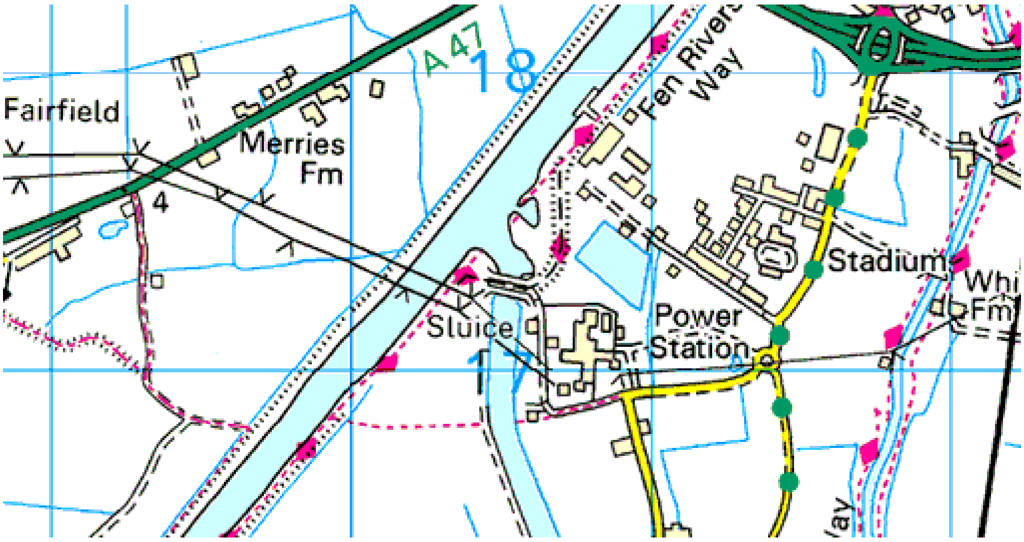
Installation of Galebreaker Windshield
at
Kings Lynn Power Station

Location. Willows Business Park, Saddlebow, King's Lynn, Norfolk PE34 3RD



Report By
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17th May 2006

Comment from Kings Lynn Power Station

-----Original Message-----
From: Wiglusz, Edmund (mailto:edmund.wiglusz@centrica.com)
Sent: 22 May 2006 15:06
To: 'Simon'
Subject: RE: GBR report on ACC improvement after fitting Galebreaker Windshields

Simon
Thanks for the report which I have reviewed, the report is well presented and generally consistent with the results that we obtained from the data.

You have our authority is proceed with issuing your promotional report.

Regards,

Eddie

Report Contents

Review of Kings Lynn Power Station Data
Reference the installation of Galebreaker Windshield

1. Introduction

The Air Cooled Condenser (ACC) at Kings Lynn Power Station has been fitted with a Galebreaker Windshield (WS), with the aim bringing it's performance back to the original design specification

The station experienced reduced ACC performance under windy conditions and decided to install Galebreaker Windshields in a "cross" formation within the ACC, extending from the underside of the fan units in a continuous curtain to ground level, approximately 13 metres in height. See appendix 1 for layout of installation. The material used being PVC coated polyester mesh being 55% solid with 2mm x 2mm holes.

The power station has provided a set of data for a period before and after installation and the purpose of this report is analyse this information and evaluate the benefits.

The power station has stated that they believe that there has been an improvement in the ACC performance during windy conditions.

2. Summary of Outcomes

The measure of improved Power Station performance after WS installation is ultimately about delivering more energy for less expenditure, The data set doesn't provide this financial information directly, however it does indicate;-

- Improved ACC vacuum in the order of 5.4 to 6.0 mbar based on an average wind speed conditions during full load operation

The data set, as outline in Section 4 was supplied by Kings Lynn PS, then analysed by GBR, the results of which have been consistent with the findings by KL engineers.

