COMPRESSED AIR LOCOMOTIVES.

E. P. LORD, PITTSBURGH, PA.

Mr. President and Gentlemen:

Mining has been one of the most active means of giving prominence to compressed air. In these days of active competition and imperative demand for decreased cost of production, greater economies and improved appliances for cheapening the mining of coal have been absolutely essential to profitable mining. New fields, as soon as developed, have felt at once the necessity of installing the most approved machinery for mining, pumping and haulage; in fact, these improvements have been imperative to keep in business. The mule, which has so long been used for hauling, has been very generally supplanted by the more powerful agents, steam, electricity and compressed air. It is to the latter power as applied to the motor for haulage purposes that I intend to principally confine my remarks.

In much work—in mine tunnels, confined spaces, etc., compressed air has fully demonstrated its superiority over steam or any other power. The work accomplished with it in your own Jeddo Tunnel, at Hazelton, needs no reference to here. Early uses of compressed air hardly presaged the wonderful development and application of this power to-day. For mine haulage it is very largely supplanting the steam locomotive, with its attendant disadvantages, and now electricity is about its only competitor. Until this competition manifested itself, air was generally considered a very undesirable power at best, and in many installations, more particularly haulage, it was not thought of. I do not wish to be construed as saying that electricity and compressed air do not very frequently work in mutual harmony. Each has its own field of work for which it is singularly fitted, and where no question of competition can arise.

Electricity can be used in most cases quite successfully for haulage. It can also be used for pumping, and made a success as far as operation is concerned, but in many cases at a large

This paper was read before the Anthracite Coal Operators Association of New York, to whom the Institute is indebted for the loan of the cuts which accompany this article.

excess of cost over compressed air. But when you come to cut coal with electricity, many operators claim that no such results can be obtained as with compressed air, to say nothing about the increased cost of installation and subquent operation. I have found it extremely difficult to get any statements from those using electricity for coal cutting, and there is no doubt or question but that there are some veins of coal which cannot be cut with the type of machine which is driven with electricity that could be successfully cut with what is called the punching or pick machine. Where compressed air is superior for transmitting power for coal cutting and pumping, is it not reasonable to conclude that a good deal of consideration should be given to it for haulage?

Most of our engineers frankly admit that the electric motor is not an economical machine where the use of power is to be variable and intermittent, it being essentially a constant speed machine. If we so block an electric motor that it cannot move, a considerable current of electricity will run through, without doing any work; while a compressed air engine wastes no air or energy in starting, for air only escapes with piston movement.

The average mine engineer will usually show the liveliest interest when approached on the subject of an air haulage plant; but when he is called upon to choose between air and its very universal and most elaborately advertised competitor, electricity, no doubt he feels that the best known and understood agent is the best and safest in his case, although the compressed air plant, if successfully installed and started, might prove the most economical to his company.

I am pleased to state that in the introduction of our motor we have found in the Bituminous district the most exacting, but at the same time, most tolerant listeners to our claims for recognition; and the reports which have, and are now, reaching us from plants already installed among the operators of your region lead us to hope for and promise even greater achievements in the advancement of this simple but all-powerful agent, compressed air.

The last few years have witnessed a very remarkable development of compressors and compressed air apparatus, due no doubt quite largely to the active competition of electricity in the many fields where this power is used. The great improvement made in compressors, together with reduced cost, have led to their more extensive adoption and the enlargement of their uses. In all respects its progress has fully kept pace with that of electricity. The compressor people are now called upon to design and construct machines to develop heat and produce cold; to move air with a force only sufficient to press gold into a sensitive tooth, and to blow the shot from a cannon. There is hardly a department of any large shop or manufactory that cannot testify to the remarkable economies that this power, ingeniously applied to various mechanics, has established. There are not less than 200 distinct and established uses of compressed air—to 90 per cent. of which electricity is inapplicable; and in the remaining 10 per cent., constituting the field open more or less to other agencies besides air and electricity, we find air generally has the advantage. Except within the last few years, compressed air catalogues have been almost the only literature on this very important subject, while to-day we can hardly pick up an engineering paper without running across some article, paper or special mention of the great benefits that this new power is establishing for its recognition in the mechanical world.

COMPARISON WITH OTHER POWER AGENCIES.

Compressed air has marked advantages over any other class of haulage, in that it is free to go wherever there is a track laid; the distance run with one charge of air is only limited by the capacity of the motor tanks. Great advancement has been made in the improvements of compressors, pipe lines, pipe connections, motors, methods of charging, etc.; so that for efficiency it is admitted that compressed air runs electricity very close for a long-distance transmission. It is equally efficient and safe in fiery and non-fiery mines, and materially assists ventilation by the air given out by the exhaust. Too much stress must not be laid on this, for efficient ventilation must be provided for, in any case; but compressed air is now used for driving mining machines in rooms or in butt entries, ahead of the general work and beyond the range of general ventilation. It not only supplies the necessary power but furnishes an ample supply of fresh air, thereby materially reducing the risk to life or property. In the butt entries and rooms where ventilation has been difficult, and where, on account of low roofs, light rail, etc., other classes of power have not been introduced, the compressed air locomotive has been installed with very manifest success. It is in this class of service that we know our motor to have special claims for recognition.

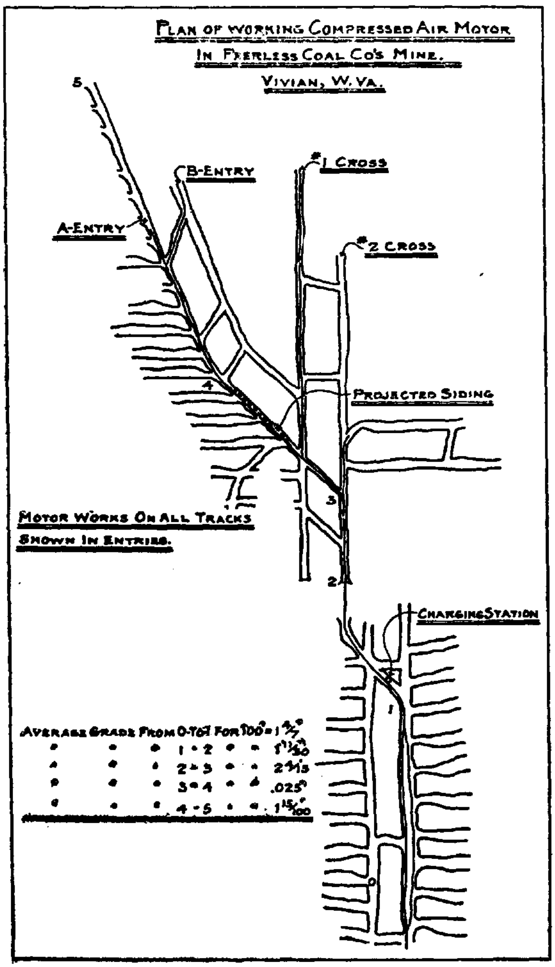
Some years ago we installed two light compressed-air motors in mines in West Virginia, the motors being of special design and to be used in gathering coal from the rooms and hauling the same along the butt entries to the main entry, where the loads were hauled out by steam locomotive. Just as this plant was about to be installed, a change was made in the management; and after several years of very nearly constant service, the present general manager, who was in no way concerned in the initial purchase of the plant, writes us quite fully in regard to the actual performance of these motors. Inasmuch as we believe the application of compressed air to motor service is peculiarly adapted to the gathering of coal from the rooms and extreme points in butt entries, we believe that any information in regard to this special class of service will be of much interest to mine operators, and we therefore take the liberty of quoting a few paragraphs from a letter recently received from the general manager of the company referred to above. He writes as follows:

"I have your favor of the 5th instant, asking if we have any available figures concerning the workings of our air-haulage plant. Not all of the information which would be of interest to you is at hand, but I hope the enclosed sketch of the underground workings of our mine, which are served by one engine at present, will contain most of what you require.

