Compressed Air Haulage

Compliments of H. K. Porter Co.

Compressed Air Haulage

System of

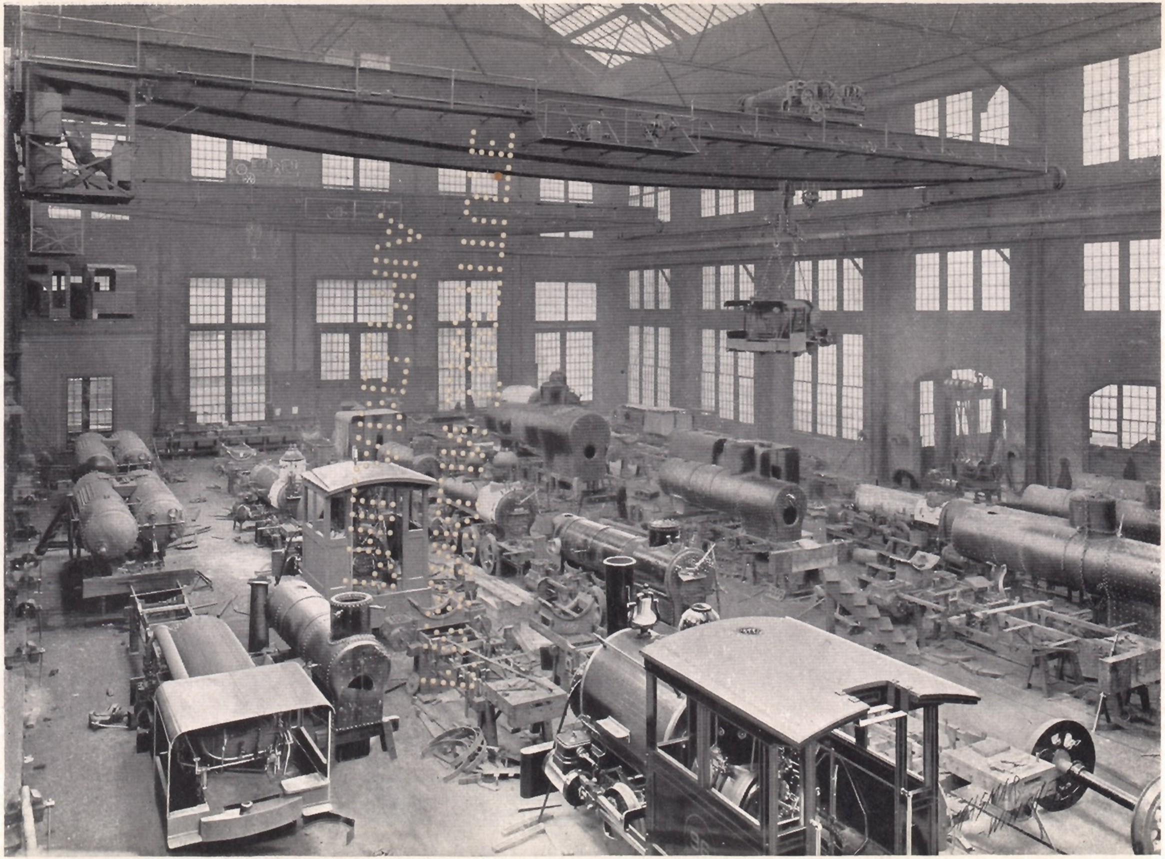
H K Porter Company

Builders of

Light Locomotives

Steam and Compressed Air

Pittsburgh Pennsylvania



One end of erecting floor showing air and steam locomotives under construction and a small air mine locomotive on the crane

H K Porter Company

Office: 541 Wood Street

Works: 49th Street and Allegheny Valley Division of Pennsylvania Railroad

Pittsburgh Pennsylvania

Builders of

Compressed Air and Steam Locomotives

Manufacturers of

Reducing and Stop Valves, Charging Stations, Storage Tanks, Pipe Flanges, Elbows and Tees, etc., for use in connection with Compressed Air Locomotives.

Designers of and Contractors for

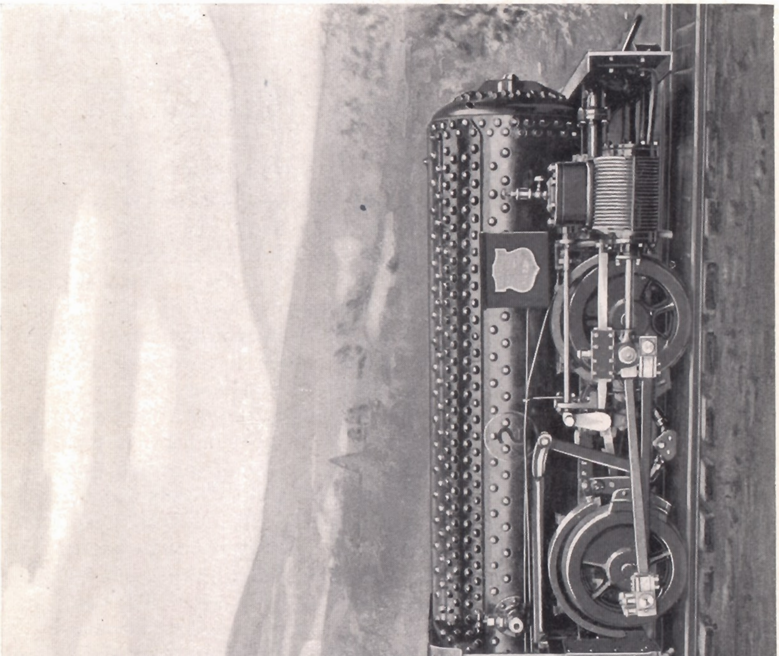
Complete Compressed Air Haulage Plants, inclusive of Locomotives, Compressors, Pipe Lines, Storage Tanks, Charging Stations and all necessary fittings and valves.

Compressed Air Haulage

As Installed by

H K Porter Company Pittsburgh Pa

COMPRESSED air locomotives were first built by H. K. Porter & Company in 1890. The original firm to which the H. K. Porter Company is successor began building light steam locomotives in 1866. These early compressed air locomotives were crude in many respects, but many of them are still running regularly and doing good work. In 1895 compressed air locomotives were built having all the essential features of our most recent productions. Since that time many practical improvements in details have been made, among which may be mentioned an increased pressure in the main storage tanks, and an improved type of automatic reducing and stop valve for maintaining a uniform pressure at the throttle valve. Not only the locomotive, but the compressor, pipe line, charging stations, valves and fittings have all been subjected to a most searching scrutiny, with a view to eliminating any defects which experience has developed. The Ingersoll-Sergeant Drill Company and The Norwalk Iron Works Company are to-day building compressors for pressures as high as 600 to 2,500 pounds per square inch, with the same certainty of obtaining the desired results as in any other department of their business. The governing devices, valves, lubricators, intercoolers, water jackets and all other details have been gradually improved in the light of past experience. We are therefore exceptionally well prepared to submit estimates for complete installations, including compressed air locomotives, charging stations, pipe line or other system of stationary storage, and compressor, and to state the amount of steam or other power which may be required. We offer to our customers the advantage of dealing with one competent concern which stands behind the entire equipment, ready not only to replace within a reasonable time any parts which shall show defects other than those due to ordinary wear and tear and carelessness in handling, but also to guarantee an installation well proportioned in all its details and fully up to the required capacity. Having built about four times as many compressed air locomotives as any other builder, we have been justified in making greater expenditures in equipping our shops with special tools, and of giving our engineers special training for this class of work. Special tools mean good workmanship at minimum cost. Experienced engineers insure proper materials, good designs and successful adaptation of means to ends. The demand for compressed air locomotives has been so far beyond our most sanguine expectations that we have again been compelled greatly to increase our facilities. In view of the practical results already obtained, we feel justified in claiming that the compressed air locomotive has passed the experimental stage and now stands as one of the well established means for the transportation of materials in and about industrial works and mines of all descriptions. We urge our customers to satisfy



Typical gathering locomotive. One of five in use at Cambria Mining Company's Atelope Mine, Cambria, Wyoming themselves in regard to our equipment by inspecting our past installations, and by examining the locomotives under construction in our shops and the systems and methods there employed. The more thorough your examination of all the various systems of haulage, including our own, the better we consider will be our chances of obtaining your business.

The Field for the Compressed Air Locomotive

We have obtained most satisfactory results with compressed air locomotives under a great variety of conditions. We have built them for gauges of track varying from 18 to 56½ inches, for grades from level up to 10 per cent., for curves as sharp as 15 feet radius, and for trains varying from a few thousand pounds to four or five hundred tons, and for hauls varying from a few hundred feet up to three miles. Our underground installations include haulage plants for anthracite and bituminous coal mines, both gaseous and non-gaseous; for main haulage work with heavy trains, and also for the lighter work of gathering coal from the working faces in single cars and light trains. For surface work we have installed our locomotives not only in places where a reduction of the fire risk was an important consideration, as at woodworking plants, lumber yards, magazines for storage of explosives, and powder yards, but also at points where the fire risk introduced by the use of steam or electric locomotives was unimportant, and where compressed air locomotives were adopted because of their general utility, economy and reliability, as, for instance, at malleable iron works, gas works, copper reduction works and mills for the refining of precious metals.

The above statements serve to indicate what has been done, but we feel that the field of the compressed air locomotive is capable of being still further extended, and that as it becomes better known to the engineering world, its use will become more and more general. Our installations include small plants with single locomotives and larger plants with from six to thirteen locomotives operated from one central power station. We have installed them at coal mines, where fuel was a secondary consideration, and the crudest type of steam engine was used to drive the compressor, and at points in the far West where fuel was very expensive and the highest type of compound condensing engine was used for the generation of power.

Essential Features of a Compressed Air Haulage Plant

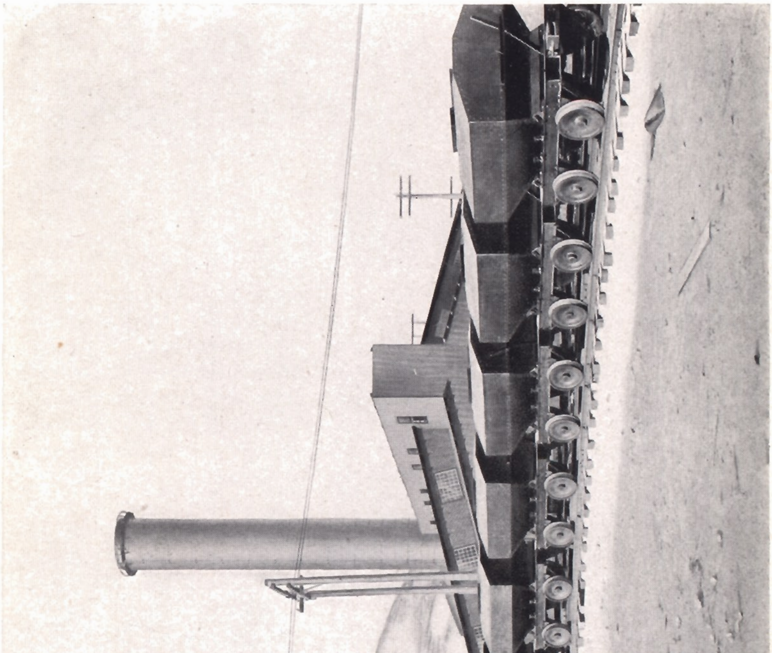
1. One or more compressed air locomotives of proper design and capacity to suit the conditions.

2. One or more air compressors of sufficient capacity.

3. One or more charging stations.

4. A storage system (usually a pipe line) of suitable capacity and properly designed to admit of placing charging stations at convenient points.

5. Last and most important, all parts must be properly combined to form a satisfactory working plant as a whole.



One of thirteen in use at Anaconda Copper Mining Company's new reduction works, Anaconda, Montana.
Size 9½ x 14 inches. Class B-PP. Weight, 27,000 pounds.

Some Advantages of Air Haulage

RELIABILITY.—A haulage system that can be depended upon to work all day and every day in the hands of workmen of ordinary ability, is a reliable system. Other qualities are desirable, but reliability is a necessity. In developing our system of haulage by compressed air locomotives we have kept the vital importance of this quality constantly in mind, and have never lost sight of it in our efforts to reduce the selling price and secure a high mechanical efficiency.

Persons not practically familiar with air haulage frequently have the impression that serious difficulty is to be anticipated from freezing in the exhaust passages of the locomotive. Compressed air locomotives have been used for thirteen years, and no such difficulty has developed. This difficulty is suggested by the freezing which frequently occurs when air is used at lower pressures. With the higher pressures used in connection with locomotives this difficulty is eliminated, as practically all of the moisture is squeezed out of the air in the process of compression and deposited in the stationary storage or in the tanks on the locomotive, where it can be drawn off at convenient times. The outside of the locomotive cylinders and valve chests becomes cold and frequently coated with frost, and the exhaust, when it comes in contact with the outside air, condenses moisture in it, producing an appearance similar to that of low-pressure steam, which almost immediately disappears; but there is no moisture in the working parts of a compressed air locomotive, and if a suitable oil is used there is nothing inside the locomotive which can be frozen.

As compared with all other systems, the machinery of a compressed air haulage plant is simple, strong and accessible, with the power limited by the design, and hence capable of being worked up to its full limit without danger of breakage or liability to the frequent temporary delays which are so annoying in connection with the operation of many of its competitors.

ADAPTABILITY.—Compressed air locomotives are more easily operated than steam locomotives, as the skill necessary to preserve a steam boiler in proper condition is entirely eliminated. Compressed air locomotives are an everyday working success, with all the good features of the electric storage battery locomotives, and some others of their own, in that the tanks do not deteriorate as the batteries do, are not injured by shocks or excessive demands for power; they are compact, and can be built to conform to any ordinary limitations of height and width, as, for instance, in any place where mules can be used. Our compressed air locomotives are capable of running from 3,000 to 15,000 feet with one charge of air. These distances may be more than doubled by the use of a tender carrying an additional supply of air. A locomotive can easily be charged in from one to two minutes, and with charging stations located at convenient points, the radius of action for the locomotive with one charge of air is abundantly large for mining and industrial service, and there are no overhead or underfoot obstructions corresponding to the trolley wires of the electric system or sheaves of rope haulage.

These features make compressed air locomotives exceedingly convenient for industrial service in mills and manufactories where traveling cranes, belts and other machinery render the location of the trolley wires for electric haulage very difficult. The fact that compressed air locomotives carry a considerable supply of energy with them makes this system the ideal haulage for gathering coal from the working faces in mines, and it is, in our opinion, the only mechanical power that can do this work successfully. The experiments with storage battery electric locomotives in this service have not been very encouraging, and the "cable-reel" device, to the mechanical mind, seems very much in the nature of a makeshift. The compressed air locomotive will run wherever rails are laid, and will operate successfully on steeper grades than are practicable with steam or electric locomotives. Moreover, they may be worked for an indefinite length of time up to their full capacity without danger of injury, which is not true of the electric locomotive, as all electric locomotives are built with motors which depend for their continued existence upon frequent periods of rest in which to cool off.

Repair Accounts and Operating Expenses

The repair account of a compressed air locomotive is less than that of a steam locomotive, since all the boiler repairs of a steam locomotive are eliminated. This, combined with the less expensive men required to run them, has been a sufficient reason for the adoption of compressed air locomotives where a number were to be operated from one central power station. A comparison of the cost of repairs for compressed air locomotives and electric locomotives is decidedly in favor of the air. (This matter is treated more fully a little further on.) As compared with rope haulage it is nearly always less, but the life of rope and sheaves is so dependent upon the straightness of the haul and upon atmospheric and other conditions that any general comparison is impossible.

The cost of operatives (locomotive runners and trainmen) for compressed air locomotives is lower than for any other system. It is a mistake to trust good machinery of any sort to ignorant or careless men, but high-priced expert labor is unnecessary in connection with the air locomotive. Experience has proved that where mules are replaced by our air locomotives, it does not take long for a mule driver to become a satisfactory locomotive runner.

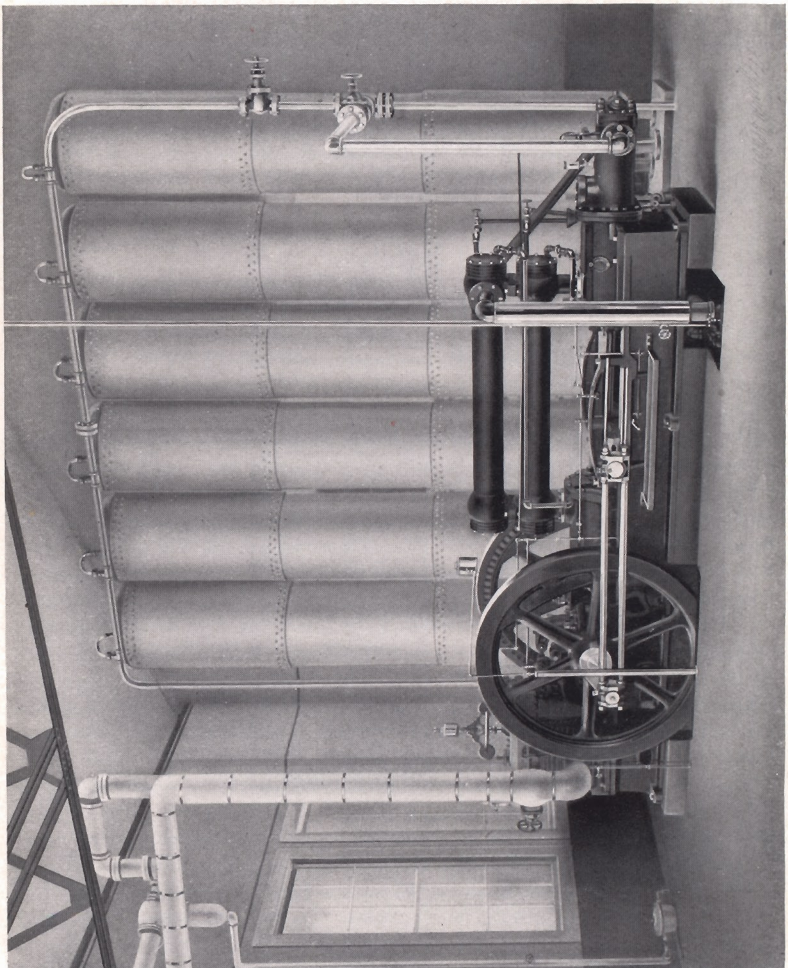
The compressor is self-regulating and runs at moderate speeds, so that the man in charge can easily attend to other duties in the same or adjacent buildings. The compressor is not subjected to the sudden variations of load so troublesome in connection with the operation of the generator for electric haulage, as the locomotives when in operation are independent of the compressor, and there may be one or ten charged by one compressor, and yet by virtue of their independent action after charging all can be starting heavy trains at the same instant without in any way affecting the continuous operation of the plant. Compare this statement with the following quotation taken from an article written for one of the prominent mining journals by a gentleman identified with one of the largest manufacturers of electric locomotives in the United States.

"Annoying delays are often experienced at mine haulage plants where there are several locomotives, due to the frequent 'blowing' of the circuit breakers. It is proper, of course, that the circuits should be automatically opened when the generator is called upon to deliver a current beyond its safe capacity, but it is annoying if the service is interrupted with too great frequency. The remedy for this trouble also lies, to a very great extent, in the hands of the motorman, as the intelligent use of the controller will minimize the demand upon the generator. This trouble is aggravated by the simultaneous starting of all of the locomotives when the circuit breaker is reset by the engineer at the power house, since each locomotive requires a comparatively large current when starting, and the sum of their starting currents is often sufficient to immediately blow the circuit breaker again. In this way it often happens that the entire haulage system may be interrupted for a half hour or more. The engineer occasionally becomes righteously indignant, allows the circuit breaker to remain out a few moments before resetting it; and the relations between the employes of the power house and the motormen become strained, with no good results to the company."

Safety

The economy, adaptability and reliability of air haulage deserve due weight in the choice of a haulage system, but under many conditions the positive safety of a compressed air locomotive, as compared with any known form of motive power, should be decisively in its favor. As a matter of history, an examination of the records shows no deaths or injuries which can be in any way attributed to defects or weaknesses of this system. There are at the present time between 50 and 75 air haulage plants, each with one to thirteen of our air locomotives in everyday service, so that our claim that air haulage is safe is based upon a considerable mass of evidence. The high pressures used in connection with this system may seem to the uninitiated rather dangerous; but if the same factor of safety be maintained for 800 to 1,000 pounds pressure as is maintained with 80 or 100 pounds pressure, and if in addition the material used is not subjected to the injurious influences of fire, scale and corrosion, there is no reason why 800 to 1,000 pounds should not be as safe as 80 or 100 pounds; and the result of an explosion with 800 to 1,000 pounds of air is not as dangerous as would be the case with 100 to 150 pounds of steam, as the air may bruise but it will not scald. If electric haulage could be made as safe as air haulage, or if air haulage had resulted in one-quarter as many deaths as has electric haulage, we feel certain that the facts would have been most thoroughly ventilated in the engineering and mining press. Even as it is, the claim is set up that while contact with an electric wire carrying 500 volts may sometimes be fatal to horses and mules, it is not fatal to men. The official records, however, show that this statement is unquestionably false, and conservative managers are now insisting upon a maximum limit of not over 300 volts wherever naked wires are to be employed with which men may accidentally come in contact. During four years, in ten collieries—mostly operated by one company—and all in one district of one State, eighteen men were killed by the electric shock. We have no data as to how many men during the same time may have come in contact with the wires and escaped with their lives.