This report gives details of how this was established

3. Underlining Assumptions and Information

Maintaining sufficient ACC Vacuum is one of the prime contributors to operating a power station at maximum efficiency, the greater the vacuum created by the ACC then the more efficient it performs. However this is dependant on operating within the design parameters of the steam turbine.

4. Data Set

The data set includes the following information:-

Date Range:- 12/8/1998 to 11/8/1999
Periodicity:- ½ Hourly,
The key variables being:-

- ACC Vacuum
- Plant Load
- Ambient Temperature
- Wind Speed
- Wind Direction

- Plus 52 other variables including Static Air Pressure, Steam Pressures, Flows, Fan current etc.

The Wind Shield installation was completed on 12/2/1999 (the half way point of the data set)

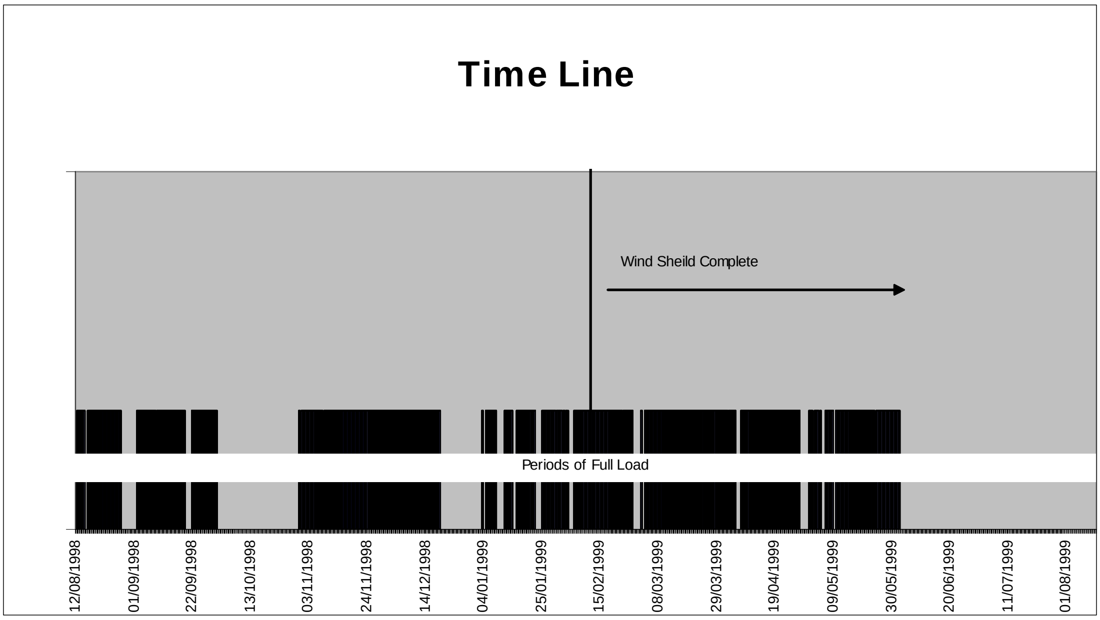
Table 1 Data Population

Total lines of Data	17,520
Valid lines of Data	17,395
Lines of Data at full load:- Load >300MW * and GT Guide Vane Pitch. 95% * open	8503
Lines of Data before WS complete (at full load)	4861
Lines of Data after WS complete (at full load)	3642

*These parameters used following advice from Kings Lynn. At these values the station will be operating at full power ensuring that the ACC performance data, before and after installation of the windshield, were comparable.

The following chart indicates the load profile for the 12 month period of this study. The plant operated at full load for 49% of the time.

