A

ABOUT the end of 1896 the directors of the company found that their steam plant was no longer capable of keeping up with the continual increase in their machinery; and at the same time, they realised the necessity of economising in fuel, since the engines and their other steam appliances required more steam than their battery of five Cornish boilers could supply. With the increase in cost of wood fuel, their weekly bill for this item averaged £33. This for about 101 tons by measurement of wood—a ton being taken as 50 cubic feet. It was assumed that the power at present required would be about 300 I.H.P., since the then existing engines showed this power. These engines were both simple cylinder condensing engines working with steam at about 45 lbs. One was horizontal (17in. x 42in.), showing little expansion, and at 60 revolutions developing about 130 I.H.P. The other was vertical (20in. x 36in.), expanding three times, and at 46 revolutions developing about 170 I.H.P. There was no means of eliminating the steam used in the dye works scouring room and elsewhere from the total steam evaporated in the boilers, so it is not possible to accurately state at what duty these engines worked. The accompanying advertisement card contains the best record views of the old plant. The open corner shown in the right hand side of the central view was the space eventually chosen for the erection of the new plant, and for fitting it up with counter shafts and rope gearing. About 3000 feet of the floor area was left available, which was converted into a roomy machine tool shop for repairs, and a smithy and storeroom. The writer was called in as consulting engineer in January, 1898, and with the assistance of Mr. Grainger, the manager of the company, has carried out the improvements, and erected the engine, of which he submits the following trial records for your discussion.

Tenders were obtained from the following firms:

1. Hick Hargreaves, of Bolton; triple expansion engine, 15in. x 24in.;
2. 26in. x 42in.; Corliss type, jet condenser.
4. Brush Co.; 27½in., 41in. x 17in., at 210 revolutions; Corliss type, jet condenser.
5. Phoenix Foundry Co., Ballarat; tandem compound, 19½in., 38in. x 60in., with piston valves and link motion; jet condensing.
6. Thompson & Co., Castlemaine; tandem compound, 15in., 39in. x 60in.; trip valves, jet condenser.
6. Thompson & Co., Castlemaine; compound vertical, 15in., 39in. x 60in.; Corliss valves, and Fleming and Ferguson's patent crank and valve arrangements, jet condenser.

7. Austral Otis Engineering Co. (accepted); compound engine, 18in., 37in. x 60in.; trip valves, separate surface condenser.

This last tender was by far the most complete in detail of any submitted, and was also by some £1400 the lowest of the Victorian tenders, and practically as low as the tenders from Great Britain, and was accordingly accepted. In working out the details a large number of practical difficulties were experienced, and the writer considers that they have been all satisfactorily overcome. In the first place the writer wished the proportions of the cylinders to be altered to 16in. and 38in., but it was found that this would necessitate a heavier crank shaft and fly wheel, to obtain the steady driving so necessary for high-class weaving and spinning, and as a compromise the dimensions were altered to 17in. and 37 1/2in. respectively, and since the writer calculated that with the boiler pressure of 160lbs. which he was providing, these dimensions would be more suited for 600 h.p. than for 300, he had the L.P. cylinder bushed up to 36in. diam. At this size the engine, when running at 500 i.h.p., should show about 18 expansions, and when that power is exceeded perhaps it will be in the interests of economy to bore out the cylinder to its ultimate dimensions, and so give an increase in the ratios of the cylinders from 4 1/2 to 5 1/2. To facilitate driving in the mill, he introduced cross-rope driving for the worsted shaft, which was placed behind the engines. He also made alterations in several minor details, such as the air and circulating pumps, where the sizes are now 9in. steam, 10 1/2in. circulating, 15in. air, and 15in. stroke, and had special valves introduced into the air pump. As a result of all these alterations, the total weight of the plant was increased by about 14 per cent., and to the credit of the contractors (the Austral Otis and Engineering Company) it should be recorded that they agreed to these alterations without making any charge for extras. The plant was erected at Christmas last, and the greatest praise is due to Mr. Grainger, the manager of the Company, for the expedition with which he effected the alterations. A little thought will show that it was no light matter to remove so scattered a plant as the former one, and on its site erect an entirely new plant, including a new battery of high-pressure boilers, with new machine, tool shop, smithy, store-room, flues, a nd new wool-drying loft of 70ft. x 36ft., all in six weeks, yet that is what he actually effected. The worsted plant stopped on 30th November, and the main engine stopped on the 13th December, 1898, and the new plant started in the first week of February, 1899, and has worked without a hitch ever since. The power (i.b.p.) developed is rather less than that recorded from the old engines. Possibly this is due to the large size of the condensers which they worked. It is now about 280 i.b.p., and on equal work to the old engines has recorded an average of only about 264 i.b.p. These powers show a duty of under 18lbs. of steam at 160lbs. pressure per i.h.p. per hour, and the plant works for eight hours on a consumption of about two tons of Newcastle coal. At ordinary time, however, it is found more economical to use about 1 1/2 tons of Newcastle coal, and about as much
more wood. Owing to the large surface of the boilers the use of waste heat to dry wool spread in a loft above, there is a consumption of fuel in the boilers equivalent to 80lbs. of Newcastle (AAA) coal per hour to be allowed for apart from the heat which goes to generate steam. The exact economy of this plant as compared with its predecessor cannot be accurately determined; but we hope to eliminate the quantity of steam which is required for the general purposes in the mill, and is now entirely supplied by one of the old boilers, and consequently we will be able to approximate to this. We are also investigating some interesting points connected with the engine, such as (1) jacket economy (the trial here recorded was taken without steam in the jackets), and (2) whether any economy can be obtained by using the Meldrum forced draught, which has been fitted to the furnaces. The present records are merely laid before this Institute with a view to discussion. Up to now the writer has not completed all the essential observations; for instance, he has not tested the calorific value of the coal samples taken during the test; and he has only used the dimensions of the engines when taken cold in the machine shops, for calculating the indicated horse power. He is, however, preparing a completed balance-sheet of heat, which, with the subsequent tests in prospect, should form a useful record of what he ventures to think is an interesting plant. With a view to make the records more intelligible they have been kept in the diagrammatic manner. It would perhaps have interested members if more drawings of the plant had been produced, but as this paper is only designed to form half of a sitting, and for the purpose of promoting discussion they have been kept back.
DISCUSSION "ON DUTY TRIALS OF BALLARAT WOOLLEN MILLS ENGINE."

