Installation of Galebreaker Windshield at Coryton Power Station

Report By
Adrian Melhuish BSc
and
Simon Melhuish I.Eng., M.I.Agr.E., M.I.I.E.

Version 3.3
25 November 2005

Review of Coryton Power Station Data
Reference the installation of Galebreaker Windshield

1. Introduction

The Air Cooled Condenser (ACC) at Coryton Power Station has been fitted with a Galebreaker Windshield (WS); with the aim of bringing it's performance back to the original design specification. The power station decided to commission a CFD modelling exercise to determine cause and potential remedy, this CFD modelling showed that during high winds there was wind shear under the ACC unit, which caused the fans to operate less efficiently as well as imposing additional wear and tear to the fan mechanism. Overall the station was losing performance and the CFD modelling exercise showed that the problem could be improved by the installation of Galebreaker windshields around the lower edge of the ACC existing windwall. Various heights of WS were used as detailed on the site layout drawing Appendix 1. 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 the period before and after installation and the purpose of this report is analyse this information and establish the benefits. The power station has stated that they believe that there has been a significant improvement in the ACC performance during windy conditions.

2. Summary of outcomes

The measure of improved PS performance after WS installation is ultimately about delivering more energy for less expenditure and the data set doesn't provide this financial information directly. However the data does indicate

- Improved ACC vacuum of 4.8mbar for wind speeds of 13 kph (3.6 m/sec), with increasing improvement for higher wind speeds. Site average windspeed is between 10.2kph and 15.7kph
- Dis-benefit for windspeeds below 5.25kph (1.5 m/sec), probably due to restricted flow. For this site windspeeds are below this figure for around 16% of the year.

Based on a notional price of £35/MWHr with the plant running at full load for 60% of the time this suggests that the WS improves overall performance to the station by around £186k per year. It should be noted that feedback from Coryton suggests this figure is overstated & an additional output of up to £100k a year would be more in line with their experience.

This report gives details of how these figures were 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. There is a lower limit for vacuum below which it would start to cause damage to the low-pressure steam turbine blades. For Coryton, designed minimum ACC vacuum is 67mbar.

It can be demonstrated that PS output increases with improved vacuum (see Chart No5), therefore as the installation of the WS improves vacuum then this improvement can be translated into increased output. This in turn will represent an improved overall efficiency. The price of this improvement can then be given a value based on a unit price.

It is assumed that the increased vacuum, and hence performance, is all pure efficiency gain with more power being able to be extracted for the same input energy.

4. Data Set and Time Line

The data set includes the following information: -

Date Range:- 1/1/2004 to 31/7/2005 Periodicity:- Hourly

- Date and Time
- Ambient Temperature
- Ambient Pressure
- Wind Speed Km/Hr
- Wind Direction
- Plant Load
- ACC Vacuum
- GTA Firing Temp
- GTB Firing Temp
- Plant at Full Load (Yes/No)

Please note that throughout this report Wind Speed is displayed at Kph, table 1 below is given for cross-reference to M/sec.

Table 1 Wind Speed Cross Reference

Kph	0.0	2.5	5.0	7.5	10.0	12.5	15.0	17.5	20.0	22.5	25.0	27.5	30.0
M/Sec	0.0	0.7	1.4	2.1	2.8	3.5	4.2	4.9	5.6	6.3	6.9	7.6	8.3