"The elevations above point of frog at end of siding farthest from the working places are shown on the blue print. By these you will note that the grade varies considerably, running from level to over 2½ per cent., and not always with the load.

"On the haulways 35-lb. rail is laid. In the rooms we use 16-lb. rail. The turnouts into the rooms are on curves of 23 feet radius, and a light switch with needle rails is laid. Frogs are cast iron. Entries are of the grades shown, and the rooms are on the strike of the vein, and therefore nearly level.

"The locomotives work in the following manner: They are charged at the point marked 'Charging Station' when work starts in the morning. They drop down to end of siding, which is shown on blue print, couple to from three to seven cars, pull them up to the upper seven rooms on 'A' entry, cutting off one at a time as they pass the mouth of the rooms, where the miner pushes them to the face of the working place. Engine then drops back to, say, room No. 13; switch is thrown and engine runs down room to where car is loaded; it is coupled to the car, pulls it out to entry, to a point between No. 12 and No. 13, where it is left. Engine drops back to room No. 12, goes in there, pulls car out to entry and couples it to one already there. Both these cars are pulled back to a point between rooms No. 12 and No. 11, where they are left, and engine goes into room No. 11, pulls out car to entry, and couples to other two and pulls them back to a point between rooms No. 10 and No. 11—and so on until a trip of three to seven or eight cars, depending on amount of air in the tank, is made up, when they are taken back to siding and engine recharged. Engine next fetches up trip of cars, depending on how many were taken down loaded, and drops an empty



at mouth of rooms visited on previous trip, the miner taking it to face of working place.

"Generally speaking, the above is the method used in handling the traffic; but there are times when local shifts have to be made, such as, for instance, when the machine must get behind the empties and push them into the headings.

"The locomotives are satisfactory for several reasons: (1) They seldom get off the track, even though some of the places they run over are not of the best surface and line. The car will leave the rails oftener than the engine. (2) They are rapid, and can when necessary be run at a high rate of speed, say ten to twelve miles per hour. (3) They can do shifting fast—and there is plenty of it to do. (4) They have considerable reserve power, so that when working on sand it is possible to pull an unusually heavy load when necessary. (5) They are inexpensive as regards repairs. (6) They do the same work as mules can do.

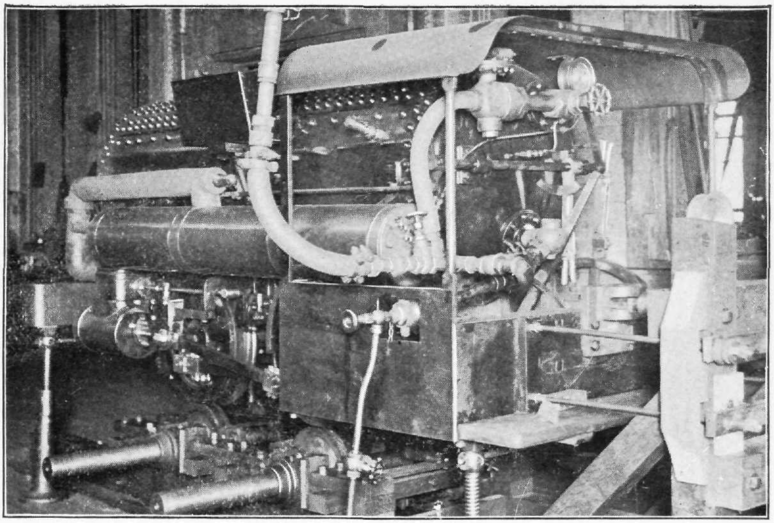
"The best record as to tonnage with us is to deliver from 'A' and 'B' headings, and the first 13 rooms shown on blue print, to the main siding, 140 gross tons in three hours. This includes weight of cars.

"I am glad to advise that during the time the plant has been in service, there has never been an accident which injured property or persons. * * * * *

"The repairs which are required are such that any mechanic can make. Any person who knows a steam engine knows the air motor.

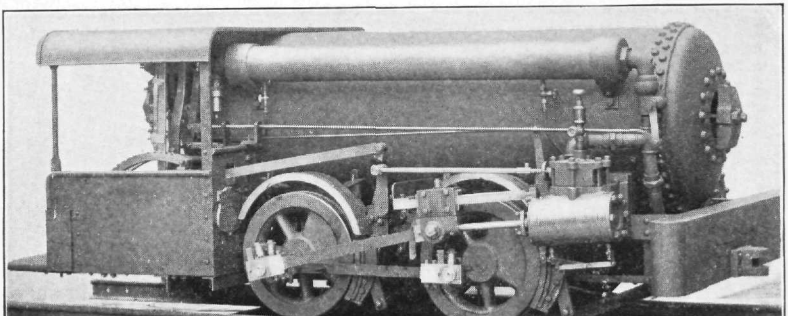
"While we have never had the whole plant worked to its fullest capacity, we feel that installing it, first in the field, we have made no mistake."

A general description of this engine is as follows: Cylinders, 5 inches in diameter by 10 inch stroke; four driving wheels, 23 inches in diameter; weight, about 10,000 lbs.; tank capacity, 47 cubic feet of air at 600 lbs. maximum charging pressure; height, 53 inches; width, on 44 inch gauge of track, 5 feet 8 inches; length over all, 10 feet 5½ inches. This locomotive was designed for working on butt entries, as outlined above; running into the mine rooms, taking three loaded cars to the main entry and returning with three empties; weight of each loaded car, 8,500 lbs. Each locomotive was to make three round trips per hour, the length of the round trip varying from 4,500 to 9,000 feet. Rail, 16 lbs. per yard; curves, 24 feet radius (15 feet curves are practicable). A 3 inch diameter pipe was used to connect the compressor to the charging station; the pipe line serving as a storage reservoir. This company purchased electric mining machines, but adopted compressed air instead of electricity for haulage, on account of its greater convenience, economy and adaptation to the service required.



LOCOMOTIVE FOR THE ANACONDA COPPER MINING CO.

ON TESTING STANDS IN THE SHOPS OF H. K. PORTER & CO.



LOCOMOTIVE FOR PEERLESS COAL AND COKE CO., VIVIAN, W. VA.

SAFETY.