PROF. Kernot:—There are several points mentioned at the end of Mr. Anderson's paper that I would like some further information on, viz., the question of jackets or no jackets, and that of the "Meldrum" forced draught. I do not think there is sufficient information given in the paper, such as tabulated results which could be compared with other engine tests. The general results obtained seem to be good. The proportion of the cylinders, 17 x 37 1/2, seems somewhat unusual. They are generally about 15 1/2 x 26, which is a different proportion to that adopted. Is the former an advantage or not? I would also like to have seen the actual vacuum line shown on the diagrams, so that we could see how good the vacuum in the cylinder is. Some data might be given as to the temperatures and value of the water passing through the condenser.

The President (Mr. Arnot) :—At the last meeting Mr. Anderson promised to obtain more information and further particulars of the calorific value of the fuel, etc.

Mr. J. T. N. Anderson :—I have not yet tested the calorific value of the coal used, etc., and owing to the mills being continuously working, I have not had an opportunity of taking the necessary observations to get the other particulars. When I do so, a tabulated statement will be laid before the Institute. Re the Meldrum draft. Up to now the results obtained have not been favourable to this apparatus. It is all right when working with one boiler instead of two; but we have not found any saving with it so far. Re use of the jackets. During this trial they were only used for the first half-hour until the cylinders were well warmed. The results reported to me were that more stoking was required when the jackets were on, and the engine was run with them, and without them; but more fuel was required with them, owing to them having been carelessly carelessly constructed, which caused a considerable waste of steam. Re the increase in the proportions of the cylinders. I can refer you to a paper read by Prof. Thurston before the American Institute of Mining Engineers in 1897, in which the results of his experiments are given, and of a triple expansion engine of 350 H.P. as first working as a compound engine compounding from the high pressure cylinders to the intermediate and cutting off the low pressure one. There is a ratio of 1 to 3; second, as a compound engine running from the high to the low pressure, a ratio of 1 to 7. The results were an economy of under 15 lbs. as a triple expansion; 17 lbs. as a high compound with larger ratio of expansion, and 19 lbs. as a compound with low ratio of expansion. A large number of marine engineers in Great Britain have recently been turning out engines having a ratio varying from 5 to 6. In the records of marine engineering in March, 1897, a number of these engines are recorded. Messrs. Hick and Hargreaves also recommend them up to 180 lbs. with high ratio of expansion. Most of the engineering firms on the north-east coast are also fol-
lowing the same practice in marine engineering. At Ballarat the results, so far, have not proved disappointing, the economy showing about 173 lbs. per I.H.P. per hour. These engines are working at 280 H.P., although calculated for about 600 H.P., which materially affects the results obtained. Re absolute vacuum line. This was an omission which I will have rectified. The temperatures of the water passing through the condenser are shown, but I had no opportunity of measuring the quantity of water.

Mr. Stone: I would like to have some further details with respect to the auxiliary machinery, so that we could determine what proportion of the 18 lbs. of steam per I.H.P. is actually required by the main engines.

Mr. Anderson has not told us, but, I believe, the 18 lbs. includes the steam used by the feed, air, and circulating pumps. Unless we know this we are not in a position to judge as to the efficiency of the main engines.

Mr. Anderson: Yes; the total power of the pumps, which are combined, is only 13 I.H.P.

Mr. Stone: That is, the auxiliary machinery requires between 4 to 5 per cent. of the I.H.P. of the main engines? This appears to me to be a very large amount of power required by the pumps. I should only have allowed about half that, or, say, 2 per cent. of the I.H.P. of the main engines. As these pumps are of the direct-acting type they will take a large steam consumption per I.H.P. A good compound pump of about the same dimensions will require about 60 lbs. of steam per I.H.P. hour, and a simple pump from 90 lbs. per I.H.P. hour upwards. On this basis the auxiliary machinery would require from 15 to 20 per cent. of the total steam consumption. You will, therefore, see that without a knowledge of further details with respect to the pumps we can come to no definite conclusions concerning the performance of the main engines. The paper deals with the efficiency of the whole plant and not of the main engines alone. Under these circumstances details should be given of the auxiliary machinery, such as length and diameter of exhaust pipe between engine and condenser, the disposition of the air pump with respect to the condenser and dimensions of connecting pipe, the type of air pipe, and conditions under which the various pumps have to work. A set of diagrams, from the air pump and corresponding temperatures of the condenser, would have been very interesting and, possibly, instructive. It seems to me a curious fact that engineers should be so particular with respect to a ½ per cent. in the efficiency of the main engines and at the same time almost totally ignore the efficiency of the auxiliary plant which, in some cases, uses a very large proportion of total steam consumption, and, therefore, would admit of a large saving being made if more economical machinery were employed. In the Old World considerable attention is given to these matters now. I have here copies of tests of the steam consumption of the auxiliary machinery of the American cruisers *Brooklyn* and *Minneapolis*, showing the actual steam consumption per I.H.P. hour of the various auxiliaries employed, which ranges from 55 lbs. to 318 lbs. The lowest steam consumption of the electric lighting engines—which, I presume, had fly-wheels and worked expansively—was about 56 lbs., per I.H.P. hour and the highest 128 lbs. Such variable
steam consumptions as the above surely indicate the necessity for further
details concerning auxiliary machinery. Mr. Anderson mentions altera-
tions to the air pump valves. If there is no secret, it would be interesting
to know what the alteration was, and how it effects the action of the pump.
Very little appears to be published with respect to air pumps, and it is
extremely difficult to obtain reliable information as to the actual duty
performed by them. Recently a new type of air pump has been introduced
by Mr. Edwards, and it appears to be gaining in considerable favour in
England. A three-throw 12" x 12" pump of this type has been put into
the electric light station at Glasgow, where it is operated by means of an
electro-motor, and appears to give very good results.