Chart 1 Time Line

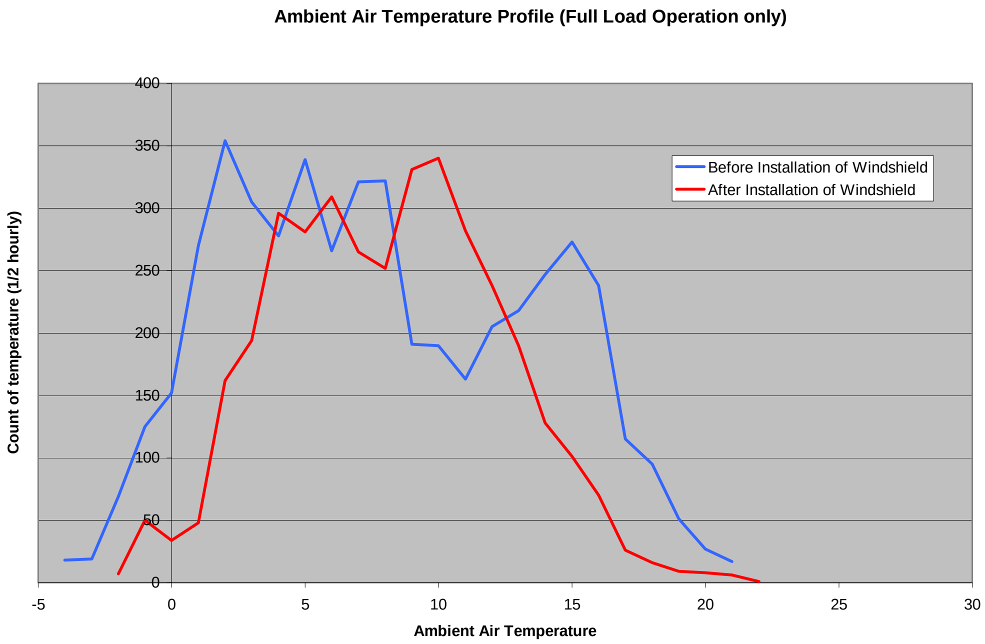


5. Comparison of performance before and after installation of Windshield

To compare the performance before and after the installation of the WS it is important to take into account the effects of the atmospheric variables,

- Ambient Air Temperature
- Wind Direction
- Wind Speed

Ambient air temperature has a significant effect, the following chart shows the profile over the period of the study and (based only on the periods of full load operation)



The chart shows a wider spread of ambient air temperatures before installation of WS and as air temperature can have a significant effect on the ACC performance it was decided to restrict the range of air temperature range used in the analysis. The various average air temperatures were:-

Overall Average air temperature from all data	10.5^{o}
Average air temperature during period of full load	8.0^{o}

Therefore initially the study was carried out within the ambient temperature range of:-

9 0^{o} +/-5 degrees 4^{o} to14^{o}.

More analysis of effects of varying air temperatures is given later in the report. Following filtering of the data, as above, there were 5177 lines of data remaining, 2467 before installation of WS 2710 after. Representing 61% of the data points. This was able to provide a good set of comparative data to analyse ACC vacuum against wind speed and direction.

6. Wind speed and Direction

The following table was constructed from the full data set. The average wind direction was 191^{o} and average wind speed of 4.3 M/S.

