due to the difference of level. At the same time the compressors were sending down air to work machinery at practically the same pressure below as above.

If a company were to start in Sydney ~~to supply~~ compressed air to work elevators, sewing machines, and the thousand and one appliances that are now worked in the city by hand power and by little kicking and often dangerous steam engines, what a convenience and saving in cost and worry would be affected, a saving that would many times compensate for the mere loss of power between the source and its application. In the great Derby shops of the Midland Railway Company compressed air is used, and the author saw the cylinders of a locomotive being rebored in their places, the power being supplied from a little air engine cramped on to the frame, and supplied with air through a rubber tube. It is used for cranes at Portsmouth Dockyard, and a factory at the great Seraing Works has all the cranes worked by air.

The application of compressed air to torpedo work is quite a modern development, and the pressures used go up into the thousands, but its consideration is rather beyond the object now in view, and the author would like to conclude this paper, already longer than he had intended, by drawing some comparisons between the present tramway system of Sydney, the cable roads of San Francisco (that we hear so much about), and the Pardy low pressure air system. First, however, your attention is asked for a short time to an application of compressed air in connection with hydraulic elevators, which is called

THE HYDRO-PNEUMATIC ELEVATOR.

The necessity for applying elevators to the lofty buildings of this city is now pretty well understood, and the advantages of hydraulic power for the purpose is duly appreciated. A large experience in hydraulic elevators and an examination into their details and construction as carried out in the principal cities of America and Europe has proved that moderate pressures are the most satisfactory in their results, and that pressures up to 700 lbs. are troublesome, work with shocks, and are not to be compared for smoothness of working with pressures of say 100 lbs. or thereabouts.

To get a pressure of 100 lbs. from an open tank, it would require to be up as high as the top of the Post Office tower, and if a loaded accumulator of, say, 30 cubic feet capacity is used, it becomes an expensive item. In the hydro-pneumatic system a close reservoir of wrought iron or steel is substituted for the tank or loaded accumulator, and the water is pumped into this reservoir against an air pressure equal to the head required. The air in the accumulator can be let out easily if less pressure is wanted, or more air can be put in by opening snifting valves in the pump if more pressure is wanted, and thus for special cases the attendant can command a higher pressure than that used for ordinary work. The variation of the pressure during the use of the water is, of course, dependent on the proportional volumes of air and water in the reservoir, and the proportion of the pump power to the elevator work. The reservoir may be made large enough to store a great number of lifts if required. This reservoir is, of course, nothing but an enlarged air vessel, to the pump, but as arranged for an accumulator it greatly simplifies and cheapens the cost of a hydraulic elevator, and besides it can be made of any shape, and can be placed horizontally or vertically, so as to be got in the least valuable space available. I need scarcely say that with the compressed air accumulator the loss by friction of packing is done away with. I hope shortly to be able to invite members to see one of them at work. Fig 12 illustrates the new application to an elevator.

Comparison of Three Systems of Tramway Propulsion.

The rival systems of motive power for tramways most likely to be brought into competition with the low pressure pneumatic system that the author has attempted to explain this evening, are—First, The cable roads as so successful in San Francisco; and Secondly, Our present steam locomotive arrangements

A great deal is often heard about the cable roads of San Francisco, and it has been put forward that they are just the thing for the requirements of Sydney. The author knows this city well, and he has had every opportunity of becoming acquainted with the tramway system in the capital of the Golden State, both by observation and description; the result is, that he yields to no one in his admiration of the skill and ingenuity of the engineers, as well as of the enterprise and foresight of the capitalists, that has led to their mechanical and financial success, but Sydney is not San Francisco, and the conditions that apply to tramways in these two Queen Cities of the Pacific are altogether different.

Firstly, the cable roads in San Francisco have grades as steep as one in five or six, to work up which, no ordinary locomotive, whether air or steam propelled, would be suitable. The six principal cable roads rise over hills from 250 to 300 feet high, and in several cases pass over two such hills in their run. The latest road up Telegraph Hill is, it is believed, about one in three, and only wants tilting a little more when it would not be a tram-road at all, but an elevator, and for such conditions as these, the author knows of no system so suitable as the cable ; but although Sydney is a hilly city, as cities go, we have no grades on our tram-roads that locomotives cannot climb, and thus the first motive for a cable road does not exist.