Electric wires and machinery above ground, and more particularly under ground, are liable to derangements which may easily develop



Compressor and storage tanks furnishing power for locomotive at Iona Island, N. Y.

enough heat to start destructive fires. It would be difficult to overestimate the losses within the past few years due to this cause. Electric sparks, either from the trolley or at the commutator, will set fire to mine gas just as quickly and certainly as would the flame of a lamp or match. The statement has been made that more fires have been started by miners disobeying orders than have been started by electric apparatus, and doubtless this is true; but it would be a very reckless mine operator who would use the presence of one danger as a justification of neglect to remove another danger.

In closing the discussion of this feature of compressed air locomotives, we make the following brief quotations from the report of the Bureau of Mines, Department of Internal Affairs of Pennsylvania, for the year 1899, page XIII:

"Besides the increased danger from explosive gases, other elements of danger have been introduced into the mines by the use of mining machines and electricity. These have been introduced during the past ten years, and it is the opinion of the writer that the use of electricity in any form in coal mines is a menace to life, limb and property."

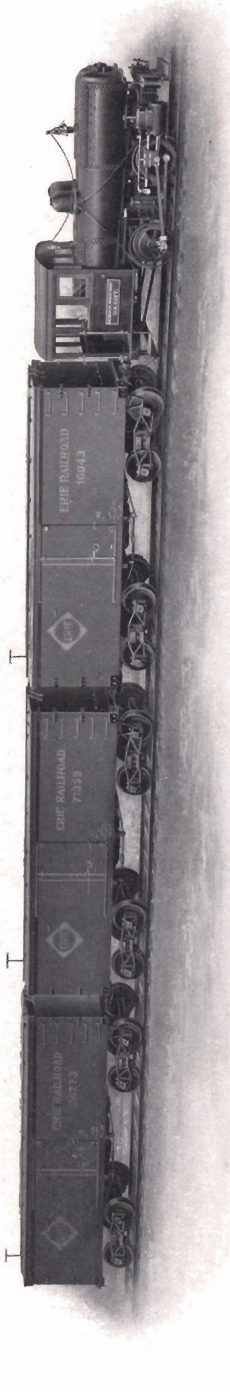
In the report of the same Bureau of Mines for the year 1901, on page 3:

"Electricity is one cause of fatalities in the bituminous mines (seven having lost their lives through it in 1901) that so far has not proved fatal to any person in the anthracite mines. Electricity in various forms has been the cause of many deaths in the soft coal mines, either from the men coming in contact with the electric trolley wire or with the electric wire that carries the power to the electric cutting machines. In my opinion separate traveling ways should be provided for the workmen when the haulage is done by electricity, unless the wires can be raised to a distance of at least six feet from the rail, and even then there should be sufficient room for passing on the main haulage roads at all points, as men cannot always reach the 'safety holes' in time. In every case where electric machines are used for cutting coal, the wires should be made absolutely safe, as men in the hurry of their work forget about the 'deadly wire,' touch it, and all is over, and the report follows, 'killed by an electric shock.' Humanity demands protection for the workingmen from this most deadly agent recently introduced and employed in the coal mines. I hope the time will come when 'compressed air,' 'liquid air' or some other agent will supplant electricity in coal mines, but this will not take place until the necessary power can be generated as cheaply as by electricity. In gaseous mines electric cutting machines or electric motors should never be permitted in use, as otherwise sooner or later they will be the cause of a great catastrophe."

In the report of the same Bureau of Mines for the year 1902, on page 4:

"Again I wish to enter my solemn protest against the use of electricity in the coal mines of this State, unless wires can be so protected as to prevent its being a menace to life. Had I authority, I would prohibit its use in any form in gaseous mines, as it is my firm belief, if the use of it is not prohibited, that sooner or later there will be a terrible loss of life from this cause. Seven lives were lost from this cause in 1902 and the same number in 1901, making fourteen lives sacrificed from the use of this deadly agent in two years. This adds another to the great number of perils incident to the mining of coal."

Other extracts could be made from the reports of the Bureau of Mines for the above and other years, which give frequent instances of



This locomotive is in service hauling explosives, shells, etc., between railroad siding and magazines of the United States Government, at Iona Island, N. Y. Duplicate plant at Lake Denmark, N. J.

deaths caused by electricity. The mine inspectors of the various districts are competent men, with no reason for condemning electricity or favoring compressed air, other than their observation of the two systems in operation.

As a contrast to the dangers of electricity, no accident was reported from the use of compressed air. On the contrary, a number of instances are cited where the presence of compressed air has been the means of preserving life. In mine explosions as many lives are lost as the result of "afterdamp" as are lost at the time of the explosion itself. The explosions frequently cause falls, which cut off the miners from the shaft, slope or other exit from the mine, and it is in these cases that the pipes have been instrumental in saving life, the miners either opening the valves or breaking the pipes to obtain a supply of fresh air, which could not reach them in any other way. The air pipes may also be used to carry water in case of fire, thus avoiding the delay incident to laying special lines to get the water where it is required.

SUMMARY

Electricity	Compressed Air
Has killed many and cannot save life.	No deaths reported and a number of lives saved.
Is a frequent cause of fires and of no assistance in putting them out.	Cannot cause a fire, and the air lines may be used for water to put out fires.
Is prohibited by law in mines where locked safety lamps are used.	Absolutely safe in gaseous mines and in powder mills.

Two-Tank Four-Wheel Compressed Air Mine Locomotive

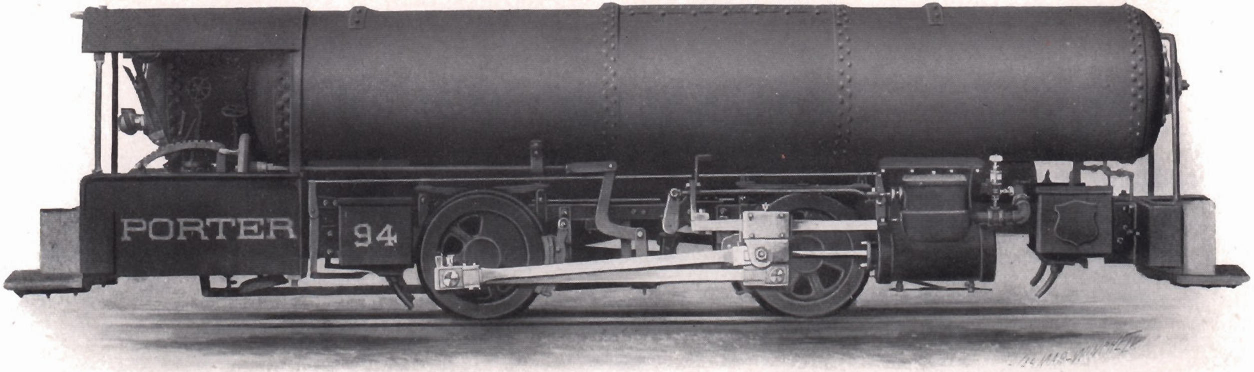


ILLUSTRATION NO. 94. CLASS B-PP

SEVEN SIZES, each with **code word,** of the above design are described on the opposite page, and the principal dimensions, weight, power and other particulars are given in the column assigned to each size. We are prepared to build other sizes, and to construct these locomotives for any practicable gauge of track and size of entry. The dimensions of the locomotive, the pressure and the capacity of the tanks are in every case adjusted to the height and width of the entry, length of haul, grades, loads and working conditions, and a suitable reserve is provided for emergencies. These locomotives run very steadily, pass sharp curves easily, and surmount as steep grades as are practicable for any locomotive on ordinary rail. Two inches clearance between the highest point of the locomotive and the lowest place in the entry is abundant, as the height of the locomotive cannot increase, but will decrease a trifle by the wear of tire and journal brasses.

CODE WORD	PIPIZO	PIPRIS	PIROTE	PISAVI	PITOIT	PITYUS	PIULCO
Cylinders, diameter, inches	6	7	7	8	9	10	11
Cylinders, stroke, inches	10	12	14	14	14	14	14
Diameter of driving wheels, inches	23	24	24	24	26	26	28
Wheel-base usually desirable, feet and inches	4-0	4-8	5-3	5-3	5-3	5-9	5-9
Usual length over bumpers, feet	12 to 14	14 to 16	16 to 18	16 to 19	17 to 19	17 to 20	18 to 21
Usual length of tanks, feet	10 to 12	12 to 14	14 to 16	14 to 17	15 to 17	15 to 18	16 to 19
Usual diameter of tanks, inches	24 to 26	26 to 28½	28½ to 31¾	28½ to 31¾	31¾ to 34½	31¾ to 34½	34½ to 38½
Extreme width at tanks, inches	52½ to 57	57 to 62	62 to 69	62 to 69	69 to 77	69 to 77	77 to 85
Excess of width at cylinders over gauge of track, inches	24½	26	26	28	30	32	34
Extreme height least desirable, feet and inches	4-6	4-9	5-0	5-3	5-3½	5-5	5-8
Approximate cubic feet capacity of tanks	60 to 80	100 to 120	120 to 140	140 to 170	160 to 190	180 to 220	200 to 240
Maximum tank pressure usually advisable, pounds	800	800	800	800	800	800	800
Approximate weight in working order, pounds	12,000	16,000	18,000	22,000	26,000	32,000	37,000
Weight per yard of lightest rail advised, pounds	20	25	30	30	35	40	40
Radius of sharpest curve advised, feet	25	30	35	35	35	50	50
Radius of sharpest curve practicable, feet	15	16	20	20	20	25	25
Maximum pressure per square inch usually desirable for auxiliary reservoir, pounds	140	140	140	140	140	140	140
Tractive force, pounds	1,860	2,915	3,400	4,440	5,190	6,410	7,200

Single-Tank Four-Wheel Compressed Air Mine Locomotive

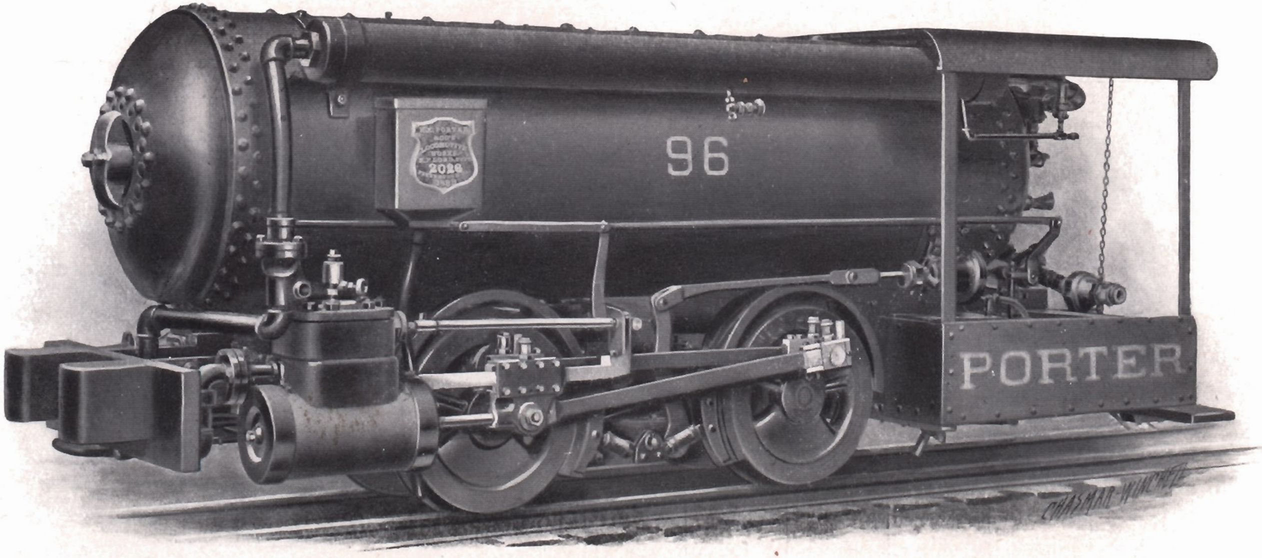


ILLUSTRATION NO. 96. CLASS B-P.

FOUR SIZES, each with **code word,** of the above design are described on the opposite page, and the principal dimensions, weight, power and other details are given in the column assigned to each size. We are prepared to build other sizes, and to construct these locomotives for any practicable gauge of track and size of entry. The smaller sizes are especially adapted for extremely narrow gauges, say 18 to 24 inches, usual for gold, silver and copper mines. The dimensions of the locomotive, the pressure and the capacity of the tank are in every case adjusted to the requirements and conditions. These locomotives run very steadily, pass sharp curves easily, and surmount as steep grades as are practicable for any locomotive on ordinary rail. Two inches clearance between the highest point of the locomotive and the lowest place in the entry is abundant, as the height of the locomotive cannot increase, but decreases a trifle by the wear of tires and journal brasses.

CODE WORD	PLAGAL	PLAKAT	PLANXI	PLATON
Cylinders, diameter, inches	6	7	7	8
Cylinders, stroke, inches	10	12	14	14
Diameter of driving wheels, inches	23	24	24	26
Wheel-base usually desirable, feet and inches	4–0	4–8	4–8	5–3
Usual length over bumpers, feet	12 to 15	15 to 17	17 to 19	18 to 21
Usual length of tank, feet	9 to 12	12 to 14	14 to 16	15 to 18
Usual diameter of tank, inches	31½ to 40	33 to 40	33 to 40	33 to 42
Excess of width at cylinders over gauge of track, inches	24½	26	26	28
Extreme height least desirable, feet and inches	4–8	5–0	5–3	5–6
Approximate cubic feet capacity of tank	50 to 60	75 to 85	80 to 90	85 to 100
Maximum tank pressure usually desirable, pounds	800	800	800	800
Approximate weight in working order, pounds	10,000	15,000	17,000	20,000
Weight per yard of lightest rail advised, pounds	20	25	25	30
Radius of sharpest curve advised, feet	25	30	30	35
Radius of sharpest curve practicable, feet	15	16	16	20
Maximum pressure per square inch usually desirable for auxiliary reservoir, pounds	140	140	140	140
Tractive force, pounds	1,860	2,915	3,400	4,100

Two-Tank Six-Wheel Compressed Air Mine Locomotive

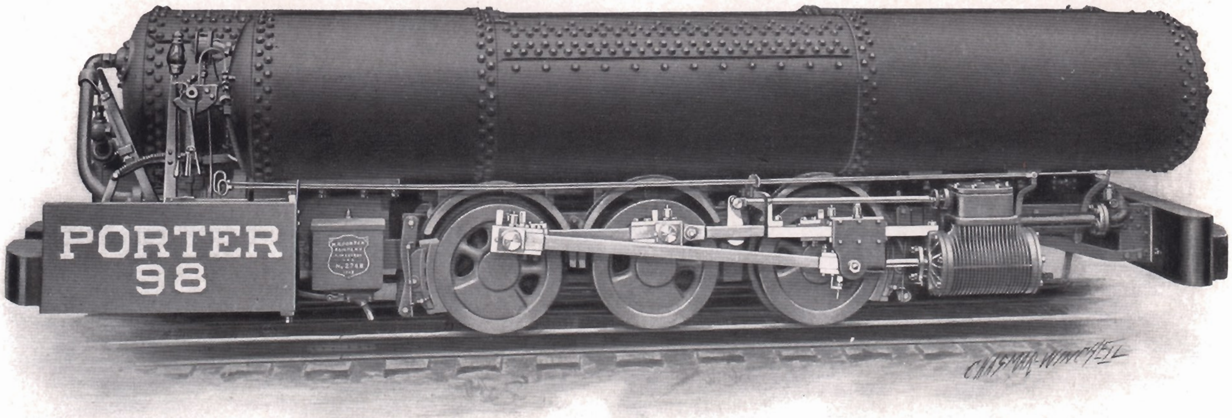


ILLUSTRATION NO. 98. CLASS C-PP

SEVEN SIZES, each with **code word**, of the above design are described on the opposite page, and the principal dimensions, weight, power and other details are given in the column assigned to each size. We are prepared to build other sizes, and to construct these locomotives for any practicable gauge of track and size of entry. The dimensions of the locomotive, the pressure and the capacity of the tanks are in every case adjusted to the height and width of the entry, length of haul, grades, loads and working conditions, and a suitable reserve is provided for emergencies. These locomotives run very steadily, are very easy on the rail, pass curves easily, and surmount grades as steep as are practicable for any locomotive on ordinary rail. Two inches clearance between the highest point of the locomotive and the lowest place in the entry is abundant, as the height of the locomotive cannot increase, but will decrease a trifle by the wear of tires and journal brasses.

CODE WORD	PLAUSO	PLAZOS	PLESSO	PLEURA	PLEYON	PLIADE	PLIGHT
Cylinders { diameter, inches	7	8	9	10	11	12	13
Cylinders { stroke, inches	12	14	14	14	14	14	16
Diameter of driving wheels, inches	22	23	24	26	26	28	30
Wheel-base usually desirable, feet and inches	4–8	5–0	5–6	5–6	5–6	6–3	7–0
Usual length over bumpers, feet and inches	17–5	17–5	19–5	19–5	19–5	21–6	24–0
Usual length of tanks, feet	14 to 16	14 to 16	16 to 18	16 to 18	16 to 18	18 to 20	20 to 22
Usual diameter of tanks, inches	$26\frac{1}{2}$ to $28\frac{1}{2}$	$28\frac{1}{2}$ to $31\frac{3}{4}$	$31\frac{3}{4}$ to $34\frac{1}{2}$	$31\frac{3}{4}$ to $34\frac{1}{2}$	$31\frac{3}{4}$ to $38\frac{1}{2}$	$34\frac{1}{2}$ to $38\frac{1}{2}$	$34\frac{1}{2}$ to 42
Excess of width at cylinders over gauge of track, inches	26	28	30	32	34	38	42
Extreme height least desirable, feet and inches	4–8	4–$10\frac{1}{2}$	5–$3\frac{1}{2}$	5–5	5–7	6–0	6–6
Approximate cubic feet capacity of tanks	130	150	180	200	240	275	350
Maximum tank pressure usually desirable, pounds	800	800	800	800	800	800	800
Approximate weight in working order, pounds	18,000	23,000	27,000	31,000	37,000	43,000	51,000
Weight per yard of lightest rail advised, pounds	20	25	25	30	35	40	45
Radius of sharpest curve advised, feet	25	30	35	35	35	40	50
Radius of sharpest curve practicable, feet	20	20	25	25	25	35	40
Maximum pressure per square inch usually desirable for auxiliary reservoir, pounds	140	140	140	140	140	140	140
Tractive force, pounds	3,180	4,630	5,620	6,410	7,750	8,575	10,730

Two-Tank Four-Wheel Compressed Air Industrial Locomotive

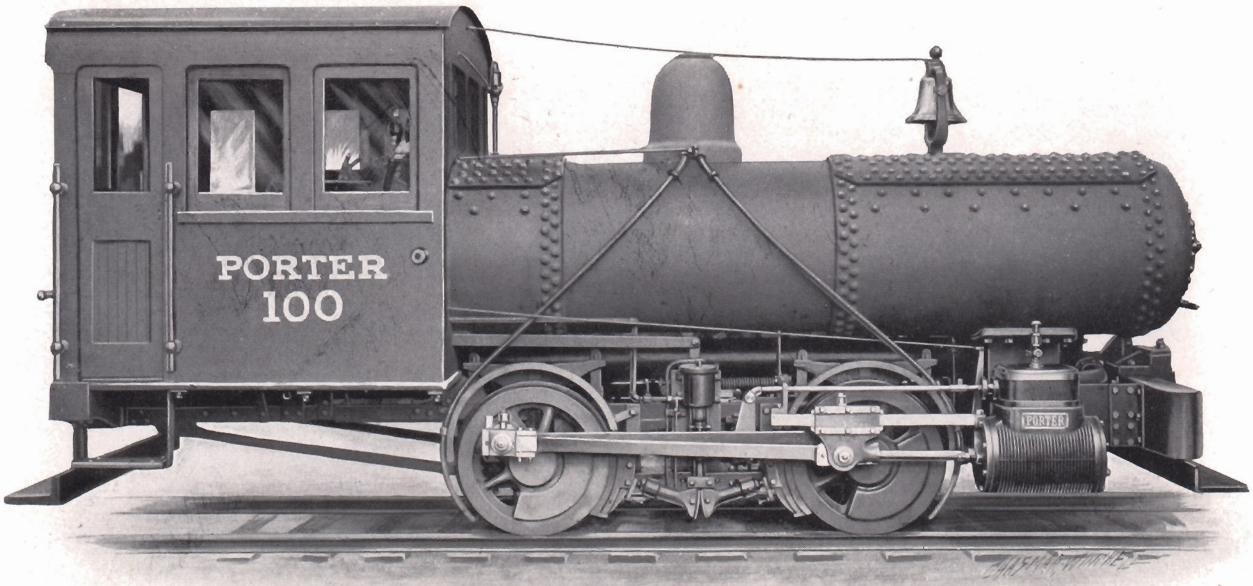


ILLUSTRATION NO. 100. CLASS B-PP

EIGHT SIZES, each with **code word,** of the above design are described on the opposite page, and the principal dimensions, weight, power and other particulars are given in the column assigned to each size. We are prepared to build other sizes, and to construct these locomotives for any practicable gauge of track or limits of head room or side room. The pressure, capacity of tanks and the details of construction are arranged to secure the best efficiency and convenience, and a suitable reserve is provided for emergencies. These locomotives run very steadily, pass very sharp curves, and surmount as steep grades as any locomotives on ordinary rail.

