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Euromot Comments on "Report of the Task-Force Energy Efficiency - Large Combustion Plants BREF TWG" as of 11 Dec 2014

At the intermediate informal meeting of the TWG for the review of the Large Combustion Plants Best Available Techniques Reference Document (LCP BREF) held in Seville 17 – 18 June 2014 it was decided to create a TWG task-force to deliver additional data or information (many submitted TWG comments by end of September 2013 to the LCP BREF D1 had shown that there was a big need to revise/gather more information on this topic) on energy efficiency /1/.

In this paper we provide our comments on the "*Report of the Task-Force Energy Efficiency - Large Combustion Plants BREF TWG - Activities coordinated by EPPSA and EURELECTRIC 11 December 2014"* to the EIPPCB in Dec 2014. The paper is intended to be complementary to the Task Force's report and further elaborates and amends issues which are specific to internal combustion engines and which were not raised at all, are only partially covered or got mistaken by the report. We have also highlighted some changes of the Task Force report which are needed in order to get a correct view of the efficiency in context with reciprocating engines.

We are looking forward to continue providing our industry's' input into the discussions with the EIPPCB and other stakeholders.

1. General observations

1.1. In the report, <u>single cycle reciprocating engine plants and combined cycle reciprocating engine plants are put in the same tables/graphs</u>**.** They need to be handled separately like it was done for gas turbines ("open cycle = single cycle"; "combined cycle"). The Maltese combined cycle plant is consisting of 8 big diesel engines and **one common steam turbine**. This plant should have been handled separately from the other (almost merely single cycle) reciprocating engine plants. With only one combined cycle reciprocating engine plant as background no wider conclusions can/should be drawn about this special concept and a general text should be in place (see paragraph 2.5.1 below for proposal to general text about the subject).

1.2. In power plants 4-stroke and 2-stroke reciprocating engines are used. In the pictures and graphs used in the report efficiency information of both the 4-stroke and 2-stroke reciprocating engine types is put in without any marking showing/separating these types from each other. Both engine types have pros and cons, e.g. 4-stroke engines have lower NOx-emissions and are much compacter than 2-stroke engines (with a lower fuel consumption and thus a higher efficiency). The majority of power plants utilize 4-stroke engines and only in some special cases other engine types such as 2-strokes are used. 4- and 2—stroke engines have a very different design from each other and shall thus be treated as own types. These engine types should have been treated as “own” types in the graphs/pictures, which is not the case now. This leads to a skewed/misleading picture of the efficiency performance.

1.3. ISO 3046/I which is widely used in the reciprocating engine sector for defining fuel consumption and output of the unit, this standard has an allowed (fuel consumption) tolerance of +/-5 % and if nothing is stated about the tolerance when a figure is given it means in practice that the fuel consumption is given with a hidden +5 % tolerance which should be put on top of it in order to get the correct value. Most of the plant/unit references which participated in the study did not report if a 0 or 5 % tolerance had been used for the reported value (in the BATIS “Questionnaire for collecting plant-specific data for the review of the BAT Reference Document (BREF) on Large Combustion Plants (LCP)” information on tolerances used is missing. Task- force used/collected from BATIS information from totally 33 engine units (or 29 “plants”). Due to limited time the submitted information to BATIS was double checked with plant operators for only 16 selected engine units) thus some of the reported efficiency values probably should be lower than now shown in the report. This put big doubts on the correctness especially on the highest reported efficiency values. In addition in some case information was missing if given efficiency was netto or brutto and no parasitic consumption figures were given.

1.4. Only one CHP (Combined Heat and Power) and one mechanical drive reciprocating engine plant were reported. Thus broad conclusions cannot be derived from these cases. Special site specific conditions such as the heat recovery system applied (hot water, steam, etc.), inlet water temperatures, heat recovery ability of the surrounding process will put frames on achievable total efficiencies. Mechanical drive applications can be direct or indirect coupled to the engine or in some cases the engine produce electricity (as a power plant) and an electric mechanical drive is applied. Thus no general conclusions can/should be drawn from obtained plant data on typical efficiency ranges of these applications. General texts are preferred, see general texts in below paragraphs 2.3.1 and 2.4.