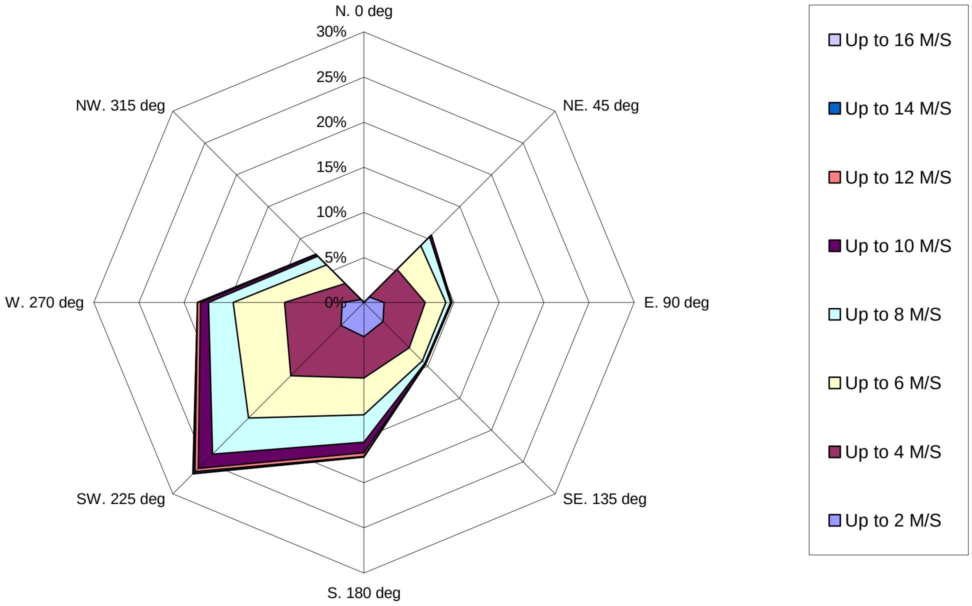
Table 2

Wind Direction and Speed (% of time between 12/8/1998 and 11/8/1999)

Direction	N	NE	E	SE	S	SW	W	NW	Totals
Degrees	0	45	90	135	180	225	270	315	
Wind Speed M/S									
Up to 2	0%	1%	2%	3%	4%	4%	2%	0%	16%
Up to 4	0%	4%	5%	4%	5%	8%	6%	3%	34%
Up to 6	0%	4%	2%	2%	4%	7%	6%	3%	27%
Up to 8	0%	1%	1%	0%	3%	6%	3%	1%	15%
Up to 10	0%	0%	0%	0%	1%	2%	1%	0%	5%
Up to 12	0%	0%	0%	0%	0%	1%	0%	0%	1%
Up to 14	0%	0%	0%	0%	0%	0%	0%	0%	0%
Up to 16	0%	0%	0%	0%	0%	0%	0%	0%	0%
Totals	0%	11%	10%	10%	17%	27%	18%	8%	100%

A wind rose representation of this the above data is given below chart 2.

Chart 2 Wind Rose



Note; - There were only 1 point in the range of 337.5^o to 22.5^O hence the “dip” in the North edge of the wind rose.

The affects of wind speed on the ACC vacuum were then analysed within ambient air temperatures 4 – 14^oC.and the various directions. The following graph shows the effects before and after installation of WS for all directions.

Chart 3 Vacuum versus Wind Speed (All Directions)