Professor Kernot: What are the relative merits of the independent air
pumps and the connected air pumps? All steamers have the direct air
pump worked by the engine. The independent air pump is a rather later
innovation. If these Worthington's are so bad (as it is alleged) there
seems to be a tremendous loss and we should go back to the practice of
working up the pumps direct from the engine. A few revolutions of the
engine are sufficient to form a vacuum, so why have these independent
pumps at all? In a trial made not many years ago on a non-condensing
engine the steam used by the pumps was only 50lbs. per hour. This was
an engine that was not cutting off until \( \frac{3}{4} \) of the stroke. The results
quoted from the Minneapolis seems to want some explanation. Professor
Peabody, of Massachusetts University, worked out a lot of details of these
auxiliary pumps, and I will bring them down on another occasion. There
are a lot of points that require sifting out. I recollect a compound tandem
put in at Geelong years ago, in which the air pump was worked from the
tail rod. Have we gone back since that day?

Mr. Stone.—Professor Thompson mentions a little engine with four
cylinders, 2½in. diameter, 3in. stroke, a simple engine, single acting,
exhausting into the atmosphere, 150lbs. pressure, which works with 20½lbs.
I.H.P. It cuts off almost at once. He used highly super-heated steam,
with a tappet valve.

Mr. Fyvie:—The direct acting pump is one of the biggest frauds I
ever came across, and we would not dream of using such a thing. It is a
Yankee abortion; and the whole of the work is done in the last 3in. of
the stroke. I take diagrams off our vacuum pumps to see if the
valves are all right without dismantling them. I agree with Mr. Stone's
remarks. Auxiliary engines take more steam than engineers allow for,
and I would prefer them being worked off the engine. With a high
pressure engine the steam should be taken from the intermediate receiver
and exhausted into the hot well, by which the best results are obtained.
If the feed pump is sufficient to absorb the whole of the water, you get all
the units. If there is a Green's economiser connected with the plant, it
affects the result. In marine engines the steam is exhausted into the hot
well. The area of the exhaust pipe is a matter which is terribly neglected
in working at low pressures. For an engine of about 600 H.P. we use an
exhaust pipe 4ft. in diameter. If it were reduced it would tell on the
results obtained. It would be interesting to have more details of the
machinery under review.
Professor Kernot:—I am sure Mr. Fyvie has had a wide experience in these matters, and I have been interested in his remarks. I never heard the Worthington's independent air pumps so thoroughly discussed before. At the Spottiswoode Pumping Station they have this class of pumps, which work in the most extraordinary way. They do not seem to make two strokes of the same length—sometimes only a quarter of the full length. With regard to the size of the exhausts, I think our engines at the Electric Light Works at Richmond have not large enough exhaust pipes, and I have always considered that the vacuum in the cylinder is not as much as we ought to get, which is attributed to the deficient size of the exhaust valves. A 4ft. exhaust pipe with 600 H.P. engine takes my breath away. The indicated horse power of the Courier on her trial trip was about 3000, and the diagrams published at the time showed a good vacuum in the low pressure cylinder. The exhaust pipe is about 4ft. long and 2ft. diameter; but, according to Mr. Fyvie, it should be about 8ft. in diameter.

Mr. Fyvie:—The pipe is not connected with the same engine, but with a vacuum pan. If the area of that pipe be reduced it will affect the results very much, and if it does so in that case it will make the driving engine suffer in a similar manner.

Mr. Anderson:—Re consumption of the auxiliary machinery: The estimate was made that the consumption of steam in the auxiliary engines would be about 40 or 50lbs. per H.P. hour, and I find from actual experiments that this has been their average consumption. Although I told the directors they would lose £40 to £50 per annum if they had an independent engine, they decided on having it. Re the loss between the low pressure cylinder and the condenser: I did not have a mercury guage at this plant, but at Mildura I had one, and I had the satisfaction of seeing that although my ratios were worked in the same way as here, there was no appreciable difference between the vacuum from the low pressure cylinder and the vacuum in the condenser. From the point of view of the man who has to find the money, I do not think there is much to find fault with, but I do not know what the size of exhaust may be from an ultra-scientific point of view.

The discussion was then adjourned to the next ordinary meeting.
INDICATOR DIAGRAMS TAKEN AT DUTY
TRIAL OF BALLARAT WOOLLEN ... WORSTED
CPS. NEW ENGINES, 13.4.99

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<th>Scale</th>
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Legend:
- No. 2
- L.2 engine
- L.2 valve
- L.2 impulse
- L.2 exhaust
- L.2 air
- L.2 inlet
- L.2 exhaust
- L.2 impulse
- L.2 valve

Diagram notes:
- N.2 engine
- L.2 valve
- L.2 impulse
- L.2 exhaust
- L.2 air
- L.2 inlet
- L.2 exhaust
- L.2 impulse
- L.2 valve

Graphical representations of engine performance over time.
Professor Kernot:—I am sure Mr. Fyvie has had a wide experience in these matters, and I have been interested in his remarks. I never heard the Worthington’s independent air pumps so thoroughly discussed before.
Mr. ANDERSON'S PAPER ON BALLARAT WOOLLEN MILLS ENGINES.

MR. ANDERSON, in reply, stated most of the questions asked had been dealt with in the course of the discussion, and to finally close the matter he now laid before the Institute a tabulated statement giving certain details which had been asked for. He had not been able, owing to it being exceedingly difficult to do so, to eliminate entirely the performance of the air and circulating pumps from the performance of the whole engine; but he had had a trial with that object in view, with the result that the steam consumed by the whole engine, without separating the condensation from the air and circulating pumps, was found to be 15lbs. per I.H.P. per hour.
## RESULTS OF TRIAL OF POWER PLANT AT THE BALLABAT WOOLLEN MILLS.