The PS also advised: -

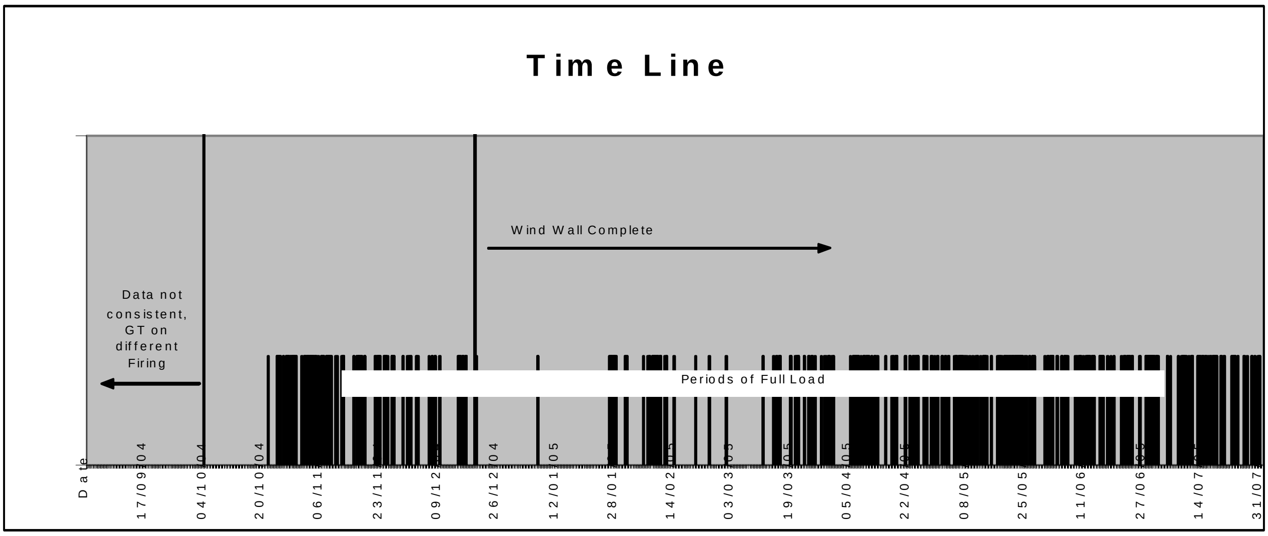
- Wind speed data is reasonably accurate, but wind direction may not be due to possible wind cock wind deflection.
- GTs operated at different combustion firing temperatures up to 4/10/04, therefore not to make comparisons before this date.
- They suggest only use data when station was operating at full load, to ensure conditions were consistent.

Table 2 Data Population

Lines of full load data, (from 4/10/04 to 31/7/05)	806
Lines of data before WS complete 20/12/04	222
Lines of Data after WS complete	584

Based on this information the following time line indicates periods of full load.

Chart 1 Time Line



Note the above operating regime is not typical for Coryton, which would normally run at full load for at least 60% of the time plus a further 10% in excess of 95% full load.

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 main variables, principally; -

- Ambient Air Temperature
- Wind Direction
- Wind speed

The data sets for comparison cover different seasons of the year. The "before" data being autumn and early winter whereas the majority of the "after" data occurs in spring to summer. This reduces the range of data that can be compared. For ambient air temperature, the ranges were as follows: -

Table 3 Temperature Ranges

Temperature range "Before" WS	4 to 17^{o}C
Temperature range "After" WS	3 to 33 ^{o}C
Temperature range used in comparison (Insufficient values available beyond this range)	8 to 16 ^{o}C

The wind direction has a varying affect on ACC performance. In some circumstances the influence of the WS appears to be a dis-benefit to ACC performance, more on this later. Therefore it was decided to restrict the comparison to a range of prevailing wind directions. For 2004 the wind directions were analysed and the following values used in the comparison analysis. See tables 4 and 5 below

