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MODERN
COAL-WASHING PRACTICE

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BY

R. C. R. MINIKIN

1928

ERNEST BENN LIMITED LONDON

TO

MY PUBLISHERS

IN APPRECIATION OF TRUST AND PATIENCE THROUGH A MOST DIFFICULT PERIOD.

GRATEFULLY,

R. C. R. M.

PRINTED IN GREAT BRITAIN

PREFACE

The present work was undertaken by the author in the first instance as a series of notes upon the Modern Coal-washing practice in this country, mainly for personal use. As the subject matter became more extended and the details more elaborate, they were placed in handy form for reference and remodelled in such a manner as is hoped will provide a long-felt want of colliery owners and engineers by the publication of the present volume.

As the washery practice in this country is without doubt the best and most thorough of its kind, and as there is, to the author's knowledge, no other work published which treats of Coal Washing as a complete subject, it is hoped that the present volume may give such information to those associated with the coal and other industries as to facilitate the adoption of the particular plant to suit their needs, or the maintenance of existing plants in an up-to-date manner.

The greater part of Coal-washing research has been carried out by private companies, and the data have been, in the majority of cases, preserved by them, so that great difficulty has been experienced by those interested in the subject in acquiring a comprehensive knowledge of the fields covered by different machines or systems.

Ideas and methods of treatment have been localised by particular plants erected in the neighbourhood, and no comparative results have been available.

The notes and the data given in the following pages have been gathered mainly from an extended experience in this country and to some extent from foreign practice, particularly in Germany, which is the home of some of the most successful systems of Coal Washing. In this connection, it should be emphasised that our own practice, while borrowed originally from the Germans, has been substantially improved in the past few years. The solidity of British workmanship has everywhere proved superior to that of foreign makers, and an all-British plant is by far more reliable and less expensive in upkeep than any other, the reason being that it is more satisfactory to make a substantial job free from temporary breakdowns than to cut down the design to lower the initial cost. As a Coal-washing Plant is generally linked up with the screening systems or with a carbonising plant, breakdowns must as far as possible be avoided, so that the general work of the whole system may be carried on without hindrance.

The author trusts that the information given in these pages may be of practical use in the standardisation of types of machinery and colliery practice, and where criticisms have been made it is trusted that they will be accepted in the spirit in which they are offered, and that they may be fruitful of modifications and improvements to the benefit of the whole.

His thanks are due particularly to

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for very valuable assistance and information supplied, and to many engineers of various collieries for their kind assistance.

The practical help of these gentlemen has enabled the author to cover a wide field of real practical value, and he wishes to particularly acknowledge the many favours granted to him by Mr. Ivor Williams, Chief Engineer of the Powell Duffryn Co.

In the actual preparation of the text he is particularly indebted to the patient and indefatigable assistance of his wife.

R. C. R. M.

Brades House,
Oldbury.
1927.

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CHAPTER I

GENERAL CONSIDERATIONS

MUCH of the theory of wet separation, and many of the principles of systems of washing, have been borrowed from the practice in ore-dressing plants, where conditions are similar but of different degree. Coal being a relatively cheap article, the handling in bulk at an economical rate is the main drawback to the wider adoption of the more elaborate plant used in ore dressing. The older the colliery and the more nearly it approaches to the exhaustion of its resources, the greater is the necessity for coal washing.

The consumers of coal in large quantities are now beginning to demand a fixed maximum ash percentage in their supplies. Clean coal to-day, instead of being a luxury, is a common commodity, and competition between the different collieries necessitates a reliable and non-fluctuating standard of quality, particularly when the coal has to be taken overseas, the freight charges forming a great proportion of the whole cost. A raw slack may contain 26 to 30% of ash, and the cost of washing this to a reasonable degree of purity results in a considerable saving of freight charges, especially when the freight per ton may be two or three times greater than the total cost of washing. Thus by the extraction of 20% of dirt an enormous saving is effected in transport and handling to the overseas buyer, who is, accordingly, ready to give a better price.

Commercial requirements are the deciding factor on the type of plant required, and conditions of treatment are mainly based upon the system adopted. If the coal be relatively easy to wash, the outlay on plant may be kept down to a minimum in the first instance; but it is as well to bear in mind that coals may vary widely in quality throughout one seam, thus the plant should be capable of being adapted to any change in quality.

All coals should, of course, be submitted to a thorough technical analysis before the type of plant is definitely decided upon.

Sufficient regard has not been had to technical supervision of the construction of washing plants, it being considered that a scheme if put forward by one particular designer may be the best on an average to suit the conditions. Those capable of utilising washing machinery have, in fact, been diffident, or they have lacked the necessary experience in imposing upon the designers particular or definite specifications of their requirements in the construction of the plant, apart from conditions relating to sales, qualities, or sizes. Though cumbersome machinery may be employed, the process of separation is extremely delicate, and little latitude in the successful working is possible, the specific gravities of good and bad coal having no definite demarcation.

There is little doubt that in the near future mining engineers will go more extensively into the subject, and specify their requirements of washing plants as an indispensable unit of the surface arrangement. The future developments of this branch of separation will, no doubt, become more dominant as the coal reserves become less and the quality of the slacks becomes poorer.

The events which have occurred in the coal-mining industries within the last few years are sufficiently illustrative of the commercial basis on which these undertakings are founded.

The many good things found in the earth only become valuable when demand has been manufactured and habit or profit renders the supply necessary. Improvement in the manufacture of commodities is likewise necessary to maintain a steady demand; for, given one product of marketable value, it is almost certain that substitutes will be found by the opportunist commercial world. The mining industry has hitherto been so conservative and self-satisfied that this fact has been neglected, but with the advent of new fuels of great efficiency (which rob the coal producer of much business that was reckoned as a perpetual source of revenue) the collieries are constrained to modernise their marketing methods, or, perhaps, to drop out of business.

Colliery managers have, however, been awake to the fact for many years; but not being holders of the purse, the best they could do was to advise their boards—in a few cases with success, but in a number of instances their advice was considered as merely a technical point of view and not as a commercial necessity.

The inability to sell an inferior coal at the present day has succeeded in bringing those in authority to a realisation of the position, and it is causing them to deliberate upon the best modern methods of organisation and machinery for the production of a saleable quality of coal from the total output at the pithead.

Profit is the root cause of all commercial enterprise, and economy the gauge of the organising ability. Therefore, it becomes incumbent upon the management to adopt any method to improve the quality of the coal marketed if it is at all possible to do so at an increased profit.

There is always a demand for good-quality goods at reasonable prices, and hence in introducing a coal-washing system the main consideration is, Will the products be improved sufficiently to warrant a higher price being charged to cover the expense of the washing process, and is there likely to be a good return upon the extra outlay of capital?

The Nature of Impurities

The slack coal as delivered from the screens to the washery contains impurities which impair its value for industrial and domestic use; the most serious of these is the shale and the sulphur content.

Coal being a relatively bulky and cheap material, the means employed to remove these impurities must be the simplest possible. The specific gravities of the impurities being higher than that of the pure coal (shale, 2·6; iron pyrites, 4·5), a system of separation founded on the settling of bodies of varying specific gravity in some cheap and easily obtainable medium is a reasonable solution.

The removal of the sulphur from the coal is still a very debatable point. If the impurities are intimately associated with the pure coal or carbon, improvement by washing is practically impossible, but, on the other hand, if the ash or shale portion is high in sulphur, a marked improvement in the quality can be effected.

The presence of sulphur and ash in the coal is a great drawback to the utilisation of its coke product for steel-making purposes. While a good pig iron can be manufactured with high sulphur coke, unless the quality of the coke is maintained constant, the resulting product from the furnaces will vary considerably. If a coke high in ash and sulphur is used, the furnace charge will be made up in the correct proportion to counteract these impurities. It should not be forgotten that the coke employed in steel manufacture has a two-fold function, that of a chemical agent and a fuel, so that its exact composition must be carefully determined before use.

If a washed coal were utilised to produce a coke which followed an unwashed charge of coke in a furnace, the immediate result would be that the better quality of fuel and the lesser proportion of impurities would make the furnace too hot and tend to produce a high silicon pig.

If the charges were added to the furnace in the reverse order, that is, if a washed coal coke were followed by an unwashed coal coke, the furnace would become cold and produce a high sulphur pig.

The above considerations emphasise the need of a good standard quality of coke of uniform composition, *i.e.* constant in its impurities. A further advantage to be derived from a washed coal product is that the quantity of flux used to remove impurities is considerably lessened and consequently the effective capacity of the furnace increased.

In the coking process, there is likewise much to recommend the use of a clean coal. Assuming, for example, that a raw slack contains 22% ash and it is washed to 8% ash by the extraction of 15% refuse, the actual utility of the ovens would be increased by the increased useful capacity due to the substitution of good coal for the useless dirt, and at the same time the volatile matter and the carbon value of the product would be greatly increased.

Application to Other Industries

It has always to be borne in mind that the principle of the separation or purification of fuels is not by any means confined to the treatment of coals. Certainly so far as mere bulk is concerned coals provide the main opportunity for the employment of separation plant, but there is a growing tendency in this country towards the installation of apparatus for the recovery of combustible matter from ashes, clinkers, and other partly burnt residues.

The subject of fuel washing is, therefore, of direct interest, not only to fuel producers, but also to fuel consumers, and to-day it is possible to obtain small recovery plants which will effect undoubted economies if operated in conjunction with large batteries of steam boilers. As an example of the opportunities which exist for effecting fuel economy and the conservation of our national fuel resources might be mentioned some of the larger electricity generating stations throughout the country. In many such instances the monetary loss involved in the combustible matter which remains in the ashes sent to the waste dumps is now receiving attention; and where the quantity of coal consumed runs into large figures, a strong case can be made out for the installation of recovery plant.

Again, one must not neglect the opportunities presented by the great gas undertakings of the country. Here washing machinery can profitably serve a two-fold purpose. In the first place, there is usually a comparatively high proportion of combustible matter (coke) present in the ashes withdrawn from retort-bench producers, water-gas generators, and steam boilers. In some of the larger gasworks washing machinery has become a common feature, and recovered "pan coke" is a by-product which is turned to profitable account in the works themselves, or which, if sold to outside consumers, fetches a price usually equivalent to half the current price ruling for coke, and in some cases very much more.

Secondly, gasworks have in some localities a demand for a high-quality coke, frequently "cut" coke, from which the shale and other inert matter have been separated. Coke washing, as well as "pan-breeze" washing, is, therefore, growing in popularity in gasworks, and "washed coke" now figures quite commonly in the list of products supplied by gas undertakings.

The washing machinery employed for dealing with coke or with furnace residues is almost identical with that employed for treating coal. For this reason, therefore, the descriptions given of apparatus in the following pages will not be without interest to engineers who meet with problems dissociated from those of the coal producer.

CHAPTER II

THE CONSTRUCTION OF WASHING PLANT

A LARGE and important item in the use of any machinery is the extent of the building site and the quality of the building required for its accommodation. In a great many cases coal-washing plant has been housed in buildings of inferior quality, of frail or of too massive structure, necessitating constant repair and causing endless anxiety to the engineer for upkeep and adaptation to more modern methods of working.

The first coal-washing plants erected in this country were placed in squat buildings constructed of huge masses of brickwork, requiring enormous mattresses of concrete in the foundation to support the dead load of the structure.

These buildings naturally required a large ground area, and, furthermore, hindered the utilisation of that ground for sidings, and necessitated the construction of separate storage bunkers for the washed coal.

With modern methods of construction, however, the greatest possible care is taken to ensure the freedom of the ground site, thus making provision for future extension—present needs of siding accommodation—or improvement of plant.

There are four popular methods of construction, depending upon the cheapness of the material locally or the financial resources of the company working the colliery.

In Scotland and in the smaller collieries throughout England, many buildings are built of rough sawn timber—strengthened by a light steel framework. Though this construction when erected was cheap and has served its main purpose over many years, it cannot now claim any advantage for durability or usefulness. There are few mines nowadays where the directorate is so unenlightened as to instal a coal-washing plant and not provision themselves with a modern and durable building of concrete, brick or steel construction.

In first cost, an all-steel construction is by far the most economical. The cost of brick or reinforced concrete varies considerably and is greatly dependent upon the cost of material at site and labour in the locality.

A rough average of the prices ruling at present is :—

Steel building erected . . .	£28 per ton.
Reinforced concrete . . .	£12 per cubic yard.
Brick	£6 per cubic yard.

A steel building is relatively productive of a large expense for upkeep, but it is very adaptable for future extension or alteration and occupies a small ground area. Reinforced concrete likewise occupies a small area, is much more durable, and requires little or no maintenance, but it is expensive and difficult to adapt for alteration or extension. The most durable and solid construction is the old-fashioned massive brick construction, requiring no upkeep, but which is readily altered or extended. It occupies, however, a tremendous ground area, and presents difficulties in alteration of sidings.

The best and most economical construction for all purposes of colliery use is a combination of all three materials, not only in initial cost, but also in maintenance and any additions in the future.

The lower part of the building should contain coal bunkers, pump and sludge sumps, and workshops, and be built of reinforced concrete directly over sidings, so that a continuous loading into wagons of washed coal may be possible.

The superstructure is then specially designed of steel framework to house and support the machinery, being completely enclosed by half-brick panels, built in between the vertical steel sections.

This composite structure is by far the most efficient and adaptable for colliery uses and constitutes the best British practice.

In the following chapters particular attention will be paid to the details of construction and the relative value of materials to the design of the plant.

The great advance of the design in reinforced concrete has been so much utilised in colliery equipment that, where necessary, the various methods of reinforcement will be explained.

Examples of confined sites for Washery Buildings are those shewn in Figs. 1 and 1A., the latter presenting many difficulties.

The only available position is on the edge of a large refuse heap, which is retained on the siding edge by a massive brick retaining wall about 35 feet high from the rail level. The refuse heap is in several places on fire, and for that reason cannot be utilised as a foundation for the building.

The screens are situated about 200 feet from the revetment wall and are separated therefrom by several colliery sidings and a main-line passenger track.

The ingenious method of supporting the Washery on the retaining wall as a central pivot and the offside on columns between the sidings with the near side cantilevered from the wall by heavy concrete beams was resolved upon. The concrete cantilevers and struts were made of massive section to resist the detrimental action of the heat of the refuse heap. The Washed Coal Hoppers were all built over the one available siding and the inner sides of the hoppers were cast close up to the wall, being let into the latter to the thickness of a half-brick. The whole of the building was carried out in reinforced concrete, not only for purposes of durability, but of necessity, as being the only material suitable for the ground conditions.

The difficulties of the situation can be appreciated from the manner of the delivery of the slack from the screens to the washer box. A conveyor band picks up the slack at the jigging screens, and, supported from the bottom edge of the truss spanning the main-line tracks, delivers into the feed hoppers

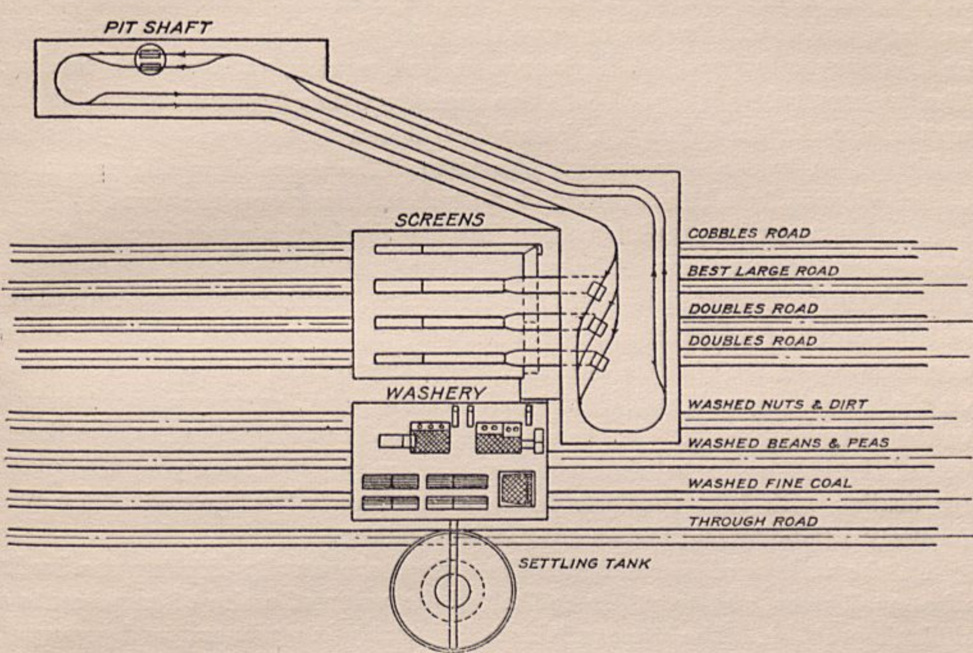

Fig. 1.—Surface Lay-out of a Modern Colliery.

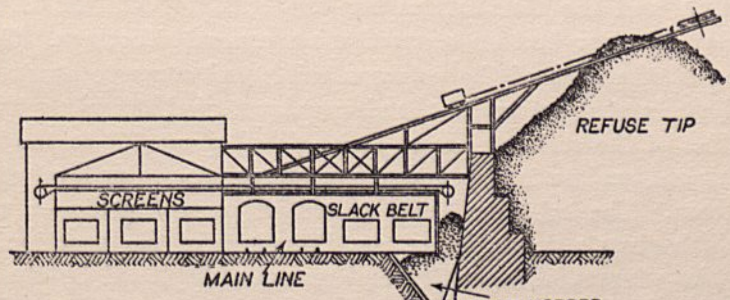

Fig. 1a.—Arrangement Shewing Slack Belt Conveyor Crossing Main Line Tracks.

by long concrete shoots, from which it is again elevated to the washer boxes by the feed elevator, which is placed between the washed coal siding and the retaining wall.

The feed hopper is also supplied with foreign coal from end-tipping wagons by an overhead electric rope tippler. The empty wagons coming from the tipplers are run under the washed-coal bunkers on the same siding.

A further provision for loading the washed coal at the lowering jib end of the screens is obtained by a band conveyor, collecting the products at the washery, and to still further increase the utility of the plant a second washed nuts conveyor is provided for transport and mixing, to a storage bunker. The washery refuse is loaded into two cantilevered or floating bunkers higher up the slope of the refuse tip, from which it can be transported by tubs for discharge on to the common pit stone tip. The stone from the screens is likewise tipped from tubs running on an inclined track over the truss.

A massive settling tank is tucked into the side of the retaining wall at the far corner of the washery. The weight of water and building in the complete settling-tank structure is no less than 1,100 tons, which is sufficient indication of the reliability of present-day washery engineers' practice. As it is often necessary to utilise the fine coal at the colliery boilers, a tub track is slung on the side of the wall and, skirting the settling tank, runs by a slight incline to the boiler stokehold. On the whole, this job is worthy of being considered one of the best and most daring of our modern practice, as a complete plant for dealing with 1250 tons per day has been erected on ground which was formerly a liability and not an asset of the colliery.

In the valleys of South Wales the sidings are usually skirting the banks of a small river, and to utilise to the full the value of a site often presents a difficult problem. The site available is frequently in waste or marshy ground, in a valley lying between two adjacent shafts and providing a tip for the refuse. Such a site the author recollects where the river was spanned by a concrete arch and the foundations for the building columns were carried down below the river bed on stepped mass concrete footings. To prevent any closing at the base of the columns reinforced concrete struts were run between the columns just under the sleeper level of the tracks. The ground on both sides of the stream rises at an angle of about 30° to the horizontal and the original surface is at about 2 feet above the water level at the edge of the stream. The relative levels of the respective collieries was about 80 feet, which gives a good idea of the difficulties of the situation, and also illustrates the amount of ingenuity and resource displayed by the engineers in placing the plant on valueless ground and yet maintaining its adaptability for future needs and present demands. The path of the river is directly under the lower rail level tracks for about 300 yards, and the upper rail level tracks run over a feed hopper supplying the washery. A ropeway feed picks up the slack from the screens of one pit at the ropeway terminal or loading station and discharges it at the delivery terminal into a large feed storage hopper of about 600 tons capacity, on the low-level sidings.

The storage hopper is also fed from the near pit screens by a scraper conveyor supported on a mild steel truss housed in half-brick panels. A by-pass arrangement is fitted at the top of the raw-coal bunker so that the washery may be supplied direct from ropeway or conveyor; this avoids the waste of power that would ensue by drawing the whole feed from the hopper and elevating it to the washer floor. The dirt disposal of a washery is often a source of great anxiety to the engineer, as it is an entirely useless product; some easy means of disposing of it is absolutely necessary to keep down running and capital cost. Often, however, the situation of the washery building does not allow of a ready solution, and in some collieries, as the loading and subsequent tipping of a wagon of refuse costs an appreciable rate per ton, in some cases 2*s*. 2*d*., it is found more economical to instal conveyors or ropeways to carry the dirt direct to the refuse heap or bing, or load it into tubs running on the pit refuse roads.

Sufficient storage for one hour at least is allowed for in a dirt bunker over a hutch road. A boy can attend to all the loading and shunting necessary, and as the power required is only 6 H.P. for a conveyor of about 200 feet length, little more than the capital cost will provide for the advantages of this apparatus. An approximate cost of the rate per ton for this particular type conveyor will be but 1*d*., including interest upon capital. Dirt ropeways are now becoming more popular, particularly in South Wales, where dirt tips are often on the summit of mountains.

Figs. 2 and 3 are suggested ideal arrangements, due originally to Mr. S. Hunter, for a washery the main purpose of which is to supply washed coal for coking and provide a certain amount of nut coal for sales purposes. The feed hopper and feed belt conveyor are shewn as constructed of reinforced concrete. The feed hopper has a capacity of 900 tons and is provided with a separate feed hopper of 100 tons capacity at the top of this bunker. There are two feed elevators, one extracting the slack from the large hopper and the other from the small hopper. The purpose of this is to avoid any congestion at the screens end of the plant due to an irregular supply; should the small hopper become full from this reason, the surplus will automatically fall into the large storage hopper.

A plant such as this would be extremely costly, though very desirable, and, in the opinion of the author, greater advantages at less cost could have been derived from a modified siting of the plant. Had the washery building been placed closer to the screens, a direct feed would have been obtained from the screening plant by an extension of the slack conveyor, and providing a large underground storage of, say, 400 tons which should suffice for all normal irregularities in the feed. The principle of delivering the coal directly from a conveyor, which discharges at some point above the washer floor level, should always be to collect it into some regulating hopper and thence to flush it direct to the washer boxes.

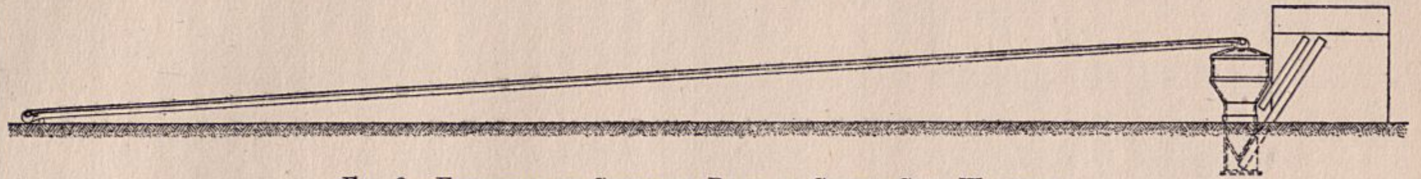

FIG. 2.—ELEVATION OF CONVEYOR BAND OF COKING COAL WASHERY.

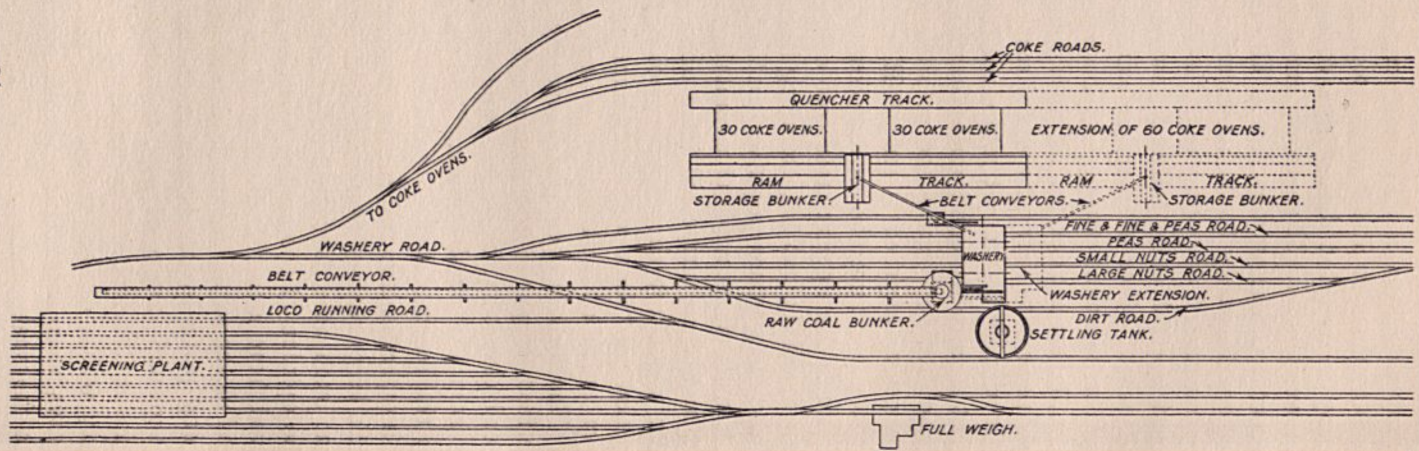

FIG. 3.—SITE FOR COKING COAL WASHERY.

It is bad practice even to feed into a small elevated hopper and then re-elevate into the washer box. We will return to this point in the chapter on elevators. The washed coal could be delivered from the new position to the service bunkers by a ropeway, which would be more economical in first cost and maintenance than a long band or scraper conveyor. Further, it would only be necessary to provide a conveyor to deal with the coking coal.

The ropeway is relatively cheaper and can be adapted to any further extension (see Fig. 257). The washed sales coal from this new site could be carried across by conveyor to the lowering jib end of the screens to be

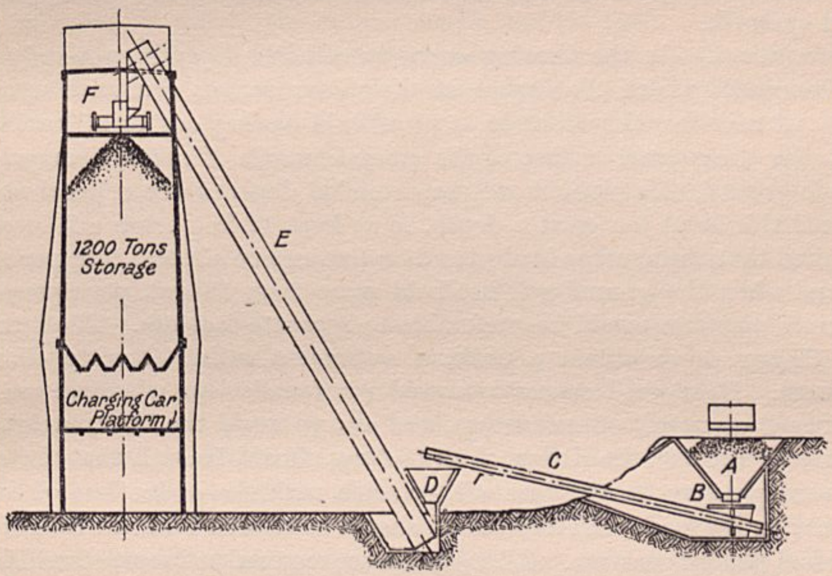

Fig. 4.—Service Bunker and Feed Hopper.

loaded into the wagons with the large coal. The same weigh could also be used for the loaded wagons of washed coals as for the screens.

The siting of storage and service bunkers for coke ovens often presents problems of coal handling not encountered in washery construction. A service bunker, as shown in Fig. 4, is situated at about 200 feet from the only available siding, which is on an embankment. The coal is brought in wagons to the hopper, A, from which it is drawn by the feed table, B, and thence by conveyor, C, to the elevator boot, D, and then by bucket elevator, E, to the crushers, F. The main consideration in this layout is to obtain an efficient combination of machinery; this is attained by a slight slope on the band conveyor and one of 60° to horizontal on the elevator. The feed table is installed to regulate the maximum supply to the crushers. As there are two crushers of only 30 tons per hour each, it is incumbent that the supply shall at no time exceed 60 tons per hour, to prevent congestion of the crushers and to ensure a regular size of crushed coal.

Hitherto the adoption of coal washing by collieries has only been attended with interest from the commercial, and not from the scientific side. The greater part of the plant used by collieries has been subject to a more or less exact examination of its utility and design before placing the order for its installation. Colliery engineers have not shown the same attention to the details of construction of their washing plants and bunkers that they have to the older and more simple types of the buildings and apparatus of dry separation. As a guide to construction of the buildings the following provides a good example.

Foundations.—As the bearing capacity of soils depends, not only upon their composition and the degree of their compactness, but also upon the amount of moisture they contain, a pit should be dug out to at least 6 feet deep below the normal surface of the ground in soils of average composition. In made ground, this pitch should be extended down to the original surface, or should this be at too great a depth, to at least 12 feet below rail level. It is required that the average load placed on footings be about 2 tons per square foot, and when the ground will not hold more than 15 cwt. per square foot, a concrete mattress would be preferable to separate footings. The intention of all designs is to obtain a uniform settlement rather than to eliminate settlement. Reinforced concrete is used for foundations wherever possible, to reduce the amount of excavation, and also to avoid the heavy weight due to massed concrete; the design of all footings should be such that the centre of upward pressure on the base will coincide with the centre line of column transmitting the load. All loose earth should be cleared from the base of footings before placing concrete. All engineers are required to become familiar with the following instructions and to carry out carefully every detail of construction in strict accordance with the plans and on the lines indicated. They must always be present on the erection of shuttering, mixing, and placing of concrete and the removal of the shuttering; the steel reinforcement should be checked with the plans before the placing of concrete. A daily record of the progress of the work must be kept, likewise the state of the weather. All drawings must be carefully studied and any inconsistencies between drawings and specification should be reported to the head office at once, all work in connection therewith to be delayed pending confirmation.

Shuttering.—All timber shuttering should be rigidly constructed and strong enough to withstand any damage or misplacement during handling. Particular care should be exercised in erection to see that all column boxes are plumb and the four corners vertical, that is, that the shuttering has not been twisted. It should be borne in mind that the shuttering has to withstand the weight of a heavy liquid concrete and the added load of the men employed in placing it without the slightest deflection. All shuttering and supports must be strongly braced and cross-braced to resist strong winds and any shaking or shock due to heavy locomotives passing the site. To avoid honeycombing or sponge concrete, all joints of the shuttering must be made tight, to prevent leakage of the liquid. The best method of shuttering is to arrange the forms so that only the sides of beams may be removed first, allowing the bottoms of the beams to be supported for a longer period. Bevelled strips are fitted at the corners of all columns and beam boxes. Beam boxes when over 10 feet span should be given a camber of $\frac{1}{4}$ inch for every 10 feet; an opening must be left in the shuttering of the column boxes near the base to adjust the reinforcement and to clean out before placing the concrete. The engineer should not allow nails to be driven to their full length and the minimum number of nails should be used, as the endeavour should be to use the timber as often as possible throughout the construction. The carpenters should be made to exercise every economy with the timber, as this latter represents an overhead charge of at least 15% of the construction costs.

Steel Reinforcement.—All steel arriving at the site should be stored and sorted into groups of equal diameter and checked against the bar specifications; before placing the steel in the forms, all loose scales should be cleaned by a stiff wire brush; when placed in position, it should be firmly wired to prevent movement when pouring the concrete. It is a matter of paramount importance that the plans of the steel positions and their proper bending should be strictly adhered to. It is not enough that the steel is placed or bent nearly in the positions as drawn; it must be exactly placed. The bending of all bars below $\frac{7}{8}$ inch will be done cold, such bending to be applied evenly and not with a jerk; and damage to bars during bending is sufficient justification for the scrapping of that bar and a new one being utilised in its place. To facilitate the adjustment of the steel in the shuttering, one side of the box should be left open, only to be closed up just prior to the pouring of the concrete. Templates should be made and used for all bar spacings, and the lapping of column bars must be done with the utmost care. All splicing wires to be pulled taut and the ends securely fastened. The column wrapping or hoops should be pulled tight and the ends of the wires bent back into the heart of the column. Wire ties are quite useless if there is the slightest amount of sag. In all beams there should be at least 1 inch of concrete between the shuttering and the steel reinforcement; the shear members or stirrups should be carried up to within 1 inch of the top of beams.

Cement.—The storing of cement at the site should be in a perfectly dry building; it is preferable to arrange for two cement stores, so that the second lot of cement to arrive shall not be mixed with the first lot; this ensures the using of the first batch before commencing with the second, and therefore avoids the deterioration of the cement consequent on the length of time it is kept in storage. All cement used must be of uniform colour and free from lumps. If the engineer has any doubt about the quality of the cement, a sample should be sent to head office for analysis and test.

Sand.—The sand should consist of grains of a hard, sound rock without shewing any evidence of chemical decay. It should be free from impurities, such as loam or clay, or any organic matter. The best quality of sand is that in which there is double the amount of coarser grains than of finer. It should pass through a screen of 20 meshes to the lineal inch and be retained upon a screen of 30 meshes to the inch.

Aggregate.—Broken stone, gravel and hard dolomitic limestone are suitable aggregates. As the strength of the concrete is directly dependent upon the strength of the stone, a good, hard, dense quality should be used. It should be entirely free from impurities; all blast-furnace slag should be tested in a laboratory before use, to ensure that no chemicals are contained which may be injurious to the steel. Owing to its porous nature, it takes 25 to 30% more cement than either sand or stone. The sizes of the aggregate should not exceed the following: $\frac{5}{8}$ inch for small beams, columns, and slabs, and in no case larger than 1 inch, with the exception of column footings and foundations; for settling tanks and hydraulic structures, all aggregates should be crushed to a maximum size of $\frac{5}{8}$ inch and be of a hard, dense, non-porous nature.

Mixing the Concrete.—The water used for mixing the concrete should be fresh clean water, free from organic matter, acids, or strong alkalis. The following mixtures should be used. For footings or walls of greater thickness than 8 inches, 1 part cement, 3 parts of sand, and 5 of crushed aggregate. For beams and slabs, 1—2—4 mix. For supporting columns, 1, $1\frac{1}{2}$, and 3 mix. For the containing walls of water tanks, etc., 1, $1\frac{1}{2}$, and 3 mix. All concrete should be machine mixed. The three constituent parts should be loaded into the mixer dry, and after being thoroughly and intimately mixed together, sufficient water should be added to produce a fairly liquid or mushy concrete.

The proportion of these mixtures in the batch must be arranged to avoid any chance of error on the part of the workmen. A duplicate check should be kept on all cement used, which must at all times be from the same store, until the lot in that store is used up. The water should be added by measure from the tank attached to the mixer support, so that all mixes will be of the same consistency.

Placing Concrete.—All forms and boxes must be free from foreign matter of all descriptions, and the concrete must be placed in the shuttering from the mixer with the minimum delay, which should never be longer than 10 minutes. All beams and slabs should be entirely filled to the top of the shuttering in one operation. All column shuttering should be filled to the bottom of the

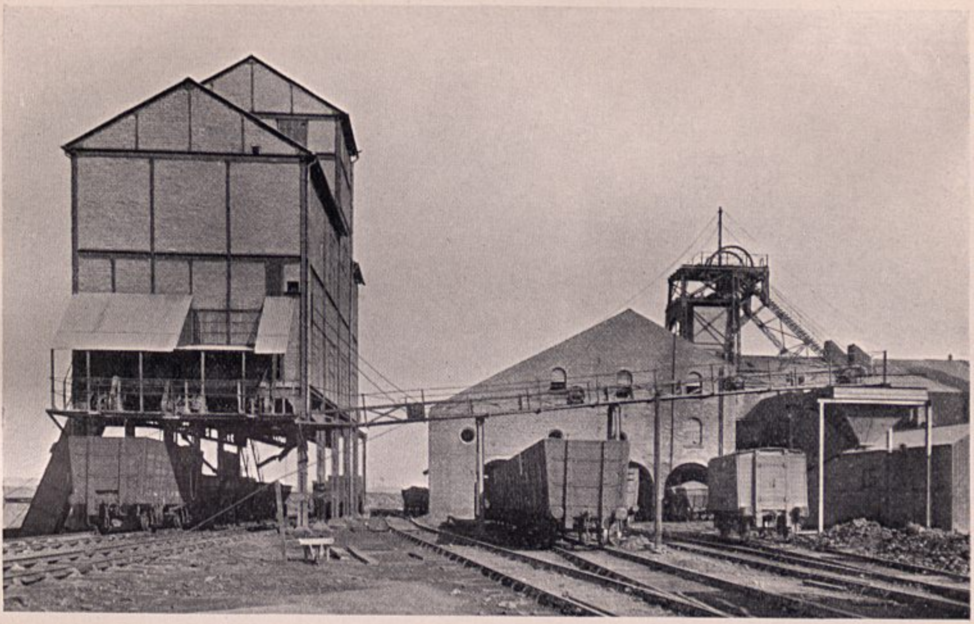

FIG. 5.—WASHERY BUILDING. NOTE THE CLEAR SPACE UNDER BUILDING FOR SIDINGS.
(*Hugh Wood and Co., Ltd.*)

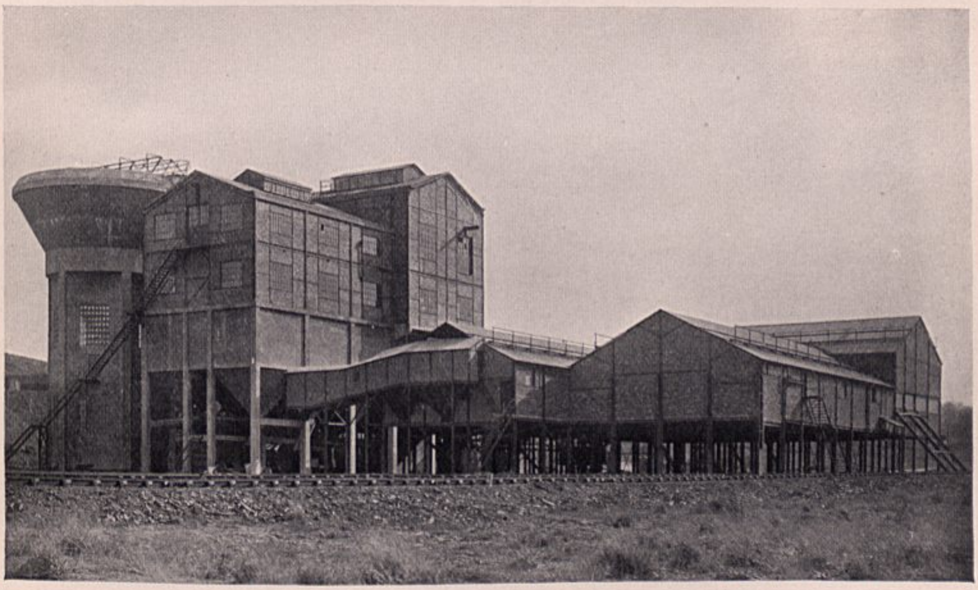

FIG. 6.—WASHERY AND SCREENS, A FINE EXAMPLE OF PRESENT-DAY PRACTICE.
(*Coppée Co. (Gt. Britain), Ltd.*)

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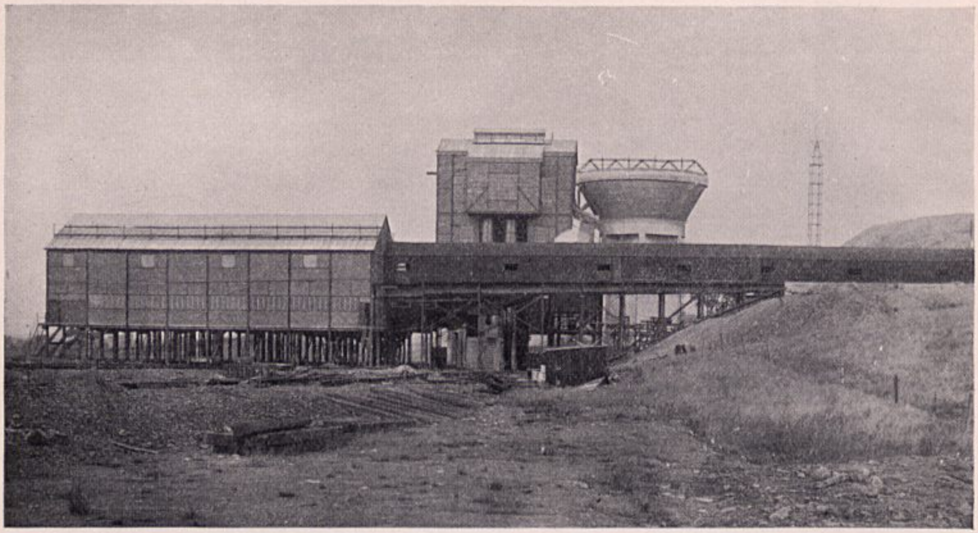

Fig. 7.—Washery and Screens Buildings, shewing Gantry from Pithead to Screen and the Massive Settling Tank. (*Coppée Co.* (*Gt. Britain*), *Ltd*).

Fig. 8.—180 Tons Per Hour Washery. Note the Large Concrete Shale Bunkers which receive Dirt from Screen and Washery. A Ropeway carries the Refuse from there to Tip. (*Coppée Co.* (*Gt. Britain*), *Ltd.*)

first beams in one operation. Beams entering columns should not be poured until 10 hours have elapsed from the placing of the concrete in the column. Once having placed the concrete, it should be undisturbed until set. This rule should be rigidly adhered to. Any concreting done during frosty weather should be well covered with straw or cement bags before leaving the job at night. In a prolonged spell of frosty weather, the engineer should communicate with head office for instructions. Engineers should see that all beams are completed to the centre of the column or the centre of the span ending in a vertical joint before leaving off the work overnight. Slabs should be stopped either directly over the centre line of beams or in the centre of the span, making a vertical joint.

Removing Shuttering.—The removal of the shuttering demands the greatest care and should be done gradually without shock. The engineer should be satisfied that the concrete is sufficiently set and hardened before the removal of the supporting timber. The concrete should have a good clear ring when struck with a hammer, if properly set. Ten days at least should be allowed for columns, and not fewer than 15 days for floor slabs and floor beams. The shuttering from the unsupported portions being first removed, the engineer will be able to satisfy himself as to the advisability of removing the supporting posts beneath the main members. In case of any doubt, temporary supports should be left under these members for at least 10 days. All main beams should be supported for at least 1 month. These times are for good weather; under damp and unsettled conditions they would be proportionally lengthened. Test blocks of 9-inch cube should be cast during this period, at the discretion of the engineer, to help him in his judgment. Upon the removal of the shuttering, a cement finish of 1 part cement to 2 parts sand should be used in exposed positions, where indicated on drawings.

In the author's practice he has had occasion to use blast furnace slag cement for washery and settling tank construction. It was found to set "woody" and took several months to harden. To remedy this evil, the cement should be aerated by spreading over a dry floor for 24 hours before using.

In Fig. 5 is shewn a building of one of the latest concentrating table plants. It is of steel framework and brick filling throughout. The single span over the two sidings leaves a clear space for the wagons. The concrete settling ponds and the pumps for the water service are placed at the ground level.

In Fig. 6 an excellent building of a large washery.

The substructure and the settling tank are of reinforced concrete construction and the machinery housing or superstructure is of steel framework and brick panelling.

The layout of this massive plant shews the modern tendency for concentration of the surface cleaning plant over adjacent sidings.

CHAPTER III

FEED HOPPERS

In the majority of washery installations provision is made for the supply of slack coal to the plant by two or more ways, by belt conveyor and truck, by ropeway and truck, and in a few cases by all three, so that in the event of a breakdown of one the other will be available for the supply.

It is particularly necessary for the efficient working of the washer boxes that the feed be regular and constant. To this end, a supply of slack is dumped into a hopper, from which the flow into the conveying medium can be regulated. For the convenience of filling by either method, this hopper is generally placed below rail level, as shewn in Fig. 9.

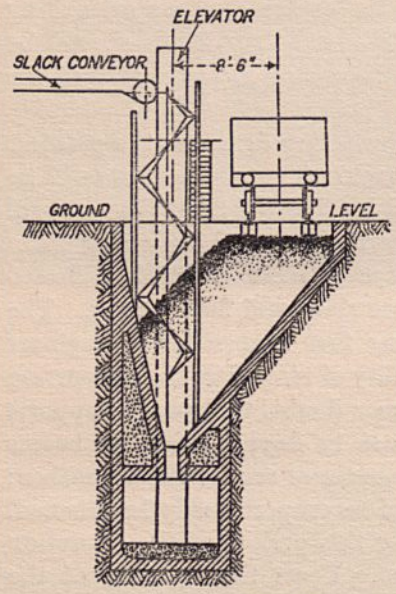

Fig. 9.—Ordinary Type Track Hopper.

Should the line of rails be parallel with the line of the elevator, the supply wagon will have to pass over the hopper at a sufficient distance to one side to clear the feed elevator and the ladders placed on the side of the casing. This distance is usually about 8 feet 6 inches from the centre line of the elevator to the centre line of the track, allowing for a clearance of 2 feet. This necessitates making the hopper cross-section of an irregular form, that is, the side directly under the wagon will have less slope than that of the far side. Where a conveyor feed is brought to the hopper over the tracks, it is advisable to instal a spiral shoot to avoid breakage of the larger sizes (see Fig. 10, shewing an enclosed spiral from screens conveyor).

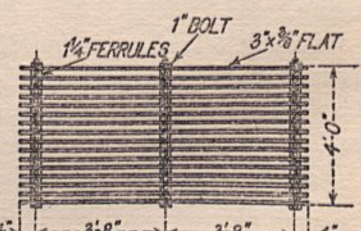

Fig. 11.—Hopper Grid.

Grids.—The plant being designed to treat coal of a certain maximum size, precautions have to be taken that no larger sizes than those allowed for enter the hopper. This is done by covering the top of the hopper at rail level by a steel grid, built up of 3-inch flats, ⅜ inch thick, placed on edge, spaced at the required distance apart, and bolted together. For the convenience of renewal and access, they are built in sections of about 8 feet by 4 feet wide, as shewn in Fig. 11. A bolt of 1 inch diameter is passed through the centre and two others at about 4 inches from the extremities. The grid flats are kept on

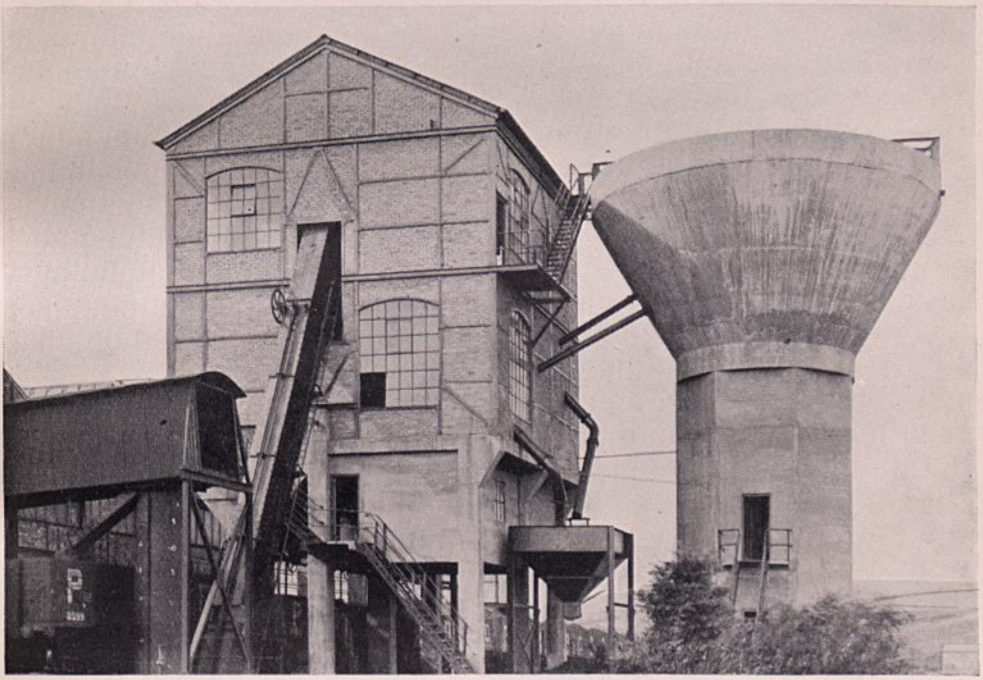

FIG. 10.—SHEWING FEED CONVEYOR DELIVERY BY SPIRAL CHUTE INTO FEED HOPPER AND WASHERY BUILDING. (*Nortons Tividale, Ltd.*)

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edge and at the correct spacing by the insertion of $1\frac{1}{4}$-inch gas tube ferrules, placed around the bolt between each flat.

The most popular type of feed hopper is that shewn in Fig. 12.

The construction is of reinforced concrete and comprises two chambers, one to receive the dry coal and the other to house the feed elevator. The walls of the coal chamber are 6 inches thick up to within 18 inches of rail level, where a heavy sill is added to withstand the shock of passing wagons and the ground pressure. The reinforcement of this type is of $\frac{3}{8}$-inch round bars spaced 12 inches apart on the face of the inside wall and 24 inches apart on the face of the outer wall, vertically and horizontally. The outlet is situated at the apex of the inverted pyramid and the size is fixed by the dimensions of the sliding door in the elevator boot.

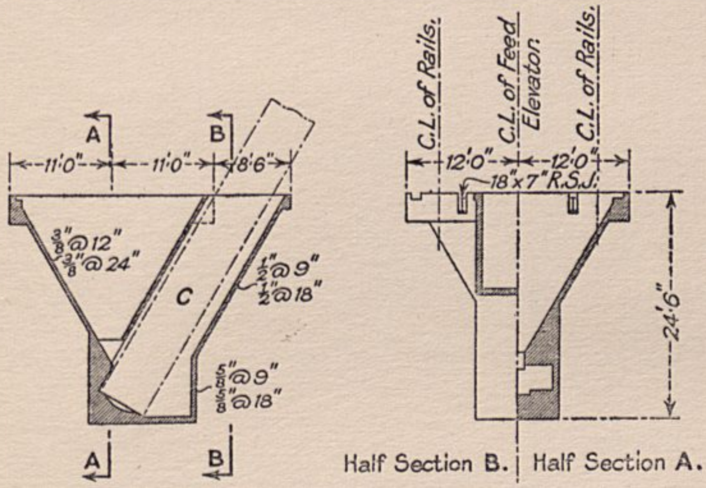

FIG. 12.—FEED HOPPER UNDER TWO TRACKS.

The chamber, C, forms the housing of the elevator and is made sufficiently wide to allow a man to pass round three sides of the elevator and to withdraw the bottom shaft of the sprocket to one side for repairs (see Chapter VI, on Elevators).

The vertical wall at the bottom of the chamber, C, should be thickened out to 8 inches, and the floor, if not wider than 8 feet and of 12 inches thickness, need not be reinforced.

The rails are carried across the hopper on steel joists and require stout pads of concrete under them at the supporting ends. It is not good practice to build in concrete beams, as they are much more expensive than steel sections, and they obstruct the fall of the coal and do not provide a good support for the grids.

The site allotted to washery buildings is sometimes so small that it becomes necessary to construct the feed hopper almost directly under the outside wall of the building.

A brick-built hopper of large capacity, constructed under these conditions, for 100 tons per hour plant, is shewn in Fig. 13.

The wall separating the elevator chamber from the coal compartment is constructed of horizontal steel joists with the ends embedded in the brickwork and panelled with mass concrete. The proximity of the washery wall causes the elevator to be set at a very steep angle, and, as will be noted in the chapter on elevators, is not to be recommended.

In large plants, where the products of different seams are washed, two com-

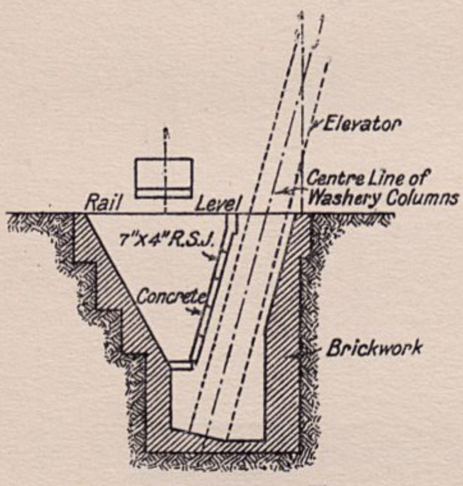

FIG. 13.—BRICK-BUILT HOPPER.

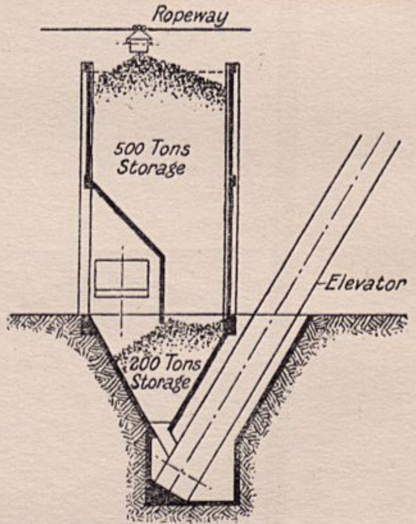

FIG. 14.—500 TONS STORAGE FEED HOPPER.

partment hoppers are provided; that is, there is a division wall in the large compartment. This construction facilitates the mixing of the two dry slacks in any proportion required. In the central wall a gate is fitted, so that one compartment can be emptied in the event of breakdown. It is usually of brickwork with reinforced concrete partition wall and steel-built girder carrying wagon track and tipplers.

Where the supply of slack varies greatly, a method must be adopted to ensure a uniform feed to the elevator and some arrangement made for the storage of the coal delivered to the site so that it can be readily fed into the hopper. This is particularly the case where the feed depends on a ropeway used alternately for coal and refuse disposal, and also in the case of a large discharge from the screens belt during certain hours of the day.

As it is advisable to place the side slopes of the hopper at a minimum angle to the horizontal of 60°, it will be readily seen that there is an economical limit to the dimensions of an underground storage chamber. For every foot of added depth the elevator is increased in length by approximately 14 inches and the surface width and length by 13 inches. To overcome these inconveniences, a bunker above rail level is erected as shewn in Fig. 14.

Where the washery is of large capacity and is fed by several collieries, particularly if a ropeway is employed, an overhead hopper is almost a necessity.

This construction is expensive, but it has the compensating advantage of providing four or five hours' supply and lessens the risk of rendering the plant idle at any part of the day. While this provision is of paramount importance in a large colliery where demands on rolling-stock fluctuate between wide

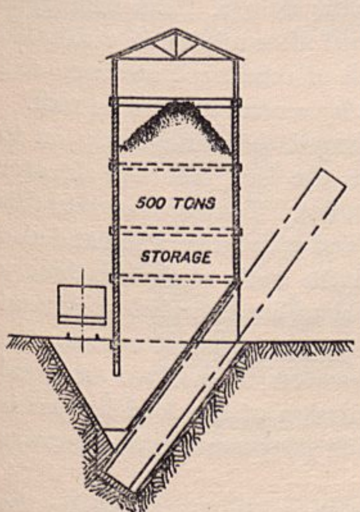

Fig. 15.—Storage Feed Hopper and Track Hopper.

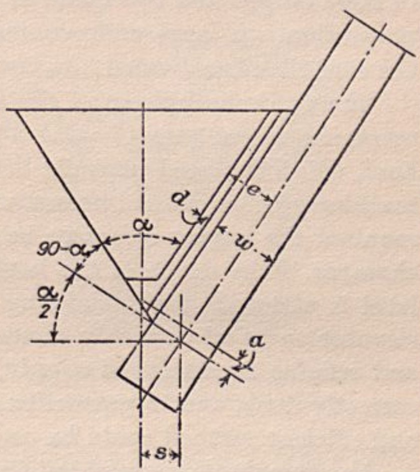

Fig. 16.—Diagram shewing Method of Approximating Construction Centres.

limits, the capital outlay is such as to prohibit the adoption of the scheme in the smaller collieries.

This type of hopper is also suitable for mixing purposes where the coal product of the washery is to be of a standard quality. The larger the storage the better the resulting mix, and the ropeway when not in use for the conveyance of slack can be utilised as a refuse-disposal track from the feeding collieries.

The construction of the hopper over the tracks considerably increases the cost of the storage bunker and where possible should be avoided.

The type shewn in Fig. 15 is preferable, as here the siding skirts the edge of the bunker and feeds into the hopper lip. To facilitate the clearance between rails and the side of the hopper, the outer wall should be vertical under the far rail for a depth of at least 3 feet.

To fix the centre of the hopper accurately with reference to the centre of the elevator sprocket, the following example will facilitate the calculation (see Fig. 16) :—

$$d \tan (90 - \alpha) = a$$

$$\text{and} \quad a \tan \frac{\alpha}{2} = b$$

$$\text{then } (l - b) \cos \frac{\alpha}{2} = S,$$

the distance required.

The letters and symbols are indicated on the illustration.

In one of the large South Wales collieries a feed hopper is served with slack from the screens direct and by wagons over the sidings. The washery is of large output and two qualities of coal are washed after mixing in a suitable proportion. A large underground hopper is built of reinforced concrete and the coal chamber divided into two compartments by a central division wall.

The two mouthpieces of the hoppers are arranged to feed directly on to revolving tables (see Chapter V) which regulate the feed into the elevator boot, which is placed centrally between the two tables. To accommodate this machinery below ground necessitated a very deep and wide excavation and also required the hopper slopes to be suspended from the walls of the machinery chamber. The depth of the hopper or elevator chamber floor below ground level is about 50 feet, rendering the whole job very costly and causing the elevator to be of unwieldy dimensions. Feed elevators themselves are good and reliable regulators of supply, providing the design of the feed hopper is correctly done, and to proportion mixes for washing purposes a less expensive and efficient method could be used.

An example of an overhead feed hopper is that shewn in Fig. 17, where the supply is brought direct from the screens, the feed hopper being immediately below the jigging screens, and the washery covering the same tracks as the screens building and tippler house. This design is not of frequent occurrence, the present tendency being to place the washery to the side of the screens building, over separate tracks or sidings.

This avoids congestion of wagons and the accidental mixing of washed and unwashed coal caused by spill from the loading jibs at the picking belts.

Feed-hopper mouthpieces are frequently choked by the coal arching in the apex of the hopper or by a piece of wood or a " tramp " bolt holding back the coal.

For this reason the author would advise that the hopper mouthpiece be arranged as shewn in Fig. 18, and not, as is the general practice, within a few inches of the back cover-plate of the elevator and inaccessible to workmen.

A short steel chute with detachable cover-plate answers the purpose, and this should be inserted between the elevator boot and the mouthpiece. The near wall of the containing chamber should be carried well back for the boot of the elevator, to allow a man to pass, as shown in the illustration.

A small sump should also be made in the floor to provide a means for the draining of the water which collects here.

If there is no wagon feed into a hopper, as sometimes happens where coal is fed direct from screens building by conveyor, the hopper should be completely closed in at rail level, and in all cases handrails should be placed round the sill of the elevator chamber at rail level.

In calculating the capacity of a pyramidal hopper allow 45 cubic feet to the ton and take only half the actual enclosed volume.

In building the underground hoppers great trouble is often experienced from the percolation of water.

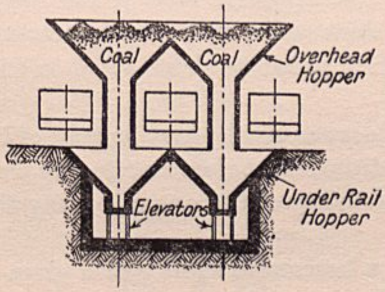

FIG. 17.—OVERHEAD HOPPER FEEDING INTO SMALL UNDER-RAIL HOPPERS.

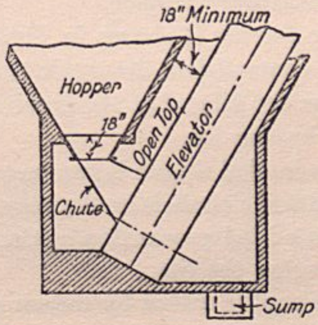

FIG. 18.—SUGGESTED METHOD OF FEEDING INTO ELEVATOR BOOT.

An effective means of dealing with this is to place a 6-inch pipe into a sump extending 2 feet below the hopper foundations and just sufficiently long to project 2 inches above the floor of the chamber. Into this insert the suction end of a small pump, usually a 3-inch duplex is ample, and allow the pump to keep on working until the concrete or brick walls are well above the water-bearing strata.

The pump may then be disconnected and a wooden plug jambed into the 6-inch pipe and tamped with cement.

Drainage holes should not be placed in the hopper walls, as the only tendency of the water pressure, assuming that the design is correct, will be to float it, and this is hardly likely to happen.

In finishing off the inner surface ensure that near the apex of the pyramid there are no ridges left by the concrete shuttering, as these adversely affect the free flow of the coal.

The hopper mouthpiece casting should not be less in depth than 18 inches.

CHAPTER IV

WAGON TIPPLERS

IN various districts, the type of the wagons in use requires special apparatus for the discharge of the coal into the feed hoppers. In the majority of cases, the wagons are provided with flap doors on the underside of the flooring and two labourers can readily discharge twelve 10-ton wagons per hour into the hoppers. In some localities, particularly the South Wales coalfield, the wagons have flap doors at one end only, so that it is necessary to tip the wagon to empty it of its contents. As all the wagons do not enter the siding with the doors at the near end, the apparatus must be capable of tipping in two opposite directions towards the centre of the hopper.

There are many designs of wagon tipplers in use, but the most direct and simple may be classified as the Vertical Screw tippler, the Electric Rope tippler, and the Rotary tippler.

The former is shewn in Fig. 19. At two opposite sides of the hopper and placed centrally on the track two large tables sufficiently long to accommodate a wagon are hinged at the inner edges, which protrude about 3 feet on the inside of the hopper lip.

The loaded wagon is run on to the table, over which short lengths of the rails are laid and a chain is hooked over the far draw bolt, before starting up the motor —as an added precaution against the possibility of the wagon leaving the table rails during the lift.

The motor drives by means of a belt a horizontal shaft which gives motion through reduction and bevel gearing to a large nut, through which runs a vertical threaded rod or ram connected to the underside of the wagon table by a strong hinge and pin. The ram is of about 8 inches diameter and is screwed with a double thread $\frac{5}{8}$ inch square and of about 2 inches pitch, the top extremity being in the form of an eye-bolt to fit into the filbow hinge and to take the connecting pin, whereas the bottom extremity is free.

The revolving nut which engages with the thread of the ram is made from a machine-cut bevel gear wheel of forged steel. The teeth engage with the gearing driven directly by the shaft. The nut is about 12 inches deep and is supported in a large oscillating box fitted with hollow trunnions, which rest in heavy bearings bolted to built-up mild steel supporting beams, which transmit the load to the sides of the ram pit.

As the top end of the ram has a circular path about the centre of the table hinge, the supporting nut must be able to adjust itself to the change of slope of the rod as it rises or descends. This is done by allowing freedom of movement to the oscillating box about its trunnions, and necessitates the latter being hollow to allow the pulley shaft to pass through to the gearing, trunnions and shaft being concentric.

The rise of the ram causes the table to turn about the hinge and the rod to swing out, as indicated by the dotted lines, the crosshead or the oscillating box swinging about the centre line of the trunnions.

Upon the upper surface of the table a horn-shaped chock grips the wagon axle and prevents the wagon sliding during the tilt. Some makers fit a locking strut operated by a system of levers from the ram, so that in the first few revolutions of the actuating nut this locking strut is forced up against the axle

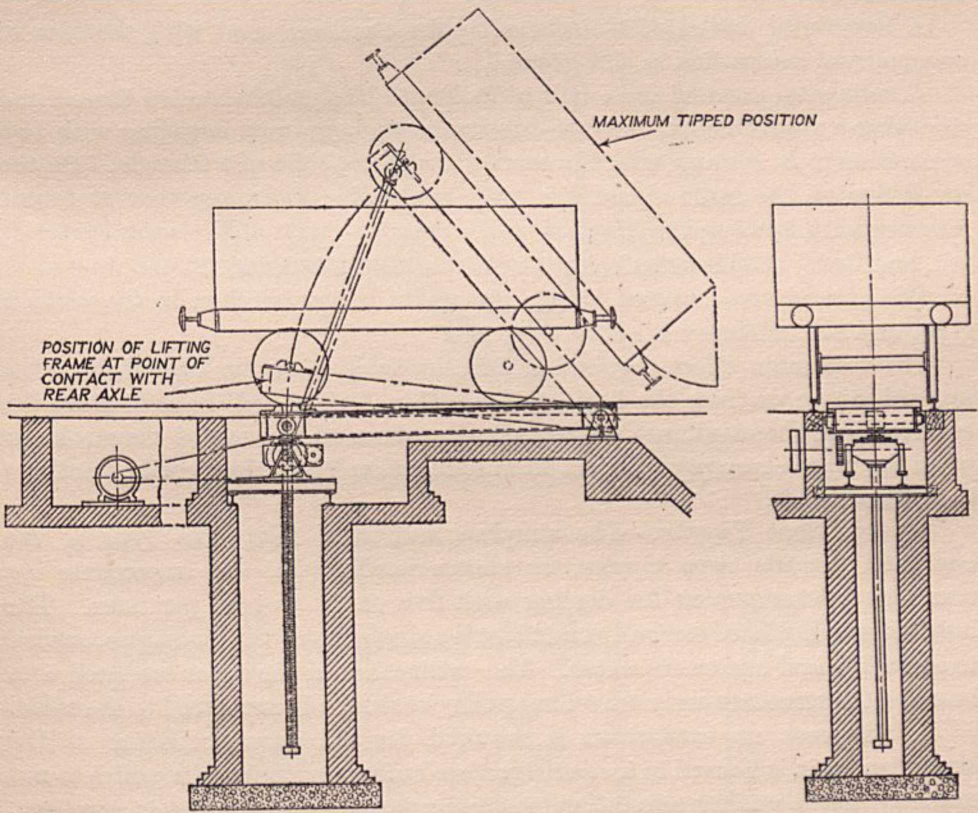

Fig. 19.—Arrangement of Truck Tippler with Lifting Frame for Emptying Trucks through End Doors on Continuous Rails.

and is not released until the load is again taken from the rams, *i.e.* in the rest position on the ram pit chocks.

The travel of the ram is sufficient to lift the table to a maximum tilting angle of 50° with the horizontal. An angle less than this does not give satisfactory results and encourages the labourers to damage the wagons by striking the sides with wooden mallets to release any coal adhering to the sides and flooring. The extra wear and tear occasioned to rolling-stock by tipplers is sufficiently heavy, without adding to it by decreasing the tipping angle.

This type of tippler is expensive and has the disadvantage of occupying a relatively large ground space for motor-house shafting and rod pits. The rod chambers are at least 20 feet deep by 8 feet square. A large amount of dust and grit accumulates on the rod and gearing, and causes heavy scratching and necessitates a lavish use of lubricating oil.

The outstanding advantage of this design is that the apparatus is entirely " foolproof " and positive in action, with no parts exposed to accidental breakage, etc.

A horizontal design of the above tippler has been used with the idea of economising excavation in soft ground.

A horizontal screwed rod—half of its length being a left-handed thread and the other a right-handed thread—has on it two large nuts engaging with two connecting rods, forming with the screwed rod three sides of a triangle. On the revolution of the screwed rod the nuts are either drawn together or forced further apart, causing the hinge of the connecting rods at the apex to rise or fall, and being at this point connected to the tipper table to tilt the wagon.

The ground area covered by the apparatus is greater than in the vertical type, and the efficiency is about 50% less.

The maximum effort required to lift the table is at the beginning of the upward stroke or from the horizontal position, but, as will be seen from the construction, the maximum vertical thrust occurs at the end of the stroke or when the wagon is empty. Apart from foundation loads, this type has nothing to recommend it.

Electric Rope Tippler.—The simplest and most adaptable type is the overhead electric rope tippler, as shewn in Fig. 20. It represents an economical arrangement for dealing with five or six wagons per hour. The hoisting gear is placed centrally and there is a single drum with two ropes, one led to one table and one to the other. The extremities of the ropes are fixed to a beam on the structure and a travelling pulley or sheave is connected to the table.

In this case no excavation is required for the accommodation of the apparatus, as it is housed in a steel structure built over the tracks, which is not so costly as the underground chambers and much more accessible at any time.

The winding drums are at a height of about 24 feet above the rail level. The wagon is run on to a table and the chain slung on the draw bolt of the wagon, as in the case of the screw tippler.

The motor is then started. The high speed of the motor is reduced by means of the reduction gearing in the ratio of about 35 to 1. The winding drum rotates 6 r.p.m. and the diameter is about 20 inches, so that each revolution winds in 5·0 foot of rope, and as the table is double slung, the upward travel is 2·5 feet per revolution. The wire rope has one end secured to the winding drum, and after passing round the travelling pulley is brought up again to be anchored on the structure. This pulley carries a large hook, which is slipped into the link on the extremity of the table. The table is built up of 9 by 3 inch channels and hinges at the hopper end. The wagon axle is gripped by projecting horns on the table. The disadvantage of this apparatus is that the slings are in the centre of the track and have to be hauled up out of the way to allow wagons to clear.

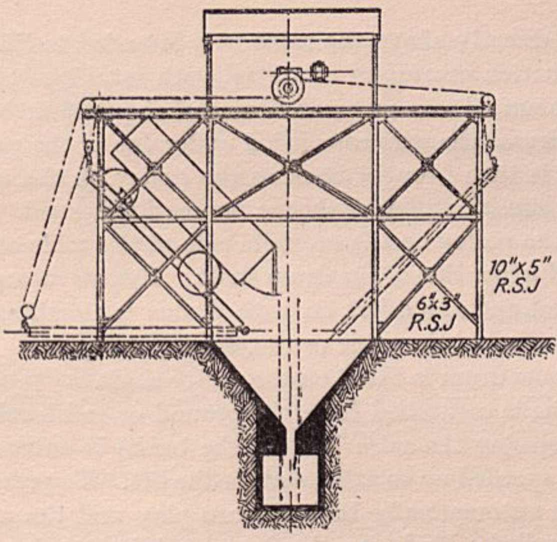

FIG. 20.—SINGLE-HOIST ELECTRIC ROPE WAGON TIPPLER.

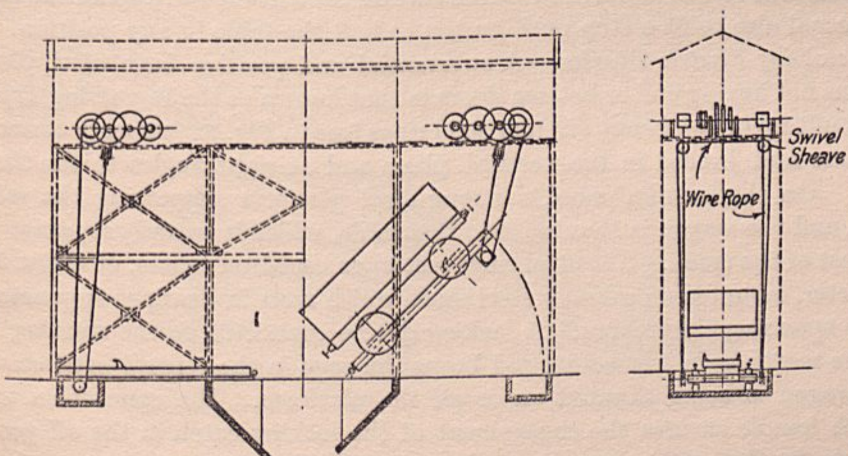

FIG. 21.—DOUBLE-HOIST ELECTRIC ROPE WAGON TIPPLER.

A limit switch, electrically operated, prevents overwinding. The hoisting gear consists of worm reduction and one set of gears. The brake of a solenoid type acts automatically when the current is cut off. The table is placed between the tracks, with the hinged end some 9 inches above rail level to prevent the wagon buffers coming into contact with the rail.

In Fig. 21 is shewn a double-ended wagon tippler of the latest type with two hoisting engines electrically operated.

Each hoist is placed on a separate strongly braced structure, connected at the top, for the convenience of the attendants, by a decking of timber on steel beams.

Each hoist is directly above the table it is intended to lift and consists of three sets of reduction gearing of cast steel with machine-cut teeth. On the drum shaft are mounted two cast-iron drums of about 20 inches diameter, and from one of the drums the wire rope is led under one of the pulleys at the side of the table and is then brought back to the pulley on the under side of the deck across to a similar pulley or sheave on the further side of the deck, and thence down to the pulley on the opposite side of the table and back again to the drum on the further side of the drum shaft. By this means an endless rope haulage is effected and the effort on both drums is equalised, irrespective of the manner of loading of the table or the stretch of rope.

A solenoid brake drum is fitted on the motor shaft.

This apparatus is controlled from the ground or rail level by push-button switches. On pressing the raise button, the brake is automatically released and the motor is speeded up to full speed for the lift. To prevent overwinding, a limit switch is automatically brought into play and the current is cut off and the brake applied. To lower, the down push-button is pressed, and when the table is at rest a second limit switch cuts off the current and applies the brake. It is usual also to fit a stop push-button to halt the table in any position.

Revolving Electric Tippler.—A substantial and positive form of tippler for wagons not having end or bottom doors is that known as the Revolving Tippler. It is built up of two heavy circular steel rings (see in Fig. 22) strongly connected together and braced in the vertical plane and at right angles to the line of rails. On the bottom chord a strong steel platform supporting the rails is built, and the wagon is shunted into this table, which is entirely separate from the rest of the track. The steel rings rest upon cast-iron rollers, of about 2 feet diameter, mounted on a heavy steel shaft, which rests in bearings supported by joists spanning the hopper. A locking device connected to the starting lever of the motor by a connecting rod keeps the cage in the central position while the wagon is being shunted on or off the platform. The connection to the switch handle ensures the engagement of the locking catch in the off position and the freedom of the cage to revolve when in the starting position.

Fixed on the main frames are two built-up clamps, which by rotation of a hand wheel are brought to bear upon the top of the wagon side, so as to hold the wagon on the rails during the turning movement. The four hand wheels are mounted on shafting which is fitted with bevel gears, so that when one is turned, the other three are turned to the same amount. This prevents any one clamp receiving more than its due share of the weight. Between the motor and the driving rollers, a worm reduction gear is fitted, so that the speed of turning is not greater than one revolution per 2 minutes. In the figure it will be noticed that the main rings are placed at about the distance of the axle base apart, to reduce bending of the shafts. This particular design is not to

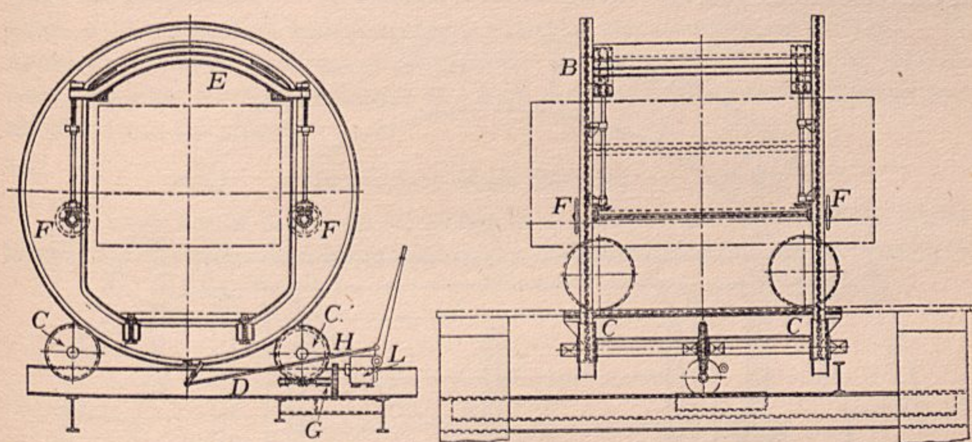

FIG. 22.—REVOLVING WAGON TIPPLER.

be advised, as, in turning, half the total weight of the load comes upon the weakest part of the wagon, that is, at the top side, and the spring connections on the under side of the body. So severe was the damage done by tipplers of this design that the colliery company took them out and installed a new set, as shewn in Fig. 23. The alteration took the form of increasing the span between the rings and putting in strong cross bracing and a heavy built-up table, *b*, to

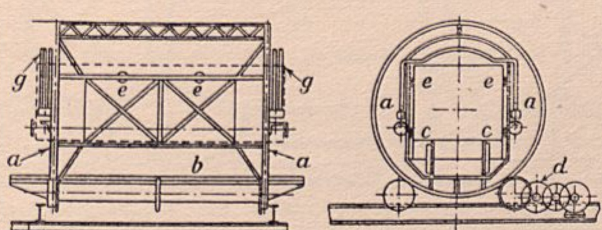

FIG. 23.—REVOLVING WAGON TIPPLER FOR LARGE WAGON.

take the heavy bending moments, due to a full wagon. The rings were placed at just less than the wagon length apart, so that the clamps, *g*, engaged with the top of the wagon at just above the end panel, and between the rings and the frame, *a*, double checks, *c*, operated by a screw were inserted, to take the side load on turning.

The lower chock was at the level of the wagon bottom, and the top chock, *e*, at third points of the sides, to prevent bulging.

A further great disadvantage of this type of tippler lies in the fact that upon the discharge of the load, the wagon springs, being relieved of their pressure, react upon the clamps securing the wagon, so that the original pressure put upon them by the attendant's full force is further increased by the amount of the load discharged.

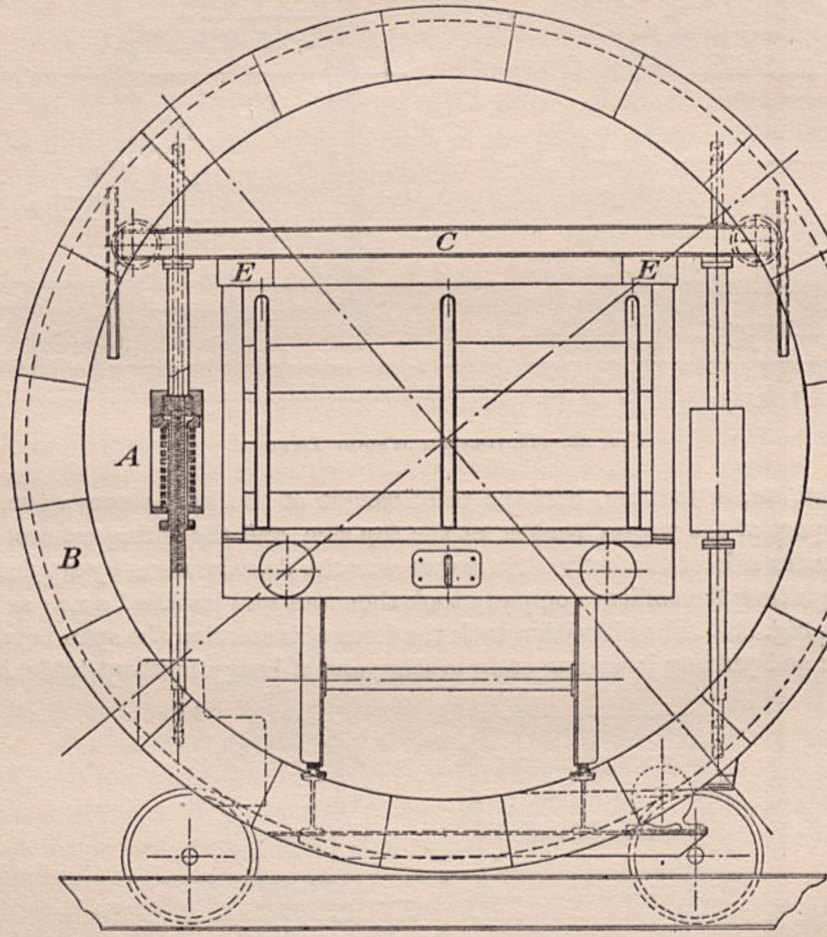

FIG. 24.—REVOLVING WAGON TIPPLER.

It is therefore clear that to release this the workman has to resort to a toggle, or, more frequently, none too gentle treatment with a crowbar. Unless these tipplers are a prime necessity they should be avoided.

In Fig. 24 is shewn a diagrammatic section of a type of revolving tippler. While very expensive, this tippler can claim to be the most efficient of its kind.

It does not make a complete revolution, but the angle of tip is controlled by limit switches, so regulated that on reaching this angle the actuating machinery is reversed and the tipper brought back to the loading position.

The clamping gear is likewise operated by motor, and is provided with a limit switch, so that the maximum amount of pressure applied to the wagon shall not be excessive. To further provide against any damage to the wagon sides, a heavy section helical spring is fitted on the clamping screw rods. To avoid the sudden application of pressure to the wagon on starting up the clamping gear, a travel clearance of ½ inch is allowed between the screwed rod shoulder and the spring.

Hydraulic Ram Tippler

The rams are of cast iron 12 inches in diameter, turned to size the whole length and suitable for dealing with up to 16-ton trucks with a water pressure

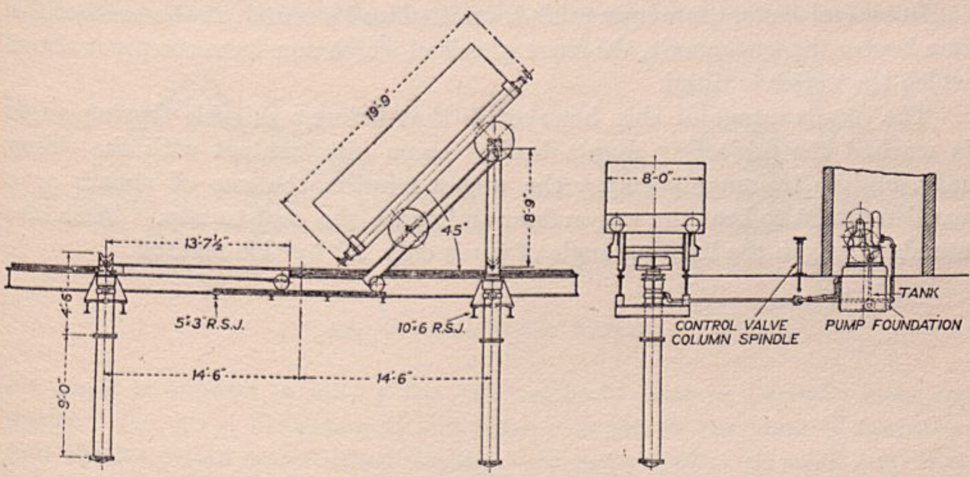

Fig. 25.—Arrangement of Hydraulic Tippler.

of 300 lb. per square inch. A low pressure and a large diameter ram ensure an absolute rigidity when the ram is fully extended on maximum load.

The ram casings are usually of cast iron in two lengths, the top length being fitted with stuffing-box and gland, and with feet cast on same for supporting the ram and cylinder on girders or concrete foundations. The top of the ram (as shewn in Fig. 25) is fitted with a very wide and substantial crutch for engaging the axle of the truck and with trunnion pins for taking the lifting cradles. The cradle is of steel construction throughout, with channel side frame and bracings and covered with chequered plate, steel axles, and running wheels, with special self-oiling arrangement of dust-proof design. The operating valves for raising and lowering are of special design three-ported slide valves with screw-operating spindle and column and operating handle for standing on the yard level.

The pressure and flow pipes between the ram, ram pumps, and storage tank are usually 2-inch-diameter drawn-steel tubes.

There is generally one galvanised storage tank of about 40 cubic feet capacity, one pressure gauge, one relief valve, one set of pumps, 3-throw hydraulic ram type, 3 inches diameter by 6 inches stroke, vertical type, mounted on heavy cast-iron bedplate with **A** frame, crankshaft, gearing, driving pulleys, and striking gears complete. The tank can be placed in any suitable position with the pressure and flow pipes thereto.

The whole of the plant is of thoroughly substantial design, practically fool-proof and very simple to operate, and given a good sound protection from frost are quite efficient during all weathers. The fixed ram and rolling table is much more satisfactory than the swivelling ram type, giving a steady delivery, and is subject to much less wear and tear.

In several cases, the wagon table is omitted and a crutch at the head of the ram houses the wagon axle, the front wheels of which now form the pivot about which the wagon is tilted.

The disadvantage of this, however, is that before a suitable tipping angle is reached the projecting wagon buffers come into contact with the siding rails, and to thoroughly empty the wagon requires the use of shovel or a wooden mallet to beat the wagon floor and cause the coal to slip. With the standard wagon the limiting angle of tip is only 28° by this method.

CHAPTER V

FEEDERS

To regulate the supply of slack to the washery from the feed hopper it is sometimes necessary to instal automatic feeders. These are generally operated by gearing, chain belts, or lever arms suitably engaging with the mechanism of the conveying medium.

There are two classes of feeders: the intermittent and the continuous, depending upon the method of regulation. The first class is of the type shewn in Fig. 26, where a sliding door, A, working in guides on the mouthpiece, has attached to it by a hinged joint two parallel rods, B, which are connected at the top ends by a stout steel bar. On the shaft, D, two cams are firmly keyed and caused to revolve by chain gearing with the sprocket shaft of the elevator. The revolutions of the cams lift the door, A, to the full-open position by pressing against the horizontal bar, and then by a rapid

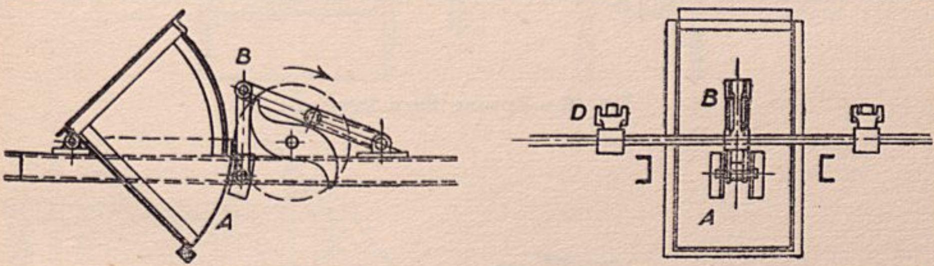

FIG. 26.—CAM TAPPET FEEDER.

release it is allowed to fall by its own weight to close or partially close the outlet. The great drawback of this class of feeder is the noise of operation and the uncertain action when dealing with large slack; for small coal they are much more reliable. The design is sometimes varied by replacing the curved plate with a flat door and operating it by a connecting rod engaging with a short crank arm on the end of the elevator sprocket shaft.

The continuous type is much more efficient and up-to-date, though more expensive.

A continuous feeder can be used with an alternate bucket elevator equally as well as with a continuous bucket elevator, if the precaution is taken of inserting a back plate between the skid angles, and as close to the back plates of the buckets as possible.

The commonest type of continuous feed is the star or paddle feeder as shewn in Fig. 27. Four or six blades radiate from a common centre in the form of a paddle and fixed at the ends to stout steel circular discs. These are fitted securely to a central steel shaft, which is supported in the side plates of a casing which encloses the whole of the apparatus, excepting rectangular openings at the inlet and outlet. The star is caused to revolve by chain gearing to the elevator or conveyor sprocket shaft, and thus the full compartments empty themselves into the boot. This apparatus works satisfactorily with 1½-inch slack downwards, but is not suitable for larger sizes.

The great disadvantage lies in the inaccessibility of the moving parts, due to the enclosing casing, as when choked with a full hopper it is necessary to remove the greater part of the apparatus; however, with a small slack it is very reliable. It is particularly suitable for regulating the supply to the

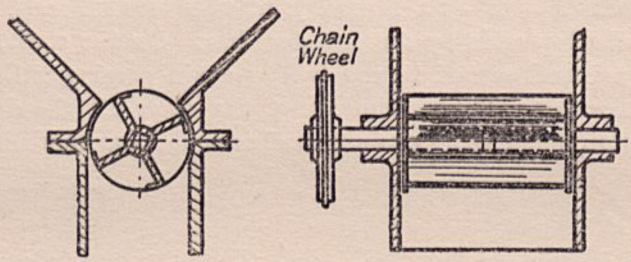

FIG. 27.—ROTARY STAR FEEDER.

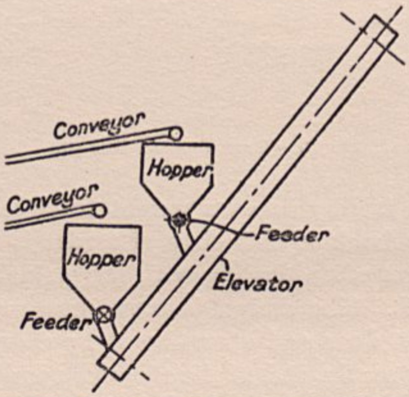

FIG. 28.—DOUBLE-REGULATED FEED.

elevator, where the buckets are required to be loaded at several points in the length as shewn in Fig. 28. This arrangement can be regulated to a nicety, and avoids any overfilling as well as facilitating a correct mixture of different qualities of coal.

In Fig. 29, a jig feed is shewn delivering into a crusher and thence to the elevator, *via* a star feeder.

Feed Tables.—The feeder *par excellence* is the cumbersome, but most efficient, revolving feed table.

Two large cast-iron semi-circular castings, *a*, are bolted together to form the table as shewn in Figs. 30 and 78.

The castings are of strong section with machined flange at j and radial webs at quarter points, with two circular webs at and near the periphery.

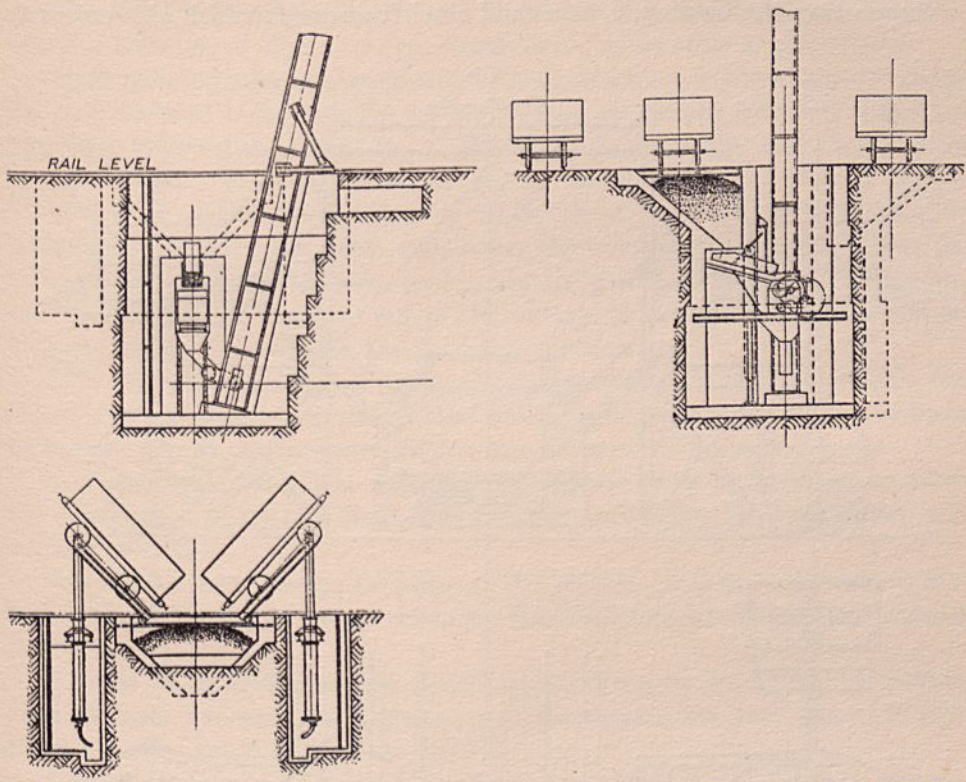

FIG. 29.—FEED APPLIANCES TO WASHERY, SHOWING HYDRAULIC TIPPLERS AND CRUSHER BELOW GROUND.

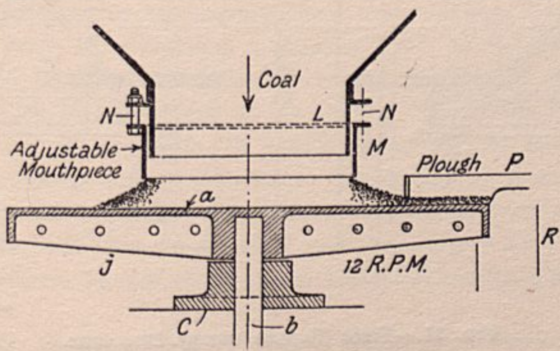

FIG. 30.—FEED TABLE AND MOUTHPIECE.

At the centre, a circular boss is bored out to 3 inches diameter, with a half-width keyway cut in each casting. The table is mounted on a vertical shaft, b, supported in a footstep bearing and bearing c.

The shaft is turned to a smaller diameter in the step, leaving a shoulder which is supported on a ball race and steel rings.

Supporting the bearing, *c*, is a mild steel framework which also supports

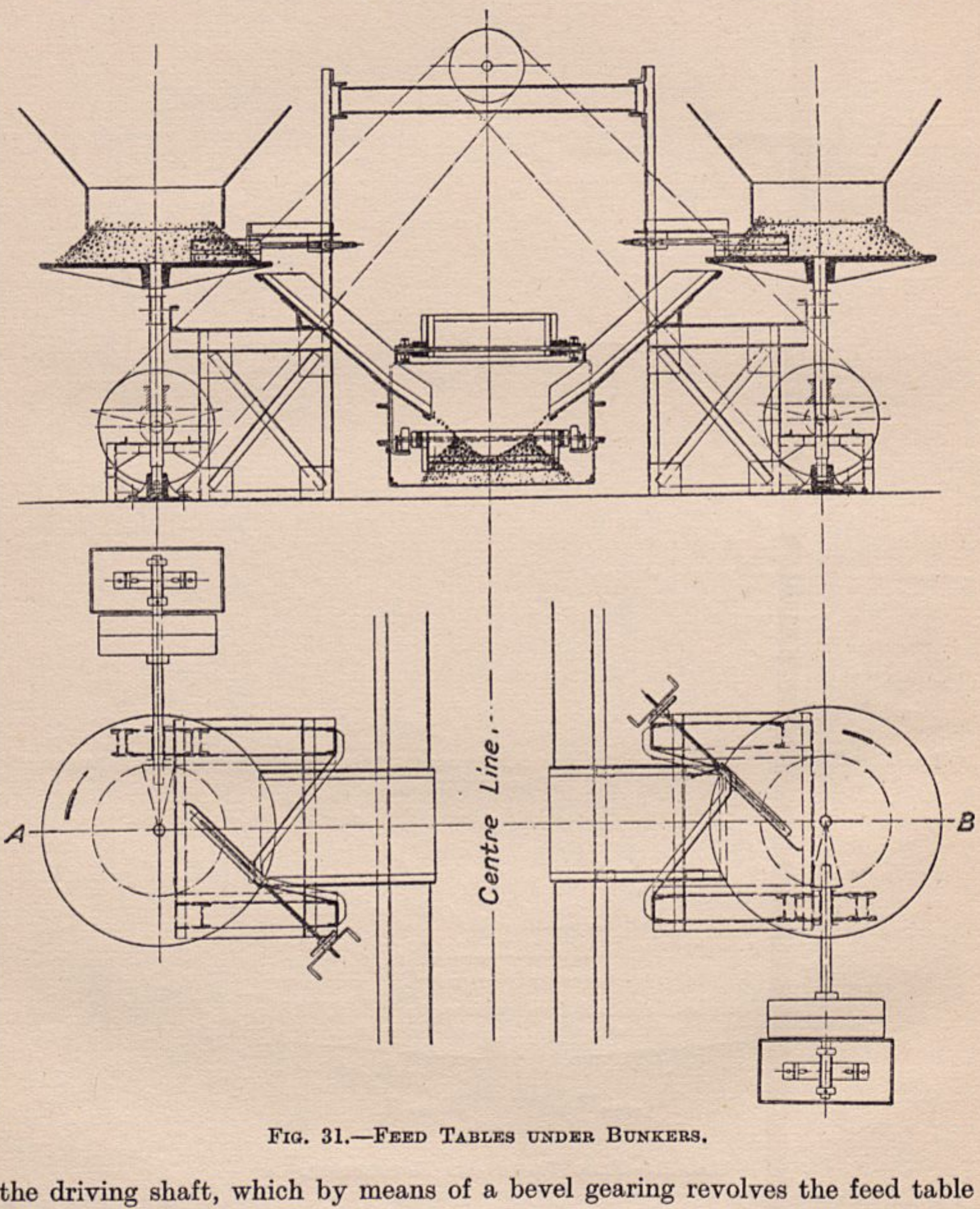

FIG. 31.—FEED TABLES UNDER BUNKERS.

the driving shaft, which by means of a bevel gearing revolves the feed table as shewn in Fig. 31.

An oil pipe entering into the side of the footstep bearing conveys the necessary lubrication to the ball race.

The central point of the feed table is placed directly beneath the central point of the circular mouthpiece of the hopper.

The fixed mouthpiece, *l*, of about 36 inches diameter, has fitted over it a circular tube, *m*, of slightly larger diameter, so as to make it telescopic.

Both have circular angles riveted to the outsides, and these are connected by long screwed bolts, *n*. By screwing up or slackening off these bolts, the clearance between the top of the table and the bottom edge of the mouthpiece can be varied. The coal in the hopper is, therefore, resting directly on the table surface and naturally spreads itself out at an angle from the hopper mouthpiece edge to the table top, when the tube, *m*, is raised. When the table starts revolving, this free coal gradually travels towards the outer edge, and by varying the angle of cut of the plough, *p*, a larger or smaller stream of coal can be diverted into the discharge chute, *r*.

This plough is merely an ordinary angle section pivoted just outside the rim of the table, and is so placed that the outer edge of the coal cone or layer upon the table is cut into and guided into the receiving machinery.

The maximum lift of the tube above the table must be sufficient to allow the largest size of coal in the hopper to pass, otherwise the mouthpiece will become choked.

Regulation must always be done by the plough; and once the tube is set, it should not be altered except when the slack entering the hopper is increased in size.

A table of 7½ feet diameter revolving at 12 r.p.m. is capable of dealing with 60 tons per hour of 2 inches maximum diameter, and one of 8 feet diameter will deal with 80 tons per hour.

Higher speeds than 12 r.p.m. are not to be advised, and where a greater capacity is required it is preferable to instal two or more units.

Sometimes these tables are used to feed into elevator boots, but this is a most expensive way of obtaining a regular feed, and totally unnecessary, as the duty could be done satisfactorily by star feeders or simple slide doors coupled up with variable gearing or jig feeds. The horse power to drive a feed table, while not greater than six, is still an item which means a permanent charge on the working and maintenance costs, and it demands every consideration before introducing even this most satisfactory apparatus. The best practice is to instal the feeder only in connection with a conveyor where a regular and uniform feed is essential to the good working and maintenance costs of the plant.

The feed table shewn in Fig. 31 has a duty of 50 tons per hour and is driven by belt from the driving shaft centrally placed between tables and carried by a stretcher between the table supports. The tables deliver into a scraper conveyor of the roller type. There is a fast and loose pulley on the table horizontal shaft to supply means of stopping one table whilst the other is working. Note the manner of delivery into the scraper; to save height, the coal is delivered into the bottom under the top guide angles. The hatched portion over the feed table represents the form of the slack as fed from the mouthpiece and deflected at the discharge side by the plough. The outside edge affects a spiral pattern, due to the centrifugal force on the free coal. It will be readily noticed that if the plough is turned with its nose further towards the centre of the table, a greater slice of coal will be deflected on to the conveyor, and, therefore, free the outer edge of the mouthpiece, so that a more rapid feed will take place.

The mild steel supports in the examples are of 6 by 3 inch channels and are preferable to cast iron, inasmuch as the height of the plane of the table above the floor often varies a considerable amount in each different job. With a built-up support, it is a simple matter to vary the dimensions, whereas

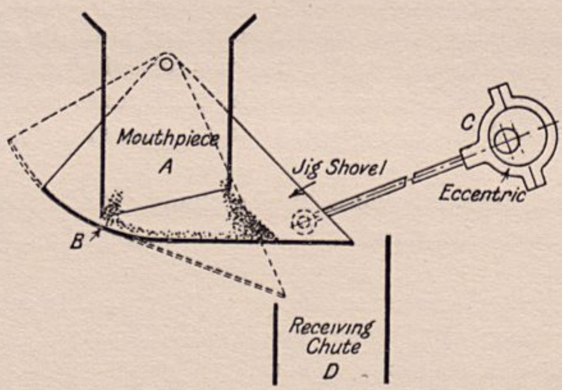

FIG. 32.—JIG FEEDER.

with cast iron there would always be the expense of new patterns or the necessity to build up special foundations, which are not always practicable.

As the direction, or nature, of the transporting medium is seldom the same in each job, cast iron would not be adaptable to varying conditions.

Small feed tables are sometimes used in place of sliding mouthpieces at the outlet of drainage bunkers, as in the example, as they admit of a large open space being left, by which the drainage water may escape without interfering with the efficiency of coal discharge. In these circumstances, a circular trough is fitted just below the outer edge of the rim to collect the escaping water. They are usefully employed to convey coal some little distance from the centre line of the mouthpiece to a conveyor placed eccentrically with that line. This is often done to maintain the dryness of the conveyor band under drainage bunkers.

In Fig. 32 is shewn a useful type of jig feeder which, on account of its cheapness and adaptability for all sizes of coal, is increasingly popular. The mouthpiece, A, is cut away at one side to allow the coal to spread out over the shovel, B, which is flat at this side and radiused up at the other. It is slung on a pivot and given a slight motion by the eccentric, C. The coal spread out on the shovel is carried forward on " out " stroke and the pressure of the rest behind it prevents it going back on the " in " stroke, thus ensuring a regular feed into the discharge chute, D. 100 r.p.m. is ample for most jobs.

CHAPTER VI

ELEVATORS

THE amount of coal which it is required to elevate having been fixed at so many tons per hour, it will now be necessary to determine the size and type of bucket and the chain speed which will best fulfil the conditions. As the subsequent working of the plant will in a great measure depend on the regular supply of the raw coal, a good deal of care and practical experience are very necessary in the selection of these two factors.

In the author's experience a great many of the faulty coal elevators to be found are the productions of inexperienced designers, and no amount of attention will nullify their bad working.

Speed.—The speed of the buckets is perhaps the most important point, and only practical knowledge of the working conditions and the class of men operating the plants can fix this with any degree of success. The chain speed of elevators used for coal washeries has been found from long practical experience to be most economical between 70 and 80 feet per minute, and for fine coal to storage bunkers this may be increased to 100 feet per minute under certain conditions, which will be explained in the chapter on Fine Coal Elevators.

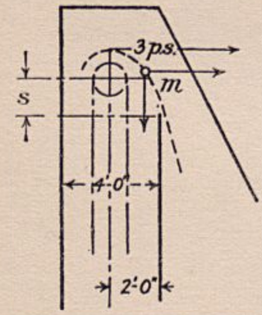

FIG. 33.—PATH OF DISCHARGE. VERTICAL ELEVATOR.

In no case should feed elevators to washeries have a chain speed of over 100 feet per minute, for, above this velocity, cobble and nut coal is subject to breakage on discharge and the discharge shoots are quickly worn through. A high velocity entails greater supervision of the bearings to prevent heating, and more care has to be taken in the take-up of the stretched chain. It is also necessary to make special feeding arrangements into the boot of the elevator, so that a constant supply of full buckets is obtained. The lips of the buckets ploughing through the spill at the base of the elevator are also more quickly worn out.

The velocity of the buckets is very important, not only as regards the maintenance, but it also affects the position of the elevator and the discharge shoot.

In Fig. 33 the head of a vertical elevator is shewn, and the particle m is just on the point of leaving the bucket.

Let the velocity of the chain be 200 feet per minute, then on rounding the top of the sprocket the particle has a horizontal velocity of about 3 feet per second, but the forces of gravity are acting on it, and it is pulled down into the path shewn in dotted line.

If the elevator is, say, 4 feet deep, and we require to find the minimum distance, s, between the centre of the sprocket and the top of the plating to obtain a clean discharge, we proceed as follows :—

As m moves horizontally at about 3 feet per second, it will pass over the plate p in $\frac{2}{3}$ of a second, but in that time the pull of gravity will have caused it to fall a distance s, obtained from the equation :

$$s = \tfrac{1}{2}\, gt^2$$

where $g = 32{\cdot}2$ ft. per sec. per sec., the acceleration of gravity,
$t =$ time in seconds.

Therefore,
$$s = \tfrac{1}{2} \times 32{\cdot}2 \times (\tfrac{2}{3})^2$$
$$= 7{\cdot}1 \text{ feet.}$$

Hence, the minimum distance required will be 7·1 feet, less the $\frac{1}{2}$ diameter of the sprocket.

The above is not strictly true, as the resistance of the air modifies the path of the particle, and the actual discharge does not take place in a well-designed bucket immediately over the top centre, but at some point about 30° over.

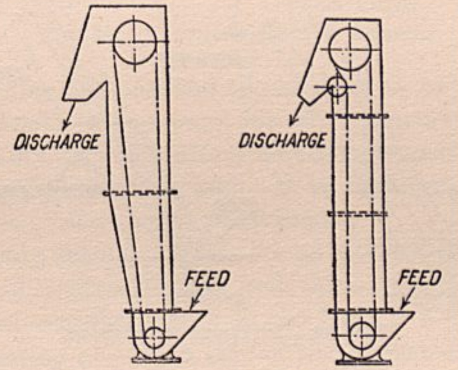

FIG. 33A.—VERTICAL ELEVATORS.

The effect of centrifugal force is only useful at a speed of 200 feet per minute and above.

The expedient of making the top sprocket larger than the bottom to obtain a cleaner discharge is effective only when the revolutions are maintained, as the force varies directly as the revolutions and inversely as the diameter.

The above remarks serve to illustrate the impracticability of running vertical elevators at a speed of less than 200 feet per minute, and therefore other means have to be devised to obtain clean discharge of coal to washeries.

To overcome the disadvantages of a bad delivery of the vertical elevator, various schemes have been introduced, of which those shewn in Fig. 33A are the most popular.

The head sprocket is made larger than the bottom sprocket, and the loaded chain is brought vertically up so that the empty chain is inclined inwards away from the discharge shoot, thus allowing a slight gain of receiving edge.

In this connection, it should be borne in mind that a small pulley of rim speed of 200 feet per minute has a greater centrifugal force than a larger one of the same rim speed.

The second method is that of the jockey pulley or idle sprocket, placed so as to cause the chain to bend in away from the discharge shoot.

These expedients cannot be recommended, especially for the type of machinery required for the handling of nut coal, and as the vertical elevator is for the most part useless to us, greater details are not necessary.

Inclined Elevators.—The best and most natural way of avoiding the above-mentioned troubles without recourse to mechanical contrivances is that of inclining the elevator from the vertical.

In Fig. 34 it will be seen that the minimum distance between the top of the sprocket and the receiving lip is much less than that of the vertical type, and a

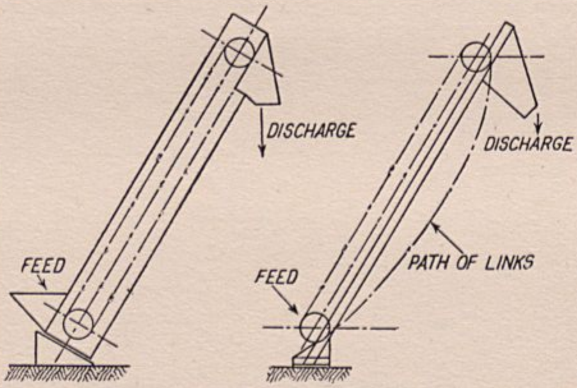

Fig. 34.—Inclined Elevators.

cleaner delivery is obtained, so that a low velocity can deliver the slack without difficulty.

There is no doubt that an inclination of about 60° from the horizontal is the best slope for an elevator, as at that angle, apart from running advantages, a moderate ground space is occupied and the appearance is not unsightly.

The coal industry is peculiar to the general practice, insomuch that the article handled is relatively cheap and bulky, but of such a tender or brittle nature that it must be handled with the greatest care.

As the value of coal is directly proportional to its size, it behoves the washery engineer to give that attention to detail so sadly lacking in many arrangements at the pit head.