### DETAILS OF PLANT
- Coupled Compound Condensing Engines: Cylinders, 17 in. and 30 in. diameter; Stroke, 60 in.
- Duplex Combined Air and Circulating Pump: Steam Cylinders, 9 in. diameter; Air Pump Plungers, 13 in. diameter; Circulating Plungers, 10 in. diameter; Stroke, 15 in.
- Condenser Cooling Surface: 1386 sq. ft.
- Receiver Heating Surface: 50 sq. ft.
- Two Lancashire Boilers: 8 ft. diameter, 30 ft. long, with fires 28 ft. 3 in. diameter, each boiler having 46 sq. ft. grate area and 1000 sq. ft. heating surface.
- Duplex Direct-acting Boiler-feed Pump: Steam Cylinders, 9 in. diameter; Plungers, 3 in. diameter; Stroke, 7 in.

### Date of Trial
- **Apl. 13th, 1889.**
- **Apl. 12th, 1889.**
- **Apl. 12th, 1889.**
- **Apl. 14th, 1889.**

### Duration of Trial
- 8½ hours.
- 2½ hours.
- 8 hours.
- 3½ hours.

### Conditions of Trial

### PRESSURES
- **Steam Pressure at Boilers**
  - Engine House
  - Receiver
  - Steam Chest of Air and Circulating Pump
- **Vacuum**
- **Barometer**

### TEMPERATURES
- **Temperature in Engine-room**
  - inside Engine-room
  - outside Engine-room
  - of Feed-water in Dam
  - of Circulating Water from Condenser
- **Temperature of Boiler-house**
- **Mean Revolutions of Main Engines**
  - Air and Circulating Pump
  - Mean Revolutions of Feed Pump
- **Mean Piston Speed of Main Engines**

### Notes
- No Steam in Jacks. Boiler Steam in Receiver to Pump Exhaust to Condenser.
- No Steam in Jacks. Boiler Steam in Receiver to Pump Exhaust to Condenser.
- No Steam in Jacks. Boiler Steam in Receiver to Pump Exhaust to Condenser.
RESULTS OF TRIAL OF POWER PLANT AT THE BALLARAT WOOLEN MILLS.—Continued.

**FEED WATER**  
Mean Piston Speed of Air and Circulating Pump: 426, 426, 43, 50.4
Mean Piston Speed of Feed Pump: 11, 11, 11, 10
Total Weight of Feed Water measured in Tanks: lbs. 41,890, 15,000, 16,450, 15,390
Weight of Feed Water used per hr.: lbs. per hr. 5,078, 5,456, 5,483, 4,348
Water from High Pressure Cylinder Jacket: lbs. per hr. 134, 134, 134, 134
Weight of Water from Receiver Heating Tubes: lbs. 175, 175, 175, 175
Weight of Water from Low Pressure Cylinder Jacket: lbs. 206, 218, 219, 174
Leakage from Boilers, Steam piping, Feed Pump, etc., per cent. on total: lbs. per hr. 174, 180, 190, 125
Moisture in Steam delivered from Boilers at 15° c: lbs. 6,600, 1,564, 3,091, 3,607
Coal Used During Trial: lbs. 400, 2,386, 2,386, 1,171
Wood: lbs. 74, 74, 44, 44
Coal Used per hr. during Trial: lbs. 668, 606, 148
Wood Ash Obtained: lbs. 17, 17, 18, 88
Ash Obtained: lbs. per hr. 234, 75, 75, 72
Steam Used by plant, deducting leakage and moisture: lbs. 4,629, 5,274, 2,526, 1,417
Feed Water Evaporated, deducting 3° c per cent. of gross weight for moisture: lbs. per hr. 4,629, 5,274, 2,526, 1,417
Water Evaporated per lb. of fuel: lbs. 6.86, 7.80, 5.37, 4.06
Equivalent Evaporation per lb. of combustible from and at 212 deg.: lbs. per hr. 9.10, 8.15, 5.15, 4.15
Fuel Burnt per sq. ft. of grate area: lbs. per hr. 10.47, 9.31, 6.25, 5.19
Water Evaporated per sq. ft. of heating surface: lbs. per hr. 10.47, 9.31, 6.25, 5.19
Steam Used by Air and Circulating Pump: lbs. 277, 277, 277, 277
Feed Pump: lbs. 90, 90, 90, 90
Number of Sets of Diagrams taken during Trial: 34, 5, 5, 5
Mean Effective Pressure in High Pressure Cylinder: lbs. per sq. in. 33,99, 30,73, 33,95, 27,10
Low Pressure Cylinder: lbs. per sq. in. 6,51, 7,80, 8,25, 8,27
Mean Effective Pressure in Main Engines: lbs. per sq. in. 367, 260, 221, 221
Horse Powers: lbs. 9,20, 8,92, 8,92, 8,92
Total Horse Power of Main Engines: lbs. 1,950, 1,950, 1,950, 1,950
Total Horse Power of Plant, including Air and Circulating Pump and Feed Pump: lbs. 2,007, 1,993, 200, 200
Steam per T.E.C.P. of Main Engines per hr. shown by Indicator Diagrams: lbs. 12, 12, 12, 12
used per Horse Power of Plant per hr: lbs. 17,82, 17,82, 17,82, 17,82
by Main Engines and Air and Circulating Pump: lbs. per hr. 18,70, 18,70, 18,70, 18,70
by Main Engines alone: lbs. per hr. 4,627, 4,627, 4,627, 4,627
per Horse Power of Main Engines and Air and Circulating Pump: lbs. per hr. 4,627, 4,627, 4,627, 4,627
per Horse Power by Main Engines alone: lbs. per hr. 4,627, 4,627, 4,627, 4,627
Fuel Used per Horse Power of Plant per hr: lbs. 2,17, 2,20, 2,20, 2,20

* Including Wood.