Safety is no doubt the first consideration in mining, and a careful study of reports of inspectors of mines of various states, as well as those of foreign countries, clearly shows that more explosions occur in non-gaseous mines, or in mines where a limited amout of gas has previously been detected, than in mines known to be producers of large volumes of fire-damp. Certainly such a condition of things emphasizes the importance and necessity of applying every precaution that is reasonable as to price and has been proved practicable for the protection of life and property. With electric haulage the danger of sparking of brushes on the motors, rupture of the cables conveying the current and the contacts made in cables and switches, is very manifest. Even at a low voltage it is possible to obtain a very severe shock, while with a 600-volt circuit, on a damp floor or in water, the results might be very serious. Fatal accidents are not of rare occurrence, and even with extreme care and caution accidents are very apt to occur. We note one case where a miner was killed while taking a rail into a mine; and when near the room where he worked, he lifted the rail to his shoulder and started to carry it. One end of the rail coming in contact with a live wire, the man was shocked to death. We have another case before us, where a miner was killed while climbing into a car, when the back of his head touched the wire. There are many other cases with which no doubt you have been made familiar. The very active competition among electric companies furnishing electric motors for mine haulage, has no doubt militated against the introduction of plants having a proper margin of power to secure the best results. The competition has been very severe, and the tendency has been to install plants altogether too light for the requirements of the service, resulting in the plant being driven to its utmost, causing over-heating of motors, failures, etc. Economy in the use of lighter wires for conveying the current has necessitated an increase in voltage, which introduces still another element of danger.

Aside from the question of safety, compressed air recommends itself for many practical advantages, such as moderate cost of plant and installation, due to the absence of any overhead wires or obstructions; economy of operation, secured by durability of construction; convenience and simplicity of operating and management; minimum risk of delay from breakdown or derangement; exceptionally low cost of maintenance; safety, due to the large factor of safety of all parts subject to strain, and the practical impossibility of over-charging; the absolute absence of fire, thereby enabling it to be used without the slightest risk, where steam or electricity is equally objectionable; cleanliness and quietness with which it can be operated, and flexibility, adapting it to almost any requirements. Again, it can be adapted to any varying requirements of service, so that the entire plant can be run economically at only a fraction of its full capacity, no more power being generated than is needed for the work to be done. We recommend the installation of a plant under the direction of one of our engineers; but when once properly installed, no skilled mechanic is required to maintain and inspect the same, in order to be satisfied that the plant is in condition to perform its work promptly and without delay.

Steam power is the origin of compressed air and electricity, alike. It is the cost of maintenance, depreciation, operating, repairs, etc., as a transmitter and distributor, that should be considered. Air being a perfect gas, is not subject to the losses of condensation like steam, although of course subject to some loss, during expansion, from contraction due to fall in temperature. All air-driven machines undoubtedly run longer, and with less leakage and repairs, with compressed air than with steam,—on account, no doubt, of the absence of heat and better lubrication.

Compressed air locomotives are designed and constructed for a very wide range of service. Some of the principal uses are as follows:

Underground haulage in mines, both coal and mineral, and whether worked by shafts or slopes, hauling trains through tunnels and city streets, transporting material at industrial establishments, such as powder mills, lumber mills, paper mills, cotton mills, warehouses, cotton shipping plants; also, various manufactories of an extra hazardous nature, where there are any special fire risks; general haulage, where fuel is expensive and water power available; street railways in large cities.

The air for mine locomotives is stored in one or two steel tanks having a cubic capacity designed for the length of run, weight of train, grades, etc. These tanks usually occupy the space that the ordinary boiler does on the steam locomotive. They are constructed with a large factor of safety, and are tested to a much higher working pressure than they are designed to carry; the tanks that are to carry 600 lbs. pressure we test to 1,000 lbs. hydraulic pressure. The air from the main tank or tanks is conducted through copper pipe connections to an auxiliary reservoir of suitable diameter. The pressure in this auxiliary tank can be regulated anywhere from 30 up to 300 lbs., as required. The air is reduced and controlled from the main tanks by a specially designed reducing valve and stop valve, which can be regulated to any pressure at a moment's notice; and when once set, maintains a constant, fixed pressure (usually 150 lbs.) in the auxiliary reservoir, thereby preventing any undue waste of air, unnecessary slipping of driving wheels, etc., by injudicious handling. In case only light loads are to be handled, the pressure can be materially reduced in the auxiliary reservoir, thereby securing a decided gain in economical use of the air. On the other hand, in emergencies where increased power is required, the higher pressures can be at a moment's notice utilized. In the auxiliary reservoir the air is controlled and delivered to the cylinders by specially designed differential throttle valve. The port openings in the cylinders are specially designed for the use of air, and there is absolutely no back pressure in the cylinders, no matter at what load the engine is working, and no trouble is ever experienced from the freezing of the exhaust. All fittings are screwed into large cast steel flanges, riveted to the tanks, securing very great depth of thread and increased strength. A manhole is provided at one end of tank, reinforced with heavy cast steel ring. No cast iron is used in any fittings subject to high pressures. We test all our motors in the shop, running them with the full complement of tank pressure, supplied by a three-stage compressor.

The actual cost of operating the first plant we installed in the Anthracite region was found to vary from 1 to 1¼ cents per ton, mile net weight hauled, including all expenses, interest and depreciation of plant. The saving by the use of compressed air over mule haulage being equal to the entire cost of plant in 2¼ years, averaging 204 working days each. One locomotive being used to only one-half its capacity, and the other about one-fifth of its capacity. To operate both motors to their full capacity, and also the compressor, would add very little to the steam, lubrication, repairs, etc., but would reduce the cost of operating even below these very low figures.

Mr. J. H. Bowden, Chief Engineer of the Susquehanna Coal Company, in a report remarks as follows:

"Compressed air haulage, of which this is the first example in the Anthracite region, has much to recommend it, being cheaper than wire rope haulage, except perhaps under the most favorable conditions for the latter, and very much more flexible, as a locomotive has a considerable radius of operation beyond the charging stations, and can run anywhere on the tracks without previous preparation, provided only that there is sufficient room for it. Extensions of pipe line are easily and cheaply made.

Absolute freedom from fire puts it beyond comparison with electric haulage or steam locomotives in gaseous mines—and, indeed, anywhere where avoidance of danger from fire is of importance."

Charging stations are all metallic, as shown on drawing, consisting of heavy cast iron tee, extra heavy gate valve, with metallic flexible couplings, bleeder valve and screw joint, which couples to a similar screw joint on the locomotive.

In installing a compressed air plant the most important items of installation are the boilers, compressor, pipe line, charging station and motor. The size and capacity of these various units depend upon the physical characteristics of the mine and the required output in tons of coal per day. Upon the number of times that the motor is to receive a full charge of air per hour, is based the capacity of the compressor, while the pipe line serves as a storage reservoir for storing up air while the motor is in service. The pipe line should be of such diameter and length as will give a cubic capacity of air at a certain pressure, sufficient to equalize immediately in the tanks of the motor when connection by couplings is made. In the old principle of installation pipe lines were not generally used, but large, expensive air receivers were substituted, and the motor generally took its charge of air from them direct, and then made its round trip, charging again at the end of the same. But in all plants as at present installed, we recommend the laying of pipe lines of a certain cubic capacity; the size and length of pipe depending largely upon what points in the mine it is necessary to reach in order to arrange charging stations so that the motor can conveniently receive its charge of air without any delay.

