

His firm had supported the scheme because there was not a better one before them. We in England wanted aniline colours, and unless something was done we should soon be without a supply. The general tone of the discussion was that the scheme should be managed entirely from the business side. That, however, seemed to him to be a very sad state of things.

Mr. MERRIMAN said that he understood that Germany obtained a lot of raw material from this country. If we used it ourselves their output would be limited to some extent.

Mr. WOOP said that under this scheme any surplus English raw material was going to be sent to Swiss works and they were to return an equivalent quantity of dye to this country. The rest of the raw material was to be kept at home, so that in any case Germany would get far less raw material in the future, whether the scheme were successful or not, after the war. Firms who did not subscribe to the scheme would not get any dyes while the war lasted.

Scottish Section.

Meeting held at Glasgow on Tuesday, 26th January, 1915.

MR. ROBERT HAMILTON IN THE CHAIR.

THE FRACTIONAL COLLECTION OF CRUDE TAR.

BY GEO. THOMSON PURVES, A.M.I.C.E.

The complete collection of crude tar in fractions does not appear to have received the attention which its importance justifies. Apart from the purely commercial aspect, it is worth considering how far the primary separation of the crude tar into the usual first fractions in the closed condensing system would be helpful to the reduction of atmospheric pollution. In some tar works the gases evolved from the tar are burned direct and in others passed through purifiers. In the case of direct fractionation this gas would go to augment the volume of permanent gas produced.

If the tar can be collected in the ordinary practice of the carbonising work, in those fractions into which the distiller ultimately splits it up, this would clearly be a desirable attainment provided the cost of so doing is not excessive. And considering the cost in wages and fuel and possibly transit which the primary distillation in the tar works involves, there would seem considerable scope for the successful practice of direct fractionation. It is a well-known fact that in the distillation of tar decomposition of certain products occurs, and the content of free carbon is increased. I have distilled a sample of heavy crude tar which was liquid at ordinary temperature, but after remixing the fractions, warming and allowing to cool the product was solid, showing considerable alteration in the component products. Such a change in the tar might in some cases be beneficial but in others would be objectionable. Direct fractional collection avoids the submission of the heavy tar to the high temperatures obtaining in the still towards the end of the distillation. The object in this paper, however, is to consider the question from the carboniser's rather than the tar distiller's point of view.

In gas works practice the crude gas from the retorts is very commonly drawn through a liquor

seal in the hydraulic main and here heavy pitchy tar is deposited; later in the slow condensing main, then in the final coolers and tar extractors, and lastly in the distribution system lighter and lighter fractions are separated, in each case by cooling and frictional scrubbing. This is distinctly fractional separation of tar. Further it would be a difficult matter to get other than fractional separation. But so little is it the intent that the carboniser carefully runs his fractions into the common tar well.

It will be interesting to consider one or two factors which have governed practice in tar extraction and the effects of these on the gas, on by-product recovery, and also on the trend of development towards complete direct fractionation. Before doing so, however, I wish to refer to a point in regard to the nature and the removal of tar fog. When the fog is first precipitated in the gas it must be in an extremely fine state of division, and the question arises, how fine? In a recent descriptive paper on the "Electrical Detarring of Crude Gas" as applied at the Semet-Solvay Coking Installation, Detroit,* the following statement is made in referring to the paper stain method of determining the amount of tar fog present in crude gas. "When the gas carries large quantities of tar mist the aspirator bottle will be full of the dense brown fog which has passed through the papers," i.e., two filter papers. In the face of this no practical tar scrubber could be expected to remove such fog completely. At the actual moment of condensation the minute drops of a liquid would all be of the same size and consist of the smallest number of molecules which could satisfy the conditions of equilibrium for the liquid state. In order to remove tar fog it is necessary to allow sufficient time to elapse for the elementary liquid drops to agglomerate to the relatively very large drops which we are able to deal with in practice. The size of the globules will be increased not only by aggregation but also by the solution in them of other vapours from the gas. I find a recognition of this principle in the work of Henry Aitken, a collaborator of Wm. Young. In the Aitken process, patented in 1874, "the settling of tar fog was promoted by sending gas at 190° F. into a very large settling chamber and keeping it there for as long as possible at that temperature."† The conclusion I wish to draw from this is that tar fog cannot be simultaneously precipitated in the gas and removed by frictional means from it.

In former years, when the candle-power of town's gas was higher than it is to-day, slow cooling of the gas was favoured as a means of keeping up this candle-power by retaining in the gas as vapour a larger amount of the illuminating condensable hydrocarbons. In the Saxon industry where lignite is carbonized for its valuable tar products we find "the cooling effect is produced solely by external air, and it is important that the vapours should pass through as long a track of tubing as possible. It has been found that if the vapours are artificially cooled (by water) in a short condenser to the same temperature as is attained in the atmospheric condenser, they still contain condensable constituents, whereas these are almost entirely absent when air is used. The most important point in the condensing process is the gradual cooling."‡ Exactly opposite results are thus apparently claimed for the same operation. As the crude gas from the retorts cools down its dew points with respect to different hydrocarbons, etc., are reached one after another, and the substances settle out as constituents of tar fog. The minute drops comprising the fog float

* The Gas World, Oct. 31st, 1914.

† Wm. Young, an appreciation by Alfred Daniels.