1.5. In some case it can also be observed that a to BATIS reported erroneous efficiency figure has been used in the report.

In the Task-Force report at the end of page 7 in section “The following elements should be considered when asking for information to engines operators” certain aspects of above points 1.1. 1.2. 1.3 are briefly highlighted. On the same page there is also a reference given to the Euromot position paper “BAT Associated Efficiency Levels” /1/ for more information.

2. Comments on individual sections of the Task Force report

2.1. Table ES.5.a: Power Plants - Reciprocating Engines - Net Efficiency Ranges

– "Up to year 2010", efficiency range values: The figures given are not from the double checked (references: 166, 176, 177, 178, 179, 180, 181, 186, 362, 363, 364. 365; note references 362 – 365 consist of 2 engines each).

We checked from BATIS and noted that the upper value seems to be from reference unit 428-7 (engine commissioned year 1997) "4. Energy efficiency Sheet", but in "3.Operating information Sheet" of the same unit is given following data:

- "Total rated thermal input" = 15.85 MWth
- "Gross electric output" = 6.1 MWe
- Gross electrical efficiency = 38.48 % << 48.5 % (net)!

I.e. given efficiency figure in the BATIS questionnaire is erroneous (and note above calculated gross < given net figure !, no tolerance either given in the questionnaire). Reference unit 428-6 (engine commissioned year 1997) from the same plant is of same engine type/size, for this unit in sheet "4. Energy efficiency Sheet" is reported electrical efficiencies: 38.3 % (net) and 39.6 % (brutto). For reference engine unit 428-8 (engine commissioned year 1997) of same engine type/size in the same plant the corresponding reported figures are: 36.9 % (net) and 39 % (brutto), i**.e. the upper range figure indicated in the table is erroneous!**

The lower range figure is too low, it needs also to be checked.

– "After year 2010, data": The range value of 48.1 % is from references 362, 363, 364, 365 which from the Delimara plant, i.e**. one plant consisting of 8 engines and 1 steam turbine,** <u>thus, this is one plant and not four as suggested</u>. There is one common steam turbine in function to reach this efficiency.

- The Maltese plant is a combined cycle plant and not a single cycle plant and shall thus be handled separately from single cycles ("open cycle") as in the case for gas turbines. In our understanding, a separate "combined cycle" table needs to be included for the Maltese plant and it should be deleted from the "single cycle" table ES 5.a. In the header of present table ES 5.a "single cycle" should then to be added for clarity.

- The "**combined cycle" Maltese diesel engine plant** has in earlier submitted information to BATIS (year September 2012 tests) reported total net efficiencies of 46.9 – 47.3 %, which are much lower than the data reported (48.1 % net efficiency) which was obtained in November 2014 from the plant. This should be taken into account as a range: 46.9 – 48.1. % in the new combined diesel cycle plant table.

Conclusion: The table ES.5.a is containing incorrect information and is misleading. It requires a major revision.

2.2. Table ES.5.b - Power plants - Reciprocating Engines – Gross Efficiency Ranges

We would like to raise the following issues:

- We checked from BATIS and noted that the upper value seems to be from reference unit 428-7 (engine commissioned year 1997) "4. Energy efficiency Sheet", but in "3.Operating information sheet" of the same unit is given following data:

    - "See calculation above: **Gross** electrical efficiency = 38.48 % << 51.8 % **(gross**) !

I.e. given efficiency figure in the questionnaire is erroneous (no tolerance either given in the questionnaire). Reference unit 428-6 (engine commissioned year 1997) from the same plant is of same engine type/size, for this unit in sheet "4. Energy efficiency Sheet" is reported electrical efficiencies: 39.6 % (brutto). For reference engine unit 428-8 (engine commissioned year 1997) of same engine type/size in the same plant the corresponding reported figure is: 39 % (brutto).

I.e. used upper range figure indicated in the table is erroneous !

- "After year 2010": The range value of 49.4 % is from references 362, 363, 364, 365 which is the Delimara plant, **i.e. one plant** consisting of 8 engines + 1 steam turbine. Thus, this is one plant and not four as suggested. There is one common steam turbine in function to reach this efficiency.

