Energy Studies Review Volume 12, No. 2 2004 pp143-152

ATMOSPHERIC FLUIDIZED BED COMBUSTION (AFBC) PLANTS: A PERFORMANCE BENCHMARKING STUDY

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INTRODUCTION

The authors analyzed data from a fluidized bed boiler survey distributed during the spring of 2000 to begin the process of developing AFBC (Atmospheric Fluidized Bed Combustion) performance benchmarks. The survey was sent to members of CIBO (Council of Industrial Boiler Owners), who sponsored the survey, as well as to other firms who had an operating AFBC boiler on-site. The useable response rate to the survey was approximately thirty-two percent, resulting in thirty-five useable surveys to analyze. (It should be noted that there are approximately 110 operating AFBC units in the United States to whom the survey was directed.) The survey respondents principally used AFBC technology in steam and power plants ranging in size from a few MW (megawatts) to several hundred MW in size.

The authors acknowledge financial support from the National Energy Technology Center (NETL) - Morgantown in developing this research. They also acknowledge the support provided by the Council of Industrial Boiler Owners (CIBO). All conclusions are the authors' and should not be attributed to the sponsoring agencies.

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There were three primary purposes for the collection and analysis of the data contained in this fluidized bed boiler survey:

1. To start the process of developing AFBC benchmarks on technical, cost, revenue, and environmental issues.
2. To inform AFBC owners and operators of contemporary concerns and issues in the industry.
3. To improve decision making in the industry with respect to current and future plant start-ups and ongoing operations.

These three purposes were identified by research engineers and project managers at the U.S.D.O.E (United States Department of Energy) and CIBO leadership and members as being key to improving the operating efficiency and performance of AFBC plants.

BENCHMARKING ANALYSIS

A listing of the benchmarks, which were developed from the survey, is contained in Attachment 1. The decision as to which benchmarks to develop was made based on extensive discussions with the same individuals referenced in the previous paragraph. The consensus was that this information would be extremely valuable in analyzing operations at individual AFBC plants. These benchmarks would be classified as being examples of competitive benchmarks and industry benchmarks. It should be noted that what are referred to as benchmarks in this study could be more accurately classified as industry operating averages for the firms participating in the study. A company would generate the information for the current survey and then utilize the survey results to improve their firm's performance.

The AFBC plants of survey respondents that were not included in the analysis were: (1) those who indicated that the plant was used for peaking purposes (i.e., only used occasionally), (2) those plants that were in curtailment for a significant portion of time in 1998 or 1999, and (3) those plants which produced steam only (since there were only two such respondents). The reason for leaving plants out of the study that were only used for peaking purposes or were in curtailment during the timeframe of the study was that it was felt introducing such data could bias the study's results. To include data for plants that were used only a very small portion of time would not allow one to get a clear view of how the vast majority of plants were operating. In this case, there were only three plants that fell into the category of either being used for peaking purposes or were in curtailment during the study's timeframe. These three units were in addition to the thirty-five boilers included in the study. The logic for leaving steam-only generators out of the analysis is that with a sample size of only two, it would be nearly impossible to develop reliable benchmarks for this group.

It should be pointed out that unless the respondent indicated specifically that the plant was indeed a peaking unit or was in curtailment, one would need to analyze the operating data supplied by a respondent to try and make this determination. If there were any questions concerning data interpretation (e.g., significant down time, data that did not fit what was expected), the respondent would have been contacted to clarify such issues. A suggestion for a further study would be to include a response item specifically indicating if the boiler was used for peaking purposes or was in curtailment.

Another issue, which came up in interpreting the survey data, related to those surveys that indicated multiple boilers were contained in the plant. Questions here had to do with whether the other boilers were also AFBC units or not and whether they were driving the same turbine. At times it was difficult to determine whether the data in a particular survey, for those indicating multiple boilers, referred to a particular boiler or was aggregated over all boilers at the site. As mentioned in the previous paragraph, if there were any questions concerning data interpretation, the respondent would have been contacted to clarify such issues.

A possible concern any time a survey research effort is performed relates to the possibility of bias in the collected data. In reviewing individual responses, it was determined that the range of respondents was very much in keeping with the characteristics of the population from whom the data was being collected. Since the authors guaranteed confidentiality to the respondents, there should be no particular reason why a respondent would be reluctant to participate due to the fact that their facility might be performing better or worse than the industry as a whole. Further, the fairly high response rate for this survey (32%) in relation to the typical response rate for such surveys should help to further reduce possible bias in the data used to develop the study's results.