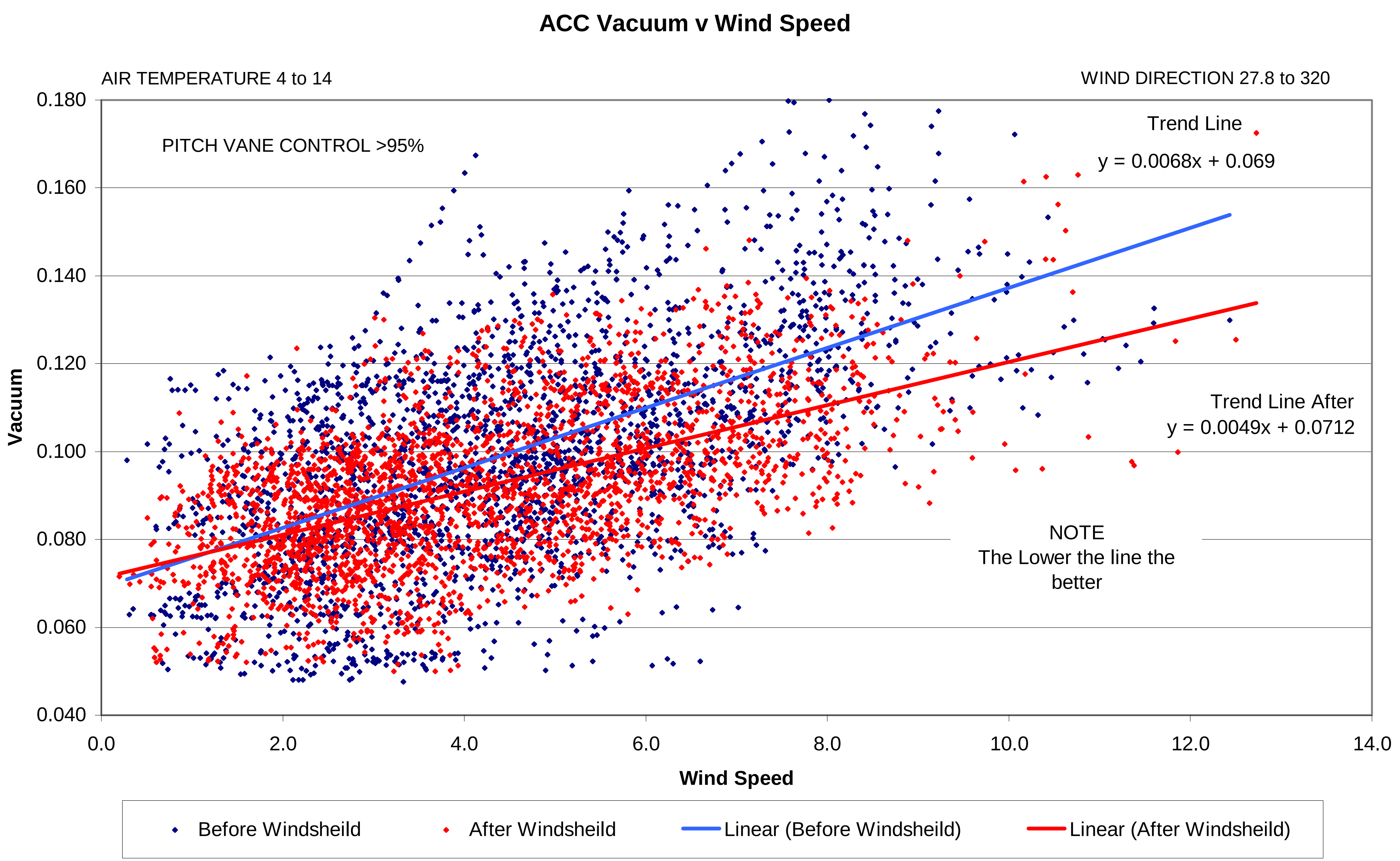
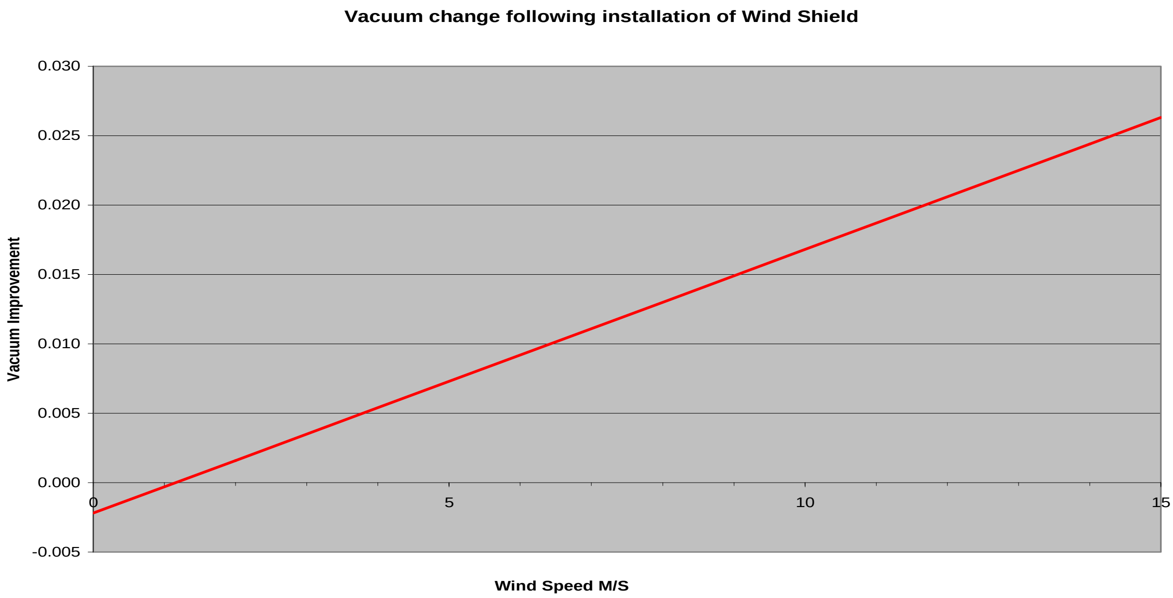