    - The Maltese plant is a combined cycle plant and not a single cycle plant and shall thus be handled separately from single cycles ("open cycle") as in the case for gas turbines. In our understanding, a separate "combined cycle" table needs to be included for the Maltese plant and it needs to be deleted from the "single cycle" table ES 5.a. In the header of present table ES 5.a "single cycle" needs to be added for clarity.

    - The "combined cycle" Maltese plant has in earlier submitted information to BATIS (year September 2012 tests) reported total gross efficiencies of 48.3 – 48.6 %, which are much lower than the data reported (49.4 % gross efficiency) which was obtained in November 2014 from the plant. This should be taken into account as a range: 48.3 – 49.4. % in the new combined diesel cycle plant table.

Conclusion: Table ES.5.b is containing incorrect information and is misleading. It requires a major revision.

2.3. Table ES.8.b - CHP plants - Gaseous fuels fuelled plants other than boilers - Total Efficiency Ranges

Concerning the item "Up to year 2010": The range value of 43.18 % is the reported gross (**not** mentioned in the table header !) electrical efficiency of the gas engine plant (reference 186). On 16. September 2014 Hungary updated this info to **gross** 43.48 %. The total efficiency is higher and Hungary informed in September 2014 to BATIS the total gross efficiency (electricity + heat (hot water)) to 84.76 %

This plant has a low own electrical consumption (when studying the net electrical efficiency these special features (**"Special topics of plant"***,* not applicable in all plant cases) should be noted) due to following special features:

- It generates the energy **at same voltage as the receiving grid**. Typically, transmission lines operate at a higher voltage (to minimise transmission losses) – meaning that the energy generated at the plant will typically have to be stepped up over a transformer. The corresponding loss over **the transformer is typically in the region of 0,5% of the gross output.**

- This installation is **located in a residential area, having very strict noise requirements**. To fulfil these, the plant cooling **radiators are of special design** – featuring big cooling areas with very low airflow rates. This means that the **power consumption of the radiators is considerably smaller than for a typical plant** = low installed power. Furthermore, the radiators are operated with **frequency converters** – thus making the actual energy consumption more efficient than conventional design with the control on the water side.

- A part of the excess **heat generated in this plant is utilised for producing hot water**, the actual **heat load to be cooled off by auxiliary cooling system is considerably less (in the region of 50% compared to norma**l) This is only partly consumed by the energy consumed by the district heating water pump

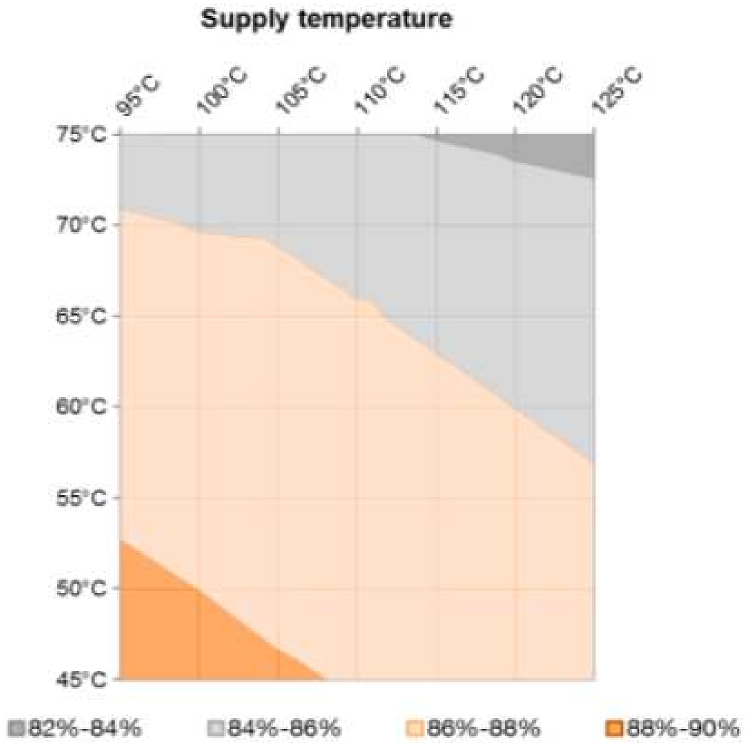
Note that the data is based on **only one special designed plant**, thus the following additional text, (as also submitted earlier in an e-mail communication to the Task Force as of 25th of September) should be added below the table to allow for a better insight into the CHP case:

"*Combined cooling, heating and power*

Combined heat and power (CHP) plants are designed to meet the customer's specific needs, be it steam generation, district heating, hot or chilled water, or a combination of the above. Total plant efficiencies up to about 90% are possible (dependent on e.g. inlet water temperature and exergy of the produced energy, see below diagram) in e.g. hot water production and lower in applications requiring a higher exergy (such as steam) of the produced energy. The heat recovery systems used in stationary (reciprocating) engine CHP plants are often of the post engine "hang-on" type, and thus don't directly influence engine performance or operation. The engine will thus yield the same high electrical efficiency and output, regardless of the rate of heat production.

(continued on next page)

Picture 1:



Total attainable efficiency for a Wärtsilä CHP system depending on hot water supply and return temperatures

(Source: http://www.wartsila.com/file/Wartsila/en/1278540642271a1267106724867-Wartsila_Power_Plants_Solutions_2014_brochure.pdf at page 58).

In reference 186 the total CHP brutto efficiency is reported to be about 84.7 % (inlet district hot water temperatures: inlet/outlet 69/90 degree C. This plant is in fact heating up the inlet feed water to a nearby district heating boiler plant and thus a special case). In a case with a higher inlet water temperature e.g. 100 degree C and outlet temperature of 125 degree C the total efficiency should drop to about 64 % (gross). Fouling of internal surfaces of heat exchangers, boilers, etc. play also a big role, in order to achieve high efficiencies internal heat exchange surfaces are to be cleaned at certain intervals, thus the achieved total plant efficiency will vary between the cleaning intervals. In Northern Europe district heating plants have lower inlet/outlet district heating water temperatures than in countries in Southern Europe, i.e. the total achievable total efficiency might vary greatly between countries and thus a case by case approach is required."

Conclusion: The total efficiency in a CHP plant is very plant specific and dependent on:

- the surrounding process energy exergy quality need (steam instead of hot water then total efficiency drops);
- the inlet (return) feed temperatures of water to engine plant heat recovery circuits (higher inlet temperature then lower total efficiency);
- the total energy absorbing capacity of the consumer plant (can all or only a portion of the available heat be utilized or not at all);

2.4. Table ES.9.b - Mechanical Drive Plants Efficiency Ranges

Concerning the category “Up to year 2010” and the reported range value of 37.96 %: Regarding the mechanical drive reference (no 166) it can be observed that it is quite old (1985) and only some few parameters values from the plant (for instance no information on parasitic loads), no tolerance information on fuel consumption (operator informed in the “double-check” phase that he does not know if 0 or 5 % tolerance on the fuel consumption figure was used for the calculated mechanical efficiency value !), etc. have been obtained. Thus in our opinion it should be logical to disregard this reference and, if this kind of application needs to be considered at all, only write a short text (submitted earlier in our e-mail communication as of 25th of September) such as:

“Reciprocating engines are also sometimes used in mechanical drive applications.
The compressor or other device can either be directly connected to the shaft of the engine (in many cases a gearbox is needed between) or the stationary engines in a nearby stationary power plant are feeding electricity to the motor of the drive. Thus the overall efficiency of the application will depend on the overall configuration and therefore an overall typical efficiency figure span cannot be given.”

2.5. Graph 4.4: Reciprocating engines producing only power

The gross electrical efficiency is not stated. The highest efficiency point in the graph is from the combined cycle Maltese Delimara plant (362, 363, 364. 365; note references 362 – 365 consist of 2 engines each. All reciprocating engine units produce steam for a **common** steam turbine). This information should be clearly given by a footnote, preferable in a separate table with an additional text, see below *, (sent in e-mail dated 25.09-14 to the Task Force)- otherwise misleading information, other dots in the graph are for single cycle engine units/plants ! Preferable, as the case with the combined cycle and open cycle gas turbines reciprocating single and combined cycle engine plants to be separated into own graphs/tables.