The extravagant breakage of coal between the pit mouth and the slack belt is no concern of the washery, but as the resulting products of the latter are guaranteed in quality and quantity, the efficiency of the system has necessarily to be considered from the moment of delivery of the slack in the feed hopper to its eventual discharge in wagons for the consumer. To avoid breakage should be the axiom of all washery builders.

Buckets, Chains, and Links.—An important factor in the successful working of the elevator is the shape of the bucket, which should be selected with the greatest care. Slack coal may at times be wet, and, if much small is among it, it will have a tendency to stick on the sides of the bucket, so that the dimensions should be generous and the enclosing angles should not be less than those shewn in Fig. 35, and the bottom rounded off at a radius of not less than 3 inches.

The engineer will have to decide between a bucket and link, or a continuous bucket elevator.

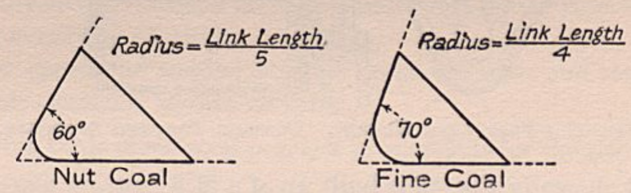

FIG. 35.—ELEVATOR BUCKET ANGLES.

If the slack contains nut coal and the amount to be elevated is small, the continuous bucket would be too small for efficient working, for it is essential that the supply shall not only be uniform, but of sufficient volume when entering the washer box to spread over the bed. It is, therefore, preferable to use an alternate bucket type of elevator in small plants.

In Fig. 36 is shewn a bucket suitable for an inclined chain link elevator. It is built up of a curved bottom plate, $\frac{1}{8}$ inch thick, and two flanged side plates, $\frac{1}{8}$ inch thick, riveted together; and on the back a 4 inches by $\frac{1}{2}$ inch M.S. flat is riveted, projecting over each side of the bucket about $2\frac{1}{2}$ inches. This

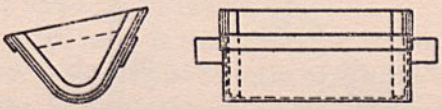

FIG. 36.—CHAIN LINK BUCKET.

flat acts as a crosshead for the bucket, the ends running over angle guides in the outer casing. On the lip and around the top sides a $1\frac{1}{4}$ inches by $\frac{1}{4}$ inch M.S. flat is riveted to strengthen the ploughing edge.

The chain link is riveted to the 4-inch flat by a bracket plate welded on every fourth link, and as the links are 6 inches, centre to centre of the pins, the pitch of the buckets is 24 inches. With a chain speed of 72 f.p.m. this elevator has a capacity of 40 t.p.h. of slack below 2-inch mesh. There are two lengths of chain of built-up stamped wrought-iron pieces connected with $\frac{7}{8}$-inch diameter pins. Width of bracket is 24 inches and depth 12 inches.

In Fig. 37 is shewn a Jeffery M.S. bucket made out of one plate $\frac{1}{8}$ inch thick, suitable for a vertical elevator and with a chain speed of 200 f.p.m., having a capacity of 36 t.p.h. It will be remarked that the latter bucket is merely bolted on to the link pins, with the intention of facilitating speedy renewal.

In this connection, it is worthy of note that cast-steel chain, where used in several lengths, is liable to uneven stretching, which causes considerable wear and noise. With mild-steel or wrought-iron stampings, this fault is absent.

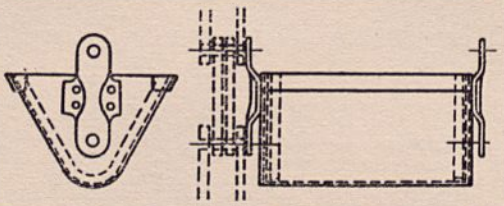

FIG. 37.—FLAT LINK BUCKET. OUTSIDE TOOTHED SPROCKET.

The bucket shewn in Fig. 38 is built up of a M.S. bottom plate $\frac{1}{8}$ inch thick, curved from the back to the front, and is connected to the side plates of $\frac{1}{4}$-inch M.S. by an angle iron of 2 inches by 2 inches by $\frac{1}{4}$ inch. The ingenious method of bulging out the bottom radius beyond the pin centre is to obtain a larger capacity without increasing the length of the link. To the lip of the bucket is riveted a 2 inch by $\frac{1}{4}$ inch flat, and on the lower edge of the side plate a flat

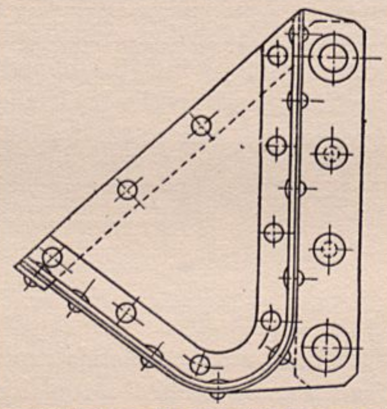

FIG. 38.—ELEVATOR BUCKET (ALTERNATE TYPE).

of 2 inches by $\frac{3}{8}$ inch is riveted to serve the double purpose of strengthening the side plate and acting as connection and part of the link chain. This elevator is of the inclined bucket and link type and has a capacity of 40 t.p.h. at 72 f.p.m. with buckets 24 inches wide.

Continuous Buckets.—This type is the most suitable for coal washeries of over 30 t.p.h., and of the many advantages the following are well worth noting :—

A continuous feed can be maintained without mechanical contrivances.

No ploughing in the boot of the elevator is necessary.

There is no spill over the top of the buckets.

The feed can be arranged at any point in the length of the elevator and at more than one point if required.

The back and side plates of the preceding bucket at the point of delivery act as a shoot for the following bucket and ensure a clean discharge.

There is no side spill on the links and skids.

A steady stream of slack is kept up and the elevator runs very smoothly, wearing evenly in all parts.

A slow speed and smaller buckets make the wear and tear lighter than that of an alternate bucket elevator.

The following table gives good practice proportions for the size of buckets :—

TABLE I

Elevator Bucket Capacities

Capacity, t.p.h. . . .	50	80	100	125	150
Width	12″	12″	14″	16″	24″
Depth	11″	16″	16″	16″	16″
Link centres	16″	20″	20″	20″	20″
Speed, f.p.m.	80	72	72	80	72

In Fig. 39 is shewn a good example of an elevator bucket of the continuous inclined type suitable for 80 t.p.h. at a speed of 72 f.p.m. The bottom plate and side plates are of $\frac{3}{16}$-inch M.S., connected by $1\frac{3}{4}$ inches by $1\frac{3}{4}$ inches by $\frac{1}{4}$ inch angles to the bent plate of $\frac{1}{8}$-inch thickness.

The side plates are made so that they overlap when on the straight portion of the run, and, therefore, the internal breadth of the one bucket is greater than that of the other. The part of the side plate which projects beyond the bent plate acts as a shoot for the discharge when rounding the top sprocket.

The side plates are also connected directly to the links, so that the links and the bucket form one whole. Immediately under the break of the bottom plate the link pin or bolt passes from side to side, and the former is likewise connected to it by $\frac{1}{4}$-inch hinges, which add a great deal to the strength of the chain.

The hinge bolt is $1\frac{3}{16}$ inches diameter and is secured at the ends by a $1\frac{1}{8}$-inch collar, through which a taper pin is driven and riveted over at the ends. The $\frac{3}{8}$-inch flat links are riveted to the buckets A, and on the bucket B the $\frac{3}{4}$-inch link flats are placed on the outside of the former. Whereas on bucket A there are a $\frac{3}{8}$-inch flat and a 1-inch forging, making in all a section of $1\frac{3}{8}$ inches, on the bucket B there are two flat links of $\frac{3}{4}$ inch each, making a $1\frac{1}{2}$-inch section. The clearance of the flats on the pins is $\frac{1}{32}$ inch per link or $\frac{3}{32}$ inch in all on each side of the bucket. The swelling out of the 1-inch link has no particular advantage apart from preserving the value of the section at the pin hole. All links could be made flat throughout by suitably proportioning links in bucket B. Flat links are considerably cheaper.

Chain Links.—As the majority of vertical elevators have a chain speed of

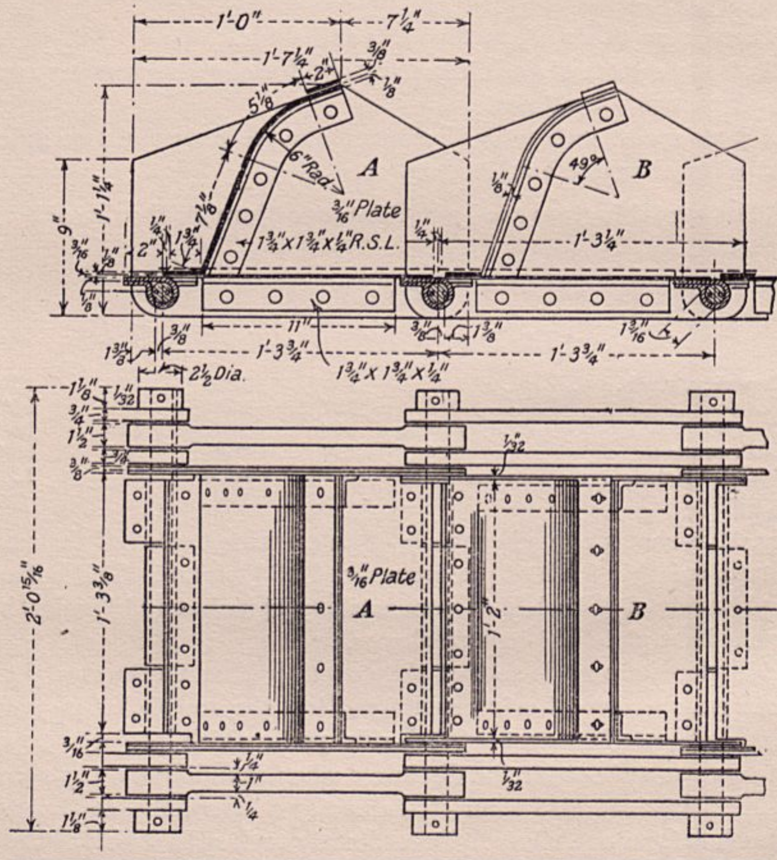

FIG. 39.—ELEVATOR BUCKETS.

over 200 f.p.m., the chain type is much more suitable than the flat link. In Fig. 40 two of the most successful makes are shewn; the first is that manufactured by Ewart's Chain Co., and the other has had a very extensive use in America and is known as the Jeffery chain.

The only stresses acting on a vertical elevator are those due to the weight of the buckets on the one side and the buckets full on the other side, plus, of course, the internal friction of the chain when rounding the sprockets and the starting pull.

Thus let W = total load on one side,
w = total weight of buckets on one side,
F = starting pull to overcome inertia of mass.

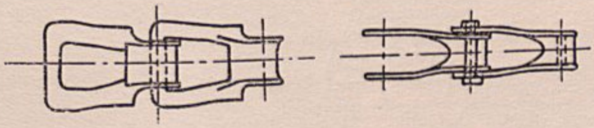

FIG. 40.—EWART'S AND JEFFERY TYPE CHAINS.

Then to give movement alone :

$$\text{Force} = \text{mass} \times \text{acceleration}$$

$$F_1 = \frac{(W + 2w)}{g} \times a,$$

and as the total load of buckets and material is held by the top sprocket, if P = the total pull of the dead load, then the maximum stress on links $= P + F_1$,

$$= \left(\frac{W + 2w}{g}\right)a + (W + w);$$

for practical application this should be multiplied $1\frac{1}{2}$ times.

Built-up Flat Links.—This type is almost exclusively employed on inclined elevators where the velocity is low and the capacity over 20 t.p.h. They are always used in pairs and are invariably utilised as slides for the buckets.

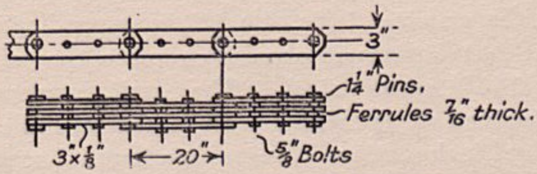

FIG. 41.—DETAIL OF FLAT MULTIPLE LINKS.

Flats of $2\frac{1}{2}$—$3\frac{1}{2}$ inches by $\frac{3}{8}$—$\frac{1}{2}$ inch are the sizes most usually employed, with hinge bolts of diameter equal to two-fifths of the width of the flat. The flat is longer than the length of the link centres by two bolt diameters plus $\frac{1}{2}$ inch, and is rounded off at the corners as shewn in Fig. 41.

The stresses on the chain in an inclined elevator may be calculated approximately in the following manner :—

Let

d = inclination of elevator to horizontal.
F = force to overcome inertia.
W = load.
w = weight of buckets on one side.
P = pull of the dead load.
a = acceleration.

$$P = (W + w) \sin \alpha.$$
$$F = \left(\frac{W + 2w}{g}\right) \times a$$

Total stress
$$S = F + P.$$
$$= \left(\frac{W + 2w}{g}\right)a + (W + w) \sin \alpha.$$

As the friction of the links on the guides and the pin friction plays an important part, this result should be doubled for practical use.

It not infrequently happens that the elevator is utilised for small slack and the buckets become overloaded in the boot, so that the coal is spilled over the sides on to the links, which causes the spaces between the flats to become choked, and in time, owing to the collected moisture and the non-circulation of the air, the links become rapidly rusted and bent. In several such cases the author found that a good remedy was to insert packing pieces of oak between the flats. In fine coal elevators feeding at points above the boot, this precaution is well worth the extra expense.

Mr. Ivor Williams, of the Powell Duffryn Co., has informed me that a great deal of trouble with the links of his large elevators has been overcome in the following manner.

The links and the wearing strips of a 150 tons per hour elevator were so rapidly worn out that it was resolved to replace the mild-steel links and rubbing strips by 0·05% carbon steel. The result, however, did not justify the change, and he then experimented with mild-steel links and oak rubbing strips of 3 inches by ½ inch section. It was then found that where the coal was moist the trouble was completely overcome, but in the case of a very dry slack the strips wore similarly but no more rapidly than the mild steel. The bucket links in the latter case, however, did not experience anything like the wear formerly occurring, hence oak rubbing strips are now being fitted in the elevators of this important colliery company.

In Fig. 41A is shewn a curved elevator of sound construction.

Two channels form the main framework and the skids are bracketed from them. The bearings supporting the shafts are of the angle pedestal type and

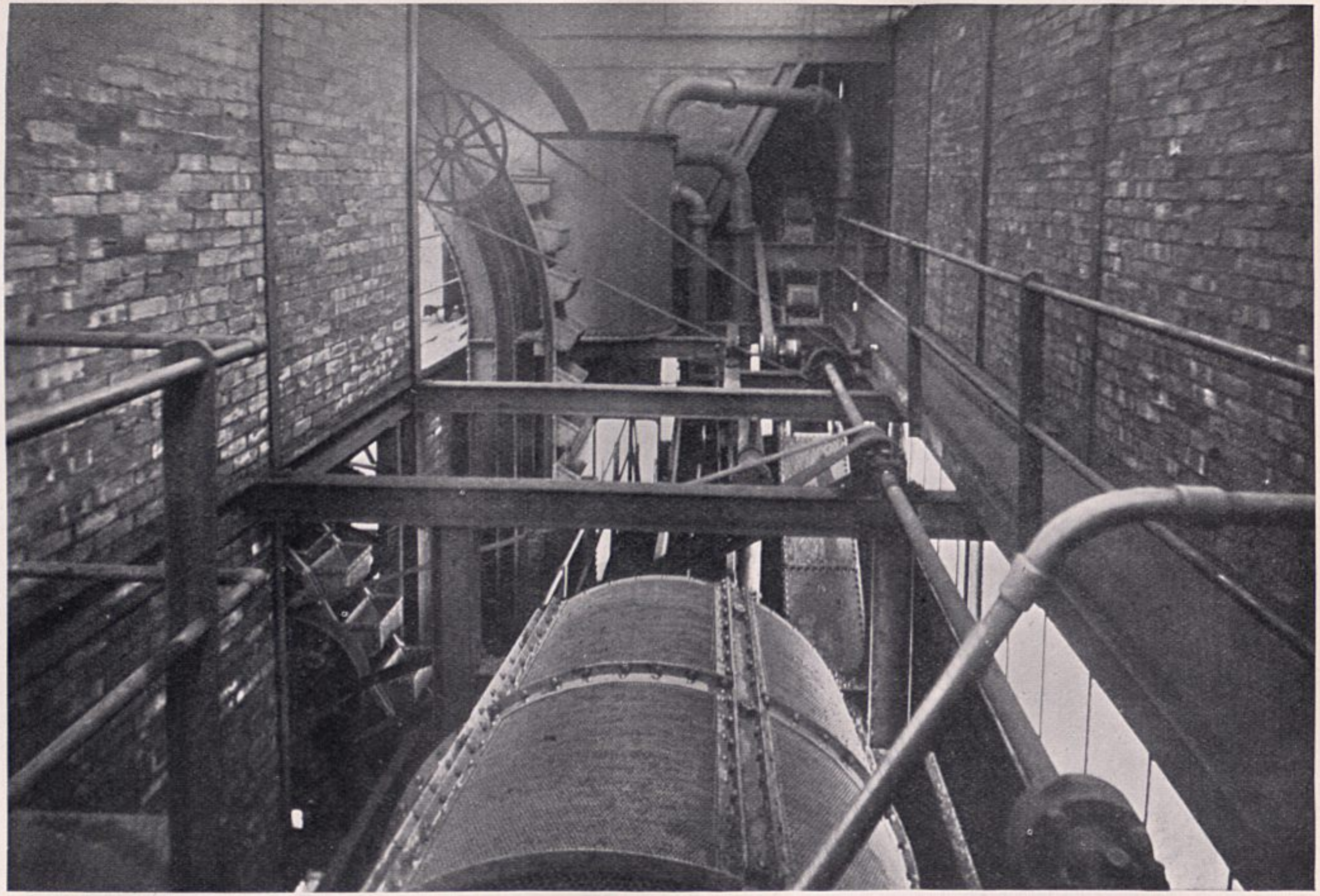

Fig. 41a.—Shewing Curved Elevator and Tubular Revolving Screen.
(*Butterley Co.*)

[*To face page* 60.

are bolted direct to the channels. The loaded side is completely open, but the return bucket side is troughed in to guide the spill back to the boot. There are three elevators shewn in this photograph, and each is of the alternate bucket type. Note the method of connecting the perforated screen plates to the channel rib of the revolving mantle. Small angles are riveted to the mesh plates, and these are bolted to the projecting flange of the channel. In this position they are always accessible.

Sprockets.—The chain is put into motion by the revolution of a toothed sprocket at the head of the elevator as shewn in Fig. 42; generally this sprocket is round with chain links and polygonal with flat links. The teeth engage with the chain in the same manner as a bicycle drive and thus pull the bucket over

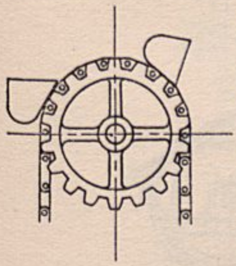

Fig. 42.—Toothed Sprocket.

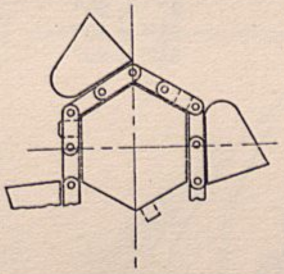

Fig. 43.—Alternate-toothed Sprocket.

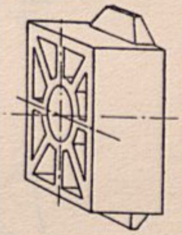

Fig. 44.—Tumbler Sprocket.

the top centre. Chain sprockets are sometimes made with flat faces long enough to house two links at the same time, the projecting tooth engaging with the first link only, and the bucket link riding on a blank face as shewn in Fig. 43.

The form of sprocket in most general use with heavy elevators is the square or tumbler disc shewn in Fig. 44. There are only four faces, with projecting guides or lugs on two opposite faces, which serve to guide the link and keep the bucket central on the shaft. This type is exclusively used for flat links.

The round or toothed sprocket prevents slip by the projecting teeth, but in the tumbler type it is impossible for slip to take place, as the links are at all times at right angles over the head of the tumbler, or, in other words, in the position of maximum leverage. This design of head gear is actually borrowed from the German practice and is without doubt the most reliable.

The single chain requiring only one sprocket is only suitable for buckets of a maximum width of 16 inches, and even then is to be used with care, to ensure an evenly distributed fill to prevent twisting of the chain. The single sprocket is more suitable for vertical elevators, where there is no side drag as on the skids of inclined types.

Side- and double-chain sprockets are shewn in Fig. 45; the former is always centrally placed, but the latter may be at the sides or at equal distances from the centre line within the width of the bucket.

For economy of material in the elevator casing it is advisable to keep the sprockets as small as practicable, and the following table may be taken as a good practice :—

TABLE II

Dimensions of Flat Links and Sprockets of Elevators

Capacity of elevator.	Links.		Sprockets. Face.
30 tons per hour.	2½″ × 12″		9½″
50 " " "	3″ × 16″	Continuous	13″
75 " " "	3″ × 20″	"	17″
100 " " "	3″ × 20″	"	17″
125 " " "	3½″ × 20″	"	16½″
150 " " "	3½″ × 20″	"	16½″

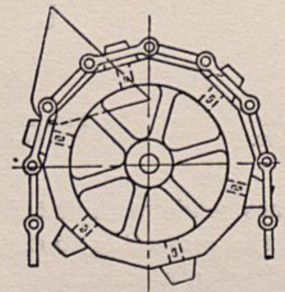

FIG. 45.—SIDE SPROCKET FOR DOUBLE CHAIN.

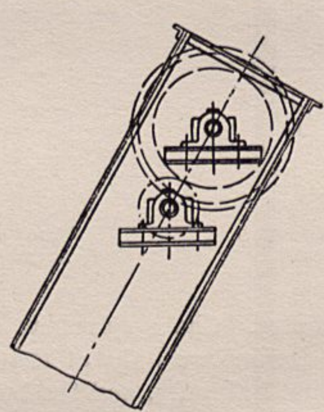

FIG. 46.—EXTERNAL BEARINGS, INCLINED ELEVATOR.

In Fig. 46 is shewn an economical method of supporting driving shaft and sprocket shaft of a small inclined elevator. Channels of 6 by 3 inches or 8 by 3 inches section are bolted to the web plates, and the bearings, of ordinary plummer block type, are bolted thereto.

Horse Power.—The horse power required to drive an elevator may be found as follows :—

$$\text{H.P.} = \frac{\text{W} \sin \alpha + \mu(\text{W} + w) \cos \alpha \text{V}}{33{,}000}$$

where V = velocity per minute.
μ = coefficient of friction 0·3 for guides.
0·15 for rollers.
α = angle of inclination to horizontal.
$\text{W} + w$ = in lbs. weight.

A rough rule which the author has applied with considerable success is :

$$\text{H.P.} = \frac{(\text{W} + \frac{1}{10}w)}{300} \text{ for inclined elevators between } 55^\circ \text{ and } 70^\circ.$$

Diameter of Shafts.—The diameter of the shafts at the head of the elevator may be found by the following formula :—

$$d = \sqrt[3]{\frac{321{,}000 \text{ H.P.}}{fn}}$$

where d = diameter in inches.
f = allowable stress in steel.
n = revolutions per minute.

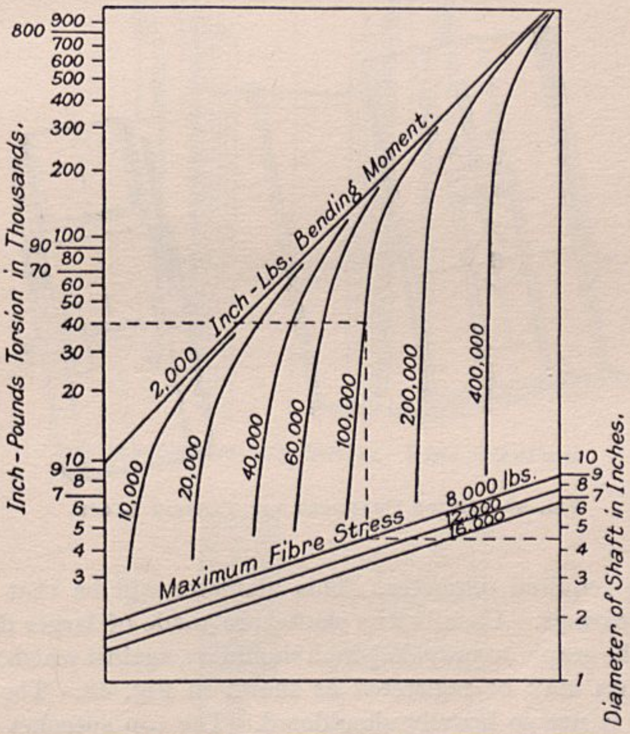

FIG. 47.—DIAGRAM TO FIND SHAFT DIAMETERS FOR COMBINED TWISTING AND BENDING.

From the formula it will be noticed that the greater the number of the revolutions the less the diameter required.

The bottom sprocket being merely an idle guide and serving only as a tension pulley, the shaft on which it is mounted may be of smaller diameter than the head shaft.

The above formula does not take the bending of the shaft into account, but is quite suitable for small elevators where the width of bucket is not greater than 10 inches. Beyond this width, the shaft should be designed to withstand bending as well as the twisting moment. In Fig. 50 is shewn a graph giving suitable diameters of shafts for various bending moments and twisting moments at different maximums of allowable stress in the steel.

The dotted line indicates how the graph may be used. The example given is to find the diameter of a shaft having a twisting moment of 40,000 inch-lb. and a bending moment of 100,000 inch-lb. From the left-hand side of the diagram follow the ordinate across from the given torsion until the curve of given bending moment is encountered, and then drop vertically to the line of the required allowable stress and then horizontally to the left side of the diagram.

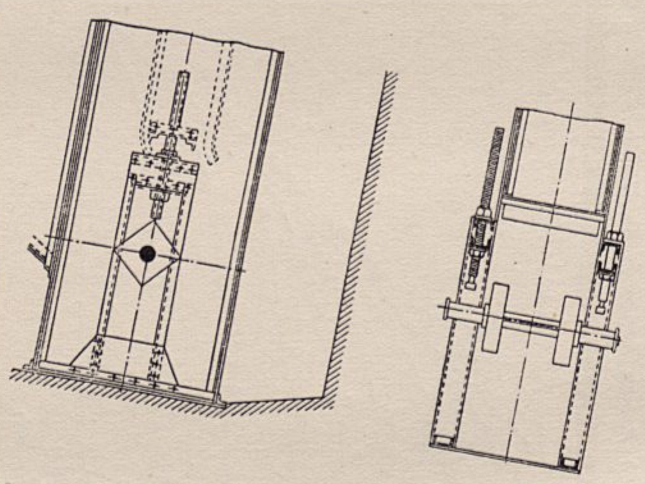

FIG. 48.—GUIDE CHANNELS FOR TENSION BLOCK.

This gives the required diameter. This diameter will be that of the shaft between the bearings. Usually the shafts are made of larger diameter than that given by the graph, to provide ¼-inch shoulders, against which the sprockets and the bearings may be registered as shewn in Fig. 48. The idle bottom sprocket shaft is not so heavily shouldered. The top sprocket shaft is held in the bearings by an end locking cap of ⅞-inch circular disc, into which the end of the shaft is socketed and held by three countersunk set screws, ½ inch diameter, to give sufficient clearance to the fast pulley. The other ends of the shafting are all secured by lock nuts or a loose collar as shown in Fig. 49, which gives the general arrangement of the elevator head. The driving shaft wheel is run at 65 r.p.m. and the sprocket shaft at 13 r.p.m. The spur is of cast iron, while the pinion is of forged steel, both machine-cut teeth.

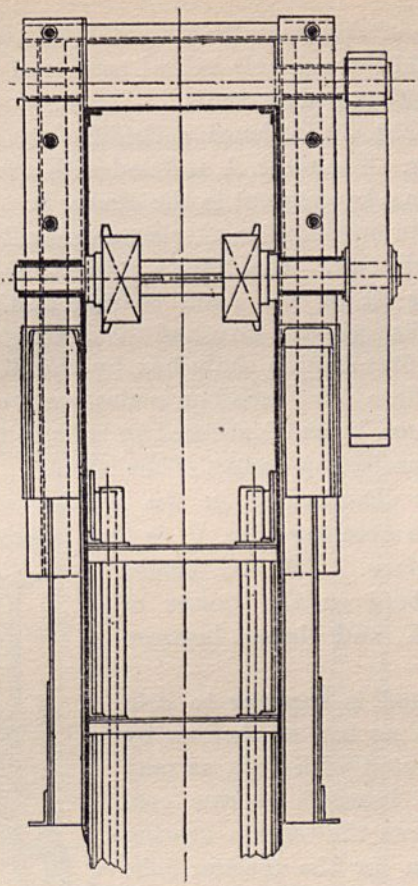

FIG. 49.—DRIVING END DETAIL. FEED ELEVATOR.

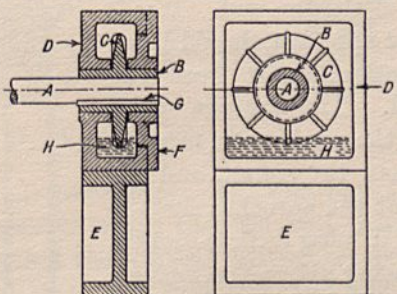

FIG. 50.—BEARING BLOCK FOR LARGE ELEVATOR DRIVING END.

In the heavier type of elevators, the spur wheel should be of cast steel, but if of cast iron it should have double helical teeth and be about $1\frac{1}{2}$ times the width of face of the cast-steel plain tooth.

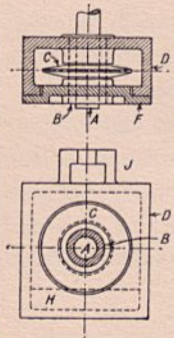

FIG. 51.—BEARING BLOCK, LARGE ELEVATOR. TENSION END.

In Fig. 50 is shewn a detail of an efficient oil-lubricated bearing. The shaft, A, is fitted with a feathered key, G, which fits into a keyway cut in the sleeve, B. This sleeve, B, is cast with a projecting disc, C, placed centrally and tapered towards the perimeter. This sleeve rotates with the shaft and is a running fit in the main bearing casting, D. This casting takes the form of a box, and the driving shaft box is connected to the first motion shaft box by the distance piece, E. The cover plate, F, of each box is also bored out to a running fit for the sleeve, B, and is secured by bolts to the box, D, registering on the projecting flanges of the latter.

The chamber, H, in the box is partially filled with oil, and the rotating disc, C, is thus constantly carrying oil on its surface. This oil drains down between the bosses of the castings, D and F, and thence between the running surfaces.

This positive method is superior to drip lubrication, as there is no fear of choking by the oil becoming saturated with dust, as may easily happen in the bearings of raw coal elevators. Fig. 51 shews the tension bearing with the lug extension for the tension bolt. The cover plate is provided with an oil level gauge and tapping plug. In Fig. 52 is shewn an arrangement of tension end. It will be noted that the upper sprocket should be of much heavier construction, apart from the quality of the material. The average speed of the main shafting in the washery is, in good practice, never more than 180 r.p.m., and the reduction to 12 r.p.m. at the sprocket shaft is obtained by inserting a driving or first-motion shaft in the elevator casing above the former, and communicating its motion by means of a spur and pinion gearing with a reduction of about 5·1.

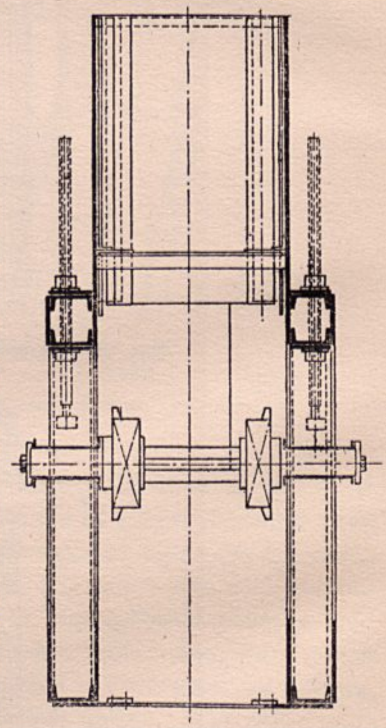

FIG. 52.—FEED ELEVATOR. DETAIL TENSION END.

The bearings for these shafts are sometimes supported on M.S. channels placed across the side casing of the elevator as shewn in Fig. 46, or in special castings, placed between M.S. channels in the run of the framing as shewn in Figs. 48, 49, and 52.

Both methods are quite good; the former has the advantage that one shaft may be removed from its bearings for repairs without disturbing the other, whereas in the latter case it is necessary to remove the shafts and bearings bodily. Where a top end tension is required the latter method of supporting the shafts is invariably employed.

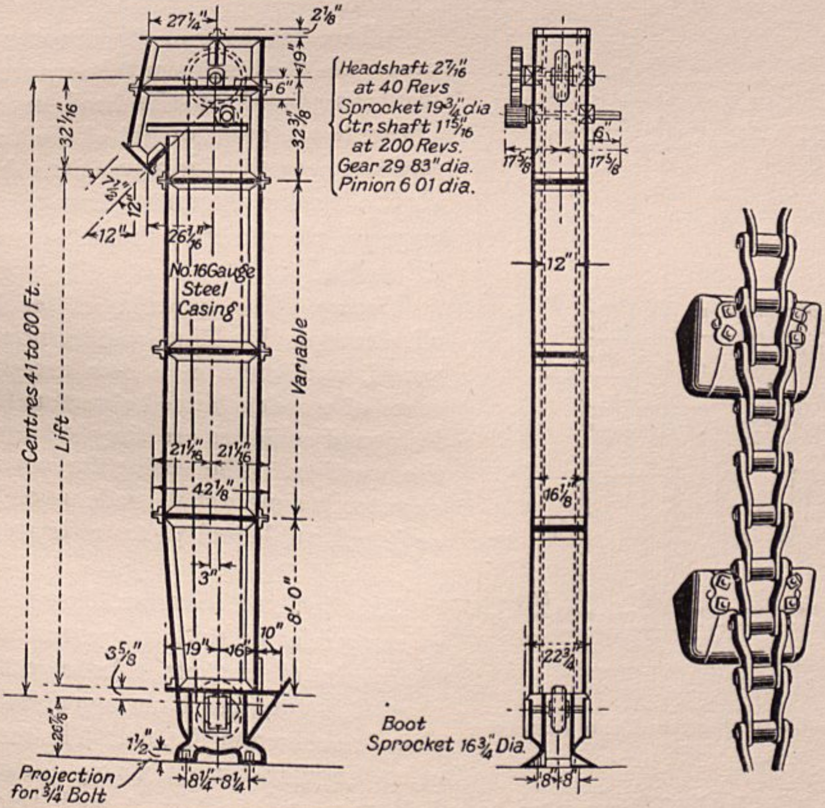

Fig. 53.—Vertical Elevator (Jeffery Type).

Take-up or Tension Arrangements.—The link pins are generally $\frac{1}{16}$ inch less in diameter than the holes in which they fit, and therefore when the chain is hung on to the top sprocket the top and bottom centres are not exactly at the distance apart at which they were designed, and when subject to a constant load, wear and tear, and stretching of the material, this distance is further increased. For good steady working the link chain must engage freely and evenly with the top and the bottom sprockets and, therefore, any stretch must be taken up. This is effected by making the top sprocket a fixture and the bottom sprocket movable in guides.

Each side bearing of the bottom shaft is kept in place laterally by the channel guides and vertically by the tension screw-bolts, *f*. The head of the bolt is bellied out and fitted in a socket in the top part of the bearing casting, while the threaded end passes through the channel, *d*, and is secured thereon by a lock nut. A sufficient length of thread at the end is allowed to take up a stretch equal to one link length plus 3 inches, so that after stretching this amount, two links, one on each side, may be removed from the chain and the sprocket brought back to the original centre.

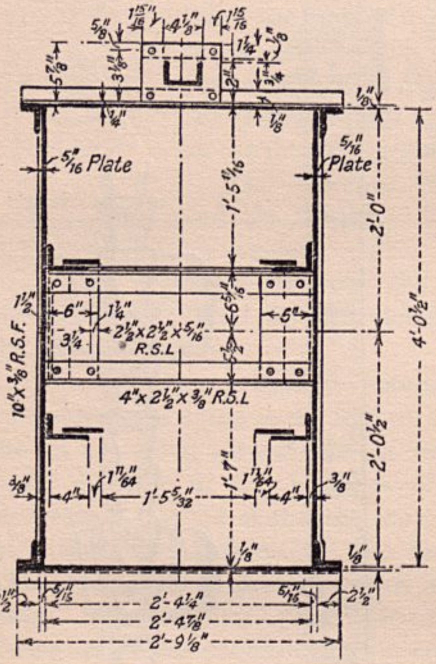

FIG. 54.—CROSS SECTION, FEED ELEVATOR CASING.

Where the boot of the elevator is inaccessible, the tension or take-up arrangement is placed at the head sprocket. Owing to the great weight of the buckets and the necessity for moving the driving shaft a similar amount to keep the gears engaged, this practice should be avoided if possible.

Casing.—The practice of enclosing all elevators handling coal is now universal, and only in a few exceptional cases of wooden-framed elevators in old-fashioned collieries are they left open to the weather. The casing for a vertical elevator is a mere shell made up of ⅛-inch or ¼-inch mild-steel plates as is shewn in Fig. 53.

The inclined elevator, however, requires guides or skids to prevent sag in the chain of buckets. An elevator of about 100 tons per hour is generally enclosed as shewn in Fig. 54. The casing is of rectangular section, having side or web plates $\frac{5}{16}$ inch thick, connected to a bottom plate ⅛ inch or $\frac{3}{16}$ inch thick by main angles 2½ inches by 2½ inches by $\frac{5}{16}$ inch section. The web plates are strongly connected together by cross ties and gusset plates every 7 or 8 feet. The whole of these are riveted together, while the top plate is bolted on to allow of easy access to any part. At intervals of 7 or 8 feet vertical angle stiffeners are riveted to the web plates.

The elevator section so built up is generally made up in the shops in lengths of 15 to 20 feet, dispatched to the job, and there joined together. The top and bottom lengths are specially designed to house the tension and driving-shaft castings. The web plates should have manholes cut in them at intervals of 20 feet to allow inspection of the bottom chain and buckets.

To prevent the sagging of long elevators it is necessary to support the casing from the ground or building by struts inserted at intervals, depending upon the load and the slope.

For a slope of 60° to the horizontal the above example would require supports every 50 feet of length as a maximum interval. The boot of the casing should rest on a concrete base, which should be dished out to allow of the extension of the links one bucket length as shewn in the chapter on Feed Hoppers.

The bottom sprocket of a continuous-bucket elevator should be placed at about 12 to 18 inches below the lower lip of the feed hopper outlet. On the top plate of the casing directly opposite this outlet an aperture of slightly less than the width of the bucket, and two links long, should be cut. Covering this opening in the casing is a ½-inch plate slide. This slide is operated from the ground level or the washery floor by means of a hand wheel and rack and pinion connecting with the slide by a channel of light section, say 4 inches by 2 inches by 7·9 lbs.

On the inside of the casing the bucket guides are bolted, not riveted, for facility of renewal.

When used with a square sprocket or tumbler, these guides are not spaced equidistant from the centre line of the elevator; the top guide angle being nearer to the centre line than the lower angle. The skid angle in small elevators is continuous and is usually of 4 inches by 2½ inches by ⅜-inch section, with the shorter flange connected to the web plates and separated therefrom by circular packing pieces or washers of about 2½ inches diameter and 1¼ inches thick.

By separating this angle from near contact with the web plate, pitting or corrosion of the latter locally is avoided, and there is less risk of the webs pulling the angle out of a true line, or of uneven wrinkling of the thin web plates.

The bolts connecting the skid angle to the side plates should be at a minimum pitch of 24 inches.

On the top side of the projecting flange a mild-steel rubbing strip of 3 inches by ⅜-inch section is bolted by countersunk bolts at 8 inches pitch. If carbon steel is used for the links the rubbing strip must also be of carbon steel.

The position of the top guide is arrived at in the following manner. If the links are built up of 3-inch flats and 16-inch centres, then the sprocket face will be equal to the length of the link, less the width of the flat, assuming the centre of pin in the centre line of the link, that is, 13 inches.

When the tumbler is placed square to the centre line of the elevator the top face will be at 6½ inches from the centre line; but when the tumbler is diagonally across the centre line the upper corner or the bottom of the link will be at

$9\frac{5}{8}$ inches from the centre line, so that the link chain will rise and fall $3\frac{1}{8}$ inches at the sprocket. To equalise the movement of the buckets the mean of this bumping motion is added to the minimum diameter of the sprocket faces, *i.e.* $6\frac{1}{2}$ inches + $1\frac{1}{2}$ inches = 8 inches will be the distance of the top guide from the centre line of the elevator.

After rounding the top centre, the surface of contact or rubbing edge of the link is reversed and hence the distance of the bottom guide from the centre line is increased a full link depth, and as the backs of the buckets of a continuous elevator serve as a shoot to those following, it is of advantage to run as close to the bottom plate of the discharge shoot as possible. As the maximum diagonal distance of the sprocket is $9\frac{1}{8}$ inches and the width of the link is 3 inches, the minimum distance of the guide angle should be $12\frac{1}{8}$ inches from the centre line. To prevent binding or tight working and to obtain good delivery 1 inch to $1\frac{1}{2}$ inches are added to the above, so that the bottom guide would be placed at $13\frac{1}{8}$ inches from the centre line.

This type of elevator works satisfactorily up to 50 tons per hour and at a slope of not less than 55°.

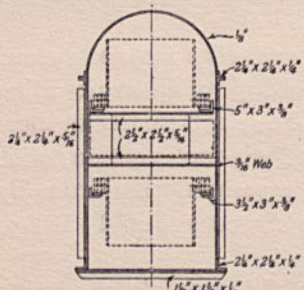

Fig. 55.—Large Elevator Casing.

The skids wear out quickest at the boot end, due to the greater friction caused by accumulated dust and dirt. They are stopped short of the sprockets and the runner angles bent down from the rubbing surface.

A heavier type of casing used for elevators of from 100 to 150 tons per hour is shewn in Fig. 55.

The main portion of the casing is made up of two $\frac{3}{16}$-inch web plates placed at the required distance apart to accommodate the width of the bucket. The depth of the web plate is three-quarters the overall depth of the casing from the bottom.

The main angles are riveted along the edges, and the webs are strongly connected by cross ties and gusset plates. To further strengthen the casing, internal cross bracing of angle sections is run zig-zag fashion throughout the length of the elevator.

The bottom plate of the casing is made flat and bolted to the $2\frac{1}{4}$ inches by $2\frac{1}{4}$ inches by $\frac{1}{4}$ inch corner angles. Suitable cross stiffener angles of $1\frac{1}{2}$ inches by $1\frac{1}{2}$ inches by $\frac{1}{4}$ inch are riveted at four-feet intervals.

The top quarter is made semicircular to avoid the deposit of dust. It is found in practice that flat top surfaces rust quickly and are soon eaten through, but with this type the rain will wash off any accumulation of dust on the surface. It is made $\frac{1}{8}$ inch thick in lengths of about 4 feet.

Side stiffeners of $2\frac{1}{4}$ inches by $2\frac{1}{4}$ inches by $\frac{5}{16}$-inch section are riveted to the web plates at intervals of about 4 feet.

As in the former example, the casing is made in convenient lengths for transport and built up on site.

It is not good practice to overlap the web or side plates, but the runners and cross bracing should be so divided that one of the members is exactly halved at the joints.

For convenience of oiling and accessibility to any part, it is good practice to run side ladders of light section on each side of the elevator and connected by gusset plates to the side stiffeners.

Elevators dealing with larger amounts of coal than 50 tons per hour require some method of link support which shall have less frictional resistance than the continuous-skid angles and rubbing strips. Roller bearings or supports of about 12 inches diameter, placed at about 9-feet centres, prove effective in reducing friction at least 50%, providing they are kept greased. The rollers are supported on a $1\frac{3}{4}$-inch bolt running from side to side of the web plates and free to revolve in a circular bearing bolted to the web. The rollers are keyed on to the shaft, so that they are kept in the correct position immediately under the links.

It is not necessary to place rollers on the empty bucket side, where the elevator is inclined at an angle of 55° or over, but at more acute angles they should be spaced as above, but connected to the web bearings independently by a short bolt. A through bolt cannot be fitted on account of the return buckets being underslung, *i.e.* hanging below the link support.

The contact points of the rollers are placed at a distance from the centre line as in the case of the skid angles.

To avoid the nipping of the links between rollers when starting from rest and to support the buckets when repairs are being carried out, skid angles are fitted to the casing between each pair of the rollers and at about 3 inches below the tight chain or the upper tangent of the roller surface. In this case, no rubbing flats are required, as there is no moving contact.

Where continuous-skid angles and flats are fitted on the return side, it is advisable to place a roller support at 5 to 6 feet from the bottom sprocket to save abnormal wear of the flats and skid at this point due to a local hard bearing or hunching up of the links when ploughing the coal in the boot of the elevator.

The author has had brought to his notice elevators which have worn out M.S. rubbing strips of $\frac{3}{8}$ inch and an angle flange of $\frac{3}{8}$ inch in the exceedingly short time of 12 hours' working from the time of the starting up of the new plant, and the subsequent adoption of the above suggestion proved effective in avoidance of further trouble.

To keep the buckets central side guides are bolted to the web plates in a manner similar to that of the skid angles. They are generally of $\frac{1}{2}$ inch by 3 inches flats and are placed with the bottom edge flush with the contact point of the roller and link.

The operating slide and gear are on the top plate of the elevator and are similar to those already described.

At the joints, strong butt straps amply riveted to the web plates connect up the sections, whereas the top and bottom quarters of the casing are bolted together by cover plates or tee angle sections.

Curved Elevators.—From the point of view of maintenance, curved or bent elevators are not to be recommended, and their use can only be excused on the score of a cramped ground site. They differ from the straight type insomuch that they require a larger number of roller supports top and bottom around the curved portion.

In the continuous-bucket type they need not be closer than 2½ links length.

In rounding the curve, it is good practice to increase the depth of the side plates and the distance apart of the link supports by taking the same radius of curvature for the top and bottom plates. This method equalises the stress due to the bending moment throughout the section. The cross-section of a bent elevator is invariably rectangular with heavy web plates of ¼ inch and well stiffened by vertical angles. If the rise of the elevator from the boot is more than 75°, it will be necessary to fit top and bottom guides over the links on the loaded and empty sides to prevent any jerkiness in working and to keep the bucket in line during repairs.

Fine Coal Elevators.—This type of elevator, having to deal with a material of a loose and clinging nature, must have a bucket which is shallow and broad and containing no sharp angles.

To avoid choking, it is not usual to make these elevators with continuous buckets, and in Fig. 56 is shewn the type of the bucket used. In construction they are similar to the raw coal elevators, with the exception that for the same capacity they have buckets 50 to 60% wider and 30% shallower, and, therefore, the casing will be reduced in depth but increased in width.

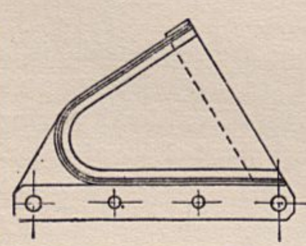

FIG. 56.—CRUSHED COAL ELEVATOR BUCKET.

The bucket shewn in Fig. 39 is not suitable for a fine washed coal type owing to the fact that the bottom plate, being at an angle of 70° to the link, would, on rounding the top sprocket of an elevator inclined at 60°, be at 50° to the horizontal, which is not enough to shoot off any material falling thereon.

For this reason it is good practice to make fine-coal elevators of the bucket and link type, taking the precaution to insert packing pieces between the link flats, to avoid the lodging of small coal and dirt in these spaces and a consequent increase of friction and wear.

In calculating the capacity, the bucket must be taken as only half full, as in the most favourable of conditions a fair amount of small coal becomes embedded in the corners and can only be removed by hand scraping. The initial cost of a fine coal elevator is greater per ton of capacity than the raw slack elevator.

German engineers favour the type of elevator which scoops up the coal in the boot, rather than the elevator which has a feed into the buckets. The elevator is made broader than in our general practice, and the boot regulating slide is so placed that it allows the natural slope of the coal in the boot to drown the bucket passing round the bottom sprocket.

This method is adopted (in preference to feeding higher up the casing as in the British practice) to lessen the chances of spill on to the links and to avoid the necessity for automatic feeders to deliver into an entering bucket.

The casings have main members of about 10 inches by 5 inches R.S.J. section running throughout the length, and on these, cross members of $2\frac{1}{2}$ inches by $2\frac{1}{2}$ inches by $\frac{3}{8}$-inch angles to the top and bottom flanges, the angle being square to the flange. Hard up against the R.S.J. are two vertical angles of similar section, serving as supporting struts for the runner angles, which are $3\frac{1}{2}$ inches by $3\frac{1}{2}$ inches by $\frac{3}{8}$ inch.

The casings are thus a mere shell connected to the joist sections and can therefore be of light sheeting, generally about $\frac{1}{8}$ inch thick.

The bottom sprocket is fixed relative to the casing and is supported in cast-iron bearings of a length equal to three diameters bolted to the R.S.J. The advantage of scooping up the coal from the boot of the elevator is negatived by the great disadvantage of having to apply the tension at the head of the elevator.

The driving or first-motion shaft is supported in bearings held in position by a double-headed screw bolt between that bearing and the sprocket shaft bearing, this latter being secured by only one tension bolt with a single nut.

There is little check for side play on the channel guides, and any movement out of centre of the bucket chain will be communicated by the sprocket guide flanges to the bearings and tend to bend the tension screws. The gear wheels and pulleys are secured by set pins or stout driven keys.

In British practice, the bearing casting is flanged to prevent lateral play and hence prevent bending of the tension bolts.

The distance screw between the bearing castings is not to be recommended, as faulty adjustment will put the shafts out of line and cause excessive noise and wear of the teeth of the gearing.

Since these shafts are generally in an inaccessible position, behind the spur and pinion wheels on the one side and the pulley on the other, a fine adjustment is impossible without unshipping all wheels.

After a period of working when the gearing becomes worn and the shock of the teeth more pronounced, the likelihood of the screw bolts slackening back is sufficient to condemn the practice for use in British collieries.

In Fig. 57 is shewn a novel type of elevator bucket for slack coal. It is a type which is strong and durable and suitable for dry coals, and could be easily standardised, the manufacture being of a simple nature, the same curvature being employed for all sizes of bucket.

A good representation of the throw off at the elevator head and the necessity for properly designing the back plate of the bucket are shewn in Fig. 58.

Fine and damp coal lodges readily on the back plate, and if this is not placed at the correct angle a large amount of material will be constantly returned to

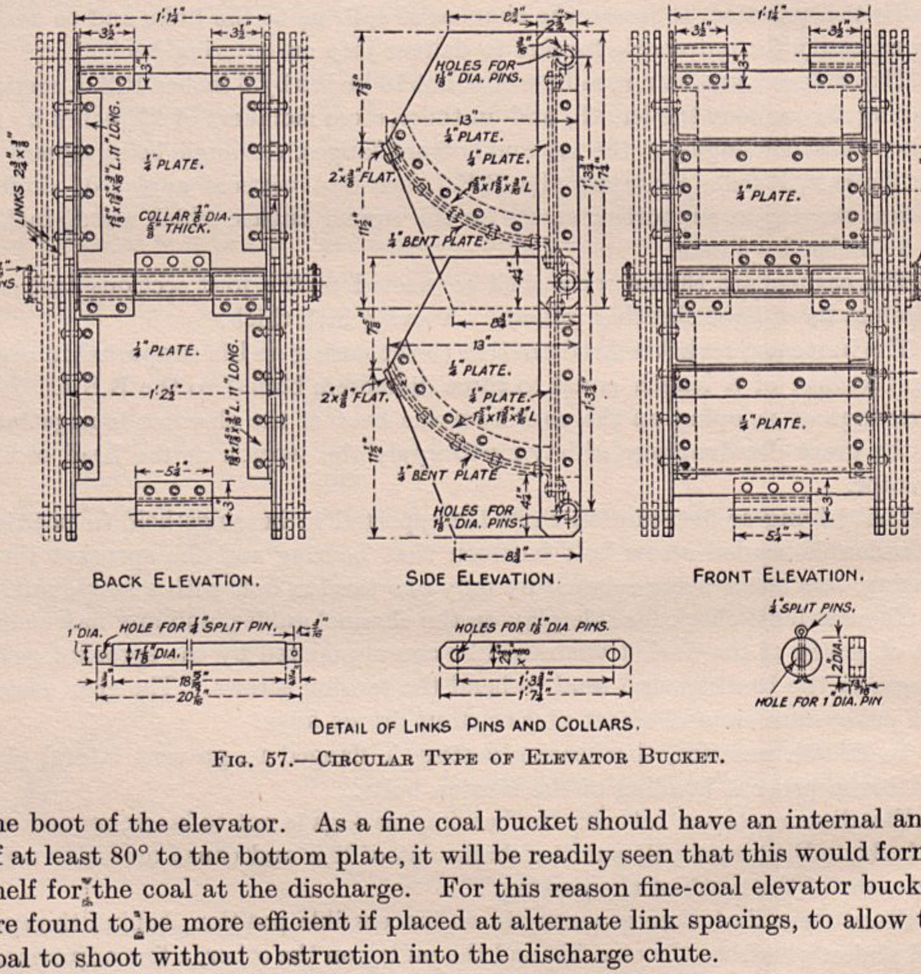

Fig. 57.—Circular Type of Elevator Bucket.

the boot of the elevator. As a fine coal bucket should have an internal angle of at least 80° to the bottom plate, it will be readily seen that this would form a shelf for the coal at the discharge. For this reason fine-coal elevator buckets are found to be more efficient if placed at alternate link spacings, to allow the coal to shoot without obstruction into the discharge chute.

The shaded portions of the buckets represent the contours of the coal in turning over the centre. In bucket *a* the coal is heaped up near the lip and in *b* it begins to flatten out, and then in *c* it is discharged from the top first, the remainder shooting over the back of the preceding bucket.

Between the bottoms of the bearing castings and the mild steel elevator support frame it is good practice to insert hardwood packing to take up any inequality of surface, and to diminish the rattle and vibration often occurring where steel is placed on steel.

There is no hard and fast rule regarding the relative positions of the sprocket and driving shafts; either may be placed on top.

Shale or Dirt Elevators.—This type of elevator is utilised to empty the washer boxes of the shale extracted from the raw slack in the process of washing.

As the boot is some 12 to 14 feet below the water level in the washer boxes (see Fig. 59), it is necessary to make the lower part of the casing water-tight.

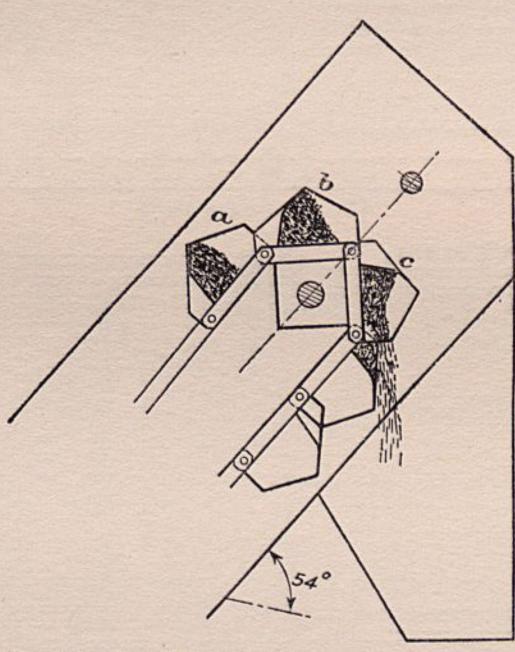

FIG. 58.—DISCHARGE OF CONTINUOUS ELEVATOR.

The slope is generally 60° to 65° to the horizontal and the top sprocket at about 9 feet above the top of the washer box, so that the length varies from 20 to 24 feet. The lower part being constantly full of water, the casing is made sufficiently strong to withstand the pressure of water, and is never less than $\frac{3}{8}$ inch thick, from the boot to about 3 feet above the maximum water level. From this point to the head the elevator is merely cased in on the back to form a return trough for the drainage water from the buckets.

As shewn in Fig. 61, the buckets are perforated with $\frac{3}{16}$-inch holes and are made long in proportion to the depth, to ensure easy drainage in the ascending chain. As the wet shale clings to the buckets, the receiving lip of the discharge shoot should be kept well down or almost vertically under the tangent to the sprocket face.

Unlike slack elevators, the tension arrangement is fitted at the head and has tension and pressure screw bolts to secure the sprocket shaft in position (see Fig. 60).

As the driving shaft must of necessity rise with the sprocket shaft take-up,

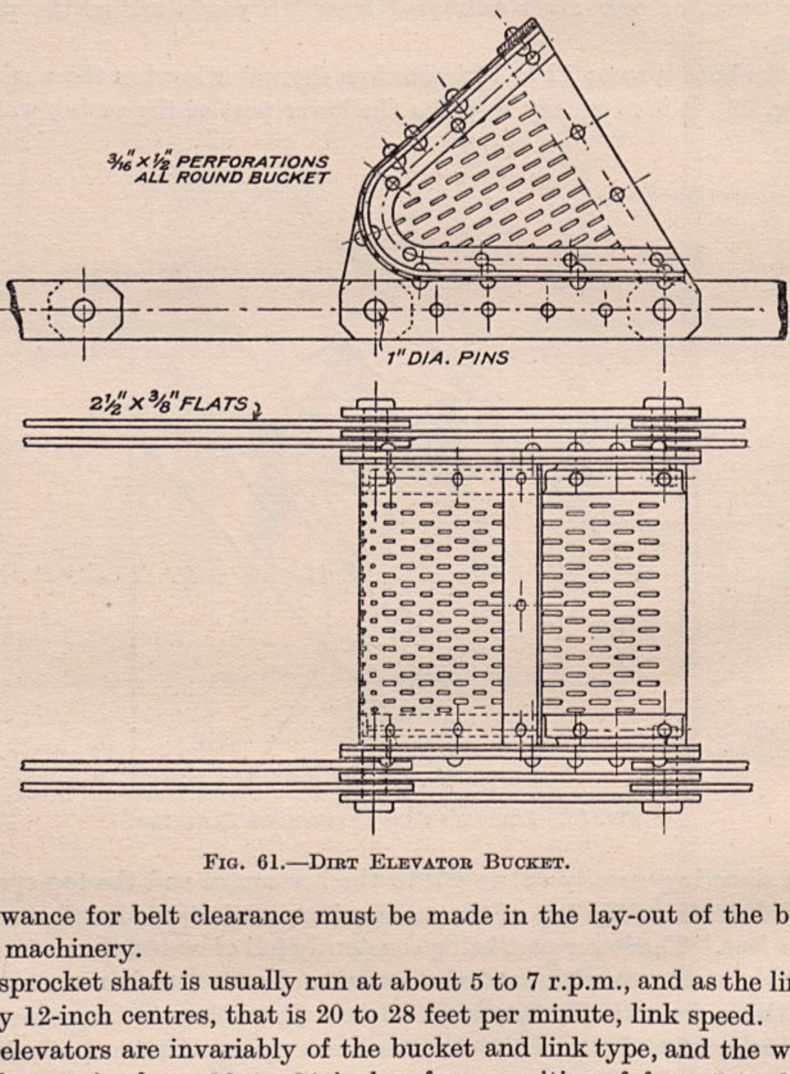

FIG. 61.—DIRT ELEVATOR BUCKET.

due allowance for belt clearance must be made in the lay-out of the building and the machinery.

The sprocket shaft is usually run at about 5 to 7 r.p.m., and as the links are generally 12-inch centres, that is 20 to 28 feet per minute, link speed.

The elevators are invariably of the bucket and link type, and the width of the bucket varies from 10 to 24 inches for capacities of from 5 to 15 tons per hour.

The illustration shews the similarity in the design of skids and casing to that of raw-coal elevators; it should be noted, however, that the casing is

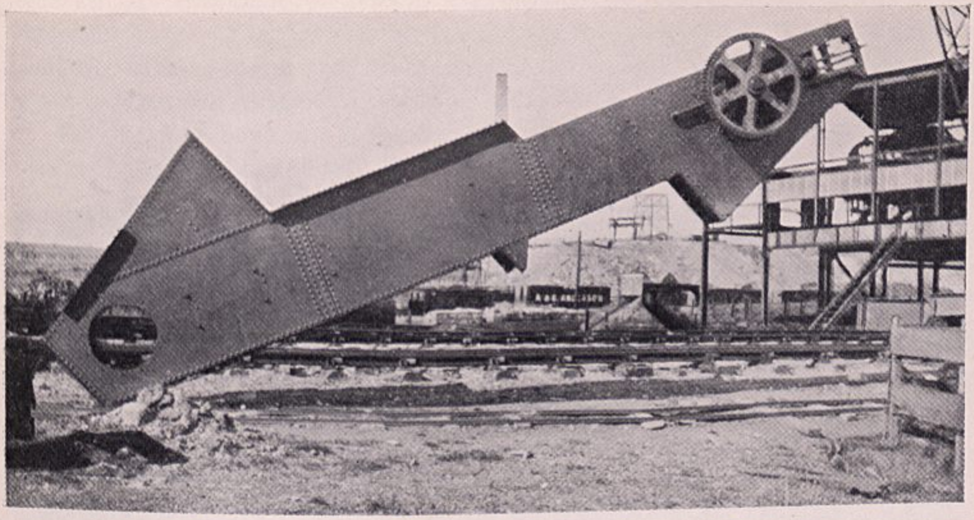

Fig. 59.—Dirt Elevator.
(*Nortons Tividale, Ltd.*)

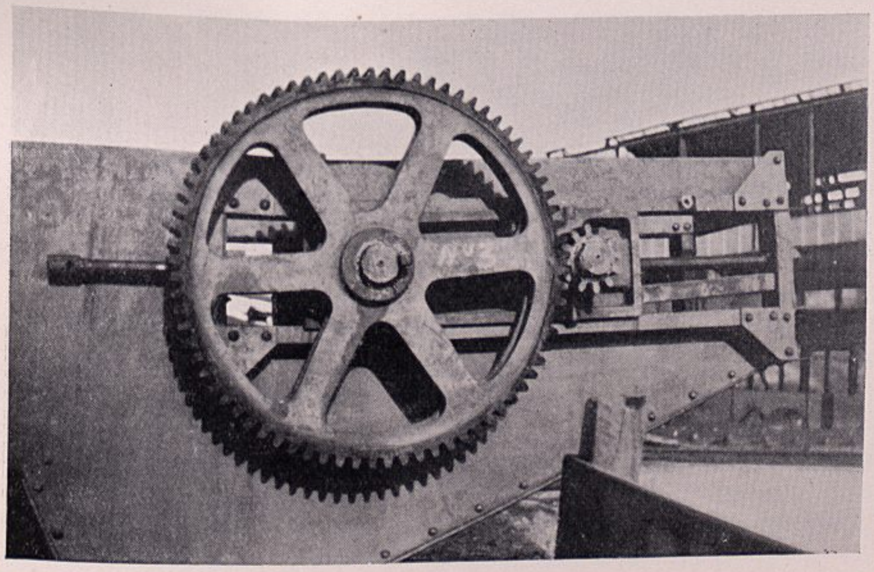

Fig. 60.—Dirt Elevator Gearing.
(*Nortons Tividale, Ltd.*)

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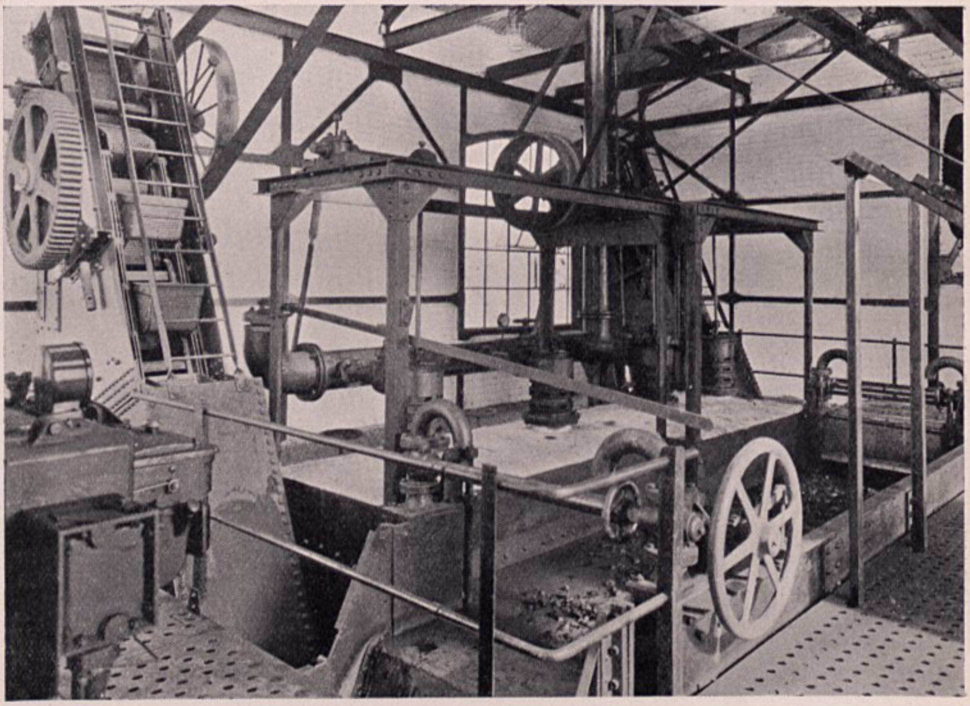

FIG. 61A.—A BAUM TYPE WASHER BOX.
(*Nortons Tividale, Ltd.*)

riveted up throughout and that the connections are suitably designed for caulking water-tight. Rivets should be spaced at not more than 5 diameter centres. The link flat and rubbing strips are sometimes of carbon steel if the refuse contains a quantity of sand or grit.

In Fig. 61A is shewn a photograph of the inside of a washery, the dirt elevators being plainly seen.

Wet Coal or Smudge Elevator.—The elevator used for the feeding of the partly-washed fine coal from the spitzkasten or smudge sump into the rewasher box differs in several points of construction from the above types.

There is no boot and the material is scooped up in a similar manner to a dredge. From the water level to the bottom sprocket there is no casing required, but from this point to the head the elevator should be totally enclosed. The guide angles and runners are strongly braced together and are made up of 4 inches by $2\frac{1}{2}$ inches by $\frac{3}{8}$ inch section angles.

The bottom and side plates of the casing are water-tight and riveted

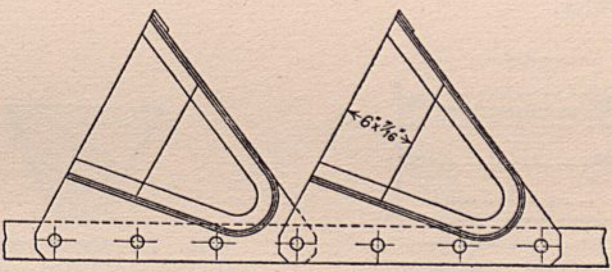

FIG. 62.—SMUDGE ELEVATOR BUCKETS.

throughout. The casing is one complete whole and is seldom built up in sections.

The sprockets and castings and the tension arrangements are of a similar design to those of the shale elevator, but of heavier proportions.

The buckets are arranged consecutively and are found to give best practical results, wide and deep as shewn in Fig. 62.

The best practice is to make the link 16 inches centres and from 42 to 50 inches width of bucket to deal with 30 to 60 tons per hour. There are no perforations, as any water carried up with the coal serves the useful purpose of flushing the material into the rewasher box from the discharge shoot, and avoids the accumulation of fine coal in the angles of the buckets.

One or two $\frac{3}{8}$ inch diam. holes are punched in the base of buckets to release the contained air on entering the water of the sump, on the return side. Neglect to have these would result in the buckets coming up empty since the trapped air would not allow the material to settle in the buckets.

With some systems, the wet-coal elevator is used as a drainage or dewatering medium. The bucket is completely perforated with the bottom end in the "spitzkasten," or fine coal-collecting sump. They are not efficient as dewatering mediums, but certainly extract a large part of the free water.

In the ascending chain, the water drains out, the greater part through the perforations over the level of the contained coal, though a certain amount of slurry is trapped by drainage or filtration through the coal.

When so used, the elevator becomes a mere chain of buckets with a trough on the lower side to return the waste water to the sump.

Drainage Elevators.—Drainage elevators are sometimes installed as an auxiliary to drainage bunkers or drying machinery to further the process of extracting the free moisture in the fine coal.

Their use is not attended with satisfactory results, as in the most favourable conditions they seldom reduce the moisture more than 1%. The general construction is similar to that of the raw coal types, but owing to the necessity of having only shallow and broad layers of material, the buckets are made considerably wider.

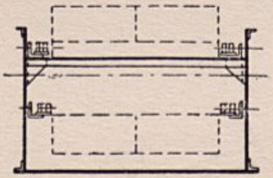

FIG. 63.—CROSS-SECTION OF DRAINAGE ELEVATOR.

FIG. 64.—DRAINAGE ELEVATOR BUCKET, SHOWING LIE OF COAL.

As is shewn in Fig. 63, the casing is 6 feet wide, to accommodate a bucket 5 feet 6 inches in width for a required capacity of 125 tons per hour. In actual working, the coal does not fill the bucket, but lies across it as shewn in Fig. 64, so that the allowance must be made when calculating the capacity.

The complete surface of the bucket should be perforated, usually with $\frac{3}{16}$-inch holes. Sometimes only the back half of the curved plate is perforated, and the argument in favour of this is that the drainage water from the preceding bucket is kept clear of the following bucket, and so on. This is not only a weak argument, but is in practice extremely wide of the mark, as the lie of the coal over the unperforated portion is not conducive to good drainage. What actually happens with a fully perforated bucket is that the drips run down the outside surface of the plate and only drop off when the lowest point is reached; in other words, at the tip of the curve, which in a well-designed bucket should be vertically clear of the back edge of the following bucket. As the drainage wholly depends on gravity, the shorter the path to the bucket surface the better the results, and this can only be accomplished effectually by complete perforation.

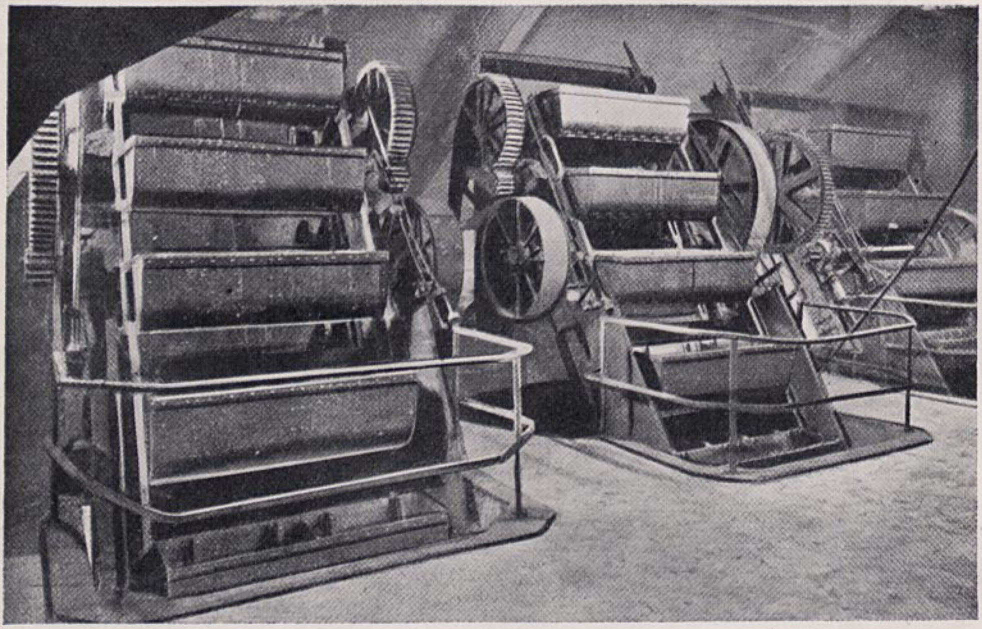

Fig. 65.—Drainage Elevators.

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The links are usually at 20-inch centres and have a chain speed of 35 feet per minute or, say, 20 buckets per minute.

The tension and driving gear is similar to that described previously, but owing to the low velocity and the width between bearings, the driving and sprocket shafts are of larger dimensions, being in the example above of 5 inches and 8 inches diam., respectively.

The author considers it advisable to avoid the installation of these expensive and cumbersome elevators, and where moisture troubles with fine coal are present, to utilise the drying machinery described under that heading.

A very ingenious method of increasing the efficiency of a drainage elevator is that used by the Dinnington Colliery engineer. An iron bar about 12 inches long is hinged to a support in such a manner that as a bucket rises the free end of the bar is carried up with the bucket.

At a certain height the bar slips and the free end drops with a bang on to the lip of the following bucket. This blow causes a slight vibration of the bucket plate and clears the apertures or drainage holes sufficiently to allow an added discharge of moisture.

Fig. 65 shews a series of three drainage elevators for different sizes of coal.

CHAPTER VII

CONVEYORS

WHERE it is necessary to transport coal on the level or at an incline of less than 40° to the horizontal special apparatus must be designed to suit the conditions.

Generally it may be taken that at angles between 20° and 40°, a type of conveyor resembling the elevator design will best fulfil the duty, while below 20° the design may be considerably modified, as the conditions are less exacting. In the first case, a tray conveyor would be installed, and in the second case either a belt or scraper conveyor would be used.

The conveyors used in coal-washing plants are required to work under very varying conditions, and in the majority of cases carry out extremely heavy work in the distribution, mixing, and draining of the wet slack. The design for this reason is very different from the ordinary type of conveyor.

Where a transporting medium has a slope of between 30° and 40°, and were it designed as an elevator (*i.e.* with elevator type buckets), it would not be productive of high efficiency. The coal would be entirely on the back plates, and the lip of the ordinary bucket would in that case be useless.

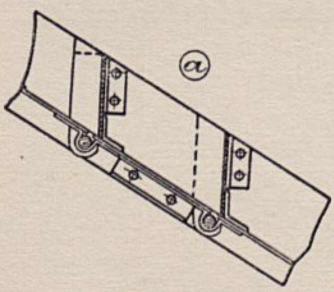

FIG. 66.—TRAY CONVEYOR ON INCLINE.

The height or depth of the bucket need not be so great, and to make up for the lack of depth the width of the bucket should be increased in the same proportion, to obtain an equal duty.

Tray Conveyors.—In Figs. 66 and 67 are shewn two good types of inclined-tray conveyor bucket, the former being suitable for fine coal and the latter for nut coal. They are invariably continuous.

The trays are built up of $\frac{3}{16}$-inch mild-steel plating and 2 inches by 2 inches by $\frac{3}{16}$-inch angles, having a bottom plate slightly less in length than the link centres and on the edges of which are riveted $\frac{1}{4}$-inch bent plate hinges passing round a $1\frac{1}{4}$-inch diam. link pin, the hinges of one tray being interspaced with the other.

The depth of tray, from the surface of bottom plate to the top edge of side webs, is usually between 5 and 8 inches, seldom less than the former and never exceeding the latter. The back plate is connected to the bottom plate and side plates by angle lugs, the top edge of which is about $\frac{7}{16}$ or $\frac{1}{4}$ inch below the top edge of the side plates.

The latter are about 3 inches longer than the link length so as to provide the required overlap when opening out in rounding the sprockets.

The side plates are carried down to the bottom edge of the links and riveted to the nearest link, the outside trays being directly connected, and the inside trays with packing pieces or ferrules between the link and the side plate through which the rivet passes.

Type *a*, which is mostly used for the nut coal, has the back plate fitted perpendicularly to the bottom plate and placed midway between the link pins.

This method ensures a clean throw off at the discharge point and a delivery well towards the top of the sprocket, avoiding any spill down the return shoot.

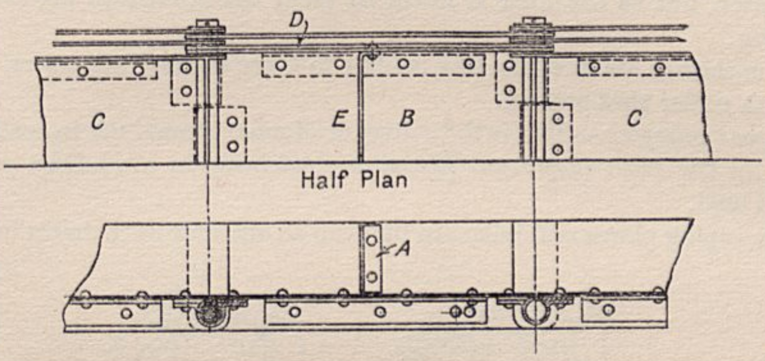

FIG. 67.—TRAY CONVEYORS.

This type is cheaper to construct than the trays with back plates placed nearer to the link pins.

In type *b*, the back plate is placed at an acute angle to the bottom plate, and is particularly useful as a fine coal or drainage conveyor where the material has the tendency to level itself horizontally. For this reason the back plate is best placed vertically. The relative large gain of capacity by this novel design is shewn in Fig. 68. The depth of the side plates is the same in both cases, but by inserting a vertical plate in place of the perpendicular plate, a clear gain of 40 to 50% of cross-sectional area is obtained. The back plate being placed at an acute angle to the bottom plate, the corner would soon be filled up with fine coal if it were placed at the middle points of trays, hence to avoid this the expedient of placing it just behind the leading pin of each tray is resorted to. By this means, in opening out over the top sprocket the whole of the contents are freely dumped into the discharge shoot, as shewn in Fig. 69, there being a clear run over the bottom plate, the preceding back plate offering its surface as a shoot. The link pins are about $1\frac{1}{4}$ inches diam. for conveyors up to 40

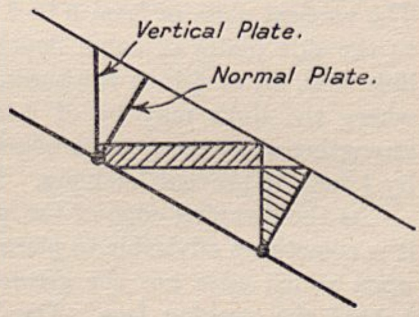

FIG. 68.—COMPARISON OF TRAY CONVEYORS.

tons per hour and $1\frac{1}{2}$ inches diam. for those of 75 tons per hour. They are preferably run from side to side of both link chains, and secured by a loose collar. This collar is secured to link pin by a taper pin of about $\frac{3}{16}$ to $\frac{1}{4}$ inch diam. riveted over at both ends.

The links are generally of 3 inches by $\frac{3}{8}$ inch mild-steel flats, but in special cases of wide trays or heavy duty, these may be made of carbon steel. The shafting and bearing and the tension details differ but slightly from those of the elevator, but as the load is never so great the scantlings are reduced in proportion.

As the casings are in every way similar to those of small elevators, they are dealt with under that section.

Scraper Conveyors.—This is the conveyor of most general use in coal washing and one of the most important pieces of machinery in a washery producing classified coal.

The scraping plates and links are built up as one unit as is shewn in Fig. 70.

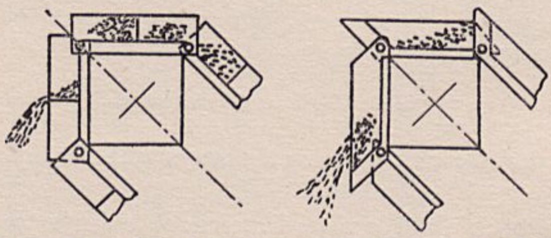

FIG. 69.—COMPARISON OF DISCHARGES OF TRAY.

The vertical plate of from 5 to 8 inches in height is connected by angle cleats to the side plates of equal depth, and these are directly riveted to the near link flats, all of $\frac{3}{8}$-inch thickness, except in the case of large duty conveyors, where the links may be of $\frac{1}{2}$-inch carbon steel. The scraping plates are strengthened at the bottom edges by an angle section of 2 inches by 2 inches by $\frac{1}{4}$ inch to prevent buckling. They are placed behind the pushing face.

As the scraping edge of the plate is reversed after rounding the sprocket, it is sometimes advisable to place this angle centrally or at the top, depending upon which edge has the greatest duty. In any case, it should be placed behind the pushing face. The links vary in length from 12 to 20 inches, according to the capacity of the conveyor. The speed of scraper should not be greater than 60 feet per min.

The overlap of the side plates of scraping conveyor need not be greater than twice the link pin diameter, the bottom corners of the side plates should be rounded off in the same manner as the link flats. It is customary to rivet the side plates to the link alongside. When the scrapers are not deeper than 5 inches or wider than 2 feet 6 inches, the scrapers and the side plate may be

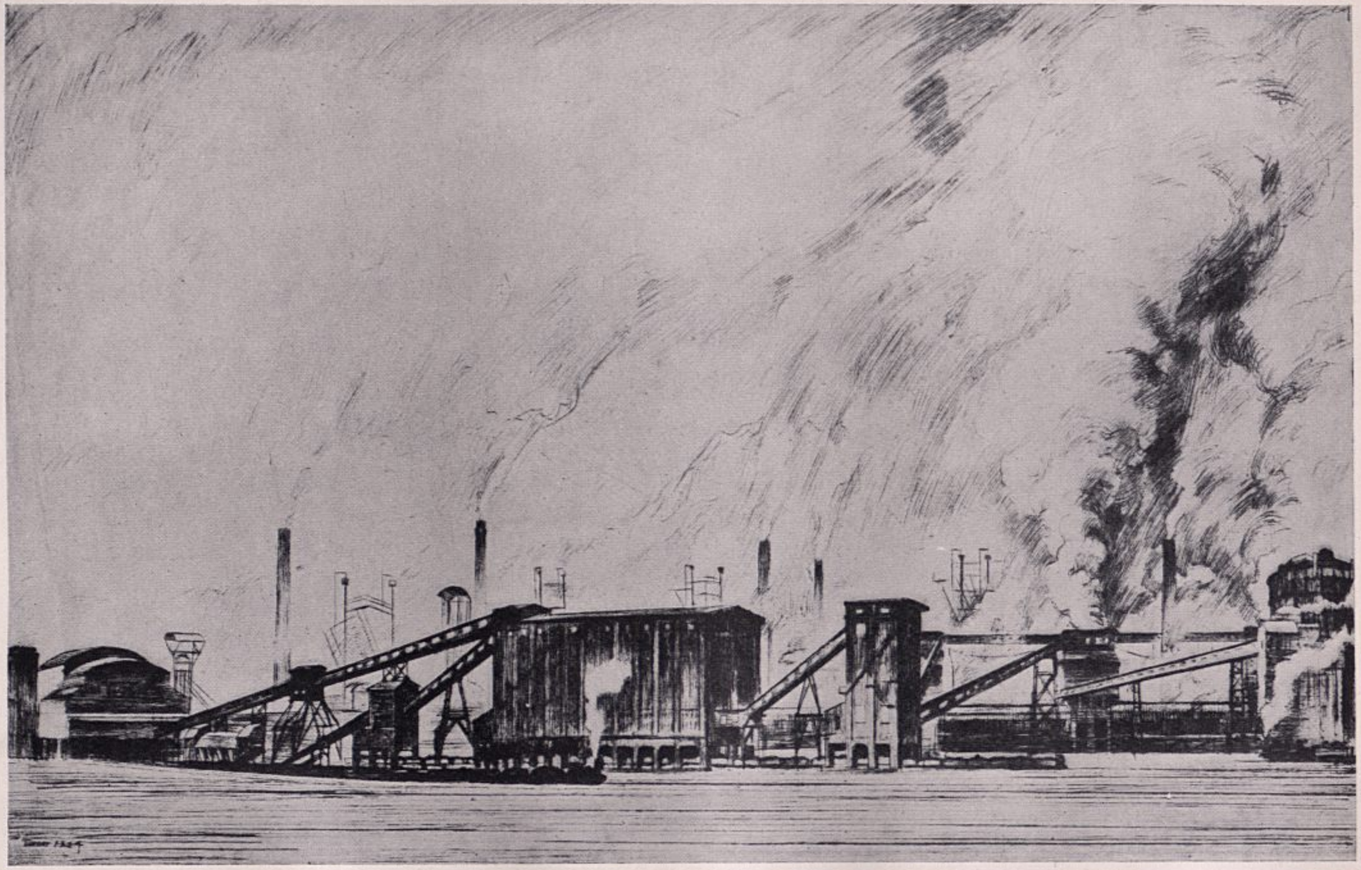

Fig. 72.—Screens Washery Service Bunkers and Coke Ovens shewing the Linking up by Conveyors.
(*Baum A. G.*).

[*To face page* 83.

$\frac{1}{4}$ inch thick. Any increase of these dimensions should mean an increase of this thickness.

The link pins are only sufficiently long to take in the width of the flats and do not extend from side to side as in the case of the tray conveyor, excepting at every fourth or fifth link.

There is no bottom plate connected to the links, as the cross member merely serves to push the material along the bottom plates of the casing.

In Fig. 71 is shewn a section of a 30-inch conveyor which is formed of two vertical web plates 28 inches high with main angles of 2 inches by 2 inches by $\frac{1}{4}$ inch at each edge. The webs are connected at intervals of about 5 feet by cross bracing of $2\frac{1}{2}$ inches by $2\frac{1}{2}$ inches by $\frac{5}{16}$-inch angles strongly gusseted to the webs. On the side plates are bolted the skid angles in the same manner as for elevators, but in this case they are of 4 inches by 3 inches by $\frac{3}{8}$ inch with the largest flange placed horizontally, on which the rubbing flats are bolted.

The links rest with their narrow edges on these flats where the scraper does

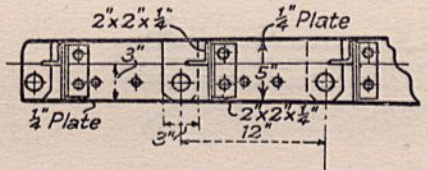

FIG. 70.—DETAIL OF SCRAPER PLATES.

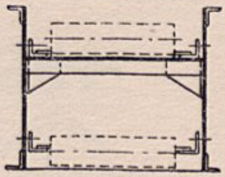

FIG. 71.—SECTION OF SCRAPER CONVEYOR.

not exceed 42 inches in width or 80 feet in length. Where these lengths are exceeded it is advisable to fit rollers at the link pin extremities to reduce friction.

The rollers are generally of 6 inches diameter with a slight raised rim to guide them on the skids.

Where rollers are fitted, the corners of the sprockets will require to be chamfered to give clearance to the rim.

The sprockets are generally hexagonal or square, preferably the latter, as then there is less liability to slip with a heavy drag. In Fig. 72 is shewn an engraving of a Baum, A.G. plant linked up from the screens to the washery and thence from the service bunkers to the coke ovens by scraper conveyors.

In Fig. 73 is shewn a scraper conveyor having four delivery points and receiving the load in the centre of its length. The positions of delivery having been fixed at the points A, B, C, and D, the intermediate portions of the scraper bottom plate are closed up by a $\frac{5}{16}$- or $\frac{3}{8}$-inch plate being riveted across from web to web to form a scraping surface over which the scraper plates push the coal, shewn in heavy line. The coal is allowed to drop on to the bottom plate, E, fitted immediately below the upper link chain, and is pushed along to the end of the plate at F, where it drops through the sliding door to the bunker, A, or is scraped to the bunker, B. When A and B are full the sliding door at H is opened and the coal now passes to the bottom plate, G, below the lower set of links, and by opening the doors at D or C the respective bunkers are filled. Between the bottom plate and the scrapers a clearance of about $\frac{3}{4}$ to 1 inch is allowed for smoothness of working and to save wear and tear. Every four or five links one scraper plate is made $\frac{3}{4}$ to 1 inch deeper than the others so that when travelling along the bottom the surface plate is cleared of any smaller coal left by the other scrapers. This type of scraper is very reliable and works satisfactorily up to an incline of 24° to the horizontal, but beyond this the efficiency falls off rapidly.

Where the friction is heavy, due to the want of attention or to a heavy load on the length travelling towards the tension end, the links often slip over the driving sprocket. This can be quickly remedied by placing an angle guide rail round the driving end as at L, so that no jump can take place.

In long runs it is advisable to fit rollers on through pins or bolts. These

FIG. 73.—DISTRIBUTING SCRAPER CONVEYOR.

rollers run on the skid angle. A very general objection to rollers is that they are often out of action, due to a continued want of oiling by the men in charge. This is not a fault of design, and it devolves on the washery management to see that reliable men are placed in control of these appliances. To prevent the shrieking noise caused by grinding of coal between the scrapers and the deck plate, it is a good plan to fix oak strip ploughs on the extended plates.

Some makers supply a type of roller which is self-oiling and when once supplied with lubricant may be safely left unattended for a considerable period. They are fitted with an oil reservoir which ensures an ample supply for at least one week. Not only is the efficiency of the conveyor increased by this contrivance, but the repair cost is considerably reduced. There are several methods of fastening the roller upon the pin, the most general of which are riveting over the head a lock nut and bent pin, a loose collar with riveted taper pin, and a gripping toothed hard steel washer which grips into the bolt.

Drag or U link Conveyors.—The scraper conveyor being relatively very costly and heavy, a lighter type of trough or U link conveyor is utilised for dealing with small quantities of coal or refuse in the washery.

Two light channels of 6 inches by $2\frac{1}{2}$ inches by 12 lb. form the web or side plates and a bottom plate of $\frac{3}{16}$ inch mild steel acts as the scraping surface.

The bottom flange of the channels is riveted to this plate and at the extremities a web plate of about 18 inches wide is riveted to the vertical flanges of the channels to house the bearings for the sprockets as shewn in Fig. 74. Ordinary square castings are used for the bearings of the sprocket shafts and inserted between two angles or light channels riveted to the web. The return links are supported every 5 or 6 feet on rollers connected to vertical struts and provided with side guide plates. The links are built up of 3 inches by ½ inch or 2½ inches by ⅝ inch flats bent over three sides of a square and slightly turned out at the free ends to prevent side movement in the trough. The pins acting as hinges are slackly riveted over at the ends, and should be the full width of the scraper and be placed hard up against the face of the scraping flat, the lips of one U being placed over the closed end of the other. The sprockets are of the square tumbler type to fit a 12- to 14-inch link.

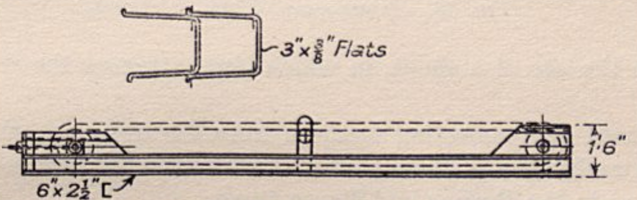

FIG. 74.—ARRANGEMENT OF U-LINK CONVEYOR.

The speed seldom exceeds 80 feet per minute, and the following table gives a good average practice.

TABLE III

U-*Link Conveyor Apparatus*

Tons per hour.	Width.	Depth of link.
15	12 inches	3½ inches
20	12 ,,	3 ,,
25	18 ,,	3 ,,
30	24 ,,	3 ,,
35	24 ,,	4 ,,

Worm Conveyors.—In confined spaces over short lengths, it is impracticable to use the ordinary direct type of conveyor, and recourse is had to the worm conveyor. They are mostly used as an auxiliary to other conveyors which are unavoidably placed out of a direct line to the receiving or loading point.

As shewn in Fig. 75, a square central shaft is supported at intervals in underslung bearings, and between these supports spiral blades are fitted. The blades are fitted singly, each one being interchangeable, and by reason of the square shaft no set pin or keyway is necessary. There is a clearance between the edge of the blade and the casing of about ¼ inch.

The casing may be of cast iron or of mild steel.

The coal may be loaded at any point and delivery obtained at any or several points of the length by arranging the blades to push right or left hand or by inserting a combination of both, as shewn in Fig. 76.

The capacity and the efficiency of a worm conveyor is very small and for this reason its use is limited to conditions unsuitable for the use of other conveying medium.

It often happens that the feeding point of a scraper or belt conveyor is placed to one side or the other of the line of the conveyor and in such a manner

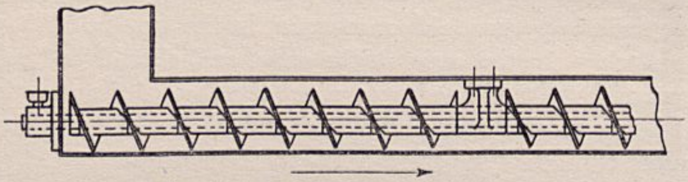

Fig. 75.—Right-hand Worm Conveyor.

as to preclude the use of a shoot, in which circumstances the worm becomes most useful.

It is also used as a collecting medium from the drying machinery and in some types of washer boxes where a small and distributed feed is collected and concentrated, as in the Brauns and Baum types.

The diameter of the blades should be such that the total amount of the delivery required should be obtained by considering the trough as one-third full only.

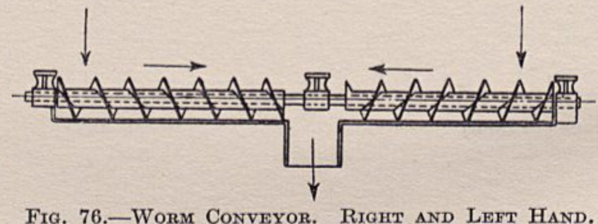

Fig. 76.—Worm Conveyor. Right and Left Hand.

The pitch of the blades is in the best practice about four-fifths of the extreme diameter and the worm should not run at more than 50 r.p.m.

In Fig. 77 is shewn a worm conveyor for fine coal containing 15% of moisture. This coal is fed from a hopper by means of a star feeder revolving at a speed of 14½ r.p.m. The feeder is 24 inches diam. and 3 feet long, and is fitted to the hopper to avoid the choking that would assuredly happen if the coal were fed directly upon the worm conveyor. The great disadvantage of the worm is that when receiving an unlimited feed it tends to bore a tunnel through the material and maintain this tunnel. This is specially the case with fine wet coal, which is sluggish in movement and arches readily. The feeder is enclosed in a cast-iron casing attached to the mouthpiece of the hopper, and is driven

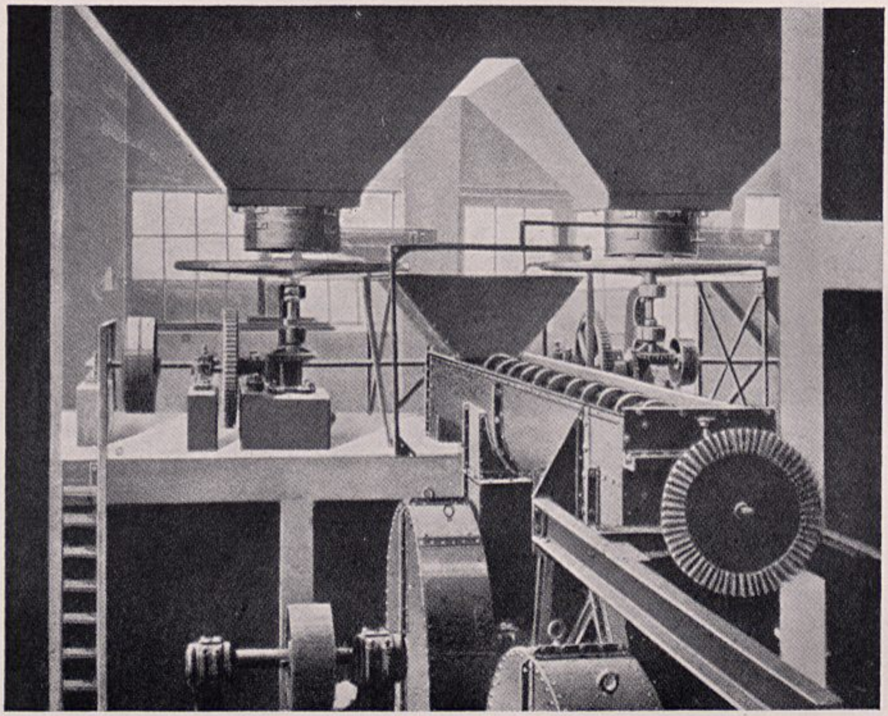

FIG. 78.—WORM CONVEYOR AND FEED TABLES. DISINTEGRATOR IN THE FOREGROUND.

[*To face page* 87

from the shaft, A, by the belt pulleys, B. The sides of the feeder chamber are of mild steel and are perforated for the shaft, which is supported in cast-iron bearings riveted to the plate. Immediately below the feeder a conveyor worm 20 inches diam. and 16 inches pitch of blades is supported in a mild steel trough of $\frac{3}{4}$ inch thick of U shape with the top open. The worm is caused to revolve at 40 r.p.m. by the chain wheels C, driven from the shaft, A. It will be noticed that the feeder only delivers a sufficient amount of material to fill the conveyor to one-third of its theoretical capacity. The duty of the above apparatus is 50 tons per hour and may be considered a good type of the best practice.

In Fig. 78 is shewn a worm conveyor receiving coal from two revolving tables and delivering the mixed product into disintegrators.

Belt Conveyors.—From the point of view of cheapness and efficiency, a belt conveyor is the most useful of transporting mediums. Its use, however,

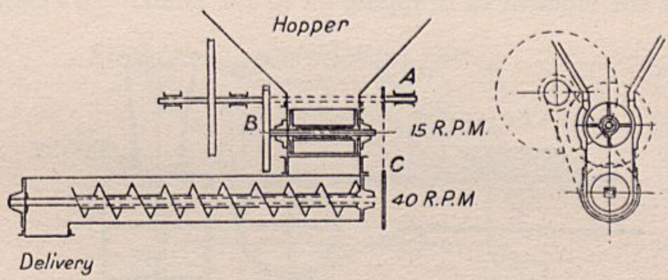

FIG. 77.—FINE-COAL WORM CONVEYOR AND ROTARY FEEDER.

in coal-washing plants is confined to the unwashed slack or the washed large or nut coal, where delivery is required at one point only. Owing to the relatively high speed of travel, viz. 300 feet per minute, the discharge is clean and regular. The best practice seldom exceeds this speed for nut coal (to avoid excessive breakage) and in small slack to reduce spreading dust and consequent loss of a saleable product.

The use of belts for fine washed coal or dirt (shale) has hitherto not been very successful owing to the sticky nature of the material causing it to adhere to the surface. One very obstinate case brought to the author's notice at a Welsh washery was as follows.

A 20-inch belt conveyor about 100 feet long working on the level was installed for the disposal of the small shale. When operating, about 20% of the load adhered to the return surface after passing the delivery end, and running over the flat idlers covered the surface of the belt with a thick layer of pulp, in which smaller particles of the shale were held, and eventually dropped in the return length. Brushes at the delivery drum end failed to remove the trouble, so that metal scrapers were tried, but still without success. The engineers concerned then devised the expedient of water jets to impinge on the belt as an aid to the scrapers, but the material obstinately refused to be removed.

The eventual remedy was to remove the belt and replace it by a water flushing trough and a drain sieve at the delivery point. Another case was that of a fine coal belt which was inclined at 20° to the horizontal on a run of 120 feet.

The moisture in the coal caused the particles of less than $\frac{1}{16}$ inch (or 3 mm.) to adhere to the belt in rounding the drum, and to be dropped in the return run to the amount of about 2% of the total carried. These troubles do not exist with dry coal.

One of the necessities to the efficient working and maintenance of a belt conveyor is often neglected by designers.

Reference is made to the initial speed of the material and the direction of the travel at the moment of dropping on to the band. To extend the life of

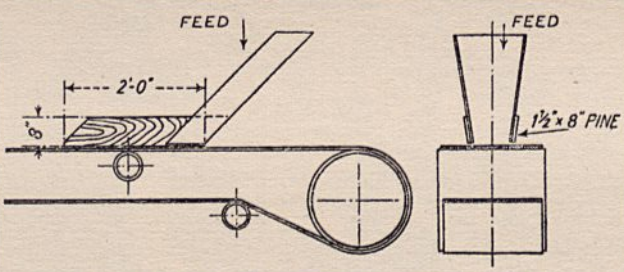

FIG. 79.—BELT CONVEYOR. FEED SHOOT.

the belt and to ensure a smooth working and uniform load the material should be shot on to the belt in the direction of the subsequent delivery and at a speed equal to that of the band. This can easily be effected by a shoot sloping at a minimum angle of 45° and with an outlet half the width of the band and guarded on either side by wooden guide strips as shewn in Fig. 79.

The belts which concern us most are of the troughed type as shewn in Fig. 80.

One or more horizontal drums are loosely mounted on a spindle or shaft and act as the load carriers. These drums are about 6 inches diameter. This spindle is socketed or keyed into a small cast-iron bracket, which is bolted to a wood stretcher or bearer. On the outer side of the bracket a small inclined spindle is socketed for the guide or troughing pulley or roller. The spindles are hollow and generally made of cold drawn steel tube perforated at suitable intervals to admit of the lubrication of the moving parts. This lubrication is supplied by Stauffer type compression grease cups, screwed into the extremities of the spindles. The angle of inclination of the outer rollers is usually between 20° and 30°.

The group of the supporting rollers is mounted on channels bearers, *h*, on the bottom flanges of which the group of the return idlers, similarly fitted on straight hollow spindles, are bolted.

The spacing of the supporting rollers for belts of 15 to 30 inches wide is usually about 5 feet, and on wider belts 4½ feet. The flat idlers are spaced at double this distance.

In long runs it is advisable to put in guide pulleys for the flat return belt at every 30 to 40 feet as shewn in Fig. 81. The bearer channels extremities are separated about 6 to 9 inches to allow of the guide pulley bracket being inserted so that the edge of the belt will bear near the centre of the roller.

The tension end of the belt, which should always be the receiving end, is run round a pulley slightly wider than the band and about 2 feet diameter for belts of 12 to 18 inches in width to 3 feet in diameter for belts of 36 inches wide. This drum is mounted on a bright steel shaft supported in a dust-proof ring oil

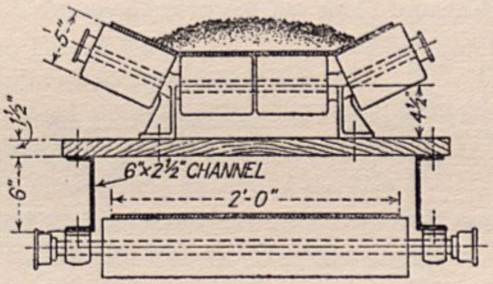

FIG. 80.—CROSS SECTION OF BELT CONVEYOR.

bearing provided with spring wipers to avoid the spreading of the oil along the shaft and the consequent collection of the dirt and dust. The bearing is fitted on an inverted channel support or guide in the hollow of which runs a screwed bolt fitted at one end in a socket, and a toggle wrench at the other or outermost end. The bearing casting carries a nut which engages with the screw and any motion given to the toggle is communicated to the drum. By this means the belt can be readily tightened or slackened.

The driving end, which should always be the delivery end, has a drum of equal size to the tension drum. This drum is supported in bearings rigidly bolted to the channel runners.

The driving shaft is extended beyond the bearings to carry the spur wheel engaging with the pinion of the first motion shaft which is likewise supported on the belt framework.

Where the belt is run partially on the horizontal and on an incline, an easy change of gradient should be made by setting out the rollers in as large a radius of curvature as possible.

In good practice an incline of 18° is seldom exceeded, as above this the efficiency falls off rapidly.

Where the conditions are such as to preclude the introduction of a gradual change of curvature in the vertical plane, such as is shewn in Fig. 82, where the belt collects slack from under the screens and delivers at a higher point just beyond, a special contrivance is necessary. An intermediate throw-off chute is inserted and the belt is run over one drum, and under a second drum, from which the straight incline commences. The material is shot on to the running belt over the drums, and from there carried up the incline to the point of delivery.

To obtain a maximum arc of contact, the lower belt is usually run over a gripping pulley placed so that the return belt is lifted up to about half the drum diameter from the upper belt.

The best class of belt for colliery use is made up of layers of canvas covered with rubber sheathing. The rubber is thickest in the centre of the belt where the wear is the greatest and thins out towards the edges. The canvas, on the

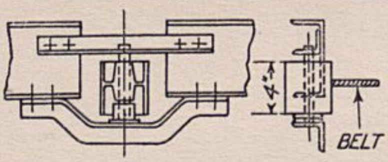

Fig. 81.—Guide Roller Return Belt.

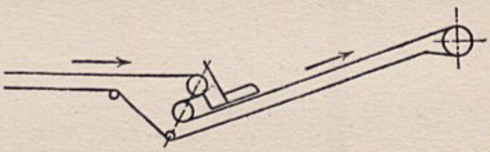

Fig. 82.—Belt with Sharp Upward Lift.

contrary, is thickest at the edges and thinnest in the centre, to preserve a uniform section throughout.

This disposition of the materials gives undoubted satisfaction and is the best for troughing belts.

The following table gives a few particulars of the belts mostly required in connection with coal-washing plants.

Table IV

Capacity of Band Conveyors

Width.	Capacity.	Speed per min.
12 inches	20 tons per hour	300 feet
14 ,,	40 ,, ,,	,, ,,
18 ,,	75 ,, ,,	,, ,,
20 ,,	100 ,, ,,	280 ,,
24 ,,	120 ,, ,,	,, ,,
30 ,,	160 ,, ,,	,, ,,
36 ,,	200 ,, ,,	,, ,,

Conveyors.—The following hints on the selection of band conveyors are the result of much practical experience, and as this type of transporting medium is becoming more popular with colliery engineers, they will no doubt be useful to many others.

Idlers and Rollers.—Should be of about 5 to 6 inches diameter and about 6 inches long. The edges should be rounded off to avoid sharp corners which may injure the underside of belt by nipping it between neighbouring rollers. They should be as light as possible and well balanced.

The return idlers should be in one length, that is, one roller for the full width of the band. This ensures a steady run due to a lighter roller.

Guide rollers should be used sparingly and only when absolutely necessary. See page 93.

Troughing rollers should be spaced at :—

5 feet centres for a band 24 inches wide.
4 feet 6 inches centres for a band 36 inches wide and over.

Return rollers twice this spacing.

Pulleys.—The pulleys should be of strong construction to withstand the heavy pull on the loaded belt. The rims should be of thick section and suitably ribbed. They should be properly balanced and cast whole. They should be 2 inches wider than the width of the band. Wherever possible the pulleys should have a diameter of at least 30 inches.

The author has found that the following dimensions give very satisfactory results :—

Bands of 18 inches width, 24 inches pulley.
18 inches to 28 inches, 30 inches pulley.
Bands of 30 inches and above, 36 inches pulley.

There are occasions when it is incumbent to instal a pulley of much smaller diameter. Great care must be exercised in not adopting so small a radius that the stress cause the plies of cotton and rubber to separate. The diameter of the pulley shafts is generally one-eighth to one-sixth the width of the belt. The driving end of the band should be the delivery, and the frames supporting the pulley bearings should also be made to support the bearings of the driving shaft and reduction gear. The tension end of the band should be held in strong bearings resting in a take-up guide. These bearings should be self-adjusting so as not to nip the drum shaft when the opposite take-ups are run out unequally. The length of take-up allowed should be at least equal to one belt width. The usual practice is to place the centre line of bearings on the produced centre line of the band supporting channels.

Inclined Conveyors.—With a uniform feed of fine coal a band conveyor will work efficiently at about 22°, but sized nut coal will require a maximum of 18°. The belts are usually of 4-ply cotton in the centre, increasing to 7-ply cotton at the edges, giving about $\frac{1}{8}$ to $\frac{3}{16}$ of rubber cover on the centre.

The following table gives the capacity of belts of various widths at a speed of 300 feet and 250 feet per minute on an incline of 18°.

TABLE V

Capacity of Inclined Conveyors

Width.	300 F.P.M.	250 F.P.M.
12 inches	18 tons per hour	14 tons per hour
18 ,,	35 ,, ,,	30 ,, ,,
24 ,,	75 ,, ,,	60 ,, ,,
30 ,,	100 ,, ,,	80 ,, ,,
36 ,,	150 ,, ,,	125 ,, ,,

It is current practice to put in a width of conveyor with a capacity equal to twice the required duty, that is, only half the above capacities given in the table are expected from the bands.