J. T. NOBLE ANDERSON, 8 | 12 | 99
DISCUSSION ON "DUTY TRIALS OF BALLARAT WOOLLEN MILLS ENGINE,"

Mr. Higgins: It seems to me that it is contrary to custom to employ compound engines when the steam pressure is 160 lbs. or more. I think triple expansion engines are almost invariably employed when the pressure is 160 lbs. or more, while compound engines generally employ steam at 110 lbs. or 120 lbs. pressure, and we have few instances indeed of them working at 160 lbs. pressure.

Steam Jacketing.—We will be glad to hear the results of the steam jacket tests. Some years ago we were favoured with the results of Prof. Thurston's experiments, and there has been a good deal of discussion since. Steam jacketing is now admitted to be economical when applied to the low pressure cylinders in compound engines, and it seems to be comparatively unimportant whether or not the high pressure cylinders be jacketed. The only way to prevent condensation in the high pressure cylinders seems to be to super heat the steam. I am surprised to hear that so far as can be ascertained the jackets in this case meant a loss, which must have been caused through the jackets leaking. Re the Meldrum forced draught, we will be interested to know how this acts. As in about 90 per cent. of the ships now being built in Great Britain the Howden forced draught is employed, it seems a remarkable thing that the latter has commended itself to so many makers.

Independent Condensing Plant.—Much has been said in the discussion of this paper against the principle of having an independent condensing plant. It seems to me, however, that there are certain circumstances under which it becomes judicious to employ an independent plant. Indeed the fact that so many engine makers in the British Islands are turning their attention to manufacturing such plants seems to indicate that they are coming into favour. Take, for instance, the case of a suction dredge, which has one or more sets of engines driving centrifugal pumps, also a set of cutter engines and a number of smaller but important auxiliary engines. These various engines sometimes work simultaneously, but occasionally some are running while others are idle. Moreover, their relative speeds sometimes vary. Now the choice in relation to the condensing plant lies between three different plans, (1) the largest set of engines may be provided in the ordinary way with an air and circulating pump of capacity sufficient to deal with the steam from all the engines, or (2) each set of engines, or several of them, may have their own condensers, or (3) a separate condensing plant may be employed. It is a matter for consideration then which of the three plans may be the most judicious, and I am satisfied that under certain circumstances it will be found that an independent plant is the most convenient and economical, for its speed can be varied to suit the number of engines in action at a given time. Many war vessels and steamships have these condensing plants. The
Argonaut not only has an independent condensing plant with each set of triple expansion engines but also an auxiliary condensing plant, driven by an independent engine, which treats the exhaust steam of all the auxiliary engines. The independent plant is not to be considered in a wholesale way, and I am supported in this by a number of engine builders in England and other countries, who adopt it. I do not see why it should be more extravagant, as the same engine is employed to work the circulating pumps and condensing pumps.

**Steam for Driving Auxiliary Engines.**—Mr. Fyvie advocates taking steam from the intermediate receiver and exhausting into the hot well. Is this better than taking steam through a reducing valve from the boilers? The latter plan ensures that the initial pressure shall always remain constant, and this should favour economy. I do not remember any precedent for the course Mr. Fyvie is in favour of. The principle adopted in certain triplicate expansion and quadruple engines of taking steam from the auxiliary engines into the long pressure receiver is a good one, and tends to economy.

Mr. Fyvie: I think Mr. Higgins is somewhat under a misapprehension. I think direct condensing pumps are useful in many cases; it is the direct acting duplex pumps that I object to. Re the independent condensing plant. This is not so very essential for a mill engine, because often after a start is made in the morning there is very little variation (5 or 6 per cent.) till the engine stops at night; but with a plant that varies considerably, I agree that it would be a great advantage to be able to split up the condensing plant into various sections. I cannot bring to mind a single case in which direct acting air pumps of the duplex principle are used for mill engines. There are a few cases where independent condensing plants are used in the navy, but not many in the merchant marine. This paper would have been much more interesting if more details had been given, i.e., the leading dimensions of the plant, with the temperature of feed water to boiler, flue gases to chimney, etc., which would have placed members in a better position to discuss the paper. The diagrams given are all that could be desired—in fact, they are ideal diagrams from a theoretical point of view, but of a class the old experienced engineer does not always enjoy from a maintenance point of view. I notice the writer says “to adopt the 16in. and 38in. as the respective diameters of cylinders would necessitate a heavier crank shaft and fly-wheel,” which I can hardly follow. It is well known that engines of such large ratio of expansion require exceptionally heavy parts, such as crank shafts, fly-wheels, and other connections, as the greater part of the work or energy is given (gas-engine fashion) in the first few inches of the stroke, when the crank is in its least effective position. This is productive of an excessive amount of tear and wear. Like the old style of Corliss engine, where we used to have one very large cylinder cutting off at about 1/10 or 1/14 of the stroke, and pounding away like a steam hammer, having no sympathy with the crank or cross head pins. I had some very unhappy experiences with them, some 18 years ago, when they were greatly favored for mill engines. An old fashioned beam engine, of about similar power, working beside two of the former, was much the cheaper when everything was considered. The cost of running an engine must not be figured out by the
coal consumption alone, but all costs connected therewith, such as repairs, adjustments, renewals, &c., which are often at overtime rates, and the work has generally to be done on Sundays. This engine of the author's is out of all proportion to the work required at the present time, having over 100 per cent. in hand for future extensions. It is well to look ahead, but to my view it would have been better to put down a compound engine, with a much less ratio between the cylinders, sufficient for, say 400 I.H.P., and arrange so that a larger cylinder could be added, when necessary, and make a three crank triple engine, of say 600 I.H.P. I am quite satisfied the repairs and general up keep would be less, and a much more equal turning motion is important. A large ratio of expansion is, of course, important for economy, but I think it is better to do it in multiple cylinders. The general results would be better, with equal economy in consumption of fuel. Re auxiliary engines and air pumps, I do not like the direct acting steam driven air pumps at all. I would strongly advise those who have them to take a few diagrams of both steam and air pump cylinders, and compare results, and it will be found that alterations are going on in the corner where the air pump sits before long. The diagrams will speak for themselves. Re size of exhaust pipes for condensing engines, when I spoke at the last meeting of a four-foot dia. exhaust pipe, for 600 H.P., I was speaking from memory, and I should have said 40in. dia.; and as we usually reckon 30lbs. water for I.H.P. per hour, this gives a vapour speed in the exhaust pipe of about 180 feet per second, and if we were to much exceed this, the efficiency would fall off to such an extent that we prefer to try a larger exhaust pipe. In measuring low pressures like this, I don't think the mercury gauge is sensitive enough, it is better to use a water column, by which the fluctuations would be better seen. I know of a large steam engine by a noted maker, where the exhaust pipe is of such a size that the vapour speed, with constant flow, could not be less than 1800 feet per second, or = 20 miles per minute, but as the vapour must flow from the cylinder to condenser in a pulsating sort of manner, say one cylinder's volume to pass in one-tenth of a revolution, it would give about 100 miles per minute, the vapour speed should not exceed 600 to 600 feet per second in the exhaust pipe to condenser. This point, I think, is much neglected by many engineers. You will often find the exhaust pipe of a condensing engine no larger than that of a non-condensing engine of similar size, as if the relative volumes had not been considered. In my opinion, the air pump should be constructed on the same principle as an air compressor; the diagrams from which are fac similes of those from an air pump.