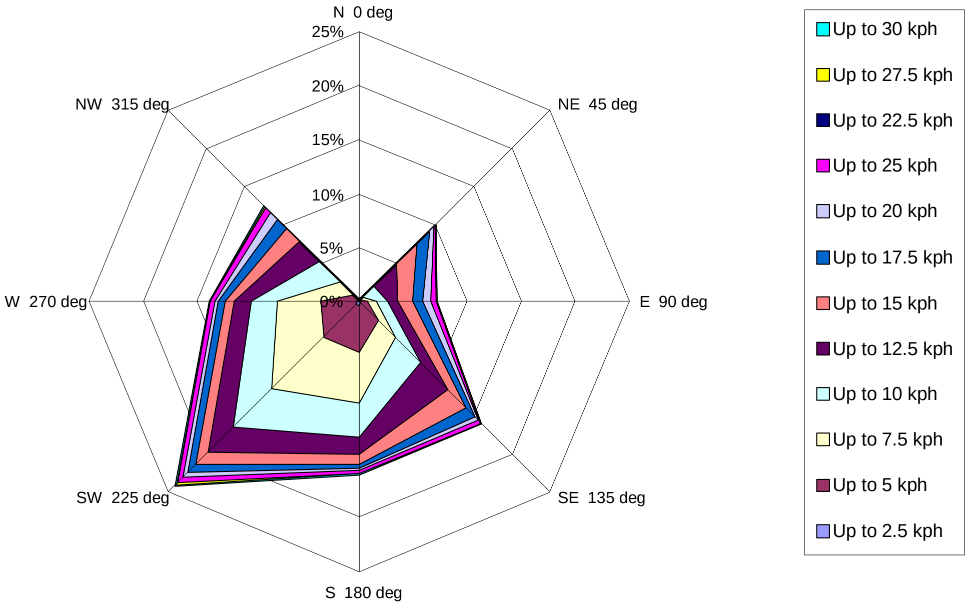
Table 4 Wind & Speed Directions

Wind Direction and Speed (% of time in 2004)

Direction	N	NE	E	**SE***	**S***	**SW***	**W***	NW		***Predominate Direction**
Degrees	0.0	45.0	90.0	**135.0**	**180.0**	**225.0**	**270.0**	315.0	Total	
Wind Speed										
Up to 2.5	0.00	0.00	0.06	**0.19**	**0.42**	**0.39**	**0.30**	0.09	1.45	**1.30**
2.5 to 5.00	0.01	0.15	0.64	**2.35**	**4.27**	**4.25**	**3.32**	0.75	15.73	**14.19**
5.0 to 7.5	0.02	0.38	0.87	**2.16**	**4.73**	**6.76**	**3.96**	1.73	20.61	**17.61**
7.5 to 10.0	0.06	1.39	1.07	**3.23**	**3.14**	**5.10**	**2.39**	2.62	19.00	**13.87**
10.0 to 12.5	0.08	2.93	0.97	**3.65**	**1.66**	**3.32**	**1.57**	2.64	16.83	**10.21**
12.5 to 15.0	0.03	2.69	1.30	**2.39**	**0.90**	**1.55**	**0.82**	1.73	11.41	**5.66**
15.0 to 17.5	0.00	1.61	1.01	**1.20**	**0.32**	**1.12**	**0.66**	1.22	7.13	**3.29**
17.5 to 20.0	0.00	0.69	0.72	**0.39**	**0.19**	**0.55**	**0.36**	0.91	3.81	**1.49**
20.0 to 22.5	0.00	0.15	0.26	**0.34**	**0.20**	**0.42**	**0.23**	0.36	1.97	**1.20**
22.5 to 25.0	0.00	0.03	0.23	**0.08**	**0.10**	**0.34**	**0.13**	0.18	1.09	**0.65**
25.0 to 27.5	0.00	0.01	0.08	**0.02**	**0.06**	**0.23**	**0.08**	0.17	0.65	**0.39**
27.5 to 30.0	0.00	0.01	0.01	**0.00**	**0.09**	**0.14**	**0.02**	0.05	0.32	**0.25**
Totals	0.20	10.03	7.21	**16.01**	**16.09**	**24.16**	**13.84**	12.46	100.00	**70.10**

