide on both edges, which

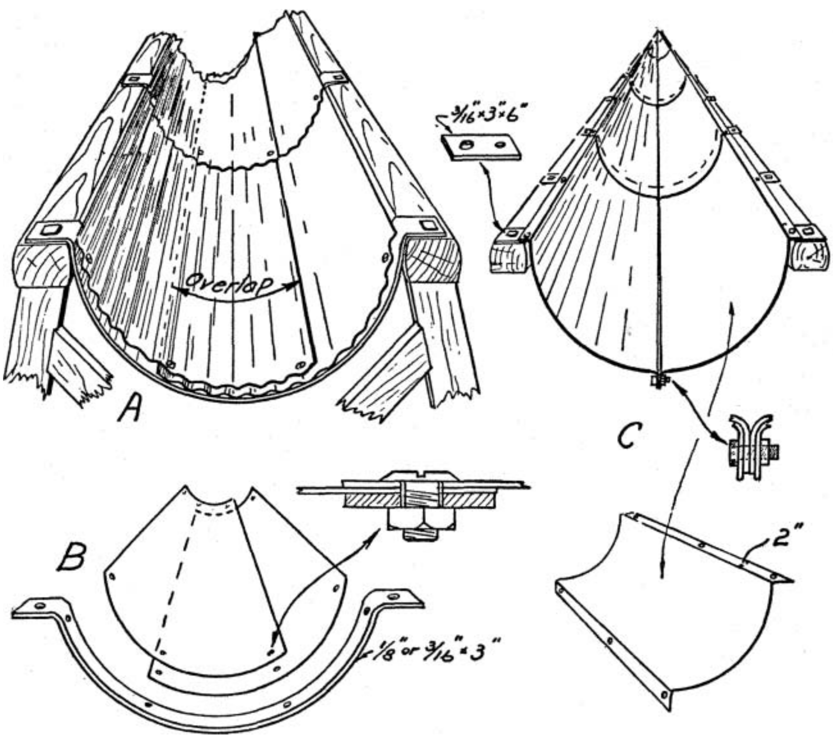

Fig. 40. The Dutcher portable and reversible sheet iron chute. *A* and *B*, the overlapping, and C, the flange-joint type.

serve to form an angle joint at the bottom and also on the side for bolting the trough at 5-foot intervals to the stringers. This type permits only two reversals for decreasing the wear, but it has the advantage over types A and B in that there are no bolts inside the trough itself. The overlap of each section is 3 inches.

The sizes and weights of sheet iron chutes which are offered by the manufacturer are shown in the accompanying statement.

SPECIFICATIONS, DUTCHER SHEET IRON CHUTE

	Dimensions of semicircular trough			*Weight of chute channel, pounds*			
				Gage of plates			
Type of Chute	*Width inches*	*Depth inches*	*Length feet*	*18*	*16*	*14*	*12*
A[22]	32	16	9.75	15.0	19.3	23.2	. . .
	26	13	9.75	13.3	15.8	19.3	. . .
B and C[23]	35	17.5	9.75	. . .	19.5	23.6	30.2
	33	16.5	9.75	. . .	15.0	19.1	26.0
	28	14.0	9.75	. . .	12.5	16.0	21.5

The above chute is quoted at prices ranging from $1.10 to $2.40 per linear foot, based on type and dimensions.

(B) Steel.—The substitution of steel plates for the wooden parts of a chute trough is a recent development which contains much promise, based on the limited experience which loggers have had with it.

Steel troughs have the following advantages as compared to those built from wood:

(1) Greater durability. Although data are not available on which to base a thoroughly trustworthy comparison, experience indicates that a properly constructed and maintained steel trough will transport ten times more timber than a pole chute before it is worn out.

(2) Greater portability. A chute trough made in 10-foot sections can be assembled and dismantled readily and easily transported to a new site.

(3) Uniform and low frictional resistance. Steel chutes are less affected by weather conditions than wooden ones and, therefore, the resistance is more uniform. The steel surface also is smoother than the face of wooden timbers and hence the angle of repose is less. This is an important advantage on moderate slopes.

(4) Smooth operation. The movement of a log is more uniform in a steel

[22] Corrugated, galvanized iron sheets.

[23] Smooth, galvanized or black iron sheets dipped in red oxide.

than in a wooden trough, and the channel can be fashioned readily into any desired shape. Experience indicates that logs jam and "jump" less on a steel channel than on a wooden one because there is less lateral motion.

The chief tests of steel chutes have been made by two Canadian pulpwood firms whose equipment is described below.

So far as is known, the first steel chute, here called the *Price Brothers* chute, was designed by J. L. Kelly of Price Brothers and Company of Canada and was installed in Quebec in 1926 as a gravity chute for transporting 4-foot pulpwood bolts.

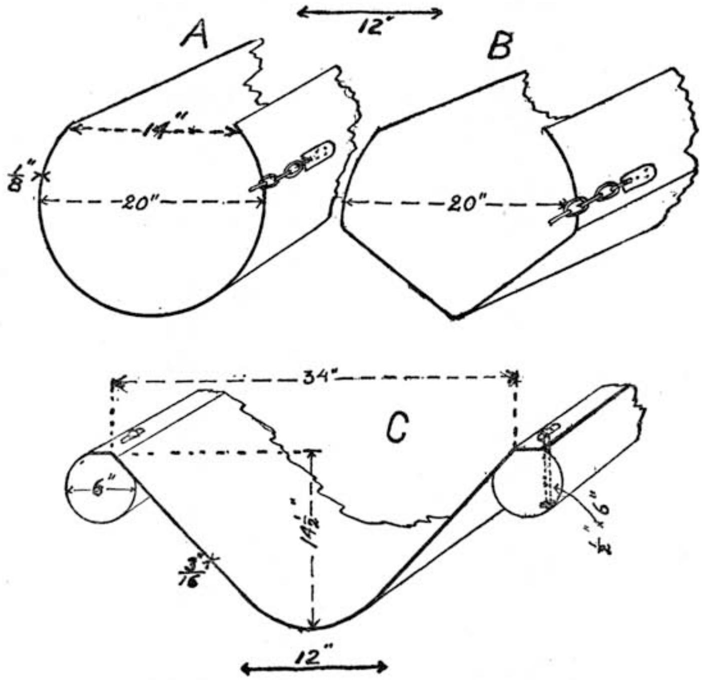

Fig. 41. Steel chute troughs. *A* and *B*, Price Bros. type; *C*, the Saint Anne type. Quebec.

Two trough patterns were developed: a semicircular one, having a radius of 10 inches and an open top width of 14 inches, and a V-shaped one, the apex angle of which was 140° (Fig. 41, A and B). The latter was found to be more practical on steep grades because there was less lateral movement of the logs and a minimum of vibration. On the other hand, the round trough had the advantage of offering the minimum frictional resistance on flat grades. The trough sections, made fronl Io-gage steel plates (about 1/8-inch) were 4 feet wide and 10 feet long, weighed approximately 180 pounds, and each cost about $13 (1926).

Each section was reinforced by a 3/8 by 1 1/4-inch steel band. The ends of adjoining sections were fitted into each other with a 3-inch overlap and held in position by two chains, each 12 inches long, the free ends of which were caught in wrought iron claws riveted to the trough. The latter was supported on notched crossties, placed at la-foot intervals when the chute followed the general ground level, and on the notched caps of trestles and on two longitudinal pole stringers when it was elevated above the ground level.

The cost of dismantling, moving, and reassembling a chute of this character is stated to be from 2.5 to 6 cents per linear foot. The chute has not been operated long enough to determine its probable life.

A chute of a somewhat different type, the so-called *Saint Anne,* was designed by V. E. Johnson and constructed in 1928 by the Saint Anne Division, Abitibi Power and Paper Company, in Quebec Province, Canada. Two chutes were constructed on relatively steep grades for the transport by gravity of 4-foot pulpwood which averaged approximately one hundred pieces per cord.

The V-shaped trough (Fig. 41, C) was 34 inches wide at the top, 14.5 inches deep, with a curve radius at the base of 6 inches. The la-foot sec-

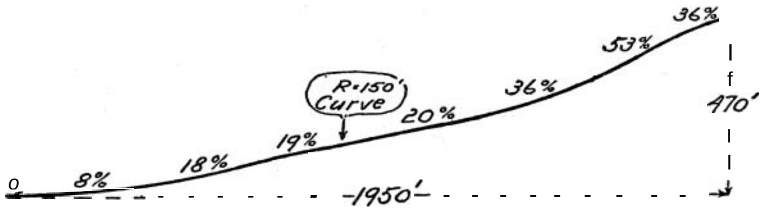

Fig. 42. The general profile of one of the Saint Anne chutes. Beaupre, Quebec.

tions were made from 7-gage (approximately 3/16-inch) steel plates, each section when joined having an overlap of 1.75 inches. The flanges on the edges \vere 1.75 inches wide, and each had three slots through which 1/2 by 6-inch bolts were inserted for fastening the section to the two hewed poles which served as a longitudinal support for it. The total weight per section was about 350 pounds and the initial cost (1928), $17.50.

The profile of one of these chutes, roughly shown in Fig. 42, had grades varying from 53 per cent near the upper end to approximately zero at the lower terminal, with an average gradient of 22 per cent. The total length was 1,950 feet, and the difference in elevation between the head and the point on the bank of the Saint Anne River where the logs were dumped was 470 feet. At a point about midway down the chute where the gradient was 19 per cent, there was a 30-degree change in direction, and here a horizontal curve with a 150-foot radius was inserted.

The irregularity of the ground profile made it necessary to support much of the trough on trestle work. The average elevation above the ground level was 20 feet for about one-half of the total chute length, with a maximum of 45. Only in a few places was the trough less than 5 feet above ground.

The trestle bents, spaced 10 feet apart, were made from peeled softwood poles, the posts being 7 or 8 inches in diameter, the caps 6 inches, the braces 4 inches, and the longitudinal poles which supported the trough 6 inches.

The construction of the entire chute required 700 pounds of 60d. spikes, 1,700 pounds of 8-inch spikes, and 200 pounds of ½ by 6 and 8-inch bolts.

The cost of chute construction (1928) per linear foot for the Saint Anne type is shown by the accompanying statement.

COST OF STEEL CHUTE CONSTRUCTION

Construction items		*Per linear foot*
Steel trough	$1.75	
Transport of trough to chute site	.35	$2.10
Construction cost		
Clearing right of way	.27	
Cutting and hauling chute timber	.50	
Trestle erection	.66	
Trough installation	.30	
Miscellaneous expense	.09	
Overhead	.38	2.20
Total		$4.30

Of the construction cost, 88 per cent was manual labor, 6 per cent horse labor, 5 per cent materials, and 1 per cent miscellaneous items.

When this chute was first placed in operation some trouble was experienced by bolts leaving the channel, especially at the curve, even though the trough at that point was tilted at an angle of 25°. This defect was later overcome by installing 8-inch birch fender skids along each edge of the trough, as shown in Fig. 43.

The company installed this chute with the expectation of transporting 15,000 cords of wood, over a 5-year period, from the upper slopes of the mountain to the Saint Anne River at the cost shown below, which was approximately one-half of the estimated cost of sled haul by animals.

ESTIMATED COST OF CHUTING, SAINT ANNE RIVER

Cost items	*Per cord*
Depreciation of chute, 5-year period	$0.46
Interest on investment at 6 per cent, 5 years	.14
Maintenance and repairs	.24
Chute tenders	.11
Miscellaneous expense	.13
Total	$1.08

During the first two operating seasons more than 5,000 cords of pulpwood were transported without undue depreciation of the steel plates, and it is probable that the 5-year life estimated by the constructors will be realized. The general opinion is that this form of steel trough has proved more satisfactory than a pole chute for the existing conditions. The tendency of the logs to leave the channel on curves and steep pitches probably could be greatly reduced by using a V-shaped trough with steep walls.

Suspended channel. The discrepancy between the natural ground profile on very rough terrain and the desired profile for an efficient chute has led operators to give serious consideration to the possible development of a type in which the trough is suspended on one or more cables stretched between two or more supports. A satisfactory suspended chute would make the logger more or less independent of topography and greatly cheapen chute transport on terrain which is badly broken.

Although this idea has only recently been considered on this continent, a

Buko\vina forester in Austria patented a suspended firewood chute more than 25 years ago. However, evidence is not available that the idea was further developed or used to any extent.[24] The Austrian chute patent called for a trough made from wooden planks screwed to semicircular irons which were suspended from a rope. All suspended chutes designed on this continent have been based on the use of sectional metal troughs and a steel suspension cable.

The chief interest in suspended chutes has been manifested by pulpwood operators in eastern Canada. Considerable experimentation will be necessary before a satisfactory type is developed, and the present unfavorable economic conditions have deterred loggers from making the necessary investment. So far as kno\vn, suspension chutes have not yet been installed at any point on this continent.

The chief merits of sectional suspended chutes are believed by their advocates to be as follows:

(I) They may be installed on terrain which is so rough that the use of animals and the usual type of ground-supported chutes is precluded.

(2) The cost of construction on very rough terrain would be much less than for the ground type of chute because trestle work and ground supports would not be required except at the points of suspension. Little or no right of way clearing would be needed.

(3) The profile of a suspension chute would be uniform and straight, thus eliminating sharp changes in horizontal and vertical directions.

(4) The portable character of the chute would be an obvious advantage.

(5) The regularity and smoothness of the channel would eliminate excessive wear and give a relatively long life to the chute.

(6) A suspension chute would provide much greater latitude in the choice of location on rough terrain than a ground type. Also the chute profile could be altered within certain limits by increasing or decreasing the tension in the supporting cable, by changing the location of the bottom anchor, and by using guy ropes. The relative ease with which the chute apron at the dump could be shifted by means of guy lines, removal of lower trough sections, and similar devices would make it possible to distribute wood over a relatively wide storage area rather than concentrating it in one large pile.

[24] See "Amerikanische Trockenriesen," by Julius Duhm. *Wiener Allgemeine Forst- und Jagd-Zeitung,* p. 2, Vienna, Jan. 2, 1931.

(7) A suspended chute could be used to replace cribbing where a ground chute crosses a deep depression.

(A) Salkeld chute.—This was designed[25] in 1929 for transporting pulpwood bolts in eastern Canada over very rough terrain. It is probable that such a chute may be adapted for the transport of logs as well as pulpwood bolts. It has not been given a practical test to date, although the idea has been favorably received by some loggers.

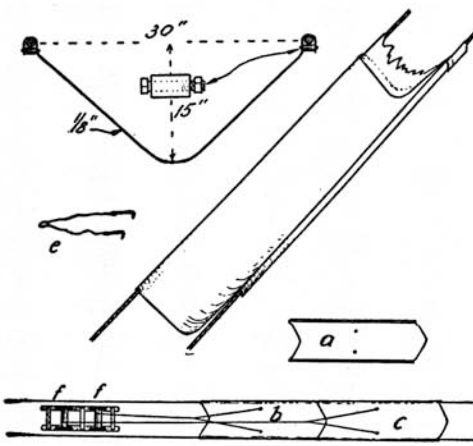

Fig. 44. The Salkeld suspension chute. *a, b,* and *c,* sections of steel chute; *e,* the crotch line for holding the sections in position during assemblage; *ff,* the hand winch for holding and lowering the sections during assemblage.

The trough, unlike the types later described, is supported by two wire cables (Fig. 44). Although not yet proved by practice, the inventor believes that spans of 2,600 feet, with a difference in elevation between the two ends of 1,000 feet, are practical. The following estimates were made by the inventor for a pulpwood chute 600 feet in length, a cable span of 900 feet, a difference in elevation of 300 feet, and a vertical cable deflection at the center of the span of from 50 to 75 feet. The inventor recommended two ¾-inch steel cables for this chute, each having a hemp core and six strands of seven wires each, having a weight of 0.92 pound per linear foot and a breaking strength of 20.4 tons. The trough is made from 10-gage

[25] W. B. Salkeld, inventor.

steel plates in sections 10 feet 2 inches long, the 2 inches being for overlap. The weight per section is approximately 230 pounds.

The total weight of the 600 feet of chute and the 1,800 feet of cable is 7.8 tons. The maximum stress on the top anchor may reach 20 tons and that on the lower anchor 16 tons, due to the weight and friction of the wood, and hence the two cables provide a factor of safety of 2.

ESTIMATED CONSTRUCTION COST—SALKELD CHUTE

Steel trough sections, 10 feet	$1.50	
Cable, ¾ inch	.50	
Hand winch	.28	
Bolts and nuts	.06	
Chains and anchor fittings	.13	
Cables for winches and anchors	.05	
Freight and toting	.17	
Tools and miscellaneous expense	.33	
		$3.02
Labor at $3.50 per day		.20
Total		$3.22

The inventor suggests the following installation procedure. The cables are transported to the head of the chute, where they are firmly anchored at the proper distance apart, and the coils are then unrolled downhill along the route. The cables, on reaching the lower end, are properly spaced and then given the required tension by means of a double hand winch,[26] and the free end of each cable is anchored to a "deadman." The winch is then moved to the top of the chute and used in the installation of the trough. Two sections (Fig. 44, b and c) are adjusted on the main cables and held in position by auxiliary lines controlled by the two brake drums "f," "f." A third section, "a," is then placed in position on the main cables and bolted to the second section, "b." The auxiliary cable holding "c" is then slackened and detached and placed in position on "a," following which the

[26] The inventor recommends the so-called Beebe hand winch, mounted on skids. This weighs 100 pounds, is equipped with a positive self-locking brake, and can exert a direct line pull of 5 tons.

auxiliary lines are slackened and the trough permitted to slide down the main cables for a section length. The above operations are repeated until the entire trough has been installed. Two lengths of cable are then attached to the top section and anchored in the rear. The winch is then removed and the chute is ready for operation.

The chute is dismantled by a reversal of the above process. Salkeld estimates that it would require four men from three to eight days (depending on skill and experience) to install and dismantle 600 feet of chute. The accompanying statement is his estimate of the cost of materials and labor per linear foot.

(B) Koroleff chute.—The following suggestions concerning improvements in the Salkeld chute were made by A. M. Koroleff in an address before the 1930 Annual Meeting of the Woodlands Section of the Canadian Pulp and Paper Association:

(1) The use of one suspension cable only. The uniform tensioning of two cables would be difficult, if not impossible, under average operating conditions.

(2) The use of a main cable of a size adequate to withstand the strain, both of the load and of snow and wind pressure, for which Salkeld made no special provision.

(3) A trough with greater depth in order to guard against logs leaving the chute on the steeper grades.

(4) The attachment of the chute trough to the main cable instead of having it only rest on it. The plan followed by Salkeld subjects a given joint to the stresses set up by the entire weight of the sections above and below it, which might be greater at times than the metal could withstand.

(5) The use of a more simple method for assembling the trough. Single sections or a few joined together might be slid up or down the suspension cable to the proper place, by means of an auxiliary rope and a 'Ninch, and there joined and attached to the main cable by clips. This procedure, however, would require the services of a rigger at that point.

Koroleff has embodied these general ideas in a chute of the type shown in Fig. 45. The steel trough made in Io-foot sections is hung under the suspension cable by means of a light sling, the ends of which are attached to a broad steel band support which passes around the trough and also provides a method for joining the sections. For the latter purpose each section has an "ear" protruding on each side of the trough near its ends, and these "ears" pass through apertures in the supporting band and are locked by a metal key inserted through holes in the "ears." The slings are held in position on the suspension cable by means of clips.

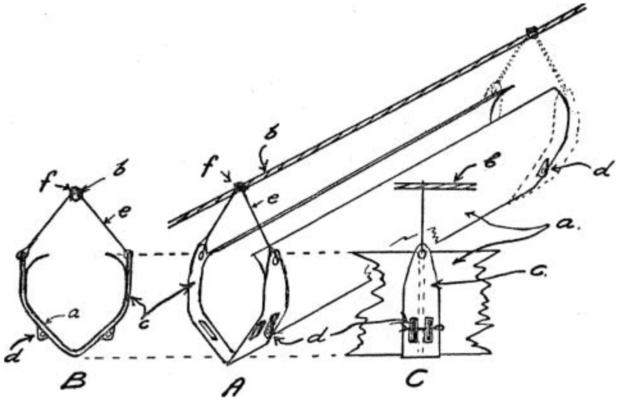

Fig. 45. The Koroleff suspension chute. *A*, suspended section; *B*, cross section; C, side view of a joint uniting two sections. *a*, the trough; *b*, the supporting cable; *c*, the steel band for supporting the trough; *d*, the "ears" fitting into the steel band; *c*, the sling; and *l*, the clip by means of which the sling is attached to the supporting cable.

A chute suspended as above, with a V-trough made from two planks, undoubtedly would be satisfactory for chuting small-sized wood on relatively short spans.

(C) Koroleff tubular chute.-Loggers in Canada have experimented, to a limited extent and with a fair degree of success, \vith enclosed wooden chute troughs in order to overcome the tendency of logs or bolts to leave the channel. Such wooden chutes are not portable, however, and are rather expensive to build and maintain. Koroleff suggests that a sectional, tubular steel trough chute, though untested under actual operating conditions, should have the following desirable qualities:

(1) Portability and ease of assemblage.

(2) Elimination of wood "jumping," regardless of the chute profile.

(3) Freedom from weather influences such as snow or ice accumulations in the channel; therefore, a more or less uniform frictional resistance.

The possible disadvantages of such a type of chute are the jamming of logs within the enclosed trough and the greater amount of metal required for an enclosed, as compared to an open, trough. Whether or not logs will jam can only be determined by experiment; however it seems probable that this would not occur on an enclosed steel chute which had a grade steep enough to cause logs to run by gravity and into which the \vood .was fed at a reasonable rate.