We find that there is an erroneous idea that considerable time is lost in charging a compressed air locomotive; while in fact the largest motors which we have constructed can be brought to a standstill, the couplings made and broken, and the full charge of air received, in a minute to a minute and a half.

After the pipe line is once installed it ordinarily requires no extensions if additional locomotives are purchased; the only essential being to have compressor capacity sufficient to charge the original line to its full pressure a greater number of times, in order that the additional motors when taking air may always have sufficient to charge the tanks to the full complement of pressure. Therefore it will appear clear to you that the first installation provides for a very large extension of plant, with additional outlay of only what is required to possibly increase the compressor capacity and purchase the additional motors.

The pipe line gives flexibility; the motor making a single or round trip with one charge of air; we never having found it necessary to arrange for charging in the middle of a run.

The quality of pipe, character of its connections, charging fittings as regards tightness and safety, cannot be given too careful attention, and should always be delegated to the engineer whose experience and knowledge in such installations is the proper guarantee of satisfactory results. Simplicity in design, with absolute correctness; safety and ease in operation are requisites in all properly installed plants; but, like every good device, these results cannot be assured except by much care and experimenting.

Below is a list of a few of the different types of compressed air locomotives which we have designed and installed:

Two 7 x 14, class B motors, Susquehanna Coal Co.: 5 feet, 3 inches wheel base, 36 inch gauge, 130 cubic feet capacity of motor tanks; weight in running order, 18,500 lbs.; length over all, 17 feet, 6 inches; width, 5 feet, 2 inches; height, 5 feet; working pressure, 600 lbs. This locomotive hauled a trip of 16 empty cars (about 2,500 lbs.) from foot of shaft, 3,700 feet into gangway, and trips of 16 loaded cars (each with about 6,700 lbs. of coal), back to the shaft, with one charge of air; starting with a pressure of 575 lbs., and ending with a little over 100 lbs. The heaviest work is hauling empty trips up grade. Average grade, 1.07%; maximum grade, 2.8%, favor of loads. The weight of each empty trip with 16 cars, including locomotive, is about 60,000 lbs.; and of a loaded trip, including locomotive, 166,000 lbs. This locomotive makes from 25 to 50 miles per day, depending upon the length of the run and the time required for making up trips. At 20 trips per day, the output amounts to about 1,070 tons, and with one motor. Approximate cost of such a plant, all complete, $12,000 to $14,000. This includes cost of compressor house and foundations and material for same; all steam connection; 6,000 feet of 5 inch pipe, 4,000 feet of 3 inch pipe; compressor and two locomotives.

We have recently completed for The Rochester & Pittsburgh Coal and Iron Co., two 9½ x 14, class C locomotives, having 5 feet, 6 inches wheel base; 6 drivers, 26 inches diameter; weight, 28,000 lbs. in working order; capacity of the two motor tanks, 187 cubic feet of air at 600 lbs. maximum pressure; height, 5 feet, 3¾ inches; width over front bumper, 74 inches for 42 inch gauge; width over tanks, 72 inches; length over bumpers, 19 feet, 5¼ inches. These locomotives are designed to run on 30 and 35 feet radius curves, and are to run on a 25 lb. rail, which they can do very safely. Where the rails are light we recommend a six-wheel type. The locomotives are of our recent design, and have given exceptionally satisfactory results. They are running a distance of 6,000 feet on butt headings, or 12,000 feet, round trip, with one charge of air. They are hauling over a 4% grade with empties weighing 1,600 lbs. each, and 22 to 28 cars per train; cars holding about 2 tons each. Total weight loaded train, including locomotive, 92 tons. The first locomotive we built for these people, in 1892—a very crude machine compared to our present design—runs 5,900 feet from place of charging, with empties, and return with loads, making round trip of 11,000 feet with one charge of air and hauling 22 cars each way.

We have also completed the installation of a number of plants in the Anthracite territory, notably two 7 x 14 class B motors, for the Mill Creek Coal Co.; one 10½ x 14 for the Cross Creek Coal Co., Drifton, Pa. Plants recently completed in the Bituminous districts are, one 8 x 14 Class B motor for The Mount Carbon Co., West Virginia; and the Carbon Coal Co., Greensburg, Pa., one 8 x 14 class C motor.

We built a 5 x 10 class B motor for a large copper mining company in Montana, which had a 3 foot wheel base, and designed to run on curves of 12 feet radius; for 18 inch gauge; four drivers, 23 inches in diameter; weight in working order, about 10,000 lbs.; 47 cubic feet of air, 550 lbs.; height, 58 inches; width, 58 inches over cab; length over bumpers, 10 feet, 4½ inches. This motor was equipped with re-heater, and we made a special test of the same in our shops in order to ascertain the relative efficiencies when working under cold and hot air.

The economies of compressed air haulage are best obtained by using the air expansively in the cylinders. The tendency is usually to work a motor up to its highest practical capacity, allowing the air to follow the piston the greater part of the stroke. This means decreased expansion in the motor cylinders and less efficiency than could be obtained with larger cylinders and greater expansion of the air. It is very essential that the total weight of the motor in working order should be somewhat in excess of what is the general custom with steam locomotives, inasmuch as there is always at hand a higher pressure than the working pressure, which can be utilized, provided a fair margin has been allowed for weight on drivers. It is our custom to make our engines considerably heavier than is ordinarily followed in locomotive construction generally. Not only does the frictional resistance of mine cars frequently run extremely high, but greasy and wet rails, poor line and surface are disadvantages which very largely contribute to the slipping of locomotive drivers, and emphasize the great importance of not depending upon too low a co-efficient for weight of motor to tractive force of same. For best results we have assumed that the tractive force must be equivalent to one-fifth the weight of the motor, although in the minutes of your meeting, February 1, 1897, I estimate the pull required of a 6½ ton electric motor to be 3.82 per cent. of the weight—certainly much too low, according to experience.

It is a very common, but no less erroneous, opinion that on account of the intense cold produced by the expansion of air in the motor cylinder there is naturally a closing of the exhaust due to frost. We have never experienced this trouble in either shop tests or regular service. It has been observed that the higher the air pressures have been, the less liability there is to freezing. Air at low pressures when exhausted will be cold enough to freeze whatever moisture there is in it. The same is true of air at high pressure. But to get the same power from low pressure air, very many more cubic feet must be used. The temperatures being equal and the moisture depending on the volume, with the low pressure we have passed through the motor more moisture.

One cubic foot of air at 600 lbs. pressure in the motor tanks, when distributed by the reducing valve in the auxiliary tank through 6 cubic feet of 100 lbs. pressure, is only one-sixth saturated.

Indicator cards from air locomotives show a very economical and perfect distribution of the air; the back pressure line being identical with the atmospheric line on the card, due to the large exhaust opening; while with the steam locomotive we frequently have a back pressure varying from 5 to 20 lbs.

SIZE OF MOTOR AND ENERGY REQUIRED FOR STATED TRAINS ANDLENGTH OR RUN.

METHOD OF CALCULATION.