CODE WORD	PLOMOS	PLUMES	PLURAL	POBEDA	PODOCE	POEBEL	POENTO	POIDOU
Cylinders, diameter, inches	6	7	7	8	9	10	11	12
Cylinders, stroke, inches	10	12	14	14	14	14	14	18
Diameter of driving wheels, inches	23	24	24	24	26	26	28	36
Wheel-base usually desirable, feet and inches	4–0	4–8	4–8	5–3	5–3	5–3	5–9	5–9
Usual length over bumpers, feet	12 to 14	14 to 16	16 to 18	16 to 19	17 to 20	17 to 20	18 to 20	18 to 21
Excess of width at cylinders over gauge of track, inches	24½	26	26	28	30	32	34	36
Height above rail when head room is not limited, feet and inches	7–0	7–6	7–6	8–0	8–3	8–6	8–6	9–0
Approximate cubic feet capacity of tanks	60 to 80	100 to 120	120 to 140	140 to 170	160 to 190	180 to 220	200 to 240	220 to 260
Maximum tank pressure usually desirable, pounds	800	800	800	800	800	800	800	800
Approximate weight in working order, pounds	12,000	16,000	18,000	22,000	26,000	32,000	37,000	43,000
Weight per yard lightest rail advised, pounds	20	20	25	30	35	35	40	45
Radius of sharpest curve advised, feet	30	35	35	40	40	40	50	50
Radius of sharpest curve practicable, feet	15	16	16	20	20	20	25	25
Maximum pressure per square inch usually desirable for auxiliary reservoir, pounds	140	140	140	140	140	140	140	140
Tractive force, pounds	1,860	2,915	3,400	4,440	5,190	6,410	7,200	8,575

Single-Tank Four-Wheel Compressed Air Industrial Locomotive

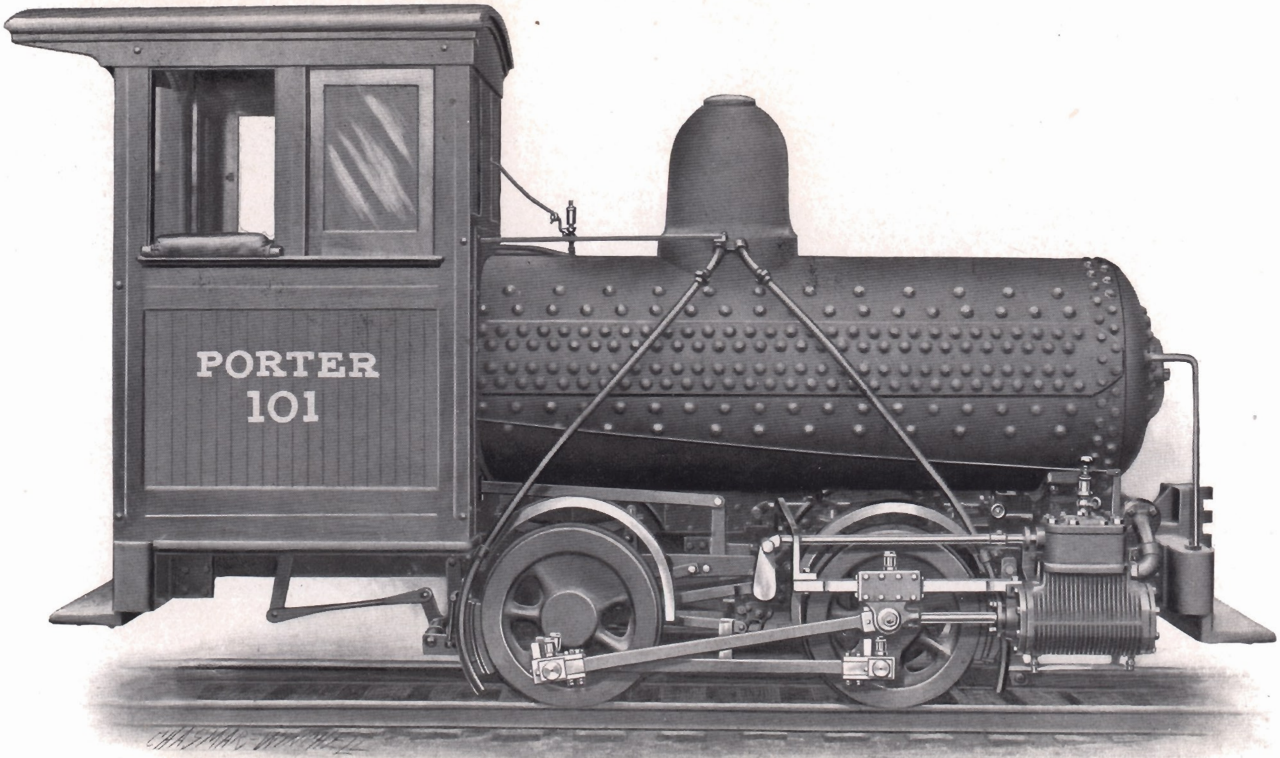


ILLUSTRATION NO. 101. CLASS B-P

SEVEN SIZES, each with **code word**, of the above design are described on the opposite page, and the principal dimensions, weight, power and other particulars are given in the column assigned to each size. We are prepared to build other sizes, and to construct these locomotives for any practicable gauge of track or limits of head room or side room. The pressure, tank capacity and details of construction are arranged to secure the greatest efficiency and convenience, and a suitable reserve is provided for emergencies. These locomotives run very steadily, pass very sharp curves, and surmount as steep grades as any locomotives on ordinary rail.

CODE WORD	PRAEDA	PRAZER	PRECON	PREFET	PREIAR	PREITO	PRELAT
Cylinders, diameter, inches	6	7	7	8	9	10	11
Cylinders, stroke, inches	10	12	14	14	14	14	14
Diameter of driving wheels, inches	23	24	24	26	28	30	30
Wheel-base usually desirable, feet and inches	4–0	4–0	4–8	5–3	5–3	5–3	5–9
Usual length over bumpers, feet	12	15	16	16½	17	18	18½
Excess of width at cylinders over gauge of track, inches	24½	26	26	28	31	33	34
Height above rail when head room is not limited, feet and inches	7–0	7–6	7–6	8–0	8–3	8–6	8–6
Approximate cubic feet capacity of tanks	50	75	75	80	90	100	100
Maximum tank pressure usually desirable, pounds	800	800	800	800	800	800	800
Approximate weight in working order, pounds	12,000	15,000	17,000	20,000	25,000	30,000	35,000
Weight per yard lightest rail advised, pounds	20	25	25	30	35	35	40
Radius of sharpest curve advised, feet	30	35	35	40	40	40	50
Radius of sharpest curve practicable, feet	15	16	16	20	20	20	25
Maximum pressure per square inch usually desirable for auxiliary reservoir, pounds	140	140	140	140	140	140	140
Tractive force, pounds	1,860	2,915	3,400	4,100	4,820	5,560	6,720

Four-Driver Compressed Air Mine Locomotive with Air Tender

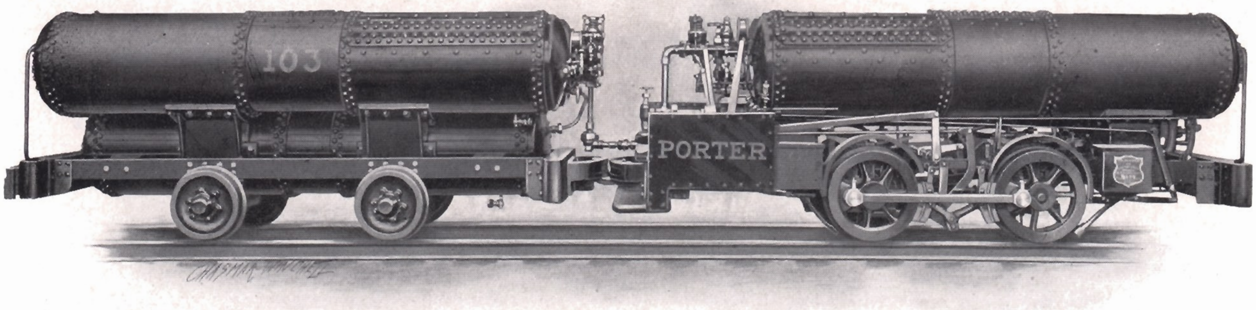


ILLUSTRATION NO. 103. CLASS B-PP-T

TEN SIZES, each with **code word,** of the above design are described on the opposite page, and the principal dimensions, weight, power and other particulars are given in the column assigned to each size. We are prepared to build other sizes, and to construct these locomotives for any practicable gauge of track or limits of head room or side room. Illustration No. 103 shows a locomotive with inside connected cylinders and crank axle, a construction by which the extreme width of the locomotive is only about 12 to 18 inches greater than the gauge of track. Unless for very narrow entries, outside cylinders are preferable. This design is intended for long hauls, short curves, and limitations of height and width, which make it impossible to store the required amount of air on the locomotive. The tender can be uncoupled and the locomotive operated separately when in use on short hauls. The pressure, the capacity of the locomotive tanks and of tender tanks, and the dimensions of these locomotive are arranged to secure the greatest efficiency and convenience, and a suitable reserve is provided for emergencies. These locomotives run very steadily, pass very sharp curves, and surmount as steep grade as any locomotives on ordinary rail.

CODE WORD	PRETIO	PREVOT	PREZEA	PRIECO	PRIERE	PRIMOR	PRIMUS	PRINOS	PRINUM	PRIONO
Cylinders, diameter, inches	6	7	7	8	8	9	10	11	12	13
Cylinders, stroke, inches	10	12	14	12	14	14	14	14	14	16
Diameter of driving wheels, inches	22	24	24	24	24	26	26	28	28	30
Wheel-base of locomotive usually desirable, feet and inches	4–0	4–8	5–3	5–3	5–3	5–3	5–9	5–9	6–0	6–0
Usual length engine and tender, feet and inches	24–0	26–0	27–6	29–0	31–0	33–6	35–0	37–0	39–6	43–0
Excess of width at cylinders over gauge of track, for outside connected cylinders, inches	24½	26	26	28	28	30	32	34	36	41
Extreme height least desirable, feet and inches	4–6	4–9	4–9	5–0	5–3	5–3½	5–5	5–8	5–8	6–0
Approximate cubic feet capacity of engine and tender tanks	150	220	240	260	280	315	340	375	450	600
Maximum tank pressure per square inch usually desirable, pounds	800	800	800	800	800	800	800	800	800	800
Approximate weight of locomotive, pounds	12,000	15,000	17,000	20,000	23,000	26,000	32,000	36,000	40,000	50,000
Approximate weight of tender, pounds	10,000	12,000	14,000	16,000	18,000	20,000	22,000	25,000	30,000	38,000
Weight per yard of lightest rail advised, pounds	20	20	25	30	30	35	35	40	45	50
Radius of sharpest curve advised, feet	30	30	35	35	35	40	50	50	60	60
Radius of sharpest curve practicable, feet	16	16	20	20	20	25	30	30	40	40
Maximum pressure per square inch usually desirable for auxiliary reservoir, pounds	140	140	140	140	140	140	140	140	140	140
Tractive force, pounds	1,945	2,915	3,400	3,810	4,440	5,190	6,410	7,200	8,575	10,730

Typical main haulage locomotive, operating in mines of Mill Creek Coal Company, New Boston, Pa.

How Satisfactory Results May Be Secured with Compressed Air Locomotives

THE first step is to buy proper equipment. It must be designed to meet local conditions. The component parts should be standard machinery, built on the interchangeable system, in order to insure prompt shipment of repair parts, and to reduce the cost of construction to the lowest limit consistent with thoroughly good workmanship and material. But the various parts must be properly combined.

The Locomotive, or Locomotives

They must be suited to the conditions, and heavy enough to secure sufficient adhesion. The adhesion is usually about one-fifth the weight on driving wheels, and ordinarily the tractive force developed by the cylinders should be equal to the adhesion, and both the adhesion and tractive force, due to the cylinders, must be fully up to the requirements imposed by the weight of train, grades, rolling friction and curves. Ordinarily, the gauge of track may be made to suit the convenience of the user. Very narrow gauges are only justified by special conditions. A locomotive to do any given amount of work is no cheaper if built for 18 inches gauge than if it were built for 56½ inches gauge, and if the locomotive were a large one, the special features of construction made necessary by very narrow gauge might render the narrow gauge locomotive the more expensive of the two. Thirty-six inch gauge is usually wide enough for the heaviest compressed air locomotive built. Gauges from 18 inches to 24 inches are only to be used when the gangway in a mine is very narrow, or when unavoidable obstructions near the track render the use of a very narrow locomotive essential. In such cases the locomotives used are generally small, and the narrow gauge presents no serious difficulties. Locomotives of 6 tons weight are easily built for 18 inches gauge, and a 14-ton locomotive can be built to suit 24 inches gauge without departing to any great extent from standard designs.

In opening a mine, local conditions should govern in selecting a proper gauge of track. If haulage roads are most economically driven and maintained by making them relatively low and wide, a correspondingly wide gauge of track should be used. If for instance, a height of 4 feet 6 inches above rail, and a width of 10 feet in the clear is to be the section of entry, a track gauge of from 42 inches to 48 inches would allow the use of locomotives and cars of greater capacity than would a narrower gauge. If, on the other hand, a bad roof and thick seam in a coal mine, or a narrow vein in a copper, gold, or silver mine, would render the driving and maintenance of wide entries expensive, and the section of entry determined on is, height 5 feet 6 inches above rail, and width 5 feet in the clear, a track gauge of 22 inches to 30 inches would best suit locomotives.

Special conditions can be met by special designs. For one company we have built five compressed air locomotives 5 feet 6 inches wide, to run on 48 inches gauge. These motors were built with the cylinders between the frames, instead of the usual American construction with outside cylinders.

These suggestions may serve as a guide to those who are opening new mines or building new establishments.

When the track is laid and the entry driven, it is cheaper and better to design a locomotive to suit the conditions than to change the conditions to suit the locomotive, though a compromise, with some adaptations on both sides, may in certain cases be necessary in order to achieve the best possible results. After determining the gauge, weight, size of cylinders, width and height of the compressed air locomotives required, the next essential feature to be settled is the capacity of storage reservoirs on the locomotive, the required capacity depending upon the amount of work to be performed with one charge of air. This amount of work depends upon the weight of train, the grades, the distance, and the design and condition of track and rolling stock. This last determines the coefficient of rolling friction. On standard steam railroads the coefficient of rolling friction is frequently as low as 6½ pounds per ton of 2,000 pounds. In industrial or mining operations a coefficient of 30 pounds per ton is by no means uncommon where unfavorable conditions exist, and poor design and neglect assist in making the cars run hard. The coefficient of rolling friction as here used is the force measured in pounds that must be exerted in order to move one ton of 2,000 pounds at a uniform velocity of six miles per hour on straight and level track. If then the system of tracks operated over by a locomotive are nearly level, and if the cars and track are in such condition as to make a coefficient of 30 pounds apply, about four and one-half times as much power will be required to do any given amount of work as would be required to do the same amount of work with a coefficient of rolling friction of 6½ pounds per ton. With heavy grades the influence of the coefficient of rolling friction is not so great, but it is always an important factor in determining the amount of work which must be performed.

How the Plant is Designed

The work to be performed may be calculated as follows:

Let C=Coefficient of rolling friction in pounds per ton.
G=Grade resistance in pounds per ton.
R=Resistance due to curves in pounds per ton.
W=Weight of train and locomotive in tons.
D=Distance in feet.

Then the work to be performed, expressed in foot pounds, will be equal to DW $(C + R \pm G)$. G is plus when the train is going up grade, and minus when the train is going down grade. When G is minus, and greater than $C + R$, the train will roll down grade without using power. The grade resistance is equal to 20 pounds per ton for each one per cent. of grade. The ton used in these calculations is a net ton of 2000 pounds. If down grades do not require the brake in order to control the speed within safe limits, the grade resistance G may be averaged without causing an error. After determining the total amount of work to be performed between charges, provision must be made for storing sufficient compressed air on the locomotive to do the required amount of work. It may be found that the tanks required to contain the air are too heavy or too bulky, in which case arrangements for charging more frequently must be made.

The calculations indicated above must be gone through with for each installation, and if there are several trips in different directions, with differing grades, curves, and loads to be hauled, calculations must be made for each run, and the locomotive tanks proportioned and charging stations located to secure the best results at minimum cost.

The Stationary Storage

This must do two things:

FIRST. It must be capable of containing a supply of compressed air immediately available for charging the tanks on the locomotive to the full specified pressure. To secure this result the conditions represented by the following equation must be fulfilled:

Let V = volume of the stationary storage in cubic feet.
v = volume of tanks on locomotive in cubic feet.
P = pressure in stationary storage in pounds per square inch.
p = desired pressure in tanks on locomotive in pounds per square inch.
p′ = residual pressure in pounds per square inch in the tanks on the locomotive just before charging.

Then $V(P-p) = v(p-p')$.

To illustrate the use of the above equation, suppose the tanks on a locomotive contain 100 cubic feet, and that it is desired to charge them to 800 pounds, the residual pressure before charging being 100 pounds, and that the pressure in the stationary storage is not to exceed 950 pounds. What must the volume of the stationary storage be in order to instantly charge the tanks on the locomotives to 800 pounds.

Then V is unknown.
P = 950 pounds.
p = 800 pounds.
p′ = 100 pounds.
v = 100 cubic feet.

Transposing the above equation, we find that $V = v\left(\frac{p-p'}{P-p}\right)$. Substituting the above values, we have $V = 100\left(\frac{800-100}{950-800}\right) = 466\frac{2}{3}$ cubic feet.

When two or more locomotives are to draw on the same stationary storage system, the capacity of the stationary storage should be somewhat increased, so that if two or more locomotives should be charging at about the same time each may receive approximately a full charge.

SECOND. It must consist of such pipe, or combination of pipe and tanks as will best serve to connect the compressor with the charging station, or charging stations. The charging stations must be located to suit the locomotives and the work. The compressor must be located as near the boilers as possible in order to get dry steam. Other things being equal, the shortest and most direct connection which can be made between the compressor and charging stations will be the best, but attention must be paid to convenience in laying, and accessibility for inspecting and repairing the pipe. Keep the pipe in plain sight as far as possible; its condition will then be known, and leaks, if they occur, will be found and remedied. Make the pipe line as straight as possible; a crooked line costs more than a straight one, though a few bends are a good thing as they serve to take up expansion. If the line is of considerable length the pipe should be of sufficient size to give the required volume. This plan cannot be improved on, and in the majority of cases is the one that has been used. There are exceptions to this rule, as follows: If the required volume necessitates the use of pipe larger than can be economically handled and laid; if the surrounding conditions are such as to make the preservation of the pipe in good condition difficult and expensive; in either case a smaller pipe should be used to convey the air, and one or more storage tanks used to make up the required volume. In the use of compressed air at lower pressure for pumps, coal cutters, rock drills, etc., lines of pipe convey the compressed air from the compressor to the drills, cutters and pumps. In this case it is primarily a passageway; the air is in almost constant motion, and the size of the pipe depends upon the quantity of air needed, the pressure required at the machines, the pressure at the compressor, and the length of the line. The pipe is then made sufficiently large to convey the required quantity of air at a velocity which the predetermined difference in pressure is capable of imparting to the air contained in the pipe. Now note the difference in the function of a pipe line for compressed air locomotives. The pipe line in this case is primarily a receiver. Air is pumped into it constantly, and drawn off intermittently. When a locomotive charges, the air nearest the charging station flows into the tanks on the locomotive, the air farther away simply expanding to fill up the vacant space. The compressor running constantly is, however, only crowding air into the end of the line nearest to it, which serves to compress the air in the further end of the line.