‡ Shale Oils and Tars, by Dr. W. Scheithauer.

in the gas for a considerable time, depending largely on their specific gravity and the amount of frictional resistance encountered. This tar fog has a solvent action on those hydrocarbons, etc., still present in the gas as vapours provided the temperature is not above their boiling points, and it will dissolve a proportion even when the gas has not cooled down to its dew point with respect to the particular substance. If the fog remained in the gas for a sufficient time, a state of equilibrium as regards solution would be established when the vapour pressure of the substance in the fog equalled the partial pressure of the substance in the gas; hence by passing the gas through a slow condensing main where the fog-globules will coalesce and settle from the gas slowly, the gas is largely denuded of its light oil constituents as is claimed in the lignite industry. Lignite carbonising being a low temperature process, a considerable proportion of the tar produced is very light specifically, and so the fog is slow in settling from the gas. The explanation of how the slow condensing main of the gas works helps to keep the lighter hydrocarbons in the gas is to be found partly in the nature of the tar produced, but more largely in the higher outlet temperatures at which the slow condensing main is operated. By fractionally collecting the tar I found in a particular test that the gas produced was capable of carrying as vapour at atmospheric temperature and pressure all the light oil produced. The cooled gas contained 3.5% of hydrocarbons absorbable by fuming sulphuric acid. All the tar present as fog at 80° C. was scrubbed out and amounted to about 2.75% of the weight of coal carbonised, and contained only a trace of solvent naphtha. By further quick cooling and scrubbing in cold water sprays to about 20° C., about 0.13% of crude naphthalene crystals is obtained. So that by the time the gas has cooled to 80° C. about 95.5% of the tar which has to be removed by the extractors has separated out as fog. If now such a crude gas at 80° C. was passed through a slow condensing main, the fog would be steadily removed while the gas cooled relatively very little, and so the tar fog would have a much reduced opportunity of exerting any solvent action on the hydrocarbon vapours in the gas, with the result that these would be largely retained by the gas and the candle-power enhanced. As the temperature at which the slow condensing main is operated is lowered, increasing amounts of benzene vapour, etc., would be removed from the gas. It is probable, however, that at temperatures even considerably below 80° C. little benzene would be removed, for the gas is considerably below the saturation point with regard to this vapour. The principle involved is clearly the retarded cooling of the gas while the bulk of the tar fog is removed. The time occupied in the operation does not appear to be a material factor. The ideal state would be the complete removal of all tar fog before the gas reached the temperature at which the light hydrocarbons would be dissolved. This is fractional tar collection in a degree. Prof. Lewes writes "it was realised that sudden cooling of the gas and condensation at too early a period affected the illuminating power more than slow cooling. This is partly due to the tar being thrown out as a whole, while with slow cooling some of the benzene is carried away as vapour by the gas, etc."* It is not, however, speed of cooling but rather one of time contact between tar fog and cooled gas that is the material factor. For—as has been shown above—the crude gas can be quickly cooled, and the condensable tar removed almost wholly in one and completely in two operations with prac-

tically no removal of benzene. At Granton Gas Works, the slow condensing main is on the counter-current principle, and so the condensed tar has the minimum opportunity for solvent action on the gas. The slow condensing main at the Greenock Gas Works is on the direct current principle, and so the condensed tar has here the maximum opportunity for solvent action on the gas. The important point in the working of the slow condensing main is that the outlet temperature shall not be low enough to permit of the benzene, etc., being absorbed. Dr. H. Colman, when working on the removal of the heavy tar fog from the hot gas (about the year 1897), had two special objects in view—1st, to remove the naphthalene more completely from the gas in the condensers, and, 2nd, to retain more of the vapours of the light oils in the gas and thereby increase the illuminating power. To effect these results one factor which he proposed* was to pass the hot gas through a "Cyclone" extractor. The gyratory motion imparted to the gas in such an apparatus causes a centrifugal action which is much greater in the case of the tar drops than in that of the surrounding gas owing to their higher specific gravity. The tar drops are therefore thrown to the periphery of the centrifugal separator, where they coalesce and can be drained away. With the ratio of naphthalene to light oils obtaining in those days these objects were achieved. But with the larger production of naphthalene in later carbonising practice it was found that the crude naphthalene, etc., came down in a semi-solid mass in the condensers and blocked them. In Dr. Colman's method partial tar fractionation was thus used as a means of overcoming two definite carbonising troubles.

As we would expect, the writings of William Young are rich in reference to fractional condensation of tar. In the Young and Aitken process the central feature was the analyser in which fractional condensation was carried out. No effort was made, however, to collect separately the tar fractions deposited in the different sections of the analyser. The tar was allowed to flow downwards from section to section, so allowing the gas to take up as much of the lighter constituents of the tar as possible, this being the principal intent in the process. Fractional condensation with a counter current flow of condensed products thus took the place of sending the gas and condensed products in the same direction. In an address Mr. Young gave to the West of Scotland Association in 1876 on "Condensation," he showed that to retain the highest lighting value in the gas we must keep the gas and condensed tar warm until they have physically separated, and in order that the tar particles will settle out the crude gas must be kept warm and allowed to travel slowly, and further, that the tar be allowed to cease contact with the gas only at such a temperature that it could not absorb the lighter hydrocarbons.† In other words, there must be the shortest time contact between condensed tar and cooled gas. It will be shown later that all this is effected in complete fractional tar collection. In later years, when the ratio of naphthalene to light oils in the gas had largely increased, Mr. Young abandoned the principle of the Aitken and Young process on account of the fact that when it was applied the cooled gas was saturated with naphthalene vapour. With possibly the exception of the gas produced in continuous vertical retorts, complete tar fractionation will always leave the gas saturated with naphthalene vapour when a high carbonising temperature is applied.

* The Carbonization of Coal, by Vivian B. Lewes.

* British Patent No. 4742/1899.

† William Young, an appreciation, by Alfred Danfell.

