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.. The Central .. Railway and Engineering .... Club .... of Canada

OFFICIAL PROCEEDINGS

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PROCEEDINGS OF THE CENTRAL RAILWAY AND ENGINEERING CLUB OF CANADA MEETING.

Rossin House, Toronto, January 21st, 1908.

The President, Mr. McRae, occupied the chair.

Chairman,—

We will call the meeting to order. The first order of business is the reading of minutes of previous meeting.

You have all been supplied with copy of minutes of last meeting, and in order to proceed it will be necessary for some person to move that these minutes be taken as read.

Moved by Mr. Patterson, seconded by Mr. J. A. Mitchell that the minutes be taken as read.

Chairman,—

We are now at the first meeting of the new year and it is also the first meeting at which I have the honor to occupy the chair as President. Our first year has been most successful, and I certainly trust that the interest of the members will not abate during the ensuing year in securing new members. The financial statement of the Club is prepared and I believe is about to be submitted to you. The year ended Oct. 31st and I am glad to say we have a nice surplus.

It is my desire that we find more congenial quarters to meet in than we are in at present, for the reason that we are restricted here. A great many of us would like to smoke during the evening, but as you know we are prohibited doing that here. I think smoking would make it more sociable and would bring out more discussion and suggestions. I propose to appoint a committee to look into this matter. I am of the opinion that the members of the Club will coincide with me in this.

Unfortunately the Past President of the Club is unable to be present with us to-night, although he intended to be here. As you are all aware that at the meeting of the Executive held last week, it was decided to present Mr. Kennedy with a watch chain charm, which I might say has been decided as a "Standard," in recognition of his services as President of this Club, which I shall pass around for each member to examine, and as I have said before it being impossible for Mr. Kennedy to be present with us to-night the Secretary will be instructed to forward same to him.

Chairman,—

The next order of business is the announcement of New Members, which I will call upon the Secretary to read.

LIST OF NEW MEMBERS.

Mr. Jos. Haines, Manager D. K. McLaren Co., Limited, Toronto.

Mr. Hartley Spencer, Draughtsman, G.T.R., Shops, Stratford.

Mr. H. H. Wilson, Chief Engineer, W. A. Murray Co., Toronto.

MEMBERS PRESENT.

S. W. Price.
Robt. Patterson.
W. R. McRae.
H. Rowell.
Albert Attle.
Frank Stortz.
W. B. Cookson.
C. L. Webster.
T. J. Ward.
W. H. Smith.
A. G. McLellan.
Jas. J. Fletcher.
J. A. Mitchell.
H. H. Wilson.
A. W. Shallcross.
Geo. Mott.
Geo. Shand.
T. G. Lewis.
Harry Dover.
W. Price.
A. Taylor.
John Griffin.
J. Hay.
R. A. Cole.
G. F. Lilley.
I. O. Frost.
A. J. Lewkowiez.
A. M. Wickens.
J. R. Armer.
J. C. Garden.
F. A. Rothwell.
Joseph Haines.
A. W. Durnan.
Wm. Carter.
J. F. Campbell.
F. R. Wickson.
Robt. Pearson.
F. W. Brent.
R. A. Miller.
C. A. Jefferis.
F. Tushingham.
P. F. McCabe.
Acton Burrows.
C. A. Jackson.
H. Cook.
James Bannan.
H. G. Fletcher.
J. C. Armer.
H. Cowan.
W. A. Archer.
A. Hallamore.
E. D. Bly.
W. R. McRae.
J. McWater.
J. J. Campbell.
Harry Clifford.
John. C. Blanchflower.
Jas. V. Jackson.
J. C. Garden.
Chas. Geldart.
J. M. Clements.
W. Corrigan.
W. J. Jones.
S. Miller.
R. N. Card.
D. Campbell.
J. D. Scott.
C. L. Worth.

Chairman,—

The financial statement of the Club for year ending October 31st, 1907, which was read by the Secretary, the members will see that the Club is in good standing.

Acton Burrows,—

I think this reflects great credit on the Secretary, he has certainly done well. I think it is in order to refer this statement to the Audit Committee.

Moved by Mr. Burrows, seconded by Mr. Fletcher that same be referred to the Audit Committee.

Chairman,—

The next order of business is reports of special committees: Nil.

Reading of reports and discussion thereof.

Chairman,—

Mr. Duguid, of Stratford, has kindly consented to give us a paper to-night on compressed air. I now call on Mr. Duguid to kindly give us his paper.

COMPRESSED AIR AND AIR APPLIANCES IN THE MACHINE SHOP.

BY MR. J. DUGUID, ERECTING SHOP FOREMAN, GRAND TRUNK RAILWAY, STRATFORD.

Compressed air for mechanical purposes has been known from the earliest ages and was used many generations before we have any record of the use of steam. It was used for the reduction of ores and forging of iron more than two thousand years before the Christian era.

In some of the older countries such as China, India, the primitive methods of compressing air are still in use such as the air treading bags, the wooden cylinder and the china wind box.

Weldhurst, a Danish engineer in 1799 compressed air to 210 pounds per square inch and transmitted it to a motor in a mine and in 1800 he patented a means of propelling carriages by compressed air. This was the beginning of our present high pressure air.

Now it is not necessary for me to waste any time regarding the early use of compressed air as the present is what particularly interests us and I have only used these introductory remarks to show that compressed air is not by any means a modern idea.

I think that most of you will agree with me when I say that the compressed air problem is pretty much neglected. We hear any amount of discussion regarding steam engines, electricity, boilers, etc. There has also been volume after volume printed and read on these, but we hear very little about compressed air, which is just as important as any of these I have mentioned.

I need not waste your time by giving a description of the various classes of air compressors now in use as you are all thoroughly familiar with the mechanical operation of these. I suppose about the first thing that would be necessary to know when considering a compressed air plant, would be the cost of compressing air to a given pressure, but in considering the actual cost, there are many cases where the use of compressed air is imperative, whatever it costs, but as the cost has to be paid, it is as well to know it and you will find it is not very low.

Supposing a steam driven air compressor with steam and air cylinders both 20 inches diameter and running 75 revolutions per minute using steam at 80 pounds, 180 cubic feet of steam at 80 pounds would give you 94 cubic feet of air at 80 pounds, or 1 cubic foot of air costs nearly two cubic feet of steam. For lower air pressures, the steam will have a little more advantage and for higher pressure, a little less.

Few persons in dealing with air compressors make the necessary allowances and deductions for all the sources of loss and in consequence, the efficiencies of the air compressors are generally represented higher than they really are. The first deduction to be made is for the friction of the machine. This has been found to be from five to ten per cent. according to the class of machine. The second loss that is seldom recorded is the increase of temperature and therefore the reduction of weight of air admitted to the cylinder as the air cannot pass through heated passages and into a heated cylinder without being heated and increased in volume so that a less weight or actual quantity is sufficient to fill the cylinder. The loss from this heating has been estimated to about equal the friction loss of the compressor.

