Ash and Dust Disposal: State-of-the-Art in N.S.W. Power Stations

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Asche- und Staubabförderung in Kraftwerken in New South Wales
Traitement de la poussière et des résidus: centrales électriques de Nouvelle Galles du Sud
Eliminación de cenizas y polvo: tecnología actual en las centrales de Nueva Gales del Sur

灰塵処理：N.S.W.発電所における処理法

新南威尔士电力站的灰尘清除工艺

التخلص من الرماد والغبار : من هذا العمل محطات الطاقة في نيو ثوث ويلز

Summary

This paper deals with ash and dust disposal in New South Wales power stations. It outlines the factors used in the selection of a suitable site for disposal of solid wastes from a coal fired power station. A number of different methods of handling the ash and dust from the collection hoppers in the power station to the disposal area are discussed. The potential of utilisation of these materials is very high and must be considered in the light of existing markets for building materials.

1. Introduction

Coal fired power stations produce large quantities of non-combustible solid waste by-products of the combustion process which must be conveyed away from the power station site and disposed of in economically and environmentally acceptable areas.

Approximately 0.3 m^3 of ash is produced from each tonne of coal burnt in New South Wales power stations. This means that up to 45 million m^3 of ash will be produced from a power station of four 660 MW generating units over a nominal 20 years life. This ash is produced in several different forms:

Fly ash (also referred to as "dust") constitutes the major part of the total ash in coal, is a fine grain material similar in appearance to cement and is removed from the boiler flue gases in one of the various types of dust collecting plants.

Furnace ash is a heavier, larger material which falls into collection hoppers at the bottom of the boiler combustion chamber.

Economiser grits are medium size material which collects in hoppers located below the economiser at changes in direction of the flue gas path through the furnace.

Other solid waste by-products to be disposed of are:

Mill rejects are the materials not suitable for milling, discharged from the pulverising equipment into hoppers located adjacent to this equipment.

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All these different waste materials must be collected and conveyed to disposal areas remote from the main plant.

This constitutes a large waste disposal problem and is a major consideration in the selection of a power station site. In recent projects undertaken by The Electricity Commission of New South Wales the provision of ash and dust handling plant and a suitable disposal area has cost in the order of 3 % of the total capital cost of the power station.

In all recent projects hydraulic disposal of ash and dust has been used.

This paper generally outlines the factors used in selecting a suitable disposal site, the methods of ash and dust handling used to convey the waste material to the disposal sites and the possibilities of utilisation of these waste products.

2. Quantities and Rating of Equipment

The quantities of ash produced in 1980 from New South Wales power stations are shown in Table 1. This table also shows, in summary form, details of the basic handling plant parameters.

Ash and dust handling plants should be rated to remove all solid waste products from the power station to the disposal area under all operating conditions likely to be encountered during the life of the power station so as not to affect boiler output nor exceed environmental limits.

Plant handling rates have been adopted for recent New South Wales power stations based on the maximum continuous production of ash in the boiler overfire condition burning coal with the maximum possible ash content. The division of the total ash produced for rating purposes is as follows:

Furnace Ash	20 %
Dust (Fly Ash)	100 %
Economiser Grits	10 %
Mill Rejects	Nil (Tube Mills)

It is noted that these ratings cover 130 % of the total ash produced, however, this overlap is necessary to ensure that plant is rated adequately to cover all operating conditions. This division will vary according to the furnace type, pulverising plant and coal conditions and the above divisions reflect the upper limits for each type of ash.

Table 1: Ash quantities and basic handling plant parameters in N.S.W. power stations

Power station	Unit size and number	Estimated total ash produced during 1980 (tonnes)	Mixed or separate pumping	Number of stages of pumping	Length of disposal pipeline (m)
Vales Point A	3 x 200 MW 1 x 275 MW	225,080	combined ash and dust	2	1700
Munmorah	4 x 350 MW	688,300	separate	1	610 (ash) 2590 (dust)
Liddell	4 x 500 MW	1,464,400	separate systems	4	2700 (ash) 3200 (dust)
Wallerawang C	2 x 500 MW	175,070	separate	3	1400 (ash) 3000 (dust)
Vales Point B	2 x 660 MW	692,570	separate	2	1590 (both)
Eraring	4 x 660 MW	not yet in service	separate	1 dust 2 ash	1290 (ash) 1120 (dust)
Bayswater	4 x 660 MW	will not operate until 1985	separate	1	760 (ash) 1700 (dust)
Other Tallawarra Wallerawang & Wangi	890 MW	346,500			
Grand total		3,591,920			

Typical rating figures for the Eraring Power Station in New South Wales (4 x 660 MW) are:

Furnace Ash	75 t/h
Dust (Fly Ash)	375 t/h
Economiser Grits	40 t/h
Mill Rejects	75 t/h

The properties of these various types of ash are shown in Table 2. Because the materials to be handled are extremely abrasive and often corrosive it is the practice in New South Wales power stations to provide 100% standby units of all equipment where possible. In items of key equipment where the boiler output is directly affected by breakdown an in-situ spare is also provided.

