No. 671,264. Patented Apr. 2, 1901.

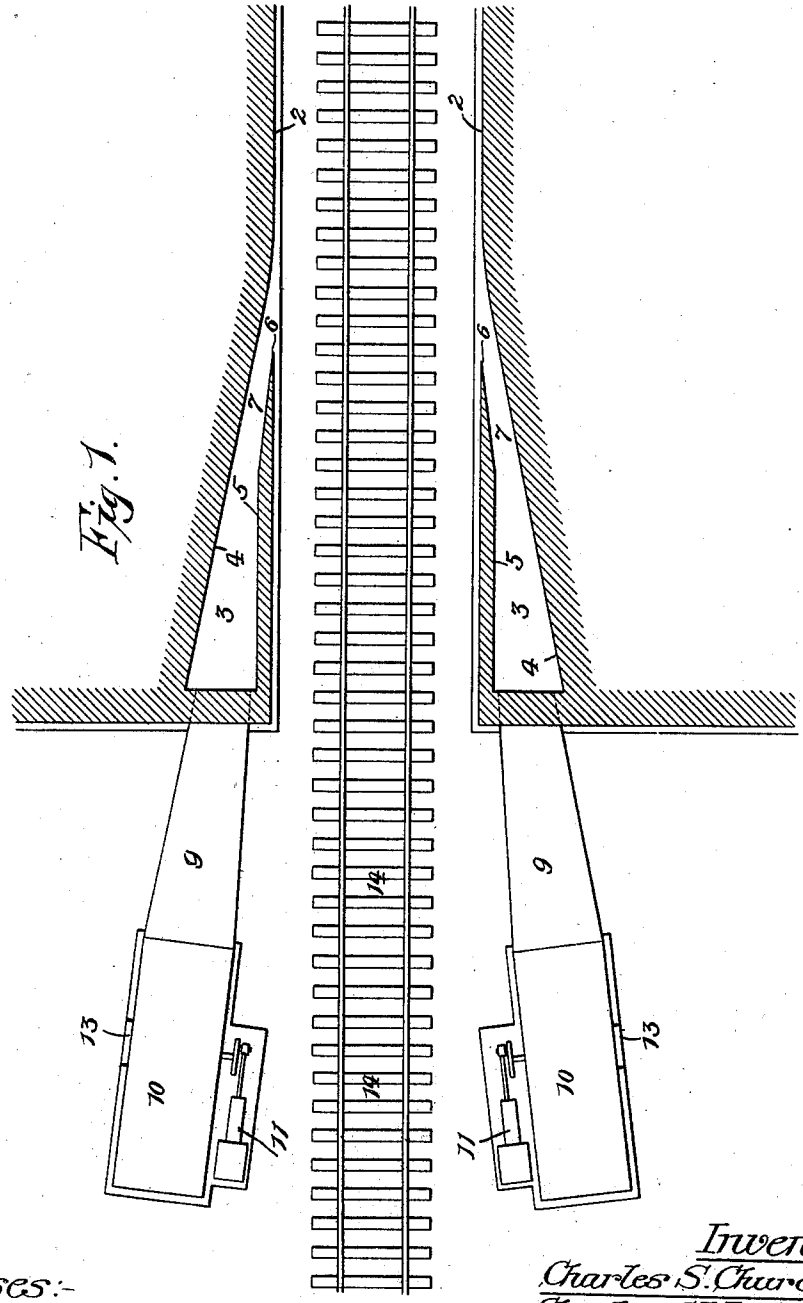
C. S. CHURCHILL & C. C. WENTWORTH.

MEANS FOR VENTILATING TUNNELS.

(Application filed Nov. 10, 1900.)

(No Model.) 3 Sheets—Sheet 1.

Fig. 1.



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Chas. H. Whitehead.

Inventors:
Charles S. Churchill.
Charles C. Wentworth.
by their Attorneys:-
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THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