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

Chart 2 Wind Rose

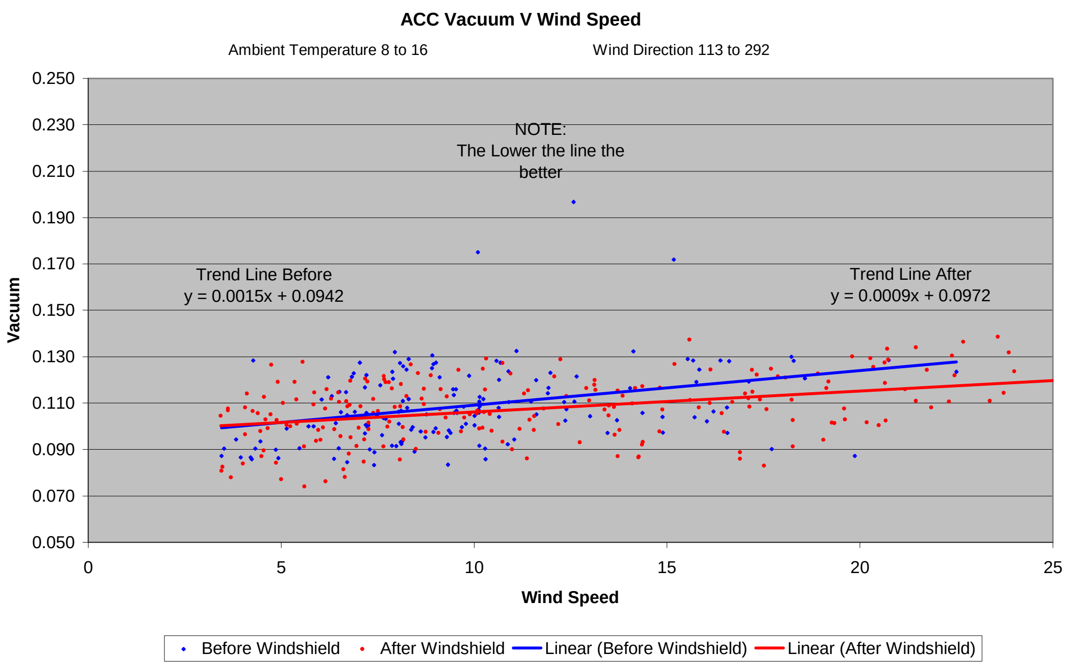


Note; - There were only 18 points in the range of 337.5^o to 22.5^O hence the "dip" in the North edge of the wind rose. See table 5 for a summary of wind direction

Average wind direction 193^o

The affects of wind speed on the ACC vacuum were then analysed within ambient air temperatures 8 - 16^{o}C.and the predominate 180 ^{o} wind range of 113 ^{o} to 292^o (SE, S, SW, W). The following graph shows the effects before and after installation of WS

