



Scholars' Mine

Professional Degree Theses

Student Theses and Dissertations

1882

Tunnels

Ashnah B. Schrantz

Follow this and additional works at: https://scholarsmine.mst.edu/professional_theses

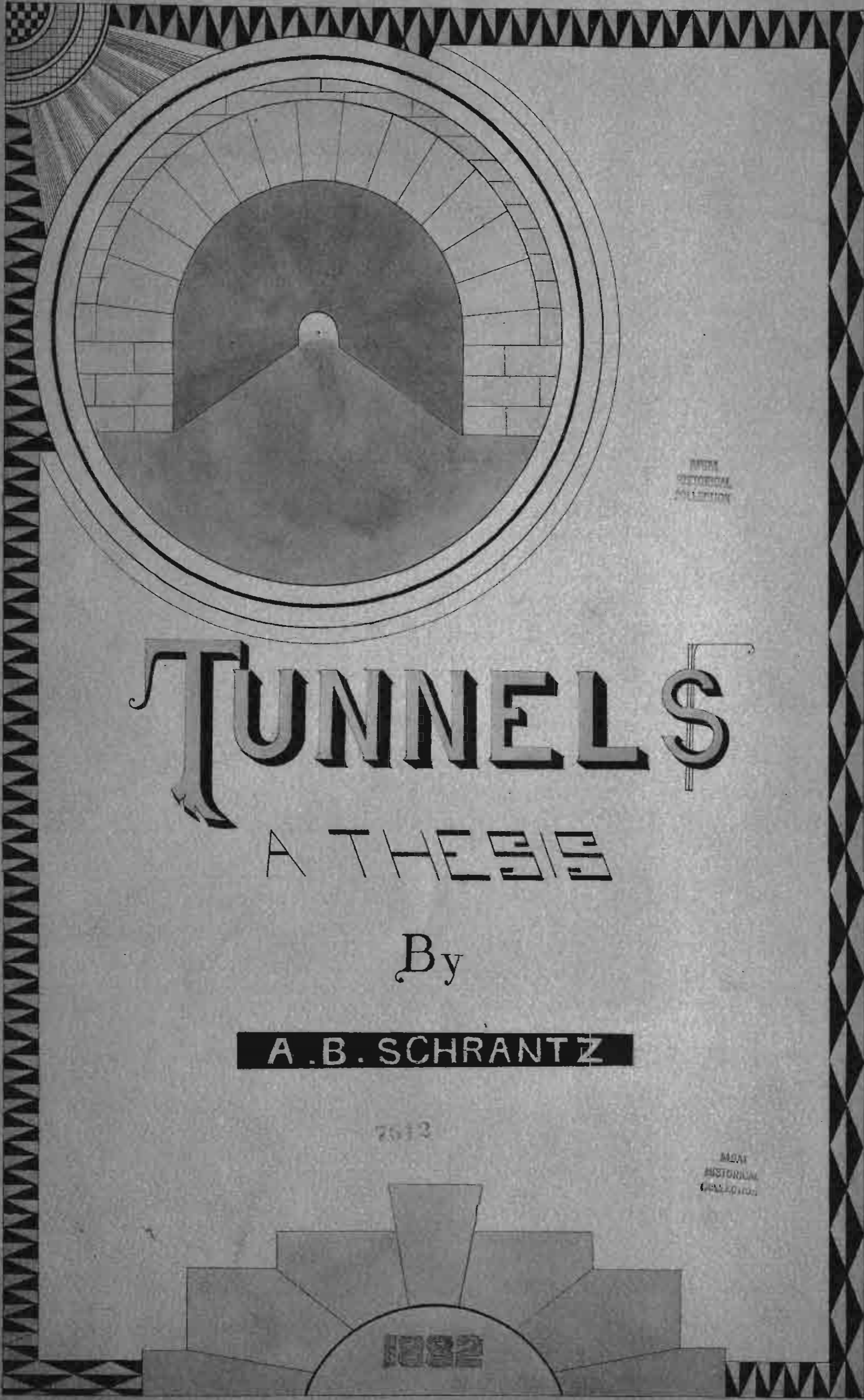
 Part of the [Civil Engineering Commons](#)

Department:

Recommended Citation

Schrantz, Ashnah B., "Tunnels" (1882). *Professional Degree Theses*. 229.
https://scholarsmine.mst.edu/professional_theses/229

This Thesis - Open Access is brought to you for free and open access by Scholars' Mine. It has been accepted for inclusion in Professional Degree Theses by an authorized administrator of Scholars' Mine. This work is protected by U. S. Copyright Law. Unauthorized use including reproduction for redistribution requires the permission of the copyright holder. For more information, please contact scholarsmine@mst.edu.



UNIVERSITY OF MICHIGAN
HISTORICAL COLLECTION

TUNNELS

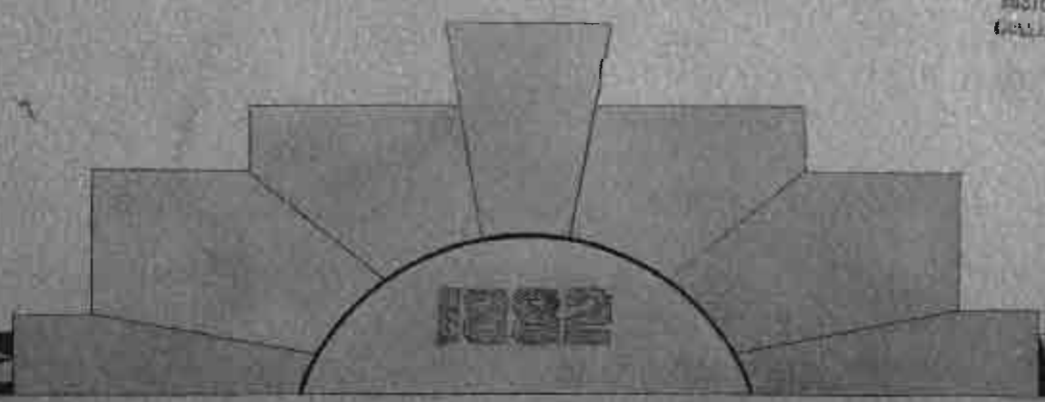
A THESIS

By

A. B. SCHRANTZ

7513

UNIVERSITY OF MICHIGAN
HISTORICAL COLLECTION



1882

Among the early tunnels, Herodotus mentions one on the island of Samos, through a mountain 900 ft. high, the length of the tunnel being 427 ft. and its cross-section 818 ft.