Koroleff has designed t,vo types of tubular troughs (Fig. 46, A and B),

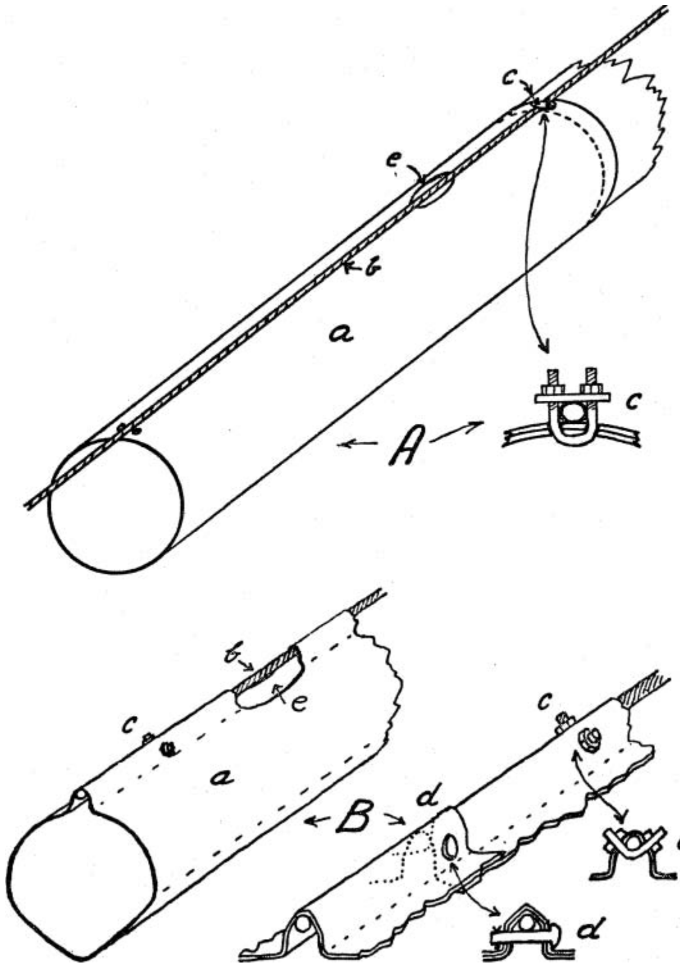

Fig. 46. The Koroleff tubular chute. *A,* cylindrical, and *B,* V-type. *a,* cylindrical trough; *b,* supporting cable; *c,* clip for joining sections and attaching them to the supporting cable; *d,* bolt (a substitute for the clip, *c)* for joining sections; *e,* emergency opening for repairs and for breaking jams.

both of which are well adapted for suspension. The sections are attached to the suspension cable by clips which also serve to fasten them together by means of the overlap. The suggested size of a tubular trough for average sized pulpwood is 24 inches, made from 10-gage (1/8-inch) steel sheets. The simplicity of trough type "A" is in its favor. The suspension cable may be inside or on top of the trough. Type "B" may prove to be more advantageous, however, because the V-shaped form will reduce the lateral movement of the moving wood to a minimum.

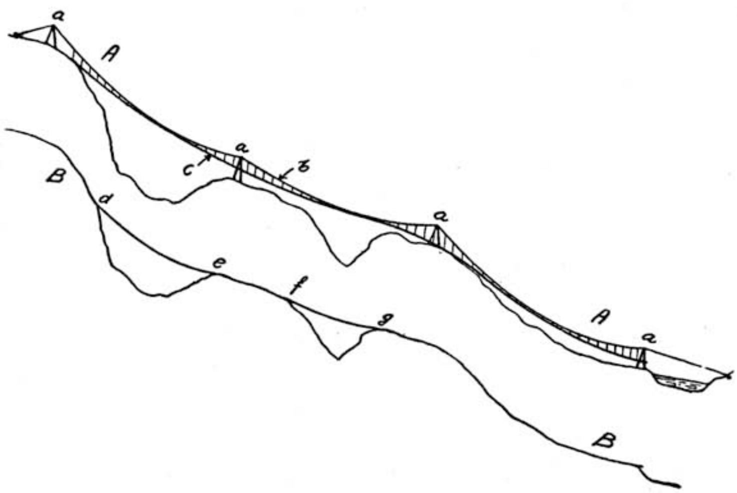

Fig. 47. *A*. The Munro method of steel chute suspension by means of intermediate supports. *a*, supports; *b*, main supporting cable; *c*, chute trough. *B*, same profile as *A* with the two depressions, *de* and *fg*, spanned by a suspension chute and the remainder covered by a ground chute.

(D) Munro chute.—This chute, designed by D. J. Munro, of Quebec, Canada, deals with a method of trough suspension and not with a trough design itself. The suspension cable is supported on tripods (Fig. 47) or masts at varying intervals, depending on topographic and other conditions. A steel trough is suspended from the main cable by slings in the same manner as the floor of a suspension bridge. The installation of a chute with this form of suspension is more complex than that of the suspended chutes previously mentioned, and much more time and labor would be required to dismantle and reassemble it at another site. Therefore, it is less portable than the suspension types previously described and would be adapted chiefly for conditions where the quantity of wood to be moved was great.

RAIL CHUTE

A chute, the trough of which is made of steel rails, has been occasionally used on logging railroad operations in the United States to bring logs down steep slopes to a railroad under conditions where wagon haul with animals was impracticable. A chute of this type is shown in Fig. 48. The channel is formed by four rails of any convenient weight, two of which are spiked to a standard crosstie and another one is spiked to each of the 45° faces of the blocks which are driftbolted to the crosstie. These blocks usually are made by cutting a crosstie through the center at the proper angle.

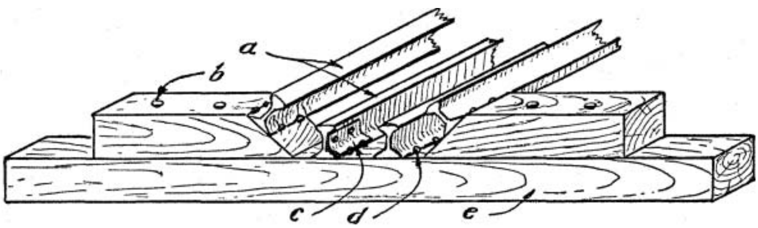

Fig. 48. A chute channel made from steel rails and crossties. *a)* rails; *b,* bolts; *c,* angle bars connecting the rails; *d)* railroad spikes for attaching rails to the crossties; *e,* crosstie. United States.

When necessary to maintain a desired grade the chute may be supported by cribwork made from crossties, other\vise it rests directly on the ground. An experienced crew can install about 50 feet of chute daily, using 45-pound rails for the channeL When a chute is dismantled, the rails and crosstiesusually are returned to the stock used for logging railroad construction.

A rail chute is best adapted for transporting medium to large sized logs, and for this purpose they function satisfactorily because projections, even on rough logs, do not catch but travel between the rail heads.

ROLLER CHUTE

Sections with metal or wooden "dead" rollers may be installed on gravity chutes for starting logs or bolts when the slope of the chute head is below the angle of repose, which condition may exist when it is desirable to have a comparatively flat grade at the feeding point so as to provide ample space for log storage. It also may prove feasible to install rollers in sections of V-chutes in which the grade is so low that otherwise logs will not run by gravity.

A roller gravity chute, constructed by J. Turner and used in Newfoundland for the transportation of 4-foot pulpwood on flat grades, is shown in

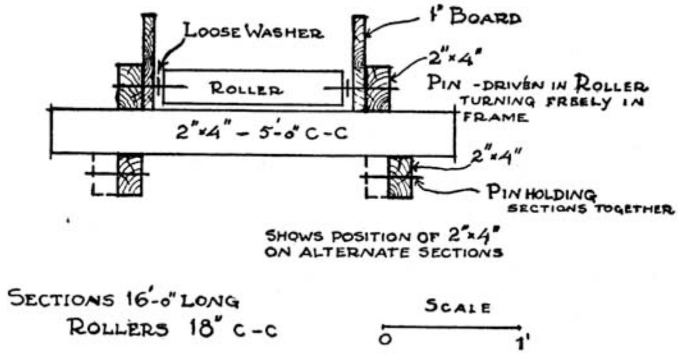

Fig. 49. Turner gravity roller chute. Newfoundland.

Fig. 49. The rollers were made from peeled pulpwood bolts, 3 by 16 inches in size, and were spaced 18 inches c. to c. in a framed section 16 feet in length which was made from lumber. The sections were bolted or wired together with hay wire and were supported on stumps, piles of brush, pulpwood, or any other handy material. Although this chute was rather crudely fashioned because it was designed for moving only a small quantity of wood, it proved very mobile and gave satisfaction.

Concave, spiked, wooden rollers, the arbors of which are attached to some form of friction device designed to regulate the speed of rotation of the rollers, have been tried out as braking devices, but with little practical success because of the relative high cost of construction, installation, and maintenance.

UNUSUAL CHUTE TYPES

In addition to the various types of chutes previously discussed, which include the great majority of those in use or those recommended, there are a few others which have been designed for very specific conditions.

Among these may be mentioned a permanent gravity chute, comprising a furrow in the earth lined with smooth granite blocks, which was constructed in the Carpathian Mountains in Czechoslovakia. Properly maintained, such chutes would last for many years and would prove serviceable for forests under management from which a large annual volume of cuttings are transported. The relatively high cost and the short period of use make such a chute impractical on this continent.

A unique type, reported from Sweden, for lowering logs down a high waterfall was designed on the same principle as a spiral fire escape. The velocity of the logs was controlled by centrifugal force and the friction of the logs against the spiral walls of the channel.

Devices Used for the Control of Log Velocity in Chutes

Topographic conditions frequently are such that a chute cannot be built at a reasonable cost with maximum grades low enough to make it possible to transport logs without excessive breakage or damage to the chute or logs or both. The construction of a chute under these conditions, therefore, either must be abandoned or some method or methods devised by means of which the velocity of the logs can be kept within safe limits. Theoretically, especially for short wood, chutes should be most efficient on steep grades, and operators have experimented with various methods of velocity control which will overcome the difficulties arising from a very steep gradient. A highly efficient speed-retarding device would be of great value because it would make possible the construction of a channel which could follow closely the ground level, thus obviating the necessity of constructing high and expensive trestles, making deep cuts, and adding to the length of the chute in order to keep the grades to the maximum permissible when such devices are not used.

The importance of efficient brake devices on gravity chutes increases as the grade of the chute increases. They also may serve a useful function on sections of trailing chutes over which logs can be dragged safely during dry weather, but on which the frictional resistance may be so reduced by dew, rain, snow, or ice that they are then unsafe to operate.

VELOCITY REDUCTION

The many methods and devices employed to regulate the velocity of logs traveling in a chute vary from the simple to the complex. Some of the more common forms are inefficient and destructive and their use should be discontinued, while some others, but little known and used, give promise of providing the desired results.

Loggers have made more or less sporadic efforts to develop new, and to improve existing, braking devices, but progress along this line has been slow. Careful research and experiment by a competent agency would be of great value to chute users and owners of mountain forests, because the elimination of existing faults would greatly reduce the log damage and pave the way to a far more extensive adoption of chutes than is now the case.

A satisfactory brake device should embrace the following characteristics:

(1) It must possess the power to check effectively the speed of logs. The required braking work will be governed chiefly by the velocity of the logs, which is dependent on the form and character of the chute channel and the diameter, weight, density, length, and condition of the log (large or small, heavy or light, long or short, wet or dry). Thus a given brake may be called upon at different times to exert a low, a medium, or a high braking effect, depending upon the character of the logs being transported and on the weather conditions.

(2) It must be flexible in its action in order that it may be adaptable to varying conditions. This flexibility, in so far as possible, should be automatic in order that the brake may adapt itself to all sizes of logs and conditions of weather without requiring the services of a chute guard.

(3) It should be of such character that it can be constructed and operated cheaply in order that it may be profitable to insert an adequate number of brakes in temporary chutes down which only a limited number of logs are to be transported. Expensive braking devices are impractical in temporary chutes having steep grades, because the object sought should be to use enough brakes to prevent logs from attaining excessive velocities rather than to attempt to check excessive velocities which have developed. The latter tendency exists when the costs of installation are high.

Several general principles have been adopted as the bases of the various braking devices, the chief among which are the following:

(1) Increasing the frictional resistance between the chuted log and the chute channel by roughening the surface of the latter.

(2) Inserting a brake which has a weighted arm or one which is depressed by a spring. The arm is raised as the log passes underneath it, and thus the log loses velocity.

(3) Using low-grade, horizontal, or counter-grade sections, in traveling over which or up which the log loses velocity, due to the action of both gravity and friction.

(4) Inserting horizontal curves in which the log loses a portion of its energy by impact against the outer wall of the channel.

The manner in which loggers have attempted to apply these principles is discussed below.

Physical properties of the wood used **for the** chute **channel.** The frictional resistance of a chute is influenced by the species used for the construction of the channel. Chutes made from conifers usually are slower than those made from hardwoods, and in a region where both kinds of wood are available the choice of construction timber may be made on the basis of the chute gradient. On low grades, hardwoods are preferable to softwoods for the bed logs of the channel because their surface is smoother and offers less resistance to a moving log. A channel made from rough logs (unrossed) is slower than one made from hewed or rossed logs and may be used on steep grades when only a limited amount of wood is to be chuted. The frictional resistance of such chutes decreases with use because the moving logs tend to ross the channel timbers, hence the increased braking effect of rough logs persists only for a short period.

Channel profile. The frictional resistance in a V-shaped channel increases as the angle between the two hewed faces becomes less. One authority[27] states that the angle of repose of a V-chute having an angle between faces of 125° is 5 per cent greater than one having an angle of 150°. Advantage may be taken of this fact to control speed by making the angle on steep grades less than on low ones.

Water as a velocity retarder. Under summer conditions water on a chute channel may either retard or accelerate the velocity, according to the quantity present and the frequency and continuity of its application. When dew or rain moistens the smooth members of a wooden chute channel which are either dry or greased, the frictional resistance is temporarily reduced.[28] However, the constant application of water to a chute increases the frictional resistance because the wood is softened and its surface splinters more readily and becomes rougher with use. Wooden chutes which are kept moist continuously wear out rapidly.

Some loggers in the Rocky Mountain region who use V-chutes secure a

27 P. Neff, U.S. Forest Service, District 1, Missoula, Mont.

28 Following the application of grease to the wooden members of a chute channel, the surface is less slippery, temporarily, than before it was greased.

mild braking effect by diverting small quantities of water from adjacent streams into the channel. The success of the above procedure is dependent on having a channel which rests directly upon the ground surface and which is more or less water-tight. This method has a limited application, only, because its efficiency is low and depends upon a combination of conditions which rarely exist; also the life of the chute is shortened.

An occasional application of water lubricates the trough and reduces the frictional resistance. When a limited amount of ,vater is applied continuously it tends to act as a brake, and when considerable water is applied it again tends to reduce the resistance, provided the depth of water is sufficient to partially float the logs. The chute then becomes a combined chute-flume.

Abrasive materials. A simple method, mild in action, for reducing log velocity, especially on trailing chutes, is to throw earth, sand, gravel, cinders, or other abrasive materials upon the face of the chute timbers. This procedure is seldom followed on gravity pole chutes in eastern Canada and thenortheastem United States because of its low efficiency for small, short wood. This above method is flexible but increases the rate of depreciation of the channel timbers and also requires the services of an attendant or "sand monkey." The most commonly used and best abrasive is sharp sand which often can be secured in the immediate vicinity of the chute.

The efficacy of any abrasive is greatly reduced if it is moist. When the channel is wet or frosty (winter operation), sand should be applied both dry and hot. The usual practice is to heat it over an open fire alongside of the chute and to throw it into the channel in front of the passing logs.

Sand has proved serviceable on trailing chutes which have excessive grades and on portions of chutes which function satisfactorily in dry weather, but on which logs tend to acquire an excessive velocity when the chute is wet, or when a summer trailing chute is used in winter, during which season it proves too fast.

Experience in the Rocky Mountain region indicates that sharp sand applied to a V-chute will prevent logs from running on grades of from 25 to 30 per cent. Under the same conditions logs would run on an unsanded chute having a 20 per cent grade.

Some loggers oppose the use of sand to check the log speed during rainy weather in summer because its application so roughens the surface of the channel that trailing in dry weather is less efficient.

The "beat" of a "sand monkey" on a trailing chute frequently is the same as that of a trailing team (often 500 or 600 feet) although it may be less on steep grades and more on sections which require but little attention.

"Sand monkeys" who work on trailing chutes in winter often are emplayed to grease the slow sections of a chute during summer operation. They should possess both experience and good judgment, because if too much sand is applied the logs may stop, while if not enough is used the logs may get out of control and cause damage, both to the log and the chute, and likewise endanger workmen who are employed at points below. The usual procedure followed when logs approach a fast section is for the "sand monkey" to throw the requisite amount of hot sand into the channel. Because of the difficulty of judging the log speed from a distance, he usually watches the tow chain which, if slack, indicates the need for more sand than if the tow chain is taut. Full responsibility for errors in judgment sb9Uld be placed on the "sand monkey" who should not be subordinated to the teamster.

When logs stop because of the application of too much sand, usually it is necessary to separate them by means of a crowbar so that when the team again starts the tow, the logs ,vill impact against one another and thus set all in motion. Sometimes it is necessary to roll one of the middle logs from the chute in order to provide space between the ends of the remaining logs.

Chains. Chains have been used experimentally in the following ways as braking devices on fast chutes, with results varying from failure to a fair degree of success, although in no case have they proved highlyefficierit.

(1) Several closely spaced, heavy chains, the lower loose ends of which lie in the chute trough, are suspended from a crosspiece placed above the channel and at right angles to it. When logs pass down the chute and strike the chains they lose some of their velocity, due to the energy expended in deflecting the chains or in raising them. This method has not proved very effective, due to the weight and high momentum of the logs. Short chains provide but little braking force, while logs become entangled in long ones. Further, the retardation of speed is not properly coordinated with the log velocity.

(2) Chains placed around the forward end of the first log in a tow so that its speed will be retarded by the friction of the chain against the chute trough. This method is seldom used because of its low efficiency, lack of flexibility, the damage which results to the chute, and the tendency which

logs have to leave the channel when the latter is shallow and the grade rather steep.

(3) Chains so arranged that logs must pass over them. One method, not recommended however, is to pass chains around the bottom logs forming the chute channel. Pairs of chains from 2 to 4 feet long, made from ½-inch iron, fastened on both sides of the channel, provide a more efficient device

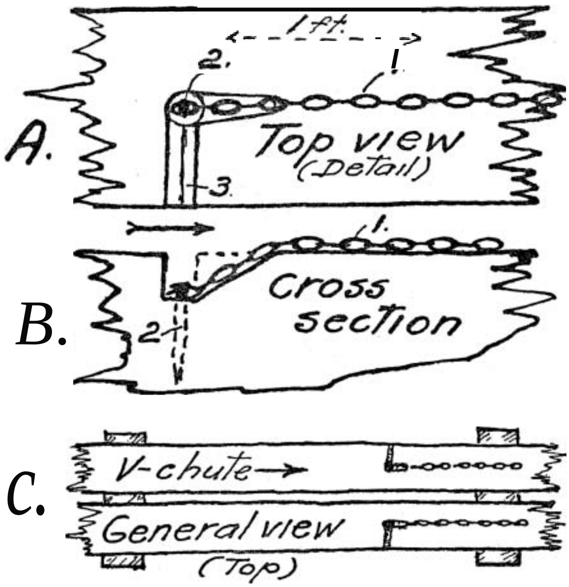

Fig. 50. Chains used for reducing the velocity of logs on chutes.

(Fig. 50). The top end of each chain is countersunk into the chute timber and spiked firmly. A groove leading from the countersunk hole brings the chain gradually to the surface where it rests on the face of the chute timbers. This arrangement diminishes the impact of the log against the chains and reduces the tendency of the logs to leave the channel. Another groove at right angles to the chute channel leads out from the point where the chain is fastened and serves to house the latter when it is not desired for braking. The chains are spaced far enough apart so that small logs may pass between them without contacting, hence they do not suffer any retardation in velocity. A chain brake of this character tends to retard velocity to a limited extent by the impact of the front end of the log with the chain, but the chief action results from the added frictional resistance caused by the passage of the log over the chains. This method is used occasionally in the Rocky Mountain region on saw log chutes, where it has proved reasonably satisfactory when a low degree of braking work is desired. It is less effective than the gooseneck described below; however, the latter does more damage to the log.

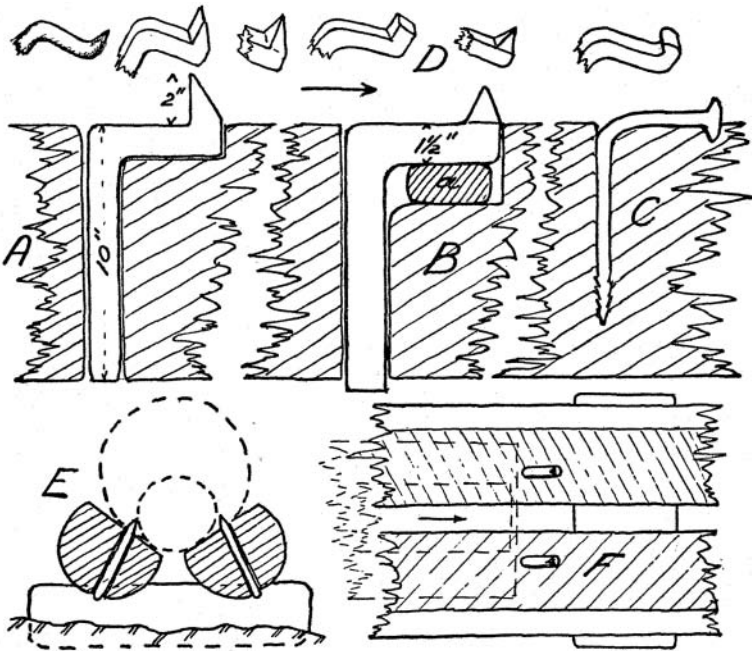

Fig. 51. Goosenecks and spikes used for the reduction of log velocity on chutes. *A*, a standard arrangement for a gooseneck; *B*, adjustable gooseneck; *C*, steel spike sometimes substituted for a gooseneck; *D*, standard gooseneck points; *E* and *F*, arrangement of goosenecks in pairs, shown on end, and top view of chute.

