HOW THE DESIGN OF A MANUFACTURING PLANT WAS EVOLVED FROM A CHEMICAL FORMULA.

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At the Leeds Conference, in England, of the Institution of Gas Engineers, held in June, 1930, Mr. C. F. Broadhead, the Engineer of the Metropolitan Gas Company, Melbourne, presented (in absentia) a paper, entitled "The Preparation of a New Road Binder." This paper traversed the deterioration and decline of continuous vertical retort tar as a road binder, and discussed the tar position in Australia, Britain and the United States of America. It was pointed out that in order to combat heavy importations of bitumen, and to regain the lost tar market, an intensive chemical research had been carried out in the Metropolitan Gas Company's laboratories. This research proceeded on highly original lines, and was ultimately crowned with considerable success by the production of a new road binder to which has been given the name of Bitural.

Road engineers and others interested in road making are referred to Mr. Broadhead's paper, which was reported, in extenso, in the "Gas Journal" of 11th June, 1930, and the "Gas World" of 7th June, 1930.

From the first laboratory experiments to the final commercial production the work can be divided into three distinct phases:

(a) Purely chemical research.
(b) Translation of the laboratory formula to commercial operations, where the engineer aided the chemist.
(c) Purely engineering considerations of commercial production and constructional design.

The new process did not bear the slightest resemblance to any existing method of tar distillation. It required the bringing together of measured quantities of crude tar, formalin, and .890 ammonia in a closed vessel, applying heat and raising the mixture to about 140 degrees F., and maintaining at that temperature for several hours until digestion was complete. The next stage was to increase the temperature to, and hold it steady at, about 180 degrees F. while air was being drawn over the surface until dehydration was complete, and then, while still maintaining the air blast, the final stage of polymerisation was carried out at about 290 degrees F. for fifteen or sixteen hours. During the polymerising stages, oil, having a boiling range of 170 degrees to 300 degrees C., is evaporated off, and
the residue, "Bitural," very closely resembles and is little, if anything, inferior to the natural bitumen.

It is not intended to discuss in any way the chemical research in this paper, which deals only with the engineering design; but, just as a word of explanation in order that the cycle of operations may be made clear, it is pointed out that the main object of the process is to change the nature of the unsaturated hydrocarbons and tar acids in the tar. This is achieved by polymerisation and molecular condensation, which is the coalescence of molecules to form higher boiling complexes, and is a property possessed by most unsaturated compounds. In this case it produces gummy resinous bodies, which have all the inherent qualities of good road binders.

The first phase then is not in the province of this paper; this was devoted solely to chemical research, and it was not until results pointed to some definite procedure that laboratory experiments could be abandoned in favour of a larger scale working.

The second phase of the investigations was carried out in a large scale experimental plant, which had a capacity of 125,000 gallons per annum. This plant was the acme of simplicity; for, as is usual in any new process, there were no data for design. Data had to be collected as the experiments proceeded.

The first units to be provided were two welded steel digesters with dished bottoms, each eight feet diameter and five feet ten inches deep, which were set in brickwork. There was no special virtue in the shape of these; they conformed to existing tar-distilling practice. In any event they did not prove the most suitable type. The heating arrangements were a compromise between internal steam coils and external gas burners. Steam at 150 lbs. was used for the first stages of the process, and gas heat was added for the later stages. This arrangement was adopted for the convenience of the experimental plant. A small spare gas exhauster drew the polymerising air over the surface of the tar. A little later a pipe condenser, or cooler, with water sprays, was inserted between the blower and the digesters to aid in the recovery of oil. Steam-heated Bitural storage tanks and an oil-collecting tank completed the outfit.

A great deal of valuable investigation was carried out on this plant, and it produced 125 tons of Biturai up to the end of last year. It afforded facilities for extensive road trials of the new product, at the same time allowing the chemical staff to perfect the process and, more or less, to fix the amounts of materials, polymerising air, temperatures, times, etc. The plant is shown diagrammatically in Figure 1.
During this period much work was carried out on certain tentative designs. Plant of several different capacities were projected, but they all suffered from lack of data, and, what is more important, they were only treated as an academic study, for at that time there was no definite call for a plant of this description. It was, however, established that desirable units should be of 2500 gallons and 5000 gallons capacity.

But the academic stage definitely disappeared shortly before last Christmas, when the Albion Quarrying Company decided to instal a plant for the manufacture of Biturai. This required the speedy preparation of designs, as it was desired that some portion of the summer road-making contracts could be secured. It was not easy to construct something out of nothing; although Biturai was being produced successfully in the experimental plant, there was a world of difference between the experimental stage and commercial production. However, a concrete case was a much more pleasant task than a purely academic discussion, and the existing data were carefully collected and analysed, and attempts to bridge any hiatus were made by certain assumptions.

At that time, for various reasons, it had been definitely decided to make the digesters circular tanks, and to heat them by steam; but the circular form had to be discarded in favour of a rectangular vessel, on account of the difficulties in providing adequate heating surfaces and the complication of bulky
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steam coils. In addition there was the problem of getting even and thorough circulation of the polymerising air over all the surface of the tar. These difficulties forced consideration of some other shape. In the square vessel it was possible to admit the air at two opposite sides, and, with suitable ducts, it could be led away at the centre with the certainty that every square inch of tar would be swept. The steam coils proved a more simple matter than in the circular vessel; but there were so many of them that calculations became involved as efforts were made to determine the size of vessel that would be required to hold not only 2500 gallons of tar, but the coils as well.

At this point the situation became more complicated by the discovery that the process could be speeded up by raising the working temperatures in the digester from 290 degrees F. to 400 degrees F. This immediately ruled out the use of steam as a heating agent, for the pressure of saturated steam at 400 degrees F. is 235 lbs. gauge, and after making allowance of 50 degrees F. for heat transfer the gauge pressure would have to be about 400 lbs. per square inch. The use of superheated steam at a lower pressure would not be possible, because it would not condense at the temperature of the tar, and the heat added to the steam by superheating would be small, say, 5 per cent. of the heat of condensation.

The matter was reconsidered from all angles, and finally oil-fired furnaces were decided upon. In the manufacture of Bitural roughly 80 per cent. by weight of the crude tar is returned as "Bitural"; the remaining 20 per cent. consists of oil having a boiling range of 170 degrees to 300 degrees C. This has a calorific value of 16,800 B.T.U.'s per lb., so that it is, amongst other things, an excellent fuel. A burner, capable of consuming either tar or oil, was then decided upon, as this would allow a new plant to start working with tar fuel until enough oil had been recovered to enable a change over to be made. Having a liquid fuel to design for made the heating problem very simple, though a number of assumptions had still to be made. The first was the heat transfer rate from hot gases to tar, the second the amount of oil that might be required, and finally the furnace gas temperatures that would be necessary to complete the batch in a given time without local over-heating.