When Caesar went to Alexandria he found the city under ruin with aqueducts. The aqueducts of the ancient Romans, Mexicans and Peruvians include many remarkable tunnels. A tunnel was commenced in 398 B.C. to Tap Lake Atlixco. It was built at the instance of the Olympic race, and was 6.72 long, and of cross-section 8:3.0 ft.

Fifty shafts were sunk on the line and the work completed within a year after it was commenced, although it was driven through the hardest lava. From the above it will be seen that tunnelling is by no means a modern art, but was extensively practiced by the ancients, without the knowledge of explosives, and without even the most simple machinery.

Without concerning myself with the ancient methods I shall endeavor to treat the subject, in this paper as follows.

1. Considerations to be ~~made~~ made before building a tunnel

2. Compressed air
3. Rock drills, Arrangement of plant etc.
4. Explosives. Blasting.
5. Methods of excavating
6. " " Timbers
7. Shafts, ventilation.
8. Centers
9. Masonry. drainage
- 10.

Tunnels are seldom curvable owing to their great cost, but if in an open cut the material has a tendency to slide or run, or if in a mountain region it be exposed to the drifting of snow; or if a frequent crossing of a river can be avoided, or the general alignment of the road be improved so as to warrant the cost a tunnel should then be made.

Or when the depth of an excavation passes beyond a certain limit, it becomes cheaper to tunnel. To determine when to change from an open cutting to a tunnel; let x be cost per cu. yd. of excavation & the cost per running foot of tunnel to the base of excavation, & the ratio of the side slope, and z the depth at which the cost of tunneling and excavating are equal. Then

Cross section of excavation = $x(10+5z)$
 Contents for one running ft. = $x(10+5z)$
 Cost of running ft. of excavation = $\frac{x(10+5z)}{27} \times z$
 " " " " " Tunnel = 7

$\therefore \frac{x(10+5z)}{27} \times z = 7$ from which

$$z = \frac{-6}{25} \pm \sqrt{\left(\frac{27^2}{25} + \frac{6^2}{45^2}\right)}$$

Unless it be an exceptional case a greater depth than that found by the formula should be had before commencing to tunnel owing to the uncertainties and delays of the work.

A tunnel is preferable

Tunnels in granite porphyry, gneiss dolerite basalt & gneiss hard drilling and generally good roofs, and as a rule tunnels in these formations are dry. Tunnels in graywacke and argillaceous shales, even in solid varieties need as a rule artificial support, in the carboniferous and sub-carboniferous slates and sand stones artificial support is needed, for whereas the rock is quite hard when first excavated it is liable to slack on exposure. In Europe tunnels in the "new red sand stone" and upper carbonaceous sand stone are cheap and often require no support, and tunnels in the Permian formations, Triassic limestones, Keuper and Jurassic formations are apt to be sufficient, as they are not subjected to great pressure.

Tunnels driven in the marl beds of Roth, in Keuper and carbonaceous formations, in the clays of the Jura formation, and in the sand and marl beds of the tertiary and Cretaceous groups show great pressure and are very wet.

There are four mountain formations under which tunnels are located, viz. Isolaña peaks, Montañas slopes, Montañas spurs and divides, Isolaña peaks generally slope in all directions

A steady ^{or ascending} drainage grade is generally required in tunnels of this class & conforms with the grade of the fall line of the road. Tunnels of this class as a rule show but little water, owing to the small area of the deposit, the rock therefore shows but little tendency to disintegrate, and is generally solid. Moreover tunnels through formations of this character are most always short.

In locating a tunnel through any mountain formation, there are many things to be carefully considered, thus Fig 1, Plate I of S is a soft stratum between two hard ones b, b, which will not pass away, the ~~stratum~~ at d will tend to bring in more water if the depression be of any great length. This would be more apt to occur with tunnels through ~~strata~~ ^{strata}, and if there be a water bearing stratum in the flow will be all the greater.

In Fig. 2, Plate I ^{is another} example, the stratum c being ~~at~~ ^{very} ~~near~~ ^{close} to basin a, may be loosened by the construction of a tunnel in it, and such great amount of air it may bear water absorbed from basin a. Hence the beds are ~~stratified~~ ^{stratified} horizontally see Fig 3, Plate I the tunnel may be exposed to a heavy flow of water, from ~~basin~~ ^{basin} ~~a~~ ^a, which would pass the plateau above and pass the basin a. Tunnels through mountain's slopes are apt to be difficult

owing to the fact that they are seldom deep enough to be below the debris of the mountain tops, and the rock is generally somewhat decomposed and water bearing, and the pressure is apt to be very irregular, and it is especially dangerous when the strata conform to the slope of the hill, see Fig 2. Note 1

in which are embodied all the dangers of water ore silica pressure and ~~rock~~ sliding

since spurs of mountains are water sheds in themselves. Tunnels through them are apt to be unfavorable locations, see Fig 4. Note

which shows a tunnel to be under a natural dam

Fig. 5 shows a tunnel location in a fault, where we may expect much water and warm rock, In Fig 6

it would have been a better location than 5, being in a water bearing stratum

Fig. 7 shows a tunnel location unfavorably located in a depression, caused by the fracturing and eroding of the rocks of an antediluvial summit.

Geological examinations are of little value if they cover only the ground over the tunnel or in its immediate vicinity.