Goosenecks and spikes. These forms of brake devices are used chiefly on steep sections of saw log chutes in the United States and western Canada. They are seldom if ever used in other countries. The typical gooseneck comprises a round or square pin from 1 to 2 inches in diameter, bent at a sharp angle at one end, with the point turned upward so as to form a blunt or sharp-pointed prong (Fig. 51, D), usually the latter. The most effective type has a long sharp-pointed prong, but these scarify the logs badly and greatly depreciate them—the incisions in the log often are from 1 to 3 inches deep. Goosenecks which have long, blunt points tend to raise the logs too much, causing them to jump the chute and, therefore, are not desirable.

The goosenecks are inserted in holes bored through the chute timbers, thus permitting dirt and refuse to drop to the ground rather than to choke up the cavity. A recommended practice is to provide a groove into which the crook and point of the gooseneck can be dropped below the level of the chute timbers when not required as a brake device. When in use, a block of wood is inserted under the crook which elevates the prong to a level which will provide contact with the passing log (Fig. 51, B). The degree of retardation thus may be regulated by the thickness of the gooseneck support.

Goosenecks are used in pairs, one member of the pair being set exactly opposite the other and at a uniform distance from the longitudinal axis of the chute; a log striking a geoseneck on one side only would be thrown from the channel. The members of each pair usually are spaced from 10 to 15 inches apart so that the smaller logs, whose velocity is less than that of the larger ones and seldom needs retardation, may pass without coming into contact with the brake; also, small logs are greatly depreciated by scarification.

A practice sometimes followed but not recommended is to place the goosenecks so that a rotary movement is imparted to the log. This increases the braking effect but usually causes serious injury to the log because it is scarified along spiral lines, thus damaging the outer portion of the log from which the most valuable lumber is secured.

The number of goosenecks required for a given chute is determined by trial. As an illustration of use there may be cited a saw log chute in Idaho ½ mile in length which had an average grade of from 30 to 35 percent and on which, depending on weather conditions, from twenty to forty pairs of goosenecks were used for summer operation, and one in Montana (Fig. 52) having a section 1,000 feet in length and a slope of from 50 to 60 per cent on which twenty-six pairs of chisel-shaped points were used and, in addition, from thirty to thirty-five pairs of railroad spikes. The logs in both cases were badly scarified. The operator justified the use of this method on the basis that it prevented excessive breakage at the landing.

All forms of goosenecks require chute guards or attendants to keep them in order and to bring them into or throw them out of action as needed. The heavy labor charge plus the severe damage to the logs is a drawback to the use of such brake devices.

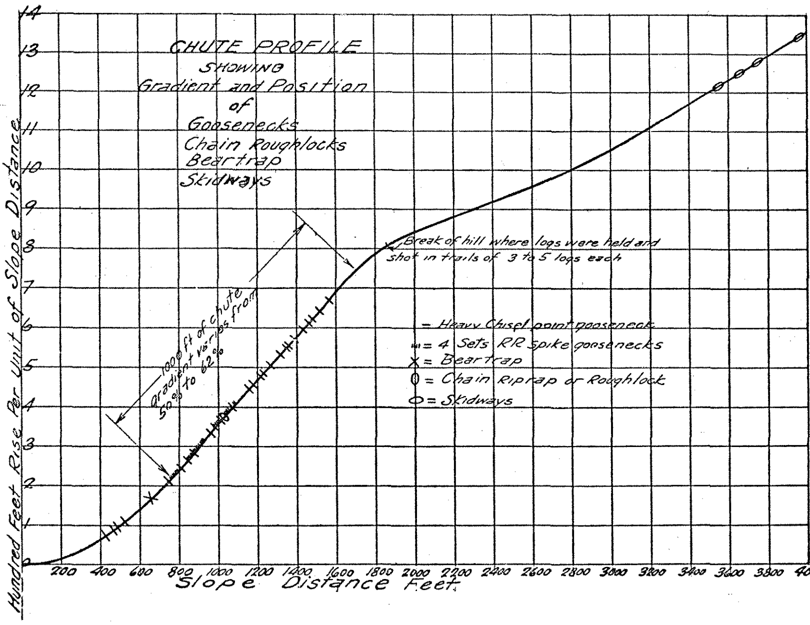

Fig. 52. The profile of a chute showing the location of the devices used for velocity reduction. Idaho. (After I. V. Anderson, U.S. Forest Service.)

On the lesser grades where a low braking effect only is required, *long nails* (½ inch by 12 inches with a 2-inch head) or *heavy spikes* may be substituted for goosenecks and used in a manner similar to the latter. The nails or spikes are driven into the chute logs and bent over so that the heads protrude above the chute timbers (Fig. 51, C). Unlike goosenecks they cannot be thrown in and out of action to meet the varying frictional resistance.

Both goosenecks and nails and spikes are inefficient in checking the speed of frozen timber, because the points do not dig readily into the logs, but tend rather to raise them above the bed of the chute, causing them to leave the channel. Both of these types of brakes are impractical as devices for retarding the velocity of pulpwood bolts and similar short material.

Wolf brake. The wolf brake, also called the "bear trap" by some loggers on this continent, \vhen properly designed and constructed, is one of the best devices for controlling velocity on steep grades. Although in recent

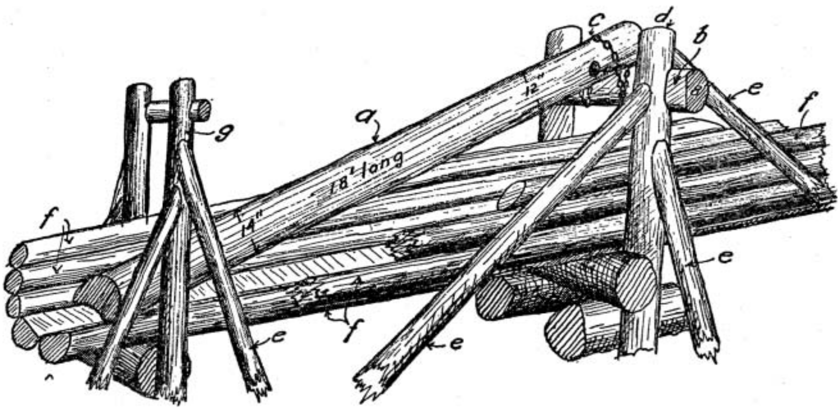

Fig. 53. Side view of a typical rigid-axis wolf brake. *a,* brake arm; *b,* cross support on which the brake arm rests and to which it is chained; *c,* chain used to fasten the arm to the cross support; *d* and *e,* supporting posts and braces; *f,* logs comprising the chute channel; *g,* framework to hold arm in position and to prevent it from being thrown too high in the air.

years loggers in the United States and Canada have become more or less familiar with this type, they have done little to change the usual inefficient form into one which functions with a relatively high degree of efficiency.

The wolf brake (Figs. 53, 54, and 55) comprises one or several logs, called brake arms or, when rigidly joined, a brake table, the upper end or ends of which are supported above the chute, with the free end or ends resting on the channel bed. Brake work is performed when a chuted log strikes the free ends of the arms or that of the brake table and raises them as it passes underneath. The retardation of velocity is due to the reduction of the kinetic energy of the log (I) by impact of the log against the arms or table, (2) by the energy required to lift the arms or table (and bending it if it is flexible), and (3) by the increased friction between the log and the bed of the chute and between the log and the arms or table.

The maximum reduction in velocity can be secured only by a more or less continuous action of the brake, hence the best results are obtained when the initial impact bet\veen the log and the brake table is kept as low as possible.[29]

There are many types of wolf brakes in use, nearly all of which have a straight arm or table suspended from a rigid axis. A curved arm or table has certain advantages because the natural crook lies more or less parallel to the chute trough, and the moving log strikes nearer the point of suspen-

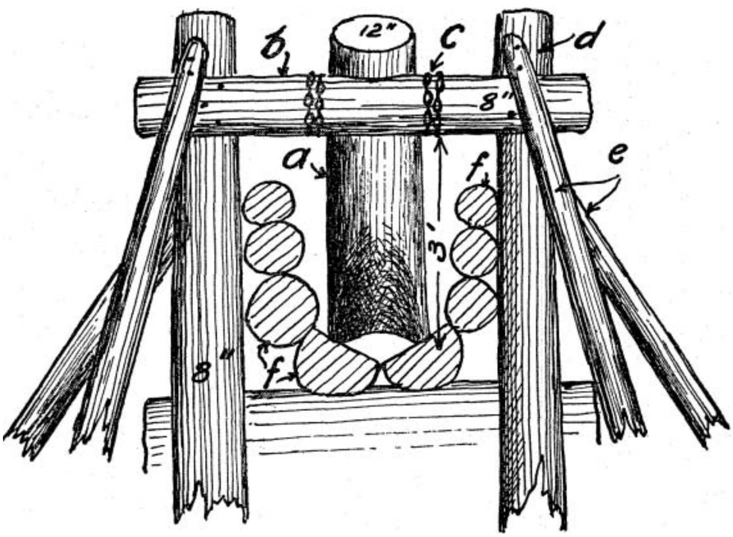

Fig. 54. End view of a wolf brake showing a convex form of the free end of the arm which sometimes is used to enable small logs to pass under it without contact.

sian than when a straight arm is used, thus requiring a greater work effort to lift it, due to the added weight (Fig. 56).

In recent years some work has been done in Europe on the development of an elastic method of suspension which permits a certain degree of play in the arms or table. This method has been advocated by Austrian forest engineers on the basis of theoretical studies. Experimentation also has shown it to have merit (see page 85).

29 See pp. 126 to 137.

Short-arm wolf brake. This simple form of braking device (Fig. 57) is used occasionally in eastern Canada to check the velocity of chuted pulp-

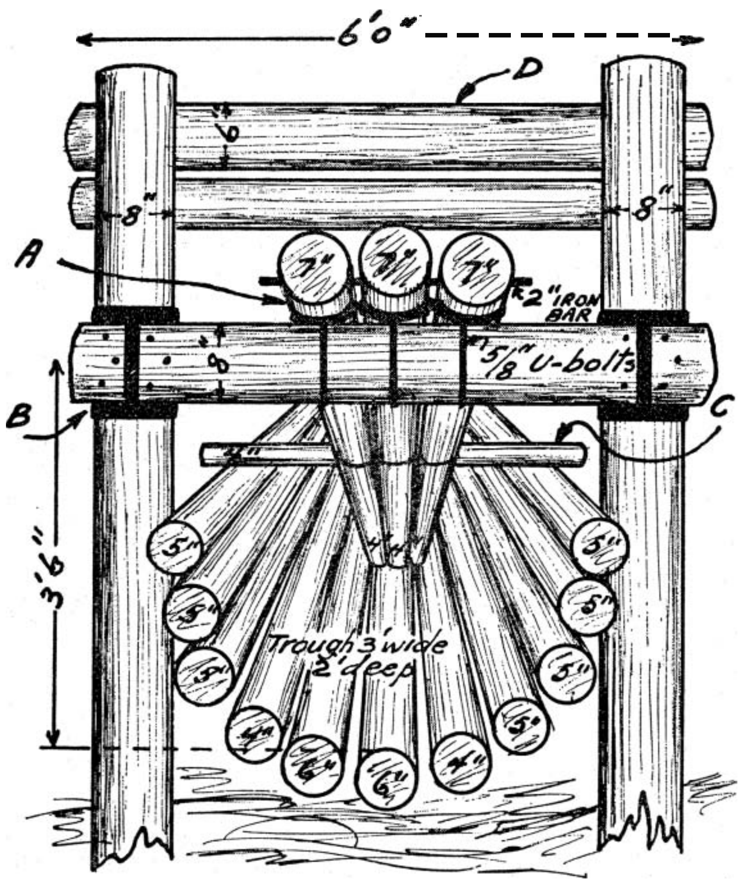

Fig. 55. A 3-log arm or brake table which sometimes is substituted for a 1-log brake on wide chutes.

wood. It may be considered as a primitive short-arm wolf brake. The heavy hardwood bolt is suspended by chains from an overhead support, the angle between the main axis of the bolt and that of the chute channel being very sharp. The clearance between the end of the bolt and the bed of the chute is either very small or the bolt may rest on the chute bed itself. The log velocity is retarded by impact against the bolt. The advantage of this device is the ease with which it may be constructed. However, its efficiency is

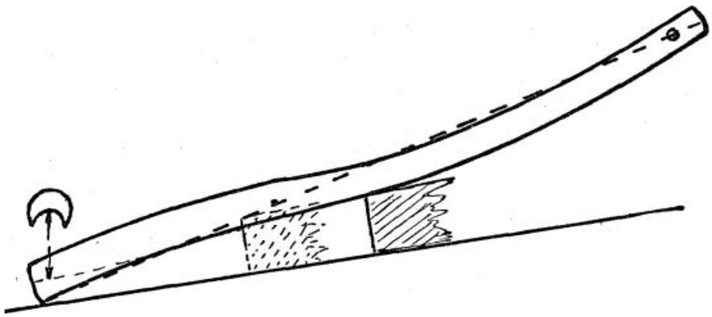

Fig. 56. A curved rigid suspension brake arm which provides a greater area of contact than a straight one.

less than that of a brake equipped with a longer arm. It functions best when the pulpwood bolts are of uniform and medium size and when the velocity is relatively low. It is not efficient as a powerful braking device because, with high velocities, the single impact is too violent and bolts tend

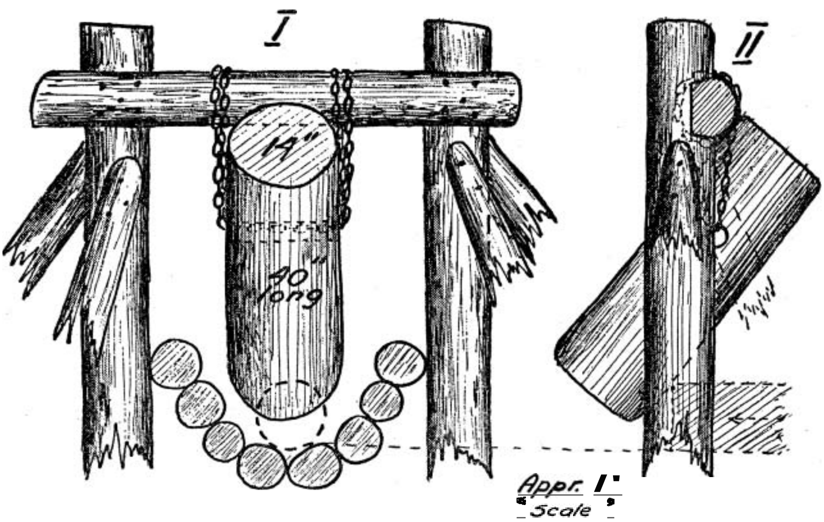

Fig. 57. A short-arm wolf brake used by some pulpwood operators.

to leave the chute and damage themselves and also the chute and brake, unless the two latter are very strongly constructed. Also the arm may be thrown so high that the following bolt will pass through the brake before the arm has returned to its normal position.

Typical wolf brake. This comprises a brake table made from one or more logs which is supported near the upper end on a crosspiece fastened to two strongly braced posts. The usual method of attaching the brake table to the crossbeam is by means of chains, as shown in Figs. 53 and 54. In some cases an iron bar or a cable is substituted for the crossbeam, being passed through a hole in the brake table and fastened to the two upright posts. The log or logs forming the brake table usually are placed with the butt end resting in the channel, although when the table is made from several small logs the tops may be at the free end in order to provide greater elasticity.

A 1-log brake table is adapted for chutes having a narrow channel, while one made from several logs is used on wide chutes and for braking the smaller sizes of logs because a wide brake table prevents small logs from passing between the end of the table and the side of the chute. When several logs are used to form a table they may have the free ends connected rigidly together with a heavy rod, or the ends may be interlaced with a cable so that there may be considerable play on the part of individual logs. The latter plan enables small logs, which require the minimum braking work, to raise only one member, while large logs must raise all of them.

In some cases a limited amount of clearance between the free end of the table and the chute channel is provided so that small logs may pass underneath without contact. This clearance may be secured by fastening a crossbar to the table (Fig. 58, A) or by supporting the end of the table by means of a chain attached to an overhead bar (Fig. 58, B). The latter method has the advantage that it is easy to regulate the amount of clearance desired by lengthening or shortening the chain. Single-log brake tables also may be made concave on the under side of the free end so that small logs will not contact with the table itself. Changes in weather conditions or in the size or character of the logs being chuted necessitate a varying amount of brake work because of the increase or decrease in the frictional resistance. This may be compensated for by raising one, several, or all of the brake arms above the channel when the resistance is great, or by partially raising some or all of them when only a limited amount of braking work is desired. An increase in braking work may be secured by loading the free end of the table with iron or rock which is placed in a box rigidly attached to its free end. Spring devices also may be employed to regulate the

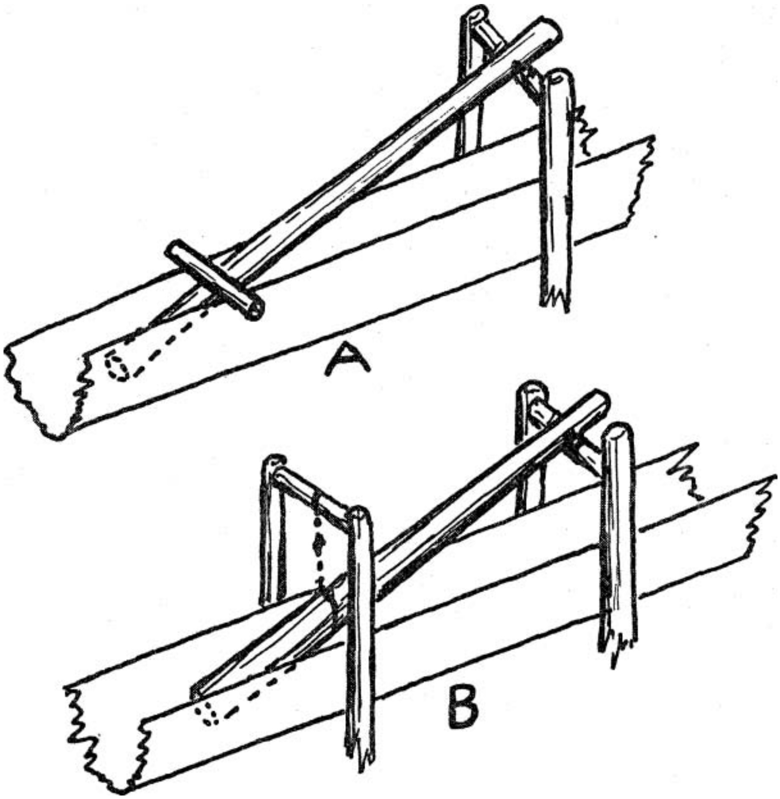

Fig. 58. Methods of suspension of a wolf brake arm so as to provide a space between the free end of the arm and the channel bed. *A* is a method for providing a fixed distance, while in *B* the space may be varied by shortening or lengthening the chain.

amount of braking work, but their use is accompanied by numerous technical difficulties which have not yet been satisfactorily solved (see page 84).

(A) Size of brake table members.-The dimensions of the log or logs comprising the brake table vary with the amount of braking work required, which, in turn, depends on the character of the chute profile, the chute gradient, the size and character of the logs being chuted, and the frictional resistance.

A brake table made from one birch log from 10 to IS inches in diameter and from IS to 20 feet in length has been used in eastern Canada for braking 4-foot pulpwood which averages about 100 pieces to the cord. When such a table is made from several smaller logs, the latter usually range in diameter from 5 to 10 inches.

One brake table for a saw log chute in the Rocky Mountain region was made from three logs, varying in size from a 7-inch top and a 12-inch butt and a length of from 30 to 35 feet up to a 12-inch top, 20-inch butt, and a length of 45 feet from the point of suspension to the tip of the free end.

The weight of the brake table should conform to the size and velocity of the chuted logs. Owing to the many variables involved, the relation between the weight of the brake table and the weight of the log cannot be calculated accurately, and operators determine this by trial. However, it may be assumed as a safe rule that the weight of the table should be greater than that of the chuted log.

(B) Angle of suspension of the brake table.-The angle formed by the brake table and the channel is an important factor in determining the amount of braking work performed. The upper end of the brake table must be high enough above the bed of the chute channel so as to eliminate any possibility of a moving log striking the cross beam or other support for the brake table. The usual height of suspension is from 3 to 4 feet.

The slope of the arm \vill depend upon its length and the height of the point of suspension. The angle between the point of contact of the free end of the brake table and the chute channel should not be greater than from 8° to 11°.

(C) Construction.-Many wolf brakes constructed by loggers are not built strongly enough to withstand the hard usage to which they are subjected. Very strong construction, both in the framework and brake table, is essential for satisfactory service. The chute channel, at points where brakes are located, should be made from large material, and the channel itself should be carefully braced so that there will be no play or motion. Bolts instead of spikes should be used to fasten together the members of both the chute and the brake. Sheet iron or flat or round bars,[30] placed longitudi-

[30] Round bars are made from ¾-inch round iron, several feet in length. The two ends, upset at a 90° angle, are sharpened and barbed and then driven deep into the chute timbers.

nally, should be used to armor both the chute channel and the underside of the brake table. A birch brake arm will be worn out after chuting about 600 cords of pulpwood unless the end is armored.[31]

The cost of installation of a wolf brake varies with its size and the availability of construction materials. It usually is relatively low unless there is much haphazard experimentation in an effort to remedy an improper initial construction. The type of brake shown in Fig. 57 has been built in Quebec Province, Canada, for $8, including the cost of materials and labor, the latter representing 1.5 one-man days.