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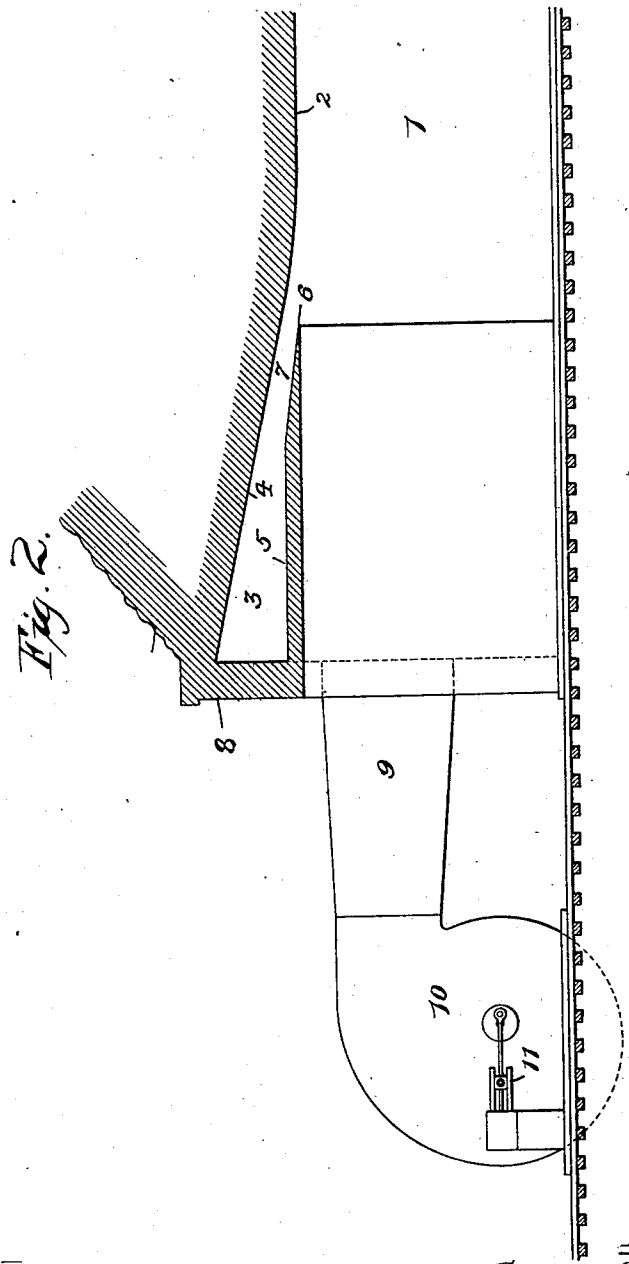
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(Application filed Nov. 10, 1900.)

(No Model.) 3 Sheets—Sheet 2.

Fig. 2.



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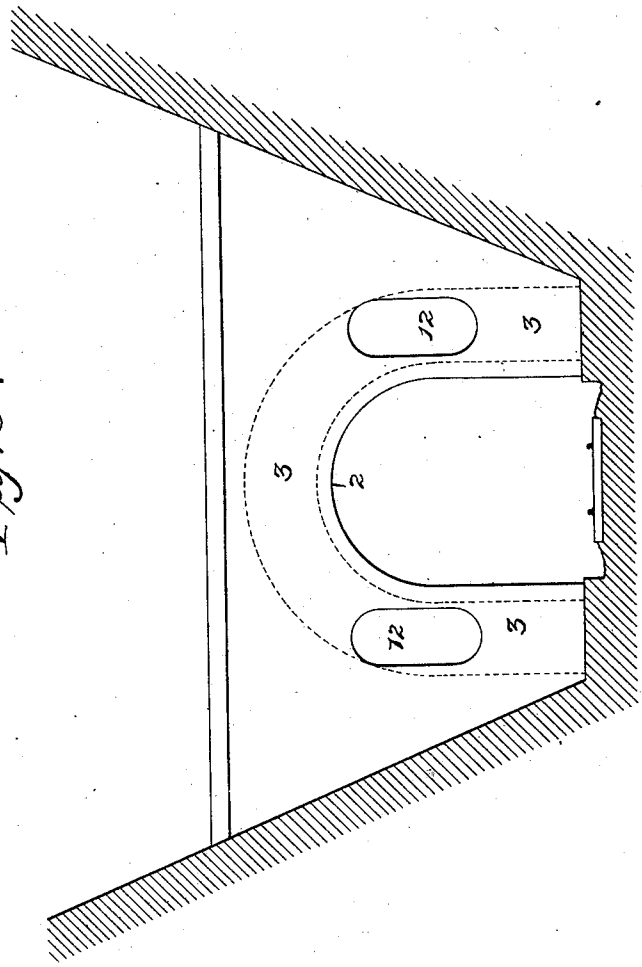
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MEANS FOR VENTILATING TUNNELS.

(Application filed Nov. 10, 1900.)

(No Model.) 3 Sheets—Sheet 3.

Fig. 3.



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UNITED STATES PATENT OFFICE.