They should extend over a great area, and this can be facilitated by the state and government geological reports.

Friends are returned

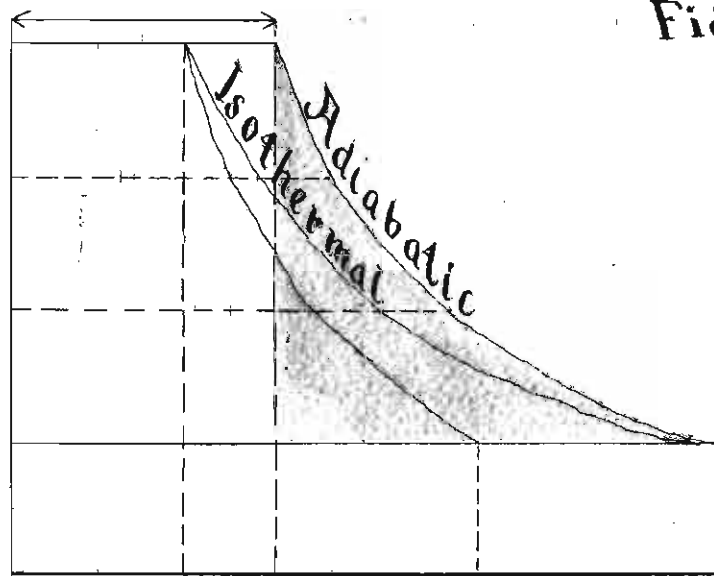


Fig. 2

PLATE

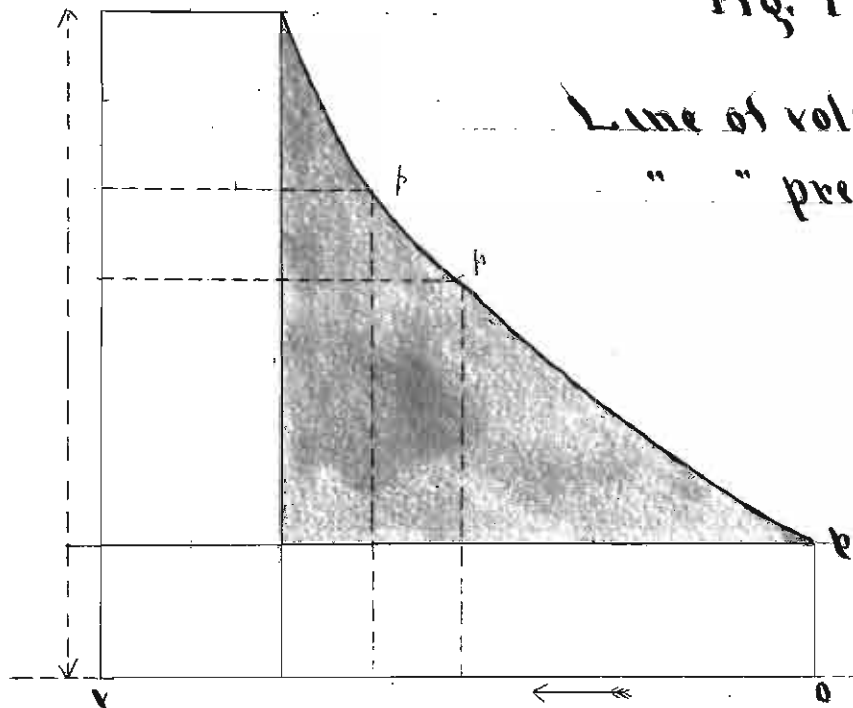


Fig. 1

Line of volume ov
 " " pressure op

Compressed air: Since air is one of the permanent gases, it must obey the law that applies to them.

Volume varies directly as the temp. and inversely as the pressure. At a constant pressure the density varies inversely as the volume, which varies as the absolute temperature. From the weight of a gas the velocity of its molecules can be calculated for any pressure. Thus a cu. ft. of air at normal pressure weighs about $\frac{1}{8}$ lb. and the pressure of nearly a ton on each side of the cube is due to the striking of the molecules against it, and may be represented by $\frac{1}{3}mv^2$ the work accumulated by a moving body represented by $\frac{1}{2}mv^2$ or $\frac{2}{3}$ the kinetic energy. From which $v =$ equals about 20 mi. per min.

The first law of gases may easily be stated thus, $p v = \text{constant}$

$p =$ pressure (in this case 1 atmosphere)

$v =$ vol. 1 cyl. full.

From the equation we can draw the curve in Fig. The equation is that of an hyperbola referred to its asymptotes. One property of the curve is, that the area contained by the co-ordinates of any point P, is equal to the area contained by the co-ordinates of any other point, that is all the rectangles p. v. are equal in area. So that for any

value of v as at $\frac{8}{9}$ stroke when the
vol. is only $\frac{3}{8}$. we may find p by in-
verting the fraction, representing the
new vol. Thus, p (see dotted lines) = $\frac{8}{3} = 2\frac{2}{3}$
atmosphere absolute pressure.

The area of the shaded part
of the diagram, represents the negative
power expended in isothermal compression
and the remaining portion of the dia-
gram above the atmospheric line repre-
sents the power required to deliver the
air after compression. It is a common
mistake to suppose that during the isother-
mal compression no heat is generated
but it will be found that when de-
livering air into a receiver at any
given pressure more heat is generated
during isothermal than during adiabatic
compression. In each case the heat
is the thermal equivalent of the power
expended in compression. Isothermal
compression can only be carried out when
the heat is carried off as soon as gen-
erated. If the air be compressed too
slowly the heat will disappear by ra-
diation but if compressed too quickly
for the heat to get away in this man-
ner special arrangements must be
made to prevent the rise of tempera-
ture. Suppose that no attempt is
made to keep the air cool, and that
the air is compressed in a cylinder

that we must take up any heat itself, nor allow any to pass out of the air while being compressed. This would be a case of adiabatic compression, and we should find that when the volume had been reduced to one half the pressure would not be doubled as in isothermal compression, but more than double because the heat generated during the compression would still be in the air. In making a diagram to show how the pressure varies in this case, we must not only take into account the reduction of volume but also the effect of heat generated while that reduction was being made. A simple way to make a diagram of adiabatic compression, is to draw first the isothermal curve, and then add to it at various pressures the extra volume due to heat generated while compressing up to that point. This extra volume can be found by taking the natural logarithm corresponding to $\frac{2}{\gamma}$, the log. of the pressure, which gives the ratio of volume after adiabatic compression to volume after isothermal compression. Thus at 20 atmospheres absolute the volumes would be 1.22 137 and 1.48 51, and as the power expended in compressing the air, is proportional to the final volumes