An example with figures and dimensions may serve to explain more clearly the meaning of the preceding remarks. The locomotive tanks to contain 100 cubic feet; the pressure just before charging, 100 pounds; the desired pressure after charging, 800 pounds; the pressure in the stationary storage, 950 pounds. By our previous calculation, the capacity of the stationary storage is to be 466⅔ cubic feet. Suppose the compressor to be located 5,600 feet from the charging station, then 4-inch pipe would give the required capacity, as 12 lineal feet of 4-inch pipe contain one cubic foot. The operation of charging consists of the air nearest the charging station flowing from the stationary storage into the tanks on the locomotive until the pressure in the tanks on the locomotive is equal to the pressure in the stationary storage, when the flow will stop. To increase the pressure in the tanks on the locomotive from 100 to 800 pounds will require $\frac{(800-100) \times 100}{14.7} = 4762$ cubic feet of free air. One cubic foot of air at pressure of 950 pounds gauge is equivalent to $\frac{964.7}{14.7} = 65.6$ cubic feet of free air. It will, therefore, require $\frac{4762}{65.6} = 72\frac{1}{2}$ cubic feet of air at 950 pounds gauge pressure, to furnish the amount of air required to charge the locomotive tanks. It will require $72\frac{1}{2} \times 12 = 870$ lineal feet of 4-inch pipe to contain this amount. The air contained in the 870 lineal feet of pipe nearest the charging station will, therefore, be pushed into the tanks on the locomotive by the expansion of the air contained in the remaining 4730 feet of pipe. The compressor is working during the time of charging, but the quantity compressed during so brief a period does not materially affect the above described operation. We have, when the charging station valve is first opened, a difference in pressure of 850 pounds per square inch, sufficient to give the air a very rapid motion. As the operation of charging nears completion, the difference in pressure decreases, but the quantity of air to be moved decreases as the difference in pressure decreases, so that unless the pipe is made absurdly small, no serious delay can occur. THE ENTIRE OPERATION OF CHARGING, INCLUDING THE TIME OCCUPIED IN MAKING THE COUPLING AND BREAKING IT, SELDOM OCCUPIES MORE THAN 1½ MINUTES; AND THE CHARGING STATION VALVE IS NEVER OPEN MORE THAN 40 OR 50 SECONDS FOR EACH CHARGE. At the compressor end of the line, the time occupied in replacing the air drawn off in charging is anywhere from ten to sixty times as great, depending upon the number of locomotives and the character of the work. It is plain, then, that if large pipe is to be used to reduce the friction, it should be put in near the charging station rather than near the compressor.

One other point must not be lost sight of. Most of the air locomotives recently built require a pressure of 800 to 1,000 pounds per square inch in the stationary storage. The compressors ordinarily used in connection with rock drills, coal cutters, pumps, etc., deliver the air at a pressure of 80 to 100 pounds per square inch. The volume after compression of any specified quantity of free air will be inversely as the absolute pressure. The absolute pressure is obtained by adding the atmospheric pressure (14.7 pounds per square inch at sea level) to the reading of the pressure gauge. Any specified quantity of free air after being compressed to 800 pounds pressure will therefore have about one-tenth the volume that the same quantity of air would have after being compressed to 80 pounds pressure. A given diameter of pipe will therefore convey a much greater quantity of free air when it is compressed to 800 or 1,000 pounds than it would if the same quantity of air were compressed to only 80 or 100 pounds.

The Compressor

Its capacity is determined by the frequency with which the locomotives must be charged, and the quantity of air required for each charge. Having calculated by the method above indicated the amount of air required per trip, the number of trips per charge (or of charges per trip) will depend upon the capacity of the locomotive tanks. To compute the required compressor capacity in cubic feet of free air per minute:

Let C = The required capacity of the compressor expressed in cubic feet of free air per minute.

C′ = The cubic feet of free air required to charge the locomotive.

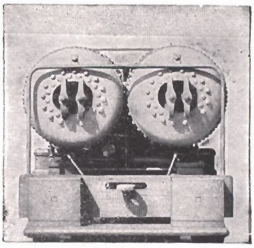
N = The number of charges required to do the required amount of work in any specified time.

T = Time in minutes.

Then, $C = \frac{NC'}{T}$

If the locomotives are to be charged at approximately equal intervals of time throughout the day, one application of the above equation will be sufficient. In any other case several applications should be made to determine the maximum and minimum rates of consumption, and a compressor selected capable of supplying air in sufficient quantity for all conditions of service, and, at high altitudes, the rarified condition of the atmosphere must be taken into consideration.

With a plant properly designed and installed, only ordinary care and mechanical ability is required to maintain it in serviceable condition. Use a *low cold* test oil in the cylinders of the locomotive (we recommend a pure, natural West Virginia well oil which shows about 29 gravity and a cold test of five degrees below zero Fahrenheit), and as *small* a *quantity* as *possible* of a *good* air compressor oil in the cylinders of the compressor. See that all bearings are properly lubricated with good engine oil, and that all parts of both locomotive and compressor are kept reasonably clean, and your compressed air haulage will be the least troublesome piece of machinery about the establishment.



Front view of Double-tank Air Locomotive

The explanation of the principles of compressed air locomotives, together with the necessary compressor, storage system and charging stations given in the foregoing pages, is, we realize, extremely elementary, and even if they were as exhaustive as they could be made with print and illustrations, still the experience of the engineer who has installed numbers of successful plants would be valuable. We do not ask our customers to design their own plants, nor to modify their plants to suit our locomotives. Our engineers are competent to design air haulage plants to meet any practicable requirements, and their experience is at the service of our customers.

Data Required for Basis of Estimates

We desire to furnish to correspondents, for their convenience in supplying us with the information necessary to enable us to submit promptly satisfactory estimates of cost of air haulage plants, a blank form for this purpose identical with that which here follows. This blank form we furnish in duplicate, that one copy may be retained for reference and the other copy mailed to us. *It is extremely desirable that all the questions be answered as clearly as possible, even if, as is the case with operations not fully laid out, some items must be estimated.*

Memorandum of Conditions and Requirements for Estimate of Cost of Air Haulage Plant

MEMORANDUM FOR PERSON FILLING OUT THIS BLANK. In case the work may be varied and difficult to state, do not abandon the idea of giving us the required information. Please state the conditions as clearly and as fully as practicable, since we need something definite on which to base our estimate. If found desirable later on, one of our engineers can call upon you.

Mine entry: Width at level of rail____________; at top____________;

height at center above top of rail____________; at sides____________

Distance from center line of entry to center line of track____________

(If possible, send sketch showing cross-section of entry.)

If locomotive is to be operated on the surface or in buildings, give distances from center line of track and top of rail to nearest obstructions________

Gauge of track____________

Weight of rail, in pounds, per yard____________

Weight of empty car____________

Weight of load on each car____________

Total car loads to be handled per day of________hours________

Condition of track and rolling stock____________

If material is to be hauled between more than two points, treat each division of the work separately, giving information under columns A, B, C, etc. (see sketch on back).

QUERIES	A	B	C	D	E	F
Steepest up grade for loaded cars .... per cent.	....	....	....	....	....	....
Length of this grade .... feet	....	....	....	....	....	....
Steepest up grade for empty cars .... per cent.	....	....	....	....	....	....
Length of this grade .... feet	....	....	....	....	....	....
*Average up grade for loaded cars .... per cent.	....	....	....	....	....	....
*Average up grade for empty cars .... per cent.	....	....	....	....	....	....
Radius of sharpest curve .... feet	....	....	....	....	....	....
Length of track occupied by this curve .... feet	....	....	....	....	....	....
Grade, if any, on which this curve occurs .... per cent.	....	....	....	....	....	....
Number of cars to be hauled in one train	....	....	....	....	....	....
Number of car loads per day of .... hours	....	....	....	....	....	....
Distance between terminals .... feet	....	....	....	....	....	....

If there are any combinations of grade and curvature that may require more power, state them here, saying that they exist on runs A, B or C, etc., as the case may be. ____________

____

____

____

*The average grade is the grade that would exist if the grade were uniform for the entire distance between terminals.

If more than one type of car is used, state weight and capacity of each type ____________________

____

Send sketch of cars showing draught rigging so that locomotive may be arranged to suit.

What per cent. down grade is required to just keep your empty cars in motion? ____________________

What per cent. down grade is required to just keep your loaded cars in motion? ____________________

Is the mine operated by shaft, drift or slope? ____________________

If shaft, give depth ____________________

If slope, give length and pitch ____________________

Give distance from convenient location for compressor to head of shaft or slope ____________________

If a drift mine, state distance from convenient location for compressor to parting outside where locomotive will deliver loaded cars? ____________________

Compressors require but little attention, and are best located in the same room with other engines, so that attendant's time may be more fully occupied.

State elevation above sea level of compressor location ____________________

Will compressor be operated by steam or water power? ____________________

If steam, state pressure ____________________

Have you surplus boiler capacity, if so, how much? ____________________ H. P.

Is fuel expensive with you? ____________________

Do you use compound or compound condensing engines to secure economy in the use of steam and fuel? ____________________

____

If water power, give details in full ____________________

____

Give as clearly as possible the proposed plan of operation ____________________

____

____

A ground plan and profile of the haulage roads will greatly assist us in making intelligent recommendations. If you have no accurate map, a rough sketch showing the relative position of the haulage roads, compressor, etc., will help us to understand your case. (*On the other side of this sheet we show how such a sketch may be made.*) *Please be sure to give us a full list of grades*, as nearly correct as practicable, and either noted on a sketch, or in any manner most convenient. If haulage roads are to be lengthened, indicate which ones, and at what rate in feet per year they may be expected to increase in length. If the output is to be increased, say how soon and from which roads the increase is to come, giving the amount of increase for each road.

Name of mine or plant ____________________

Name of owner ____________________

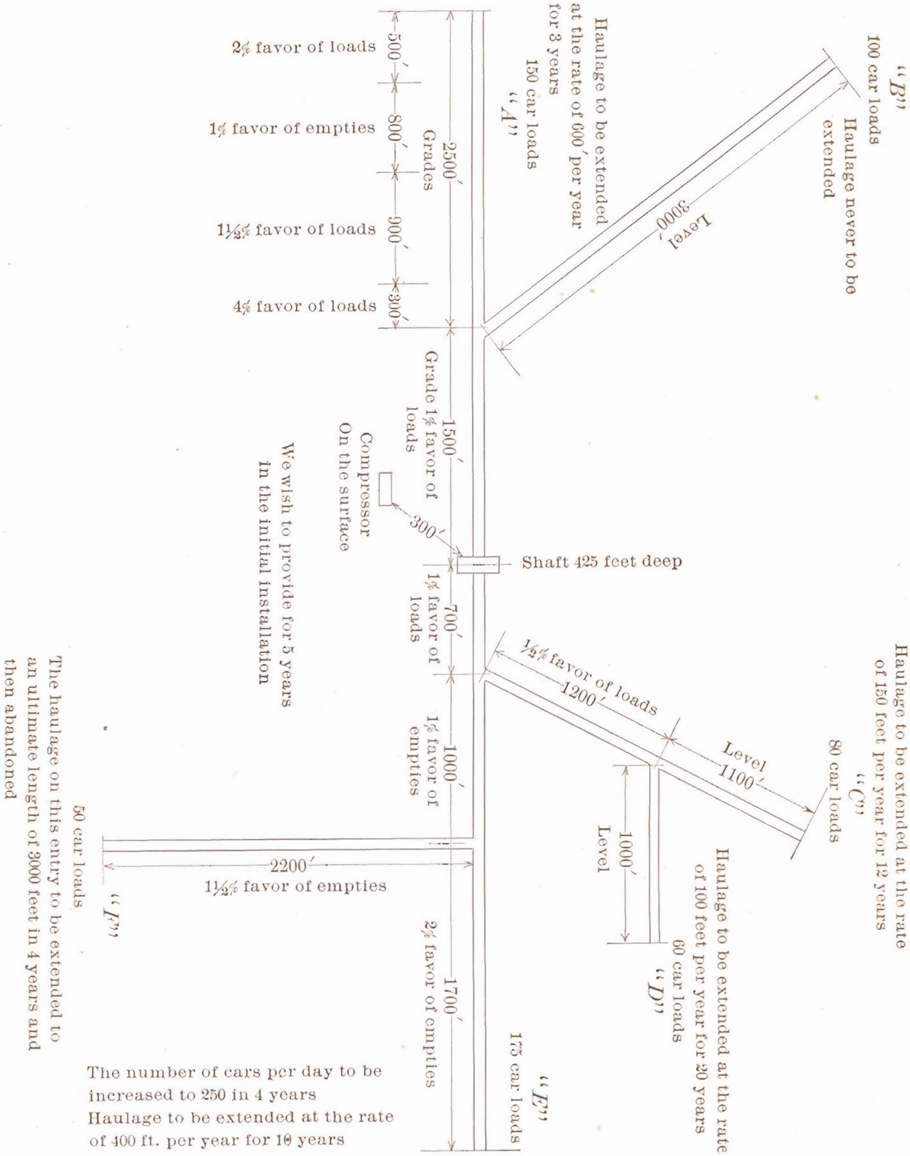
Location of mine or plant ____________________

Address letters to ____________________

Post Office at ____________________

____

Date ____________________



(MEMORANDUM. The above sketch, with data, is intended only to serve as a hint to our correspondents. A rough pencil sketch is sufficient if accompanied by full information.)

Some of the Mechanical Features

Common to all Compressed Air Haulage Plants Installed by the H K Porter Company

The Locomotives

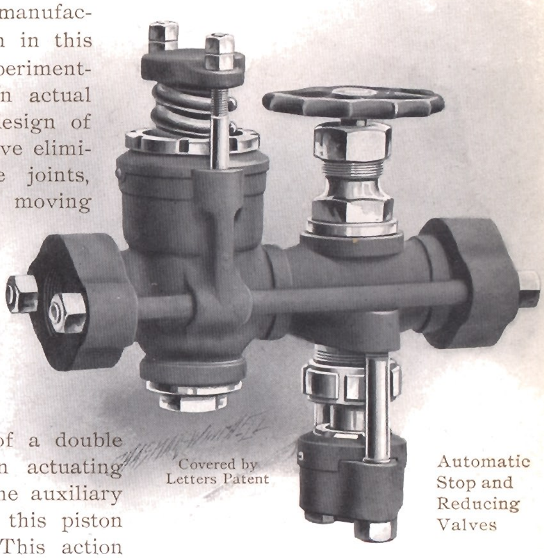
THE MAIN STORAGE TANKS on the locomotives are made of the best quality flange steel plates, of a tensile strength of 60,000 to 65,000 pounds per square inch. The longitudinal seams are sextuple or octuple riveted, with butt joints and welt strip inside and outside; the circumferential seams are double riveted. All rivet holes are reamed after the tanks are fitted up. The rivets are of soft steel, and are driven by a power riveter capable of exerting a pressure of 300,000 pounds. All caulking is done with round-nosed tools and pneumatic hammers on edges planed to a true bevel. The heads of the tanks are spherical in shape, formed by hydraulic pressure from steel plates 35 to 50 per cent. thicker than, and of the same quality as, the cylindrical sheets. After the heads leave the flanging press they are turned in order to insure a perfect fit. The front head is fitted with a man-hole. The man-hole cover is of cast steel, and the plate around the hole is heavily reinforced by a steel casting. The man-hole is an essential feature of good construction, as it allows of riveting in the last head, and provides for inspection and a proper method of securing tanks to saddle. If there is no man-hole, the last head must be put in with patch bolts, or else must be flanged concave. Either method is bad, and the question of which is worse is hardly worth considering. The tanks, after they are completed, are subjected to a test pressure about 30 per cent. greater than the working pressure, and are made absolutely tight at this test pressure. With our designs, the bursting pressure of a tank is so far in excess of the working pressure that absolute safety is insured.

The exceptions to the above method of storage tank construction are as follows:

First. For very high pressures we use seamless steel tubing tested to double the working pressure.

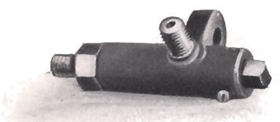
Second. For tanks of small diameter, for ordinary pressures, we use welded wrought iron cylinders, tested to a pressure 50 per cent. in excess of the working pressure.

THE AUTOMATIC REDUCING AND STOP VALVE.—The duty of these parts of the compressed air locomotive is to maintain automatically a specified uniform pressure at the throttle valve (usually 140 to 150 pounds per square inch), the pressure in the main storage tanks meantime fluctuating between the limits of 800 or 900 pounds just after charging, and 140 or 150 pounds just before charging. The valves should be absolutely tight when the locomotive is at rest, or drifting down grade, and also be capable of maintaining the specified pressure at the throttle valve when the locomotive is working at its maximum power, and when the pressure in the main storage tank is reduced to approximately the same pressure that is required at the throttle valve. We have tried various regulating devices made by manufacturers of the highest reputation in this class of work, but after much experimenting, both in the shop and in actual service, we finally adopted a design of our own. In our design we have eliminated diaphragms and toggle joints, and reduced the number of moving parts to a minimum. This device has been patented, and will be used only on compressed air locomotives built by the H. K. Porter Company. It consists of one automatic reducing valve and one automatic stop valve. The reducing valve consists of a double seated balanced valve and an actuating piston. The air pressure in the auxiliary reservoir acts on one side of this piston tending to close the valve. This action is opposed by a spring properly adjusted to hold the valve off its seat until the maximum allowable pressure is reached in the auxiliary reservoir, when the pressure of the air overcomes the resistance of the spring, and the valve closes. The pressure in the auxiliary reservoir is easily adjustable, as the pressure varies with the tension of the spring, which can be altered by turning two nuts. This valve alone would be sufficient, if the locomotive was always using air. The necessity for a supplementary valve is only apparent when the locomotive is not using air. To meet this condition, we have designed a second valve to be placed between the above described valve and the main storage tanks on the locomotive. This valve is single seated, and closes with the pressure. The motion of this valve is controlled by the throttle lever and the high pressure air. When the throttle valve is open the valve is entirely open, and when the throttle valve is closed this valve is closed with sufficient pressure to insure absolute tightness. Thus, by the use of two valves, we have secured a combination possessing every desirable attribute, viz., close regulation at all times, absolute tightness when no air is being used, simplicity and a repair account so low that it approached the vanishing point.



Covered by Letters Patent

Automatic Stop and Reducing Valves



Auxiliary Three-way Valve operating automatic stop valve in connection with throttle lever

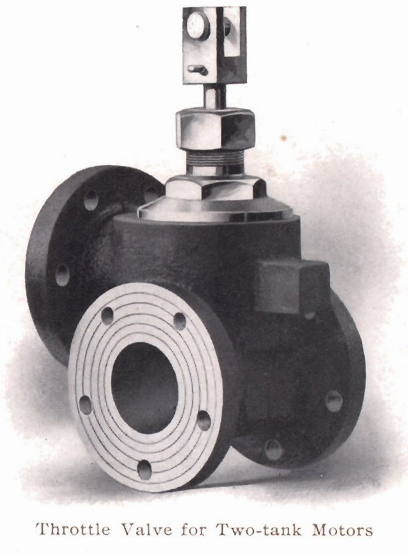
THE AUXILIARY RESERVOIR simply serves to equalize the fluctuating demands of the cylinders. It is usually a piece of pipe from 4 to 9 inches in diameter, and from 6 to 15 feet long.

THE THROTTLE VALVE we use is of special design. We tried the ordinary double-seated locomotive type of throttle valve, but found difficulties in its use, so we designed a single-seated balanced valve which after a few experiments has been found extremely well adapted to the

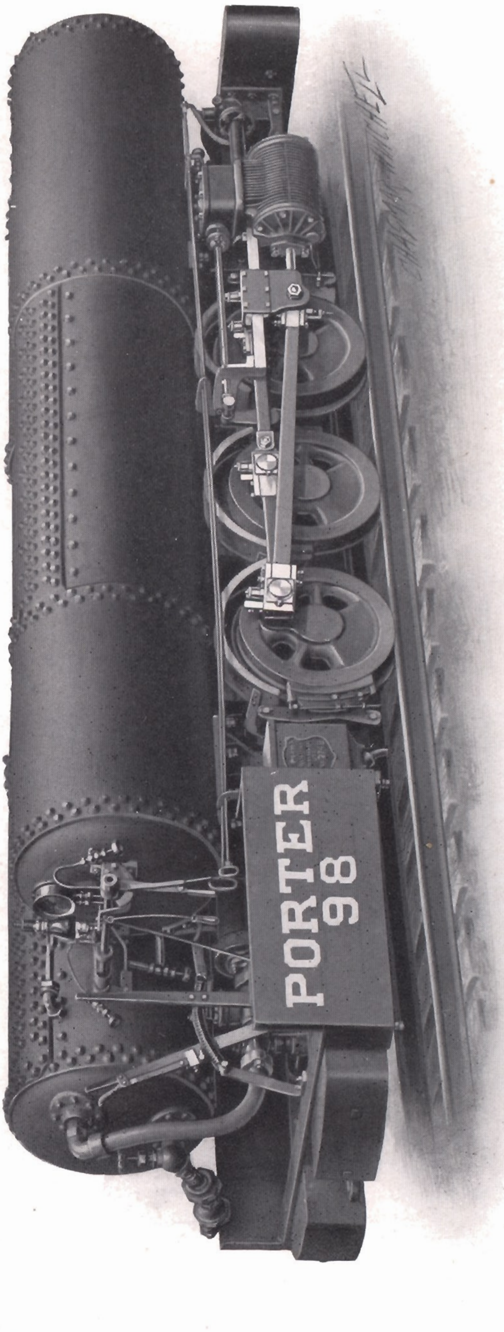
2½-inch Throttle Valve

service. It is a compound valve with a small valve opening first to equalize the pressure on the two sides of the larger valve, which is then readily opened.