The dimensions of the digester had, by now, been fixed at 11 feet square by 4 feet 6 inches deep to contain a batch of 2500 gallons. These sizes would give ample room for the tar, the heating tubes, and the polymerising air, which would sweep an exposed area of 121 square feet of tar.

With regard to heating, it was necessary to determine the time to be taken to produce the batch, and the B.T.U.'s per hour required. The West Melbourne plant had been turning
out two batches a week, and it was felt that this must be speeded up to make the process commercially possible. A limit of 60 hours was arbitrarily fixed, and this time would be divided into two known periods, i.e., Digestion at 140 degrees F. for 10 hours, Polymerisation at 400 degrees F. for 40 hours or more, and three unknowns, viz., the times taken to reach 140 degrees F. from the tar temperature of, say, 66 degrees F.; the time required for dehydration, and the time necessary to reach 400 degrees F. from 140 degrees F.

The first assumption with respect to the design of the furnace and the heating flues was a heat transfer of 5 B.T.U.'s per hour per square foot per degree Fahrenheit, and that 240 square feet of area in the heating flues could be conveniently provided. It was also assumed, from figures derived from the working of the West Melbourne experimental plant, that six gallons of oil per hour would be required for each digester. It was obvious that this was an inordinately high figure for a sixty hour batch, requiring as it would 360 gallons of oil. A close study was therefore made of all the possibilities of heat recovery from the waste gases and the polymerising air.

With regard to the flue gases the position was further complicated by the need for keeping the heating gases down to a comparatively low temperature, so as not to produce local “overcooking” around the heating flues nearest the furnace, and thus obviate any risk of damage to the plant by overheating. One of the first suggestions was the use of the waste gases for polymerising purposes, but this was quickly abandoned on account of risk of fire or explosion. A recuperator was rejected on the grounds of cost.

The third and last alternative considered was the recirculation of the waste flue gases through the heating flues, thus increasing their velocity and consequently the heat transfer rate. The design of the furnace and heating flues permitted this to be simply carried out; and so it was adopted.

The furnace is a steel box, external to, but integral with, the digester, and is brick lined, with slagwool insulation between the bricks and steel. The dimensions inside the combustion chamber are 5 feet 4 inches x 12 inches square. The rotary oil burner finally selected had a capacity of five gallons per hour, and the air to the burner was supplied at 16 inch water gauge, the secondary air being drawn in at atmospheric pressure. The furnace gases are collected in a distributing flue, and from this flue, which is outside the digester, six 6 inch diameter steel tubes extend across the digester and terminate in two 12 inch diameter steel headers, three tubes to each. From each of these headers three similar tubes return to the waste heat collecting flues, which form extensions, one on each side, of the
central distributing flue. The tubes are welded solidly into the front plate of the digester, but the headers, into which the opposite ends are welded, are left free to move with expansion. Return flues are placed above the distributing and waste heat collecting flues, and connect with the furnace, where they continue in the brickwork to the back of the furnace, dividing and returning above and below the combustion chamber, and terminating in nozzles set at the end of the oil flame. Connections are made, on each waste heat flue, to the waste heat stack, and just beyond these connections venturi tubes are fitted with nozzles in the throats, through which air at 16 inch water gauge pressure is discharged, which causes recirculation of the hot gas.

This was very effective; the waste gases, discharging back into the furnace at the end of the oil flame, produced a turbulent effect, and allowed an intimate mixing of the two gases, tempering them to the required degree of heat. It was expected that this would prove efficient, and that no more than five gallons of oil per hour would be needed. A hope was even entertained that the consumption would be half of this amount, but for the purposes of compiling a final conservative balance sheet on the completion of the designs, the higher figure was adopted.

The next important point which had a direct bearing not only on the fuel consumption, but on the speed of the process, was the polymerising air. It was assumed that 1000 cubic feet of air per minute at atmospheric temperature was required, and this amount, plus the oil vapours, left the digester at a temperature of about 300 degrees F. Thus in one hour about 300,000 B.T.U.'s would be carried away. It was then decided to investigate the possibilities of a heat exchanger to return some of this heat back to the incoming air. It was assumed that a heat transfer of 2 B.T.U.'s per hour per square foot per degree might be expected, and an exchanger 5 feet 6 inches diameter x 8 feet long was designed. This contained 336 tubes, 2½ inches diameter x 6 feet long, giving an area of 1320 square feet. The incoming air entered a header at one end, and after passing through half the tubes, returned through the remainder to the header, which it left in two streams, being conveyed to opposite corners of the digester. Here the polymerising air was deflected along a duct, formed of a curtain plate dipping into the tar, to the opposite end, where it returned along a similar duct. The curtain plate of this duct was inclined towards the tar, and was pierced with holes so that the air was distributed and deflected down to the tar, over which it passed to a central duct, which it entered from both sides through a similar series of ⅛ inch diameter holes. The hot air and oil vapours left the digester and entered the heat exchanger, passing round the
tubes on a contraflow principle, baffles being interposed to give the longest travel possible.

The design of the digester, with its furnace and heating flues, together with the heat exchanger and the travel of the polymerising air completed, the remaining plant was a simple matter. This included blowing plant for the furnace and polymerising air, and it was considered economical to keep the furnace blower separate from the polymerising air blower, but to make each of a capacity large enough to serve two units. Thus the furnace blower capacity was 500 cubic feet per minute, and the polymerising air blower 2000 cubic feet capacity, both 16 inch water gauge, and each directly coupled to its own motor.

It was recognised that some portion of the oils would be recovered in the heat exchanger, and that the blower, which would discharge to atmosphere, would, by centrifugal action, probably aid in some further recovery; but how much would be recovered at both points was problematical. It was felt that further safeguards should be provided to remove all the oil from the outgoing air, as this would be a valuable item, worth about £9 to £10 a batch. Accordingly a pipe condenser,
or cooler, consisting of two 12 inch diameter vertical headers, with ten 4 inches diameter x 10 feet 6 inches long horizontal pipes set between was designed to go at the outlet of the heat exchanger. The hot air would pass along five of these pipes, returning through the remaining five, and water sprays would be provided. As a further safeguard a cyclone oil extractor was placed at the blower outlet, and discharged through a high vertical pipe. The flow-sheet of this plant is shown in Figure 2. This appeared to cover all requirements for manufacture, and there only remained the storage. The storage of tar and of the recovered oils was not considered as part of the design, so that left only the provision of ammonia and formalin storage tanks and measuring tanks, fuel oil tank for the furnace, and a Bitural storage tank.