In order to determine the proper size of motor, and tank capacity for the same, it is in most cases necessary to figure out the energy required in foot-pounds for doing the work. The factors entering into this calculation are:

1st. Frictional resistance—usually 20 to 40 lbs. per ton, depending upon the condition of track and rolling stock.

2d. Grade resistance—20 lbs. per ton for each one per cent. of grade.

3d. The curve resistance, depending upon the length and sharpness of curves.

4th. Weight of empties and weight of load; daily output in given pounds, and most desirable size of train.

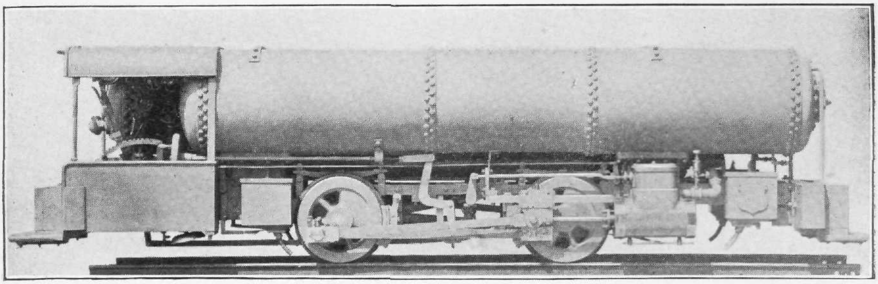
Having determined the weight of train, the daily output and the severest conditions of grade, etc., the size of motor required, the next point to determine is the size of storage tanks on motor, sufficient for making certain round trips between charging points with one charge of air. From this it will be seen that in order to make a correct estimate of what is necessary to meet the requirements of the service, we should know the grade and conditions for each varying section of track.

Regarding the limitations of pressure which it is safe to carry on mine motors, we would state that for mine service there are very few motors at present built for a pressure higher than 700 lbs. per square inch. When long runs are necessary between charging points—say, 1½ to 2 miles, it becomes necessary for the usual size of mine motors to carry a higher pressure in the motor tanks—say, 750 to 800; and we are prepared to build such tanks, that are equally safe with the ones with the lower pressure.

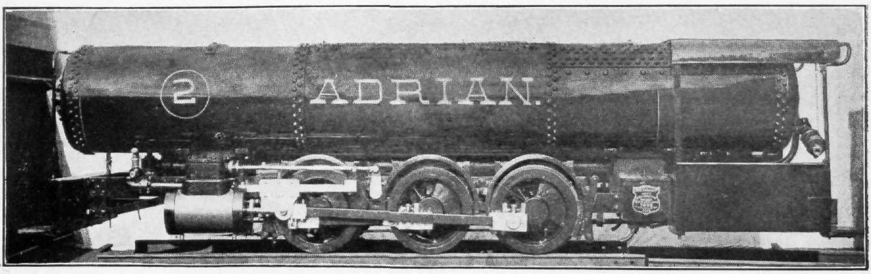
In connection with these higher pressures, it is often possible to heat the air, in order to obtain the greatest possible work from them. This heating can be done either by direct heater, or by injecting steam into the auxiliary tank while the motor is charging with air. When the auxiliary tank is employed as a heater, it is from a half to two-thirds full of hot water and steam, and the air made to pass through the same on its way to the throttle and cylinders. Again, the moisture taken up by the air when heated by hot water helps materially to lubricate the cylinders and valve surface. We have several designs and devices for heating the air direct, using coke or oil as fuel; and the simplicity of these devices we think should certainly recommend them for most careful consideration where the heating device can be used without danger or risk in non-fiery mines. Heat supplied to hot water is used five times as efficiently as an equal amount of heat employed in generating steam. It requires comparatively little heat to raise the temperature of air rapidly. If air at normal temperature in a pipe line is re-heated, and thereby expanded, the additional volume of air resulting from the expansion is produced by an expenditure of heat much lower than the original volume of air was compressed for, and by a much lower expenditure of heat than is required to produce an equal volume of steam.

PIPE LINES.

Air leakage is less dangerous than electric leakage. But with the marked advancement which we have made in the laying



LOCOMOTIVE FOR SUSQUEHANNA COAL CO., NANTICOKE, PA.



THREE-DRIVER TYPE OF LOCOMOTIVE.

of pipe lines for high pressures, the element of leakage has been almost wholly eliminated. Where the matter of the specifications, purchasing and installing of pipe lines are left to us, we see that the purchaser takes no risk, but provide him with what we know to be safe and most economical for his purpose. Our shop facilities have enabled us to make most exhaustive tests of all the different pipe connections, fittings, etc. Those that we have finally accepted have been put to much more severe air tests than they can ever receive in actual service.

Air in passing through pipes is subject to friction in the same manner as water or any other fluid. Frictional resistance in pipes conveying fluid are proportional to the density of the fluid; consequently, at equal velocities, the frictional resistance of air is enormously less than that of water. Air may be transmitted in mains, without serious loss or fall of pressure, at ten to twenty times the velocity practicable with water in water mains. Air at 90 lbs. is 115 times lighter than water, and frictional resistance at equal velocities is less than one per cent. of that of water. In air mains velocities of 25 to 50 feet per second are allowed without serious frictional loss. In consequence of this high velocity, large amounts of air power can be transmitted by air at moderate pressures in pipes of moderate dimensions.

In the installations we have made, we have never found it necessary to recommend anything above 6 inches in diameter; 5 inches has been the size of pipe most utilized, and as low as 2 and 3 inches. We have found that in pipe lines of a mile or over, the difference in pressure at both ends has been hardly appreciable. The fact that while the motor is doing its work the pipe line is receiving its full complement of air from the compressors, indicates that any loss from friction does not militate against the motor, inasmuch as the capacity of the pipe is such as to always give to the motor its full pressure of air when necessary; the cubic capacity of the pipe line being such as to equalize almost instantly with the motor tanks. Any loss due to friction in charging up the pipe line would only be indicated in the increased resistance in delivering the air from the compressors.

COMPRESSORS.

In selecting a compressor for a haulage plant, the first question to be settled is whether the mine has already installed a low-pressure compressor system; and in case this compressor system represents a surplus in power, it frequently occurs that a small two-stage compressor can be utilized as a locomotive charger, taking the air from the mine system instead of from the atmosphere. This materially reduces the cost of installing a locomotive charging compressor. In this connection, however, it is well to state that in many mines where the air used for the locomotive is a large percentage of the air supplied for the general mine system, great care should be exercised on the part of the engineer to satisfy himself that the amount of air in excess of what is required to operate the general mine system is at all times sufficient for supplying the locomotive charging compressor. Unless he does this trouble is very apt to occur. Say, for instance, the locomotive compressor is designed to take air at 80 lbs. and compress it at 800 lbs. If the pressure of air in general mine system is allowed to decline, as might happen, the locomotive compressor might be getting its supply of air, at times, at pressures say as low as 35 to 40 lbs., sometimes even lower; and in order to compress the air from these very low pressures to 800 lbs., a greater amount of heating might be developed, and a temperature close to the flashing point of the oil used might be reached, and with considerable danger. Therefore we believe that it is better for high pressure machines to be so designed as to take their air from the atmosphere, unless the installation, as stated above, is in connection with a large and liberal supply of air to the mine system. In case the low-pressure system is already worked to its capacity, and it is thought well to install independently a system of compressor and pipes for the haulage, we usually recommend two, or, preferably, a three or four-stage compressor, taking the air from the atmosphere and compressing it to the required storage pressure in the mine pipe line. Where the air is to be compressed to these high pressures necessary to pneumatic haulage installations, we recommend the use of the compound principle of compression. Single compressors, which have been quite largely used for delivering air at low pressures, have an increasing resistance with the advance of the piston, and increasing temperature of the air, and it is quite necessary to equalize in some manner this vast difference in pressure. The compound compressor secures more uniform resistance at all points of the stroke, and is by far the most economical and efficient machine for mine service. With a single compressor the temperature of the air has at times been found to be as high as 400 or 500 degrees.