(*) Proposal for additional text:

“*Steam turbine* :

- *There exist only a few liquid/gas fired engine plants equipped with a steam turbine for additional electricity production. There is often one common steam turbine in the stationary multi-engine power plant. The investment cost of low/medium pressure (typically 11 - 20 bar (g)) slightly superheated steam system is relative high per kWe capacity.*
- *The steam turbine output (and efficiency) is very dependent on the condenser inlet water temperature and these plants are thus in general raw water cooled or by a cooling tower (i.e. a relative high raw water need).*
- *Air cooled condensers impacts are: a lower efficiency/less electricity yield, higher investment cost, bigger parasitic load and footprint compared to cooling towers but tendency is to use them more and more due water scarcity in many areas.*
- *Rough “rule of thumb”:*
    - *Between ambient air 25-35°C and cooling water inlet 25-35°C temperatures (in case of cooling towers), a steam turbine typically increase in plant gross electrical efficiency is:*
    - *- 3,5 … 4,0 % pts for a lean burn gas SG (Spark ignited)-engine type plant, i.e. if SG-type gas engine (brutto) efficiency is 43 .. 46.2 % at alternator terminals, the total plant gross electrical efficiency should typically become 46.5 .. 50.2 %*

  - *-3,0-3,5 % pts range for a HFO diesel engine plant, i.e. if diesel engine (brutto) efficiency is 42.5 .. 44.8 % at alternator terminals, the total plant gross electrical efficiency should typically become 45.5 .. 48.3 %*
  - ***Above is based on assumptions of no engine derating (engine type dependent) at above temperature intervals.***
- *Higher ambient air temperatures might have a big impact on the output/efficiency of the steam turbine, due to:*
  - *Flue gas temperature change out of the engines*
  - *Condenser cooling water temperature increase, i.e. a higher condenser cooling water temperature will decrease the output yield from the steam turbine but a higher flue gas temperature (dependent on engine type) might compensate this impact.*
- *Thus above efficiency figures are only of general/typical nature, for a specific project the steam turbine impact is to be checked case by case.*"

The efficiency of an engine is very dependent on its size, i.e. larger engine units have higher efficiencies than smaller ones. Two stroke diesel engines (Reference 176 is from year 2004 is a 2 stroke engine with a 44.8 % gross electrical efficiency; Reference 181 commissioning year 1988 ditto a 2-stroke engine with a 47 % gross electrical efficiency; reference 179 is a newer engine (compared to mentioned 2-stroke reference examples) of 4-stroke type from year 2010 with a **LOWER** brutto electrical efficiency of 42.5 %) with higher NOx emission have in general a higher efficiency than 4-stroke engines.

However, the graph appears to tell a different "efficiency development" story, so we believe it should be deleted as it is misleading.

Conclusion: The graph needs to be corrected: different reciprocating engine types 2- and 4-stroke need to be in different graphs or clearly separately marked. A combined cycle process shall not be in same graph with single cycle plants. We question the gross electricity efficiency shown. Present graph 4.4 gives a misleading / incorrect impression and should be deleted.

2.6. Table 6.2.b: Power Plants – Net efficiency - Recorded Ranges:

- Column "50 ,, 100 MWth" contains the Delimara plant equipped with one steam turbine and 8*18V46 big diesel engines of a reported net efficiency of 48.1 % (note also above text in context with table ES 5.a and the efficiencies earlier reported). As for the gas turbine case the diesel combined cycle needs to be clearly separately stated otherwise information is misleading when presented in same table containing almost merely single cycle reciprocating plant data..

- Column 100 < … < 300 contains the reference 176 reported net efficiency. Here it should be added that this is a big 2-stroke engine type otherwise important information is missing and the information given is misleading.

- Column 0 < … < 50: We question the values. The lower value appear to be too low and higher end value 48.5 % too high (the erroneous figure reported seem to be taken from reference 428-7, see also above comments for "Table ES.5.a").

Conclusion: The table needs to be corrected, now misleading, combined cycle clearly to be separated from single cycle plants, 2- and 4-stroke engines to be clearly separated from each other, erroneous data to be taken out of table.