3. Selection of Ash Disposal Site

A detailed economic, technical and environmental assessment should be carried out to compare alternative disposal sites before the final site is selected.

Firstly, the volume of ash to be stored over the life of the power station must be estimated from ash analysis from all coal sources to be used considering the projected capacity factors over the life of the station.

Table 2: Typical ash analysis

Chemical

Component	Typical	Range
SiO_2	59	45—75
Al_2O_3	26	15—35
Fe_2O_3	8	1—30
TiO_2	1.4	0.4—2.2
Mn_3O_4	0.16	0.1—0.7
CaO	0.67	0.1—2.3
MgO	0.75	0.2—1.4
Na_2O	0.30	0.1—0.9
K_2O	1.5	0.8—2.6
P_2O_3	0.34	0.1—1.6
SO_3	0.45	0.1—1.5
Size		
Furnace ash	50 mm	5 — 200 mm
Economiser grit	100 microns	50—200 microns
Fly ash	10 microns	1— 40 microns
Mill rejects	50 mm	5—200 mm
Specific Gravity		
Furnace ash	1.0	0.5—1.5
Economiser	2.0	2.0—2.2
Fly ash	2.2	2.0—2.5
Mill rejects	2.0	1.0—3.0

Using this requirement suitable alternative sites are selected and information for each site gathered relating to the topography of the disposal area, the hydrology of the catchment and any foundation requirements (for earth fill dams). All these factors affect the cost of developing a disposal area.

Costing is then undertaken of the technically and environmentally suitable methods of conveying the ash from the power station to the disposal site and consideration is given to the operational reliability of these various methods. The environmental factors which may affect the alternative sites are then assessed and a decision on the most suitable site made according to all these factors.

The most recent power stations built in New South Wales have been located close to the source of coal. Suitable ash disposal areas close to the power stations have been developed by constructing earth dams across valleys which have been subsequently filled with ash. The ash has been slurried with water in the power station and pumped to the disposal area.

Because of the relatively large particle sizes the furnace ash, economiser grits and mill rejects are pumped together at high velocities (3 m/s) to prevent the solids settling out and blocking the pipeline. The high friction losses with pumping slurries at such velocities and the high cost of basalt-lined steel disposal pipelines required for this duty means that there is a significant advantage in locating the furnace ash disposal area as close to the power station as possible. Ash disposal pipeline lengths are generally restricted to approximately two kilometres.

Fly ash is a fine material and fly ash slurries can be pumped long distances at low velocities and thus fly ash disposal areas can be more remote from the power station.

Due to environmental constraints these landfill areas are now designed to have zero discharge to local watercourses under normal rainfall conditions, and all water used to convey the ash to the disposal area is returned to the power station for re-use.

The cost of developing this type of disposal area have varied between \$0.66—\$0.35 (Aust.) per m³ of ash stored for recent power stations (1980 figures) depending upon topography and foundation considerations. Ratio of storage to embankment volume is typically about 10:1.

Older power stations built closer to the centre of the transmission system load have used disposal systems based upon transporting the solid wastes basically dry by road transport to a disposal area remote from the power station, because of competing land-use local to the power station.

Power stations in Europe, where land utilisation is generally more intense than in Australia, also use this type of disposal, typically transporting the ash to disused mine workings or pits where it is used for reclamation purposes. The C.E.G.B. of the United Kingdom now boast of having established farmlands on areas previously used for gravel pits and subsequently filled with ash.

4. Ash Handling

4.1 General

Furnace ash, economiser grits and mill rejects (if any) are usually handled together in the ash handling plant. The ash handling plant basically consists of hoppers to collect the solid wastes, conveying equipment to remove it from the individual hoppers to a central collection and handling area and equipment to discharge it from the central area to the disposal area. In more recent installations in New South Wales one central ash handling plant has been provided to service the whole power station (typically 4 x 660 MW units). This plant has been located centrally between the boilers Nos. 2 and 3 to minimise sluiceway length.

