TESTS OF FUELOIL ADDITIVE PERFORMED IN THE POWER PLANT OF "Gallega de Cogen"

Technical document RB-6

rb bertomeu , S.L.
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Pol. Ind. Fondo de Llitera, Par. 82-83 - E-22520 Fraga, Huesca (Spain)
Tel. +34 974 47 48 04 / +34 630 43 08 43
www.rbbertomeu.es - rbbertomeu@rbbertomeu.es

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We cannot include this annex due to its extraordinary length

1 - INTRODUCTION

During the first trimester of 1997, additive tests of the fuel oil consumed in power plants were carried out between the company **Gallega de Cogen**, owner of the plants and the manufacturer of the fuel additives, **rb bertomeu S.L..**

The tests were made in order to verify the efficiency of **"rb bertomeu"** fueloil additives, amply demonstrated already in many other cogeneration plants , and to try to quantify the economic benefit that would **Gallega de Cogen** obtain from the systematic use of the aforementioned additive .

Gallega de Cogen decided that the test would be carried out in the power plant of San Cibrao, where 2 Engines Wartsila 18V32 are installed with a total production capacity of 12.6 Mwe , and that the cited tests should begin in the month of August 1997 , immediately after the overhaul of the two Engines that had to be done during the month of July. The approximate duration of the tests was established at 6 months, at the end of which, **rb bertomeu, SL** would complete the corresponding report .

These reviews were made on the following dates :

Engine nº 2 : 14-July-97 , with 21,083 total working hours
Engine nº 1 : 28-July-97 , with 21,429 total working hours

rb bertomeu S.L. , were present at these reviews , surveying the valves of the Engines and completing the appropriate weighing of residues and photographic records .

rb bertomeu S.L. , also supplied and installed , along with Gallega de Cogen, a pump for the dosing of the additive in the feed line to the fueloil tanks .

rb bertomeu S.L. , provided the additive **"rb bertomeu" beco F1/ASF**, as well as the regulatory product safety documentation.

The present report , elaborated by **rb bertomeu S.L.** , describes the execution of the tests and presents the results obtained in the period of August 1st to December 31st 1997 (5 months) regarding **Gallega de Cogen.**

Pol. Ind. Fondo de Llitera, Par. 82-83 - E-22520 Fraga, Huesca (Spain)
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2 - TEST PLANNING

The test was planned by **rb bertomeu S.L.** together with the technical personnel of **Gallega de Cogen**, so that the greatest possible amount of data could be obtained of the period of test and from the same corresponding months of the 2 previous years so that they could be used to compare effects . Thus, it was decided to take following data:

Data	Responsibility
1 - Monthly production of energy by Engine	Plant
2 - Monthly consumption of fuel oil	Plant
3 - Monthly analysis of the fuel oil received	Plant
4 - Monthly analysis of the fuel oil before and after purification	Plant
5 - Monthly consumption of oil by Engine	Plant
6 - Engine down-time and reasons	Plant
7 - Purifier cleaning hours and cost	Plant
8 - Control of fuel oil sludge generated in tank and purifier	Plant
9 - Control of oil sludge generated in oil purifier	Plant
10 - Cost of handling of all the generated sludge	Plant
11 - Control of the evolution of engine temp. at constant load	Plant
12 - Monthly analysis of the exhaust gases of the Engines	rb bertomeu
13 - Weighing of residues on exhaust valves, in the overhauls of the Engines, at the beginning and end of the test	rb bertomeu
14 - Photographing of the exhaust valves, in the overhauls of Engines, at the beginning and end of the test	rb bertomeu
15 - Making of graphs and tables from obtained data	rb bertomeu
16 - Control of the consumption of the additive	rb / Plant
17 - Compiling of the final report	rb bertomeu

All the points except 7, 8, 9 and 10 have been checked in the period of the test.

Of the previous years, 1995 and 1996, it has only been possible to obtain the corresponding data to points 1 , 2 , 5 and 6 . Point 3 for the year 1996 has been partially determined.

3 - ANALYSIS OF THE FUELS USED

Until the beginning of the test the plant was using fuel oil No. 1 BIA, of which we have been able to gather the analysis accomplished during the first semester of 1997. It has not been possible to have data related to 1995 and 1996. From the beginning of the test the fuel was changed to fuel oil No. 1, a fuel with more impurities than fuel oil No. 1 BIA as can be observed in the comparative analysis data, as a result, therefore, one can expect more problems in its management and combustion.

