(No Model.) 2 Sheets—Sheet 1.

P. KRAUS.

METHOD OF AND APPARATUS FOR DRIVING TUNNELS.

No. 512,037. Patented Jan. 2, 1894.

Fig. 1.

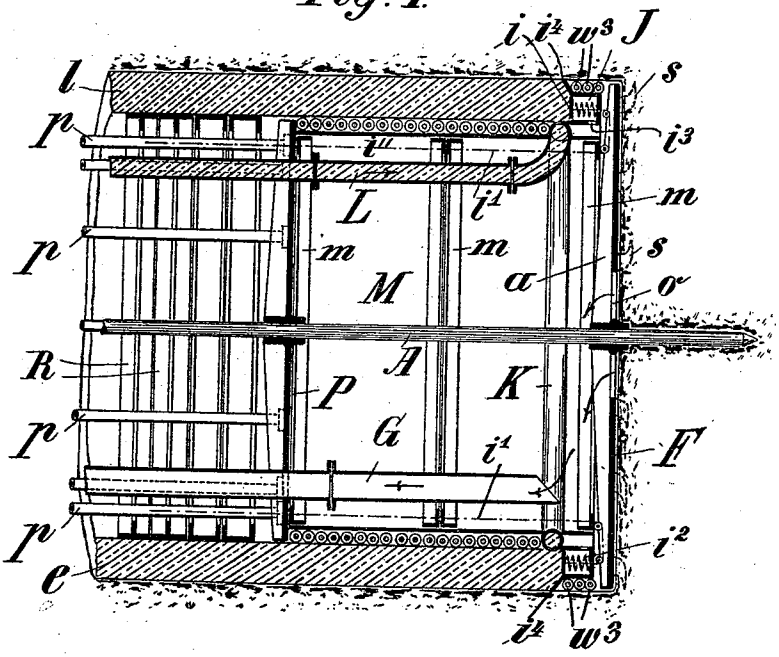
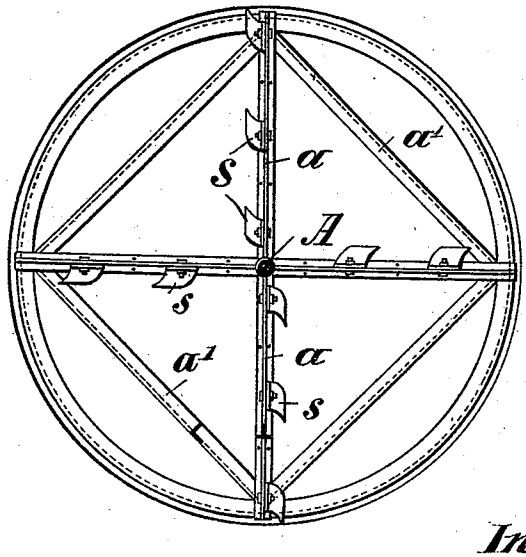


Fig. 3.



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(No Model.) 2 Sheets—Sheet 2.

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Fig. 5.

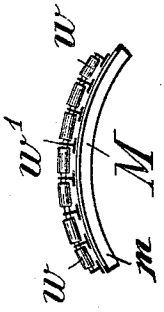


Fig. 6.

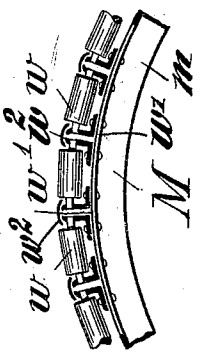


Fig. 4.