CHARLES S. CHURCHILL AND CHARLES C. WENTWORTH, OF ROANOKE, VIRGINIA.

MEANS FOR VENTILATING TUNNELS.

SPECIFICATION forming part of Letters Patent No. 671,264, dated April 2, 1901.

Application filed November 10, 1900. Serial No. 36,088. (No model.)

To all whom it may concern:

Be it known that we, CHARLES S. CHURCHILL and CHARLES C. WENTWORTH, citizens of the United States, residing at Roanoke, county of Roanoke, State of Virginia, have invented certain new and useful Improvements in Means for Ventilating Tunnels, of which the following is a specification.

Our invention relates to means for ventilating tunnels, and particularly to such means as are applicable to railroad-tunnels which need to be cleared of smoke and gases and supplied with fresh air.

One object of our invention is to provide means for ventilating the tunnel without interfering in the least with the passage of trains and without decreasing the area of the cross-section of the same, whereby the danger to life and property which exists in the systems of ventilation heretofore proposed and with which we are familiar is prevented.

A further object is to provide means for ventilating tunnels which will be effective in operation and properly and quickly perform the work of ventilation in the most economical and safe manner.

With these objects in view our invention consists in the novel construction and the details thereof, as hereinafter described with reference to the accompanying drawings, and more particularly pointed out in the claims.

In the drawings, Figure 1 is a plan view of an end portion of a tunnel with our invention applied thereto. Fig. 2 is a central vertical longitudinal section thereof. Fig. 3 is an end view.

Referring to the drawings, in which similar reference characters relate to the same or corresponding parts in all the views, the numeral 1 indicates a section of the tunnel to which our invention is applied, which tunnel is constructed in the usual manner, having an inner wall of masonry 2. In order to ventilate such a tunnel, we provide means for creating an induced draft through the tunnel from one end, so as to force the gases, smoke, or foul air out the other end of the tunnel, and which deleterious gases are replaced by the fresh air carried into the tunnel by the induced draft, and we apply our means for inducing this draft at any convenient point, preferably at one end. As shown in the drawings, we form an air chamber or passage 3 in the side walls and roof of the tunnel near the end, which chamber gradually tapers from the end of the tunnel toward the contracted opening 7, through which the current of air is discharged into the tunnel adjacent to the walls thereof, the axis of this chamber being as nearly parallel to the axis of the tunnel as possible in order that there may be the least obstruction to the free flow of the air-current. The area of the opening 7 must be proportioned to the size and length of the tunnel, as will be hereinafter shown. This chamber is formed by an inner wall 5, an outer wall 4, and the end wall 8 of the tunnel. The inner wall 5 is tapered to as thin an edge as possible at its extremity 6, so that there may be no eddies formed in the air-current as it is discharged through the opening 7 from the chamber 3 into the tunnel. The inner face of the wall 5 is preferably in prolongation of the main wall of the tunnel, so that there is no reduction in clearance and no hindrance offered to the passage of trains beyond that caused by the main walls of the tunnel. If desired, however, the inner face of this wall may be slightly outside of the walls of the main tunnel, the essential object being to so construct this chamber that its inner wall shall not project inwardly beyond the main wall of the tunnel to any material extent. The wall 4 may be made of masonry in the prolongation of the structural work of the main tunnel, and the wall 5 may be likewise of masonry or aluminium, copper, or wood, or of any suitable material which will resist the action of the gases discharged by locomotives passing through the tunnel. The chamber 3 is provided with one or more air-inlets 12, which are connected by a suitable pipe or pipes 9 to a blowing apparatus 10, (preferably fans,) driven by a suitable motor 11, situated at convenient points near the end of the tunnel or near the point where the air-chamber 3 is located in the tunnel. The blowing apparatus is preferably so arranged that the blast will be delivered in line with the axis of the cham-

ber 3 and as nearly parallel to the axis of the tunnel as possible, so that there will be the least obstruction offered to the free flow of the air, and the fresh-air inlet 13 to the blower should be located on the side away from the track or away from the axis of the tunnel or at some convenient distant point, so that a partial vacuum cannot be formed at a point in front of the mouth of the tunnel, as at 14, as would be the case if the air were taken from the side of the blower next to the mouth of the tunnel. Such partial vacuum would retard the useful effect, as it would prevent the free flow of the induced current of air through the tunnel. With the construction thus described it will be clear that the blower or blowers force air into and through the chamber 3, the latter being tapered, as described, so that the air will issue at an accelerated velocity into the tunnel and adjacent to the walls thereof through the opening 7, thereby causing an induced current of air through the tunnel from one end to the other. It will thus be seen that by the arrangement of the air-chamber and blowing apparatus so that the air shall be delivered as nearly as possible in a direction approaching lines parallel to the axes of the tunnel the inducing-current is caused to take a direct course into and through the tunnel.