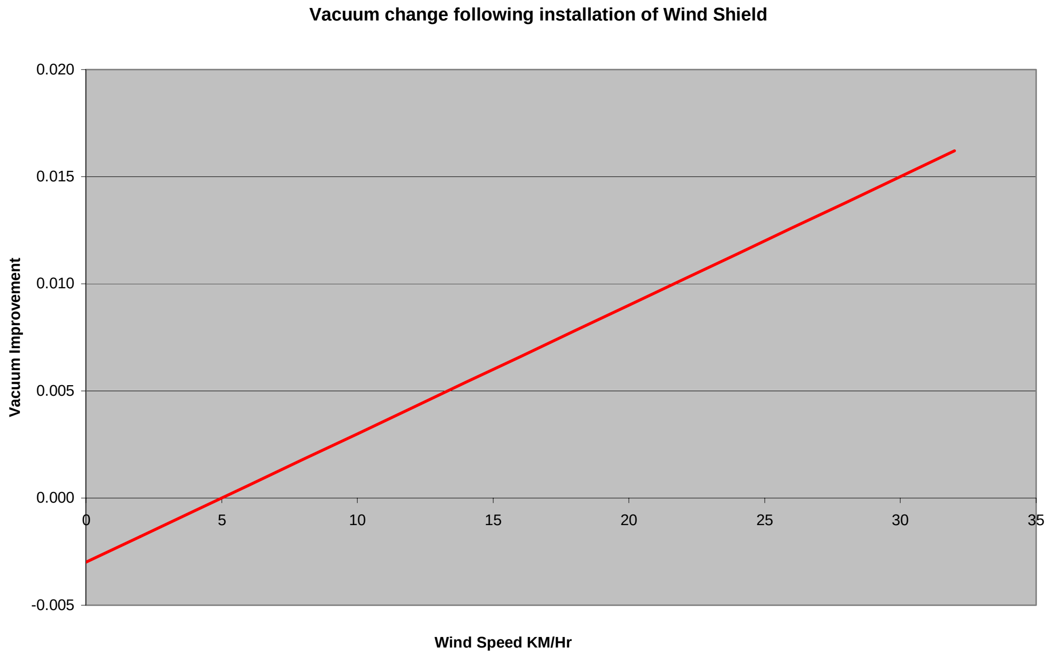
Chart 3 Vacuum versus Wind Speed



The figures indicate a flatter wind speed vs. vacuum profile after installation of the Windshield and chart 4 summarises the vacuum change. It indicates a dis-benefit below 5.25kph (probably due to the restricted airflow) and an improvement above, with the differential increasing with greater wind speed. The average wind speed for the PS over the data period is given below, showing the average wind speed well in excess of 5.25kph.

Average "Full Load" wind speed	15.7 kph
Average wind speed (from full data set)	10.2 kph

Chart 4 Vacuum Improvement



6. Consideration of Ambient temperature

The improvement in vacuum during full load operation at the average wind speed of around 13kph is 4.8mbar. In order to check the effects of ambient temperature on these results, a series of additional analysis of wind speed vs. vacuum were undertaken in 1°C steps between 8 °C and 16 °C. Unfortunately the limited amount of data points gave erratic results rendering the graphs unusable; therefore a summary is given in the table below.

Table 5 Temperature analysis

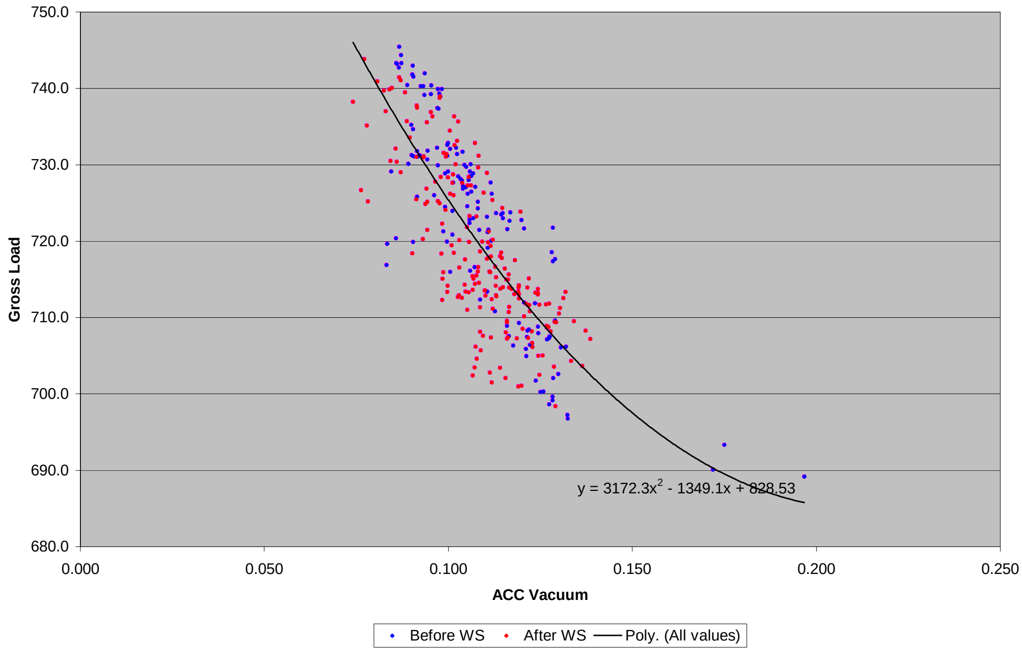
Ambient Temperature	Number of data points Before WS	Number of data points After WS	Nominal Vacuum	Vacuum Improvement mBar
8	6	5	0.080	4.20
9	2	7	0.090	0.00
10	14	14	0.095	0.80
11	31	23	0.100	3.30
12	35	26	0.105	5.00
13	15	26	0.115	11.70
14	19	25	0.115	9.20
15	10	37	0.120	1.70
16	9	36	0.125	10.00
Weighted Av'			0.109	5.78