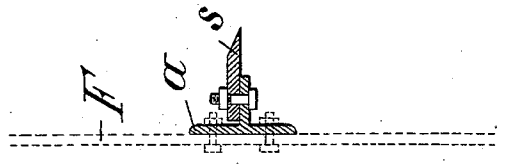
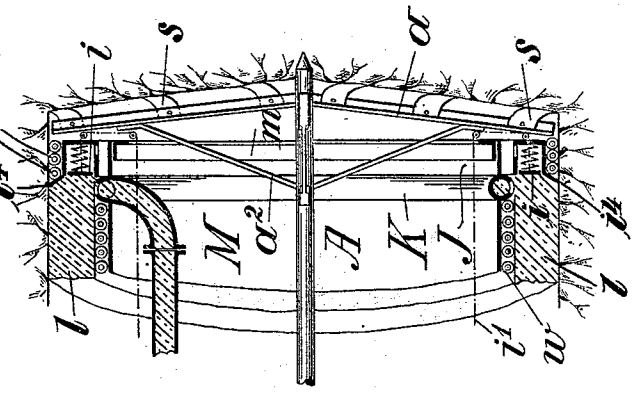


Fig. 2.



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UNITED STATES PATENT OFFICE.

PETER KRAUS, OF VIENNA, AUSTRIA-HUNGARY.

METHOD OF AND APPARATUS FOR DRIVING TUNNELS.

SPECIFICATION forming part of Letters Patent No. 512,037, dated January 2, 1894.

Application filed June 2, 1892. Serial No. 435,302. (No model.)

To all whom it may concern:

Be it known that I, PETER KRAUS, a subject of the Emperor of Austria-Hungary, residing at Vienna, in the Province of Lower Austria, in the Empire of Austria-Hungary, have invented certain new and useful Improvements in Methods of and Apparatus for Driving Tunnels and other Subterranean Passages; and I do hereby declare the following to be a full, clear, and exact description of the invention, such as will enable others skilled in the art to which it appertains to make and use the same, reference being had to the accompanying drawings, and to letters of reference marked thereon, which form a part of this specification.

My invention relates to the art of excavating or driving tunnels or other underground conduits; and the difficulties encountered when a tunnel or other conduit is to be driven into a sandy or gravelly stratum or through clay are well understood by engineers, as well as the great cost of properly lining such tunnels or conduits. On the other hand, if such stratum is also a water bearing stratum the difficulties are considerably increased.

The methods of and means for tunneling or driving underground conduits in drifts of the nature referred to and heretofore brought into use afford no protection against subsidence or caving in of the walls of the drift, tunnel, or conduit, except by the use of expensive artificial means, so that the driving of a tunnel or conduit under a building or water course through a loose sandy or gravelly or clayey stratum presents technical difficulties of such a nature or involving so great an expenditure and risks as to necessitate the abandonment of the work.

My invention has for its object the provision of means whereby these difficulties may be overcome and a lining provided for the conduit that is not only of sufficient strength to resist the pressure of the soil about it, but that is cheap as compared with the cost of such linings as were heretofore provided.

To these ends the invention consists in a novel method of, and in the means for driving and simultaneously lining tunnels or other underground conduits, as will now be more fully described, reference being had to the accompanying drawings, in which—

Figure 1 is a longitudinal sectional view of a portion of a tunnel or other underground conduit, and of my improved excavating machine. Fig. 2 is a like view illustrating a slight modification in the construction of the excavator. Fig. 3 is a front elevation of the excavator shown in Fig. 1, and Figs. 4, 5, and 6, are detail views.

My improved excavating machine consists essentially of a revoluble excavator, means for forming a lining for the tunnel or conduit as fast as the excavation proceeds, a support for said lining adapted to move with the excavator as the latter penetrates into the drift so as to afford time for the lining to set before the support moves away from it, means for supporting or strengthening the lining after the excavator has moved beyond the set portion of such lining, means for compacting the lining, means for removing the spoils, and a suitable motor or motors which I have deemed unnecessary to show as these may be of any desired or preferred and well-known construction. In addition to the above-described elements I provide means whereby the caving in of the face of the drift is prevented when working in very loose sandy or gravelly or clayey water bearing strata, as will appear hereinafter.