(D) Number and size of brakes required.—It is impossible to establish any practical rule as to the size and number of wolf brakes required for a

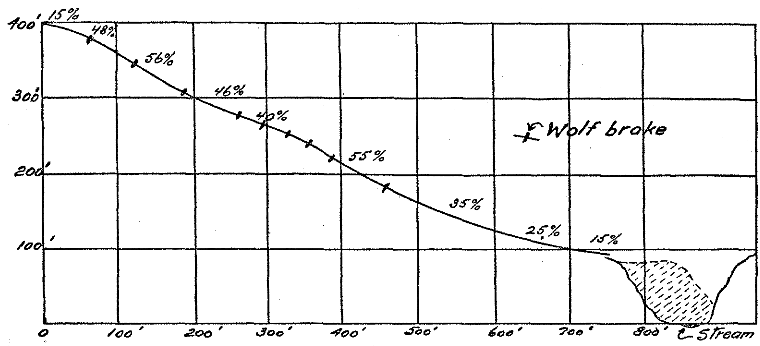

Fig. 59. The general profile of a wooden pole chute showing the position of wolf brakes. Quebec.

given chute, due to the great variety of conditions which may exist. The proper number can best be determined by experiment. Operators should guard against the tendency to use too few or too powerful brakes on steep chutes, because a greater number of lighter and less powerful ones usually will give better results.

The profile of a pulpwood chute in Quebec equipped with nine brakes of the type shown in Fig. 53 is illustrated in Fig. 59. This was a winter chute made from poles and served to move 4-foot pulpwood, averaging about 95 pieces per cord. On cold clear days all of the nine brakes were used, in

[31] Spikes or spurs are sometimes driven into the end of the arm to increase the braking work. This practice is inadvisable because the spikes scarify the logs badly.

spite of which the wood often acquired a velocity in excess of 30 miles per hour (44 feet per second). On ordinary ,vinter days six brakes were used and in moist weather only three. The average speed of the logs on this chute averaged from 20 to 25 miles per hour (30 to 37 feet per second). The loss through breakage was less than 1 per cent of the volume moved.

The profile of a pulpwood chute in Newfoundland is shown in Fig. 60. This was equipped with five brakes of the type shown in Fig. 55. Four-foot pulpwood bolts, averaging about 125 pieces per. cord, moved over this

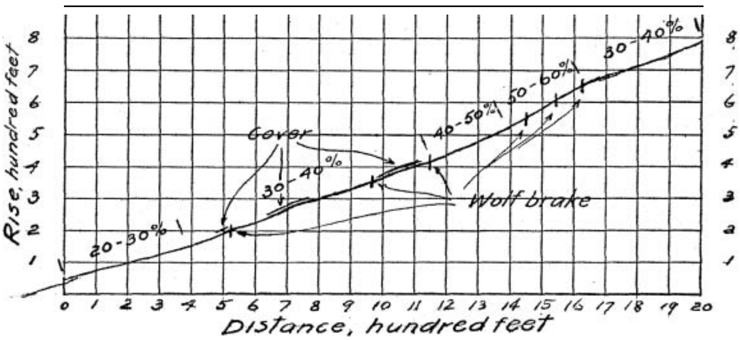

Fig. 60. The profile of a chute showing the position of the wolf brakes and the points at which the channel was provided with a cover to prevent logs from leaving it. Newfoundland.

chute under winter conditions at the rate of 60 miles per hour (88 feet per second) when brakes were not used. The five brakes mentioned reduced this velocity to 40 miles per hour, or 33 per cent.

Flexible brake table. Brake arms made from poles or small logs possess a certain amount of flexibility and give rise to a limited amount of spring-like action ,vhich increases the efficiency of the brake and reduces the shock.

Jack Turner, of Quebec, has applied this principle in pulpwood chutes by making the brake table from a fair-sized bundle of long, tough tree tops or flexible poles, wired together tightly and weighted on the free end (Fig. 61). This brake table was suspended in the same manner as a rigid wolf brake table, with little or no clearance between the free end and the bed of the channeL

The brake work was due as much to the "spring" of the tops as to their weight. Pulpwood logs of small size readily deflected the lower end of the brake table where its flexibility was greatest. Larger logs contacted higher up where the tops were more dense and the resistance greater.

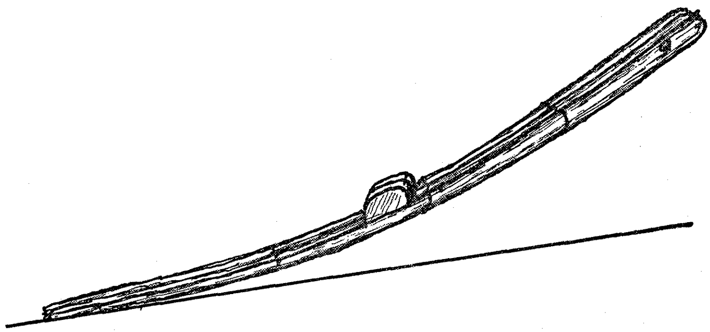

Fig. 61. A flexible-arm brake table adapted for small and medium-sized logs when a mild braking effect is desired.

This form of brake is worthy of more extensive use when the logs are small or medium-sized and a mild braking effect only is desired. Its effectiveness undoubtedly could be increased by constructing it on the principle of the compound brake. A device of this character has been commented upon favorably by Austrian authorities on chute operation.

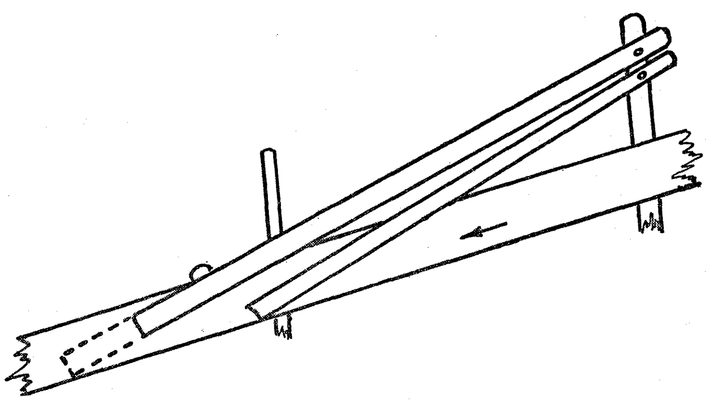

Fig. 62. A compound rigid wolf arm, the use of which has been suggested on steep grades.

Two-table wolf brake. A form of brake having two tables, the top one longer than the lower and each made from several poles (Fig. 62), has been suggested by Koroleff. Although the efficiency of a brake of this type has not been proved, it appears worthy of trial because it is believed that passing logs would not hurl the tables upward to as great a height and that the continuity of action and the velocity retardation would be greater than when the usual type of wolf brake is used. The braking effect on small logs also could be reduced, which is desirable, by supporting the upper table on a cross piece resting on the top of the trough, thus providing ample free clearance for them between the end of the top table and the chute channel.

Compound wolf brake. It has been suggested by Hauska,[32] based on theoretical studies, that a brake composed of two or more arms suspended one above the other, with the free ends resting one on top of the other, might prove practicable as a braking device. The purpose of such a form of brake would be to enable the use of lighter arms and a steeper angle of slope to the chute channel on sections which have grades so steep that excessive velocities result.[33] This form of brake table has not been given a practical test so far as known, but experiments with it may be justified, particularly on very steep grades.

Spring brake tables. In eastern Canada thought has been given to the design of a rigidly suspended spring brake table in which the brake work results from the weight of the brake table, supplemented by increased pressure induced by powerful springs. The use of this type is accompanied by certain technical difficulties concerned with construction, and the idea has not yet been adopted by chute users. Such a brake, however, promises more positive action than some others and offers a possibility of the retardation of log velocity consistent with their speed and a more rapid return of the arm to its normal position in the chute trough. A form of curved spring brake table devised by Jack Turner, of Quebec, formerly of Newfoundland, is shown in Fig. 63.

When only a mild braking effect is desired for small, short logs (pulpwood) the lower member of the brake table may be made of one or more flat bars of spring steel about 5 feet in length. The brake, when designed

[32] *Theorie der Riesen,* by Leo Hauska.

[33] See p. 128.

for large or long logs, should be supplemented by a heavy coiled spring placed behind the point of suspension. This spring should be so adjusted that its tension may be altered in order to regulate the braking force as frictional conditions change. Additional study and experimentation will be

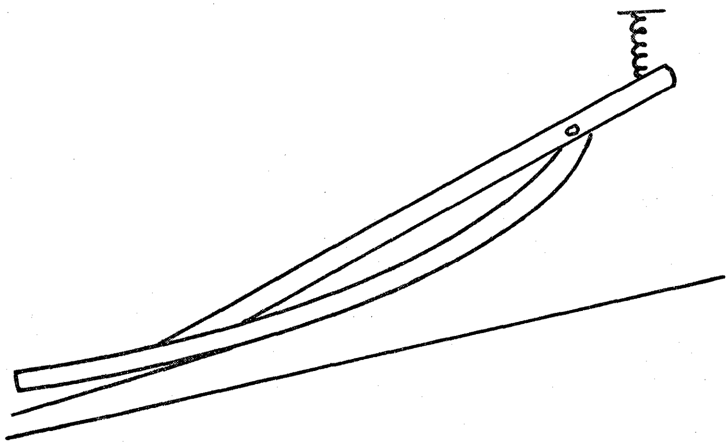

Fig. 63. The Turner spring brake.

necessary to secure the proper balance of the brake table and to determine the type of spring most suitable for the purpose.

Pearson's brake. N. Pearson, of British Columbia, Canada, has designed a powerful brake with a straight, rigid arm, operated by compressed air, for controlling the velocity of large logs on chutes having steep grades. This device, which has been patented but not yet constructed and used, is shown in Fig. 64.

The general principle on which it operates is that, when the logs strike the lower side of the table, the log not only will have to overcome the resistance caused by the weight of the table but also that induced by the compressed air in the vertical cylinder, the piston of which is attached to the free end of the arm. The worth of this type can only be established by trial. Due to the complexity of its construction and the high cost,[34] it is doubtful if it will be used extensively.

[34] Pearson states that a medium-sized brake would cost about $300, exclusive of the air compressor and pipe line.

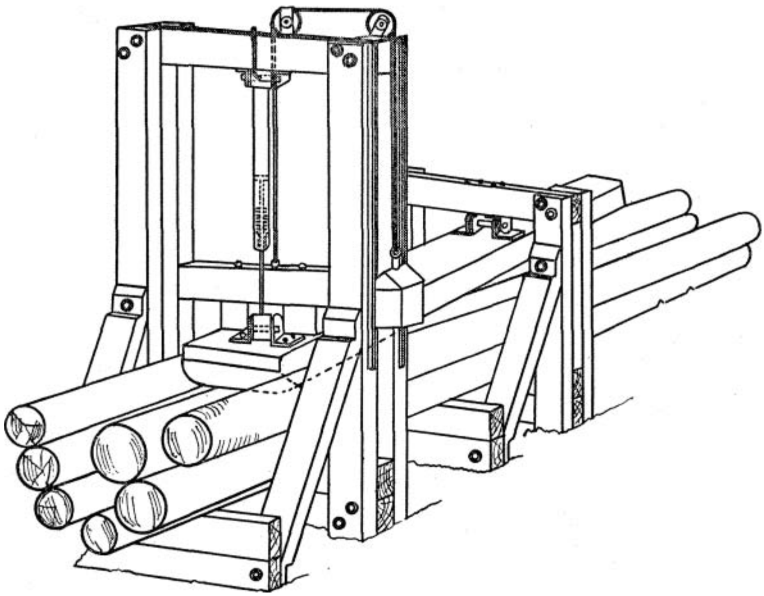

Fig. 64. The Pearson patent compressed air wolf brake. Canada.

Elastic suspension brake table. All of the forms of brake tables previously discussed are suspended from a rigid axis. Within recent years Baltz, of Austria, and Miura, of Japan, have suggested the adoption of an elastic form of suspension to be attained by supporting the brake table on a cable so that there may be more or less play during the course of the brake action. This form of suspension, although described as having been successfully used on an estate near Köflach, Styria, Austria,[35] is but little known in Europe and has never been tried on this continent.

As shown in Fig. 65, the brake table is suspended by means of a strong cable[36] stretched between two strongly braced posts on opposite sides of the chute, the distance between posts being from 15 to 20 feet. The tension on the cable varies, but preferably the deflection should only be that which is caused by the weight of the brake table itself. Due to the low tension of the cable and the elasticity which results, the arm when struck by a moving

35 See "Eine Betrachtung tiber Theorie und Praxis der Rieswege," by O. Baltz. *Oesterreichische Forst- und Jagd-Zeitung,* p. 340, Vienna, Nov. 6, 1914.

36 The cable passes through a horizontal hole bored through the arm.

log is thrown not only upward but also slightly forward, thus providing a more gradual and continual braking effect. The action due to impact is less violent than when a rigid axis is used, because the impact is less.

The cable is wedged tightly into the hole in the brake arm, which subjects the former to a certain amount of torque when its free end is thrown upward, thus increasing the brake work.

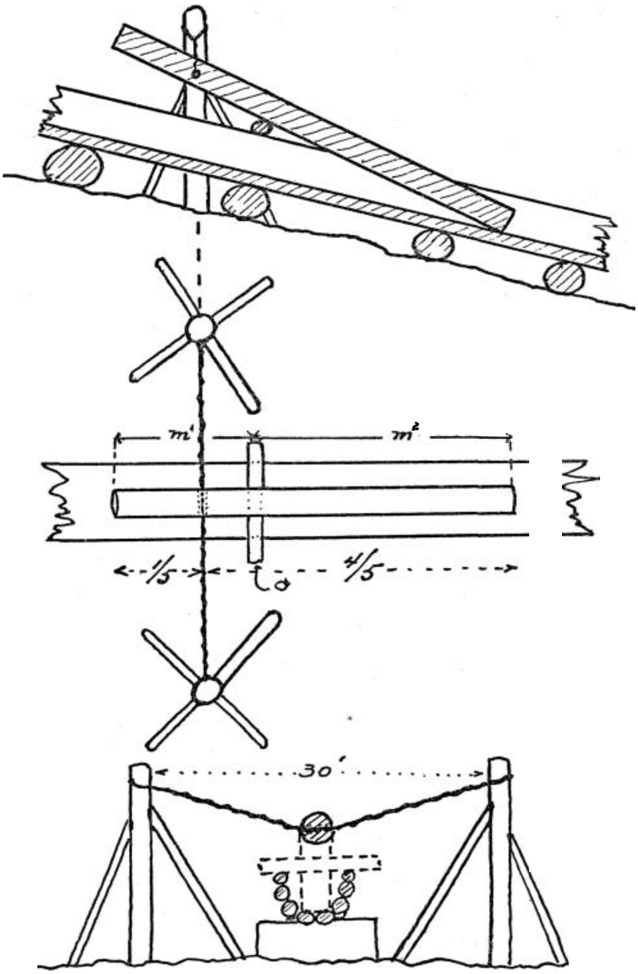

Fig. 65. The general arrangement of the so-called elastic suspension wolf brake.

Some of the data relating to laboratory experiments made with the elastic form of suspension are given on pages 129 to 137. In general, the experiments above cited indicate that this form of suspension performs about twice as much brake work, under certain conditions, as a similar table with a rigid axis.

This type of brake is worthy of a thorough trial on this continent.

Low, horizontal, and counter grade sections as braking devices. The velocity of a log decreases on those sections having a gradient below the angle of repose, or where the grade is an ascending one.[37] Advantage may be taken of the above fact when topographic conditions permit, and low, horizontal, or counter grades may be inserted to check the velocity of the chuted logs. This procedure often is not feasible, however, and in practice is seldom resorted to except at the lower terminal or discharge points.

Curves as braking devices. A horizontal curve with a short radius tends to retard the velocity of logs because centrifugal force causes the logs to travel on the outer side of the channel and, in so doing, they press against the outer wall, thus giving rise to added frictional resistance. Curves are not inserted in chutes solely as brake devices, but when a curve is essential it may be used as a braking section.

Switchbacks as braking devices. One or more switchbacks are sometimes used on European chutes where the topography is such that a continuous channel would have grades so steep that the log velocity would be excessive. A chute containing switchbacks is more expensive to operate than one which is continuous, because guards must be stationed at each switchback in order to make sure that the logs roll from the upper to the lower part of the chute section. They are used, therefore, only when some other form of braking device is not practicable. The schematic arrangement of a switchback is shown in Fig. 66.

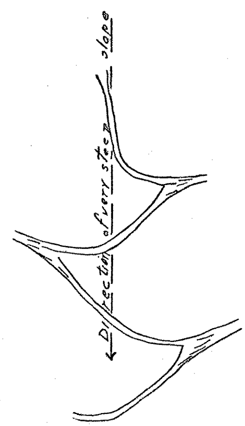

Fig. 66. Schematic arrangement of switchbacks on a road slide.

[37] See pp. 105 and 106.

The snub line as a braking device. Snub lines are rarely used for lowering logs down very steep grades because of the relatively high labor cost. This method has been used on earth chutes in Europe in rare cases where, according to Förster,[38] five men, using a cable 200 feet long, daily lowered from thirty to forty logs down an earth chute from 1,000 to 1,200 feet in length.

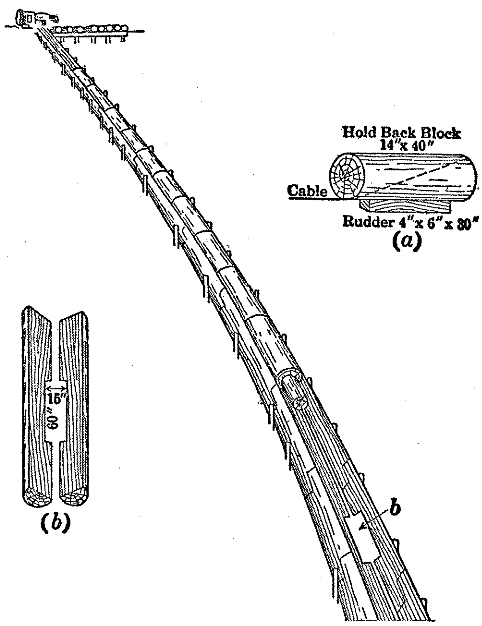

Fig. 67. A snub line chute used for lowering large and long logs down steep grades. United States. (Adapted from *The Timberman.*)

A more satisfactory snub line method (Fig. 67) for large logs is that described some years ago[39] by a logger in Oregon who was confronted with the problem of lowering 10 million feet of timber from a bench to a railroad below. The difference in elevation was 600 feet. A 2-log V-chute,

[38] See *Das forstliche Transportwesen,* by G. R. Förster, p. 23. M. Perles, Vienna, 1888.

[39] See "Practical Plan for Lowering Logs," by P. S. Robinson. *The Timberman,* p. 36, Portland, Oregon, March, 1915.

1,600 feet in length, was constructed which had an average grade of 38 per cent. The logs, when put into the chute, attained such a high velocity that the loss in damaged logs was too great.

A drum, driven by a 6-horsepower gasoline engine, was then mounted at the head of the chute and on this a $\frac{9}{16}$-inch steel cable or snubbing line was wound, to the end of which was attached a round hold-back block 14 by 40 inches in size, on the bottom of which was fastened a rectangular rudder block 4 by 6 by 30 inches. The cable passed diagonally through the hold-back block as shown in Fig. 67, a, thus keeping the cable below the logs and also tending to pull the block tight against the bed of the chute. The logs forming the trough were spaced 5 inches apart at the base, and in this groove the rudder and the cable traveled.

An ingenious device was used to trip the hold-back block near the lower end of the chute so that the logs would continue to the end of the chute and automatically leave it. An opening, 15 by 60 inches in size, was cut in the chute bed near the lower end, and when the hold-back block reached this point the pressure of logs behind caused it to turn down into the opening so that the logs could pass over it. The hold-back block was pulled out of the opening and drawn up to the head of the chute by reeling in the cable. The logs, after being rolled into the channel at the chute head, were held in check by the hold-back block. The average load was from 1,500 to 2,500 feet, log scale, a round trip requiring about 8 minutes. Two men were required to operate this system: one to attend the brake and the other to scale the logs and roll them into the chute.

VELOCITY ACCELERATION

It often is desirable to reduce the frictional resistance on *trailing* chutes whose gradient is less than the angle of repose in order that maximum loads may be towed with the minimum of effort. A section of a gravity chute also may have a grade so low that the smaller logs travel too slowly or even may stop en route.

There are various methods used to reduce frictional resistance, the chief of which are the following:

(1) The use of smooth hardwood timbers for the channel (see page 66).

(2) The substitution of sheet steel for wood for the channel members (see page 50).

(3) The increase in the angle between faces of a hewed pole chute (see page 66).

(4) The use of water to moisten the chute members (see page 66).

(5) The placement of cylindrical or concave rollers within the body of the chute (see page 22). These occasionally are installed at the head or on other sections having a very low gradient, but their use is very restricted because of the relatively high cost and the operating difficulties arising from moving irregularly shaped logs over them.

(6) Rossing the chuted logs in whole or in part. The removal of the bark makes the log smoother and reduces its frictional resistance, but this procedure is seldom resorted to because of the expense. The log may be wholly rossed or the bark removed only on the "ride" or that face of the log on which it will slide. Sniping or "nosing" the ends of large logs also somewhat reduces the sliding resistance, but is seldom done because of the cost.

(7) The application of grease to the channel members during the summer and the formation of an ice cover on them during cold weather. The above procedure is the most effective known method for reducing the frictional resistance on hewed V-chutes. It often is used on trailing chutes and occasionally on slow sections of gravity chutes.