The third or principal loss is the heating of the air during compression. This is the one source of loss that is generally recognized and often treated as the only one.

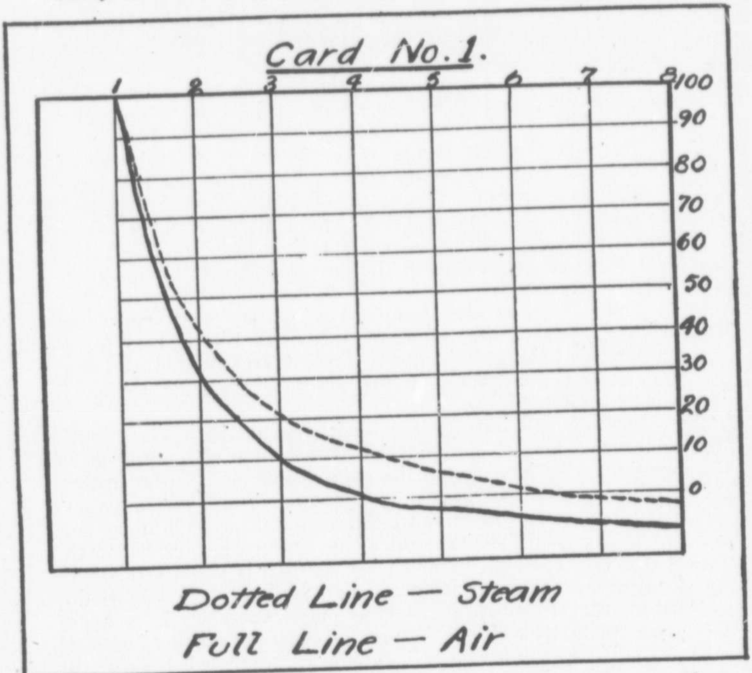
The fourth source of loss is the clearance at each end of the stroke. It is customary for the air compressor people to say that this clearance does not mean a loss of power, but only of capacity. The clearance does practically represent a loss of power or an expenditure of power without any result. These four items of loss will leave the compressor with about 60 to 75 per cent. efficiency.

You will notice that I am not going very deeply into the technical side of this subject, neither do I intend to for I suppose that the great majority present are situated as I am and are more interested in the practical than the technical side of these questions.

But now as I have given a slight idea of the power cost of compressed air, what about the power value of it after compression. We have found the compression of it to be costly, if indeed we do not think it costs too much and yet we go on using it more and more and I think we find profit in doing so, but at this point, we have got to be careful what use we make of it or our cost will be much higher than it appears this far, for if we now take our compressed air and go to use it as we do steam, that is substitute it in a place where we have been using steam, we will find that our cubic foot of air that has cost two cubic feet of steam to compress it, is not worth as much as one cubic foot of steam at the same pressure.

We have here diagram No. 1, which illustrates this. Here we have one volume of air and one volume of steam, both at 100 pounds pressure, each expanded into several additional volumes until the pressure of each falls below that of the atmosphere. It is easily seen that these two expansion lines are very different and that the effective pressures of the steam is much higher than the air or one volume of steam at 100 pounds represented by the dotted line reaches atmospheric pressure after expanded to about 6½ times its original volume, while the air drops to the same pressure after expansion to about a little over four times, its original volume. The mean effective pressure of the steam on this card is 27.38 pounds, and that of the air is 19.51 or only 71 per cent. of the steam.

Now we will note card No. 2, which shows steam and air expanded to atmospheric pressure at the end of the stroke. On this card you will note that the air line is outside or above the steam line and shows a higher mean effective pressure, but you will note at the expense of a larger initial volume

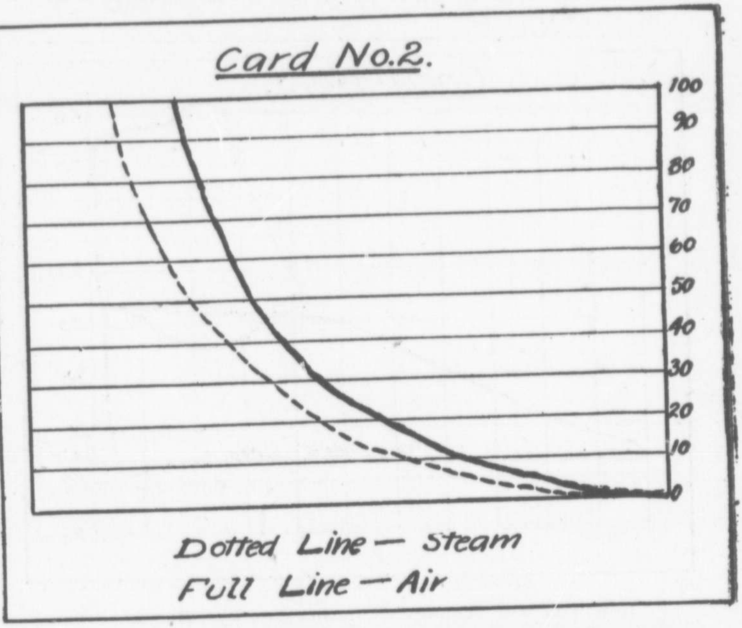


or otherwise a later cut off. The mean effective pressure of the air in this case is 41.6 and the steam 33.46, but the volume of air used is .2353 and the volume of steam used is .1473, the saving in the use of steam here is 25 per cent.

These two cards show clearly that compressed air should never be used in place of steam unless in a case of long transmission, which we will see about a little further on in this paper. Steam could also be used much cheaper than air for running any class of motor if it were not for the great loss in transmission and the excessive heat and exhaust steam which makes the use of air imperative at its high cost.

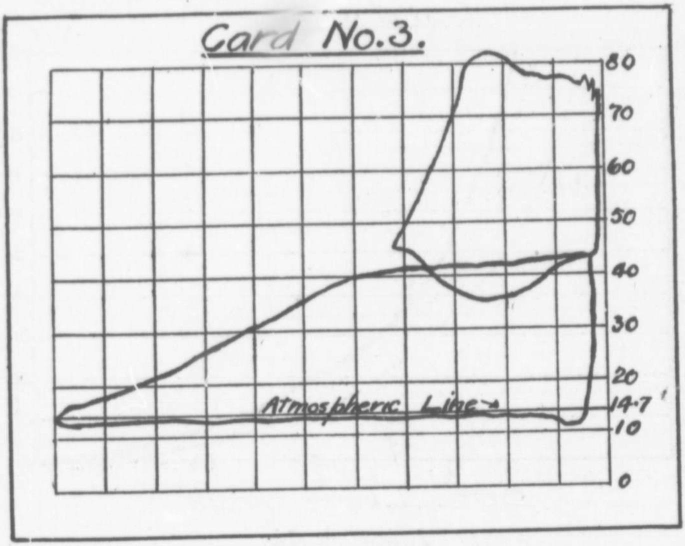
Now, with as few words as possible, let us look at the different means of compressing air or the different styles of air compressors or at least the direct steam driven compressor.