The excavator consists of a shaft, A, driven by any suitable motor, and provided with four, more or less, radial arms, *a*, to which are secured the excavator shovels, *s*, which may be of any suitable form, as for instance, of the form of plow shovels, as shown in Figs. 1 and 2, or of the form of cutter teeth, as shown in Fig. 4. The radial arms, *a*, are preferably constructed of T-iron, to the web of which the cutters, *s*, are secured, and in the web of the said arms, *a*, are formed bolt holes for securing thereto a shield, F, to prevent the caving in of the face of the drift when working in a water bearing stratum of loose sand or gravel, or of clay, said shield having bearing on the face of the drift in rear of the cutters, *s*, and the said shield has an axial opening, *o*, through which the spoils pass. If necessary the radial arms, *a*, may be braced by diagonal braces, *a'*, Fig. 3, preferably of angle iron, to which braces cutters may also be secured if desired. Of course it will be understood that the diameter of the excava-

tor, or more properly, the reach of the outer cutters on the arms thereof, will determine the diameter of the tunnel or other conduit to be driven minus the lining.

When working in non-water-bearing strata I prefer to connect the radial arms, a, of the excavator adjustably with the shaft, A, that is to say, they are preferably hinged to or otherwise articulated on said shaft, and have connected therewith suitable stays a^2, Fig. 2, adapted to be secured to the shaft, whereby the arms, a, may be more or less inclined, and it will be readily understood that by varying the inclination of the said arms the diameter of the tunnel may be varied, and consequently the thickness of the lining therefor, according to the nature of the stratum through which the drift is cut. On the other hand, by varying the inclination of the arms relatively to each other, by shifting them forward and backward according to the varying radius to be cut, a drift of ellipsoidal or oval form in section may be cut, and this shifting of the arms may be effected by any suitable means, as for instance eccentric guides. In this case the support for the lining must have a form corresponding to the cross-sectional form of the drift. This support consists of a drum, M, of the proper form in cross section and of sufficient strength to stand the pressure brought upon it; as shown in the drawings it is made up of angle or T-bars, w', parallel with shaft, A, and bolted to angle iron supporting rings, m, and provided with roller bearings, w. I prefer to construct the periphery of the drum, M, of angle bars w', for the reason that these can be so arranged that separate bearings are provided for each of the rollers, w, as shown in Fig. 6, which is not the case when T-bars are used, where a single bearing has to be used for two roller journals, as shown in Fig. 5, which arrangement is liable to result in frictional resistance between the abutting faces of said journals. In order to protect the journals and their bearings from contact with cement or concrete of which the lining of the tunnel is formed, I cover them with a shield, w^2, Fig. 6, so as to avoid too rapid wear or prevent the journal bearings from becoming clogged. For tunnels of great diameter, or when the support is subjected to very great pressures it is built up accordingly of correspondingly strong metal plates or girders combined with levers. The rear end of the drum support, M, is closed by a head P, through which pass the spoil pipe or pipes, G, and the concrete supply pipe, L. The spoils may be removed from within the support by suction or in any other desired manner, and emptied into the tunnel a proper distance in rear of the drum, M, and taken from thence by endless chain buckets or other suitable conveyers, or in trucks out of the tunnel or conduit, or if desired the said spoils may be removed from the support, M, by means of a chain and bucket or other mechanical conveyer.

The concrete supply pipe, L, is connected with an annular delivery pipe, K, that has suitable openings to deliver the concrete in a plane on a level with the peripheries of the roller bearings, w, that not only serve to facilitate the propulsion of the drum support, M, but also to roll the concrete lining smooth, as will be readily understood. In front of the delivery pipe, K, is arranged the rammer, which consists of a circular box, J, the inner end of which is open, and is provided with peripheral roller bearings, w^3, like the drum support, M, which rollers, w^3, have bearing on the inner face of the drift and hold it against caving in, and in rear of said rollers is a guard plate, i^4, having bearing on the lining and preventing the same from falling onto said rollers, w^3.