In considering the placing of this section, and the fact that gravity feed was required, it was necessary to put the Bitural storage tank, or "kettle," as it is now known, above ground at a height that would permit discharge directly into tank wagons. This kettle had to have some means for keeping its contents hot, and as the digester had to be above it for gravity feed, it was found that the most suitable shape would be to make the kettle a replica of the digester, using the same type of heating flues, but with a smaller burner and furnace. The other storage tanks would require to be placed above the digester.

Next rose the question of the arrangement of all these pieces, so that some symmetrical lay-out could be obtained, and, at the same time, provide for future expansion. The design that was finally evolved provided a central square control structure, and against each of its four faces would be set an individual unit of 2500 gallons capacity. This gave a ground plan in the shape of a Greek cross. The structure would contain three floors; the lowest, at the level of the storage kettles, accommodating the four furnaces and two sets of furnace blowers (one for two units). The second floor would contain the digester furnaces only, while on the upper floor would be placed two sets of polymerising blowers and cyclones, oil, ammonia and formalin tanks.

This made a very neat arrangement, and allowed of a very easy and "get-at-able" disposition of the piping for the polymerising air, furnace air, fuel-oil, ammonia, formalin and waste gases. It also simplified the disposal of the oil-recovery pipes and sumps from the heat exchangers, condensers, blowers and cyclones. It allowed one or more, up to four, units to be constructed as required; and the addition of any future unit would in no way interfere, during its erection, with the working of the existing plant.
The designs and estimated balance sheets receiving general approval, the Albion Quarrying Company let a contract with Messrs. Chas. Ruwolt Pty. Ltd. for the installation, at Burnley, of a first unit; and shortly after fabrication started they paid the designs a subtle compliment by ordering, "sight unseen," a second unit.

In accordance with the usual practice of the Metropolitan Gas Company, the structure and plant was specified to be completely welded, using Quasi-Arc No. 10 mild steel electrodes, except in the digester, kettle and furnaces, where special boiler electrodes were specified on account of the high temperatures. No attempts were made to follow other than conventional practice in either the structure or the plant; for the demand for speed and study of the most economical commercial production overshadowed everything else. A very favourable impression was made during the fabrication and erection of this plant, which is illustrated in Figure 3, by the high standards of workmanship and skill exhibited by Ruwolt's, and the work was erected and fitted together without the slightest hitch.

When the erection of the first unit was about three parts completed, instructions were received for the preparation of designs and estimates for remodelling and extending the Biturai plant at West Melbourne. The requirements were that the two existing digesters, which had a combined capacity of 2500 gallons, should be linked together to form one unit, and that a further digester should be provided, together with the necessary recovery plant, so that the whole would be brought into line with the Burnley design. It was felt that it was unfortunate that the urgent requirement for this extra plant precluded any delay, and that the designs had to be undertaken before practical working experience would be gained from the first Burnley unit.

The data and assumptions that had governed these designs were again carefully reviewed, for it was uncertain whether there had been too much or too little attention given to the questions of heat and oil recovery. Most of the data on which the calculations were based were definite, but it remained to be seen whether the assumptions were anywhere near the mark. If they were, then the evidence contained in Table 1 indicated that there were great potentialities in the direction of heat recovery.

At first the designs were laid out on the lines of the Burnley plant, but with the exception that the surface area of the digester was increased, still keeping the batch at 2500 gallons. It was suggested that the catalysing effect of the oxygen of the air during the polymerising period would be increased and the process hastened; therefore the digester was made 15 feet square, and this, with a 12-ton charge, would give an exposed
area of 18.75 square feet per ton of tar, compared with 10 square feet at Burnley.

The study of the Burnley plant during its erection showed a neat and workmanlike job, but, as the predominant factor governing its design had been commercial production, the plant had therefore followed conventional practice in the details of its construction. With that phase satisfactorily dealt with, it was possible to approach the West Melbourne designs from a different angle, and exploit to the utmost extent all the inherent economies of the electric-arc welding process. This stage is difficult to describe, for it represented a period where imagination played a far bigger part than mere attention to practical details. The advantage of having an actual structure before the eyes assisted the ideas that were slowly forming, and these were gradually focussed on to the condensers. There seemed some possibility that, instead of being a separate unit, these might be expanded into the structure itself. The idea was placed on paper, and the condenser headers were extended so that they formed tubular columns with the condenser tubes set between. An extension of this idea showed that by rearranging the position of the blower and cyclone, and placing them at ground level, separate piping would not be required, for the tubular columns would perform this function just as well.

This was the position that imagination had led to; and, as one change invariably suggested another, fresh consideration was then given to the sequence of operations required for the production of a batch of Bitural.

The complete process had been estimated to take 60 hours, but though that figure was a reduction on the time taken by the experimental plant, the time still appeared too long. The process of heating, digestion, dehydration and polymerisation each required its own range of temperature, and the quantity of heat required from the furnace was therefore a varying amount throughout the batch.

As a two-unit plant was projected, consideration was now given to the possibility of providing a separate vessel in which digestion and dehydration could be performed, thus allowing the other two vessels to complete the polymerisation at relatively steady temperatures. The polymerisation vessels, or "reactors," would perform their duty in 48 hours, therefore two reactor units discharging once in 48 hours would give a batch a day, while the digester, giving a batch a day, would feed each reactor in turn. This arrangement appeared to lend itself admirably for purposes of design and production. The digester was designed to be an exact replica of the reactor, and to be placed high enough to discharge into it by gravity, the latter being kept at such a height as to discharge also by
gravity into the existing ground level storage tank, or into tank waggons.

In this design the furnace was made a separate unit and placed on the ground level. The secondary air at 16 inches water gauge was arranged to be provided by the furnace blower. The arrangement and number of the reactor heating flues, together with the headers, precisely followed the Burnley design. No recirculation of the waste flue gases was provided for. The burner had a bigger capacity, and could consume up to eleven gallons of oil per hour. It was assumed that furnace gases at 800 degrees F. to 900 degrees F. would be sufficient to maintain the reactor at 360 degrees F. It was also assumed that the waste gases leaving the reactor would be at some temperature above the tar (300 degrees F.), and that they would therefore be quite hot enough to do all the heating required in the digester dehydrator, where the tar would not need to be more than 180 degrees F. at the most. The lay-out was arranged so that this method of heating could be carried out, with the addition that extra heat from the furnace could be supplied to the digester if required. In addition, either the reactor or the digester could be bye-passed entirely.

The general disposition of the digester, reactor and furnace, together with the necessary heating arrangements, having thus been decided, investigations into the tubular column were continued. It became obvious that air for polymerising could be drawn down one column and then taken off, half way, to the heat exchanger. From the second pass of the heat exchanger the hot oil vapours would be led into the next corner column, which would also act as a condenser header; from here the oil vapours would pass through six 4 inches diameter tubes to the third column, counting in a clockwise direction, and then return through a further six tubes and pass down through the second column. At a point near the bottom of this column a connection was to be made for the blower and cyclone, which in this design were placed on the ground floor; from the cyclone the cooled air, now nearly free from oil, was to be led up the fourth column, from which it discharged to atmosphere.