The failure of Brunck's direct ammonia recovery process was principally due to the presence of large deposits of tar in the saturator, resulting in highly discoloured and unmarketable sulphate. This difficulty was overcome in the Koppers semi-direct process by cooling down the gas, then removing the tar, and after reheating the gas passing it through the saturator. Reverting to the original idea of Brunck, Dr. Hilgenstock, of the "Otto" Company, perfected his process of scrubbing the crude gas with a spray of hot tar and so completely removing the tar fog, without cooling the gas below its dew-point temperature with regard to water, then passing it through the saturator. After passing the saturator naphthalene and light oils are removed by cooling and scrubbing with cresote oil. In the Simon-Carvès direct recovery process, before the gas reaches the saturator tar is removed in two separate fractions based on their different specific gravities principally, but also partly on different temperatures. The first is removed in a "cyclone" on similar lines to that used by Dr. Colman (Messrs. Henry Simon owned the original patent rights of the Cyclone dust collector), and the second in a patent "dynamic extractor," where a much more intense centrifugal action is used and the remaining tar fog completely removed from the gas. We thus see that the success of the direct ammonia recovery process is dependent on fractional separation of the tar.

In 1907 Walther Feld proposed* to scrub the crude gas in his patent washers successively at 160° C., 80° C., and 60° C., and so obtain as separate fractions pitch, heavy oil, and a lighter oil. He further developed his process to include the extraction from the gas of naphthalene, ammonia and cyanide, etc. His process is applied at a number of Continental gas works, but I do not know with how much success. To get the first, the pitch fraction, the gas from the collecting main is passed through heat-insulated pipes into the first washer at a temperature from 200° C. to 160° C. This latter temperature is given by Feld as the dew-point temperature of the high-boiling-point hydrocarbons constituting the pitch. The washing oil in the upper part of the washer is a solution of pitch in a portion of the next condensate, and in the bottom chambers the pitch fraction itself. Before the gas enters this washer it must have deposited an almost solid pitch containing a large proportion of the free carbon. It is difficult to see how this can be worked up with the true pitch fraction on the lines of the Feld process. This appears to be borne out to some extent by the fact that soft pitch produced by the Feld process contains only 1% to 3% of fixed carbon, which is less than is usually found in crude tar. If the crude gas enters the first washer at the higher temperature and the fall of 40° C. takes place in there, it is fairly certain that some of the fog then produced would pass this washer and so lower the efficiency of the fractionation. This difficulty would be experienced in each washer where a fall of temperature occurred. Such a procedure is in fact attempting simultaneous production and removal of fog. Feld seems to have expected, or else found, this difficulty, for he proposed to improve the fractionation and to lower the temperature of the gas at one stage by pumping into it a portion of the product extracted at a later stage. This on evaporating would leave behind some of the former fraction which had been carried forward. In this way he no doubt partially helps the fractionation.

Two years ago Dr. Davidson expressed the view that the partial fractionation of the tar by the sensible heat of the crude gas could be simply

effected in vertical retort and coke oven installations.* He also described a method of producing in the gas-collecting main a distinct and marketable pitch fraction in addition to the crude tar, which would certainly be lower in free carbon than that obtained in ordinary practice. Briefly his method is as follows. In the collecting main of the Dessau retorts an agitator works continuously. A few minutes before the draw, tar is run into the main to a depth of 10½ inches, and when the charging of the nine retorts is complete the level of the tar in the main is brought down to 4 inches. During the ensuing carbonising period the remaining tar, due to addition of pitch from the gas and to distillation, is converted to pitch, which at the high temperature of the main (350° F.) is liquid. By regulation of the amount of tar added and run off, a soft or hard pitch may be obtained free from ammonium chloride. Obviously tar fog carrying free carbon will pass from the collecting main to the condensing system, and so the whole pitch fraction will not be obtained. Undoubtedly, however, a distinct pitch fraction is produced. It will be noticed that the temperature in the Dessau main, i.e. 350° F., is much below the final temperatures obtaining in tar stills, and so the process is more one of evaporation than distillation. In my opinion Dr. Davidson's collecting-main method of producing the pitch fraction is superior to Feld's.

In the "Cava" process† for the distillation of tar the highest temperature to which the tar is subjected is from 200° to 250° C., according to whether a soft or a hard pitch is required. In this process the distillation, or, more correctly, evaporation of the tar is effected by passing heated air over the tar contained in a horizontal retort. Blades mounted on a revolving central shaft plunge into the tar and expose thin layers of it to the oxidizing and evaporating action of the brisk current of air. Some of the lighter products are oxidized, and so the amount of the bituminous substances in the pitch increases, and likewise the yield of pitch, and it is claimed that on account of the low working temperature there is no increase in free carbon. The evaporated products are condensed and treated in the usual way. Dr. Davidson's method involves at least the principle of the "Cava" process, but the separation of the tar products is limited to the pitch fraction, and this is not quite all recovered.

In order to carry out the complete direct fractionation of the tar within the condensing system, and also the evaporation and fractionation of a further quantity of crude tar by means of the sensible heat of the crude gas, I would suggest the following method, using the plant indicated diagrammatically in Fig. 1. Briefly the method is as follows. The crude gas from the collecting main passes by the upstand pipe, A, and the foul main, B, to the scrubber at C. Here the gas is scrubbed by a screen of anthracene oil containing some pitch, and all the tar fog containing the free carbon removed. The oil, etc., collecting in the receiver below flows to the pump, D, to be recirculated, and there is also a continuous flow of the oil into the collecting main. The amount passing into the collecting main would be just what is necessary to maintain the bulk in this main which would tend to decrease by the removal of pitch at E, and by evaporation. The gas passing C, after further partial cooling, is scrubbed in F for the removal of anthracene oil. The oil collecting in the receiver here is circulated by the pump, G, and all the surplus flows to the pot, H, and from there to the storage. The pot, H, being in communication with the inlet to the pump, D,

* Transactions, Scottish Junior Gas Association (Western District), 1913-14.

† British Patent No. 29,897, 1912.