THE CYLINDERS are ribbed for the absorption of heat from the atmosphere, instead of being lagged to retain the heat, as in steam locomotive practice.

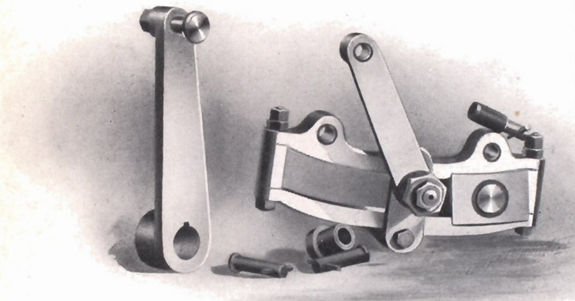


Throttle Valve for Two-tank Motors



Six-wheel main haulage locomotive, shows arrangement of automatic reducing and stop valve, also operating levers on cab.

THE VALVES, LINKS, FRAMES AND RUNNING GEAR are in all respects the same as for our standard steam locomotives, except that in general all parts are somewhat heavier and the bearing surfaces somewhat more liberal. The links are fitted with case-hardened, renewable bushings and pins, and are of the skeleton pattern, providing a ready means for taking up wear. The driving boxes and connecting-rods are provided with removable bronze bearings, adjustable for wear, and readily renewable. The driving wheels are fitted with steel tires that can be turned two or three times and then renewed. The seats of the slide valves are raised so that they can be faced off in case of wear. In fact, the entire locomotive is so built that wear is reduced to a minimum, and the parts are so made that when they do become worn it is only necessary to renew the material that is worn. For example, when a link pin becomes worn, it is only necessary to knock out the old pin and bushing and replace them with new ones, when the link is as good as before; or if the tread of the driving wheels is so worn that there is a flange on each side of the rail, it may be that the tire will only require turning; but if they are too badly worn for turning, it is simply a question of renewing the tires only, the wheel centers, crank pins and axles remaining intact. The frames are protected from wear by cast iron shoes and wedges. *This principle of making the surfaces subject to wear renewable is carried out to the furthest possible degree in every detail of the locomotive construction.*

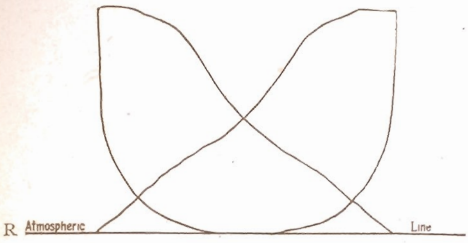


Link with Lifter and Lifter Arm
Note that all wearing surfaces are bushed or easily adjustable

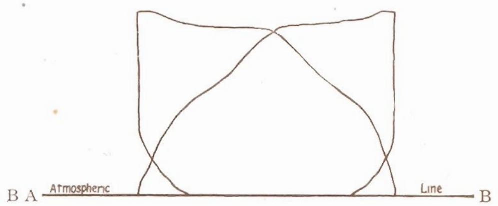
SAND BOXES. Sand is always needed (more especially in mines) to prevent slipping of the driving wheels. Dry sand must be used, and all of our larger locomotives are equipped with approved sanding apparatus operated by compressed air.

OILING DEVICES. The crank pins are supplied with compression grease cups, the cylinders and slide valves with automatic lubricators. The driving boxes are provided with cellars packed with woolen waste, the eccentrics and guides with oil cups of approved design. These are the most important bearings and wearing faces. All others have oil holes conveniently located.

THE OTHER DETAILS of compressed air locomotives are in all respects similar to the steam locomotive, except that the exhaust is taken as directly as possible to the atmosphere, as it is not needed to create a draught. The exhaust passages are so free and open that with an ordinary indicator spring it is impossible to detect the slightest evidence of back pressure.



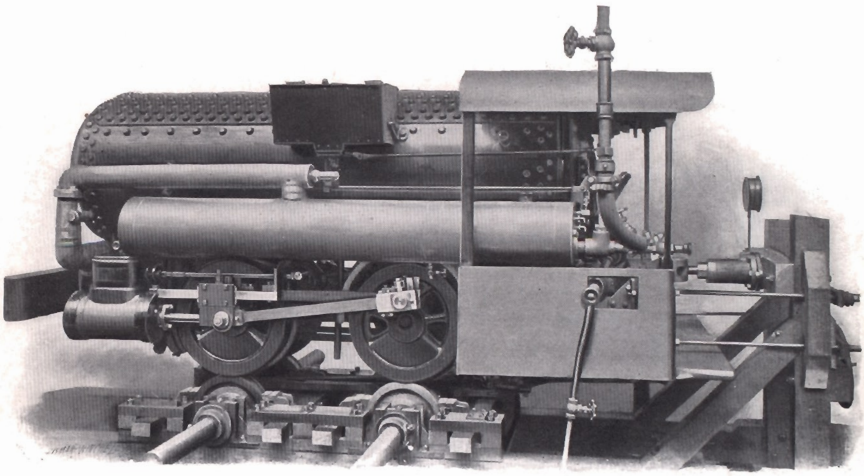
No. 1



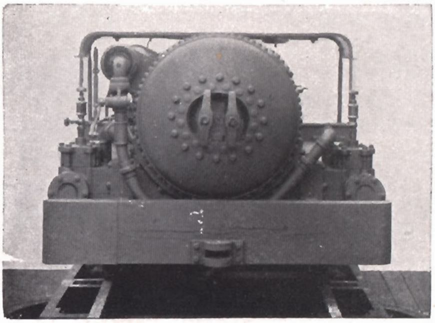
No. 2

Indicator cards of Compressed Air Locomotive during shop tests. Cut No. 1 shows early, and cut No. 2 late cut-off. The line A—B is atmospheric line. There is no back pressure. The above cuts are one-fourth size of original cards.

The illustration below shows **a shop test of a pneumatic locomotive,** having 5 x 10 inch cylinders, designed for 18-inch gauge of track and equipped with hot water reheater. All reheating attachments and auxiliary reservoir are carefully covered with insulating material, so that the air when once heated reaches the cylinders without any loss in temperature. The main storage tank is constructed of one cylindrical sheet, which clearly shows the method of riveting. Ample arrangements for sanding the rails, etc., are shown on photograph. The locomotive rests on friction rollers, which are provided with prony brake, and the tractive force developed is measured by dynamometer. A record is made each minute of the main and auxiliary reservoir pressures, temperature, dynamometer and indicator



and driving wheel revolution readings. The results are tabulated for air used, running with and without reheater, distance run and total energy developed in foot-pounds. All motors which we construct and send out of our shops are tested on friction rollers, the motors being charged with full pressure of air which they are designed to carry in service, and the combination, regulating and automatic stop-valves being carefully adjusted, so that as soon as the motor is placed in regular service it can take up its work with every assurance of satisfactory performance and without requiring any special adjustment or attention.

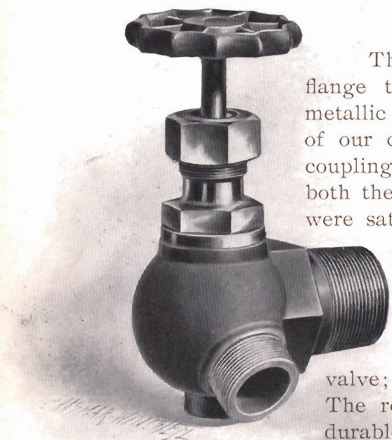


Front view of Single Tank Air Locomotive

Reheating

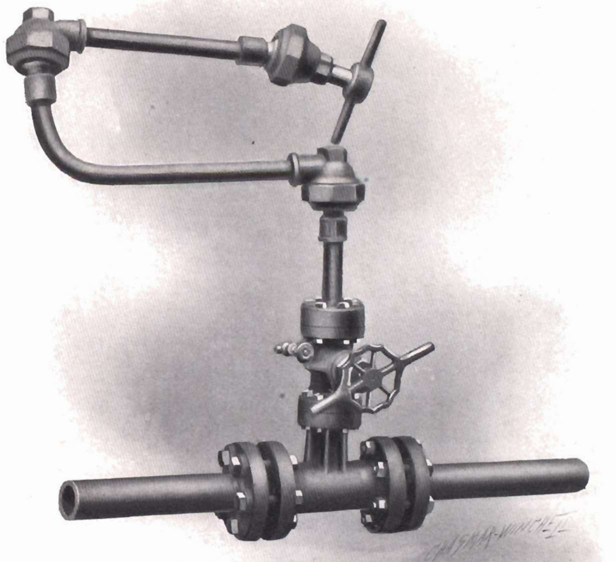
We have applied reheaters of various designs to our compressed air locomotives, and the increased efficiency attained makes the subject a most attractive one, more especially for surface work, but it is doubtful if the increased efficiency justifies the additional complication, except in special cases where the locomotives are making an unusually large mileage and the cost of fuel is extremely high. We are, however, ready to equip locomotives with reheaters whenever the circumstances justify it. We are working on an improved reheater which may render a more frequent application of this feature desirable.

Charging Stations



Charging Check Valve

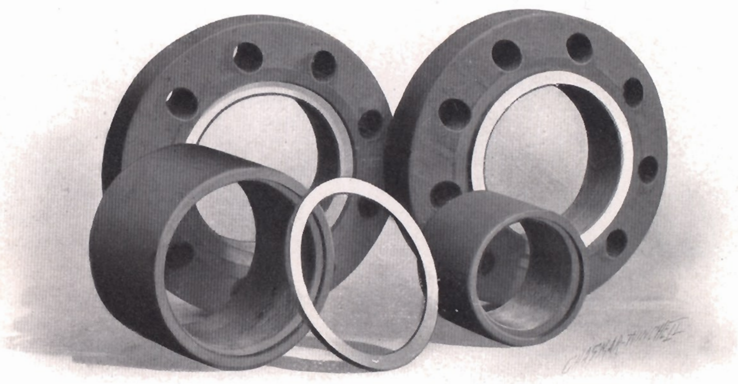
The charging stations consist of one extra heavy flange tee or elbow, a special stop valve, and flexible metallic coupling and bleeder valve. The special features of our charging stations are the stop valve and flexible coupling. We tried several designs of stop valves, of both the globe and gate pattern, and while some of them were satisfactory for a week or a month or two, none of them would remain permanently tight without constant attention. We then decided to make a stop valve of our own, the main features of which were plenty of metal, a valve seat of case-hardened mild steel and a hard bronze valve; the valve and seat both to be easily renewable. The result was most satisfactory; the valves are tight, durable, easy to operate and easily repaired. The flexible metallic coupling consists of three ball joints and three pieces of extra heavy 1½-inch wrought iron pipe, and a screw coupling. The thread is coarse so that only four turns are required to couple the locomotive to the charging station. Without this flexible coupling it would be necessary to stop the locomotive exactly at the same point every time a charge of air was taken. With it a range of several inches each way is permissible. This feature saves much time in charging. The bleeder valve is used for exhausting the air between the charging station stop valve and the check valve on the locomotive, after the operation of charging is completed.



A Charging Station for 3-inch Pipe Line. Scale about $\frac{1}{16}$

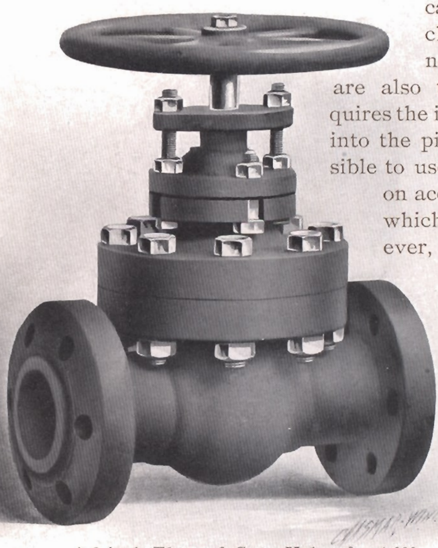
Pipe Lines

When pipe is used for stationary storage, we use a special grade, rolled to our specifications from selected wrought iron skelp, and each length is tested by hydraulic pressure.



A pair of Flanges, Soft Metal Gasket and Pipe Sockets for Pipe Lines for 1,000 pounds pressure

We use two forms of pipe coupling—one, the usual sleeve coupling, but of greater weight and recessed at ends for caulking. This form of coupling has given entire satisfaction. It is not intended that all joints should be caulked, but if a leak should occur a strip of soft metal hammered into the recess will put an immediate stop to the difficulty. The other form is a flange coupling designed and manufactured by us. It is intended for use at intervals of 200 to 400 feet, in order that any joint in the pipe line may be easily accessible in case a length of pipe should for any cause require renewal, or in case a change of location should become necessary. The flange couplings are also to be used when the location requires the introduction of bent lengths of pipe into the pipe line, it being generally impossible to use sleeve couplings with bent pipe on account of the great radius through which the bent end swings. It is, however, quite frequently possible to put small bends in the pipe with the sleeve coupling by making the bend near the free end of the pipe, thus reducing to a minimum the radius through which the bent end swings. In installing pipe lines, care must be exercised to relieve the line of all initial strains. If a bend is required, heat the pipe to a red heat and bend it to the required shape. Do not attempt to spring it into position after screwing it into the preceding length.



A 3-inch Flanged Gate Valve for 1,000 pounds pressure

We have men specially trained for this class of work, and their services are at the command of our customers at a nominal price.

When stationary storage tanks are used we construct them in the same thorough manner as the main tanks of our locomotives.

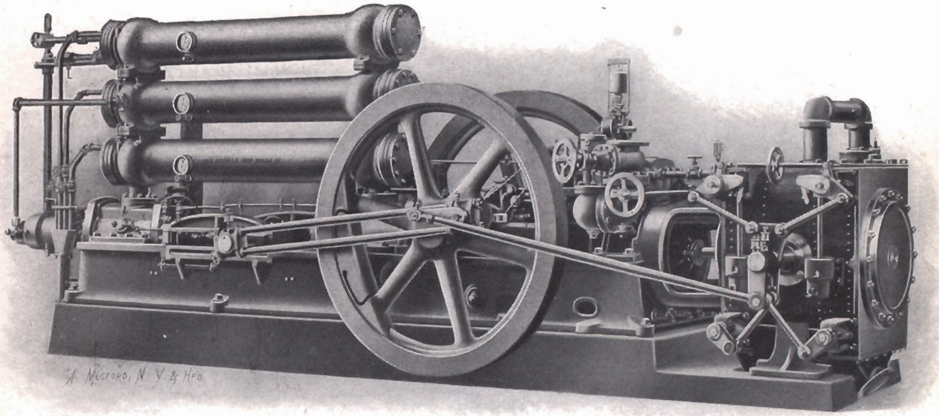
The Compressor

For charging air locomotives the pipe line pressure to be maintained by the compressor is seldom less than 700 or more than 1,200 pounds per square inch. For these pressures the three or four-stage compressor is required. The three-stage straight-line machine is the most economical construction, and the four-stage duplex the most expensive. Massive construction, properly proportioned water-jacketed cylinders, good castings, intercoolers of ample capacity and valves and pistons of proper design, and the best of material and workmanship throughout are the essential features of the successful high-pressure compressor. The compressors are furnished with speed and pressure governors, and gauges to show the pressure after each stage of compression.

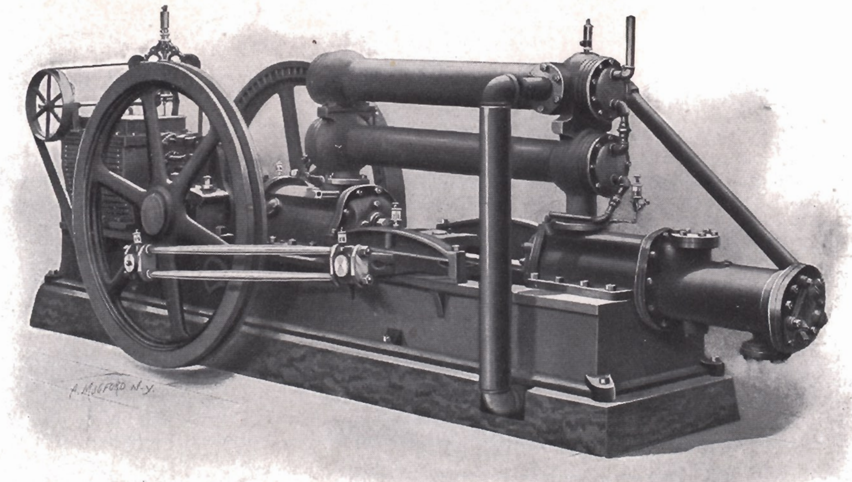
The design of the compressor may be modified to meet special conditions. The operating power may be water power or electricity, if preferred to steam. If driven by steam the engine may be the simple slide valve, or the highest type of compound condensing engine, or any type of engine between the two which may be called for by the cost of fuel and the character of the installation. An auxiliary two-stage locomotive compressor with intake of air at 80 to 100 pounds pressure, may be used where there is a surplus of low pressure air, but, although attractive by reason of lower first cost, this plan is not recommended because in practical working it is impossible to avoid objectionable fluctuations in the supply of low pressure air. The three-stage locomotive high pressure compressor may be modified to deliver, when desired, a correspondingly larger volume of low pressure air, an arrangement sometimes very convenient for night work.

In our estimates of cost of air-haulage plants, we include, at manufacturers' prices, locomotive air compressors of type and details to give the best results, and we guarantee their satisfactory performance. By the courtesy of The Norwalk Iron Works Company, of South Norwalk, Conn., and of the Ingersoll-Sergeant Drill Company, of New York City, we herewith present illustrations of

Standard Designs of Locomotive Compressors

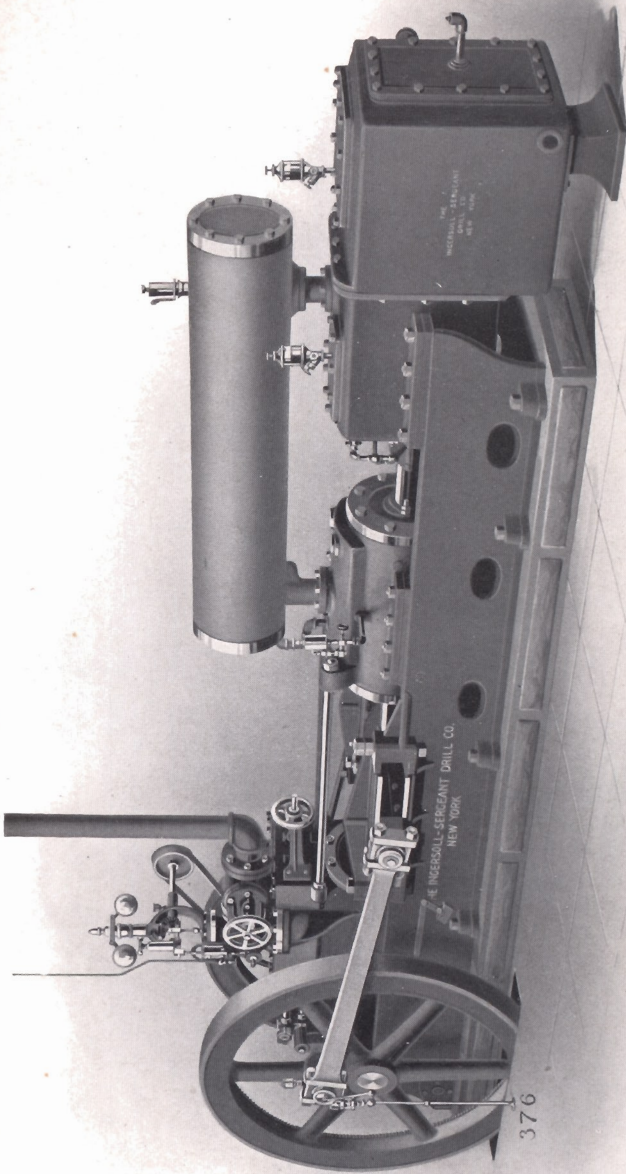


Norwalk High Duty Locomotive Charger with Compound Corliss Steam End



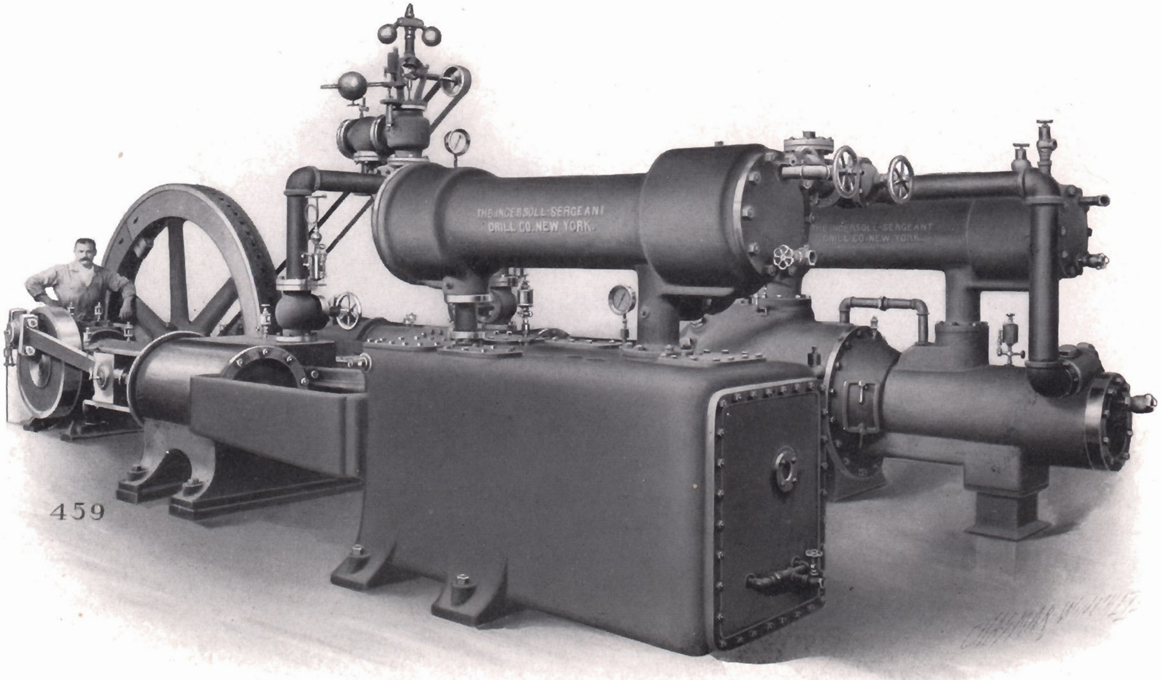
Norwalk Three-stage Locomotive Charger

The above illustration shows the Norwalk standard type of locomotive charger for situations where a three-stage compressor taking air at atmospheric pressure is required. The steam end is fitted with adjustable steam expansion valves and speed governor. The first air compression takes place in the large double-acting cylinder in the center of the machine. The water jacket by which this cylinder is surrounded, takes away a share of the heat of compression, after which the first intercooler extracts the remainder, bringing air to the second cylinder at or near the temperature of the cooling water. From the second cylinder, which is also water jacketed, the air is led through the pipe shown in front of the machine to the second intercooler, and thence into the third cylinder through the inclined pipe shown at the back. In this third cylinder, which is also jacketed, the compression is completed, and the air is discharged into the pipe line or storage reservoir through the connection shown at the bottom. The pistons of the second and third cylinders are in direct line with the piston of the first cylinder and the steam piston. All the strain of compression is direct push and pull on a straight steel rod. High pressure stuffing boxes are avoided. Notwithstanding the compact construction, all parts are extremely accessible.