Greased chutes. A greased surface is more effective than a wet one for summer operation; also, there is less depreciation of the chute channel than when water is used. When a greased chute becomes moist, due to dew or rain, the resistance is temporarily reduced, but increases as the moisture disappears until finally the resistance is greater than before the channel became wet, because the surface is softened and becomes rougher with use.

Several grease compounds are used, of which the following are the most efficient: (I) crude oil mixed with paraffin; (2) axle grease mixed with kerosene and tallow; or (3) other mixtures in which crude fuel oil is the chief ingredient.

Grease may be used during cold but not frosty weather when it is not feasible to ice the channel, in \vhich case the lubricant must be made thinner than that for summer operation in order that it may be applied readily.

Usually the grease is applied with a brush to the hewed faces of the channel timbers by an unskilled laborer whose "beat" coincides with that of a given trailing team. The amount of grease required varies with the type of chute, the angle of the hewed face, weather conditions, and the quality of the grease. On a 2-1og V-chute in Montana about IS gallons of grease were used daily on sections varying from 500 to 1,000 feet in length. On a trailing chute frolu one to two miles in length, over which an average of 80,000 feet, log scale, was moved daily, the greasing cost was from 20 to 30 cents per thousand feet, the greaser's wages being 42 cents per hour and the grease cost 10 cents per gallon.

Snow and iced bottom. A snow or iced cover on a chute channel may be produced naturally by a snowfall, frost, a freeze following a rain, or by the direct application of snow or water by workmen (see page 37).

The accompanying table, based on the experience of some operators in the western part of the United States, indicates approximately the relative advantages of an iced chute surface as compared to other surfaces, gaged by the volume of logs which a team, exerting a given tractive force, can haul at one time on a slight down grade (also see COEFFICIENTS OF FRICTION on page 139).

RELATION BETWEEN THE CHARACTER OF THE CHUTE SURFACE AND OUTPUT

Character of bottom	*Output per team Feet, log scale*	*Approximate increase in output Per cent*
Bare ground (snaking)	350	. . .
Dry V-chute (rough)	500	40
Wet V-chute	1,000	180
Greased chute (smooth)	1,250	280
Greased and wet chute	2,000	470
Iced chute	4,000	1,040

An example of the superior advantage of an iced as compared to other chute surfaces when the grades are favorable is shown by the record of a team which in one tow moved 110 logs aggregating 12,000 feet, log scale (weight approximately 50 tons), over a 3-mile iced V-chute in Montana having minus grades of from 7 to 15 per cent and an average of 12 per cent.

DEPRECIATION OF TIMBER AS A RESULT OF CHUTING

Wood transported in chutes may be subject to depreciation in quality and also to an actual loss in volume. In general, there is no quality or quantity loss in moving timber over *trailing* chutes, and but little or none on steep gravity chutes which are properly designed and operated. The maximum

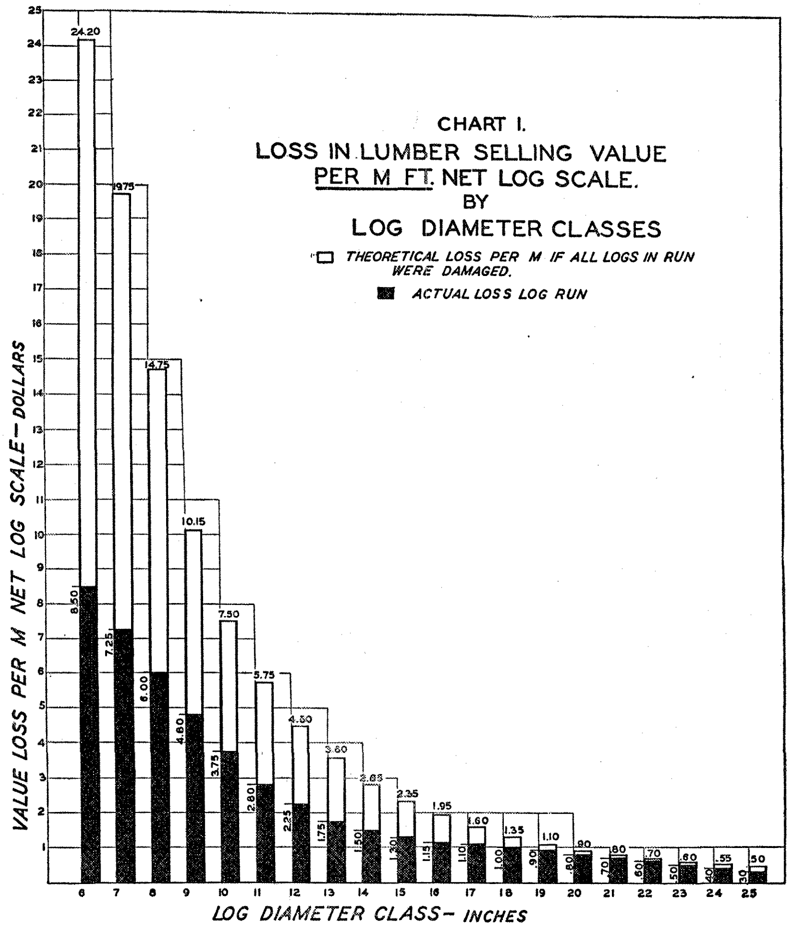

Fig. 68. The loss in lumber sales value per M ft., log scale, by diameter classes for 16-foot chuted logs. Idaho. (After I. V. Anderson. U.S. Forest Service.)

loss occurs on fast gravity chutes in which logs or bolts are permitted to attain excessive speeds which cause them to leave the chute or to be discharged at the lower end at such a high velocity that they are split or shattered when they strike against other wood or obstacles on the dumping ground.

The quality loss may be due to damage inflicted by goosenecks, spikes, and similar braking devices, and to splitting, breakage, or brooming resulting from the discharge of the wood at the lower end of the chute. When the log or bolt is permitted to attain an excessive velocity, the quality loss is much greater for poles and saw logs than for short bolts, such as pulpwood and firewood.

The quantity loss in chuting, other than the more or less complete shattering of the pieces at the discharge end, is due chiefly to the failure to return to the chute those pieces which have been thrown out of a channel which has improperly designed curves or other sections.

The amount of damage may be expressed in terms of the per cent of the total volume or of the total number of pieces depreciated or destroyed. European experience indicates that the loss may range from nearly zero to 10 per cent or more of the volume when the wood is roughly handled on very steep earth chute channels. On this continent the damage to saw logs varies from 1 to 10 per cent and frequently averages from 2 to 3 per cent of the total volume on chutes which are considered as reasonably efficient. When short and small material is transported, the loss, even on steep slopes, frequently is less than 1 per cent, although on poorly built and carelessly operated chutes it may run from 3 to 5 per cent, and sometimes more. The actual loss often is more or less disregarded by operators or only roughly determined. Accurate data for this continent are available only from one specific source; namely, a study[40] made of the depreciation of 16-foot Idaho white pine logs which were transported in "trails" over a 2-pole hewed chute of the usual type used in the Inland Empire region. The chief braking devices employed on this chute were goosenecks and spikes; one "bear trap" brake was installed but was broken early in the study and its use then discontinued (Fig. 52).

The procedure in determining the loss was to scale[41] the logs previous to and after chuting, followed by a careful check at the sawmill to ascertain the loss in lumber volume and value of the chute-damaged logs of the various diameter classes.

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40 See "Log Damage on Gravity Chutes," by I. V. Anderson. *The Timberman*, pp. 38-40 and 202, Portland, Oregon, March, 1930.

41 Scribner "Decimal C" log rule.

The loss in lumber sale value per log was much greater for small than for large ones (Figs. 68 and 69). This was due chiefly to two causes: (a)

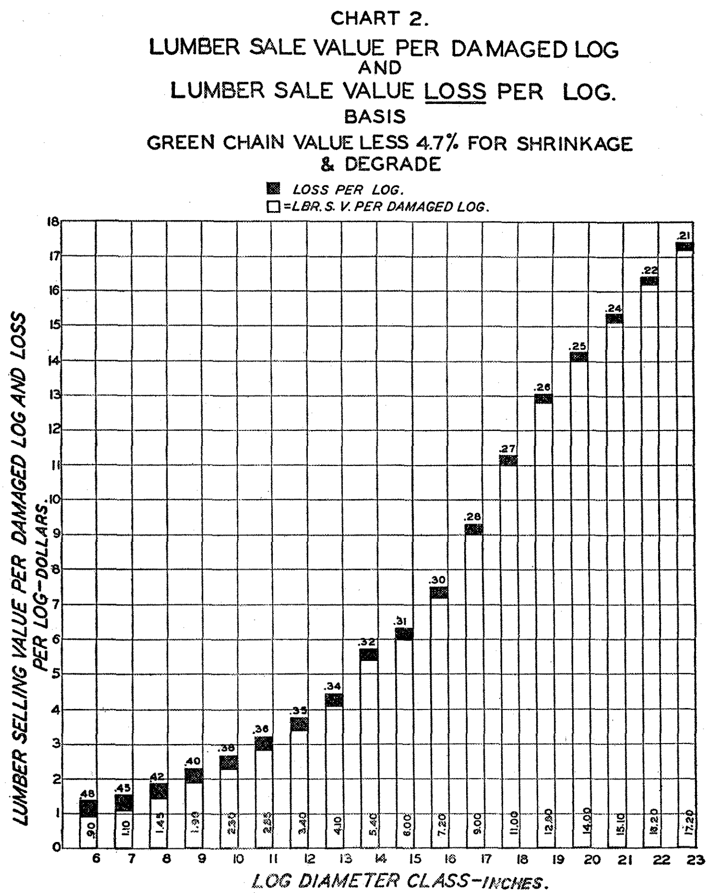

Fig. 69. The lumber sale value per damaged log and lumber sale value loss per log for 16-foot chuted logs. Idaho. (After I. V. Anderson. U.S. Forest Service.)

the small logs were as deeply scarified by the goosenecks as the large ones and, therefore, a greater per cent of their gross volume was damaged; and (b) when a small log passed between a set of goosenecks without contacting, it did not have its velocity reduced, and because of its small diameter it was more subject to splitting and brooming when it bumped against larger logs during the passage along the channel. The records showed that 46 per cent of all logs were depreciated, the relation between log size and the number of pieces damaged being indicated in the accompanying table.

RELATION BETWEEN LOG SIZE AND NUMBER OF PIECES DAMAGED

Log size[42] *Number per M feet, log scale*	*Per cent of total number of pieces damaged*
8–9	4
10–12	5
13–14	6

The character of the depreciation was separated into four classes by per cents, as follows: slab injury 14.8; brooming 32.2; splitting 36.5; and breakage 16.5. The slab injury was due to scarification by the braking devices, which were so inefficient in checking the speed that more than two-thirds of all damaged logs were depreciated by brooming and splitting, due to logs contacting during their movement down the chute. The heavy loss from brooming was due chiefly to an inadequate trimming length allowance, and consequently the length of the pieces of lumber had to be reduced at the sawmill. Anderson states that three properly constructed wolf brakes would have eliminated the greater part of the damage.

Under average operating conditions in Idaho the volume depreciation of saw log stock on steep chutes which usually are equipped with inadequate braking devices is approximately 5 per cent of the log scale.

[42] This represents the average number of 16-foot logs per thousand feet, log scale.

PART II

THEORETICAL CONSIDERATIONS IN GRAVITY CHUTE CONSTRUCTION AND OPERATION

THE chief factors which must be considered in the design of a chute down which logs are to be moved by gravity are:

(1) The movement on straight chute sections.

(2) The movement on vertical curves.

(3) The movement on horizontal curves, including the form of horizontal curves and the minimum curve radius.

(4) The control of velocity by means of

(a) Brake devices.

(b) Brake sections.

Chutes may be grouped into two broad classes based on grade conditions:

(1) Summer chutes with relatively steep grades, the channel being used in a dry or a moist condition.

(2) Winter chutes usually with moderate grades and used when the chute channel is covered with frost, light snow, or ice. (Winter pulpwood chutes often have relatively steep grades and then require the installation of devices for the control of log velocity.)

Each of the above groups also may be classified in accordance with the class of material for the transportation of which the chute has been constructed.

(1) Long-timber chute.

(2) Log chute.

(3) Firewood or pulpwood chute.

The important problenl the designer must solve is to construct the chute so that logs will neither attain a velocity great enough to cause them to leave the channel and be damaged by breakage, nor one so low that logs will come to rest at some intermediate point along the channel. The problem is complicated by the fact that the velocity at which a log travels is influenced by the grade of the chute; the frictional resistance caused by the roughness of the chute channel; chute curvature; the form, character, weight, and degree of dryness of the log; the length of chute section included within a given grade; the initial velocity with which a log enters any given chute section; and air pressure.

Attempts to develop mathematical formulæ to cover all of these various factors have met only with a limited degree of success. The number of factors involved are so many and the possible combinations of conditions which may occur are so numerous, because of rapidly changing weather and log conditions, that a formula that would apply at one time would not be applicable at another. Experience indicates that frictional conditions may vary widely during the course of a day's operation. Nevertheless, data computed for a given set of conditions often are of value in fixing maximum and minimum velocity limits.

The determination of all of the above factors calls for detailed and frequently complicated calculations which discourage the practical chute builder who is not an expert mathematician. Forest engineers sometimes overcome this by the use of simple approximate formulæ which, in general, serve the purpose, because it has been found that chute specifications based on theoretical calculations alone seldom prove satisfactory. It is not practicable to design a chute so that it will conform wholly to all of the frequently changing operating conditions; therefore, the builder strives to meet average requirements and relies upon the possibility of changing operating procedure to meet special conditions. Thus, chutes with relatively low grades may be serviceable only during the winter periods when the chute channel is coated with snow, frost, or ice, and those with very steep grades may be serviceable only during the summer when the absence of a smooth surface leads to the development of greater frictional resistance which, in turn, tends to check the speed of the log. Further, on a chute of average grade, it may be necessary to separate the various kinds of wood into size classes, transporting small sizes when the chute channel is moist and the larger sizes when the channel is more or less dry. Often on very steep sections where some method of velocity control is needed, it also may be desirable to separate the logs into size classes so that the average velocity of the pieces being moved at any given time is approximately the same.

The operator has been slow to adopt theoretical calculations as the sole basis for chute design, preferring rather to rely upon a "cut and try" method, building permanently those portions of the chute where there is reasonable assurance that the operation will be satisfactory and constructing, more or less temporarily, those sections on curves and steep grades where operating troubles may result. Various logs are sent over the doubtful sections, and those that operate successfully are built permanently and the remainder altered as experience dictates. This is the usual method followed on the American continent where chutes are designed and constructed chiefly by woodsmen.

To-day, in Europe, where chute construction has attained its highest development, the design is chiefly in the hands of technical men who give attention to the theoretical aspects of the problem. Here it is recognized that a chute built solely on the basis of theoretical calculations may not and probably will not function satisfactorily, but one in which theory and practice are combined should and usually does prove superior to one designed and built solely in accordance with one point of view.

MOVEMENT OF LOGS ON A STRAIGHT SECTION

It is of prime importance that the structure shall be designed and constructed so that the logs neither attain a velocity great enough so that they will leave the chute, nor one so low that they will come to rest in the channel en route. The two faults may be avoided, at least in part, by adjusting the chute length l or by modifying the chute angle α or the coefficient of friction f. However, the length can seldom be altered without changing the slope α, and the usual practice is to secure the desired results by modifying either the grade or the coefficient of friction or both.

If it is desired that a log shall traverse the chute channel at a uniform velocity, the chute channel throughout its length must have a slope angle equal to the angle of repose (see formula 3). However, because of topographic conditions and high construction costs it is impractical to maintain a uniform grade and a uniform coefficient of friction throughout; hence, a log will travel at a varying rate of velocity on different sections of the chute.

When the slope greatly exceeds the angle of repose, provision must be made to keep the maximum velocity within the limits of safety, and also care must be taken to see that the slope will not be so much below the angle of repose that the velocity of the log will drop to zero.

European practice[43] indicates that the ideal maximum speed consistent

[43] See "Das Gefälle der Holzriesen," by Karl Petraschek. *Mittheilungen aus dem forstlichen Versuchswesen Österreiches*, Vol. I, Part II, Vienna, 1878.

with a minimum loss of wood from breakage is from 10 to 16 feet per second for logs and long timbers and from 28 to 36 feet per second for bolts and split wood not exceeding 6 feet in length. The above values, however, are frequently exceeded, due to the necessity of using steep grades in order to avoid excessive construction costs.

One of the most difficult problems is the determination of the coefficient of friction for chuted wood because of its instability, changing frequently during the day, due to weather conditions, and also because it is dependent on the form, size, and weight of the logs, which vary for each individual log.[44] In general, a constant coefficient of friction is assumed in practice for a given set of conditions since there are other variables, impractical to compute with accuracy, which may have as great or a greater effect on velocity than the coefficient of friction.

Formulæ used in practical chute design neglect the resistance offered by air to the movement of a log because it is relatively small and actually is included in the coefficient of friction.

The most favorable slope for a chute head (the first few hundred feet) is from 25 to 50 per cent (14° to 27°), although steeper grades may be used when necessary. In the intermediate section the gradient may vary from 5 to 100 per cent (3° to 45°), but it should not be horizontal if it can be avoided; in any case, a horizontal section should be relatively short in length. On a horizontal curve, when the velocity is low, the grade should be from 5 to 10 per cent (2° to 3°) greater than on a tangent because of the greater frictional resistance. However, if a curve follows a steep section, the former may serve a useful function as a braking section, in which case no change in grade would be required.

Very steep and very low grades should be avoided in the main body of a chute and should be used only on straight sections, otherwise the logs, in the first case, may leave the slide or, in the second case, wholly lose their velocity and stop. Average grades only should be used on sharp curves, and the latter should not follow a steep straight section if it can be avoided.

However, steep grades are preferable to low ones because if the vertical and horizontal curves on the former are properly designed and constructed and the lower part of the chute has been properly built the chute will func-

[44] Coefficients of friction for different wood assortments and for various chute surface conditions, as determined by Petraschek, are given on page 139. The values developed by him are satisfactory for use under the specified conditions to which they apply.

tion satisfactorily, while low grades on long sections usually cause operating difficulties.

The lower terminal should have a sufficient length of horizontal section to reduce the velocity of the chuted wood to nearly zero, or if topography does not make such a section possible, a counter grade should be inserted. A curve at the lower terminal also will aid in reducing the velocity of the logs.

The following formulæ are of value in chute design because they indicate the probable velocity which a log will attain under given conditions. However, the values derived by the use of these formulæ may not conform wholly to actual conditions because of the difficulty of determining what these conditions are.

The movement of a log in a chute, due to gravity, is subject to the same physical laws which govern the movement of a body on an inclined plane. The force of gravity may be resolved into two forces: F acting in a direction parallel to the chute channel and P acting perpendicular to it (Fig. 70). The movement of a log down the chute channel is induced by the force F while the force P tends to retard it; therefore, the two forces, F and P, oppose each other. When a log moves upward on a chute channel, such as on a counter grade, F and P both act as opposing forces and both tend to retard the movement.

Assuming the weight of the log to be W, the pressure the log exerts on the chute channel to be P, and the force which tends to cause the log to move down the chute to be F, then three separate conditions may exist; namely,

$$F - P \begin{smallmatrix} > \\ = \\ < \end{smallmatrix} 0$$

Assuming that the value of the coefficient of friction[45] remains constant, then when $F > P$ there will be a uniform acceleration in velocity; when $F < P$ there will be a uniform retardation of velocity; and when $F = P$ the movement will continue at a uniform rate.

The value of F (Fig. 70) is equal to $W \sin \alpha$ and that of P is equal to

[45] Friction is directly proportional to the pressure of the two surfaces against each other; that is, the pressure of the log against the chute channel. That proportion of the chute pressure, which must act as a moving force merely to overcome friction, is called the coefficient of friction and usually is expressed as a decimal.

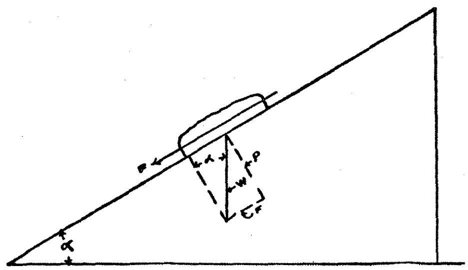

Fig. 70. The relation of the forces which affect the movement of a body on an inclined plane. α, the slope of the plane; W, the weight of the body; F, the component tending to slide the body down the plane; P, the pressure normal to the plane.

$W \cos \alpha$. However, the downward movement also is opposed by friction, and hence the force opposing the downward movement of a log is

$$P \times f = W \cos \alpha \, f$$

The value of F, or the force causing the log to move down the chute, is, therefore,

$$\begin{aligned} F &= W \sin \alpha - W f \cos \alpha \\ &= W (\sin \alpha - f \cos \alpha) \qquad (1) \end{aligned}$$

When a log moves up an inclined plane, such as a counter grade, its velocity is retarded by both of the forces F and P; therefore,

$$\begin{aligned} F + P &= W \sin \alpha + W f \cos \alpha \\ &= W (\sin \alpha + f \cos \alpha) \qquad (2) \end{aligned}$$

When $F = P$ the log is in equilibrium and

$$l = 0,$$

$$\begin{aligned} \text{hence, } W \sin \alpha &= W f \cos \alpha \\ \sin \alpha &= f \cos \alpha \\ \tan \alpha &= f \qquad (3) \end{aligned}$$

that is, under the above condition the coefficient of friction f is equal to the tan α.

This angle, tan α, is known as the angle of repose or angle of friction, which angle changes in magnitude according to the character of the moving body and of the chute channel. Thus, the angle of repose for a log of given weight and smoothness is less on a smooth channel than on a rough one. Also the angle of repose is greater for a log at rest than for one in motion.

The equation $\tan \alpha = f$ is of value in determining how great an angle must be given to a chute in order to cause the log to start moving downward.