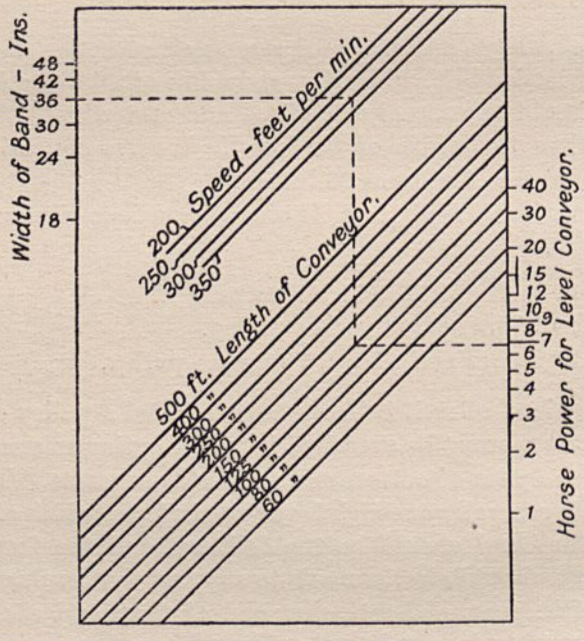

FIG. 83.—DIAGRAM TO FIND HORSE POWER OF BELT CONVEYORS.

In Fig. 83 is shewn a diagram from which the horse power required to drive the usual sizes of conveyors met with in colliery practice is given. To use this table, select the width of the conveyor at the top left-hand corner, traverse the graph horizontally to the required speed line in feet per minute, then descending vertically to the line representing the length of conveyor and thence to the right of the diagram, will give the horse power required for a fully loaded conveyor running on the level. For inclined conveyors, add $\frac{1}{1000}$ part of the horse power for each foot-ton of lift per hour.

In Fig. 84 is shewn a very neat arrangement of band conveyors, bringing

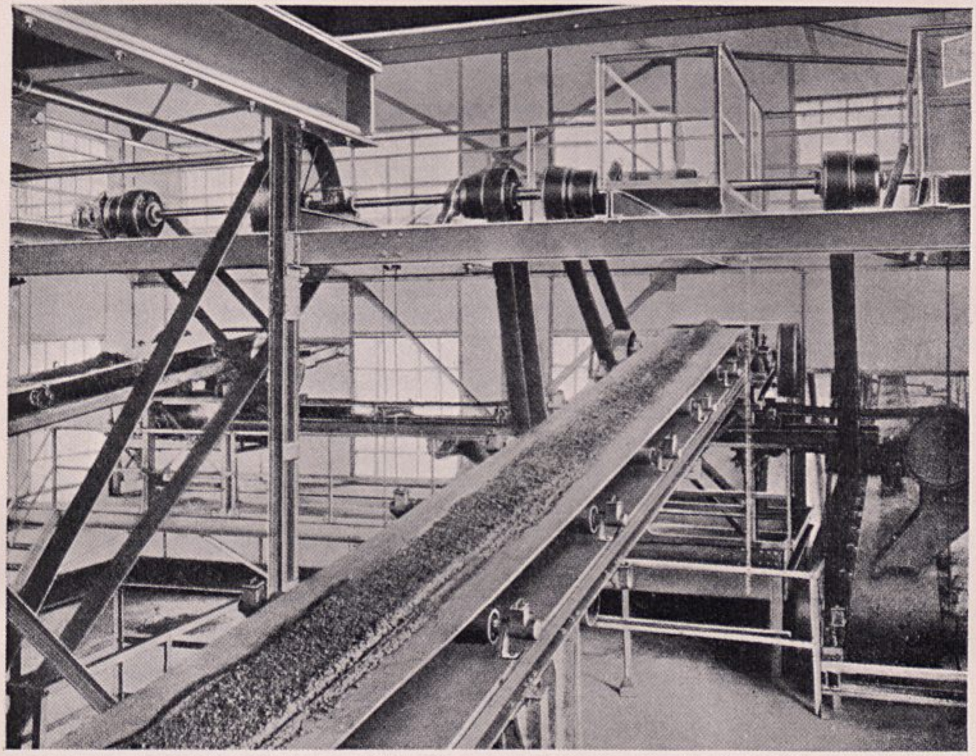

Fig. 84.—Band Conveyors.

[To face page 92.

washed coal to a cross band and thence on to a conveyor passing out of the building.

Note the special type of bearing for the supporting rollers. There is an oil well with wick feed covered by a cap lubricating the revolving shaft which revolves—as against the more usual practice of Stauffer lubricators and tubular fixed shaft carrying grease to revolving rollers.

The best type of driving pulley for band conveyors is that which is built up of two cast-iron end flanges mounted on a mild steel shaft and the drum built up of oak strips.

The oak strips are about 3 inches × 2 inches section and are bolted to the flanges. The drum is then placed in the lathe and turned with a crowned face. This construction is most effective against slip and ensures the belt riding centrally.

To dispense with the use of side guide rollers and the attendant disadvantage of wearing the edges of the rubber band, the alternate idlers should be placed slightly diagonal to the run of the band and the intermediate idlers inclined equally in the opposite direction; by this means the tendency of the band to creep up one roller is counteracted by the adjacent rollers, with the result that the band follows a straight track.

On starting up at the beginning some slight adjustment will be necessary at different points depending upon the amount of contact between the individual rollers and the band.

The bolt holes in roller brackets should be elongated for this purpose, and it is good practice to have swivelling or spherical bearings to support rollers to prevent nipping.

CHAPTER VIII

DUST EXTRACTION

ONE of the most difficult problems of coalwashing is the elimination of the dust from the slack before washing.

No commercially successful method has yet been devised for universal application, notwithstanding a large number of experiments and much expense in a great number of collieries.

The subject is particularly interesting, however, in the light of the great advantages that would be derived from a successful and economical process.

A great factor in the dust treatment is undoubtedly the quality of the coal itself. Should the slack be the product of a wet mine or one where the natural moisture is greater than 4%, it is almost useless to attempt dust extraction by mechanical methods. If drier than this, however, the possibility of successful treatment is much more likely.

Plants using run of mine coal are peculiarly liable to suffer from a large percentage of dust, particularly so if the crushing arrangements are not designed with care.

The great advantage of dust extraction prior to washing lies in the fact that the ash content of dry dust is considerably less than that of the recovered slimes after washing, due, no doubt, to the fact that there is an appreciable breaking up or disintegration of the shales during their passage through the washer boxes, and such added small refuse is intermixed and carried along with the washed products to the dewatering apparatus and thence to the bunkers.

The slurry problems and thick washing water troubles could be considerably simplified by a judicious and economical dust extraction plant, as the lower percentage of ash contained in the dry dust would allow it to be mixed in reasonable proportion to the fine coal without lowering the value appreciably, and also help to a large degree in the reduction of the percentage amount of moisture contained in the washed fine coal product.

The resulting slime in the settling tank would be of large percentage ash, and would be mainly derived from the disintegration of the large shale in the boxes. This slime could be disposed of on the rubbish heap without adversely affecting the balance sheet. The amount would not be more than $\frac{1}{2}$% in the majority of British washeries.

A further advantage of this treatment would be the more rapid drying of the fine coal over the vibrating sieves, as it would not contain the very small particles which act as a cementing medium, blocking the air spaces and impeding the dewatering process.

The presence of dust in the raw coal hinders the washing process throughout the whole system. Modern demands require a clean coal of all sizes from the maximum downwards as an economical yield; and no good coal must be wasted, no matter how small.

As the small coal below $\frac{1}{16}$ inch cannot be improved in washer boxes at present in use, the passage of such particles through the whole plant represents a waste of power apart from the tendency to make an inefficient washing. (See chapter on Principles of Washing.)

The large quantity of slurry or slime collected in the settling tanks of the present day washery calls for a considerable amount of power and much expense in its recovery, and even then attendant drawbacks are the large amount of moisture and ash content. In other words, the original quality when in dry state has been lowered by unsuitable treatment.

The maximum size of the dust to be extracted will depend upon the uses to which the product of the washery is to be put and the quantity of ash in the different sizes as found by analysis.

Where the product is to be used in coking, the ash content should be a minimum so that the minimum size of washable coal should be the maximum size of the dust.

Where the product is disposed of in sales the dust can with advantage be taken out through a $\frac{3}{16}$-inch mesh and mixed with the washed fine coal.

It is not advisable to mix dust containing more than 25% ash with the fine coal, as the quality of the washed products would be lessened to a greater extent than the resulting gain from the added weight. Such low quality dust is best utilised in the colliery boilers or for the manufacture of briquettes.

Of the many types of dust plants the following three examples embody the main principles employed.

Humboldt System.—The raw coal is fed from a feed elevator on to a shaking screen in the highest part of the washery building, as shewn in Fig. 136. All the fine coal below $\frac{3}{8}$ inch is extracted and elevated to the breeches chute, *d*, Fig. 85, which distributes it over a battery of small vibrating screens, *a*. The supply to these screens is regulated by adjustable sliding gates in the casing.

The screens, *a*, are covered with wire mesh of $\frac{1}{10}$- or $\frac{1}{16}$-inch apertures and are slung from the centre support by two hickory laths, *h*, the top extremity resting on a multiple cam, *b*, and the far or lower edge of the tray on the outer dust chamber casing.

The cam in rotating lifts the tray and in the drop the hickory springs give sufficient kick to cause the coal to slide evenly and slowly over the wire mesh.

The oversize is dropped from the bottom edge into the flushing launder at the side and thence into the washer boxes, whereas the undersize is collected in the chambers, *e*, beneath the trays.

The whole of the casing below the tray surfaces is made dust-proof with manhole doors at convenient points for inspection purposes.

It is claimed that dust of $\frac{1}{32}$-inch can be extracted where moisture is not greater than 3%.

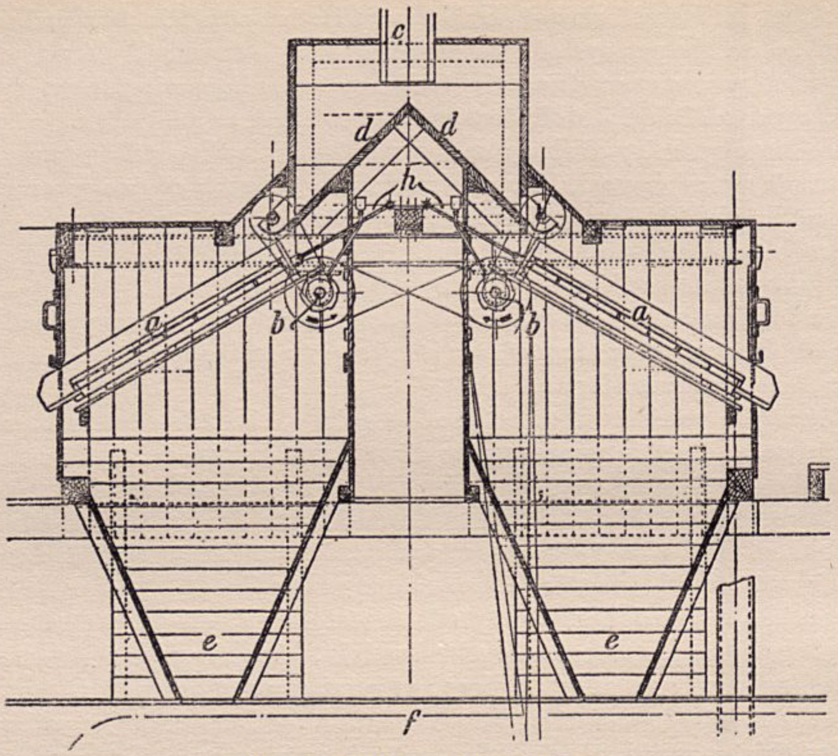

FIG. 85.—HUMBOLDT DUST SCREEN.

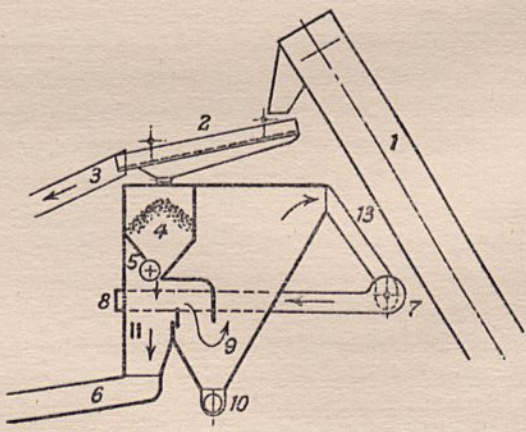

FIG. 86.—MEGUIN DUST PLANT.

The great drawback of this system is the heavy expense of the plant and the necessary building accommodation so far from the ground.

Each vibrating screen of about $1\frac{1}{2}$ square metres area is capable of dealing with about 4 tons per hour, so that in an average British washery of 100 tons per hour capacity no less than 10 units would be necessary.

One or two Yorkshire collieries using these screens speak very favourably of the results obtained, but no analysis of the cost of operation and repairs is available.

Meguin System.—An air system which has been employed with fair success on the dry coal in Continental mines is shewn diagrammatically in Fig. 86.

The raw coal is first screened on the jigger, 2, the oversize passing along the trough, 3, and all below 10 millimetres is fed into the chamber 4, from which it is drawn by the roller feed regulator, 5. The coal is thus discharged as a sheet into the air blast.

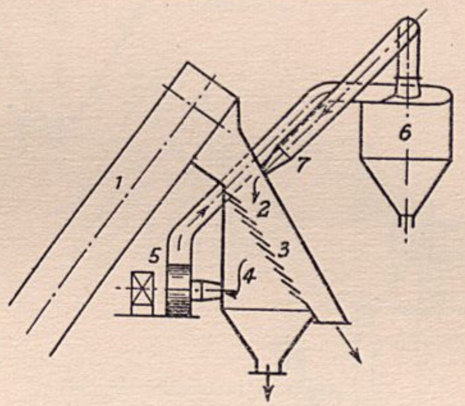

FIG. 87.—SIMON BUHLER DUST PLANT.

This feeder is placed so that the fine coal may drop vertically just to the side of the dividing plate between the chambers 11 and 9. The dividing plate is stopped at about 4 feet below the inlet and an adjustable slide fitted to regulate the quantity extracted.

The chamber 9 has a baffle plate fitted in the centre with the bottom edge just below the level of the top of the dividing plate. The fine coal dropping from the inlet is subjected to a concentrated blast of air entering at 8. The pressure is regulated by experiment so that all particles of coal below 2 millimetres are driven out of the vertical into the chamber 9, while the larger material is dropped to the flushing launder, 6, and conveyed to the washer boxes.

The dust collected in the chamber, 9, is conveyed to a dust bunker or to be mixed with the washed fines by the worm conveyor, 10. The air is kept in circulation through the chamber to prevent back currents by the suction pipe, 13, which communicates with the blower or exhauster, 7.

7

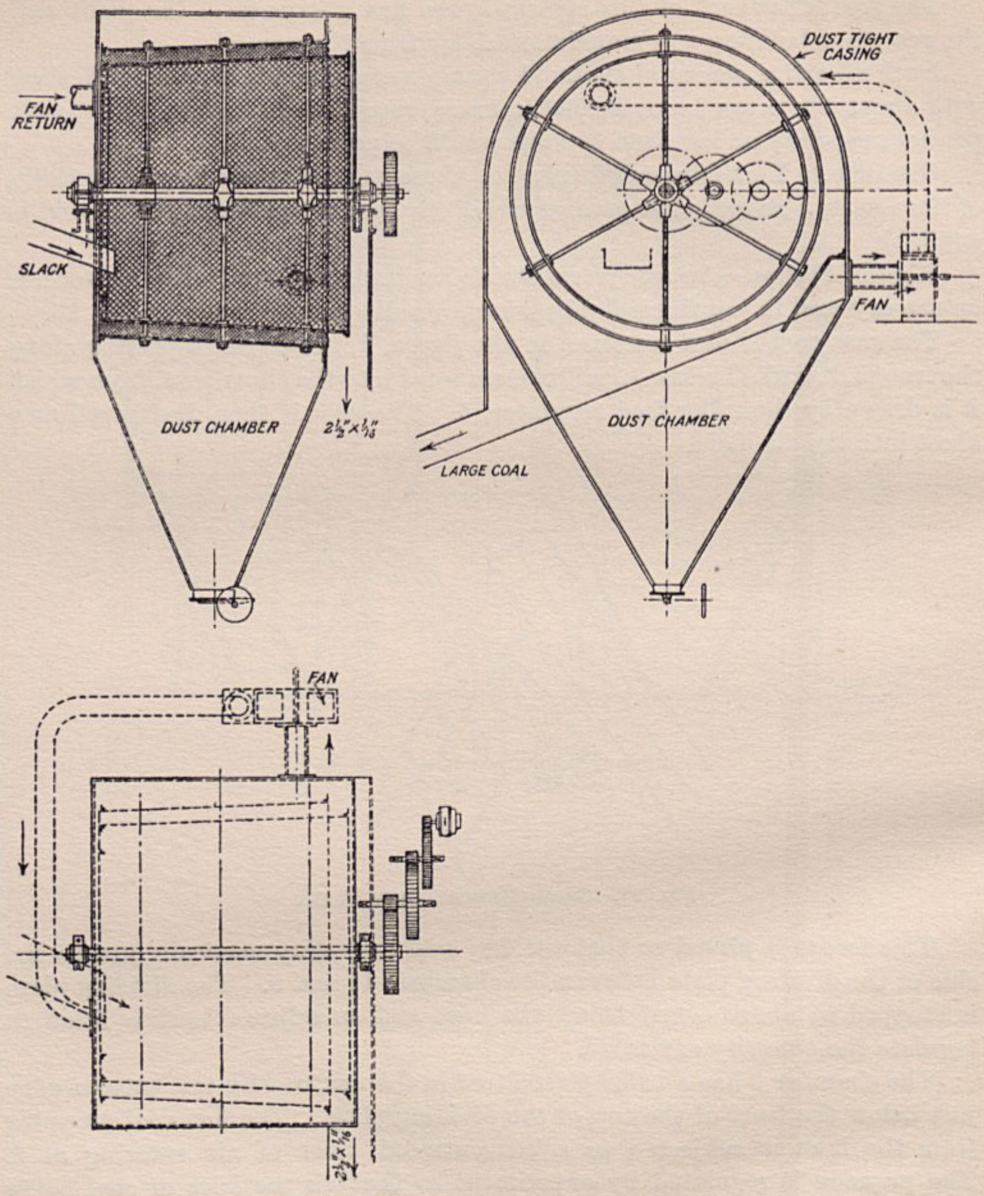

FIG. 88.—DUST PLANT OF LARGE CAPACITY.

A variation of this design is shewn in Fig. 87, where the dividing wall is fitted with louvres to allow passage to the blown dust. In the bottom of the chute from the elevator, I, a series of vanes, 3, is placed, over which the coal tumbles. An exhauster, 5, draws the air from the hopper, 4, and thus entrains the dust in the coal into this chamber. The discharge from the exhauster is led by pipes to the conical settler, 6, to cause a deposit of the very fine particles. The purified air is then led back to the chute, 2, by the pipe, 7. This type has not given a great deal of satisfaction on account of the eddy currents set up by the vanes keeping the dust in circulation.

Overscreening Method.—Several collieries have adapted the concentric revolving screen to dust extraction purposes by taking out coal through a $\frac{3}{16}$ perforation as shewn in Fig. 88.

The screen is about 11 feet maximum diameter tapering to 10 feet 6 inches and about 12 feet long, constructed with two mantles, the inner mantle being

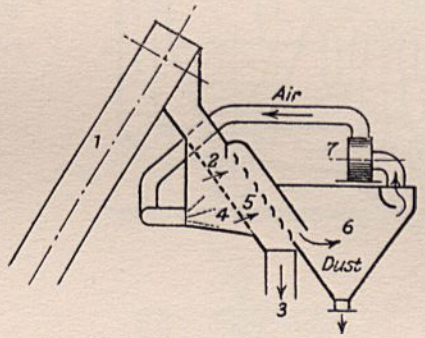

FIG. 89.—MINIKIN DUST PLANT.

of $\frac{3}{16}$ plate perforated with 1-inch holes and the outer mantle of $\frac{1}{10}$ wire mesh, which is preferable to square perforations. The whole is in a dust-proof casing and is capable of dealing with 100 tons per hour of raw coal at 3 r.p.m.

The results obtained with this method of screening have been very profitable, as the washing water has been vastly improved and the dry dust mixed with the wet fines has speeded up the dewatering process. The use has been mostly confined to the anthracite pits.

In Fig. 89 is shewn a scheme devised by the author as the result of extended investigation of the dust problem.

If a batch of coal is allowed to fall freely down an open chute it will be found that the dust rises in the form of a cloud, *i.e.* that the smaller particles are above the surface of the coal in the chute. The discharge from the bucket of the elevator tends to bring this about as the smaller particles hang back in the bucket until the maximum discharge angle is reached, and those carried out by the larger pieces are freed when they impinge on the bottom of the chute.

Therefore it would seem that to draw the small particles through the bottom plate of the chute as in Fig. 87 is to counteract the natural tendency instead of utilising it to assist the extraction. Thus in the illustration the feed elevator, 1, delivers the coal on the bottom of the chute in which a perforated plate or wedge wire sieve, 2, is placed. A blower, 7, induces a current of air to enter the chamber, 4, in which distributing vanes lead the wind or draught over the surface of the perforated plate and thus up through the coal running down the chute. On the top plate of the latter a series of specially designed vanes, 5, is placed in such a manner to allow passage of the dust-laden current but to prevent the passage of large particles of coal. A deflecting plate is placed

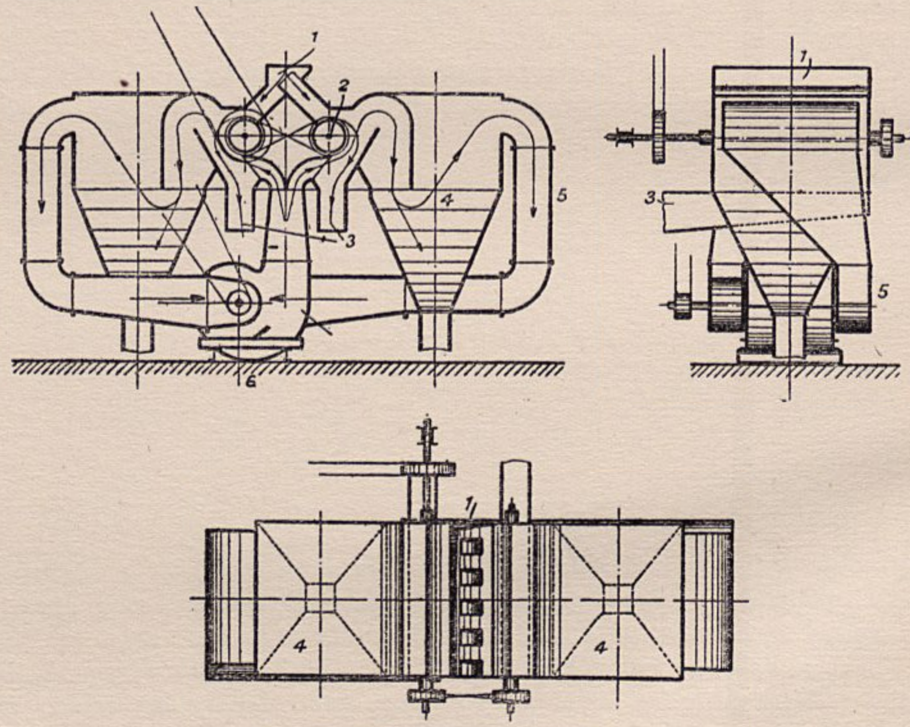

FIG. 90.—HUMBOLDT AIR-DUST PLANT.

behind these vanes and causes the current to pass through the chamber, 6, where the dust is deposited. The circulation of the air is of the totally enclosed type already discussed. The large coal is discharged into the trough, 3.

With this method all the fine dust can be readily extracted, but there are difficulties yet to be surmounted with particles over $\frac{1}{16}$.

Humboldt Air Dust Plant.—A very simple and effective machine has been devised by the Humboldt firm for dealing with dust by blower extraction. The principle employed follows closely that outlined above in so much that

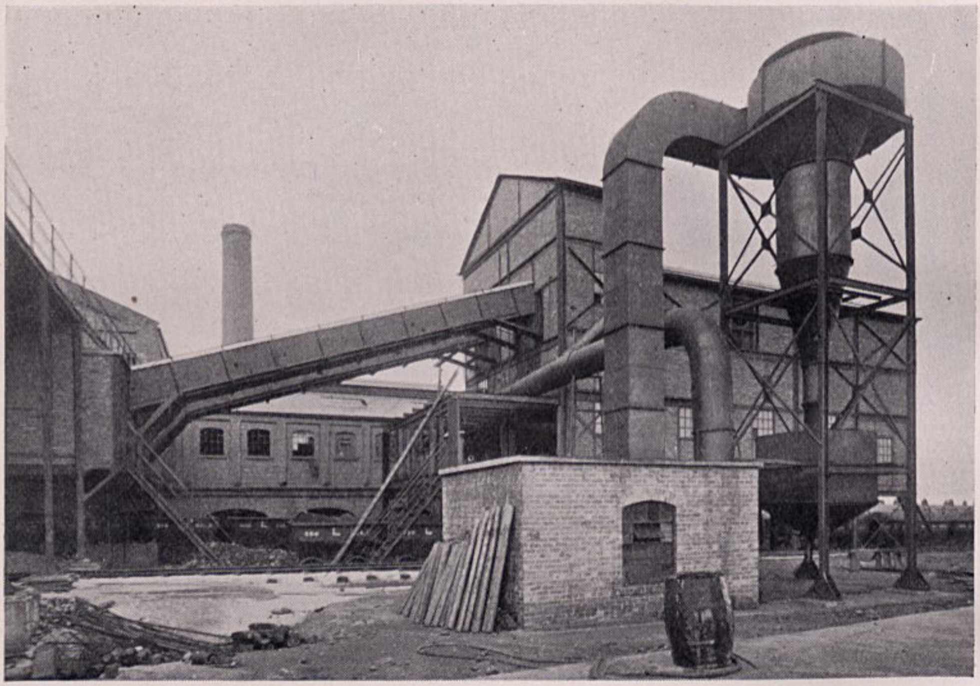

Fig. 91.—Dust Collecting Plant. The Gantries shewn house the Conveyors bringing the Raw Coal from the Screens to the Washery.
(*H. Wood and Co., Ltd.*)

[*To face page* 101.

the dust is not brought down through the mass of coal but is blown out above it. In Fig. 90 an outline diagram of the machine shews that a two-way chute, 1, delivers the fine coal of about $\frac{3}{8}$ inch on to the upper surface of a smooth roller, 2, which rotates in the direction of the fall of the coal. A blower, 6, delivers air in a narrow, rectangular jet tangential to the lowest point of the roller or drum. The coal dropping from this latter into the upper part of the chute, 3, is therefore subjected to a concentrated blast of air as it falls. The dust supported by the current is carried into the dust chamber, 4, in which a deflecting plate is suitably placed. The exhausted air is brought back to the blower by the pipe, 5. It has been found that the machine acts better in tandem as shewn and the results dealing with coal of moisture content of 3 to 4% have been highly satisfactory.

Fig. 91 shews a " Sirocco " dust collecting plant dealing with about 30 tons of coal dust per 24 hours in use at Seaham Colliery.

The method of filtering dust-laden air is to pass it through a series of cloth-woven filtering bags. To prevent these choking after being in use for some time it is necessary to beat them with a stick or other implement.

CHAPTER X

THE SIZING OF COAL

The sizing of the coal while in itself a simple process has given rise to much controversy as to when and where the size classification of the coal should take place.

While historical details are not necessary to elucidate the question it is worth while to take a cursory glance at the developments of classification and the various points of view arising from them.

The different groups of colliery and washery engineers divide themselves in favour of one of the two following methods :—

(*a*) screen and wash,
(*b*) wash and screen,

and arising from these two washing slogans is yet another point of difference in the two following processes :—

(*c*) screen from fine to coarse,
(*d*) screen from coarse to fine.

The question of when the coal should be sized is essentially one of the method of washing and depends largely upon the type of the washer box and the maximum and minimum sizes of the coal treated. There is much to be said for and against both methods, and the existence and commercial success of both systems at the present day would seem to point to local conditions as being the governing factor. There is a limit to which the sizing of the coal before washing can be carried efficiently, and this is treated under the heading of Coal Washing.

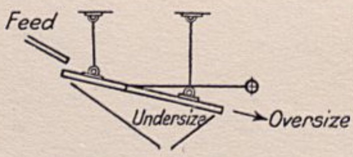

Fig. 92.—Early Type of Screen.

The earliest method of screening was that of the hand screen and belongs to the class (*c*), that is, the fine coal was first taken out and afterwards the large sizes in a progressive fashion from the residue of the material left in the first screening.

On the introduction of mechanical contrivances to supersede those of manual labour a crude type of jigging screen as shewn in Figs. 92 and 93 was devised. A perforated steel plate or tray is suspended on a slight incline by the hanging rods and given a swinging motion by the eccentric shaft. The capacity of these screens was very low as the motion was too uniform to help the material over the surface of the perforated plates.

From this simple arrangement was developed the type shewn in Fig. 94, where the higher suspensory rod is done away with and the eccentric shaft is placed immediately behind the tray, so that the vertical motion of the eccentric is communicated to the tray and a varying tilting surface takes the place of the regular swinging motion. By this means the material was passed more quickly over the screens and a more closely-sized product was obtained. This type, which is still installed by some manufacturers, requires an inclination of about 12° to the horizontal to give sufficient forward motion to the coal; any inclination less than this does not give the requisite jerk to the material.

The next innovation was a motion given by two eccentric shafts of equal throw, with keyways cut so that the motion imparted to the screen is the same

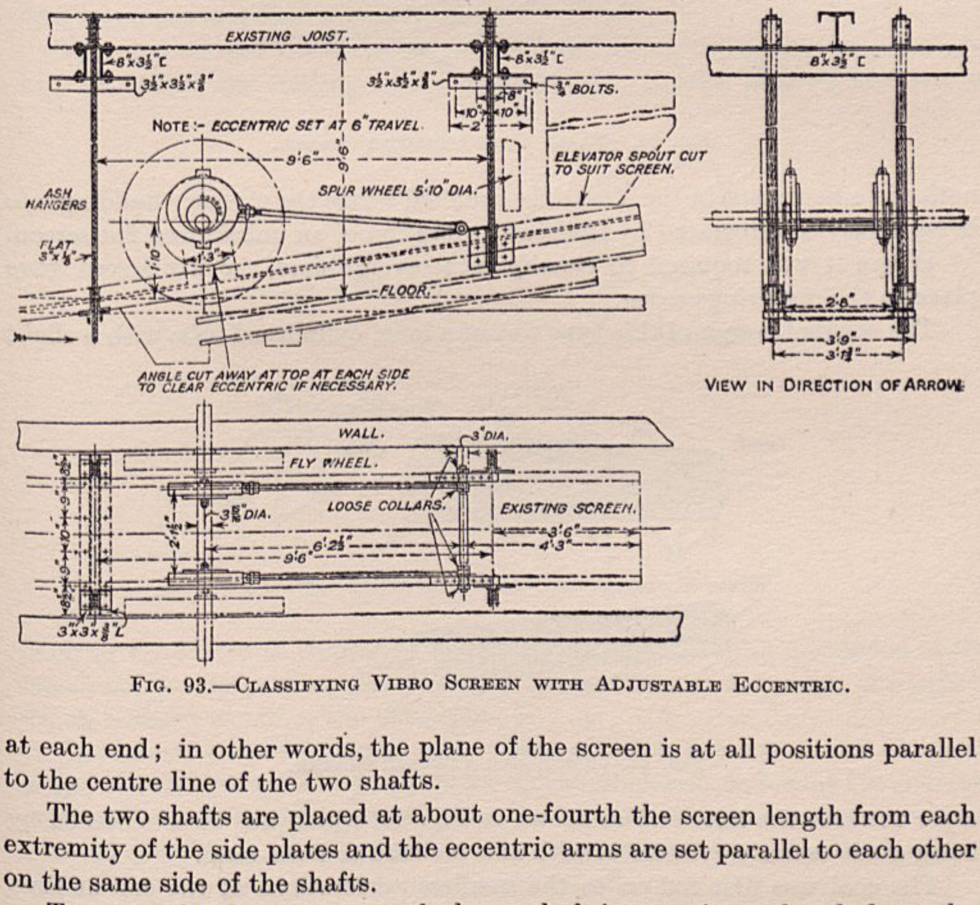

FIG. 93.—CLASSIFYING VIBRO SCREEN WITH ADJUSTABLE ECCENTRIC.

at each end; in other words, the plane of the screen is at all positions parallel to the centre line of the two shafts.

The two shafts are placed at about one-fourth the screen length from each extremity of the side plates and the eccentric arms are set parallel to each other on the same side of the shafts.

To economise the screen area the lower shaft is sometimes placed above the frame. Where the lower shaft is under the screen about 2 feet length over the full width of the screen is wasted, due to the shaft protection from the wet screenings.

Flat screens, unless carefully designed and well balanced by trial running in the shops before actually being put into commission, are apt to give trouble.

The high speed of 180 r.p.m. and the heavy mass in a continual reversal of direction cause a great deal of vibration in the supports and the tray, and unless the workmanship is good frequent repairs will be necessary.

A badly designed screen of this type was recently brought to the author's

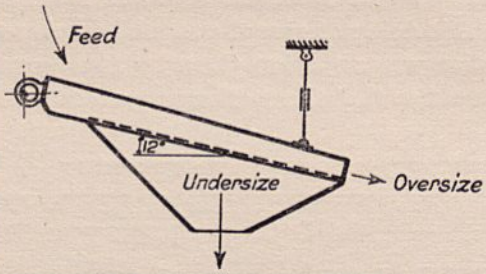

Fig. 94.—Early Type Swinging Screen.

notice in a new plant in the Yorkshire coalfield where the washery building was being slowly disintegrated by the heavy vibration of an unbalanced flat screen.

Where it was required to classify into several sizes, the flat screen gave place to the revolving screen.

The original design of this type was of a long, cylindrical tube with a slight

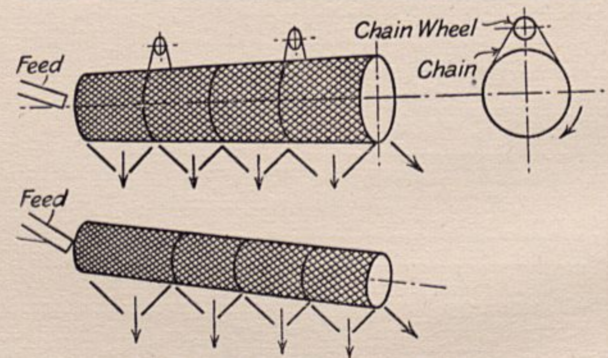

Fig. 95.—Revolving Tubular Screen.

taper towards the inlet end as shewn in Fig. 95, which was later modified by being made entirely cylindrical with axis inclined to horizontal.

The coal was first fed on to the smallest perforations at the end of least diameter and the largest size ejected at the lower end, the intermediate portion being perforated in the ascending scale.

This screen proved to be too unwieldy for large quantities of coal, as the length became prohibitive for practical purposes.

A still greater disadvantage was the uneven wear of the perforated plates and the large expenditure of power in operating the fully loaded screen. The product was generally of very poor sizing quality, as the full quantity of the feed having to pass over the smallest perforations, a large mass was constantly being revolved in the first sizing, preventing the smaller sizes passing through the perforations.

This design was, therefore, modified and a great saving in wear and building space was effected by adopting the telescopic pattern or a series of concentric mantles of different diameters, placed one within the other, as in Fig. 88.

The revolving screen of this type has the great advantage of dealing with large quantities of coal very efficiently, due to the fact that the large size is first taken out and then the next smallest and so on.

The coal on the screen follows a zig-zag path on the mantle as shewn in Fig. 96, where the feeding trough delivers the unsized coal at the lowest

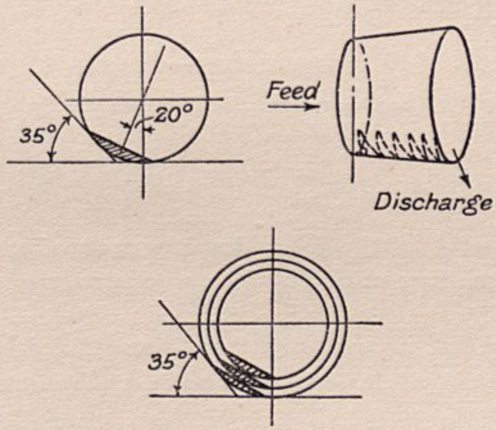

Fig. 96.—Tapered Mantle Concentric Screens.

point of the screen at the end of the smaller diameter. The revolution of the screen carries the coal up the rising side until the slipping angle is reached, which is about 25° from the horizontal.

The effective screening takes place during the fall from this point, the path of the oversize being in a vertical plane on the climb and, following the shortest path on the return, slightly inclined towards the discharge end during the fall. This zig-zagging is directly due to the taper in concentric screens and in cylindrical screens to the inclination of the shaft.

The normal position of the oversize on the mantle is about 15° to the vertical plane passing through the axis of the screen. The upper portion of the mass on the plates is constantly at the slipping angle, and therefore there is a continual turning over of the material in a flattened spiral path.

The diameter of the mantle should be such that the surface of the coal in each layer when working under the maximum load shall be well clear of the outer surface of the inner mantle. The spacing between concentric rings in the best practice is 8 inches, that is, a difference of diameters of 16 inches.

The diameter of the smallest mantle should be such that it will pass the maximum load at 3 square feet per ton area. The peripheral speed is usually between 120 and 150 f.p.m. for soft coals, to ensure a low slipping angle. Higher speeds than this carry the coal too far up the side, the consequence being a large amount of breakage.

There is a limiting speed at which the material is kept on the screen surface due to the centrifugal force, and this takes place when

$$\text{Velocity}' \text{ per min.} = 240\sqrt{\text{Diameter}'}.$$

The best practice is embodied in the following table :—

TABLE VI

Speeds of Revolving Screens—Concentric Type

Max. diameter.	Revs. per min.
9 feet	4
10 ,,	4
12 ,,	3
15 ,,	3

The most successful of the later developments of screening machinery was due to the French firm of G. Pinnette, who introduced the vibro-screen in its present form.

As shewn in Fig. 97, a perforated tray is suspended by hickory hangers from fixed supports, the angle between the plane of the tray and the hangers being about 60°.

The hangers are rigidly bolted to cast-iron brackets on the tray and at the point of suspension.

An inclined ash connecting rod is rigidly bolted to the top side of the tray members and to an eccentric strap on the shaft. The revolution of the shaft gives a sharp jerking motion to the tray and causes the material on the plates to jump forward.

In Fig. 98, let m be a particle of material on the tray, then the forward stroke of the connecting rod causes the tray to rise from the position, y, to the new position, z, and the hangers to bend as shown. The particle, m, has imparted to it a velocity in a direction at right angles to the hangers or springs. When the top position of the tray has been reached, this particle being free to move has sufficient momentum to continue its movement in the direction, s. When gravity overcomes this movement the tray has already covered some portion of its return stroke and the particle falls back on the surface of the plate in the new forward position, m^2, and so on throughout the length of the screen.

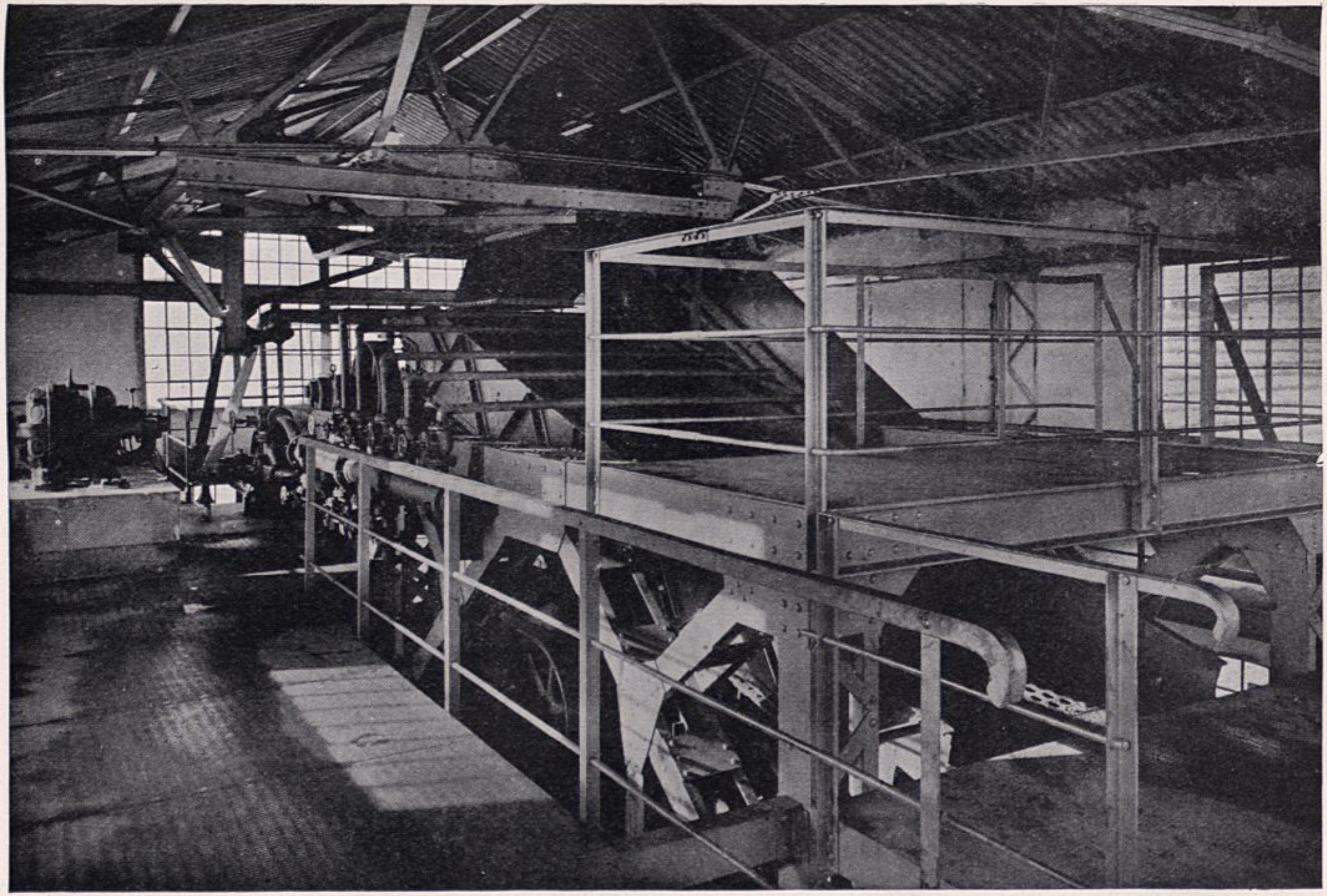

Fig. 97a.—A Circular Motion Type Flat Screen, shewing Spraying Apparatus with Regulating Valves to wash the Sediment of Fine Clay from the Nut Coal. This Screen had been in Commission for Nine Months when the Photograph was taken. The Neatness and Cleanliness are Points to be Noted.

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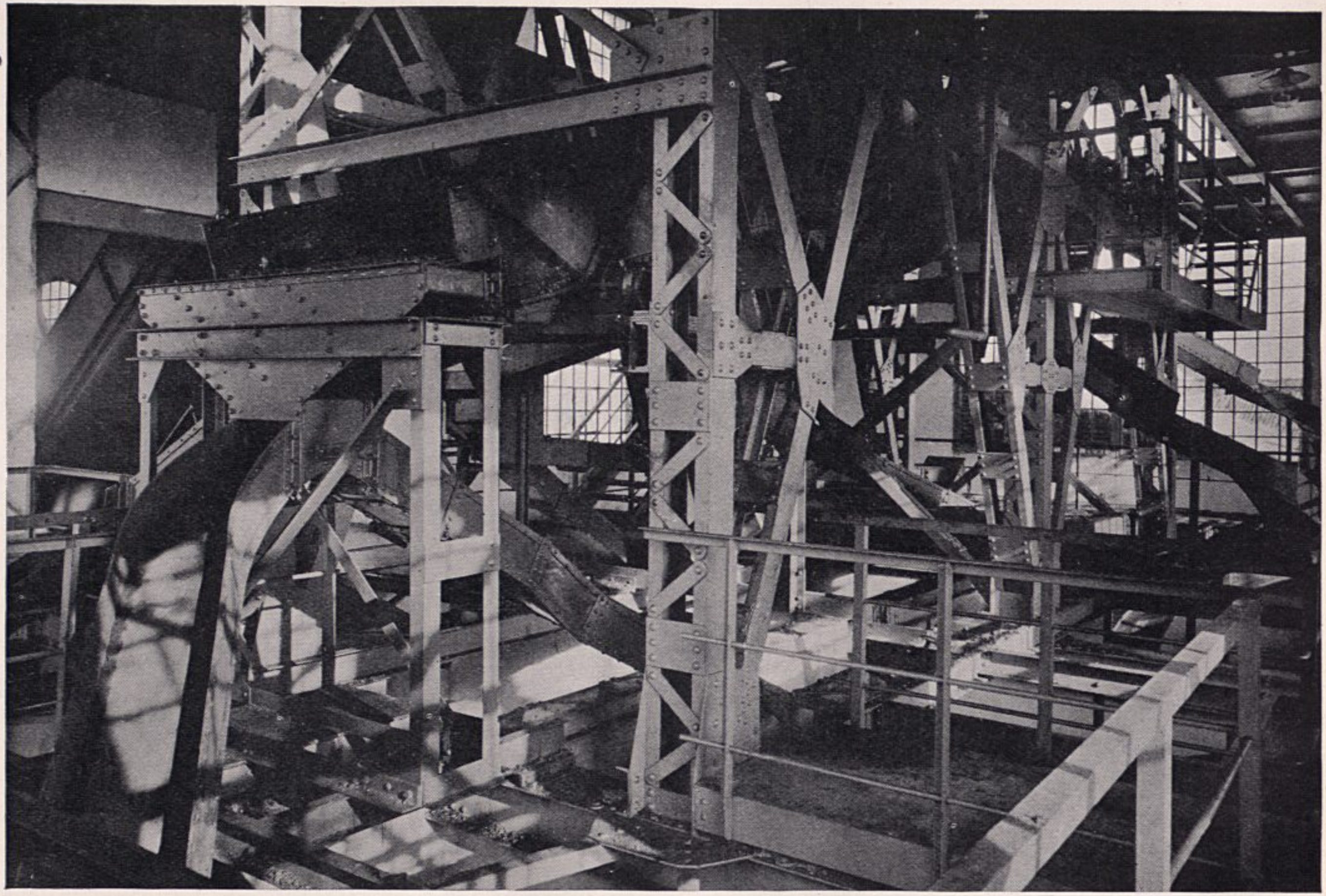


Fig. 97b.—Photograph of the Supports and Shoots into Bunkers of the Classifying Screen shown in Fig. 97a.

This action is a great help in difficult screening. On the forward and upward stroke, the pressure of the material on the tray sorts out the sizes, and the constant throwing forward and turning over of the particles ensures a good and reliable screening.

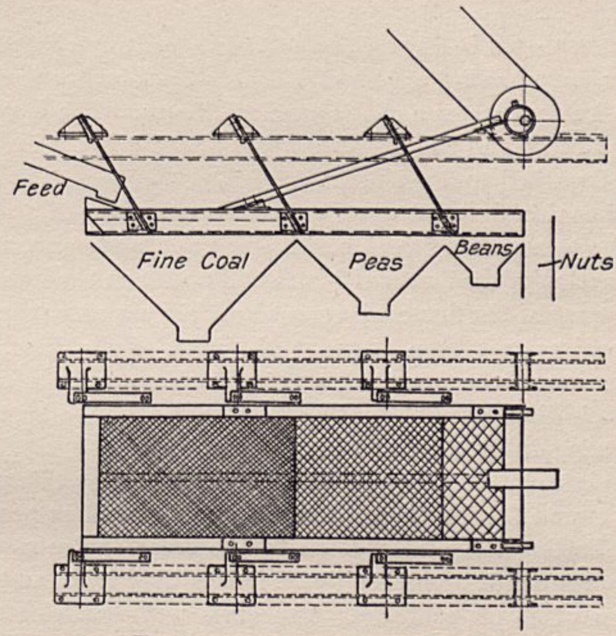


FIG. 97.—SINGLE VIBRO SCREEN.

The direction of rotation should always be against the direction of motion of the material when passing over the top centre of the eccentric shaft.

Running in the reverse direction does not give good results, as there is a tendency to accelerate the passage of the material over the tray, due to the

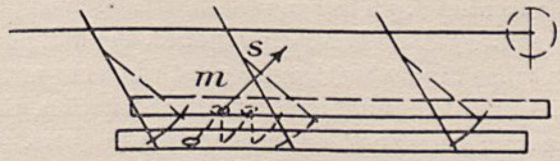


FIG. 98.—PATH OF PARTICLE ON VIBRO SCREEN.

upward jerk of the ash connecting rod occurring at the same time as the forward throw of the springs.

The general practice is to run at 200 to 250 r.p.m. on the eccentric shaft with a throw of $\frac{5}{8}$ to 1 inch.

The screen area required varies from 0·85 to 1·2 square feet per ton of coal per hour on variation in sizes of 0 to $1\frac{1}{4}$ inches to 0 to $2\frac{1}{2}$ inches.

Flat screens on account of the sliding motion given to the coal do not cause the same amount of breakage in the larger sizes as revolving screens. The constant tumbling of the coal in the latter, especially when of small diameter and relatively high speed, is productive of a large percentage of fine coal and dust.

The flat screen shewn in Figs. 97*a* and 97*b* is built up of strong web plates about 20 inches deep having angles of 2 inches by 2 inches by ½ inch section at the top and bottom edges and diagonal stiffeners. The length of the web plates is about 22 feet and the distance apart about 6 feet 8 inches for dealing with 100 tons of washed coal per hour.

The washed coal is first fed upon an idle screen plate of about 9 feet long with ¾ inch holes to separate ¾ inch and below as an undersize, and to promote the further reduction of the fine coal ⅜ inch and under on the lower screen plate. This saves the wear of the fine coal screens and gives a more rapid separation, as the larger coal cannot then obstruct the path of the finer. To ensure a complete separation of the fine coal, a third deck contains a length of 6 feet 8 inches of ⅜ inch diameter holes. The further run of the bottom plate is of ¾ inch peas, passing an oversize of 1 inch beans.

The screen plates are overlapped at their junctions, as this proves to be in practice much more effective than a flushed joint, as well as providing a more easy means of bolting the plates down to the cross angles supporting same. The angle supports are of 2½ inches by 2½ inches by ⅜ inch, and are riveted to cross web plates of ample stiffness. The cross webs are cleated to the main webs and likewise connected in the run of the screen to each other by ⅜-inch plate webs or angles double cleated to ensure a rigid framework, as the total loaded weight of the screen is about 5 tons and is subjected to heavy vibration and knocks due to the reversal of motion. The main webs are further strengthened by diagonal angle members to prevent buckling. The screen is supported on a heavy shaft about 6 inches diameter at the feed end, and is slung from a similar shaft at the front end. The connection of the screen plate to the angles is made as simple as possible to facilitate renewal, the bolts on the web angles being fitted with a collar to prevent dropping out when the nut is taken off. All the bolts are fitted with lock washers to prevent rotation, the cheese-headed bolts used having snugs under the head for this purpose. This screen has proved to be very effective, and providing the shafting and flywheels are designed with care, the heavy vibrations transmitted to the building by similar types of screens may be greatly lessened. The shafts, which are supported in heavy type ring oil bearings of 2½ diameters long, are mounted on a strongly trussed support directly connected to the tops of the bunkers, adequate cross-bracing being rigidly fitted between the two legs. The shafts carry two flywheels which should be balanced by trial in the erecting shops before being dispatched to the washery. These flywheels are connected by belting on one side of the screen to transmit the same motion from one to the other shaft, one of the shafts receiving direct motion from the main line shaft of the washery.

It is very necessary to fit the connecting belt between the two shafts with the necessary degree of tightness in order to prevent slipping, for otherwise a large amount of knock will occur owing to a laggard action on the part of one of the shafts.

It would be a wise precaution to insert a tightening jockey on this length of belt. The eccentric sheaves, which are directly connected to the under side of the main webs, should be of at least 5 inches width and of the spherical pattern to eliminate any faults of alignment which may otherwise cause serious defects in the apparatus. Note the elaborate clean water sprays for the coal.

Balanced Screens.—As the greater part of the sizing of washed coal takes

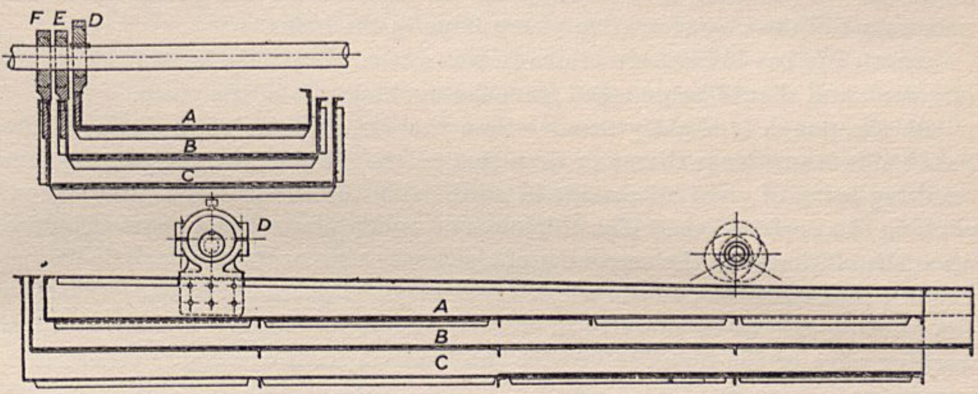


FIG. 99.—SWANN PATENT BALANCED SCREEN.

place prior to discharge into bunkers, it is usual to place the screens at some considerable height above the ground level, and over the bunkers in such a manner that discharge may be effected by direct chutes. A great deal of vibration results from these heavy reciprocating machines and often causes serious damage to buildings ; to absorb these vibratory forces, various methods of balancing the screens have been tried, the most efficient of which is undoubtedly the Swann patented balanced screen. In place of the superimposed decks of the ordinary type of classifying apparatus, a nest of trays, independently operated by separate eccentrics, are slung from two horizontal shafts.

In Fig. 99, A, B, C, are three separate trays carrying perforated screen plates for the extraction of the different sizes.

The tray, A, is supported by four eccentrics, D, and the tray, B, by the four eccentrics, E, while the tray, C, is slung from the four eccentrics, F. The trays are nested one within the other, the top tray taking out the largest size, the second tray the next largest, and so on.

The smaller the material, the larger the screening area required and therefore the largest area of tray is provided by the increase of width. Both shafts are rotated at similar speeds in the same direction and a circular motion is imparted to each tray. The trays remain at all times parallel, and as each set of the eccentrics is keyed at 120° apart a good balance is maintained at all positions of rotation. The throw of the eccentric sheaves differs slightly to equalise the balance and the weights of the separate trays and to provide ample clearance between the neighbouring trays during rotation.

The screen is very efficient in sizing and the manufacturer claims that per unit area a greater screening capacity is possible than in the superimposed type—due to the greater freedom of travel, consequent on the less liability to choking of the perforations. As two adjacent trays at certain points in rotation approach one another a slight cushion of air between the plates gives the necessary fillip to any straggling pieces lying in the holes.

Screen Plates.—The perforations in the screen plate may be slotted square or round, and should be punched from the working side of the plate.

As the punch is slightly smaller than the die, the size of the hole on the punch side is smaller in diameter than that on the die side, the slight taper thus resulting being of great advantage in minimising the chances of a piece of coal choking the perforations. The thickness of screen plates has a great influence upon the efficiency of the screening of the smaller sizes; particularly is this so below $\frac{3}{8}$ inch diameter, as the whole taper may not extend sufficiently close to the working side to be effective in clearing the perforations. The sharper the working edge of the hole the greater the freedom from choking. Where it is important to have good stout screen plates, as, for example, in positions where it is difficult to renew them, a wise precaution is to rimer out the perforations to a sharp edge on the top side. With square holes this is not practicable, therefore relatively thin plates must be used. For perforations $\frac{3}{8}$ inch and below, an ample thickness of screen plates is $\frac{1}{8}$ inch, above $\frac{3}{8}$ inch the plate may be $\frac{3}{16}$ thick. The disposition of the perforations on the plates, while dependent upon the size of the hole and the thickness of the plate, is also dependent upon the shape.

Round holes, which are those most commonly used, are most effective along lines crossing each other at 60°, and at $1\frac{1}{2}$ diameters centre to centre, *i.e.* with a bar $\frac{1}{2}$ diameter wide between the holes and the lines joining the centres of any three neighbouring holes forming an equilateral triangle.

With thick plates it is possible, though not advisable, to place the holes closer together.

It is usual with square perforations to leave a bar between adjacent holes equal in width to the side of the hole, and to space the holes in parallel rows, one row being placed to blind the other. The holes are placed diagonally to the line of travel of the material.

Slotted holes are uncommon in coal washing and are only to be found on the older plants.

The limit to which screen sizing of wet coal may be profitably carried out on punched plates would appear to be $\frac{5}{16}$ inch, and even at this size the efficiency is seldom greater than 80%.

In Scotland it is customary to extract a saleable product no greater than $\frac{1}{8}$ inch, and to do this a high period vibrating screen of woven wire is employed. The wires are threaded over and under one another at right angles at the required distance apart, and as the surface is thus very uneven and tends to impede the progress of the material over the surface, it is advisable to pass the screen through rolls before placing it on the screen tray.

Wire screens are comparatively cheap and give a more uniformly screened product, but have the disadvantage of choking more rapidly than plate screens.

Wedge wire screens have been sometimes used for these smaller sizes and have given very good results when employed with a cubical coal, but where there is a quantity of flat-shaped pieces slightly larger than the slit, the effective screening from the commercial point of view is not satisfactory, as the product known in Scotland as pearls is often made up of the elongated pieces, which on a wedge wire slit screen would pass into the gum product. To compute the efficiency of a screen it is necessary to know the actual size contents of the material before screening. This may be approximated to by experiment upon some reasonable quantity of material by hand appliances. Thus, say that in a given lot there is 60% of oversize, and that in passing over the screen it is found that there is 70% of oversize delivered into the bunkers. There is a shortage in the undersize of 33·3% and an excess of oversize of 14·3%, and as the duty of the screen is to classify the products, the quality of the latter is the one that suffers and the former in quantity only.

It is therefore reasonable to compute the efficiency from the quality, though it would be more exact to take a combination of the quantitative and qualitative percentages.

In the above example, out of a possible 40% of undersize, only 30% of the original material is extracted, hence :—

$$\text{Quantitative efficiency} = \frac{30}{40} \times 100 = 75\%.$$

Out of a possible 60% of oversize 70% of original is separated.

$$\text{Qualitative efficiency} = \frac{60}{70} \times 100 = 85{\cdot}7\%.$$

Therefore the efficiency of the screen may be taken as :—

$$\frac{75 \times 85{\cdot}7}{100} = 63{\cdot}9\%.$$

CHAPTER X

CRUSHING

Where run-of-mine coal is taken direct to the washery special breaking machinery becomes necessary in order to reduce the larger pieces to washable dimensions, and due regard must be paid to the design of the plant to avoid unwarranted increase in the amount of dust entering the plant.

For instance, it is not good practice to tip the tubs into a hopper feeding directly into a breaker, as all the coal, large and small, in passing through the breaker produces an unnecessary amount of small coal and dust, which is provocative of slurry troubles in the washery and bad washing throughout.

The better practice would be to instal machinery to by-pass the small coal; for example, a jigging screen which extracts all the coal of washable dimensions and passes the larger sizes through the breaker, discharging the whole into a common feed hopper. This plant, although requiring a jigging screen, effects a considerable saving of power, involving less capital cost, and less maintenance.

An alternative scheme would be to have a fixed grid, and in the majority of cases is the one to be preferred as being the most economical and adaptable to varying conditions.

The breaker is placed at a lower level than the grid and protected by suitable housing from the coal passing through the grid into the hopper. All coal larger than the required size for washing will not pass through the grid, hence it is dragged or thrown into a small hopper. The labour necessary for this is never of large amount and can easily be done by the labourers shunting the wagons. There is not a great effort required to drag large pieces over the grid bars, and with suitable rakes a large amount can be shifted in a short while.

Breakers.—In coal washing there are only two occasions for utilising breakers. They are, first, to reduce run-of-mine coal to suitable washing dimensions and, secondly, to separate the bone or intergrown coal into recoverable coal and useless shale, so that on re-washing these different products may be completely separated.

In both cases there is no intention of complete reduction or comminution, as the aim throughout is to preserve the coal in the largest possible dimensions. Any breakage required is, therefore, only undertaken from the necessity of obtaining the maximum utility and profit from all material leaving the pit mouth or screens.

This peculiarity of coal-washing breakage requires a special type or types of breakers. Those mostly used are the spring corrugated rollers for middles, or bone coal, the spring spiked breaker for run-of-mine coal, and the reciprocating spiked breaker for run-of-mine coal.

The rollers are about 12 inches diameter and 15 inches long, with corrugations $\frac{3}{16}$ inch deep. They are built up of rings suitably keyed on to a solid drum, each corrugation being a separate ring. The drum is mounted on a heavy steel shaft, the bearing for the drum being fixed in a stout cast-iron frame, while the other drum is supported in a bearing, free to move in the frame guide away from the companion roller.

At the tail end of the frame is a heavy spring given initial compression by nest bolts to force the rollers hard up against each other or at any required distance therefrom. Generally the rolls are separated in a set position of ½ inch as a minimum to 1 inch as maximum. The bearings holding the shaft of the movable roller are connected to the spring cross-head by a stout rod, to the end of which a screwed nut is tightened up against the spring to alter the set of the rollers whenever required. The material which is fed into the receiving hopper drops between the rollers, and being gripped between the two by the friction of the material against the roller side is carried through and broken. The sizing of the material is an important factor in success.

In this particular case we are dealing with a substance whose coefficient of friction is very slight, especially when in a wet condition, such as obtains upon being discharged from a shale elevator after a primary washing. It often happens that the larger sizes of the material refuse to be gripped or seized by the machine, but keep slipping upward upon the faces of the rolls. This is especially the case with the corrugated middles breakers. The spike breakers dealing with the larger kind of coal have a similar trouble, but in a lesser degree. The rolls are caused to revolve in opposite directions at equal speeds, in a sense such that the shaft keyways move towards each other over the top centre, so that the tendency is to grip any material dropped between them by friction in the first instance, and subsequently in increasing pressure, as shewn in Fig. 100. If A is the stationary roller and B the moving roller, a piece of coal, which falls so as to be supported on the periphery may not be gripped by the machine if the angle enclosed by the tangents to the circle at the points of contact be larger than twice the friction angle, that is, if the tangent of the angle is greater than the coefficient of friction. If the set S of the machine be now increased to S_1 it will be seen that the points of contact have been lowered, consequently the angle A has been reduced and the liability to seizure has thereby been increased. It will, therefore, be apparent that the set of the machine will have to be adjusted so that the gripping angle A for the maximum size of coal is less than twice the friction angle of the material. The coefficient of friction of coal upon steel equals 0·4, hence the gripping angle should not be greater than 21°. Much of the difficulty experienced with these machines has been due to non-observance of this fact. Breakers have been fitted with a standard size of roller and set without the proper adjustment for dealing with the larger sizes. The corrugations on the roller surface are

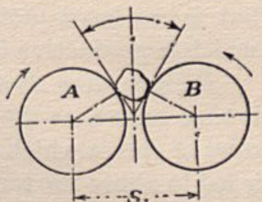


FIG. 100.—DIAGRAM OF BREAKER ACTION.

required to improve the breaking power of the machine and are not effective in improving the seizure, as is erroneously supposed.

Breakers for bone coal would be much more effective if they were plain cylinders with roughened surfaces. The following formula for calculating the minimum diameter of the rollers may be considered good practice: $D = \frac{1}{1 \cos \alpha}(S - A)$, where D = diameter, A = set of the machine, S = size of coal, α = friction angle, or $D = 30 (S - A)$.

Spiked Roller Breaker.—The spiked roller breaker is built up in a similar manner to the above machine (see Fig. 101), but in place of the corrugated rings, cast-steel circular rings, armoured with conical spikes or saw-like teeth at about 1½- to 2-inch centres of points, are used. The great disadvantage of this type of machine lies in the fact that it produces an enormous amount of fine coal in breaking the larger. The steel spikes scratch their way through the soft coal and, therefore, do not produce the regular sizes so much desired by the colliery engineer. The same trouble of slipping occurs with this machine, but is rendered more objectionable by the scratching action of the points, which is productive of much duff coal.

Reciprocating Breaker.—A type of breaker much used on the Continent is that known as the Galland breaker. It is built up of two opposite double rows of spikes which have a reciprocating action. The material to be crushed is fed in above the teeth, and is caught between the spiked jaws and broken in a clean manner. The action is similar to that of the breaking of ice with a steel needle, the coal splitting along the plane of least resistance without any secondary grinding. The success of this machine has been due to its regular production of uniformly sized products and the small amount of fine coal resulting from the process.

Single-roll Breaker.—This breaker is of the type known as a single-roll jaw breaker, and is pre-eminently suited to coal breaking. The rolls are formed of projecting teeth, every fourth row having more prominent teeth, so as to ensure a positive grip upon the material to be broken. Fig. 102 shews a diagrammatic arrangement. In Fig. 103 is shewn the British design of a similar type devised by Hadfields.

Pin Disintegrator.—For reducing slack coal to a size suitable for coke-oven purposes, a type of crusher similar to that shewn in Fig. 104 is used. Coal being of a brittle nature, a sharp blow shatters the cohesion of the particles. The coal is fed into the centre of a large casing of about 6 feet diameter in which two heavy discs, armed with steel pins, are revolving rapidly in opposite directions. The steel discs are concentric and have circles of steel pins riveted to them at about 8 inches between the centres of each row of pins.

The extremities of the pins of the larger disc are connected by a circular steel plate and are about 16 inches long. At about 3 feet apart on the outer

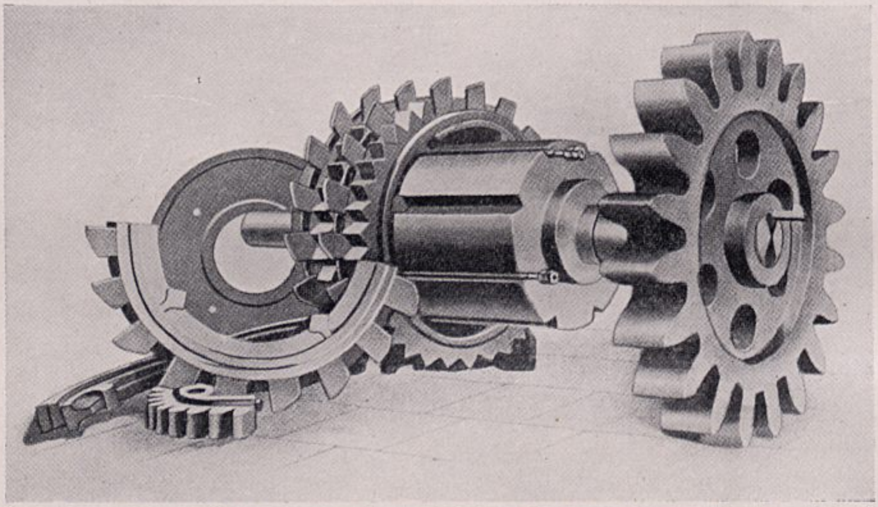


Fig. 101.—Spiked Roller Breaker.

[To face page 115.

circumference, a steel bar is bolted to the disc and ring. This bar is armoured with projecting pins about 3 inches long, or an angle iron will serve the purpose. The whole is mounted upon a shaft of about 6 inches diameter supported in

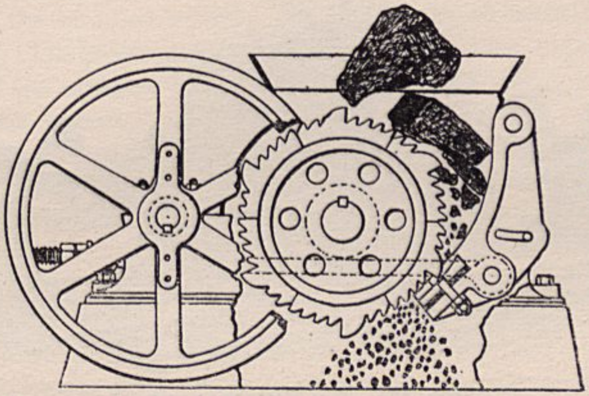


FIG. 102.—JEFFERY ROLL CRUSHER.

heavy double bearings, between which the driving pulley is mounted. The shaft has a $\frac{3}{4}$-inch shoulder turned on it to form a thrust collar in the near bearing. The smaller steel disc has only one circle of pins riveted into it; these are about 12 inches long. The extremities of these pins are riveted into a wide

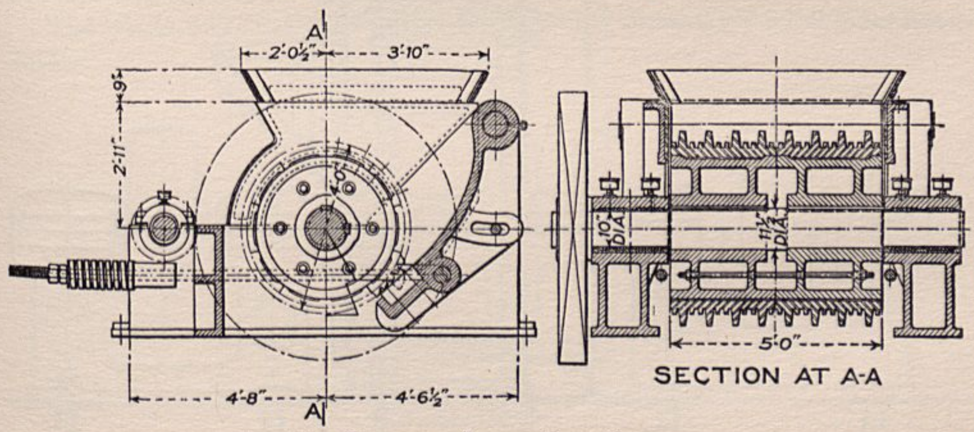


FIG. 103.—HADFIELD SINGLE ROLL CRUSHER.

circular plate about 10 inches wide; at a distance of 8 inches from the inner circle of pins a second row or circle of pins is riveted into this plate and connected at the other extremity by a narrow circular plate, so that the pins of the outer and inner discs form concentric rings at equal distances apart.

The circle of pins of the small disc are thus nested into the circles of pins of the larger disc.

The direction of rotation of the former is against the direction of rotation of the latter. The shaft on which the small disc of pins is mounted is similar to the other, but has a greater overhang from the near bearing. When coal is fed

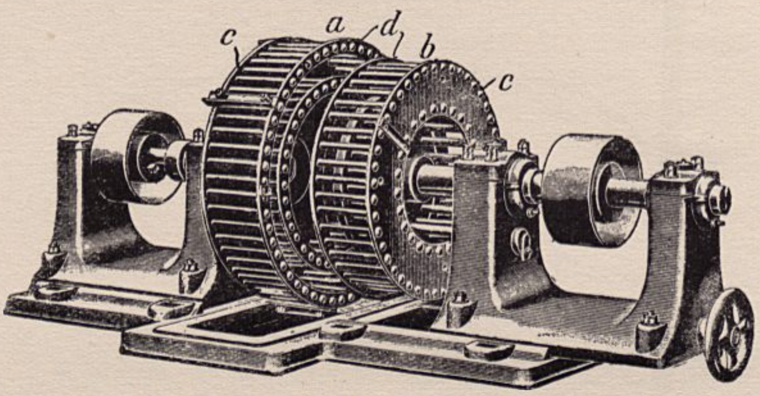


FIG. 104.—PIN DISINTEGRATOR.

into the centre of the chamber the rapidly revolving rings strike the coal at a high velocity one against the other, so that the coal is quickly disintegrated into

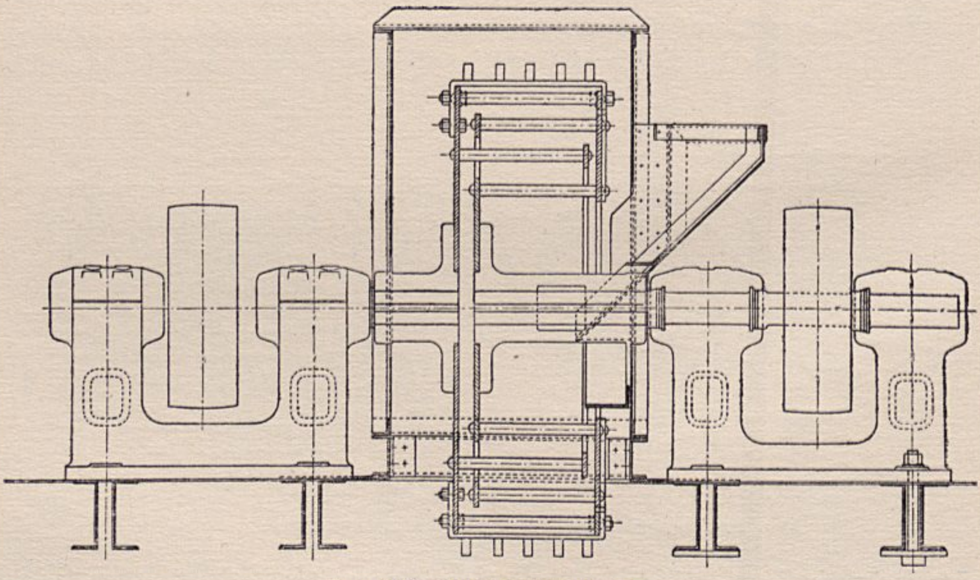


FIG. 105.—PIN DISINTEGRATOR.

a very small size. As the speed of each shaft is from 200 to 250 r.p.m., the average peripheral speed is about 3500 feet, or the pins are passing each other at the rate of 7000 feet per minute. This enormous velocity delivers a terrific blow to the coal, as each blow which is struck is positive before the coal has a chance of leaving the cage. To prevent any coal dropping between the side of the chamber and the small disc pins, a large angle is bent in semi-circular form just under the shaft and riveted to the side of the casing. The vertical pins on the outer rim are fitted to clear away any packing of the fine coal by centrifugal force on the circular casing. The latter is constructed throughout of $\frac{3}{16}$-inch plating. The bearings must be in true alignment to obtain good working, and to this end the machine should be bedded upon a strong foundation.

A better and more evenly working crusher is that in which the double bearing gives place to a long single bearing, of a length equal to eight times the diameter of the shaft. In this case it is advisable to fit an overhung fly-wheel pulley on the offside of the bearing. By this means a better balance is obtained and the machine works with considerably less vibration and with less expense of maintenance.

In Fig. 105 is shewn this latter type of crusher. The bearing contains two bushes, between which the thrust collar shoulders are placed; both bearings are of the self-oiling ring type, as shown in the detail. A split steel ring in diameter over 3 inches larger than that of the shaft is hung from the top side of the shaft, with its bottom side resting in an oil well formed by the lower half of the bearing casting. This ensures a continual oiling. The bearings are protected from dust by close-fitting collars, fitting over spigoted projections on the bearing casting. This type requires a good solid foundation carried hard up to the underside of the pillow block.

The whole is of very substantial design and is thoroughly reliable for heavy duties.

CHAPTER XI

THEORY OF COAL WASHING—WET SEPARATION

The specific gravity of commercial coal varies between 1·3 and 1·5, and the specific gravity of the contained shale and dirt is 1·5 and above. As we do not deal commercially with the absolutely pure material, the exact specific gravity of the combined chemical elements does not concern the investigation. The real separation is the grouping of material of slight variations of S.G. within certain limits.

The average S.G. of the slack as received at the washery may be 1·5, and the laboratory separation of the same material may reveal that it is composed of coal and shale varying in S.G. from 1·3 to 2·6 in a gradually increasing scale, that is, without any sharp division between the qualities.

Where the raw coal contains a well-defined light and heavy mixture, the separation is comparatively easy.

The difference of weight of the useful coal and the valueless shale indicates the principle to be utilised in their separation, and the problem for the mining engineer to solve is therefore reduced to that of finding the most economical method of differentiating between, and grouping together in classes, of bodies of varying densities irrespective of size.

As the human faculty of judging the differences of weight of small bodies, apart from the tedium and cost of hand picking, is not sufficiently accurate, this method is confined to large coal only. There are several possible solutions to this problem of separation, and those most readily applicable are :—

(1) Sliding friction.
(2) Flotation in liquids of equal densities.
(3) The fall of bodies in air.
(4) The flotation in liquid.

As the friction of a body to movement upon a plane surface is directly proportional to the weight, this would seem to be a very feasible solution. Many inventors have exploited machines on this principle, but few with satisfactory results. We will, however, leave the discussion of this to the chapter on Friction Separation.

A very exact method of separating materials of different densities, irrespective of size, would be to immerse them in liquid of densities equal to the bodies.

Take, for example, a raw slack containing refuse varying from 1·5 to 2·3 and commercial coal of 1·3 to 1·5. An immediate solution would be to immerse the raw slack in a liquid having a S.G. of 1·5, then all the floatings would be of a required commercial use, while all the sinkings would be disposed of on the refuse heap.

There could not be a better or more exact method if a suitable liquid could be found of reasonable cost. The liquid would necessarily have to be of a neutral chemical character and would furthermore have to be easily obtainable in sufficient quantities.

Such a liquid is chloroform, but the cost of this would be such that a coal separated by its aid would be prohibitively expensive.

Water, which is the most abundant liquid, could not economically be rendered sufficiently dense by solutions to attain the desired end.

Therefore, to separate statically seems at present to be a possible but impracticable solution, and we must turn to methods based on ingenuity in the utilisation of common materials and principles.

The fall of gravity upon any free body we know to be dependent upon the mass of that body, and one of the first steps in technical instruction is to learn the Law of Falling Bodies, *i.e.* that bodies falling in a vacuum under the influence of gravity alone all have the same velocity and the same acceleration.

However, with various densities of media the velocity and acceleration are retarded. The old experiment of school days of a feather and a lump of lead occurs to the memory.

A body falling in air has opposed to its motion the resistance of the air, and as the force acting on a freely falling body is equal to its weight or :—

$$\text{Force} = \text{Mass} \times \text{Acceleration.}$$
$$\text{F} = m \times a$$
$$= \frac{\text{W}}{g} \times g = \text{W},$$

and the resistance is proportional to the cross-sectional area of the body, it is logical to assume that of two bodies of equal shape and different densities or weights, the heavier will advance over the lighter when starting from rest. The force producing the acceleration is greater in the former than in the latter, but the resistance is the same in both cases.

Therefore, given a suitable distance through which to fall, and two similar particles of shale and coal, the former would be the first to reach the ground.

The drawback, however, is that the interval between the arrival of the particles would be too short for practical purposes, to say nothing of the breakage of the coal. The difference of the acceleration due to air resistance on such bodies is extremely slight, and the separation is not permanent, but is destroyed as the ground is reached. This method, therefore, does not hold any practical possibilities of economical accomplishment.

A gaseous enveloping medium, as air, does not possess sufficient resistance to displacement to make the difference of acceleration sufficiently marked at the beginning of the fall to permit of the heavier body or the one subjected to the greatest force to advance appreciably over the lighter. On the other hand, if the enveloping medium had a density such that the resistance to displacement was relatively great in comparison to the density of the falling bodies, the increment of advance at the beginning of motion would be more pronounced.

Such considerations lead us to the fourth method of separation, namely, settlement in a liquid medium of density less than the bodies immersed in it.

This brings us back to the second method of flotation in liquids. The possibility of a combination of the floating method with the third method of falling bodies presents alluring prospects to the inquiring mind. The damping effect of water upon the fall of bodies due not only to the resistance of displacement, but also to the robbing of the gravitational force or weight of such body due to the partial flotation, emphasises the tendencies to separation in both cases.

This latter method has been extremely successful, and owing, no doubt, to the use of water as the separating medium, has become known as "coal washing" in France and this country.

For much of the scientific data in connection with coal washing we are indebted to the German professors and engineers, who have undoubtedly contributed the most popular systems of separation in use to-day. The great majority of experiments upon the laws governing the settlement of particles in a liquid medium under varying conditions have been carried out abroad, primarily because the coal of foreign countries, not being of such good quality as our own, made the improvement a necessity. There is no doubt that had the coal-washing trade of Germany not been developed, the coal of the country would have been unsaleable in competition with our own. The experiments for the greater part were carried out on materials of a greater range of specific gravity than is usual in wet separation, but recent experiments of British and American professors confirm the applicability to this branch of the subject.

We have endeavoured in the following paragraphs to simplify the arguments, as coal is a relatively cheap product, and engineers engaged in this industry are practical men; the theories have been shorn of much of their rigorous exactness in their original form and are here presented as approximately correct for practical application rather than academical investigation.

Fall of a Particle in Still Water.—A large particle of greater weight than the volume of water which it displaces, when placed freely in a tank, will sink and in sinking will cause a further displacement of water in its path downwards. If the particle is just heavier than an equal volume of water, that is, of a slightly greater density, its downward movement will be sluggish, but, on the other hand, if it is several times more dense than the water, it will sink rapidly. These facts are of everyday observation and can be readily tested by the reader. The cause of this difference of movement is not difficult to solve. During the sinking the particle must displace the enveloping water, and this movement offers resistance to the fall. The moving particle must necessarily impart velocity to the water, which is dissipated in eddies throughout the whole mass.

To impart this velocity upon the liquid a force must be employed, which is the difference between the weight of the particle and an equal volume of water. As the resistance is then totally absorbed by the eddy formation, we can term it " Eddy Resistance." A heavy particle will produce a more violent eddy formation than a light particle. From experiment, the eddy resistance can be expressed as :—

$$E = CA\frac{v^2}{2g}\delta W.$$

where W = Specific weight of water.
E = Eddy resistance.
A = Cross-sectional area.
v = Velocity.
g = Gravity symbol.
C = Constant $\begin{cases} 0{\cdot}49 \text{ for sphere.} \\ 1{\cdot}28 \text{ for cube.} \end{cases}$
δ = Density of particle.

To give velocity to any particle from rest, it must be subjected to some external force, which in this case is the gravitational force modified by the buoyancy of the surrounding medium, which reduces the amount of the force by the weight of the equivalent volume of liquid displaced by the particle :—

$$\text{thus Force producing acceleration} = V(\delta - \delta_o)W,$$

where V = Volume of particle.
δ = Density of particle.
δ_o = Density of liquid.

From the equation of eddy resistance it will be seen that the latter is proportional to the square of the velocity, that is, that the resistance grows rapidly with the increase of velocity, or as the force producing the acceleration is independent of any variable, it must necessarily remain constant, and therefore at some time the falling particle will attain a velocity such that the eddy resistance will become equal to the force. From this instant the velocity will remain constant, irrespective of the distance passed over. This velocity we will call the *terminal velocity* of the particle, and equating the above expressions :—

Eddy Resistance = Force producing acceleration,

$$CA\frac{v^2}{2g}\delta W = V(\delta - \delta_o)W$$

$$\text{whence } v^2 = \frac{V(\delta - \delta_o)}{A\delta} \times \left(\frac{2g}{C}\right)$$

considering the particle to be a sphere

$$C = 0{\cdot}49$$

$$V = \frac{\pi d^3}{6}$$

$$A = \frac{\pi d^2}{4}$$

$$\text{Therefore } v^2 = \left(\frac{\frac{\pi d^3}{6}}{\frac{\pi d^2}{4}}\right)\left(\frac{\delta - \delta_o}{\delta}\right) \times \left(\frac{2g}{0{\cdot}49}\right) = d\left(\frac{\delta - \delta_o}{\delta}\right) \times \left(\frac{2g}{0{\cdot}49} \times \frac{2}{3}\right).$$

As the dimensions we are dealing with in the above investigation are extremely small, it is customary to avoid the awkwardness of expression in small fractions of an inch to use the metric system. In this system of dimensions, the gravity symbol, g, is 9·81 metres per second, per second, per second, against the equivalent English measure of 32·2 feet per second, per second, per second.

Substituting this value for g in the above, we get

$$v = \sqrt{26{\cdot}16d\left(\frac{\delta - \delta_o}{\delta}\right)}$$

When the liquid medium is water the density $\delta = 1$,

therefore $v = 5{\cdot}11\sqrt{d(\delta - 1)}$ metres per second,

which is the terminal velocity for a sphere.

If we now insert the value of the constant for a cube in the above equation we get, if S = side of cube.

$$v^2 = S(\delta - 1)\left(\frac{2g}{1{\cdot}28}\right)$$

$$v = \sqrt{15{\cdot}32 \times S(\delta - 1)}$$

$$v = 3{\cdot}9\sqrt{S(\delta - 1)} \text{ metres per second.}$$

which is the terminal velocity for a cube particle.

Wherever there is free movement it is always taken for granted that the body will move in the direction of least resistance, so that an elongated particle placed in water should generally fall with the least cross-sectional area across the plane of movement, or the greatest length in the plane. This, however, is not entirely borne out in practice, though it is admitted that angular particles, or heavy, flat, and long bodies, do certainly appear to fall in this manner. Laminated particles and long, narrow particles seem to get a tumbling or slight zig-zag motion when sinking, as in the exaggerated example of a falling leaf. This indecision of movement retards the progress through the water and hence the terminal velocity of unevenly-shaped particles is less than those of regular shape of equal cross-sectional area, thus for angular particles :—

$$v = 2{\cdot}5\sqrt{d(\delta - 1)}.$$

From the above we can arrive at the general formula for the terminal velocity of the fall of free particles in still water

as
$$v = C\sqrt{D(\delta - 1)},$$

that is, the velocity varies as the square root of the diameter and the density minus one.

Those particles which possess the same terminal velocity are said to have equal settling properties, irrespective of their diameters or densities. This is sometimes spoken of as "equivalence" under free settling conditions. Thus, given two particles, one of shale and the other of coal, although the former may be only one-eighth of the diameter of the latter, if the terminal velocity as found by the general formula is the same, then they are of equal settling properties.

The period of time from rest to the attainment of the terminal velocity will depend upon the acceleration of the particle, and as the acceleration is directly proportionate to the force, we may readily find how it affects the particles of different densities. Thus

$$\text{Force} = \text{Mass} \times \text{Acceleration}.$$

$$V(\delta - \delta_o)W = \frac{V\delta W}{g} \times a$$

$$a = \frac{V(\delta - 1)\,W \times g}{V\delta W}$$

$$= \left(\frac{\delta - 1}{\delta}\right)g$$

That is, the acceleration is entirely dependent upon the density of the particle, and of two particles of equal settling qualities, the denser will advance over the lighter until the terminal velocity is reached. The denser particle, having the greater rate of acceleration, will naturally reach its maximum velocity first and will increase its lead over the other from rest to that point. Immediately it has done so, however, the lighter particle will creep up until its terminal velocity is attained. This velocity being the same in both cases, and remaining constant, the two particles will now travel onward at a constant distance apart. Fig. 106 shews a graph of the fall of the two particles, from which it will be seen that the curve A of the denser particle increases more rapidly at the beginning, to eventually develop into a straight line. The curve B of the lighter particle increases its distance from curve A until it passes the time ordinate at which the curve B reaches the terminal velocity point, and it then gradually approaches a maximum when the point of terminal velocity C is reached, when it runs parallel to the curve A. The above may be summarised as follows :—

That of two particles of equal settling properties, though of different diameters and densities, the denser will have the greater rate of acceleration, or, in other words, the one of the greater specific gravity will advance at the start over the one of lesser specific gravity.

The fundamental laws of coal washing are based entirely upon the above argument, and in actual practice the difference of results and application is only one of degree.

The above conditions are considerably modified in the case of very small particles. The resistance to the fall being due more to skin friction or viscosity

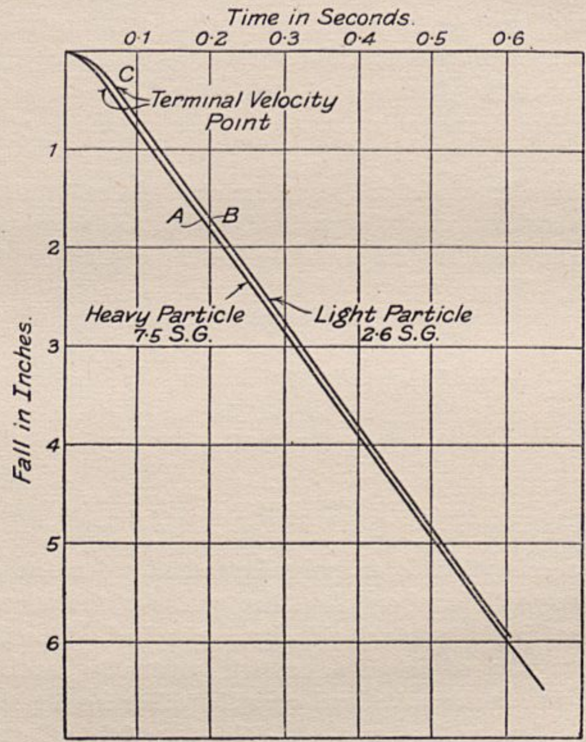


FIG. 106.—GRAPH OF EQUAL-FALLING PARTICLES.

of the liquid than to eddy resistance, the terminal velocity is relatively low, particularly so if the particle is dry. Everyone has noticed that when small particles are let fall on the surface of water, even though their density may be many times that of water, they often float. This is an example of viscosity. The terminal velocity will then vary as D^2 or as found by experiment :

$$v = C(\delta - 1)D^2 \text{ millimetres per second.}$$

where C = Constant.

,, = 400 for shale.

,, = 310 for coal.

D = Diameter in millimetres.

Since there is such a great difference between the factors of the two equations for terminal velocities of large and small particles, in the former varying as $\sqrt{D}$, and in the latter as D^2, there must be some critical diameter at which the change takes place. It cannot be assumed that this happens suddenly, as there can be no doubt that in practice the change is gradual, and between limits both skin friction and the eddy resistance must affect the velocity at the same time. Hence the change must take place when

$$C_1(\delta - 1)D^2 = C\sqrt{D(\delta - 1)}.$$

Squaring both sides of the equation, we get

$$(C_1(\delta - 1)D^2)^2 = C^2 \times D(\delta - 1)$$

$$D^3 = \frac{C^2}{C_1^2(\delta - 1)}$$

substituting values

$$C_1 = 300$$
$$C = 160$$
$$\delta = 1{\cdot}35$$

we get $D = 0{\cdot}96$ millimetre.

Hence at about 1 millimetre the viscous resistance becomes of greatest moment in the subsequent velocity of the particle.

So far we have considered that the particles were not only free to fall, but that they were likewise mutually free, that is, so disposed as not to interfere with one another. In practice, these conditions do not and cannot obtain, and the particles which are subjected to this means of separation are necessarily bunched together so that the freedom of fall is hindered one with the other. Further than this, it would be impracticable to deal with the bulk of the particles in still water, on account of the large space that would be required to contain the water and the material. As we have seen, the settlement into classes is dependent upon the relative values of the terminal velocities of the particles constituting the material to be treated. In place of allowing the particle to acquire a velocity due to its weight in water, it is reasonable to suppose that, should the water be given an upward velocity, then the materials having a terminal velocity of equal amount would be suspended in the current. Those particles having a higher velocity should sink through the current, while those of a less velocity would be carried upward by the current. Here we have a much more practicable proposition; it is a simple matter to carry out these conditions by a suitable disposition of machinery. It is found by experiment that these new conditions bring about a change of terminal velocity.

Owing to the packed condition of the bed the change operates as though the density of the liquid medium had been increased.

In the case of coal washing carried out in a jigging machine, this density may be taken as 1·15. As illustrative of this effect we will consider the actual change in the equal-falling ratios under free settling and hindered settling conditions. In the former, taking shale as having a specific gravity of 2·4 and coal a specific gravity of 1·3, the relation of equal-falling particles must be :—

$$\frac{D_C}{D_S} = \frac{2{\cdot}4 - 1}{1{\cdot}3 - 1} = \frac{1{\cdot}4}{0{\cdot}3} = 4{\cdot}66,$$

that is, the particle of coal would settle at a velocity equal to that of a particle of shale $\frac{1}{70}$th as large in volume. Under hindered settling conditions, this would be altered to

$$\frac{D_C}{D_S} = \frac{2{\cdot}4 - 1{\cdot}15}{1{\cdot}3 - 1{\cdot}15} = \frac{1{\cdot}25}{0{\cdot}15} = 7{\cdot}3,$$

that is, the particles of shale and coal of equal settling velocities would have diameters in the proportion of 7 to 1. This is of great advantage, in so much that it is thereby possible to separate between wider limits of size under hindered settling conditions. So far we have considered only particles of regular shale, whereas in practice there are countless variations. Rittinger, who carried out elaborate experiments in this respect, came to the conclusion that under hindered settling conditions the constant C of the equation $v = C\sqrt{D(\delta - 1)}$ metres per second, could be given the following values :—

C = 0·833 for small spherical particles.
0·49 for rounded particles.
0·536 for angular and flat particles of uniform shape.
0·307 for large rounded particles moving in a mass of smaller particles, when difference of diameters is pronounced.

So that if we were to take account of the difference in shapes, we would find that the equal-falling ratio of a large coal particle and the smallest shale particle would be

$$\frac{D_C}{D_S} = \left(\frac{2{\cdot}4 - 1{\cdot}15}{1{\cdot}3 - 1{\cdot}15}\right) \times \left(\frac{0{\cdot}536}{0{\cdot}307}\right)^2$$
$$= 8{\cdot}3 \times 2{\cdot}89 = 22 \text{ times}$$

by considering the shale particles as being of flat or angular shape, which shows that the limit of separation is still further increased. In actual practice, however, the limits of specific gravity of the commercially recoverable products are not so favourable. It is considered in the best practice that the washable coal for commercial purposes should vary only between 1·3 and 1·55, all the material having densities greater than the latter figure to be considered as waste; hence a reasonable washability factor would be the following :—

$$\frac{D_C}{D_S} = \left(\frac{1{\cdot}55 - 1{\cdot}15}{1{\cdot}3 - 1{\cdot}15}\right) \times \left(\frac{0{\cdot}536}{0{\cdot}307}\right)^2$$
$$= \left(\frac{0{\cdot}4}{0{\cdot}15}\right) \times 2{\cdot}89 = 7{\cdot}54$$

so that we can take it that the ordinary type of machine working on the principle of hindered settling will only deal with material varying in size eight diameters, that is, if material up to 2 inches diameter were washed, shale as fine as $\frac{1}{4}$ inch would be extracted. There are machines which give better results than that indicated above, as there is no doubt that the smaller particles of shale may be considered as lying between angular particles and small spheres, hence the constant c will be increased to some figure between 0·536 and 0·833.

We may summarise the above as follows : in an ascending column of water

(1) of 2 particles of the same size, that of the lowest specific gravity will rise higher than that of the greater specific gravity;

(2) of 2 particles of the same specific gravity and different diameters, the smaller will rise higher than the larger;

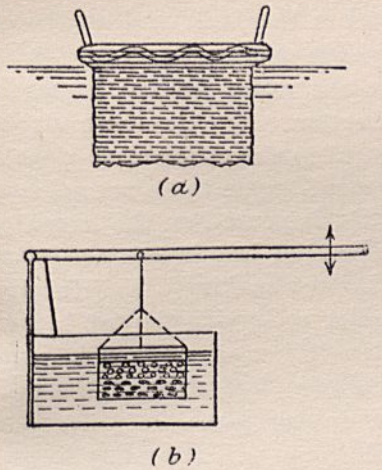


Fig. 107.—Early Type of Washer.

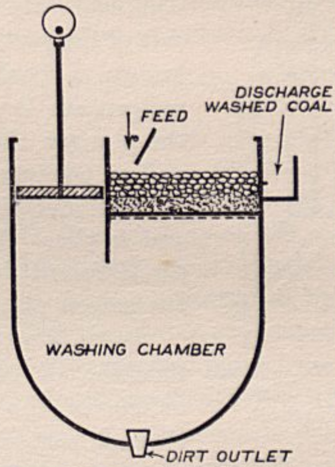


Fig. 108.—Original Basher Box.

(3) of 2 particles having the same settling velocities, that of the greater density will fall at a greater rate in the ascending column of water than that of the particle of lighter density, if the ascending current be less than their terminal velocities;

(4) of 2 particles of equal diameter and of different densities, that of greater density will advance rapidly over the lighter, and of 2 particles of the same specific gravity the larger will advance at a greater rate than the smaller;

(5) of 2 particles having the same terminal velocities and different specific gravities, the heavier will advance at the beginning, but be overhauled after a short interval by the lighter.

The earliest type of machine jig used in wet separation took the form of that shewn in Fig. 107 (a). It is a crude form of wickerwork basket which, when about half filled with coal, was placed into a tank of water and given an up-and-down motion for such a period as the workman found necessary. The movement in the water caused a rough stratification of the material, leaving the lighter and pure coal on top and the heavier coal on the bottom of the basket. When the operator takes the basket out of the water, he scrapes off the upper half of the contents as washed coal, and the remainder is dumped on the refuse heap. This rough method gave place eventually to the hand-operated jig as shewn in Fig. 107 (*b*), where in place of the basket a box about 18 inches square, with the bottom of a perforated iron plate, was suspended from a lever arm. The same method of sorting was here carried out. After passing through many varied changes the former gave place to a mechanical device in which a tank, E, is divided into halves by a centre plate, as shewn in Fig. 108. On one side a perforated screen plate is fitted at some suitable distance below the water level in the tank, and on the other side of the partition plate a piston or plunger—or, as it is better known, a basher—at about the water surface, is made to reciprocate in a vertical direction. On the down stroke of the plunger, the water is caused to rise at the sieve-plate side, and on the return stroke to recede again to its normal level.

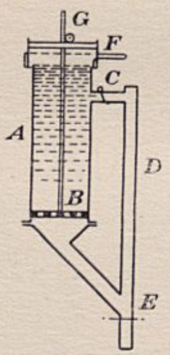


FIG. 109.—NOVEL FRENCH WASHING MACHINE.

The material to be washed is poured on the screen plate and is there classified or separated into layers, according to the different densities, the heavier making a bed directly on the screen plate and the lighter occupying the top layers.

In this connection a description of a French washing machine of 1850 is particularly illustrative of the definite action of the stratification taking place in water flowing through material of different densities. According to records this machine gave very satisfactory results at the time of its operation. A cylinder, A, Fig. 109, contains a perforated plate, B, operated by a rack and pinion, G. The cylinder is filled with water and the piston or plate is drawn up by the pinion to its top position. A quantity of slack is fed into the cylinders above the piston, which is allowed to slowly descend so that the water may flow through the perforations and agitate the coal, or to cause it to scuffle for density positions. Having reached the bottom position, it is again drawn up and the material is found to have been stratified with the heavier shale on the plate and the lighter material ranged upwards relative to their densities. On drawing up the piston, the dirty water covering the coal cannot return through perforations, on account of the layer of densely-packed fine coal formed on the surface, and is therefore forced through the non-return flap valve, C, into the down pipe, D, and back into the bottom of the cylinder, after having deposited the fine slurry or slime at E, where it is drawn off by the valve, H. The larger material on being drawn to the top of the cylinder is scraped off by the scrapers, F. This apparatus contains, in a very crude form, all the characteristics of a present-day washery, and as far as the author can gather, has the distinction of being the pioneer of sludge recovery and water clarification.

The majority of inventors since that day have not exercised the same amount of care with water economy and slime recovery as shewn in this example.

The fundamental process of coal washing may, therefore, be stated as follows: that a quantity of slack material of different densities, if subjected to an intermittent rising and falling current of a body of water in a contained vessel, will arrange itself into layers according to their respective densities, the heavier particles on the bottom and graduating to the lightest particles on the top.

In the jig the current moves in two distinct directions, first upwards and then downwards. On the rising current, if we can conceive the stroke to be sufficiently long and definite to give the smallest particle of shale time to sort itself out, and that all the material on the screen plate is contained in the limits of the equal-falling ratio, *i.e.* $\frac{D_C}{D_S} = \left(\frac{\delta - 1}{\delta_1 - 1}\right)\left(\frac{C}{C_1}\right)^2$, then all the shale, from the smallest particle to the largest, will be found on the screen plate, and all the coal will occupy the upper portion of the bed, that is, there will be a complete separation, and we should find that in the two layers of high- and low-density material the larger shale particles would be immediately on the screen plate and the smallest shale particles adjacent to the largest coal particles at the line of separation of the layers, with the intermediate portion filled by the other sizes in the increasing scale downwards. Similarly the bed of coal departing from the largest particle at the line of separation to the smallest particle on the top would be uniformly graded if the material were but of two different densities.

On the other hand, if there were a third product of intermediate density there would be an interspersing of material in the same proportion as the difference of the densities, that is, between the pure coal and the shale there would be a middle product occupying the middle bed. If the materials have not been sized within the limits of the above-mentioned equal-falling ratio, there will be a distinct overlapping at the centre of the particles of shale below the critical size and the larger coal. On the return stroke there is a quick change of conditions, and as the fall is now with a descending current the large low density particle will advance over the high density particle (see Fig. 115), which would mean a complete reversal of the favourable position of the particles on the upstroke, so that some means must be devised to lessen this effect, hence the downstroke should be made slowly, so that the particles may be preserved in their positions. In the actual washer box this is sometimes arranged for by a special mechanical device, but apart from that, the clearing of the water and pure coal into the flushing trough, the rounding of the top centre by the crank arm of the plunger, and the influx of fresh washing water into the box counteract this tendency, so that actually, on the top end of the stroke being reached, the bed of coal is more or less allowed to settle as though in still water.

There is one great advantage of a suction stroke or descending current that should not be lost sight of, that is, the small heavy particles which may be intermixed with the larger low density particles will be drawn down (see Fig. 115).

Some engineers are of the opinion that the ascending current of water lifts the bed on the screen plate as a compact body, so that the free movement of the individual particles is not merely hindered, but prevented, and the smaller and lighter particles are given no preference by the ascending current and only the top layers which are free to move obtain any appreciable benefit from this upward action. This would seem to imply that the change in the disposition of the particles upon the bed takes place from the upper layer downwards in a successive movement.

As soon as the top surface becomes free to move, the following layer would be released and so on to the bed. In view of the fact that the feed takes place upon the surface of the bed, there would be a distinct advantage to be derived from this movement. On the return stroke a descending current of low velocity would cause the bottom layer to move under the influence of free settling in still water, thus releasing the next higher layers and so on throughout the bed, that is, the particles of greatest density, irrespective of size, would accelerate or advance over those of less density and thus collect on the screen plate. It is, therefore, reasonable to assume that there is a limit to the compactness of the bed for efficient washing.

Small and light particles on the middle layer would seem to have little chance of sorting themselves out unless the bed is maintained in a sufficiently loose condition by a judicious proportion of pulsation.

In Fig. 110 is shewn a graph of the velocity of fall of two shale particles, having diameters of 2 millimetres and 9 millimetres respectively, plotted with time as the ordinate. It will be noticed that the rate of increase of velocity of the smaller particle (the upper curve) decreases rapidly after 0·1 second, at which moment it has passed over a distance of $\frac{3}{4}$ inch (Fig 111), whereas the rate of increase of velocity of the larger particle does not appreciably alter until 0·2 second has elapsed, when there is a rapid change.

At this moment the latter has traversed a distance of $3\frac{3}{4}$ inches ; the smaller reaches its terminal velocity after $\frac{1}{5}$th of a second, whereas the larger particle does not reach its terminal velocity until $\frac{1}{3}$ second has elapsed. A graph of the fall of the same two particles is shewn in Fig. 111. At the beginning the large particle does not advance to a great extent over the smaller, but at just beyond $\frac{1}{10}$th of a second the large particle advances rapidly; the smaller, having by this time almost reached its terminal velocity, travels uniformly, whereas the larger is still accelerating. In Fig. 112 is shewn a graph

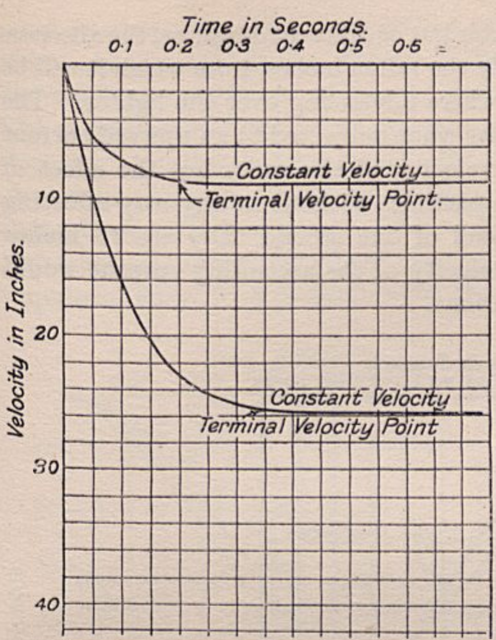


FIG. 110.—VELOCITY GRAPH OF TWO SHALE PARTICLES OF DIFFERENT DIAMETERS.

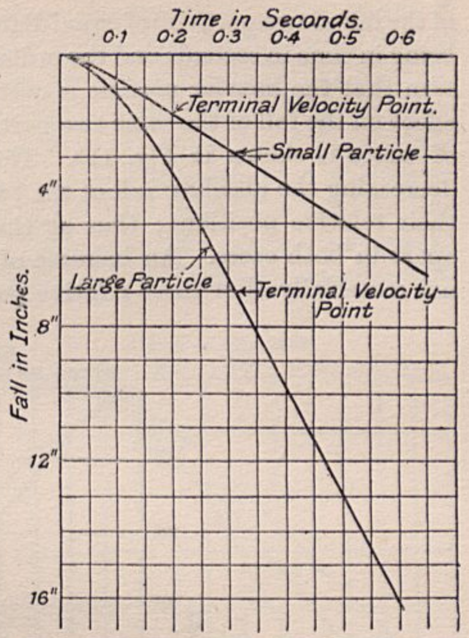


FIG. 111.—FALL GRAPH OF SAME TWO PARTICLES.

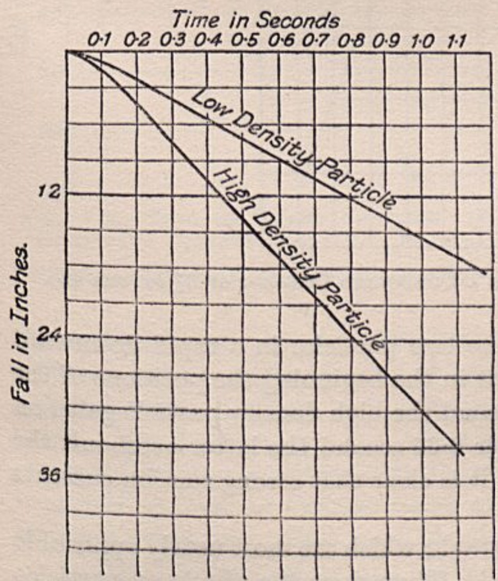


FIG. 112.—FALL OF TWO PARTICLES OF EQUAL DIAMETERS AND DIFFERENT DENSITIES.

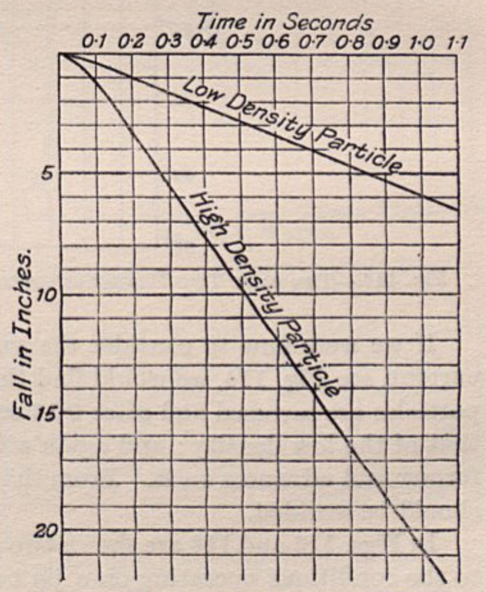


FIG. 113.—FALL OF SAME TWO PARTICLES SUBJECTED TO AN UPWARD CURRENT 1·0 FT. PER SEC.

of the fall of two particles of equal diameter but of different densities, the abscissæ being in time in seconds and the ordinate the fall in inches, from which it will be seen that the heavier particle is everywhere advancing over the lighter. The effect on the fall of the same two particles when subjected to an upward current of water is shewn in Fig. 113. The velocity of the water has the effect of decreasing the absolute fall of the two particles without in any way affecting their relative positions; thus at the end of one second they are 15 inches apart in both cases. An increase of velocity of the ascending current would not materially alter these relative positions.