In the test made of the compressed air installation of the Susquehanna Coal Co., the air from the three-stage compressor—taking air from the atmosphere and compressing it to 600 lbs.—was only 18 degrees at the point of discharge. This shows the manifest benefits of compounding and proper intercooling. Some of the best designed three-stage compressors, compressing to 2,200 lbs. pressure, the air, after undergoing the three stages of compression, shows a final temperature after leaving the last or high pressure cylinder, of 336 degrees; this with the temperature of the intake air at 60 degrees. We know of observations, also of records of ordinary compressors for compressing air to mine pressure of about 80 lbs., where the temperature of the discharge from the second or high pressure cylinder was 224 degrees, with 82 degrees temperature of inlet; and another case, when compressing to 65 lbs. pressure, the intake temperature was 52 degrees, and the final discharge 180; also, with intake air temperature at 30 degrees, and discharge temperature of 120 degrees, and air pressure 80 lbs. Of course, we have seen cases where the temperatures were much higher than the above; but it has generally been due to insufficient cooling surface or faulty construction.

The value of proper cooling attachments is that they effect a direct saving of the power required for compression, and by keeping the parts cool, assist largely in maintaining thorough lubrication.

When we know that by heating air to 325 degrees we can increase the efficiency of our motor some 40 to 50 per cent., one realizes the loss that is incurred when the compressor delivers its air to its pipe line or receivers at a temperature approximating the above. It certainly behooves every careful operator when considering the purchase of compressors to be particular in making his specifications clear in the matter of securing proper cooling of the air before it is delivered for service in the mine. Five thousand pounds is the limit of pressure for compressors to-day, and manufacturers are prepared to guarantee their machines to work at this tremendous pressure with the same ease and efficiency as the lower pressures of 600 and 700 lbs.

There has been some little discussion going on of late, more particularly in the magazine "Compressed Air," on the subject of explosions and fires in air compressing engines and air receivers. In every case the cause of explosion or ignition is unquestionably due to an increase of temperature above the flash point of the oil which is used to lubricate the compressor. Thin oils, with high flash point, and as free from carbon as is consistent with good quality, should be used; but, unfortunately, a mistaken idea of economy often is responsible for the use of thick and cheap grades of cylinder oil, which are in no sense suitable for the purpose, and give anything but economical results, besides introducing an element of danger which is not appreciated, possibly, until after some serious trouble occurs. We believe that the cases that have occurred in general practice have been wholly confined to the single acting compressors, where the matter of cooling and proper distribution of work is not so manifest, and not the compound type. If compound compression was specified for all mine pressures above 60 pounds, the result would be low temperatures and better results. We know that if air is admitted at 60 degrees Fahrenheit, and is compressed without cooling to 73½ gauge pressure, the final temperature will be 414.5 degrees Fahrenheit, and the total increase of temperature 354.5 degrees. Where suitable oils are used under these conditions, and there is still ignition at temperatures apparently in excess of what we can directly account for, there are no doubt other agencies at work which are responsible for the increase of temperature necessary for ignition. Taking the air in at high temperatures, from engine rooms, etc., instead of from low temperatures, outside, is unquestionably a very bad condition; but we are inclined to believe that some of the trouble may be traced to a manifest increase in the temperature of the incoming air, which is made excessive by the sticking of one or more of the discharge valves, thereby allowing some of the hot compressed air to flow back into the cylinder, and in that manner influencing the temperature before compression. It has been pointed out that the discharge passages or discharge pipes in course of time will accumulate a deposit of carbon from the oil, which will so constrict the passages that the volume of air delivered to the compressor is much impeded. Such cases may occur, but with proper designs and proper care an operator need not apprehend danger from cylinder explosions. Only very recently, in starting up and making final trial of a compressed air plant, we did find that the cheapest and poorest quality of oil had been used for lubricating the compressor, and in such amounts as to cause the sticking of the inlet and discharge poppet valves. The compressor was receiving its intake air through a much reduced area. And consequently there was dissatisfaction on the part of the operator, who claimed that it was taking several hours to pump up the final pressure of 850 lbs. Our engineer immediately located the trouble, and in a few minutes' time had cleaned out the poppet valves, which were sticking, and in less than forty minutes had pumped up the full complement of pressure—indicating at once that even on newly installed plants ignorance or carelessness will be responsible for inefficiencies, which probably in many cases are unexplained except possibly in some such manner as outlined above. Many engineers running compressors treat an air compressor with the same kind of logic that they apply to other machinery. If there is heat, he reasons there must be friction, and the compressing air cylinder is accordingly dosed with oil, resulting in useless waste of oil and a paving of the way for possibly much more serious trouble later on.

Compressors of recent design have embodied in them one feature which certainly is worth careful consideration, and that is, that when the locomotive compressor or charge is not operating as such—say during the night—it can be used in the capacity of a low pressure machine, for furnishing air of low pressure for the general mine system. This conversion of a high pressure into a low pressure machine is accomplished in a very short time and with very little trouble.

EFFICIENCES.

With the increasing use of compressed air motors in mine service there is stimulated an inquiry regarding their efficiencies. By the word "Efficiency" we mean the percentage which the power given out by the motor bears to the power required to compress the air in the compressor. The ultimate power developed at the motor is frequently a small percentage of the power expended. In very many cases the losses are due to poor designing and faulty installation, and cannot be directly charged to faults of the system or bad workmanship. If we were to make a careful test of a compressed air mine plant, including the indicating of the pumps, hoisting engines, drills, etc., we might be surprised at the low horse-power resulting, as compared to the indicated horse-power of the compressor. We might arrive at an efficiency as low as 25% to 35%, which would perhaps appear unfavorable and misleading, did we not take into consideration the manner in which the power is used. Indicator diagrams from almost all the pumps in use would take the form of a perfect parallelogram, with a terminal pressure equal to the initial pressure, and when the exhaust lets go the pressure of the air would fall in a straight line to atmospheric pressure, and the refrigeration would be tremendous. This condition of things is also very true in the hoisting engines or drills. Of course, these machines would use steam under the same wasteful conditions, and would show a correspondingly poor efficiency if compared with the same volume of steam used expansively in an economical engine. As one writer states it, "the only intelligent way of making comparisons of the efficiency of the air system would be to compare volumes, and not horse-powers." The air locomotive uses the air expansively, and its efficiency is correspondingly increased.