In the annular box, J, is fitted a circular rammer, consisting of a flat ring, i, that is normally held in the open end of the box by coiled springs, i^2, and to said plate and passing through the coiled springs are attached wire ropes, i', guided by suitable pulleys, said ropes passing finally through the rear head, P, of the drum support, and at a suitable distance from the latter are connected together and to a single rope. It is obvious that when the ropes are pulled upon, the rammer plate, i, will be drawn into its box, J, against the stress of its spring, and that when said ropes are released the springs will throw the rammer plate forward against the concrete being delivered by pipe, K, whereby such concrete is rammed solid. As shown, the shaft, A, projects some distance in front of the excavator, so that it may be thrust into the face of the drift and thus serve as a guide to the excavator and drum support which are simultaneously moved toward the face of said drift as fast as the excavating progresses. Any suitable mechanical appliances may be provided to impart this forward motion to the apparatus, such appliances being well known in mining and tunneling machinery. If for instance, the power that moves the apparatus forward is applied directly to the rear head of the drum support, M, at different points, it is possible to vary the direction of motion of the apparatus. Thus by applying greater power on one or the other side, or above or below the axis of the drum support, the apparatus will deviate from a straight line either to the right or the left, or upwardly or downwardly, according to the point at which the greater propelling power is applied. Any suitable mechanism may be employed, whereby this power is applied to the head, P, of the drum support, M; in the drawings I have shown a series of pipes p, applied to said head through which air under pressure may be applied at various points around the edge of the head, P, and if it is desired to produce a deviation of the excavating apparatus from a straight line, the air may be supplied at various pressures to one or more pipes of the series, and this can readily be done by placing

valves in the communications between the pipes and the source of compressed air supply, and regulating the flow of air to the several pipes, or the valves may be weighted valves and the weight thereof varied. The concrete may be forced through the supply pipe, L, and delivery pipe, K, by any desired means, as for instance by hydraulic pressure, and at a rate corresponding to the rate of progress of the excavator, or this may be effected by means of compressed air.

In order that the rammer box, J, may be kept free from any concrete carried into the same by the rammer, *i*, said box is provided with ports or openings, i^3, on its inner periphery, through which such concrete is discharged into the drum support, from which it is removed with the spoils, the rammer acting as a scraper within the box to prevent the concrete from adhering to the inner walls of the latter.

A longitudinal reciprocating motion within the limits of compressibility of the still plastic concrete may be imparted to the drum support, M, when compressed air is employed as a propelling power by producing alternating pressures in the pipes, *p*, as will be readily understood, so that the concrete lining will be smoothly rolled by the alternating or pulsating motion of the drum support, M, and the concrete prevented from choking the rollers. The concrete as it is delivered at the forward end of the drum support, M, is of course quite soft or pasty, and to give it time to set before the said support moves from under it, the support is made of sufficient length, so that the lining will be self-supporting for a length of about ten to thirteen centimeters, and to avoid all danger of caving in of the lining, brace rings, R, preferably U-shaped in cross section are introduced, which may afterward be removed, but when the lining is subjected to great pressure, or the drift is cut into a very loose sandy or gravelly or clayey stratum, and especially when this is a water-bearing stratum, the brace rings, R, are left in place and form a permanent part of the conduit, so that the lining will be composed of a shell of concrete and a lining therefor of metal rings. In order that these rings may be rapidly positioned, I prefer to construct them in sections of proper curvature, so that when a ring is inserted it will conform in configuration to that of the cross section of the lining, said sections being provided with bolt flanges for bolting the same together.

In case a considerable volume of water is encountered it may become necessary to operate with compressed air within the drum support, M, in which case the compressed air chambers may be formed by means of partition plates within the drum, M, itself, or in rear of said drum by means of partition plates bolted to the flanges of the supporting rings, R, and as the excavating proceeds these partitions are shifted forward.

From the foregoing description it will be seen that there is no danger of a caving in of the drift or lining, whatever the nature of the stratum into which the drift is cut or driven. It will also be seen that all staying, shoring, &c., are avoided, and as the lining is built up mechanically, the work proceeds at a much greater speed and more economically than is possible otherwise.

Having thus described my invention, what I claim as new therein, and desire to secure by Letters Patent, is—

1. In the art of constructing underground conduits, the improvement which consists in conveying concrete in a plastic state to, distributing it over and compacting the same on the face of such conduit by pressure, and applying the compacting pressure in directions parallel with and perpendicular to the said face of the conduit.

2. In the art of constructing underground conduits, the improvement which consists in conveying concrete in a plastic state to, distributing it over and compacting the same on the face of such conduit by pressure, applying the compacting pressure in directions parallel with and perpendicular to the said face of the conduit, and maintaining said perpendicular pressure until the concrete has set or hardened.