In the first place, we have the single stage compressor. These were the only kind in use until a few years ago, but on account of the high temperature generated in the cylinder, it became necessary to use two stage compressors and cool the air between the stages by means of air intercooler. It is still



an open and debatable question as to whether two stage compressors are necessary for compressing air up to 100 pounds. Some maintain that for this pressure, single stage compressors (with properly jacketed cylinders and air cylinder heads and using smaller units rather than one large unit), will show greater economy than a two stage compressor. I do not agree with this, but I do think that the most of plants either single or two stage compression are not giving proper economy on account of the compressors not having capacity to meet the demand of air used, thereby causing high piston speed, excess heating of the air cylinder destroying lubrication and heating of the free air before compression, therefore reducing its volume, also the slamming of the valves causing them soon to leak.

The principal reason why I think two stage compression is necessary even for pressures as low as 100 pounds, is that as air is a poor conductor, that very little is accomplished in cooling the air by water jacketing and about all that it does is to keep the compressor at a normal temperature, but with an intercooler, the air can be split up and passed through small areas between the cooling pipes and cooled to about its original temperature and therefore received into the second stage cylinder in a larger volume.



Here you will experience another loss by using an intercooler that is too small. Card 3 is a rough card which will show this. The depressed inlet curve of the second stage card shows this loss which is due to the small area of the intercooler and to the shrinkage of volume in it caused by cooling and causing a loss in the second cylinder. With cooling receivers of the proper capacity this loss would not be. Card 4 shows the economy of two stage compressors to 100 pounds.

The economy in power saved by two stage compressors for even as low a pressure as 60 pounds is very evident by inspection of this table, which shows for 60 pounds, a saving of 14.5 per cent. and for 100 pounds, 17.8 per cent.

Of all the steam driver air compressors in use, the ones showing the very worst results as far as the economy of steam is concerned are those used on locomotives for operating the air brakes. For compressing a given volume of air to a given pressure, the air pump uses about eight times as much steam as the best air compressors use for the same amount of work and I suppose there are more of these pumps in use than all the other air compressors combined, but while it is not economical, there is still good reason for its use. It is very compact and simple and always ready and the steam it uses, is generally waste steam. The pump is doing most work when stops are being made or running down grade with engine shut off and excess steam would be blown off through pop valves, if pump was not using it. It is only when the air brake pump is used

Card No. 4.

H.P. Developed to Compress 100 Cu. Feet. of Free Air to Various Pressures.

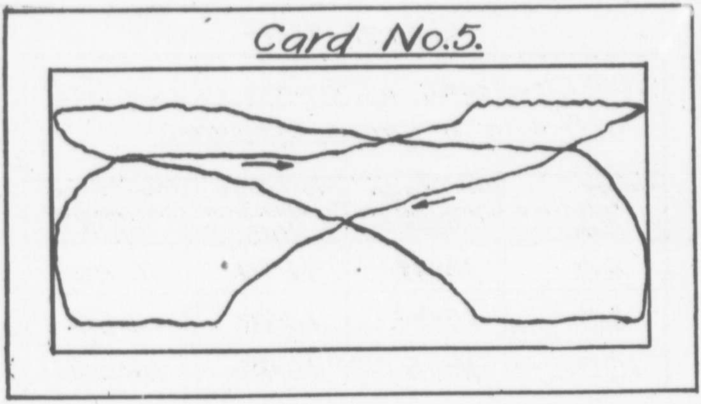
Guage Pressure Lbs.	One Stage Compression H.P.	Two Stage Compression H.P.	Four Stage Compression H.P.
60	13·41	11·70	10·80
80	15·94.	13·70	12·50
100	18·15	15·40	14·20.

for general air supply that its use should be condemned. Card 5 shows excess steam used by this class of pump.

There is another important matter and that is to get the free air as low a temperature as possible, thereby getting a larger volume in the cylinder. This is, I believe partly well looked after now by users of compressed air, but formerly air was taken at a high temperature from the engine room. There is one form of intake pipe in use which seems to me to be objectionable. This is a pipe usually running up through the roof and a top on it in the shape of a ventilator. I believe that the wind will form a partial vacuum in the pipe and interfere with the flow of air in the cylinder.

There is another matter I wish to note in regard to air compressors. The question often asked is their danger of explosion in the air cylinder of a compressor. I believe there is but not much and it is generally a matter of carelessness, even if an explosion did take place, hydrocarbon vapours and air explosions rarely exceed 300 pounds per square inch and the compressor would have a limit of strength to withstand this.

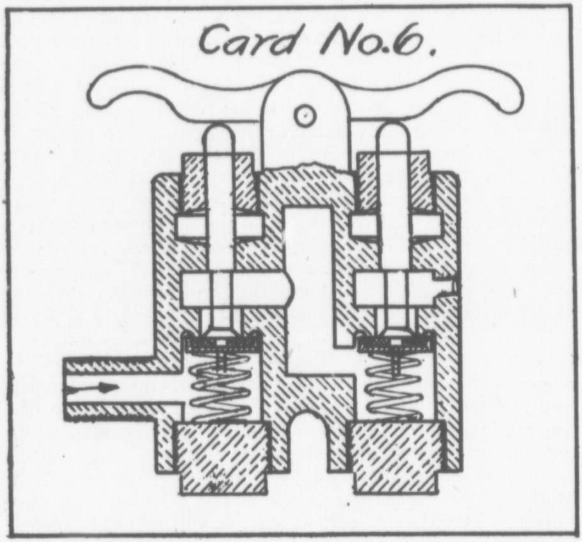
Most cases of explosions are no doubt, due to poor oil but an excess of oil sometimes causes ignition. When too much oil is used, there is a gradual accumulation of carbon which interferes with the movement of the valves and chokes the passages causing high temperature and explosions and then again sometimes, kerosene oil is put in the cylinder for the purpose of cleaning the valves. As this is very inflammable, it should not be used. Leaky discharge valves are also a source of danger by explosions as the hot air leaking back into the



cylinder to be again compressed with an additional temperature perhaps high enough to ignite. As a remedy for this, the discharge valves should be cleaned often and only the best oil used for lubricating the air cylinder.

