The design and application of ash handling pumps

by WA Clennell, 1958

The furnace bottom ash from large, modern power stations is invariably disposed of by means of high velocity sluicing systems of high handling rates, involving the use of ash pumps for discharge of the ash and water mixtures either to overhead storage bunkers or to remote settling lagoons or disposal areas. Even before the high handling rates were required in modern power stations, however, hydraulic sluicing systems of either the low or high velocity type were frequently installed. In early designs, the low velocity sluicing systems, ash handling pumps of vertical spindle design, were used, but in general, the tendency was for horizontal spindle pumps to be installed.

In early applications to ash handling, the type of solids-handling pump used in the gravel and ore reclaiming industries was applied. These pumps were generally designed to handle solids of considerable size and at a low head. However, as higher duties became necessary for handling ash at high rates, special pumps were designed.

Design of ash pumps

An early ash pump design which developed directly from gravel handling pumps is shown in Fig. 1. In this design, the casing is split on the vertical center line and a replaceable volute liner of wear-resisting iron is provided. All the parts in contact with ash and water flow are of wear resisting steel and designed for easy replacement. Other special design features include provision for water sealing on the suction and driving sides of the impeller, a long stuffing box (the shaft being provided with a renewable wearing sleeve where the shaft passes through the stuffing box), and heavy and substantial bearings for the shafting.

As the impeller is of the single entry type, the out-of-balance thrust is taken up by means of a thrust bearing of the michell type.

The pump design described here has, in general, been superseded by the improved design shown in Fig. 2. This pump is also of the single entry type, the impeller being designed to pass solids of 3.75 in (9.5 cm) diameter. This provision is sufficient for all normal operating conditions, as it is customary to crush coarse ash or to pass it through screens before discharging to the ash sump.

Again, the pump has renewable side plates. These are adjustable to minimise the clearances between the side plates.
and the impeller, and so reduce re-circulation. In addition, the impeller is provided with rudimentary vanes designed in particular to reduce pump pressure at the back of the impeller. The part of the pump casing which comes into contact with the flow of ash and water is of wear-resistant steel, as are the impeller and suction throat liner. As before, the shaft with renewable sleeves and water sealing is provided at the front and rear of the impeller. The pump has shaft rings of the white metal-lined type (see Fig. 2). This is satisfactory for pump speeds up to 750 rpm. It is also normal practice to provide pump bearings lined with dynn metal, offering greater resistance to wear. These pumps can then be operated satisfactorily at speeds up to 1000 rpm. At these speeds, however, wear begins to be excessive and the company with which the author is associated never operates ash handling pumps at higher than 1000 rpm.

Some years ago, this company installed at a power station in the UK ash pumps generally similar to those shown in Fig. 2, but of the 10 in (25 cm) size, with Timken taper roller bearings to take both axial and radial loads instead of the sleeve bearings and michell thrust bearing. These pumps have given very satisfactory service and have now been adopted as standard for the 10 in (25 cm) size. It is probable that the design of the other size will also be changed to include taper roller bearings, these being less affected by ill-use and lack of maintenance.

In some applications where certain operating difficulties apply, ash handling pumps of the rubber-lined type have been installed. These pumps are again invariably of the overhung shaft type with single entry impellers with wide vanes to allow solids of substantial size to pass through the pumps. All surfaces in contact with the flow of ash and water are rubber lined to resist abrasion.

In the author's experience, these pumps are not very satisfactory in cases where ash of large particle size has to be handled, as there is a tendency for particles to lodge between the sides of the impeller and casing walls, as well as in the fine clearances of the pump, resulting in cutting of the rubber. The pumps appear to operate admirably, however, where the solids to be pumped are small in size and below the size of the smallest clearance in the pump. In this case, the resistance to abrasion is excellent. Additionally, the pumps are resistant to the corrosive conditions which sometimes apply, as, for example, in a system where ash conveying water is re-circulated constantly without dilution, so that its pH value is reduced to a low figure.

In a contract currently in the design stage, it is necessary to use a pump to discharge fly ash and water at a rate of 200 t per hour dry solids content through a pipeline three miles (5 km) in length. A special slurry handling pump suitable for this function was designed in association with a well-known pump manufacturer and will be installed within the next few months.

**Applications**

Ash pumping equipment is applied to various ash disposal problems but the examples described here represent some of the different systems.