7. Load versus Vacuum

Considering load versus vacuum, from the following graph it is possible to determine the increased output for a given improvement in vacuum. Note the chart shows two sets of data points (before and after WS installation), the black trend line being calculated from all data points, thus giving fair valve for the load/vacuum formula viz: -

$$Load = 3172.3*Vac^2 – 1349*Vac + 828$$

Chart 5 Load versus Vacuum



8. Estimation of Annual Benefit

The estimated annual benefit is calculated as follows:

MW improvement x Operating hours/year x £/MWHr x Wind speed factor*
(* Wind speed factor being the percentage of the year that each wind speed prevails)

The following table shows calculation of benefit for based on full load running for 60% of the year (5256 Hours) for wind speed values in the predominate directions (SE, S, SW & W). 112.5 to 292.5 degrees.

Table 6 Benefits

Wind		Vacuum			Load			
Speed Kph	% of time	Before	After	Improve ment	Before	After	Change	MWHr
Up to 2.5	1.3%	0.096	0.098	-0.002	728.2	726.5	-1.6	-112
2.5 to 5.00	14.2%	0.100	0.101	-0.001	725.5	724.9	-0.5	-399
5.0 to 7.5	17.6%	0.104	0.103	0.001	722.8	723.3	0.5	482
7.5 to 10.0	13.9%	0.107	0.105	0.002	720.3	721.8	1.5	1107
10.0 to 12.5	10.2%	0.111	0.107	0.004	717.8	720.3	2.5	1321
12.5 to 15.0	5.7%	0.115	0.110	0.005	715.4	718.8	3.3	995
15.0 to 17.5	3.3%	0.119	0.112	0.007	713.2	717.3	4.2	722
17.5 to 20.0	1.5%	0.122	0.114	0.008	711.0	715.9	4.9	388
20.0 to 22.5	1.2%	0.126	0.116	0.010	708.9	714.5	5.7	355
22.5 to 25.0	0.6%	0.130	0.119	0.011	706.9	713.2	6.3	215
25.0 to 27.5	0.4%	0.134	0.121	0.013	704.9	711.8	6.9	141
27.5 to 30.0	0.3%	0.137	0.123	0.014	703.1	710.5	7.5	98
Total	70.1%							5313
							£/MWHr	£35
							Total	£ 185,954

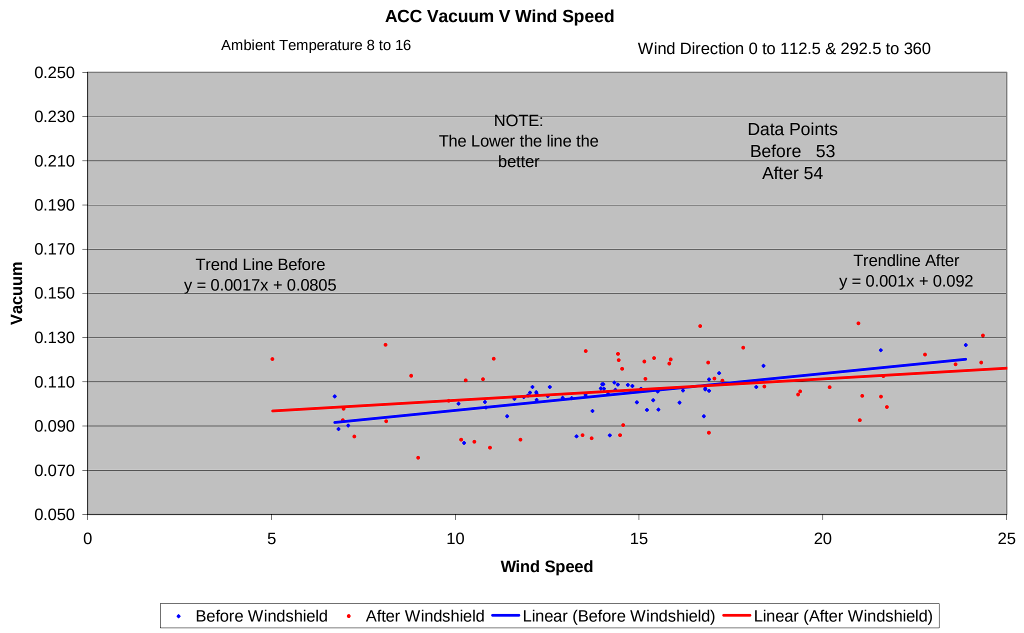
The additional output could be increased by approximately 10% to account for running the PS at between 95% and full load.