In order that the principles on which our invention is based may be properly understood, we may say that, supposing the construction as above described is located at one end of the tunnel, the essential object is to create a current of air through the tunnel by blowing a blast of air through the tunnel away from the ventilating apparatus and at a rate of speed sufficiently great to clear the foul air from the tunnel in a reasonably short time. The resistance offered to the desired motion of the air in the tunnel in order to thus clear it of foul air is that due to friction. This resistance varies as the square of the velocity of the current, and hence it necessitates the continuous performance of work in order to maintain the current at a uniform speed and at such a speed as to effect the purpose desired.

It will be understood that when a blast of air is forced through the opening 7 at a high initial velocity the induced or ventilating current will be discharged from the other end of the tunnel at a comparatively low velocity, and hence the difference between the high initial velocity of the air at the opening 7 and the final comparatively low velocity of the ventilating air-current throughout the tunnel will represent the work done. Now while the initial velocity and volume of a blast of air discharged from the chamber 3 into the tunnel must be sufficiently great to enable it to make up the necessary units of work above indicated in overcoming the friction, &c., the volume of this blast must be less than this volume of air blowing through the tunnel per unit of time, as otherwise part of the air would be forced back to 14, and thereby lost, in that such a counter-current would retard the useful effect intended to be derived through the action of the air-blast from the chamber 3. As the volume of this blast is less, as above stated, the remainder of the air flowing through the tunnel is necessarily supplied by an induced current flowing into the tunnel from 14, and the acceleration of this induced current is part of the work which the air-blast must perform. The volume of induced current or draft depends on the coefficient friction in the tunnel. The less the friction the greater will be the available work developed by the blast and available for the induced draft. In order, therefore, to proportion the parts of our construction for ventilating a given tunnel, there may be generally used a ratio, which we may call R and which is constant for a given tunnel. The length of the tunnel may be represented in feet by L, the area of the cross-section of the tunnel in square feet by A, and we can find the ratio R by the formula:

$$(a)\quad R=\sqrt{\frac{.042\ L}{\sqrt{A}}+1.}$$

If we then assume the velocity at which it is desired to have the air-current move through the tunnel as V feet per minute and call the required velocity of the blast at the outlet of the air passage-way S feet per minute, we can put

$$(b)\quad S=R\ V\ .$$

and the required area C in square feet of the outlet at 7 is

$$(c)\quad C=\frac{A}{1.2\ R}.$$

The volume of the blast in cubic feet per minute is then SC. This will enable the blast requirements to be met by makers of blowing machinery. For example, for a tunnel four thousand feet long, with an area of cross-section two hundred and fifty-six square feet, R is 3.39 and the required area of the blast-outlet is 63 square feet. If the velocity of air through the tunnel is desired to be one thousand feet per minute, the velocity of the blast at 7 should be three thousand three hundred and ninety feet per minute and the volume of air to be delivered by the blowers is two hundred and thirteen thousand five hundred and seventy cubic feet per minute.

From the foregoing it will be seen that the main point to be considered in applying the system embodied in our invention is to properly proportion the area of the air-outlet at 7 to the area and length of the tunnel. This being done, it is of no importance how much air is delivered per minute by the blowing machinery as far as the creation of a current in the tunnel is concerned or at what corresponding speed it passes through the outlet

C. The question is "in how short a time must the tunnel be cleared." This will fix the desired velocity V, which velocity can be attained by forcing a corresponding amount of air through the blast passage-way 7, as heretofore explained.

From the foregoing description it will be seen that by the use of our invention the air-blast can be discharged into the tunnel in a direct course without obstruction, that the maximum velocity of induced current for ventilation can be secured with the minimum expenditure of work for a given velocity of ventilating-current, and that no dangerous obstructions to the passage of trains exist, because the clearance of the tunnel is not reduced by the application of our invention thereto. It is also apparent that our invention can be readily applied to existing tunnels, as well as to new tunnels to be constructed or in the course of construction, and, further, that it may be utilized on mining shafts or tunnels or other like underground works where it is desired to remove foul and other gases.