Mr. Anderson : I hope to go to the mill during the present month to make absolutely final tests of the engine, and I will tabulate the results and bring them before the next meeting of the Institute.

Mr. W. Stone read the following extracts from a discussion on the "Economy of Steam Pumps" before the American Society of Engineers:

"Also take the following engines used at the Refineries of these companies by which they agitate the oil. It had been the custom to use the direct-acting type of blowing engines, or what they term 'blowers' (and they do blow a fearful amount of steam away to no good purpose!) These so-called 'blowers' will consume, on an average, at least 120lbs.
DUTY TRIALS OF BALLARAT WOOLLEN MILLS ENGINE.

weight of steam per H.P. hour," and the comments made are unfavourable to the direct acting air pump. I have also some details of the vertical air pumps used on the U.S. Cruiser Brooklyn. The engines were indicating 18,248 H.P.; the combined I.H.P. of the air pumps was 16:15 — less than 1/10 per cent. of the I.H.P. of the engines. The importance of this matter can hardly be overrated. In this ship the air, circulating, and feed pumps took 176·5 H.P.—a little less than one per cent. of the I.H.P. of the main engines. There were many other auxiliary engines which these feed pumps had to supply, The blowers took 269 H.P. These auxiliary engines take a good deal of power, and the engineer in charge should always know what they are taking. Regarding the forced draught, it is a curious thing why this is used at all. Some claim that it is a great advantage to have a little steam jet under the fire-box. It will be interesting to have the results of this draught when ready. There seems to be great diversity of opinion as to the size of the exhaust pipes. We seldom have it stated what the vacuum is in the condenser and the vacuum in the cylinder. It is found in some cases that there is very little benefit derived from the vacuum in the earlier part of the stroke. With Parson's especially they take the vacuum in their (so-called) cylinders. It is a small flat turbine at the tapering end of a drum, at the end of which they bore a hole, and allow the vacuum gauge to record the true pressure inside of the cylinder. If it is taken a foot or so from the exhaust pipe a different vacuum is obtained.

Mr. J. T. N. Anderson, in reply, said—All things being equal, I would have preferred the triple expansion engines; but other circumstances had to be considered. The building was already in existence; the engines had to suit the existing shafts and also the land available, and we were restricted in length and width. Local prejudice had to be taken into account. There are no triple expansion engines at Ballarat, and the directors and their engineer were afraid of them. The compound engine is simpler, and under the circumstances was found to be the most suitable. There were a considerable number of precedents for using a compound engine up to 160lbs. pressure, viz., many marine engineering firms, Hick, Hargraves, and others. In my opinion a range of 140 to 150 deg. can be got in one cylinder without marked loss. Triple expansion engines are now working in several large steamers up to 240lbs. pressure, which, I consider, is almost the same as a compound engine at 160lbs. pressure. These engines are working with four parts—the steam is admitted through one part and exhausted through a separate one—and the losses are not so great as in the ordinary slide valve cylinder. I believe the loss in the jackets has now been overcome, and better results have been got lately re forced draughts. I agree with Mr. Higgins that draughts are an advantage, and we might get as good evaporation with these boilers with a forced draught working mechanically as we get at present; but with the three large boilers there is no need to force under the circumstances. The fuel consumption is 13.5 lbs. per square foot of grate area. The Meldrum draught is very useful indeed, and was obtained as a standby in case of emergency, and is used every morning, which prevents it from getting out of order; and to have Howden's draught, under similar circumstances, was not considered advisable.
Mr. Higgins has mentioned a few cases where the independent condensing plant is an advantage, but in this case the matter was decided by the directors, and I do not wish to join issue with Mr. Fyrie in condemning the Worthington type of air and circulating pumps. I agree with Mr. Steane that the method of working them was not so economical as if driven off the main engine. With variable power it is an advantage to have an independent air pump, but in this woollen mill there is a great deal of variation. During the first month I found from the indicator cards a variation from 190 up to 286 H.P., so that our conditions are much in favour of an independent air pump. Re taking steam from the intermediate receiver to heat the feed water. In one engine on the Ophir they get their feed water at over 200 degrees, and the temperature is raised by taking a small proportion of steam between the intermediate and the low pressure cylinder, more or less live steam, and they claim an economy by it.

Mr. Fyrie: It is a decided economy.

Mr. Anderson: We allow steam into the boilers from the auxiliary engines, and exhaust into the receiver. A larger amount of steam goes from the receiver than that which passes from the high pressure cylinders so as to be getting the economy of a compound engine with the ordinary single engines which drive the auxiliaries.

Mr. Higgins: With extravagant auxiliary machinery it is a good thing to exhaust into the low pressure cylinders.