Table 1 below displays the results of the benchmarking analysis for the eighteen benchmarks based on plant size. (These benchmarks are defined in Attachment 1.) There were sufficient responses to break the data down into five plant sizes (1-19 MW, 20-49 MW, 50-74 MW, 75-99 MW, and $\geq$ 100 MW). (It should be noted that in order to maintain confidentiality of respondents, each category must contain a sample size of at least three units.) The use of "NA" in the table references situations where there was insufficient data collected to both maintain the confidentiality of respondents and ascertain the validity of the reported research results. To interpret the data in Table 1, it shows, for example, that for Benchmark 1 (Number of FTE [full time equivalent] staff per million MWh [megawatt hours] generated) the average value for plants of the 1 – 19 MW size was 177.8. It was noted that this industry average decreased significantly as the plant sizes increased. In this case, for plants 100 MW or larger in size, the average number of FTE staff per million MWh generated was 41 (or approximately 23% of the number in plants in the range of 1 - 19 MW). This observation is not surprising when one takes into account efficiency of size issues and the difficulty in specific delineation of "boiler operators" in smaller operations. To use the information in Table 1 for a particular benchmark value, a firm would simply identify the plant size range that would be appropriate for their plant and then use the benchmark value to see how their operation compares to the industry average for similarly sized plants.

Table 1

Bench-mark	**Plant size (MW)**				
	1-19	20-49	50-74	75-99	≥100
1	177.8	90.3	85.1	49.2	41
2	NA	NA	12042	NA	10643
3	NA	12267	12327	11700	10665
4	89.9	94.7	85.1	88.2	90.9
5	89.9	94.9	85.1	94.3	91.3
6	NA	98.3	90.6	88.4	78.9
7	NA	10.8	8	-5	-4.9
8	0	2.6	8.1	2.7	-4.8
9	0	0	0	0	0
10	11	9.3	8.5	3.3	5.9
11	45.3	83.9	74.3	58.6	56.3
12	24.8	45.6	37.9	29.5	22.4
13	0	0	6.6	2.4	0.5
14	0	1956	354	0	0
15	NA	0.1325	0.1316	0.1339	0.1395
16	4.2	NA	2.31	2.39	2.37
17	15.5	87.5	80	70	57.96
18	15	83.3	76	67	55

Table 2 below displays the research results for the eighteen benchmarks, when the results are broken down into five plant sizes and three primary fuel types (coal, culm [waste anthracite], and gob [waste bituminous]). (Again, these benchmarks are defined in Attachment 1.) There were enough responses obtained to break down the data in Table 2 into eight combinations. To interpret the data in this table, it shows, for example, that for the first benchmark (Number of FTE staff per million MWh generated) for plants of the 20 – 49 MW size, which burned coal as a primary fuel, was 135.5. To use this information to analyze either one's current operation or potential staffing for a new operation, the procedure would be again to find the industry average value appropriate for their plant size and fuel combination. This would then allow one to compare their staffing level to other current or future facilities of similar size and primary fuel type. As observed in Table 1 for this benchmark, the FTE staffing level per million MWh generated decreases as the size of plants increases, irrespective of type of primary fuel.

Table 2

	Plant Size (MW) and Primary Fuel Type							
Bench Mark	20-49 & coal	50-74 & coal	50-74 & culm	50-74 & gob	75-99 & coal	75-99 & culm	75-99 & gob	≥ 100 & coal
1	135.5	134.3	NA	44.6	40.5	50.4	55.6	40.4
2	NA	NA	11186	11169	NA	NA	9688	10643
3	11489	12518	11750	12643	NA	11989	11398	10675
4	94.7	72.5	93.8	94.1	60.7	92.5	98.2	90.4
5	94.3	72.5	93.8	94.1	NA	92.6	98.9	90.9
6	99	86.3	NA	93.7	NA	91.9	93.7	76.3
7	14.6	10.3	NA	-0.7	NA	-5	NA	-5.2
8	2.6	NA	NA	NA	NA	5.4	0	-5.7
9	0	0	0	0	NA	0	0	0
10	5.5	4.8	7	8.7	6.5	2.3	3	5
11	81.7	74.1	78.8	78.3	59.5	66.7	34.5	49.4
12	54.2	54.8	42	34	NA	38.1	NA	21.5
13	0	14.8	0	0	NA	3.4	0	0.7
14	1956	401	NA	330	NA	0	NA	0
15	0.0748	0.131	NA	0.213	0.2275	0.071	0.224	0.1127
16	NA	1.82	2.96	2.63	NA	2.38	2.47	2.27
17	100	100	100	33.3	50	66.7	100	47.4
18	100	100	100	33.3	25	70	100	NA

