With a condensing steam engine about the greatest practical range of temperature is that which is between 400° and 100° Fah. and between 400° to 212° in a non-condensing engine. Steam is not a perfect gas (condensing to water below those temperatures), but air is a perfect gas and may be reduced in temperature by expansion many degrees below the zero of Fahrenheit's thermometer as is done in hundreds of refrigerating machines every day. If then that law of thermo-dynamics is true, which says that the greatest work which any heat engine can exert is represented by $W = H \left(\frac{T - t}{T}\right)$ the advantages of the greater range of temperature possible with air become apparent. Air again has a very low specific heat, only one-fourth that of water for constant pressure and only one-sixth that of water for constant volume; while therefore 772 foot-lbs. is equivalent to the raising of 1 lb. of water 1 degree Fah. and with no practical increase of volume the same work would raise the temperature of about 4 lbs. of air, or say 50 cubic feet 1 degree and result in a very perceptible increase of volume.

From careful observations as to the effect of heating and moistening the air taken with the Paris machinery, it is found as recorded thus:

The efficiency of air atmosphere temp. being	1.00
It is increased by heating it up to 200° C. or 392° Fah...	1.42
And by heating and water application to	1.90
Put in another way a cubic metre of compressed air	Foot Lbs.
at 85.3 lbs. per square inch performs work equivalent to ...	578,604
When heated to 200° C. or 392° F. it is increased to ...	810,000
And when heated with water application to	1,084,000
The work done in the steam cylinder being	1,247,692
The efficiency with heat and water of the air motor rises to	86.9°/o

This is claimed to be done by .44 lb. of coke, and 6.6 lbs. of water per horse-power of supplementary application.

In *Engineering* of July 19th last, Mr. Sidney R. Lowcock wrote to the following effect; taking exception to the statement that the efficiency was 86.9 per cent. and saying:—

"The efficiency of air engine is correct, 46.2 per cent, but no allowance is made for the additional power imparted by the heating," and he argues—"to raise a cubic metre compressed to 85.3 lbs. per square inch (=18.55 lbs of air) from 53° Fah. to (200° Cent.) 392° F. will require 1,496 heats units, or by J. 1,154,312 foot lbs."

These added to the 1,247,692 foot lbs. given out by the cylinder of steam engine makes 2,402,004 foot lbs., and the power given out (stated as 810,000 foot lbs.) is not 64.8 but 33.7 per cent. of the total power supplied to the air.

No doubt Mr. Lowcock is quite right in his figures, but certainly not in his inferences, for he does not point out that —while the 1,247,692 foot lbs. represented by the work of the Company's engine required the exertion of ten times that number of foot-lbs. in the actual work represented by the combustion of the fuel as consumed under the steam boiler—the additional 505,360 foot-lbs. were obtained by the application of heat direct to the air, and without the losses incidental to the steam engine and boiler.

It will, perhaps, make this more clear to compare these different effects in percentages of a horse-power-per-hour, and keeping to the cube metres as better for the purpose than cube feet. It thus appears that—

	Foot lbs.	Horse-power per hour.
A cube metre of compressed air at 85.3 lbs. per square inch above the atmosphere performs work equal to ...	578,640 ...	.292
Do., do., when heated 200°C = 392° F.	810,000 ...	.409
Do., do., when heated with water ...	1,084,000 ...	.547
The work done in the steam cylinder to effect the compression is	1,247,692 ...	.630
In order to raise this air (18.55 lbs. weight) to 392° requires	1,154,912 ...	.583

Now the work done in the steam engine under most favorable circumstances will require 1¾ lbs. of coal per horse-power per hour, and 1.75 lbs × .63 gives 1.1025 lbs. coal required to produce the cube metre of compressed air. The heat required to be directly transmitted to this air to raise it to 392° is stated (in objection to the claims set up) to be 1,154,312 foot lbs., equal to 1493 heat units.

Now, taking the thermal value of a pound of coal at 14,000 to 16,000 units, and the heat of combustion at 3000 degrees Fah., the proportion of the heat that is available between 60° and 300° is $\frac{3000 - 60}{3000 \times 461}$, or about 80 per cent., say 12,000 units, or 9,264,000 foot lbs. (see Reynolds on General Theory of Thermo-Dynamics); but the 1493 Joules' units are only .124, say one-eighth part of the 12,000 heat units which are available in one pound of coal as burnt; thus showing that if the whole heat of combustion available could be communicated to the compressed air, it is only that resulting from the combustion of .124lb. coal which is required to produce the .583 additional horse-power per hour shown above, or in conjunction with water, to increase the effective horse-power from .292 to .547.