This method of drawing the curve is useful. These numbers give also the final absolute temperature in terms of the absolute temperature before compression. In the equation of the adiabatic curve $\gamma = 1.4$, being the ratio of the specific heats at a constant volume and constant pressure, 1.4 is here taken as the ratio of the elasticities of the air. The shaded area represents the engine power expended in adiabatic compression see Fig. 2 which is less than the shaded part of Fig. 1. But the final volume is so much greater here, that the area of the whole diagram is more than the isothermal diagram.

If there were no friction & working with air at high temperatures, and if it could be taken from an evaporator with out any heat being lost, air compressed adiabatically would by expanding give back the whole power expended in compressing, neglecting all power lost by friction &c. But as these ends cannot be obtained in but few cases, the superiority of the isothermal method will at once be seen.

Plates II. & III show two styles of compressors. The advantage of the inclined steam cylinder in Plate II is to give the steam the greatest advantage when the pressure is greatest. The method of introducing water

Water around the cylinder is also seen,
in some places

In the arrangement of planks great
care and good judgement should be used
so as to get the best results with the
greatest economy. All the conditions
under which the machinery is to work
should be considered before selecting a
site for the power. It is often to carry
the air or steam some distance, if
by so doing the compressor and boiler
will be handy to fuel and water.

The boiler should be near the machinery
it supplies, and the steam pipes should
be kept well covered to prevent loss of heat
by radiation. From the compressor the
air should be discharged into a receiver
near by, and it is better to pass the
air into a small receiver at the end of
the pipe. The air should pass in and
out of the receiver at right angles, or
on the same side of the receiver, in any
horizontal. A large pipe should be used
so as to lessen the friction as much as
possible. Sharp turns should be avoided,
as much power is lost by them.

Rock drills are run by either steam or compressed air, steam should always be used in preference to air when circumstances will permit. The principle will at once be seen, by referring to plate IV which represents the form in which the valve is moved by a tappet which is a common although not the best form of drill, which will become evident when we consider that the tappet is struck by the piston from 3 to 500 times per minute and must therefore wear and break rapidly. The best form is the one in which the valve which admits the steam or air into the cylinder, & moves the cylinder is itself moved back and forth by the steam or air used in the drill. The piston is a solid bar of forged steel moving back and forth in the cylinder, the same as the piston of an ordinary engine. The drill steel, or the end of which the cutting bit is forged, is firmly attached to the end of the piston by means of a chuck and there two pieces of steel come receive the shock of the blow. The piston is also rotated at each backward stroke and moves straight and far on the forward or cutting stroke. By its device and one X shaped bit a perfectly round hole can be made. In very loose kinds of rock a Z shaped bit is sometimes used to advantage.

The supports or rock drills are the tripod, the carriage and the column. The tripod is much used for surface work and for taking up the bottoms of tunnels after the drift has been run. The legs of the tripod can be extended and thus adapted to very rough and uneven surfaces. They are generally weighted to give them greater stability. The drill carriage is a device by which a number of drills may be made to work on the same rock face at the same time. A common form is shown in plate V.

The column for tunnelling (see plate VI) is a cylindrical bar into which an iron base is shrunk. By means of two jack screws the column is lengthened or shortened and held fast between the roof and floor of a tunnel or the walls of a shaft. For drifting the lateral arm is clamped to the column, and the drill is fastened to the arm by means of a clamp. The drill can be moved in or out on the arm, or up and down or around the column, thus commanding a large portion of the rock face, and making a frequent shifting of the column unnecessary. The drill can be placed to drill holes at any angle up or down or to the right or left.

The screws and top of column must rest on short pieces of plank or timber. Experience has shown that the column

is the best mounting for drills in drifts and tunnels of various size.

(Plate VII, shows drill mounted on column) and it can be used to great advantage in large tunnels by running a drift of convenient size in the extension of the line of the roof, and taking up the drift with drills mounted on tripods. In this way a greater number of drills can be used in the work, and each drill can be placed in the most advantageous position, and worked independently and consistently. Immediately after starting they can be placed in position, without losing time in removing the rock.

If the drills be mounted on carriages the track must be cleared before the carriage can be advanced into the heading and when thus the drills can be all be worked to the best advantage along the narrow face of the rock, and to the fact that each drill is attached to a common base.

The diamond drill is inferior to the percussion drill for tunnel work, but is the best for sinking shafts; it is used in the popular "long hole" process of shaft sinking.

In rollers the shape of the shaft is marked out by a requisite number of thin holes bored to the depth required for the shaft. The ~~open~~ area increased by these holes is thus honey-

worked by drill holes reaching about to the bottom
of the shaft. This being done the drill
was removed, and the hole filled with
sand, after which the hoisting and
raising of the rock can be done without
further use of the drill. Plate III. shows
common drills mentioned for shaft work



PLATE

In blasting the explosives ^{most commonly} used are
black powder, nitro-glycerine, and dynamite.

Black powder is being gradually replaced
in works of this character, in fact by the
more powerful explosive, nitro-glycerine. For
owing to the dangers of using this as a
liquid, it is combined with some kind
of absorbent dope, which takes up a great
percent of the liquid. The best dope now
used, is infusorial earth, which is com-
posed of minute spines and silicious shells.