Secondly, the cost of cable roads is very great in construction, maintenance, and working expenses. This, in itself, would be no objection if the conditions for great earnings were commensurate ; but in San Francisco the conditions do not as they do here present seven or eight suburban tram lines, all converging to one focus, and then, figuratively speaking, running strangled together down a side street to a terminus in a back yard nowhere. Unfortunately for us, through the physical configuration of Sydney, we have something of that kind here. There the streets are straight, each cable road has its terminus in a populous centre of city traffic, and it runs out through main streets which correspond to our George, Pitt, York, King, and Park streets, but on a much larger scale. The tram lines there command also separate avenues of intramural traffic, such, for instance, as is carried in Sydney by the Railway omnibuses, and they also perform the greater part of the work that is here done by our suburban railway. There is thus an enormous traffic, and one much more uniform throughout the day than we have here, owing to so many of their leading business streets being traversed by the tramways.

Thirdly, it has been estimated in San Francisco that cable roads cost at least five times as much to construct as horse tramways, and three times as much as a road and air main for the pneumatic tramway. In the case of the cable it is in constant motion, with its supporting pulleys, and wear and tear is going on whether one car an hour or one car per minute is the service on the track. With an air main there is no wear and tear proper, and no more depreciation than belongs to an ordinary gas or water main.

Fourthly, the cable roads consume a large portion of the power exerted, to work their own destruction in the wear and tear of cable, which constitutes such a large proportion of the dead weight or non-payable load. In an able paper on the cable roads of San Francisco, read by Mr. Hanscom before the Technical Society of the Pacific Coast, the average working of seven principal cable roads is summarised thus :—Out of the total power exerted by the engines, 68 per cent. goes to move the machinery and cable, 28 per cent. to draw the cars, and 4 per cent. only to carry the passengers. If you give any consideration to these four points in the cable system just referred to, you will, probably, like the author, conclude that the conditions for its successful adoption in Sydney do not exist, and so we will next proceed to consider the system we actually have in use.

Under existing arrangements here in Sydney we commonly have a 16 ton locomotive drawing two cars of a weight aggregating eight tons, and sometimes ten tons, or collectively say 24 tons of dead weight in a train.* And although for an hour or two at morning and evening, the cars may be crowded, yet on many lines the average throughout the day is said to be only about 20 passengers. As a basis for comparison, and to give our present system every chance, we will take 45 passengers instead of 20, as the average load, then at 15 persons to the ton, the live load will be 3 tons, which, added to the 24 tons dead weight, makes the total load 27 tons. That is to say, *make the best of it, and then only* 11 *per cent. of the power is exerted to move the passengers, and* 89 *per cent. is required to drag the dead load about*, and DESTROY THE PERMANENT WAY.

Lastly, under the pneumatic system, where light cars at frequent intervals are proposed, we take for comparison a London metropolitan horse car for 40 passengers, which weighs $2\frac{1}{2}$ tons, if to this is added one ton of reservoirs, &c., and half a ton of engines, &c., the weight ready for work becomes four tons. Assume it to be only half loaded, or with 20 passengers at 27 cwt. (we have taken 45 for present system, remember), the total running weight would be 107 cwt. Of this gross load the 27 cwt. of passengers would be just over 25 per cent., instead of being only 11 per cent., as in the present system with 45 passengers; but if we consider the air car as fully loaded,

* During discussion said to be nearer 30 tons.

or with another 27 cwt., making a total of 6 ton 14 cwt., then the proportion of useful effect or payable load rises to over 40 per cent. The light air cars can be started every half hour, every ten minutes, or every minute, according to the requirements of the traffic, and if they are made to carry no roof passengers they can be managed with only one man to drive and collect fares, as is done with the bobtail cars used in some cities. Looking at all these points, The author thinks no hesitation can exist as to the advantages of air cars over our present system. As regards speed, the cable cars cannot run over say seven to eight miles per hour, but the air cars have besides the advantages already enumerated, the further one that they can "make up time" when on less busy parts of their route, as any reasonable speed is possible.