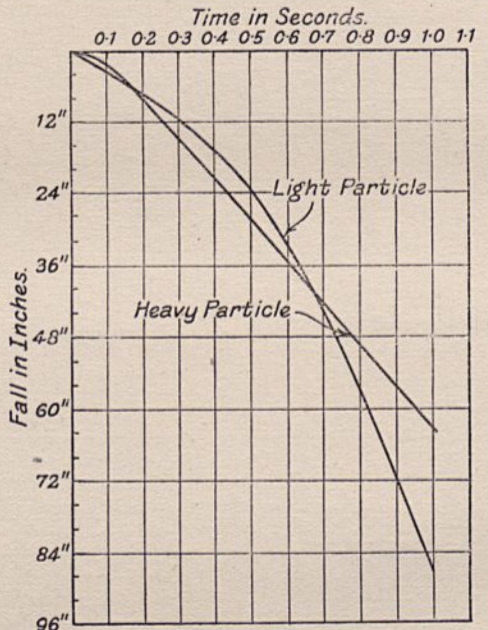


FIG. 114.—THE SAME TWO PARTICLES UNDER A DOWNWARD CURRENT OF 3½ FT. PER SEC.

If we were now to consider the same two particles in a rapid downward current, see Fig. 114, we would find that in the beginning the positions of the particles are reversed and after 0·16 second the high density particle gains on that of the low density; and again after 0·66 second the latter overhauls the former and advances on it. From this it is clear that strong suction currents should be avoided.

In Figs. 115 and 116 are shewn two graphs which are most nearly applicable to the conditions operating on a jig bed. They shew the effects on particles over a space of 3 inches, and it will be seen that the relative positions of the particles are seriously affected by a rapid downward current. Fig. 115 represents the small time interval at the beginning of Fig. 114 on a larger scale.

A comparison of these two graphs will show the need of a careful design of washer box, so that in the reversal of the plunger strokes the downward flow of the washing water is not such as to undo the benefits of the ascending column. The separation effected by an ascending column is preserved to a slightly lesser degree by the fall in quiet water; for this reason the upstroke of the plunger should be made as slowly as possible so as to approximate to a still-water separation. Various devices, such as differential gear, have been used for this purpose, and other washer boxes have been designed with a continuous upward impulse of water with no suction stroke; the water, constantly rising, separates

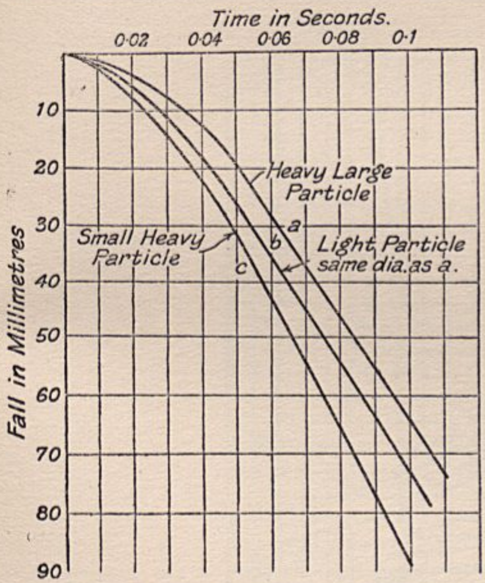


FIG. 115.—FALL OF THREE PARTICLES IN DOWNWARD CURRENT OF 3·4 FT. PER SEC.

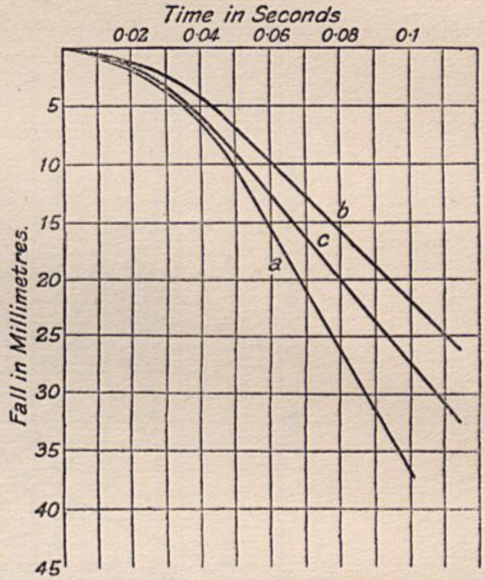


FIG. 116.—FALL OF SAME THREE PARTICLES IN STILL WATER.

Particle a = heavy of large diameter. b = light of same diameter. c = heavy of small diameter.

the material, and this is maintained in this position until a second upward pulsation occurs. This effect is obtained by the use of a rotating valve giving communication suddenly to a large head of water and then a gradual closing of valve. The Baum washer box, while not exactly without a suction stroke, is so regulated by its air pistons that the suction effect is almost nil. The change from full pressure to exhaust being gradual, the air in the chamber likewise exerts a cushioning effect upon the downstroke.

In Fig. 117 is shewn a graph of the velocities of fall for equal-falling particles of different specific gravities, and the respective diameters. This graph shews that the range of final velocities of particles of equal diameters and different densities is relatively great.

For example, coal of 2 inches diameter and velocity of fall of 9 inches per second can be readily separated from shale of about ⅛-inch diameter. Another point worthy of note is that there is a wider range of diameters with equal velocities upon a slight variation of the specific gravity between 1·2 and 1·5 than between an equal interval higher in the scale of diameters.

The difficulty of removing the whole of the bone coal from the washed products is emphasised in this diagram. The slope of the curves between these two quantities is too gradual and shews little difference in the equal falling diameters. The smaller the coal treated the more difficult it becomes to separate the middlings from the pure coal.

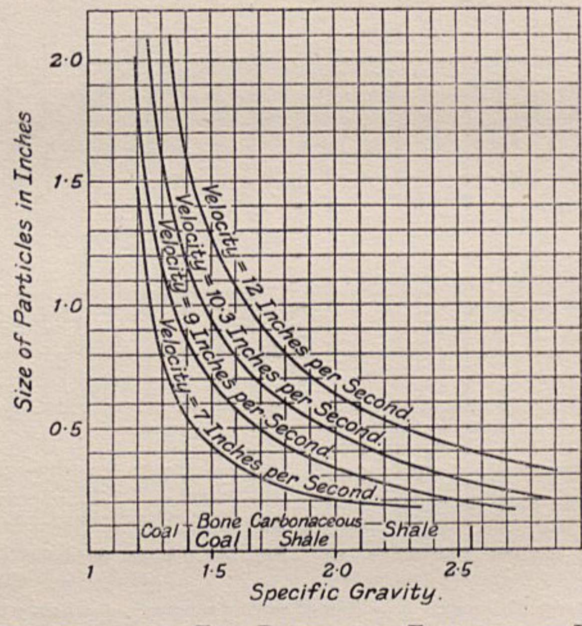


FIG. 117.—VELOCITY OF FALL DIAGRAM FOR EQUAL-FALLING PARTICLES.
EXAMPLE.—Coal 1·5 inches diameter and S.G. 1·33 and shale 0·26 diameter, both have equal falling velocities of 10·3 inches per second.

In Fig. 118 is shewn a graph of the yield of washed coal plotted against the contained ash in the washed product. Taking the original slack as 1, the yield and ash are plotted in percentages of that quantity. The yield is the percentage of coal delivered as a washed product after the extraction of the refuse; that is, if the raw slack amounts to 100 tons, and the extracted dirt from that amount during washing be 12 tons, then the yield would be 88 tons or 88%.

The figures to which the graph is plotted are obtained by tests carried out in a laboratory as explained in the chapter on Flotation Analysis.

Thus at the point A on the curve the yield is 93% against an ash content of

10%, the original slack containing 18% ash. This represents a reduction of 44·3% on the total ash content, with a loss of 7 tons of material. At the point B on the curve, for an ash content of 7% the yield is 86%, so that the ash reduction is 61·1%, with a loss of 14 tons, which means that the initial washing out of 7 tons of slack reduced the ash content $2\frac{2}{3}$ times more than an extended washing out of a further 7 tons. The curve being of gradual increasing slope indicates this point, that in the initial stages the ash percentage may be reduced considerably by separating the heavy dirt, and that there is some point on the curve where the yield and ash content bear the most economical proportion to the original slack; that is, at the point of most rapid change of curvature.

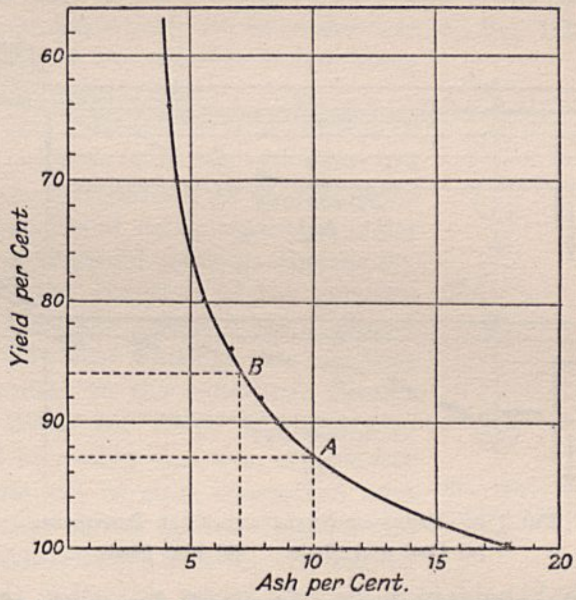


FIG. 118.—WASHABILITY CURVE.

Gravity Washers.—The practical application of the above argument is exemplified in the gravity washers and upward-current classifiers. In the beginning of fall the particles are subjected to the accelerative force and those of heavier density sort themselves out with greatest rapidity.

Owing to the confined space upon the washer screen plate, it is not possible to allow the shale to fall a sufficient distance in one pulsation to separate itself from its lighter neighbour, as it would do in free falling if it were practicable to provide a machine deep enough for the purpose. Hence to overcome this disability a succession of sharp impulses is imparted to the material on the bed, each impulse having an effect on the particles similar to that of free fall in jerking order. Thus, if the first stroke caused a separation of shale and coal particles of $\frac{1}{8}$ inch, a succession of 8 strokes would separate the particles by 1 inch, and if the bed is about 20 inches deep it would take 160 strokes to bring the shale particle to the screen plate.

Now the fall of the shale is not perpendicular, but as each successive stroke moves the bed as a whole towards the discharge, the shale particle follows an inclined path downwards, whereas the coal particle remains in the upper layer, rising and falling with the pulsation of the water, as shewn in (*a*) Fig. 119. The shale particle on entering the bed is subjected to a water current from the inlet to the outlet distinct from the pulsation. This is due to the flushing water entering with the slack coal, and a certain amount of water sizing will, therefore, take place before entering the washing bed. The shale particle closely hugs the surface of the trough and enters the box against the

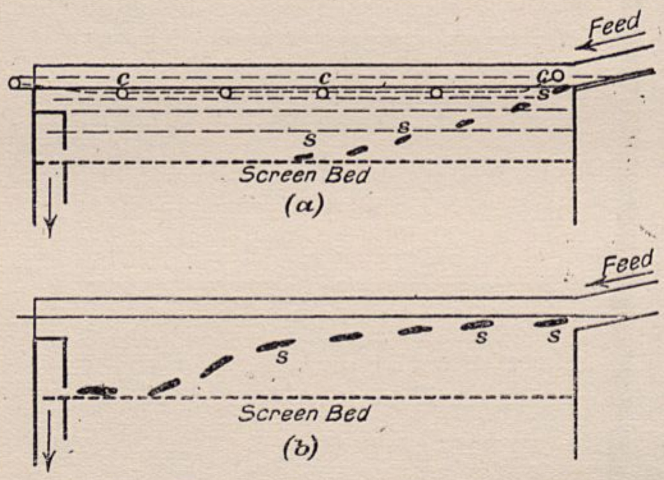


FIG. 119.—PATHS OF SHALE AND COAL PARTICLES.
(*a*) Coal and Shale. (*b*) Flat Shale.

obstruction of the material already deposited, due to the sharp inclination downward of the inlet casting. This observation has reference to the Baum and the Brauns boxes and is no doubt one of the factors productive of good washing, since the material to be washed is not actually dropped upon the bed, but has the benefit of a partial water sizing before entering. The shale particle will then struggle through the middle portion at a disadvantage, due to the compactness of the material at that point, and, therefore, will not have the full benefit of the pulsation effect as already described. Its path will, in consequence, be rather flat whilst passing through the middle layers, and it will, consequently, not reach the screen bed until some relatively considerable interval of time after the coal particle which entered with it has been discharged over the weir; this is graphically illustrated in the figure, where the successive positions are as indicated by the letters *s* and *c*.

Many washer boxes have difficulty in eliminating the very flat shale from the washed coal, especially those where the feed is dropped directly upon the pulsating bed, as the Coppée, Meguin, and Bash type. This fact is no doubt due to the body taking up a position on the surface of the bed with its largest cross-section parallel to the screen plate, and being in this position actually floated by the coal which it covers. This particular feature, however, is not so common with the water-flushed inlet below the working level of the water. In this case, as in the two examples already mentioned, the shale enters favourably against the bed and at some point below the surface before having the benefit of the pulsating mass. At the same time, although it enters horizontally, it is not in a state of equilibrium and has a tendency, due to the flushing current, to turn edgeways, but owing to the compact nature of the centre layers this is delayed and its probable path will be as shewn in (*b*), Fig. 119, where it travels the greater length of the chamber before being tilted towards the screen plate.

In (*a*), Fig. 120, is shewn the ideal position of coal and shale particles upon the bed when the pulsations and the material treated are within the limits of size capable of being separated under the conditions of hindered settling, whereas (*b*), Fig. 120, shews the positions of the particles upon the bed when the material has a greater range of sizes than that which gives a complete separation according to the conditions already enumerated. When the shape is taken into account, it will be readily seen that the smaller particles of shale will be more intermixed with the coal than that shown by the diagram and hence will be productive of a none too well-washed smaller coal. It is for this reason that the rewashing of the fines becomes necessary for coking purposes.

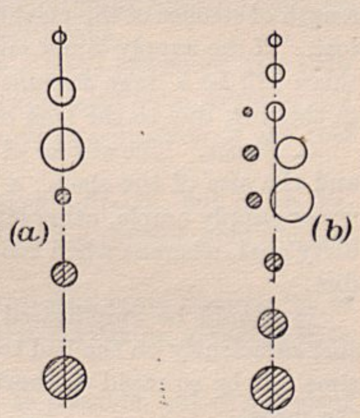


FIG. 120.—WASHER BOX. RELATIVE POSITIONS OF SHALE AND COAL.

There is one particular feature of the large coal box treating unsized slack, and that is the range of sizes it is possible to treat can be slightly increased if a judicious adjustment of the downstroke and water supply is made to cause a light suction, which draws down the small heavy particles.

The details of the construction and control of a gravity jig are entirely a matter of experience, and although the principle is the same in all, the details are different, due to the claims advanced by the manufacturer in support of his wares.

The points of operation which may be classed as common to all are :—

1. *Regular feed in quantity.* If the feed is varied in amount the following will occur : an increase will bring about an increase of dirt in washed coal and an increase of free coal in the dirt. Decreasing the amount of feed will result

in a clean washed coal and a higher percentage of coal in the refuse, due to the rubbing of the shale bed.

2. *Water supply.* The supply of water to the box is a great factor in the even washing of the slack and likewise counteracts the tendency of suction at the screen plate during the upstroke of the plunger. Therefore, if the water supply be too small a heavy suction effect will result in the washed coal carrying off a quantity of small free dirt and leaving an amount of large coal among the extracted refuse, whereas if this suction effect were adjusted with care the advantage of drawing down the small shale particle would benefit the washing.

Too great a water supply will reduce the percentage of coal in the refuse at the expense of the washed coal, which will be burdened with a high percentage of free dirt. The water supply depends also upon the number and length of strokes of the machine, as the make-up should just balance the amount lost. If the supply is not enough to float the coal throughout the stroke, then there will be a large amount of dirt with the coal and a large amount of coal in the dirt, due to the lack of water separation.

3. *Stroke.* The stroke of the machine should be varied to suit the quality and the size of the slack ; a long stroke should be of moderate speed and the water supply ample, otherwise a clean dirt will be obtained at the expense of a dirty coal, whereas when too slow there will be found a quantity of coal in the dirt.

It should be emphasised that strokes should be proportioned to lift the coal sufficiently on the bed to reduce the tightness of the mass, and at the same time not be so rapid or short that the effect is not communicated throughout the mass.

4. *Refuse control.* The most important point in the washer is the adjustment of the escape gates. It is the most direct way of controlling the operations and should have the greatest attention on the part of the attendant. If the washed coal contains too much dirt and the refuse is small in amount, the gate should be opened wider, whereas if the dirt contains too much coal, the gate should be narrowed down.

No hard-and-fast rules can be applied to all boxes, since a great deal depends upon the attendant sensing the working of the box.

CHAPTER XII

MODERN PLANTS AND SYSTEMS

In the following pages attention is given to all the modern plants and systems which have proved efficient in the carrying out of the work for which they were erected or designed.

There are a good many plants erected at the present time on old-fashioned lines. Unfortunately, these plants have been installed by small colliery companies, where initial cost has been the chief consideration, little regard being paid to the eventual economical production of the plant.

When it becomes a necessity for a colliery company to adopt a washing system for their coal, consideration should only be given to those plants which are thoroughly up to date. The times have not only changed in the method of marketing the coal, but have also wrought a tremendous improvement on the design and efficiency of the present-day washery plant.

The plant to be modern must necessarily shew a large efficiency, not only in the separation of the shale from the coal, but must also have suitable and efficient apparatus for the necessary preparation and classification of the coal for sales purposes.

The elevators must not only be of good and strong design, but be so disposed as to be adaptable to the needs of the plant over a considerable number of years after erection.

The classifying screen and the dewatering apparatus must likewise be of such quality and so disposed as to be used to their maximum capacity with high efficiency.

The whole of the machinery should be as light as possible, but of sufficient strength and of a design to bring maintenance costs to a minimum.

The washery building itself should be of good solid construction, requiring little upkeep, and placed upon the colliery site so as to be adaptable to all future needs. The argument often adduced by colliery engineers against the installation of a washery is that the probable life of the colliery would be of too short a period to warrant the spending of the capital upon a modern and up-to-date plant. They therefore adopt some old-fashioned system housed in a weak structure, with the intention of keeping down the initial cost, but this eventually entails a comparatively large account for maintenance expenses, especially considering that the quality of the coal is becoming worse, and that the plant becomes less and less capable of dealing with it.

However small the amount of money the colliery company may be prepared to spend, they would be well advised to spend that amount upon having the latest machinery. We shall, therefore, confine our remarks to the few successful systems in use to-day.

Baum or Air-compressor System.—The Baum system has enjoyed a large popularity in this country and has proved itself a reliable machine. The original Baum system has changed considerably during the last few years. Great improvements have been made in the design of the washer box to deal with all sizes of coal without classification.

The Baum slogan was wash first, screen afterwards, and it caught on rapidly as being a most practical and economical arrangement.

The original design of the Baum box, however, was not in accordance with this method. The first plants of this system to be erected in this country were based upon the principle of close sizing before washing.

In Fig. 121 is shewn one of these boxes and the troughs leading to it from the screens. These different sizes were all washed separately and then again mixed and reclassified upon another screen, into saleable products.

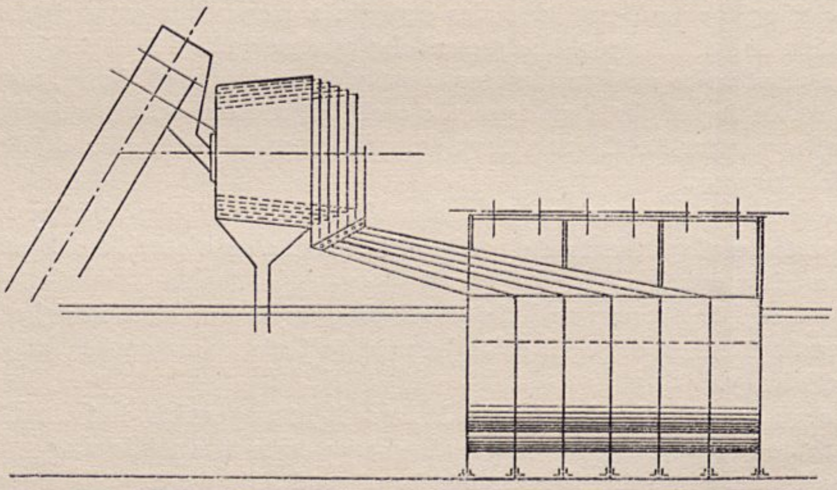


FIG. 121.—ORIGINAL BAUM BOX.

The difficulty arising from this close sizing was emphasised in the case of smaller coal.

The bed of coal upon the screen plates of the fine-coal boxes was so densely packed that it did not allow passage to the water, and for that reason little effective separation took place. The expedient of adding a certain amount of larger coal with the fine, so as to loosen the bed, proved that a better sizing was attained.

Experiments were, therefore, carried out with unsized coal, and it was found that within certain limits the washing was not only satisfactory but that the cost and the increased rapidity of the processes were distinct advantages.

The air spaces between the different-sized coals gave that necessary looseness of the bed to facilitate the internal sorting out or separation of the individual particles. Not only was the method of sizing influenced by the new design, but also the method of extraction of the dirt.

In place of having a large number of dirt outlets requiring individual regulation, they were reduced to two outlets and so placed in the box as to increase the length of time of the passage of the shale over the screen plate, so that a good natural bed of shale was formed on the screen plate, which promoted the efficiency of the separation and also prevented the finer coal from passing through the perforations.

In Figs. 122 and 122A are shewn Baum-type washer boxes. The raw unsized slack is fed direct from the feed elevator into the washer box, via the trough, P. A water jet impinges on a baffle plate at the back of this trough,

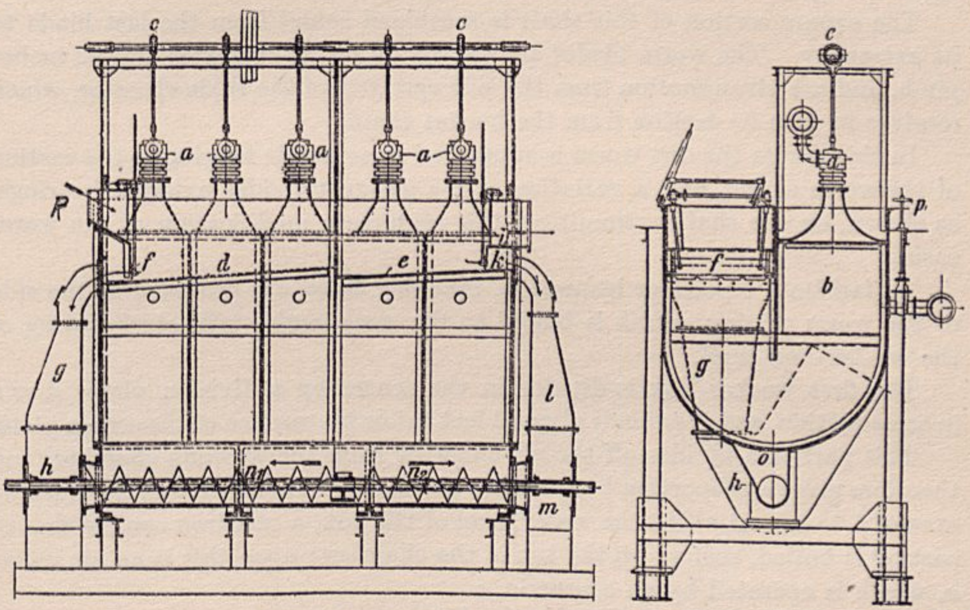


FIG. 122.—BAUM WASHER BOX.

which spreads out the water on the base plate and so washes the coal gently upon the coal bed, *d*.

The screen plate in the first washer box is placed at a slight inclination to the horizontal, to facilitate the travel of the shale upon its surface towards the dirt outlet at *f*. The outlet at *f* is provided with a sliding door, which can be raised or lowered by operating the hand levers shown in the cross-section. The maximum opening in this slide is sufficient to allow passage to the maximum size of material for which the washer box is designed.

The regulation of the slide is sometimes effected by a small rack and pinion gear, operated by a hand-wheel, bracketed on to the inlet casting and for fine adjustments; the shaft to which the pinion and hand-wheel are connected is provided with a small ratchet and pawl gear, which is given the necessary amount of motion by a small screw similar to the second close adjustment of surveying instruments.

The dirt then passes through the casting, *g*, bolted to the washer box at about the level of the screen plate and over the full width of the bed into the boot of the shale elevator, *h*. The finer dirt which may have fallen through the perforations of the screen plate is collected in the bottom of the washer box by the dirt worm, n_1.

This dirt worm is built up of a series of cast-iron or cast-steel spiral blades mounted upon a square shaft, which on passing the end of the washer box forms the sprocket shaft of the dirt elevator.

The square section of this shaft is machined round from the last blade to its extremity. The worm blades are usually 14 inches diameter and 12 inches pitch, and are given motion from the side sprocket of the shale elevator, which receives in turn its motion from the bucket chain.

In this design the dirt worm is supported in an inside bearing in the casting of the worm casing, and a variation of the design provides external bearings, as shewn, on the shaft extremities; this requires a modification of the worm casing.

To facilitate repairs or inspection, manhole doors are provided in the side of the worm casting, which is bolted to the semicircular mild-steel plating of the washer-box shell.

The first washer box is divided in the centre by a division plate, shewn in cross-section, and it extends about 3 feet below the surface of the screen plate.

This partition divides off the air chamber from the washing chamber, and therefore gives a proportion between the plunger or impulse area to the washing area of 1 to 1. At about the water level of the box, a cast-iron conical-shaped casting is bolted, sealing up the top of the chamber; upon this is an air valve, *a*, which is operated by an eccentric, *c*.

The air valve is a special feature of design. There is one inlet port and three exhaust ports, the relative areas being as $1 : 2\frac{1}{2}$. By suitable adjustment of the valve the inlet and exhaust may be regulated without interference with the length of stroke of the air piston. This is convenient where there is likely to be any change in the size of coal to be washed, and together with an air-pressure regulator affords a wide latitude to the quality and quantity of coal that may be treated by a given washer box.

On the back of the air chamber, about 3 feet below the floor level, a water valve is fitted, of a wedge type sluice or gate, having a hand-wheel mounted on a long spindle, so that it can be operated from the washer floor. The water supply enters the box by this valve, and as this water is generally under a head of pressure of about 12 feet, the entering current is rather violent. It was found that by placing the valve in this position the best results are obtained and the violence of the current by the time it reaches the screen plate

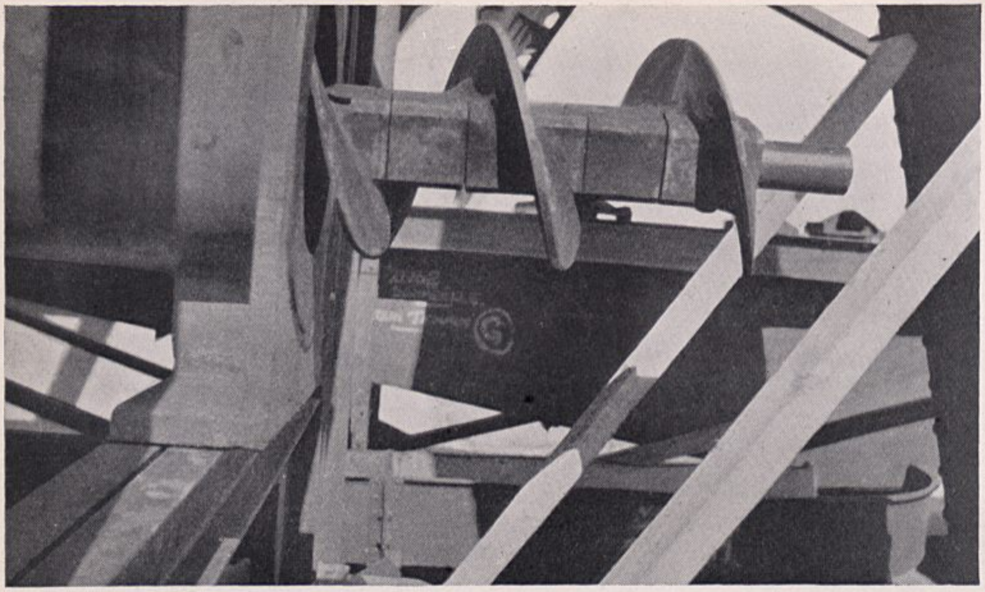


Fig. 122a.—Shewing Dirt Worm Conveyor Blades.
(*Nortons Tividale, Ltd.*)

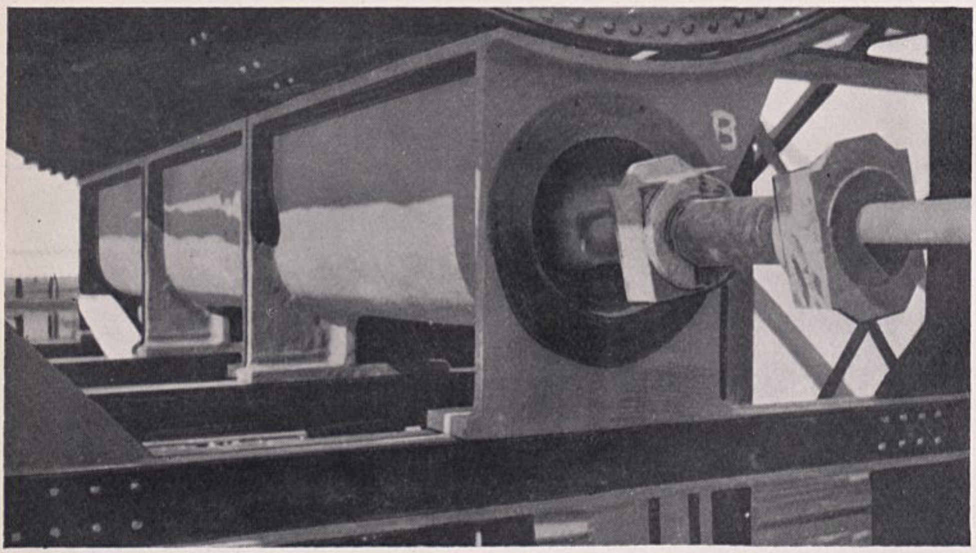


Fig. 122b.—Shewing Dirt Worm Casing and Dirt Elevator Sprockets.
(*Nortons Tividale, Ltd.*)

[*To face page* 142.

is lessened and spread out over the whole area. To give strength to the cross bulkheads, wrought-iron tubing with screwed flanges or cast-iron pipes is bolted between the dividing plates of the chambers. Each separate air valve and water valve is placed upon separate compartments of the washer box to equalise duty over the washer bed.

The end chamber is cramped by the inlet casting, and the pulsations would cause an air lock or buffer in this chamber were not some means found to relieve it. For this reason, the inlet casting is carried up in a narrow box for about 1 foot above water level, and to the tops are bolted plug cocks as shewn in cross-section. These cocks are opened sufficiently to allow a free passage to outlet and inlet of the air; during the pulsation these must be so adjusted that the air lock will not be sufficient to retard the passage of the dirt from the regulating slide.

The coal on entering the box heaps itself up on the bed, and being subjected to the rise and fall of the water, is caused to separate, as we have seen in the chapter on Wet Separation. The length of pulsating stroke is of sufficient amount to flush the maximum size coal over the overflow weir, which is a projection of the cross partition or bulkhead separating the first washer box from the second. The pulsations being due to air pressure, the air must be compressed to such an extent that it overcomes the inertia of the water for the required length of stroke. This pressure is usually from 1½ to 2 lb. per square inch.

The heavier dirt is extracted on this bed, which actually extracts the greater portion of the contained dirt. On overflowing into the second washer bed *e*, the coal is again separated in a similar manner, but now the proportion of bed area to plunger area is as 1½ to 1, so that as the pressure is the same and the number of strokes are the same, the upward lift is not so violent or great. The screen plate, *e*, is more often placed horizontally, but in the example shewn it is slightly inclined.

The dirt which now settles upon the horizontal bed is of less density than that of the first washer box, and the width being increased, the coal is virtually subjected to a second washing of longer duration, ensuring a positive separation.

As the travel of the bed is towards the outlet, *i*, it is not necessary to slope the screen plate towards the dirt outlet, as the natural tendency is for it to approach this point. The dirt in this case consists of middles and smaller particles and is collected in the boot of the elevator, the finer dirt passing through the screen perforations into the worm, n_2, being also collected by the dirt worm and conveyed to the elevator boot (see Figs. 122A and 122B).

As the middles elevator and No. 1 elevator have both the same motion, this dirt worm, being operated from the former, is of the opposite hand to that of No. 1 Box. If in the latter it was a right hand, the former should be a left hand, and *vice versa*. The outlet casting encroaching on the bed in the same manner as the inlet casting is likewise provided with air-snifting valves. The regulating shale outlet valve is also similar.

In Fig. 123 is shewn a diagram which illustrates the whole of the Baum

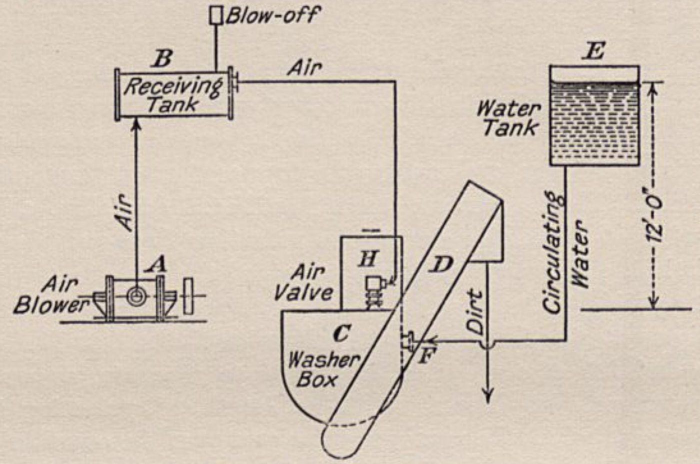


FIG. 123.—BAUM FLOW DIAGRAM.

principle. A is an air compressor delivering into receiving tank, B, which supplies the air valves, H, and the washer box, C, the dirt being extracted from the latter by the dirt elevator, D. The water supply to the boxes from the

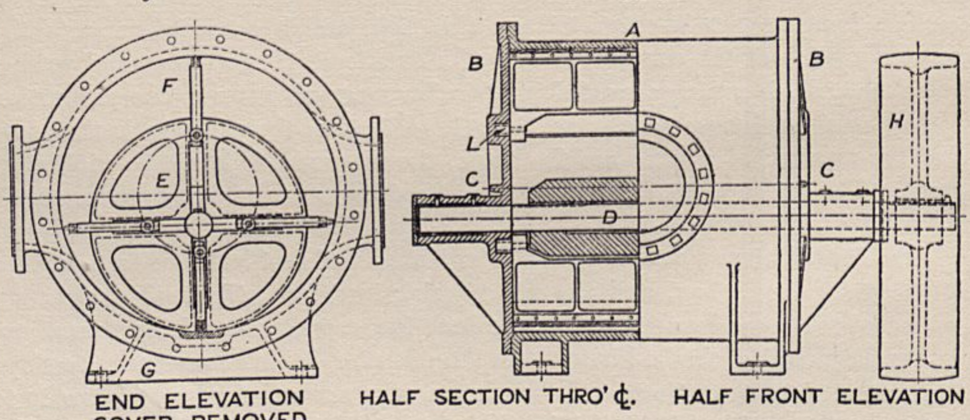


FIG. 124.—GENERAL ARRANGEMENT OF ROTARY BLOWER.

valve, F, is obtained from a tank, E, which provides a head of water of about 12 feet.

This comprises the essential principle of Baum washing.

The air compressor is of special design for this purpose, as shewn in Fig. 124. The sizes vary from 36 inches for 50 tons, to 48 inches for 150 tons, this dimension representing the diameter and the length of the chamber.

The main casting is cylindrical, with two 12 inch-diameter flanges diametrically opposed, one being the inlet and the other the outlet.

The cylinder casting, A, has two cover plates, B, bolted to each end. The cover plates are designed with a bearing, C, of four shaft diameters long provided with two Stauffer lubricators on each.

The centre of the shaft bearing is eccentric to the centre point of the main casting, A. In the end covers, a recess, L, is formed to take projecting pins on the loose vanes, F; mounted on the shaft is a drum casting, E, divided into quadrants by slots, in which the vanes are fitted. These slots on the bottom centre are sufficiently long to house the entire vane, as the inner drum has only a clearance of $\frac{1}{16}$ inch at the lowest tangent.

At the central point in the base of the casting, A, is a sealing wooden strip, G, connected to a cover plate to seal up communication between the inlet and the outlet.

On passing this point the vane tip is flush with the drum surface, and on passing the top centre is almost three-quarters of its length out of the slot.

The tips of these vanes are covered with leather strips to ensure close contact with the walls of the chamber. The circular groove in which the pins of the vanes are guided is concentric with the main casting, A, and this causes the vanes to fly out during the blowing stroke.

The whole of the machine is of cast iron. A flywheel, H, is keyed to one end of the shaft. The revolutions vary between 90 and 100, depending upon the size of the washer box and the pressure of air necessary, which in turn vary with the class of coal treated.

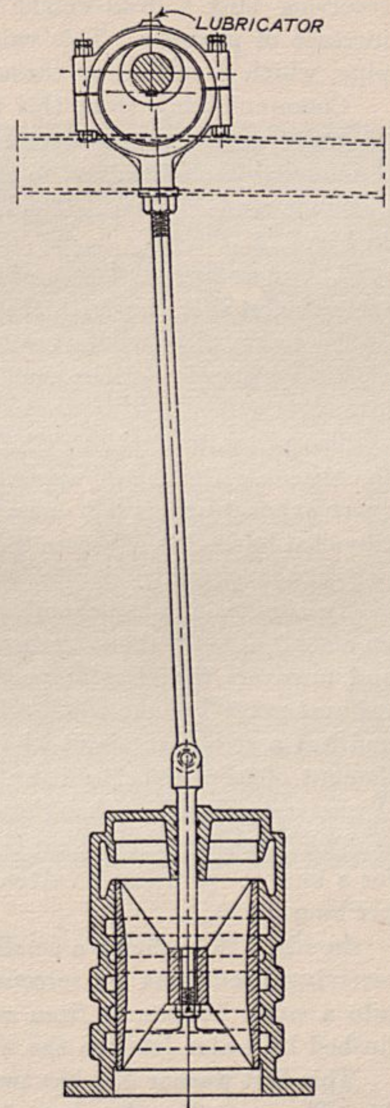


FIG. 125.—AIR VALVE GEAR FOR WASHER BOX.

The inlet flange is merely covered with wire gauze to prevent the inlet of any solid material.

The receiving tank, which is placed in the roof of the building, is usually of 40 inches diameter and 8 feet long, built up of $\frac{3}{16}$- or $\frac{1}{4}$-inch plating. On this receiving tank a dead-weight blow-off valve is fitted to prevent any undue increase of pressure. This valve is generally placed at the extremity of the pipe, which is carried up through the roof of the building.

Communicating from this tank to the washer boxes a cast-iron pipe of about 10 to 12 inches diameter is fitted, with branch mains of about 6 inches diameter to the air valves, so that ample area is provided in the piping for all demands made upon it. The air valve on the washer box is of a type shewn in Fig. 125.

The main casting has an inlet port which runs round the whole of the casing communicating with the upper part of the chamber.

There are three exhaust ports, which also completely surround the casting, with the exception of the small ribs, which divide these circumferential ports into slots.

The piston is of plain cylindrical type with ports cut in the circumference to coincide with the two upper exhaust ports at the required moment, and the lower exhaust port is left uncovered, as the bottom end of the piston has then travelled beyond it, whereas the inlet port is completely covered by the upper part of the piston.

To admit air to the chamber, the piston, which is operated by an eccentric on a shaft directly above the washer box by the connecting rod, is forced down and uncovers the circular port, admitting the air at the same time as the exhaust ports become wholly closed. This piston is about 12 inches diameter and has a stroke of about $1\frac{1}{2}$ inches. There is little wear, due to the small amount of work done by it and the simple manner of its construction. The strokes are very seldom less than 90 per min. and seldom more than 120 per min.

The horse power required is about $\frac{1}{4}$ per valve. The horse power required for a blower operating 9 valves, *i.e.* for a washery of about 150 tons capacity per hour, is 20.

In Fig. 126 is shewn a small washery with a capacity of 20 tons per hour, receiving direct from the screens by a belt conveyor, 2, which deposits the coal into a small hopper, 3, from which it is regulated by slide mouthpiece and flushed by water jet into the washer box, 4.

This first washer box has two valves receiving air from the air compressor, 14. The second washer box, 5, has likewise only two valves.

There is only one dirt elevator for this small washer box, as the dirt is, collected to one end by a worm conveyor running the full length of the box but there are two dirt outlets, as in the large box already described, a further dirt outlet being carried down by a steel casing, so that the dirt is deposited into the channel of the conveyor worm.

The dirt elevator delivers into dirt tubs running upon an elevated track.

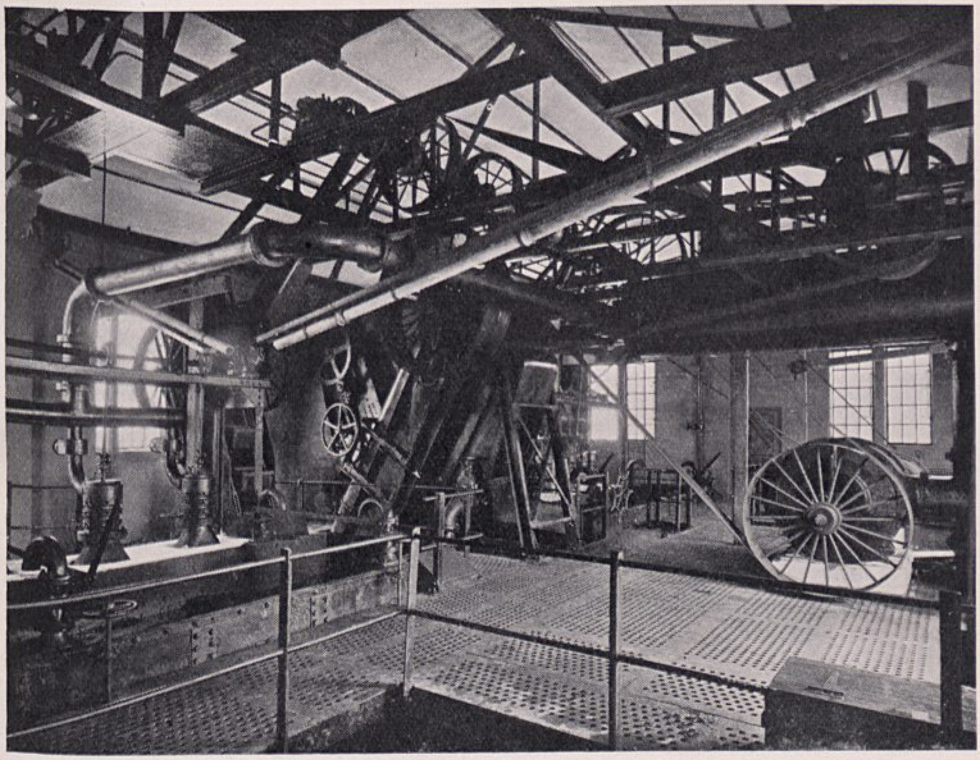
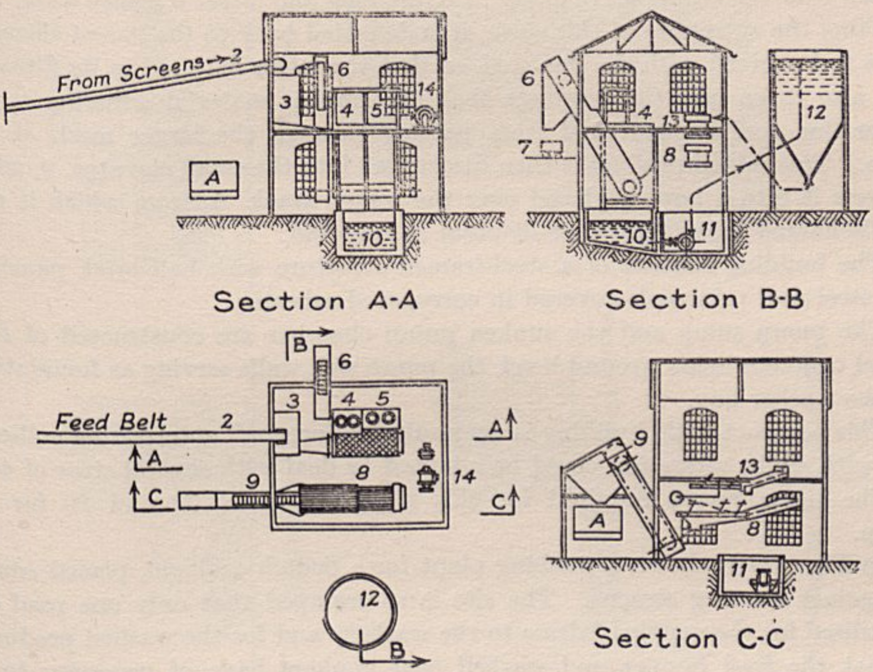


Fig. 125a.—Shewing Inside of Washery. Blower in Foreground and Air Valves are clearly seen. (*Baum A. G.*).

[*To face page* 146.

To the head of the dirt elevator is fitted a large casing provided with hopper mouthpiece and slide, so that any accumulation of dirt during the changing of the tubs is collected as provided for.

On this plant there is only one size, *i.e.* 0 to ½ inch. The products are required in connection with a small coking plant, and, therefore, the washed coal is dewatered only. On leaving the box it is flushed over an inclined



Reference

A. Siding.	6. Dirt Elevator.	11. Centrifugal Pump.
2. Feed Belt.	7. Dirt Tub.	12. Settling Tank.
3. Feed Hopper.	8. Dewatering Sieve	13. Slurry Recovery Sieve.
4. Washer Box.	9. Elevator and Hopper.	14. Air Compressor.
5. Washer Box.	10. Pump Sump.	

FIG. 126.—25 TONS PER HOUR WASHERY.

fixed sieve, 8, about 4 feet wide and 9 feet long, to extract the greater part of the flushing water before depositing it upon the shaker sieve.

This shaker sieve is provided with three sets of hickory springs, each of a double 3 inches by ½ inch section. The sieve is given a vibratory motion by two ash connecting rods, connected rigidly to shaft eccentrics and the tray. This shaft likewise gives motion to the slurry recovery sieve.

The slurry after having been concentrated in the steel settling tank, 12, over the conical outlet, is forced by the head of water pressure over the fixed sieve, 13, where the waste water is collected and led into the pump well, 10. The waste water from the dewatering sieve, 8, is collected in glass-lined troughs between the trays and also discharged into the pump well, 10. The whole of the waste water is then pumped by the centrifugal pump, 11, back into the settling tank.

The slurry after being reduced on the fixed sieve to a less liquid state is passed over the shaker sieve of about 8 feet long and 3 feet 6 inches wide. On reaching the extremity of this sieve, it is deflected back to the lowest sieves, 8, so as to be mixed with the fine coal, so that the latter may aid in its filtration and also to so mix the products that the smaller material adhering to the larger fine coal is prevented from passing through the larger mesh of this sieve. This mixed product is then discharged into the small elevator, 9, which delivers it into a hopper placed over the wagon track, A, from which it may be discharged into wagons for disposal as required.

The building consists of a steel-framed structure with half-brick panelling and steel roof principals covered in corrugated asbestos.

The pump sump and the sunken pump chamber are constructed of reinforced concrete below ground level, the pump well walls serving as foundations for the washer box.

This compact little building is very suitable for small enterprising collieries and with slight alteration could be adapted to deal with several sizes of coal.

The horse power required for this plant would be 30 and 20 for the pump.

In Fig 127 is shewn a washing plant for a Scotch coalfield, placed snugly up against existing screens. The site is so cramped that only one road can be utilised for the supply of dross to the washery and for the washed products, so that the feed hopper and washed coal bunkers have of necessity to be placed upon the same siding.

The dross is delivered into the feed hopper, which is of large capacity, namely, 100 tons, by the dross conveyor, 2, coming directly from the screens, and is discharged on to a spiral shoot directly over the hopper outlet to avoid breakage.

The foreign dross is brought to the hopper over the track, A_1.

The elevator, 4, discharges directly into the first washer box, 5, having a second chamber, 8.

There are two dirt elevators, 6 and 9, which discharge into a scraper conveyor, 7, placed on the outside of the building in such a manner that its discharge may be shot on to the existing dirt scraper of the screens.

The coal is flushed from the washer box over the fixed drain sieve, 10, which takes out the flush of water before depositing the coal upon the vibro screens, 11.

The vibro screens are of the superimposed type on the first tray, and the

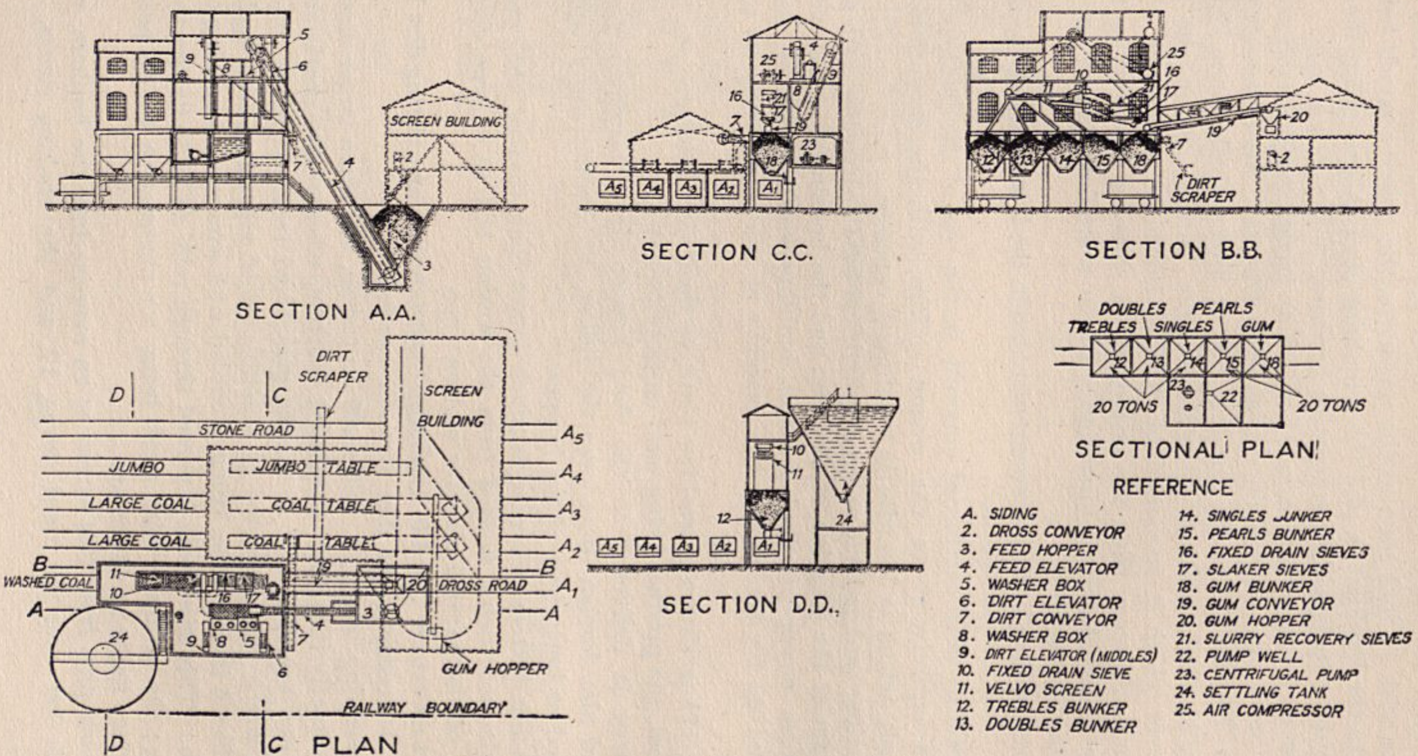


FIG. 127.—50 TONS PER HOUR WASHERY.

pearls and gum are taken out on the upper plate, again sub-divided on the screen plate with $\frac{3}{16}$ inch gum as the undersize, the oversize pearls being discharged into the bunker, 15, and the remaining sizes taken out on the second tray, being deposited to their respective bunkers.

The gum on leaving the screen, 11, is led by troughs to the fixed sieve, 16, of $\frac{1}{2}$ mm. mesh, and thence on the shaking tray, 17, for dewatering, after which it is deposited into the bunker, 18, or alternatively upon the band conveyor, 19, which delivers it into the gum bunker, 20, in the screens building, over which it is carried by tubs to the boiler stokehold.

The slurry recovery from the concentrated slime of the settling tank is affected by the fixed and shaking sieves, 21, in a similar manner to that of the preceding example.

The pump well and pump room are situated in the lower part of the washery building.

This building is of reinforced concrete to the top of the bunkers, and is constructed entirely above the wagon sidings, with the exception of the settling tank, which is likewise in reinforced concrete.

This settling tank is built up on a cylindrical base or housing, with a heavy circular beam at the junction of the tank and the housing.

The horse power required for this building would be 65 on the main shafting and 40 for the pump, the capacity of the plant being 50 tons per hour.

In Fig. 128 is shewn a washing plant to deal with 100 tons per hour of Scottish coal, the product being used entirely for sales.

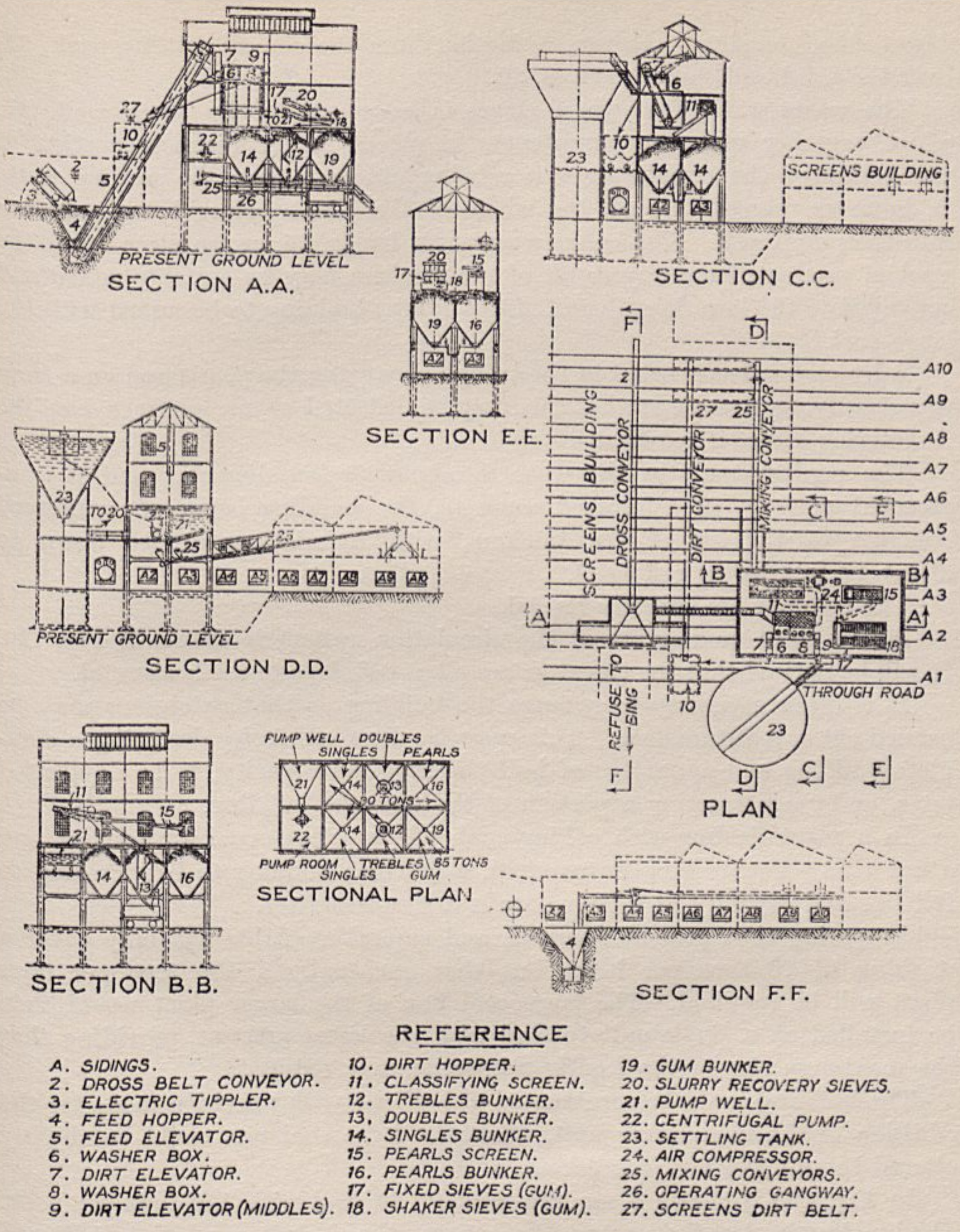
The dross is delivered to the feed hopper by a conveyor from the screens and also foreign dross over the siding, A2, electric screw tippers, 3, being placed at both sides of the hopper.

The washer box in this case is much larger than that of the preceding example, the coal being flushed from the washer box to a large classifying screen, 11, of the parallel circular motion type.

The dirt elevators, 7 and 9, discharge the refuse into an existing dirt hopper, 10, which also receives the dirt from the screens.

The classifying screen, 1, takes out four sizes, the three larger sizes being deposited directly into their respective bunkers, whereas the pearls and gum are taken out together and run over glass-lined troughs on to the pearls screen, 15, which is constructed of a double set of vibrating trays each 9 feet long by 3 feet 6 inches wide, being provided with wire mesh screening trays to take $\frac{1}{8}$ inch. This wire mesh is passed through rolls so as to flatten the point of crossing; the ordinary wire mesh being too obstructive to the passage of the coal seems liable to choke up.

The pearls pass from this screen as an oversize into the bunkers, whereas the gum is led over the fixed sieves, 17, and the shaking sieves, 18, for



REFERENCE

A. SIDINGS.
2. DROSS BELT CONVEYOR.
3. ELECTRIC TIPPLER.
4. FEED HOPPER.
5. FEED ELEVATOR.
6. WASHER BOX.
7. DIRT ELEVATOR.
8. WASHER BOX.
9. DIRT ELEVATOR (MIDDLES).
10. DIRT HOPPER.
11. CLASSIFYING SCREEN.
12. TREBLES BUNKER.
13. DOUBLES BUNKER.
14. SINGLES BUNKER.
15. PEARLS SCREEN.
16. PEARLS BUNKER.
17. FIXED SIEVES (GUM).
18. SHAKER SIEVES (GUM).
19. GUM BUNKER.
20. SLURRY RECOVERY SIEVES.
21. PUMP WELL.
22. CENTRIFUGAL PUMP.
23. SETTLING TANK.
24. AIR COMPRESSOR.
25. MIXING CONVEYORS.
26. OPERATING GANGWAY.
27. SCREENS DIRT BELT.

Fig. 128.—100 Tons Per Hour Washery.

dewatering, the slurry recovery being led from the conical settling tank, 23, over the fixed and shaking sieves, 20.

The waste water from these sieves is conveyed to the pump well, 21, which together with the pump room is placed in the concrete portion of the building; the circulating water being obtained from the settling tank, is, however, passed through the whole of the plant before being collected into the pump well. The bunkers conveyor bands, 25, are so placed that the washed products from any or all of the bunkers may be suitably mixed and conveyed to the lowering jib end of the screens building to be mixed with the large coal.

A by-pass valve is fitted in the trough conveying the pearls and gum from the classifying screens, so that this may be deflected as one product over the dewatering sieves if required.

The conical tank in this case is about 40 feet diameter and is constructed entirely of reinforced concrete, the building being of reinforced concrete to the top of the bunkers, with foundations carried down to about 17 feet below rail level.

The columns are suitably braced.

A flow sheet or diagram of the circulation system is shewn in Fig. 129. It will be noticed that the elevators are all at 60° slope to the horizontal.

It is often necessary to arrange the building so that extensions may be carried out at a future date. This may be done either by designing a complete building and apparatus of half the required capacity, to be duplicated later, or by constructing a portion of the ultimate building.

In a plant dealing with coking coals where a large coal washer box and a fine coal rewasher box are required, a half-size building to be increased to full size and capacity at a later date is a simple matter.

Supposing that present demands and capital available will only cover a washing of 70 tons per hour, but that eventually a 100 tons per hour plant will be required. The large coal box of the larger plant would then be installed as a single unit to deal with the lesser amount, providing that the maximum size of the feed is proportionately reduced.

The building could be constructed of half size with provision made for the addition of the completing unit, when the large coal box could be slightly altered to suit the new conditions.

In Fig. 130 is shewn a modern washery to deal with 130 tons per hour. The building is placed close up to the screens, the slack from which is delivered into a large underground hopper, 3, beneath the screens siding. The band conveyor, 2, delivers the slack to this chamber, from which the feed elevator, 4, delivers it direct into the washer box, 5, and thence into 7 for a second washing. The heavy shale is taken out in the first compartment by the shale elevator, 6, and discharged into the dirt bunker, 24, whereas the elevator, 8, collects the

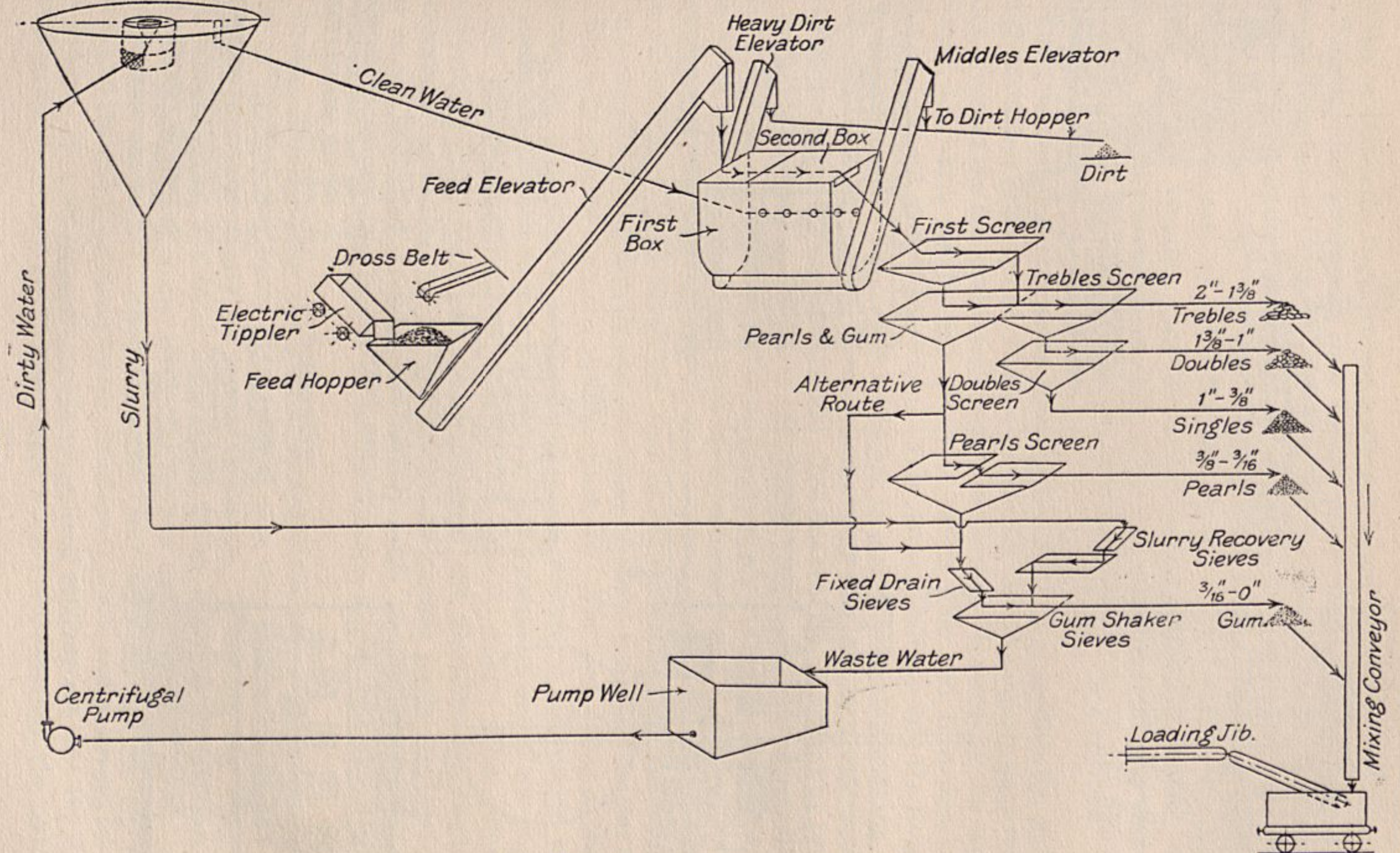


Fig. 129.—Flow Diagram for Fig. 128.

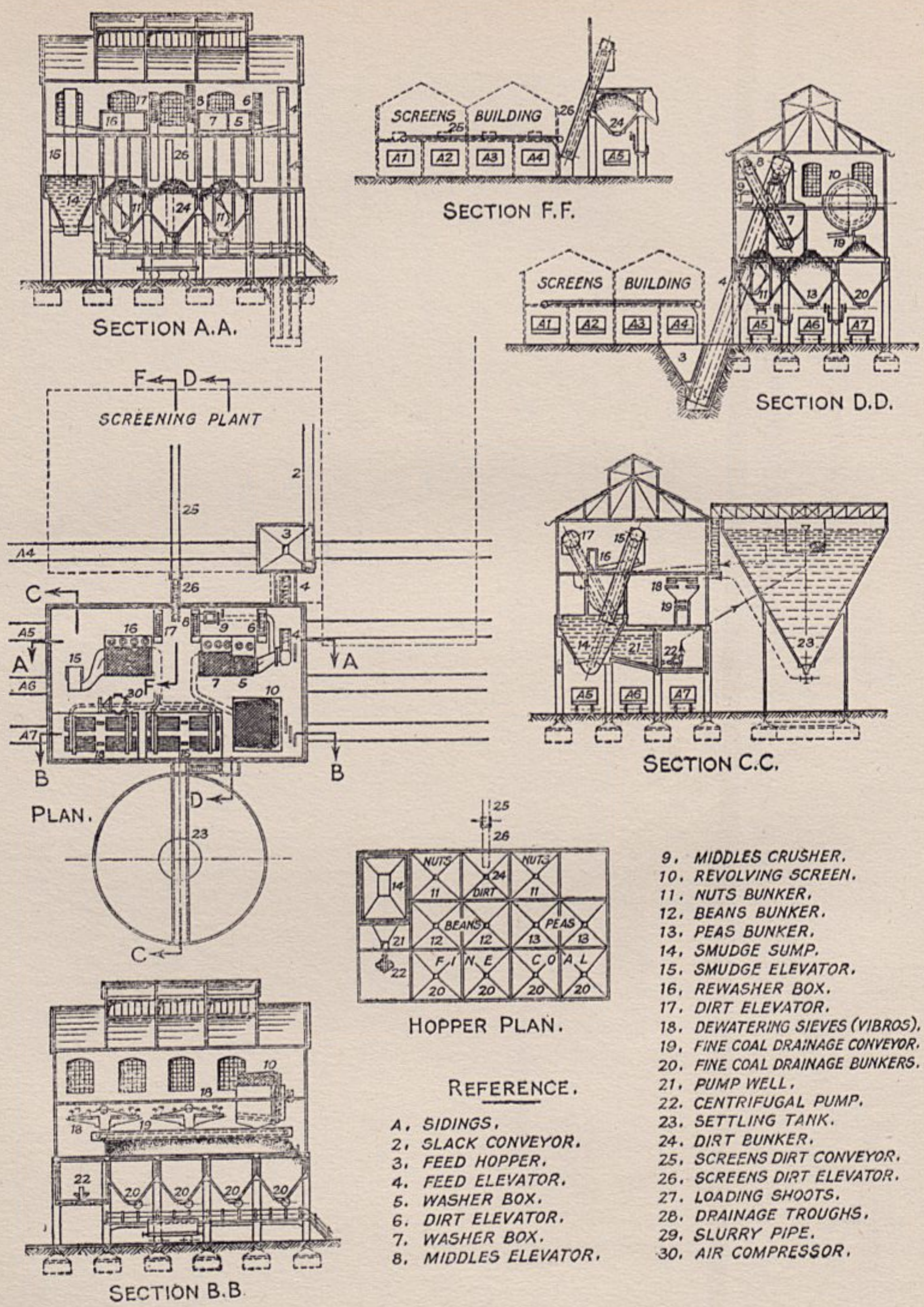


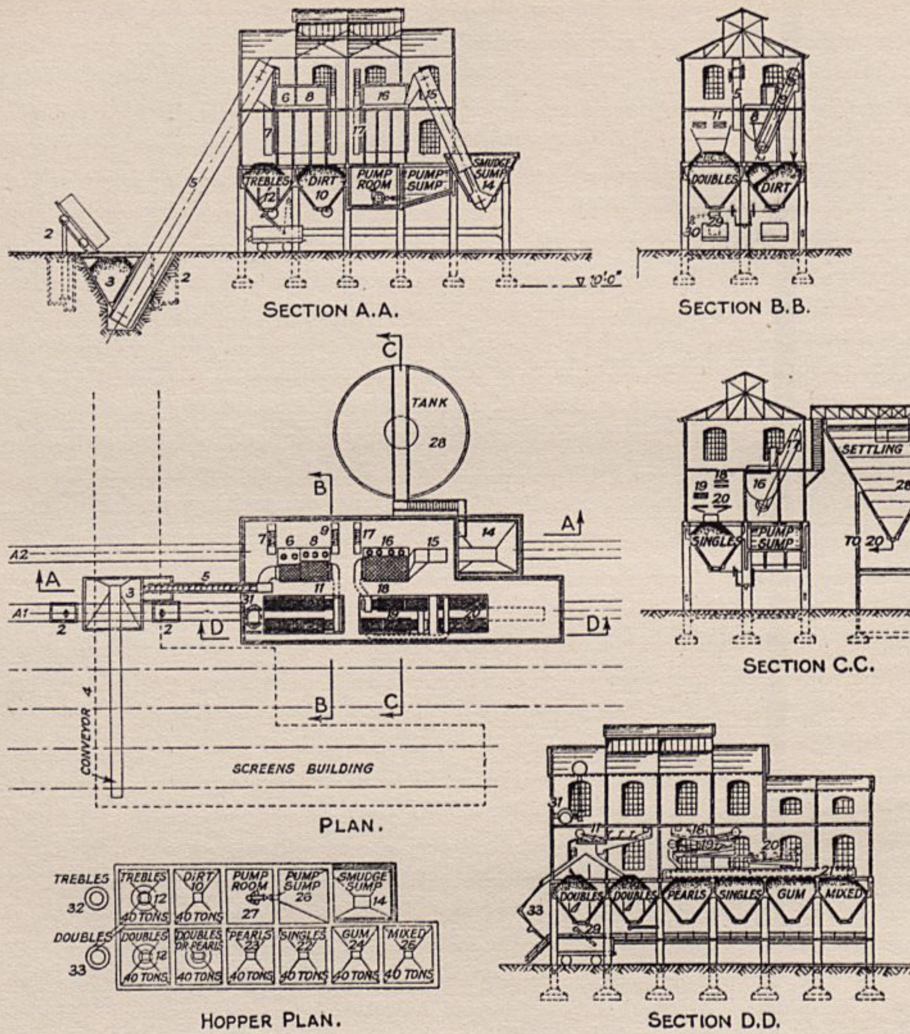
Fig. 130.—130 Tons Per Hour Coal Washery.

middles or bone coal from the compartment 7 and delivers it into a crusher, 9. This middles product is then broken up to about $\frac{3}{8}$-inch cubes in the attempt to separate the good coal from the intergrown shale. The crushed product is then flushed back into the washer box, 5, by the trough passing behind the water box. By this method a good deal of coal is recovered with small percentage of ash. On leaving the washer box, 7, the coal is flushed through launders into the revolving screen, 10, of about 15-feet diameter, and there separated into four sizes, nuts, beans, peas and fine coal, which, with the exception of the latter, are passed by chutes into their respective bunkers.

The fine coal and the water from 7, however, are run into the smudge sump, 14, about the edge of which a peripheral trough collects the overflow water, whereas the fine coal is collected in the base of the sump by the smudge elevator, 15, which has buckets about 48 inches wide and 16 inches link—and a chain speed of 50 feet per min. This elevator delivers into the rewasher box, 16, in which the fine coal is subjected to a very searching washing on a screen-plate of large area, the extracted dirt being collected by the elevator, 17, which delivers into the dirt bunker, 24. The fine coal is now flushed by troughs on to the dewatering sieves, 18, of the double vibro-balanced type, and when rid of the water is distributed by the drainage conveyor, 19, into the bunkers, 20. The waste water from 18 is led back into the pump well, 21, from which it is drawn by the centrifugal pump, 22, and delivered into the settling tank, 23. The concentrated slimes about the apex of the conical settling tank are run off in a semi-fluid condition by cast-iron pipes of about 8 inches diameter on to the fine coal passing over the shaken sieves, 18. The coal, acting as a filter, recovers the fine particles of slurry. A novel feature of this design is the proximity of the plant to the screens and the utilisation of one of the hoppers of the washery building to collect the screens stone. This refuse is conveyed by the scraper, 25, to the boot of the elevator, 26, which discharges into the bunker, 24; by this means the screens roads are freed from dirt wagons without hampering the washery roads, as there are only the two products, nuts and dirt, loaded on siding A5, the former being of relatively small quantity.

In Fig. 131 is shewn the general arrangement of an elaborate washing plant of 100 tons per hour. The slack is of a very brittle nature, and considerable care is necessary to prevent breakage. There are two sources of feed to the hopper, 3, a band conveyor, 4, brings the dross from the screens, and the wagon tippers on the siding, A1, deliver the foreign coal.

The feed elevator, 5, delivers into the two-compartment washer boxes, 6 and 8, and the dirt is collected by the elevators, 7 and 9, and delivered into the dirt bunker, 10, over the siding, A2. It will be again noted that the dirt is loaded on the same road as the larger-sized washed coal—namely, the trebles—



REFERENCE.					
A	SIDINGS.	12	TREBLES BUNKER.	23	PEARLS BUNKER.
2	HYDRAULIC WAGON TIPPLERS.	13	DOUBLES BUNKER.	24	GUM BUNKER.
3	DROSS HOPPERS.	14	SMUDGE SUMP.	25	MIXED PRODUCT BUNKER.
4	DROSS CONVEYOR.	15	SMUDGE ELEVATOR.	26	PUMP SUMP.
5	FEED ELEVATOR.	16	RE-WASHER BOX.	27	CENTRIFUGAL PUMP.
6	WASHER BOX.	17	DIRT ELEVATOR.	28	SETTLING TANK.
7	DIRT ELEVATOR.	18	SINGLES SCREEN.	29	LOADING SHOOT.
8	WASHER BOX.	19	PEARLS SCREEN.	30	DRAINAGE TROUGH.
9	MIDDLES ELEVATOR.	20	GUM DEWATERING SIEVES.	31	AIR COMPRESSOR.
10	DIRT BUNKER.	21	MIXING SCRAPER.	32	TREBLES LOADING SHOOTS.
11	VIBRO SCREENS.	22	SINGLES BUNKER.	33	DOUBLES LOADING SHOOTS.

FIG. 131.—ARRANGEMENT OF 100 TONS PER HOUR WASHERY.

for the reasons already given. On leaving the washer box, the coal is flushed on to the large vibro classifying screens, 11, of about 24 feet long and 4 feet wide, having a screening area of about 190 square feet and taking out three sizes only—trebles, doubles, and below.

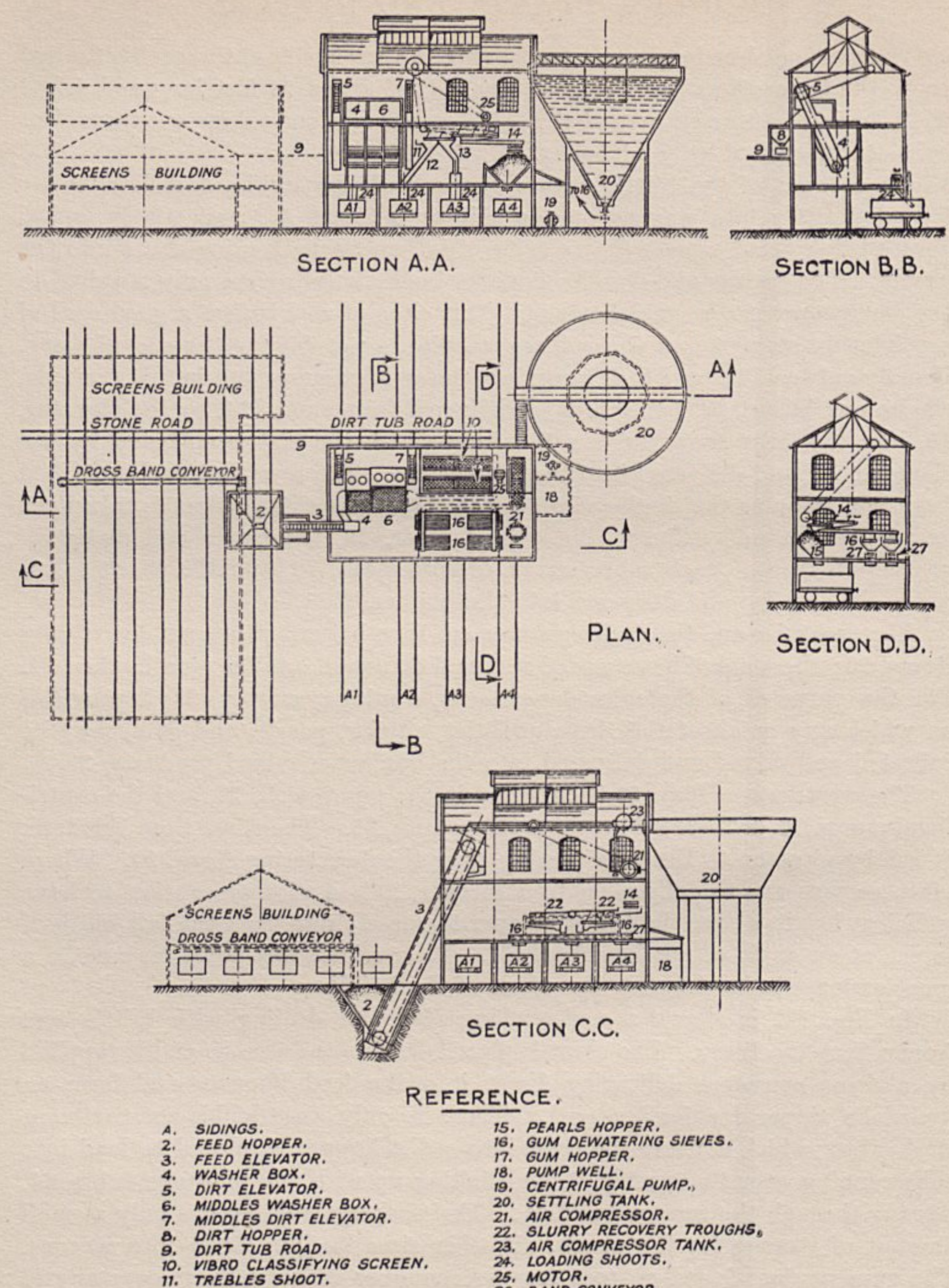
On account of the brittle nature of the coal, the trebles and doubles are loaded directly into wagons on the sidings, A_1 and A_2, respectively, spiral chutes being fitted to ease the velocity of fall on to the loading chute into the wagon. The trebles and doubles bunkers in the building are only required in the emergency of a wagon shortage. This class of coal suffers a good deal of breakage in storage and the colliery people do not favour the use of same. Usually only coal below $\frac{3}{8}$ inch is run into the smudge sump, but in this example, singles and below, *i.e.* $\frac{7}{8}$ to 0 inch, is delivered from sump, 14, by the elevator, 15, into the large rewasher box 16—from which the dirt is collected by the elevator, 17, and delivered into the bunker, 10. The rewashed coal is flushed from box 16 on to the singles vibro screen, 18, where this product is taken out as an oversize and delivered into the bunker, 22, the water and undersize passing on to the pearls vibro screen of wire mesh, 19, and the pearls taken out as an oversize and delivered into the bunker, 23.

The undersize and the flushing water are then led on to the gum dewatering sieves, 20; these are of brass wedge wire and delivered into the gum bunker, 24. For the purposes of the sales department, a mixing scraper, 21, is provided on which any or all of the three qualities, singles, pearls, and gum, may be collected and mixed and delivered into the bunker of mixed products, 25.

The waste water from 20 is collected in the pump well, 26, and the centrifugal pump, 27, delivers it into the settling tank, 28. The slime from this tank is led by pipes on to the gum passing over the dewatering sieve, 20. Where vibro screens are to deliver on to a scraper, it is a wise precaution to have sufficient height above the top of scraper to run a chute from the full width of screen at an angle of not less than 45°. To overlook this point may mean a great expense in heightening the whole of the building.

In Fig. 132 is shewn a coal-washing plant for dealing with brittle coal from a Scotch colliery. The plant is placed close to the screens and is supplied by a dross conveyor delivering direct into the feed hopper—and from an hydraulic tipper for foreign coal. There is only one double-compartment washer box, which delivers the shale into a dirt hopper, 8, placed to load into tubs running over the gantry, 9, and linking up with the pit-stone tub road, passing through the screens building. The washery building has only a small amount of storage for the pearls, all other sizes loading direct into wagons. The gum product is fed on to a scraper conveyor which delivers over any of the three wagon roads, A_2, A_3, A_4, for mixing with the other products.

The pump well and sump are placed between the settling tank and the washery. The feed hopper and settling tank are constructed of reinforced



REFERENCE.

A. SIDINGS.
2. FEED HOPPER.
3. FEED ELEVATOR.
4. WASHER BOX.
5. DIRT ELEVATOR.
6. MIDDLES WASHER BOX.
7. MIDDLES DIRT ELEVATOR.
8. DIRT HOPPER.
9. DIRT TUB ROAD.
10. VIBRO CLASSIFYING SCREEN.
11. TREBLES SHOOT.
12. DOUBLES SHOOT.
13. SINGLES SHOOT.
14. PEARLS SCREEN.
15. PEARLS HOPPER.
16. GUM DEWATERING SIEVES.
17. GUM HOPPER.
18. PUMP WELL.
19. CENTRIFUGAL PUMP.
20. SETTLING TANK.
21. AIR COMPRESSOR.
22. SLURRY RECOVERY TROUGHS.
23. AIR COMPRESSOR TANK.
24. LOADING SHOOTS.
25. MOTOR.
26. BAND CONVEYOR.
27. DRAINING AND LOADING CONVEYOR.

FIG. 132.—100 TONS PER HOUR SCOTCH COAL WASHERY.

concrete, but the washery building is entirely of steel framework and half-brick panelling, supported upon built-up stanchions of rolled-steel joists. This plan was adopted to cut down initial outlay. As the greater part of the coal is for export from a colliery within a few miles of the harbour, and the owners being fortunate to possess a large number of wagons and private sidings, no storage for washed coal was considered necessary.

In the examples given above the washing of the coal has been done in two boxes without preparatory sizing, and the coal immediately after washing is classified and delivered into bunkers or trucks for the consumer.

The raw coal treated has been in fairly regular quantities of each group of sizes, and the plants did not require any provision for a large increase of the smaller qualities. When a plant, however, is primarily erected for the production of washed coal for coking purposes, a very radical change is made in the treatment following the preliminary washing.

In these plants the proportion of fine coal in the raw slack is generally greater than in the previous examples and varies considerably in amount, especially if obtained from different pits.

We have already dealt with the limits of washable sizes, and it is generally admitted that coal below $\frac{1}{8}$ inch is difficult to wash clean in the ordinary jigs. When washed together with coal of larger size, say 2-inch nuts, the difficulty is even greater, as taking an average discard in the coking-coal washing as being of density 1·5 and pure coal as 1·3, we get the equal falling diameters :

$$\frac{D}{d} = \left(\frac{0{\cdot}536}{0{\cdot}307}\right)^2 \times \left(\frac{1{\cdot}5 - 1{\cdot}15}{1{\cdot}3 - 1{\cdot}15}\right) = 6{\cdot}67$$

so that the minimum size to be dealt with in one washing should be

$$\frac{2}{6{\cdot}67} \text{ inches} = \frac{3}{10} \text{ inch.}$$

It should be observed that in the washer boxes under review the washing is more favourable, due to the length of time the material is on the bed and the particularly good jigging effect of the pulsations, but nevertheless the percentage of dirt left in the small coal when dealing with nuts is on the high side for coking purposes. The fine coal below $\frac{3}{8}$ inch should for this reason be either taken out by preliminary sizing or preferably be rewashed after the classifying operation.

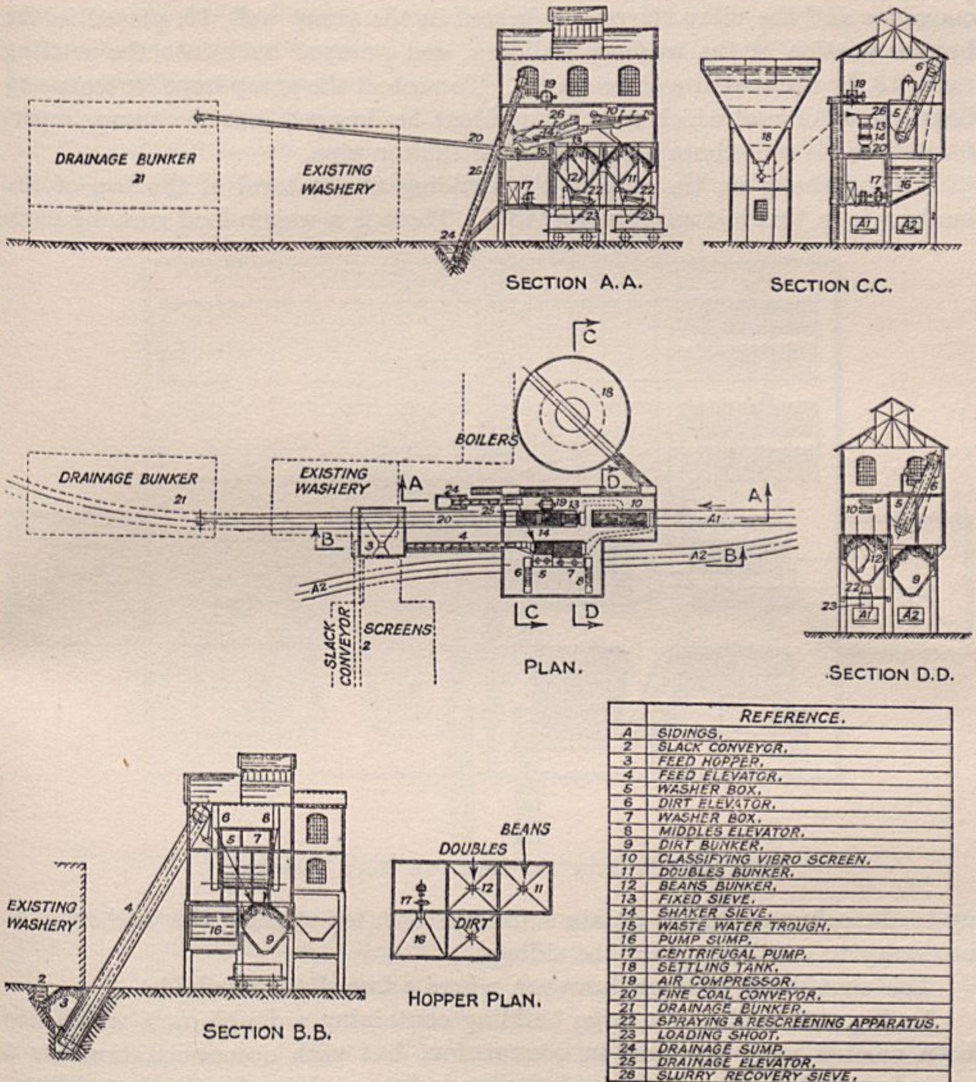
The water sizing of the first renders the small coal more subject to treatment for rewashing, as all the particles are already brought into a definite zone of washability. The larger particles will have been cleansed of some considerable portion of the dirt, so that the coal now to undergo a second or third washing contains only dirt of a small size.

To ensure a good washing of the fine coal, particularly when the quantity is large and containing a large proportion of shale dust, a rewashing is preferable to a preparatory sizing and single washing, seeing that the material to be treated is already water-sized to some extent. One of the most simple and efficient methods is to flush the fine coal and waste water, leaving the classifying screens into a separate sump, often placed outside the main building as shewn in Fig. 131. This sump should be of large size, so that the fine coal is deposited into the boot of the sump, whereas the clearer water at the surface overflows into the peripheral trough, free from any coal of larger size than that classified as slime. It has been found in using smaller sumps that the overflow water carries away a good deal of the fine coal into the pump sump, causing damage to the pump and eventually blocking up the slime circulation. The overflow water is collected in the pump sump, which is provided with an overflow pipe, to ensure that the water does not rise beyond the maximum level, though in working conditions the accumulated water in this sump is seldom much above the pump inlet; the centrifugal pump returns all water from the sump into the settling tank. A bucket elevator dredges up the fine coal collected in the base and delivers it into the rewasher box. This elevator is usually of the continuous bucket type and is from 40 to 48 inches wide; the rewasher box is of similar construction to the slack box, but has only one width of bed, the ratio between the screen area and the plunger area being as 3 : 1. The dirt slides, however, are made of saw-tooth pattern, and in place of being lifted they are drawn to one side. The apertures in the teeth when fully open coincide with notched apertures in the escape-gate guides, so that a fine adjustment may be secured. There being only one class of coal treated in the box, only one elevator is required; this is placed at the opposite end to the feed, seeing that the general movement of the material upon the bed is in that direction, and hence the greater part of the shale is collected at the coal-outlet end. The dirt trapped at the inlet end is collected by a shoot bolted to the end of the washer box and communicating with the dirt worm running the full length of the box as shown. The screen plate is horizontal throughout, there being no necessity to cause the shale to travel back on the bed as in the case of the large coal box. With this type of box there is no need of a feldspar bed, the perforations, while greater than the small size coal or less than the maximum, being usually $\frac{1}{4}$ inch diameter, and hence the larger shale is collected to a thickness of about $1\frac{1}{2}$ inches, which forms a sufficient protection to prevent the passage of the fine coal into the washing chamber. The efficiency of this box is equally as good in a whole product as the larger washer box, the majority of firms using this type being highly satisfied with the results.

In Fig. 133 is shewn the general arrangement of a small washing plant of 50 tons per hour, the products of which are utilised for coking.

A $2\frac{1}{2}$-inch slack is brought to the washery, of which 7% is nuts, $1\frac{5}{8}$ to $2\frac{1}{2}$ inches 20% beans, $\frac{13}{16}$ to $1\frac{5}{8}$ inch and 73% fine coal below $\frac{13}{16}$ inch, of which

53% is below $\frac{1}{16}$ inch. The beans and nuts are screened out upon leaving the washer box for sales purposes, whereas the fine coal and the flushing water on



	REFERENCE.
A	SIDINGS.
2	SLACK CONVEYOR.
3	FEED HOPPER.
4	FEED ELEVATOR.
5	WASHER BOX.
6	DIRT ELEVATOR.
7	WASHER BOX.
8	MIDDLES ELEVATOR.
9	DIRT BUNKER.
10	CLASSIFYING VIBRO SCREEN.
11	DOUBLES BUNKER.
12	BEANS BUNKER.
13	FIXED SIEVE.
14	SHAKER SIEVE.
15	WASTE WATER TROUGH.
16	PUMP SUMP.
17	CENTRIFUGAL PUMP.
18	SETTLING TANK.
19	AIR COMPRESSOR.
20	FINE COAL CONVEYOR.
21	DRAINAGE BUNKER.
22	SPRAYING & RESCREENING APPARATUS.
23	LOADING SHOOT.
24	DRAINAGE SUMP.
25	DRAINAGE ELEVATOR.
26	SLURRY RECOVERY SIEVE.

FIG. 133.—ARRANGEMENT OF 50 TONS PER HOUR WASHERY.

leaving the vibro screens, 10, are run over the fixed and vibro drain sieves, 13, and dropped on to the draining conveyor, 20, which discharges into a bunker, 21.

The draining conveyor is 24 inches wide and about 60 feet centres. The slurry from the base of the settling tank, 18, is passed over a set of fixed and shaker sieves, 26, and is then brought back to drop on to the fine coal already loaded into a conveyor.

The building is entirely of reinforced concrete. The drainage from the conveyor and the vibro sieves is collected in the pump well, 16, placed in the hopper portion of the washery building, and pumped back into the settling tank, 18, by the centrifugal pump, 17. To protect the pump impeller from any large pieces of coal which may by accident be dropped into the sump, a perforated box is sometimes placed over the suction pipe.

The overhang on the side of the building at the level of the top of the bunkers is in this instance unavoidable. There is a wagon-load running close

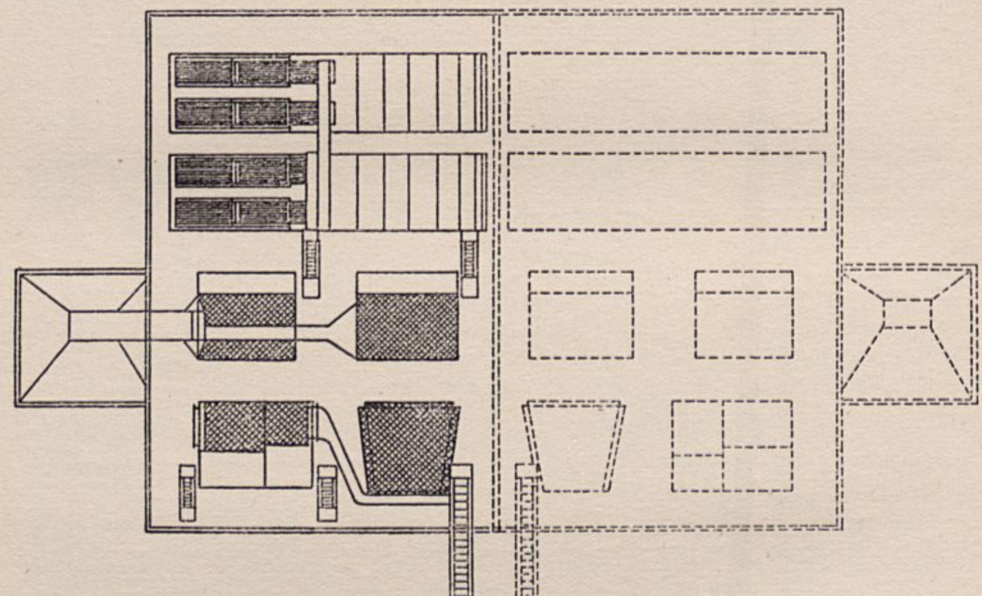


FIG. 134.—PLAN OF 300 TONS PER HOUR WASHERY.

up to the columns, and to obtain sufficient room for working the washery it is necessary to cantilever over the sidings.

This should not be done, however, where a free site is available.

In Fig. 134 is shewn a large building containing a double unit which has been erected with one unit in commission, but with accommodation for a second unit of equal capacity and similar design, as shewn by the dotted lines. When completed, the plant will be capable of dealing with 300 tons per hour. There are three washer boxes, the large washer box receiving the raw slack and flushing it after washing into a double mantel revolving screen, which takes out the peas and nuts, depositing them in bunkers for sales purposes. As the plant is mainly to be used for the preparation of fine coal for coking purposes at a distance, all the bunkers are placed over sidings, there being four through-ways under the structure. The fine coal, which is the undersize on the screens, is led into two large smudge sumps, from which the water overflows into the peripheral trough and is led to a pump well at the bottom end of the draining band.

Having a large quantity of fine coal to deal with, two fine-coal rewasher boxes are installed. They are both 12 feet wide by 14 feet long.

After rewashing, the fine coal is led into distributing troughs over a double set of fixed and shaker sieves placed immediately above the bottom sprocket of the draining band. This method of reducing the moisture content before

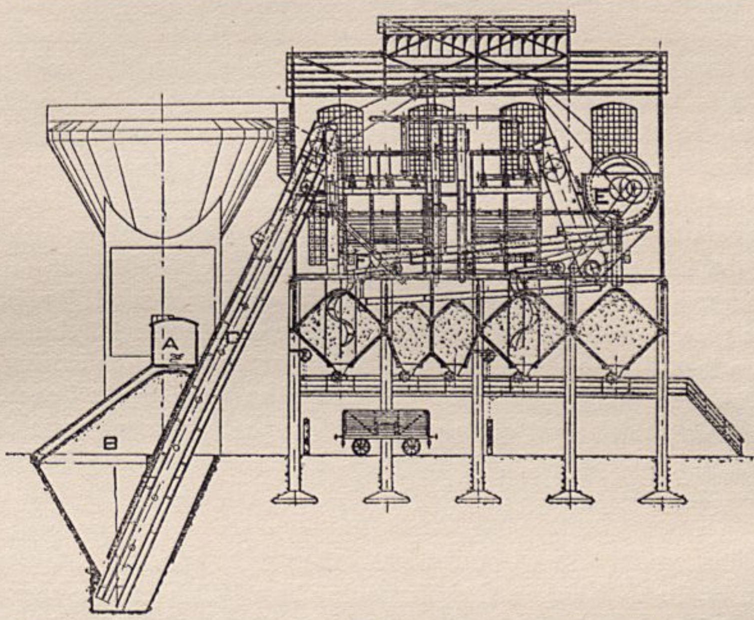


FIG. 135.—LONGITUDINAL SECTION OF WASHERY, SHOWING SMALL SMUDGE SUMP.

depositing the fine coal into the draining conveyor will ensure a greater percentage of dryness before being discharged into the bunkers, the settling tank in this case being entirely conical and supported upon concrete housing. It is 55 feet diameter and about 75 feet high.

The main building is of steel-armoured brickwork, and is possibly the largest of its kind in the world.

A space between the existing and the future extension of the building is reserved for a dust extraction plant.

From these examples of a draining band structure, there would appear to be little doubt that only the more wealthy collieries could entertain the construction on these lines.

The draining band does not possess any advantages in proportion to its enormous cost, and especially in view of the large range of present-day dewatering machinery costing a tithe of this massive appliance, colliery engineers would be advised to forgo prejudice and instal a more rational mechanism.

To distribute the feed from the draining bands over the three bunkers allotted to the fine coal, two scraper conveyors are placed under the discharge outlet of the fine coal hopper.

In Fig. 135 is shewn a longitudinal section of a 100 tons per hour plant. There is a covered-in feed hopper, B, which receives the slack from the conveyor, A. The fine coal and water from the revolving screen, E, is collected in a mild steel casing which acts as a large boot of the smudge elevator feeding the rewasher box. This boot is of open top and at the edge is provided with a peripheral trough of ample proportions to take the whole of the washing water, and lead it to the pump well. The comparatively high velocity of the overflow due to the small capacity of the boot carries away a large amount of fine coal into the pump well and causes endless trouble with the pumping—choking the impeller of the centrifuge. The fine coal collecting or smudge sump should always have a capacity of not less than one-sixth of the settling-tank capacity for the plant, if these troubles are to be avoided.

The larger coal is flushed by glass-lined troughs over small jigging screens which are placed over the bunkers and deliver on the special chutes. These screens are installed to drain off the flushing water before delivering the coal into the bunker. They are more effective than fixed drain boxes, and by reason of their small height often cause a corresponding economy in the height of the building.

Coppée

As evidence of the trend of British coal-washing practice is the change in the design of the well-known Coppée washer box. This washer box originally was of the plunger or bash type, but recently this firm have modified the box by doing away with the plunger and using air as the pulsation medium. It differs radically from that of the Baum in that there is still classification before washing. The detailed design of the box is a complete change from that of the ordinary type of jig washer. The coal is fed in at the back of the box and the screen plate is inclined downwards towards the air chamber partition, while the forward half is horizontal. There are three dirt dampers or escape gates to each box, two for the heavy dirt placed in the corners at the inlet end, whilst the escape gate at the washed-coal outlet is that for the middles or mixed coal. The dirt falling through this outlet is guided to the base of the box between the outer casing and an inner casing.

The heavy shale falls directly down through the water of the washing chamber. A rotary valve, shewn in Fig. 136, receives this dirt. It is in the form of a cylinder with one quarter of its circumference cut away to allow the entry of the dirt whilst in the open position. This rotary shale valve is cast complete with pintles on its centre axis, which are supported in cupped bearings contained in the flange, cast-iron plates forming the sides of the chamber. On the longer pintle or shaft a small spur wheel is carried which engages with an actuating pinion mounted upon a belted-driven shaft. In the figure the valve is shown open, and in this position it receives the shale, the number of revolutions being regulated to dispose of the maximum amount of dirt.

If it is required to keep the middles separate from the heavy shale, the rotor is divided into two compartments, as shewn in Fig. 137.

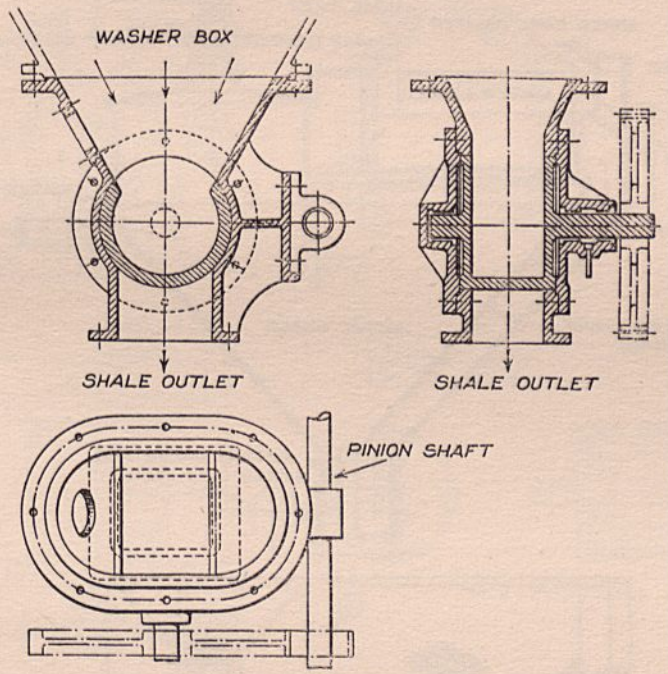


Fig. 136.—Rotary Shale Valve for Nut Washers. C.I. Body, C.S. Rotor.

A cast-iron cover-plate on the air chamber provides a flange seat for a rotary air valve, which is cased in a cast-iron chamber provided with inlet and outlet ports communicating with the washer box and the atmosphere. As shewn in Fig. 138, the cast-iron rotor, which is a plain cylinder, is provided with four longitudinal slits mounted on a shaft supported in the cast-iron side plates and provided with a spur wheel at one end engaging with the pinion of the belt-driven actuating shaft. The air inlet is on the top of the cast-iron chamber having a longitudinal port which coincides with the port of the rotor, at the same time as the opposing port of the rotor is in communication with the air chamber during the pulsation stroke. A further one-eighth of a revolution brings all ports of the rotor opposite the four exhaust ports in the casing, two of which are open to the atmosphere and two are in communication with the air chamber, allowing the pressure in the latter to become that of the atmosphere, thus giving a clear exhaust, this principle being similar to that of the Baum air valve.

In this connection, it should be remarked that the pressure of the air in

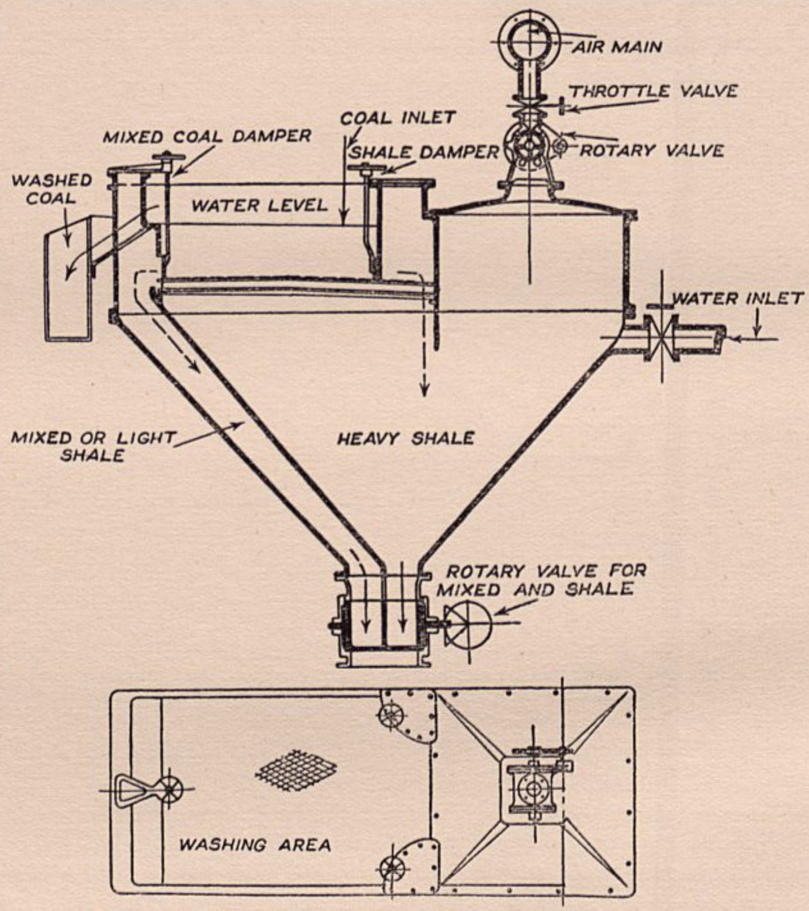


FIG. 137.—" COPPÉE " NUT WASHER.

the air chamber at the opening of the exhaust port is considerably less than that at the time of entering and, therefore, a greater area of exhaust port is required to obtain the necessary speed of pressure decrease, the area of the Baum valve ports being in the proportion of 3 to 1, whereas in this case it is 2 to 1. Each revolution of this rotor represents four complete cycles of washer-box pulsations.

The fine-coal rewasher box of this type is shewn in Fig. 139, where it is seen that there are two units placed together with a central weir upon the bed and that, unlike the nut washer, the feed is across the box from inlet to outlet and not from the air chamber side to the edge of box, the first box extracting the heavier shale and the second the lighter, the air valves and shale valves being identical with those of the nut washer.

The central division plate does not, in the opinion of the author, extend deep enough into the washing water, and for this reason it is more than possible that an uneven washing will take place upon the bed.

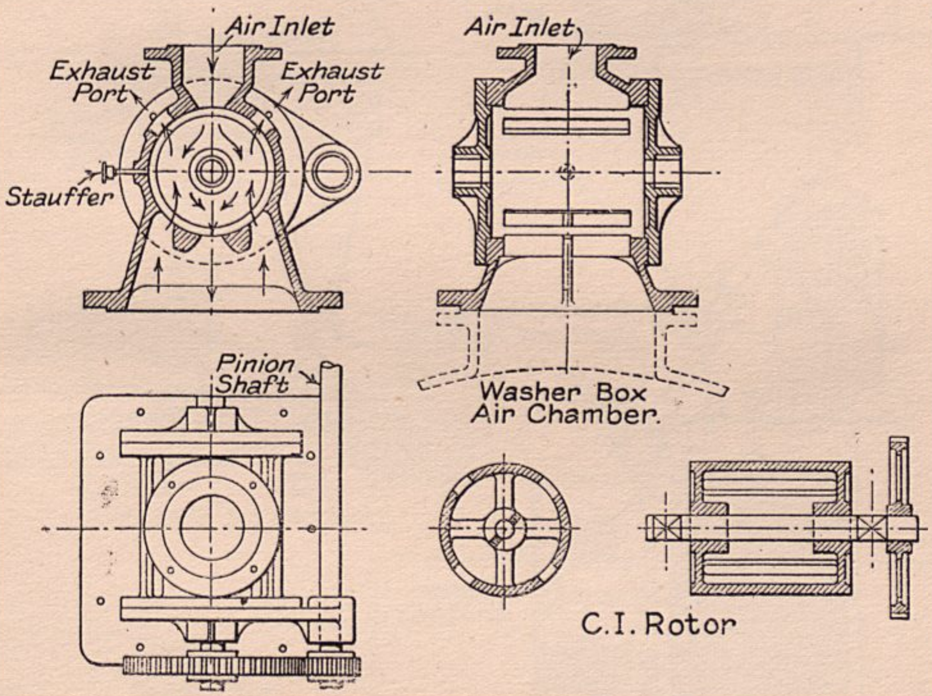


FIG. 138.—ROTARY AIR VALVE. "PRESSURE 1·6 LB." GAUGE DESIGNED TO DEAL WITH 10,000 CUBIC FEET PER HOUR. C.I. BODY and ROTOR (4 IMPULSES PER REV.).