376

Ingersoll-Sergeant Three-stage Straight Line Compressor, Class "AC-3."
Suitable for pressures from 700 to 1500 pounds. Special machines for higher pressures.
Capacities from 127 to 864 cubic feet of free air per minute.



459

Ingersoll-Sergeant Four-stage Duplex Compound Air Compressor, Class "GC-4."
Suitable for pressures from 700 to 1500 pounds. Special machines built for higher pressures.
Capacities from 200 to 1194 cubic feet of free air per minute.

Operating Expenses

These are made up under three main heads: cost of labor; cost of power; cost of repairs, oil, waste, etc.

COST OF LABOR. Mule drivers and trackmen can, and are running compressed air locomotives successfully, and no cheaper form of labor can safely be put in charge of even half a dozen coal cars if they are to be moved. We recommend, however, that when the drivers are put on the locomotives they be given slightly increased wages to insure care and energy. In large plants consisting of several locomotives, the cheaper runners often render compressed air locomotives more economical than steam locomotives. The compressor is self-governing and requires but little attention, and one man can easily run three or four compressors, or a compressor and fan engines; or, as in the case of the Susquehanna Coal Company's plant, described on another page, the compressor and a pair of engines operating a timber hoist. Besides these men there are the trip riders, or brakemen. These men make couplings, throw switches, and look after the train generally. It is well to select a good steady young man for this position, as his work renders him familiar with the duties of the locomotive runner, and he is valuable as an understudy for the more important position. At some large plants a man who acts in the capacity of trainmaster is sometimes employed, and when several motors are used, he becomes valuable in directing the efforts of the locomotive runners. But usually one engineer and one man to attend to car brakes and switches with each locomotive, and the man partially employed in running the compressor, constitute the entire force of operatives.

COST OF POWER. Next in order of importance is the cost of power, and this is true even at coal mines where the price of fuel is lowest; and if, as seems most convenient, we include under this head the total of all the items that make up the cost of the steam delivered to the compressor, we have every item of expense affected by the mechanical efficiency of the plant; and the cost of power in the form of steam, even at a coal mine, is by no means unimportant. In a paper read by Mr. Bowden, and reprinted herewith (see page 62), we find that with the cost of fuel and firing at the low figure of fifty cents per ton of 2,240 pounds, and with interest, repairs, and depreciation on 174 horse-power of cylinder boilers at $261 per year, we have a total cost for steam delivered to the compressor of $676.28 per year of one hundred and seventy-nine working days. If the plant had been working three hundred days per year, the cost for steam would have been $1,057. So much for dollars and cents. If we figure the cost of the steam delivered to the compressor as a percentage of the total operating expense, exclusive of fixed charges, we find that the cost of steam for the compressor is approximately 30 per cent. of the entire amount. If we include the fixed charges we find that the cost of steam forms approximately 12 per cent. of the expenses connected with the operation of the haulage.

The cylinder boilers used evaporated but 5 pounds of water per pound of coal. With good boilers 7½ pounds of water could be evaporated, reducing the fuel account by one-third, and with the higher steam pressure that could be used with the better boilers, compound non-condensing engines would be used to drive the compressor, reducing the steam consumption per indicated horse-power from 34 to 25. Then

$$\frac{25}{34} \times \frac{2}{3} = \frac{50}{102}.$$

We have cut the fuel required in two. By cutting off one-half the fuel we would save $1.16 per working day, to be balanced by about $600, the additional cost of the compressor with compound steam end. It is certain that there would be little, if any, difference in the cost of the boiler equipment, as 125 horse-power of high-grade boilers would replace 174 horse-power of low-grade cylinder boilers. Deducting $60 per year for interest and depreciation on the additional investment, we have a net gain of $207.64 — 60 = $147.64 per year of 179 working days, or about 82½ cents per day. This plant was installed six years ago, and the cylinder boilers were in place at the time, and 82½ cents per day was not a sufficient inducement to bring about the installation of a new boiler plant. It is well to note in this connection, however, that in hunting fuel economy reliability must not be sacrificed. This plant is hauling 675 cars of coal per day of ten hours, and each car contains 3⅛ tons of coal, or a total tonnage of 2,109 tons per day of ten hours. The loss of one hour's time due to break down means about 210 tons of coal less that day. It is true that the coal is still in the mine, but during the delay the time of all day men employed in moving coal is a dead loss, besides incidental losses more or less numerous and important, all the result of the interruption in the regular progress of the day's work. So important is regular work that many managers would willingly pay the entire amount of the fuel bill to insure it. In this case the fuel bill is $2.32 per working day. The electricians have had much to say of the low efficiency of compressed air as applied to haulage. These statements in regard to the low efficiency of compressed air locomotives are occasionally repeated to us by prospective customers. Our reply is stereotyped: "Compare the boiler capacities recommended." If the efficiency doesn't save steam it doesn't save anything. The comparison is usually conclusive, and makes the electrician's demonstration of superior efficiency extremely difficult. These results have not been attained by the use of a superior type of steam engine to drive the compressor, the compressors in all cases compared being driven by slow speed single-expansion non-condensing engines, equipped with Meyer's adjustable valve gear. The dynamos were driven by high speed automatic cut-off engines, the advantage, if there is any, being in favor of the high-speed engine. We have used compound non-condensing and triple expansion condensing engines to drive compressors, and have secured an economy in the use of steam for industrial haulage work never attained by electrical haulage under similar conditions.

COST OF REPAIRS, OIL, WASTE, ETC.—Again referring to Mr. Bowden's paper for definite figures, we find that for two years the total cost of all repairs, including both labor and material, was $299.94. The total cost of the plant being $15,156, the cost of repairs figured as a percentage of the initial cost is a little less than one per cent. a year, which is certainly a low figure, but its trustworthiness cannot be questioned. We have made improvements in the details of construction since this plant was installed, which will undoubtedly result in a still lower repair account.

The total cost for oil during the same period was $281.45. This plant was the first installed in the anthracite field and was virtually the pioneer in the development of compressed air haulage in its present form. It has been from the start, is now, and is likely to continue for years to come a mechanical and commercial success. As compared with our more perfected modern installations, the motors, compressor, pipe line and charging stations were all somewhat crude, and in quoting the repair account of this plant we are certainly telling the worst that can be expected. A greater number of working days per year, or more hours per day, would certainly tend to increase the cost of repairs, but the manager who figures his repair account as two per cent. on the initial cost will be reasonably sure of an agreeable disappointment. The cost of oil and waste depends upon the location of the plant, and the care exercised in limiting the quantity used to the necessary amount. It can usually be estimated upon quite closely in any individual case, but the general treatment of this subject is manifestly impossible.

Comparative Cost of Haulage in Coal Mines

By Means of

Compressed Air and Electricity

FIGURES for compressed air haulage taken from a paper read by the late Mr. J. H. Bowden, Chief Engineer of the Susquehanna Coal Company.

Figures for electricity taken from the catalogue of the General Electric Company, No. 1,030, entitled "Electric Mine Locomotives," published August 6, 1901.

The compressed air haulage plant is located at Glen Lyon, Pa., No. 6 shaft and No. 6 slope of the Susquehanna Coal Company.

The electric haulage plant is located at Forest City, Pa., No. 2 shaft of the Hillside Coal & Iron Company, Mr. W. A. May, superintendent.

The compressed air haulage plant was installed 1895 and 1896; one locomotive, one compressor and the pipe line for the shaft locomotive, September, 1895, and the slope locomotive and pipe in May, 1896. A second compressor was ordered April 7, 1900, to provide sufficient air for the increasing length of haul and output. The figures given are for the year 1898.

The electric haulage plant was installed 1896.

Both plants used two locomotives.

Items	Cost of Compressed Air	Cost of Electricity	
	1	2	3
Number working days per year..	160	200*	141¼†
Output per day, tons	2,109	989	989
Engineer, power house	$1.16	$1.20	$2.84
Motormen	4.20	4.23	9.31
Helpers (brakemen)	3.20	3.20	3.61
Electrician	....	1.67	3.68
Repairs to motors..	.74	5.95	8.42
Repairs to line	....	....	.46
Repairs to generator	.57	....	.61
Fireman	....	....	2.50
Depreciation at 5 per cent	4.74	5.20	8.17
‡Interest	4.73	....	4.41
Interest, repairs and depreciation, 174 horse-power boiler	1.63	....	....
Oil and waste for motor	.25	.22	.35
Oil and waste for generator	.47	....	.74
Steam (fuel and firing)	2.32	....	....
Totals	$24.01	$21.67	$45.10
Cost per ton	.01138	.02192	.0456

*Estimated for. †Actual time.

Mr. Bowden, in his paper, figures 1,245 ton-miles per day. Figure in Column 1 is tons of coal hauled.

‡Compressed air, 5 per cent. Electricity, 3 per cent.

Column 1 is taken from Mr. Bowden's paper, with the exception of the cost per ton, which was calculated by the writer. Mr. Bowden reduces the cost to the ton-mile unit. The cost per ton-mile given by Mr. Bowden is $1\frac{93}{100}$ cents. The average length of haul was less than one mile, hence the cost per ton hauled is less than the cost per ton-mile. The other costs per ton were taken direct from the catalogue of the General Electric Company.

Conditions unknown to the writer might have a tendency to compensate partially for the great difference in cost, but it would be hard to find conditions sufficiently unfavorable to the electrical haulage entirely to equalize them.

The ton-mile basis is not a fair basis of comparison, as the delay at terminals forms so large a part of the entire time consumed by the locomotives. The time lost in this way would remain a fixed quantity regardless of the length of haul, and, therefore, if the haul were longer the locomotives would make a better showing on the ton-mile basis.

The compressed air locomotives under consideration were respectively the fourth and fifth built by the H. K. Porter Company, and were crude in many ways when compared with the compressed air locomotives now being built. We have no doubt that the electric locomotives built for the Hillside Coal & Iron Company were also inferior in many ways when compared with the present product of the General Electric Company. But why should one type improve more than the other?

Why should the cost of repairs be less with compressed air locomotives than with electric locomotives, under like conditions?

There are two principal reasons :

First. Because the electric locomotive will not stop when overloaded, like a compressed air or steam locomotive, but will persevere until the wheels slip or the windings burn out. Fuses and circuit breakers are employed to protect the motors from an excessive current, but these appliances are only a partial protection, as they must permit the motor to use temporarily a current which, if continuous, would burn out the armature. The amount of power which a given motor can safely develop, depends upon the number of amperes of current which the windings can carry without heating them to a degree injurious to the insulation; the amount of heat generated depending upon the resistance, the current being constant; or with a constant resistance, the amount of heat generated will be as the square of the volume of the current. This heating is taken care of in two ways, by absorption and by radiation. At starting, the heat is mainly absorbed by the materials of which the motor is constructed. As the temperature of the materials increases they begin to radiate heat to the surrounding atmosphere, the rate of radiation depending upon the difference in the temperature, and the freedom with which the atmosphere can circulate about the heated parts. A given motor to carry a given load indefinitely, must be capable of radiating all the heat generated by the passage of the required current at a temperature low enough to prevent injury to the insulation. Electric motors for mine locomotives are not built in accordance with this principle. A motor of 50 horse-power, as ordinarily rated for mine or industrial locomotives, would only carry a load of 12 horse-power, if required to do so continuously for a period of say eight hours. It is therefore necessary that electric locomotives have periodical rests to cool off in order to keep the temperature down to a safe limit. These necessary periods of rest are frequently provided for by down grades and stops at terminals ; but when a rush of work or a change of conditions render these rests insufficient, trouble begins, the repair account goes up by leaps and bounds, and the service when most needed becomes exceedingly unreliable.

A compressed air locomotive can be worked all day at its maximum capacity without injury. An electric locomotive might be built which would do the same thing, but it would be exceedingly heavy, bulky and expensive.

A compressed air locomotive capable of developing 5,000 pounds tractive force, will develop this tractive force at any reasonable speed, and can do it for 9½ hours out of every 10, the remaining half hour being consumed in charging and oiling.

SECOND. In starting trains, and in operating on heavy grades where the tractive force required is close to the slipping point of the driving wheels, it is much easier to prevent slipping with the compressed air locomotive than with the electric locomotive. This is due to the fact that the power which turns the driving wheels is limited in the compressed air locomotive by the dimensions of the cylinders and driving wheels and the pressure in the auxiliary reservoir, whereas the motor of the electric locomotive is only limited in the amount of power it will develop by its own capacity to resist destruction. The motors of an electric locomotive must, therefore, have a large surplus of power always ready to spin the wheels, unless the most careful and intelligent handling of a properly designed controller prevents. That this careful and intelligent handling of a well designed controller is hard to get at reasonable wages, is proved by the extremely short life of the driving wheels on electric locomotives in general use. This feature is aggravated by the inability of an electric locomotive to work well on sand. The average mileage made by the driving wheels of electric mine locomotives is from 7,000 to 10,000 miles (chilled cast iron wheels). The average mileage made by one set of steel tires on a compressed air locomotive, is from 50,000 to 70,000 miles, the tires being turned once or twice during the period occupied in traveling the above named number of miles.

In addition to these reasons, the electric locomotives require a far more rigid system of inspection in order to insure the best results, as dirt and neglect are far more apt to result in a serious breakdown with electric equipment than it is in the case of compressed air locomotives.

Another quotation from the same article on electric locomotives referred to earlier, may be of value in this connection:

"The maintenance account, one of the principal criteria of good management, is a necessary evil, and eternal watchfulness is the only means by which it may be reduced to its minimum. The smallest street railway systems almost always have a system of rigid inspection, and every night each car is thoroughly cleaned and carefully examined. *Mine locomotive service is even more severe than ordinary street railway work, and the proper care of the apparatus is of correspondingly greater importance.* At night each locomotive should be run over a pit and should be carefully inspected and cleaned for the next day's work, while an extra thorough cleaning should be given the entire locomotive at least once a month. In this way loose nuts and bolts, worn-out gears, thin bearing linings, and a number of other minor defects, would be discovered and remedied before they became the source of more serious trouble. *A spare armature or two* should always be carried in stock, and each of the armatures should be regularly replaced, and then thoroughly cleaned and repaired and given a coat of insulating paint. The work of inspection should devolve upon a careful and painstaking man of some mechanical ability, and if there are many locomotives, he, with his assistants, should be employed as an *all-night force*. The inspector should also be required to make a daily report on suitable blanks, covering the condition of each locomotive. This may seem to be an unnecessary refinement, but it interests the inspector in his work, places before the management the result of his labor and constitutes a powerful incentive to faithful service. The inspectors will soon become expert and learn just where to look for trouble, the maintenance account will be surprisingly reduced, and the efficiency of the entire haulage system markedly increased. Under this system the all too frequent interruptions of service will be almost unknown, and only when a most serious break down occurs will the use of a locomotive be lost for a day. The efficiency of the inspection system, the importance of which cannot be over-estimated, may be greatly increased by carrying in stock in the repair shop at the mines a liberal supply of those parts of the locomotive which experience has shown to be subject to wear or renewal. The stock need not be large, but it should be maintained by placing frequent orders."

Compressed air locomotives do not require anything like the attention which the above quotation advises as economical in the operation of electrical locomotives. We recently sold a second compressed air haulage plant to one of the large coal operators in Western Pennsylvania. Before making this second purchase an exhaustive investigation into the relative merits of the two systems was made. Bids were obtained and reports secured upon the relative costs of operating the two systems. We secured the contract, the principal reason being that our compressed air locomotive previously installed has not cost $50 per year for repairs, whereas the best reports obtained from people operating electrical locomotives showed about $240 per year per locomotive.

But even more important than the difference in the actual cost of the repairs is the way in which the necessity for repairs arises. The cause of a very large percentage of the repairs to an electric haulage is burned out armatures, controllers and resistance, all of which result in a more or less serious delay, generally costly and always annoying. With the compressed air haulage 95 per cent. of the repairs are those due to worn bearings, valves and wheel treads, which can always be detected well in advance and be renewed, refitted or trued up, as the case may be, at the most convenient time.

In the year, 1902, at a meeting of the superintendents of one of the largest combination coal interests in the United States, which meeting was called together for the purpose of inspecting a recently installed compressed air haulage plant, it was the general consensus of opinion on the part of the general superintendent and those present, that for reliability, economy, safety, flexibility and convenience in handling, compressed air was fast demonstrating its superiority to electricity as a means of mechanical haulage. These conclusions were all the more strongly emphasized by the fact that with the exception of the compressed air plant which these people were called together to inspect, almost all the mines, covering a very large district and territory, had been previously equipped with electric haulage.

[Transactions of the American Institute of Mining Engineers.]

Notes on the Compressed Air Haulage Plant at No. 6 Colliery of the Susquehanna Coal Co., Glen Lyon, Pa.

BY THE LATE MR. J. H. BOWDEN, WILKESBARRE, PA.

(Canadian Meeting, August, 1900.)

The shaft plant here described was put in operation in September, 1895, and the No. 6 slope motor was started in May, 1896.

The plant comprises:

One Norwalk three-stage compressor, 12½, 9½ and 5-inch diameters of air, and 20-inch diameter of steam cylinder, all 24-inch stroke; capacity at 100 revolutions, 296 cubic feet of free air per minute, compressed to 600 pounds per square inch. A main pipe, 5 inches diameter, 4,380 feet long, with five charging stations in No. 6 shaft, and a branch of 3-inch pipe, 3,100 feet long, with three charging stations, in No. 6 slope. These pipes on each line charge a Porter compressed air motor, with 7 x 14-inch cylinders and four 24-inch drivers, weighing about 8 tons, with a tank capacity of 130 cubic feet of air at 550 pounds pressure in the main tank, reduced to 160 pounds in the 8-inch auxiliary tank of 4.2 cubic feet capacity, supplying the cylinders. The No. 6 shaft run averages 4,000 feet each way, on grades of ½ to 2¾ per cent., and averaging close to 1 per cent. in favor of the loaded cars. The No. 6 slope run averages 2,100 feet with nearly the same grades. The mine cars weigh 2,800 pounds empty and about 9,800 pounds loaded, and are hauled in trips of 12 to 20, averaging about 15 cars. The shaft motor now hauls about 355, and the slope motor 320 cars per day of 10 hours, replacing in the shaft 17 mules, and in the slope 15 mules, or in all 32 mules, against 27 replaced in 1896.