9. Wind Direction

As mentioned earlier the data suggests the degree of ACC performance improvement after the installation of the WS varies dependent upon wind direction. Attempts were made to plot wind speed vs. vacuum for each of the eight directions (N, NE, etc), however like the attempt to analyse further the effects of temperature, the limited amount of data points gave erratic results.

Therefore to give an overview of the effects of wind direction Chart 6 gives wind speed vs. vacuum for the 180 ^{o} wind range of 292 ^{o} to 113^{o} (NW, N, NE, E) not included in Chart 3.

Chart 6 Vacuum versus Wind Speed



Note that the total data points for this Chart equals 107 (13% of the data pool), whereas Chart 3 has 699, and with a limited sample the accuracy of the results have a larger question over them.

However the analysis does indicate that the WS gives better improvements for S to W winds (as shown in Chart 3) than for N to E winds. Whilst the WS are only 4m high on this side of the ACC Chart 6 indicates the possibility that the combination of installing WS with the other structures adjacent to the ACC (i.e. steam inlet duct, PS buildings) could result in restrictive airflow, although this would only be the case for wind directions of NE and E.

Chart 6 indicates the wind-speed where it switches from dis-benefit to benefit to has increased from 5.25kph to around 17kph. Historical data indicate that for this site the wind blows in the directions NW, N, NE and E for 30% of the year.

10. Observations

Figures indicate an overall benefit of improved ACC vacuum after the installation of Galebreaker Windshield; there may also be additional benefits such as less mechanical wear and tear on the fans sited on the ACC. On-site experience supports the overall 5mbar vacuum improvement in this report, but places the financial benefit at around £100,000 a year, not £187,000 as this report suggests. Reasons for this discrepancy could be:

- The limited data sample of 12 weeks before installation. This was due to the different combustion firing temperatures of the two GT's prior to 4-10-04.
- There is a financial loss for the wind directions NW, N, NE and E which would offset the £187,000 saving calculated.

As advised by Coryton there seems to be some corruption of the wind direction data as there are very few northerly reading, however it is understood that a new weather station is due to be commissioned shortly.

It appears in the case at Coryton that there is less benefit when the wind is from the direction North to East. This may be due to the existing obstructions to airflow. (i.e. buildings and steam inlet ducts).
It may be worth considering reducing the WS along that part of the ACC. but perhaps not before firm weather station data is available to monitor the effects closely.

Whilst compiling this report it has become apparent that in order to gain good evidence for ACC improvements after any modifications it important to have a large data sample covering at least a year pre and post WS installation thereby ensuring all weather types are included.

11. Acknowledgements: _

Thanks to Roy Bailey Operations Manager Coryton Power Station in providing the data for this analysis, proof reading this report and his general help.

Report Principal:-

Adrian Melhuish
9 Dordon Close
Shirley, Solihull
West Midland
B90 1AH
[25/11/2005]

Firstade@blueyonder.co.uk
0121 474 5515
0773 652 0232

Appendix 1
Coryton Power Station Layout and Wind Rose

Based on data from Jan' to Dec' 04