* British Patent No. 20,130, 1907.

allows the anthracene oil to keep up the bulk in the first scrubbing system which would tend to be reduced by the flow into the main and also by evaporation. Several fractions, depending on the

main of a coke oven installation may reach 300° C. The temperature to which the gas must be reduced before reaching the first scrubber, is about 150° C. to 170° C. This reduction would be largely

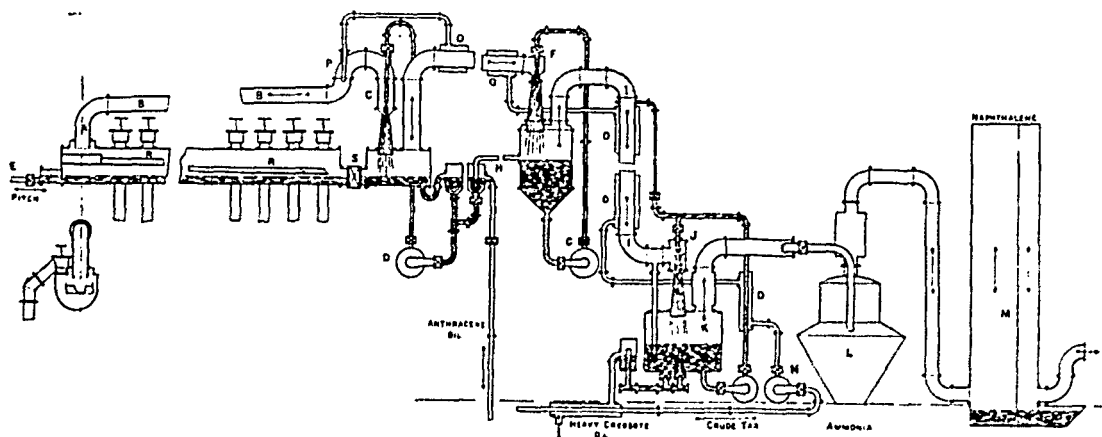


FIG. 1.

Combined Evaporation and Fractionation of Tar.

lowering of the temperature of the gas by successive stages, could still be separated, but the separation of only one more fraction above the water dew point of the gas will be considered. After passing F, the gas is cooled in the down pipe, I, to its water dew point and all the fog removed in the scrubber, J, by means of a spray of ammoniacal liquor. The tar oil collects in the receiver, K, separates from the liquor, and then flows to the storage. The liquor remains in the circulating system. The gas, completely freed from tar fog but still carrying all the water as vapour, is passed without further cooling through the direct recovery saturator, L, where the ammonia is removed. It is then quickly cooled in one section of M and naphthalene removed in the other. The naphthalene collects in the settling tank beneath as crude crystals. The gas now passes through the exhaustor and is forced through the usual creosote scrubbers for the recovery of benzol, etc.

As has been stated the crude gas is successively cooled between the different scrubbing systems. This is partly done by air cooling but also as far as possible by an externally applied counter current flow of crude tar brought in from other carbonising installations. This tar is forced by the pump, N, through the successive heat exchangers, O, into the foul main at its highest point, P. It would now flow down against the crude gas, cooling the same and being itself further heated. It would here yield up to the gas the bulk of its lighter constituents and finally reach the gas collecting main by the open tray, R. The work which has been done in the "Cava" process and by Dr. Davidson shows how simple and practical it is to produce pitch in such a vessel as the collecting main—it is sometimes too easy. In both of these methods the hot pitchy tar is kept mixed by mechanical agitators. This is not difficult in a short main such as is used with the "Dessau" retorts or in the "Cava" still which is only about six metres in length. But when dealing with say a 60-oven coking plant having a collecting main about 200 ft. long it is quite a different matter. To obtain the necessary agitation here several jets of high pressure steam blowing into the body of the liquid tar would be effective. Very little steam would be required, and after doing its work would pass away with the gas and be finally condensed. The gas leaving the collecting

effected by the crude tar entering the foul main at P and partly by external air. It would probably be advantageous to lag these mains and use all the sensible heat of the gas for heating and evaporating added tar. The oil from the first scrubber flowing in by the sluice valve, S, mixes with the highly heated tar in the collecting main. From the conditions of working, the tar in the collecting main would consist almost solely of pitch and anthracene oil, and in flowing to the outlet weir valve, E, would be evaporated by the heat of the crude gas till only pitch remained. By regulating the flow of pitch from E a soft or a hard pitch would be obtained. The crude gas, carrying as fog a portion of the pitch hydrocarbons and free carbon, would be cleaned in the first scrubber with oil at a temperature somewhat below the dew point temperature of the gas with regard to the lowest boiling compound of the pitch fraction. The gas temperature would vary with the conditions of carbonising, with the nature of the pitch required, and with the amount of added tar evaporated. Without added tar it would probably be about 150° C. With added tar, however, the dew point temperature would rise corresponding to the richness of the added tar in the lower boiling point members of the pitch fraction required. It is quite possible, therefore, that the proper working temperature at this point would vary by 20° or 30° C. between the conditions of working hard pitch with added tar and soft pitch without added tar. The lowest temperature at which this section could be worked would be that which would just maintain the oil level in the receiver. The type of scrubber proposed for cleaning the gas here is the "Otto" spray but using instead of crude tar the fraction here collected. A large proportion of the pitch fraction is deposited from the gas in the collecting main and the balance would be extracted in the first scrubber. This balance dissolves in the scrubbing oil and flows continuously into the collecting main. With these conditions the pitch fog is removed, not with the pitch fraction itself, but with a solution of a portion of the same dissolved in anthracene oil. This oil when sprayed through the gas in the scrubber would be partly evaporated and collected in the next scrubbing section. The temperature of the gas is lowered by this evaporation and more fog produced. But I have determined by experi-

ment that the bulk of this fog goes forward with the gas. The time during which the fog remains in the spray after its formation is too short for the drops to get big enough for extraction. The oil carrying the pitch into the collecting main is evaporated and comes down again in the condensing systems. There is thus a continuous circulation of anthracene oil carrying the balance of the pitch fraction back to the collecting main. An issuing pressure of 20 lb. per sq. inch would be sufficient in the first scrubber, this pressure being raised in a pump of the "Albany" or the "Drum" type.