We will now consider the question of the transmission of compressed air. It is generally considered that for economy the actual velocity in the main pipes should not exceed twenty feet per second. It would be well if more attention were given to the capacities of the distributing pipes as it often occurs that while the main pipes are of proper capacity, the small pipes or hose are too small and very often, velocities of as high as 50 feet per second are used and I think you will agree with me when I say that in the majority of plants, that the piping arrangements are outrageously bad. In these plants, the use of compressed air was started on a limited scale. Its use was then increased and distributed all over the shops and in a good many cases, the pipes have not been increased to meet the demand. The small distributing pipes are also launched out in every direction, all these defects tending to give poor economy.

With proper piping arrangements, compressed air can be transmitted great distances with less loss than any other power and any loss by transmission is not worth considering for ordinary shop use. One of the most important things in the transmission of air is to have it thoroughly cooled before it enters the pipes. If it is allowed to cool in the pipes, the moisture deposited in the pipes by the air cooling, rusts and



scales the pipes. This is then carried along to the motors, etc., and destroys the valves and pistons in them. Not only does this rust and scale do damage, but the water destroys the lubricants used on the different air tools. I believe that about 75 per cent. of the repairs required to air tools can be attributed to this.

To overcome this difficulty, I think that an after cooler (of about the same style as the intercooler) should be used as close to the compressor as possible, so that the air will be thoroughly cooled before it enters the transmission pipes and all moisture extracted.

Another important matter is to have as few elbows in the pipes as possible. Authorities differ regarding the retarding effect of elbows. Richards, who is a celebrated engineer on compressed air claims that one elbow has the same retarding effect as 14 feet of pipe. He also claims that gate valves should be used in place of the ordinary valves. Bends of large radius in pipes are therefore preferable to elbows. Not only will this have a less retarding effect on the flow of air, but it will also give less joints liable to leakage.

The leakage of air from joints and connections is I think the greatest loss in the transmission of air. These are generally small leaks all over the plant and are not noticed on account of the noise of the running machinery. The way that these small leaks are looked after at the Stratford locomotive shops is that after working hours, the air pressure is kept up and these leaks then can be heard and marked and repaired. To give you an illustration of the amount of air that will escape through a small opening (without going into a lot of figures) a 3-32 hole will keep a $9\frac{1}{2}$ inch Westinghouse air pump running 45 single strokes per minute to maintain 70 pounds per square inch in the main reservoir. This illustration will show you the importance of looking after small leaks in any part of the plant.

One great objection that has been raised in the use of compressed air, is that freezing up of the air pipes under certain conditions. By the freezing up of the air, of course, we understand a disposition of moisture on the sides of the pipes that convey the air and its accumulating and freezing there until the area of the channel is reduced and the flow of air is prevented. This moisture alone can cause no trouble as long as the temperature continues high enough, neither will a low temperature of the air freeze up as long as there is no freeze moisture present. The principal cause of the rapid freezing up of the air pipes when exposed to low temperatures is that it is generally taken too direct from the compressor, in some cases, quite hot and when it enters pipes exposed to a freezing temperature, it cools rapidly, depositing moisture which freezes and chokes the pipes. The after cooler, which I have previously mentioned, would reduce the liability of this freezing, but not altogether, as it would be impossible to cool the air so that when exposed to frost, it would not deposit some moisture, but the freezing process would then be slow. Another means to prevent freezing would be to compress the air to a greater pressure than required. It could then be cooled and used through a reducing valve and expanded to a lower pressure. In view of these facts, I consider that all out door compressed air pipes should be protected from frost, the same as water or steam pipes.

A great deal of discussion has taken place regarding the economy of reheating dry compressed air, but little is generally known as the actual economy of such a practice or the conditions under which, it is practicable. Some authorities claim that a saving of 25 to 38 per cent. can be made by re-heating, others claim that there is not one case in a thousand where one cent can be realized by re-heating the air.

At a meeting of the Master Car Builders' Association, some manufacturers of air appliances claimed that superheated compressed air used in air lifts, jacks, engines, etc., increases the efficiency 50 per cent. Their committee reported that the manufacturers either were not responsible for their words or that they did not know what they were talking about. The only place that any economy was got, was in a steady running motor with re-heating close up to it.

Large receiver capacity is of great importance in maintaining a uniform pressure on machines and acting as an accumulator in relieving the compressor of shocks due to sudden load fluctations and it is almost impossible to have too much receiver capacity. A difference of pressure of three pounds between the compressor receiver and furthest end of compressed air plant should be the maximum allowed, and a properly laid out system of piping should not show any appreciable loss of pressure. A well designed distribution system should hold pressure on the receiver over night and a 5 per cent. loss should be the utmost limit of leakage allowed.

The source of a great waste of air is, I think, in air lifts. You will find that in a great majority of cases that the cylinders of these are altogether too large for the maximum amount they are required to lift. This, of course, would not waste air if it was not for the class of air cock generally employed which is a three way plug cock. This is generally turned on full when making a lift and when the piston has reached the top of the cylinder it is not shut off. This, would, you see, with a cylinder 10″x4′ use about 3,700 cubic inches of air at 100 pounds per square inch to lift, say only 300 pounds, when the same amount of air would lift over 7,000 pounds. We are, therefore, using as much air to lift 300 pounds as 7,000 pounds. This, of course, is the fault of the operator in not shutting off the cock when the piston is nearly at the top of the cylinder. Card 6 is a cut of an air lift valve that saves a great amount of air and is used quite extensively. You will notice it shuts off automatically. A lift can also be made to the desired height much easier than with the 3 way cock.

It is not necessary for me to enumerate all the different applications of compressed air, but if you look up some of the different books on this subject and see the numerous uses it has been put to, it will surprise you. We all know it has about revolutionized all structural iron and boiler work; also the braking of railroad trains and when enumerating all the different purposes that compressed air is used for, you will find that in a great majority of cases, it is the only kind of power suitable and it has been estimated that for locomotive shop work, the cost of compressing air is ten cents, while the actual saving of labor by its use is fifteen dollars so that although the compression of air costs high, it pays to do so, and no doubt, some person present will make a contradiction to the statement that it takes about two cubic feet of steam to compress one cubic foot of air to the same pressure as the steam. Air compressor catalogues give it at about 1⅓, but I think you will find the former about correct.

A very important matter is the care of pneumatic tools. Very often they are allowed to take care of themselves. When they clog or fail to work satisfactorily, they wonder what is the matter and probably blame the makers of the tools. Now tools of this class such as air hammers and motors are necessarily of high grade workmanship and contain some delicate parts, but they will stand a large amount of very hard work if they are given anywhere near the amount of care, they should receive.

