Improving the Free Flow Capability of Power Station Coal Bunkers

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Summary

Flow property based options to improve the free flow capability of unit coal bunkers are currently being successfully demonstrated at National Power’s, Drax Power Station, U.K. The selective use of UHMW polyethylene as a wall liner has almost doubled free flow capability from about 30% up to about 59%. Comparison of the unlined bunkers of units 3 and 4 with the lined bunkers of units 1 and 2 indicates a reduction in total coal flow failures from 2,096 to 796 over the nine month period June 1993 to February 1994. New measures now being evaluated, involving the use of specially profiled feeder inserts coupled with a single gate arrangement, indicate the possibility of further reduction in coal flow failures towards the preferred zero option.

1. Introduction

The majority of power station unit coal bunkers in the U.K. were built in the early 1970s or before. Coals were coarser then and the bunkers did not have the flow problems they have now. Also, two decades ago abundant manpower was available to clear any coal blockages that occurred.

Nowadays, with the advent of closer sizing plus the incorporation of multi roll filter (MRF) fines, the cohesive quality of coal, whether it be indigenous or imported, has worsened. Coal flow failure is now regarded as one of the most important power station problems yet to be solved. Of late, this has increased to such an extent as to put at risk, not only the capability to generate power to specified levels, but also, on occasions, the safety of the workforce and plant.

Coal handleability is at the heart of power station efficiency and, in a typical station, the coal route from rail reception to boiler is fraught with problem areas which reduce throughput rate. The heart of these handling problems is invariably centred around the bunkers that supply the pf mills.

National Power plc – Drax Power Station are currently pursuing a range of projects aimed at the upgrade of their unit bunkers to bring them as close as possible to 100% free flow. This paper begins by analysing the flow capability of the existing design based on measured coal flow properties. The main conclusion to re-line the bunkers using UHMW polyethylene is evaluated by assessing the OIS data recorded at the station relating to coal flow failures. Following this, the paper describes feeder based retrofit work undertaken to further improve the free flow capability of the unit bunkers. At 4,000 MW, Drax is the largest coal fired station in Europe and burns about 36,000 t/day of coal.

2. Description of the Bunkers

There are six units at Drax power station and each of these has five twin outlet bunkers that deliver coal to the pulverized fuel mills. The nominal capacity in each bunker is 1,000 t. These bunkers are essentially of a rectangular pyramidal shape as indicated in Fig. 1. The main bunker outlet of about 3 m square incorporates...
two rectangular outlets sized at 0.9 m x 3 m. The division between the outlets is an inverted small steel pyramid. Each outlet incorporates a drag link feeder which serves a mill. For each unit, the ten bunker/feeder arrangements are designated from A to K. For each bunker slotted outlet, three cut off gates are provided to seal off the feeder when required. The supports for the gates effectively divide the slot length into three 1 m sections. The bunker top dimensions are about 15.15 m x 11.4 m and the vertical height is about 14.12 m.

The bunker wall slopes are irregular. Two opposite slopes are 73° and the other two are 70° and 64°. The valley angles are about 60° and 64°. All wall slopes are measured to the horizontal.

3. Flow Property Tests
The assessment of the free flow capability of the Drax unit bunkers was based on the flow properties of a sample of Gascoigne Wood coal at its most cohesive moisture content. This coal currently represents about 75% of Drax’s coal supply per day.

The flow property and bunker design assessment revealed that, assuming conical flow, the minimum valley angle needed to enable UHMW polyethylene to give mass flow (all the particles moving on feeder discharge – slip at the walls) would need to be 71° to the horizontal. The minimum slot width with instantaneous and 24 hour storage plus impact filling was determined at 0.845 m. With such a slot outlet width, the maximum recommended slot length to allow for proper transfer of coal, without destroying the benefits of mass flow obtained from a correctly designed bunker design, is 2.5 x the slot width which equals 2,113 m.

4. Flow Property Assessment of the Drax Unit Bunker Design
Whilst the majority of the wall slopes look reasonable, it is the sharp, shallow valley angles that have made these bunkers flow so poorly in the past, particularly with a rough wall lining and fine wet coal. The outlet size to the drag link feeder appears quite reasonable at 0.9 x 3 m but the aspect ratio of 3.3:1 is too large. Without correct profiling of the outlet in the direction of flow, to allow both horizontal and vertical expansion of the flowing coal, the feeder tends to pull coal from the back and allow heavy progressive build-up at the front. This compounds the problem of ratholing and rough wall arching of coal on coal caused by the shallow valley angles. As the feeders work in opposite directions to each other there is severe build up in diagonally opposite corners of the bunker.

Of more serious concern are the gate supports. These effectively create a 0.9 m square outlet which means that even in the instantaneous flow state, requiring a 0.866 mm diameter, the outlet is close to arching. In this scenario, impact filling and even small periods of time storage create serious blockage problems.

5. Past Attempts to Improve Flow
Over the years a variety of flow aid devices have been tried at Drax, some with more success than others. The ones that have remained are the air cannons although it is not known what the true benefits are in a quantitative way. There is still much to be learned by sellers and users as to the correct positioning and sequence firing of air cannons to obtain the benefit of improved bunker flow.