In one power station ash handling system, the ash is removed from eight 180 000 lb/h (81 646 kg/h) boiler units by means of a high velocity ash sluicing system. The boilers are fired by a mixture of coal and coke and the resultant ash from the chain grate stokers is very abrasive. The ash hoppers beneath the stoker units are designed for 24 hours' worth of make of ash and the ash is removed once per day by means of high velocity water jets directed into the ash hoppers. These break up the ash mass and cause the water and ash mixture to flow into a sluiceway. From here, it is passed through to the ash bunkers at a height of approximately 90 ft (27.4 m). The life of each impeller and volute liner is only about 15 000 tonnes of ash pumped due to the arduous conditions.

A long sweep bend is fitted at the suction inlet to the pump, with a similar bend fitted at the discharge side (see Fig. 3). These fittings are of meehanite and are specially thickened for a longer working life under the highly abrasive conditions.

In another power station, ash and fly ash are removed from each of the boiler units and conveyed to an ash sump by means of a high velocity sluicing system. Three boiler houses are served, and sluicing water is drawn from an adjoining river where a pump house is located. From boiler house 1, the ash and water are discharged at a distance of approximately 1 mile (1.6 km) and it is therefore necessary to employ two ash pumps operating in series. Both sets of pumps are local to the ash sump, the primary pump discharging at approximately half line pressure into the second pump, which boosts the pressure to the required full line pressure. Both pumps are of the single stage unlined type, 8 in (20 cm) size as described and as illustrated in Fig. 2.

The pumps dispose of 1700 gpm (6435 l per minute) of ash and water mixture against a combined total head of approximately 320 ft (97.5 m). The pump speed is 960 rpm and the bearings are dynn metal lined. In boiler-houses 2 and 3 of this power station, similar equipment is installed, but the pipelines discharge to the ash and dust lagoons at different points.

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**Appendix I: Specification of 10 in (25 cm) horizontal spindle fully lined ash pump**

The ash pump is of the horizontal centrifugal type with 10 in (25 cm) suction and delivery branches (see Fig. 1). The pump casing is of cast split on the vertical centre line. The rear pump casing includes a stuffing box and glands, which are in two halves bolted together, facilitating removal for repacking. The casing is fully lined with a renewable ma steel volute liner. The impeller is of the shrouded type, made of manganese steel. The driving sideplate and suction side plate are also manganese steel. On the suction side impeller, a suction throat liner is fitted made of manganese steel so that all parts subjected to the erosive effect of the ash are in wear resisting materials. The cast iron casing is therefore fully protected.

The impeller is mounted on a high tensile shaft enclosed in a hardened steel sleeve where passing through the stuffing box. The stuffing box casing also carries a grease-lubricated bush and a hand stuffer. The shaft is operated externally in two white metal mounted ring lubricated bearings arranged in housings of robust construction. At the tail end of the shaft a heavy type michell double thrust bearing is incorporated to locate the rotating parts and to take the hydraulic thrust from the pumps.

The pump is provided with a sealing water piping harness to provide sealing water on the suction and discharge sides of the impeller. The harness is complete with pressure gauges and control cocks to regulate the supply of water. It is extended to include supply piping to a priming ejector fitted to the suction adaptor of the pump. The sealing water harness also includes blowdown vessels arranged to keep the pressure gauge connections free from fine silt. The pumps and bearing pedestals are mounted on a heavy cast iron bedplate which is extended to receive the pump driving motor.
and the length of the discharge pipeline therefore varies.

Five 240 000 lb/h (108 862 kg/h) boiler units are installed, with provision for a sixth. Separate dust and ash sluiceways are provided under each row of boilers, and these are graded down to the cross sluiceway discharging to the pump sump. Reference may be made to another arrangement where ash and fly ash are removed hydraulically from the boiler units and transferred to ash sumps. In the pump house, primary ash pumps are installed which pump the furnace bottom ash and water to an overhead storage bunker. On completion of this duty, the prim pumps pump the fly ash and water mixture into a booster pump. The final head is developed by the booster pump which is sufficient to discharge the ash and water mixture through a long disposal pipeline to settling lagoons.

**Appendix II: Specification of horizontal spindle unlined ash pump**

The ash pump is of the horizontal spindle, centrifugal type, a cross section of which is shown in Fig. 2. The pump and volute casings are of extra-heavy WA grade meehanite construction, fitted with feet suitable for mounting to the bedplate. The suction cover with centrally formed inlet, and the rear cover incorporating a loose stuffing box housing, are of cast iron.