Mr. Anderson, in answer to Mr. Fyrie: The ratio of expansion will not be so great when the engines are running at their full power. As to the suggestion that 400 H.P. engines would have been more suitable, the directors considered that as their plant had been doubled during the last ten years, it would probably be again doubled during the next decade, especially as Federation is soon likely to be an accomplished fact. The reason of the heavier fly wheel is that with woollen mill engines very steady working indeed is required to keep the velocity fluctuations within close limits. The maximum variation in this case being \( \frac{3}{5} \) per cent. Re the size of the exhaust pipe, there must be some error in the calculation of the vapour speed, which was estimated to be under 600 ft. per second. With regard to the "Brooklyn" tests, referred to by Mr. Stone, I am surprised at these figures, and am not aware of any corresponding British figures. If you take 18 lbs. of steam per I.H.P. per hour the feed pump will require \( \frac{3}{10} \) per cent of \( \frac{3}{4} \) of the total amount required by the air, circulating, and feed pumps. In a slight test I made to determine how much less steam was used with the feed water heater shut off, as far as I could make out it was under 7 per cent of the whole amount. With the Mildura engines, for a long time the duty of the pumps was only 55,000,000 instead of 70,000,000 required under the contract, and we found that the loss was due to the air and circulating pumps; the maximum vacuum that we could get was 18 in. to 20 in. By making some alterations to bring the water from the main to the air pump, we increased the vacuum to 26 in., and raised the duty to 74,000,000.
DISCUSSION ON "DUTY TRIALS OF BALLARAT WOOLLEN MILLS ENGINE."

PROFESSOR Kernot.—I have seen this engine at work, and it seemed to be working very well, and some indicator diagrams that I saw showed that the engines had been very much underloaded. At the time Mr. Anderson was then making some further trials which, I believe, have turned out satisfactorily. The only point I wish to refer to is that to which Mr. Fyvie has already referred, i.e., as to the desirable destination of the steam from the auxiliary engines. In the Ballarat engine, the steam went to the intermediate receiver of the main engines, and Mr. Fyvie points out that the correct thing to do is to take the steam to the hot well. Then you can condense the steam from an engine, use it for heating water on its way to the boiler; thus all the units of heat rejected by the engine are recovered and taken back to the boiler. The engine then works as an engine of perfect efficiency. I do not know what difference would be made at Ballarat if this plan had been adopted. It is but a small proportion in all of the total amount of steam used. This plan of utilising the heat of the steam for heating purposes, and simply passing it through the engine incidentally on its way to its destination is one largely used in sugar works, and is analogous to the action of an injector. An injector applied to a boiler is economical and beneficial. A considerable amount of steam is used; but the heat of that steam comes back to the water entering the boiler. It does not matter how much steam is used; you get the benefit of it all back again. At our electric light station at Richmond, we have had for several years this arrangement in connection with a minor engine. We have a considerable number of engines there for different purposes. The plan adopted is to use the exhaust steam of one of the smaller engines to heat the feed water on its way to the boilers of the larger engines, getting the benefits of a condenser. One of the smaller engines works with condensation, but without a vacuum and heats the water for the boilers. This is done by using the injector condenser on one of the smaller engines which is worked, but with a limited quantity of water and does not give a vacuum. In that way we get almost boiling feed water and yet have the benefits of the condenser on the larger engines. I can congratulate Mr. Anderson on putting in a large, and by all accounts, satisfactory and successful motive power plant, but I would like to see the load on it increased by 100 per cent, to properly test it.

Mr. Anderson.—It has since been increased 20 per cent. and works satisfactorily.

Professor Kernot (continuing).—Certain statements have appeared in English journals recently to the effect that engines are being worked with highly superheated steam, in one instance to 650 Fahr., which is higher
than the temperature of melting lead. The engine is a triple one (each part of it only single acting) and not of specially large size, and has worked for a considerable time at less than 9 lbs. of steam 1 H.P. per hour. If this is accomplished with engines of not more than 200 H.P., it would seem to open up a new vista in economical power production. I have written to England for further particulars.

Mr. J. Tipping (contributed): I learn the members have recently been discussing the "Duty Trials of the Ballarat Woollen Mills Engine," from which I gather it is using 18 lbs. of steam per H.P. hour. That, I may say, within my own knowledge, was the standard of steam consumption by compounds working on 80 lbs. boiler pressure at the Lancashire Cotton Mills in the year 1872; so that although a consumption of 18 lbs. of steam may be worth recording in these colonies, it is certainly only abreast of those of 27 years ago, which I have mentioned. I have just to hand some particulars of a steam power plant by a Belgian manufacturer of repute. Engine, single cylinder, boiler pressure 10 atmospheres or 147 lbs., vacuum not given, cylinder 450 x 900 m.m., say 17½ in. dia. by 35 in. stroke; speed, 70 revolutions per minute; H.P. varying from 80 to 100; steam consumption per H.P. hour, 5.8 to 6 kilos, or 12.96 to 13.41 lbs. had this not been verified, it would be generally considered incredible. The maker guarantees that consumption subject to a penalty of Frs. 1000 per 100 grammes of steam consumed in excess, providing the steam pressure used is 10 atmospheres, and that the H.P. exerted does not vary more than 20 per cent. less than the rated H.P. for the plant. There is really nothing surprising in such a report. I have been advocating precisely the same thing during the past 5 years. The comparatively low cost of fuel in British manufacturing districts continuously discourages British engineers from accomplishing high duty. Consequently high duty is not accomplished by them; and yet it is very simply achieved, involving none of the complexities which might be expected. The cost of fuel in these colonies, away from the seaboard, is quite equal to that on the European continent, therefore there ought to be equally economical steam power, and doubtless there will be when there is sufficient demand to encourage builders. The difference between 18 lbs. and 13.41 lbs. of steam is closely about 25½ per cent., or 25½ tons of fuel in every 100 tons. The natural reduction of vacuum at Ballarat elevation accounts for very little. French H.P. is ]86387 of British, a minute difference. Since writing the foregoing drawings of the Belgian engine have come to hand. No condenser, air pump, or connections for same are shown, and, as they are not mentioned, no option remains but to conclude it is a non-condenser, which makes the consumption of steam for a single cylinder non-condenser 12-96 to 13.41 lbs. per H.P. hour appear incredibly small to those who have not been closely following developments during late years. A London company has furnished, and at work, and offers to furnish compound condensing engines over 250 H.P. under guarantee to consume rather less than 9 lbs. of steam per H.P. hour. Now 9 lbs. for the London compound condenser, as against 13.41 lbs. of steam per H.P. for the Belgian single cylinder non-condenser, is about the exact proportion between the 18 lbs. of steam per H.P. hour, used by the Ballarat Woollen Mills engines, and an equally well proportioned ordinary single cylinder.
non-condenser, which tends to confirm the evidence that the Belgian may be accepted as a genuine non-condenser. There is nothing experimental or novel in either engine.