There is likewise some doubt, in the author's mind, as to the advisability of allowing the heavy shale to drop through the wash water at the point of maximum water pressure. The cramped outlet end of the nut box where the side slope of the chamber comes up to meet the screen plate at an acute angle cannot be considered an advantage.

It has been found by experience that a washer box having a deep-water chamber proves much more efficient in its duty than that in which the depth of water is restricted. While not exactly a wave action, the pulsation effect is much more evenly spread over the surface of the screens when the depth of water below is sufficient to eliminate the skin friction on the sides of the chamber. Likewise, a large mass of water in motion has a more definite movement than that of a small body.

There is another point to be considered, and that is, the settlement of the fine dirt passing through the screen plates. The larger the body of water beneath the screen plate the greater is the likelihood of a rapid settling in the base of the box.

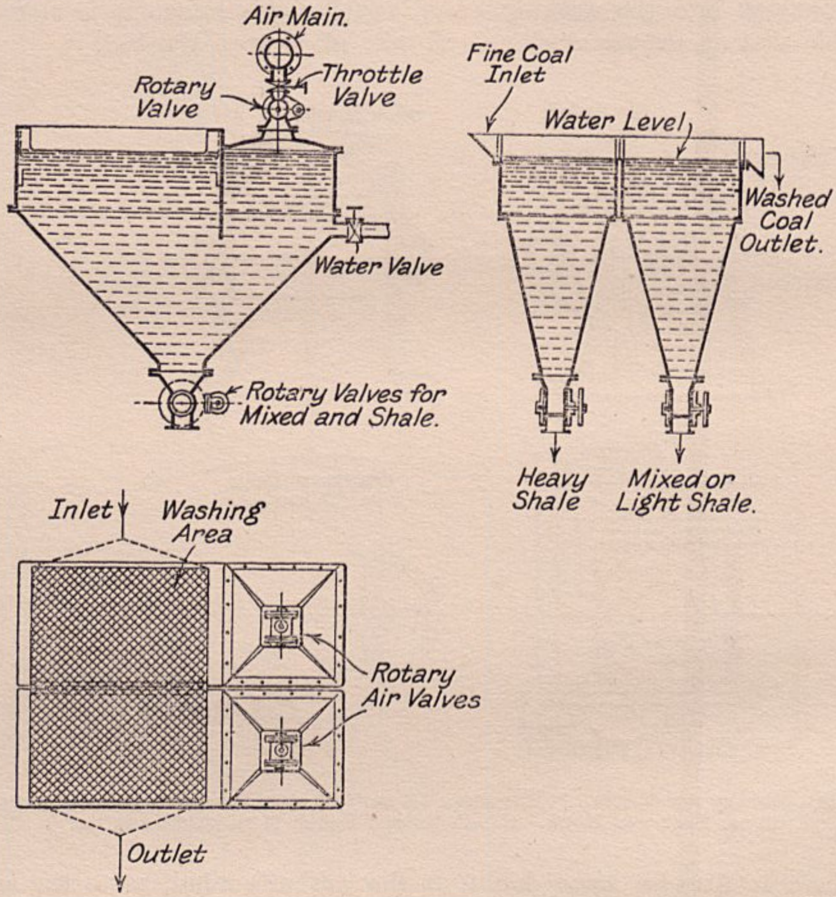


FIG. 139.—FINE-COAL WASHER.

However, this particular washer box has not yet had a sufficiently long trial to enable one to give a more definite opinion as to its merits.

In Fig. 140 is shewn a plant capable of dealing with 100 tons of slack per hour, on the Coppée System.

The raw coal is brought to the washery by wagons running over the track, 1, and discharged into the feed hopper by two overhead tipplers of an economical design and operated by a small electric winch.

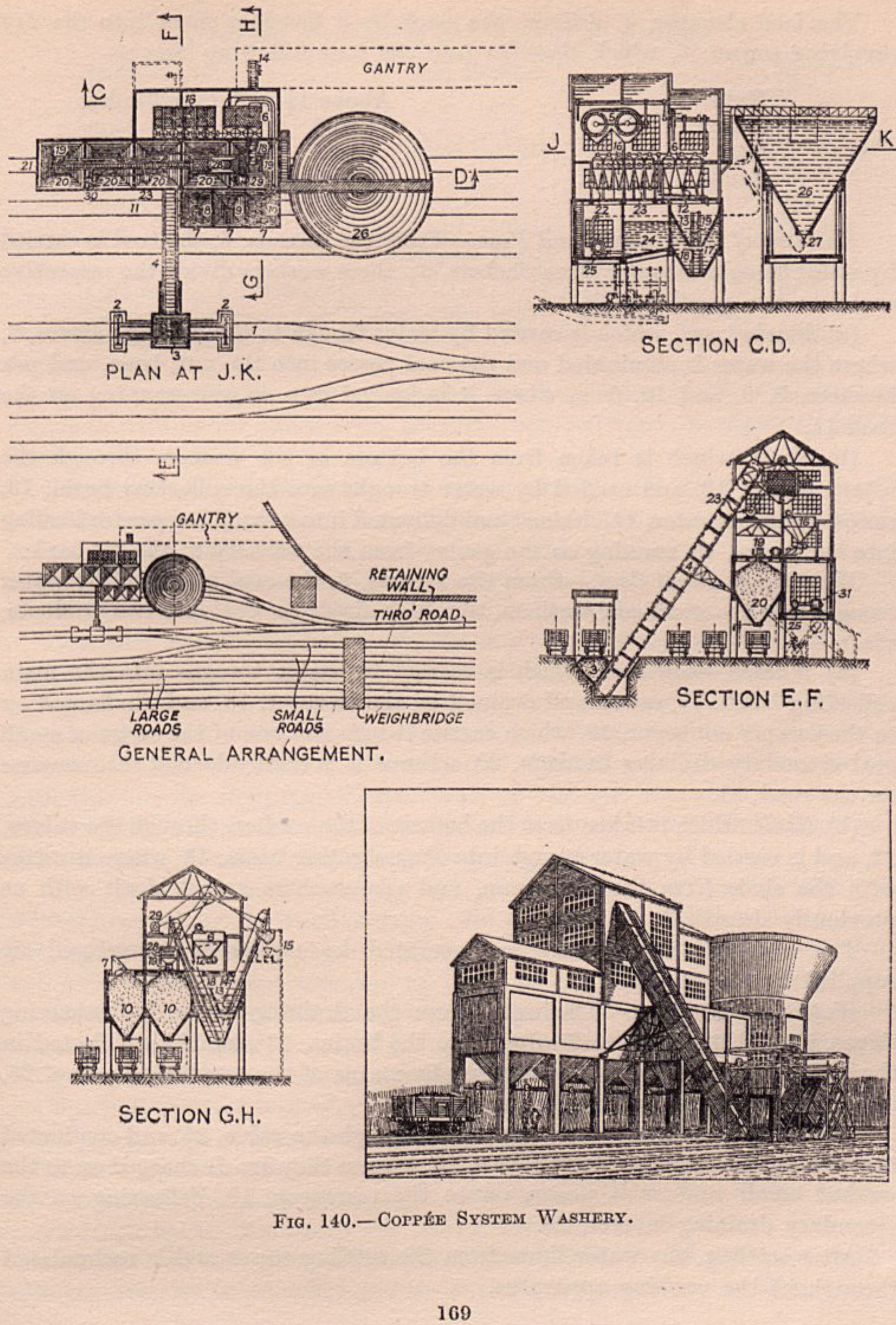


FIG. 140.—COPPÉE SYSTEM WASHERY.

The feed elevator, 4, delivers the slack by a breeches shoot into the dry revolving screen, 5, which classifies into the four following sizes :—

Nuts	Above $1\frac{1}{4}$-inch round holes.
Beans	$1\frac{1}{4}$ to $\frac{3}{4}$,, ,, ,,
Peas	$\frac{3}{4}$ to $\frac{3}{8}$,, ,, ,,
Small	$\frac{3}{8}$ to 0 ,, ,, ,,

Washing of Nuts, Beans and Peas.—From the screens, 5, the coal is carried by water troughs into the three washers, 6; these washers divide the respective coal into two products, viz. :—

(a) *Washed coal*, which is carried by water trough to the draining sieves, 7, where the water is eliminated and the coal passes into the nut, bean, and pea bunkers, 8, 9, and 10, from where it is loaded into wagons running on the road 11.

(b) *Shale*, which is taken from the bottom of the washers through the rotary valves, 12, and carried by water troughs into the collecting basin, 13, raised by the elevator, 14, drained and delivered into a small hopper for loading into the trams, 15, running on the gantry from the washery to the pit bank.

Washing of Small Coal.—From the screens, 5, the coal is carried by water troughs into the small-coal washers, 16, which divide the coal into two products, viz. :—

(a) *Washed small coal*, which is carried by water troughs into the main collecting basin, 17, raised and drained by the elevator, 18, and discharged on to the scraper conveyor, 19, which carries it into any one of the series of small coal secondary draining bunkers, 20, whence it is finally loaded into wagons on the road, 21.

(b) *Shale*, which is taken from the bottom of the washers through the valves, 22, and is carried by water trough into the collecting basin, 13, where it mixes with the shale from the nut, bean, and pea washers and is dealt with as previously described.

The whole of the washers are operated by means of compressed air supplied by the blower, 23.

Water and Settlings.—The water from the draining sieves, 7, dewatering sieves, 17 and 28, and overflowing from the basins, 13 and 17, is collected in the pump basin, 24, whence it is taken by means of the centrifugal pump, 25, and delivered to the settling tower, 26.

The settlings in this tower are run off through the valve, 27, and conducted through pipes to the dewatering sieve, 28, whence they are discharged on to the washed small coal as it passes on to the conveyor, 19, delivering to the secondary draining bunker, 20.

After settling, the water flows from the settling tower and is recirculated throughout the washing apparatus.

Loading of Products and Storage of Bunkers

Nuts	One Bunker . . .	45 tons.
Beans	,, ,, . . .	45 ,,
Peas	,, ,, . . .	45 ,,
Small	Five Bunkers . . .	72 ,, each.
Raw-coal-receiving hopper		25 tons.
	Total . . .	520 tons.

Motive Power

One motor for washery, 29	70 H.P.
One motor for the dewatering sieve and small-coal conveyor, 3	10 H.P.

Space is provided in the building for the installation of two coal crushers complete with motor and driving gear and belt conveyor, as shewn in dotted lines.

The dewatering of the fine coal in this system has not made equal progress with the rest of the plant. It seems to be a none too desirable method to collect the fine coal from the washer-floor level and deposit it into the wet sump, 17, 40 feet below, and then re-elevate it by the draining elevator to the scraper conveyor for distribution into the bunkers.

A similar remark applies to the method of collecting the shale into the basin, 13, and then using the elevator, 14, for dewatering purposes.

In all washeries the machinery that requires most attention is always an elevator, and this should be kept down to minimum lengths, or, if possible, eliminated from the plant. The necessity of fitting an elevator is generally such that on the stoppage or breakdown of any one, the whole of the plant has to remain idle until it is put into commission once more. This is especially the case with elevators used for drainage purposes.

The revolving screens used for the preparatory sizing, placed inside the washery, are a certain disadvantage. No matter how well they are cased in the beginning, after a time the dust begins to find its way into the building, and the washery then becomes as dirty as the heapstead screens. It is advisable with preparatory sizing to shut the screens into a particular corner of the building specially prepared for their use and thus avoid all the consequent evils of the flying dust among moving parts.

The feed elevator is of very substantial design and of the wide bucket type. Results from this washery have given great satisfaction.

Brauns System.—The development of the Brauns system was due in the first instance to a large number of tests upon an ordinary basher washer, carried out by H. Brauns at the Eschweiler Colliery, Germany. From the results of these tests it was discovered that the water did not move with a uniform velocity at different points on the screen surface. In Fig. 141 the arrows shew the path of the water due to the plunger action, and as the water set in motion prefers to follow the shortest path, exact dimensions were taken of the rise of the water surface above the screen.

For the enlarged section, this rise of the water surface on the down stroke of the plunger is represented by the hatched area, the dimensions being those of the rise at the respective points; thus at the back of the screen or the point of feed it was found to be $4\frac{3}{8}$ inches, and at the discharge lip only $\frac{5}{8}$ inch, so that the body of water had an unequal buoyancy effect upon the coal, that

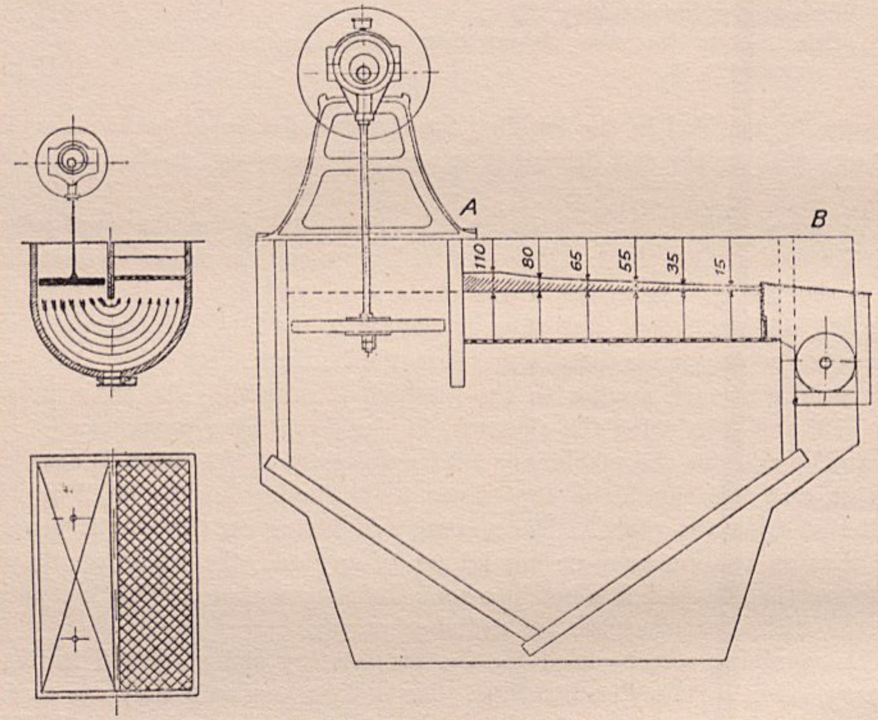


FIG. 141.—BASHER WASHER BOX.

at the nearer side rising with a greater velocity and amplitude than that on the further side, so that the separation of the coal is unequally spread over the screen surface and is equivalent to a reduction in area of the latter. This irregularity not being conducive to efficient washing, the above-mentioned engineer produced a washer box to eliminate this drawback.

In this connection, it is worth noting that one of the most modern American washer boxes has been designed with special arrangements to counterbalance this effect. This box is known as the Elmore washer box, and immediately below the screen plate and adjacent to the partition plate between the plunger chamber and the washing chamber a series of U-shaped deflection plates is fitted, so as to cause the rising water to be spread out more evenly over the box. This defect, however, was overcome by Brauns in placing the plungers

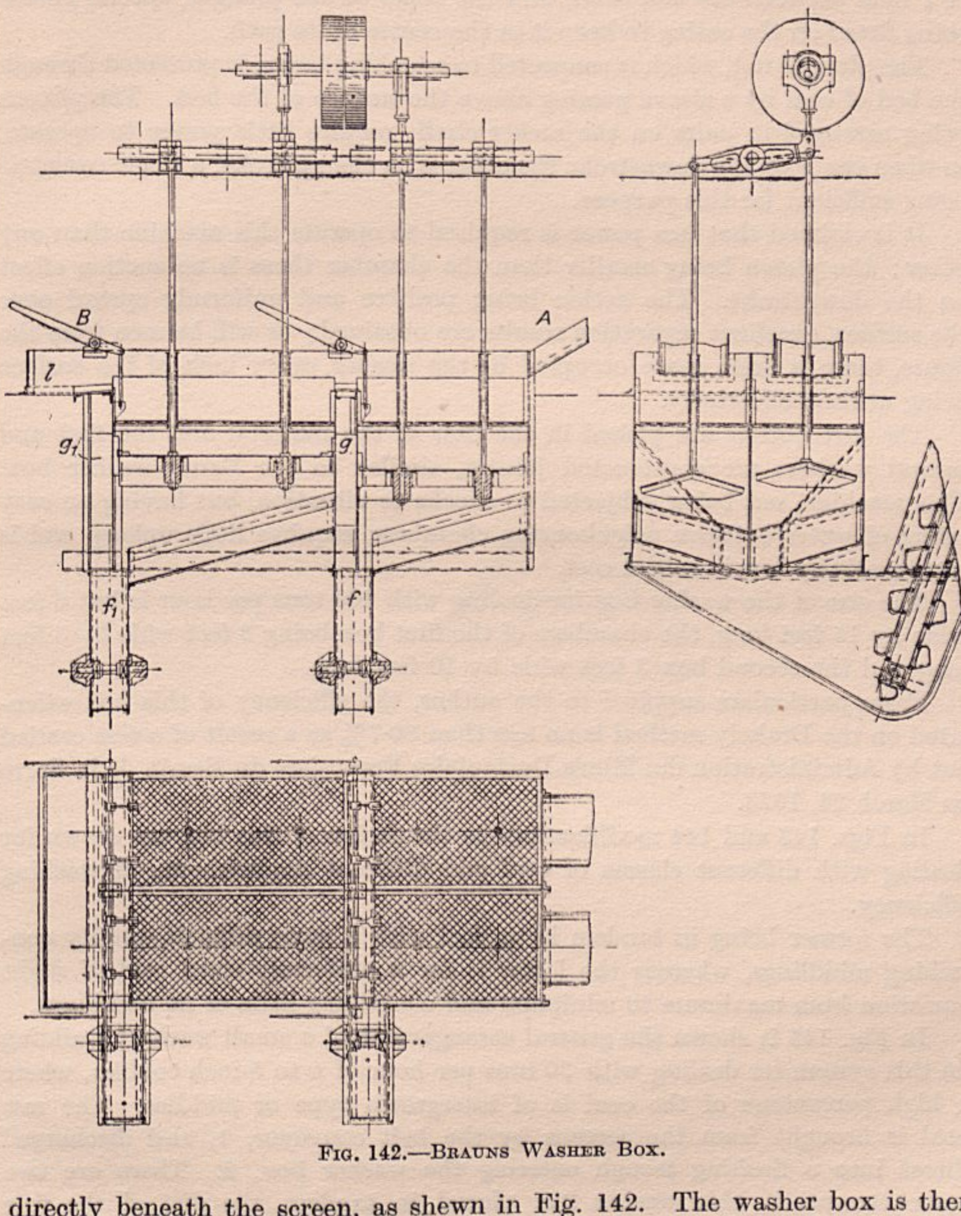


FIG. 142.—BRAUNS WASHER BOX.

directly beneath the screen, as shewn in Fig. 142. The washer box is then built up in a series of vertical troughs with the bottoms sloping towards the boot of a shale elevator. The plungers are bent slightly from the centre line, having the two sides at an angle of 130°, so that any fine dirt falling through the screen plates will slide off into the bottom of the box. The plungers do not cover the same area as the chamber in which they work, having a clearance of 1 inch between the side walls and the edges of the plunger, special guides being fitted on the casing to keep it in the centre of its path.

The plunger rod, which is connected to a rocking beam, is protected through the bed of coal by a sleeve passing above the surface of the bed. The pistons being arranged in pairs on the rocker shaft, require little power to operate, as when one is on the downstroke the other is on the upstroke, a single eccentric being sufficient for this purpose.

It is claimed that less power is required to operate this machine than any other; the piston being smaller than the chamber there is no suction effect on the downstroke. The action being positive and uniformly spread over the surface, excellent separation results are obtained; as will be seen from the figure, there is little space occupied by the washer, every inch of the surface being utilised effectively.

The dirt outlets are placed in the flow of the material and the first and second washers are constructed jointly, similar to the Baum washer box. This machine, not being subjected to shocks or vibration, but having an easy swing of water between neighbouring chambers, requires little upkeep and is comparatively low in initial cost.

The size of the washer box for dealing with 100 tons per hour is but 6 feet wide by 15 feet long, the chambers of the first box being 3 feet wide by 5 feet long and the second box 3 feet wide by 10 feet long.

From particulars supplied to the author, the efficiency of this box calculated on the Drakely method is no less than 80·7% as a result of a test carried out by Administration des Mines Domaniales Françaises du Bassin de la Sarre on March 24, 1923.

In Figs. 143 and 144 modifications in the design of this box are shewn for dealing with different classes of coal and different requirements of washing efficiency.

The former being in tandem is to deal with a more difficult quality containing middlings, whereas the latter is for a uniformly sized coal of slight variation from maximum to minimum and containing little or no middlings.

In Fig. 145 is shewn the general arrangement of a small washery building on this system for dealing with 30 tons per hour of 0 to 5-inch cobbles, where a high percentage of the coal is of intergrown type or middles. The raw coal is brought from the screens by the belt conveyor, 1, and discharged direct into a flushing trough entering the washer box, 2. There are two compartments in this washer box placed in tandem, the dirt of the first washer box being discharged into the shale bunker, 18, from which it is loaded into tubs at the ground level. The dirt from the second compartment of the washer box, 2, containing a large amount of bone coal from the elevator,

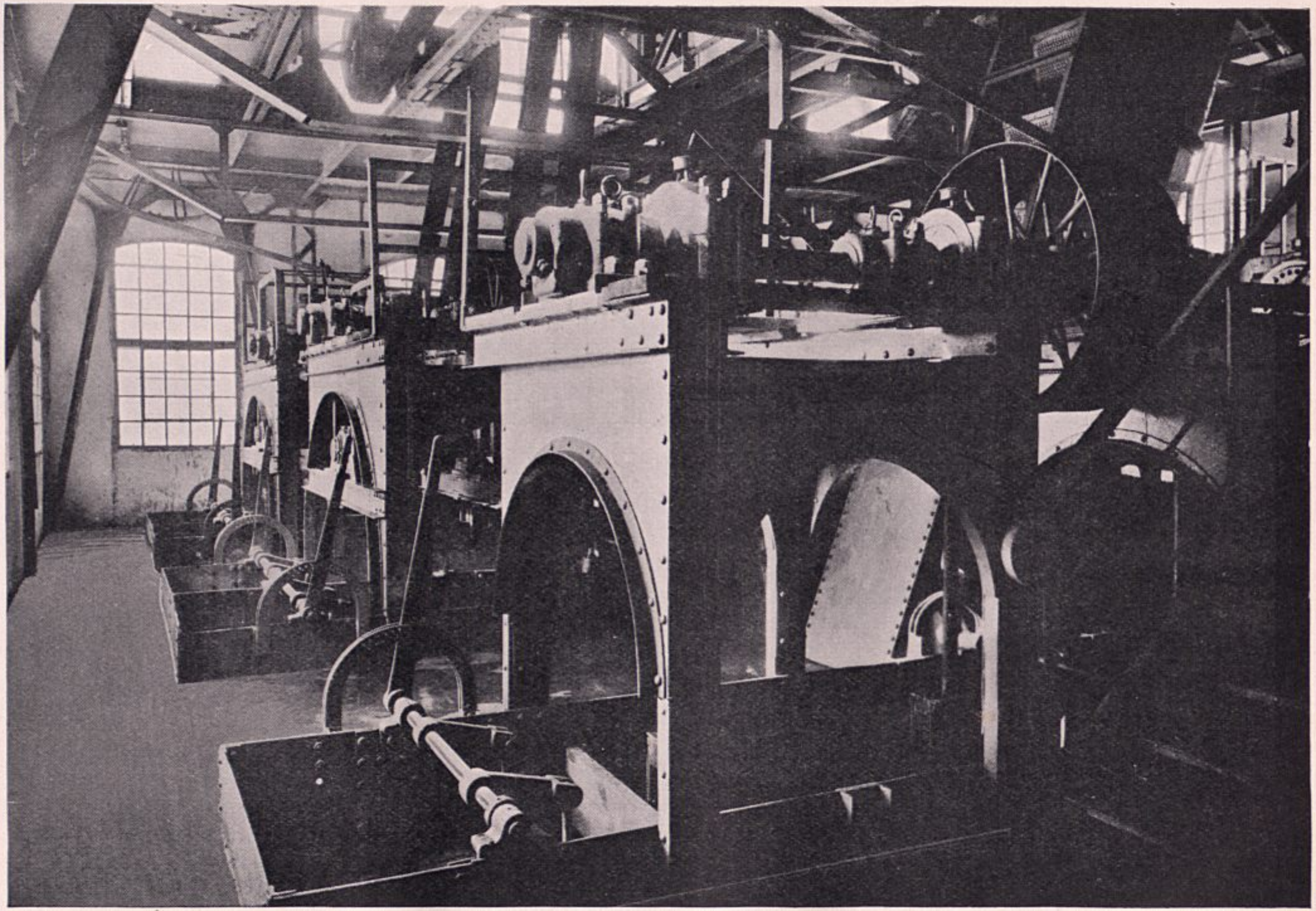


Fig. 142a.—The Tandem Washer Box Arrangement of the Brauns Washer Boxes of the Washery shown in Fig. 8a.

[To face page 175.

is increased in length and brought up at a steeper angle to promote a better drainage than the elevator, 17, and also to obtain a discharge at a sufficient height to deliver the middles into a roll breaker, 22, which is placed at a suitable height above the floor to obtain sufficient fall in the trough, 23, to

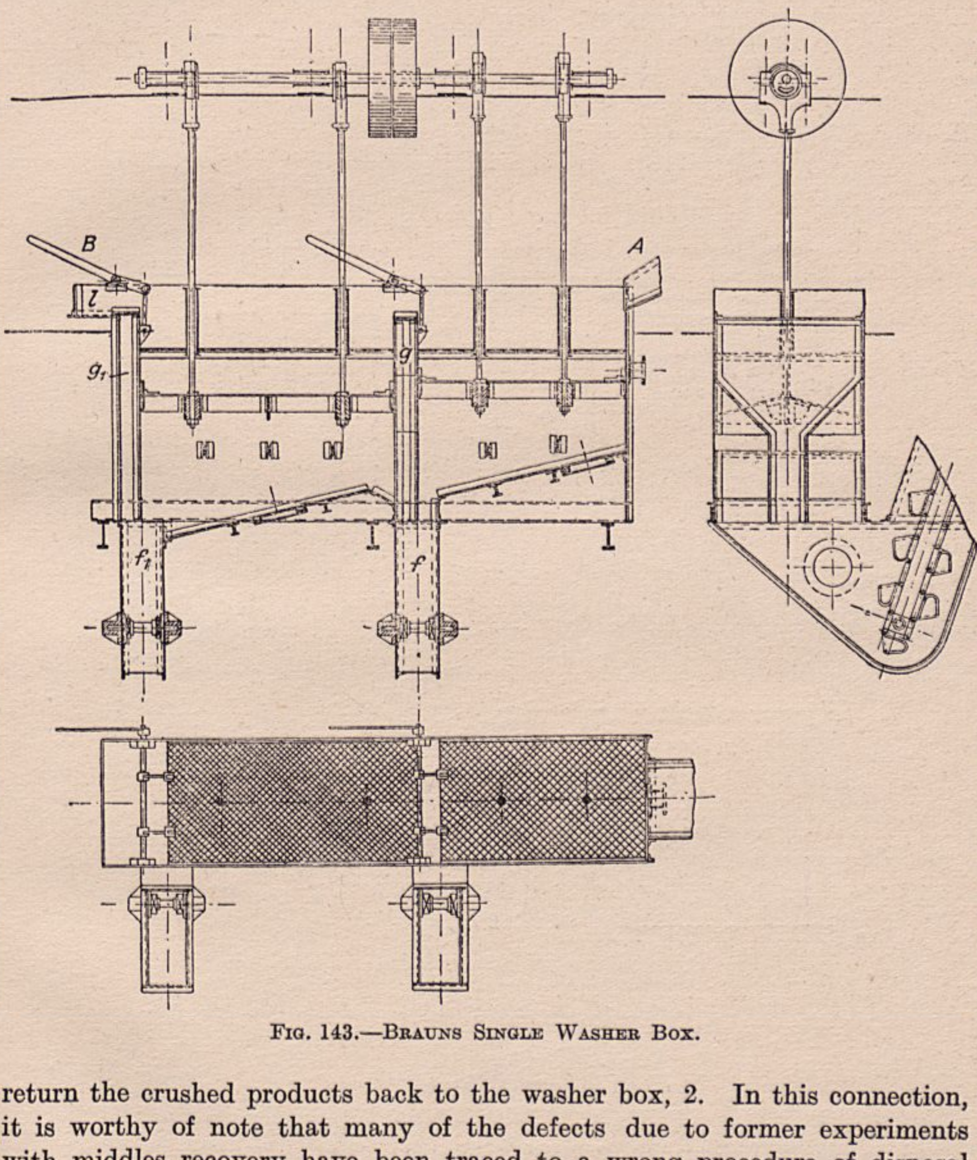


FIG. 143.—BRAUNS SINGLE WASHER BOX.

return the crushed products back to the washer box, 2. In this connection, it is worthy of note that many of the defects due to former experiments with middles recovery have been traced to a wrong procedure of disposal after leaving the breaker. It was customary to flush the crushed material into the rewasher box, so that the result was that this added material not

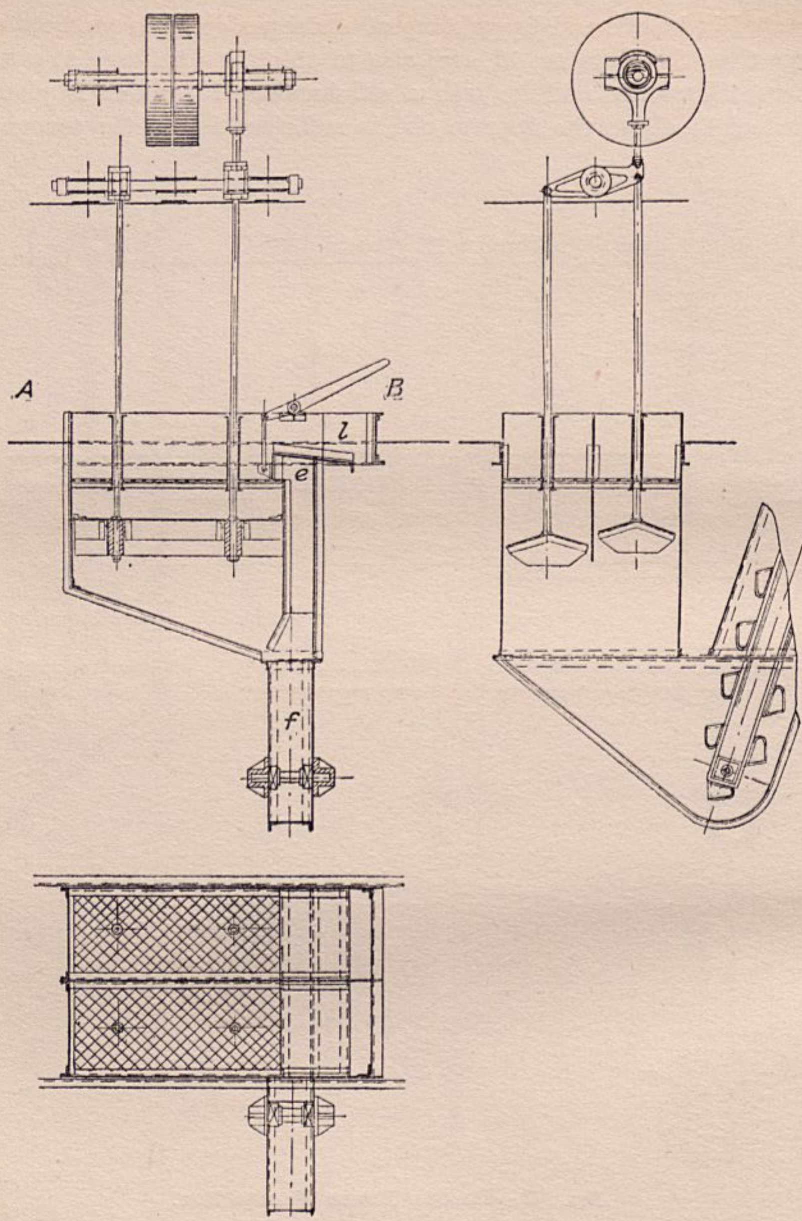


FIG. 144.—BRAUNS PAIRED WASHER BOX.

being water-sized as were the other products passing through the box it did not have the benefit of the correct washing. For this reason, when returned to the first box, any heavier material is immediately extracted on the first

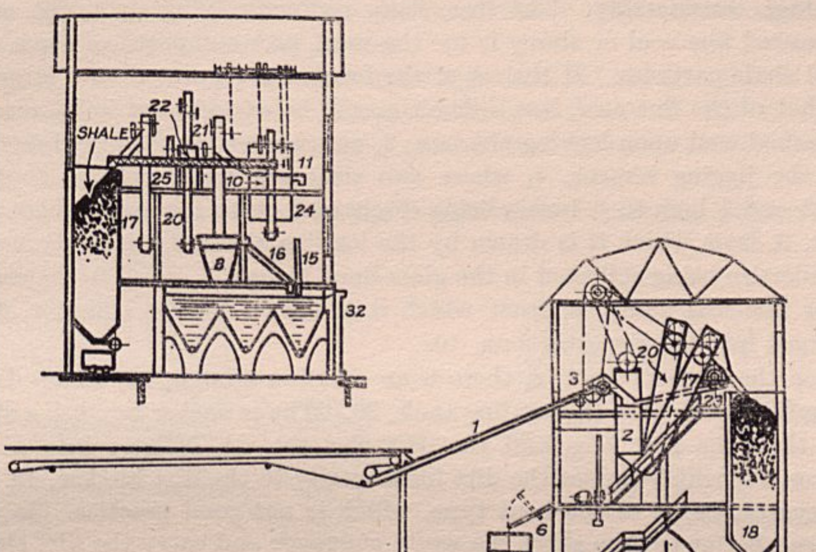


FIG. 145.—" BRAUNS " SYSTEM WASHING PLANT.

elevator, and those middles which have returned unseparated will again pass through with the middles product. It is also a good plan to maintain a maximum size of the middles, breakage being preferable along or near the cleavage lines rather than to break up shale and coal together. Broken shale has the great disadvantage of losing its sharp corners in passing through the washer box and forming a fine powdery mixture, which not only mixes with the washed coal, but in the settling ponds or tanks increases the ash percentage considerably. The fine, flaky sediment lying upon the surface of deposited fine coal or slurry is for the most part composed of these infinitesimal shale particles. If the set of the breaker is regulated to a larger size than that of the fine coal, less difficulties will be experienced in its recovery. The washed coal upon leaving the box, 2, passes over the flushing launder, 3, on to the jigging screens, 4, where two sizes are made nothing to ½ inch through and ½ inch to 5 inches being discharged on to the spiral shoot in the bunker, 5, from which it is drawn by the loading shoot, 14, into the wagons. The undersize being collected in the glass-lined trough, 7, is led to the elevator boot or fine-coal sump, 8, from which it is drawn by the elevator, 9, and discharged into the rewasher box, 10.

Upon the elevator boot, 8, there is an overflow trough, 16, which delivers the overflow water into the settling tank, 26. The rewasher box has a shorter stroke than the first box, and the dirt elevator, 24, delivers into a worm conveyor, 25, which carries the dirt horizontally to the dirt bunker, 18. The dirt elevator, 24, is of the bent type, which is not good practice. It would have been better to stop short the worm conveyor and carry the dirt elevator straight up at a slope sufficient to shoot sideways into the worm. The fine coal on leaving the rewasher passes by the trough, 11, on to the dewatering sieves, 12, before being delivered into the bunker, 13.

The waste water from these sieves is returned to the settling tank, 26, by the trough, 15. This settling tank consists of a battery of six inverted pyramids built in arch brickwork or concrete, the circulation of water in the washery being effected by the centrifugal pump, 28, drawing from a stream or rose in the higher part of the water and furthest from the inlets.

The slurry is recovered from the settling tank, 26, by extraction from the apices of the pyramids by the valves, 27, which discharge into a concrete trough leading to the slurry sump, 29, from which a centrifugal pump, 30, elevates it on to the fine coal passing over the shaking sieve, 12.

There are three small motors required for this building, that for the main drive and one for each of the pumps. It will be noticed that the main and second shafts are parallel and likewise all the drives in the washery, which is a considerable advantage in running the plant.

This building, which is of the very latest German design, is much larger than would be constructed by British engineers for a similar capacity of plant.

The plant shewn in Fig. 146 is one designed for a difficult site and is of 100 tons per hour capacity, dealing with nuts, peas, and fine coal, of which the latter forms the greater part of the raw slack and is to be utilised for coking purposes. The feed to the washery is direct from the screens by the belt conveyor, 1, delivering into a feed hopper, 2, of 100 tons capacity.

The feed hopper and washery are constructed upon an old refuse heap adjoining the sidings from the screens.

The raw coal is delivered into the large washer box, 4, which is 10 feet wide and 16 feet long, representing a screen bed area of 160 square feet per 100 tons of coal, which is a 30% greater area of screen surface than that of most washers.

On leaving the washer box by the trough, 5, the coal is run into the double

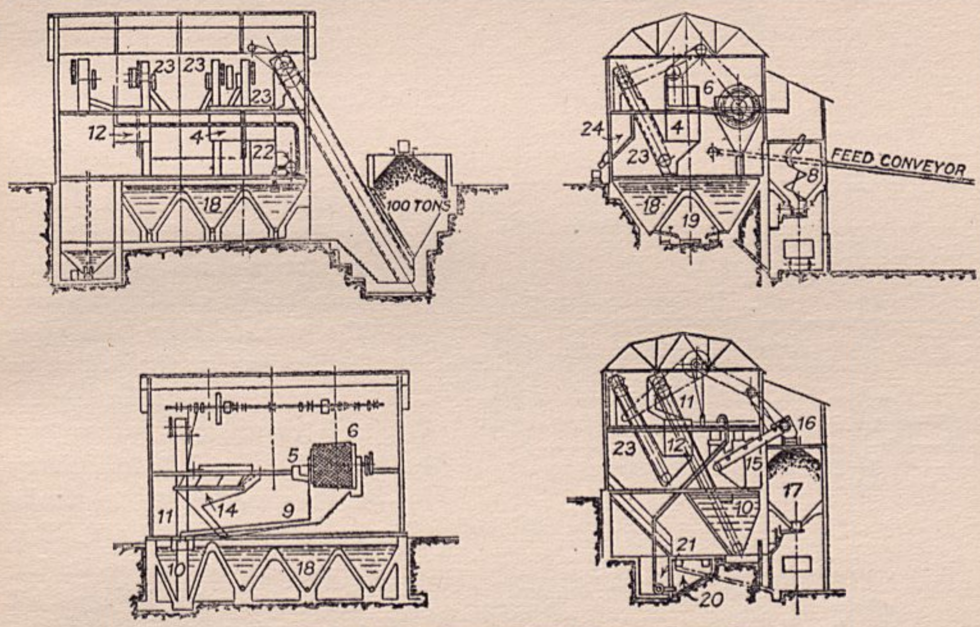


FIG. 146.—BRAUN'S SYSTEM WASHING PLANT.

mantle screen, 6, where the two oversizes are flushed over drain boxes into their respective bunkers, 4 and 8, whereas the fine coal is carried by the flushing launder, 9, to the wet-coal sump, 10.

The smudge or wet-coal elevator, 11, scoops the coal from the base of this hopper and delivers it into the rewasher box, 12, which is 10 feet wide and 13 feet 6 inches long, which represents a screen plate area of 2 square feet per ton of coal, which is a gain of 30% over most other washer boxes of equal capacity.

On leaving the washer box the coal is flushed by the launder, 13, over the dewatering sieve, 14, which delivers the dried coal upon an inclined drainage conveyor, 15, delivering into distributing scraper conveyor, 16, over the

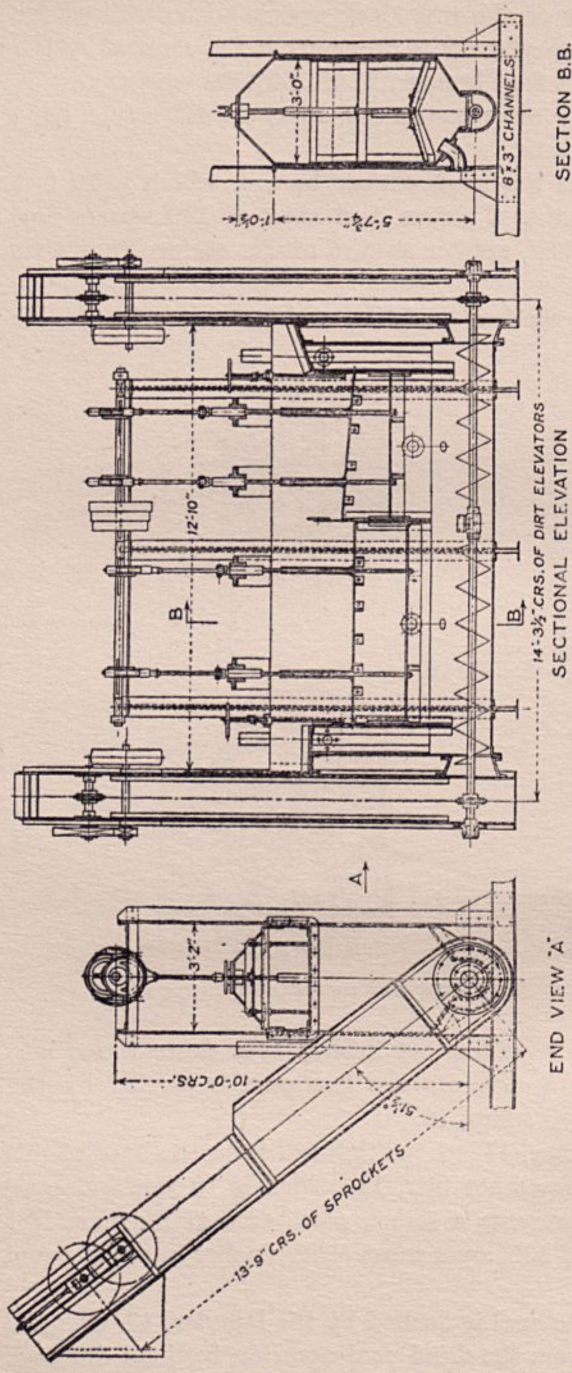


Fig. 147.—British Brauns Washer Box.

fine-coal bunkers. The de-watering sieves are of brass wedge wire 4 feet wide and 20 feet long, of which there are two sets. The waste water from the sieves is collected in a glass-lined trough and delivered into the settling tank, 18, in the base of the building, forming the foundations for same. The circulating system is operated by the centrifugal pump, 22, which draws the water from the surface of the settling tank and pumps directly into the washer boxes. Placed upon the water-supply pipe there is a large stand pipe carried to a height of 14 feet above the washer floor, this pipe being open at the end so as to preserve a uniform pressure of water.

The precipitated slurry is drawn off from the tanks by the valves, 19, feeding into concrete troughs on the floor of the tunnel and led into a slurry sump, 20, from which it is pumped by the pump, 21, on to the fine coal passing over the shaker sieves, 14, for filtration, so that the resulting product is actually fine coal and slurry intimately mixed. The dirt from the first washer box is collected by two dirt elevators, which deliver into the dirt bunkers, 24, situated to one side of the washery. The dirt bunkers are provided with side shoots delivering into tubs which are run on to the pit dirt tramway.

This type of washery is of very substantial and economical construction, and from figures supplied to the author has a decided advantage in initial cost and upkeep when compared with the majority of present-day systems.

In Fig. 147 is shewn a general arrangement of the Brauns box as designed by the author for dealing with a difficult cobble coal known as Lancashire " Ravine " of 4-inch cube. The various lengths of stroke are effected by an adjustable eccentric and the number of strokes by a stepped pulley. The box is utilised for the separation of middlings, of which there is about 30% in the original raw coal, and it is dealing very effectively with this coal, and only requires 7 H.P. to drive it on full load. The capacity is 15 tons per hour. The box was particularly designed for erection in the screens building to do away with a hand picking plate belt.

Humboldt System.—This system of washing is one of the Basher systems which has survived the test of economical production.

It is mainly to be noted from the elaboration of the design of the buildings

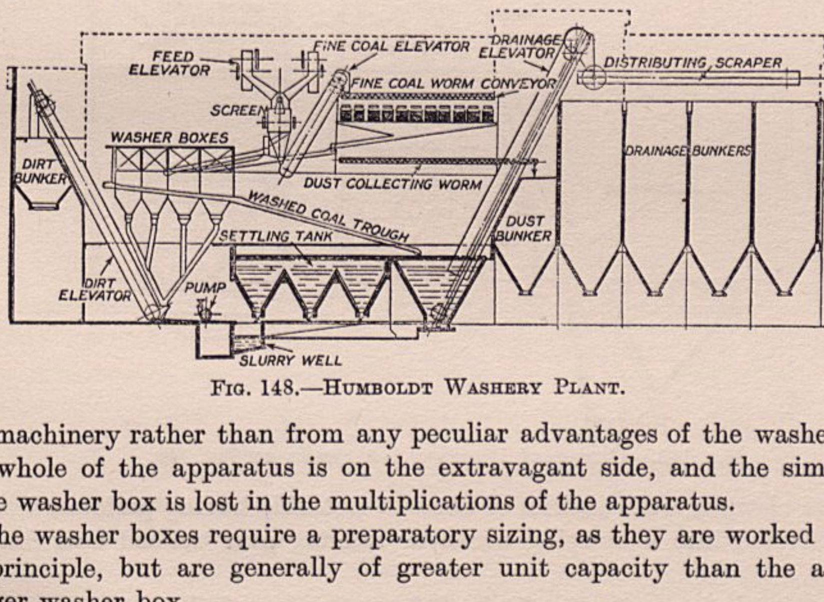


FIG. 148.—HUMBOLDT WASHERY PLANT.

and machinery rather than from any peculiar advantages of the washer box. The whole of the apparatus is on the extravagant side, and the simplicity of the washer box is lost in the multiplications of the apparatus.

The washer boxes require a preparatory sizing, as they are worked on the old principle, but are generally of greater unit capacity than the average plunger washer box.

In Figs. 148 and 149 are shewn the general arrangement of a large existing plant dealing with 120 tons per hour. The raw coal is delivered into the building upon a large shaking screen, where it is separated into two sizes. The fine coal below $\frac{3}{8}$ inch is extracted and fed into the boot of an elevator which discharges into a worm conveyor feeding the battery of dust screens. Here the dust is extracted and delivered into a large dust bunker by a long worm conveyor, while the fine coal which passes the dust screens as an oversize is flushed into the fine coal washer boxes.

These washer boxes discharge the dirt on the submerged principle, that is, the dirt is collected by long tubes fitted on the base of the inverted pyramid washer box and delivered into the boot of an elevator which is of the perforated bucket type for the draining of the dirt before discharging it into the dirt bunker. This method of dirt collection and disposal is not only extremely costly in the apparatus, but also entails considerable expense in the construction of a suitable building, as the space occupied by these dirt tubes and elevator is rendered useless for other purposes.

The washed coal is then flushed into a large hopper in the base of the building, the flushing water overflowing the top edge into a pyramidal settling tank. The coal is then dredged from the base of the hopper by a large

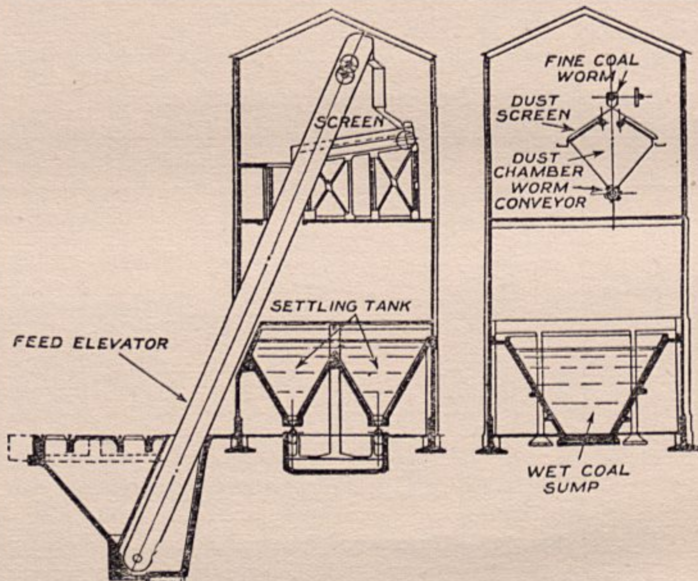


Fig. 149.—Humboldt Washery. Sections of Fig. 148.

drainage elevator, with buckets of about 6 feet wide having perforated plates, and delivered into a scraping conveyor running over washed coal drainage bunkers.

The circulating water is obtained from the top of the settling tank and pumped up direct into the washer boxes.

The concentrated slime over the mouthpieces of the settling tank is run out into a collecting channel which delivers it into a sludge well, from which it is pumped up by a centrifugal pump on to slurry sieves, delivering into the drainage elevator at about 12 feet above the level of the washed coal well. This slurry sieve consists of an inclined fine mesh brass wedge wire fixed sieve delivering on to a similarly inclined wedge wire hammer type sieve. The operation of this latter is similar to that of the Humboldt dust screen

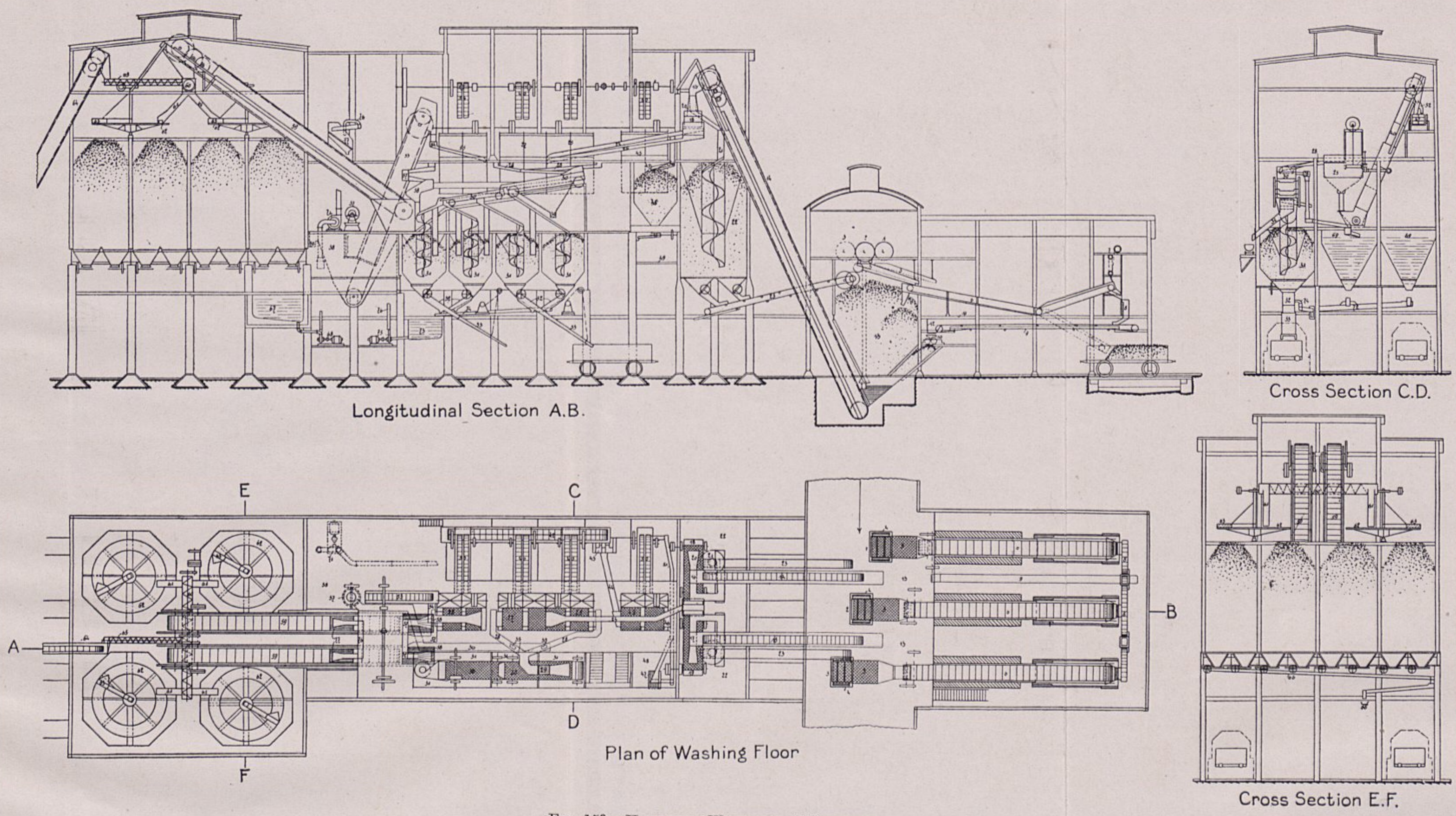


Fig. 150.—Humboldt Washery. 150 tons per hour

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and is actuated by a multiple toothed cam delivering blows on the under side of the sieve frame. This plant is entirely for the production of washed coal for coking purposes, and therefore there is no second classification for sales. The moisture content of the coal as delivered by the elevator is very large and has proved a serious disadvantage in this particular plant.

Sufficient attention or care has not been paid to the design of the slurry recovery apparatus, and the large amount of moisture contained in the elevator delivery is mainly due to this fact.

It is a simple matter to drain nut coal, but where fine coal is added thereto it is only reasonable to reduce the moisture content of this latter to a minimum before mixing. This can only be done by mechanical means, and, as the use of machinery on this system is very generous, the same principle should have been applied to the slurry sieve.

A comparison of the areas of the dust screen and the slurry plant is remarkable, insomuch as the former is about ten times the area of the latter, although the quantity of slurry will not differ in the same proportion.

The building itself is of large dimensions and provides easy access throughout, but for the amount of work done by the plant seems to be on the large side, as there is a good deal of waste space. That above the settling tank is entirely vacant.

The quality of washing on the Humboldt principle compares very favourably with any other system and is particularly good where dealing with fine coal.

In Fig. 150 is shewn a very interesting arrangement on the Humboldt system of screening and washing coal. Both buildings are over the same sidings, which in this case is not of great moment, since the greater part of the coal is utilised in coking and only a small part is dispatched for sales.

In the screens building, the loading jibs are arranged to load into wagons or be tilted up to shoot into the cross conveyor, 8, and thence by the conveyor, 9, to the feed hopper, 13.

The greater part of the smalls are taken out by the jigging screens, 3, and delivered direct into the feed hoppers.

The two feed elevators, 12 and 15, dredge up the coal and deliver it on the screens, 18 and 19, respectively. In the event of a stoppage in the washery, a by-pass chute, 21, receives the coal from the elevator and drops it into the spiral shoot in the bunker, 22. This arrangement is to avoid the stoppage of the screens and the haulage at the pit. From this bunker the coal is fed back to the hopper by the band conveyors, 23.

The screens, 18 and 19, make two sizes, 0 to $\frac{3}{4}$ inch and $\frac{3}{4}$ inch to 3 inches, the latter being conveyed in the flushing launder, 24, to the washer box, 25, and the former by the flushing trough, 26, to the washer box 27. After washing, the coal from both boxes is led by the troughs, 28, to the classifying screens, 30, a portion of the water being taken out by the drain box, 29. In the bottom of the trough, 28, there is a by-pass flap for extracting the washed coal and leading it by the trough, 36, to the breaker, 37, which is of the bell or coffee-grinder type. The large coal passing through the breaker is broken up into the required size and dropped direct into the smudge sump, 38.

On the classifying screens, 30, five sizes are extracted; the fine coal of $\frac{3}{8}$ inch and under is taken out with a quantity of water and led to the sump, 38, the larger sizes being fed into the respective bunkers, 31, to which drainage grids, 32, and loading chutes, 34, are fitted, the drainage water from these being led by the trough, 74, to the sump, 73.

From the sump, 73, the fine coal is elevated to the rewasher box, 55, by the smudge elevator, 53. After washing, the fine coal is led by the troughs, 57, over the drainage grids or boxes, 58, for preliminary dewatering and thence on to the draining conveyors, 59, and delivered into the distributing worm conveyor, 60, which feeds on to the revolving tables, 62. Each of the revolving tables feeds four bunkers and by regulation of the plough, 63, any of these may be filled. The dirt from the washer boxes is collected in the elevators, 40 and 56, and carried by the scraper conveyor, 42, into the middles breaker, 45. This is of the double roller type and not like the breaker, 37, as the duties of the two are different. The former is to separate the intergrown dirt from the coal, while the function of the latter is to grind up the coal into small particles. After breaking, the coal from 45 is led into the rewasher box, 45, and subjected to the washing process. The washed product is then led by the trough, 46, into the bunker, 48, from which it is drawn for use in the colliery boilers, and the dirt from the elevator, 50, is led into the dirt bunker for disposal on refuse heap.

The Meguin System.—One of the proved types of washer box is that known as the Meguin. Formerly it was little different from the ordinary basher box as shewn in Fig. 151, but latterly the design has been altered to that shewn in Fig. 152. The revised type has the plunger placed below the coal bed and entirely submerged. The coal is fed in at one end on to the first bed, and here the heavy shale is extracted through the sluice gate immediately under the inlet and slides down a side shoot into the boot of the dirt elevator. After this partial washing, the coal is flushed by the pulsations over a weir separating the second from the first bed. In the second compartment, the middles dirt is extracted and led into the side shoot and into the boot of the middles elevator, which is placed in the same casing as the dirt elevator. The plunger, which is operated by eccentric strap and sheave, is made slightly spherical to take the tilt due to the throw and causes in its stroke a suction effect on one bed and a pulsating effect on the other at the same time, the inlet of the water reducing the effect of the suction. In the Meguin plants, the method can be summarised as follows : All dust below 3 mm. is taken out of the raw coal and the remainder is then divided into two sizes, viz., 3 to 12 mm. and 12 mm. to maximum, generally about 80 mm. The two larger sizes are washed in separate boxes as in the Humboldt plants. In Fig. 153 is shewn a typical Meguin plant of 180 tons per hour combined with screening plant.

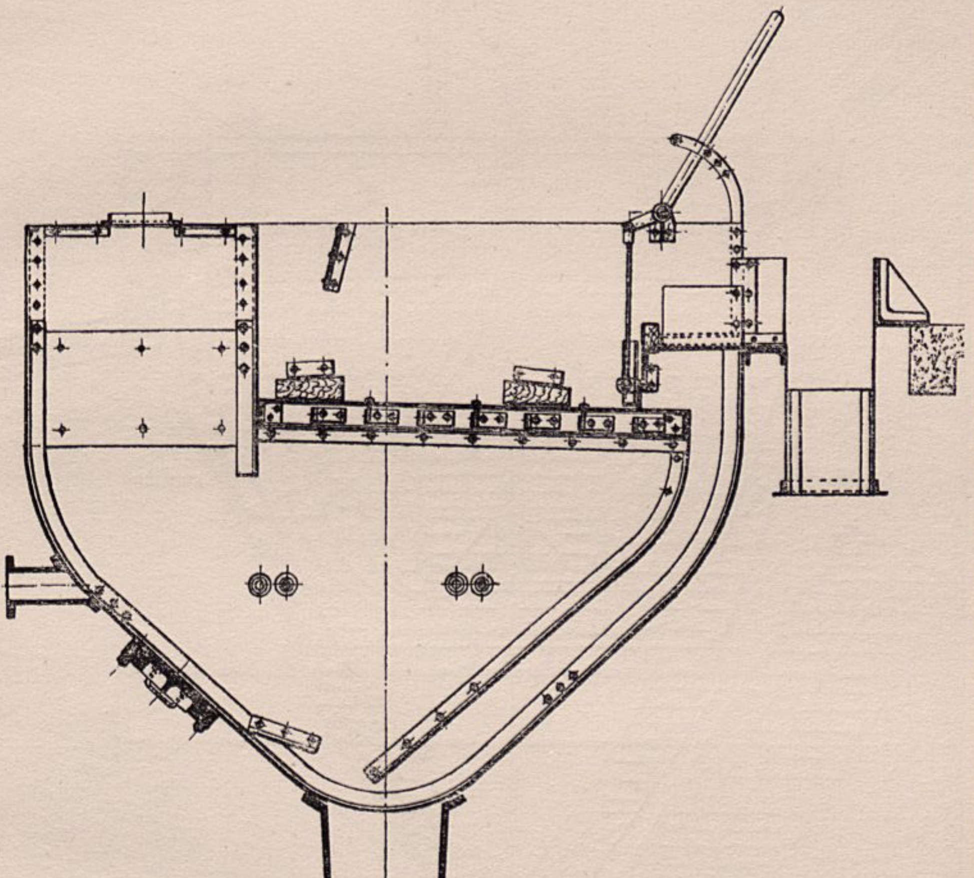

FIG. 151.—ORIGINAL "MEGUIN" WASHER BOX.

The feeding arrangement is similar to that of the Humboldt with the exception that a dust plant is inserted to extract all below 5 mm. The through size on the revolving screen, 26, is passed over the dust grid, 42, and subjected to jets of air from the blowers, 43, drawing off the dust which is settled in the cyclones, 44 and 22, and thence into bunkers. There are two sizes made in the screen, 26, the larger being led to the washer-box, 34, and the smaller

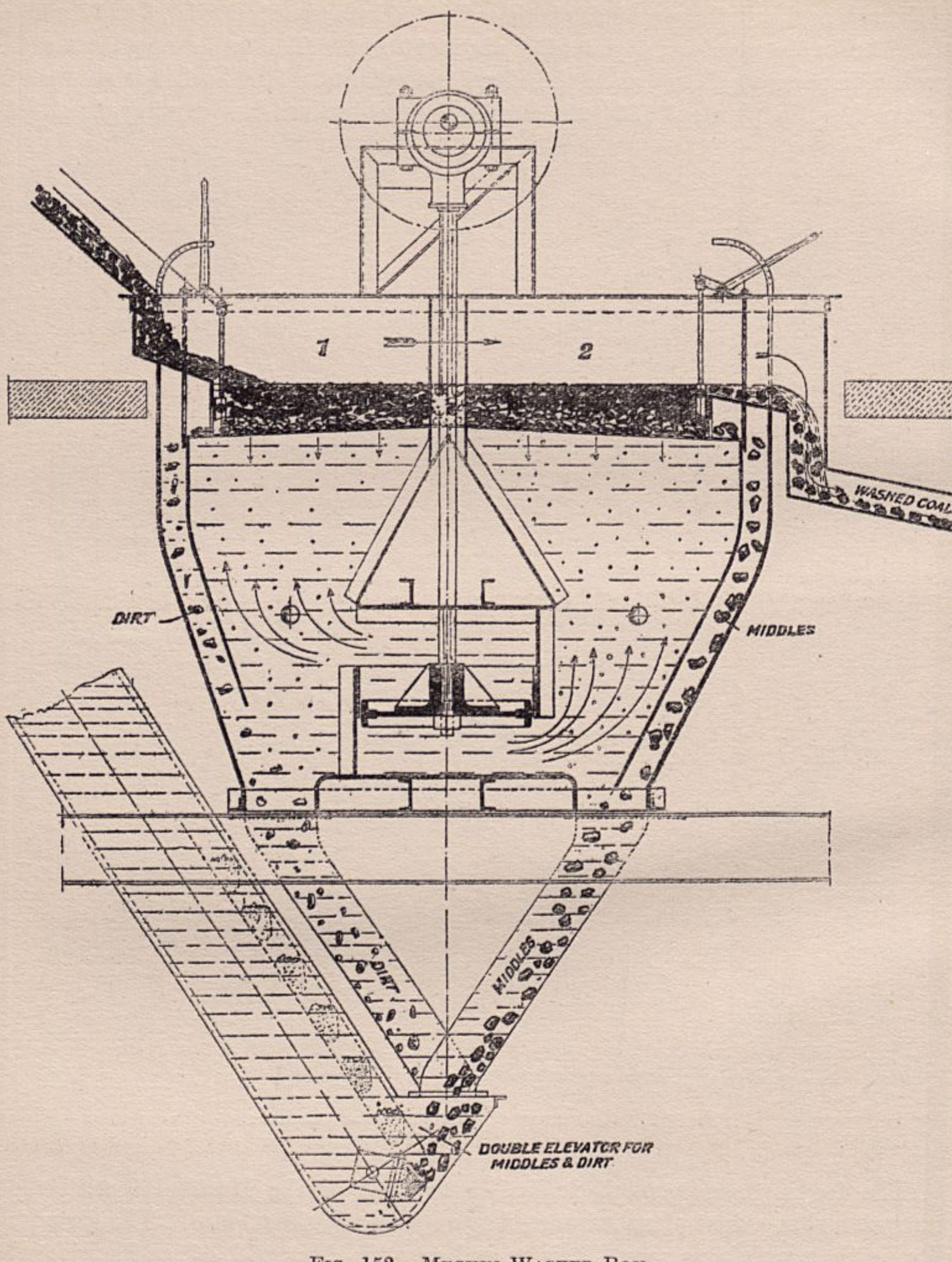

FIG. 152.—MEGUIN WASHER BOX.

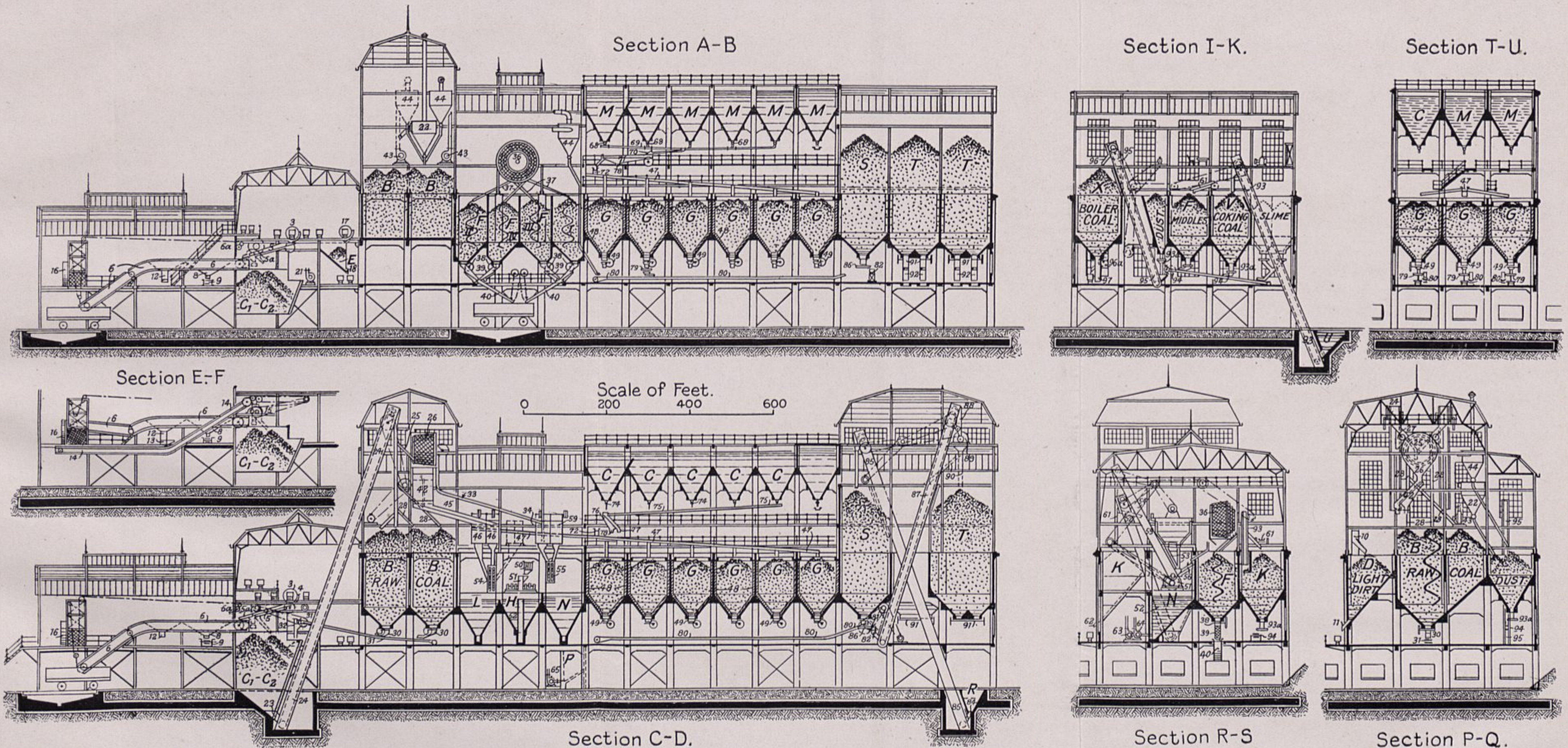

Fig. 153.—Meguin Washing Plant. 180 tons per hour.

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to the fine coal washer boxes, 46. The product from the former is flushed to the classifying revolving screen, 36, and made into four sizes which are delivered into the bunkers, F. The washed fine coal from 46 is led by the troughs, 47, to the draining bunkers, G, from where the water is drained into the sump, L. In these bunkers special arrangements are made for the rapid draining of the coal. In each chamber there is a series of four draining boxes, 48, placed on the sides and communicating with the collector at 49. The dirt from both washer-boxes is discharged into a bunker direct, but the middles dirt is collected on a scraper and after passing through a breaker is delivered into the rewasher box, 59.

The through size on the screen, 36, is collected in the sump, H, and elevated by 52 into the box, 46. Arrangements are made for the extraction of all or any sizes from the screen, 36, for reduction by the crusher, 51, to fine coal size. After breaking it is fed into the sump, H, and re-elevated to the box, 46. There are three settling tanks in the roof of the building, one for the circulating water for the main washer boxes, one for the circulating water for the rewasher box, and one for the spraying of the washed coal and the make-up. The slurry is recovered by draining from the settling tanks over the sieve, 71, and then mixing it with the fine coal in the troughs, 47. The sump, N, is for the collection of the water coming from the rewasher box.

Provision is also made to feed the unwashed dust on to the conveyor, 80, carrying the washed coal to the elevator, 82, and thence via the crusher, 89, into the storage bunkers, T.

Feed tables, 79, are used to deliver the coal from the drainage bunkers to the conveyor, 80.

The Robinson Washer.—A type of washer which has been subjected to a great deal of criticism in this country has, strangely enough, been much exploited in the States of recent years, while at the same time British plants on this system have either been remodelled or entirely replaced by those of other systems. Some tests carried out by Dr. Drakely on the Robinson washer were not flattering or such as would influence colliery engineers to adopt them or bear long with their faults.

In Fig. 154 is shewn this type of washer. It is essentially an upward current classifier and for this reason is well worth description. It is a conical-shaped vessel or tank of about 20 feet diameter at the top edge. At the apex of the cone the dirt outlet is sealed by a double interlocking valve. When the upper valve is shut, the bottom one may be opened, and similarly when the bottom is shut the top may be opened, a special gearing being fitted to avoid the opening of the one before the shutting of the other. The reason for this is to trap the dirt in the space between the two valves and then discharge it into tubs or a bunker without disturbing the contents of the washer. The water inlet, which is the true washing medium, is just above the dirt outlet, and a large supply of water is pumped into the vessel, so as to provide the necessary velocity to suspend the coal while allowing the dirt to fall. To preserve a loose bed and avoid any consolidating of the material in the chamber, a series of vertical arms suspended from a cross piece mounted on a vertical shaft in the centre line of the chamber is caused to rotate. The raw coal is fed by a shoot into the upper surface of the tank and being caught by the current of water flowing towards the outlet or overflow, is classified according to the laws of equal settling.

In Fig. 155 is shewn a diagrammatic arrangement of this washer. A feed elevator discharges directly into the surface of the chamber, and the washed coal overflows on to a fixed sieve and is then discharged on to an inclined draining conveyor, which elevates it to the screens in the higher part

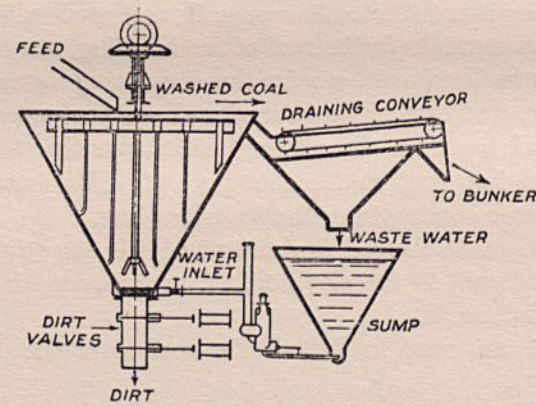

FIG. 154.—DIAGRAMMATIC ARRANGEMENT OF ROBINSON WASHING PLANT.

of the building, discharging the undersize into the hopper feeding the fine-coal elevator, whereas the oversize is led by a shoot into the crusher placed immediately above the elevator boot.

This scraper conveyor, which serves as the dewatering medium, consists merely of flat scraper plates, pushing the coal up the inclined deck, the drainage of the coal finding its way down the incline of the neck, so that the whole of the drainage which takes place in the first loaded compartment has to pass in succession through all the others following it up the incline. This means that the length of time taken to obtain the drainage of the first compartment just before delivery on to the screen has been wasted, as the compartment immediately behind has been absorbing it.

The author can see no possible excuse for this type of draining conveyor, as the period of drainage allowed in passing from one sprocket to the other is almost completely nullified by the draining back of water from compartment to compartment.

The drainage water is run from the conveyor boot into a small settling chamber of about the same size as the washer.

The Chance Washing Plant.—The difficulties of dealing with anthracite coal have given rise to a novel method of separation, the principle employed being that of the mechanical production of a dense medium by a mixture of very fine sea-sand and water.

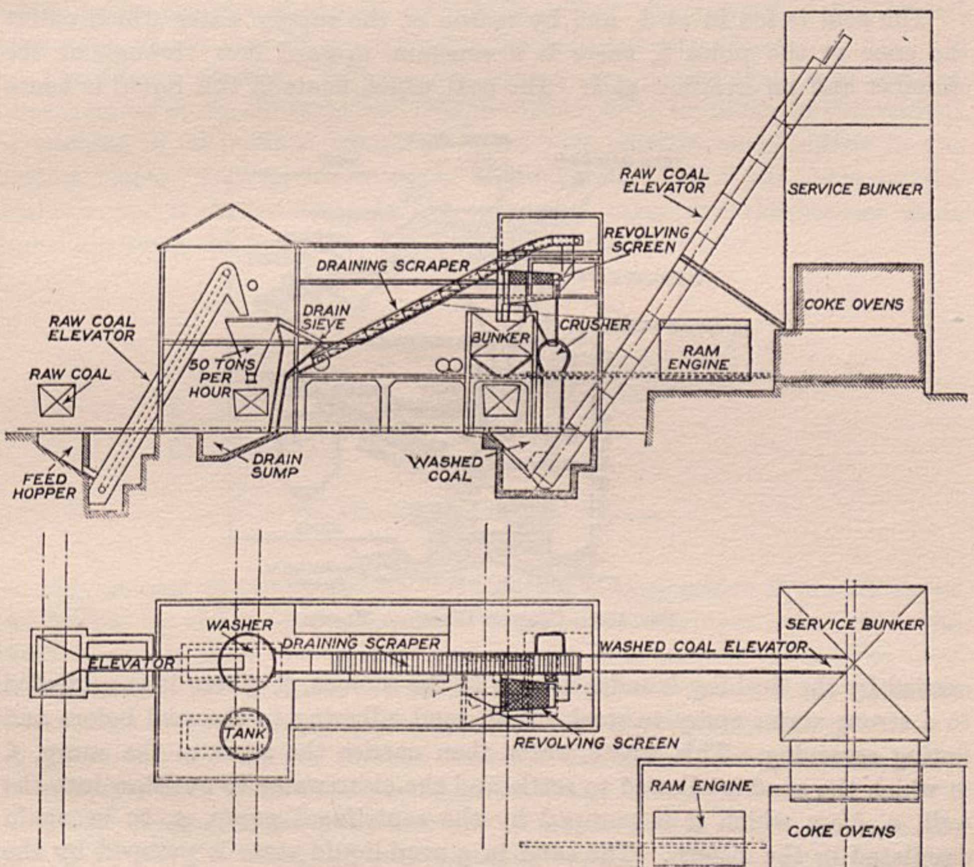

FIG. 155.—ARRANGEMENT OF A ROBINSON COAL WASHERY.

In Fig. 156 is shewn a diagrammatic lay-out of the plant: *a* is a conical tank containing the mixture of sand and water. A paddled agitator revolving at about 14 r.p.m. keeps the mass in a liquid condition, the sand being fed in from the top of the cone and the water in at the bottom. A neck on the bottom mouthpiece swells out into a larger chamber having dirt slide valves at each end, similar to those of a Robinson washer, the central chamber being used to collect a large quantity of dirt before discharge. The cone, which is about 15 feet diameter, is designed to deal with anthracite maximum of 2 inches. The specific gravity of the mixture is maintained greater than that of the coal. The precautions taken to ensure a more or less constant specific gravity consist of placing floating balls in the mixture of a density greater than that of the coal, and the workman is obliged to exercise sufficient attention, so that these balls are not allowed to disappear from view, any tendency to sink being counterbalanced by adding more sand.

The coal is fed in at *h*, and by reason of the supply water which enters the cone at the point *b*, there is a constant upward flow throughout the chamber and an overflow at *k*. The coal which floats in this liquid is hence

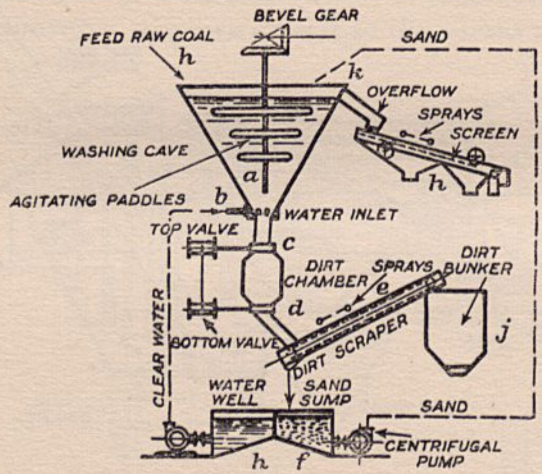

FIG. 156.—CHANCE WASHING PLANT.

carried by the flushing launder from *k* to the screens, *h*, where it is subjected to a strong water spray to wash off all sand adhering to the coal before and during screening. This waste water then carries the sand to the sump, *f*, in which the sand is allowed to settle and the clear water to overflow into the well, *n*, from which it is pumped by the centrifugal pump, *p*, to be again circulated in the cistern. The sand in a semi-liquid state is pumped by the pump, *g*, from the sump, *f*, to the top of the cone. All refuse heavier than the liquid density sinking to the throat of the cone is subjected to the current of inflowing clear water and is thus more or less cleansed of sand before passing the valve, *c*, into the dirt chamber. Before opening the valve, *d*, to empty the latter, the valve, *c*, is closed, and on the actual plants precaution is taken to make them interlocking, so that one cannot be opened before the other is shut, otherwise the cone would be emptied of its contents did the attendant forget to take this precaution.

The refuse is dumped upon an inclined conveyor, where it is subjected to spraying to extract all sand, and conveyed to the sump, *f*, before discharging the dirt into the hopper, *j*. This single cone has a capacity of 100 tons per hour.

This new plant opens up quite a new feature of coal washing, and it is possible that it is the beginning of a new departure of coal washing methods. At the present it would be premature to forecast the uses to which this principle of manufacturing a dense flotation medium may be carried. The drawback seems to be the rule-of-thumb manner in which the density is maintained constant and the lack of provision for the accumulating slurry.

The Trough Washer.—This type of washer may be described as a modern improvement of the old-fashioned trough washer, or an auxiliary to the method of washing in an inclined trough provided with suitable shale outlets in the bottom plates. In Fig. 157, A is the original trough and C the shale outlets. The raw coal is carried along by the current of water and the heavier shale travelling along the bottom is trapped in the outlet C.

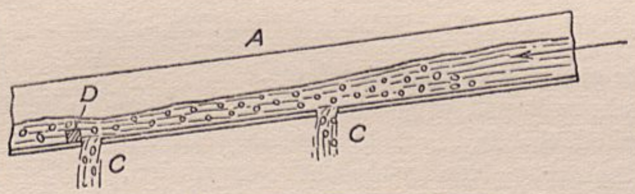

FIG. 157.—SIMPLE TROUGH WASHER.

This process was improved by the addition of obstruction D placed across the further lip of the openings. The effect of these barrages is to deflect the shale on the bottom out of the main current and prevent it jumping over the openings. The difficulty, however, arose from the fact that the deflected current also carried through a proportion of fine coal with the shale.

In an inclined trough, through which a current of water is passed, the forces acting on a solid body placed in the water would be :—

1. The weight of the body less the weight of water which it displaces; that is, $V\delta$ less the weight of water of equal volume. $V(\delta - 1)w$, where $V =$ volume and $\delta =$ density of particle, $w =$ specific weight.

The friction on the bottom of the trough, which is a function of the former, or $F = \mu D^3(\delta - 1)w$.

2. The impulse of the water current which depends on the surface area of the body and the square of the velocity of the current, or :

$$I = C_1 D^2 v^2.$$

3. The resolved gravity forces along the plane of the trough. This is so

small that we can leave it out of account, so that just at the moment before movement

$$I = F$$
$$C_1 D^2 v^2 = \mu D^3 (\delta - 1) w$$
$$v = \sqrt{\frac{\mu D^3 (\delta - 1) w}{C_1}} = \sqrt{\frac{D\mu}{C_1}(\delta - 1) w}$$

4. This may be written

$$v = C_2 \sqrt{D(\delta - 1)}$$

where
$$C_2 = \sqrt{\frac{\mu w}{C_1}}$$

so that the velocity of the current, in which particles of varying densities are held in equilibrium, is dependent upon the expression $D(\delta - 1)$.

This means that to give two particles of shale and coal placed in the flowing water an equal velocity, it would be necessary to select the former of a size $\left(\frac{\delta - 1}{\delta_1 - 1}\right)$ times the diameter of the coal particle, where δ and δ_1 are the densities of the coal and shale respectively.

From the above it will be seen that it is necessary to limit the range of sizes to be washed, that is, the maximum size should not exceed the minimum size by more than that given by the above expression.

A greater range of sizes would result in imperfect washing, as it would be impossible to avoid the smaller shale being carried along with the coal.

It is, therefore, necessary to classify the unwashed slack between suitable limits, or in " equal velocity " sizes, dependent on the maximum and minimum densities of the material.

It is further necessary to impart to each classification a velocity sufficient to support the lighter coal in the current while permitting the heavier shale to travel along the bottom of the trough, in such a manner that in passing the opening the flow is divided into two currents, one carrying the coal over, the other carrying the shale on the bottom through the apertures.

As a result of much experimental work on this type of trough, the tumbler washer was developed.

Fitted on the bottom of a trough is the chamber, B, as shewn on Fig. 158. This chamber is provided with deflecting or baffle plates, which guide the inlet water from the pipe, D, which is under pressure of about 12 feet head, into the base of the trough through two openings, one on each side of a triangular rocking member, C. This triangular body takes the place of the old barrage, and causes an added disturbance or perturbation of the water in the trough when tilted against the downward current. The slack being fed into the higher end of the trough, A, is carried along by the current, the heavier shale being trapped over the openings and sinking through the flushing water from the pipe, D, is caught in the revolving vanes, G, and evacuated over the drainage sieve, which traps the waste water before discharge of the dirt into the tubs. This apparatus, therefore, is but an auxiliary of the crude trough washer, and introduces a second current to augment the efficiency of the first. The most apparent difference between the two currents is that

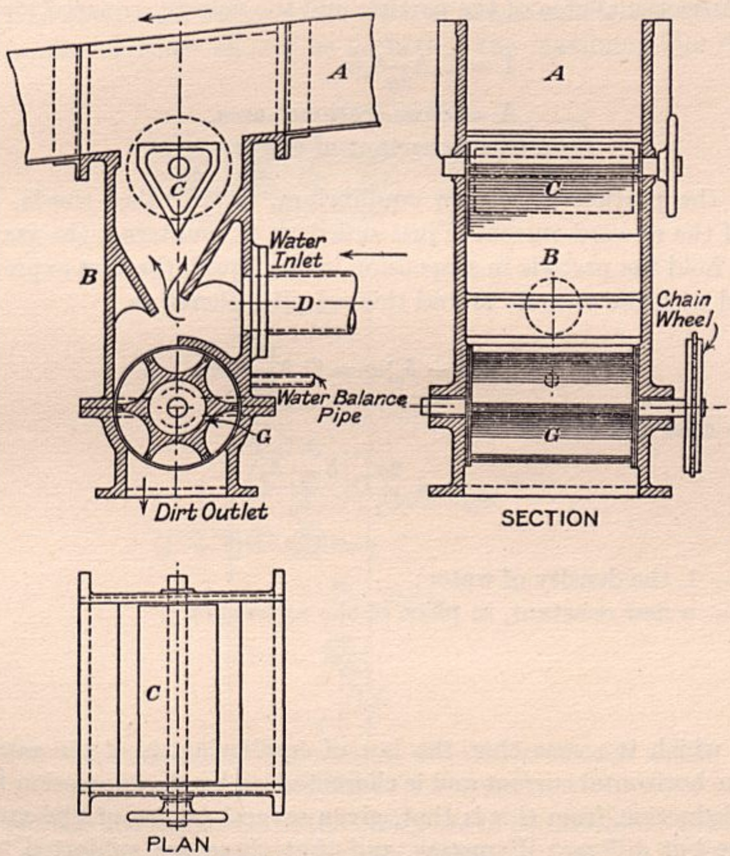

FIG. 158.—MINIKIN TROUGH WASHER.

of direction; in the one case, that already cited, there is a flow of water slightly inclined to the horizontal, which sorts out the equal velocity particles by friction on the bottom of the trough, whereas the washer further adds to the current another with an upward flow almost at right angles to the line of trough.

It will facilitate the argument to consider this second current as though isolated from the first. Let us conceive a particle, M, placed in a vertical current. The forces acting on the body will be (1) the weight of the particle less the weight of the displaced liquid, *i.e.*

$$V(\delta - \delta_0)w$$

where δ_0 = density of liquid — w = specific weight of liquid
V = volume of particles and δ = density.

Opposed to this is the upward impulse of the current, which is proportional to the cross-sectional area of the particle and the velocity squared, or

$$I = C_1 A \frac{v^2}{2g} \delta_0 w$$

where A = cross-sectional area.
C_1 = constant of shape.

When the particle is held in equilibrium, or, in other words, when the velocity of the upward current is just sufficient to counteract the gravitational forces and hold the particle in suspension in the liquid, the first expression may be equated with the second; to find this velocity, therefore,

$$V(\delta - \delta_0)w = C_1 A \frac{v^2}{2g} \delta_0 w$$

In the case of a sphere

$$v^2 = \frac{2g}{C_1} D\left(\frac{\delta - \delta_0}{\delta_0}\right)$$

$$v = C_2\sqrt{D(\delta - 1)}$$

where $d_0 = 1$, the density of water;
where C_2 = a new constant, in place of the expression :

$$\sqrt{\frac{2g}{C_1}}$$

From which it seems that the law of equilibrium is of the same form as that in the horizontal current and is characterised by the expression $D(\delta - 1)$.

The deduction from this is that, given several bodies of the same density and shape but different diameters, and that these are subjected to a rising current sufficiently strong to maintain the largest in equilibrium, then the relative velocities will vary directly as the square root of the diameter and the respective positions of the bodies at any instant of time will be as that shewn in Fig. 159 for each density.

The smallest body will be in advance of the next larger, and all will at every moment be increasing the distance separating them from the largest, which is just held in the current.

If now the bodies be considered of varying density and the same diameter, and the velocity of the current is only sufficient to maintain the lightest in equilibrium, then, as the velocity is directly proportionate to the square root of the density minus 1, the heaviest body, not having a current strong enough to support it, will sink in the liquid with a velocity greater than the next lighter, and so on.

From the above it is evident that, given a mechanically mixed lot of bodies, with sharply-defined densities and of slightly varying volumes, the separation of the light from the heavy would be a comparatively simple process.

When, however, the variation of sizes is considerable, the velocity of the upward current classifier should be such that the maximum size of the light

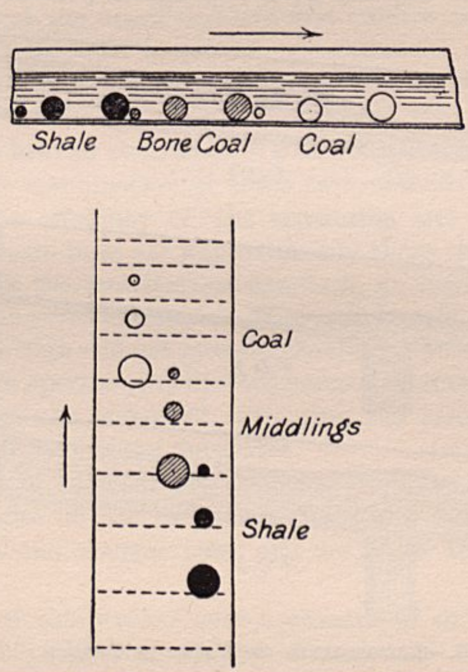

FIG. 159.—ARRANGEMENT OF PARTICLES IN HORIZONTAL CURRENT AND IN RISING CURRENT.

material and the minimum size of the heavy are in equilibrium; in other words, the range of sizes is fixed by the "equal velocity" law. It is, therefore, incumbent to first size the slack within certain limits before admission to the apparatus; the closer this sizing is, the more efficient classification results. The essential of success in the operations of the upward current is the care with which this sizing is carried out. Where bodies of equal volume are dealt with, the separation is perfect, as then the density only is the determining factor.

These considerations are confined to a short interval of time, that is, at the instant when the particles or bodies are subjected to the current.

The above-mentioned apparatus embodies, therefore, a twofold means of separation, the horizontal and the vertical current, and in this combination of functions a useful secondary advantage is attained. In Fig. 160 is shewn the exaggerated stream-lines of the water current as :

(*a*) The inclined trough with aperture.
(*b*) The vertical classifier.
(*c*) The combined effect of (*a*) and (*b*).

The flow of water upstream of the aperture (*a*), when divided into the two currents, necessarily loses in depth, so that the stream-lines tend to become more inclined to the horizontal over the shale outlet.

This fact tends to trap the good and lighter particles in the descending

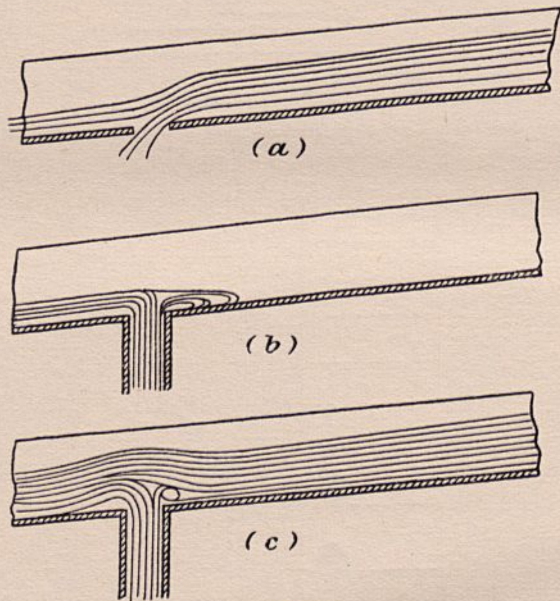

FIG. 160.—STREAM-LINES OF WATER IN TROUGH.

stream-lines, which is the primary cause of the inefficient separation by this device. The classification already effected in the higher run of the trough by the impressed velocity of the current is destroyed by the rapid loss of head immediately over the aperture, and this slackening off allows a portion of the transported particles to change their original disposition in that stratum of the current regulated to their "equivalence," so that actually a rapid change and reshuffling take place at a critical time.

The upward current stream-lines as illustrated in (*b*) show a rapid fall off in the velocity of the current immediately on admission to the base of the trough. The lines curve equally outward from about the centre and spread over the floor on the upward side before being overcome by the forces of gravity due to the incline. They are then stationary on the upside, and the influx of more water causes the downward or emptying current to take effect in the direction of the arrow. The effect of this top-side flow-back is to introduce a neutral zone, due to the rapid and complete change of direction. The velocity requisite to the classification is destroyed immediately on leaving the vertical chute, so that above the outlet of the latter the entering water merely acts as a flushing or transporting medium for the particles which have been sorted out by the current. The stream-lines are, therefore, bent sharply towards the discharge outlet of the trough, the head of water at the aperture providing the flushing velocity. From this we may say that particles dropped into this apparatus at the upper end will first enter a neutral zone, in which the velocity will not be equal to provide separation for the heavier particles, and passing through this zone the upward impulse of the classifying current will maintain the light particles in the neutral zone until they are carried off to the discharge, while the heavier particles will sink down through the current.

The effect of the combination of these two methods results in a marked improvement of the efficiency of the separation and the stability of the apparatus. The stream-lines are approximately those shewn in (*c*), Fig. 160. Here the junction of the two streams results in an increase of level directly above the inlet of the vertical trough. The particles which are borne along by the current from the high end are already classified, and on the meeting of the two streams over the aperture the upward current maintains this classification and further provides the means of extracting the heavy particles without destroying the equilibrium of the apparatus.

The vertical stream-lines are now deflected from the upstream lip, due to the downward impulse of the inclined current, and bunched up above the inlet. They lessen the neutral zone and maintain the full effect of the separating velocity.

The advantage of this washer over apparatus of similar type lies in the adaptability to widely different classes of coal, and to the fact that the degree of perturbation of the junction of the two currents can be regulated without interfering with the velocities of the currents. This is brought about by the rocking member of triangular section (see Fig. 156), placed almost midway between the main chamber sides, so that there are two rectangular openings which allow the passage of the vertical current into the trough.

As shewn in Fig. 161, the central position shows the rocker with upper face horizontal, and in this position the more clearly defined specific gravity slacks can be dealt with. In proportion to the range of specific gravity of the refuse to be extracted, the rocker is inclined towards or against the current, with an effect similar to the old-fashioned barrage already mentioned in connection with the simple trough. The second opening is also effective in trapping any shale not caught by the first, and by suitable adjustment this may be of a lighter density than that trapped by the latter.

The same apparatus has a novel method of evacuation, and is constructed on the simple lines.

The vane chamber is in communication with the standpipe, and the empty returning vane boxes are filled with water before entering the base of the refuse compartment.

By this means there is no secondary current set up by the evacuation of the shale and no loss of water, all currents being positive and usefully employed.

The apparatus is capable of dealing with large and small slack with equal efficiency.

In this trough washer the material moving along the bed is subjected to a varying velocity, due to its respective position in the different velocities of the stream-lines. Owing to the skin friction with the sides of the trough, the

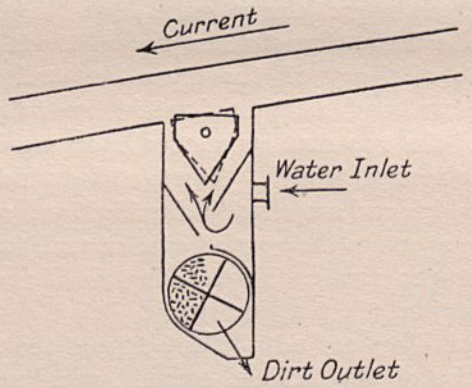

FIG. 161.—MINIKIN WASHER ROCKER.

heavier shale lying on the bed will move along at a much slower rate and will tend to accumulate in a layer upon the bed. This causes the lighter particles to enter into the more swiftly flowing current in the centre of the wetted section, so that this bottom layer will be gradually pushed along towards the slit in the washer, and be there trapped. If the apparatus be suddenly stopped, this accumulation of shale on the bed of the trough can be readily seen, and for an efficient working it is advisable to maintain the shale bed by a suitable regulation of the current to a depth of about 2 inches when treating coal of 1 inch and over, and a depth of about 1 inch when dealing with the smaller sizes.

In Fig. 162 is shewn a diagram of a general arrangement on this trough-washer system.

The feed elevator delivers into a preparatory sizing screen, taking out three sizes, 3 to $1\frac{1}{2}$ inches, $1\frac{1}{2}$ inches to $\frac{3}{8}$ inch, and below $\frac{3}{8}$ inch.

This small size is passed from the base of the casing over a roller feeder, which acts as the inlet regulator of a dust-extraction system. The blower providing the air impinges upon the coal in the fall from this feeder on to a lower star feeder.

During the passages the very fine is blown into the dust chamber, whereas the fine coal of $\frac{3}{8}$ inch to 2 millimetres is led by the flushing launder to the washer. Each size has its respective trough and washer, placed at suitable inclines to give the necessary velocity for the water separation. The two larger sizes are collected after washing upon a flat jigging screen, for separation into commercial qualities.

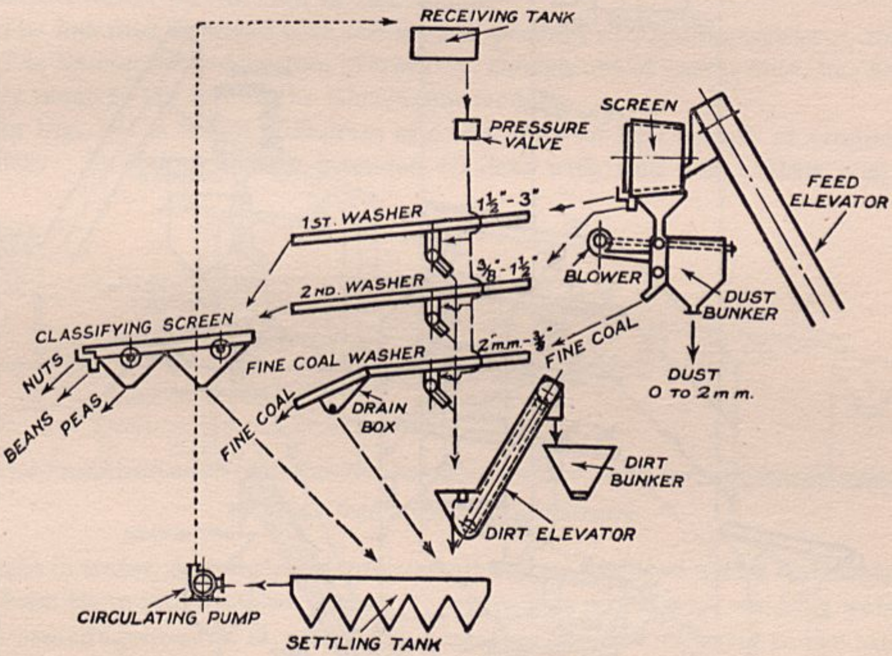

FIG. 162.—FLOW DIAGRAM, MINIKIN TROUGH WASHER.

The first portion of this flat screen is provided with wedge wire sieves for dewatering purposes.

The fine coal, on leaving the washer, is passed over a large drain box or shaker sieve for dewatering, and is dewatered from both machines, being collected in the V-shaped settling tank.

The dirt from the washers is collected by flushing troughs into the boot of a single elevator, from which the overflow water is led to the settling tank.

The circulating water in the system is provided by the centrifugal pump filling a large receiving tank in the roof of the building, and thence passing through a regulating pressure valve to the washers.

This apparatus can deal with 50 tons of coal per hour.

In Fig. 163 is shewn a diagram of a similar apparatus for dealing with 100 tons per hour of a difficult coal, containing a large amount of middles.

In this case five sizes are extracted on the preparatory revolving screen. The dust extraction dealing with the coal below $\frac{3}{16}$ inch takes out the dust of less than 2 millimetres.

The four larger sizes are carried to their respective washing troughs, in

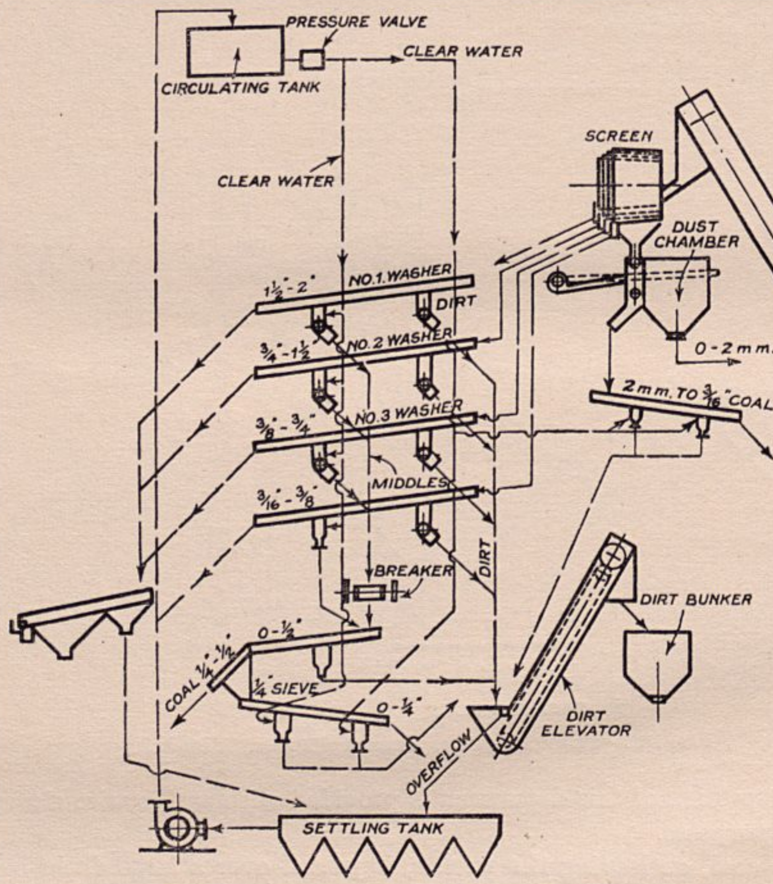

FIG. 163.—FLOW DIAGRAM, MINIKIN TROUGH WASHER.

which there are provided two washers, the first washer taking out the heavy dirt and the second dealing with the middles, the heavy dirt being conveyed by the trough into the boot of an elevator as in the former case, whereas the middles are collected from the three larger sizes and passed through a breaker, after the necessary dewatering, whence they are delivered, together with the coal of $\frac{3}{16}$ to $\frac{3}{8}$ inch, into the washing trough specially provided for dealing with this product.

At the discharge end of this trough the washed middles are passed over a draining sieve provided with $\frac{1}{4}$-inch mesh wire, which takes out the water and the smaller sizes for a second and more vigorous washing in the trough provided with two washers. This ensures a complete and excellent separation, the dirt from all machines being disposed of as formerly described.

A particular feature of this apparatus is the ease with which the operations are controlled, there being but one regulating pressure valve for the whole system, the individual adjustments being made by the inclination of the V-shaped rocker on the floor of the trough.

The fine dust is mixed with the washed product of 2 millimetres to $\frac{3}{16}$ inch.

The Rheolaveur.—A system of washing, though not of recent date, has been lately much to the fore in the Rheolaveur troughs.

In Fig. 164 is shewn a diagram of a test plant of this system at Ormonde Colliery. It was primarily intended to deal with duff coal. Raw coal is

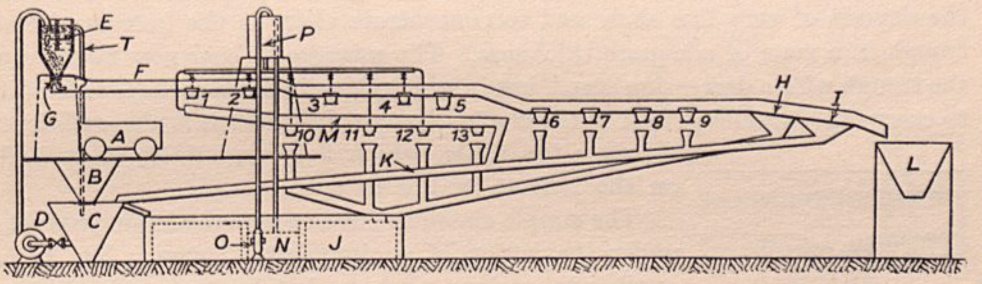

FIG. 164.—THE RHEOLAVEUR WASHERY.

brought in trams, A, and tipped into a small hopper, B, fitted with a distributor, and from there into a second hopper, C, where it is mixed with washing water.

A centrifugal pump, D, delivers this mixture of coal and water to the tank, E, which is divided into two compartments and fitted with an overflow, T, which maintains a constant head of water in the tank, E. This overflow falls into the hopper, C.

It is a well-known fact in washing that if dust be dropped into a liquid this dust collects into a series of masses in which the periphery only is wetted whilst the inside remains quite dry.

In this washer these masses are dissociated by the centrifugal pump, and the particles in suspension in the washing trough are absolutely free. If it happens that any small agglomeration occurs by their passage in the centrifugal pump, they are drawn through the overflow, T, and subjected to subsequent passages through the pump until they are finally dissociated. These masses, being extremely light owing to the fact that the interstices between associated particles are full of air, are easily drawn by the light upward currents produced by the overflow in the second compartment of the tank, E.

The mixture of water and raw coal is then fed into the washing trough, F, by means of the valve, G. The trough, F, is composed of three principal lengths, connected by the cascades, the inclination of each length diminishing progressively, the washing current having thereby a decreasing velocity, as shewn in Fig. 165.

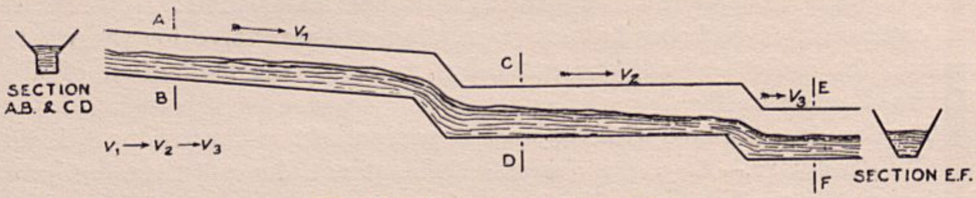

FIG. 165.—RHEOLAVEUR CASCADE.

The section of the two first lengths is identical. The section of the third length is trapezoidal. The sections have been specially designed to facilitate the deposit of very fine shale and to concentrate them in the bottom of the trough in a zone of adequate thickness. The mixture of coal now flows into the trough with a decreasing speed, but in which the minimum value is sufficient to carry the particles of coal to the end of the trough, whilst it is also sufficient to carry the shale, which is progressively deposited on the bottom of the trough.

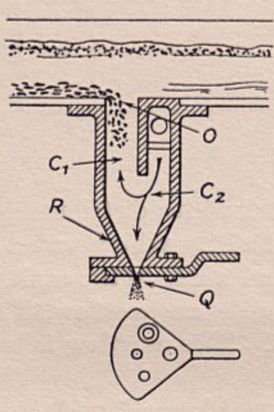

FIG. 166.—RHEOLAVEUR EVACUATOR.

The simple classification in a trough of raw product, under the action of an impulsive current, has been applied to various washers, but by these systems an efficient means to extricate the deposit of shale cannot be effected without producing perturbation or eddies in the washing current, which destroy in great part the advantages of this classification.

Suppose in the bottom of the trough there are placed openings spaced at certain intervals, the successive deposits of shale would be extracted, without any doubt, but they would produce at each opening descending currents which would also draw with them the product of the upper strata. To counteract this, a box, R, Fig. 166, is fitted to this opening, divided into two compartments, C_1 and C_2, and having an adjustable evacuation orifice, Q. The compartment C_1 forms a kind of flue adapted to the slot, O; compartment C_2 is connected by pipes fitted with a regulating cock to a feeding tank of constant head. The evacuation orifice, Q, is then regulated in such a manner that the section is of its minimum size, that is to say, allows of an evacuation of product without obstruction.