Influence of the Chute Slope on the Velocity of Logs

When the angle of the chute is greater than the angle of repose the log will start to move down the chute acquiring an acceleration G. The magnitude of this force G may be expressed as follows:

$$G = \frac{F}{M} \text{ and } M = \frac{W}{g}$$

in which F is the force causing the log to move downward, M the mass, W the weight of the log, and g the unit rate of acceleration due to gravity.[46]

Substituting in the first equation the value for M we get

$$G = \frac{F}{\frac{W}{g}}$$

$$= \frac{Fg}{W}$$

Again substituting for F its value as given in formula (1) we get

$$G = \frac{W (\sin \alpha - f \cos \alpha)}{W} g$$

$$= g (\sin \alpha - f \cos \alpha) \quad \ldots \ldots \quad (4)$$

The retardation in velocity of a log moving upward on an inclined plane will be represented by the formula (see formula 2)

$$G = \frac{W (\sin \alpha + f \cos \alpha)}{W}$$

$$= g (\sin \alpha + f \cos \alpha) \quad \ldots \ldots \quad (5)$$

The equations for determining for a *free fall* the velocity v and the dis-

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[46] Equal to 32.2 feet per second.

tance l for a given time t, when the movement is one with a uniform acceleration g, are

$$v = gt \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

$$\text{and } l = \frac{gt^2}{2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

Substituting in equation (6) the value of t as found from equation (7), we get

$$v = \sqrt{2gl} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

For an *inclined plane* the value of G (formula 4) is substituted for g (formula 8) and we then get

$$v = \sqrt{2Gl}$$

$$\text{hence, } v = \sqrt{2g\,(\sin\alpha - f\cos\alpha)\,l} \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

Since, due to topographic conditions, it is impractical to maintain a uniform slope throughout the length of the chute, frequent changes in gradient will occur. When the chute has a gradient in excess of the angle of repose, it is necessary to determine what length of chute of given gradient may be used without the log attaining a velocity greater than a safe maximum.

When the initial velocity is zero, the length of chute l, which must be traversed by a log in order to attain a velocity v, may be found from the following formula derived from formula (9).

$$l = \frac{v^2}{2g\,(\sin\alpha - f\cos\alpha)} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$

Examples: What will be the final velocity v of a log, starting with an initial velocity of zero, after it has passed over a chute section 200 feet in length, the slope of which is 15°, and the coefficient of friction 0.15 (snow cover on chute and the bolt 6 feet in length)? [47]

$$v = \sqrt{2gl\,(\sin\alpha - f\cos\alpha)}$$

$$= \sqrt{64.4 \times 200\,[.2588 - (.15 \times .9659)]}$$

$$= 38 +$$

[47] See Petraschek's coefficients of friction, p. 139.

Or, what length of chute is necessary in order that a bolt 6 feet in length with an initial velocity of zero shall attain a final velocity of 30 feet per second, the chute slope being 10° and the coefficient of friction 0.15. Then

$$l = \frac{v^2}{2g\,(\sin\alpha - f\cos\alpha)}$$

$$= \frac{30^2}{64.4\,[.1736 - (.15 \times .9848)]}$$

$$= 539.8 \text{ feet}$$

When the initial velocity at which the log enters the chute section is not zero but c, and the angle α is greater than the angle of repose, the values for v and l for a *free fall* are found from the following formulæ.

$$v = c + gt$$

$$l = ct + \tfrac{1}{2}gt^2$$

$$v^2 = (c + gt)^2$$

$$= c^2 + 2cgt + g^2t^2$$

$$= c^2 + 2g\,(ct + \tfrac{1}{2}gt^2)$$

$$= c^2 + 2gl$$

For an *inclined plane*, substituting the value of G (formula 4) for g, we get

$$v^2 = c^2 + 2Gl$$

$$= c^2 + 2gl\,(\sin\alpha - f\cos\alpha)$$

$$\therefore v = \sqrt{c^2 + 2gl\,(\sin\alpha - f\cos\alpha)} \quad . \quad . \quad . \quad . \quad (11)$$

and the length of chute l, at the end of which the log will have attained a velocity v, starting with an initial velocity c, will be

$$l = \frac{v^2 - c^2}{2g\,(\sin\alpha - f\cos\alpha)} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (12)$$

EXAMPLES: What will be the final velocity v of a bolt 6 feet in length after it has passed over a chute section l, 300 feet in length, the slope of which is 10°, the initial velocity c on entering the section 10 feet per second, and the coefficient of friction 0.15? Then

$$v = \sqrt{c^2 + 2g\,(\sin\alpha - f\cos\alpha)\,l}$$
$$= \sqrt{10^2 + 64.4\,[.17364 - (.15 \times .9848)]\,300}$$
$$= 24.51 \text{ feet per second}$$

$$\text{and } l = \frac{v^2 - c^2}{2g\,(\sin\alpha - f\cos\alpha)}$$
$$= \frac{600.77 - 100}{64.4 \times .02588}$$
$$= 300 \text{ feet}$$

When, however, the angle $\alpha <$ the angle of repose, the equation $(\sin\alpha - f\cos\alpha)$ and also the entire formula becomes negative (since $\sin\alpha < f\cos\alpha$). The formula then will read

$$l = \frac{c^2 - v^2}{2g\,(-\sin\alpha + f\cos\alpha)}$$
$$= \frac{c^2 - v^2}{2g\,(f\cos\alpha - \sin\alpha)} \qquad (13)$$
$$\text{and } v = \sqrt{c^2 - 2gl\,(f\cos\alpha - \sin\alpha)} \qquad (14)$$

that is, the final velocity is less than the initial velocity c.

EXAMPLES: What length of chute will be necessary to reduce the velocity from 20 to 10 feet per second when the chute slope is 6° and the coefficient of friction is 0.15?

$$l = \frac{20^2 - 10^2}{64.4\,[(.15 \times .99451) - .1045]}$$
$$= 104 \text{ feet}$$

When the $\sin\alpha = \tan\alpha$ (angle of friction $= f$), then

$$\sin\alpha - f\cos\alpha = \sin\alpha - \tan\alpha\cos\alpha$$
$$= 0$$

Hence, $l = \infty$ and the velocity will remain uniform.

If the chute section is horizontal, then $\alpha = 0$, $\sin\alpha = 0$, and $\cos\alpha = 1$. When a log enters such a section with a velocity c, the length of chute necessary to reduce it to v may be found by substituting the above values in formula (12).

$$l = \frac{v^2 - c^2}{2g\,(\sin\alpha - f\cos\alpha)}$$
$$= \frac{v^2 - c^2}{2g\,(-f)}$$
$$= \frac{c^2 - v^2}{2gf} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (15)$$

and the final velocity v for a given length l will be

$$v = \sqrt{c^2 - 2gfl} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (16)$$

EXAMPLES: A log enters a horizontal section with a velocity of 40 feet per second and it is desired to reduce it to 10 feet per second, the coefficient of friction being 0.15. Find the necessary length of horizontal section.

$$l = \frac{1600 - 100}{2 \times 32.2 \times 0.15}$$
$$= 155 \text{ feet}$$

Or, what will be the final velocity of a log after passing over a horizontal section 250 feet in length, the initial velocity being 50 feet per second?

$$v = \sqrt{2500 - (2 \times 32.2 \times 0.15 \times 250)}$$
$$= 9.2 \text{ feet per second}$$

If it is desired to find that length of horizontal chute at the end of which the velocity will be zero, the value $v = 0$ is introduced into the formula. If the initial velocity c is 40, then

$$l = \frac{c^2}{2gf} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (17)$$
$$= \frac{1600}{2 \times 32.2 \times 0.15}$$
$$= 165 \text{ feet}$$

Counter grades are useful as braking sections following steep grades and as a means for checking the speed of logs at the lower terminal where logs are discharged from the chute channel. The substitution of a counter grade for a horizontal section at the lower terminal reduces the length of braking section and decreases construction costs when the topography does not make possible a cheaply constructed level section. It is not desired in either of the above cases to reduce the velocity c with which the log reaches the counter grade to zero, but to a value v.

The length l of counter grade necessary to reduce the initial velocity c to v may be found from the following formula:

$$l = \frac{c^2 - v^2}{2g\,(\sin\alpha + f\cos\alpha)} \quad . \quad . \quad . \quad . \quad . \quad . \quad (18)$$

and the velocity v at the end of a given chute length l will be

$$v = \sqrt{c^2 - 2gl\,(\sin\alpha + f\cos\alpha)} \quad . \quad . \quad . \quad . \quad (19)$$

If it is desired to know the length of counter grade at the end of which the velocity will be zero, the value zero is substituted for v^2 in formula (18) which then will read

$$l = \frac{c^2}{2g\,(\sin\alpha + f\cos\alpha)} \quad . \quad . \quad . \quad . \quad . \quad . \quad (20)$$

Examples: What length of counter grade having a slope of 15° will be necessary to reduce the initial velocity of 20 feet to 5 feet, the coefficient of friction being assumed as 0.15?

$$l = \frac{400 - 25}{64.4 \times .4076}$$
$$= 143 \text{ feet}$$

What length of counter grade having a slope of 15° will be required to reduce the velocity from 20 to zero feet?

$$l = \frac{400}{64.4 \times .4076}$$
$$= 152 \text{ feet}$$

Vertical Curves

Changes in the gradient of the chute channel should be made as seldom as possible, because it is not always feasible to connect the two sections having different slope angles with suitable vertical curves on account of topographic conditions.

When there is a difference in the slope of two adjoining sections of chute, one of the three following cqnditions will exist.

(a) A change from a steeper to a lesser grade (Fig. 71, a).

(b) A change from a descending to an ascending grade (a counter grade) (Fig. 71, b).

(c) A change from a lesser to a steeper grade (Fig. 71, c).

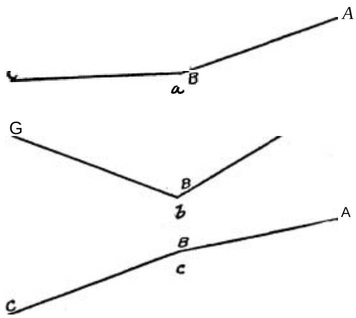

Fig. 71. The slope conditions represented by grade differences between two adjoining sections of chute.

In cases (a) and (b) the log will tend to strike the chute channel at the junction of the two sections and, due to impact, the log or chute channel or both may be damaged. In case (c) when the log reaches *B* (Fig. 71, c) it will tend to leave the channel and again return to it after a free fall in the form of a parabola. In chute construction it is necessary to round off the angle between the two connecting sections so that the log will not only remain within the channel, but also will not impact against it.

In the cases of (a) and (b) there will be a retardation in the acceleration, due to impact at the point of junction of the two chute sections Band also because the lower section of (a) has a slope angle less than the upper section and in (b) the lo\ver section is a counter grade. In (c) there will be a tendency for an acceleration in movement because the lower slope angle is greater than the upper.

The use of a lesser slope angle or a counter grade for the lower chute section has practical application in chute operation because it permits the introduction of low grade, horizontal, or upward sloping sections which serve to retard the acceleration, thus providing what are known as *brake sections.* When a change in grade occurs, a spiraled circular curve should be used to connect the two tangents in order to provide a smooth passage of the log from one gradient to the other, and to prevent the log from damaging itself or the channel by heavy impact. A change in grade should be avoided, if possible, on a chute section where a horizontal curve also is required, since such a combination often causes the log to leave the channel.

Impact cannot be eliminated, wholly, by the use of a spiraled circular curve because it is impractical to build the channel (except possibly in the case of a metal one) so that it will be a perfect spiraled circular curve. Rather, it will be a curved channel, the bed of which is a polygon with many short sides. At the junction of any two sides there will be an angle which will give rise to impact and, therefore, to a loss in velocity. There also will be a loss in velocity in passing over the curve because the angle of repose of the curve will be less than that of the section preceding it. The amount of retardation in velocity due to the curve will depend, therefore, on the length of the curve and of its radius. The actual loss in velocity due to the two above factors would be difficult to determine in advance for the usual type of chute because of differences in the quality of the channel which will result from the relatively crude form of construction.

Calculations of changes in velocity necessitate the use of formulæ which are too complicated for general practical use. As a rule, the loss in velocity due to the insertion of a suitable spiraled circular section may be disregarded because the probable variation in smoothness and regularity of the channel will lead to greater changes in velocity than the curve itself.

In a spiraled circular curve the radius at each point of spiral[48] is ∞ and the degree of curvature zero. The radius of the spiral and its degree of curvature at the point where the spiral joins the circular curve are the same as that of the circular curve itself. The degree of curve at any point on the spiral, intermediate between the points of spiral and their junction with the circular curve, varies directly as the distance of this point, measured along the original tangent, from the point of spiral.

IZubelka states that for logs having a maximum length of about 100 feet, the curve radius should be not less than 656 feet (200 meters) and that the total length of the spiraled curve should be that shown in the accompanying table.[49]

48 The point of origin of the spiral curve on each tangent.

49 See "Der Riesweg als Holzbringungsanstalt des Hochgebirges," by A. Kubelka. *Centralblatt für das gesamte Forstwesen,* pp. 325-377, Vienna, Aug.-Sept., 1903.

RELATION BETWEEN GRADE DIFFERENCES AND THE LENGTH OF CURVE

Grade difference between sections *Per cent*	*Length of curve* *Feet*
10	62
20	128
30	187
40	250
50	312

Since the object sought in installing a spiraled circular curve is to secure a chute channel which is flat enough so that the whole length of log will rest on the bottom of the chute, sharper curves than the above may be used for pulpwood and short logs, especially when topographic conditions are such that the cost of construction can be appreciably reduced thereby.

Grade changes between chute sections are seldom in excess of a maximum of from 15 to 20 per cent (8° to 11°, approximately); hence, a total curve length of from 90 to 130 feet only would be called for by the above schedule and a tangent distance of from 45 to 65 feet. A 20-foot spiral length on each end of the circular curve will be adequate for a pulpwood chute, and one of 40 feet will serve for standard length logs.

The length of curve is influenced by topographic conditions, and while sharp curves tend to retard the velocity of the log, the loss in speed may be neglected in most chutes except those of low grade because the velocity usually is in excess of that required to keep the logs in motion and the more or less rough character of the channel introduces a variable not easy to compute, which may have a greater effect on velocity than the curve itself.

LOCATION OF A VERTICAL SPIRALED CURVE

Vertical spiraled circular curves may be located by means of offsets to the arc drawn from the tangents *AB* and *CB* (Fig. 72), based on a system of right-angled coördinates. To simplify the location problems, an Austrian forest engineer has devised the following method by means of which the right-angled system of coördinates may be converted into an oblique-angled system in order that the points on the arc may be perpendicular to the horizontal plane of the tangents rather than to the tangents themselves[50] (Fig. 73, a and b).

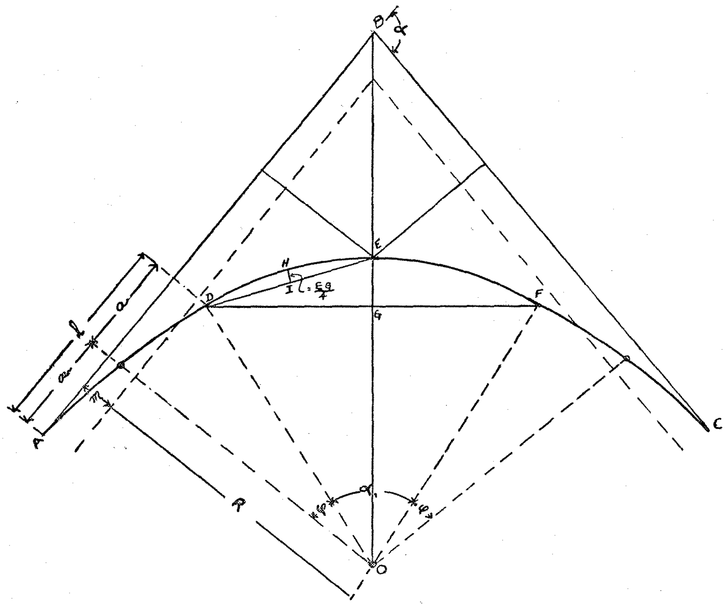

Fig. 72. A spiraled circular curve. $AB = CB$, tangents of spiraled curve; R, radius of circular curve; m, spiral offset; $l = 2a$, length of spiral; EG, middle ordinate of circular curve; DF, long chord of circular curve; HI, offset, "quarter method," for circular curve; α, angle of intersection of spiraled circular curve; α_1, central angle of circular curve.

He also prepared a table of values for the various factors needed for location, but based them on constant radii and lengths of spiral; hence, his tables are adapted only for a given set of conditions which may not apply in a specific case. The methods of determining these values are given here

[50] See "Hilfstafeln zum Trassieren von Rieswegen," by Oskar Baltz-Balzberg. *Wiener Allgemeine Forst- und Jagd-Zeitung*, pp. 127 and 128, Vienna, May 31, 1929.

and also one table showing right-angled offsets for two radii and two spiral lengths. Those for other radii and other spiral lengths may be computed by the following formulæ.

In a right-angled system of coördinates having the point of spiral as its origin (Fig. 73, a and b), x is the abscissa and y the ordinate, while in the oblique-angled system, x_1 and y_1 are the abscissa and ordinate, re-

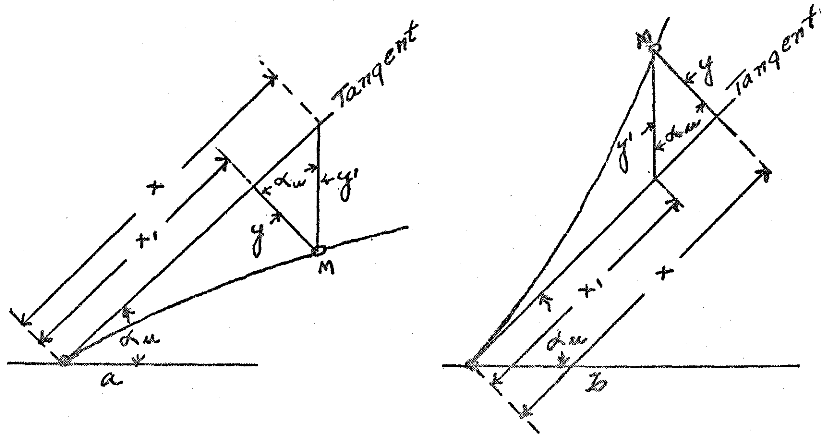

Fig. 73. The relation between a right-angled and an oblique-angled system of coördinates for use in locating a vertical spiraled circular curve. *a*, the lower part of a convex curve which also conforms to the upper part of a concave curve; *b*, the lower part of a concave curve which also conforms to the upper part of a convex curve. (After Baltz-Balzberg.)

spectively. M is any point on the spiral at which a stake is to be set. α_o is the slope angle of the upper tangent and α_u of the lower tangent. In a convex curve $\alpha_u > \alpha_o$, therefore, $\alpha_u - \alpha_o = +\alpha$; and in a concave curve $\alpha_u < \alpha_o$, therefore, $\alpha_u - \alpha_o = -\alpha$.

The right-angled offsets, y, for a spiral at any point, x, on the tangent are

$$y = \frac{x^3}{6lR} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (21)$$

in which x is the distance from the point of spiral to the point where the offset is made, l is the length of spiral, and R, the radius of the circular curve.

The offsets to a circular curve having a spiral at each end are

$$y = (R + m) - \sqrt{R^2 - x^2} \quad . \quad . \quad . \quad . \quad (22)$$

in which m, the spiral offset, is as follows:

$$m = \frac{l^2}{24R} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (23)$$

The above values are computed in the office and for ready reference should be combined in a table similar to the following. Reference tables for several radii and those lengths of spiral which experience indicates will be most frequently required may be prepared in advance and will then serve for all future work, for both vertical and horizontal spiraled circular curves.

RIGHT-ANGLED COÖRDINATES FOR RADII OF 600 AND 700 FEET AND SPIRALS 20 AND 40 FEET IN LENGTH

Tangent distance x (*feet*)						
	Length of spiral l (feet)		20		40	
	Radius, R (feet)		600	700	600	700
	$m \left(\frac{l^2}{24R}\right)$ (*feet*)		0.028	0.023	0.111	0.095
	$R + m$ (*feet*)		600.028	700.023	600.111	700.095
10	Spiral	Ordinates y‡ (feet)	0.014	0.012	0.007	0.006
20*			0.111	0.047	0.055	0.047
30			0.778	0.633	0.187	0.160
40†			1.427	1.173	0.444	0.380
50			2.127	1.813	2.111	1.885
60	Circular		3.027	2.603	2.971	2.675
70	Curve		4.127	3.533	4.211	3.605
80			5.427	4.613	5.471	4.895
90			6.827	5.833	6.901	6.695
100			8.427	7.203	8.511	7.295

* Last point on 20-foot spiral. † Last point on 40-foot spiral.

‡ The value of y for a spiral is $y = \frac{x^3}{6\,lR}$ (formula 21). For a circular curve between two spirals, $y = (R + m) - \sqrt{R^2 - x^2}$ (formula 22).

Having chosen the radius and length of spiral[51] to be used for a given curve and computed the values for x and y, it is necessary to convert these values into those of an oblique-angled system, which may be done by the use of the following formulæ.

For a convex curve

$$x_1 = x + y \tan \alpha_u \text{ (lower part)} \quad . \quad . \quad . \quad . \quad . \quad (24)$$

$$x_1 = x - y \tan \alpha_o \text{ (upper part)} \quad . \quad . \quad . \quad . \quad . \quad (25)$$

For a concave curve

$$x_1 = x - y \tan \alpha_u \text{ (lower part)} \quad . \quad . \quad . \quad . \quad . \quad (26)$$

$$x_1 = x + y \tan \alpha_o \text{ (upper part)} \quad . \quad . \quad . \quad . \quad . \quad (27)$$

The value of y_1 for both convex and concave curves may be found from the following:

$$\text{(upper part) } y_1 = \frac{y}{\cos \alpha_o} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (28)$$

$$\text{(lower part) } y_1 = \frac{y}{\cos \alpha_u} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (29)$$

The angles α_o and α_u are taken from the field data secured at the time the profile is made.