As regards the losses that are frequently chargeable to a compressed air plant, one compressor builder very concisely expresses them as follows:

"1st.—Friction of compressor—amounting ordinarily to 15 or 20 per cent.; never probably reduced below 10 per cent. 2d.—Loss occasioned by pumping air drawn from the engine room instead of from the outside or some other cooler place. This loss varies with the seasons, the amounts varying from 3 to 10 per cent. This can all be saved. 3d.—Serious losses arise in the compressing cylinder. Insufficient supply, difficult discharge, defective cooling arrangements, poor lubrication, and no end of other causes perplex the designer and rob the owner of power. The fourth loss is found in the pipe line. No leak can be too small to require immediate attention."

By adopting recent designs, with all the latest improvements, the cubic feet of air compressed per hour per horse-power has been raised from 264 to 367—a decided advance. The power can be transmitted, say at a pressure of 60 lbs., to two miles distance with an efficiency of 50 per cent. on the indicated horsepower of the compressor engine; this without re-heating. By heating the air this efficiency may be raised to 70 per cent. This is a very good result, particularly when one considers the fact that compressors have the advantage over electric generators, inasmuch as they can be run all the time at full load, owing to the ease with which the air may be stored.

In actual tests which we have made of pneumatic motors, under most adverse conditions, we have been able to show efficiencies between 30 and 40 per cent. with cold air. Again, we have demonstrated in our shops by actual test the number of foot-pounds of energy that can be developed by one cubic foot of hot air and one cubic foot of cold air. These figures, which we have demonstrated by actual practice, we are gratified to state, have checked up very closely with what we had assumed to be correct in most of our calculations in making estimates on inquiries received.

When it is understood that compressed air motors carrying 600 to 750 lbs. of air can run a distance of from a mile and a half to three miles, according to physical conditions of mine, and with one charge of air, the question is often asked why higher pressures cannot be used with economy, so that the motor may never require to charge except at one most convenient point in the mine system. As stated before, riveted tanks of large diameter cannot be made with a guaranty of safety for pressures much above 750 lbs. per square inch. If we were to resort to higher pressures, say 1,500 to 2,500 lbs., we would have to substitute Mannesmann tubing for the tanks at present constructed. This means much increased cost, as the price of this tubing, now made only in Germany, is very high. And again, a proper storage system, either in pipe line or receivers, would be necessary in order to charge the motor promptly. Therefore there would be no saving in cost of installation. Where the height of entry is limited, high pressure motors as above could be used advantageously, but at an increase in first cost. They could be constructed to meet the same limited heights as electric motors.

Mannesmann tubing is now being used very generally for storage reservoirs and storage receivers in street car service, and tubes of 9 inches in diameter, having a thickness of shell of 11-32 inches, are carrying 2,000 to 2,500 lbs., and are certified to have been tested to over 4,000 lbs. before shipment. Tubes of this character have been tested to a point of rupture at a pressure of over 8,000 lbs.

When people understand the very large factor of safety which has to be carried in all compressed air apparatus, and the very thorough and careful tests which should always attend its manufacture, we are satisfied that they will concur with us in the statement that compressed air when intelligently applied is not only the safest and cleanest, but the most reliable agent that is used to-day. Fifty-five cubic feet at 2,000 lbs., re-heated, is propelling street cars to-day a distance of from six to twelve miles with one charge of air, encountering grades, etc.

Before concluding, I believe it would be of some interest for me to read a letter received, under date of August 18, 1895, from one of the foremost general managers in the soft coal districts of Pennsylvania, and to whom we sold the second air locomotive which was constructed and operated in this country.

"I would state that as far as my observation goes,—and also an experience of eighteen years, I consider compressed air far superior to electricity for operating mine machinery; and I know of but one or two instances where I would be tempted to supplant compressed air with electricity. The best results are obtained, of course, where one can use the power transmitted for the greatest number of purposes. Electricity can be used in most cases quite successfully for haulage; it can also be used for pumping, and made a success, as far as operation is concerned, but at a very large excess of cost over compressed air. But when you come to cut coal with electricity, no such results can be obtained as with compressed air, to say nothing about increased cost of installation and subsequent operation. In other words, I consider compressed air will successfully cut coal, and pump water, and haul coal cheaper than electricity, and can be furnished for very much less money to begin with, and operated with much more economy for all time afterwards. Another point: even where the grades may be such on certain headings in the mine that a locomotive, neither electric or pneumatic, could not be successfully employed, the pneumatic locomotive can be used on low grades; and having the mine equipped with air, it is perfectly practicable to put in small anchored haulage engines, driven by compressed air, right inside the mine, and use rope haulage on these air engines.

"Our pneumatic locomotive furnished by you has been a success, and furnishes a very economical and cheap haulage. We have had no trouble with the performance of the regulating valve, and it has maintained the pressure under varying pressures in the storage reservoir, and the reduction of the air pressure has not resulted in any trouble from freezing."

It has been the purpose of this paper to place before you to-day an impartial and unprejudiced statement of the manifest advantages and economies which we believe should be credited to the use of compressed air for haulage purposes. We have endeavored to emphasize some of its best features, as well as calling your attention to some details where we believe improvement can be made. With all the plants we have so far installed, we have generally had to meet in competition the electric companies; and what we have accomplished in the way of securing orders has never been by misrepresentation or endeavoring to prejudice an intending purchaser in our favor when we fully believed that possibly electricity was better adapted to the most economical results in operating his mine. There are unquestionably conditions to-day that can be met with greater economy by electrical installation than by compressed air; but with the advancement that is being so rapidly made in the designing of compressed air motors, we believe that even this slight difference in the adaptability of both powers to all conditions of service will be soon dissipated.

Compressed air is no longer an experiment; it needs no apologist. Without numberless engineers who have made it their special business to exploit and apply it, it has steadily advanced in its field of usefulness; meeting the crucial test of competition; standing to-day as one of the most efficient agents for the establishing of economies which are so essential to the prosperity of shops, mines and other industries. We have not been driven to the wall, as a few of our contemporaries would have you believe; nor are we making unreasonable claims that the application of compressed air for your needs in the mining industry is what is going to sell for you your coal. We only ask that what we advocate shall secure your attention and careful consideration; for what we have to offer is an applied power, which may possibly be better adapted to your special needs than electricity or any other energy, and has only waited for a chance to be fairly presented before you. Conservative operators and capitalists who have held aloof, we trust will follow the example of others equally progressive, and adopt it. We wish to reach those who will admit that what we have to offer is no experiment, but a well-tried, well-applied and established power.

PRESIDENT RAY: You have heard an able paper on Compressed Air Locomotives. Are there any questions you desire to ask, or any points to be cleared up?

MR. STRAWN: What is the speed with which it can be run in the haulage of coal?

MR. LORD: There is no limit to the speed, any more than with the steam locomotive. You can duplicate the speed of the steam locomotive under any conditions. As far as operating goes, any boy or man can be instructed in ten minutes how to use it. He cannot abuse his machine, because everything is controlled automatically, as far as pressure goes. The pressure is increased or decreased by moving the regulator.