Thus the four columns were all performing a double duty. Something had been dispensed with entirely; whether this was the structure or the piping has not yet been determined. Then had to be considered the practical details of how the digester and reactor were to be carried, and how the main beams were to be secured to the circular columns. It did not take long to see that the two opposite sides of each vessel would make ideal plate girders, and thus obviate any need for main supporting beams. Their connection to the columns was solved quite simply by arranging that slots should be oxy-cut in the columns,
deep and wide enough to enable the plate sides of the reactor and the digester to be passed right through the columns, allowing one inch of projection on the outside. By this means the loading could be placed directly on the centre of the column, and both column and plate girder would be homogeneous, giving an extremely rigid connection. Appropriate stiffeners were added.

The plates of the flat floor of each vessel had to be carried by steel channel beams. These were to be supported by increasing the depth of the side plates to one inch below the underside of the floor beams, and oxycutting to the profile of the channels—slots into which the ends of the beams were inserted. This possessed a double advantage in that it provided direct support for the floor beams, which were allowed to remain free to move in the slots until the floor had been welded up complete; also it gave the extra depth required for the strength of the girders.

The designs were now beginning to fall in line with the latest practice of the Metropolitan Gas Company's Construction Department, which is developing a special technique in the design of welded structures. This has been termed "metallic joinery." The object is to secure metal to metal bearing, and also interlocking. The convenience of the electric-welding-arc renders this possible to a very great degree.

The heat exchanger was made smaller in diameter than for the Burnley plant, but much longer, being 4 feet diameter x 16 feet 4 inches long, with 172 tubes 2\(\frac{1}{2}\) inches outside diameter and 14 feet long. Though the heating surface was about the same, the velocity of the air through the exchanger would be greater, and thus give a greater rate of heat transfer. The heat exchanger was arranged to be suspended by saddle plates from the sides of the digester, and this extra weight required the addition of flange plates to strengthen the girders which constituted the sides. The top plate was extended for three inches over each side to form top flanges, whilst 6 inch x \(\frac{1}{2}\) inch flats were welded on to form the bottom flanges.

The provision of air to the reactor, for polymerisation, required to remain constant throughout the batch, but air is only required in the digester for dehydration. As one exhaust fan only was to be provided, it was at that time intended that, when dehydration commenced, a valve should be opened between the digester and the inlet to the condensers, and the fan would then draw the water vapour and hot oil vapours through the rest of the plant.

The designs had now reached a stage where it was possible to present balance sheets and estimates, and very soon authority was given to proceed with these extensions.
While fabrication was rapidly proceeding in the Company's workshops, the completion of the first Burnley unit was announced. This news had been awaited with some eagerness, as there would at last be an opportunity for getting some practical working experience. The plant started up without a hitch, and it was soon manifest that the time of 60 hours allowed for the process was very conservative, for the first batches were produced in 48 hours. A series of batches were then run through in order to determine the requirements of polymerising air for best commercial conditions; a thousand cubic feet per minute had been allowed for, but between 500 and 600 cubic
feet was found to be the right amount. Under these conditions the oil consumption in the furnace averaged about 2.2 gallons per hour, and observations showed that this would have been 4.4 gallons had the heat exchanger not been installed. With the atmospheric temperature of 56 degrees F., the polymerising air was raised to 146 degrees F., after passing through the heat exchanger; while the hot oil vapours leaving the digester at 205 degrees F. were reduced to 118 degrees F. during their passage through the exchanger. The final discharge temperature to the air was 108 degrees F.

A very pleasing feature of the plant was the complete absence of any leakage through the joints, for hot tar and the light tar oils impose a more severe test on the tightness of a joint than anything else. The behaviour of the plant was carefully watched for some time to ascertain whether any improvements could be suggested for that going up at West Melbourne. It was, however, functioning so well, and had so far exceeded expectations, that it appeared difficult to improve on the design. One thing that did suggest itself was that there appeared to be a possibility of reducing the West Melbourne batch time from 48 hours to 36 hours, which would, of course, make the estimated financial balance sheet appear even more favourable.

The erection of the West Melbourne plant proceeded rapidly on the lines of the original design, with one exception, viz., that it was decided not to bring the dehydration air with its water vapours to the condenser, and there to mix it with the hot oil vapours as originally proposed; for it became apparent that the latent heat of water being approximately eight times that of the oil, greater condensing plant would be necessary. This change appeared to necessitate the provision of a further fan to discharge the dehydrating air to atmosphere; but it had been observed at Burnley that the exhaust from the cyclone was somewhere about 50 degrees F. above atmosphere, and it was decided to use this warmer air in the West Melbourne plant. Here it was found an easy matter to provide two valves and one extra connection between the exhaust head of the column and the air inlet to the digester, and use the warm air from the pressure side of the fan. Figure 4 represents the process as now operated.

The design did not present any problems either in fabrication or at erection, and it was successfully brought to a rapid conclusion. This plant also started up without a hitch, and also functioned beyond expectations. Again, it was found that the estimates had been based on conservative lines, for the batches came out in 24 hours. The working showed that it was not necessary for the furnace gases to be above 900 degrees F. at the first stages of the process when forcing the pace during
the heating up, and that 700 degrees F. was all that was required during the major portion of the time; in fact, to keep the temperatures down to these limits it was necessary to turn the burner completely off from time to time. With the furnace gases at 700 degrees F. the temperature at the reactor outlet flues was 500 degrees F., and the inlet to digester flues 450 degrees F. At these temperatures the tar was digesting at 140 degrees F., while the final stages in the reactor were being performed at 365 degrees F. The atmospheric air temperature of 65 degrees F., was increased to 265 degrees F. after passing the exchanger. The reactor air outlet of 305 degrees F. was reduced to 210 degrees F. after the exchanger and the final outlet from the cyclone 100 degrees F. These figures, however, change from hour to hour according to the stage of the batch, but they show a comparison between the temperatures throughout the plant.
These temperatures indicate that expansion had to be provided for, and this was met by arranging for complete freedom of movement of the heating tubes and headers inside the

Figure 5.—Bitural Plant at the West Melbourne Works of The Metropolitan Gas Company.
reactor and digester. These vessels being a homogeneous part of the structure, provision had to be made for the whole to move by placing loose plates between the column bases and the concrete, and providing 1½ inch diameter holes in the base plates to pass the one inch holding down bolts through. The nuts on these bolts were screwed down "finger tight" only. The condenser tubes were provided with expansion joints, while the external flues could move through the angular bends in their length.