One observation pertaining to Table 2 is that the benchmark values for Benchmark 4 (Percent of time on-line in 1999) for 50-74 MW plants that burn coal and 75-99 MW plants that burn coal seem unexpectedly low. The authors do not have any additional insight as to this occurrence, other than that the few plants in question may have been undergoing extended modifications or may operate only on a seasonal basis in a co-generation mode.

It was observed that for Benchmark 5 (Percent of time actually operating in 1999) in Table 2 the industry average value for 50-74 MW plants that burn coal seems unexpectedly low. The authors have no additional information as to why this may be the case. This particular plant size was too large for the initial FERC [Federal Energy Regulatory Commission] classification for non-utility generators and too small for the later update of this classification. Such plants were typically built to burn waste streams from facilities that desired to co-generate power and steam for industrial processes, which may explain reduced operations due to cyclic industrial applications.

Relating to Benchmark 9 (Percent increase in external customer base from 1998 to 1999) in both Tables 1 and 2, it would appear that the plants in this analysis had a very stable set of external customers from one year to the next due to there being no observed increases. Many of these units are above or approaching twenty years of operation and are still under the initial construction contract to a single electrical distributor.

Potential owners may find that the data in Benchmarks 3 (Total net plant efficiency), 14 (Amount of steam used by customers other than to generate electricity), 15 (Tons sorbent per ton of fuel), and 16 (Calcium to sulfur ratio) provide insight into forecasting development expenses, particularly for required output verses fuel and sorbent cost expectations. The data in Table 2 indicates that in general better efficiency occurs from larger, low sulfur, coal-burning units. Project planning would require an analysis of tradeoffs concerning locally available fuels and transportation costs for remotely located fuels. Actual expenses for this tradeoff could be accurately estimated from Table 2 data, as well as payback on initial investment for building a more efficient, oversized unit that perhaps could have excess capacity diverted to cogeneration until industrial process requirements expand.

SUMMARY

As this is the authors' first attempt to develop an appropriate set of industry average operating benchmarks for AFBC plants, one would hesitate to draw too definitive a set of conclusions from the analyzed results. However, a number of benchmarks did point out some resultant differences between the ranges of plant sizes and types of primary fuels being used by these facilities. Based on participant feedback and discussion, this initial benchmarking study was successful in accomplishing the three primary purposes described in the Introduction section of this research paper. Practical information was compiled to assist plant owners, operators, and developers to understand their operations concerns and to assess potential solutions or to establish preventative maintenance programs. One would anticipate being able to draw additional conclusions from an analysis of the data to be generated related to a planned additional survey study by the authors.

The process of generating appropriate performance benchmarks for AFBC plants is still in its formative stages. However, one would believe that this type of information would be extremely valuable for companies currently utilizing or planning installation of AFBC combustion technology.

ATTACHMENT 1

AFBC BENCHMARKS

1. Number FTE staff per million MWh
2. Total gross plant efficiency (expressed as BTU's [British thermal units] / gross KWh [kilowatt hours])
3. Total net plant efficiency (expressed as BTU's / net KWh)
4. Percent of time on-line in 1999
5. Percent of time actually operating in 1999
6. 1999 capacity factor percent of MCR (maximum continuous rating)
7. Percent change in output (1998 to 1999)
8. Percent capacity factor change (1998 to 1999)
9. Percent increase in external customer base (1998 to 1999)
10. Number of total outages in 1999
11. Percent of 1999 total outages that were forced
12. Percent of 1999 total outage hours that were forced
13. Man-days of lost time accidents in 1999
14. Amount of steam used by customers other than to generate electricity (in billion BTU's)
15. Tons sorbent per ton of fuel
16. Ca / S (calcium to sulfur) ratio
17. Percent of fly ash used for beneficial purposes
18. Percent of bottom ash used for beneficial purposes

ADDITIONAL SOURCES OF INFORMATION ON THIS SUBJECT

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