The stuffing box housing is arranged in halves so that it can be removed readily to give access to the back of the impeller. It is of ample depth to accommodate no fewer than five turns of packing and the gland is of the Saveall type in cast iron. A lantern neck bush ring and water service connection are provided in the stuffing box to prevent grit entering the packing. A similar water service is also provided at two points on the suction cover into the annulus of the impeller eye to prevent grit entering the working faces at this point. The suction, front and rear covers of the pump are provided with liner plates of manganese steel secured in position firmly and forming easily-renewable wearing plates.

The manganese steel impeller is of the single entry type with a 4 in (10 cm) tip width, i.e. capable of passing 3.75 in (9.5 cm) spheres. It has rudimentary vanes on the outside arranged to equalise, as far as possible, the difference in pressure between the suction and discharge sides, and to prevent, as far as possible, recirculation of fines. This causes rapid wear at the impeller eye ring. The impeller is bolted to a steel hub securely connected to the end of the spindle. The large-diameter pump spindle is of quality high-tensile steel turned and ground true. It is provided with a renewable hardened steel sleeve at the point of passing through the pump stuffing box. The spindle is supported externally in two ring oil dynn metal-lined bearings, arranged in cast-iron shells embodied in a robust cast-iron housing with a removable type cover. Both bearings are arranged in a common house which is attached securely to the back of the pump casing by means of tie bolts for additional rigidity. An extremely sturdy assembly is formed to prevent distortion between the pump and bearing housings.
in certain definite steps and the modified speeds are expected to operate for a suitable length of time, as would be the case when filling separate disposal lagoons. The speed variation is obtained by changing the ratio of the gears in the gearbox. An advantage of this method is that the initial cost is low and the operating efficiency is high.

- By introducing fluid couplings between the squirrel cage motor and the pump. This method is used at Barking Power Station, and its advantages are that the pumps can be started up under closely controlled conditions, minimising surges in the discharge pipelines, and that speed variations on the pumps can be effected very simply at any time. However, there is loss of efficiency amounting to approximately 5% under the most favourable conditions. When there is a substantial difference between motor speed and pump speed, the drop in efficiency of the fluid coupling can be considerable.

- If the pump is driven from the motor by means of a V-belt drive, it is possible to change speed by variation of the driving and driven pulley ratios. However, this system is subject to the same limitation as that of the reduction gearbox drive.

Application

The conditions of solids size (usually determining minimum pipeline diameter) and handling rates (usually determining maximum pipeline size) establish the range of duties of ash pumps. For these reasons, the great majority of applications range between pumping approximately 500 gpm (193 l/minute) and 3000 gpm (11 356 l/minute) of ash and water mixture.

Also, as it is not considered advisable to run an ash pump above 1000 rpm, the maximum head which it is possible to generate is also limited. The maximum head obtained from an 8 in (20 cm) ash pump is about 180 ft (55 m) at 960 rpm and from a 10 in (25 cm) pump, approximately 200 ft (61 m) at 960 rpm.

Note that, at suitable speeds and full impeller diameters, a fairly high maximum efficiency is obtained, well in excess of many designs of pump now used in gravel handling. These results reflect the progress in design made necessary by the present-day arduous duties of pumps handling ash.

The housing incorporates an oil reservoir of ample dimensions and has an inspection opening, lifting eye bolts and a thrower adjacent to the gland to prevent water from entering the housing. A heavy type michell thrust bearing is mounted at the driving end of the housing. It takes the maximum possible thrust load from the pump and locates the rotating parts with ease. This is arranged for water cooling by means of a jacket and the water supplied from the sealing water distribution system. The pump is mounted on a heavy cast-iron bedplate extended to receive the driving motor pump driven through a pin-type flexible coupling by a totally enclosed von cooled squirrel cage induction motor of 200 bhp (149 kW) at 970 rpm.

A coupling guard is provided over the flexible coupling. Each pump is fitted with a gauge board mounted above the pump. This consists of a suction gauge connected to the suction inlet of the pump and a pressure gauge connected to the discharge flange of the pump. A mercury type switch is also provided and arranged to break contact on the failure of the sealing water supply service, tripping the ash pump motor automatically.

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