2.7. Table 6.3.b Power Plants - Gross Efficiency - Recorded Ranges:

In general about same general comments as for above 6.2.b. Note also above text in context with table ES 5.b about efficiencies reported especially for the different power ranges: Maltese plant, reference 428-7 (with erroneous reported efficiency figure) and 2-stroke reference 176.

2.8. Table 6.4.b: CHP plants - Total Efficiency - Recorded ranges:

The value of 43.18 % is the reported **gross** (**not** mentioned in header of table !) **electrical efficiency** of the gas engine plant (reference 186, note Hungary updated the questionnaire 16. September 2014 and figure shall be gross 43.48 %). For other information such as the total efficiency is higher, see also our comments on table ES.8.b above: additional text on CHP, etc.

2.9. Table 6.5.b Mechanical Drive - Efficiency - Recorded ranges:

Regarding the mechanical drive reference (no 166) it can be observed that it appears to be quite old (1985) and only some few parameters values from the plant (for instance no information on parasitic loads) have been obtained. Thus in our opinion this reference should be deleted and a short text according to above ES 9.b. be added.

2.10. Table 7.2.a

We would like to seek clarification on these 10 engines and on their references

2.11. Table 7.2.b Power Plants - Net efficiency- Recorded Ranges with Standard:

– Column 50 ,, 100 MWth is the combined cycle Delimara case (with one common steam turbine). It should be clearly marked that this is a combined cycle and not a single cycle plant, see also our comments above on table ES 5.a regarding efficiencies, etc. reported especially for this plant.

– Column 0 .. 50 MWth: The upper value of 44.5 % is for a 2-stroke engine (reference 181), hence should be marked as such.

2.12. Table 7.3.a

We would like to seek clarification on these 10 engines and on their references.

2.13. Table 7.3.b: Power Plants - Gross Efficiency - Recorded ranges with Standard:

Similar comments as above on table 7.2.b

3. Conclusion

In above text we have highlighted important needed updates/corrections of the "*Report of the Task-Force Energy Efficiency – Large Combustion plants BREF TWG - Activities coordinated by EPPSA and EURELECTRIC 11 December 2014"* in order to get a correct picture of the energy efficiency of the reciprocating engine plant.

The LCP BREF D1 in regard of the reciprocating gas engines did not include the high pressure gas diesel ("GD") technology, thus efficiency of the "GD" technology was not included in the Task-Force report and Euromot position paper /1/. "GD" technology is a different technique than the spark ignited ("SG") or low pressure gas dual fuel ("DF") engine technology and need does to be handled separately. A typical gross efficiency of a "GD" engine (**at MCR, ISO 3046-I conditions**) in gas mode can for instance be found from source /2/, see page 20: electrical gross (brutto) efficiency at engine alternator terminals (0 % tolerance): 42.3 .. 43 % (units >= 15 MWth) dependent on engine type and size.

We support the Task Force remark that the metric for setting BAT conclusions for energy efficiency in LCP BREF should be based on a single rated efficiency at full load (MCR = Maximum Continuous Rating) value assessed at commissioning or major upgrades, not on calculation of annual averages. In our opinion the **electrical gross efficiency at engine alternator output** describes best the efficiency of the specific prime mover, see /1/ for more details.

4. References

/1/ Euromot Position: "BAT Associated Energy Efficiency Levels"; as of 5 September 2014; submitted to EIPPCB BATIS but also available under:
http://www.euromot.org/download/5453c772de27a3a6fea5ce05

/2/ /
http://www.google.fi/url?sa=t&rct=j&q=&esrc=s&frm=1&source=web&cd=1&ved=0CCgQFjAA&url=http%3A%2F%2Fwww.wartsila.com%2Ffile%2FRussia%2F1278526776145a1267106724867-Power-Plants-Product-Catalogue-2012-2nd-edition.pdf&ei=AdL6U4H8Foev0QXIiIC4BQ&usg=AFQjCNEWm2KLdVrT7O5G8IGmYi51ItO6wQ&bvm=bv.73612305,d.ZWU

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