Chart 3 indicates that the windshield has a greater benefit as wind speed increases Chart 4 below summaries the vacuum change versus wind speed. It shows a benefit when wind speed is above 1.1M/S. For the average wind speed of 4.3M/S the vacuum improvement is 6Mbar.

Chart 4 Vacuum Improvement



7. Consideration of Ambient Temperature

Table 3 below gives the various vacuum improvements, before and after installation of WS for various temperatures based on the average wind speed of 4.3M/S.

Table 3

Ambient Temp range	Data points before	Data points after	Vacuum Before mBar	Vacuum After mBar	Vacuum Improvement mBar
-2 to -1	92	31	64.7	68.8	-4.1
-1 to 0	151	44	63.4	61.7	1.7
0 to 1	195	37	64.5	59.9	4.6
1 to 2	307	119	64.8	68.7	-3.9
2 to 3	352	141	69.6	72.1	-2.5
3 to 4	300	264	69.7	79.1	-9.3
4 to 5	329	286	75.1	77.0	-1.9
5 to 6	269	283	84.1	82.2	1.8
6 to 7	319	304	87.8	84.1	3.8
7 to 8	333	251	93.1	88.1	5.0
8 to 9	230	303	96.4	92.5	3.9
9 to 10	183	331	104.0	93.3	10.6
10 to 11	170	336	109.5	97.2	12.3
11 to 12	205	237	115.1	101.6	13.5
12 to 13	179	225	120.0	105.6	14.5
13 to 14	250	154	127.5	111.8	15.6
14 to 15	246	117	130.0	112.7	17.4
15 to 16	257	92	136.3	123.2	13.2
16 to 17	195	35	143.5	133.1	10.4
17 to 18	89	21	145.1	133.0	12.1
18 to 19	78	11	149.1	142.0	7.2
19 to 20	42	9	150.0	141.9	8.1
20 to 21	24	9	159.9	147.6	12.4
Weighted Av			97.2	91.2	5.4

It is interesting to note that as ambient temperature increases the there is generally an increasing vacuum improvement after the installation of the WS. In the worst case the dis-benefit is 4.6 Mbar (0 to 1 degrees) and at best the improvement is 17.4 mBar (14 to 15 degrees). However the overall weighted average improvement from this analysis is 5.4mBar.