PRESIDENT RAY: In installing a haulage plant on this system, in which, for instance, the locomotive is to haul to the bottom of a shaft from the main points, would you provide a place to charge the locomotive at each end?

MR. LORD: That would depend upon the length of the haulage. In making the installation in the first place, if the distance is half to a mile and there is not an excessive grade, you would charge the motor at the shaft and make the round trip. In case of extensions, it is more economical to put in a pipe line, even if you do not want to charge at both ends. To put in receivers, it will cost as much, and may cost more. I always advocate the pipe line independent of any other line for driving any other automatic machine.

PRESIDENT RAY: In case of a mine machine and haulage being run with compressed air, you would have a separate line for each?

MR. LORD: I would not unless the haulage is extensive. I would put in a reducing valve, if there are three or four machines. In regard to the pipe line, the question of leakage is often brought up. I will say if the line is installed properly, this element of leakage will cut scarcely any figure at all. If I superintend the installation, I will be willing to guarantee no leakage. In a five inch pipe line I recommend a grade of pipe between common pipe and extra heavy pipe, tested to 15,000 pounds; connection made by an extra heavy wrought iron sleeve, recessed at both ends so if there is any leakage after the line is installed there will be place for calking. I have a piece of pipe here gotten up for this special purpose, and it shows this principle clearly. The sleeve is of extra heavy wrought iron with a recess here (indicating). We use copper or lead for calking.

MR. LOVE: In running a locomotive with compressed air under a pressure of five or six hundred pounds, what would be the tendency, if any, to freeze the cylinders of that locomotive?

MR. LORD: As I stated before, the tendency to freeze is most manifest when you get below a hundred pounds. In shop tests and regular service we never notice much ice until it gets below a hundred pounds. I have never had any trouble with freezing in locomotives, and I have made many inquiries among operators to find that out. Nobody has reported failure or embarassment on that account. I think it is only manifest in low pressure service, mining machines or pumps. Why, I do not know, unless they are poorly designed. Freezing is only caused by a precipitation of moisture and if the air is dry when it goes into the compressor there is no trouble of that sort.

MR. WILLISTON: Do you take any precautions to have the air dry?

MR. LORD: Under the old system of compressing, the air was cooled in the cylinder. Now, it is all done by inter-coolers and jackets, which secures greater efficiency in inter-cooling. I do not know of any special means of drying when it goes into the cooler, but I think the method of cooling gives dry air.

MR. PALMROS: You spoke about a locomotive made by your people of 27,000 pounds which pulled 24 empty cars. What was the approximate speed in climbing that grade?

MR. LORD: That is not stated. It has only been in service three or four weeks. I would not imagine the speed is over six miles an hour, that is, with that load. This is merely a guess: I could not say positively. I expect to have positive information on that point in a week or two.

MR. PALMROS: Did I hear right, that the car weighed five or six hundred pounds empty, or fifteen hundred?

MR. LORD: That weight was about forty tons, I think, the total weight. That motor you speak of was built about six years ago, and I have a copy of Mr. Robinson's letter which I might read an extract from which will explain that more clearly. (Reading.) "We run the engine 5,900 feet from the place of charging to where it gets the load. The mine cars weigh fifteen hundred pounds and we haul twenty-two of them up considerable grade and deliver them at the point of starting."

MR. PALMROS: Assuming six hundred pounds, that would be nine tons total weight, at six miles an hour,—an electric locomotive will haul twice or three times as much.

MR. LORD: I would like to say in regard to those figures, the motor is not really in service yet. That is the guarantee as to what the locomotive will do, and we would be very much disappointed if it did not do a good deal more. As far as locomotives are concerned, we can haul just as much as you can with a steam locomotive, and very likely a little bit more, because the weights run a little more for the diameter of the cylinder than for a steam locomotive.

PRESIDENT RAY: Would it be practical to use electricity for cutting coal and this for hauling coal?

MR. LORD: I see no objection to it at all. There was a plant installed in West Virginia of that character,—the electric plant for cutting coal and pneumatic haulage were installed at the same time. Now, for the same company, we are figuring on quite a large pneumatic installation for a large colliery in the Anthracite region. It has been decided to put in a compressed air installation in this mine although it is in a gaseous mine.

PRESIDENT RAY: Do you say that you are already installing plants in which the two systems are used?

MR. LORD: We are figuring now on a number of plants where they are using electricity, figuring on putting in compressed air haulage. The one mentioned is the only plant now installed of that character.

SECRETARY HASELTINE: After you have charged your boiler with compressed air to five, six or seven hundred pounds pressure to the inch and started on a trip, and after you have exhausted half the air in that receiver, how do you maintain the pressure on the remaining half to the point at which you started?

MR. LORD: If you have six hundred pounds in the receiver, we have what we call our auxiliary tank about seven inches in diameter, and in passing into the auxiliary tank it goes through a reducing valve, so that when the pressure is two hundred in this tank it is still one hundred and forty in the auxiliary tank, etc.

SECRETARY HASELTINE: As long as the pressure is above the valve set, you have increased pressure on the main boiler?

MR. LORD: Yes, sir. Below that it reduces on each side of the valve in proportion to the pressure on the main receiver.

SECRETARY HASELTINE: It strikes me to be a most excellent motor for gathering the coal in the rooms and delivering at a common center.

MR. LORD: I think there will be developments in that special line of work, because it will go where the smallest mule will go and where a mine car will go and stay on the track and will run on wooden rails. These motors run all the way from eight to ten thousand pounds. In regard to matter of repairs, there is little to wear out and it is very economical in that way. The repair account is hardly worth considering.

MR. STRAWN: One thing in connection with use of compressed air in mining, I think is not appreciated, and that is the improved sanitary condition of the men by the use of it; carrying the compressed air right into the workings instead of the ventilation as it oftentimes exists.

MR. BEATTIE: As regards any improved condition of the ventilation by the use of air machines in coal mines, I cannot see where there is any improvement as the air coming from the machines after being used is in such a contaminated condition that it is really an injury to the air.

MR. PALMROS: Mr. Lord, taking the same conditions, comparing compressed air to electric or rope haulage, how would the prices or first cost compare, not considering depreciation or repairs?

MR. LORD: In reply to that question, I will state that a year or two ago it was my impression that the first cost of a compressed air installation was slightly in excess. Of course, we had the benefit of figuring upon slightly decreased cost in future extensions. But I had reason only a month ago to make two propositions on very large haulage plants, involving three or four compressed air motors of the largest size and very extended pipe lines, and the engineer in charge passing on the bids advised me that I was a little bit lower than the proposition received for electric installation. I was a little surprised to hear it, but I think with the advancement made in the building of motors and compressors to-day, we can meet almost any competition. There might be certain mines where the compressed air system would be slightly more expensive. In regard to rope haulage, of course it is generally cheaper and I do not think we could compete with rope haulage.

No desire for further discussion of this subject being evidenced, Mr. Love moved a vote of thanks be extended to Mr.

Lord for the valuable paper presented by him. Motion seconded; carried.

PRESIDENT RAY: The next paper provided on the program is one by Mr. Andrew Roy. Mr. Roy, however, we are very sorry to learn, is ill and not able to be present; but the paper will be read by his son, Mr. C. F. Roy.