This is not only in the interest of the longer life of the tools, but the amount of work they will accomplish and this means the mount of money they save or earn during the year. The easiest and most economical way is to have a system by which they will all be cared for regularly. At Stratford, all air motors and hammers are sent to the tool room once a week for inspection and cleaning. The proper way to give an air hammer an ordinary cleaning is to stand them handle down in coal oil over night. In the morning, they are dipped in benzine and blown out with air pressure. After this, they should be thoroughly oiled. This keeps them in good condition. Motors are treated in the same manner only that they need not be put in coal oil, but the oil put in the cage.

Oiling should receive careful attention and a few suggestions may save trouble. Tools in constant use give better results if oiled once an hour with a good light oil. It is important that it be not too heavy. The air used in the tools expands quite rapidly and the result is a lower temperature than in most machinery so that a heavy oil will chill and be gummy.

The best way to oil hammers is to disconnect the hose and oil through the air inlet. The nose pin should also be oiled occasionally as this will make the hammer work easier and last longer. One of the most important points with air tools is to see that they are getting the proper supply of air. This should be from 80 to 100 pounds. Sometimes the pressure is reduced at the tools by piping or hose being too small or kinks in the hose, etc. In my estimation, a pressure over 100 pounds should not be used on either hammers or motors. If they will not do the work required of them at this pressure, tools of a larger capacity should be used. Another very important point to watch when using air hammers is to see that the handle does not jar loose. This controls the joint between the handle and the valve box and all these valves will be seriously damaged if used only for a few minutes with a loose handle.

Chairman,—

We are going to take ten minutes intermission. The Secretary says he will be pleased to receive any dues which have not been paid for the ensuing year.

Chairman,—

I am going to call on Mr. Carter who will give a discussion in connection with Mr. Duguid's paper.

Mr. Carter,—

It is indeed a great pleasure for me to be with you to-night to take part in this discussion of the many advantages of compressed air, which is a subject in which I am not a little interested being as I am in the air compressor business. The point which I propose to discuss is the re-heating of air and the advantage gained by the same, which Mr. Duguid has led us to believe there is not much gained by re-heating air. I will touch briefly on where re-heaters have been and are being used at the present time, and under different conditions. Considerable re-heating of air took place at the construction of the wheel pits at Niagara Falls, Ont., where compressed air was used to operate all classes of machinery at all seasons of the year and under, I may say, extreme conditions as to cold weather, and I doubt if they could have operated as successfully as they did with exposed lines, if they had not used air re-heaters. In all cases the re-heaters used at Niagara Falls were set up close to the machines which were operated by air, and they found it economical in some cases to use the re-heaters all the year round. Their object being to reduce the amount of air being consumed. The re-heaters increasing the volume of air in proportion to the increase in temperature (under normal conditions air at any given pressure at 60 degrees temperature re-heated to about 300 degrees will increase in volume about 50 per cent.) I recently had the opportunity of seeing in operation in one of the large quarries in Ohio an engine operated at the end of a two-mile air system. This gave them some trouble in winter time and they installed a re-heater which is heated with natural gas and keep it going at all times when the engine is running. Their chief engineer told me that he had experienced no trouble since and gave me the following figures: That by the proportion expenditure of the equivalent of two and a half pounds of coal per hour, he has increased the horse power developed by two and a half horse power or increased the capacity of the air by 25 per cent. on this ten horse power engine. (I have not in my possession the size of the re-heater used in this instance, but if any of the members would like to have the same I will gladly give it to them upon application to me.) I have noticed many other places where in winter time, particularly, they use re-heaters of different design. The one most noticeable was in the shipyards of Messrs. M. Beatty & Sons, Welland, Ont., where eight or ten pneumatic tools are being used in the open all the year round some three thousand feet from where the air is compressed, the pipe line being exposed for about five or six hundred feet. They experienced considerable trouble with the pneumatic tools in cold weather, while yet the pipe line was giving no trouble and very little moisture was coming through the line, having been all extracted before leaving the compressor room. The trouble was the air being low in temperature and any oil they could secure became sluggish and at times the tools would operate, but most unsatisfactory and their motor hoists would not work at all. To overcome this trouble they installed a few feet from the end of the air line and close up to a receiver an air re-heater and all the above mentioned troubles were eliminated, and, in fact, the tools worked more satisfactory on re-heated air than under the average good conditions. Considerable re-heating of air is done by carvers and stone dressers throughout the country using their tools as they do mostly in the open. One particular and noticeable feature about using re-heated air with their tools is that being of such fine construction the air must be clear and sharp to operate satisfactorily. I could touch on many other points, but I do not wish to take up more of your time and wish to hear some of the other members take part in this discussion.

In closing the subject of re-heating air, I must say that each case should be taken separately and studied out by itself and will admit that there are places where people have gone the limit with re-heating air, but this is generally done more or less in all classes of engineering. I trust I have been able to show you re-heating of air is a subject worthy of consideration to all users of compressed air more particularly to those who are using it transmitted a long distance in the open and using it in the open and I cannot bring Mr. Duguid's point too strongly before you that air pipes in the open should receive as much consideration as to covering as would a steam pipe line. The various tests made using different kinds of fuel seem to come back to a uniform basis of the equivalent of one pound of coal expended or consumed to every horse power gained in re-heating air.

In conclusion, I would recommend in all installations the use of up-to-date after-coolers to condense or extract as much moisture from the air before it enters the pipe lines and, as above stated, where the case demands the use of air re-heaters they be installed also, and particularly where there are continuous running motors and pneumatic tools used in the open. I would like to touch on the subject of compressed air for railroad shops and other general uses but I am not in possession of such information at the present time to do so. In any case, Mr. Duguid has covered the subject very completely and I must take the opportunity to congratulate the Club on having a member who can give us such an excellent and instructive paper.

And I hope that we will have a hearty discussion from all the members present.

Chairman,—

We shall be pleased to hear from Mr. Garden on the subject.

Mr. Garden,—

I am not familiar with the subject enough to discuss it. However, I have been very much interested in the remarks made already.

Mr. Geldart,—

Mr. Chairman and gentlemen, this is a very interesting subject to us all, and I presume the discussion here to-night is going to show what we are up against and show how to overcome some of our difficulties. I had thought perhaps we would hear from the Street Railway people as they have a number of compressors installed.

I would like to say, gentlemen, that compressed air as a power is one of the most interesting things to engineers in general, and has become more important during the last quarter of a century. It has been the means of introducing some very important labor and time saving machines. I think it is a good idea to get thoroughly acquainted with all its points. Mr. Duguid has thoroughly gone over the subject and it does not leave much for a man to say after it is gone over already.