The gas from the first scrubber is now cooled as explained above to the dew point temperature for the anthracene oil fraction and scrubbed with this oil. This oil flows through the pot, II, to the storage. Since the pot, II, is connected to the inlet of the first scrubber pump, the oil will naturally keep up the bulk in the first section. In this way the temperature of the scrubbing oil in the first scrubber will be lower than the temperature of the gas which it has to clean. As the temperature falls I have found the fog which is produced more and more difficult to extract. But I consider a spray pressure of 30 lb. per sq. inch would be sufficient in this section. The extraction temperature here would likewise vary with the carbonising conditions, but would be somewhat over 100° C.

The gas now enters the down pipe, I, at a temperature of at least a few degrees above the temperature at which ammonium chloride deposits occur, about 93° C. It is now cooled by the external counter current flow of tar as already described and also by ammoniacal liquor sprayed into it, which dissolves the ammonium chloride formed and so prevents deposits of that salt. This liquor returns to the receiver by the sealed dip pipe. In cooling the gas it will become itself heated above the working temperature and this is corrected in the heat exchanger. The gas, now cooled to its dew point with regard to water, is scrubbed in J by a jet of ammoniacal liquor at about 90 lb. per sq. inch pressure. This high pressure is necessary to extract the lightest fog. For the first two sections the "Otto" spray scrubber was suggested and the method of operation is similar to the usual practice, using, however, different scrubbing fluids. For this third section, however, in order to utilize the work done on the gas by the high-pressure jet, I think the best type of scrubber would be one designed on similar lines to the Körtling ejector condenser. This would reduce considerably the work to be done by the exhausters. In the receiver, K, the tar oil would separate from the scrubbing liquor and float on the top of it, finally passing away by the overflow to the storage as a heavy creosote oil. The liquor would remain in the circulating system. During the past year or two on the Anchengeich direct recovery plant I have made a number of experiments with the "Otto" spray tar extractor, and using creosote oil, liquor, and tar and liquor mixed at varying temperatures I have got efficient tar extraction. The most important point is to ensure that the fog which is to be extracted is present in the gas before it reaches the scrubber. The extraction temperature in this section would be from 70° to 80° C. according to carbonising conditions. From this point the gas is treated in normal direct recovery manner. For instance it is first freed from ammonia in the direct recovery saturator, L, and then naphthalene removed in, say, an "Otto" water spray naphthalene extractor, M. The gas is then forced by the exhausters through the usual creosote scrubbers for the recovery of light oils. If the gas was required for town lighting, however, purifiers would take the place of the creosote scrubbers. In this particular case it is to be

remembered that the gas would be saturated with naphthalene vapour and any fall of temperature would cause a deposition. The content of naphthalene could be reduced by anthracene oil in the following way, somewhat on the lines of the Young and Aitken process and using the plant indicated diagrammatically in Fig. 2.

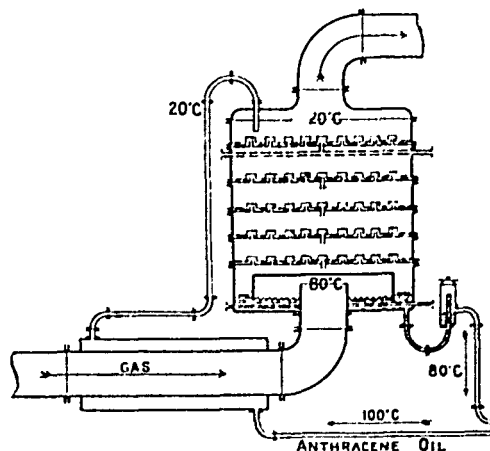


FIG. 2.
Naphthalene Washer.

The cooled gas or a proportion of the total bulk after being heated to 80° C. passes into the bottom chamber of a washer similar in principle to the Young and Aitken analyser. Exhaust steam, or the sensible heat of the recovered tar fractions, or both could be used for this heating. This is not indicated in the diagram, but a heat exchanger is shown in which the washing oil is cooled from its recovery temperature to the temperature of the gas, the gas being itself partly heated. The cooled anthracene oil fills each of the trays up to the level of the overflow and runs through the washer in a continuous stream. In the bottom of the washer by means of a steam coil the oil is maintained at 80° C., at which temperature it leaves the washer. At 80° C. the anthracene oil cannot dissolve benzene and in fact, so far as examination of direct recovery tar extracted at this temperature indicates, very little solvent naphtha even is removed from the gas. This is no doubt due to the fact that the light oil vapours are far from saturating the warm gas. It is quite likely, therefore, that such a washer could be operated considerably below 80° C. without material effect on the benzene content in the gas; the lowest practical temperature could be found only by experiment. This oil outlet temperature being much below the boiling point of naphthalene, the anthracene oil will dissolve some of this hydrocarbon. The cold anthracene oil falling from tray to tray will be heated by the gas to 80° C. and the gas cooled. To ensure the gas being in contact with the oil at atmospheric temperature in the final tray, a cold water coil is placed in the gas space under the top tray. When the oil in the washer is saturated with benzene either by admixture or by extraction from the gas, no further action on the benzene in the gas can take place.