Prior to the current programme referred to in this paper, the main route to flow improvement was centred around wall linings. All of the foregoing flow property assessment of the Drax unit bunker design serves to indicate why the extensive and expensive experimental wall lining programme carried out from 1986 until 1990 was considered to be largely a poor investment in terms of improving mill feed bunker operation. During this period the following lining materials were investigated (a) Hyflow 420R, (b) Glass Tiles, (c) Cromwell 3CP12, (d) 304 stainless and (e) UHMW polyethylene. None of the unit bunkers was lined with a single material. Eleven bunkers had two linings, fifteen had three, and four had four. The one exception to the above view was that unit bunker 2J/K was generally assessed, in a qualitative way, to be much better than the rest since being fitted with UHMW polyethylene in 1986. The lower 2 m of this bunker was, however, lined with 304 stainless steel.

6. The Use of Appropriately Bunker Linings to Improve Flow
A study undertaken in April 1992 for Drax by Dr. H. Wright & Associates estimated the live capacity or free flow capability (the percentage of the stored volume that could move due to feeder action and gravity) of a typical 1,000 t unit bunker (Fig. 1) as being about 280 t. This estimate was based on the flow properties of Gascoigne Wood coal referred to in Section 3 above. The existing design would generate stable ratelines with strong arching tendencies. The bunker shape would not self empty nor self clean as product descended to the feeders. The effect of the three gate closing mechanism would be to reduce further the free flow capability in an indeterminate and random way depending on whether or not arching and ratholing were occurring.

On the face of it there was a clear mismatch between the theoretical requirements of mass flow wall slopes based on UHMW polyethylene linings and what the unit bunker could offer without serious modification. A 71° valley angle is needed for Gascoigne Wood coal and those of the existing design are 60° and 64°. However, UHMW polyethylene has unique low adhesion properties when the bulk material being stored is wet. It has been observed that wet coal will mass flow at wall slopes some 5 - 10° less than those predicted by the Joekes method. Whilst it is not recommended that this bonus be used in a greenfield site design it can be very usefully employed in a tight retrofit situation like the one pertaining at Drax.
On the above basis of analysis the report recommended the use of UHMW polyethylene linings. These linings were expected to just about double the percentage free flow up to a value of about 53%. The report postulated further increases in performance up to 80% free flow and beyond by improving flow through the unit bunker outlet gate and feeder.

During the outage of 1993, units 1 and 2 bunkers were completely lined with UHMW polyethylene. In 1993 units 5 and 6 were lined and units 3 and 4 in 1994.

7. UHMW Pe Linings Assessment Using OIS Coal Flow Failure Data

A coal flow failure is considered to have occurred at Drax power station when:

(i) The coal flow failure micro-switch device in the feeder has been activated.

(ii) The mill outlet temperature > 110 °C.

The frequency of coal flow failures has been monitored over a nine month period from June 1993 to February 1994 following the fitting of UHMW polyethylene linings in all of the bunkers of Units 1 and 2. Also monitored for the same period is data pertaining to the then unlined bunkers of Units 3 and 4. The coal flow failures responded well to statistical analysis. Fig. 2 shows the relationship between coal flow failures as identified by the OIS data collection system and the "percentage free flow" or free flow capability.

Figs. 3 and 4 show the percentage free flow for the UHMW polyethylene lined unit bunkers 1A – 1K and 2A – 2K over the period June 1993 to February 1994. The average free flow capacity of unit 1 bunkers was 58.9% with a standard deviation of 8.01. For the UHMW polyethylene lined unit 2 bunkers the corresponding figure was 59.8% with a standard deviation of 9.04.

The total number of coal flow failures over the nine month period for all of the bunkers in units 1 and 2 was 796. The average number of coal flow failures per individual bunker/feeder per month for units 1 and 2 was 4.42.

Figs. 5 and 6 show the average free flow capacity for the "experimentally" lined unit bunkers 3A – 3K and 4A – 4K over the period June 1993 to February 1994. The average free flow capacity of unit 3 bunkers was 25% with a standard deviation of 10.59. For the unit 4 bunkers the corresponding figure was 35.5% with a standard deviation of 13.73.

The total number of coal flow failures over the nine month period for all of the bunkers in units 3 and 4 was 2,096. The average number of coal flow failures per individual bunker/feeder per month for units 3 and 4 was 11.64.

The indication is that over the nine month period June 1993 to February 1994 units 3 and 4 bunkers generated about £250,000 more in coal flow failure related MW losses than the UHMW polyethylene lined unit 1 and 2 bunkers. Clearly, there are also other costs relating to coal flow failure that need to be considered such as (i) air lancing and washing down bunkers, (ii) cleaning out feeders, (iii) taking mills out of service, (iv) bringing replacement mills into service, (v) use of oil etc. The on-going work at Drax will focus on these areas to identify the true cost in lost revenue of a genuine coal flow failure.

It should be noted that, whilst Drax have lined all of their unit coal bunkers with UHMW polyethylene, there have been a few serious problems experienced with this material at other power stations. It is imperative, therefore, to ensure that prior to this beneficial wall lining being used, the risks are minimised.