To make this plainer still, we can present the horse-power gained from this direct application of heat and the horse-power from the steam engine on a level footing, one being .63 and the other .583 horse-power. Assuming that the heat of .124lbs. of coal can be communicated so as to add .583 horse-power to the air, then $\frac{.124 \text{ lbs.} \times .63}{.583}$ = .134lbs. required for .63 horse-power, or in other words, that amount of power which is produced by the steam engine and compressor with consumption of 1.1025 lbs. of coal, is also produced as an addition to that already stored by the absorption of the heat which is given out as available, by the combustion of .134lbs. of coal, or less than one-eight of that applied to produce equal results by the steam engine.

The following are the results of actual experiment with a ten horse-power engine, and air cold and dry, hot and dry, and hot and moist, to develop one horse-power:—

No. Experiment.	Initial Temp.	Exhaust Temp.	Cubic metres of air consumed.
1. Without heating ...	17.°C	—60C	38
2. With air heated ...	170°	+ 8C	22
3. Heat and water applied	170°	+70C	16

WITH 50 HORSE-POWER ENGINE.

1. With simple heating	... ...	15 to 16
2. Heating and water application	... ...	12

The waste of power is greater with small motors—

WITH 4 HORSE-POWER.

1. With heated air	... ...	30
2. Heat and water injection	... ...	22

ONE HORSE-POWER.

1. With simple heating	... ...	45
2. Heating and injection	... ...	27

The Apparatus used for heating in Paris is shown by Plate X., Figs. 2 and 3, being a small coke furnace, the air circulating up and down the cells between the fire and the outer casing. For very small installations a gas jet can be used in the manner, and with the economy of a gas water heater; the author has devised a plan by which the gas is compressed and actually burnt inside the air reservoir. This need not be referred to further now, however.

Cost of Hydraulic Power.

Let us now turn again to hydraulic power. In Professor Robinson's valuable work on Hydraulic Machinery it is stated that the mean cost of pumping, including 15 °/₀ for interest on capital and depreciation of machinery as taken from eight of the largest installations in England is 1.26d. per 100 foot-tons delivered into the mains, and allowing 80 °/₀ of pressure to be available. Then as 1 horse-power for an hour = 834·8 foot-tons, 1.26d. × 8·348 = 10·518d, and allowing the water engine to yield the very large efficiency of 66 °/₀, the actual cost of a horse-power in the driven motor would be 15.77d. per hour in England, and with 20 °/₀ added for difference of cost here, one horse power developed in the consumer's machine by the company's water would cost 18·9d. per hour if calculated on that basis.

The London Hydraulic Power Company charge from 4s. to 8s. per thousand gallons, and they get their water from the Thames for nothing. A company in Sydney would have to do one of four things. (1.) Use salt water and soon choke up their mains and their customers' machinery; (2.) Find a supply of fresh water of their own; (3.) Lay return mains and bring all the water back to their engine house; or (4) Pay the Government 1s. 6d. a thousand gallons for it like any other customer. Now, if we take the cost of water at the mean London price, 6s., and add 1s. 6d. to it for the water itself, it makes 7s. 6d. (it is questionable whether this would pay a company here interest on its capital), let us see how this price works out for the consumer.

1,000 gallons at 277 cubic inches per gallon, and 700lbs. pressure $\frac{277000}{12} \times 700 = 16,158,380$ foot lbs. for 7s. 6d.

Then 16,158,380 : 7s 6d :: 1,980,000 foot lbs.: 11.02d.

That is to say the cost here based on London mean prices would give 11d. per horse-power per hour, instead of the 18.9d. before quoted.

	Horse-power per hour.
At 10s.* per thousand gallons, it should be ...	14.66 pence.
And at 12s. 6d.† per thousand gallons, it would be	18.32 „

Cost of Gas Engine Power.