Referring again to Fig. 1, the plant from the third scrubber on is already applied in the direct ammonia recovery process, so that it is only that part between the collecting main and this third scrubber which is added to the ordinary direct ammonia recovery plant, for the fractionation of the tar. The cost of this addition, together with

the plant for dealing with the inbrought tar, for an installation carbonising 300 tons of coal per day would probably not exceed £3000 and would serve for the fractionation of all the tar produced and added. The inbrought tar which could be dealt with might possibly reach 75% of that produced from the coal carbonised. The main attendants already required on such a coking installation could quite well look after the two extra pumping sets, etc. The storage tanks required would be the same as those used in a tar distillery of the same capacity.

On account of the increased demand for benzene and toluene at the present time, there is added interest in the fractional method of recovering the tar products. In the ordinary condensing practice these products are divided between the tar and the cooled gas, so that to recover the whole of each, washing of the gas and also distillation of the tar must be resorted to. With direct fractionation only one operation, the washing of the gas, is required. Anything tending to increase the output of toluene, either by better recovery methods or by increased production per ton of coal carbonised, is highly desirable at the present time, not only on account of the better financial return but also on account of national requirement. The required conditions in carbonising would seem to be such as would give a high partial pressure of methane at the moment of destructive distillation. From experiments I have made on ammonia production in bulk carbonisation I consider the ratio of toluene to benzene produced will follow the yield of ammonia.

I have endeavoured above to show that in many of the special methods applied for the extraction of the tar, fractional separation has been an underlying factor. The condition "that the tar should leave contact with the gas only at such a temperature that it could not dissolve the light oils" which Mr. Young stated in 1870, is fulfilled in direct tar fractionation. Mr. Young abandoned the principle of the Young and Aitken process on account of the trouble with the condensers, etc., due to the greater amount of naphthalene produced in later carbonising practice but, as I have indicated above, an extended application of this principle using naphthalene-free anthracene oil would overcome this difficulty. I consider the method advocated by William Young so many years ago is still the correct one for gas works condensation practice and particularly so with carbonisation in continuous vertical retorts. In a number of works using these retorts, surprisingly low candle-power of the gas has been found on account of the light tar fog persisting with the gas till almost the final stages of cooling and so removing from it illuminating hydrocarbons.

DISCUSSION.

Mr. McLEOD said, in regard to counter current *versus* direct current flow in condensation, that it was really a temperature question. There was only a thin trickle of liquor and tar running down the slow condensing main, so that the actual contact was comparatively slight and there could be no very great scrubbing action: hence, provided the temperature did not fall—and in Greenock it did not fall below 140°—whether there were direct current flow or counter current flow did not make much difference. In Greenock Gas Works the naphthalene problem had been solved by putting down a separate washer with special washing oil, and in addition to that vaporising a little low boiling point oil into the gas after washing was finished. The system described by Mr. Purves was, however, a much simpler process.

Mr. VASS thought that there would be a saving of the fuel required to re-heat the tar. To apply

the system to gas works would involve a serious alteration in the mains.

Prof. THOMAS GRAY said that the method proposed by Mr. Purves for the fractional condensation of coal tar appeared to be quite practicable. It involved no new principle, as the method of separating liquids by bringing their vapours into equilibrium with condensates at different temperatures had long been practised in column stills; and the means which was proposed for establishing this equilibrium was one which had been in regular use for several years in connection with the Otto direct system of recovering by-products from coal distilled in coke ovens. He found it difficult to accept Mr. Purves' statement that the work in connection with the plant, involving as it did the regulation of temperatures in a somewhat elaborate system of heat interchangers, could be supervised by the same operative who takes charge of the simpler Otto plant. In order to ensure uniform results in practice it would be necessary to exercise very careful supervision and to employ more highly skilled labour. It would be interesting to have estimates of the costs of installation, upkeep, and working of a plant of the size proposed, for comparison with the corresponding figures for a plant designed to collect the tar in one fraction, combined with stills for the distillation of 15 tons of tar per day. While Mr. Purves was not in a position to give actual figures, he might be able to give some indication of the working costs from his experience in handling the "Otto" plant.

Mr. MOORE said that he had seen Feld's first plant in operation in Austria about six years ago, and which had failed, not because the process of condensation was a failure, but because in Austria they could not use the products and on account of duty charges they could not send them into Germany. Since then he had seen Feld's process successfully at work in Germany. It could produce pitch quite easily with a melting point varying from 70° C. to 90° C. A new plant on the Feld system in course of erection last year at Sterkrade was estimated to cost £80,000.

He considered the plant proposed by Mr. Purves would prove difficult to work as at present arranged, and saw no reason why a much simpler plant after the style of the bubble washer could not be used. That washer would require considerable pressure to force the vapour through the columns, but he thought the same result would be obtained.

Mr. W. H. COLEMAN asked whether the various condensates were obtained in a marketable condition. If they had to be distilled before they could be sold, then it was questionable whether it would not be more profitable to collect the whole in one fraction and distil at once rather than to collect and distil them all separately. He would like to know exactly what Mr. Purves meant by the statement that the yield of toluene followed the yield of ammonia. He thought he was right in saying that the yield of toluene decreased as the temperature increased, that is to say, when carbonising at a higher temperature the tar contained larger quantities of benzene than low temperature tar. He had examined some hundreds of samples recovered from coke ovens, and on the average there was three times as much toluene per ton of coal in the gas as there was in the tar recovered from that same ton of coal; so that if all the toluene were recovered from the gas there would be very nearly enough for the purposes for which it was required to-day.