There are many other dopes, such as
sawdust, etc. The electric machine
and platinum rings are used in
firing blasts, as they have the great advan-
tage of giving any number of charges
simultaneously.

Plate I, shows a form
of an electric explosion. The layout
for can be changed by a per-
turn of the large plate, and then
adjusted by pressure. The interior

This is a new and good form, although
the one in most common use is a small
electro magnetic machine. The arrange-
ment of charges for simultaneous firing
is shown in plate I, and a platinum
fuse in plate B. When black
powder is used clay is the best tamp-
ing, but sand and soft rock are
often used. Nitro-glycerine needs
no other tamping than water, it
being an oily liquid and heavier

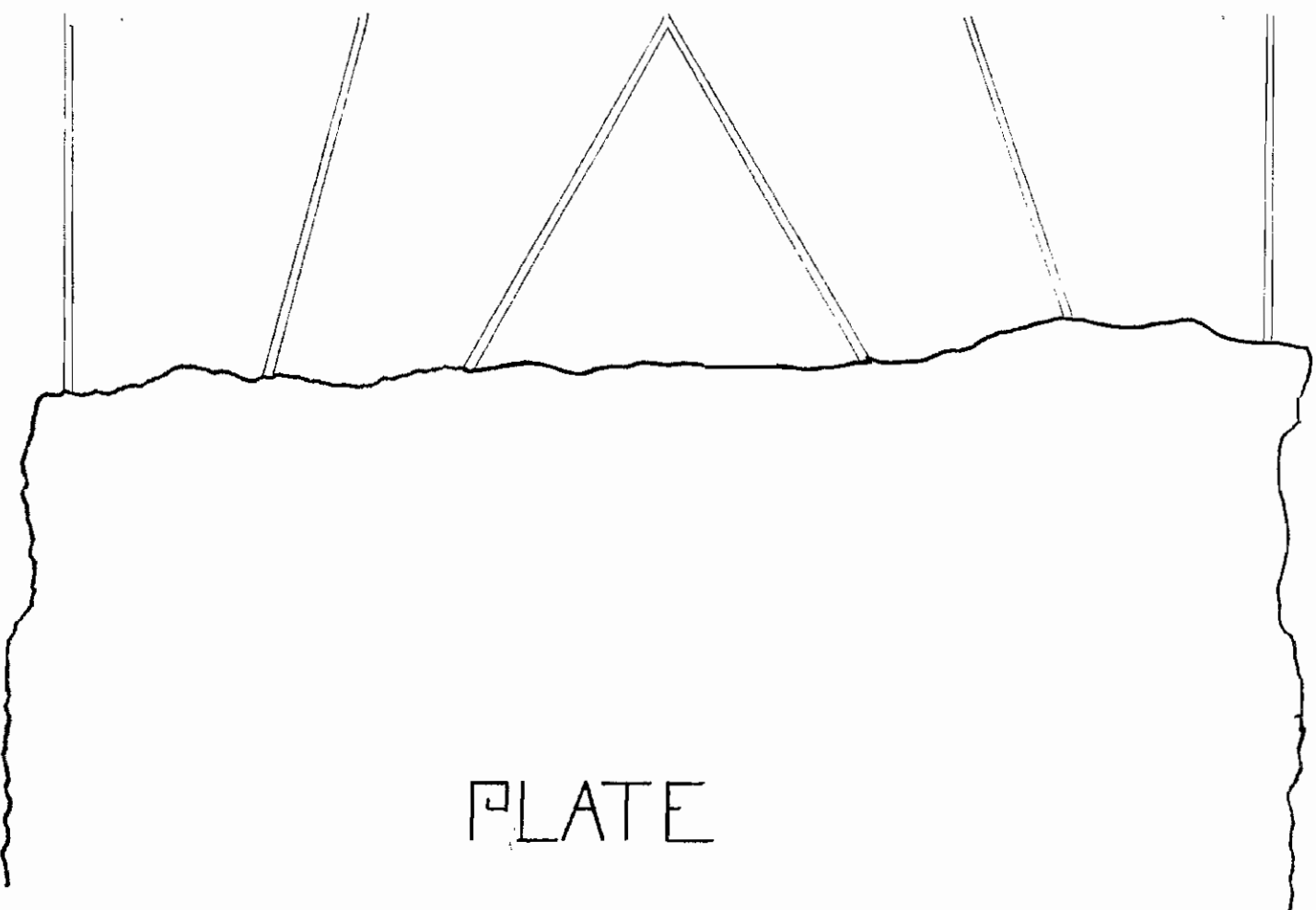
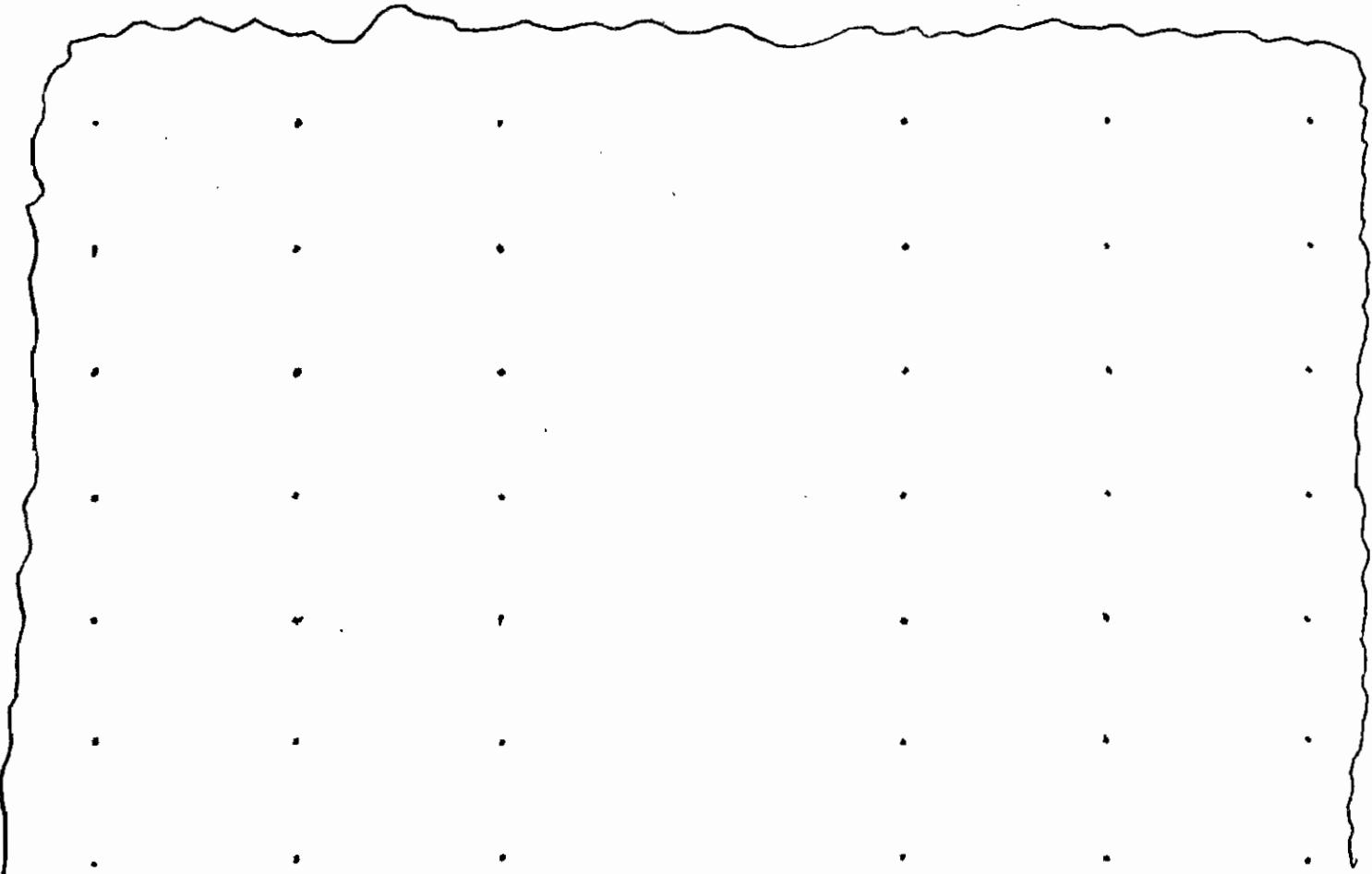
than water, it sinks to the bottom of the hole, and does not mix with it. With dynamite, the theory is that no tamping is needed; but it is better to tamp well with clay. The explosion should be placed as near the center of the charge as possible.