The question of the adoption of the pneumatic low pressure system has been under consideration by the City Railroad Company, of San Francisco, and the following extracts are taken from a copy of their engineer's report (Mr. W. H. Milliken). After considering horse power, cable, electric, coal, gas, high pressure air, and the Pardy system, Mr. Milliken says :

"The Pardy system is an improvement upon the high pressure systems in the following very important particulars :

1st. As it is operated with a low air pressure not exceeding 100 lbs. per square inch, the air may be compressd at one operation in a single machine, instead of progressively in several, as in the high pressure systems, thus saving the original cost of, and power necessary to run these additonal machines ; also at this low pressure the proportional useful effect is much greater.

2nd. It permits the adoption of light-weight motors, having small air receivers not exceeding fifty cubical feet in their combined contents, so that your present road-bed and track will amply sustain them, and the power required to move them will be much less.

3rd. It permits the replenishment of the air to recuperate the power of the motors at any point on the line, so that at every starting the motor may exert its maximum power.

4th. In its adoption, the system involves less expenditure of capital in providing motors and compressing machinery, and avoids the cost of replacing your present road-bed.

5th. *It would be less of an experiment mechanically* and financially, offering no risk whatever in its adoption.

6th. It permits the application of the machinery and motive power upon your present form of car, without encroaching upon the space reserved for passengers. It improves upon the cable system in the following points:

1st. It can be put in operation on your line at about one-fourth the cost.

2nd. It can be operated at about 30 per cent. less expense.

3rd. It is never liable to get out of order to such an extent as to suspend traffic.

4th. A better schedule time may be made, and at least one car on your main line dispensed with without interfering with the service.

5th. It may be operated on your branch line on Sutter street, and on any future branches running on streets already having cable lines.

6th. It can be put into operation without interfering with your present traffic or disturbing your road-bed.

7th. It involves no financial experiment, as its daily running expenses including interest on new capital invested in applying the system, will not increase your present expenses, but will rather materially decrease them.

It is better than the electric system—

1st. Because it will not cost over one-third the money to put it into use.

2nd. The daily expenses will be about 20 per cent. less including interest on capital invested.

3rd. There will be no disturbance of your present road-bed.

4th. It will not be affected by storm water, which, in the electric system, will at times flood the underground tubes and destroy insulation, and suspend the operation of the whole line."

The following table exhibits what is offered as an approximate estimate of the cost of constructing and operating each system, exclusive of such items as taxes, licenses, engine house or stable rent, drivers and officers' salaries, etc., for these items being common to all systems, they may be omitted without impairing the accuracy of the comparison.

COMPARATIVE TABLE.

SHOWING THE COST OF PROVIDING AND OPERATING VARIOUS SYSTEMS.

System.	Main Line.		Branch Line.	
	Cost of Providing.	Daily Expenses.	Cost of Providing.	Daily Expenses.
	Dollars.	Dollars.	Dollars.	Dollars
* Horse Power	50,000	150 00	21,250	63 75
Cable	450,000	203 00	Not	available
Electric	375,000	165 00	Not	available
Coal Gas	130,000	200 00	45,000	120 00
High Pressure Air	175,000	164 00	66,000	55 00
Low Pressure	105,000	125 00	40,000	53 00

Slight variations in small details may exist between Mr. Milliken's views and the author's; but on the whole he so thoroughly puts the case that it hardly needs an apology for so lengthy an extract from his report. A pneumatic tramway in San Francisco, however must not be expected for some time. That city is the home of capitalists and stockholders who own the cable roads, and the cable road patents throughout the U. States. In this stock millions of dollars are invested, and such great interests must be all against a rival system. We do want the best system for this city, and the object of the author has been to find the best system for our wants. If the Pardy pneumatic tramway will stand the criticism of this Association. then the inventor should have a chance to see his cars running here before long.