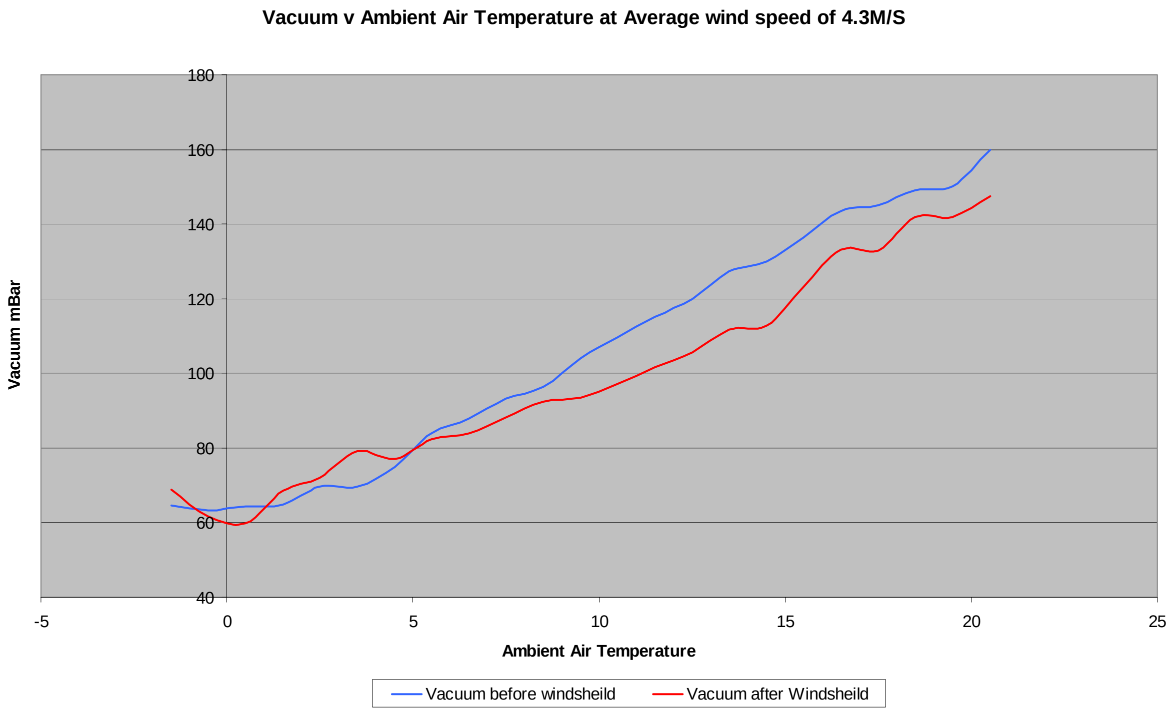
As the installation of the WS only moderates the air flow through the ACC and it wasn't expected that the effects of air temperature would be such an important effect. The results of this effect are shown in chart 5 below.

An explanation for this effect could be as follows:-

At lower ambient air temperatures (below 5 Degrees) the there is more than sufficient ACC cooling capacity (before and after installation of WS) therefore the benefits of the WS will not be displayed by improved vacuum, the vacuum is already at or about the minimum valve for optimum operation of the steam turbine. Even if the wind speed increases and hence wind sheer increases, then to compensate for this the number of fans or fan speed can be increased to provide the correct amount of cooling. The benefits of the WS at lower air temperatures should perhaps be considered in the reduced fan usage, wear and tear, and not vacuum alone.

At higher ambient air temperatures (above 5 degrees) the ACC will have increasing less cooling capacity as air temperature increases. This increasing lack of capacity is indicated by the slope in the chart (reduction in vacuum). After the installation of the WS this lack of capacity from increasing air temperature is offset or delayed by the virtue of the benefits of moderating the air flow and hence maintaining a better cooling affect at these increasing temperatures. There will of course still be a reduction in capacity as air temperature increases but the rate of loss of capacity is reduced.