With reference to the economy of two stage compression, you know one of the difficulties of compressing air is to overcome the heating during compressing. Now a two stage compressor will overcome this much more readily than a single stage by compressing in first cylinder to 27 pounds cooling to say 60 degrees and compressing to 90 pounds to 100 pounds in second cylinder you will have a lower temperature of 100 to 150 degrees, increasing the capacity of your compressor in volume efficiency 10 to 15 per cent. Another important point is by using two stage compression and duplex engines you are enabled to obtain a much earlier point of cut-off, say half stroke. When using single engine much later cut-off at least three-fourths. This is absolutely necessary for if you stop and think a single engine is working under extreme difficulties for as the steam pressure is decreasing, your air is ascending, necessitating carrying of steam for longer period. In duplex engines when side doing compressing is at lowest terminal steam pressure the other side is having full boiler pressure admitted and it takes load off other side and equalizes the loads carried by each engine. There is no question but that you effect a saving of twenty-five per cent. in steam economy and add to this your increased volume, efficiency, your power cost in compressing air is reduced, at least thirty-five per cent. over single stage compression.

The matter of re-heating air is being very much taken up by users. I concur with what the last speaker said as to reheating being one of the important points. While some firms may make rash claims, yet they certainly produce a decided economy. I noticed not long ago a test was made at a temperature of 350 degrees, and they effected a saving of thirty-five per cent. by the use of re-heaters. That shows the results of re-heating. If you are handling a number of small tools where you are using a quantity of air, re-heating of air is a decided economy, and secondarily you are getting the advantage of the full expansion of the air. Under the subject of freezing that has been well discussed.

I do not know of anything further to touch on in the matter. It is a very interesting subject to me, as I have had considerable dealing with air compressors and all these difficulties have cropped up. I would like to say that any person having compressors, (and I have repaired a number of them), that when you are not getting the capacity out of your machine, you will find it is mostly due to the piston packing. It is necessary to have tight piston rings. Another thing is to have your discharge valve perfectly clean and tight. The piston inlet people strongly point out that they get a cooler inlet and get a better capacity from the cylinder. However, the piston valve gets out of repair in a very short time.

Now concerning the matter of explosions, I noticed recently in the United States, in the Old Country and other parts of the world in the different mining districts, there have been serious accidents and explosions occur, attended by loss of life. They attribute these explosions to the discharge of carbon in the oil, and not having the intake pipe in a perfectly clean place. In one case they found it mingled with coal dust. In another case this deposit ignited at 295 degrees. It is, however, well to have oil at a high flash point, and it is necessary that the discharge and receiver pipes be thoroughly cleaned out and looked after carefully. These explosions are becoming very frequent, but I believe are having more care taken of them now.

Mr. Duguid has noted the care of pneumatic tools. I would like to say that in my experience it is due to lack of oil that trouble occurs with pneumatic tools. Boilermakers in particular do not oil their hammers enough. That is one of the troubles I find with air tools.

I think this subject should be discussed a little further as it is certainly very interesting.

Mr. Duguid,—

I did not refer to any use of long distance transmission lines, etc. I intended to say my paper concerned use of compressed air in the shops and not relating to mines, etc.

Mr. Lewkowiez,—

This is a subject I am comparatively a stranger to and I do not think I can say anything more than has been told you by the gentlemen already spoken. My experience has been rather of an exploratory nature and I might say I have not reached any results that I can refer to.

Mr. Patterson,—

While the author of the paper has stated, much attention has been paid to the improvement and design of compressors rendering them economical, it is doubtful if those using them have done as much to maintain them economically. In piping a shop for an air plant, it is money well spent to have good large diameters of pipe as they not only give a good supply of air to the different tools that they are going to supply but they act as a reservoir throughout the shop. In addition to this, the reservoirs should be placed at intervals throughout the shop where the power is to be transmitted to air tools motors, etc.

Electricity is taking the place of air in a good many instances and where the former is used in the shop, it is more economical and gives better adjustment for lifting than can be obtained from compressed air, but still there are numerous tools and appliances that compressed air is superior to any other power that we have at present. It is easily and safely handled and requires very little repairs, but no shop can afford to have air fads. I have seen machines and other appliances worked with air that would be just as easily worked from the machine shop power and would give just as good results, in fact, better, but it was thought clever to put on an air attachment which is very expensive and uncalled for.

This class of work wants to be avoided and give the compressed air its proper place and operate the tools that it can be economically used on. The author of the paper has gone very extensively into the matter of compressed air, but of course, could not take up sufficient time to enumerate the 1,001 uses to which it is put to and no doubt you are all acquainted with the ordinary uses which the compressed air is applied to any shop, mining and other appliances.

There is just one use to which compressed air is being used extensively at the present day and successfully so, which might be of interest to the members, that is in the lifting of water from deep wells. In the construction of these wells, the well is bored to the desired depth and an outside casing put down whatever it may be, 2, 4, 5 or 600 feet until a sufficient quantity of water is obtained and of a proper quality. Another casing is put inside this and an air pipe is then put down in between the outside and inside casing and turned up in the centre of the latter. Sometimes a special valve is used on the end of this air pipe and at other times the pipe is simply turned up for a short distance in the inside of the pipe.

Sometimes the water will come to the top of the well and other times it will not rise within a certain number of feet according to the location, but as a usual thing, the air lifting pipe requires to go down into the water about the same depth as the top of the water requires to be lifted into the tank or receiver. What I mean by that is that if the water does not come up to the top of the well within thirty feet, the air pipe would be required to go down about sixty feet or thirty feet into the water. It is an advantage probably to run it a little deeper than this. Now while it might be slightly more economical to put a deep well pump on the well and pump it with same, yet it is not always advisable to do this as nearly always the wells are placed some distance from the power house and there would be a good deal of loss in condensation from the boilers to the pump, also the pumps would have to be protected during the cold weather, but with the air supply, from the power house, it may be carried almost any distance and the wells worked.

The difference in economy is very small on the steam pump over the air lift, but the latter more than compensates for this by the convenience by which it can be applied. Water can be lifted to any given height by a given quantity of air and the depth which the pipe is immersed in the water below the pumping level of the water in the boring, that is the higher the lift required, the deeper down the air must be injected relative to the normal water level therein and so the height the water is to be raised determines the minimum depth which the boring must be driven.

Mr. Carter,—

I am glad my good friend, Mr. Patterson, has touched on the subject of compressed air being used for well pumping, and I take pleasure in placing before you the following figures:

In a recent twenty-four hour test pumping four wells we got together the following data: Wells about 400 feet deep. Water standing to within about six feet of the top when not being pumped. When being pumped, the water fell to about eighty-four feet. Wells were cased with 6¾ inch I.P. casing. Air pipe one and a half inches. During the twenty-four hours there were delivered 2,016,678 gallons water, lifting it about ninety-six feet. There was an average delivery of 11.15 gallons of water per horse power.

Cards were taken from the steam and air end of the compressor each hour. Average horse power of steam cylinders, 125.6. Average horse power of air cylinders, 116.14, showing a mechanical efficiency of about ninety-two per cent. or about eight per cent. of friction.