Now, as a comparison to this costly water-power, it is found that gas engines will certainly work with 25 feet of gas per horse-power per hour, and

With gas at 5s od per thousand feet, the cost is ...	1½d.	per horse
With gas at 3s 4d „ „ the cost is ...	1d.	power
With gas at 6s 8d „ „ the cost is ...	2d.	per hour.
Allowing 20 per cent. on cost of engine for interest and depreciation	1d.	„ „

Making the total cost per horse-power per hour from 2d. to 3d. without attendance or oil.

Cost of Steam Power.

Small steam engines and boilers of the very highest finish by eminent makers such as Marshall, Robey, Fowler, &c., can be purchased here in Sydney for £15 per indicated horse-power capacity.

* The cost given in Colyer's Hydraulic Machinery. † The price the Company is empowered to charge.

Allowing 10 hours a day for 300 days a year, and the large interest of 20 per cent. on first cost, the annual charge is—

£3 = $\frac{720 \div 300}{10}$ = .24, or, say, one farthing per horse-power per hour as the cost of the engine. Allowing it, further, to be most extravagant in coal and water—

7lbs. of coal at 20s. per ton	.75
5 gallons water at 18d. thousand...	.09
Add interest on engine	.24
	1.08d.
Six-horse being about the smallest actual power used, a boy attendant at 6d hour = per horse power ...	1.00
Total cost of steam-power per horse-power per hour	2.08d.

Lubrication and sundries common to the other systems not being taken account of.

Cost of Air-Power.

In Paris there is now a regular tariff for the motors and the air. You can buy your engine right out, or get it on the time payment system like a sewing machine or piano, and if preferred, rent it by the month, which is of course the dearest of the three ways. A six horse-power air motor costs 2,000 francs (£83 6s. 8d.) and the fixings 250 francs (£10 8s. 4d.) Time payment for purchase in 24 months 97 francs (£4 0s. 10d.); ordinary hire, 25 francs (£1 0s. 10d.); at 250 working hours per month the rent is 1d. per hour, or 1.66d. per horse-power per hour.

The cost of air at present supplied to customers is 2 centimes per cubic metre in the daytime, and 1½ centimes per cubic metre for driving the electric light. It has already been pointed out that the consumption per developed horse-power varies according to circumstances from 16 to 38 cubic metres per hour, and the cost of the horse-power per hour under the different circumstances and conditions in fractions of an English penny (= 10 centimes) is as under :

	Day Service.		Night Service.	
Consumption in cubic metres.	Air alone.	Air and Engine.	Air alone.	Air and Engine.
16	3.2	3,366	2.4	2,566
22	4.4	4,566	3.3	3,466
38	7.6	7,766	5.7	5,866

Summarising the cost of six horse-power from the above four different sources.

It appears the cost of per horse-power per hour is as under :—

	Pence.
Steam Engine, (including attendance)	2.08
Gas Engine, (without attendance) Gas at 3s. 4d. ...	2.0
Do. do. do. do. Gas at 6s. 8d. ...	3.0
Compressed Air Paris (including engine)	2.5 to 77.6
,, ,, Birmingham (without engine)	0.593 to 1.659
Hydraulic Power (without engine), ...	11.0 to 18.9

Having now shown as fairly as possible from the experience available the cost of the different powers, the author has placed some of the distinguishing characteristics of hydraulic power and compressed air in parallel columns for comparison.

The steam engines employed in both cases may be set down as of the highest modern class to develop 1 horse-power per hour with 1¾lbs. coal, or say one-fourth of that used in small steam engines, but while giving the Company's engines so much advantage over small private engines, affording no advantage to one system over the other. The friction in mains is of more importance.

The friction of air is about $\frac{1}{200}$ part of that of water, but as air at 70 lbs. requires ten times the volume of water at 700, the loss by water in this way is still say 20 times that of air for the same power. In fact some professors assert there is no loss at all with air, owing to the frictional equivalent in heat being imparted to the air, resulting in increase of volume, and no corresponding increase taking place with water.