The average daily car and ton-mileage of each motor was as follows:

No. 6 SHAFT MOTOR

	Cars Hauled		
	1896	1897	1898
	355	347.4	356
	Tons Hauled One Mile		
Empty, in	336	330	338
Loaded, out	1,180	1,155	1,183
Total	1,516	1,485	1,521
Net load	844	825	845

No. 6 SLOPE MOTOR

	Cars Hauled		
	1896	1897	1898
	288	288.7	319.2
	Tons Hauled One Mile		
Empty, in	143	144	160
Loaded, out	501	504	560
Total	644	648	720
Net load	358	360	400
Total for both motors, gross (including empty cars returned)	2,160	2,133	2,241
Net load	1,202	1,185	1,245

The use of steam and air in operating the compressor and motor was found by test to be:

Steam

Indicated horse-power at 131 revolutions of compressor	150
Steam consumption per horse-power per hour, from cards	34 pounds
Steam consumption per hour	5,100 pounds
Steam consumption per hour, including condensation in line	5,200 pounds
Boiler horse-power required	174
Evaporation per pound of coal (cylinder boilers)	5 pounds
Coal required per hour	1,040 pounds
Coal required per day, 10 hours	10,400 pounds (4.65 tons)
Cost of fuel and firing per day (10 hours) 4.65 tons, at 50 cents	$2.32

Air

COMPRESSOR CAPACITY.—The free air compressed per revolution of compressor is 2.96 cubic feet, according to the calculation of the Norwalk Iron Works Company, no allowance being made for leakage.

The compressor works twelve hours per day; the motors ten hours.

	Cubic Feet
Free air per minute at rated speed of 100 revolutions	296
Free air per minute at actual speed of 131 revolutions	387.8
Free air per day 12 hours at rated speed of 100 revolutions	213,120
Free air per day 12 hours at actual speed of 131 revolutions	279,216

CAPACITY OF AIR MAINS USED AS RESERVOIRS.—The capacity of the 5-inch line, 4,380 feet long, is 608 cubic feet; and that of the 3-inch line, 3,100 feet long, is 159 cubic feet, making the total for both lines 767 cubic feet.

At 600 pounds pressure these lines hold 32,505 cubic feet of free air. The capacity of the main and auxiliary tanks is 134.6 cubic feet. At 508 pounds pressure (at which they will equalize with the main, starting to charge at 600 pounds) this is equivalent to 4,845 cubic feet free air.

LEAKAGE OF AIR MAINS.—In standing twelve hours the pressure falls from 550 to 350 pounds, and of free air, 11,688 cubic feet, or 974 cubic feet per hour, are lost. The proportion of this leakage to the total air compressed is 4.18 per cent.

AIR USED BY MOTORS.—According to a test made March 29, 1900, the amount of air used for the given amount of work was as follows:

	Shaft Motor		Slope Motor
	No. 2 Plane	No. 3 Plane	
Number of trips empty	3	10	16
Number of trips loaded	3	10	15
Average No. of cars per trip, empty	15.33	12.7	11.4
Average No. of cars per trip, loaded	13	13	11.3
Average cubic feet of free air per trip, empty	1,724	5,686	1,230
Average cubic feet of free air per trip, loaded	1,631	1,898	599
Average cubic feet of free air per round trip	3,355	7,584	1,829

SUMMARY OF DAY'S WORK IN 1898.—At shaft No. 6, 356 cars were hauled per day, namely, from No. 2 plane, 6 trips of 15 cars each, using 20,130 cubic feet of free air, and from No. 3 plane, 20 trips, averaging 13.2 cars each, using 151,680 cubic feet of free air. The work at slope No. 6 was 320 cars per day in 28 trips, averaging 11.4 cars each, and using 51,212 cubic feet of free air, making a total for 676 cars of 223,022 cubic feet of free air. The amount of free air apparently compressed for this work was 279,216 cubic feet, of which 83.4 per cent. is accounted for, leaving 16.6 per cent. for leakage and slip in the compressor, leakage in air lines, and changes in temperature.

AIR USED PER TON-MILE.—The average volume of free air used per ton-mile is as follows:

	Cubic Feet
No. 6 shaft motor, gross	113
" " net	203
No. 6 slope motor, gross	71
" " net	128
Both motors, gross	100
" " net	180

The greater quantity of air used by the shaft, as compared with the slope motor, is due to the heavier curves and the switching required, especially at No. 2 plane, where a portion of trip is frequently left.

COST OF PLANT.—The cost of plant, not including steam boilers, was as follows:

Compressor	$2,880.00
Extras for compressor repairs	75.75
Shaft motor	2,743.63
Slope motor	2,918.20
Extras for motor repairs	207.93
Air connections, 5-inch line (6,000 feet)	2,914.32
Air connections, 3-inch line (4,000 feet)	1,240.46
Steam connections to compressor	278.27
Material for compressor foundations and house, and air-washing box	295.27
Labor on compressor house and foundations and 5-inch line, and installing shaft motor	1,183.01
Labor on 3-inch line and installing slope motor	46.95
Foster equalizing valves	372.21
Total cost of plant	$15,156.00

COST OF OPERATION.—The operating expenses are shown in table on page 62.

TOTAL COST, INCLUDING FIXED CHARGES.—The total actual cost in the two periods mentioned was, therefore, for the two motors (one-half to each), in 1897, per day, $22.23, and for the whole period, $3,979.38; and in 1898, per day, $24.01, and for the whole period, $3,843.83. Taking the figures of 1897 as a basis,

	1897 (179 days worked)		1898 (160 days worked)	
	Per Day	Per Year	Per Day	Per Year
2 motor engineers, at $2.10	$4.20	$751.80	$4.20	$672.00
2 brakeman, at $1.60	3.20	572.80	3.20	512.00
½ engineer for compressor, at $2.32	1.16	207.64	1.16	185.60
Oil for compressor	.67	119.49	.47	75.94
Oil for motors	.25	45.08	.25	40.94
Repairs for compressors (material)	.10	18.76	.48	76.08
Repairs for compressors (labor)	.06	10.38	.09	15.22
Repairs for motors (material)	.16	28.78	.51	81.08
Repairs for motors (labor)	.18	32.77	.23	36.87
Steam for compressor (150 horse-power) fuel and firing	2.32	415.28	2.32	371.20
Total operating expenses	$12.30	$2,202.78	$12.91	$2,066.93

FIXED CHARGES.—The fixed charges are as follows:

	1897 (179 days worked)		1898 (160 days worked)	
	Per Day	Per Year	Per Day	Per Year
Interest, repairs and depreciation of 174 horse-power boilers	$1.46	$261.00	$1.63	$261.00
Interest and depreciation of plant, 10 per cent. on $15,156	8.47	1,515.60	9.47	1,515.60
Total fixed charges	$9.93	$1,776.60	$11.10	$1,776.60

and assuming 300 days of work in a year (with consequent saving in certain items of fixed charges, superintendence, etc.), it is estimated that the total cost would be $18.22 per day, or $5,466.60 per year. A similar calculation, based upon the figures of 1898, gives $18.83 per day, or $5,649.60 per year.

COST PER TON-MILE.—For the same two periods the cost per ton-mile was as follows:

	1897 (179 days)			1898 (160 days)		
	Daily Ton-Mileage	Daily Cost	Cost per Ton-Mile	Daily Ton-Mileage	Daily Cost	Per Ton-Mile
			Cents			Cents
No. 6 shaft motor, gross	1,485	$11.12	0.75	1,527	$12.00	0.79
" " net	825	11.12	1.35	845	12.00	1.42
No. 6 slope motor, gross	648	11.12	1.72	720	12.00	1.67
" " net	360	11.12	3.09	400	12.00	3.00
Both motors, gross	2,133	22.23	1.05	2,241	24.01	1.07
" " net	1,185	22.23	1.89	1,245	24.01	1.93

COST OF MULES DISPLACED BY THIS PLANT.—There were at No. 6 shaft 17, and at No. 6 slope 15 mules, costing on an average $126.64 each, or $4,052 for the two lots.

OPERATING EXPENSE BY MULES.—The expense of operating with mules would be as follows:

	1897 (179 days)		1898 (160 days)	
	Per Day	Per Year	Per Day	Per Year
No. 6 shaft:				
Depreciation and interest on 17 mules, 25 per cent.	$3.01	$38.22	$3.36	$538.22
Feeding, attendance, harness and repairs, $141.40 per mule	13.43	2,403.80	15.02	2,403.80
6 drivers	9.40	1,682.60	9.40	1,504.00
6 couplers and spragmen .	8.10	1,449.90	8.10	1,296.00
Total cost by mules .	$33.94	$6,074.52	$35.88	$5,742.02
Cost by motor . . .	11.12	1,989.69	12.00	1,921.77
Saving by compressed air .	$22.82	$4,084.83	$23.88	$3,820.25
No. 6 slope:				
Depreciation and interest on 15 mules, 25 per cent.	$2.65	$474.90	$2.97	$474.90
Feeding, attendance, harness and repairs, $141.40 per mule	11.85	2,121.06	13.26	2,121.06
5 drivers	8.00	1,432.00	8.00	1,280.00
5 couplers and spragmen .	6.85	1,226.15	6.85	1,096.00
Total cost by mules .	$29.35	$5,254.11	$31.08	4,971.96
Cost by motor . . .	11.12	1,989.69	12.00	1,921.77
Saving by compressed air .	$18.23	$3,264.42	$19.08	$3,050.19
Both No. 6 shaft and No. 6 slope:				
Total cost by mules .	63.29	11,328.63	66.96	10,713.98
Total cost by motors .	22.23	3,979.38	24.01	3,843.53
Saving by compressed air .	$41.06	$7,348.25	$42.95	$6,870.45
Total saving in two years			$14,218.70	
Total cost of plant			15,156.00	

At the average rate of saving for 1897 and 1898, the entire cost of the plant would be saved in 361 working days.

COST PER TON-MILE BY MULE

	1897. Tonnage			1898. Tonnage		
	Ton-Mileage	Cost	Cost per Ton-Mile	Ton-Mileage	Cost	Cost per Ton-Mile
No. 6 shaft			Cents			Cents
Gross . .	1,485	$33.94	2.29	1,527	$35.88	2.35
Net . . .	825	33.94	4.11	845	35.88	4.25
No. 6 slope						
Gross . .	648	29.35	4.53	720	31.08	4.32
Net . . .	360	29.35	8.15	400	31.08	7.77
Total						
Gross . .	2,133	63.29	2.98	2,241	66.96	2.98
Net . . .	1,185	63.29	5.34	1,245	66.96	5.38

The capacity of the shaft motor is equal to fully double its present work, and the slope motor is working at but about one-third of its capacity, while the compressor is doing all that it can, and a second one was ordered April 7, 1900. To operate the plant to the full capacity of both compressors, which, under the present conditions, would be about 4,500 ton-miles gross or 2,500 net per day for 300 days per year, would bring the cost of operation including fixed charges, to about $24.60 per day, or $\frac{547}{1000}$ of a cent per ton-mile gross and $\frac{984}{1000}$ of a cent per ton-mile net load. If all the work could be done by one motor under the conditions of No. 6 shaft, up to the capacity of the compressor, for 300 days per year, using only one crew, the cost of plant would approximate $11,000, and the operating expenses, including fixed charges, would be $10.86 per day for 2,400 gross ton-miles, or $\frac{48}{100}$ of a cent per gross ton-mile and $\frac{81}{100}$ of a cent per net ton-mile.

A further reduction of cost would result from re-heating the air at the motor, by passing it through water at the temperature of steam at 90 pounds pressure, by which method tests have shown a gain of about 50 per cent. in air economy. It is probable that by this means one motor could be run to its full capacity (about 3,000 gross ton-miles per day) with one compressor, at a total cost of $10.80 per day, or $\frac{36}{100}$ of a cent per gross ton-mile, for 300 days' work per year, the saving of $\frac{9}{100}$ of a cent per gross ton-mile, or about 20 per cent. over the last mentioned conditions being due only to the greater air economy; the fixed charges and labor cost remaining practically the same.

For a detailed description of this plant, with illustrations, those who are specially interested are referred to the *Colliery Engineer and Metal Miner*, Scranton, Pa., for May, 1896, and to the report for 1895 of the *Pennsylvania Bureau of Mines*, pages 104 to 110.

Description of Pneumatic Haulage Plant

Installed for Cambria Steel Co. at their Rolling Mill Mine, at Johnstown, Pa.

PLANT INSTALLED AUGUST, 1898.

Equipment furnished:

2 compressed air locomotives.
1 Ingersoll-Sergeant four-stage duplex air compressor with cross compound steam end.
6,200 feet of special 5-inch pipe for working pressure of 800 pounds per square inch.
3,900 feet of special 4-inch pipe for working pressure of 800 pounds per square inch.
3 charging stations.

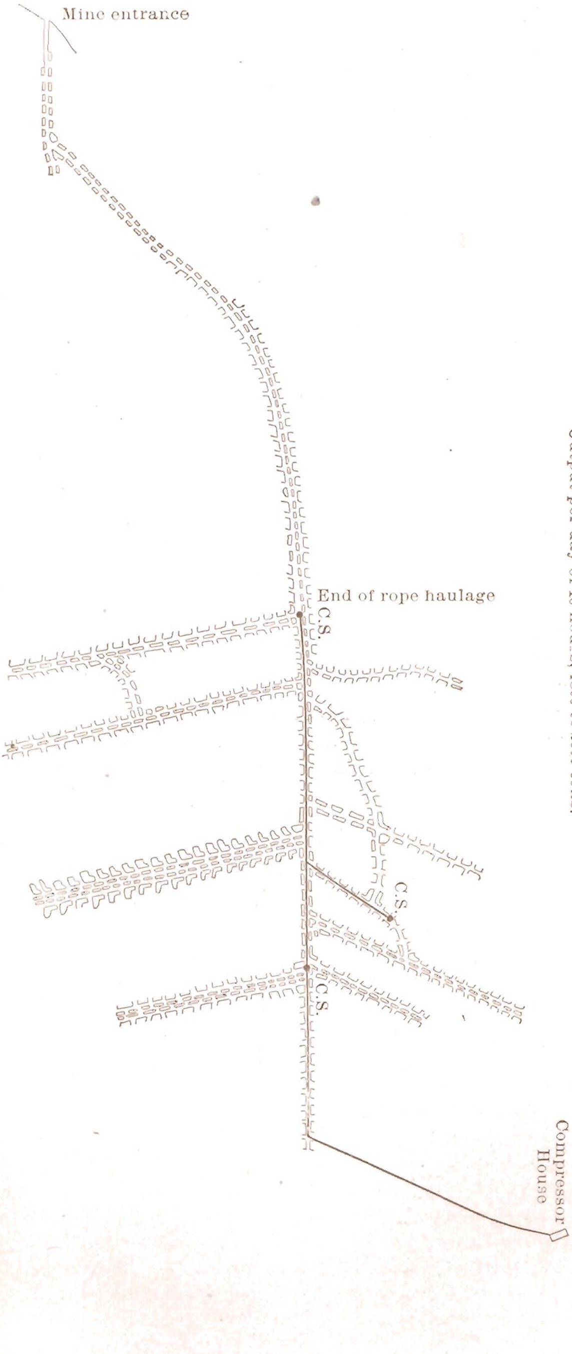
Description of locomotives:

Class C-P P, design shown by illustration No. 98, page 41 of this catalogue.
Cylinders, 9½-inch diameter by 14-inch stroke.
Six driving wheels, 26-inch in diameter.
Rigid wheelbase, 5 feet 6 inches.
Gauge of track, 3 feet.
Length over bumpers, 19 feet 5 inches.
Width (extreme), 5 feet 10 inches.
Height, 5 feet 3¾ inches.
Capacity of main storage tanks, 187 cubic feet.
Weight of locomotive, 27,000 pounds.
Maximum storage pressure in motor tanks, 700 pounds per square inch.
Pressure in auxiliary reservoir, 140 pounds per square inch.

We show herewith a diagram of the haulage roads over which the air locomotives operate. The grades are heavy and many of them against the loads. The motors haul trips of from 17 to 35 cars. For about two years this plant handled the entire output over distances varying from 3,000 to 7,000 feet. A duplicate compressor and a third air locomotive have since been installed on account of increased length of haul, the air locomotive for additional power, and the compressor more especially as an insurance against the possibility of delay.

This mine delivers the coal direct to the steel mill. Very little coal is stored at the mill, and the mine must run every day the mill does, and the entire mine and steel mill are dependent for their continuous operation upon the successful operation of the air locomotives. The pneumatic system was installed after a most exhaustive investigation into the relative merits of the various systems, including electricity, and was finally selected as the one which promised to give in the greatest degree reliability, economy and safety. The mine uses two systems of mechanical haulage, a tail rope system from the steel mill some distance outside the mine entrance to the point marked "End of rope haulage"; the compressed air locomotives on the numerous diverging entries beyond the end of rope haulage. The compressor house contains two Ingersoll-Sergeant duplex compressors for low pressure work, with steam ends the same as the high pressure machines. The compressor house is located several miles from the steel mill and tipple.

The Cambria Steel Company (as is also the rule with many other large companies), refuse to give letters of recommendation to manufacturers, but they have always shown extreme courtesy to visitors interested in the installation of similar plants, extending to them every facility for a thorough investigation.



PLAN OF HAULAGE ROADS
CAMBRIA STEEL CO.'S ROLLING MILL MINE

Scale, 2100 ft. = 1 inch.
Pipe line shown in heavy black line.
Minimum radius of curvature, 35 feet.
Gauge of track, 3 feet.

Grades variable between limits of 3% against loads and 4¼% in favor of loads.
Rail, 35 lbs. per yard.
Weight of empty car, 1700 lbs. Weight of loaded car, 6100 lbs.
Output per day of 10 hours, 1800 to 2000 tons.

Description of Pneumatic Haulage Plant

Installed for Coxe Bros. & Co., Inc., at their Drifton Collieries, West Side Slope No. 2, Drifton, Pa.

PLANT INSTALLED NOVEMBER, 1897

Equipment furnished:

1 compressed air locomotive.
1 three-stage straight-line steam-actuated Norwalk air compressor.
8,525 feet of 5-inch special pipe for working pressure of 750 pounds per square inch.
3 charging stations.

Description of locomotive:

Design C-P PP, general appearance shown by illustration No. 98, page 41 of this catalogue.
Cylinders 10½-inch diameter by 14-inch stroke.
Six driving wheels, 26-inch in diameter.
Rigid wheelbase, 5 feet 6 inches.
Gauge of track, 4 feet.
Length over bumpers, 19 feet 5¼ inches.
Width (extreme), 6 feet 10 inches.
Height (extreme), 6 feet.
Capacity of main storage tanks, 180 cubic feet.
Weight of locomotive, 30,000 pounds.
Maximum storage pressure in motor tanks, 700 pounds per square inch.
Pressure in auxiliary reservoir, 140 pounds per square inch.

We show herewith profile of haulage road over which this locomotive operates. In this case there are no sharp curves, and, as the motor operates on but a single road, a plan would be of but little interest. The location of the charging stations is indicated, and the pipe line connecting them with the compressor is laid on the locomotive haulage road.

The compressor capacity is somewhat in excess of the amount required by the air locomotive, as the company had in view the installation of a second air locomotive operating on a different level. This second air locomotive is now in operation, and a second compressor has been installed, not because additional capacity is required, but to serve as a spare and a precautionary measure against possible breakdowns. It is to be noted in this connection that this firm, after several years' experience with our air haulage, consider a substantially built steam-actuated air compressor more subject to disabling accidents than are our air locomotives.

Illustration No. 103, page 26 of this catalogue, is from one of five inside-connected locomotives, class B-P P-T, which we have built for this company. These air locomotives have tenders to carry additional air, in order to increase the amount of work that can be done with one charge. In ordering these air locomotives, the company had in view the establishment of a standard air locomotive, adapted to a variety of conditions as found to exist in their different mines. Their specification to us called for the most powerful air locomotive possible that could be built inside of the following dimensions: Gauge of track, 4 feet; extreme height, 5 feet 6 inches; extreme width, 5 feet 6 inches; extreme length, 12 feet 6 inches. The cut shows the result as worked out by us. One of these air locomotives was ordered first as an experiment, and a subsequent order for four duplicates is an eloquent indorsement of the efficiency and general utility of this type of machine.