The holes should not be located in the line of weak resistance, for the effect in case is always inward escape, and when slow burning explosives are used, only the tamping is blown out. As to the depth of holes, for "shock fissures" or very tough rock shallow holes, coarse moderately tough rock holes of average depth, brittle and solid rock works well with deep holes, and in tough rock wide holes and in brittle rock narrow holes are more economical.

The first shock in the face of the rock is always disadvantageously located, but after this, advantage should always be taken of the cavity blown out by the first shock. The American water cut system of heading blasting is shown in Fig. Plate C.

First the wedges shaped core *a a* is taken out after which the same *b b*, *c c* are blown out, and this process repeated as soon as the whole

depth d or d' is taken out, the rate of
advance depends of course upon the
tenacity of the rock



PLATE

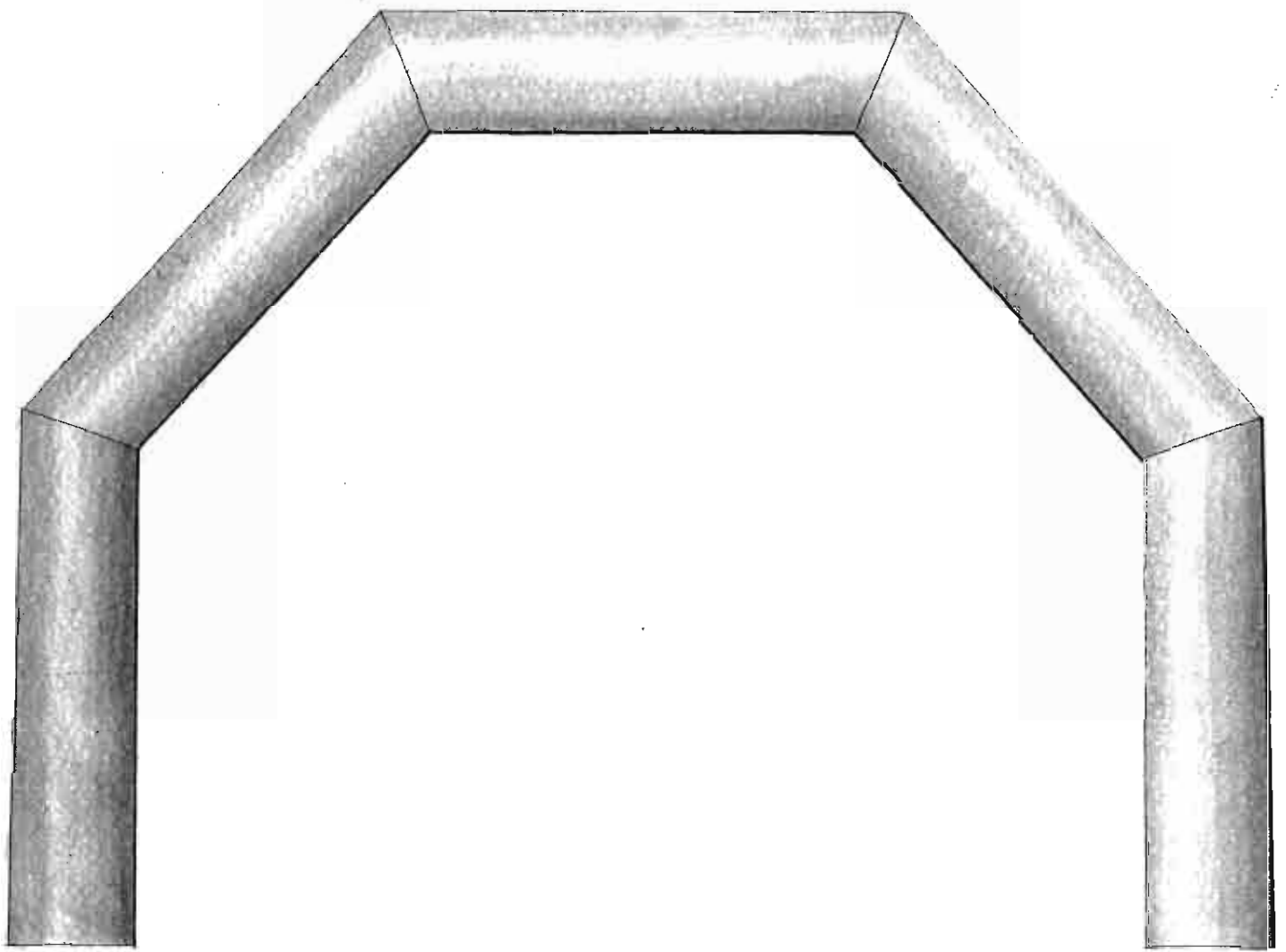
A method of excavating ~~work~~ practiced in this country, is to drive a heading at the top of the tunnel, and enlarge it to the required dimensions. another method is to drive the heading in the middle of the required tunnel, and enlarge from that, taking up the bottom first.