The following example will serve to illustrate the method of data computation:

EXAMPLE: The upper slope angle of a chute is 20° and that of the next lower section with which it is to be connected by a vertical spiraled curve is 10°. The length of radius *R* (Fig. 72) is assumed to be 600 feet and the length of spiral 20 feet. Determine the offsets for both the spirals and the circular curve.

The angle of intersection will be 20° — 10° or +10°.

The value of m taken from the previous table or computed (formula 23) is 0.028.

The tangent length $AB = CB$ will be:

$$AB = CB = \left[(R + m) \tan \frac{\alpha}{2}\right] + a \quad . \quad . \quad . \quad . \quad . \quad (30)$$

$$= [(600 + .028) \times .0875] + 10$$

$$= 62.5 \text{ feet}$$

[51] See page 109.

The values of x, x_1, y, and y_1 for a concave curve with the above conditions then will be those shown in the accompanying table (values for y are taken from the previous table).

DISTANCES x ALONG THE TANGENTS AND OFFSETS y FOR A RIGHT-ANGLED SYSTEM OF COÖRDINATES AND DISTANCES x_1 AND OFFSETS y_1 FOR AN OBLIQUE-ANGLED SYSTEM OF COÖRDINATES FOR A *CONCAVE* CURVE

	Distance along tangent from point of spiral		*Offsets from tangent*	
	x (*feet*)	x_1 (*feet*)	y (*feet*)	y_1 (*feet*)
Upper part of curve				
Spiral	10	10.005	0.014	0.015
	20	20.040	0.111	0.118
Circular curve	30	30.283	0.778	0.828
	40	40.519	1.427	1.518
	50	50.774	2.127	2.263
	60	61.102	3.027	3.221
Lower part of the curve				
Spiral	10	9.998	0.014	0.014
	20	19.980	0.111	0.112
Circular curve	30	29.863	0.778	0.790
	40	39.748	1.427	1.449
	50	49.655	2.127	2.160
	60	59.466	3.027	3.075

Location with a transit.[52] The values for x_1 and y_1 having been computed in the office, the locator is ready to stake out the curve in the field. The first task is to establish the points of spiral of the curve (Fig. 74, a and b) by measuring along each tangent from the point of intersection B for a distance equal to $AB = CB$. The transit is then set up either over

[52] Baltz-Balzberg method.

A or *C*. The height of instrument is measured and a line of sight parallel to the tangent established by turning off on the vertical arc an angle equal to α_0 or α_u, depending on the point of spiral on which the instrument is set.

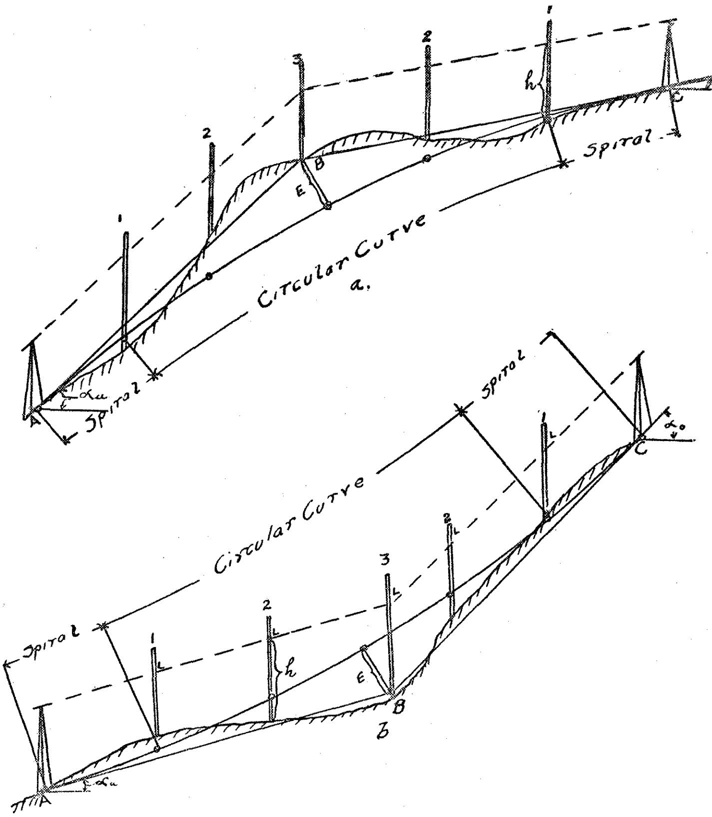

Fig. 74. Method of location of a vertical spiraled circular curve with the aid of a transit. *a*, a convex vertical spiraled circular curve; *b*, a concave vertical spiraled circular curve. (After Baltz-Balzberg.)

The vertical limb is clamped and kept at that angle until all stakes on that tangent are set.

The stakes are set vertically and not at right angles to the tangent because the values are those for an oblique-angled and not a right-angled system of coördinates.

When all of the stakes have been set on one tangent, according to the given values for x_1 and y_1, the instrument is moved to the other point of spiral and the process repeated, the offsets from that tangent being those computed for that portion of the curve.

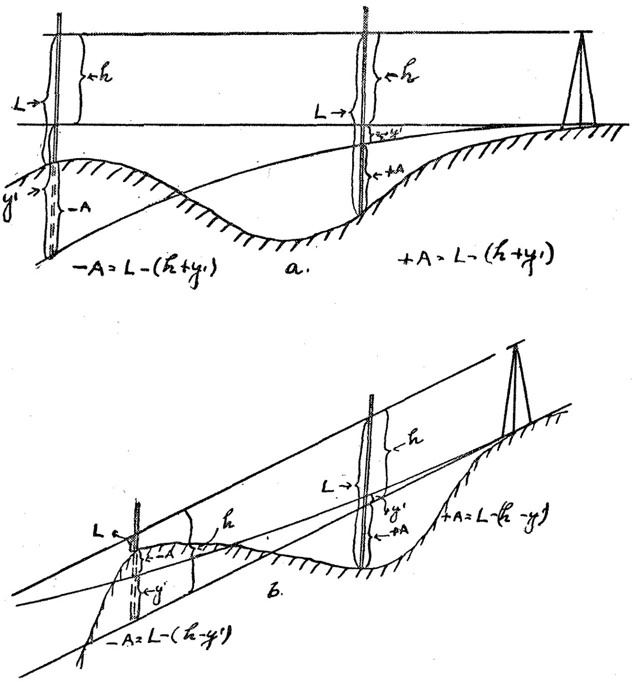

Fig. 75. Direct method of setting grade stakes on a vertical spiraled circular curve with the aid of a transit. *a,* relation of cut (—A) and fill (+A) for a convex curve; *b,* relation of cut (—A) and fill (+A) for a concave curve. (After Baltz-Balzberg.)

If the ground level at any point at which a stake is set is on the same level as the arc of the curve, the reading L of the middle hair of the telescope on a rod held at that point will be:

$$\text{Concave curve: } L = h - y_1 \quad . \quad . \quad . \quad . \quad . \quad . \quad (31)$$

$$\text{Convex curve: } L = h + y_1 \quad . \quad . \quad . \quad . \quad . \quad . \quad (32)$$

When the ground at any stake is not on the same level as the arc of the curve, a cut or fill must be made. If $+A$ represents the depth of fill and $-A$ the depth of cut, the following relations will apply (Fig. 75, a and b):

For a convex curve:

$$\pm A = L - (h + y_1) \quad \ldots \ldots \quad (33)$$

For a concave curve:

$$\pm A = L - (h - y_1) \quad \ldots \ldots \quad (34)$$

By the use of these relations the locator can determine directly the cut or fill at any given stake.

Thus, in the case of a convex curve when the height of instrument h is 4 feet, the rod reading L on the stake is 6 feet, and the offset y_1 is 0.3 foot, the arc of the circle will fall above the ground level and a fill will be necessary, the depth of which will be

$$\begin{aligned} +A &= L - (h + y_1) \\ &= 6 - (4 + 0.3) \\ &= 1.7 \text{ feet} \end{aligned}$$

If the rod reading were 2.5 feet instead of 6 feet, a cut would be required, the depth of which would be as follows:

$$\begin{aligned} -A &= L - (h + y_1) \\ &= 2.5 - (4 + 0.3) \\ &= -1.8 \text{ feet} \end{aligned}$$

Location without a transit. The stakes may be set without the use of an instrument by computing, in the office, the proper offset at each point x_1 and the required cut or fill from the ground level to the arc of the circle.

A line of levels must first be run over the tangents and the ground elevation determined at each point of offset x_1. These elevations are then plotted in the form of a profile on which the curve also is drawn. The required cut or fill is then scaled off the profile in the office and later recorded on the stakes as they are set.

The length of the tangents AB and CB must be laid off on the ground in the same manner as when a transit is used in order to fix the points of spiral. The stake setting may start either at A or C and continue until the center of the curve is reached, when staking is started at the opposite point of the spiral and continued until the center is again reached.

HORIZONTAL CURVES

The ideal type of chute is one which has a uniform grade and a straight profile. This ideal, however, cannot be realized because topographic conditions necessitate changes in slope and also deviations in the horizontal profile caused by the introduction of curved sections. The latter exercise a braking effect due to added friction caused by the log passing around the curve and impacting against the chute channel and also because a new factor, centrifugal force, not found in straight sections is present, which tends to cause the log to leave the chute at a tangent to the curve.

In order that a curve may function properly it should be constructed so that the log will move smoothly and at a uniform velocity during its passage around it. Most chutes built on this continent have been designed by woodsmen who have given but little consideration to the physical phenomena which control the passage of a log around a curve. However, the theoretical determination of the effect of these phenomena is a rather involved process, and the results found by calculation may only approximate the actual conditions.

Any given chute channel is adapted only for logs of a given length and velocity, and since logs may and do vary in length and in the velocity at which they reach a given curve, they do not all move in the same manner, those traveling at an excessive speed tending to leave the chute and those moving at a 10"' velocity tending to stop. The usual method of control has been to give the channel a sufficient slope and width to permit the passage of low velocity logs, to install braking devices, and to build up the outer side of the curve to a height sufficient to keep logs traveling at excessive speeds from leaving it. This procedure possesses numerous disadvantages because if the chute channel is too wide the logs acquire a lateral movement which prevents a smooth passage around the curve, and logs tending to travel at excessive velocities strike the outer side of the channel and by impact may destroy the log or the chute wall or both. Hence, the outer wall, which is subject to excessive wear and impact, must be very strongly constructed.

In the following discussion of horizontal curves an effort is made only to point out some of the practical factors by means of which the curve may be made to function with a reasonable degree of satisfaction.[53]

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53 An exhaustive and excellent treatise on the theoretical aspects of chute curve design may be found in *Theorie der Riesen*, by Dr. Leo Hauska. Franz Deuticke, Vienna, 1914.

It is usual to make the radius of the curve as long as topography and reasonable construction costs will permit, because curves with short radii have a strong braking tendency. Long logs naturally require a curve with a greater radius than short ones. However, it is not advisable to lengthen the curve radius for a relatively small number of long or large logs when most' of the logs are short and of small diameter. The large logs should be cut into short lengths and those of large diameter split or else abandoned. Curves are more expensive to construct and maintain than straight sections, and economy in costs, therefore, demands that when only a small percent of the logs require a curve of relatively long radius, they should be made into smaller sizes, otherwise the cost for moving the bulk of the output is greater than it should be. European practice indicates that the minimum permissible radius for short logs (pulpwood) is about 100 feet for a chute which is properly built and whose channel is, smooth enough to prevent logs from stopping. Logs from 12 to 16 feet 'require a minimum radius of 180 feet, and those 30 feet or longer require a minimum curve radius of 300 feet.

Reverse curves should not follow one another with less than a 60-foot straight section between them because the direction of movement of the log is changed too suddenly. It may be possible to combine two short reverse curves into one, and this should be done when costs of construction permit.

The width of the chute channel is related to the curve radius, and the shorter the radius, the wider the channel must be in order to permit the passage of logs of a given size.

Straight sections should merge gradually into a curve because otherwise the change in direction will be too abrupt. Two straight sections, especially when the radius of the curve is relatively short, should be connected by means of an easement curve (a spiraled circular curve). The higher the velocity, the longer the easement curve should be, but topography often prevents the use of a spiral length as long as is desirable.

On curves having radii of 1,000 feet or more, easement curves may be omitted; also, due to ground conditions, a spiral may be used on the upper end of the curve and omitted on the lower end, although this practice is recommended only when necessary to keep construction costs within the allowable limits. The controlling factors are slope relations, character of topography, length and diameter of chuted material, and cost.

Easement curves are longer than circular curves, and, therefore, the cost of construction and maintenance is somewhat greater.

A chute channel having a comparatively short radius always must be built more strongly than a channel on flat curves or on straight sections because of the pressure of the logs against the outer wall.

In the design of a curve the chief factors sought are:

(1) A velocity which will carry the log around the curve without stopping.

(2) A channel which will confine the log to the chute without undue damage to either.

Since the size of log and the coefficient of friction are variables, an attempt to follow theoretical calculations too closely in actual construction is not justified on the basis of costs. Rather, an attempt should be made to secure a chute channel which will function with reasonable satisfaction at the lowest practicable expense.

The cross section of the usual type of short wood chute on a curve conforms rather closely to the arc of a circle and, in general, may be considered as one.

A log traveling along a straight section will follow the longitudinal axis of the channel due to gravity, but as soon as it enters a curve, centrifugal

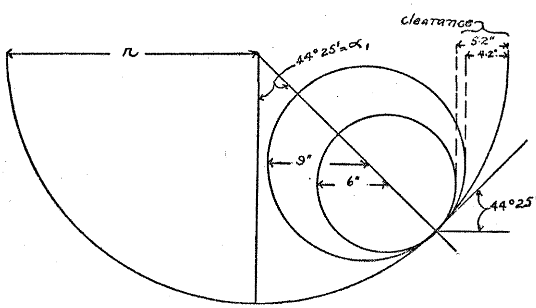

Fig. 76. A graphic method for determining the clearance of a log in a circular chute trough. In this figure $\alpha = 20° \ 35'$, $\alpha_1 = 44° \ 25'$, $v = 60$, and $r = 2$ feet.

force causes the log to leave the longitudinal axis and to move toward the outer portion of the channel; thus, the log raises itself above the bed of the channel and travels along the side of it as shown in Fig. 76. The log will move outward from the axis of the chute until the forces due to gravity and to centrifugal action are equal. This distance is influenced by the velocity with which the log is traveling, the radius R of the curve, and the radius r and the slope α of the chute channel.

The angle of deviation α_1, or that angle which the outer side of the chute channel should have with reference to the base of the longitudinal axis to conform to the path of the log, is

$$\tan \alpha_1 = \frac{v^2}{g R} \cos^2 \alpha \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (35)$$

Formula (35) does not provide for a uniform velocity around the curve because it does not take into consideration the added frictional resistance which results from the impact of the log against the outer part of a wooden channel which is not a perfect circle but is a series of polygons. Experience indicates, however, that the excess frictional resistance may be compensated for by increasing the longitudinal slope of the curve from 2° to 3° above that of the straight section immediately preceding it.[54] When the slope of the straight section is considerably in excess of the angle of friction, an increase in the slope of the curve is seldom necessary because the velocity of the log, when passing around the curve, will not be reduced to a point where it will stop. In fact, under such conditions the curve may serve as a desirable braking section.

The horizontal distance x which the log will move away from the longitudinal axis of a chute which forms an arc of a circle (Fig. 76) is

$$x = r \sin \alpha_1 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (36)$$

in which r is the chute radius.

The height h to which the log will rise above the chute bed is

$$h = 2\, r \sin^2 \frac{\alpha^1}{2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (37)$$

Formulæ (36) and (37) provide an index of that point on a semicircular channel of a given radius along which a log having a given velocity will travel. The limit is reached when the angle α_1 is 90° because the log then will leave the channel. Since the velocity of logs varies with their size and degree of smoothness, the profile should conform in width and depth to the safe angle of deviation for maximum velocities and maximum diameters

[54] See "Der Riesweg als Holzbringungsanstalt des Hochgebirges," by A. Kubelka. *Centralblatt für das gesamte Forstwesen,* Vienna, Aug.–Sept., 1903.

that are to be chuted. The chute then should function for all lesser velocities and sizes provided the minimums are not so low that the logs will come to rest.

The radius of the chute channel should be great enough to provide a clearance of about 4 inches between the outer edge of the chute and the log (Fig. 76). The inner wall may be considerably less in height than the outer one because it serves to confine to the channel only those logs which have the minimum velocity.

In determining the required chute profile it is first necessary to ascertain the angle of deviation α_1 for the given velocity, longitudinal slope, and curve radius by the use of formula (35).

The actual deviation x of the log from the longitudinal slope is derived from formula (36) and that for the height to which the log will rise above the bed of the chute from formula (37).

Assuming a longitudinal slope of 20° 35', a velocity of 60 feet per second, a curve radius of 100 feet, and a chute radius of 2 feet, we get from the above formulæ

$$\alpha_1 = 44° 25'$$
$$x = 1.4 \text{ feet}$$
$$h = 0.57 \text{ foot}$$

This would give a clearance of about 4.8 inches for an 18-inch log on a chute with a side 2 feet high, which meets the conditions.[55] A chute channel of lesser width would be unsatisfactory because the side wall would not be high enough to confine a log traveling at this velocity.

Chute widths for other curve radii, longitudinal slopes, velocities, and maximum log sizes may be calculated in a similar manner. Although this method of computing the chute width and height is approximate only, it does not involve complicated formulæ and will provide a channel which should give satisfactory results.

THE MINIMUM RADIUS

The factors which determine the minimum radius for a horizontal curve are the velocity of the log, the width of chute channel, and the length and diameter of the largest logs which are to pass around the curve.

[55] The amount of clearance for given conditions can be most readily determined, graphically, as shown in Fig. 76.

The radius of a horizontal curve should only be as long as is necessary to permit a log to pass without an undue reduction in velocity, because curved sections are more expensive to construct and maintain than straight sections. On the other hand, a curve which has a very short radius tends to cause operating troubles.

Formulæ for determining the radius of a curve for given conditions of velocity and sizes of log are somewhat complicated and are not included here. European experience indicates that the minimum radius which should be used for short logs, such as pulpwood, is one not less than 100 feet and for standard length logs, from 200 to 300 feet (see page 120).

The minimum radius for a given velocity and channel width may be checked by means of the clearance available for the log. Thus, if the computed velocity at the beginning of the curve is 60 feet per second, the longitudinal slope 30°, and the chute channel radius 1.5 feet, we may assume a provisional radius of 100 feet and determine the clearance of log for the above conditions. If it is less than 4 inches, a longer radius or a wider channel should be used.

The value of α_1 will be 39° 59' and the clearance for an 18-inch log will be 3 inches, which is insufficient.

A radius of 125 feet will give an angle of deviation α_1 of 33° 50' and a clearance of 3.9 inches for an 18-inch log, which meets the requirements, approximately. If, instead of increasing the curve radius, the chute channel radius is made 1.75 instead of 1.5 feet, the clearance will be 4.2 inches, which is greater than that for a 125-foot radius. The widening of the channel is preferable to increasing the curve radius because the latter procedure calls for a longer curve length.

LOCATION OF A HORIZONTAL CURVE

A horizontal curve with a short radius always should be a spiraled circular curve. The best method of locating such a curve is by right-angled offsets from the tangents, computed in the manner described on pages 112 and 113 for the vertical spiraled circular curve.[56]

The field location of a horizontal spiraled circular curve requires the following data (Fig. 72):

1. The angle of intersection α between the two tangents.
2. The radius R of the circular curve assumed as of a given value (see page 120).

[56] Oblique offsets as described for vertical curves are not used for horizontal curves.

3. The tangent lengths $AB = CB$ which may be computed by means of formula (30).

4. The length of spiral l. This may be determined by inspection. For pulpwood and short logs it should be from 20 to 40 feet in length and for long logs from 60 to 70 feet.

5. The spiral offset m (formula 23).

6. The central angle α_1 of the circular curve.

$$\alpha_1 = \alpha - 2\phi : \sin\phi = \frac{a}{R} : a = \frac{l}{2} \quad . \quad . \quad . \quad (38)$$

7. The external E of the circular curve.

$$E = (R + m)\ (\sec\frac{\alpha}{2} - 1) + m \quad . \quad . \quad . \quad (39)$$

8. The curve length AEC.

$$AEC = R\frac{\pi\alpha}{180} + l \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (40)$$

9. The middle ordinate EG.

$$EG = R\ (1 - \cos\frac{\alpha^1}{2}) \quad . \quad . \quad . \quad . \quad . \quad . \quad (41)$$

10. The half chord DG.

$$DG = R\sin\frac{\alpha_1}{2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (42)$$

11. The chord DE.

$$DE = \sqrt{DG^2 + EG^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad (43)$$

12. The length of the central curve DEF.

$$DEF = R\frac{\pi\alpha_1}{180} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (44)$$

After determining the length of tangent and locating the *points of spiral,* the points on the spiral curve are staked by means of the computed right-angled offsets. Following this, the external to the circular curve is measured and the mid-point on the arc of the circular curve fixed.

Starting at either point where the spirals join the circular curve, the latter then may be located by means of the quarter method, or the computed offset for the curve may be plotted on cross section paper in the office and the values for both the spirals and the circular curve placed in a notebook for field use.

The quarter method is a simple one to use in locating short circular curves and is based on the assumption, approximately correct,[57] that one fourth of the length of the middle ordinate EG or $\frac{EG}{4}$ (Fig. 72) is equal to the offset HI from the center of the chord DE to the arc of the circle. The offset from the middle of a chord connecting D and H will be $\frac{HI}{4}$ or $\frac{EG}{16}$.