Mr. ROBERTSON said that if the main were used for the purpose of making pitch, its life would be greatly reduced owing to the much higher temperature and the serious trouble that might arise, due to the presence of ammonium chloride in the tar; this substance when distilled acted strongly upon iron. With such a long main,

having regard to the danger of pitching-up, due to irregular working, and the fluctuating atmospheric temperatures, it would be difficult to keep the main at the requisite high temperature, and these difficulties would hinder very much the proper working of the coke ovens. By using steam to keep the pitch liquid, more water vapour would be carried away by the gas, and would be condensed out again on cooling the gas to remove the naphthalene, thus increasing the quantity of waste liquor to be dealt with. Mr. Purves had said that the benzol was divided equally between the tar and the gas: 95% existed in the gas, and the remaining 5% in the tar.

The CHAIRMAN said that the process proposed by Mr. Purves was rather a delicate one in respect of the balance that must be attained and maintained between the amount of heat carried into the condensing system and the cooling effects of that system. A difficulty that might upset all calculations was variation in atmospheric conditions. At any season of the year there might be a considerable variation in conditions within a few hours caused by a change from wet stormy weather to dry still weather. Moreover, he would expect a different rate of working necessary as between summer time and winter time. Manufacturers of pitch were asked to make it in various states of hardness. Some of it was wanted so soft as to be really thick tar, while, from the States, there was a demand for a quality so hard that it had lost all plastic qualities and become a very brittle substance. To produce such differences in hardness must call for great variation in the conditions of working, and he should be very doubtful whether these extreme varieties could be produced by the proposed process. He did not think the "Cava" process would be a good one for distilling tar, because the evaporation was done by means of heated air: some of the products were oxidised and a larger yield of pitch obtained. His own experience of blowing air through heated tar was that the free carbon was increased and the plastic and cohesive properties of the pitch were impaired, so he should not expect to obtain a good quality of pitch from the "Cava" process, but the principle might be usefully applied if hot gas could be used as in the hydraulic main. Mr. Purves proposed to wash out naphthalene with anthracene oil kept at a sufficient temperature to leave the benzol in the gas, but that seemed to him to depend on a rather narrow margin, and he thought it would be simpler to wash out everything and then put back sufficient benzol to give the illuminating power required. By working in that way it was possible that purification of the gas would be assisted. For instance, by washing with blast furnace oil, which was a splendid solvent for naphthalene, benzol, and carbon bisulphide, it might be possible to remove practically the whole of these substances.

Mr. PURVES, in reply, agreed with Mr. McLeod that it mattered little whether the slow condensing main was on the direct current or the counter current principle. The effect on the gas of the small quantity of condensed tar in the main was trivial compared with that of the tar fog. In regard to the suggestion made for dealing with the naphthalene problem, his intention was to show that an extended application of Young's counter current condensing practice would overcome the principle difficulty which had caused him to abandon his process. In addition to the saving in fuel which successful direct fractionation would effect, the fractionation of added tar from other carbonising plants would yield a further fuel economy. Prof. Lewes had quoted ("Carbonisation of Coal") 0.2% as the proportion of the heat applied in carbonisation, which was carried away by the gas, tar, and water. In coke oven practice

with wet coal the proportion was probably somewhat higher. As Dr. Gray had stated, the method proposed for the fractional collection of the tar involved no new principle. It was all covered by the work of William Young. The application of fractional tar collection in modern practice was, however, almost wholly the work of foreign chemists, as witness the Feld process and the direct and semi-direct ammonia recovery processes. It appeared well worth while to have a discussion on the subject by our own chemists. He selected the "Otto" tar spray for the removal of the tar fog because after practical experience with several types of tar fog extractors he considered it easily the best. The regulation of the temperature of the gas to the water dew point, as was required in the Otto process, was quite simple and was done by the man in charge of the exhausters. The controlling of the other two temperatures could quite well be done by the "main" attendants, as their ordinary duties would be done away with in such a process as this.

As Mr. Moore had remarked, the benzene and toluene were not fractionally condensed. He would draw a very distinct line between condensation of tar and absorption by tar. These two products, benzene and toluene, were not, properly speaking, condensation products. Since the permanent gas was quite able to carry the whole of each by saturation at ordinary temperature, the presence of these in the crude tar was entirely due to solution, the gas and tar having cooled sufficiently in contact with each other. He did not share Mr. Moore's opinion of the equal suitability of bubble washers. With a large bubble washer it would be more difficult to maintain constant temperature with a simple tar spray.

The fractions obtained in direct fractionation would differ somewhat from those obtained in the ordinary tar distillation and partial destructive distillation process. Comparing the products solely within the scope of direct fractionation, he would hardly expect a difference of a few degrees in the extraction temperature to make a material difference in the composition of the product. He had not actually obtained all these condensates. The process was really only a suggested one. But judging from those fractions which had been obtained and from the efficiency of the tar extractor, he was confident that the fractional separation of the products would be quite clean; for instance, the anthracene oil would not be contaminated with the tarry matter of the previous fraction. The heavy tars were more easily separated than the lighter ones. After scrubbing the hot crude gas with a hot tar spray he had seen the sulphate produced, by the direct method, snow white and later the naphthalene extracted bright yellow in colour. The melting point range of the latter was found to be 69–72° C. as against 70°–73° C. for that separated from creosote in a tar distillery. He agreed that the future of such a process would depend on the cleanness of the fractionation. In regard to the yield of toluene, he did not mean that those conditions which would give the highest possible yield of ammonia would also give the highest possible yield of toluene. In order to get the highest commercial return from a carbonising plant it was necessary to work within a certain range of temperature and other conditions. Within that range the yield of ammonia varied in the same direction as the yield of methane. As a high partial pressure of methane at the time of carbonising would seem to be the required condition for good yields of toluene, he would expect the ratio of toluene to benzene produced to vary in the same direction as that of the ammonia and the methane. The ratio Mr. Coleman gave for toluene in the gas to that in the tar was, he thought, much too low. The ratio,

however, might be anything, as it was purely a function of the method of condensation.