Generally speaking, the only difference between the Burnley and the West Melbourne plants lies in the constructional details. The general "batch" time, counting from the charging of the cold tar up to the discharge of the finished product, appears to be between 36 to 40 hours according to the degree of penetration required. Observations show that the total fuel oil consumption, per batch, in the two plants, is approximately the same.

The West Melbourne design proved very amenable to changes in the "flow" of the air and oil vapours; as, for instance, when it was decided to utilise the warm air from the pressure side of the blower to carry out dehydration. The resultant changes in the pipe connections were easily and cheaply made.

The only change that has occurred in the product itself has been to evaporate off the remaining 12 per cent. of tar oils, and replace them with 8 per cent. of asphaltic oil having a higher boiling range. This has resulted in an improvement to the product.

In reviewing the designs as they stand, the two plants appear to fulfil all requirements for economical working with a fair return on the capital expended. In considering the future expansion of the process it would seem that the most logical arrangements for "Bitural" plants erected by gas companies would be to place them adjacent to the retort houses or large boiler installations, and so make some use of the large volumes of waste heat now going to atmosphere. This would reduce the labour required to the charging and discharging periods only, for the plant, after the working periods had been correctly arranged, would only require occasional oversight from the shift engineer or chemist.

Regarding the commercial value of the product, each batch of 2500 gallons of crude tar returns about 1800 gallons of Bitural at 160 penetration. This is used for roads, paths, bituminous roofing, damp course, bituminous paint, etc. The recovered oil amounts to about 700 gallons, with a boiling range of 170 degrees to 300 degrees C., and is not only an excellent
fuel, but can be worked up into creosote oil, phenyle, fruit spray oil, etc.

The compact nature of the plant, which occupies a ground area of only sixteen feet square, is shown in Figure 5.

TECHNICAL COMMENTARY AND PROJECTED IMPROVEMENTS.

A number of interesting physical problems entered into the design, and will now be briefly surveyed.

**Heat Transfer in the Heat Exchanger.**—This was found at Burnley to be about five-eighths of a B.T.U. per hour per square foot per degree Fahrenheit difference of temperature, while at West Melbourne it was nearly one B.T.U.—higher owing to the higher velocity of the flowing air. These coefficients are both very low, and would be greatly increased with higher air velocities. The total air resistance of the exchanger at West Melbourne under working conditions was only 2.6 inches water gauge. Apart from heat economy, the function of the exchanger was to bring the air to nearly the same temperature as the tar in order to relieve the external heating system of that work. The amount so saved and recovered was nearly two-thirds of the total required to heat the air and evaporate the oils.

**Recovery of the Oils.**—Of the condensate, 31.6 per cent. was collected from the heat exchanger, 23.6 per cent. from the condenser, and 44.8 per cent. from the drains from the centrifugal fan and cyclone; whereas analysis of the partial vapour pressure of the dilute oil vapours at the various temperatures indicated that 61.3 per cent. was condensed by cooling in the heat exchanger, and 36 per cent. in the condenser, with 2.7 per cent. remaining uncondensed and lost in the outgoing air. This indicates that most of the condensed oil remained as a fog in the air, and was carried along to the centrifugal plant, where it was finally thrown out of suspension. Even the violence of the latter treatment did not precipitate all of the fog, for it was quite perceptible in the exhaust air, particularly near the end of a batch.

The excellent behaviour of the heat exchanger suggests a further improvement in the process, leading to the recovery of all the oil, and further conservation of the heat—that is, by the recirculation of the polymerising air, the oxygen of which, acting only as a catalyst, does not require replenishing. The argument is as follows:

Table 1 shows that the heat required per batch without using heat exchangers was 27,397,000 B.T.U.'s. This was based upon a high water content in the tar; but reducing this to 3½ per cent. water (i.e., 3 per cent. in the tar and ½ per cent.
in the added catalysts), the total heat requirement would have been 22,931,000 B.T.U.'s.

Table 2 shows how this is reduced to 9,255,050 B.T.U.'s following the use of the heat exchanger, with the attendant advantage of shortening the period of treatment. It will be noted from this table that less polymerising air is required; this also aids the heat economy. Table 3 shows that, over all, there is no appreciable heat absorbed or given out by the reaction, for the sum of the calorific values of the products is approximately equal to that of the constituents.

Therefore the process should involve only the supply of sufficient heat to make up for loss by radiation, for dehydration, and also to supply the latent heat in the oils, and the intrinsic heat of the Bitural itself. This is always discharged while hot, because it solidifies on cooling, and the temperature when discharged is high enough for transport in wagons which spray it directly on the roads without reheating. As indicated before, recirculation of dehydrating air might overload the condensing system, and it is not initially proposed to recirculate it; therefore, the amount of heat required for digestion and dehydration will be the same as before. Thus the process would involve all the items of Table 2 with the exception of the heat carried off in the polymerising air, so that the total heat involved amounts to 8,225,000 B.T.U.'s, which is more than one million B.T.U.'s saved over present practice. During reaction the only heat required to be discharged from the system is the latent heat of the oils, amounting to 819,000 B.T.U.'s, and it is thought that it might be possible to dispense with the condenser, leaving the unlagged piping and a partly unprotected shell of the heat exchanger to radiate the necessary heat. Otherwise, the cooling of the condenser should be controlled or curbed to the desired amount as indicated by the temperature range of the air in the cycle—i.e., so that the total radiation from condenser and piping will not exceed the latent heat of the oils. In any case, the provision for the recirculation of the polymerising air renders it possible to recirculate the dehydrating air without any further change. This may be necessary should its discharge at any time prove obnoxious. In this case condensers would have to be retained.

The recirculating air necessarily carries a residue of oil vapours and oil fog, so it has less capacity for evaporating oil in the reactor. Consequently it will be necessary to slightly increase the flow of the recirculating air. This would not entail any undue increase of pressure drop in the system, however, as it is at present only seven inches water gauge.
Only approximate estimates are possible on account of the very rough data available of specific and latent heats, temperatures, radiation losses, etc.; but there is sufficient evidence to show that recirculation of the air would save annually approximately £60 in fuel and another £100 in oils, at present lost in the discharging air. The plant is so arranged that such alterations can cheaply be put into effect. The circuit would not be hermetically sealed.

The comparative simplicity of the process for converting tar to Bitural suggests that some economical, continuously-operating plant might be evolved, but this has not been very seriously entertained, for a continuous plant could not reduce the present charges for attendance; its maintenance would probably be greater. Moreover, the intermittent plant is more amenable to the alterations of control incident to a new and only half-evolved process, and to the supply of varying qualities of product for different users. In addition to this, there would have been delay in evolving a satisfactory continuous plant, and there was an urgent market demand for the product.