By the use of the quarter method any number of desired points may be quickly located on the arc of the circle.

In case the ground level is such that cuts or fills must be made to maintain the desired longitudinal grade, it will be necessary to run a line of levels over the curve and to indicate on each stake the necessary cut and fill.

The Wolf Brake

This device for retarding the velocity of logs in chutes has been used for a long period in Europe and, to some extent, on this continent where numerous types have been in use.[58] The usual method of suspension for the wolf arms (brake table) has been a more or less rigid one. In general, such devices have not functioned with a high degree of efficiency because of the improper relation between the length and weight of the arm and the size and weight of chuted logs, and because the angle between the wolf arm and chute channel has not conformed to the velocity of the logs or the character and gradient of the chute channel. Often the slope of the arm has been too great to secure satisfactory results.

Some theoretical studies have been made in Europe concerning the physical phenomena incident to wolf brake operation as a basis for the development of a more efficient type. However, brakes of this character installed in North America have been designed by men who have given little, if any, attention to the factors which enter into brake operation, and the results have proved rather unsatisfactory because of the use of improper types, faulty installation or adjustment and weak construction. In recent years

[57] The error for an arc as great as 45° is less than 1 per cent.

[58] See pp. 73 to 86 for a description of the various types used both in Europe and on this continent.

several constructive ideas have been advanced for the improvement of the wolf brake, but adequate experience derived from its operation is lacking.

It is believed, hovlever, that wolf brakes properly designed will serve a very useful function in chute operations on this continent because, if they can be made more efficient, it "viII be possible to chute wood successfully on slopes which no\v are considered too steep for practical operation.

The chief treatise dealing with the theoretical aspects of the phenomena attending the use of wolf brakes was published some years ago by Hauska.[59] He pointed out that when a moving log strikes the lower end of the brake arm or table there arise several separate phases of action, due to the operation of the brake, which occur at increasingly shorter intervals and in constantly decreasing force until the log has passed the brake arm. When the log first strikes the arm the impact tends to thro\v the arm upward until it reaches a height at which its energy is lost, when it descends in a pendulum motion and strikes the top of the log, only to be again thrown up\vard, but to a lesser height, due to the smaller slope angle of the wolf arm.[60] These successive upward thrusts and following impacts continue with a constantly declining force until the log has passed. The force becomes less because the arm drops from a lesser height at each succeeding impact.

When the arm of the brake is steeply inclined, the impact is violent and the log or wolf filay be seriously damaged *OT,* further, the arm may be thrown so high that the log will have passed the brake before the arm has returned to normal position. The brake work in that case is low. For the above reasons steeply placed brake arms rarely, if ever, prove satisfactory. When the angle is.small the impact is less, and there are several phases instead of the initial one only, as in a very steeply placed arm, and the final result will be a greater braking effect. The aim sought is to construct the brake so that successive impacts will follow as rapidly as possible. This may be accomplished by coordinating the weight of the brake arm and the angle of suspension so that the arm during the initial phase ,vill only be raised to a height which will just permit the log to pass underneath it. The second phase ,vill then follow almost immediately, because the log has to fall only through a very limited space, and since the impact is low because of the short distance through which the arln has fallen, it will be thro\vn

59 See *Theorie der Riesen)* by Leo IIauska. Franz Deuticke, Vienna, 1914.

60 When the first impact occurs the end of the arm is resting on the bed of the chute channel, while in succeeding impacts the arm comes to rest on top of the log itself, thus decreasing the angle of inclination of the arm to the chute channel.

upward only to a very small height in this and successive phases. The reduction in velocity will be due chiefly to the friction developed by the contact of the log with the wolf arm and the bed of the chute. The violence of the initial impact may be lessened by so sniping the forward end of the log that the bevel on the log corresponds closely to the slope of the wolf arm. This procedure, however, would be impractical with pulpwood because of the labor involved in sniping and the resulting loss of wood caused by beveling the end of the stick.

It has been suggested by Hauska that the same object might be accomplished by equipping the brake with three rather lightweight arms, suspended one above the other, the free ends of the arms resting one on top of the other in the chute. When the moving log strikes the lower arm, only the top one will be thrown upward.[61] The next impact will raise the second arm. If properly constructed, the lower arm will not be thrown upward because the two top ones will have returned to their normal position on top of the lower arm before the third impact phase occurs. He suggests that if three arms are not sufficient to accomplish the desired purpose, a fourth or even a fifth might be used. An advantage claimed for this arrangement is that a small angle between the arm and the channel is not so essential as when one arm only is used and, therefore, it might prove satisfactory on steep grades where it is desirable to reduce high velocities.

Possible objections, noted by Hauska, to the above form of brake are that its weight offers too low a resistance to rapidly moving logs and much damage might result to the brake framework if the resistance offered by the arm at the moment of impact were great. This objection might be removed by using a form of suspension which would be somewhat elastic.

The weight of arm required to prevent it from being thrown higher than is necessary just to permit the log to pass underneath can be most simply and easily determined by experiment. This also applies to the determination of that slope of arm which will furnish the greatest braking power under given conditions.

Attention has been given in recent years to the development of a substitute for a rigid suspension for the wolf arm by which the impact may be lessened and the upward movement of the free end of the arm reduced.

61 Kubelka states that he does not consider this idea practicable because it leads to operating troubles, but he does not state whether his opinion is based on experience or assumption. See *Oesterreichische Forst- und Jagd-Zeitung*, p. 384, Dec. 18, 1914.

THE ELASTIC SUSPENSION BRAKE TABLE

One of the first authors to discuss in print the practical use of an improved form of wolf brake was Baltz,[62] who described a so-called elastic method of suspension of the arm; which principle also was mentioned about the same time by Hauska.[63] A bulletin also appeared in 1926 dealing with a series of investigations designed to determine the most suitable form of brake device for chutes, in which the merits of an elastic suspension as compared to a rigid one were set forth.[64]

An elastic form of wolf construction may be secured, either by substituting a cable suspension for a rigid axis or by the use of a spring on the end of the wolf arm which will tend to hold it firmly against the log. The latter method of construction has not been developed, so far as known, and appears to have certain construction disadvantages which would render its use questionable. Among these disadvantages may be mentioned the difficulty of installing a spring having an elasticity which will meet the various conditions of velocity and log size. However, the real worth of this should be determined by experiment.

Because of the potential value of the wolf type of brake, the general lack of knowledge on this continent with reference to it, and the paucity of literature on the subject, a brief statement of Miura's laboratory investigations, the form of equipment he used, and the results obtained are here given.

The laboratory equipment comprised a pole chute 20 meters (65.6 feet) in length, the first 51 feet of which had an average grade of 4.5 per cent and the remainder a grade of zero (horizontal).

An iron hammer, suspended from the ceiling of the laboratory, was used to impart velocity to the test bolt which was to be chuted. The latter (test bolt), shod with iron on the end to prevent splitting, was suspended from an oscillating horizontal axis by means of wires.

It proved impracticable to determine, mathematically, the velocity which was imparted by the hammer to the bolt, and the following empirical method was developed. The bolt was so suspended that a central impact was applied to it by the hammer which, in its fall, was guided by a circular

62 See *Oesterreichische Forst- und Jagd-Zeitung*, pp. 339 and 340, Nov. 6, 1914.

63 See *Theorie der Riesen)* by Dr. Leo Hauska, for a comprehensive treatise on the dynamic phenomena incident to the operation of a wolf brake.

64 See *Untersuchungen Zweoks rationelle'r Ausgestaltung von Bremsmitteln im modernen Riesbetrieb)* by Tejiro Miura. Bulletin No. 10, of the Imperial College of Agriculture and Forestry, Morioka, Japan, 1926.

channel. The angle of fall was measured on a near-by graduated arc by means of a pointer fixed at the center of gravity of the hammer. The suspended bolt, on being struck, was driven upward in the arc of a circle, the arc angle also being measured by a pointer and scale in the same manner as for the hammer. It was found by experiment that only a small part of the energy of the falling hammer was transmitted to the bolt, and an elastic spring was devised and placed on the end of the bolt receiving the impact. This device served to increase the upward movement from 33 to 50 per cent.

Due to laboratory limitations, the velocities which could be secured were relatively low and, in order to take full advantage of conditions, the wolf was installed at the head of the chute. The wolf arm used in the first experiments was 6.56 feet in length and weighed 24.08 pounds and was suspended from posts on either side of the chute by means of double wires .214 inches in diameter (approximately 5-gage) which were so arranged that their tension could be varied. A hole was bored through the arm at a predetermined place (a distance of one-sixth of the arm length measured from the top end), the wires passed through the hole and then wedged so that when the arm rotated the wires would be subject to a twist. Holes also were bored through the wolf arm at intervals of about 4 inches so that, when desired, a rigid horizontal axis could be adjusted on the underside of the arm. In order to test the efficiency of the brake arm when suspended at different angles to the chute channel, the posts supporting the suspension wires also were so arranged that the wolf arm axis could be raised or lowered.

The experiments were designed to determine five different factors.

(1) Influence on brake efficiency of the tension of the suspension wires.—The four different wire tensions used are shown in the accompanying table.

CABLE TENSIONS USED IN BRAKE TESTS

Tension number	*Deflection of cable (feet)*	*Tension of cable (pounds per square inch)*
I	0.2132	4.5
II	0.1049	9.0
III	0.0492	20.0
IV	0.0065	147.0

Experiments were conducted to determine the relative efficiency of an elastic and a rigid axis as compared to a chute in which a wolf was not used. The tests were first made without the use of a wolf arm, followed immediately by tests using the elastic and rigid brake suspension. It was assumed that the velocity of the bolt when it entered the brake was the same as that velocity which was imparted to the bolt by the hammer, because the wolf was placed at the head of the slide where the log started.

The following table shows the reduction in kinetic energy of the log due to the use of an elastic form of suspension.

KINETIC ENERGY OF A BOLT WHEN A BRAKE IS NOT USED AND WORK PERFORMED WHEN AN ELASTIC BRAKE IS USED (*a* AND *b* EXPRESSED IN FOOT POUNDS PER SECOND)[65]

Number of tests	*Wire tension*	(*a*) *Kinetic energy*[66] *without brake*	(*b*) *Work performed by brake*	*Energy loss due to braking* $\left(\frac{b}{a}\right)$
				per cent
4	I	14.32	6.72	47
4	II	14.39	5.93	41
4	III	14.39	4.41	31
4	IV	14.39	3.61	25

The data in the above table show strikingly the effect of the tension of the supporting cable on the work performed by a wolf with an elastic axis of suspension. The brake work for the lowest tension (I) (equal only to that tension caused by the combined weight of the arm and wire) was nearly twice that for the maximum tension (47 as compared to 25 per

65 The angle between wolf arm and chute channel for the various tensions, although not stated, presumably was as follows: I, 7°05′; II, 8°10′; III, 9°40′; and IV, 10°15′.

66 The kinetic energy values for Tension I, found by experiment, coincided very closely with those computed mathematically. The values given in columns (a) and (b) represent the average of four tests.

cent). It is evident, therefore, that a greater braking effect is secured through the use of a low tension on the supporting wire.

(2) Influence on braking work of a rigid axis.—Tests were made with a modified type of rigid axis, the point of rotation being located at various points along the wolf arm. The method of cable suspension was retained, and a rigid block resting on both edges of the channel and fastened to the underside of the arm at right angles to the channel was installed (Fig. 65). The distances (m_1) from the top end of the arm to the rigid axis were 1/20, 1/9, 1/6, 1/4, 1/3, and 1/2 of the distances (m_2) from the rigid axis to the lower end of the arm. The axis was not that of the usual type rigidly fixed to the chute channel, but one resting only on top of it, and when the chuted wood struck the lower side of the arm, it would rotate about the axis, the latter, however, showing a slight movement down the chute channel, the amount of movement depending upon the tension of the cable.

Tests with this form of rigid axis are given only for cable tensions I, II, and III.

RELATIVE BRAKING POWER OF AN ELASTIC BRAKE AND ONE WITH A MODIFIED RIGID AXIS[67]

Number of experiments	*Wire tension*	(*a*) *Kinetic energy without brake (foot pounds per second)*	(*b*) *Work performed by elastic brake*	*Energy loss* $\left(\frac{b}{a}\right)$	(*c*) *Work performed by rigid axis brake*	*Axis*[68] *location* $\left(\frac{m_1}{m_2}\right)$	*Energy loss* $\left(\frac{c}{a}\right)$
				per cent	*Av. value*		*per cent*
4	I	14.32	6.72	47	5.86	1/20	41
4	I	....	...	..	5.35	1/6	37
3	I	....	...	..	5.35	1/3	37
4	II	14.39	5.93	41	4.41	1/20	31
4	II	....	...	..	3.90	1/6	27
4	II	....	...	..	4.70	1/3	33
2	III	14.39	4.41	31	6.07	1/20	42
4	III	....	...	..	4.34	1/6	30
4	III	....	...	..	4.12	1/3	29

67 Based on Tables II, III, and IV of Miura.

68 Actual angle of inclination of the wolf arm to the chute channel is not given by Miura.

The accompanying table summarizes, briefly, the relative braking power of an elastic type of wolf arm suspension as compared to one with a modified rigid axis.

Miura summarizes the effects resulting from the insertion of a rigid axis, for all cable tensions used, as follows: The further down the arm from the point of suspension the rigid axis is located, the greater the reduction in the braking power of the wolf. Only when the rigid axis was located in the upper one-fourth of the arm (ratio 1 :3) was there an increase in braking work.

Since, however, the actual brake work was less than that of an elastic suspension, it may be assumed that the chief practical value of a rigid axis may be a temporary reduction of braking power when this is demanded by a change in the type of logs being chuted.

(3) Influence on braking work of the slope angle of an elastic suspension wolf arm with reference to that of the chute.—The same tensions were used as in previous experiments, the wolf arms being raised successively by increasing the height of the posts supporting the suspension wires.

RELATION OF CABLE TENSION TO BRAKE WORK

Angle between wolf arm and chute channel	*Loss of kinetic energy due to the elastic brake (per cent)*
TENSION I	
7°05′	47
8°50′	24
13°	16
16°20′	20
20°	26
23°	24
27°15′	19
TENSION IV	
10°15′	25
13°	20
17°15′	13
20°30′	20
24°	21
27°30′	23
31°40′	24

The following slope angles were used with the different tensions:

Tension I. 7°05′, 8°50′, 13°, 16°20′, 20°, 23°, and 27°15′.
Tension II. 8°10′, 9°50′, 14°, 17°30′, 21°, 24°, and 28°10′.
Tension III. 9°40′, 10°55′, 15°20′, 19°35′, 22°30′, 26°30′, and 30°.
Tension IV. 10°15′, 13°, 17°15′, 20°30′, 24°, 27°30′, and 31°40′.

The experiments showed that the braking power varied with the tension of the suspension cable; that is, the greater the tension, the less the brake work. The highest braking power was found in tension I for the smallest brake angle, 7°05′.

For both tensions (I and IV) there was an increase in braking work on the intermediate grades, and for the highest tension (IV), which approached a rigid axis, there was a gradual increase in efficiency with the larger angles. However, the use of high braking power on a relatively short, highly tensioned, and steeply adjusted arm is not recommended by Miura because of the violent impact to which the end of the arm is subjected.

His general conclusions were that an increase in the slope angle of an elastic wolf always may be assumed to be accompanied by a decrease in braking work, because the elevation of the point of suspension has the same effect as the use of a rigid axis.

(4) Influence on braking work of the roughness of the channel within the wolf.—Experiments were made with various chute conditions, such as a dry and wet channel both smooth and rough. However, the results secured showed many discrepancies, and no reliable conclusions could be drawn from them.

(5) Influence of the weight of the wolf arm on braking work.—In the study of this problem a wolf arm was built from two light poles of the same length as wolf arm 1 (6.56 feet), but with a weight of 16.94 pounds, as compared to arm 1 which had a weight of 23.98 pounds. Both arms were suspended at a point where the ratio was $\frac{m^1}{m_2} = \frac{1}{5}$.

The accompanying data show that as the weight of the wolf arm decreases, the braking work also decreases, but not in proportion to the loss in weight.

The author attributes this to the fact that for a wolf arm lighter in weight but of the same length as a heavier one the arms are more pliable and the upward thrust is not so great.

RELATION BETWEEN WEIGHT OF ARM AND BRAKE WORK

Wolf number	*Tension of suspension cable*			
	I	*II*	*III*	*IV*
	Loss in kinetic energy due to brake (per cent)			
1	47	41	31	25
2	41	39	32	27

(6) Braking experiments in the field.—Miura made a limited number of field tests with wolf brakes on a chute in Austria over which logs were being transported. He used several lengths and weights of wolf arms, the shortest being 16.4 feet and the longest, 26.24 feet. Logs from which to make arms longer than the latter were not available.

The lowest brake work output was realized when a 16.4-foot arm, composed of three logs of an average diameter of 8.3 inches and a total weight of 669 pounds, was used. The log which was chuted had a length of 26.24 feet, a middle diameter of 15 inches, and a weight of 1,129 pounds. The brake work output was 11 per cent only. The author attributes this low braking power chiefly to the fact that the wolf arm was too short and the weight relations between the wolf arm and the log (3:5) were unsuitable. The log had a weight nearly twice that of the arm, and the latter was so short that the initial point of impact between the log and the arm was so near the free end of the brake arms that a violent upward thrust occurred which, in turn, resulted in a low braking power. The use of an arm 26.24 feet long and weighing 1,454 pounds and a chuted log 16.4 feet long and weighing 669 pounds showed a brake work output of 33 per cent.

The best results are attained when the log strikes the arm as far from the free end as is possible so that there will be an upward pressure in the brake table and a downward pressure of the fore end of the chuted log against the chute channel.

Miura's experiments indicate the need for a low slope angle for the arm and a proper weight relation between the log and the arm. The best method of coördinating the weight of the arm and log may be to assort logs for size and to construct the lower end of the arm so that its weight can be increased or decreased by means of weights.

Briefly stated, Miura's experiments indicate the following:

(1) An elastic form of brake suspension is superior to an arm with a rigid axis of rotation.

(2) The cable by means of which the wolf arm is suspended should have a tension which does not exceed that produced by the combined weight of the cable and arm.

(3) The angle between the chute channel and the wolf arm should be small because the braking work decreases as the angle increases.

(4) The relation between the weight of the wolf arm and that of the log whose velocity is to be reduced is an important factor because the amount of braking work performed decreases as the weight of the arm decreases, although not in direct proportion to it.

From the standpoint of economy in construction, the arm should be only of that size and weight which will prevent chuted logs from throwing it upward with too great violence. If the arm is too heavy it will stop small logs, and if too light it will be thrown so high that it will not return to its normal position in time to check the following log, and, further, violent wolf arm action leads to damage to the wolf structure and calls for frequent repairs with a loss in operating time.

The elastic method of suspension undoubtedly has numerous merits not possessed by the usual form of rigid axis, but further experiments are necessary to determine the optimum angle of suspension, weight of arm as related to weight of logs, point of suspension, and the distance from the center of the chute at which the posts supporting the cable should be placed for a given set of conditions.

Based on existing knowledge, it appears that for chuting pulpwood bolts on steep grades the minimum length of wolf arm should be about 20 feet, with an average top diameter of from 12 to 15 inches; the distance of its point of suspension from the top end should be equal to one-sixth of the distance between the point of suspension and the lower end of the arm, and the angle between the wolf arm and the chute channel should not exceed 10°, preferably not more than 7°.

Both for experimental and operating purposes, the weight of the wolf arm may be varied by weighting the lower end with iron or by placing a box on its lower end, loaded with iron or stones, so that the weight may be increased or decreased as desired. It should always be borne in mind that the weight of the wolf arm should be considerably in excess of that of the chuted bolt or log.

PART III

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[69] O.F.u.J.Z. = Oesterreichische Forst- und Jagd-Zeitung. (Vienna.)
W.A.F.u.J.Z. = Wiener Allgemeine Forst- und Jagd-Zeitung. (Vienna.)
S.Z.f.F. = Schweizerische Zeitschrift für Forstwesen. (Bern.)
M.a.d.f.V.O. = Mittheilungen aus dem forstlichen Versuchswesen Österreichs. (Vienna.)
C.f.d.g.F. = Centralblatt für das gesamte Forstwesen. (Vienna.)
F.C. = Forstwissenschaftliches Centralblatt. (Berlin.)

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COEFFICIENTS OF FRICTION AND ANGLES OF REPOSE FOR VARIOUS TYPES OF POLE CHUTES AND FOR VARIOUS WOOD ASSORTMENTS[70]

Type of product	*Coefficient of friction (Average)*	*Angle of repose (Average)*
	Dry chute	
Boles (27–100 feet)	0.35	19°18′
Logs (10–26 feet)	0.38	20°48′
Bolts (6–7 feet)	0.40	21°48′
Firewood, hard, split	0.40	21°48′
Firewood, soft, split	0.44	23°45′
	Wet chute	
Boles	0.15	8°32′
Logs	0.18	10°13′
Bolts	0.21	11°52′
Firewood, hard, split	0.25	14°03′
Firewood, soft, split	0.31	17°14′
	Snow chute	
Boles	0.12	6°51′
Logs	0.14	7°59′
Bolts	0.15	8°32′
Firewood, hard, split	0.15	8°32′
Firewood, soft, split	0.22	12°25′
	Iced chute	
Boles	0.04	2°17′
Logs	0.08	4°35′
Bolts	0.10	5°43′
Firewood, hard, split	0.12	6°51′
Firewood, soft, split	0.16	9°06′

[70] From "Das Gefälle der Holzriesen," by Karl Petraschek. *Mittheilungen aus dem forstlichen Versuchswesen Österreichs,* Vol. I, Part II, Vienna, 1878.

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