4.2 Plant Details

The coarse furnace ash is collected in hoppers located at the bottom of the boiler under the furnace throat. In New South Wales water filled hoppers have been used on all the larger coal fired power stations. These have proven a reliable relatively maintenance-free method of ash storage. The ash is quenched when it falls into the hoppers producing a relatively small friable product which is easily subsequently handled. The ash hoppers have stainless steel bottoms and walls, the upper sections of the walls around the gas/water interface being fabricated from high nickel alloy (typically 20 % Cr, 30 % Ni alloy) to prevent stress corrosion cracking. The ash hoppers are generally divided into four separate compartments each with its own outlet gate. Hoppers are designed for a nominal 12 hour storage at maximum ash production. A water filled seal trough is provided around the perimeter of the ash hopper to prevent the leakage of air into the boiler and to seal a possible explosion path.

The ash gate of each hopper compartment is automatically opened once per shift and the ash/water mixture discharged at a controlled rate into sluiceways located in the boiler basement floor below the hoppers. During the emptying period water sprays keep the ash hopper walls at reasonable temperatures and extraction nozzles operate to purge the hopper. The ash hopper gate closes automatically when the hopper is empty and the hopper compartment is immediately refilled with water. The next ash hopper compartment is then emptied, every hopper being discharged to the sluiceway at least once per eight hour shift.

Simultaneous to the ash removal process, economiser grits are removed from storage hoppers using an ejector induced vacuum conveying system which discharges the grits down continuously sloping pipework to the below ground ash sluiceway. Mill rejects (if any) are dumped directly from storage hoppers adjacent to the mills into the sluiceways. All these materials are conveyed along basalt-lined ash sluiceways located in the boiler floor. High velocity jets below the ash hoppers and at approximately 10 m intervals along the sluiceway are used as the motive force.

In recent installations, where a single central ash handling plant is provided for four boilers two 100 % duty ash pits are provided, one to be used as a duty pit, the other as a standby should major equipment in the duty pit fail.

Hydraulically-operated lifting liners are provided in the ash sluiceways to divert full sluiceway flow into one of four 100 % duty ash crushers which reduce the maximum particle size to 25 mm before discharging to the in-service ash pit. Slotted grids are provided in the sluiceway immediately prior to the ash crusher to divert material less than 25 mm directly to the ash pit.

The ash pits are conical below ground structures. The ash slurries are pumped continuously from the pits using centrifugal type slurry pumps through pipelines to the disposal area. The pits and associated pumps are sized so that under normal operating conditions the slurry level is generally maintained in the conical section of the pit. Capacity is provided above the operating level of the ash pit for the in-service pipeline to drain back to the ash pit when the pumps are taken out of service.

The disposal pipelines are made of wear-resistant materials usually basalt-lined mild steel and are generally located above ground. In the layout of the disposal pipelines consideration must be given to the possibility of the lines blocking should, for any reason, the pumps stop while slurry is being pumped. If this occurs the ash suspended in the water settles to the bottom of the pipeline. For this reason pipelines must have minimum slopes of 0.5 % to be completely drained when the pumps stop either through dump valves or back to the ash pits. Ash slurry velocity is maintained between 3 to 4 m/s.

4.3 Alternative Methods of Ash Disposal

The availability of suitable landfill areas close to the power station sites allows relatively simple methods of ash disposal to be used in New South Wales. Other methods are currently being investigated where no such convenient landfill areas are available or where operational requirements vary.

4.3.1 Furnace Ash and Economiser Grit Removal Using Submerged Ash Conveyors

Submerged ash conveyors continuously remove furnace ash from a water-filled hopper located beneath the furnace throat using a "drag-link" type conveyor.

The conveyor continuously scrapes the ash from a hopper up a dewatering slope and discharges the dewatered ash through a grill onto a belt conveyor. This conveyor can be run directly to the disposal area or discharged into road or rail vehicles for more remote disposal. The economiser grits are fed directly from the storage hopper into the furnace ash hopper using sloping pipework.

This method of handling has the advantages of low water consumption and of providing a continuous dewatered product suitable for immediate use as road base or fill material. However, ash hopper storage is limited compared to other methods. This type of disposal system is used frequently in Europe where this material has ready markets.

4.3.2 Dry Furnace Ash Hoppers and Jet Pumps

This system uses dry furnace ash hoppers with similar storage capacity to the water-filled hoppers. These are emptied usually once per eight hour shift using extraction jets through ash crushers located at the hopper outlet to jet pumps which convey the ash either directly to the disposal area or to large above ground dewatering hoppers from which the ash is removed by a grab system to either road vehicles, rail vehicles, or conveyors.