We also have the following data taken from one month's report in pumping water from three deep wells:

Steam pressure, 80 pounds.
Air pressure, 68 pounds.
Tons of coal of 2,000 pounds per month, 106¾.
Cost of coal per month, $167.60.
Cost of coal per ton, $1.57.
Amount of free air per minute, 352.8 cubic feet.
Amount of free air per day of 24 hours, 508,032 cubic feet.
Amount of free air per month, 15,748,992 cubic feet.
Revolutions per minute, 45.
Pounds of coal per 1,000 feet of free air, 13.5.
Cost per 1,000 feet of free air, .0106 cents.
Amount of water pumped, 76,255,000 gallons.
Cost per 1,000 gallons, .002 cents.

Compressor in use with the above is of duplex design, having duplex air cylinders 14 inches in diameter by 22 inch stroke and duplex air cylinders 14 inches in diameter by 22 inch stroke. The steam cylinders are fitted with Meyer adjustable steam valves and the air cylinders are fitted with mechanical air valves, air taken from outside the engine room. The above cost is for the air delivered from the compressor for fuel only, that is, the cost of oil, labor and other interest for the plant not considered. Horse power, 51.

I also take the opportunity of bringing before you something that will be more particularly of interest to the railroad man who is connected with the water pumping department. It is often necessary for a railroad, or a municipality, or a factory to establish a pumping station for the supply of water some distance from where it is convenient to get fuel, yet where the water is delivered it is very convenient to secure fuel. The question which has been taken up is to do away with the two separate steam plants, the extra help, the general upkeep and, in many cases, the handling of coal. The question came up as to what the best method would be to overcome the above objections by an air or pneumatic pumping system and there is in use to-day what is known as pneumatic displacement pumps which can be installed and have been installed a distance of three miles from the point of delivery. What is done is, there is built in the ground a concrete sump and there is installed in this sump a pair of tanks which are connected up with one common discharge pipe to the point of discharge required. There is then installed a compressor at the most convenient place, generally where the water is being consumed and an air line is run to the tanks, the tanks being submerged in the water fill through their automatic valves, the air pressure being turned on comes down first on top of the water in one of the tanks. This is discharged out, when the tank has emptied the air switches and rushes in on top of the other tank, the tank just emptied filling again with water by gravity, while the other is being discharged. In Hickory, North Carolina, the municipal waterworks have their tanks submerged in the river three miles away. Their pumping station is located on the railroad and there is a ten inch stream of water being pumped continuously to the town against a three hundred and twenty foot elevation. Analysis and biological test of the water before and after being pumped at the station sees a marked improvement in quality resulting from the thorough aeration and, therefore, oxidation of organic matter. This information may be news to you, gentlemen, but it shows an important use which compressed air is and can be put to in the field of water pumping.

As to the question of cost of so many thousand cubic feet of free air, I will take an instance as given in the paper read by James F. Lewis, of Chicago, before the Canadian Mining Institute a few years ago. There has been but very little data accumulated from actual practice regarding the cost of making compressed air. We have the following from the A. T. & S. F. Railway shops at Topeka, Kansas:

Steam pressure, 80 pounds.

Air pressure, 100 pounds.

Tons of coal of 2,000 pounds per month, 155.

Cost of coal per month, $139.50.

Cost of coal per ton, 90 cents.

Amount of free air per minute, 1,712 cubic feet.

Amount of free air per day of ten hours, 1,027,584 cubic feet.

Amount of free air per month of 31 days, 31,855,104 cubic feet.

Revolutions per minute, 50.

Pounds of coal per 1,000 cubic feet of free air, 9.7.

Cost per 1,000 cubic feet of free air, .00437 cents.

The above compressor is fitted with Meyer adjustable steam valve, compound air cylinders, with mechanical air valves on low pressure cylinders. Air is taken from outside the engine room. The above cost is for air delivered from the compressor for fuel only, that is, the cost of oil, labor and interest on cost of plant has not been considered. The above machine has duplex steam cylinders 20 inches diameter by 48 inches stroke.

Low pressure air cylinder 28 inches by 48 inches.

High pressure air cylinder, 16 inches by 48 inches.

Indicated horse power, 310.

We have the following from the same paper by Mr. Wm. Forsythe of the C. B. and Q.R.R.

We have indicated the engine with the air compressor when it was compressing air to eighty pounds and found that it required forty horse power. We get a horse power with our Corliss engine with 4¼ pounds of coal per hour and the air compressed consumes 204 pounds of coal per hour and at $3.00 a ton the cost of 1,000 cubic feet of free air compressed to 80 pounds, is 10 cents. With coal at $1.50 a ton it is, of course, only 5 cents per 1,000 cubic feet.

The above are the only notes I have as to the relative cost of compressed air. They are very vague and little data has been accumulated on this subject. I trust that the next paper given on compressed air I will be able to lay before you a more complete estimate as to the actual cost of compressing air.

Mr. Lewkowiez,—

May I ask a question of some of these gentlemen who have just been giving us the saving or increased economy by re-heating of air. We hear there is about twenty-five per cent. saving by the heating of the atmosphere, but we hear nothing about the cost of fuel used to heat up to that percentage. The cost of that fuel in comparison will give us the net percentage of increased power we have.

Mr. Geldart,—

From actual tests made they have been able to produce on one pound of coal one and a half to two additional horse power.

Mr. Jefferis,—

I have not been using compressed air and have not been in any shops for the past seven or eight years where they use it, therefore, I would not like to say anything on the subject. However, I would like to hear from some of the men who are having some troubles with it.

Mr. Burrows,—

Would it not be well to hear from the Street Railway people?

Chairman,—

Mr. Geldart has remarked that we have had some experience with air compressors, but am sorry to say it is not at all favorable. Our compressor inspector is here to-night and he will in all probability give us some information on the subject.

Mr. McCabe,—

I did not come prepared to speak on the subject under discussion, that is as I understand it, Compressors and Compressed Air.

I may say that we use on the Toronto Railway Company a somewhat different type of compressor, to that generally used. We have two stage single acting machines. These machines compress the air to 300 pounds pressure; the air at this pressure is then stored in storage tanks situated in the compressor stations. From these tanks it is taken by a pipe line to the street charging boxes. These boxes are equipped with hose bags, having automatic couplers to connect with the car storage tanks. The charging valves in these boxes are worthy of some attention, inasmuch as they are self bleeding and purely automatic.

We have had considerable trouble with moisture in the air, mainly due to atmospheric conditions, during certain seasons of the year, but especially so in the early spring. This condition of the air causes freezing of the car reducing valves. Another cause for reducing valves to freeze up and prevent free passage, is due to expansion of air from 300 pounds to 40 pounds pressure for train line service.