It is now easy to understand, by supplying to the apparatus an excess of the quantity of water evacuated by orifice, Q, that this excess would flow through compartment C_1 into the trough.

Suppose the slot to be conceived to extricate a certain volume of shale. If, during the extraction of this volume, V, of shale by the slot, water is supplied to it of equal or of slightly greater volume, no perturbation would be produced, that is to say, causing no suction of the upper washing strata. This realises the end in view, and more also, for the light ascending currents loosen the small carbonaceous particles from those of shale, to which they could adhere.

The trough, E, of the plant is then fitted with nine Rheo apparatus, two placed in the first length, three in the second, and four in the third. As has been said, these apparatus extract successively the deposit in ratio to its formation, and it is easy to understand that this deposit becomes less loaded with shale as it advances forward through the trough. The first apparatus, 1 and 2, the first group, evacuate almost pure shale. Apparatus 3, 4, and 5,

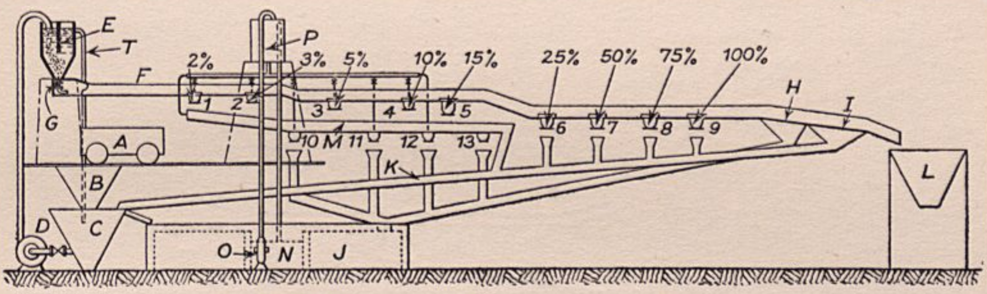

Fig. 167.—Rheolaveur Washing-trough Products.

the second group, extract lighter shale and a certain proportion of coal, and, lastly, apparatus 6, 7, 8, and 9, of the third group, evacuate a mixture of shale and coal, in which the proportion of coal is considerable.

In Fig. 167 is illustrated a diagram of the washing troughs, shewing for each apparatus the percentage in coal that the evacuated product could contain. The apparatus of groups 1 and 2 drop their product into a lower trough, where the shale evacuated by apparatus 1 to 5 is subjected to a further treatment by the same method.

The difficulty is to extract the last particles of shale without taking with them some grains of coal. To obviate this difficulty, the last Rheo, 13, of this trough is stirred up by means of upward currents such that only shale can fall through the slot, whilst it is admitted that particles of shale will pass forward with the coal.

Then the evacuated product of apparatus 6, 7, 8, and 9 of the upper trough is mixed with that which passes over the end of the lower trough, and together they run to hopper C to be rewashed.

The shale is alternately fed into two cisterns (one in operation, whilst the other is cleaned). The overflow runs into a cistern, N, whence a centrifugal pump feeds the constant head tank, P, to which is fitted the piping supplying the ascending current water to the apparatus.

The primary separation of the first series of machines, that is, in the upper trough, being imperfect on account of the thinning out of the bed of shale as the material is brought over the last Rheo, which evacuates 100% coal, to ensure the discharged product being pure, the necessity for rewashing the extracted dirt is obvious. The discharge through the dirt valve is, therefore, collected in a separate trough provided with machines through which a strong upward current is passed, as shewn in Fig. 168. The greater part of this material is shale, and hence a proportionately thick, heavy bed is to be dealt with, which greatly facilitates the separation of the small amount of contained coal to be recovered. The resulting product from the end of the trough is then returned to the wet-coal sump to be again re-elevated into the first series

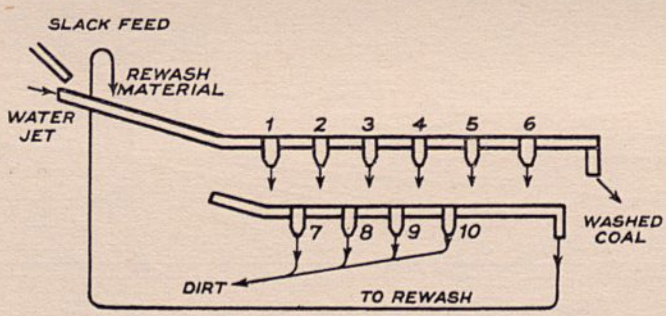

FIG. 168.—" RHEO " CLOSED CYCLE REWASHING.

of washer boxes. This has been termed by the manufacturers rewashing in a close cycle, meaning by that that the slack is passed and repassed throughout the whole process until the coal is satisfactorily washed. The shale from the second trough is conveyed to the dirt bunker for disposal on the refuse heap.

It may be generally stated that the upper trough is worked merely with the intention of extracting the whole of the shale, plus a certain proportion of coal, so that there is no risk taken with the ultimate washed product. It is claimed that this method results in a 1% free dirt washed coal. The water supplied through the Rheo is merely sufficient to replace that extracted through the evacuation orifice, whereas the machines of the lower trough have an upward current of water sufficient to maintain the classification already effected in the horizontal current, the final apparatus of this trough being supplied with a more powerful current to ensure the fall of only pure shale, on the presumption that the preceding apparatus have thinned out the shale bed to such an extent that the coal forms the greater part of the material approaching the slit. The discharge from the second trough, not having the required purity, is returned to a wet-coal sump and elevated into the upper trough together with the raw slack.

The number of Rheos to each trough varies with the capacity and quality of the coal, the three last machines of the primary trough being actually those to take up any variation in quality of the supply. With a very fine dirty coal, three tiers of troughs containing the Rheos are installed, operated on the same principle of successive partial separation and rewashing.

The machine used for the fine coal is narrowed in to a throat in inverted pyramid fashion, and this orifice is provided with a fan-shaped plate pierced with holes of different diameters, which are brought to coincide with the orifice to adjust the amount of the evacuation. These holes are counter-sunk from the top edge with the intention of obtaining a sharp-edged outlet and a compact jet.

In the washing of nut coal, the machine, while not greatly altered, has of necessity a different method of evacuating the dirt. The nut coal being much simpler to separate, the number of machines required upon the trough is seldom greater than two. To economise the amount of water passing the discharge outlet immediately below the first machine which extracts the heavier shale, a double-chamber dirt hopper is provided. In Fig. 169 is shewn an outline arrangement of the method employed. There are two tanks, A and B, of diamond-shaped section. They are initially filled with water by opening the valve C and the valve *d*, whilst the valve *e* remains closed. When full, the valve C is regulated to provide the required upward velocity for washing, and the valve *d* is then shut. The attendant has now to give his attention to the apparatus and to open the valve *d* as soon as the chamber A is completely full of shale, to allow the latter to escape into the lower chamber, B, displacing the contained water, which rises into the upper tank. When the tank B is filled, the valve *d* is then shut and the outlet valve, *e*, opened to discharge the shale into the bunker. When this latter chamber is emptied, the outlet valve is again closed and the cock, *f*, on the water-supply pipe from the main is opened to refill the chamber with water, so that the complete cycle may be again repeated. This method of dirt discharge is identical with that of the American type of Robinson washers, and is not in keeping with the efficiency of the mechanical devices of the present day. Too much depends upon the intelligence of the attendant, and there is no guarantee that the operation will be carried out regularly or efficiently. In the various plants seen by the author, this operation and attention to the one machine seemed to occupy the whole of the time of one attendant, and this factor seemed to point to the crudity of the device, as

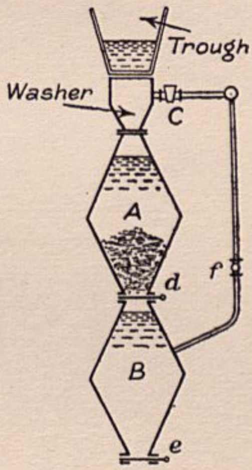

Fig. 169.—Dirt Chambers.

the mechanism provided did not appear to have that automatic action so requisite for economy. The washing machine (see Fig. 170) is provided with an adjustable slot, and a flap valve operated externally to reduce the width of the opening at uniform intervals tends to prevent the fall of stray particles of fine coal trapped in the bed of shale, the greater strength of the current through the slot consequent on the narrowed passage being sufficient to raise the fine coal back into the horizontal current. The second Rheo, as shewn in Fig. 171, having the function of extracting the middles or a mixed quality of coal, is generally worked without an upward current of water, the clack valve in this case being utilised as a false bottom in the slot which on opening allows this collected mixed material to fall into the boot of a perforated bucket elevator which re-elevates it back into the trough for a further washing.

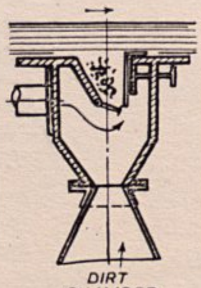

FIG. 170.—NUT COAL WASHER.

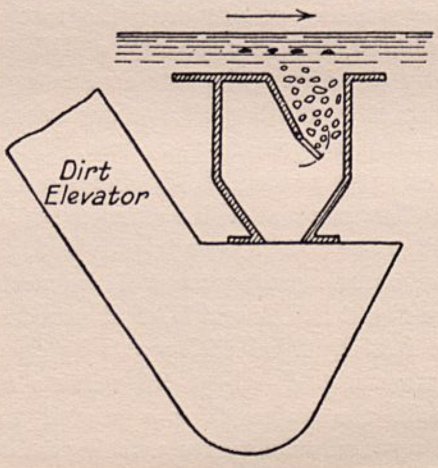

FIG. 171.—MIXED COAL EVACUATOR.

In place of the superimposed tanks in the first Rheo it would be preferable to fit an elevator similar to that invariably placed on the second machine. The coal discharged at the end of the trough is fed on to a belt screen for dewatering, which discharges the coal on to a small jigging screen for definite classification, as shewn in Fig. 172.

A point worthy of note in the later practice of the manufacturers of this machine is that they are now veering towards the more general British practice of washing before screening. The conversion of the inventor to this method is singular, insomuch that throughout his lengthy experience he has shown a decided preference for the reverse order.

The Rheolaveur and the later trough washers are the heralds of a complete change of method in coal-washing practice. They are designed to meet varying conditions of quality and supply, being extremely adaptable and more

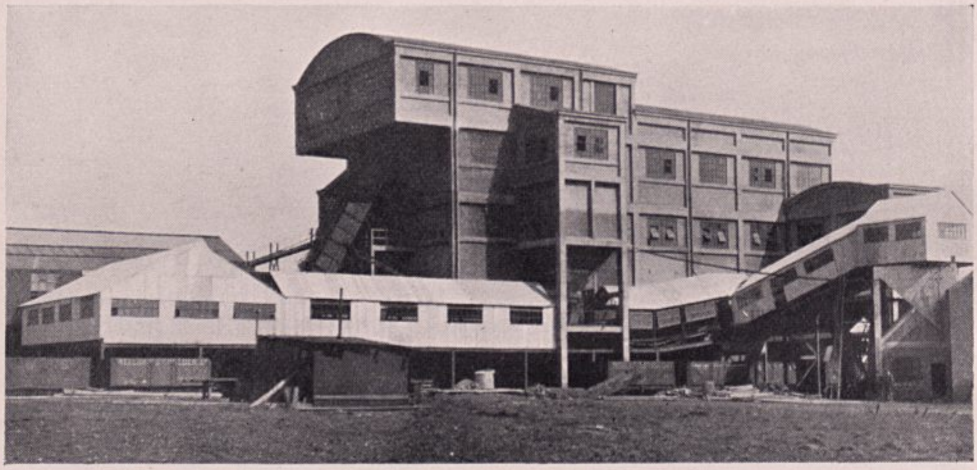

Fig. 173.—Rheolaveur Washery to Treat 135–150 Tons per Hour.

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fitted to deal with the smaller class of slack now being produced in large quantities. Many of the experiments on widely varying classes of coal carried out on the Rheolaveur plants have shewn that this system is pliable and efficient, and has many advantages over basher washing.

The Rheo requires close attention to each apparatus and a prolonged rewashing cycle to effect the separation. Having all the very fine coal mixed with the fines, the drainage of the washed product naturally suffers, the moisture content being relatively high.

A system of dust extraction to ensure the separation of the coal dust would prevent slurry troubles and assist drainage. In Fig. 173 is shewn a large washery dealing with 135 to 150 tons per hour from 0 to 2½ inches;—note the substantial character of the building.

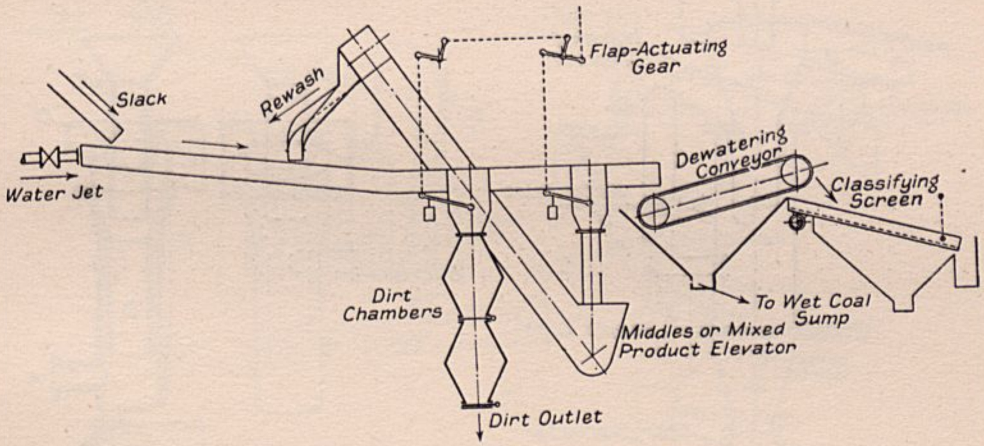

Fig. 172.—Rheolaveur Nut-washing Cycle.

The Draper Washer.—The Draper washer is similar to the Robinson washer, on a more modest scale. They are both upward current classifiers, but the latter has a less violent current than the Draper and does not possess the same advantages of concentration and uniformity.

In Figs. 174 and 175 are shewn in outline a machine of this type, and a detail of mouth. The slack is fed at *a*, into a conical mouthpiece, *b*, which drops the coal on to the strong upward current in the washing chamber, *c*. The conical shape of this washing chamber allows a certain amount of range of selection of the particles, the light coal being immediately washed over the peripheral weir into the surrounding trough, while the dirt drops through the current into the large cylindrical chamber, *c*, and thence into the evacuator valve, *h*, for discharge into the dirt hopper.

In the cylinder, *c*, is fitted a sample tube in a special recess to allow of a sample of the dirt being taken at required intervals, as a guide to the adjustment of the velocity of water. This tube is scooped out in the middle portion and can be partially withdrawn without disturbing the contents of the chamber or tube. An air vessel, *f*, is fitted to the side of the water chamber as a balancing medium for fluctuation of water pressure, the water inlet, *g*, being fitted on the side of the cylinder, *e*.

It is claimed to wash 3 inches to $\frac{1}{100}$ inch with equal ease and to wash to 1% of ash with this machine, each unit being capable of dealing with 5 to 10

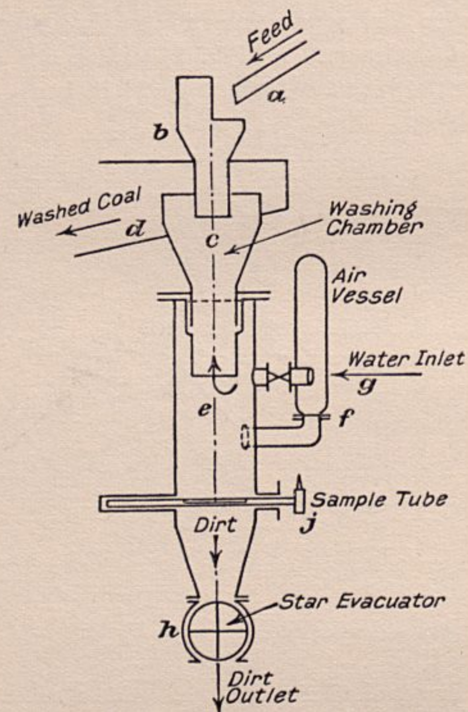

Fig. 174.—Diagram of Draper Washer.

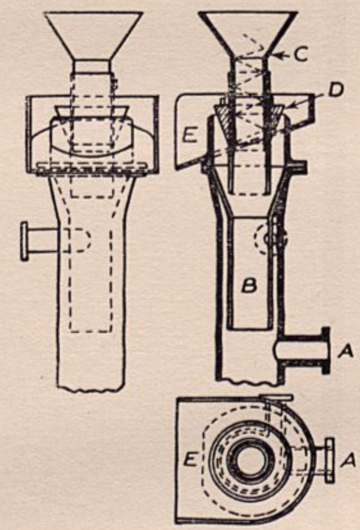

Fig. 175.—Detail of Draper Washer Upward Current Classifier.

tons per hour. The apparatus has a purely negative control, hence the introduction of the sample tube.

It is quite reasonable that the purity of the coal can be obtained to a close percentage, but what matters most is the loss of the good coal with the dirt, and as no adjustment of this machine can deal with bone coal without a proportionate disadvantage to the other products, the range is limited when used as a complete washing unit. In series, it would serve the purpose admirably, but as at present employed its uses are limited.

In Fig. 176 is shewn the general arrangement of a Draper washing plant.

The feed elevator delivers into a revolving screen by a long shoot. This screen is of the long stone screening pattern and makes four sizes, which are delivered upon the respective conveyors, which deliver the slack into the washers by breeches shoots. The washed coal is then flushed over a fixed sieve into a draining conveyor in the base of the building, the waste water from this conveyor being collected in a long narrow settling tank beneath it. The dirt is passed through the valves into a worm conveyor collecting from the ten machines and delivering it into the boot of an elevator, which discharges upon a scraper conveyor running alongside the building.

A large water tank in the roof provides the necessary pressure of water in the machines.

The plant is of very simple design, and shows the possibility of the machine.

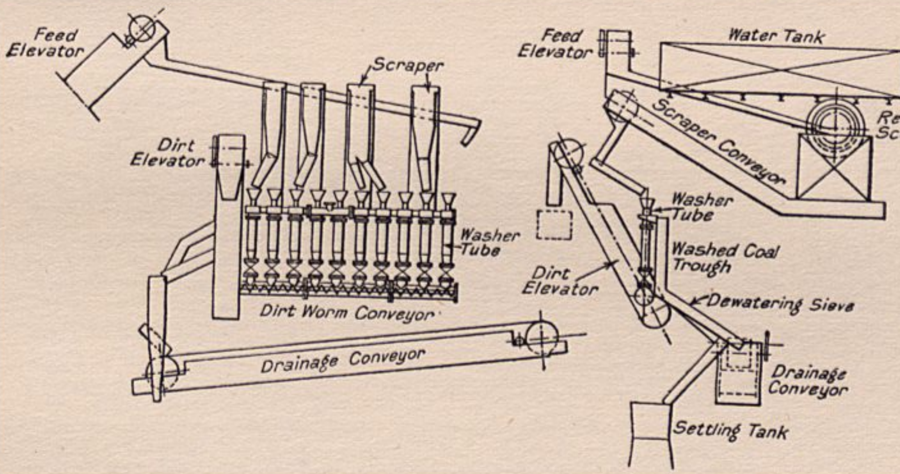

FIG. 176.—ARRANGEMENT OF DRAPER WASHERY.

The washer is really a forerunner of the trough evacuation machines, and would be better utilised as such than as a complete unit.

"Notanos" Coal-washing Table.—One of the earliest designs of coal-washing tables appeared in this country about 1909, and similarly to the concentrating table proper, the washing or separation is due to the opposition of a bumping force and a water jet.

The table is actuated by a system of cranks eccentrically placed, which gives a slow forward and a rapid backward motion, causing the material on the table to be jerked forward. This system of cranks is known as the Marcus motion.

The material travelling on the table is subjected to the impingement of a water jet or stream of water, which picks up lighter coal and flushes it away, whereas the dirt or shale resting on the table is carried forward to the dirt-collecting hopper.

In Fig. 177 is shewn a diagrammatic arrangement of the washer. The coal to be treated is fed from the hopper on to a feed tray attached to the washer, conveyed along to a suitable point for delivery into the washer deck, where it meets with a flow of water; separation takes place, the clean coal is floated down the trough over an adjustable weir on to a lower deck, fitted with finely-perforated plates, or when dealing with fine coal, wedge-wire drain trays. The water and any fine coal passing through the perforations or wedge-wire drain trays are led by launders to a settling tank, while the washed clean coal passes forward along the lower deck mentioned, to be classified if desired, and delivered out at a suitable point for storage.

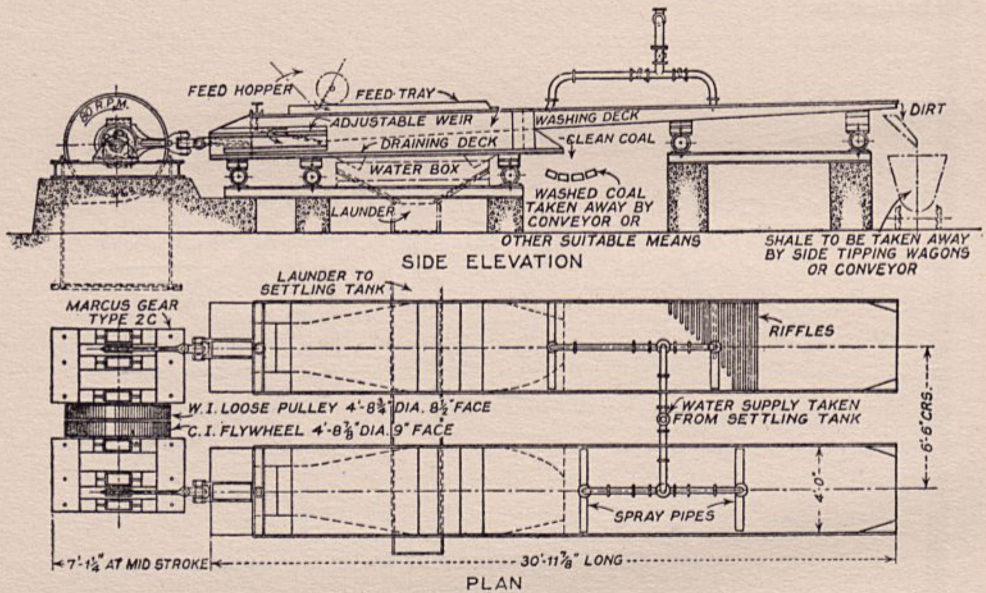

FIG. 177.—NOTANOS TABLE WASHER.

The fine coal which passes through the draining trays is led to the main settling tank, and can be recovered, if desired, by means of a scraper conveyor, and providing it does not contain too much ash can be mixed with the washed small coal. The dirt and heavy impurities fall to the bottom of the trough, and are conveyed against the flow of water to the high end of the trough, whence they are deposited into a conveyor or other means most suitable. The water supply is obtained from a sump by means of a centrifugal pump, and is fed into the washer through suitable spray pipes.

The washer is composed of mild steel plates, angles and tees firmly riveted together so as to be water-tight, and arranged generally as per outline shewn in Fig. 177.

The frame is carried on cast-iron rollers having chilled faces, supported on stools of channel iron section; the paths of the rollers are fitted with renewable wearing flats, the rollers being held in position with steel spindles coupled together with steel springs. The driving-gear mechanism is connected to the trough by means of strong channel brackets, which carry the crosshead pin. The gear consists of cast gun-metal drag-link, strong mild-steel bed-frame fitted with gun-metal steps, and efficiently lubricated.

The driving mechanism imparts to the washer trough a practically uniform accelerated forward motion, giving a pulsating action to the washed coal and sufficient momentum to the shale to overcome the flow of water.

Where two or more washers are installed, the washers can be driven in pairs by means of a balanced gear.

The consumption of power may be taken at 8 horse power per 10 tons of material washed per hour and the consumption of water at 16 gallons per ton of coal washed.

Swann System.—One of the most modern and efficient of coal-washing apparatus is that developed under the Swann patents. The improvements effected in the design of the plant shew a great adaptability to all kinds of coal without complicated additions. There is no radical change in the method to the present practice, but there is a decided improvement in the design to ensure reliable results from the most difficult of coals.

With the common types of jig-washing machines the quality of the washed product can only be regulated within very definite limits—*i.e.* the discharged products of the cleaned coal or the extracted dirt can only be adjusted to a certain point, beyond which one product suffers at the expense of the other, *e.g.* To further improve the purity of the coal the dirt outlets would be opened to allow a greater percentage of discard to escape, with the consequence that a portion of coal is drawn out with the discard. The Swann machine is designed to overcome this difficulty, so that almost any purity of coal can be extracted without any loss of useful product. The apparatus can be adapted to any existing type of jig washer, and even those of least efficiency can be greatly improved by the addition. In place of the usual single dirt outlet at the discharge end, there are two escape gates, one on the screen plate level of the washer box and the other at a higher level near the discharge lip of the box. The lower gate takes off the heavy dirt and the upper gate extracts a mixture of coal and dirt from the higher level.

The box is fitted with two dirt elevators, the one at the inlet end of the box extracting the heavier dirt and discharging it into the refuse hopper, whereas the elevator at the outlet end of the box collects the mixture of coal and dirt from the double escape gate and redelivers it into the first chamber of the washer box. By a suitable adjustment of these escape gates, the outflowing product can be regulated within very wide limits with extreme ease. The great advantage of this method lies in the simplicity of arrangement and the little attention required to attain the desired result, and lessens the risk of bad washing from lack of attention or change of quality of raw slack. The combination of this system with the jig washers used in this country would bring them up to a greater degree of reliability than has hitherto been possible.

In Fig. 178 is shewn a diagrammatic arrangement of a plant applied to the

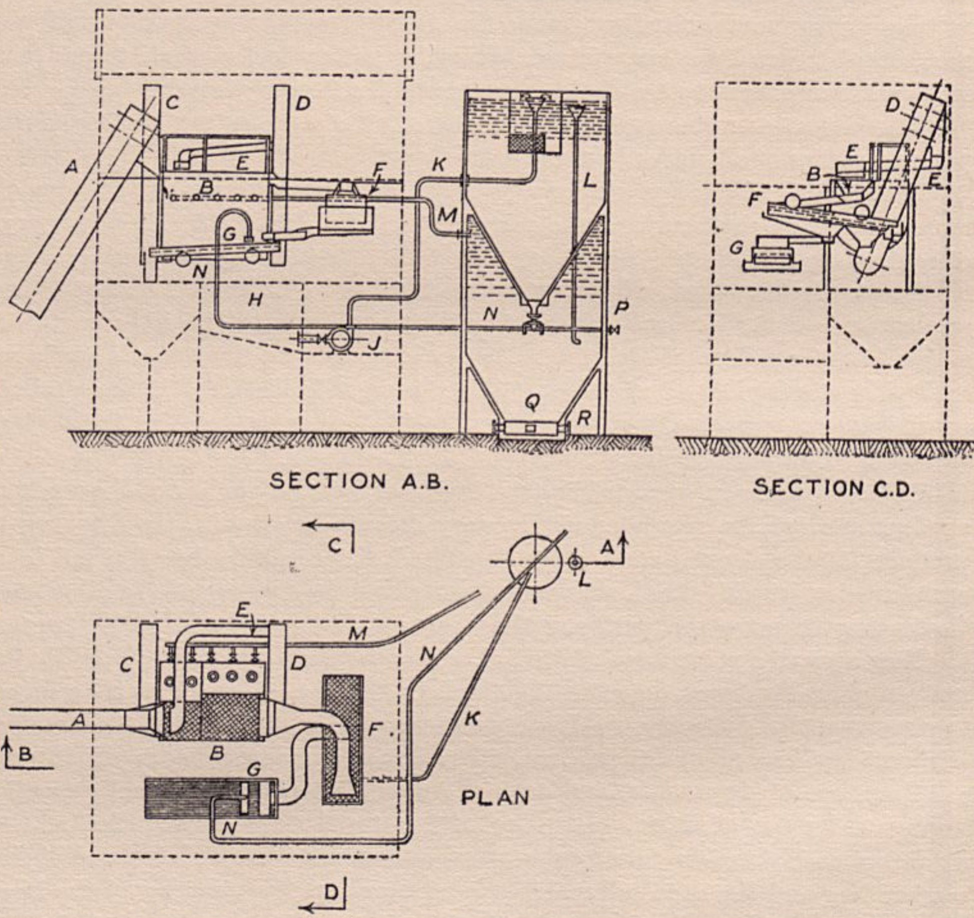

FIG. 178.—SWANN WASHERY SYSTEM.

Baum box to deal with 100 tons per hour. The slack is passed into the washer box, B, by the feed elevator, A, the dirt elevator, C, extracting dirt only, whereas the elevator, D, collects a mixture of dirt and coal from the upper layers and returns it to the first compartment of the washer box for a rewashing. This continuous circulation provides a substantial bed of shale on the screen plate and allows a generous opening of the dirt escape gate to clear the bed rapidly. The washed coal is flushed from the box on to the balanced Swann classifying screen, F, on which the various sizes are extracted, and the fine coal is carried with the water on to the pulsating shaking sieve, G. The screen has already been described on page 109. The sieve is of a similar design to the screen, but consists of only two trays, the upper holding a fine-mesh wedge wire of brass, and the lower tray is merely a shaking trough which collects the water from the sieve, but at the same time, on account of its opposite motion, there is a cushioning and slight suction of air between the trays which cause the material to lose the moisture more rapidly. The waste water from the sieve is collected into a trough and conveyed to pump well, H, from which it is pumped to the settling tank by the pump, J, via the pipe, K, which delivers in the centre of a circular curtain to concentrate the deposit into the deeper part of the tank. This tank is divided into two compartments, the upper having an inverted conical bottom which collects the deposited sediment of fine coal over the mouthpiece. This mouthpiece is fitted with a conical valve, which allows the slurry to pass by the pipe, N, on to the top of the fine coal passing over the sieve, G, to be filtered and deprived of its free water. On one end of this pipe there is a valve, P, to allow access to the pipe in case of choking and to make provision for a forcing water jet if required. The water circulation to the washery is primarily taken from the surface of water in the upper cone by the pipe, L, which, having a free delivery in the larger lower chamber, facilitates the precipitation of the lighter solids over the flat base, Q, of the chamber. These lighter solids contain a larger proportion of fine clay and are of high ash content, being therefore extremely prejudicial to the quality of slurry if retained with it. For this reason, relief valves, R, are fitted to the lower edge of the base to extract this slime for disposal on the refuse heap. The more highly clarified water of the upper portion of the lower chamber is drawn off for service in the washery by the pipe, M. The simplicity of the whole arrangement and its comparative cheapness and economy of design and maintenance do credit to British enterprise.

Dry Separation.—A method of separation lately introduced into this country from America is that known as the Spiral Separator.

The method, while new to the coal industry, has often been exploited in the treatment of heavier minerals. This type of apparatus takes the form of a large spiral shoot of treble pitch as shewn in Fig. 179. The shoots are provided with special friction arrangements which have the function of selecting the material sliding upon their surfaces. The coal is fed in at the top end into a narrow spiral placed at an inclination to the horizontal and section, and surrounded by a wider shoot placed just beneath it.

The raw slack in being whirled round the inner spiral has a certain amount of centrifugal force, and by a suitable adjustment of the separating threads by the end levers, causes the coal to jump the edge of the inner spiral and enter the outer or larger spiral. It is claimed that the friction of the shale and the coal on the chute is sufficient to cause a definite separation. It is also claimed by the manufacturers that raw slack can be separated to 2% of refuse in the coal discharge, and a similar amount of free coal in the inner discharge.

In Fig. 180 is shewn a general lay-out for a plant for dealing with 10 tons per hour. As the feed must be uniform, a jigging screen, as shewn in Fig. 181,

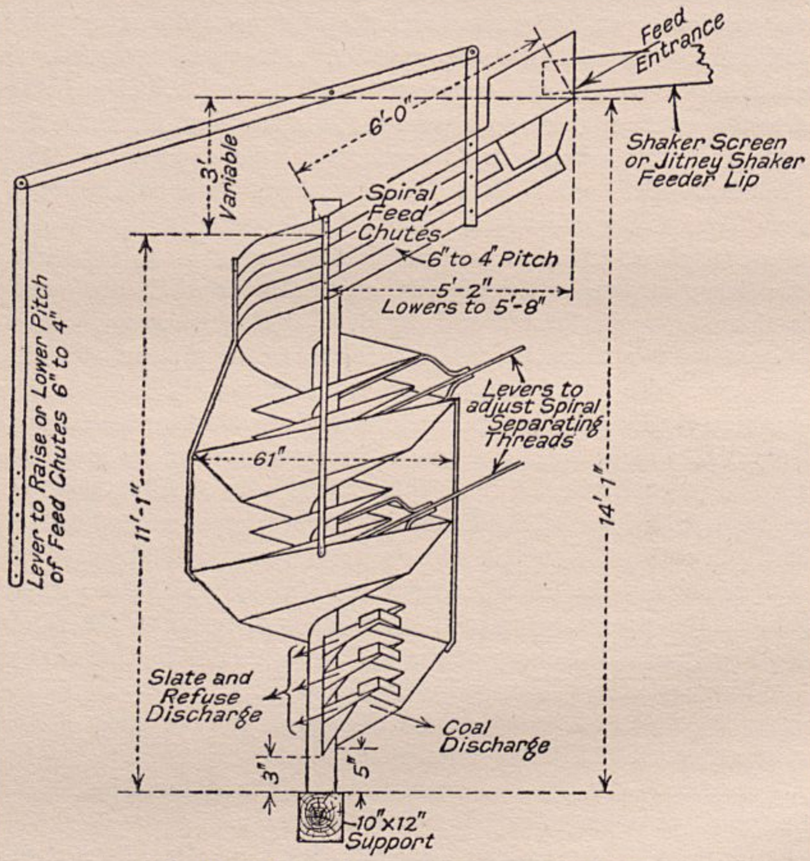

FIG. 179.—LEVER ADJUSTABLE SPIRAL SEPARATOR.

is used for feeding on to the spiral shoots, the limit of treatment being from $2\frac{1}{2}$ inches to $\frac{1}{2}$ inch.

The friction plates are designed for each different class of coal, and are therefore not adaptable to a varying quality. Several plants erected in this country have given reasonable satisfaction, and with slack of the larger sizes there is no doubt that as a simple and effective concentrating apparatus the spiral separator is of great advantage. Used in conjunction with a fine-coal washing plant, there could not be a more ready way of dealing with the average colliery slack.

Of the other dry separation processes little has been done in the industrial world, but in the near future there is every possibility of an economical development of pneumatic separation in the form of concentrating tables or jigs in which the liquid is replaced by air.

The American practice is veering rapidly towards dry separation, and within

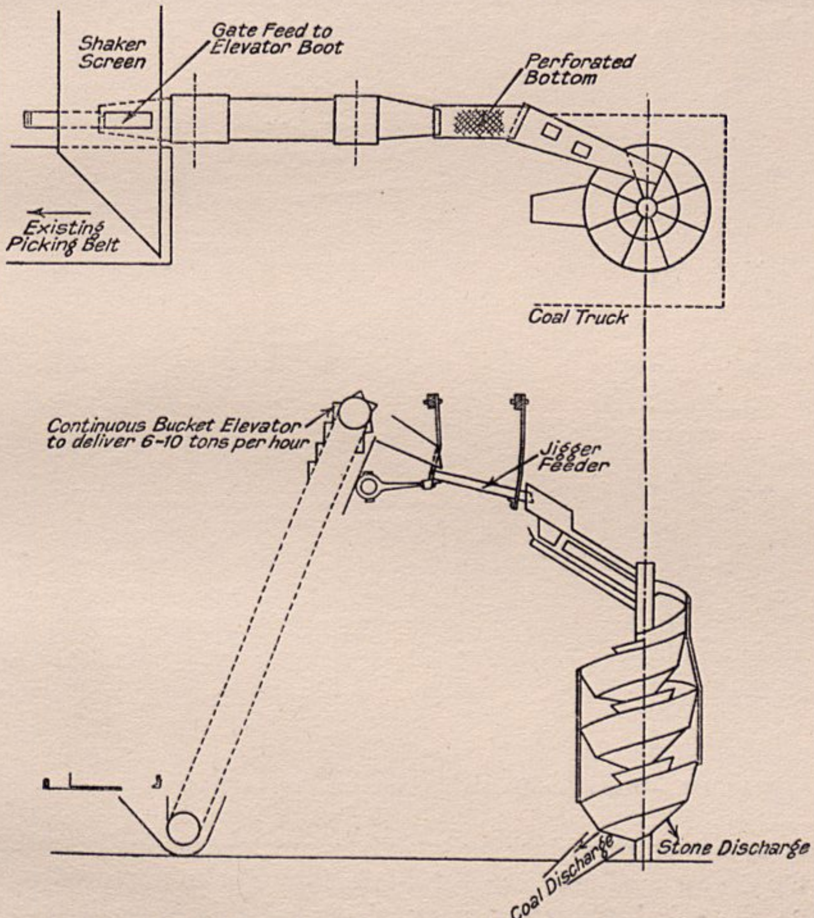

FIG. 180.—TYPICAL LAY-OUT DIAGRAM FOR EXPERIMENTAL SEPARATOR.

the last two years several plants have been erected to deal with slacks of $\frac{1}{16}$ inch to 2 inches by pneumatic separators. Experiments, however, of only a few months' duration with a particulár type of coal are not yet sufficiently developed to afford conclusive evidence of their applicability to the British coalfields.

The problem over here is to maintain the value of an ever-growing inferiority of product, whereas in the United States it is more aptly described as a selection of qualities or grades of good and less good coals. It is quite natural in a new coalfield that the latest developments of modern science should be incorporated in the plant, even at the risk of being somewhat experimental, but here we are compelled to pay greater attention to the present-day balance sheet, in view of the shorter life of our collieries and the keener external competition.

The scientific progress of our practice is at all times on a par with that of the United States, but without the commercial risk. British engineers are

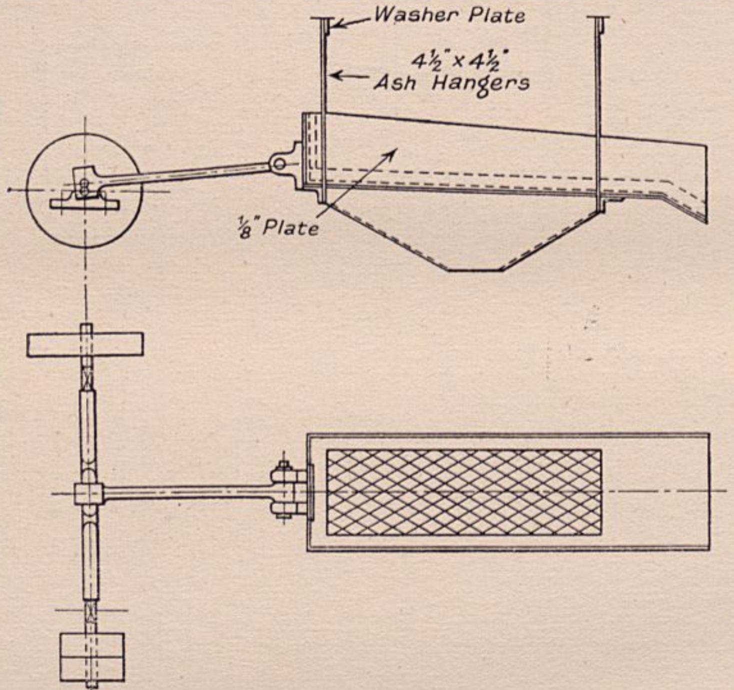

FIG. 181.—STANDARD JIGGER FEEDER FOR SINGLE SPIRAL SEPARATOR.

inclined to favour proved methods and to progress gradually, rather than scrap the known good practice wholesale in favour of an unproved system.

With the spiral separators many of our collieries have installed small plants to test the capabilities of this complete departure from the usual washing or cleaning system, and a fair amount of success has been registered. With all plants used by our collieries the great test is durability and consistency of performance, and so far it is early in the day to say that the spiral separator has come to stay. In Fig. 182 is shewn a typical lay-out of the plant. The raw coal is led to the hopper in the roof of the building, and from there is fed on to the classifying screens. All coal below ⅜ inch is taken out as duff coal and the remainder is sized as follows: ⅜—⅝ inch, ⅝—⅞ inch, ⅞—1½ inch, 1½—3 inches.

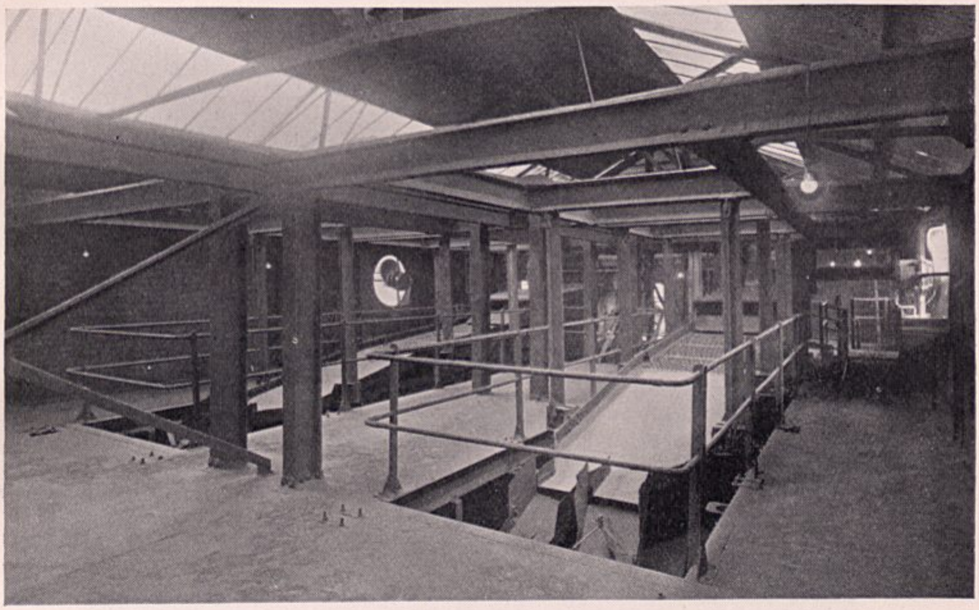

Fig. 183.—Shaker Screens above Spirals.
(*H. Wood and Co., Ltd.*)

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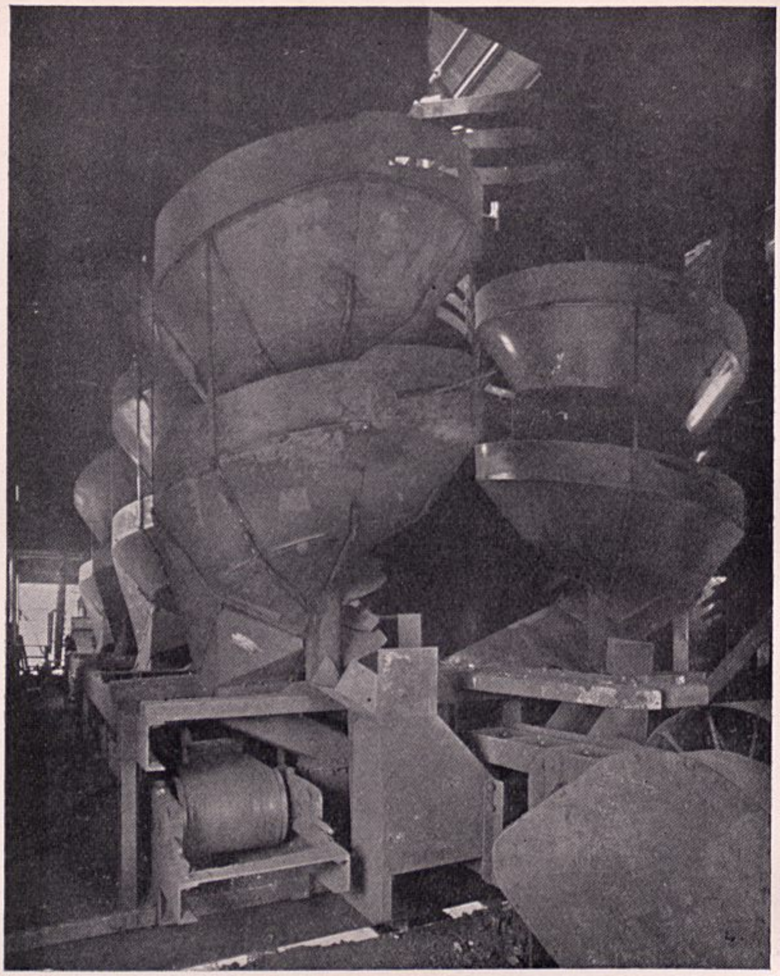

FIG. 184.—SPIRAL SEPARATORS.
(*H. Wood and Co., Ltd.*)

The four sizes are then passed over the spirals. The clean coal is collected on the cross band conveyors and delivered over the wagon roads as shewn, whereas the stone and the intermediate or middles coal are delivered on a scraper conveyor, receiving the former on the bottom deck and discharging it on the cross scraper for final disposal in the stone bunker, and the latter is carried

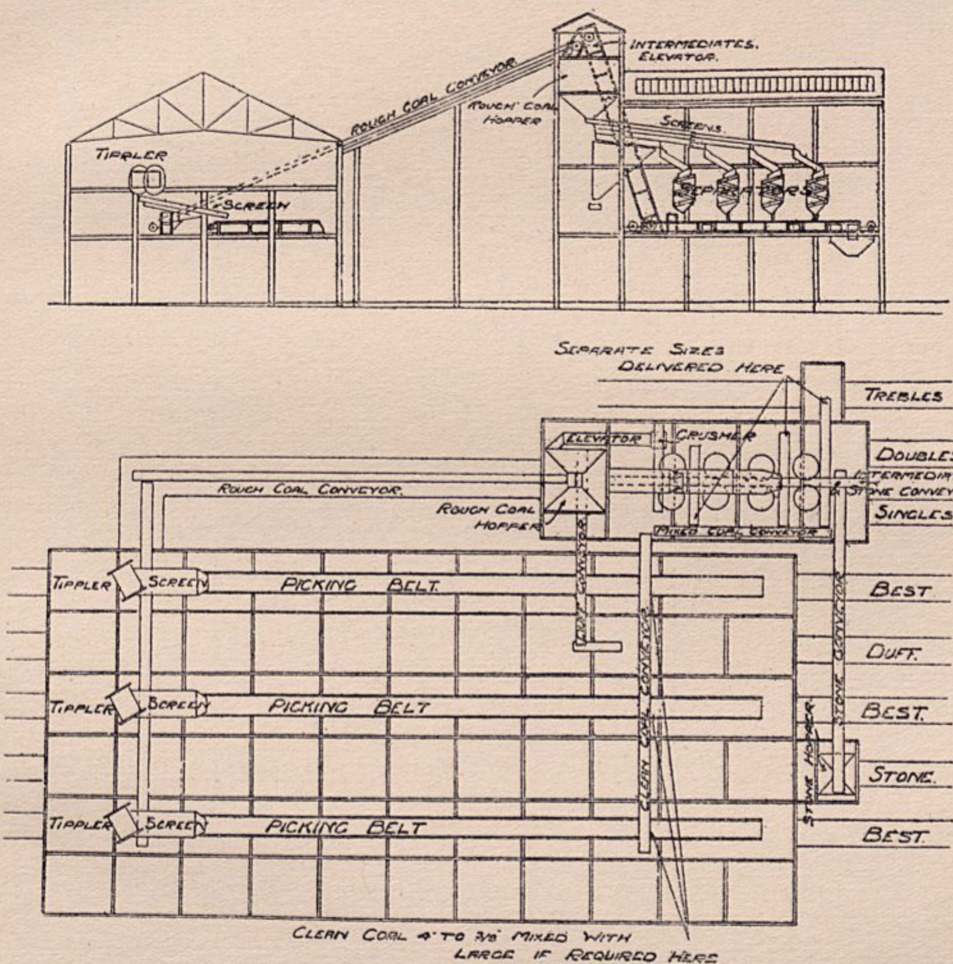

FIG. 182.—TYPICAL LAY-OUT OF SPIRAL SEPARATOR PLANT.

along to the cross scraper delivering into the breaker, and thence to the feed hopper by the elevator shewn.

Arrangements are made for loading any size or all sizes at the ends of the picking belts. The plant shewn is capable of dealing with about 600 tons per day. In Fig. 183 is shewn the classifying screens for the largest plant of its kind in this country, there being sixteen separators at work. In Fig. 184 is shewn a battery of spirals, the band conveyor receiving the coal, and the drag-link conveyor the stone and middles, the stone chute being clearly seen in the

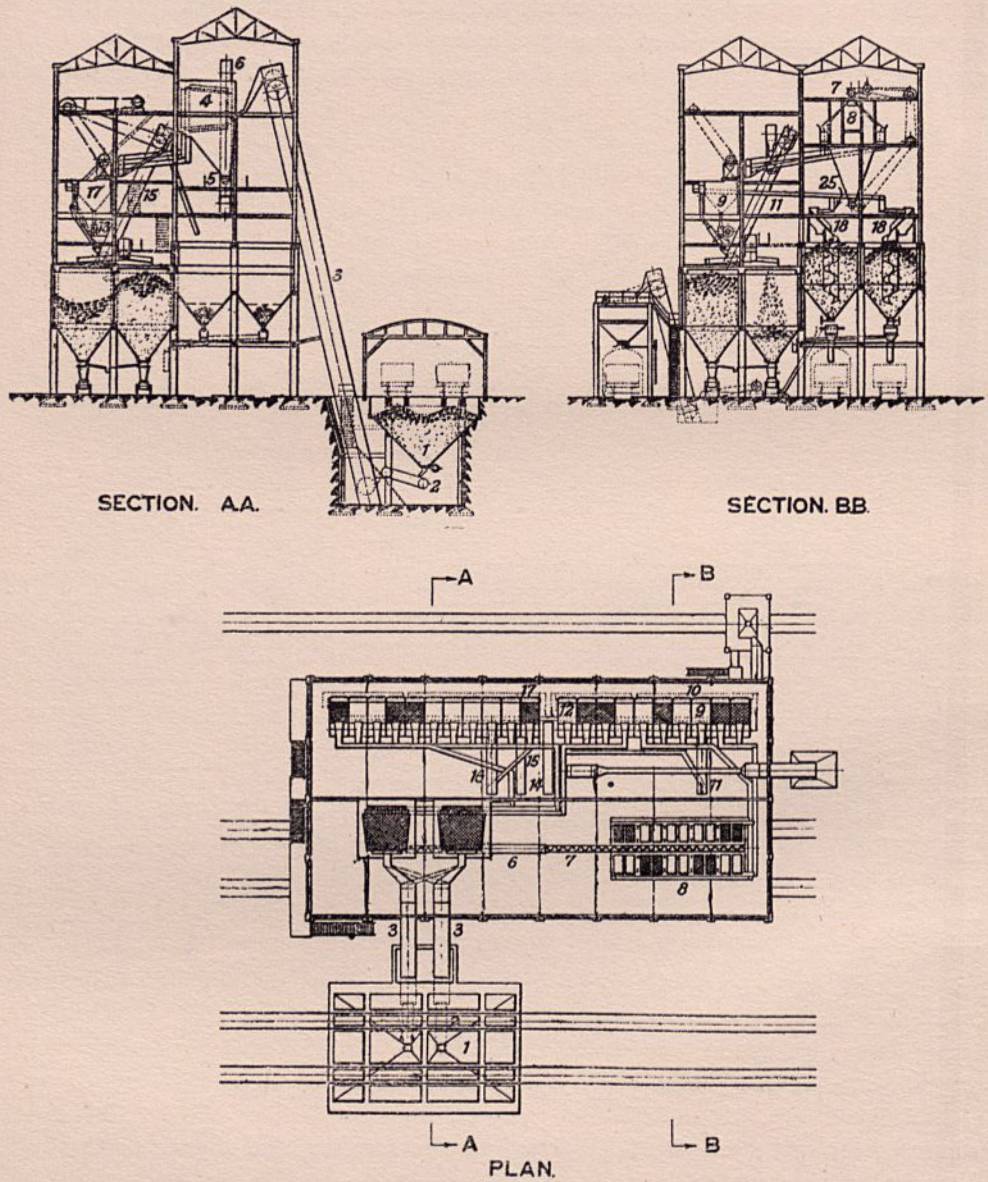

FIG. 185.—ARRANGEMENT OF HUREZ WASHERY.

front of the illustration. A basher system of coal washing which has lately been introduced is that known as the Hurez system. In Fig. 185 is shewn the lay-out of a typical plant. The coal is fed into the feed hopper over two lines of sidings, and between the elevator, 3, and the mouth of the hopper, 1, a feed belt is arranged to regulate the supply. The raw coal is fed into the revolving screens, 4, which classify into 0—$\frac{1}{4}$ inch, $\frac{1}{4}$—$\frac{2}{5}$ inch, $\frac{2}{5}$—$\frac{4}{5}$ inch, $\frac{4}{5}$—2 inches.

The smaller size is then picked up by the worm conveyor, 5, and elevated by the elevator, 6, into the distributing worm conveyor, 7, over the battery of vibro-screens, 8. In these screens the dust 0 to $\frac{1}{25}$ inch is taken out and led to a bunker.

The oversize is led by flushing trough into the washer boxes, 9, and after washing the coal is collected into the trough, 10, and carried to the bunkers. All the smaller sizes are washed in Feldspar jigs. The middles product is collected by the elevator, 11, and led to the rewasher box, 12. The larger sizes are passed by the troughs into their respective washer boxes, the dirt from which is collected by the worm conveyor, 13, and brought to a common dirt elevator, 14, which delivers into the dirt bunker. The middles from the larger washer boxes are collected by the elevator, 15, which delivers into a middles bunker drawn upon for colliery boiler use. On occasions, the middles are by-passed into the elevator, 16, and thence into the rewashing jig, 17. The larger washed coal is flushed into bunkers over suitable drainage grids, 18.

As a result of an exhaustive study of coal-washing problems, the author has devised a system of coal washing wherein simplicity of plant and operation is the main feature.

Of all the jigging machines in use the one that has proved most reliable in this country is that on the Baum air principle of pulsation. As, however, the great drawback of washing first and classifying afterwards is the relatively poor results on the fine coal below $\frac{3}{8}$ inch and the slurry troubles, it has been found possible to minimise these defects.

In Fig. 186 is shewn the washer box, divided into six compartments. The raw coal enters at 1, and is deposited on the screen bed, 5. The pulsations of air stratify the material, and the heavy shale is taken out at the escape gate, 2, into the dirt elevator, 3. The regulation of the escape gate is by worm and wormwheel, 4, so that a fine adjustment may be made in a simple and ready manner; the rods connected to the escape gate are notched and engage with a toothed pinion on the shaft carrying the wormwheel. Water is admitted freely to the compartments, 8 and 9. Following the usual practice, a weir, 6, separates the first compartment of the box from the second, and over this the coal is caused to pass into 7. The dirt or middles is taken out from this bed by the escape gate, 12, operated as before. It will be seen that there are two pulsating chambers of equal length under both beds, but the second chamber is actually 20% larger in area, *i.e.* is one-fifth wider. The further pulsations lift up the coal over the perforated plate trough, 14, in which the holes are made sufficiently large to trap the coal, etc., below $\frac{3}{8}$ inch in the suction stroke without impeding the flush of water and larger coal to the outlet, 18.

This perforated plate is made the full width of the bed at the weir, but at the outlet it is reduced, two-thirds the width, as shewn in the cross-section, A, A. At the edges of the screen plate, 14, vertical flange plates, 19, are fitted to guide the flush to the outlet, 18. Between the plate, 19, and the side of the box there is an open wedge-shaped space with the broad side at the outlet (in plan). The middles dirt passing at 12 is led by the shoot, 10, on to the deflecting plate into the conveyor worm. The vertical weir plate at 12 is also perforated to allow the small sizes to pass into the chamber, 13. In this chamber the pulsating action is confined to the small coal.

The free wedge-shaped surfaces tend to draw the coal away from beneath the plate, 14, allowing smalls to pass into free space. It is not intended to

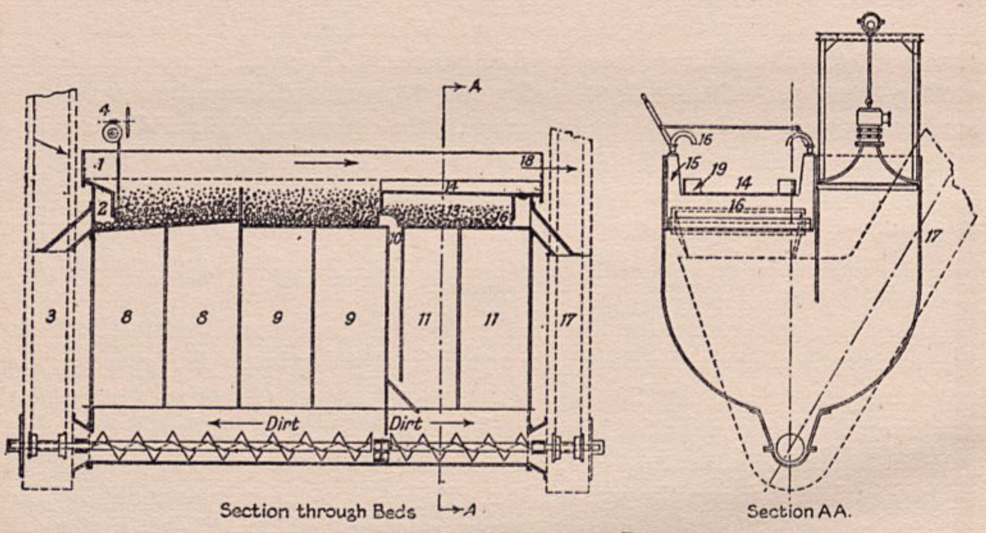

FIG. 186.—MINIKIN WASHER BOX.

draw the full quantity of the smalls through the plate, but only the small dirt, which rests on the surface of the plate, and to trap this a certain amount of good coal will also pass.

The relation between the level of the outlets for the large coal on 14 and the smalls passing the broad end of the wedge has to be adjusted on site, provision being made for raising or lowering the sill. The coal in the chamber, 13, is not subjected to a balancing inlet of water, the greater part of the make-up entering at 8 and 9, and only a small quantity in 11. The dirt from 13 is extracted at the escape gate, 16, which is made with a serrated bottom edge. The dirt passes direct into the boot of the elevator, 17, which also receives the dirt from 12 via the worm conveyor. The chamber, 13, is 1·4 times greater in area than 5. It will be seen that, within limits, by the use of this box rewashing of the fines is unnecessary, particularly since all the dust below one-tenth has been extracted.

In Fig. 187 is shewn a diagram of the system advocated by the author and covered by several letters patent.

The raw coal enters the feed hopper, 1, which is fitted with an open mouthpiece, 2, and allows access to a man at 3. The feed elevator, 4, fitted with self-oiling bearings, delivers the coal into the dust-extraction plant having a chute, 5, chamber, 6, and a blower, 7 (see Fig. 89). The coal above one-tenth is then led to the washer box by the trough, 8, and passes successively through the beds, 9, 10, and 11. and is discharged as one product over the trough, 14, into the Swann classifying screen, 15 (see Fig. 99). The coal is then sized into doubles, nuts, beans, peas, and fines, entering the troughs or chutes 20, 19, 18, 17, and 16. The fine coal and water are extracted together by 16 and led over

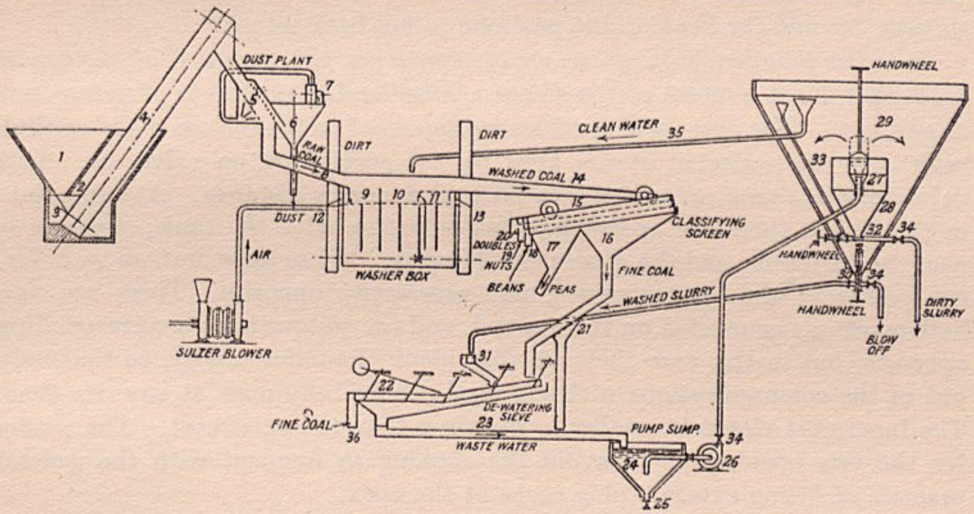

FIG. 187.—MINIKIN WASHING SYSTEM.

a partial-dewatering sieve, 21, before being deposited on the vibro-dewatering sieves, 22 (see Fig. 220) (Norton-Minikin Patent).

After dewatering, the fine coal is discharged by 36, and the waste water is collected and conveyed by 23 to the pump well, 24. There are two features shown in this sump that are not those of ordinary practice, but are recommended by the author as being of great advantage. All sumps receiving slimes or very fine coal silt up, and there comes a time, particularly with those having a flat inclined bottom, when men have to be employed to dig the deposited slime out. The sump should therefore be made either conical or pyramidal, and be provided with a large plug cock, 25, as shown, to enable the attendant to blow the sump out occasionally and avoid the deposits. The other feature, which also tends to lessen this inconvenience, is to place the pump suction downwards as shown, to cause a current of water tending to scour the sides and keep them free from deposit, and prevents the entrance of any bulky tramp wood or other material into the pump.

The circulating pump is of centrifugal type, and should be placed as low down as possible, the vertical leg of the suction pipe being not more than 2 feet long. The pump, 26, delivers the waste water containing the fine slimes into a slurry washer, 27. This washer is built up of a cylindrical internal tube or pipe, which is fixed in position, and a movable pipe with a conical mouthpiece, which may be raised or lowered by the hand-wheel on the tank platform. Surrounding this washer there is a large conical vessel, 28, fixed in position in the main concrete settling tank, 29. As the water enters 27 at a certain velocity, the movable piece is so adjusted that the induced current in the main body of water will allow the pure coal particles to be carried beyond the lip of the curtain, 28, and the heavier dirt particles to fall back into it.

It is not practicable to get an exact separation, but the great advantage of reducing the ash content of the slimes a considerable amount is of paramount importance. The purer coal particles are deposited on the surface of the settling tank, and are collected at the apex by the special piston valve, 30. This valve runs in a tube extending into the tank for some distance. At two points in the length there are apertures communicating with the tank; the one is near the extremity and the other near the apex. These apertures are on different points of the circumference, not necessarily opposite. There are two hollow pistons connected on the one rod, and the pistons have a corresponding aperture, but in this case they are coincident circumferentially, so that only one of the communications with the tank can be fully open at any one time. The innermost piston is smaller in diameter than the outermost. The reason for the two openings is to avoid the choking so frequent with the general practice of fitting external plug cocks at the apex.

There is usually a head of 40 feet of water in the tank, and the deposited slimes become hard and lumpy directly over the outlet, and it is often a daily occurrence to find the outlet choked, due to the squeezing effect of the conical sides. If, therefore, there is a difficulty in moving the slime at the lowest outlet, the inner outlet can be partially opened to prevent a stoppage of the plant, and also ease the choked portion in the manner of an ejector. The valves are made to turn by the handwheel shown, and the slurry is led to the chute, 31, to be mixed with the fines on the sieve, 22. The deposited dirt in the chamber, 28, is collected at the apex by a single piston valve, 32, and discharged to waste through the pipe at the side. A force pipe, 33, is fitted to flush out this pipe at the finish of the shift, and is opened by the handwheel at the side. Plug cocks, 34, are fitted where required, and it is good practice to fit one on the suction side of the pump and the other on the discharge, the latter for regulation of the supply and the former to cut off the sump for repairs. The type of blower used is the Sulzer, shewn in Fig. 188, of the multiple turbo pattern (for washing machine).

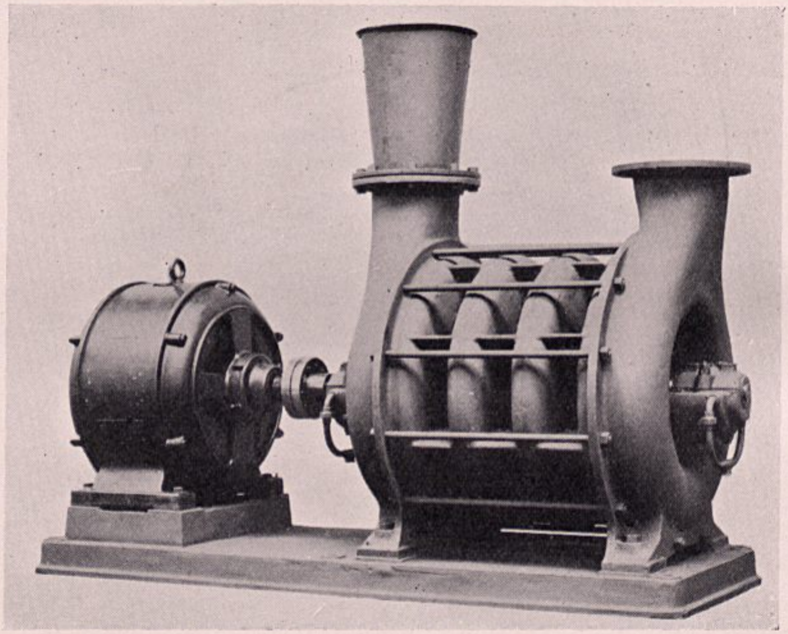

Fig. 188.—Sulzer Blower.

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CHAPTER XIII

CONCENTRATING TABLES AND FROTH FLOTATION

THE difficulties of washing very fine coal have led the most progressive mining engineers to instal concentrating tables similar in type to those used in ore dressing. Slime or slurry, which is the residue of the raw coal during washing, consists for the most part of materials already classified, that is, the coal particle is larger than the shale particle, so that to separate the two it will be necessary to use another process. This process of concentration is known as film sizing, so that now the separation will be dependent on surface friction.

The machines for carrying out this delicate work make use of the principle of friction of the particles upon a surface. When impelled forward by a thin stream of water, the larger particles, having a greater impulse due to the larger cross-sectional area, will advance over those of smaller cross-sectional area. Under these circumstances, by placing an amount of material upon a

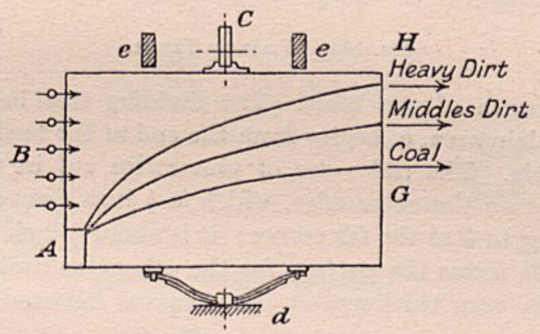

FIG. 189.—PLAIN TABLE.

plain surface and allowing it to be acted on by a thin stream of water, the particles of the largest diameter will travel faster than those of small diameter.

In Fig. 189 the feed is at the point A. The stream water enters the table at the point B. The table is subjected to blows of a camwheel, C, in the centre of the long side. Opposing the camwheel at the opposite side is a spring, *d*. The camwheel delivering blows upon the side of the table, pushes it over to one side, and the spring, *d*, returns it sharply back against the chocks, *e*, so that a series of smart blows is delivered, the number being from 100 to 150 per minute. The faster-moving material will pass over the table under the impulse of a smaller number of blows than the slow-moving heavier particles, hence the path of the former will be less curved than the latter, so that one will be delivered at G, the other at H. Accordingly, by suitably dividing these positions the good coal may be separated from the shale. The film of water passing over the table effects the discharge, while the bumping separates the qualities.

Wilfley Table.—A development of the preceding example is that known as the Wilfley table as shewn in Fig. 190.

The essential difference of the two tables is that the present example, in place of having a plain surface, is provided with a series of equally spaced grooves, called riffles, and the bumping effect takes place along the direction of motion of the heavier particles or in the length of the table.

The feed box is situated in the near acute-angled corner, and extends for

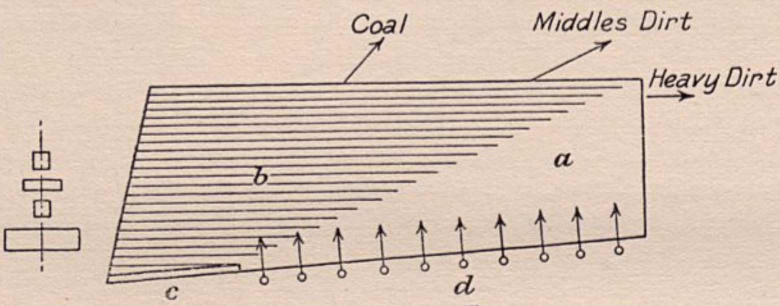

FIG. 190.—WILFLEY TABLE.

one-fourth the length of the table. The dividing line between the riffled area, *b*, and the plain area, *a*, begins from the end of the feed box to the outer corner of the table. The riffles are of pine strips cut in wedge shape, the longest being that on the outer edge, which is ½ inch deep at the top end of the table, tapering to 0 at the far corner; it is about ½ inch wide for the full length. This riffle forms the pattern for the others, as each succeeding strip is placed with the zero thickness at the diagonal between plain and riffled

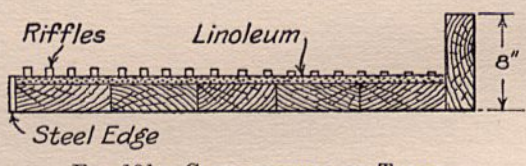

FIG. 191.—CROSS-SECTION OF TABLE.

area, so that the nearest riffle to the feed box is only about ⅛ inch at the thickest end. They are all nailed to the deck parallel to the edge away from the feed box and are about 1 inch apart. The distributing box is connected to the edge of the table, which is not quite rectangular, whereas the wash-water sprays are branched up from the supports. In some cases it is found advisable when dealing with a coal containing a quantity of middles to carry the riffles diagonal further forward towards the end of the table.

The table is constructed of pine, with vertical edge boards extending 6 inches above the surface of the table, which is covered with linoleum, as it is found that this material is sufficiently durable and possesses the correct degree of friction for the particles. It is also an impervious medium to protect the woodwork of the deck, as shewn in Fig. 191.

The table is supported upon rocking arms and is given motion by an eccentric operating a toggle mechanism, which is placed between a fixed support, and a crosshead upon a connecting rod directly attached to the table. A strong spring keeps the toggle in constant bearing, and provides the necessary force for the forward stroke. The stroke is about 1 inch at about 250 per minute for duff coal. The wash water is applied along the edge, *d*, of the plain part of the table at the same side as the feed box. The duff coal is first well mixed to semi-liquid or pulpy state, in about twice its weight of water and fed in through the box, *c*. On entering the table, the particles immediately stratify, the heavier seeking the bed between the riffles, and in this position, being more directly under the influence of the bumping action, they are forced to travel along the groove towards the plain table, which is the actual washing area. No sooner do they enter this zone than they are subjected to the flush of the stream coming from the sprays and

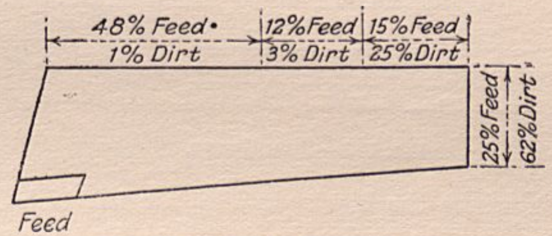

FIG. 192.—TABLE PRODUCTS.

washed back into the next riffles in a continuous progression until these heavier particles which have battled against the current are dropped off the table into a trough placed at the bottom edge. The lighter particles of coal riding on the upper layer of the stream take a more direct route from riffle to riffle until they are discharged at the edge of the table.

The separation on this table is more particularly due to the bumping action than to the water current, and as the heavy dirt and middles have a longer path to follow than the coal the separation is particularly good.

The riffles prove useful for two reasons, the first in the obstruction they offer to the heavy dirt lying on the table, and the second, the guidance of the dirt to a convenient point for collection. The refuse travels much faster under the external impulse towards its discharge than does the coal, which is not so fully under this influence, but has its movement more directly controlled by the wash water and the inclination of the table to the side.

The effective zone is, therefore, across the narrow table from the end of the feed box to the tips of the riffles, and at this latter point the struggle for selection between the middles and dirt takes place.

It is customary to divide these zones into good coal, briquetting coal, and dirt, and the part of the table of most use to washery engineers is the higher end of the offside riffle edge, as shewn in Fig. 192.

The table can be tilted across the line of motion, that is, transversely to the operating gear.

The capacity of these tables is about 1 cwt. per square foot of surface per hour, and requires about 5 cwt. of water for this duty.

This small capacity militates against the adoption of this type to any large extent. Of several particles lying on the bottom of a stream a definite position will be taken up by these particles when subjected to a current. The larger particles presenting a greater cross-sectional area to the current, and at the same time having the benefit of projecting into the more swiftly moving films of water, will always be in advance of the smaller particles of the same density. These small particles lying on the bed of the stream are only influenced by the more slowly moving films of water retarded by the skin friction of the bed, apart from the considerations already outlined in Chapter XII on trough washers. If we represent this action by the diagram

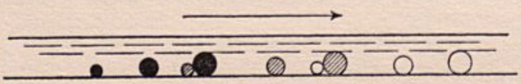

Fig. 193.—Film Sizing.

shewn in Fig. 193, where the black particles are the high density dirt, the shaded the middles, and the circles the light coal, then the relative positions after a certain interval of time will be those represented by the upper figure. Where the only impulse given to these particles is that due to the wash water, then the path followed would be a straight line and at some moment the positions would be as shewn in Fig. 193. Introducing a bumping action and inclining the table away from the feed box, the particles will be driven from the straight following path into separate paths, and the same component of travel, due to the wash water, will have effect.

The result will therefore be that the new positions of the particles will be A, B, C (Fig. 194), the dotted lines being the respective paths of the particles.

This sorting out facilitates the collecting arrangements. It will be readily seen that there can be no definite dividing line between the qualities or sizes, the classes being as variable as the number of paths, hence the grouping of good coal and waste is an average between the pure coal and the true middles.

This separating point can only be arrived at by trial and test of the ash content of the discharged product at several points. The riffles added to the table bring about a clearer definition of the products confining the selection to a constant area or zone.

Thus in Fig. 199, if we consider that the three particles of coal, middles, and dirt leave the feed box at the same time, the light and the heavy particles are immediately subjected to the influence of the wash water and the jerk of the table respectively, but with the middles there is an intermediate position between the last two, which it takes up. The bumping is now in the direction of the grooves or riffles, hence the shale resting in these grooves travels quickly along to the riffle tip, where, losing its protection, it is caught by the stream of wash water and then follows a diagonal path, under the two forces (A). The middles follows closely in its wake, but not possessing the quality to make a definite selection, is, on leaving the first riffle, caught by the wash water and thrown back upon the next riffle, where it undergoes the same treatment, not having sufficient buoyancy to mount the latter, until it is eventually discharged at or near the corner of the table (B).

The pure coal, on the other hand, makes its selection at once, and mounts the riffles, due to its greater buoyancy, and is quickly discharged (C).

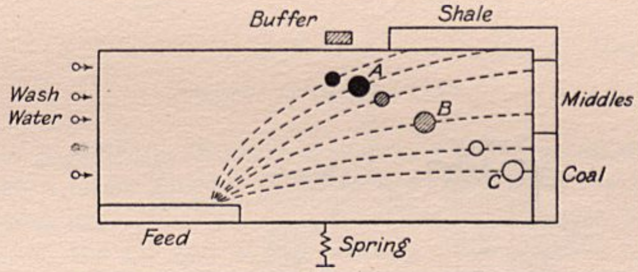

Fig. 194.—Position of Particles on Table.

Between these three positions the material of the different classes in quality and size is proportionately ranged. The obstruction of the riffles helps the ready removal of all sizes of dirt in a definite direction, so that a greater efficiency is obtained with their use.

In the plain table the external impulse was applied by a blow or bump with the intention of effecting a sudden reversal of movement to cause the material on the table to slide. It is this rapid change of direction of movement that makes the concentrating table effective.

If the movement were uniform, there would be no predilection of the material for one side, excepting that due to the slope of the surface, which is not sufficient to have the desired result. For this reason, the gathered momentum of the particles in the return stroke causes them to continue in their path of movement for the fraction of a second at the time of the bump. To bring about this effect on the riffled tables, there are several types of mechanical devices employed. In the case of the Wilfley table, this is brought about by a toggle and spring acting in opposition.

In Fig. 195 is shewn the outline of this mechanism. An eccentric on the shaft is connected to the toggle arms, one end of which engages with the projection of the bed-plate and the other with the extended operating rod of the table, which has a pin slide working in the rear guide. On this casting is a projecting flange against which a spring is compressed on the downstroke of the eccentric, by the flange on the table operating rod. On the downstroke of the eccentric, the table is brought backwards compressing the spring, which in return gives out sufficient force to make the forward stroke. As the toggles are always kept up to their work, they govern the motion entirely, the spring merely supplying the energy, but as this energy was given up by the toggles in the first instance, on the return the latter have no work to do. The maximum rate of spread of the toggles takes place at the beginning of the backward stroke, causing a rapid reversal of direction.

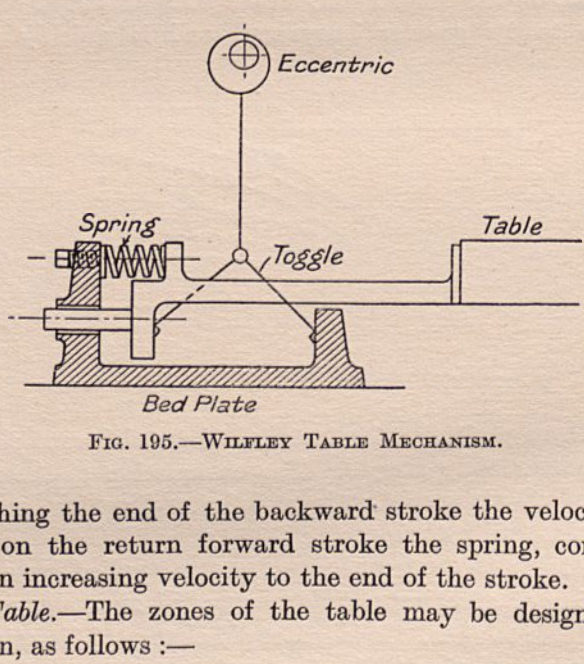

FIG. 195.—WILFLEY TABLE MECHANISM.

On approaching the end of the backward stroke the velocity of the table decreases and on the return forward stroke the spring, controlled by the toggles, gives an increasing velocity to the end of the stroke.

Overstrom Table.—The zones of the table may be designated, according to their function, as follows :—

Riffled area	Stratifying zone.
Diagonal near the end of riffle area . .	Selection zone.
Plain area	Proving zone.

In the first zone, the pure larger coal is rapidly separated and carried to discharge, but the smaller particles may stray along with the middles and dirt and almost reach the end of riffled area before being able to assert their selective property, and the middles may enter the plain area under the same circumstances. For this reason, to ensure a good separation, the selection zone could with advantage be made of relatively greater dimensions than in the former example. The Overstrom table, as shewn in Fig. 196, is designed for this purpose. The effective length of the diagonal is increased by the staggered table, and the operating mechanism, although parallel to the

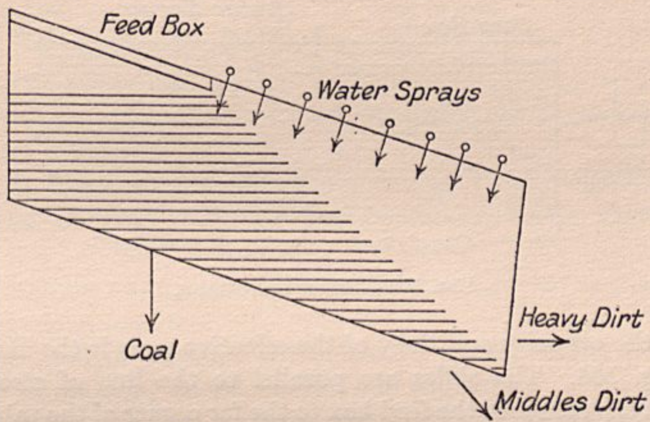

FIG. 196.—OVERSTROM TABLE.

riffles, is placed so that the direction of motion is from one corner of the table. By this means a larger number of riffles are possible at the most effective zone. The operating mechanism does not differ from the preceding example. In coal washing, the far end of the table is made parallel to the near or mechanism end.

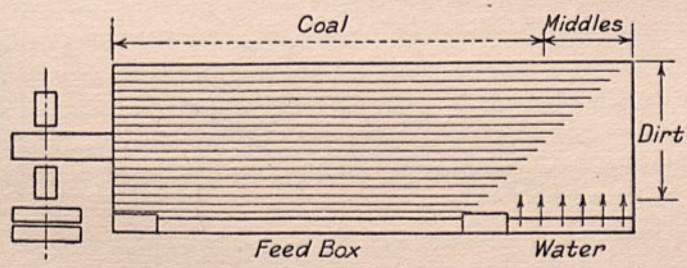

FIG. 197.—PLAT-O TABLE.

Plat-O Table.—This table was designed with the same end in view as the Overstrom, but in place of increasing the number of riffles or altering the outline of the table, the rectangular shape was preserved, and the increased effectiveness of the selective zone was brought about by placing the plain portion of the table on a higher level, so that the lighter stray particles are not only subjected to the wash water, but have the added obstruction of mounting a higher plane, as shewn in Fig. 197.

This type has been fairly successful on different coal, as the wash back of the water down the plane has a remarkable buoyancy effective upon the wandering coal. It is run at 250 strokes per minute with an amplitude of 1 inch to $1\frac{1}{4}$ inches.

Butchart Table.—A still further improvement upon the last two examples

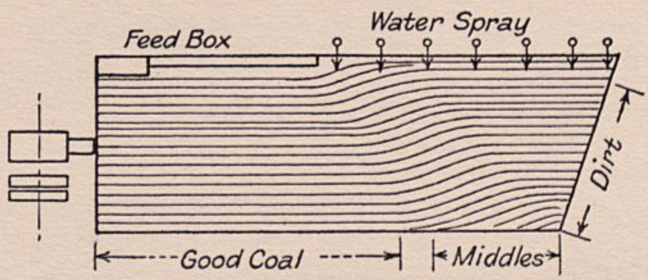

FIG. 198.—BUTCHART TABLE.

in adding to the capacity and duty of the selective zone is the Butchart table, shewn in Fig. 198. The riffles are parallel to the line of stroke until the diagonal from the corner of the feed box to the far corner of the table is reached, when they are caused to curve inwards towards the wash water, and then curved out again to the end of the table, the last length being parallel to the first, but in a horizontal plane thrown out of line by about 6 inches.

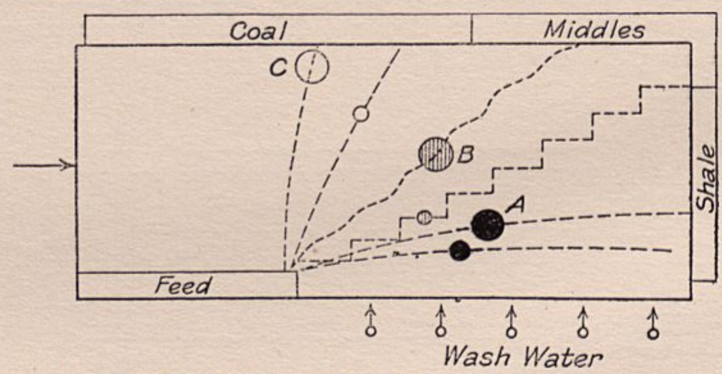

FIG. 199.—RIFFLED TABLE PARTICLES' PATHS.

The material travelling along the grooves has, therefore, to combat a steady stream of wash water deflected into each groove, and only the heavy dirt is able to overcome this obstruction and travel along to the end of the riffle. In Fig. 199 is shewn the path of particles upon a riffled table.

The *H. H. Universal Table* has been introduced into this country within the last year or so and has been tried in several collieries with great satisfaction as regards the purification of the coal. The capacity of the table is about

2 to 2½ tons per hour and the following is an analysis of a washing carried out on Durham coal of 0 to ⅜ inch, containing in the unwashed sample 30% of dirt over 1·4 S.G.

Coal Product.		*Dirt Product.*	
Washed coal (1·4 S.G.)	96·9%	Free coal	1·3%
Free dirt over (1·4 S.G.)	3·1%	Free dirt over (1·4 S.G.)	98·7%
Ash in clean coal	6·0%	Ash in coal	28·5%
Ash in free dirt	44·0%	Ash in dirt	79·33%

The table is one of the simplest mechanisms in use for coal washing, and the following description is that of the type of table on which the above results were obtained.

To a rigid frame or foundation are bolted interchangeable leg-support castings, which are alike either for floor or shaking frame, right- or left-hand table.

The castings are swung around, in a horizontal plane, so that the supports point to a common centre.

The same kind of castings are bolted in corresponding positions to the underside of the shaking frame, as shewn in Fig. 200.

Flexible supporting legs, of laminated wood strip construction, are placed between the floor castings and shaking-frame castings. These legs are made of carefully selected hickory or ash, treated in oil, graphited and wrapped with tape, which later is painted with several coats of waterproof paint. They are so constructed that the bending is uniform throughout the leg, thereby relieving it from any undue bending stress next to the castings.

At the concentrate end of the table, a flexible hickory or ash brace connects between the shaking frame and the floor frame, preventing side sway and helping to guide the table movement in its curvilinear path.

Fitting around three sides of the leg ends, and on opposite sides, are interchangeable clamp caps that fit over the sides of the leg-support castings.

A clamp-bolt passes through the casting-leg and cap, and holds the leg solidly to the castings both at top and bottom, thereby preventing any side movement.

Fitting between the head ends of the shaking frame and solidly bolted and dowelled thereto is a heavy yoke, to the ends of which is clamped fast the shaft that carries the unbalanced pulley. This weighted loose pulley is mounted between clamp collars on the shaft. Lubrication for the pulley is furnished from a grease cup screwed into the hollow shaft, the grease coming out of an oil hole placed centrally in the shaft.

Pressing against the yoke cross-piece are two coil springs that in size are proportioned to suit the power of the unbalanced weight in the revolving pulley. The purpose of these springs is to accelerate the forward and to retard and limit the backward motion. The other end of the springs presses against the top of a post which is hinged in a casting on the floor. Tension rods, for varying the spring pressure and for stroke adjustment, connect these posts to the fixed corbel.

The corbel supports the bumping post or brace, which is held rigidly to the foundation.

When the table is erected, the space between the yoke cross-piece and the end of the bumping post is about $1\frac{1}{8}$ or $1\frac{1}{4}$ inches.

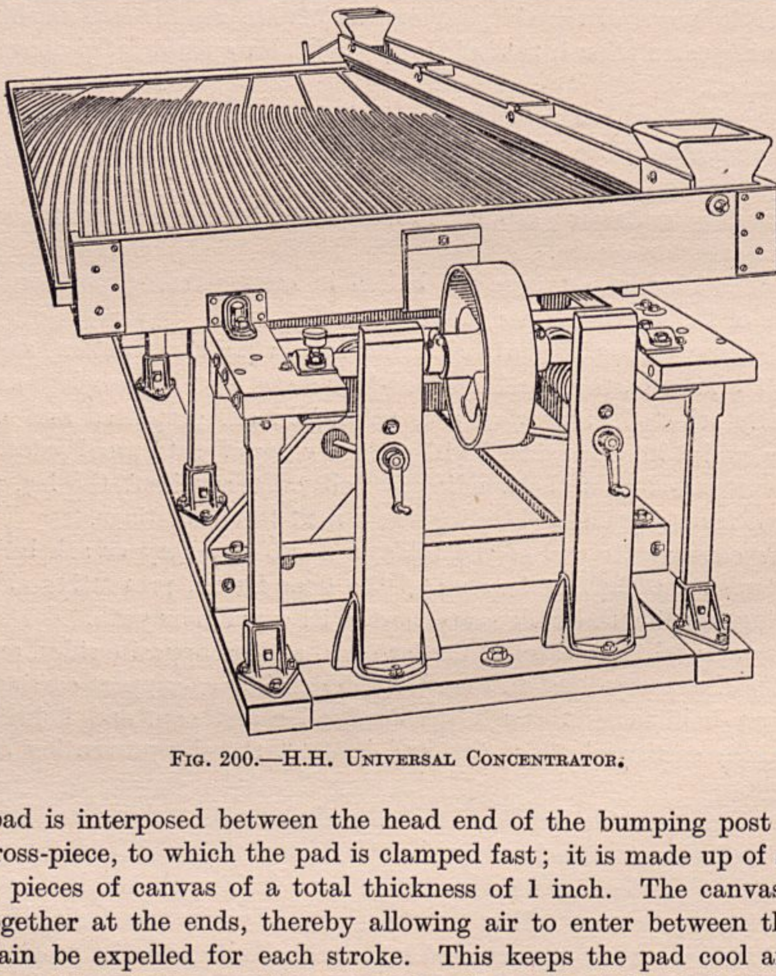

FIG. 200.—H.H. UNIVERSAL CONCENTRATOR.

A pad is interposed between the head end of the bumping post and the yoke cross-piece, to which the pad is clamped fast; it is made up of specially treated pieces of canvas of a total thickness of 1 inch. The canvas is only held together at the ends, thereby allowing air to enter between the strips and again be expelled for each stroke. This keeps the pad cool and gives just the right noiseless cushion required. From the table desk head-board is suspended a curtain pad, the lower ends hanging down in between the before-mentioned pad and the end of the bumping post. It consists of 7 or 8 pieces of specially treated canvas, the sides and lower ends being free from each other. The ends are about 3 inches below the lower side of the bumping

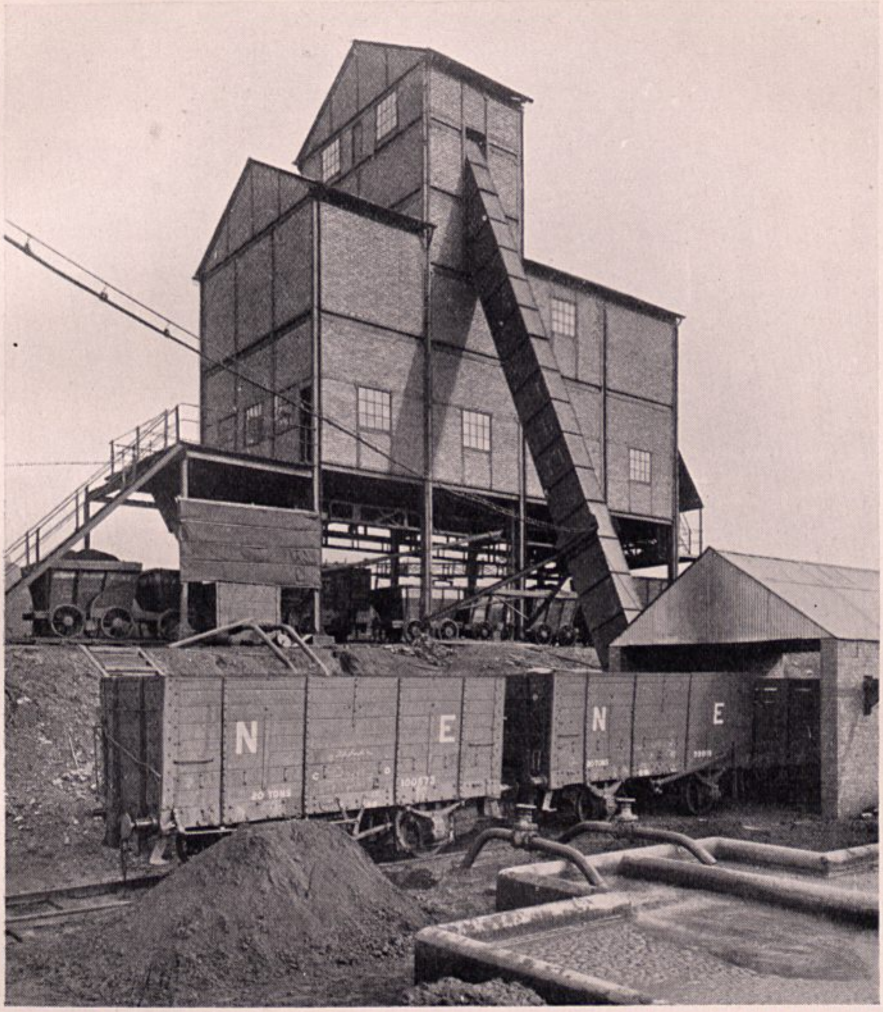

FIG. 201.—CONCENTRATOR TABLE WASHERY.

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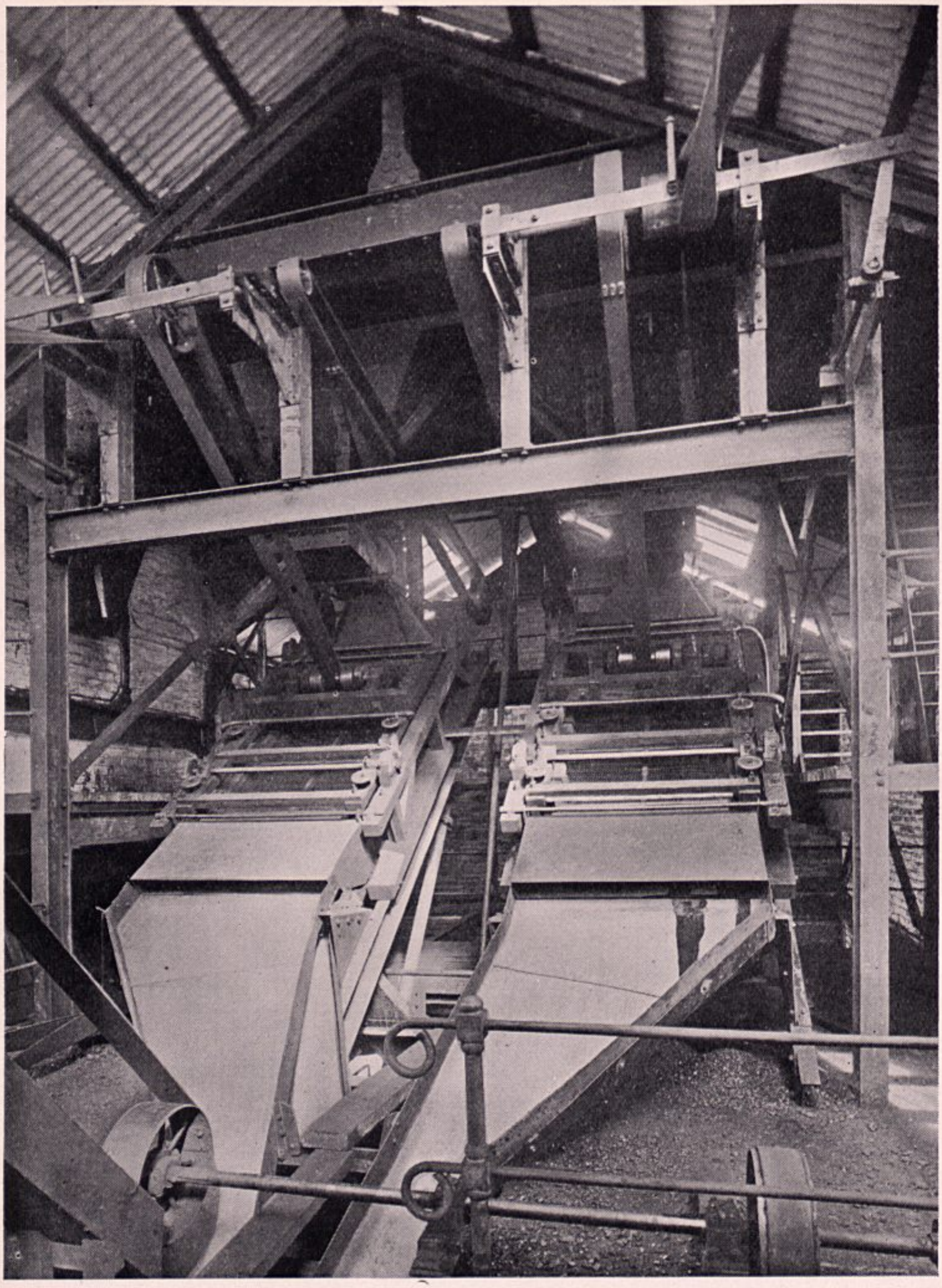

Fig. 202.—Sizing Screens.
(*H. Wood and Co., Ltd.*)

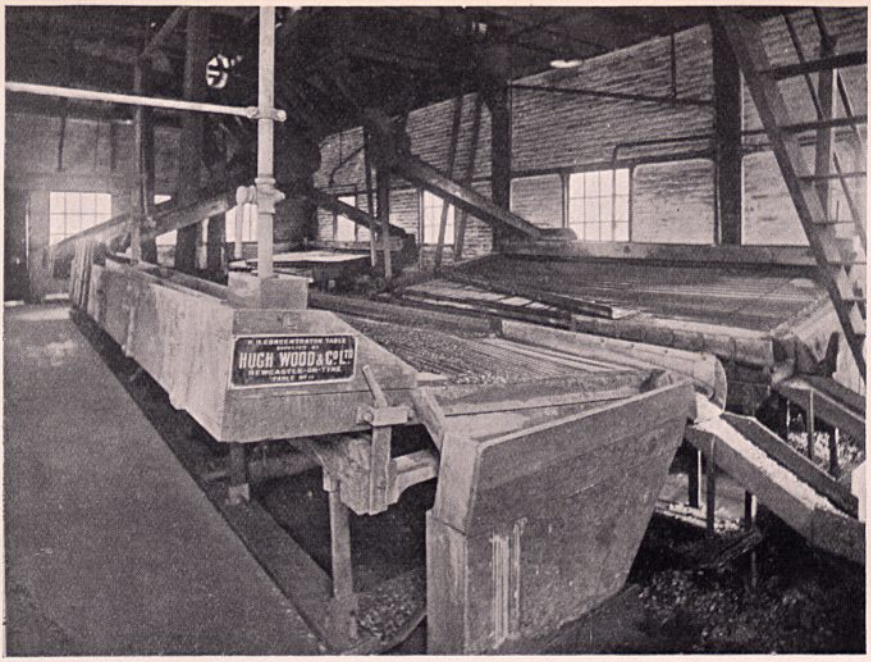

FIG. 203.—CONCENTRATOR TABLES.
(*H. Wood and Co., Ltd.*)

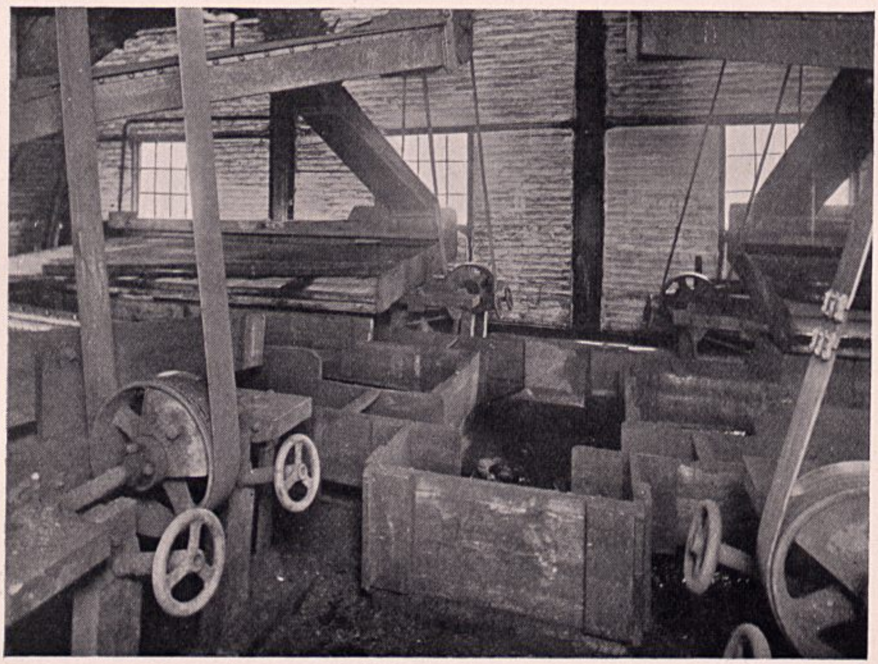

FIG. 204.—CONCENTRATOR TABLES, SHOWING UNBALANCED PULLEYS.
(*H. Wood and Co., Ltd.*)

[*To face page* 233.

post, so that one or more of these pieces of canvas can very readily be inserted to shorten—or pulled out to lengthen—the stroke while the table is running.

In this pad the air also, of course, enters between and leaves each strip of canvas for each stroke. When one-third of the curtain pad is inserted, the pulley not running and the spring pressure released, the space between the pad and the end of bumping post is about $\frac{1}{16}$ or $\frac{1}{8}$ inch.

This will give the proper length of stroke for starting up with, but it will be found that, without any load on the table, the stroke will be short. As the feed increases the stroke will automatically lengthen.

One or both of the spring posts can be employed to stop the reciprocations of the table. When the tension rods on these spring posts are screwed up, the upper ends of these posts press against the shaft, this in turn presses the pads solidly up against the bumping post and reciprocation ceases. The pulley keeps on revolving on the now perfectly stationary shaft.

The manufacturers claim that the stopping of the table by means of these posts is much superior to the old way of allowing the attendant to shift the belt on to a loose pulley.

If the table is to be shut down for any length of time, say for a day or so, it is well to insert (while the table is running) a piece of belting about $\frac{1}{4}$ inch thick, or as thick as can readily be inserted between the two pads or between the curtain pad and bumping post. This will almost stop the table in itself. Then screw upon the spring posts. This will prevent any forward set in the leg supports while the table stands idle. When ready to start up, loosen upon the spring posts and pull out the piece of belt mentioned before.

A good mechanical efficiency is gained by the use of two coil springs in the head motion end; should one of these coil springs break the remaining spring can be tightened up temporarily to give the proper stroke to avoid the necessity of stopping the table in order to replace the broken spring. On replacement, unloosen the other spring which had been temporarily tightened.

The table top is hinged to the shaking frame tail-side stringer. A multiple wedge is interposed between the shaking frame feed-side stringer and the deck cross stringers. By means of a screw at the concentrate end this wedge can be moved back or forth to give the proper transverse inclination to the deck. On the tail side of the table, the deck is hinged between brackets attached to the shaking frame. On the feed side of the table and at the concentrate end the deck is held from movement by a locking device. The hinges and locking device prevent longitudinal movement between deck and frame.

The concentrates drop into a small launder moving with the table and lead this launder through two pipes. The feed- and wash-water box is made in one so that the feed can be stopped at any point desired, according to the amount of water in the pulp. This box is held very rigidly to the table deck and cannot become loose. The wash water and tipping adjustments and the locking device are close together at the same corner of the table, thereby saving many steps for the attendant.

The table top is covered with $\frac{1}{8}$ inch thick linoleum.

The power required is $\frac{1}{4}$ H.P. for light loads and $\frac{3}{4}$ for heavy, an average of $\frac{1}{2}$ H.P.

In Fig. 201 is shewn a washer of concentrator tables of 1000 tons per day capacity. The coal is elevated into a storage bunker in the roof of the building, and from there it passes by jigger feed to the vibrating screens shewn in Fig. 202. The raw coal is fed through a $\frac{7}{8}$-inch bar screen and all below $\frac{1}{8}$ inch is taken out, the remainder being sized on the vibros into $\frac{1}{8}$–$\frac{3}{8}$ inch, $\frac{3}{8}$–$\frac{5}{8}$, $\frac{5}{8}$–$\frac{7}{8}$ inch, and then led to the respective table.

There are four tables of the H.H. type, each capable of dealing with 12 tons per hour. The smaller size is fed on to two tables and the other two sizes on one table each. The vibros run at 1400 r.p.m. and deliver into the small feed hoppers shewn at the top of the illustration (Fig. 203). It will be seen from the photograph that the clean coal is delivered into the chutes on the right and the dirt in the near chute.

Comparing Fig. 200 with the illustration (Fig. 203), it will be remarked that the outside riffles at the head of the table have been replaced by a guide plate, and the coal-collecting trough is only about one-third of the length of the table. A sieve plate is fitted in the bottom of the coal trough to take out the water, which is led to the double settling pond shewn in the foreground of Fig. 201. In Fig. 204 is shewn the driving headstocks of the four tables, the unbalanced pulley and the bump-adjusting gear are clearly defined. The amount of free dirt in the raw coal is given as 20%, which is reduced to 2% in the washed coal. The total power to drive the plant is 35 H.P., and the water make-up is about 12 gallons per minute.

The tests on the washed coal have been highly satisfactory to the colliery company.

Froth Flotation.—The treatment of very fine coal particles has been solved by the principle of Froth Flotation. This principle, stated generally, amounts to the separation of non-wetting from the wetting substances. There are some substances which resist the spread of water over their surfaces and others which seem to attract the water; in other words, the former present a stronger attraction for air than the latter, and, therefore, the non-wetting bodies resist the displacement of air from their surfaces by the water. It has been found that certain reagents, or contaminants, increase the non-wetting properties of certain substances, and are also productive of a strong air bubble which permits the production of a large quantity of froth, so that the selection between the particles is rendered more simple. The aëration of water is not sufficient to produce the required quantity of froth, as the bubbles so formed in passing through the water coalesce and on reaching the surface immediately deflate, not having sufficient skin tension to maintain their form. A surface of a wettable material allows the water to spread out as, say, upon glass. A drop of water placed upon glass will spread itself over a relatively large area, and at the point of contact the slope of the surface of the drop with the glass will be at a sharp angle, as shewn in Fig. 205. This

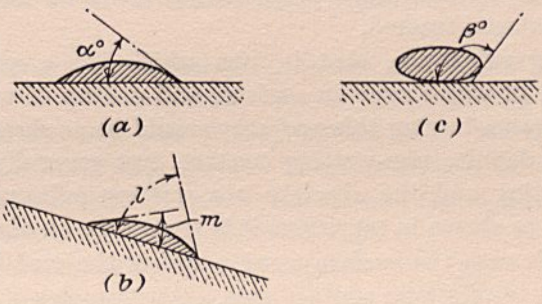

FIG. 205.—WATER-DROPS ON FLAT SURFACE.

is due to the lesser resistance of the water spreading out upon the surface, and is sometimes called the surface tension. The attraction of the substance overcomes the resistance along the plane and, therefore, causes the liquid to spread out. If this plate of glass were given a slight tilt, the drop of water would take the form *b* (Fig. 205) before movement. At one side the angle of contact with the plate *l* would be greater than the other angle *m*, and just at

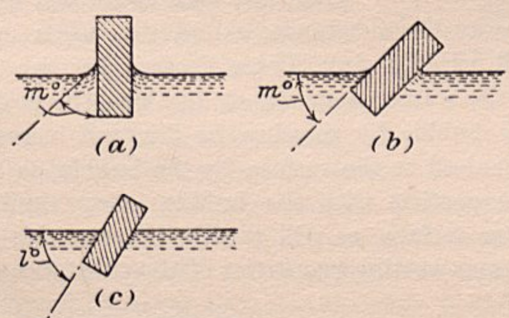

FIG. 206.—CONTACT ANGLE OF WETTED SURFACES.

the moment before the drop slides that angle would be the limit of a maximum contact angle. Similarly, at the higher side of the bubble before the point of contact moves the angle would be the minimum angle of contact. This may be explained in another form.

If a body with a plain surface be inserted vertically in water, as shewn in Fig. 206 (*a*), the water will creep up the sides forming a contact angle. If the body be now tilted, as shewn in (*b*), until the surface of the water becomes horizontal to the point of contact the angle made by the surface of the water and the plane of the body, *m*, will be the minimum angle of contact. Reversing the tilt and bringing the body back towards the vertical, the water will not begin to creep up the side until the maximum angle of contact has been reached, as represented by *l*. This particular property has a great influence upon the permanency and the strength of contact of the bubbles to the surfaces of the material treated.