In conclusion, any commendation which the designs outlined in this paper might possibly receive should not be allowed to eclipse the credit due to Messrs. C. F. Broadhead, Engineer, and R. S. Andrews, Chief Chemist, of the Metropolitan Gas Co., who originated the process. Without their pioneer work the subject of this paper would not have existed.
The dehydrator is assumed to hold 3000 gallons of tar containing 500 gallons of water.

### TABLE 1.

**Estimate of Heat Consumed in Bitural Process per Batch of 2000 Gallons of Bitural.**

<table>
<thead>
<tr>
<th>Description</th>
<th>B.T.U.'s</th>
<th>Per Cent. of Dehydration</th>
<th>Per Cent. of Combined Process</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A—Dehydration (12 hour process)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Heating Tar—2500 gallons from 60 degrees F. to 200 degrees F.</td>
<td>1,702,000</td>
<td>20.3</td>
<td>6.2</td>
</tr>
<tr>
<td>2. Heating and Evaporating Water — 500 gallons from 60 degrees F. to 200 degrees F.</td>
<td>5,415,000</td>
<td>64.6</td>
<td>19.8</td>
</tr>
<tr>
<td>3. Heat Carried Off in Air Used in Dehydrating —500 c. ft. per minute</td>
<td>910,000</td>
<td>10.8</td>
<td>3.3</td>
</tr>
<tr>
<td>4. Radiation of Heat from Walls of Dehydrator</td>
<td>360,000</td>
<td>4.3</td>
<td>1.3</td>
</tr>
<tr>
<td><strong>Total Heat: Dehydration</strong></td>
<td>8,387,000</td>
<td>100.0</td>
<td>(30.6)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Description</th>
<th>B.T.U.'s</th>
<th>Per Cent. of Reaction</th>
<th>Per Cent. of Combined Process</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>B—Reaction and Distillation (48 hour process)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Heating Tar—2500 gallons from 200 degrees F. to 400 degrees F.</td>
<td>2,430,000</td>
<td>12.8</td>
<td>8.9</td>
</tr>
<tr>
<td>2. Evaporating Oils (20 per cent. distilled off)</td>
<td>600,000</td>
<td>3.2</td>
<td>2.2</td>
</tr>
<tr>
<td>3. Heat Carried Off in Polymerising Air —1050 c. ft. per minute at 300 degrees F.</td>
<td>12,500,000</td>
<td>65.7</td>
<td>45.6</td>
</tr>
<tr>
<td>4. Radiation from Walls of Reactor</td>
<td>3,480,000</td>
<td>18.3</td>
<td>12.7</td>
</tr>
<tr>
<td><strong>Total Heat: Reaction, etc</strong></td>
<td>19,010,000</td>
<td>100.0</td>
<td>(69.4)</td>
</tr>
<tr>
<td><strong>Total Heat Combined Process</strong></td>
<td>27,397,000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
TABLE 2.

ANALYSIS OF HEAT CONSUMED IN BITURAL PROCESS AS CARRIED OUT AT WEST MELBOURNE GAS WORKS.

A—Digestion and Dehydration (12 hours).

<table>
<thead>
<tr>
<th>Description</th>
<th>B.T.U.'s.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Heating Tar—2500 gallons 60 degrees F. to 200 degrees F.</td>
<td>1,702,000</td>
</tr>
<tr>
<td>2. Heating and Evaporating Water—87 1/2 gallons 60 degrees F. to steam at 200 degrees F.</td>
<td>949,000</td>
</tr>
<tr>
<td>3. Heat Carried Off in Air—600 c. feet per minute for 3 1/2 hours from 100 degrees to 200 degrees F.</td>
<td>225,050</td>
</tr>
<tr>
<td>4. Radiation from Walls of Dehydrator Vessel</td>
<td>360,000</td>
</tr>
<tr>
<td>Total: Digestion—Dehydration</td>
<td>3,236,050</td>
</tr>
</tbody>
</table>

B—Reaction and Evaporation of Oils.

<table>
<thead>
<tr>
<th>Description</th>
<th>B.T.U.'s.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Heating Tar—2500 gallons from 200 degrees to 400 degrees F.</td>
<td>2,430,000</td>
</tr>
<tr>
<td>2. Evaporating 729 Gallons of Oil at 1122 B.T.U.'s per gallon</td>
<td>819,000</td>
</tr>
<tr>
<td>3. Heat Carried Off in Polymerising Air—600 c. feet per minute at 306 degrees F.</td>
<td>3,790,000</td>
</tr>
<tr>
<td>4. Radiation</td>
<td>1,740,000</td>
</tr>
<tr>
<td>Total, Reaction—Evaporation</td>
<td>8,779,000</td>
</tr>
<tr>
<td>Total: Combined Process</td>
<td>12,015,050</td>
</tr>
<tr>
<td>Heat Exchanger Recovers</td>
<td>2,760,000</td>
</tr>
<tr>
<td>Balance: Heat Required</td>
<td>9,255,050</td>
</tr>
</tbody>
</table>
### TABLE 3
**HEAT INVOLVED IN THE REACTION.**

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Gallons</th>
<th>B.T.U.'s per gallon</th>
<th>Total B.T.U.'s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude Tar</td>
<td>2,500</td>
<td>177,500</td>
<td>443,000,000</td>
</tr>
<tr>
<td>Asphaltic Oil</td>
<td>180</td>
<td>171,000</td>
<td>30,780,000</td>
</tr>
<tr>
<td>Formalin (40 per cent.)</td>
<td>25</td>
<td>39,600</td>
<td>990,000</td>
</tr>
<tr>
<td><strong>Total Calorific Value of Ingredients</strong></td>
<td></td>
<td></td>
<td><strong>474,770,000</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Products</th>
<th>Gallons</th>
<th>B.T.U.'s per gallon</th>
<th>Total B.T.U.'s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bitural</td>
<td>1,927</td>
<td>189,000</td>
<td>364,000,000</td>
</tr>
<tr>
<td>Oil (allowing for 3 per cent. loss)</td>
<td>729</td>
<td>149,900</td>
<td>109,100,000</td>
</tr>
<tr>
<td><strong>Total Calorific Value of Products</strong></td>
<td></td>
<td></td>
<td><strong>473,100,000</strong></td>
</tr>
<tr>
<td>Internal Heat Left in the Bitural (22,341 lbs. at 180 B.T.U.'s/lb. V.P.)</td>
<td></td>
<td></td>
<td>4,020,000</td>
</tr>
<tr>
<td><strong>Total Heat of Products</strong></td>
<td></td>
<td></td>
<td><strong>477,120,000</strong></td>
</tr>
</tbody>
</table>
DISCUSSION

Mr. W. R. Pollock, in moving a hearty vote of thanks to the authors, said he was sure all would agree that they had listened to a most interesting address, which would prove a very valuable addition to the proceedings. He had had the privilege of inspecting the plant, and the first thing that impressed him was the simplicity of the structure. At the present time the manufacture of Bitural was doubly important to Australia, because it provided an opportunity of using an Australian product.