The temperature in the main would not be higher than that already found in mains without dip pipes and working with all tar conditions. In regard to possible corrosion from ammonium chloride, he thought too much was generally made of this factor and he could not agree that any corrosion at all would occur. At the high temperature occurring here ammonium chloride would not exist at all as such, and its free radicals would not combine until the temperature fell to somewhat under 100° C. The free hydrochloric acid could not corrode the iron, as the crude gas was dry until the temperature fell and the water dew point was between 60° C. and 75° C. Once formed and dissolved the chloride was always present in excess of ammonia, and as there was no question of dissociation, there was no evidence of internal chloride corrosion in the plant after fully four years' continuous working. There would be no greater danger of pitching up than there was with other collecting mains working under all tar conditions, and the problem was not to keep the main at the requisite high temperature, but rather to bring the temperature down. The use of steam in the collecting main would certainly increase the amount of condensate ultimately produced, but this condensate was not a noxious product such as was produced from ammonia stills. He did not say that the benzol was equally divided between gas and tar and thought the proportion stated by Mr. Robertson was about correct. With direct recovery practice, however, no benzol, etc., occurred in the tar. He understood that if proper care were taken in the working of the Cava process no increase of free carbon occurred. The washing of the gas to free it partly from naphthalene as carried out in gas works was done solely to reduce the tendency to choking in the distribution system, and simple washing was cheaper than combined washing and distillation of the absorbing oil.

Meeting held at Glasgow on Tuesday, 23rd February, 1915.

MR. ROBERT HAMILTON IN THE CHAIR.

MOLASSES AS A SOURCE OF ALCOHOL FOR THE PRODUCTION OF POWER.

BY T. H. P. HERIOT.

The suitability of alcohol for generating power in the internal combustion engine has been sufficiently established by exact tests and by practical experience of alcohol motors for general purposes. The conclusion thus drawn is that, although the calorific value of alcohol is little more than half that of petrol, the efficiency per b.h.p. is from 28% to 31% compared with from 16% to 20% for petrol. This higher efficiency of alcohol is due to several factors, namely:—The volume of air required for complete combustion is about one-third of that required by petrol, thus reducing the waste of heat in the exhaust. This smaller dilution with air ensures more perfect admixture before the explosion, and, consequently, favours complete combustion. The mixture can be subjected to a pressure of 200 lb. per sq. inch in the cylinder without spontaneous ignition; the safety limit for petrol is 80 lb. Mixtures of alcohol vapour and air, containing from 4 to 13.6% alcohol, are all explosive, whereas the explosive range of petrol is from 2 to 5%, thus requiring more exact adjustment of petrol and air in the cylinder. The exhaust from the alcohol engine is smokeless and nearly odourless, and the products of combustion do not clog the cylinder valves.

In view of the rapid development of the internal combustion engine, and the increasing cost of petrol,

which may be expected to rise considerably as the limited supplies become partially exhausted, it is reasonable to regard alcohol as the fuel of the future, and to inquire whether it might not compete successfully with petrol to-day if produced from the cheapest raw material, and freed from existing taxes which artificially increase its cost far beyond the actual cost of production.

The raw materials now available are starch, cellulose, and sugar. In the case of starch, the cost of alcohol includes that of raising the crop, harvesting, and transport to the distillery before the conversion of starch into alcohol commences. In the production of alcohol from sugar, however, the by-product of an existing industry is available, namely, molasses. The cost of raising, harvesting, and transporting the cane or beet crop is rightly charged to the sugar. This comparison between starch and molasses is well illustrated by Peck, of Hawaii. "If the 21 million gallons of molasses produced in these islands in 1913 had all been converted into alcohol, over 9 million gallons of 90% alcohol would have been produced. A bushel of corn yields 2.8 gallons of 90% alcohol, and an average yield of corn is 30 bushels per acre. Therefore, to produce 9 million gallons of alcohol, 3,248,000 bushels of corn would be required, representing a crop from 108,000 acres, an area only 5000 acres less than that from which the 21 million gallons of molasses were derived together with the main crop of 500,000 tons of sugar shipped." Similarly, a bushel of potatoes yields 0.73 gallon alcohol and an average crop gives 205 bushels per acre. Thus, 9 million gallons of alcohol would require a crop from 60,000 acres, or 53% of the acreage required in Hawaii to produce the same quantity of alcohol plus 50,000 tons of sugar.

Another point in favour of molasses is that it has only to be diluted in order that fermentation may commence. In tropical distilleries adjoining the sugar factories, the air-borne yeast is sufficient to cause vigorous fermentation within a few hours after dilution or, as it is called, "setting up the wash."

The manufacture of alcohol from molasses is a long established industry, and in many countries a distillery forms an adjunct to the sugar factory and is worked under the same management. Hitherto, the manufacture of rum has been the object in view, although methylated spirit is produced in some countries. But, owing to the small demand for rum and the cost of freight and containing vessels, other methods of utilising molasses have been adopted and are referred to below. In some countries, molasses is literally a waste product, and the problem is how to get rid of it. The erection of large distilleries in sugar growing centres might solve this problem if there were a steady market for alcohol as fuel and cheaper means of transport than those now employed.

Cane molasses.

The possible production of alcohol from this source may be calculated from the statistics and analyses given in Tables I., II., and III.

TABLE I.
The world's production of sugar.

	1909-10.	1910-11.	1911-12.	1912-13.	1913-14.
	tons.	tons.	tons.	tons.	tons.
Cane	8,349,000	8,354,000	9,067,000	9,177,000	9,905,000
Beet	6,587,000	8,500,000	6,820,000	8,066,000	9,128,000
Total	14,936,000	16,854,000	15,887,000	18,143,000	19,033,000

Average for cane = 9 million tons. Average for beet = 8 million tons.