A non-wetting substance, that is, one which has a preference for air, resists the spread of water over its surface, and a drop of water placed upon a plane of a substance having this property would be as shewn in Fig. 205 (*c*), where there is a definite non-wetting contact, but generally as intermediate between the wetting and the absolute non-wetting substances the angle of contact would be as shewn in (*c*), where it is seen to be an obtuse angle greater than 90°. In this case the surface tension resists the mobility of the water, drawing it back to a minimum contact area. As examples of complete wetting and non-wetting substances, water on clear glass and insoluble oil upon water respectively may be cited.

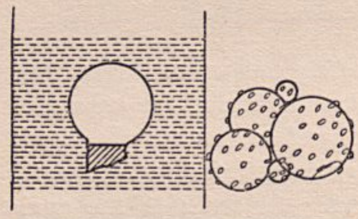

FIG. 207.—LOADED BUBBLES.

The contact angle with the surface of an immersed body will naturally tend to support that body, as there will be a drag upon the surface if the surface tension be greater than that of the water tension, such as is obtained when fine coal is thrown upon the surface of water, whereas a wettable substance, as quartz, when sprinkled over the water surface, will rapidly sink. These factors become operative when a particle of coal in the water meets an air bubble—the coal will immediately attach itself to the bubble by piercing the skin and increasing its buoyancy and by so doing is raised to the surface by the bubble, as shewn in Fig. 207. The contact of the particle with the bubble being similar to that which obtains at the water surface, as will readily be seen this selective action is directly due to the non-wetting properties of the substance or to the degree of surface tension.

In the commercial process, an insoluble oil or other free agent is added to the water, and is productive of a large amount of strong bubbles which maintain a separate existence and rising to the surface form a permanent froth, sufficiently strong to support a considerable quantity of coal. The amount of the reagent should be sufficient to emulsify the whole of the pulpy coal. If the water containing coal and reagent be so agitated as to entrain air, small bubbles are formed which attach themselves to the small particles of coal, whereas the dirt particles remain in isolated suspension in the water during the agitation. On allowing the pulp to come to rest, the bubbles with their load will rise to the surface and form a buoyant froth suspending the coal. The dirt particles, not having the help of bubbles to overcome the effect of gravity, sink to the bottom. As a commercial proposition the principles are applied to produce in as small a space as possible the separation of the small coal particles in an economical manner. A mixture of coal, contaminants, and water is alternatively agitated by paddles or air and brought to rest.

In Fig. 208 is shewn a diagram of one of the most recent machines adapted to deal with fine coal of 0 to $\frac{1}{10}$ inch. It consists of a series of compartments, A being the agitation box and B the frothing box. At the bottom of the agitation box is a horizontal paddle which is caused to revolve at about 300 r.p.m., causing the pulp to rise on the sides of the chamber in the manner shewn by the hatched lines, Fig. 209; at the same time it draws in more pulp to replace the overflow into the frothing chamber by the channel C. Over this large increase of water surface from the centre depression to the line of contact with the sides air is dragged into the mixture and bubbles are formed which, passing into the chamber, B, are deflected by a baffle plate downwards, before being able to rise to the water level. The dirt particles entering the frothing chamber are precipitated to the bottom of the chamber. When a number of minor bubbles congregate together they coalesce to form larger bubbles, which accumulate at the surface of the water and form a compact froth. The froth upon reaching the tip of the outlet overflows into the trough, D. The battery of cells is worked in series, that is, the discharge from No. 1 frothing chamber is drawn into No. 2 agitation box by the suction, due to the revolutions of the paddle. The discharge from this No. 2 agitation box into No. 2 frothing chamber is again extracted from the base to feed the agitation chamber, 3, and so on, as shewn in Fig. 209. The violent agitation of the mineral-separation machine is productive of a high-capacity value. It is built of wood of generous scantling and stoutly braced by square timbers, which are extended above the agitation box to form supports for the shafting carrying the bevelled gearing and the vertical spindles of the paddles. The paddles are formed of four blades having one edge bent at right angles to the plane of revolution so as to give the necessary fillip to the pulp. The base of the frothing chamber rests upon the bed cross-piece and is built with three sides vertical and one side sloping away from the base. The inlet for the pulp of the second agitation box is connected by a pipe to

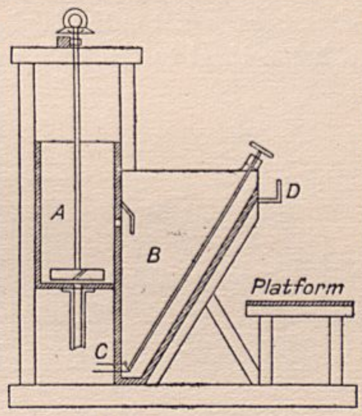

Fig. 208.—Mineral-separation Box.

the discharge outlet at the base of the first frothing chamber, and half-way between the base of the agitation box and the level of the outlet of the chamber B, a rectangular opening is made in the vertical wall to allow of the passage of the air-laden pulp. In front of this opening a baffle or deflecting plate is fitted with its bottom edge extending to about 6 inches below the water surface, so that all particles are thereby forced to run the gauntlet of flotability by being caused to descend into the water before being able to rise at the top lip of the outwardly inclined side of the frothing chamber, where about 6 inches above water level a trough is secured to carry off the overflowing froth. To facilitate the removal of this froth revolving flapping plates or skimmers are fitted just over the discharge lip. The base discharge valve is operated by a hand-wheel placed in an accessible position just above the overflow outlet. At the base of the frothing chamber the dirt outlet is placed, which is connected by a long spindle carrying a hand-wheel to the slide valve. The pulp fed into the first box consists of

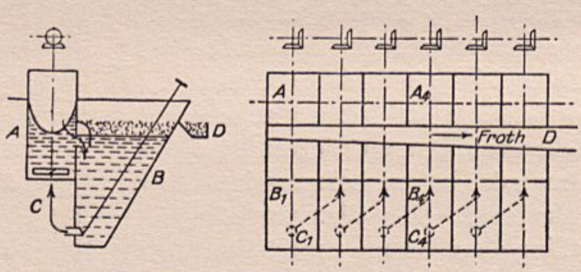

FIG. 209.—MINERAL-SEPARATION BOX.

4 parts of water to 1 part of coal with a small proportion of reagent. The level of the pulp at each box is automatically regulated by an overflow at the excess of water discharge, which also carries off a large part of the dirt.

It is claimed that this machine can deal efficiently with $\frac{3}{8}$-inch coal, but the makers prefer to limit the range to zero to $\frac{1}{10}$ inch as being the most economical.

There is little doubt that, used in conjunction with a gravity washer for the treatment of fine coal, it fills an important gap in the process of coal washing.

The following table is given as a comparison of gravity washer results compared with froth flotation.

Comparison of Jig Washed $\frac{1}{10}$-inch with Flotation Washed

Washer.	Ash % Coal A.	Ash % Coal B.	Ash % Coal C.	Ash % Coal D.
Jig	13·27	18·0	30·2	35·0
Flotation	4·54	6·8	9·1	10·4

These figures are extremely favourable to the present system, but it should be pointed out that the compared machine was of the oldest type of Baum washer and the comparison for that reason is not strictly just, but, on the other hand, it is undeniable that the figures are sufficiently different to show the positive value of this treatment with fine coal. The slime of the jig washer was not included in the above percentages, whereas the mineral-separation figures include the whole of the coal from 0 to $\frac{1}{10}$ inch.

The suggestion has been made to use this system to treat coal of from $\frac{3}{8}$ inch to 0 as the undersize of a preparatory screening of a jig washer. The froth machine will then separate the pure coal of from 0 to $\frac{1}{10}$ inch with the froth, leaving the fine dirt and all sizes of dirt and coal larger than $\frac{1}{10}$ inch with the water. The fine dirt is then disposed of with the excess water overflow, whereas the larger coal and dirt are conveyed to the fines gravity washer for further treatment.

In this arrangement the water of the washers will serve for the froth treatment, and thus a great deal of the slurry troubles of most washeries will be overcome.

The alternative method is to pass the raw slack over a vibro screen or dust-extraction plant to take out all below $\frac{1}{10}$ inch, which is the ideal size for a froth flotation machine. It is claimed by this means to eliminate all slime from the washery circuit, the useful product containing only a small percentage of dirt, whereas the discharged residue is a useless small shale. The manufacturers do not like the idea of installing the machine for the treatment of slurry as a separate product, since the results are not satisfactory and the capacity is not sufficient to prove economical.

The drainage of the resultant products from the machines has hitherto presented serious obstacles to its wider use; the delivered product from the machine is on the average 1 part of water to 1 part of coal; and to effectively dewater the product, the floccules of fine coal are gathered into a drainage bunker and allowed to settle, after which the residue is further dewatered in an Oliver type filter, which on the average will reduce the moisture content from 50 to 14%.

The makers of the mineral-separation box in their system devise a method to overcome the moisture trouble. This method consists in adding to the flotation product about 4% of tar or spent oil and agitating the mixture for a sufficient time to ensure a thoroughly intimate mixture and then submitting the whole to pressure in a small briquetting machine. The result is a small, soft briquette of ovoid pattern, which is easily broken by hand into a dry dust, but sufficiently compact to allow of handling in bulk without serious disintegration. After pressing, the ovoids contain from 5 to 9% of moisture, according to the quantity of tar intermixed and the amount of pressure to which they were submitted.

A mixture of 4% tar gave the following results under the respective pressures :—

A pressure	of	about	1	ton per	square inch	gave	9·6%	moisture.
,,	,,	,,	$1\frac{1}{2}$	,,	,,	,,	8·2%	,,
,,	,,	,,	2	,,	,,	,,	6·9%	,,
,,	,,	,,	3	,,	,,	,,	5·8%	,,
,,	,,	,,	4	,,	,,	,,	5·3%	,,

It is said that these briquettes when stacked reduce their moisture content with rapidity, one particular example being that of a small stack being reduced from 9·7% moisture to 2·5% within 24 hours, and from 9·7 to 5% in 12 hours. The flocculated mass leaving the machine is collected in a series of two or three mixing chambers, where the spent oil is added from whence the resulting mixture of agglomerates is discharged into a draining conveyor or machine, from which it is delivered into the receiving hopper of the press. On passing the machine the expelled water and ovoids are taken over a dewatering sieve, and thence the latter are discharged into a bunker. The froth flotation method has certainly succeeded in dealing with extremely difficult materials and latterly has been utilised in several coke-oven washing plants.

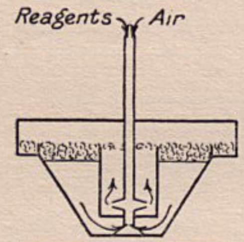

FIG. 210.—DOUBLE FLOTATION BOX.

In Fig. 210 is shewn a double flotation box with hollow spindle allowing access of air and reagents to the inner chamber. Very favourable results are claimed for this design.

CHAPTER XIV

DEWATERING OF FINE COAL

One of the most obstinate problems of the washery engineer is the dewatering of the washed fine coal. The natural moisture of the raw coal varies from 1·5 to 5%, but the smaller sizes when subjected to washing pick up a large amount of water which obstinately clings to the particles even when they are subjected to very severe mechanical processes.

The earliest treatment of this subject originated in Germany with the introduction of the massive draining band. The washed fine coal is flushed from the washer box over a length of fine-mesh draining sieve, as shewn in Fig. 211, where A is the distributing trough, B a wedge-wire brass sieve with 1 millimetre slits placed at an angle of 15° to 18° to the horizontal, and C is the waste-water collecting trough, having an outlet to the pump well.

The greater part of the flushing water is extracted on this sieve and the fine coal is dropped into the draining chambers, which are deep boxes constructed as shown. There are two heavy side or web plates connected by a central vertical plate and kept rigid by heavy brackets riveted to a bottom plate. On the bottom edge of the web plate is riveted a length of link, forming part of the connecting chain. The bottom plate is slightly curved and is perforated over the greater part of its area. The chain speed of these buckets is about 1 foot per minute, so that the capacity of the box is large, actually from 1 to 2 tons. The fine coal being fed into the chamber heaps up in the centre, and at the time of loading the central webs are slightly diverging at the top edges, but on travelling further from the bottom sprocket they become closer together and squeeze the contained coal. To increase further this squeezing effect, the path of the buckets is made so that it alternates from concave to convex, and *vice versa.* The squeezing causes the moisture to drip through the perforations and into the pump well at the base of the band. As these conveyors are about 60 feet long, as much as 40 tons represents the load carried and provides a 60-minute drainage. The success of the conveyors as dewatering mediums is, however, small, as the average percentage of moisture contained on discharge into the bunker at the upper end is about 22 with coal of ½ inch and less. The extremely heavy gearing and supports together with the large building required make the installation very costly, and the maintenance costs are heavy.

Various arrangements of vibrating sieves to take the place of the fixed sieve have been used as an auxiliary to the draining conveyor, but only slight improvements resulted.

The draining conveyor in this case accounted for less than 5% improvement on the decrease of moisture as delivered at the lower end and discharged at the upper sprocket, which represents only about 1% of the contained moisture at the initial stage.

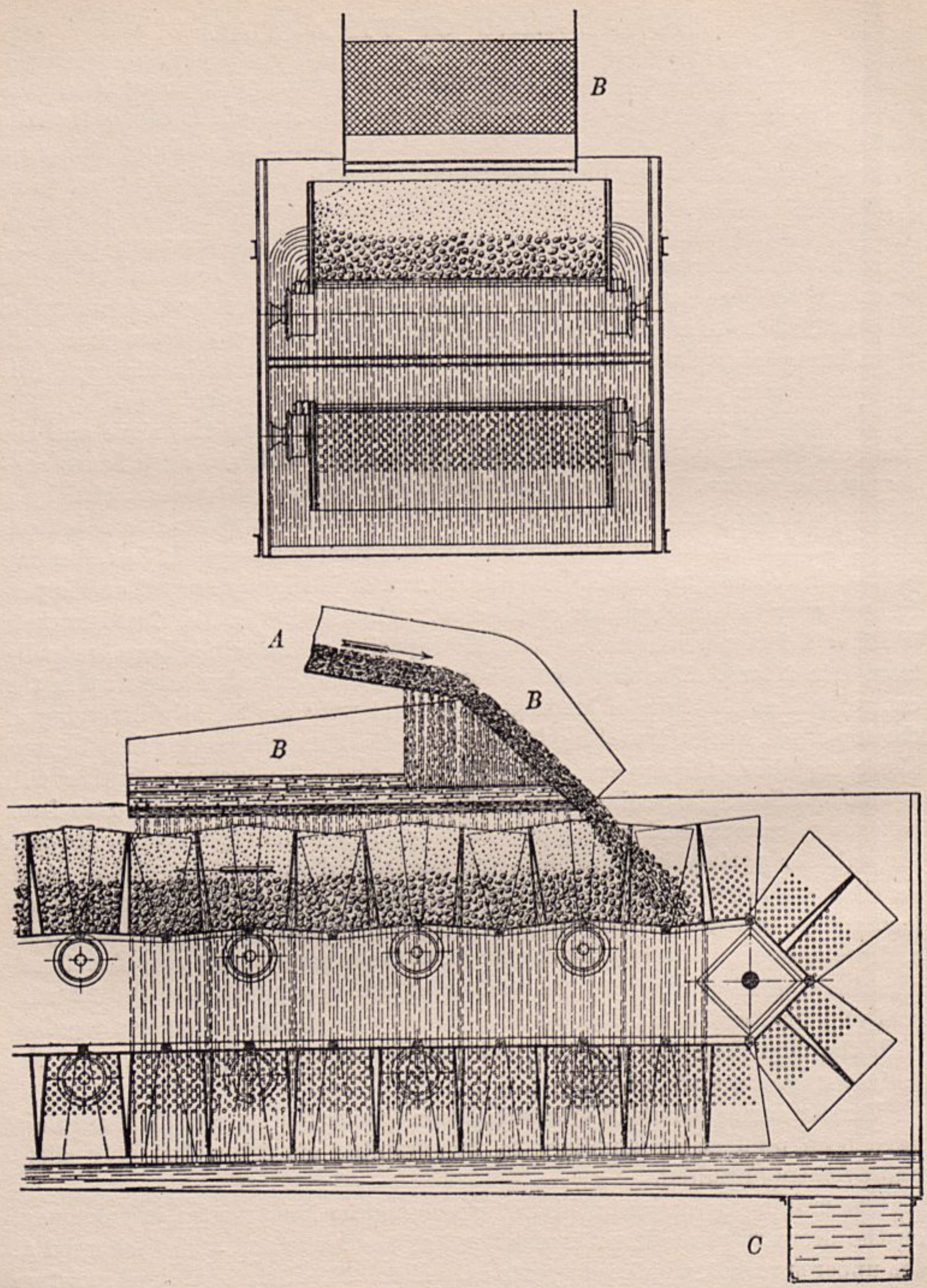

FIG. 211.—DRAINING BAND CONVEYOR.

In all the older washeries erected in this country having draining bands the moisture troubles have proved so great a hindrance to the sale of the coal that the engineers concerned have found it imperative either to cut out this machinery and instal a more modern appliance in its place, of lighter construction and lesser maintenance cost, or feed a quantity of nut coal into the draining band to act as a filtering medium for the fine coal. In several of these plants which the author has visited the large amount of very fine coal passing through has choked up the filtering spaces to such an extent

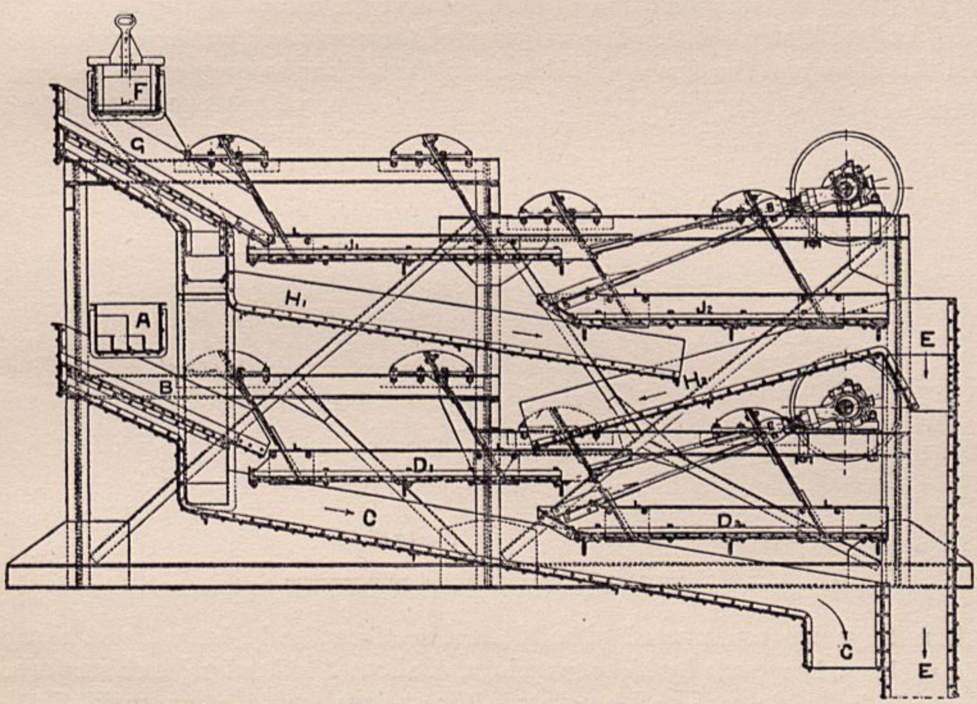

FIG. 212.—FINE-COAL DRAINAGE ARRANGEMENT WITH SLURRY-REFINER. (*Institute of Mining Engineers.*)

that a good deal of free water has been carried in the draining band for about one-sixth of its travel. The inclined wedge-wire fixed sieve as a primary dewatering medium is after a time extremely ineffective unless given constant attention by the attendant. The tendency is for the flushing water transporting the coal to leap over the sieve surface in a concentrated stream rather than be spread out over the whole area in a thin sheet. This is in part due to small masses of coal, already robbed of the water, being left stranded in patches upon the sieve at points immediately in advance of the free slits. These patches remain sufficiently obstructive to deflect the water to one side until a further patch is formed, which deflects the water so as to undermine the former, giving it sufficient momentum to pass down the sieve. Some ingenious attendants, to remedy this defect, have devised a curtain of sacking or canvas to ensure the spreading out of the stream of flushing water equally over the surface. The low efficiency of the conveyor and the heavy capital cost caused engineers to give up this cumbrous machinery and instal lighter and more efficient types of shaking sieves, subjected to high periodic vibrations. In Fig. 212 is shewn one of the latest of these dewatering sieves.

The fine coal is flushed from the washer box into the distributing trough, A, from which a side outlet causes the liquid to impinge against the back plate of the trough and be directed in a thin sheet over the brass wedge-wire sieve, B, of $\frac{1}{2}$ or $\frac{3}{4}$ millimetre slits. The majority of the contained water is extracted on this sieve and the fine coal slides down the surface to drop on to the first tray of the shaking sieve, D, of brass wedge-wire, with $\frac{1}{2}$ millimetre slits;

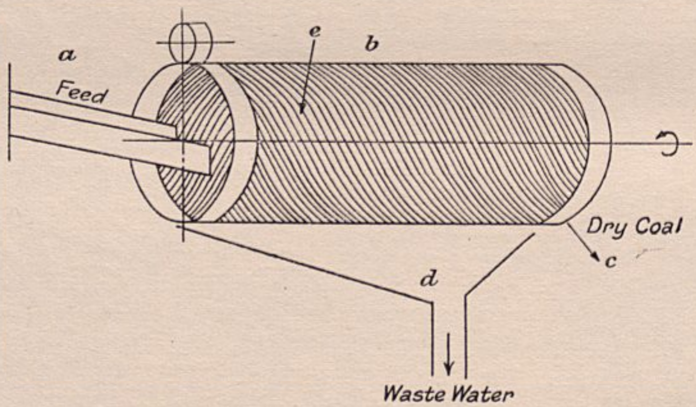

FIG. 213.—MINIKIN SPIRAL DEWATERER.

these trays are constructed of mild steel sections firmly braced and slung from channel supports by hickory springs, of about 3 inches by $\frac{1}{2}$ inch sections, securely bolted in cast-steel brackets. The springs are set at an angle of 60° with the horizontal, as in the case of the vibro screens.

The trays are given a reciprocating motion by ash connecting rods of 5- by 2-inch sections, bolted rigidly to the tray at one end and strapped to an eccentric of about $\frac{3}{4}$-inch throw at the other. This motion is modified by the radial effect of the hickory springs.

The eccentric shaft is driven at about 300 r.p.m., and the rapid reversal of direction together with the forward throw of the coal causes the latter to travel along the tray, at the same time subjecting it to a draining action.

A later development of the above shaking sieve is the spiral dewatering apparatus which takes the place of the fixed sieve.

In Figs. 213 and 214 are shewn the supply trough, *a*, distributing the fine coal on to a cylindrical sieve, *b*. This cylindrical sieve is built up of brass wedge-wires disposed spirally on the circumference. The fine coal being deposited on the inner surface is quickly drained of its water, and the rotation of the cylinder causes the coal to be slowly conveyed along the spirals to the discharge end immediately over the shaking sieve, *d*.

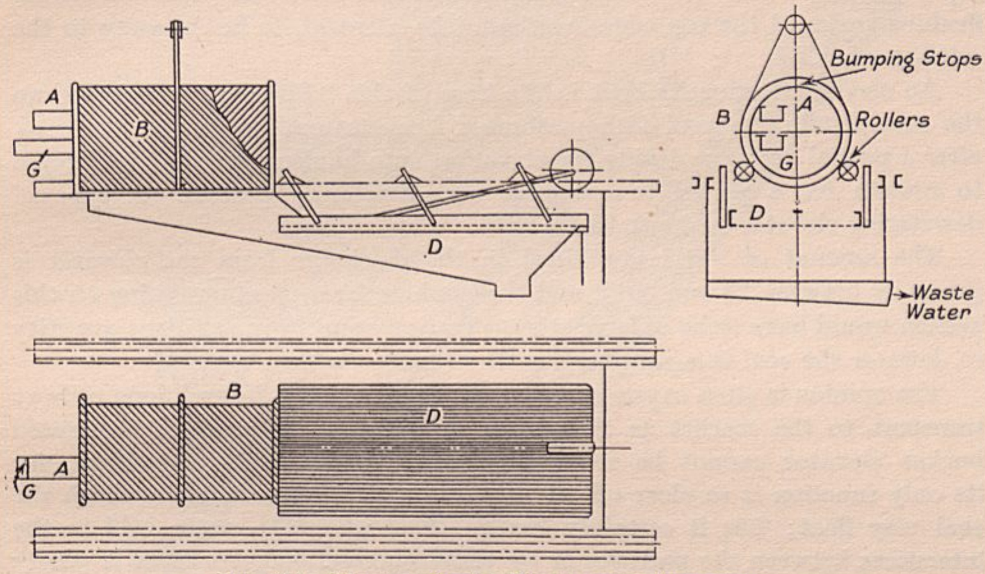

FIG. 214.—MINIKIN SPIRAL DEWATERING APPARATUS.

At a slightly lower level than the trough, *a*, is the slurry trough, G, which distributes the liquid slime from the settling tank over the fine coal in the lower level of the cylinder, so that the small particles are filtered by the layer of fine coal as well as the fine-mesh sieve.

The actual path followed by the coal along the spirals is much longer than would be the case of a fixed sloping sieve of similar length to the cylinder, and the circular movement further facilitates the drainage. The shaking sieve is added to promote a more complete drainage and mixing of the slime with the fine coal. A suitable arrangement of mechanism gives a slight bump to the circular sieve every quarter of a revolution, to prevent the coal becoming sluggish.

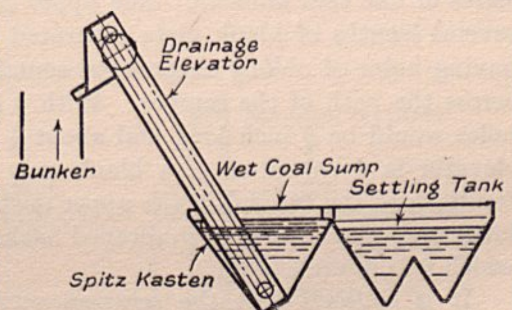

FIG. 215.—DRAINAGE SUMP AND TANK.

A system of dewatering the fine coal common to a number of washing plants is that shewn in Fig. 215. It is one of the oldest of the several types used. The fine washed coal is flushed from the washer box by troughs into a large sump or well, often called "Spitzkasten," in the base of the washery building, and forming part of that building. The well is generally of an inverted pyramid shape with a peripheral overflow constructed round the top edge. The fine coal sinks to the base of this chamber, while the clearer flushing water at the top edge overflows into a trough to be let away to the settling pond.

An elevator having its boot in the base of this "Spitzkasten" scoops up the semi-liquid fine coal into perforated buckets and discharges the coal, after a partial drainage during the elevation, into bunkers, where it is allowed to remain for a period to complete the dewatering process. A type of dewatering elevator is shewn in Fig. 216.

The amount of water contained in the discharge from the elevator is generally between 25 and 30%, and the bunkers for a plant operating on this system would have to be of large storage capacity and be in sufficient quantity to dewater the coal to a saleable limit.

The opinion is often expressed that washery engineers depend upon railway transport to the market as their main dewatering medium. A perforated bucket elevator cannot be reasonably called a dewatering appliance, for its only function is to clear off all the loose and surplus water in which the coal may float; but it certainly has no effect upon the water held in the interstices between the particles or by viscous attraction. Its effect is purely static and should, therefore, be prolonged over some considerable period to obtain results at all satisfactory. This, of course, is impossible and various contrivances have been adopted by different makers to do away with the necessity of large bunker storage. One of these is shewn in Fig. 217. It consists of a scraper conveyor having two decks or tray plates running over a series of fine coal bunkers. The upper deck of the scraper is divided up into several lengths of blank plate separated by short lengths of perforated plate having holes of oblong shape with rounded ends, with the largest dimension across the path of the scraper. With $\frac{3}{8}$ inch as a maximum size of coal, the holes would be $\frac{3}{8}$ inch long and about $\frac{1}{8}$ inch wide. The discharge from the elevator is dropped on to a blank tray and is scraped along over the perforations to the far end of the upper deck, from which it is dropped on to the lower tray plate and is then scraped back by the return scrapers to the bunker which it is desired to fill.

It is claimed that the scrapers pushing forward the coal squeeze this sufficiently to force out the contained moisture in advance of the coal, as shown at (*a*), and that on reaching the perforations this water immediately drains through into a trough which leads it to the pump well.

It is further claimed that this apparatus extricates all the free water contained in the coal and that it reduces the moisture content 50% in the

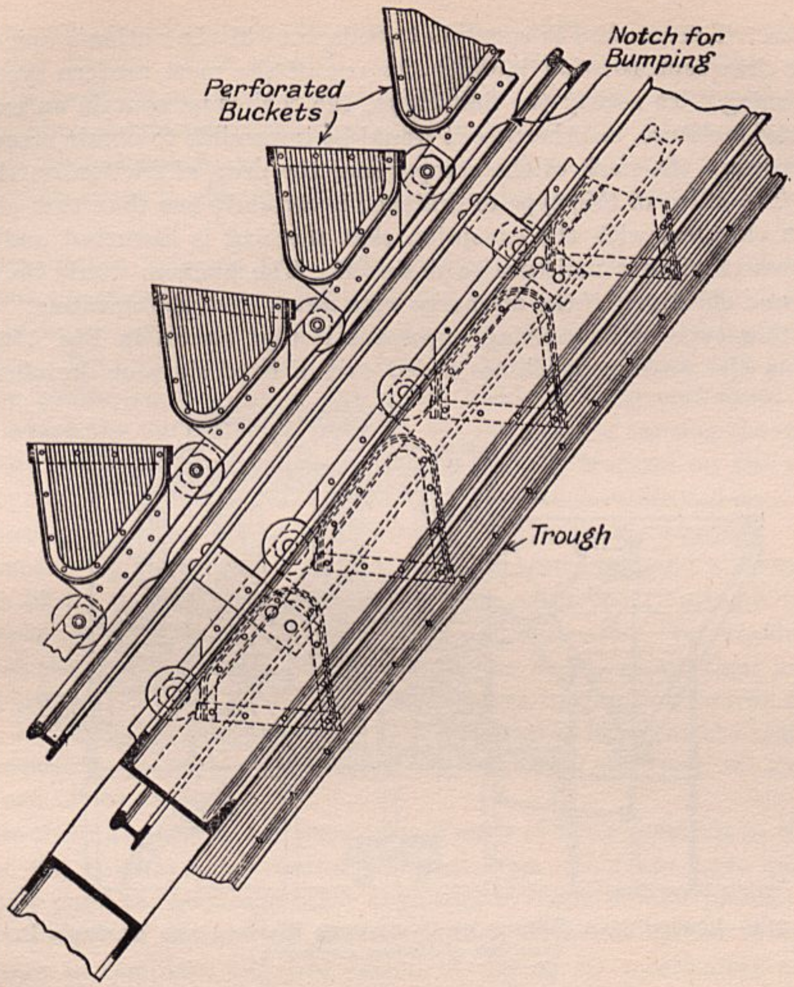

FIG. 216.—DEWATERING ELEVATOR.

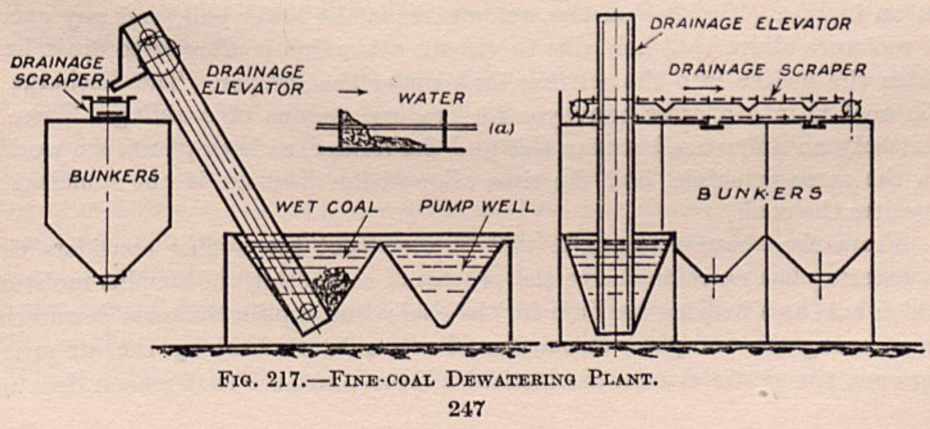

FIG. 217.—FINE-COAL DEWATERING PLANT.

operation. This method is somewhat crude, and in the author's opinion the greatest drawback to what is otherwise one of the most modern systems of coal washing. To satisfy the first claim, the coal must contain an excessive amount of moisture, as otherwise it would be impossible to obtain a squeezing effect between the push of the scraper and the drag of friction on the tray plate. The effect of this type of drainage is certainly less than that obtained from an elevator, with the exception that the coal is disturbed and allows the excess of viscous moisture to drain off. The bunkers would do this as readily and effectively if the discharge were direct from the elevators.

Another type of dewatering apparatus is that shewn in Fig. 176. The coal from the washing machines is led over a fixed sieve or draining shoot

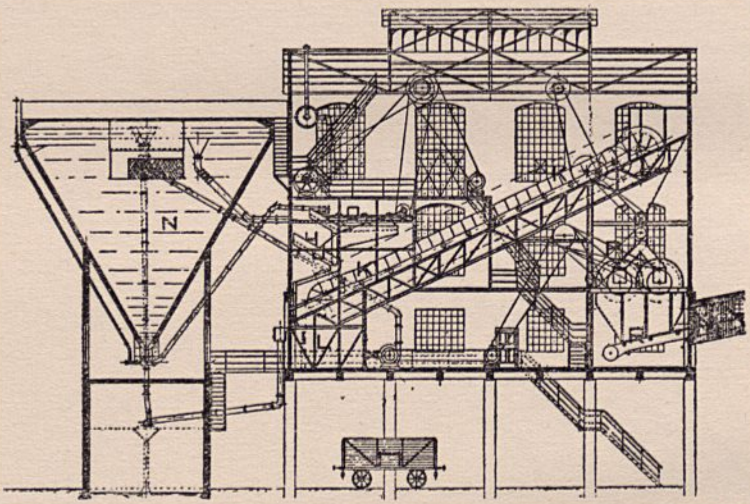

Fig. 218.—Longitudinal Section of Continuous Washing and Draining Plant. (*Institute of Mining Engineers.*)

and dropped into a draining conveyor, which is an ordinary scraper placed on an incline. The feed of the wet coal is at the lower end, and any excess of moisture above that held due to viscous attraction is allowed to drain back down the incline into the settling tank under the scraper. The discharge of the coal is into a cross conveyor for feeding wagons of a siding. There is certainly no difference between this and the former, as both plants are worked on the same principle, and the time allowed for drainage is not sufficient to dewater the coal.

From the above remarks it will be seen that the author considers that dewatering has no reference to the process of extracting the surplus moisture, which acts as a floating medium for the coal; but applies the term dewatering as meaning the complete extraction of all moisture held by the air spaces between the particles as a mechanical mixture, and for that reason does not consider any process which does not attain a 12% moisture content as a dewatering system. Fine washed coal should not be used in coking practice unless the moisture content is less than 10%. Coke-oven managers are now insisting upon a moisture content no greater than 8%. There is no reason why this should not be attained with fine coal, as without the admixture of slurry or slime it should be brought to this state within 15 hours of washing.

Various other methods have been attempted for the drying of the fine coal; but no greater success has attended their use, and the cost and the relatively large amount of machinery required have militated against their wider use. They generally take the form of centrifugal driers with revolving vanes or blades, running at a high speed inside a finely-perforated mantel against which the wet coal is forced with the intention of causing the moisture to penetrate the perforations of the screen and be trapped on the outside. The fine coal is allowed to fall in this chamber and be collected in a central mouthpiece, from whence it is transported to the bunkers.

In another type the coal is led over a perforated plate and a strong blast of air is blown through the plate, rakes being employed to stir up the coal and expose its surfaces to the action of the air currents. Yet another type is that of long tubes of large diameter revolving slowly round their axes and forming part of the flue for a fire. These tubes incline downwards towards the fire, but stop short of the same. The wet coal is fed in at the higher end and is caused to travel slowly towards the fire, being subjected all the while to the heat of the exhaust gases.

While there are one or two examples of each of these methods in different parts of the country, the results obtained from their use have not been sufficiently good to encourage other engineers to instal similar plants.

Any method of dewatering the coal which does not spread it out into thin layers to facilitate the free action of drying by mechanical or other means cannot be successful over a short period of time, such as is demanded by modern washeries depending upon sales. The static method of drainage bunkers is treated elsewhere.

There is an opportunity for inventors for an economical and efficient coal drier—particularly where the product is to be utilised for the manufacture of coke and gas. In coke manufacture, silica ovens, which are used with rapid coking times at high temperatures, are adversely affected by an excess of moisture. Thus if a coal contains 12% free water on a plant having a capacity of 500 tons, there would be about 13,500 gallons of water uselessly evaporated daily in the ovens. Apart from an increase in the coking time and the loss of temperature and the destruction of the lining, the coking quality of the coal is affected and the ammonia liquor weakened.

Whilst bunker drainage is on the average very good, there are patches of coal more wet than others due to the gravity drainage of the upper layers through the lower.

One of the latest machines for the treatment of wet coal is that known as the "Carpenter" drier shewn in Figs. 219 and 219A. It is a continuously operating centrifuge which ensures a uniform degree of moisture throughout

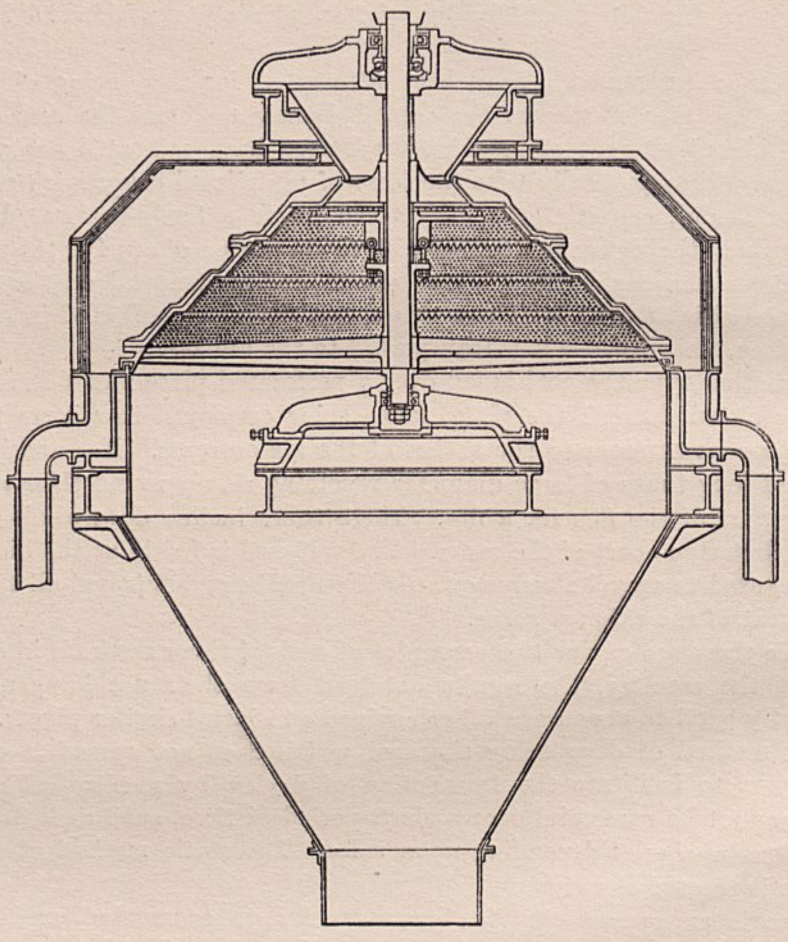

FIG. 219.—THE CARPENTER CENTRIFUGE, DIAGRAMMATIC CROSS SECTION. (*Woodhall Duckham.*)

the product. It is rotated at a high speed and consists of an inverted stepped, truncated cone driven by a vertical shaft from overhead gear and enclosed in a circular casing. The wet coal is continuously delivered into the stationary hopper placed centrally above the machine by means of a constant rate feeder. The coal falls through the hopper on to a horizontal revolving distributing disc fixed to the vertical shaft, which can be so adjusted that the orifice between the cone and the edge of the disc permits of the control of the

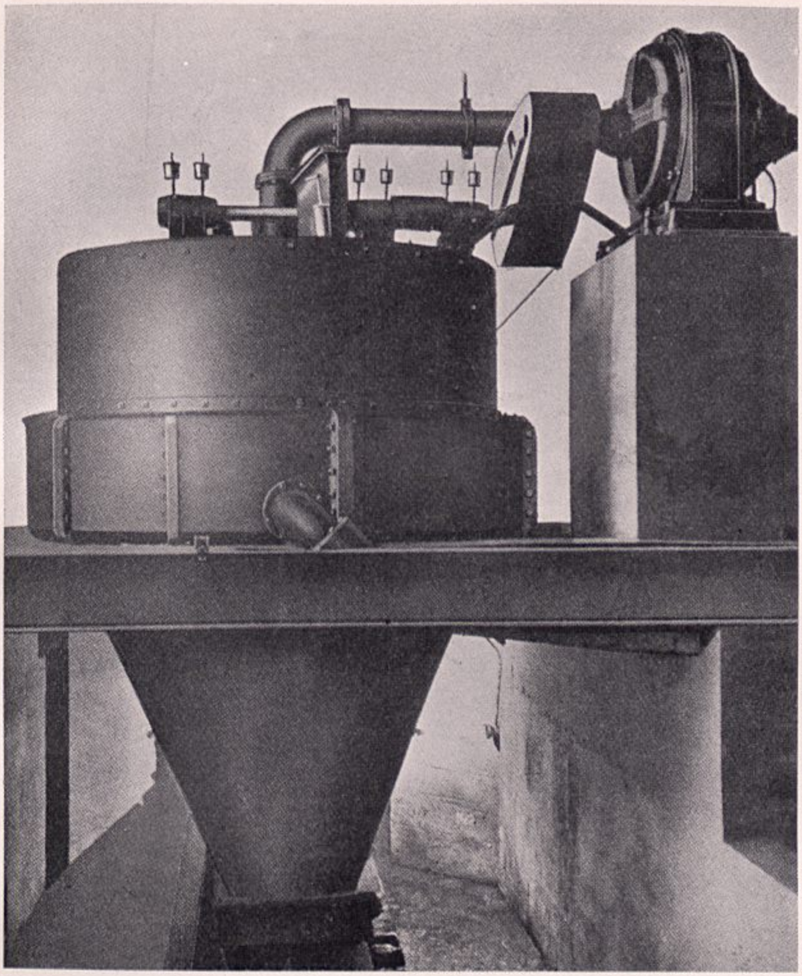

FIG. 219A.—CARPENTER CENTRIFUGE CASING. (*Woodhall Ducklam Company.*)

[*To face page* 250.

quantity being handled in relation to the fineness of the coal. The adjustment of this opening is only altered to vary the through-put or if the quality of the coal is changed. The coal is thrown off the distributing disc, and owing to the high centrifugal force impinges violently against the top screen. The water passes through the screen and is collected in the launder surrounding the machine. The partially dried coal travels down the screen on the inside until it reaches the first cascade, here it is broken up by the serrated teeth and redistributed by means of centrifugal force. There is a horizontal gap between the serrated teeth and the next screen, so that the coal is again thrown violently against the second screen plate. More water passes through and the coal, in a still drier condition, slides down the screen as before to the next cascade, and so on. The number of cascades is varied to suit the particular material being handled. The finally dried coal is discharged continuously into the central collecting hopper immediately underneath the machine and the water is taken away from the launder by means of suitable water outlet pipes.

The power required to operate the machine varies from $\frac{1}{2}$ to 2 B.H.P. per ton of coal per hour—according to the class of coal treated and the initial final water content. All centrifugal machines to be successful must have the speed adjusted so that there shall be sufficient centrifugal force to keep the material up against the screen plate and to force the water through the mesh. To avoid the massing together of the particles and a consequent obstruction to the passage of water through the screen plate, this force must be kept within certain limits. From experiments it has been proved that an increase of speed above a certain point does not have a beneficial effect upon the efficiency of the process. The compact layers of material form a definite barrier to the passage of moisture. The amount of feed is also a factor of great importance, and should be adjusted proportionately to the speed of rotation, so that the layer of coal on the screen plate is kept to a minimum thickness.

The smaller the coal particle the more difficult it is to take out the water, and the speed is proportioned inversely as the size of the coal.

The expensive arrangement of brass wedge-wire fixed sieves and the troubles experienced in actual practice due to the sluggish passage of the partially dewatered coal across them has been overcome by a more economical and efficient arrangement designed and patented by the author, in conjunction with Nortons Tividale, Ltd., as shewn in Fig. 220.

The fixed slurry sieves often become so choked that it is in many places necessary for a boy to be employed to scrape the material down to the vibrating trays.

In place of the fixed sieves, sloping troughs, 4 and 5, deliver the fine coal and slurry respectively upon the vibrating tray, 2, which is built up of channel sections supporting a fine-mesh wedge-wire brass sieve and has a sloping part running into a horizontal part. The tray is slung from a steelwork support by hickory springs and is subjected to about 600 strokes per minute with an amplitude of about $1\frac{1}{4}$ to 2 inches, depending upon the duty.

The fine coal and water are delivered direct upon the top end of the sloping sieve, and, due to the high period vibration, the water is quickly taken out and a thin layer of coal is caused to travel down the sieve. At a suitable point the concentrated slurry from the settling tank is delivered on the surface of this layer, which forms with the sieve an excellent and rapid filtering medium. The mixture is uniform and intimate and the presence of the slurry is not detected by a superficial examination. Extremely good results are being experienced with a difficult Lancashire slurry. The waste water is collected in a trough, below the shaking tray and thence conveyed to the pump well. The shaft is connected with the tray by the eccentrics

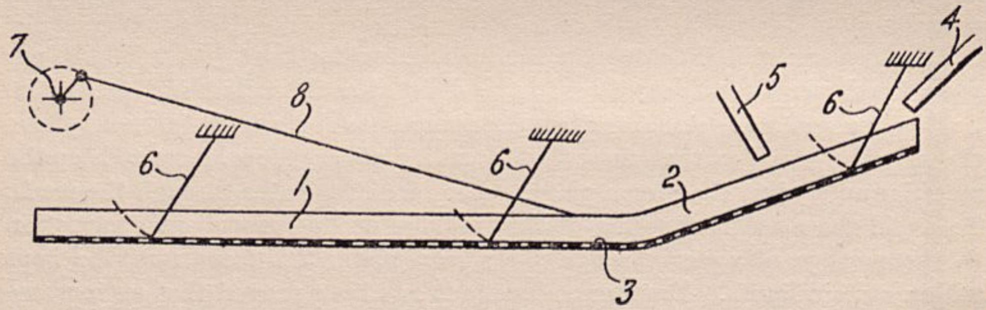

FIG. 220.—MINIKIN DEWATERING SIEVE FOR FINE COAL AND SLURRY.

and ash connecting rods shewn. These rods are sloped at about 16° to the horizontal.

In Fig. 218 is shewn an elaborate system of dewatering to meet the demands for a dry, fine, coking coal. After rewashing the coal is led to the distributing troughs over the fixed brass wedge-wire sieves, and passing over these in a thin sheet is robbed of a large part of the water before being discharged on to the shaker sieves, on which the vibratory action shakes the loose moisture out of the coal into a collecting trough beneath the trays, which conduct it to the pump well. The fine coal is then dropped in to the draining-band conveyors, on which it is again allowed to drain. We have already discussed this machinery and now take the opportunity of comparing the sizes of the two machines. The draining band weighs about 70 tons, against 8 tons of the shaker sieve, the one takes 25 H.P. and the other 4 H.P., the advantages in both cases being with the smaller for efficiency and durability. The slurry distributing troughs and piping are shown coming from the settling tank.

A type of duff coal dewaterer that is now appearing on the market is that shewn in Fig. 221.

A cylindrical drum has a number of small shallow hoppers, *a*, on its circumference, the base of these hoppers being of a finely-woven mesh filtering cloth protected by a coarser mesh, *d*. The chamber directly beneath this is in communication with a rotary valve, *b*, by the pipes, *c*.

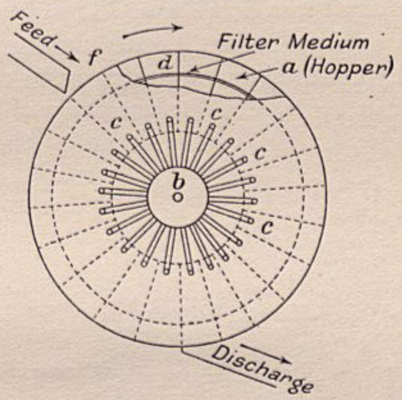

FIG. 221.—HOPPER DEWATERER.

The feed of the wet duff takes place at *f* and automatically on revolving a vacuum is formed in the chamber below the filter, drawing in the water. The material clings to the surface; but on passing a certain point the vacuum gives place to a slight pressure above atmosphere, which causes the duff to fall away and be discharged. The valve, *b*, is so arranged as to be able to trap the waste water and also reverse the pressures from negative to positive.

The apparatus is relatively expensive, and until it can treat a much greater quantity than 6 tons per hour it will not probably be in general use for fine coal.

CHAPTER XV

SLIME RECOVERY

THE earliest method of slime recovery was that of settlement in large basins. The dirty wash water was led to a series of brick-lined shallow ponds, and from these it was allowed to overflow into a ditch or drain, leaving in the chamber the greater part of the solids.

When a basin became almost full of solid matter it was cut out of the circuit and allowed to dry for a few days. The dried slime was then dug out and disposed of to colliery boilers, or for making of briquettes, etc.

The method naturally entailed an enormous waste of water, and a recovery of a fine coal of high ash content. The necessity of water economy caused the introduction of a circulating system, whereby the same water could be

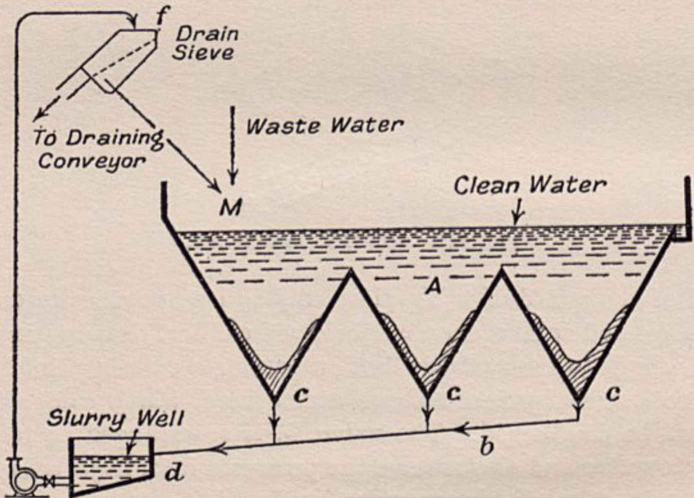

FIG. 222.—SPITZKASTEN.

utilised in the washery over some extended period. This wash water was not clarified; but, on becoming thick and heavily laden with small coal and dirt particles, was run off into a brick-lined basin, the used water being allowed to settle. The clear water was run off, and the sediment recovered as in the former method.

The washing troubles and the large variation of quality of product being more pronounced with this system, led to the introduction of a water-clarifying arrangement in the washing water circuit of the washery. The early form of the method was the interposition of the large inverted pyramid or V-shaped trough settling tanks.

In Fig. 222 is shewn a diagram of the pyramid tank, A, which receives the dirty water at the point, M. The overflow from the tank is collected in a trough skirting the far side of the tank. The overflow water is comparatively clean, due to the deposition of the solid matter in the still water of the tank. These solids are concentrated by the V-shaped chambers, with sides at 60° to the horizontal—over the mouthpieces, *c*, which are provided with valves. The valves are regulated so that the slime passing through each one is of an equal consistency and is collected by a trough, *b*, which conveys it to the well, *d*, from which it is elevated to the fine-mesh sieve, *f*, and partially drained of water before being dropped on to the draining conveyor.

The point at which this slime is delivered to the conveyor is fixed by placing it at one link length behind the delivery point of the fine coal. By this means the slime is dropped into the top of the full chamber—the fine coal acting as a filter and retaining the slime particles.

Trough Tank.—The V-shaped tank, A, receives the dirty water at point M, the clean water on the surface overflowing into the trough (*w*), and passing again to the washer box, while the solid matter is allowed to settle on the sides

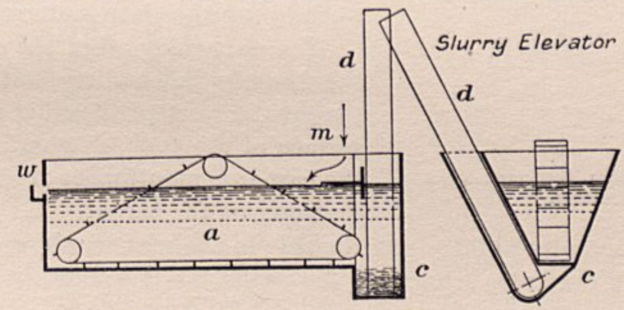

FIG. 223.—V-SHAPED SETTLING TANK.

of the tank, which are placed at 60° to the horizontal, as shewn in Fig. 223. The slime slides down the chamber sides, and is collected at the apex, where a light scraper conveyor, moving at a low speed, pushes it along to the well, *c*, in which a shallow bucket elevator, *d*, is placed, also moving at a low speed. The elevator delivers the pulpy mass into a bunker which is provided with drainage arrangements, and overflows into a settling tank, the solid being allowed to accumulate until full, when the delivery is changed over to a second bunker.

Conical Settling Tank.—This type of settling tank as used for coal washing originated in Germany, and was no doubt borrowed from the Dortmund tank. In America it is known as the Callow tank. This particular type has become very popular on account of the small ground space required for foundations and the relatively low initial cost. The main service is to clarify the dirty water by precipitation of the solid matter suspended therein, and to concentrate such slurry or slime so that the subsequent recovery is facilitated.

The best practice is to construct the tank of reinforced concrete, covering the inner surface with two coats of bitumastic enamel to improve the water-tightness of the concrete and smooth up the surface. The top of the tank is generally at 12 to 15 feet above the washer box floor. The dirty water from the washery is pumped into the tank through a pipe having a trumpet mouthpiece delivering at about 6 inches above the average level of the water. Surrounding this mouthpiece is a steel curtain suspended from a trussed gantry which also serves as a footway for inspection purposes (see Fig. 224). At the lower edge of this steel curtain, over about 240° of the circumference and for a depth of 2 feet, the plate is perforated by $\frac{5}{8}$-inch diameter holes. This is done to ease off the descending current caused by the addition of dirty water from the washery and the discharge of the clean water to the washery by the clean-water pipe.

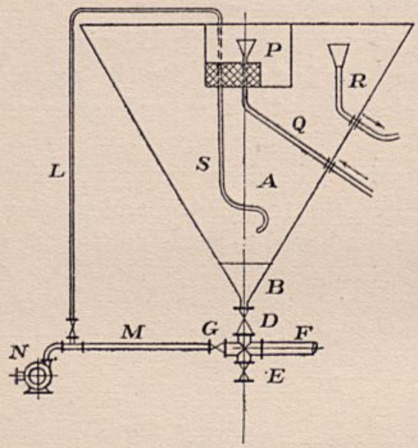

Fig. 224.—Conical Settling-tank Fittings.

The slackening off of the current causes the heavily laden dirty water to deposit the greater part of the solid matter on the surface of the cone, down which it slides to the cast-iron mouthpiece of about 10 inches diameter at the throat.

The slime actually builds upon the side in the manner shewn by Fig. 225; especially when the valve regulating the outlet is not sufficiently open. After

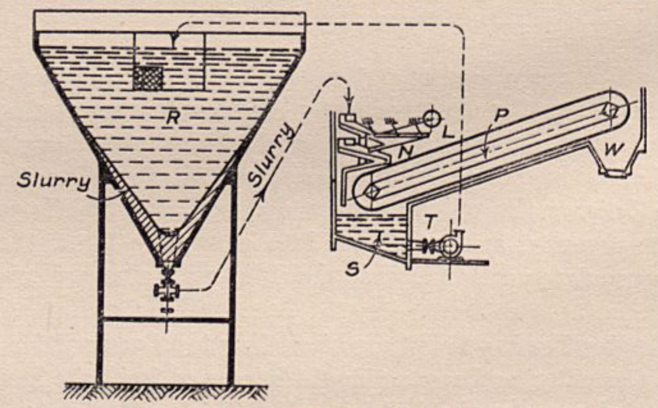

Fig. 225.—Dewatering Device.

a certain accumulation it slips downwards gradually, but maintains this form.

The slime collecting over the mouthpiece by this slip is flushed out through the valve and passing through the crosspiece is led by the pipe to the dewatering sieves or filter apparatus in the washery.

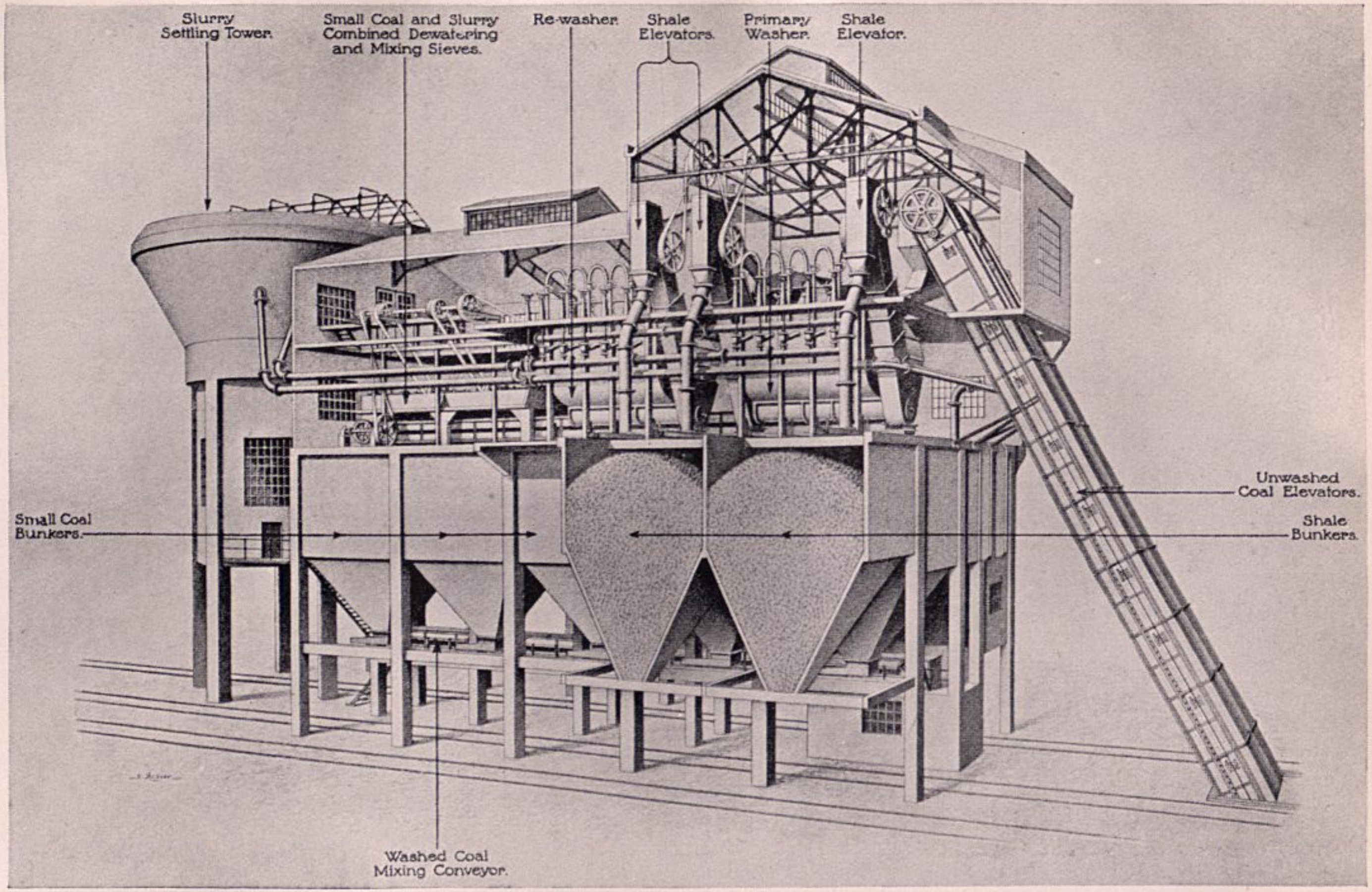

FIG. 224A.—SECTIONAL VIEW THROUGH 150 TONS PER HOUR WASHERY, SHEWING WATER SERVICE TO WASHER BOXES FROM SETTLING TANK. (*Coppée Co., Ltd.*)

[*To face page* 256.

The actual slime is in a very fluid condition, due to this accumulation on the side and the strong flow of water boring a passage-way through the apex.

There is never a deposit actually over the mouthpiece excepting when the plant is stopped, as between night and morning shifts. The slime then packs itself so closely in the throat of the cone that the head of water is not sufficient to commence movement along the pipe. To overcome this disadvantage, several means have been tried, chief of which is the ejector (see Fig. 218), connected to one flange of the cross-piece and in communication on the barrel with the top of the tank by a pipe. Water is admitted, and the flush of water coming from the top of the tank and passing through the ejector rushes by the junction piece through the discharge pipe, dragging along with it the slime in the mouthpiece. The sediment is sometimes so solidly packed that it is necessary

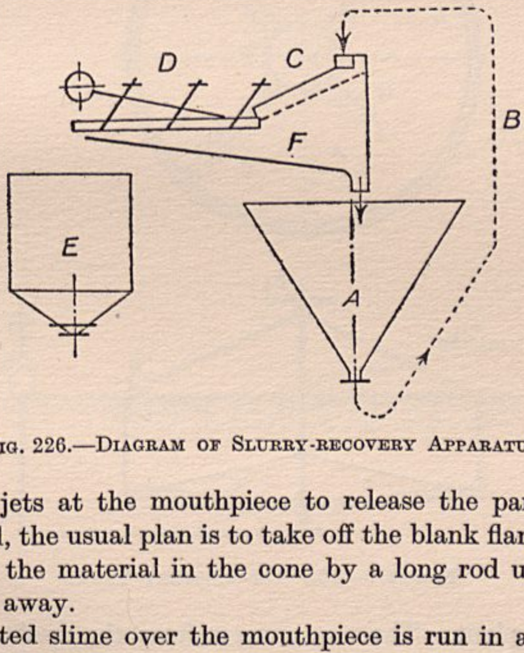

FIG. 226.—DIAGRAM OF SLURRY-RECOVERY APPARATUS.

to supply steam jets at the mouthpiece to release the particles. When all other methods fail, the usual plan is to take off the blank flange of the junction piece and stir up the material in the cone by a long rod until there is some sign of it coming away.

The concentrated slime over the mouthpiece is run in a semi-liquid state over the fine-mesh draining sieves already described in Chapter XIV and shewn diagrammatically in Fig. 226, where A is the settling tank from which the slime is drawn by the pipe, B, and passed over the fixed and shaker sieves, C and D, the waste water being collected in the trough, F, and returned to the settling tank, A, and the coal is deposited in the bunker, E.

An apparatus for slackening off the compact silt after a stoppage is operated as follows. At the apex of the conical settling tank a cast-iron mouthpiece is fitted connected by a regulating valve, to a junction piece, in the shape of a cross. The main slurry outflow pipe is connected to one side of this 4-way piece, while at the other a valve separates it from a steam ejector, to the suction flange of which a pipe is connected from the top of the tank drawing off water from the upper surface of the water. To ease the silt in the mouthpiece, steam is admitted from the pipe through the branch pipes to the mouthpiece at three points to ease the silt over the outlet, and by opening the valve connecting the junction piece with the steam ejector, water is drawn from the top of the tank and forced through the slackened sediment, carrying it off to the washery by the slurry pipe.

An apparatus of slime recovery which has attracted a good deal of attention

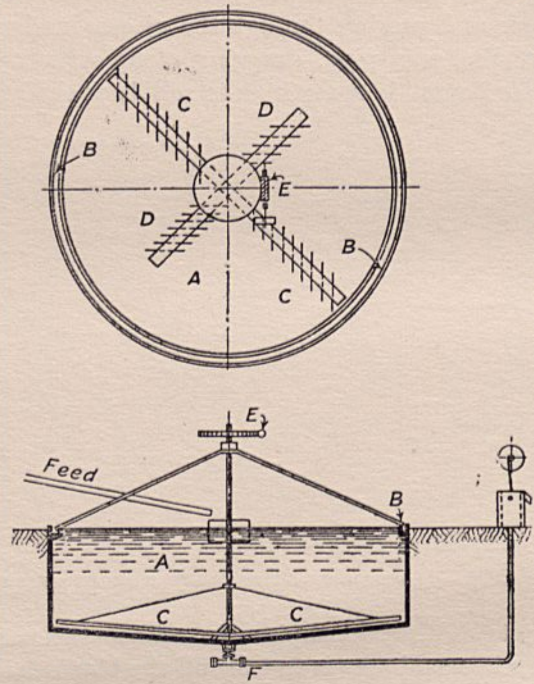

FIG. 227.—DÔR SILT-RECOVERY TANK.

lately is the Dôr plant. The waste water from the washery is delivered to an apparatus called the Dôr classifier, as shewn in Fig. 228.

A broad shallow tank, A, with the bottom sloping upwards at an angle of about 10° to the horizontal, is filled with the dirty water, the level of which does not quite reach to the top of the sloping bottom, but leaves about one-third of the length uncovered.

On the bottom a set of rakes, B, is caused to move by a special design of lever mechanism.

The main shaft, H, has a crank arm engaging by the rod, D, with the rakes, B. This shaft gives a positive reciprocating motion to the rakes along the plane, but there is also a cam keyed to the shaft which engages by the

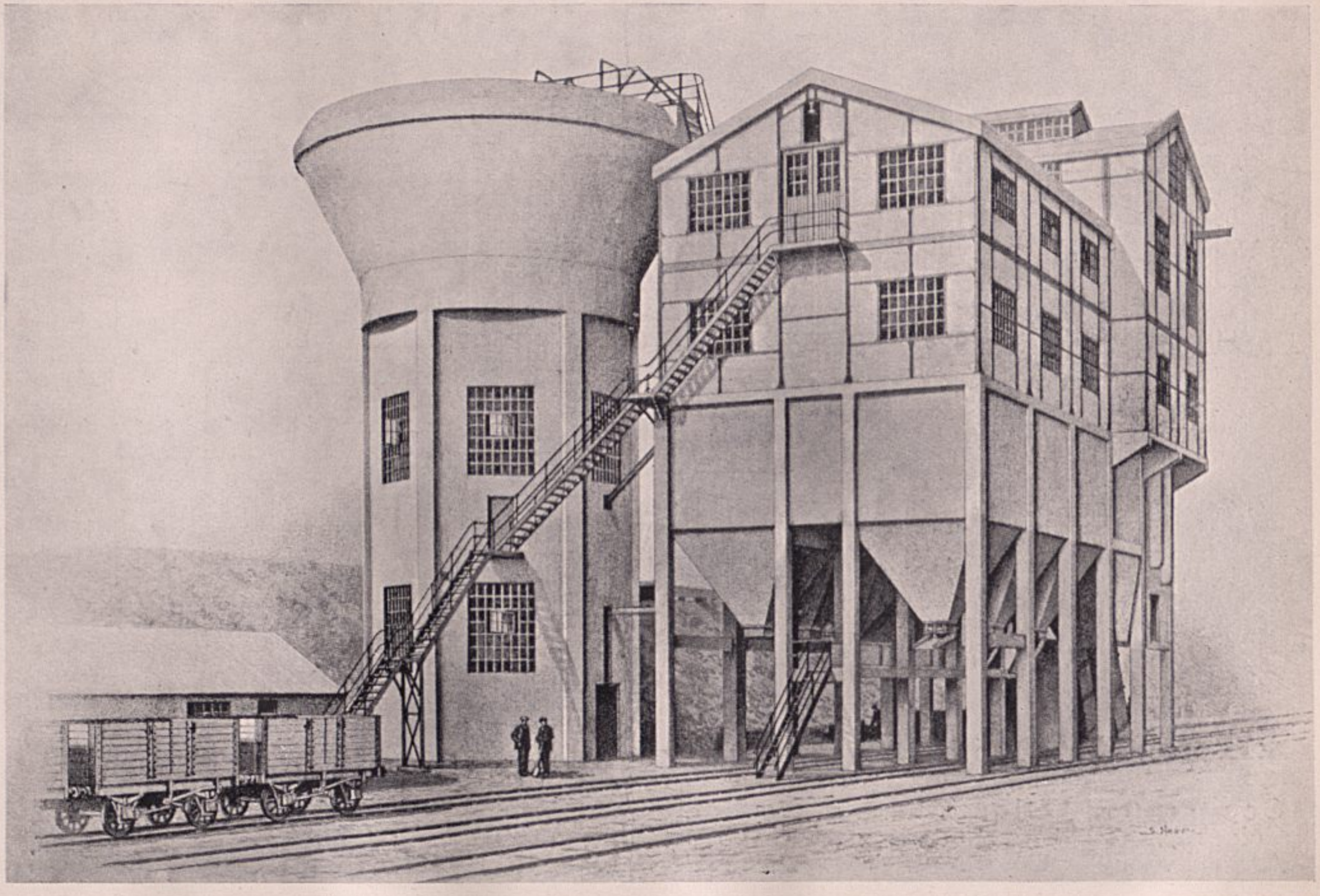

Fig. 240a.—150 Tons Per Hour Washery.
(*Coppée Co., Ltd.*)

[*To face page* 259.

rod, E, with the elbow levers pivoted at C and forming suspensory members for the tray of rakes.

The cam is so placed that on the downstroke of rakes the latter are lifted from the surface of the table and have therefore to describe a semicircle on the return, but having once passed the cam the rod, D, draws the rakes along the plane on the upstroke.

The water which enters by the trough, J, at about the centre of the tank deposits all the heavier material immediately on the base of the tank, but allows the finer to be carried away by the flush of water over the overflow, F. The heavier particles are gently and progressively raked along the bottom, to be eventually discharged into the trough, G, for dewatering on shaker sieves or bunkers.

The overflow at F is led by trough into the centre of a large circular tank provided with a peripheral overflow, so that the surface remains almost undisturbed by inlet or outlet, as shewn in Fig. 227.

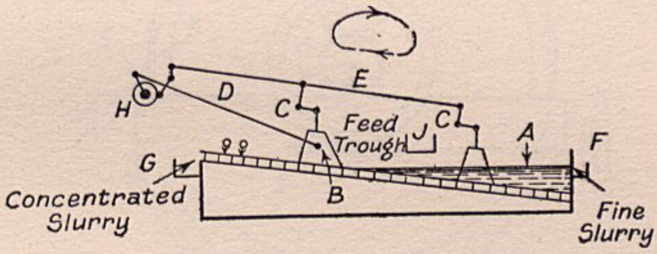

FIG. 228.—DÔR CLASSIFIER.

The inlet water being fed into a cylindrical curtain is deflected into the body of water and a slackening off of velocity causes the particles to be deposited on the floor of the tank.

Slung from a central shaft is a double set of ploughs mounted on two long and two short arms. The worm wheel and worm, E, cause the ploughs to revolve at about 6 revolutions per hour, which is just sufficient to gently push the silt deposit towards the centre outlet, where a junction piece, F, is connected by piping to the pump, G. The silt should not be allowed to become more compact than 1 of water and 1 of coal, as this is about the limit of the capacity of a pump and pipe line.

A washery of 100 tons per hour would require a tank 60 feet in diameter and to be about 8 feet deep, the governing factor being that of surface area, and not of volume. The application of this type of plant to British practice will be limited by the ground sites available.

For general practice, it would be better and cheaper to instal two conical settling tanks in place of a Dôr thickener.

A conical tank has advantages for economical working that can never be claimed by a sunken tank; even though the power required for working the ploughs is only about 1 H.P., the power for the silt pump would bring the power up to much above that for the overhead settling tank, considering that all the circulation water has to be again pumped from ground level to the washery.

This method of concentration seems, perhaps, to lack the simplicity and directness of the conical tank for washery practice where capital cost is a great stumbling block to the majority of collieries.

The slime now in a semi-liquid condition is pumped into the trough of an Oliver type filter as shewn in Fig. 229, where *t* is the casing containing the

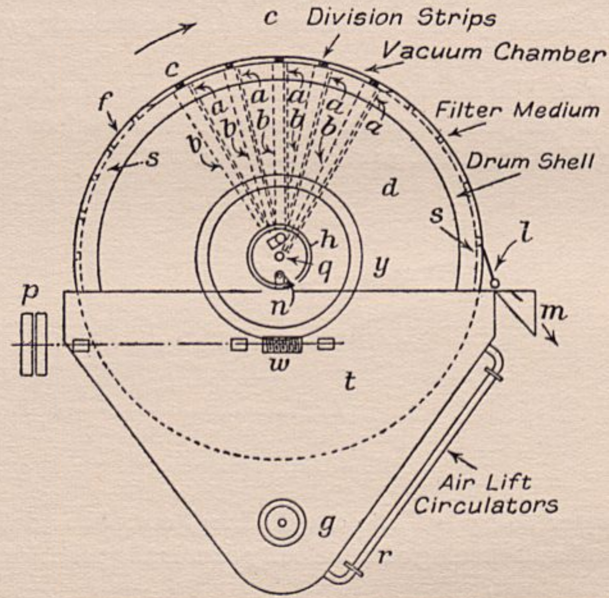

FIG. 229.—OLIVER FILTER.

slime and *d* is a large rotating drum, with a solidly constructed shell of wood, *s*, upon which division strips, *c*, are tightly bolted to form small shallow chambers or spaces around the periphery. Across the tops of the strips a finely-divided filter medium, *f*, is stretched, and on the outside of this, to protect it, is a spirally wound wire. To each shallow space a vacuum, *b*, is fitted, and an air pipe, *a*, communicating with the rotary valve, *n*; these pipes are on the inside of the drum and rotate with it, being entirely controlled by the valves, *g* and *h*. The motion is given by a worm, *w*, gearing with the wormwheel, *y*. In the base of the casing is an agitating paddle mechanism, *g*, to keep the material in a consistent state.

To promote a still further agitation, pipes, *r*, are placed on the outside of the casing, communicating with the lower and higher levels of pulp.

The drum in passing through the trough picks up on its face a layer of slime, which is slowly robbed of its moisture by the vacuum in the filter chambers, and in approaching the plough, *l*, the vacuum is released and air admitted, forcing off the dried cake of slime on to the scraper, *l*, and thence by discharge shoot, *m*, to the bunkers. On passing this point the vacuum is again in communication with the chamber, and a suction is caused at this point, causing a circulation in the pipes, *r*.

CHAPTER XVI

DRAINAGE BUNKERS

The necessity of providing sufficient storage capacity in coking plants for the fine-washed slack is governed by the amount of capital available and the limit of the moisture content required for the coking. Storage and drainage of fine coal always entail heavy expenditure, and for this reason it behoves companies undertaking this responsibility to obtain the best value for their outlay that it is possible to get. So much money has been spent on mere structures of cubic capacity alone which have not produced the required amount of drainage, that coking firms are inclined to the opinion that drainage bunkers are not effective as such beyond a certain limit, that limit being in most instances 14% moisture, whereas coke-oven managers want 8% moisture for charging.

A deeply-rooted idea of a minimum storage of 48 hours for drainage seems to be prevalent, and it is admitted that a longer period does not reduce the moisture to any appreciable extent. Wet fine coal obstinately refuses to give up its moisture, and, in draining, that water which filters through to the base carries with it a great quantity of very small particles, which eventually fill up the filtering spaces and retard the drainage. It is found that in ordinary drainage bunkers, having a maximum height of coal of 16 feet, little is gained by a longer storage than 24 hours, and when the depth of coal is 30 feet or more the 15 hours' drainage is the most effective, and beyond that period slight improvement results.

Sufficient has been said upon the ill effects of charging ovens with coal having a high percentage of moisture, and the problem is how to reduce this within reasonable limits at small expense commensurate with efficiency. A bunker of ordinary design is not a good drainage agent, nor yet is that bunker which has been designed for capacity. The filtering out of water from the fine coal can only take place when the space occupied by it can be readily filled with air.

Mere storage capacity is not a sufficient provision for drying fine coal, the drainage must be properly designed and a good air circulation provided.

It is reasonable to expect that the thinner the layer of coal, the more rapid the drying, for not only can the moisture sink to the bottom rapidly, but the air can replace it quickly.

The author has found that a flower pot filled with wet fine coal will dry to 8% moisture in the open in 6 hours, but when placed in a closed laboratory with little circulation will not dry to less than 12% in 4 days.

The great factor in drainage is air circulation, not only to the base, but also throughout the mass of fine coal. It is not unusual to have a fine coal of 35% moisture remaining in that state during damp weather for over 3 weeks.

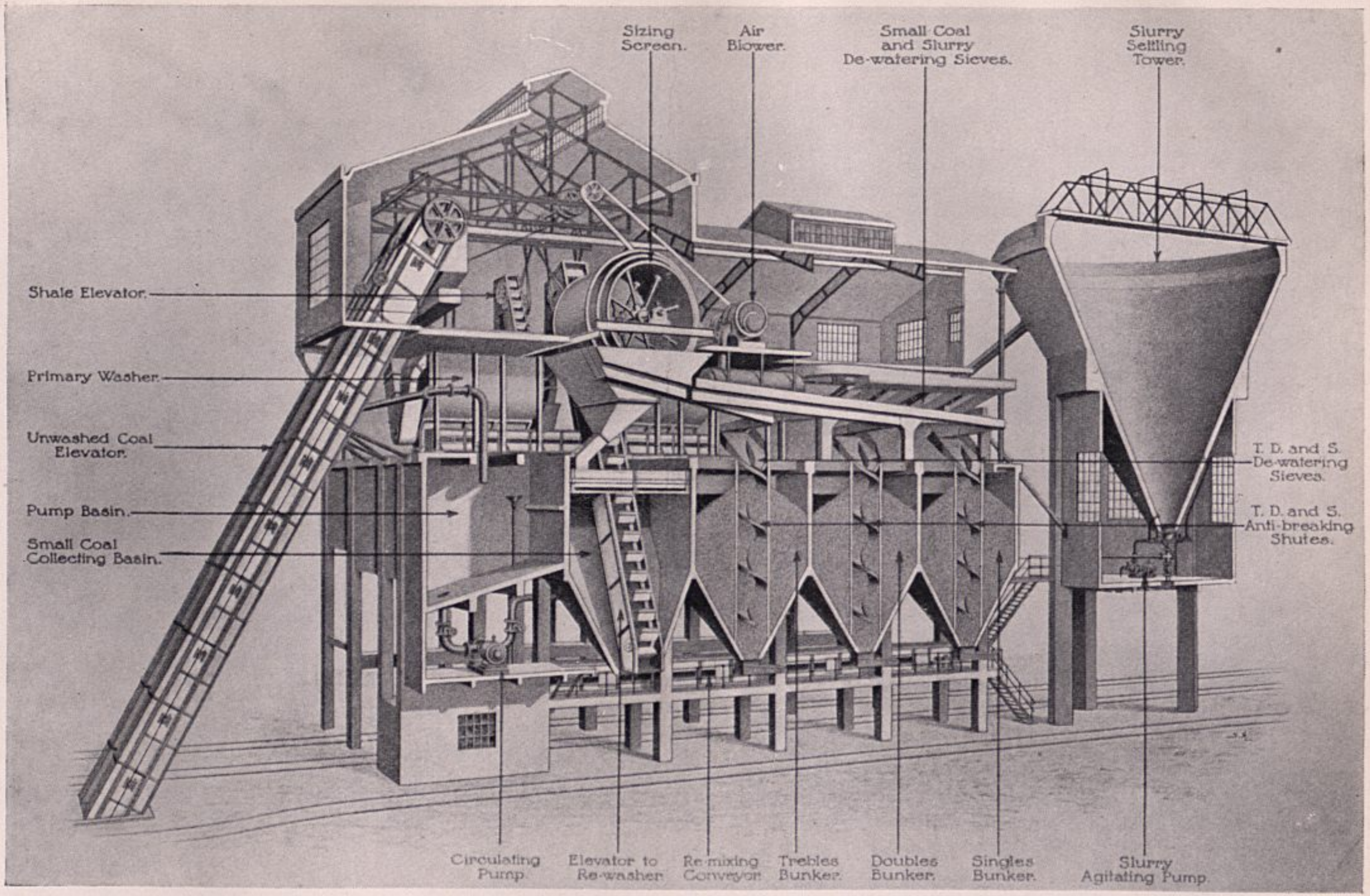

FIG. 230.—SECTIONAL VIEW THROUGH 150 TONS PER HOUR WASHERY.
(*Coppée Co., Ltd.*)

[*To face page* 262.

The surface of coal repels water, but this can only take place when there is sufficient air to take the place of the water.

If the bunker is totally enclosed and only provided with drainage through the mouthpiece, it will be very difficult to obtain satisfactory results. The design should aim at providing a constant and plentiful supply of air throughout the mass of fine coal, especially on the surface and in the heart of the deepest part. This air circulation may also take the form of a moisture extractor to prevent the filtering of the mass becoming concentrated in the base and choking the interstices with the fine particles. A well-designed bunker will reduce to 6% in 15 hours if the recovered slurry is kept separate or has been previously mechanically drained. The depth of the drainage bunker is likewise of great assistance to filtering. The shallower it is the better the drainage. It is a well-known fact that railway wagons are one of the best drainage mediums of the present day, and if a colliery could afford covered sidings and rolling stock for the wet fine coal, a difficult problem would be readily solved.

The German coke-oven plants have adopted a system of drainage much more elaborate than our own and relatively more costly, but then again what is spent in good drainage is saved in lost heat and waste gases.

A remarkable point about the German bunker design is the fact that the hopper sides are generally very flat, between 40° and 45° against the British practice of $52\frac{1}{2}°$ to 60°.

It is usually very difficult to slide wet coal, and hence it may be presumed that a labourer is required to break up the bottom compactness of the mass when the mouthpiece slide is opened.

A drainage hopper mouthpiece is usually an outlet of about 18 inches square with the sides sloping at 60°. The slides are usually perforated and provided with drip tray arrangements, as shewn in Fig. 230, where a wrought-iron sheet sliding drip tray is attached to the base of the hopper slide, to allow for movement to one side when loading into the wagons, and a small chute conveys the water into an inclined trough placed on the columns of the building for the collection of the drainage water from the bunkers.

In the particular example, the fine coal is delivered into the bunkers by a scraper conveyor, the only drainage arrangements being those shewn.

For sales purposes, this perforated slide is considered sufficient, as the journey from the washery to the consumer in the wagons is depended upon for the necessary drainage, it being usual for the colliery companies to allow 1 cwt. per ton on the weighbridge as the moisture content lost in transit.

The sides of these bunkers are at 60° slope to facilitate the easy running of the fine coal into the wagons.

Bunkers placed on a site adjacent to coke ovens are generally much lower and are usually built of large capacity and provided with more elaborate draining arrangements for the speeding up of the process, and built on the trough principle, *i.e.* the cross-section of the bunkers are the same everywhere throughout the length, and the side slopes to the hopper outlets are built up of mass concrete or drainage grids.

In Fig. 231 is shewn the longitudinal section of a drainage bunker of the Meguin type, as described in the chapter upon "Modern Systems."

It is seen that to obtain a central feed the bunker sides have been brought down to a central position, with wide mouthpieces, each of which carries a

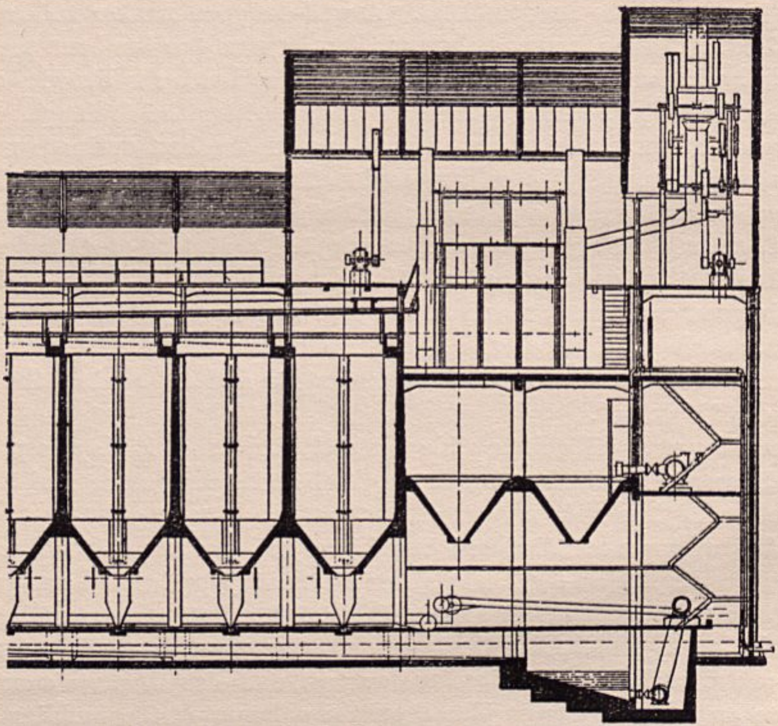

FIG. 231.—LONGITUDINAL SECTION OF WASHERY AND DRAINAGE BUNKERS.

draining grid delivering water into the underground channel and conveying it to the sump, from whence it is pumped back to the washery. The coal is delivered in the collecting conveyor on the ground level.

These bunkers are filled with washed coal and water, and for this reason are fitted with special draining arrangements, apart from the peripheral troughs. In the centre of each bunker a drainage column is fitted.

This drainage column consists of fixed flat plates punched Venetian fashion and provided with movable perforated plates, which close the slits during the filling and allow the water to percolate through the slits into the collecting waste-water system on the underside of the bunker when raised.

Placed near the central partition wall is a semicircular drainage pipe punched in a similar manner, but provided with a valve at the bottom end. This valve remains shut while filling the bunker and is only opened when the feed is switched off to another chamber, to avoid the risk of silting up of the small apertures.

The hopper sides are made of substantial thickness to take the heavy bending moment, due to the hydrostatic pressure. This means a waste of concrete, and in the conditions ruling to-day places this design in a disadvantageous light, although from the point of view of efficiency in moisture reduction it is without doubt one of the best possible arrangements.

The upper portion of the building is provided with large open windows

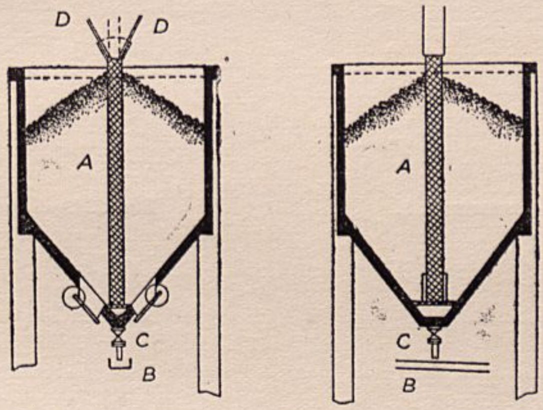

FIG. 232.—DRAINAGE COLUMNS IN BUNKERS.

to promote constant circulation of air over the top of the coal, to eliminate that dampness which militates so much against the efficiency of the average type of drainage bunker. The supports for the hopper in this case are at each corner, so that the beams of the cross partitions are supported on columns, leaving the centre line free for the passage of the conveyor.

In Fig. 232 is shewn the drainage column in section as used upon this type of bunker. In the figure it is shown entering a drainage grid placed horizontally at the bottom of the chamber and covering a small trough which collects the water from the column, A, and is discharged into a collecting trough, B, on the opening of the valve, C. The two mouthpieces are shown on the same hopper.

The drainage column apertures are opened by pulling the levers, D, across to the vertical position, as shown dotted.

In Figs. 233 to 237 are shewn one of the latest designs of modern washing and drainage plants for dealing with a large slack for sales and coke-oven purposes. It is designed on the lines found by the colliery owners to be that which most meets the conditions of dealing with a friable coal.

The plant is of 125 tons per hour washing capacity, having storage for 200 tons of classified coal and of 1000 tons drainage bunker of rapid drying facilities.

In Figs. 237 and 238 it is seen that the raw slack is delivered into the washery by the band conveyor, 2, which deposits it into a small hopper, 3, from which

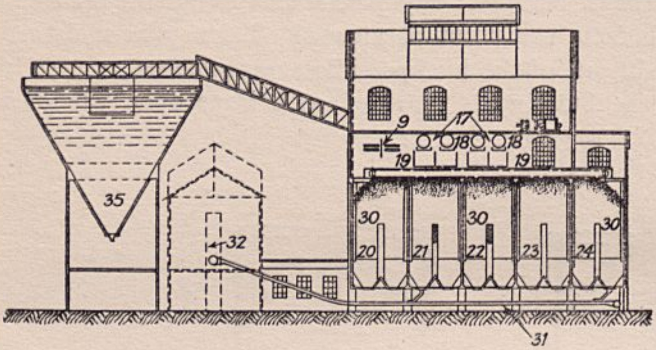

FIG. 233.—SECTION A.A.

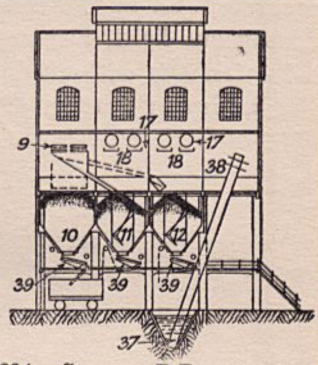

FIG. 234.—SECTION B.B.

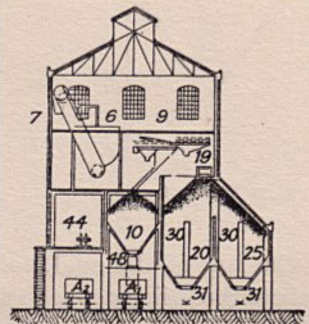

FIG. 235.—Section C.C.

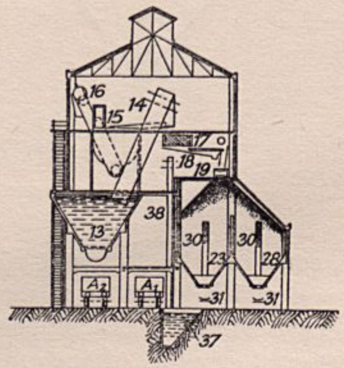

FIG. 236.—Section D.D.

DRAINAGE BUNKERS FORMING PART OF WASHERY BUILDING.

it is flushed into the first washer box, 4. After passing over the classifying vibro screens, 9, where the oversizes of nuts, beans, and peas are led into their respective bunkers 12, 11, 10 by shoots, the undersize is fed by the trough into the smudge sump, 13, in Fig. 224. From this the overflow water which is collecting in the peripheral trough is fed into the pump sump, 35. The sump being relatively deep for a large surface area, the overflow current is so weak and thin that little but the extremely fine coal is carried away.

The circulating pump, 34, delivers this water into the settling tank, 35. The smudge or wet coal elevator, 14, dredges the fine coal and delivers it into

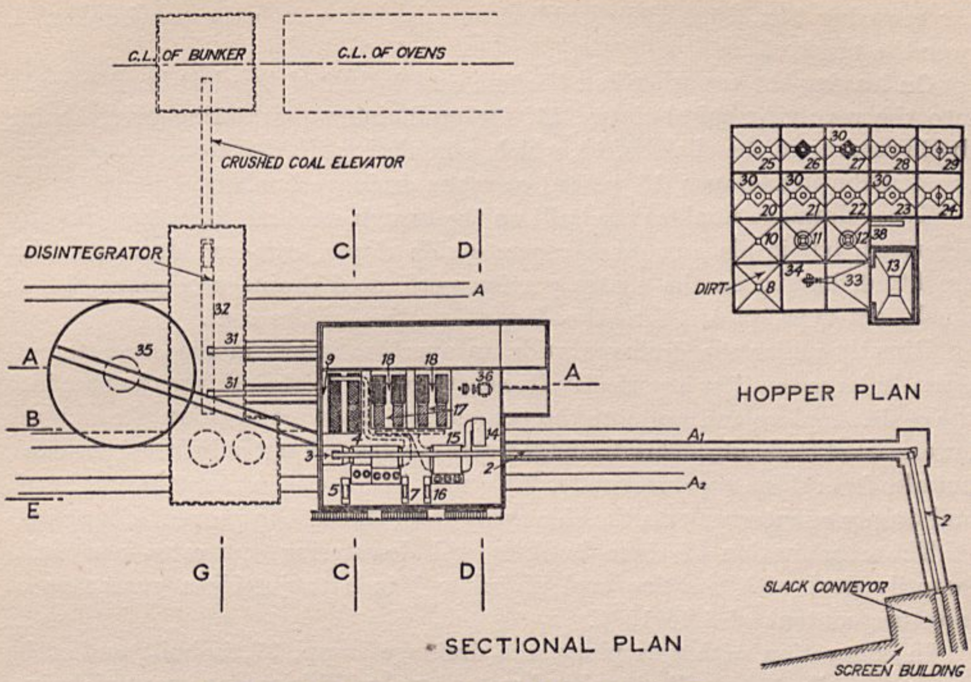

FIG. 237.—PLAN OF WASHERY AND DRAINAGE BUNKERS.

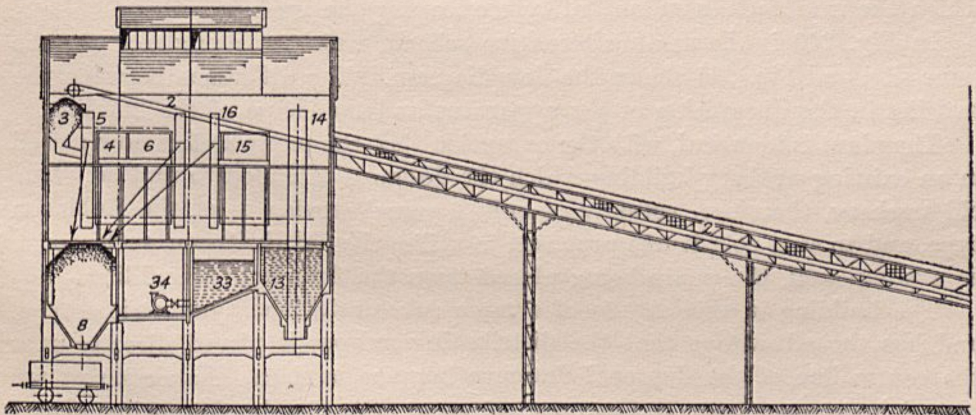

FIG. 238.—ARRANGEMENT OF WASHERY SHOWING FEED TO WASHER BOXES.

the rewasher box, 15. The dirt elevators discharge into the one bunker, 8, over the track, A_2.

On leaving the rewasher box the fine coal is flushed by glass-lined troughs into the revolving spiral sieves, 17, for preliminary dewatering before being discharged upon the shakers, 18, which, completing the dewatering, feed on to the distributing scraper, 13, placed over the drainage bunkers.

These drainage bunkers are built on the trough cross-sectional type already described, but in place of mass concrete side slopes, cast-iron drainage grids are fitted, having on the centre portion perforated drainage columns, 30, of mushroom type, placed into the deepest portion of the coal.

Directly under the drainage grids an aperture is left in the concrete sufficiently large to allow a perfectly free entry of air, so that this may enter into the coal to replace and promote the percolation of the water down through the lower part of the coal. This drainage water is collected, not only from the slides, but also from these apertures under the grids. The holes in the grids are slotted and deeply countersunk on the side away from the coal to prevent silting up.

The combination of these bunkers and dewatering apparatus can satisfactorily deal with the fine coal of below $\frac{3}{8}$ inch to justify a guarantee of moisture content of 8 to 10%.

In connection with this plant, the drainage sump, 37, is built under the ground to collect the spill of coal and water by a suitable arrangement of drains, so that it can be returned to the smudge sump by a small elevator, 38.

In this plant the percentage of lost coal through drainage water, waste, etc., is reduced to a minimum.

In Fig. 239 is shewn a flow diagram of the washing system of Figs. 233 to 238, which illustrates graphically the complete operations or processes through which the raw slack is submitted before leaving the washery.

In Fig. 240 is shewn an alternative scheme which was prepared for the same site, and Fig. 241 shews the flow diagram. The difference between the two lies in the disposition of the apparatus and the shape of the building.

The plant is identical, with the exception that the pump well is now placed in an existing washery building which the design is intended to replace. The old washery, therefore, actually of only 6 years' service, is of the Robinson type, and to save cost it was proposed to utilise the old Robinson washer cone as a pump well, the pump being placed upon the floor in this building.

The building in this case is of a more substantial and symmetrical type, and has the advantage that the distributing scraper is placed directly over the centre line of the fine coal drainage hoppers, and the shaker sieves are placed in tandem over the scraper conveyor, the dirt bunker being placed upon the same track as the nuts, but is also provided with a side shoot to deliver into a siding similar to that shewn in the other arrangement.

In Figs. 242 and 243 are shewn the section and plan of a large capacity "static" drainage bunker for fine coal.

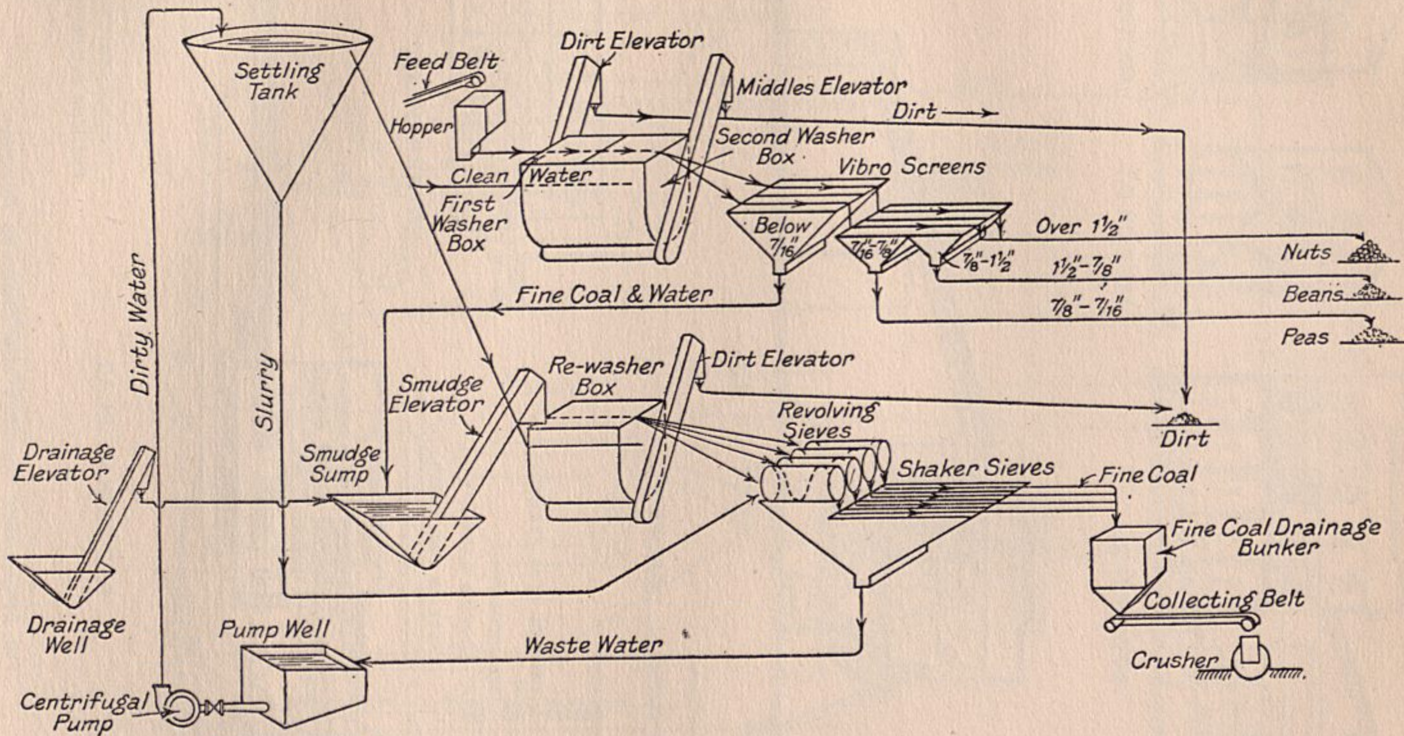

Fig. 239.—Flow Diagram.

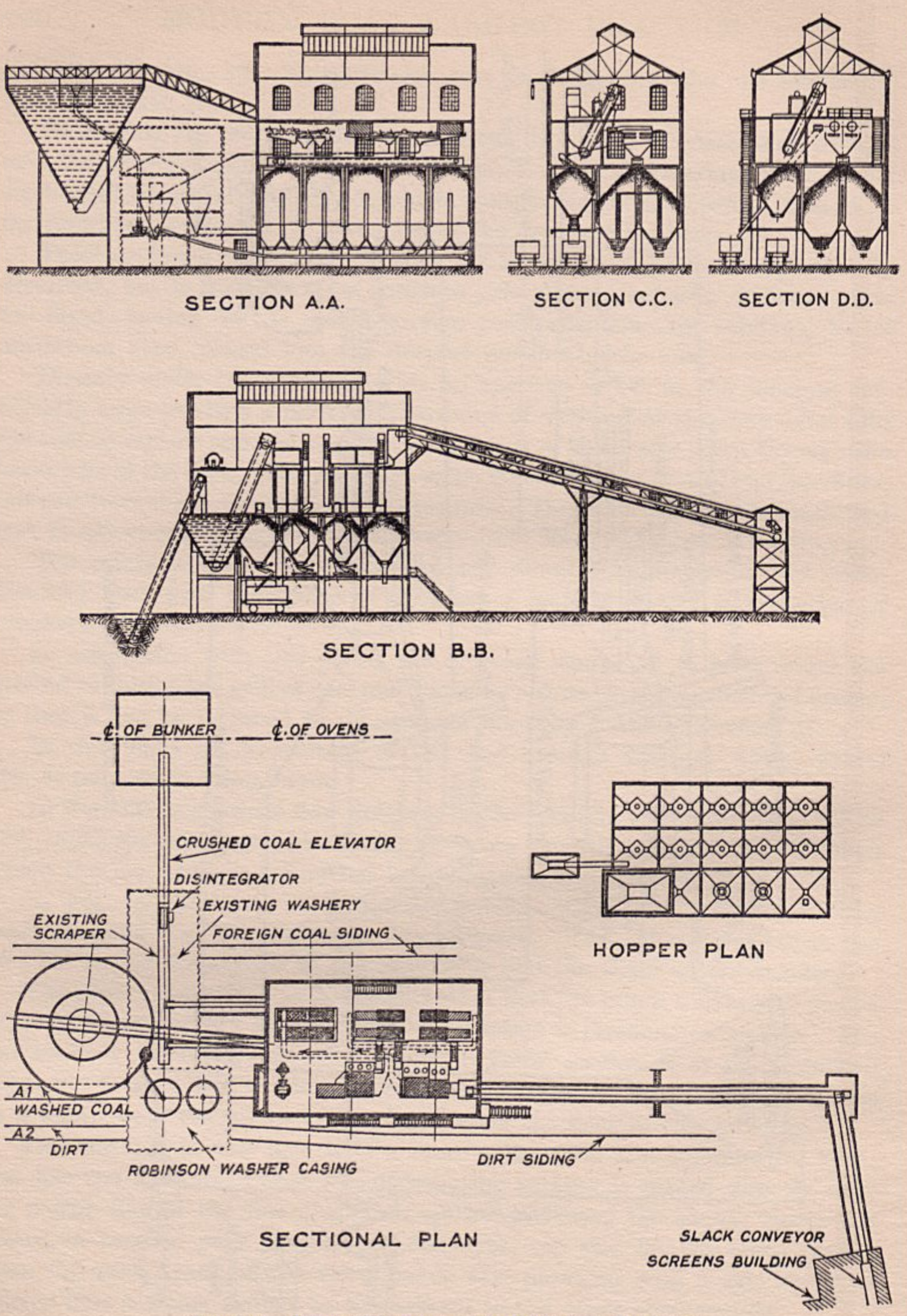

FIG. 240.—LARGE WASHERY AND DRAINAGE BUNKERS.

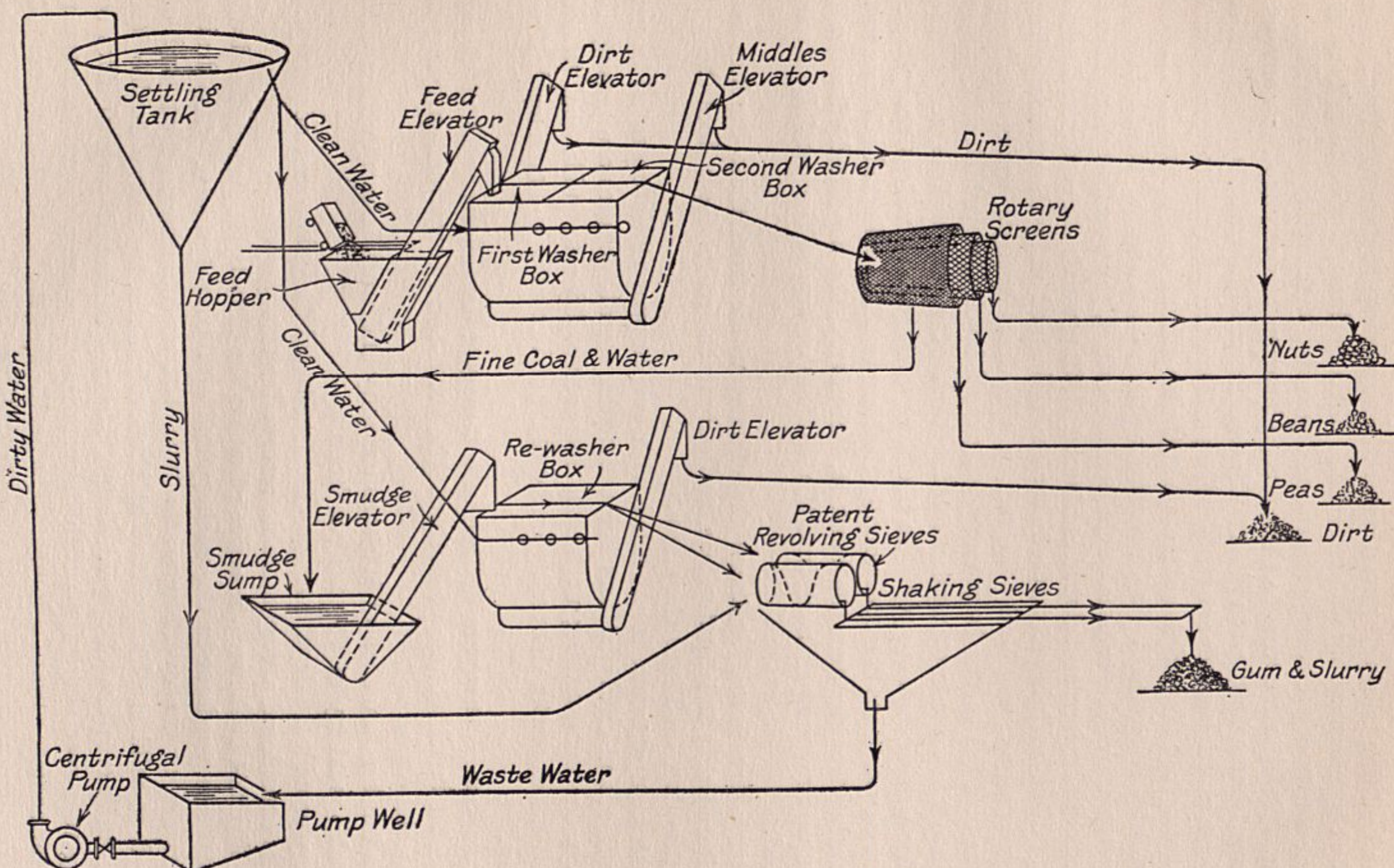

FIG. 241.—FLOW DIAGRAM.