And in what is known as the German center core system of excavating, three headings are driven, one at the top and one at each side of the bottom, an excavation is thus made around the core of the tunnel against which the supporting timbers are made to work. This system

has one disadvantage in heavy ground, which is the concentration of the whole pressure upon one particular place, viz the center core.

However this disadvantage is experienced in all radial systems of timbering, regardless of the method of excavating.

In timbering all depends upon the nature of the material supported, the pressure exerted and the direction of the pressure. In general to timber a tunnel, is to give a firm support to a series of radial timbers on which ~~is~~ is laid a lagging of heavy boards that sup-



PLATE

push the earth. A method of timbering is shown in Plate E. The strength of the timbers should vary directly as the pressure.

A method of timbering much in use in this country is the block arch, which will be understood by referring to plate -

The cross timbers should be placed exactly at right angles to the center line of the tunnel, otherwise difficulty will be experienced when advancing the arch. The locality will of course influence the selection of timber, but for temporary timbering purposes should always be given to the soft woods. Although hard wood is stronger than soft it is less elastic and more liable to suddenly break under great pressure, while soft wood will always bend before breaking and thus give warning in time to put in auxiliary timbers to counteract the pressure. Again soft wood being lighter than hard is more easily handled.

In the block arch system where the timber is put in for a permanent support, hard wood is of course preferable.

In all cases timbers should be so arranged that the pressure exerted will not disconcert the joints but

To bind them more closely together
each timber should bear its
share of the strain, and centers of
rotation should be avoided.

On very heavy ground care should be
taken not to weaken the timbers by
cutting, and the timbers should be so
arranged as to not concentrate the pres-
sure at any one point. On ordinary
ground a section of from 10 to 20 feet
can be excavated before any ~~can~~ sup-
port is required, but in sand the
supports cannot be put in so quickly.

On loose rock, the roof being sup-
ported by the rafter timbers, a tunnel
or more feet may be excavated
before the abutments are put in.

On taking out the timber care
must be taken not to leave to
great a section unsupported at one
time. When the ground is very
treacherous it is some times advisable
to wall in the timber, with very
soft ground, and quick sand it
is always necessary to wall in
the lagging.

Iron framing has been
used for supports in tunnels. It
was used to some extent in a few
foreign tunnels, and is advocated
principally by foreign engineers. Iron
has only taken the place of timber in

this country in the sinking of shafts through very soft material

The iron system may come into general use in European countries where the cost of timber is very great, as in most of them systems a great mass of timber is always required. But in America where timber is cheap, and the most economical system of timbering (the block system) has been adopted, it will be long before it will be superseded by iron, probably never.

Shafts are sunk either for working shafts, or for ventilation. There are two processes of sinking shafts that stand out pre-eminent "The Long hole process" which is used for ~~not~~ sinking through rock or any hard material, (described under the head of diamond drills), and the Lancaster process for sinking through soft material as quick sand &c. This method of shaft sinking differs little from the method of sinking pneumatic pits and caissons, and will not be described. As to ventilating shafts it may be stated that in general they are an impediment to perfect ventilation

Methods of artificial ventilation have to be resorted to in long tunnels. One is to introduce compressed air in the tunnel and have cocks along the lining at suitable intervals by which it can be turned off. Currents of air can be made to pass through the tunnel by means of a fan blower at one portal. The old method of building zinc under shafts has pretty generally been discarded. Double line tunnels are found to be more easily ventilated than single line tunnels.

Screens, and various devices have been used to promote ventilation, which need no detailed description.

For any given length of tunnel there is always a limit to the traffic that can be carried on by locomotives, beyond this limit some other traction power must be used.

In choosing timber to make centres it should be borne in mind that the centre is not to carry the arch only but the arch plus the weight of the ground, hence great strength is required, and since it should occupy as little space as possible, care should be taken not to add any superfluous material,

There must also be a source of strength coming with auxiliary braces without too much closing the tunnel incurmunity.

Arrangements must be made for attaching sloppening for the masses, and the centres must be of simple construction and be easily removed and set up.