Mr. A. E. Battle, in seconding the motion, said the paper was most interesting, enlightening and instructive, and would reflect credit upon Australian enterprise. It was a paper that would appeal to Australians.

Mr. W. D. Chapman, Inspecting Engineer, Railways Construction Branch, Victoria, said he was pleased to have had the opportunity of hearing the paper. The development of the new process was something they were very pleased indeed to see. The paper struck a new note right from its title. It provided much to think about, apart from the actual work described. The method of attack and the development of the process gave them all something to emulate. The structures were exceedingly interesting, and made them realise, as they always did when listening to anything from the authors, that they were far ahead of others in the matter of electric welding. He thought any attempt to make a dual use of the parts by the old methods of casting and riveted work would have been a failure; it certainly would have been impossible to attain the extreme simplicity that had been shown in the structure illustrated.

Mr. J. Stapleton, Manager Structural Department, Charles Ruwolt Pty. Ltd., said he had been connected with the firm of Ruwolt's for some years, and had carried out a considerable amount of welding work. The instance of structural work placed before them in the paper was outstanding in the matter of design. He had had an opportunity of inspecting the West Melbourne plant, and the design had particularly impressed him. He was not competent to comment on the actual production of Bitural, but the paper had been very enlightening to him.

Mr. J. T. Noble Anderson said he had been much impressed by the excellence of the design, but he wondered whether former speakers were losing sight of the main question, Did it pay? Obviously the plant had proved itself the first time. When tenders were opened by Richmond Council recently they found that Bitural had beaten its competitor bitumen by about
20 per cent. It was encouraging to see a local production that would supplant the imported article that had been bleeding the country to the tune of about half a million pounds a year. The production of Bitural not only replaced something that cost a great deal; it also helped one of the big natural products—the coal industry. Australia was one of the great coal-producing countries of the world, and occasions like the present depression would help to bring coal into its own again. Whether good payable oil was found in Australia or not would make very little difference. Australia recovered from the last slump by rediscovering her gold; she would recover from the present slump by rediscovering her coal.

Mr. F. St. John, Albion Quarrying Co., said he had no comment to offer upon the design, but wished to thank the authors for the assistance which they had rendered him in putting the plant to work. He extended an invitation to all members at any time to inspect the plant at Burnley.

Mr. A. R. Moon, Technical Director E.M.F. Co., said he thought it was unique to combine a plant and a building in one unit. It emphasised very definitely the difference the introduction of a new process like electric welding could have upon an industry. The successful application of welding to any class of work required the ability to forget altogether the standard methods of construction; and it was in that more than in anything else that the authors had secured their great success in electrically welded construction. In all their work they appeared to have been able to throw away the past and get down to fundamentals. It was interesting to note that in Sydney the first large welded office building was being constructed, where the structure was not merely a simple welded steel building, but was of steel and concrete. He understood the saving in cost was about 20 per cent.

Mr. O. O. Ternes, Superintendent West Melbourne Gas Works, said that for some time they had experienced considerable difficulty in knowing what to do with their tar. Bitumen proved to be a very severe competitor. The Company manufactured about 4,000,000 gallons of tar per annum, which they had found difficult to dispose of, and finally they had been compelled to burn some of it. The problem was then tackled by the chemical department, and was finally handed over to the engineer to design the plant. The fact that a suitable road material had been devised not only helped the Company to get rid of the tar, but it placed a material on the market that kept money circulating in the country. Bitural had been placed on the roads and subjected to severe tests under traffic, and had proved entirely successful. The Country Roads Board, which was very particular as to the class of material
used on the roads, had taken large quantities. It was now being made in South Australia, and would later on be undertaken in New South Wales, Western Australia, and probably in New Zealand.

Mr. J. F. Maughan, City Surveyor, Kew, said he was delighted to find the Gas Company manufacturing a new product. In 1924 he was using tar, and had no end of trouble with it. They tried out Bitural, and found it a complete success, and there was no doubt in his mind that Bitural had come to replace bitumen.

Mr. G. A. Whiting, E.M.F. Co., thanked the Institute for the invitation to attend, and commended the manner in which the authors had overcome the various difficulties of the problems involved.

Mr. J. Williams said he had pleasure in supporting the remarks of previous speakers as to the excellence of the paper, but it had provided so much food for thought that he would prefer to postpone any remarks upon it until he had had an opportunity of studying it carefully.

Mr. H. E. Grove, in reply, thanked members for the cordial manner in which the paper had been received. He had seen quite a lot of work outside that of the Metropolitan Gas Co., and had been much interested to see how the engineering profession were holding their own in the direction of welding. At Ruwolt’s works he had been much impressed with the quality of the welding work being carried out, and he had also recently seen excellent welding at Yallourn. The authors did not know all there was to be known about welding. There were others who were too modest to put forward their claims.

Mr. R. J. Bennie said he wished to express his thanks for the very kind reception accorded the paper. He hoped when the paper was circulated that there would be further discussion. The paper certainly gave prominence to the welding aspects of the matter, which were somewhat unique, but, in addition, it discussed problems of chemical engineering. They did not claim to have reached the last word even on the welding side. Perhaps it might be interesting at some future time to give a short note on tests of the application of the recirculation of polymerising air. He hoped it had been made clear that certain heat economies were yet to be secured. They had secured nine-tenths of those economies, and hoped to secure the rest.
DISCUSSIONS

The President said they were indebted to Mr. Anderson for his further valuable contribution. Mr. Anderson had brought forward a new point in his consideration of the expansion joint, and the difficulties encountered in making the expansion joint work effectively.

Mr. Wm. Chas. Rowe said he had to thank Mr. Anderson for his very valuable paper. With reference to the protection of expansion joints from the intrusion of foreign material, he had experienced the same difficulty in the tops of weighbridge tables. Those tables should be cast in one piece. Sometimes they were supplied in two pieces, and the penetration of gravel in the joint would in time force the sections apart. Could not the foreign matter be kept out of expansive joints by keeping something else in, such as graphite or some such material?

The President said the sketch that had been circulated showed that a rubber-like material had been used for filling the joints in the concrete road.

HOW A MANUFACTURING PLANT WAS EVOLVED FROM A CHEMICAL FORMULA.

Paper by R. J. Bennie and H. E. Grove.

The President, in reopening the discussion, said that the methods of treatment of tar in the manufacture of bitumen were developing so fast that that which was brought forward in the paper might perhaps be regarded as academic twelve months hence.