During the first winter after our air system was installed, we experienced considerable trouble from the pipe lines freezing up. On examination we found that we had made the common mistake of changing the size of our pipes at certain points in the line, these changes in size being governed by local conditions. Now, wherever we left an opportunity for the air to expand or contract in the pipe line, as already mentioned, we found that ice had formed inside the pipe, just at the point of expansion or contraction. Since that, I may say, we have changed our lines to one size of pipe, and have overcome that difficulty.

Again touching on the subject of compressors, as I have already stated, our compressors are designed for a straight line single acting two stage machine. What I want to say is this, that considering the high pressure, viz., 300 pounds, which we compress to, it is my opinion that better results would be obtained by the use of a three stage compressor. I also wish to point out to you, Mr. President and gentlemen, another use to which compressed air has recently been put, that is, for a system of vacuum cleaning; understand me, not vacuum from vacuum pumps, but vacuum from compressed air pumps.

I may say, if I am not out of order, that I recently competed in the yards of the Delaware and Lackawanna Railway in Hoboken, N.J., against vacuum from a newly installed plant costing $30,000, in cleaning car upholstering. The capacity of the D. & L. plant was sufficient to keep four men at work; these men would clean from eight to ten cars each per day.

In the case of the compressed air vacuum, I coupled on to the train line, and cleaned a coach ten cars back from the engine, in the same space of time as was done by the D. & L. cleaners. I had 19 inches of vacuum from 70 pound train line, supplied from a 9½ inch pump on the locomotive.

This system of car cleaning has I may say, been adopted and installed by the Toronto Railway Company, the present installation of compressors supplying the air, and has, I understand, been giving the greatest satisfaction.

Mr. J. J. Fletcher,—

The man who has all the trouble with air tools is sitting right over there, Mr. Clements. He looks after the air tools at the works. Probably he could give you a little more advice than I can.

At the boiler shop of the Canada Foundry we are carrying 125 pounds pressure, and it has been stated to-night, if my hearing does not deceive me, that if you cannot get the work done with 80 or 100 pounds pressure, you cannot with any more. I find that with 125 pounds I can put a rivet down much faster than with 100 pounds, and also find that just as soon as the air goes down to 100 pounds there is a kick and they come to me and say they cannot get the rivets down properly at 100 pounds. Although it may be detrimental to the tools to use over 100 pounds, but that is up to the manufacturers. When the tools were first introduced a representative of a pneumatic tool firm was at our works where I was once stationed, and I told him that we had increased the air pressure and they would have to increase the durability of the machine to suit. However, most of the manufacturers are making their tools to suit that capacity of air now.

I quite agree with the gentleman who spoke, that to get the full capacity out of your air tools you must oil them, and give them proper care. We are experimenting with several different kinds of oils at the present time. We oil up about four times a day with this new oil we have got, and we find that our air tools are less in the hospital than previously. We find again in using air through a hose, that at times the air tool will stop very suddenly, and upon examination we find that a remnanent of the hose had worked its way into the valves of the tool. After taking this out we find the tool runs alright again. We keep plenty of oil in the tools, in fact we are oftentimes called down for using too much oil. They are making them now self-oiling. Sometimes we find that in starting up a tool after oiling, the oil blows right through it. This, of course, is the fault of the man using the machine.

However, since we have turned over the air tools to our Mr. Clements, we have had very little trouble. I might say we are using air tools at pretty hard work for driving stay-bolts.

I wish to say in conclusion, give me 125 pounds pressure and you will get better results.

Mr. Wickens,—

I have had no experience in the handling of air tools or compressed air. I can only say that the compression of air, re-heating and cooling of it, is only a sequence. The re-heating of steam has got to be a very prominent idea among advanced engineers, and there is no reason why the superheating of air should not work just as well. If you have a long transmission distance, there is no doubt in my mind that if it is properly heated it will do better work at the other end if superheated. I think the difficulty with the air compressor people is that they have not learnt how to re-heat yet. I think that is the trouble, but, of course, I do not know whether I am right. As compressed air is being used for so many purposes in manufacture, the subject of re-heating should be fully investigated.

Mr. Smith,—

We use a little bit of air at our place but it is not very much. We have a small Franklin compressor and we use it to clean our elevators. We have a vacuum sweeper to clean our carpets. Taking it all around we do not use much air.

Mr. Clements,—

When Mr. Fletcher started to talk he said there was a man over in the opposite side of the room who should know something about the troubles of air tools. I think the trouble is caused by the neglect of the men using them. Some men will be using air tools and will not go near you for a week to have them looked at, while there are others who are coming to you two and three times a day to get their machines fixed.

Mr. McRae,—

I may say we are using compressed air on the Street Railway for different purposes. We are using air for painting in our fender department. It formerly took three men an hour to paint one fender. To-day, two men can paint fifteen fenders in two hours.

Mr. Patterson,—

How about the paint used?

Mr. McRae,—

We are using a thinner paint. The fenders only need a brightening up. We also use compressed air for painting the armatures.

Mr. Patterson,—

Our experience is that we have not saved a great deal of paint by the use of compressed air, but there is a great advantage to it. Where there are intricate parts to paint you can get into every crack. I think the experience with the spray is that generally more goes on the floor.

Mr. Fletcher,—

I may say that we are using compressed air now which we call hydro-pneumatic. This is, we use air and water for our plunger press and punches and rivetters. We can run our punches on about three gallons of water per day by compressing water with air. We have what we call intensifiers. I think the intensifier air cylinder is 32 inches in diameter, and the water end is 8 inches diameter, and with 125 pounds pressure of air. We can get on our rivetters between 1,400 and 1,500 pounds of water per square inch. I think we are about the only ones on the face of the globe who are using it. It is the invention of our Mr. Harkom. We use it continually and probábly all day. If we keep the leaks tight we could use it all day over and over again.

Mr. Burrows,—

I do not wish to shut off the discussion, but I do think we should pass a vote of thanks to Mr. Duguid for his fine paper. We are very much indebted to Mr. Patterson and the other gentlemen who come down from Stratford to attend our meetings so regularly.

Mr. McRae,—

I think without exception, that this is about the best paper we have had and it certainly has brought out probably the best discussions. Personally I have enjoyed it very much.

Mr. Fletcher,—

If Mr. Burrows will put his suggestion in the form of a motion I will be pleased to second it.

Moved by Mr. Burrows, seconded by Mr. Fletcher, that a vote of thanks be tendered Mr. Duguid for his able and instructive paper. Carried.

Chairman,—

I wish to appoint a committee of Messrs. Bannan, Lewkowiez, Worth and myself to see if it is possible to get better quarters to hold our meetings in.

Moved by Mr. Fletcher, seconded by Mr. Jefferis, that meeting be adjourned.