This method is used extensively in the United Kingdom where a dewatered product is required for remote disposal. The main disadvantage is that the hopper does not quench the ash immediately and formation of large slag lumps is frequently encountered.

5. Dust Handling

5.1 General

Fly ash (dust) is generally handled separately from the other waste materials because of its different transport properties and the quantities to be handled. The dust handling plant consists of the dust collecting plant hoppers and extraction equipment which conveys the dust dry to sluiceways where it is wetted. The sluiceways run to a central collection and handling area from which the dust slurries are pumped to the disposal area.

5.2 Plant Details

The power stations currently being constructed in New South Wales will use fabric filter dust collecting plants. The dust hoppers associated with this plant have heaters and conical bottoms to ensure a smooth flow of dust from the hoppers. Each dust hopper outlet is fitted with a manual hopper isolating valve, a counterweighted flap valve to prevent reverse flow of air from the extraction system into the hopper and blanked off emergency outlet for removal of rogue material unable to be conveyed. Dust is continuously removed from the dust collecting plant hoppers using air slide dry dust conveyors. Air slides consist of light gauge mild steel sections pressed to form two approximately rectangular compartments with a permeable membrane of tightly woven fabric separating the top and bottom compartments. A mild steel perforated support plate below the fabric and a stainless steel perforated wear plate above the fabric are provided to protect the fabric. The lower compartments or plenum chamber is pressurised with warm dry air to approximately 5 kPa which partly fluidises the dust in the upper chamber.

The air slides are inclined at approximately 8—1/2° to the horizontal which allows the dust to slide under gravity down the incline when thus fluidised. Duty and standby 100 % blowers and air heaters for the fluidising air supply are provided beneath each unit dust collecting plant.

Each conveyor is connected to a number of hoppers and discharges continuously to "ejector" type dust/water mixers, located adjacent to the dust sluiceway. Each of these mixers is capable of producing up to 40 % w/w dust slurry.

The dust/water mixers discharge to gravity type dust sluiceways of approximately 1.25 % slope which run to the below ground dust pits. The dust sluiceways are lined with basalt tiles adjacent to each dust/water mixer outlet however, thereafter are unlined.

This method of dust extraction has yet to operate in New South Wales. All previous installations used an ejector based extraction system. This is basically a lean phase pneumatic system which uses the vacuum created by a water operated ejector to produce sufficient air flow to convey dust from the collecting plant hoppers through extraction pipework to the ejector where it is mixed with the water in the ejector venturi. The dust/water slurry is then fed to sluiceways and pits for final disposal.

In both these systems the dust pits are generally similar structures to the ash pits. Duty and standby dust pits are provided and are sized so that normal operating level is in the conical section. Capacity is provided above the conical section of the pit for runback from the disposal pipelines.

The dust slurry is pumped continuously from the dust pit through asbestos cement pipelines to the dust disposal area using similar types of slurry pumps to the ash handling plant. Slurry velocities in the dust disposal pipeline are maintained in the range 1.5—1.8 m/s. The layout of the dust disposal pipeline must contain similar provisions to the ash disposal pipelines for draining when pumping stops.

5.3 Alternative Methods of Dust Disposal

Like ash disposal, the methods used for dust disposal in New South Wales are reliable and economic where suitable disposal areas are located close to the power station. Several alternative methods of dust disposal are being investigated where no such suitable areas are available.

Where dry disposal of fly ash is preferable pneumatic dust handling systems are frequently used. There are basically two types of pneumatic handling techniques: dilute phase and dense phase.

In dilute phase high conveying velocities are used with low conveying pressure and low solids ratios. In this type of system the fly ash is fed from the collecting plant hoppers through feeding valves into either a pressure or vacuum induced pneumatic pipework system. Fly ash is conveyed in the high velocity air stream to a hopper when dust and air are separated, the air being filtered before release to the atmosphere. Fly ash is fed from this hopper through dust conditioners which dampen the dust sufficiently to prevent nuisance during transport.

This type of system is frequently used in the United States and the United Kingdom.

In dense phase conveying lower velocities are used but higher conveying pressure and high solids ratios are attained. Typically dust is fed to a flow transmitter which is filled to a certain level. The feed valve is then closed and an inlet air valve at the bottom of the transmitter opens to fluidise the dust in the transmitter. A discharge valve then opens, air pressure is increased and dust flows as a dense column.

The discharge facilities for dense phase conveying are similar to that described above. Dense phase pneumatic conveying is still at the development stage for power plant use.