PROFILE OF ROAD AND OTHER DATA

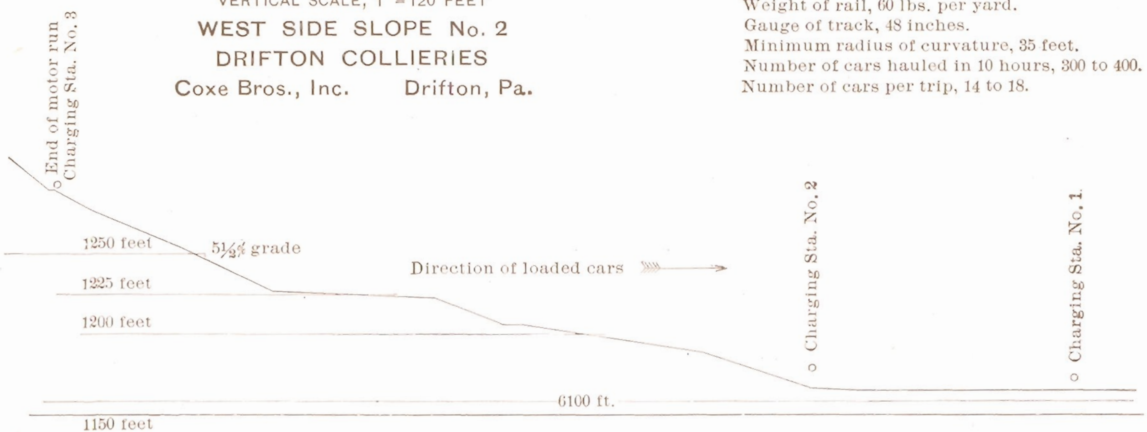
HORIZONTAL SCALE, 1″ = 1200 FEET

VERTICAL SCALE, 1″ = 120 FEET

WEST SIDE SLOPE No. 2
DRIFTON COLLIERIES

Coxe Bros., Inc. Drifton, Pa.

Weight of empty car, 3000 lbs.
Weight of loaded car, 10000 lbs.
Weight of rail, 60 lbs. per yard.
Gauge of track, 48 inches.
Minimum radius of curvature, 35 feet.
Number of cars hauled in 10 hours, 300 to 400.
Number of cars per trip, 14 to 18.



Description of Pneumatic Haulage Plant

Installed for International Harvester Co., McCormick Division, in their Lumber Yards, Chicago, Ill.

PLANT INSTALLED JANUARY, 1901

Equipment furnished:

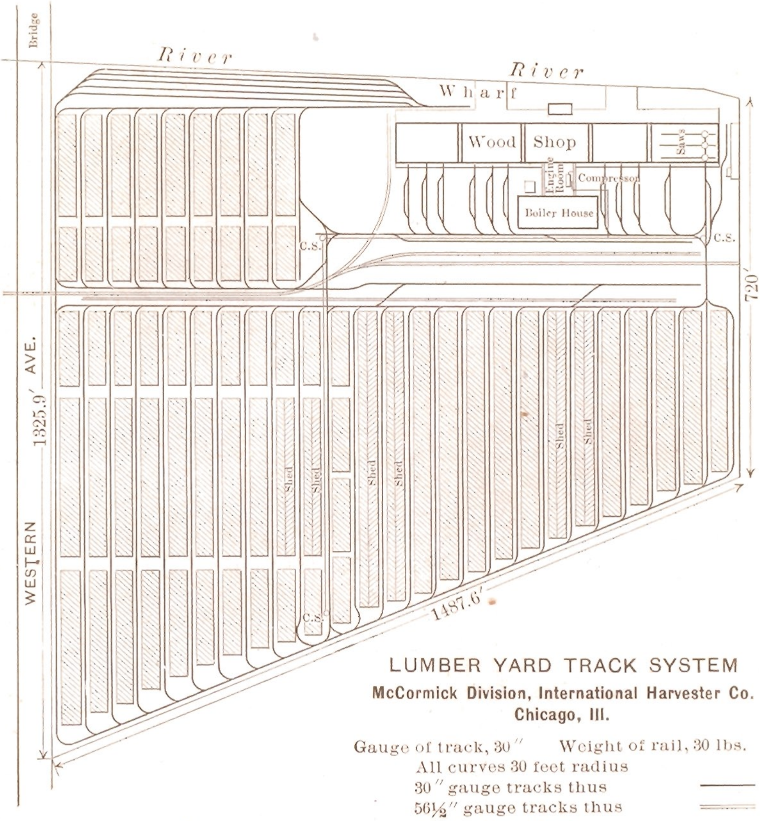
2 compressed air locomotives.
1 Ingersoll-Sergeant three-stage straight-line steam-actuated air compressor, capacity 370 cubic feet of free air per minute compressed to 950 pounds.
2,000 feet of special 5-inch pipe for working pressure of 950 pounds per square inch.
4 charging stations.
Also a number of special pipe fittings (flanges, tees, elbows, valves, etc.) needed for the proper laying of the pipe.

Description of locomotives:

Class B-P, design shown by illustration 101, page 24 of this catalogue.
General appearance shown by cut.
Cylinders, 7-inch diameter by 12-inch stroke.
Four driving wheels, 26-inch in diameter.
Rigid wheelbase, 4 feet.
Gauge of track, 30 inches.
Length over bumpers, 14 feet.
Width (extreme), 5 feet 2 inches.
Height (extreme), 9 feet.
Capacity of main storage tank, 65 cubic feet.
Weight of locomotive, 15,000 pounds.
Maximum storage pressure in motor tanks, 800 pounds per square inch.
Pressure in auxiliary reservoir, 140 pounds per square inch.

We show herewith plan of the track system used, also a cut showing the locomotive hauling a train of loaded cars away from the wharf. This cut gives a very good idea of the construction of the cars. The weight of one empty car (consisting of two 4-wheel trucks and coupling bar) is 1,300 pounds. These cars are loaded with from 2,000 to 3,000 feet of lumber; some loads, consisting of unseasoned oak, weigh from six to eight tons. From 6 to 12 cars are hauled in one train. One locomotive is used for handling the unseasoned lumber from the wharf or railroad cars (which are placed on the standard gauge tracks) to the piles where it is seasoned, the other in handling the seasoned lumber from the piles to the wood shop. The locomotive handling the unseasoned lumber frequently takes a train of 12 loaded cars from the dock, distributes them to the proper localities for piling, and returning gathers 10 or 12 empty

Showing locomotive in lumber yard of McCormick Division, International Harvester Company



LUMBER YARD TRACK SYSTEM

McCormick Division, International Harvester Co.
Chicago, Ill.

Gauge of track, 30″ Weight of rail, 30 lbs.
All curves 30 feet radius
30″ gauge tracks thus
56½″ gauge tracks thus
5″ pipe line thus
Charging Stations thus C.S. o
Lumber piles thus
Scale, 360 feet = 1 inch

cars from various localities and takes them to the wharf for reloading, the entire operation being performed in less than one hour and with but one charge of air. The average carload of unseasoned lumber is 2,750 feet board measure, so that a train load is 33,000 feet board measure. Fifteen hundred thousand feet of lumber has been distributed in one week of 60 hours by one locomotive and two men, one man to run the locomotive, the other to throw switches, make couplings, etc. The other locomotive has an easier time, as the wood shop only uses from 120,000 to 200,000 feet of seasoned lumber daily.

Under favorable conditions, with good roads, the cost of hauling the lumber with horses was from seven to eight cents per 1,000 feet. With the locomotive this cost of hauling was reduced to between one and two cents per 1,000 feet. When the roads were bad the cost of hauling by horses was frequently doubled and trebled. It is only fair to state that the horses can do the work at a cost of seven or eight cents per 1,000 during most of the year, provided that the roadways are well paved with heavy planks or cedar blocks. But the first cost of such paving is about the same as for a track system, and the cost of maintaining the pavement in good condition is much higher. In this case 40-pound rails and point switches were used. Considerable money was spent in grading, and the cars being equipped with roller bearings run very easily.

In making our calculations for compressor capacity, we used a coefficient of rolling friction of 30 pounds per net ton. The cars which were built after the calculations were made run much more easily, and this, combined with the fact that intentional provision was made for compressor capacity 50 per cent. in excess of their present needs, renders the amount of work now being done far within the ultimate capacity of the compressor. In fact, the compressor is only running about four hours per day. This running is not continuous; the compressor runs from one-half or three-quarters of an hour, and then stops for an hour, alternately throughout the day.

It is interesting to note the peculiar advantages of compressed air locomotives for this class of work. From the plan of the track and lumber piles it is plain that electric locomotives requiring an overhead trolley would not only make the plant expensive, but would also be an element of great danger both to life and property. The lumber must be piled, and a trolley wire would be very much in the way, requiring great care on the part of the men doing the work, in order to avoid the danger. If steam or electric locomotives had been used the fire risk would have to be greatly increased, and, besides, it would have been impossible to use the waste from the wood shop as fuel. All the steam power required for the wood shop and haulage system is generated by the sawdust, shavings, etc., from the wood shop, and, in addition, large quantities of the same waste materials are baled and hauled to other departments for use under the boilers there.

This company has since ordered one additional air locomotive duplicate of the first two, and also a 12 x 18 cylinder standard gauge air locomotive, Class B-P P.

Description of Pneumatic Haulage Plant

Installed for G. B. Markle & Co. at their Highland No. 5 Mine at Jeddo, Pa.

PLANT INSTALLED MARCH, 1899

Equipment furnished:

5 compressed air locomotives, all of the same size and design.
2 three-stage straight-line steam-actuated Norwalk air compressors (duplicates).
4,800 feet of 6-inch special pipe for a working pressure of 900 pounds per square inch; test pressure, 1,800 pounds.
5 charging stations.

Description of locomotives:

Class C-P P P, general design shown by illustration No. 98, page 41 of this catalogue.
Cylinders, 9½-inch diameter by 14-inch stroke.
6 driving wheels, 26-inch in diameter.
Rigid wheel-base, 5 feet 6 inches.
Gauge of track, 4 feet 8½ inches.
Length over bumpers, 15 feet 11½ inches.
Width (extreme), 6 feet 3½ inches.
Height (extreme), 5 feet 7½ inches.
Capacity of main storage tanks, 178 cubic feet.
Weight of locomotive, 32,600 pounds.
Maximum storage pressure in motor tanks, 800 pounds per square inch.
Pressure in auxiliary reservoir, 140 pounds per square inch.

The location of the charging stations and pipe line, together with the air locomotive roads, and some notes as to grades and distribution of the work, are shown by cut.

This plant was installed for a maximum capacity of 900 mine cars per day of ten hours. The highest output reached was 700 cars, with four of the air locomotives in service, the greatest length of haul being 4,500 feet at that time. This output was not due to any shortage in motive power, but to the fact that only 700 cars could be handled on the surface. These cars weigh, loaded, 12,000 pounds, and empty, 4,750 pounds, giving 3,262 net tons, which could readily have been handled by the locomotives.

The capacity of the two compressors was originally somewhat in excess of the locomotive requirements, as a No. 12 Cameron pump also received its power from the same source.

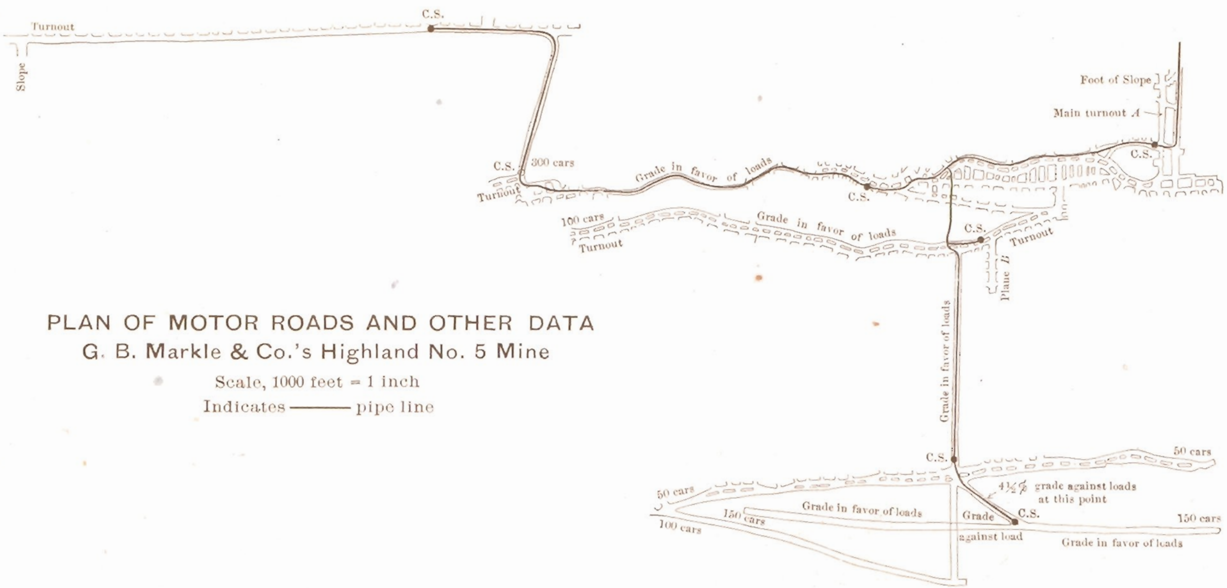
The track is standard gauge (56½ inches), and laid with 60 pound rails. The cars are hauled in trips of from 6 to 14 cars each, so that, taking into consideration the large cars, the trains are very heavy for mine practice, utilizing the full power of the air locomotives. This feature,

PLAN OF MOTOR ROADS AND OTHER DATA

G. B. Markle & Co.'s Highland No. 5 Mine

Scale, 1000 feet = 1 inch

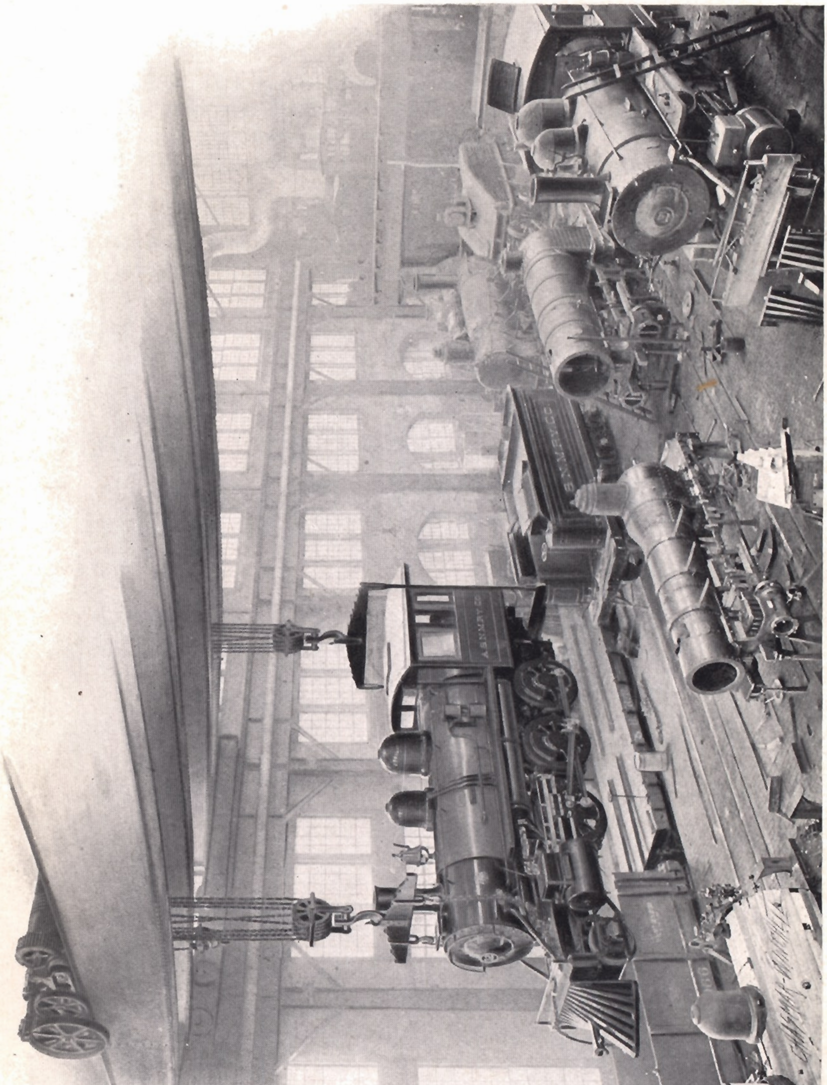
Indicates ——— pipe line



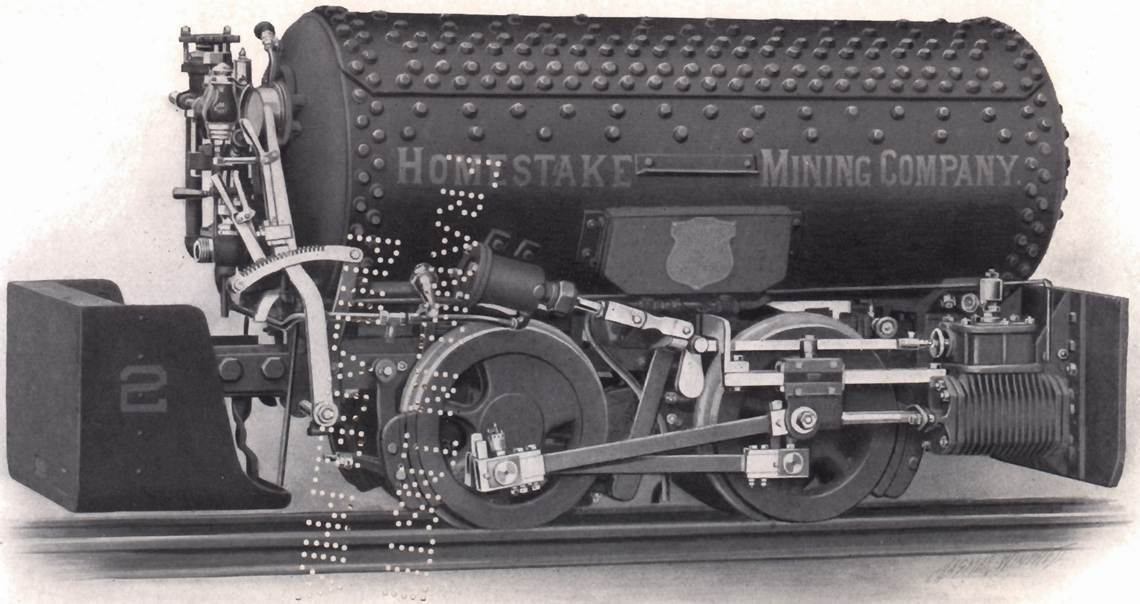
combined with intelligent supervision, has resulted in extremely low operating expenses. But four of the air locomotives were used for day work, and the fifth for night work, it being the policy of this company to make each air locomotive runner responsible for the condition of his machine. This could not be done if the night man took one of the day machines for his work.

At present the greatest length of haul is 8,100 feet, and the average output 500 cars per day of nine hours. This increased length of haul has necessitated the use of the five locomotives for day work, the installation of a third air compressor, the addition of 2,400 feet of 3-inch high-pressure air line, and two more charging stations.

The purchasers had in view absolute reliability and ultimate economy rather than extremely low first cost, and their liberal and conservative policy has been fully justified by the subsequent economical and continuous operation.

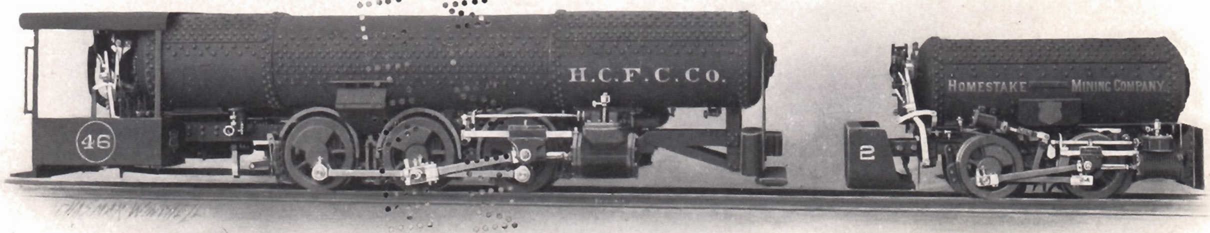


A corner of the erecting floor. A 45-ton Narrow Gauge Locomotive on the crane



Compressed air locomotive with detachable rear end. Can be hoisted on cage 9 feet long. Used in mines operating on many levels.

Weight, 9500 pounds; gauge of track, 18 inches; height, 4 feet 11 inches; width, 3 feet 3½ inches; length, 10 feet 6 inches.



The largest and smallest compressed air mine locomotives to date.

Comparative dimensions:

Weight	Cylinders	Gauge of track	Length	Width	Height
40000 pounds	12 x 14 inches	35 inches	23 feet	6 feet 6 inches	5 feet 7⅝ inches
9500 pounds	6 x 10 inches	18 inches	10 feet 6 inches	3 feet 3½ inches	4 feet 11 inches

NOTE

CORRESPONDENTS are requested to bear in mind that we are headquarters for

STEAM LOCOMOTIVES

for all gauges of track, wide or narrow, of sizes ranging from 5 x 8 cylinders, weighing about 4 tons, to 17 x 24 cylinders, weighing 50 tons, of every variety of design.

Our illustrated catalogue

LIGHT LOCOMOTIVES

will be mailed on application of intending purchasers.

IMMEDIATE DELIVERY—We keep on hand in stock finished locomotives, narrow and wide gauge, of the best type for Contractors' and Industrial service.

Chasmar-Winchell New York and Pittsburgh