Compressed air increases in volume as the load against it decreases; the actual volume used is proportionate to the resistance offered by the motor engine.	Water is non-elastic and the same volume is required to move empty engine as for full load.
Air can be, obtained for nothing from Nature's great reservoir, and be returned to the atmosphere in the cleanest apartment of any building.	Water must be obtained at comparative greater cost and must be taken away by return pipes from the engines.
Leakage cannot possibly do any harm, and will at once manifest itself by sound.	Water may leak and do an immense lot of damage before being discovered.
Air could be used for all sorts of domestic motors such as sewing machines, and be managed by women. The present price in Paris is ¼d per hour per sewing machine.	So many difficulties would attend the introduction of water at 700lbs. pressure into domestic service that it is not likely to be attempted.
Air can be introduced by flexible pipes to Ventilators, and the cold exhaust will reduce the temperature of the whole.	No equivalent qualification exists with water-power.
Air can be applied to all existing lifts in a very simple manner by driving the present machinery.	As the hydraulic lifts in Sydney now work with water at from 20 to 800 lbs. per square inch, and only a few work at 700 lbs., it is manifest that a most expensive transformer will have to be used unless new machinery altogether is put in before connection to power mains, and the friction of a transformer would probably double the power required to work the lift.
Hundreds of small manufactories in Sydney now employing steam could connect the air direct to their steam-engines and sell their boiler to utilize the space occupied, no new engine being required.	A special hydraulic engine must in all cases be employed with water power.
The power of an air-engine can be regulated by automatic expan-	Water being non-elastic no expansive working is possible, a vary-

sion gear, and the benefits of expansion as in a steam-engine be realized.	ing load on the engine demands a continuous exercise of the maximum power and consequent waste.
Air power can be used for driving refrigerators for cooling meat and other food, the exhaust air of the engine being combined to double the refrigerating effect of the machine—a most important feature in the Australian climate.	No such effect is possible with hydraulic power.
Tram cars may be operated by power from compressed air mains.	Tram cars could not be operated by water power at all for obvious reasons.
Water or sewage can be raised by the direct pressure of the air adjusting itself to requirements on surface of water.	A more complicated machine, in fact a combined pump and water-engine is necessary with hydraulic power.

No doubt Hydraulic Companies in Hull and London have been successful. The Hull £5 shares in 1886 were quoted at £6 10s. and the Melbourne Company's shares are said to be at a premium; but that is no argument in favour of water if air is better for such purposes.

In a pamphlet issued by the Birmingham Company calculations are given as to gas-engine and compressed air power, the cost by gas at the very low price of 2s. 3d. per thousand being £20 1s. 10d. for 2,700 working hours in the year, the corresponding cost by air power being only £8 19s.

For working a lift one ton 50 feet high in a minute by Hydraulic Power Company's mains the cost with the water at 5s. per 1,000 gallons is shown to be .498d., say one halfpenny per lift, but with the least economical application of air power the same is shown to be done for .1375d., or about one-fourth of the hydraulic charge.

If comparison is desired with a local installation and a power supply for 10s. per thousand gallons, we may take the new lifts at Mutual Life Association, working at maximum power with 6 horse-power gas engine.

Consumption 10 gals. per minute = 600 per hour.

6,000 per day at 10s. to the Company = £3 per day.

300 days in the year at £3 per day - - -	£900	0	0
6 horse-power gas engine including charge for engine 1s 6d per hour = 15s. per day			
300 days in the year - - - - -	225	0	0
Balance in favor of gas engine - -	£675	0	0

If the water power is taken at the low price of 5s., that is 1s. 6d. for the water itself, and only 3s. 6d. for the Company, the cost of the power would then be £450, still double that of the gas engine.

There is no need to multiply instances; hydraulic power has been a great institution, and for purposes, such as the cranes at Newcastle, it is likely to have its day for some time longer, but for general purposes its rival air has so many and such overwhelming advantages that it must supplant it. When the members of this Association held their last conversazione and exhibition, it will be remembered that all the small models were driven by compressed air. Owing to the great heat and discomfort of the grand machinery hall at Paris, it is now suggested that the next exhibition should have all the engines and machinery driven by compressed air. Hundreds of private installations now exist where all the cranes and machines of the establishments are worked with it. The Popp Company, at Paris, drive nine electric-light stations up to 750 horse-power besides the electric-lighting of four theatres, about ten cafés and hotels, the printing of the "Figaro," and two other newspapers. They have electric-light service in 102 streets, drive 7,800 clocks, and have already about 300 customers using their power. It is a subject that could be almost indefinitely prolonged, but the author feels he has already trespassed on the patience of the meeting, and with the statement that Sydney offers a grand field for a compressed air power company that would secure ten customers for every one who would prefer hydraulic power, he leaves the matter in members' hands.