In conclusion, our present tramway system is doomed. It arose under exceptional conditions, and the cry for more means of conveyance in our rapidly extending city and suburbs did not admit of a waiting for experience. After travelling and seeing the principal tramways in America and England, the author considers the low pressure air system is the best one to take its place, and thanks you for your patient attention to a rather tedious paper.

* The horse power system provides for bob-tail cars with only a driver; all the other systems provide for cars of double the capacity with a driver and conductor

DESCRIPTION OF ACCOMPANYING PLATES.

Figures 1 to 3 represent four views of a compressed air tramway car designed to carry 40 persons. It is fitted with starting, regulating, and brake gear at each end so as to require no turntable at end of journey. The inside cylinders are arranged to work in a dust-tight box, and the whole engine can be detached for repairs, and another one substituted by the removal of sixteen bolts. The crank shaft is geared, 2 to 1, on to the main axle, and the proportions of cylinder are such as to take a full load of 40 persons up a grade of 1 in 20, with 25lbs. pressure of air. The air is stored at about 100 to 120lbs. pressure in the eight reservoirs marked D to K, on figure 3. Those marked D F G H I J K are connected by small pipes, forming practically one reservoir, while the cylinder E has separate connections, and serves as a reserve for emergencies. The cylinders are supplied from the reducing chambers, marked B in elevation and plan, they are placed on the platforms, and the air in them is reduced to working pressure from the pressure in the cylinders by the valve shown in figures 9, 10, and 11. The pipes L L connect the main reservoir or battery of cylinders with the three way cock on B B, and the reserve store of air is connected by pipes M M. The working pressure is regulated by the hand-wheel and spring on top of valve. Should a little extra pressure be needed to start the car near the end of a journey, when the main reservoirs are low, the driver can, by means of the three way cock, give temporary extra power to get under way. The charging nozzle, and flexible hose is shown hanging to the platform rail in elevation, and connected to the street valve in figure 2 or end view.

The diagram, figure 4, is from a Sommeiller compressor, and is taken from Pernolet. The diagrams 5 and 6 are from a compound compressor designed by Mr. Selfe to work up to 120 lbs., and fitted with a surface condenser between the stages. It will be seen, on examination, that all the heat of the first compression is removed before the second stage begins, and the working line keeps very close to the isothermal line. The cylinders are water jacketed, but no injection of spray was used.

Figures 7 and 8 are section and plans of a street charging valve, the large cover fitted with wood blocks end grain. The double-seated valve is opened by the conical end of the nozzle pipe on hose marked C.

Figures 9, 10, and 11, show the reducing valve and regulating cock to chamber B, before referred to. It will be seen from the construction of the valve that the pressure of the spring determines the pressure in the chamber, irrespective of the greater pressure in the reservoirs, and thus keeps it constant, as the main supply is reduced from say 120 lbs. to the minimum or working pressure.

Plate 3 shows in figure 12, the machinery of an elevator with a hydro-pneumatic accumulator. The pump draws a supply of water from the square tank by pipe S, and pumps it by pipe D into the accumulator against a pressure of air. By the operation of the valve V the water under pressure passes by pipes P and C from the bottom of the accumulator to the elevator cylinder, to lift the car, and by pipe W and C from the cylinder to the waste tank to lower the car.

By the action of a self-acting regulating valve the pump works up to the required pressure and then stops, it starts again as soon as the water is drawn off for a lift.

The sections of the Sydney and San Francisco tram-roads are drawn to the same scale, in order to show by comparison the great difference in the grades.

DISCUSSION.

Mr. Pollock remarked that Mr. Selfe had had the honor of bringing the subject of air compressing prominently before the members of the Association in his able and interesting paper read at our last meeting, his principal object being to prove that the steam motors used at present on our tram lines would be advantageously superseded by Pardy air motors. Compressed air as applied to motors (above ground) was of comparatively recent date, and it was very difficult to get reliable data with which to compare his statements of the performances of the Pardy motor, so that he would have to draw his conclusions from what was known as to the economy of air when used in other machines. In mining and tunnelling, for working hauling engines, coal cutting machines, rock cutting and boring, and for many other purposes —since 1850 air had quite superseded hydraulic and steam power, its many advantages for *underground* work, outweighing its extravagance