The building is of reinforced concrete of substantial design. The fine coal is flushed by the washing water from the washery through wide troughs passing over the centre of each compartment and provided with suitable valves as shown in plan. To obtain access to the valves platforms are arranged in convenient positions, shown hatched in plan. The bunkers are fed until the deposited coal occupies a position similar to the shaded portion in section, the water meanwhile overflowing into the peripheral trough at the lip of each compartment. Since the amount of water entering and overflowing from each compartment is approximately ten times the volume of the coal deposited, the overflow troughs are of generous dimensions and sloped at about 1 in 20 towards the common discharge outlet. The remaining moisture in the coal is drained off by the vertical columns in each compartment and collected in the drain troughs under the hopper bottoms and led to the large sump at ground level, from which it is pumped back into the large rectangular settling tank over the bunkers, to provide a head for washer box supply. In the floor of this tank valves are placed in convenient positions for occasionally flushing out the collected slime into the distributing troughs over the bunkers. Similarly, the deposited slimes in the base sump are pumped back into the bunkers on top of the partially drained fine coal.

After a few hours' drainage the effluent water from these bunkers is so well filtered that it is quite clear, and only in the early stages does the water carry fine dust coal into the sump.

Each compartment is provided with two hopper slides operated by rack and pinion, and on a platform below hoppers portable chutes are arranged on runways for manœuvring under the respective slides to guide coal into the inclined fixed chutes delivering on to the band conveyors under each line of hoppers.

These band conveyors deliver into 2-way or breeches chutes at the discharge end in either one or both of the cross-band conveyors carrying coal to the coke ovens.

The bunkers are each of 100 tons capacity and work in conjunction with a Humboldt washery of 75 tons per hour.

They provide a 3 days' storage of washed coal for coke oven consumption, which is considered a very suitable reserve for this purpose.

In Fig. 244 is shewn a massive plant on the Humboldt system for dealing with 300 tons per hour in the washery and 4000 tons drainage. The drainage bunkers are of the overflow static type, but are circular in form and constructed of mild steel supported at the conical rim by heavy double joists. The mouthpieces are of special design, having perforated vertical sides connecting to a receiving pipe which delivers into the sump placed between the two intermediate rows of columns. The overflow at the top of the hoppers is led by the peripheral troughs into the main settling tank under the washer boxes.

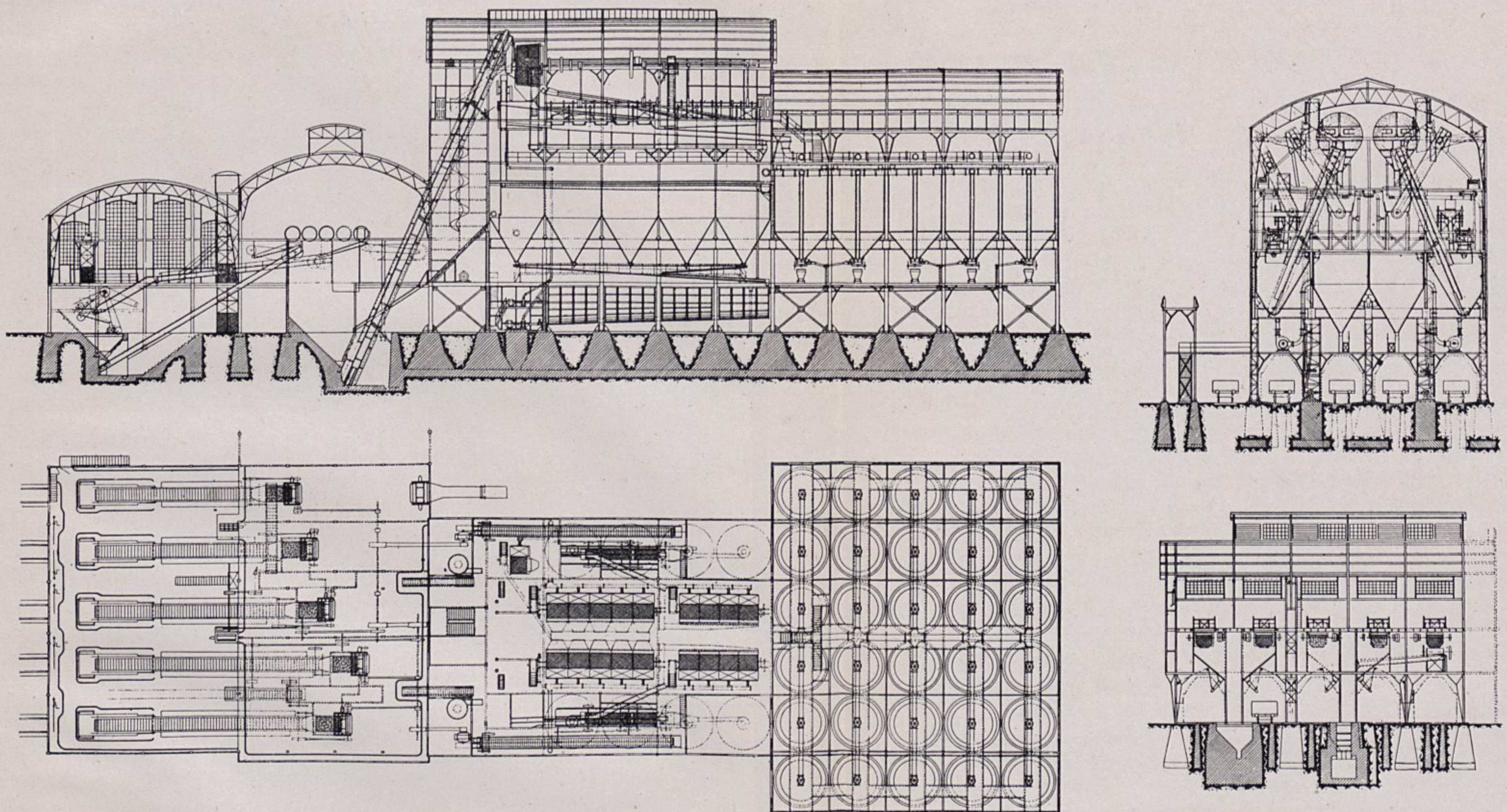

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FIG. 244.—HUMBOLDT SCREENS, WASHERY, AND DRAINAGE PLANT.

Note.—The drainage collecting tank between the intermediate supports to collect the drainage water and slurry respectively and to pump them back into the washery, the latter to the circular drainage bunkers and the former to the settling tank.

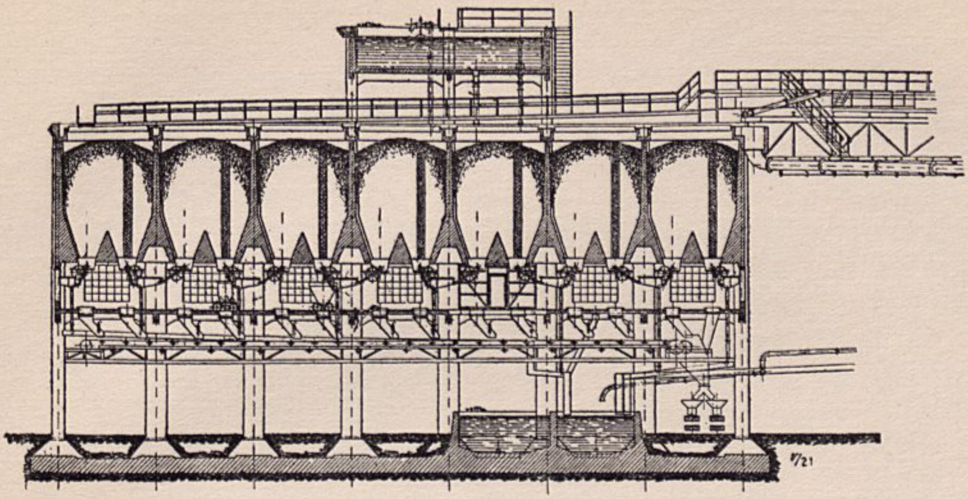


FIG. 242.—SECTION OF STATIC FINE-COAL DRAINAGE BUNKERS.

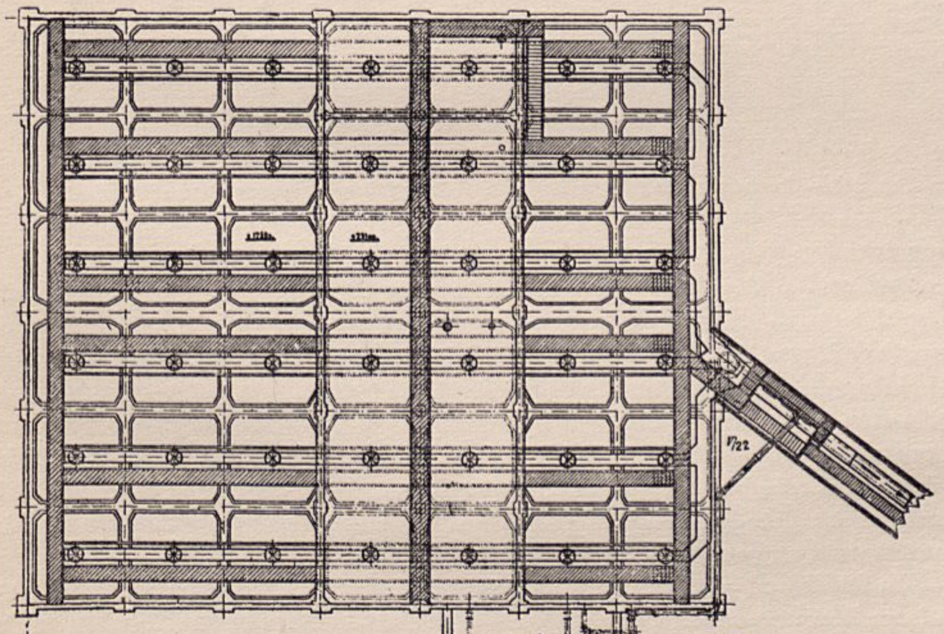


FIG. 243.—PLAN OF FINE-COAL DRAINAGE BUNKERS.

CHAPTER XVII

WASHERY BUILDINGS AND SERVICE BUNKERS

We have previously dealt exhaustively with various types of buildings, so that further description is unnecessary. There are, however, a few points of construction that make a building conspicuous for good or bad design.

Reinforced concrete structures being monolithic, every part must be designed of equal strength and reliability, otherwise one weak spot will spoil the general appearance or stability of the whole structure. There is no better material for the construction of bunkers than reinforced concrete, and if of good design it will outlast the colliery. The precautions must be taken during

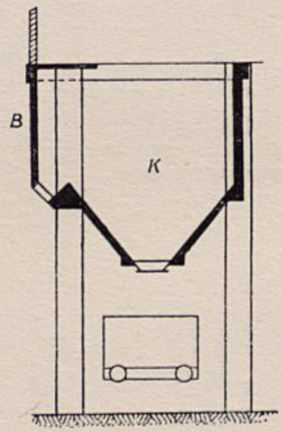


Fig. 245.—Cantilevered Bunker.

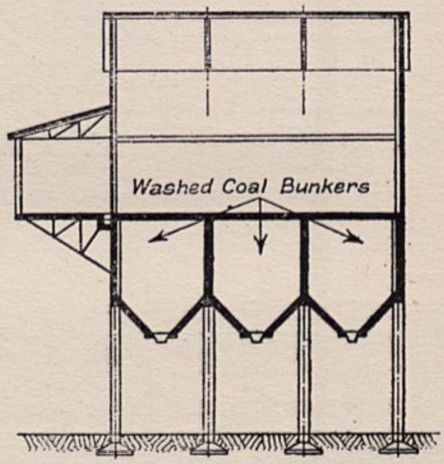


Fig. 246.—Washery Building with Cantilevered Superstructure.

construction to ensure that all bars are properly placed and that the mixture is correct and of the right quality. These have been treated of elsewhere, but a few defects of design, often due to carelessness and lack of originality, are worth calling attention to so that a repetition may be avoided.

Where the substructure is of reinforced concrete, it is not good practice to side-step the main supporting members to house the machinery. It frequently occurs that in the lay-out an elevator or a conveyor would be more suitably placed if a column or beam of the concrete could be moved to one side. The only excuse for doing this is proof that the strength of the structure remains unimpaired and compensating members placed in suitable positions.

In reinforced concrete, to obtain continuity of strength, the tension bars of a large beam are given a considerable overlap, which is impossible when ending in thin wall beams. In Fig. 245 is shewn an example of an extremely poor design in what was otherwise an excellent building. Reference is made to the overhang at B. The bunker, K, is carried beyond the ends of the columns, and the triangular beam at the bottom of the hopper is left with in-adequate depth to withstand at a reasonable factor of safety the burden imposed upon it from the bunker load. The side wall, B, of the bunker, only acts as a retaining wall for the head of coal, and cannot effectively be considered as a beam between the columns to take the load of the coal in the bunker as does the side wall on the right. The outside walls support half the weight of the superstructure and the roof, and this is transmitted to the columns by the cantilevering of the cross partition walls, which, being deep, will not be subjected to bending so much as to shear and buckling, so that they should be of great relative thickness.

It often happens that an increase in the cubic contents of buildings does not

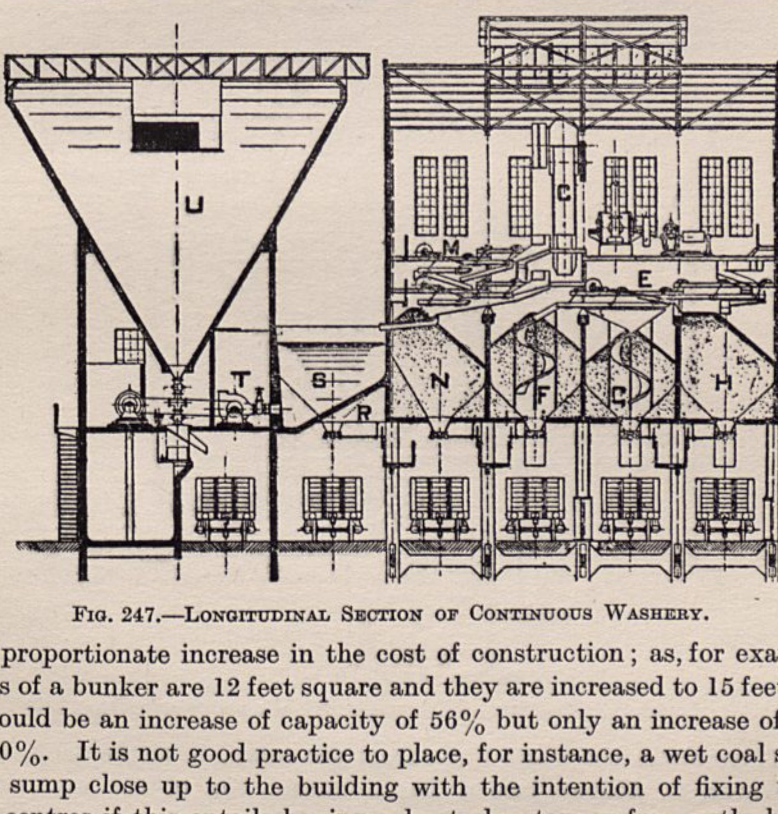


FIG. 247.—LONGITUDINAL SECTION OF CONTINUOUS WASHERY.

entail a proportionate increase in the cost of construction; as, for example, if the sides of a bunker are 12 feet square and they are increased to 15 feet square there would be an increase of capacity of 56% but only an increase of cost of about 30%. It is not good practice to place, for instance, a wet coal sump or smudge sump close up to the building with the intention of fixing uniform column centres if this entails having a bent elevator, as frequently happens. The extra cost of the bend on the elevator in construction and maintenance will be more than the cost of increasing the sump to a size and shape such that the elevator would have been straight. The overhang on the building required for vibrating machinery as shown in Fig. 246 is not good practice and should be avoided.

The columns of all washery buildings should not be subjected to cutting or additions. The amount of heavy moving machinery at a considerable height from the ground induces ordinarily a good deal of vibration in the structure, and weak columns do not help to reduce this tendency.

In Fig. 247 is shown a weak design of pump well and bunkers. The linking up of the washery and the settling tank by the pump well, S, shews a want of originality in design; the loading in the washery is variable, and in the settling tank constant, so that foundation pressures are different. The

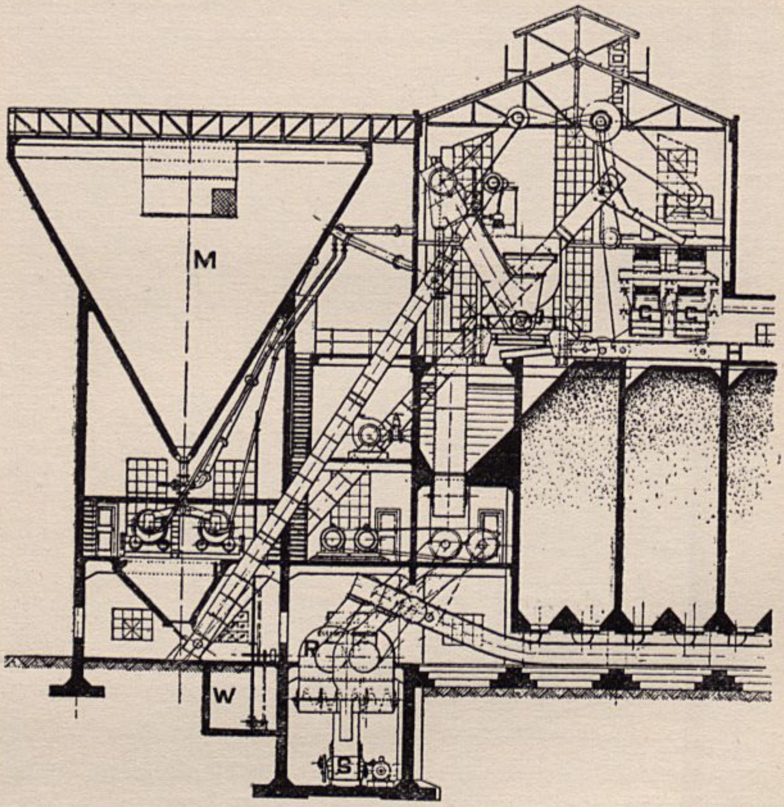


FIG. 248.—LONGITUDINAL SECTION OF INTERMITTENT WASHERY AND DRAINAGE PLANT

pump, T, circulates the waste water from the sump, S, to the tank, U. The feed elevator, C, delivers into a Baum washer box of two compartments, and the washed coal is then passed over classifying vibro screens, E. The fine coal and water is taken out by the trough, on the short length to the right, above the bunker, H, which receives the peas from the length of the screen immediately above.

The bunker, G, receives the beans from the screen tray covering the bunker, a sheet steel chute collecting these and delivering them on to the spiral chute shewn. Note the disproportionate length of screen for this size with that for the extraction of the two lesser sizes. To ensure effective screening the area for the smaller sizes should have been the greater, since not only is there more material passing over this portion, but the smaller sizes are the more difficult to separate. The oversize nuts are discharged over the end of the trays into the bunker, F, over the spiral chute.

The fine coal and water after being rewashed is passed over the lower set of vibro sieves, M, and the slurry from the settling tank is run over the upper unit and then deflected back on to the fine coal on the lower trays. The waste water from both sieves is led to the sump, S.

The siding under the settling tank is to facilitate the removal of the dirty slimes on the occasional blowing out of the tank.

All the valve cocks at the outlet of the slurry mouthpiece should be provided with guards to prevent the blowing out of the plug should the check washer become detached for any purpose or inadvertence. Gland cocks are not suitable for slurry pipe lines.

In Fig. 248 an intermittent type of washery is shewn which has certain distinctive features, some novel and some disadvantageous.

It is a Baum washery, and the section shews that the building, of reinforced concrete, is directly connected to the settling tank walls. If this connection were of a hinged nature (see Fig. 256) this could be allowed, but otherwise it is not desirable. The boot of the smudge elevator is shewn in the shafting room of the scraper conveyor and the crushers, the motors being in the room adjacent. This leads to a great deal of nuisance from the leakages of dirty water from the boot and the occasional blowing off of the smudge sump. The smudge sump blow-off cock is usually placed on the bottom of the mild steel boot. Note the mass of concrete on the right of the smudge sump wall. The washery pump is placed on the floor above the motor room between the settling tank and the building. In the tower of the settling tank two tubular Blackett washers are placed for the purpose of washing the slurry. The two small diameter pipes leading off the washery water service pipe are led down to the Blackett washers, which are supported on suitable rollers and circular guides. On the inside a spiral flange is run for the whole length, and is securely riveted to the cylinder. The washer is caused to rotate by gearing in a direction such that the spiral propels towards the inlet or higher end of the tube, the latter being inclined downwards to the discharge end. The slurry and water of washing enter together at the higher end, which is also the dirt discharge position. The rotation of the tube is to cause the propulsion of the dirt which is caught by the flange spiral to be delivered at the opposite end to that of the recovered coal particles.

The flush of water down the tube carries the lighter coal particles over a concentric projecting flange on the discharge end and thence over a fixed dewatering sieve into the bunkers shewn immediately below. The dirt and the washed coal is then drawn from these bunkers by their respective elevators and delivered into the washery, the former into the main dirt bunker and the latter into the dewatering fine coal sieves, G. These sieves deliver into the distributing scraper, H, over the large capacity drainage bunkers. It is to be noted that the slopes of these bunker bottoms are too flat (compare Fig. 242). They are actually at 42°, giving the small valley angle of 33° which is too flat to promote the run of the moist coal.

The sloping sides of the bunkers should not be less than 53°, which gives a valley angle of 45°, which should be taken as a minimum.

In Fig. 249 is shewn a graph giving valley angles for different side slopes. Thus, given two sides, one sloping at 52° and the other at 55°, follow down the

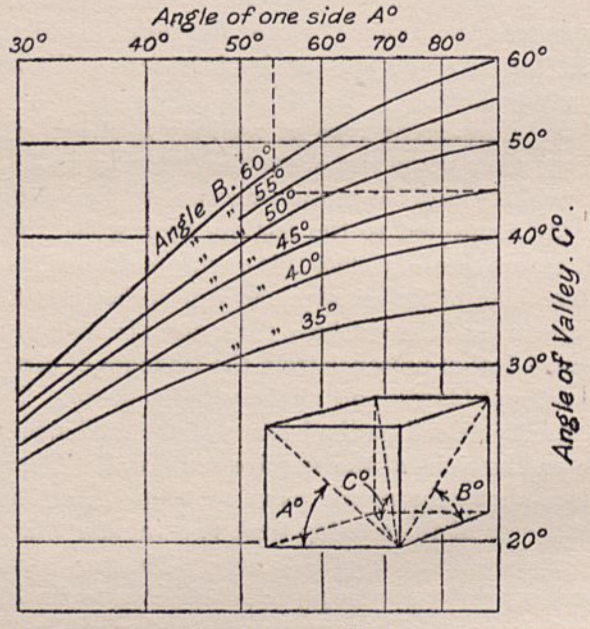


FIG. 249.—GRAPH TO FIND ANGLE OF VALLEY AT THE INTERSECTION OF TWO INCLINED PLANES.

vertical from the top line at 52° until it cuts the curve of 55°, then moving horizontal as shown in dotted lines, the angle of the valley is shown on the right.

All sharp corners or valleys in concrete hoppers should be filleted with mass concrete, so as to avoid the eventual filling up with wet small coal.

The most satisfactory arrangement of building in which there is a rewashing of the fine coal is shown in Fig. 131.

The smudge sump or well, 14, is built directly on to the main building and adjacent to the pump well on the same column line. The overflow from the sump is then collected by the peripheral trough, and led to the pump well, 26, which has an overflow at side. The wet-coal elevator is supported in the sump by a substantial mild steel boot built into the walls of the well. The elevator bottom sprocket shaft is supported in brackets bolted to the sides of this boot, and access from below is obtained through a manhole door on the right. It is a good plan to fix a 4-inch plug cock in the base of the boot for drainage purposes.

To economise reinforced concrete work, the design of hopper bottoms often takes the form shewn in Fig. 250, providing there is no heavy moving machinery in the upper part of the building. The gridwork of beams supporting the mouths of the hoppers constitute a support for the bottom ends of the slabs, and necessitate the provision of reinforcement for bending over the sloping span, as opposed to pure tension in the slung type of hopper bottom. A disadvantage of the grid support is the blocking up of the passageway under the slopes, utilised as a gangway for the operation of the mouthpieces and loading chutes.

In Fig. 251 is shewn a double-unit washery having a central concrete

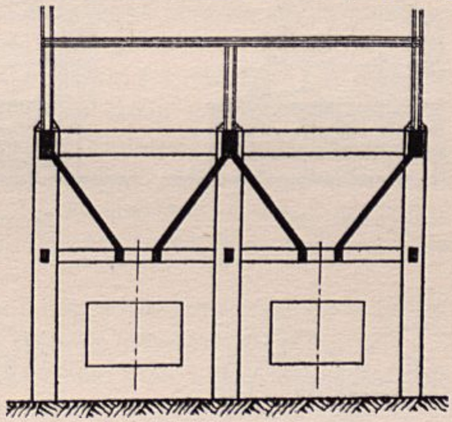


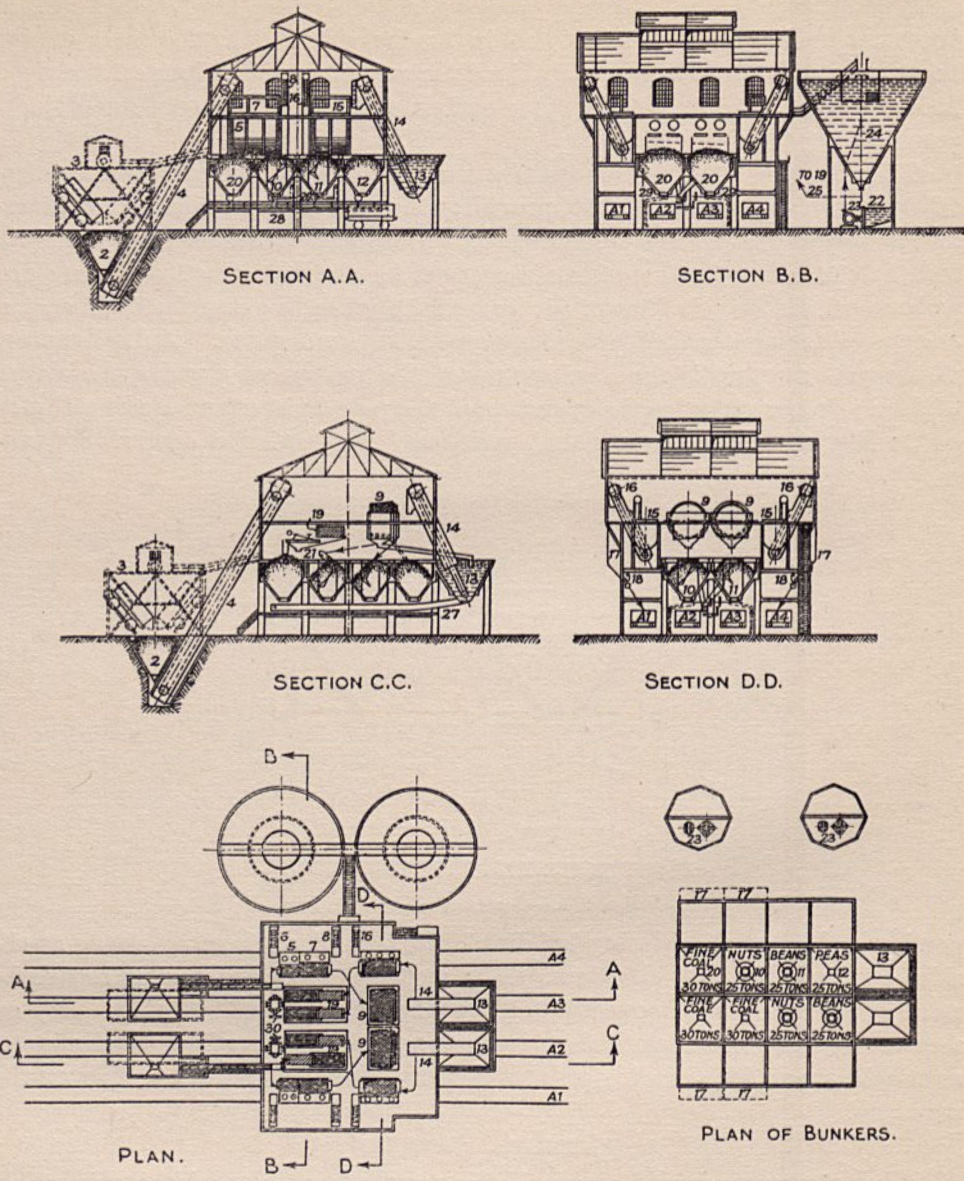
FIG. 250.—CONCRETE BUNKERS.

portion and a larger enclosing building of mild steel, with an overhang at the sides to house the dirt elevators. This method of construction is not to be recommended, and if the overhang, although slight, is absolutely necessary on account of site conditions, it should commence at the lower floor, to eliminate, as much as possible, bending on the vertical frame and put shear only on the members.

STORAGE BUNKERS

When storage pure and simple is the requirement, it would be reasonable to suggest a surface dump as the most economical proposition.

Dealing with raw slack and an ample ground space, as in American collieries, this becomes practicable, but would not be countenanced in this country, excepting under the most extreme conditions. The reasons are, first, suitable ground is not always obtainable on colliery sites, secondly, colliery companies cannot afford to stock their products, and, thirdly, there is not the margin of profit to pay for extra handling in reloading.



REFERENCE.

A. SIDINGS.
2. FEED HOPPER.
3. ELECTRIC ROPE TIPPLER WITH TABLES.
4. FEED ELEVATOR.
5. WASHER BOX (ROUGH).
6. DIRT ELEVATOR.
7. WASHER BOX (MIDDLES)
8. MIDDLES ELEVATOR.
9. REVOLVING SCREEN.
10. NUTS BUNKER
11. BEANS BUNKER.
12. PEAS BUNKER.
13. SMUDGE SUMP.
14. SMUDGE ELEVATOR.
15. REWASHER BOX (FINE COAL).
16. DIRT ELEVATOR.
17. DIRT BUNKERS.
18. DIRT ROPEWAY.
19. REVOLVING DEWATERING SIEVE & SLURRY RECOVERY.
20. FINE COAL BUNKER.
21. WASTE WATER TROUGH.
22. PUMP SUMP.
23. CENTRIFUGAL PUMP.
24. SETTLING TANK.
25. SLURRY PIPE.
26. LOADING SHOOTS.
27. MIXING SCRAPER.
28. LOADING PLATFORM.
29. DRAINAGE TROUGHS.
30. AIR COMPRESSOR.

FIG. 251.—DOUBLE-UNIT WASHERY OF 160 TONS PER HOUR.

Where storage is mostly required is at ironworks and coking plants, and occasionally at collieries selling to these firms.

Assuming that the coal is delivered in wagons, the cheapest storage would be that of pits under the tracks, as then only the washing would require power, whereas a ground stack would require power for unloading and reloading.

In Germany and America, this method of storage is fairly general both for washed and raw slack.

In America, the underground bunkers are in the form of long troughs having tracks equidistant from the centre line, and overhead a gantry crane running parallel to the centre line. This crane operates a grab for discharging the hopper and unloading into trucks or ropeways. In Germany, the pit takes the form of an enormous feed hopper, or series of hoppers of inverted pyramid form, and unloaded by an elevator fed through a slide-regulating gate.

In this country it is found that the most economical storage is obtained by placing the bunker above ground level. This is due to the cramped position of the sites and the necessity for reloading with a minimum of power and labour. The supply of the coal being more erratic than consumption is the prime necessity for storage. Drainage bunkers, while providing considerable storage, can be erected as alternatives. The design of the former differs essentially from storage bunkers. In the one case as large a surface or filtering area as possible is aimed at, in the other as great a volume as is consistent with a small enclosing surface.

The cost of a building, while proportionate to its cubic contents, can be varied considerably by a suitable arrangement of form.

The figures in sectional plan which, therefore, give the greatest economy of material will be a circle and a square, an oblong section being the most expensive.

The cost will vary with the extent of the walls of the bunker, considering the material to be the same in each case. Thus, for a circle having an area of 100 square feet, the length of side will be approximately 36 feet, against 40 feet for a square of similar area. A rectangle will be to any amount, but for comparison consider a rectangle of 12 feet by 8 feet 4 inches with total length of sides 40 feet 8 inches.

The circle, therefore, gives an economy of 10% with walls of equal thickness. When, however, the material of construction is reinforced concrete, the economy is considerably increased.

As a practical example, we will take a section of a bunker with a head of coal sufficient to give a pressure of 300 lbs. per square foot. The bending moment on the sides of the square will be as shewn in Fig. 252, which is $\frac{WL}{12}$ at each end and $\frac{WL}{24}$ in the centre. The thickness of the slab will have to be proportioned to the maximum bending moment :—

Table VI

STRENGTH OF SOLID SLABS.

Area of Steel and Safe Distributed Load in Lbs. per Sq. Ft.,

Including the Dead Weight of the Slab.

The Following Table is Based on $f_t = 16{,}000$ lbs./sq. in., $f_c = 600$ lbs./sq. in., and $p = 0{\cdot}675\%$.

	Slab Free Ended. Bending Moment = $\frac{WL}{8}$.						Slab Continuous One End. Bending Moment = $\frac{WL}{10}$.						Slab Continuous Both Ends. Bending Moment = $\frac{WL}{12}$.					
Thickness.	3″	3½″	4″	4½″	5″	6″	3″	3½″	4″	4½″	5″	6″	3″	3½″	4″	4½″	5″	6″
d.	2·31	2·81	3·25	3·75	4·25	5·06	2·31	2·81	3·25	3·75	4·25	5·06	2·31	2·81	3·25	3·75	4·25	5·06
Area of Steel.	0·187	0·228	0·263	0·304	0·344	0·410	0·187	0·228	0·263	0·304	0·344	0·410	0·187	0·228	0·263	0·304	0·344	0·410
Bars and Pitch.	$\frac{5}{16}$″ @ 5″	$\frac{3}{8}$″ @ 6″	$\frac{3}{8}$″ @ 5″	$\frac{7}{16}$″ @ 6″	$\frac{1}{2}$″ @ 7″	$\frac{5}{8}$″ @ 9″	$\frac{5}{16}$″ @ 5″	$\frac{3}{8}$″ @ 6″	$\frac{3}{8}$″ @ 5″	$\frac{7}{16}$″ @ 6″	$\frac{1}{2}$″ @ 7″	$\frac{5}{8}$″ @ 9″	$\frac{5}{16}$″ @ 5″	$\frac{3}{8}$″ @ 6″	$\frac{3}{8}$″ @ 5″	$\frac{7}{16}$″ @ 6″	$\frac{1}{2}$″ @ 7″	$\frac{5}{8}$″ @ 9″
Span. 4′	255	375	500				315	470	625				380	560				
5′	160	240	320	430			200	300	400	535			245	360	480			
6′	110	165	225	300	380	540	140	210	280	370	480		170	250	335	445	525	
7′	85	125	165	220	280	400	105	155	205	275	350	495	125	185	245	330	420	
8′	65	95	125	170	215	320	80	105	155	210	270	380	95	140	190	250	325	455
9′		75	100	130	170	240		90	125	165	210	300	75	110	150	200	255	360
10′			80	105	135	195		75	100	135	170	245		90	120	160	205	290
12′				75	95	135			70	95	119	170			75	110	145	205
14′					70	100				70	90	125				80	105	150
16′												95					80	115
18′																		90
20′																		

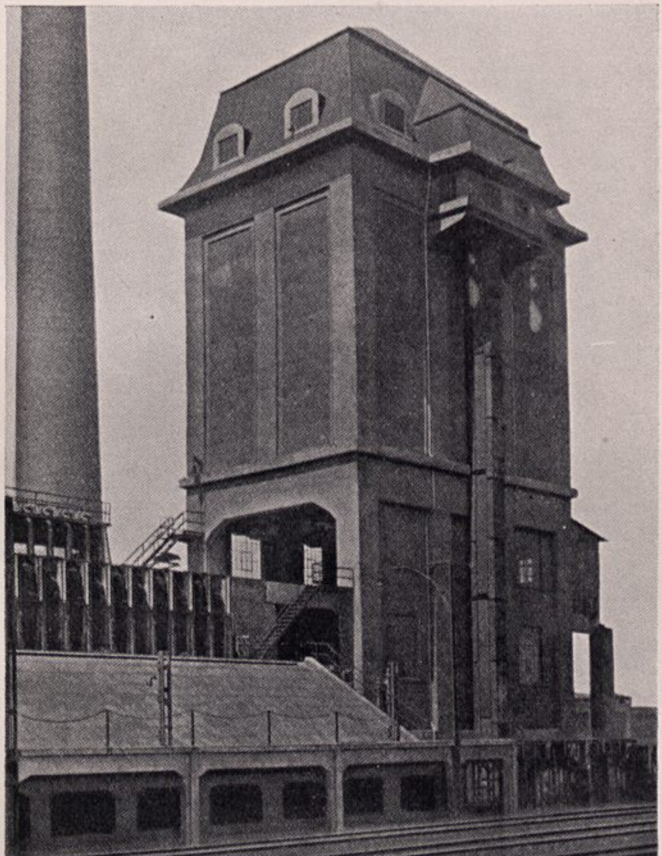


Fig. 253.—Service Bunker.
(*Meguin.*)

[*To face page* 282.

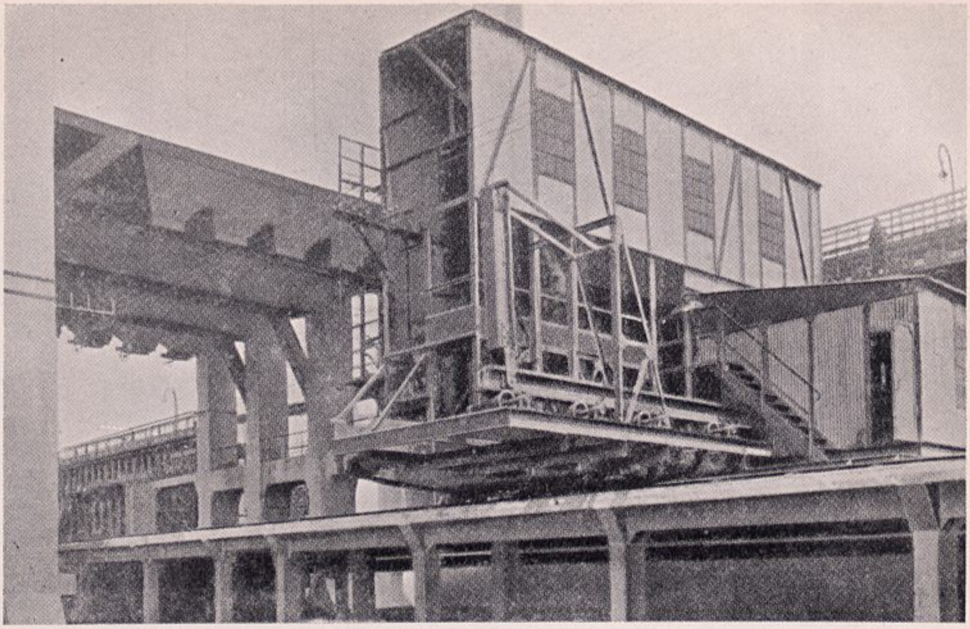


Fig. 254.—Service Bunker and Charging Car.

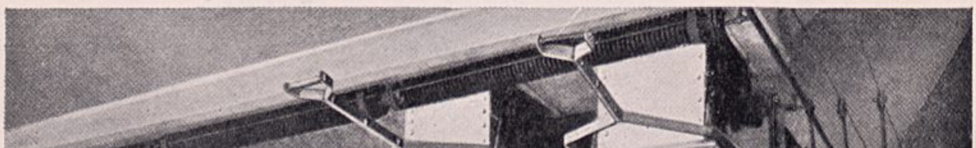


Fig. 255.—Service Bunker and Charging Car, shewing Heating Pipes and Mouthpieces.

$$\text{B.M.} = 300 \times 120$$
$$= 36{,}000 \text{ inch lbs.}$$

which will require a slab 7 inches thick (see Table VI). The circle, on the other hand, is not subjected to bending moment, but merely to ring tension, therefore the whole of the side stresses are taken up by the steel, and the thickness of the concrete need only be sufficient for wear and tear and vertical buckling stresses, 4 inches being ample.

The amount of steel being similar in both cases, the total saving of concrete in favour of the circular bunker is about 43%.

Another advantage of the circular bunker is that the sloping sides are everywhere of the same inclination, and, therefore, it is possible to make them flatter than those of the square bunker.

The great disadvantage, however, is the unadaptable shape.

A rectangular building adapts itself to uses other than that of storage, and as it is often necessary to place machinery, etc., in the superstructure of bunkers,

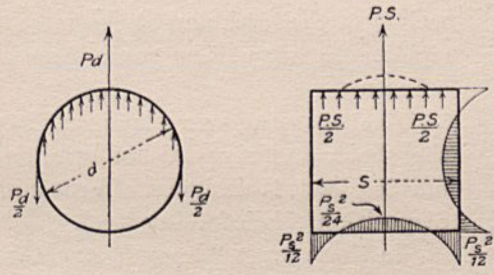


Fig. 252.—Circular and Square Bunker Stresses.

the circular pattern, while being cheapest, is passed by in favour of the rectangular.

In Fig. 244 is shewn a group of circular bunkers, each of 130 tons capacity, for washed slack. The comparison of estimated costs with that of a square bunker, if of reinforced concrete of similar capacity, is as 2 to 3.

The cylindrical shell when in concrete is supported on a deep circular triangular beam, resting on four columns 90° apart. When the diameter is greater than 20 feet, a good plan is to put in beam footing between each column, so as to ensure equal sinking.

Each bunker should have separate foundations, as, unlike square bunkers which have common sides, the circular is entirely separate.

A storage bunker is often used as a source of feed to supply several different units and also to collect its store from several points.

In Fig. 253 is shewn a large concrete service bunker for feeding charging cars of coking plants. It is of a very imposing design and has the advantage of being artistic without detracting from its utility.

The hopper mouthpieces are arranged to feed directly into the hoppers of the charging car (see Fig. 254), and a clearance of only 3 inches is allowed between the car operating house and the bunker bottom.

The whole of the building and roof is of reinforced concrete, with the exception of the roof trusses, which are of steel.

The crushers are placed on the top floor of the bunkers, and are provided with a thick concrete bed suitably supported upon a cross beam carried by the main beams spanning between columns. The thrust of the crusher house beams and pressure of the coal against the sides act together, so that every care must be taken in the placing of steel in the side columns for the large amount of bending moment transmitted, for there are no cross walls, with the exception of those at the end.

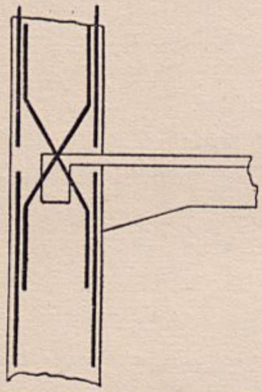


Fig. 256.—Reinforcement Bars in Columns.

The crusher house is narrowed down for appearance, and is constructed of asbestos sheeting, and as the building is of ample size, attention should be drawn to the massive cross beams supporting the hopper bottom. These beams are designed to carry the whole weight of the load, and at the same time have sufficient rigidity to act as the main braces of the long side columns.

The charging car platform, having to withstand the shock and reversals of bending moment due to a moving load, is designed of heavy section with suitable disposition of reinforcing steel.

In these large " leggy " structures it is advisable to construct the footings in one continuous unit or bed under each row of columns, so as to ensure an even distribution of stresses throughout the structure. With such high buildings an ample margin must be left for the effect of a strong side wind upon the pressure at the footings and the resulting tendency to cripple the columns. All cross beams should, therefore, be generously haunched and provided with ample compressive steel. The arrangements of steam pipes for prevention of freezing in winter and hopper mouthpieces are shewn clearly in Fig. 255.

In buildings such as the present example the safest plan is to relieve the stresses in the end walls, due to the bearing pressure of the coal, by vertical bearing columns and stiffening cross beams, and by designing the vertical columns in the manner shewn in Fig. 4. Where crushers are installed on the top floor the discharge of the coal from the rapidly revolving discs causes it to heap up against the end walls, as the span is too large to allow of risks being taken, so much depending upon the intelligence and care of the foreman concreter.

A general fault of English practice is that these buildings are designed as one single structure with a continuity and rigidity of material throughout. It is a much better plan to design it in a series of parts similar to the manner of structural steelwork, with the difference that the beams and columns be taken as rigid connections in place of simple beams. Thus, from the level of the platform to the footings is taken as one structure ; from the crusher floor beams to the top of the platform and from the roof cross-beams to the floor level as others entirely separated. This would divide up the building in such a manner that the stresses on each part could be more readily analysed, and then, in place of carrying through the column steel with the usual overlapping, the junction could be made in what is to all intents and purposes a hinged joint as shewn in Fig. 256. This hinged joint is obtained by bringing up the column steel to a suitable height vertically, and then bending it across to

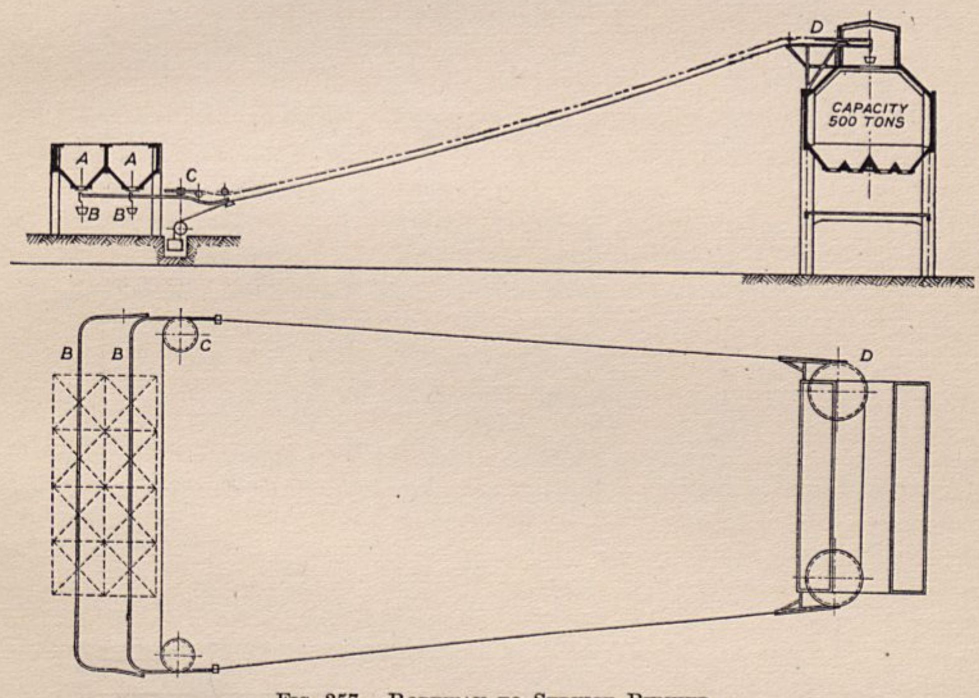


FIG. 257.—ROPEWAY TO SERVICE BUNKER.

the other side of the next floor column in such a manner that the point of intersection of opposite reinforcements is at the floor level as shewn. By this means a much simpler problem is given to the designer to solve. The structure does not lose any of its strength by this method, which has been in use in Germany for many years and introduced by the author into several British structures.

In many cases these service bunkers are placed in such a position that it is impossible to feed them by elevators or conveyors.

As an example of this type, Fig. 257 shews a steeply-inclined ropeway loading into the bunker from a low-level drainage bunker.

The bunker shewn in the illustration has given great satisfaction in its working, and this method could be adopted with advantage in many collieries. In America, where wood is cheap and the necessary labour plentiful, the bunkers are usually built of wood.

In Fig. 258 is shewn a wooden bunker of 800 tons capacity carried upon

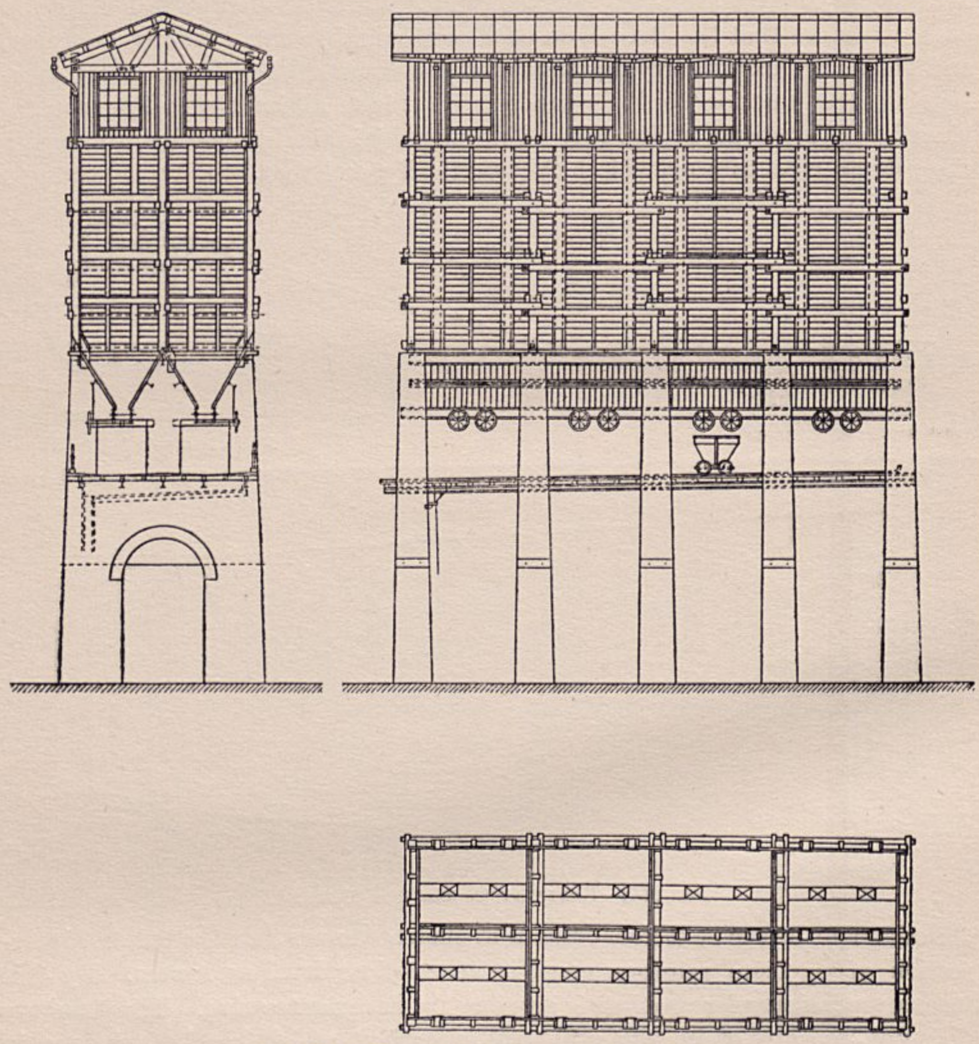


FIG. 258.—TIMBER BUNKER ON BRICK PIERS.

brickwork piers brought up to the level of the bunker bottoms, steel joists being used to support the loads over the spans between the piers.

Small bunkers of this type are still being erected at the smaller collieries in this country, especially those exploiting a legacy of Beehive ovens. As a drainage proposition, a wooden bunker not too closely seamed is hard to beat.

CHAPTER XVIII

SALES AND METHODS OF MIXING

THE sales and mixing arrangements of collieries and coking plants are becoming every day of much greater importance, due to the demand by consumers for a certain specified quality of coal.

A good deal of coke was formerly used for domestic and ordinary industrial purposes and its quality was, therefore, not of great importance, but with the increased use of metallurgical coke the quality is a very important consideration, and it is admitted that the mixing of different qualities of coal for coke production is a very desirable feature.

The advantage of the mixing is that the range of quality of the coals is thereby increased, especially in view of the fact that a large amount of inferior slack, which is otherwise suitable for coking, is to be obtainable at a cheap rate, and by a judicious admixture to a better quality fine coal, a great saving in production cost would be effected.

For sales purposes, it is becoming the practice to mix a proportion of fine washed slack with the large coal at the screens, as by this means a better price is obtained for the slack than would be otherwise possible. Having been washed, the slack is in every way equal to the large coal in quality, if not in size.

The coal on leaving the washer box is screened into various commercial sizes, the most general being, in England and Wales :—

Doubles above 2 inches.
Nuts—$1\frac{1}{4}$ to 2 inches.
Beans—$\frac{7}{8}$ to $1\frac{1}{4}$ inches.
Peas—$\frac{3}{8}$ to $\frac{7}{8}$ inches.
Fine coal—$\frac{3}{8}$ inch to 0.

These sizes are the usual washery sizes and vary slightly in different districts. In Scotland, the usual sizes as are follows :—

Trebles—$2\cdot\frac{1}{8}$ to $1\frac{5}{8}$ inches.
Doubles—$1\frac{5}{8}$ to 1 inch.
Singles—1 to $\frac{3}{8}$ inch.
Pearls—$\frac{3}{8}$ to $\frac{3}{16}$ inch.
Gum—$\frac{3}{16}$ inch to 0.

This latter size is greatly on the increase in Scotland, due to the wide use of coal-cutting machinery, and is usually of very poor quality, being in a great number of cases only used for the boiler stoke-hole.

In Fig. 259A is shewn a suitable screen for the Northern coalfields. It is the vibro hickory spring type, and takes out the four sizes in a run of about 40 feet. The fine coal is screened off with the water on the first portion of the screen, and bunkers are provided for the remaining three larger sizes, each bunker having a capacity of 80 tons and each of them loading over separate sidings.

In Fig. 259B is shewn a more elaborate arrangement of sizing for a Welsh washery. On the first vibro screen, with an overall length of 22 feet, the peas and below are extracted on the first tray and are passed over a second set of vibro screens at a lower level to separate the fine coal below $\frac{3}{8}$ inch, which is

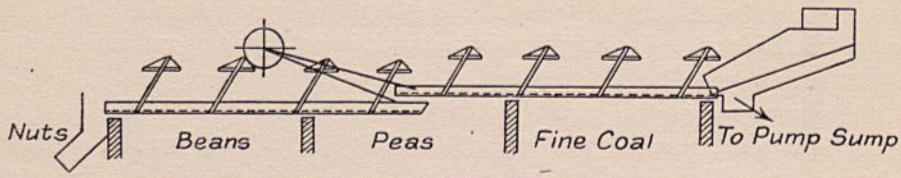


FIG. 259A.—SALES SIZING.

returned to a wet coal or smudge sump to undergo a rewashing before storage, this being necessary as the ultimate product is to be utilised in coking.

The peas, as an oversize, are dropped from the end of the screen into a bunker. The beans, which are taken out as an undersize on the second tray of the upper screen, are carried along in a shoot connected to this tray to a more inclined stationary shoot, which deposits them over a spiral into the bunker. The nuts, being an oversize from the same screen, are led direct to the spiral shoot

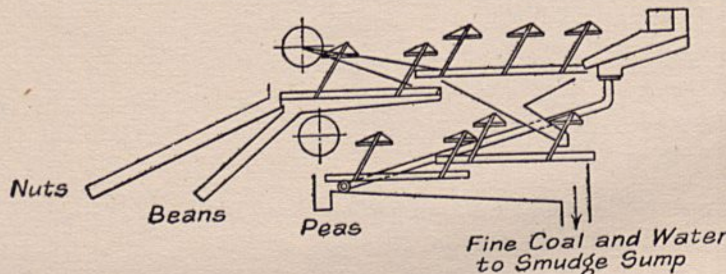


FIG. 259B.—DOUBLE VIBRO SCREEN SIZING.

in the bunker. The two larger sizes are deposited into the wagons by means of loading shoots to avoid breakage.

To facilitate the opening of the mouthpiece slides by boy labour, a platform is run between two sets of bunkers, and the hand-wheels on the slides are brought close up to the latter, the loading shoots being likewise operated from the same platform.

In Fig. 150 there are five sizes extracted on the screen 30, the smaller of which is returned with the waste washing water for rewashing and the four larger sizes are loaded into the bunkers, 31. At the discharge of these bunkers drain and spray boxes, 32, are placed, over which the coal passes before entering on to the long loading jibs, 33.

In Fig. 241 is shewn the bunker arrangement of a large washery dealing with 125 tons of coal per hour, where all the sales bunkers are placed over one siding, the fine coal being utilised for coking purposes.

The large coal, nuts, and beans are laid gently into the bunkers from large spiral chutes from the vibro screens, and below the bunkers a loading shoot eases the fall of the coal into the wagons. The peas in this case not being provided with a loading shoot, the first undersize on the screens, that is, all below ⅜ inch, is led to the smudge sump and rewashed, whence it is led by troughs to the dewatering apparatus, passing first over a fixed sieve and then over a double set of shaker sieves.

The recovery of the concentrated slime from the settling tank is effected by passing it over the fixed sieve and thence shooting it on to the fine coal on the shaker sieves, so that the contents of the bunker are a mixture of slurry and fine coal.

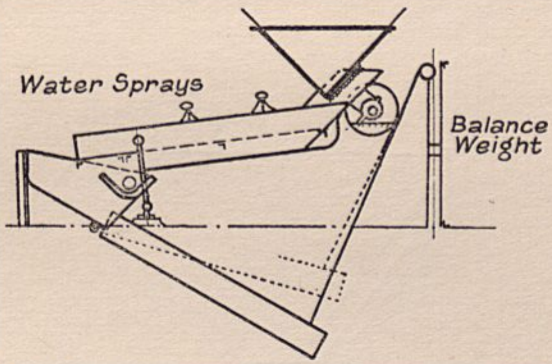


FIG. 260.—SPRAYING AND RESCREENING APPARATUS.

A small by-pass shoot is fitted to the side of the fine coal bunker to load the fine coal into tubs on an elevated gantry, for use at the boiler house.

The sizes taken out by the revolving screen in Fig. 251 are nuts, beans, peas, and fine coal, the fine coal below ⅜ inch being led to the smudge sump by the pipe coming from the underside of the screens casing, whereas the peas are dropped immediately into the bunker 12. As the nuts bunkers are too far away to shoot the coal by gravity into them, recourse is had to the aid of a flushing water jet at the head of the trough leaving the screen which carries the coal along to the drain boxes (which extract the water over a fine-mesh fixed sieve), at the head of bunkers 10, before depositing the coal over the spiral shoots.

In some washeries, the shale is so disintegrated in the boxes that a fine thin white powder coats the coal when dried. This fact militates a great deal against sale; and, as this powder is not very adhesive, it is found that a clean water spray will clean it off without much trouble.

The spraying may be done either on the classifying screens on leaving the box or on small vibro screens placed beneath the bunkers just before dispatch to the consumer, as shewn in Fig. 260. The former arrangement is cheaper and

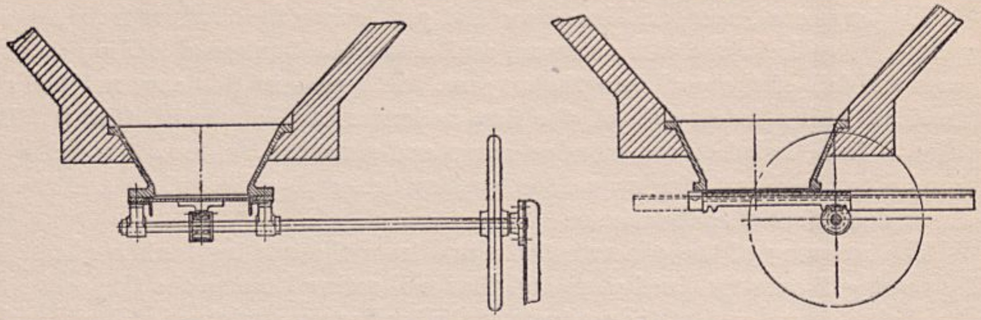


FIG. 261.—HOPPER MOUTHPIECE RACK AND PINION SLIDE.

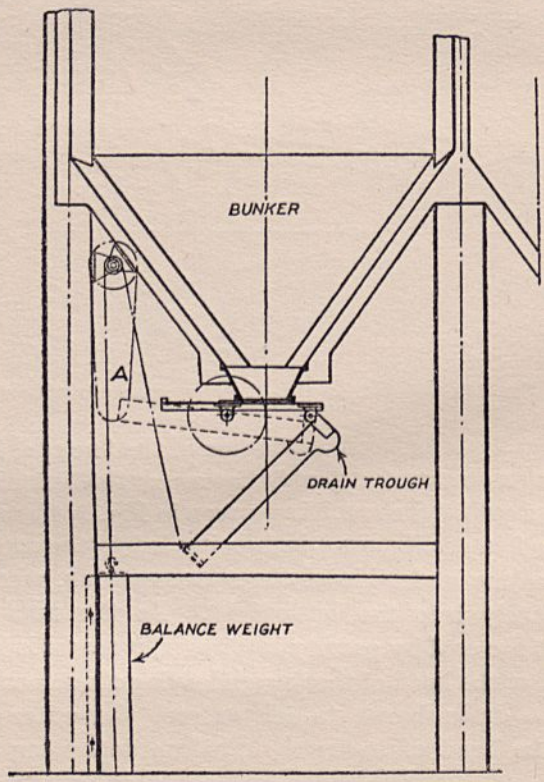


FIG. 262.—LOADING CHUTE.

more satisfactory, as a larger amount of spraying may be done without adding to the moisture content of the coal when loaded.

A side-loading arrangement can be suitably operated by using a modified form of Fig. 32; it is simple to operate and is more reliable than a fixed chute since the spoon of the jig can be placed directly under the side opening in the bunker wall to receive the coal. A very satisfactory design of mouthpiece is that shewn in Fig. 261. The casting is about 12 inches deep, with an outlet of about 18 inches square, and with sides sloping at about 60°. A perforated mild steel slide, fitted with a cast-iron rack, runs in grooves made by angles extending beyond the mouthpiece lip. A small pinion supported in cast-iron filbows is made to open the slide by means of a 36-inch diameter hand-wheel.

A diagrammatic arrangement of loading chutes serving as a drainage collector from the bunkers when in the up position is shewn in Fig. 262; an extended branch trough of semicircular section is connected to the drain trough and delivers the water into a collecting main fixed to the washery columns.

CHAPTER XIX

FLOTATION ANALYSIS

Prior to the construction of a washery, either the contractor or the colliery company should carry out laboratory tests on samples of coal proposed to be dealt with. The best possible method would be to treat the coal in an experimental plant on similar lines to the proposed washery. This, however, would mean a large unproductive expense in most cases, so recourse is had to tests on small representative samples of the coal. These laboratory tests, no matter how small a quantity is dealt with, are of great practical value in the design of the machinery and regulation of the plant when starting up, apart from the commercial aspect.

The debatable point as to what is a representative sample, and the various methods of obtaining one, are not, in practice, given the serious attention they deserve. If it is intended to deal with 500 to 1000 tons of raw slack per day, it seems hardly reasonable to take a lot of 10 to 14 lb. from one heap and consider that as a sufficiently just sample. Given a homogeneous mass, a small sample would be ample, but where the mass is the product of different parts of pit and seams, it is so heterogeneous that only a large amount could be considered reliable. The taking of the sample entails a great deal of care, and with slack coal the most reliable method, commensurate with the economy demanded by colliery executives, is to take several shovelfuls from the slack conveyor, say, 100 times a day, at regular intervals, and to dump these into a separate heap, preferably through a central shoot, so that the pile builds up evenly around the centre. There will then be about ½ to 1½ tons of coal in the heap, which is now divided into two heaps by alternate shovelfuls, and then is further subdivided in the same manner, until an average sample of about, say, 1 cwt. is obtained for the laboratory. This method, though rough, is sufficiently accurate for washing tests; but a calorimetric test, a much more elaborate procedure, should be gone through, for which the reader is referred to the excellent bulletin issued by the Lancashire Coal Owners' Research Association.

In the laboratory the sample should be first screened to the sales sizes above ⅜ inch and then from ⅜ to ⅛ inch, ⅛ inch to 1 millimetre and 1 millimetre to 0. The resulting heaps should then be subdivided in mechanical samples or by cones. The cone method is to take the heaps as they were screened, flatten them out by top pressure, and then divide them into quarters, or into portions sufficiently small to be dealt with by the apparatus.

The mixtures used for obtaining the various densities of solution for the sink and float test is generally of zinc chloride or carbon tetrachloride, the former for the lighter range and the latter for those at about 1·6. It is quite sufficient to have a range of from 1·3 to 1·6, as between those densities the good and middles coal are sorted out. Zinc chloride crystals can be added to water to form solutions of densities varying from 1 to 1·45. The solution being made, it is tested for density by a floating hydrometer and adjusted at will by adding the amount of water or chemical as indicated.

Float and sink methods of testing coals were originally applied only to coal of the larger sizes, *i.e.* above $\frac{1}{8}$ inch. It was considered useless to test the smaller coal, on account of the inability of the washing machines to deal with it satisfactorily. Modern apparatus, however, has been so greatly improved that it is possible to wash even the smallest particle, and therefore it has become necessary to apply float and sink tests to all sizes of coal from 0 to 2 inches. These tests, being positive, give a good basis upon which to rate the washability of a coal or the washing result of a treated coal.

Given a sample of coal, it should be screened into a number of different sizes, so as to obtain the relative proportions of each size in the original lot and the amount of dirt carried by each. A good testing classification is from 0 to 1 millimetre, 1 millimetre to $\frac{1}{8}$ inch, $\frac{1}{8}$ inch to $\frac{3}{8}$ inch, $\frac{3}{8}$ inch and above. The lots of each size may then be divided into two parts, one part being for the float and sink test, and the other for the ash test in the unwashed coal.

When dealing with fine coal below $\frac{1}{8}$ inch, the best specific gravity media are those of organic solutions, such as a mixture of carbon tetrachloride and benzene or toluene; particularly is this so when the results of a test are rapidly required.

With larger coal, mineral salt solutions of zinc chloride and water are satisfactory. All solutions should be chemically inert to the coal and be sufficiently stable during test, to avoid a change of specific gravity.

The testing laboratory should be kept at an even temperature throughout.

As the reliability of these tests depends upon the total wetting of the surface of each particle of coal, it is necessary to ensure that there is a uniform degree of moisture in the coal to be treated. Mineral salts should be used on coals containing a great deal of moisture, but with organic liquids the coal should be dried uniformly in the air before insertion in the test box.

Air-dried coal absorbs the carbon tetrachloride very rapidly; on the other hand, when the coal is saturated with moisture the surface is not wetted by the solution, and unreliable results are obtained.

Coal tested in mineral salt solutions should be subjected to a number of washings in clean warm water, to effect the complete removal of the salts, before weighing, whereas the organic liquids, being highly volatile, are rapidly expelled from the surface of the coal on exposure to the air.

The most suitable type of apparatus for testing coarse coals takes the form of a two-compartment wooden or tin box with sliding bottoms of fine-mesh wire gauge. The upper compartment rests in the top edge of the lower and is clamped thereto by hooks or thumb-screws. The coal to be tested is placed on the bottom of the lower compartment, and the sliding bottom of the upper compartment is withdrawn. The box is then placed in a bath of the required specific gravity and well stirred to wet all particles thoroughly. After a sufficient time has elapsed to effect the complete separation of float and sink, the sliding door of the upper compartment is pushed into position under the float, and the box is withdrawn from the bath and hung over the latter to allow ample time for drainage.

The coal is now resting on the upper slide and the dirt on the lower. The whole is subjected to a complete sluicing with warm water, and then allowed to dry in air, or placed on a laboratory hot plate when required more urgently. Using organic solutions, no washing is required. The products may now be weighed, and a further test in a different specific gravity solution can be carried out with one or the other.

A convenient size for the test box is 8 inches cube, divided into two compartments 4 inches deep.

The material on being separated into float and sink, should, on being filtered, be thoroughly washed with clean water, to eliminate all chloride solution which affects the burning on reduction to ash.

The first solution should be 1·35, the float being filtered, washed and weighed. The latter weight is then subtracted from the original, and the difference represents the sink. The sink is then placed in the next higher solution, and the float again weighed, the difference being the sink in that solution, and so on, until the full test has been carried out. For speedy separation take 1·45 first and work both ways. A reasonable amount of coal to commence with for this purpose is 8 ozs. for reliable results, but for small coals 1 oz. can be used if the experimenter is proficient and careful. The washed floats are then burned in a crucible for arriving at the ash content. The float should be crushed to a powder, and some convenient amount placed in a crucible and subjected at the beginning to a gentle heat, which is later increased to a maximum when the gas has been forced out. The residue is then weighed and compared with the original weight for percentage ash content.

The following tables give examples of sink and float tests carried out essentially for washery proposals, Nos. VII and VIII being for the same colliery, but different seams. The mixture is the slack supplied for washing.

The results of the test of the first sample show that the raw slack contains 25·4% of ash, and that the clean coal or the floatings of 1·45 specific gravity is only about 57% of the total. There is a large amount of middles product, varying from 1·45 to 1·6, the larger sizes holding the larger amount of middles or bone coal.

This would not give a coal for satisfactory washing, and to get the best results, the larger middles should be crushed and rewashed. The purest coal, that is, the lightest floated in a solution, of which there may be only one or two pieces, contains 2·4% of combined ash. In Table VIII is given the test of a coal of similar character, which shows that there is not a large amount of econo-

Table VII

Float and Sink Analysis

Colliery ________________________________

Pure Coal . . . . 2·4 % Fixed Ash, 1·29 S.G.
Unsized . . . . 25·4 % Ash.

S.G.	Size + 3/8″.				Size 3/8–1/8″.				Size 1/8″–0.				Size. . . .			
	Float.		Sink.		Float.		Sink.		Float.		Sink.		Float.		Sink.	
	Wt.	Ash.	Wt.	Ash.	Wt.	Ash.	Wt.	Ash.	Wt.	Ash.	Wt.	Ash.	Wt.	Ash.	Wt.	Ash.
1·30																
1·35	36·4	4·0			50·0	3·6			56·1	3·6						
1·40	10·0	10·8			9·0	9·6			7·5	9·2						
1·45																
1·5	8·4	17·8			11·1	16 1			6·4	16·8						
1·6	8·0	28·5	37·2	69·1	3·2	28·1	26·7	71·2	4·2	29·1	26·8	75·3				

Table VIII

Float and Sink Analysis

Colliery ________________________________

Pure Coal . . . . 1·85 % Fixed Ash, 1·28 S.G.
Unsized . . . . 28·3 % Ash.

S.G.	Size + 3/8″.				Size 3/8–1/8″.				Size 1/8″–1 mm.				Size 1 mm.–0.			
	Float.		Sink.		Float.		Sink.		Float.		Sink.		Float.		Sink.	
	Wt.	Ash.	Wt.	Ash.	Wt.	Ash.	Wt.	Ash.	Wt.	Ash.	Wt.	Ash.	Wt.	Ash.	Wt.	Ash.
1·30																
1·35	26·3	2·3			32·0	2·6			30·2	2·4			37·3	2·6		
1·40	20·5	5·1			17·4	5·2			23·3	4·2			19·8	3·8		
1·45																
1·5	9·8	10·8			10·2	11·5			7·5	11·8			11·4	8·1		
1·6	4·2	25·6	39·2	69·4	2·1	23·1	38·3	72·8	4·1	24·5	34·9	73·0	5·0	22·0	26·5	70·1

Table IX

Float and Sink Analysis

S.G.	Percentage Weight.	Percentage Ash.
1·30	72·35	4·64
1·35	81·09	5·41
1·40	86·02	6·10
1·45	87·84	6·36
1·50	88·23	6·45
1·60	89·35	6·74
1·80	91·48	7·74

TABLE X

Results of Washing of Coal, sample as in Table IX

Product.	Percentage Weight.	Percentage Ash.
Raw coal	100·0	14·2
Washed coal	78·5	7·2
Middles	7·8	19·8
Washed and Middles coal . .	86·3	8·1
Refuse	9·5	72·1
Slurry loss, etc.	4·2	—

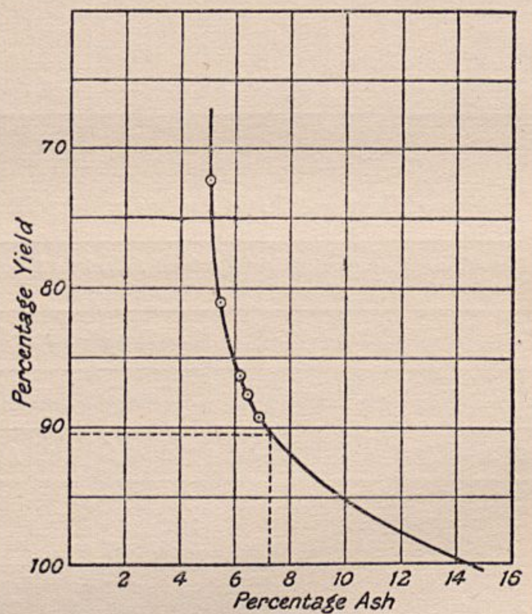


FIG. 263.

mically washable coal, although the combined ash in the lightest specimen is only of 1·85 S.G.

In the 1·5 and 1·6 solutions, however, the floats are lower than in the previous example, and it would be possible to wash to an average degree of purity. In Tables IX and X are shewn comparative tests before and after washing. In the former, float and sink tests are tabulated, and in the latter the results of an actual washing. If the results of Table IX are plotted as a graph, with the yield of float coal as the ordinate and the ash content for these floats as abscissæ, the curve shown in Fig. 263 is obtained. From this curve can be found by inspection the ash content at any yield. A very interesting deduction regarding the efficiency of the washing may also be approximated to by comparison of the above tables. The washed coal forms 78·5% of the total raw coal supplied, and contains 7·2% ash, but on referring to the curve, it is found that the yield should have been 90·6%; the ratio between these two figures should then give the efficiency, viz. $\frac{78{\cdot}5}{90{\cdot}6} = 86{\cdot}6\%$.

It will be remarked that with the yield curve the shape or degree of slope gives a ready indication of the character of the coal and the limit to which economical separation can be carried. A curve which shows a decided change of slope at about 1·4 S.G. or the corresponding ash content for that gravity is generally of easy washing character, as beyond the change in curvature when the curve begins to flatten out the ash increment increases rapidly for small increments in the yield of coal. Where the curve takes the form of a gradual slope without a decided change, it is an indication that the coal contains a large amount of middles or intergrown coal.

Of the several methods of calculating the efficiency of the washing process, having respect to the improvement in the commercial purity of the coal and the quality of the extracted refuse or loss, that suggested by Dr. Drakeley is of more frequent use, and is of a simple and rational construction. It is based upon a qualitative efficiency and a quantitative efficiency, the qualitative efficiency having as its base 100% float in the test solution, and is arrived at as follows :—

$$\text{Qualitative efficiency A} = \frac{\text{W} - \text{R}}{100 - R} \times 100\%$$

where R = percentage of float in the raw coal
W = ,, ,, ,, washed coal.

The quantitative efficiency is based upon the recovery of the coal obtained from the extracted refuse in a float and sink solution of the same density as that used for the raw slack, and is arrived at as follows :—

$$\text{Quantitative efficiency R} = \frac{\text{R} - \left(\frac{\text{DS}}{100}\right)}{\text{R}} \times 100\%$$

where D = percentage of float in dirt
S = ,, of dirt

$$\text{Efficiency of Washing process} = \frac{\text{AB}}{100}\%.$$

It has been advanced that the formula is limited in its application, on account of being dependent upon an empirical specific gravity. This amount Dr. Drakeley fixed at 1·35, as being the standard of commercially pure coal, and that all sink in this solution be considered as refuse.

In Table VII it was seen that there was a large amount of saleable coal at

1·4 S.G., and that this formula, as applied to that particular coal, would result in a low mechanical efficiency, which would, in the circumstances, be misleading.

A simple and instructive method of arriving at the efficiency of a washery is by a graphical method of plotting the various compositions of the sink and float tests as shewn in Fig. 264. On one side of the diagram is laid off the percentages of the original sample of the coal as found by the different density

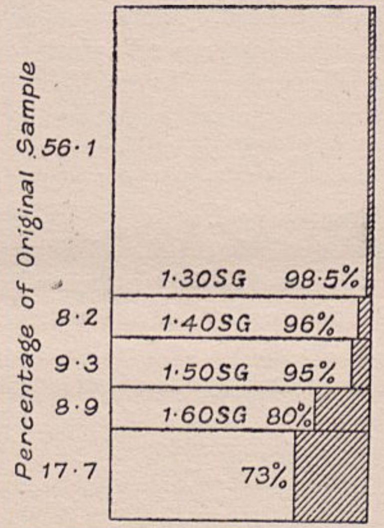


FIG. 264.—SINK AND FLOAT DIAGRAM.

solutions and horizontal lines drawn across the diagram at these points. The washed coal is then treated in the same density solution as the original samples, and the respective horizontal lines divided in the proportion of the sink and float at these densities. For example, at the density 1·30 to 1·40 8·2% of the raw coal was floated in the heavier solution, and after washing, being again placed in this solution, it was found to contain a float of 7·6% of the washed coal sample, which is 96% of the original amount. This shews that 4% only was extracted in washing, and the shaded area represents this loss.

CHAPTER XX

COMMERCIAL CONSIDERATIONS

The variety of causes which make coal-washing imperative, are a result of advancing methods and high prices, working of poor seams, and the necessity for obtaining top value for all products.

One of the great features of present-day industry is the elimination of waste throughout the manufacture of a staple material, by utilising the by-products in some form or other. In collieries, the small slack which was originally dumped on the refuse heap as waste is now treated by washing machinery to obtain a product as saleable as the larger sizes.

As all business is dependent on profit for its continuance, the washing process must be such that the article subjected to treatment is not only increased in value, but the balance of accounts, after paying for the expenses and labour incurred, should show a substantial return upon the capital invested, and a sum sufficiently great to pay off the principal within a reasonable time.

This brings us to the considerations of the following points :—

(1) First cost.
(2) Labour, control, and power consumption.
(3) Repairs and maintenance.
(4) Summary.

(1) *First Cost.*—Colliery undertakings are generally set a difficult task in deciding the extent of the capital outlay they are justified in investing in coal-washing appliances. The amount of slack per hour to be dealt with, the limit of classification, and the degree of purity required will fix the size of the mechanical plant, but the cost of the different schemes proposed by different manufacturers will vary considerably.

In point of view of initial cost it will not always be the cheapest system which will be the most economical, as the mechanical efficiency of the plant is the main factor in the production of a good balance sheet, which is the real aim.

A home-made bash washing plant may no doubt be the lowest priced of all, but against this the mechanical efficiency is generally so low, due to a lack of extended experience in design and lay-out, that in the long run such plants are, in the majority of cases, the most costly. It is as well to bear in mind that the interest on capital is not a very great item and will certainly not bear comparison with the cost per ton for washing.

The capital expenditure per ton per hour varies from £150 to £250, which represent at 5% interest £7 10*s.* and £12 10*s.* per annum, or, at 300 working days, 6*d.* to 10*d.* per day, which if of 10 hours' duration, will be 0·6*d.* to 1*d.* per ton per hour. Thus resolved, the problem is whether the additional cost of £100 per ton in the first instance is going to produce results which will counterbalance this rate per ton in washing. Washing costs vary from 2½*d.* to 7*d.* per ton with ordinary sales coal and reach about 11*d.* per ton with fines in an ordinary bash type jig, so that the difference of 0·4*d.* is exceedingly small in comparison with the running costs. Saving a few hundred pounds at the beginning may eventually mean a heavy standing charge, which never grows less with age, but increases rapidly as the plant becomes worn. Before placing an order for a complete plant, the specifications of the details should be carefully compared, especially those of elevators, scrapers, and belt conveyors, classifying screens, etc., and any plant which does not show a good wearing margin in the dimensions should be passed over, for lasting qualities are the first necessity of a washing plant.

The cost of a complete plant is greatly increased by the cost of the building and the storage required, which should be at least of 1 hour's supply. Loading direct into wagons from the washing troughs is not good policy, as any delay in bringing in a wagon, not only stops the whole plant, but also affects the efficiency of the wash, as on starting up again a good deal of dirt will be passed out with the washed coal, and good coal will pass out with the dirt.

Generally a building of reinforced concrete bunkers and steel-framed brick-panelled superstructure will represent 60% of the total cost of the plant, and for this reason it behoves an engineer to examine the building details with care, as what a contractor may drop on the machinery may be made up in the building. The first cost of a washery should not be so great a consideration to collieries as the upkeep, and the best way to estimate this is to obtain particulars from the users of a similar plant or from a study of the details of moving parts.

(2) *Labour and Control.*—The labour required in connection with the washing plant is for the internal machinery and for the unloading of wagons externally. The machinery in plants up to 50 tons per hour should not require more than one attendant, up to 150 tons per hour two attendants only should be necessary. The unloading of the wagons into the feed hopper and the loading of the washed products (when below 50 tons per hour) will as a rule occupy the time of two labourers. When above this amount, the extra services of another labourer and a boy for operating the loading slides will be necessary. Generally speaking, a washery of 50 tons per hour will require a permanent staff of three men, and five men will be required up to 150 tons per hour. This would represent a labour cost at 1*s.* 3*d.* per hour of from 3*s.* 9*d.* to 6*s.* 3*d.*, which amounts to about ½*d.* per ton per hour. These costs are for the best type of plant, where the design has been carefully carried out and represents up-to-date practice.

The horse power required for a 50 to 150 tons per hour washery varies from 75 to 200, which, at the usual charge per horse power in collieries of ½*d.* per horse power hour, represents about ¾*d.* per ton.

(3) *Repairs and Maintenance.*—The item which absorbs the largest expense of running costs in a badly-designed or low efficiency washery is that of repairs. As illustrating the large cost of repairs, a small washery was brought to the author's notice, dealing with 20 tons per hour, but costing £45 per month in repairs alone, this figure being the average of several years' working. This washery was built by the colliery company and also maintained by their own workshops, so that the cost per ton for repairs in this instance was no less than 2¼*d*. per ton. In a well-designed plant the cost of repairs should not exceed ¾*d*. per ton on the average running. Repairs should only be rendered necessary by untoward circumstances, or when the material has been worn out by prolonged service. In the first few years of the life of the plant there should be practically no necessity for repairs, with the exception of screen plates and sieve plates. The casings of the machinery, washer-box parts and troughs should be made sufficiently substantial to outlast the plant.

(4) *Summary.*—The capital value of the plant should be paid off within a period of, say, twelve years, so that taking a figure of £250 per ton per hour as the original cost, and 300 working days in the year of 10 hours per day, the charge per ton on the washed coal to cover this amount should be 1·66*d*. There is another item to consider, and this is the loss of water leaving as moisture in the washed coal. This is covered by 0·25*d*. per ton, therefore the following would represent the average economic cost of the washing process:—

Capital.

Depreciation	1·66*d*.
Interest on Capital	1·0
Labour	0·5
Repairs	0·75
Power	0·75
Water	0·25
Miscellaneous	0·25
	5·16*d*.

which shows that the average net economic cost is 5·16*d*. per ton; but as there is a certain amount of waste material to deal with which on the average is in the neighbourhood of 15% of the raw slack supplied, the cost of washing will be increased, say, ¾*d*. per ton, so that the cost will now become in the most favourable circumstances about 6*d*. per ton, apart from the charges for wagons, etc. In view of the greatly increased value of the washed slack, the capital expenditure on washeries should be rapidly recovered. If the refuse extracted from a raw slack be 15% of the supply, then the improvement in the washed slack is not 15% only, but some appreciably greater amount. If the raw coal contains 22% ash and after washing only 8% ash is present, the refuse extracted being 15% of the whole, the improvement effected may be written as follows: the relative values of the coal as fuel being (100 — 22) unwashed and (100 — 8) washed, *i.e.* the combustible matter would be in the ratio of 78 : 92, so that the actual improvement in quality to the consumer, apart from any technical considerations, would be 18%. The price of the washed product should, therefore, be this proportionate amount greater than the raw slack, but in view of the fact that freightage and handling are saved on 15%, the equitable market price should be at least 22% above that of the raw slack.

For an example, say the latter is worth 12*s.* per ton, then the washed coal at a 22% increase in value should command —

$$14/7\tfrac{1}{2}d \text{ per ton.}$$

The cost of production should be set off against this, viz. 6*d.* per ton for washing and capital charges, and 15% loss as refuse at 12*s.* per ton, which gives per ton $\left(\frac{15 \times 12}{100} + 0{\cdot}5\right)$ shillings $= 1{\cdot}8 + 0{\cdot}5 = 2s.\ 3\tfrac{1}{2}d.$, which means that the cost of production to the colliery company should be economically fixed at 14*s.* 3½*d.* at the washery, leaving a clear gain of 4*d.* per ton as the reward of enterprise. Small as this figure appears, it represents a profit of £3,000 per annum on a 60 ton per hour plant under normal working, on an original outlay of about £15,000 on plant.

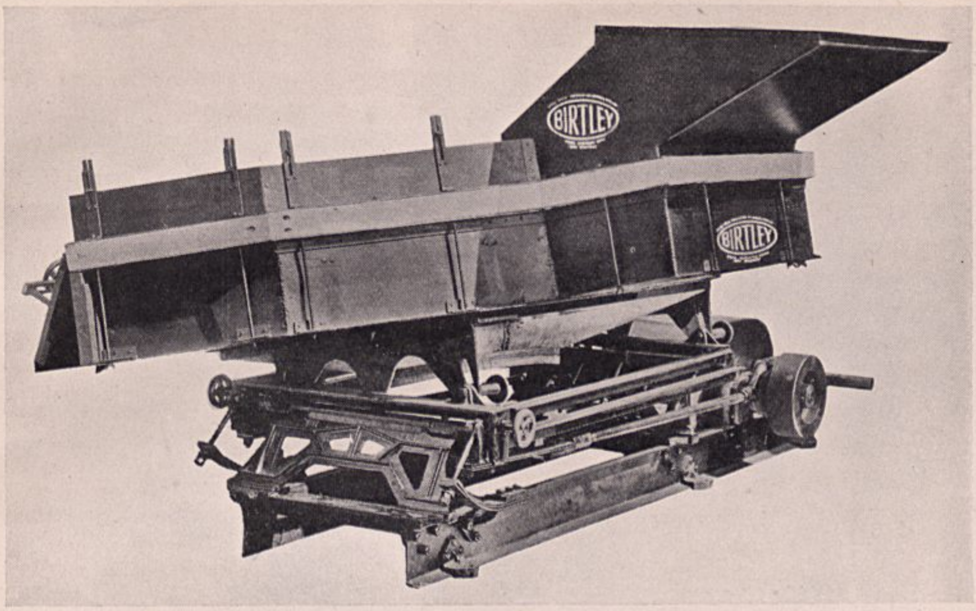


FIG. 265.—PNEUMATIC SEPARATOR.

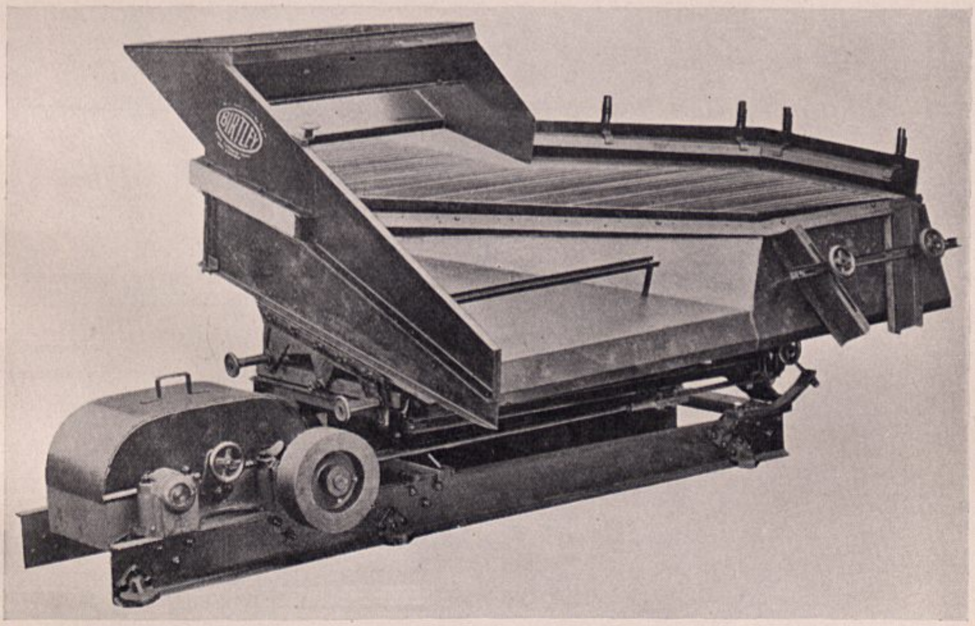


FIG. 266.—PNEUMATIC SEPARATOR.

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CHAPTER XXI

PNEUMATIC SEPARATION

The introduction of the dry pneumatic separation plant gives rise to a hopeful speculation on the possibilities of the future development of complete mechanically operated surface screening and classifying plant, not only to grade, but also to select materials in their different qualities. There is little doubt that the dry separator has a very wide field and has come to stay. One of the machines first in the field is that illustrated in Figs. 265 and 266, the one being the back view and the other the front, shewing the table upon which the coal is fed. The machine consists of an air chest to which air is supplied through a flexible joint by a fan, which is placed below or to the side of the machine. The top of the air box is closed by a pervious deck, the covering of which may be woven wire cloth, perforated zinc, or any other suitable material. The surface of the deck has riffles upon it which extend from the feed side of the machine to just short of the delivery side and taper off to nothing at the delivery end. The whole apparatus is adjustable, so that the angle from back to front or from side to side may be varied to suit different coals. In practice, the bed of the coal which is fed on to the table is made more or less buoyant by the air passing through it, with the result that stratification takes place and the heavier particles sink to the bottom, where they lie between the riffles. The lighter particles are floated over the riffles and discharged from the table into troughs suitably placed. Owing to the downward taper of the riffles, increasingly heavy particles are able to pass across them, due to the fact that the whole apparatus is jigged forwards and backwards in a direction parallel to the riffles. The very heaviest particles, however, are unable to travel down towards the front of the table until they reach the plain part at the ends of the riffles, by which time they are free from coal, and this product consists entirely of shale with a high ash content. In the result, therefore, the materials delivered from the table are in the ascending order of specific gravity from the feed or clean coal side to the delivery or shale side. The quality of the product is thus easily regulated by cutting knives or separating plates at the front of the table, which divert the shale into one receptacle, middling products into another, and clean coal into a third. The whole operation is visible, and it is quite possible to make several different classes of coal on the one table by suitable division of the discharging stream. The dust rising from the table is collected in an exhausting system and recovered.

The raw coal which is fed to the table is subjected to a preliminary sizing and tables are installed for dealing with each product or class, and the closer the sizing the better the result on the table.

With very ordinary commercial sizing, however, there is as a rule not much difficulty about getting the ash in the cleaned product to within 2% of the fixed ash in the product and not more than 1% of free coal in the shale.

The horse power of an average plant cleaning 1000 tons of coal per day from 2 inches down to $\frac{1}{32}$ inch, for all purposes including elevators, conveyors, ropeway, etc., runs from 1·5 to 1·75 kilowatt hours per ton of output from the plant. The capacity per unit runs from 60 tons per hour on coal which has passed through a 4-inch bar screen and stays on a 2-inch punched screen, 30 tons per hour from $2\frac{1}{2}$ to $1\frac{1}{2}$ inches and down according to size until the capacity per hour on dust round about $\frac{1}{64}$ inch is approximately 6 tons per hour.

The floor space occupied by a plant cleaning 125 tons per hour from 2 inches down to $\frac{1}{16}$ inch is approximately 55 by 36 feet.

When properly fed with the particular class of coal for which the tables are set up, there is no difficulty in removing all the free shale and working normally day in and day out within a figure of 2% above the fixed ash of the product.

One plant using these machines cleans 150 tons per hour of coal and sells this on a guaranteed ash basis of 7% when the average fixed ash in the product is $5\frac{1}{2}$%.

The tables will clean coal with anything up to 12 to 15% moisture, but the results are not quite so efficient as when dry coal is being used, owing to the fact that the shale dust and small particles stick to the particles of cleaned coal. Moisture, however, causes difficulty in sizing, and it is the sizing question that determines the maximum amount of moisture and not the cleaning tables, since it is possible to size under sprays and have treated a sized product down to 12% and then get the cleaning satisfactory upon the tables.

With regard to adjustments, normally when a plant is installed at a colliery the tables are carefully set up and adjusted to treat that particular coal and thereafter require no further adjustment.

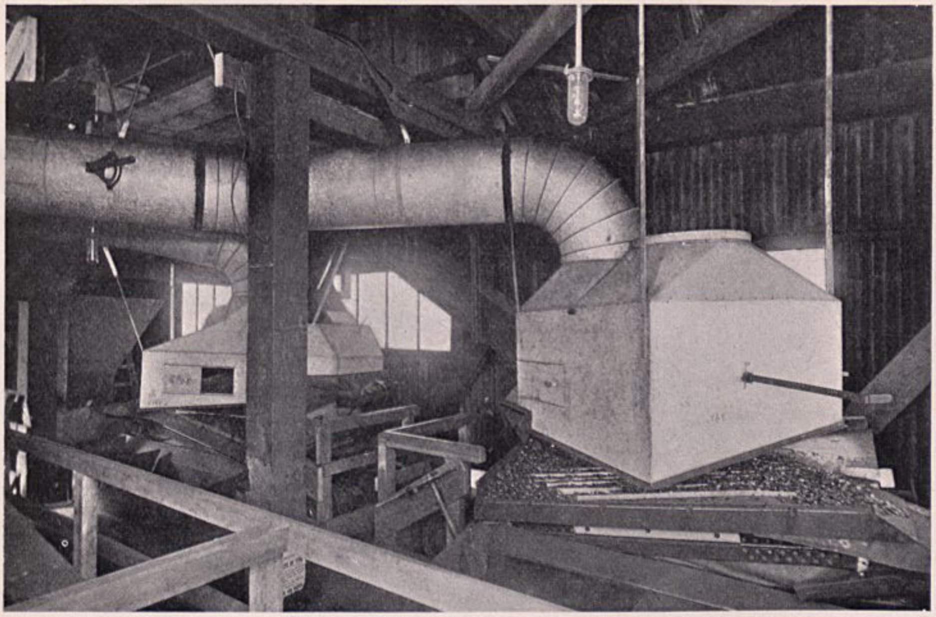
A plant requires operation by a reasonably sensible man who can be trusted to note any variations in the cleaning process and who is capable of absorbing sufficient information about it to be able to determine what is causing the variation.

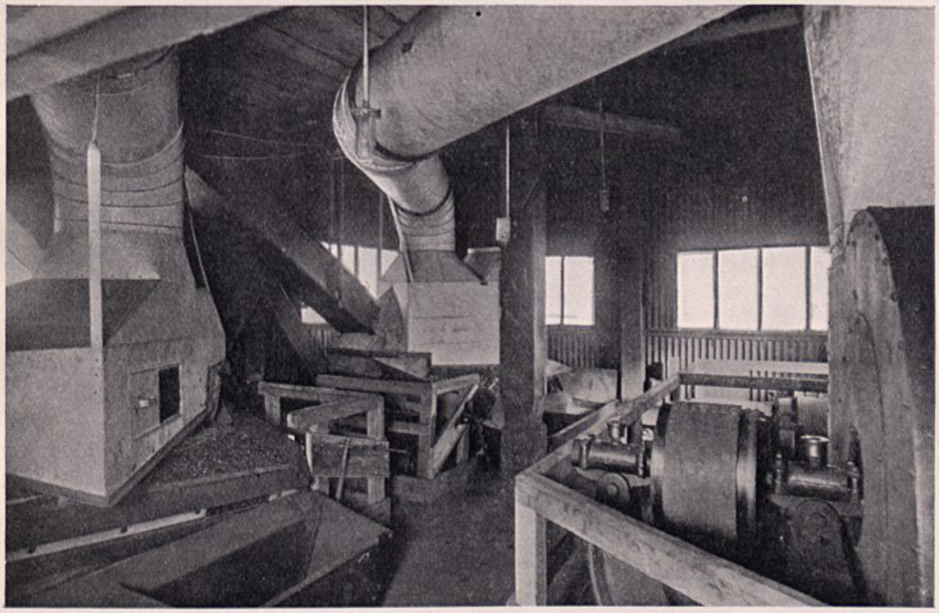
It is claimed that there is no difficulty in running plants with a fitter in charge, and it is quite possible for an intelligent attendant to run a 200-ton-an-hour plant with the aid of a boy.

Sizes may be dealt with over a wide range from well over 4 inches in size down to 150 mesh.

A further development of this table which is capable of handling the finer sizes of coal below $\frac{1}{8}$ inch without any other sizing than the removal by means of suction of dust below, say, $\frac{1}{64}$ inch, is being at present manufactured.

In Fig. 265 the machine is shewn resting upon a rectangular frame and the clamping screws or bolts for adjusting the tilt are clearly seen. The frame is supported at each end on flat plates the top and bottom edges of which rest in





Figs. 267 and 268.—Arms Air Cleaning Tables, shewing Dust Hoods.
(*H. Wood and Co., Ltd.*)

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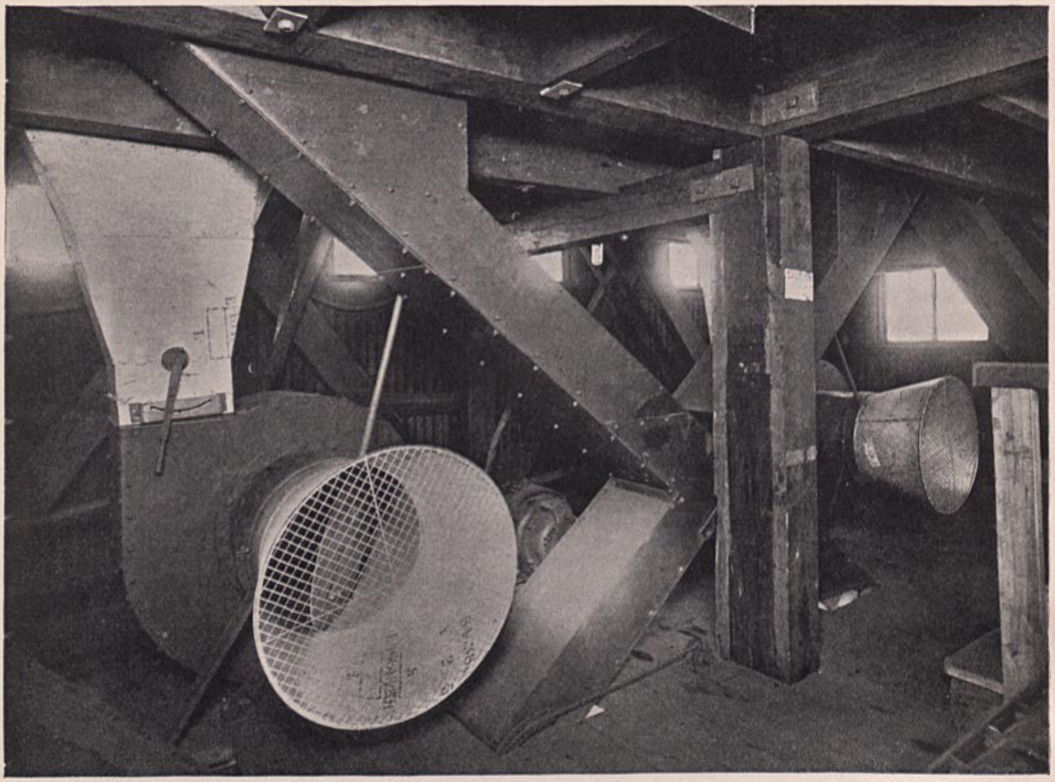

FIG. 269.—ARMS AIR CLEANING TABLE, SHEWING BLOWERS.
(*H. Wood and Co., Ltd.*)

knife-edge supports, the plate at one end being parallel to the plate at the other. The bottom edge of these plates, which are actually doing a duty similar to that of a toggle rocker, rest upon the main framework carrying the actuating mechanism shewn in Fig. 266. At the delivery end of the table there are two stout plate springs securely clamped to the stationary bedplate and connected at the free end to the moving frame by a long bolt. The combination of the toggles and springs thus brings about a movement similar to that of the concentrating tables when actuated by the gearing, causing that type of discontinuous regularity so effective in separation of materials.

The delivery chutes are clearly shewn clamped on the side of the table; the large space to the left is non-effective in separation and only forms a suitable frame for construction.

In Figs. 267 and 268 the Arms air cleaning table is shewn. It consists of a perforated or wire-mesh deck carrying riffles and subjected to a periodic jigging motion as in the former example. A blowing fan, Fig. 269, placed beneath the table forces air up through the deck on which the coal is fed. The table is adjustable in slope from back to front and from side to side to provide suitable regulation for dealing with all classes of coal. It is strongly constructed and has satisfactorily passed through severe tests.

The raw coal must be closely sized before treatment on the tables, and it is claimed that all coal below 2″ down to 50 mesh can be efficiently dealt with. Generally the higher limit of a suitable range is twice the lower limit; that is, if the coal passes a 2″ mesh it should be held on 1″ mesh in order that it may be treated on the same table. This would mean in a cleaning plant dealing with 2″ to 0″, six tables would be required. Thus—

2″—1″	capacity	30	tons	per hour.
1″—½″	,,	25	,,	,,
½″—¼″	,,	18	,,	,,
¼″—⅛″	,,	12	,,	,,
⅛″	,,	10	,,	,,
below	,,	6	,,	,,

For dealing with the latter size, however, it may be necessary to provide two tables, depending upon the amount to be cleaned. The power required for such a plant of 70 tons per hour would be about 1 kilowatt hour per ton of coal treated.

The greatest precaution in a plant of this kind is to ensure that the sizes are correctly proportioned, and the manufacturers have therefore developed a special screen for this purpose.

The above illustrations are of a North-country colliery dealing with small coal ¾″ to ⅛″, below ⅛″ being bypassed for use in the colliery boilers. There are two tables only making two sizes.

To prevent the spreading of dust large hoods are fitted over the tables, as shewn, and by means of the large diameter pipes carried to a dust filtering chamber for settling.

The future development of the air cleaning plants will be closely followed by the colliery executives, and now that the pioneering work has passed out of the experimental stage it may become in a few years the current practice.

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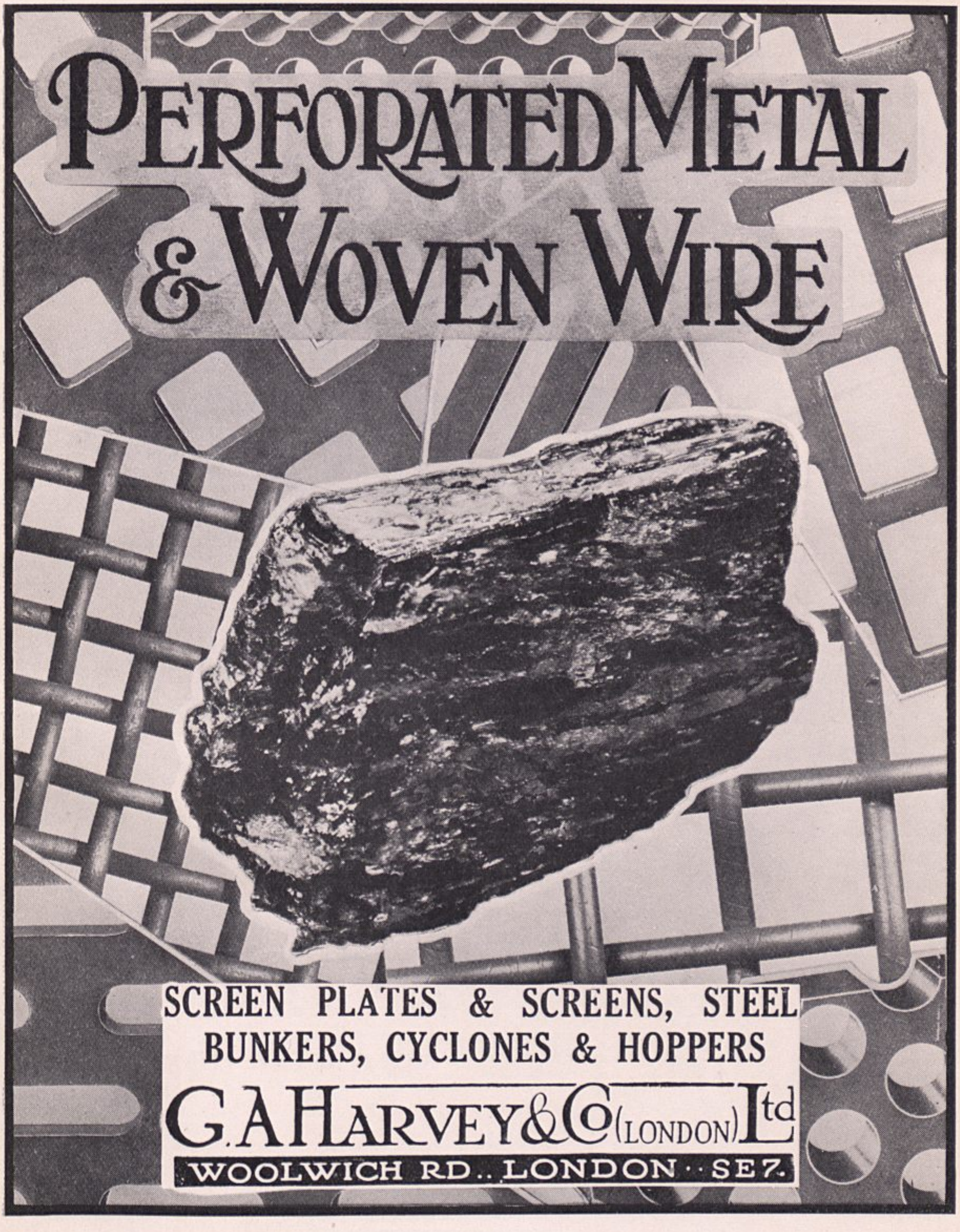
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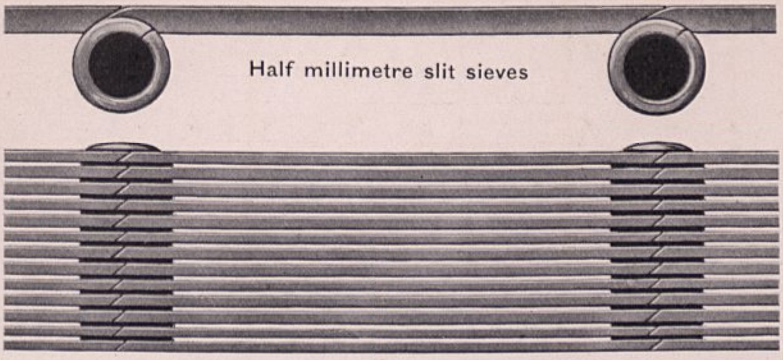

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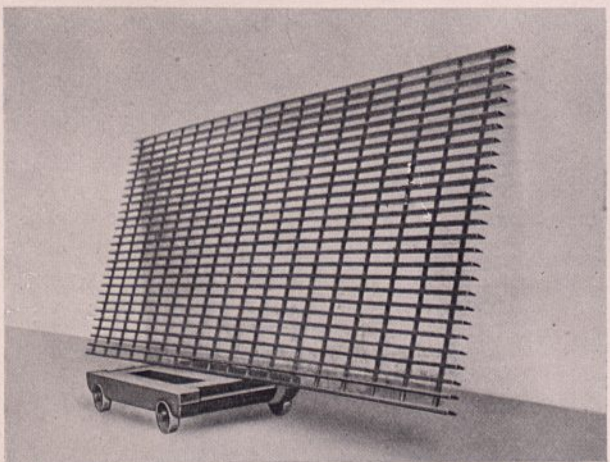

$1\frac{1}{2}'' \times \frac{1}{2}'' \times \frac{1}{4}''$ Tapered Bar Screen 9′ long 3′ 10″ wide × $1\frac{1}{4}''$ mesh.

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FULL SIZE SECTIONS BUILT UP TO SUIT REQUIREMENTS

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