The centres should have no connexion with the timbering, so that the latter may be removed without any way disturbing it.

Iron centres are sometimes used but are objectionable owing to their great weight.

Movable centres have been devised, by which the whole tunnel could be arched with the use of only one centre.

They are generally mounted on rollers and have a means of raising or lowering. The method of using is to put the centre to place, build the arch over it allow it to settle a few hours, lower the centre until it clears the arch, push forwards until nearly from under the arch completed, raise it and repeat the operations etc.

A very ingenious method of low-

centre is to have the stroke resting
in strong vessels filled with sand
these vessels have small openings at the
bottom, by means of which the sand can
be drawn off. When it is required to
strike then express an aperture, the air is drawn
out and the centre stone settles

Great care should be taken to keep
the centre exactly at right angles to
the centre line of the tunnel, otherwise
the tunnel will be narrower at some
places than at others

When selecting material for
the arches, stone should be chosen es-
pecially with reference to its crushing
weight, as great pressures have sometimes
to be sustained, the stone selected should
be of a kind that will not disintegrate
in exposure, Brick and stone were
for arches, being sometimes cheaper than
stone, the clay taken from the tunnel being
made into them. Of machine and
hand made brick the preference is al-
ways given the latter, as the mortar adheres
more closely to them forming a kind of mon-
olith

The form of the arch depends
upon the direction of the pressure, if the
pressure is vertical, the oval arch is better
adapted to resist it, (or long axis vertical
if lateral the flat arch, but for all

kind of ground, whether the pressure be vertical horizontal or otherwise, the full center arch is well adapted,

In rock of any character a tolerably good foundation can be had with our timbers, though in loose rock all the interstices should be carefully filled with hydraulic mortar. In very soft materials there is generally an upward pressure, which must be met by an invert, this invert also serves as a foundation on which to build the other masonry of the tunnel.

When the upward pressure is very great or such as would tend to close the tunnel, this invert must be laid in advance of the other work, thus giving a firm footing to the timbers that support the ground before the masonry is put in.

Whether the masonry be of stone or brick, it should be well laid in hydraulic mortar, and the intrados of the arch should be covered with a thick coating of the same material, to protect the same from water. In all cases the arch should be well backed with broken stone, to prevent any settling that would otherwise take place.

When possible, the floor of the tunnel should have a gentle slope from the centre towards each portal, so as to carry off any water that penetrates, in such cases the bottom of the tunnel is lined with broken stone or gravel, which runs a drain.

When this grade cannot be had, pumps must be resorted to, or a small heading run from the lowest point in the tunnel to some point on the surface, sufficiently below this to carry off all water.

It has been tried to drain the outer massing by leaving holes where the greatest flow of water was noticed, but this has proved a failure in nearly all cases and it is found better to make the arch as near water tight as possible.

When the work is progressing from working shafts the inflow of water is often so great that drainage, and must be either by pumps or, when the height will permit a siphon may be employed, it is always best that to connect the shafts and portals with a small heading as soon as possible and get rid of the water by this means.

Tunnels now in progress.

The Hudson River Tunnel, is to be a double track railway tunnel under the Hudson River, and is to connect New York and Jersey City. It will when completed be something over 2000 feet long, and will be through rock over two thirds the distance. Work was commenced on the Jersey side in Nov. 1874

But the working shaft was sunk on the New York side only during the past winter. The shaft was sunk by means of a pneumatic caisson the dimensions of which are, bottom 48. by 27.5 ft. top, 46 by 27.5 ft. height 26 ft. The interior space is 23 ft high, and is divided in two parts by means of a floor.

All the fine material is forced out by means of the pressure of the air, while the coarse material is shoveled to the upper floor and raised from there to the top by means of a hoist.

On the Jersey side the same method of excavation is employed in the headings. The clay is fractured and forced out by means of the pressure of the air maintained. The sand is blown out dry.

The length of the subma-
rine tunnel under the sea from the
English to the French shore will be
22 miles, and taking in the approach
20 at each end there will be a total
length of 50 miles of tunnelling.

The approach of the tunnel on
the English side descends from the
surface with an incline of 1 to 80.

The shaft near the shore is 160 ft.
deep and penetrates the white chalk
after passing through 40 feet of debris.

The present heading is 7 feet in
diameter, and machinery is being con-
structed by which it may be enlarged
to 14 feet by cutting an annular
space of 3.5 ft. width around it.

The heading is driven by the Fran-
cous and English boring machine, the
total length of which is 33 feet. The work
is done by the cutting action of short
steel cutters fixed in two revolving arms
with 7 cutters each. The bars move
forward $\frac{1}{8}$ of an inch with every com-
plete revolution of the cutters. A
circular tunnel is thus formed having
a diameter of 7 feet. The shape of
the tunnel when completed will be
a circle 14 feet in diameter, flattened
at the bottom to receive the rails.
It will be lined with two feet of con-
crete cement made from the grey

chalk excavated from the tunnel itself.

The Muller Tunnel on the line of the Northern Pacific rail road will be 3850 feet long, 16 feet wide and 20 feet to the crown of the arch.

As the work will consume considerable time, preparations were made to begin as soon as the route through Muller pass was decided upon.

On Jan. 5th 1882 a great number of the citizens of ^{St. Helena} Mt. and other places went to the scene of the undertaking to see the drills begin their work in piercing the barrier of granite. The Governor of Mt. was given charge of one drill, the Mayor of St. Helena the other, the compressed air turned on, and the task commenced. The material to be penetrated is expected to be solid granite through the entire length. Against this six drills will be ~~be~~ brought to bear, impelled by two air compressors. Steam power is to be used for hoisting, and the rate of progress as a ^{rough} estimation will be five feet per day. The work is expected to be finished by the summer of 1883.

The tunnel will be 363 feet below the top of the mountain through which it passes.

This is the first tunnel ever

undertaken through the continental
divide, and upon its completion will
take its place as an engineering feat
with the Suez canal. However, tunneling