It must also be stated, however, that despite the reduction of an individual bunker/feeder coal flow failure rate from 11.64 to 4.42 per month as a result of lining with UHMW polyethylene, this does
not constitute a fully acceptable solution to National Power's coal flow problems at Drax power station. A zero coal flow failure rate is the desired option.

Based on the above cost of MW losses alone over the period June 1993 to February 1994, the estimated average reduction in costs gained by eliminating an individual coal flow failure in unit 3 and 4 bunkers by lining with UHMW polyethylene is £192. As 100% free flow is approached, the benefit of eliminating an individual coal flow failure is expected to reduce considerably whilst the cost of implementation of hardware and procedures to achieve this will rise.

Finally, not all of the OIS flagged-up coal flow failures are purely a result of coal handling problems. Data is currently being refined to eliminate from the analysis coal flow failures caused by (i) tramp material in the bunker/feeder, (ii) feeder mechanical problems and (iii) mill failures.

8. Other Options to Reduce Coal Flow Failures

In the April 1992 report to National Power plc recommending the use of UHMW polyethylene liners in the Drax unit bunkers, Dr. H Wright & Associates also stated that additional improvements could be made to further increase the free flow capability of the bunkers by (i) modifying the existing feeder feedbox to incorporate inner profiling and (ii) replacing the three gate cut-off system and support members with a single gate. These proposals would facilitate even draw off of material from the bunkers so as not to hinder the transfer of coal through the 0.9 x 3 m slotted outlets. Detailed design recommendations regarding this were proposed to National Power in March 1993 and were based on the flow properties of a high percentage of the U.K. coals expected to be burned at Drax in the future. It was decided that these retrofit proposals would apply to the outlets and feeders of bunkers 3A and 3C. Bunker/feeder 3A would incorporate a double "bathtub" arrangement as indicated in Fig. 7 plus a single gate arrangement. Drax’s engineering staff suggested that bunker/feeder 3C incorporate just the single gate so that the value of this individual piece of equipment could be assessed. Bunker/feeders 3B and 3D would remain unmodified in any way and be used as a control.

In April 1994 a further study was carried out by Dr. H Wright & Associates to investigate the flow improvement to be gained by profiling the gate support cross beams spanning the slotted inlets of feeders 4E and 4G (Fig. 8). It was agreed with Drax’s Engineering Department that bunker/feeder 4E would also incorporate the double "bathtub" arrangement as used on 3A. Bunker/feeders 4F and 4H would remain unmodified in any way and be used as a control. The above retrofit measures aimed at a further reduction in coal flow failure were implemented during the 1994 outage. Unit 4 bunkers came on line at week 33 and unit 3 bunkers at week 35.
9. Conclusions

1. The most beneficial way of improving the free flow capability of power station coal bunkers is to base retrofit geometric design and equipment selection on the measured coal flow properties.

2. Flow property tests on Gascoigne Wood coal, which represents about 75% of Drax power stations rail borne coal supply per day, indicate that a radius of 1.5x valley angle is needed for mass flow. The minimum slot width to cope with instantaneous, 24 hours of time storage and impact filling conditions is 0.845 m. The maximum slot length should be 2.113 m.

3. There is a clear mis-match between the stored coal requirements for mass flow as given in (2) above and the core flow geometry of the Drax unit bunkers (Fig. 1). It is the sharp valley angles of about 60° and 64°, that have made these bunkers flow so poorly in the past, particularly with rough wall linings and fine wet coal. The 3:3:1 aspect ratio of the 0.9 x 3 m slot outlet is too large. This causes the feeder to pull coal from the back and allow heavy progressive build-up at the front. Of more serious concern are the gate supports. These effectively create 0.9 m square outlets which are very prone to arching.

4. UHMW polyethylene has unique low adhesion properties when the bulk material being stored is wet. On this basis of analysis, the recommended UHMW polyethylene linings have demonstrated their capability to just about double the percentage free flow from 30% in units 3 & 4 bunkers to 59% in units 1 & 2 bunkers.

5. Despite the reduction of an individual bunker/feeder coal flow failure rate from 11.84 to 4.42 per month as a result of lining with UHMW polyethylene, this does not constitute a fully acceptable solution to National Power's coal flow problems at Drax power station. A zero coal flow failure rate is the desired option.

6. Whilst Drax have lined all of their unit coal bunkers with UHMW polyethylene, it should be noted that there have been a few serious problems experienced at other power stations. It is imperative that prior to this material being used the risks are minimised.

7. Not all of the CIS flagged-up coal flow failures are purely a result of coal handling problems. These are being refined to eliminate from the analysis any coal flow failures caused by (a) tramp material in the bunker/feeder, (b) feeder mechanical problems and (c) mill failures.

8. The flow insert profiling and other feeder retrofit measures referred to in Section 8 of this paper were implemented during the 1994 outage. In July 1995, after almost a year of operation, there have been zero coal flow failures reported on bunker/feeder 3A. Similarly successful feeder flow insert modifications have also been carried out on Unit bunker 4A at National Power's West Burton power station in April 1995.

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