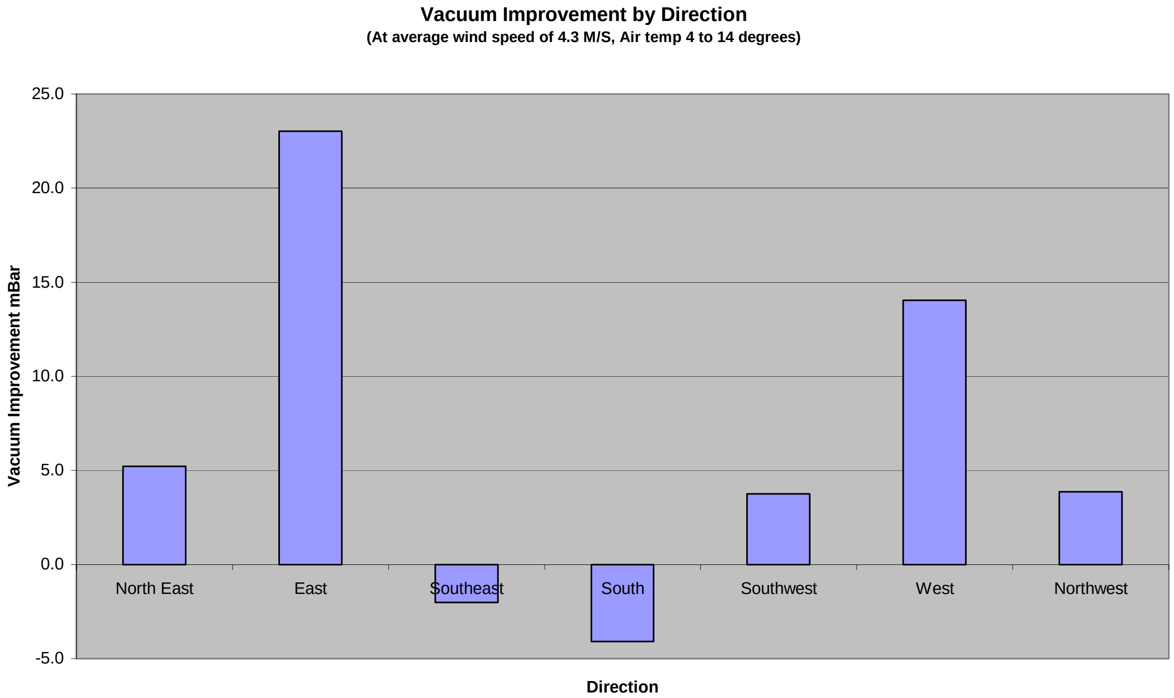
Chart 5 Vacuum versus Ambient Air Temperature



8. Effects of Wind Direction

As part of the investigation it was hoped to try and understand the effects of various wind directions and to compare this with the position of the WS. However when they were analysed the results were somewhat variable and no clear pattern or trend could be established. Never the less a summary of the findings are show below

Chart 6 ACC vacuum improvement by wind Direction



The reason for negative results for easterly and south easterly winds may be to do with effects of buildings and equipment surrounding the ACC. Although this represents about 27% of winds in that direction, the reduction in vacuum is small in comparison to remainder of the directions which show some significant improvements in vacuum. The point at issue here is that the topography of the site has a significant effect and needs to be considered when deciding on the placement of WS. One of the advantages of the WS system being that they can be quite easily moved, repositioned or adjusted so as to "fine tune" the performance of the ACC. In fact, since the original installation, that this is report has been based upon, a section of screen has been moved from the centre south leg to the northern edge of the ACC (see appendix 1)

9. Observations

Figures indicate an overall benefit of improved ACC vacuum after the installation of Galebreaker Windshield and supports the on-site experience of an improvement of about 5 mBar. There may also be additional benefits, which haven't been quantified in this report, resulting from less wear and tear on the ACC fan units

There does seem to be possible corruption in the wind direction data as there are very few readings from the north. It may be prudent to confirm correct operation of the weather station so to ensure that future ACC performance and wind direction data can be correctly correlated. This will be important in being able to "fine tune" the position and size of the Windshields.

10. Acknowledgements

Thanks to Edmund Wiglusz, Mechanical Performance Engineer, at Kings Lynn Power Station in providing the data for this analysis and his assistance

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Appendix 1 Layout of Kings Lynn Power Station