6. Environmental Considerations

In recent years increased attention has been given to the potential pollution of water courses downstream of ash disposal areas. To minimise the release of potentially harmful substances into these watercourses, the Electricity Commission of New South Wales has designed its recent ash disposal systems with zero discharge from the disposal area under normal rainfall conditions. All water used for disposal of ash and dust is returned to the power station for re-use.

The ash disposal area earth embankments are designed with submerged off-takes which feed a pumping station. Skimming or coarse filtration of the off-takes are provided to inhibit the release of any semi-buoyant ash particles which have not settled in the disposal area.

The return water pumping station consists of two 100 % duty and standby solution type pumps connected to two 100 % pipelines which discharge to return water tanks located in the power station area. The return water tanks, which are sized to provide a nominal eight-hour storage of total water requirements, are elevated to provide adequate head for gravity feed to the various water pumps located in the ash handling plant and dust handling plant.

The return water supply is contaminated with dissolved salts which concentrate due to constant recycling. Treatment of the return water is frequently necessary to ensure that adequate return water quality is maintained to prevent operational or maintenance problems with the ash and dust handling plant equipment.

A return water make-up supply must be provided to ensure adequate water supply to the ash and dust plants should the quantity or quality of water from the ash disposal area be inadequate.

7. Utilisation of Furnace Ash and Fly Ash

Both furnace ash and fly ash have a wide range of commercial uses. In New South Wales approximately 200,000 tonnes of fly ash per annum is taken from Commission power stations and used mainly as a partial replacement for cement in the manufacture of concrete and as a filler in asphaltic concrete. The quantity used in this manner is rather small because of the relatively remote locations of the power stations.

Facilities are provided for dry removal of fly ash from the dust collecting plant hoppers to storage bins. The fly ash is removed from the storage bins to concrete mixing works by large road tankers.

Ash is used for reclamation purposes by providing appropriate bunding to create properly manageable individual ponds, which are progessively filled and developed. With the application of a light soil cover such reclaimed areas can be used where low strength is required. By appropriate compaction methods, sufficient stability of the ash fill can be obtained to support concrete slab constructions with low bearing pressures, suitable for light industry, etc.

In the United Kingdom a large land reclamation scheme was set up at Peterborough in the Midlands where over 1,000 acres of deep disused brick pits were available for filing. The reclamation scheme receives approximately 10,000 tonnes per day of fly ash in rail waggons from three major power stations. When the area is completely filled it will be covered with top soil and used for playing fields, light industry and agriculture.

The commercial utilisation of ash in West Germany is most intense. At Scholven Power Station operated by V.K.R. (2,977 MW) all ash produced during the summer months is sold. Furnace ash is sold mainly as road base whilst the fly ash is sold to the building industry largely as a concrete additive. In winter months when building activity declines the fly ash and furnace ash is sintered into pellets for use as lightweight aggregate.

The nett result is that no fly ash is dumped from this major power station site. This, however, requires that the carbon content in the fly ash is maintained below 3 %.

8. Future Trends

Increased emphasis on environmental standards with respect to disposal areas and higher operating costs are causing a major re-assessment of the types of disposal methods used.

Recent ash and dust handling systems designed in New South Wales have used considerably reduced amounts of water for conveying because of the requirement that all water must be returned from the disposal area to the power station for re-use. As landfill areas become harder to find further consideration will have to be given to the disposal of ash in disused underground mine workings. This will involve further major design changes in handling plant as high density slurry pumping and dry slurry handling becomes more attractive because of the water reclamation problems.

Stringent environmental standards in the United States have resulted in the increased usage of submerged ash conveyors which have a closed loop water system with minimal losses. Dense phase pneumatic conveying of fly ash is also proving popular due to low operating costs and clean operation.

Development work is being carried out in Australia, the United Kingdom and the United States on capsule pumping where a material inside a capsule is conveyed through a pipeline by a fluid introduced into the pipeline under pressure. This has the advantages of preventing the mixing of the material to be conveyed with the conveying medium and relatively low operating costs. This may prove more economic and environmentally acceptable compared to current handling methods.

However, the key to the disposal problems lies in developing further methods of utilising this potentially useful material. As the cost of materials such as cement, aggregate and sand increases the economic viability of using ash for these applications will improve and a potentially polluting waste product will become a valuable resource. This is already the case in West Germany and undoubtedly will be the trend in New South Wales in future years.

9. Conclusion

A number of satisfactory methods of disposing of the solid waste products from the combustion of coal in power station boilers have been outlined. Stringent environmental requirements and high operating costs are forcing designers to minimise water usage for conveying ash to the disposal area and are placing increased emphasis on developing satisfactory methods of utilisation of these waste materials.

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