3. A combined tunneling and tunnel lining apparatus comprising an excavator, a support for the lining of a diameter equal to that of the drift minus said lining, and means for delivering concrete between the support and the tunnel, for the purpose set forth.

4. A combined tunneling and tunnel lining apparatus comprising a revoluble excavator, a drum for supporting the lining of a diameter equal to that of the drift minus the lining, means for forcing concrete about the periphery of the drum, and a rammer interposed between the latter and the drum for ramming the concrete supplied about said drum, for the purpose set forth.

5. A combined tunneling and tunnel lining apparatus, comprising a revoluble excavator, a drum for supporting the lining of a diameter equal to that of the drift minus said lining, means for forcing concrete about the periphery of the drum, a rammer for ramming the concrete, and a shield interposed between the rammer and excavator, said shield being arranged to bear on the face of the drift, for the purpose set forth.

6. A combined tunneling and tunnel lining apparatus, comprising a revoluble excavator, a tubular support for the lining of a diameter equal to that of the drift minus said lining, said tubular support having peripheral roller bearings arranged with their axes in planes tangential to the periphery of their support, means for delivering concrete about the peripheral bearings of the support at its forward end, a rammer consisting of a ring shaped housing open at its rear end and ring shaped rammer adapted to receive a to-and-fro motion in its housing, said rammer being

arranged at the forward end of the support and operating on the concrete to consolidate the same as it is delivered between the support and inner periphery of the drift, substantially as and for the purpose set forth.

7. A combined tunneling and tunnel lining apparatus, comprising a revoluble excavator, a tubular support for the lining of a diameter equal to that of the drift minus said lining, said support being closed at its rear end, means for delivering concrete about the periphery of the support at the forward end thereof, and means for removing the spoils from within the support, in combination with the air pipes, *p*, applied to the closed rear end of the support, for the purpose set forth.

8. A combined tunneling and tunnel lining apparatus, comprising an excavator consisting of a revoluble shaft having radial arms, excavating devices secured to said radial arms, and a shield consisting of a discoidal plate secured to the rear face of the radial arms in rear of the excavating devices, said shield provided with an opening for the passage of the spoils.

9. A combined tunneling and tunnel lining apparatus comprising an excavator consisting of a revoluble shaft, radial arms articulated to said shaft and provided with cutters or shovels, and stays pivotally connected with the radial arms and adapted to be secured to the shaft whereby the position of the radial arms relatively to one another and to the shaft may be varied, for the purposes set forth.

10. In a combined tunneling and tunnel lining apparatus, the combination with a revoluble excavator, a tubular support for the lining provided with peripheral roller bearings having their axes in planes tangential to the periphery of the support, the concrete feed pipes, L, K, arranged in front of the support and having delivery ports in the plane of the roller bearings, and a spoil exhaust pipe extending into the support, of a circular to-and-fro movable rammer interposed between the excavator and the forward end of the tubular support, and means for imparting motion to the support, for the purpose set forth.

11. In a combined tunneling and tunnel lining apparatus, the combination with the excavating devices, the tubular support, and the mechanism for lining the drift, of the ring stays or braces, R, substantially as and for the purpose set forth.

12. In a combined tunneling and tunnel lining machine, the combination with the excavator shaft, of a tubular support for the lining provided with peripheral roller bearings, said support adapted to receive a to and fro or pulsatory motion in a plane parallel with the axis of rotation of the shaft.

13. In a combined tunneling and tunnel lining machine, the combination with the excavator shaft, of a tubular support for the lining provided with peripheral roller bearings, said support adapted to receive a to and fro or pulsatory motion in a plane parallel with the axis of rotation of the shaft, and a rammer connected with said support and adapted to partake of its motion, and means for imparting a to and fro motion to said rammer independently of its support, substantially as and for the purpose set forth.

In testimony whereof I affix my signature in presence of two witnesses.

PETER KRAUS.

Witnesses:
W. B. MURPHY,
PAUL BERGER.