The Chairman (Mr. W. Stone) said it seemed that they were really discussing Mr. Fyvie’s paper in conjunction with Mr. Anderson’s, and as the former really arose out of a part of the discussion on some points in Mr. Anderson’s paper, he did not think there would be any objection to the discussion of the two papers taking place at the same time.

Mr. Higgins.—Mr. Fyvie has brought up for discussion a question that has been frequently discussed in times past, viz., the conditions under which it proves economical to heat feed water. It is generally recognised that it conduces to the durability of a boiler to supply it with hot feed water, especially if, during the process of heating, precautions are taken to get rid of the various deleterious gases which mix with the water; but it has not been so readily accepted that actual economy may be effected by the judicious employment of feed heaters—that, in fact, a feed heater may be so designed as to play the part of a regenerator. However, Professor Cotterill and others have shown how this is so, and Messrs. Weir, of Glasgow, and other manufacturers have succeeded in practically demonstrating, on a large scale, that feed heaters can be economical. I think, however, that exception is to be taken to the general form in which Mr. Fyvie conducts his calculations and states his results. He does not mean it to be inferred, as might be done from a cursory inspection of the balance-sheets, that in any given engine it would be more economical to exhaust into a feed heater than to condense, or to employ compound engines. He rightly remarks towards the close of his paper that such results as those revealed in the third case “are only obtainable when the heat from auxiliary engines does not exceed that necessary to raise the feed water to about 200 deg. Fahr., or less.” Now, in the case of a ship for instance, the number of auxiliary engines in use varies from hour to hour, and it is conceivable that on certain occasions more heat than it might be judicious to use would be yielded by the auxiliary engines, while at other times less than sufficient would be forthcoming. For this reason, therefore, the system of Messrs. Weir has much to recommend it. They conduct the exhaust from the auxiliaries, as well as that from the evaporator and feed pumps, to the low pressure receiver; at the same time they lead steam from the said receiver to a feed heater, the result being that control is exercised over the amount of steam sent to the heater. For instance, when a ship is coming into port, the heater is not usually required, and can be shut off, in which case all the small simple engines become compound, and the small compound engines become triple expansion. I have lately seen a condenser described in which the top rows of tubes were made to act in the capacity of a feed heater. It is evident that if a considerable portion of the steam should condense on coming into contact with these tubes—in other words, if the steam should yield its latent heat to the feed water—an important gain would be effected. I hope to learn more of this experiment. It differs, I think, from the old system in vogue when exhaust steam had a temperature of about 220 deg., where a small condenser was placed on top of the condenser proper, and use was made of the high temperature of the exhaust to heat the feed water, but the
particulars given in the description which I saw were meagre, and we must await further information. Very few problems in connection with the use of steam can be solved in the simple way described in the paper under discussion. There are factors, such as relative quantities and temperatures, which have to be taken into consideration. However, we have reason to be grateful to Mr. Fyvie for bringing forward his approximation to a solution in this case. Glancing at the figures, which are assumed, I think that in case No. 1 the number of thermal units, which might be assumed to be usefully employed in the auxiliaries, should be greater than 550. This number represents $\frac{5}{4}$ per cent. only of the total, notwithstanding that the engines are condensing.

Mr. Hill.—The ratio of the cylinder areas in Mr. Anderson’s paper is given as 1 to 5, whereas in most of the text books it is given as 1 to $2\frac{1}{2}$ or 8 to 7. I would like to hear a little more on that point.

Mr. Anderson, in reply to Mr. Hill, said he adopted the proportion mentioned with a view to obtaining the maximum steam economy. It seemed to him that with the higher pressures the ratio of 1 to 3 or $3\frac{1}{2}$ (the usual precedent in the colony) would not give the best economy. He had also a number of precedents, particulars of which he had given in the earlier part of the discussion, viz., experiments made by Prof. Thurston with his large 350 H.P. experimental engine, which certainly appeared to be most reliable. The conclusion came to was that the greater the ratio between the cylinders, the greater the economy likely to be obtained. Also some steamboats built in 1897 by Laird, by Richardson, and one other on the north east coast, in all of which the engines were large compound engines with a ratio of 1 to 5 and 1 to 6. He thus considered he had sufficient precedents. The end he had in view was to keep the work done by both cylinders as equal as possible, and after trials he could see from the indicator cards that the ratio of cylinders of 1 to 5 would be the best for their purposes. He mentioned that with 160 lbs. pressure, the expansion which this ratio gave would be about equivalent to that which would be obtained with 100 lbs. of steam, with a ratio of 1 to $3\frac{1}{2}$, therefore if 1 to $3\frac{1}{2}$ were the proper ratio in that case, then 1 to 5 would be the correct ratio for the high pressure. Re the advantage of the jackets. He had made a special trial to test this, and the results obtained were most satisfactory, and showed a saving of nearly 2 lbs. per I.P.H. per hour. He intended to tabulate the results of the further tests made with these engines and lay them before the Institute later on.

Prof. Kernot.—Have you an interheater between the 2 cylinders? What is its value?

Mr. Anderson.—Yes; but it is not easy to get at its value.
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