We claim as our invention—

1. In a ventilating system for tunnels, the combination with the tunnel, of an air-chamber formed in the wall of the tunnel having its inner wall substantially in line with the inner wall of the tunnel and having an opening arranged to discharge air therefrom in a direction substantially parallel to the axis of the tunnel and adjacent to the wall thereof, and means for blowing a blast of air into said chamber, whereby the blast of air issuing from the chamber into the tunnel will create an induced draft through the tunnel, substantially as described.

2. In a ventilating system for tunnels, the combination with the tunnel, of an air-chamber formed in, and extending around, the inner wall thereof, said chamber having its inner wall substantially in line with the inner wall of the tunnel and tapering to a contracted opening for discharging a current of air into the tunnel adjacent to the wall thereof, and means for blowing a blast of air into said chamber, whereby the blast of air issuing from the contracted opening into the tunnel will create an induced draft through the tunnel, substantially as described.

3. In a ventilating system for tunnels, the combination with the tunnel, of an air-chamber formed in the wall thereof, and having its inner wall substantially in line with the inner wall of the tunnel, said chamber being tapered to form a contracted opening for the discharge of an air-current adjacent to the wall of the tunnel, and means for blowing a blast of air into said chamber, whereby the blast of air discharged from said chamber through the contracted opening into the tunnel will create an induced draft through the tunnel, substantially as described.

4. In a ventilating system for tunnels, the combination with the tunnel, of a tapered air-chamber having its inner wall substantially in line with the inner wall of the tunnel and terminating in a thin edge near the wall of the tunnel and forming therewith a contracted opening for discharging a blast of air into and adjacent to the wall of the tunnel, and means for blowing air into the chamber, whereby a blast of air will be discharged through said opening into the tunnel and adjacent to the walls thereof, substantially as described.

5. In a ventilating system for tunnels, the combination with the tunnel, of an air-chamber at the end of the tunnel and having its inner wall substantially in line with the inner wall of the tunnel and terminating near the wall of the tunnel and forming with said wall a contracted opening for discharging a blast of air into the tunnel, and a blowing apparatus having its delivery in communication with the said air-chamber and so arranged that a blast of air will be caused to move in a direction substantially parallel to the axis of the tunnel, substantially as described.

6. In a ventilating system for tunnels, the combination with the tunnel, of an air-chamber formed in the wall of the tunnel at the end thereof, the inner wall of said chamber being substantially in line with the wall of the tunnel and terminating near said tunnel-wall and forming with said wall a contracted opening, and a blowing apparatus communicating with said chamber through the end wall of the tunnel, substantially as described.

7. In a ventilating system for tunnels, the combination with the tunnel, of a tapered chamber formed in the wall of the tunnel near the end thereof, the axis of which is substantially parallel to the axis of the tunnel, the inner wall of said chamber being substantially in line with the inner wall of the tunnel, and terminating near said latter wall to form a contracted discharge-opening, and a blowing apparatus having its delivery substantially in line with the axis of the chamber and communicating with the same, substantially as described.

8. In a ventilating system for tunnels, the combination with the tunnel, of an air-chamber formed in the tunnel-wall and having its wall substantially in line with the inner wall of the tunnel and having a contracted opening for discharging a blast of air into the tunnel adjacent to the walls thereof, and blowing apparatus for delivering air into the chamber, said blowing apparatus having its inlet located on the side away from the axis of the tunnel, substantially as described.

9. In a ventilating system for tunnels, the combination with the tunnel, of an air-chamber formed in the wall of the tunnel and closed by the end wall of the tunnel, the inner wall of said chamber being substantially in line with the wall of the tunnel and terminating near the wall of the tunnel to form a contracted opening for the discharge of a blast

of air into the tunnel, and blowing apparatus located on either side of the tunnel-mouth and communicating with said chamber through the end wall of the tunnel, substantially as described.

10. In a ventilating system for tunnels, the combination with the tunnel, of a tapered air-chamber located at the end of the tunnel with its axis substantially parallel to the axis of the tunnel, and having its inner wall substantially in line with, and terminating in a thin edge near the wall of, the tunnel to form a contracted opening for discharging a blast of air into the tunnel and adjacent to the walls thereof, and means for supplying said chamber with air under pressure, substantially as described.

In testimony whereof we have signed our names to this specification in the presence of two subscribing witnesses.

CHARLES S. CHURCHILL.
CHARLES C. WENTWORTH.

Witnesses:
JOHN J. QUINN,
E. J. ROWAN.