Mr. R. S. Andrews, Chief Chemist of the Metropolitan Gas Co., said he had been very interested in the paper, owing to his close association with the development of the process, and he would like to take the opportunity of adding his praise to the gentlemen who had designed and erected the plant, which had been in operation for about three months. The design was both unique and unorthodox as regarded tar treatment, and numerous visitors had been much enamoured of it. The development of the process and the design of the plant were the outcome of a rather peculiar set of circumstances. It appeared inevitable that when a radical change was made it brought a series of difficulties, and when the Gas Company adopted vertical retorts they were faced with the problem of marketing an inferior tar. The bulk of the tar was expelled before the coal reached the hotter zone, and that tar naturally had a large percentage of low temperature products in the form of paraffin and unsaturated hydro-carbons. So in developing
that process they had attempted to imitate nature by polymerisation and molecular condensation. They were attempting to do in a few days what nature had taken aeons to do. At the request of the President, he had brought some samples for inspection. One was a crude tar, which was nothing more or less than an oil. Road engineers were quick to see its inferiority, and specified bitumen. But, as a result of their experiments, they had been able to produce from tar a rubber-like material resembling the imported bitumen. At normal temperatures it was more ductile than bitumen, but at low temperature it was not so ductile. It was not as good as bitumen, but their researches had led them to believe that the best method of attacking the tar problem was by chemical means, and they hoped in time to be able to produce a material which would be as good, if not better, than the imported product.

The President said members were indebted to Mr. Andrews for his exposition of some of the chemical causes which led to the evolution of the process.

Mr. H. M. Wales, of the Albion Quarrying Co., said he was glad that the development of the new process in the treatment of tar was the work of Australians. It was a credit to Australia that, with a population of 6,000,000, she had developed such a scheme. There was one point where they might have some little trouble, and that was the exhausting of the polymerising air into the atmosphere. He understood the heat loss due to that factor was something like ten per cent. He was sure it would not be long before that was retained in a complete circuit and the heat loss avoided. Trouble through noxious gases being exhausted to the atmosphere would also be avoided. An outstanding feature of the plant erected at Burnley was the fact that the design was so thorough that the plant started off without a hitch, and the production of the plant proved to be beyond the estimate.

Mr. D. Bell, Metropolitan Tramway Board, said that during the past four months the Board had laid about 10,000 gallons of bitural, which had done everything that was expected of it. It had acted the same as bitumen. They had had some hot days, and found that the bitural would run, but it did not lift like bitumen.

Mr. J. T. N. Anderson said bitural was being tried at Richmond. It was being tried on the concrete roads, using it on the unevennesses, and so far it was giving very good results indeed.

Mr. St. John, Albion Quarrying Co., said he found that the cost of production for fuel alone showed a saving of a farthing per gallon over what it would have been if constructed without the means for heat economy incorporated in the design.
Mr. Wm. Chas. Rowe thought the construction of the plant described was a very fine piece of work. He appreciated the putting of the side plates of the tank through the columns and welding them up, also putting the cross girders through the plates and leaving one inch at the bottom, also utilising the columns as partitions. The whole work was a fine piece of engineering. With regard to the oil-burner furnace, he thought the twelve-inch cross section small. He could not understand the amount of oil used in the circumstances.

Mr. H. E. Grove said that while it was stated in the paper that five gallons would be required, they had hoped that 2½ gallons would prove sufficient, and actually the consumption had been less than that amount. The general efficiency had been so great that the burners were extinguished from time to time to reduce the heat. Therefore the quantity of oil used was surprisingly low.

The President said they were more conservative in the design of the West Melbourne plant, in that they provided a burner unduly large for the requirements; but on the other hand they secured a reserve of heating capacity.

Mr. J. Williams said he wondered whether mechanical agitation might hasten polymerisation.

Mr. H. E. Grove, in reply, said the movement of the tar itself was most violent, so much so that they were compelled to slow it up. They had originally thought of agitating it by circulating through a gear pump, but that was found to be unnecessary. They found they had more motion than was necessary. The furnace was twelve inches square, and at the end of the furnace they recirculated the waste gases, and that gave the required volume.

It was very gratifying to hear the commendation of the paper. The work had been a rare experience, and one of exceptional interest, where they had been able to co-operate with the chemist in the initial stages, follow up later developments, design and construct the plant, and finally put it into operation. They desired to acknowledge the great assistance received from Directors of the Albion Quarrying Co., and from Mr. St. John, and also from the staff of the West Melbourne Gas Works during the time of erecting and putting to work of those two plants.

The President, in replying to discussion, said he greatly appreciated the cordial reception of the joint paper, the preparation of which had been a great pleasure to the authors. He especially desired to record his appreciation of the very great assistance they had received from Mr. Andrews during the pre-
paration of the design. He would remind members that without the chemist there would have been no bitural. No doubt there were other methods for handling the material, such as continuous processes and mechanical means for circulating the tar. All had been considered, and the methods finally adopted were deemed to give the most definite results with least expenditure. One point he would like to make in closing the discussion: The amount of tar made last year was roughly equal to the amount of bitumen imported, and, in view of the present financial position, it was probable that less material would be required for road surfacing for some years to come. It was gratifying to see, therefore, that most of the demand might be met with a local product. With regard to recirculation of the polymerising air, it would be noted in Table I. of the paper that initially estimates had been based upon very high water content. The reduction of this had rendered recirculation of the air practicable, and steps had already been made at West Melbourne Gas Works for its inauguration.

PAPER

ABSTRACT OF NOTE ON A USEFUL EXTENSION OF THE LOG-LOG SCALE OF A TEN-INCH SLIDE RULE.

By Wm. Chas. Rowe.

The demonstration dealt with an extension of the Log-log scale in order to enable computations to be made involving exponents of low value. The lowest value marked on the ordinary Log-log scale of the slide rule is usually 1.1; and many problems, in fact all commercial computations, require the use of lower values, such as those corresponding to interest rates. These lower values, i.e., from 1.10 down to say 1.01, or further, may be used by extending the scale to the left, over an extra scale attached to the rule. But the inconvenience of this can be avoided by marking the extension within the slot of the rule, starting at the extreme right hand end, in the following manner:—1. The corner of the right hand end of the slider is chamfered, taking care not to deform the square end of the underneath celluloid of the slide. 2. By means of the cursor, the left hand end of the slide is set at 1.1 on the log-log scale, and the position is carefully marked at the extreme right of the slider where it was chamfered. This mark is the position of the transferred log-log on the new scale. Other values are found as in the following example:—To obtain the position for marking 1.095, the value of 1.095 to the tenth power is obtained by the use of logarithms. It is 2.4782. Then the cursor is set opposite 2.4782 on the log-log scale, and the value 10 of the
Author/s:
Bennie, Roy James; Grove, Harry Ernest

Title:
How the design of a manufacturing plant was evolved from a chemical formula (Paper &

Date:
1931

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