The mean analysis obtained, in the most relevant data, is the following:

	(A) Fuel oil No. 1 BIA	(B) Fuel oil No. 1	(B)-(A) Dif. %
P.C.S. (Kcal/Kg)	10.312,00	10.164,00	-1,44
P.C.I.(Kcal/Kg)	9.773,00	9.631,00	-1,45
Vanadium (ppm)	27,00	45,00	+66,60
Sodium (ppm)	8,00	9,00	+12,50
Nickel (ppm)	19,00	20,00	+5,30
Sulphur (%)	0,92	1,93	+109,80
Carbon Conradson (%)	8,90	10,20	+14,60
Asphaltenes (%)	1,90	4,70	+147,40
Water by distillation (%)	< 0,05	0,12	+150,00

With respect to the values of the calorific power of fuel oil No. 1 BIA, one can say that they are low in relationship to the values that we have other plants for the years 1995, 1996 and 1997. These data locate the P.C.I. (inferior calorific power) in the range 9,850-9,950 Kcal/ Kg , that is to say , 1.3 % greater in mean . Nevertheless, it is considered the value of the table for 1996 for the purpose of calculation of that year, not considering any value for 1995 for lack of data and the discrepancy found.

In regard to the greater quantity of impurities contained in the fuel oil used in the test with respect to the fuel oil used previously , it would be possible to say that the increase in theoretical problems , would be centred in the following points :

a) Greater content of Vanadium, Sodium and Nickel : more corrosion in the combustion chamber and exhaust gas circuit of the engine, particularly inlet valves, piston crowns, segments and exhaust valves.

b) Greater content of Sulphur : more corrosion in the combustion chamber and exhaust gas circuit of the Engine , particularly inlet valves , piston crowns, segments , exhaust valves and in the cold gases zone of the exhaust , from boilers on the verge of final emission. Also be expected greater sulphate encrustations, as much in the hot zone as cold , especially in exhaust valves , collectors of exhaust gases , nozzle rings , blades of turbo-compressors and boiler pipes .

c) Greater content of Carbon and Asphaltenes : greater sludge formation in the fuel tanks ; greater sludge formation in the fuel purifiers ; more difficulty cleaning the fuel purifiers ; increase of possibilities of seizure of the fuel pumps ; greater dirt accumulation in the fuel circuit; increase of carbonous residues in exhaust valves , collectors of exhaust gases , nozzle rings and blades of turbo-compressors .

d) Greater Water content: greater facility for sludge formation in tanks; more possibilities of seizure of injectors in the event of failure of the fuel purifier.

With all these possibilities of the worsening of the operation parameters due to change of type of fuel oil, the test of the additive was carried out.

4 - OBTAINED COMPARATIVE RESULTS

4 - 1 ENERGY CONSUMPTION

	Period Aug - Dec/95	Period Aug - Dec/96	Period Aug - Dec/97
Type fuel oil	No. 1 BIA	No. 1 BIA	No. 1
P.C.I. (Kcal/ Kg)	Indeterminate	9,773.00	9,631.00
MT Fuel oil consumed	9,224.227	9,462.458	9,631.00
Kwh E produced	42,402,731.000	2,452,930.000	43,258,820.000
Consumption esp. energy :			
- in Gr. Fuel/Kwh	217.54	22.89	222.64
- in Kcal/Kwh	Indeterminate	2,178.30	2,144.24

(Calculated energy Consumption in Kcal/ Kwh : Gr. Fuel/Kwh x P.C.I. / 1000)

DIFFERENCES OF CONSUMPTION DETECTED:

Period 1997 with respect to 1996 : - 34.06 Kcal/ Kwh , that is to say , **- 1.56 %**

Period 1997 with respect to 1995 : indeterminate (if a P.C.I. of 9900 is taken that which is the mean value detected in other plants , the difference would be - 9.4 Kcal/Kwh , equivalent to **- 0. 44 %**).

In cost , the difference between the periods studied for 1996 and 1997 , would be :

* 1996, Fuel oil No. 1 BIA : 222.89 x 0.144240 €/Kg = 32.1497 €/produced MWhe
* 1997, Fuel oil No. 1 : 222.64 x 0.132220 €/Kg = 29.4375 €/produced MWhe

*** A saving of 2.7122 €/produced MWhe is obtained, equivalent to an 8.44%, due to a lower energy consumption and having the possibility of using a cheaper fuel maintaining the same operability of the engines.**

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4 - 2 SERVICE FACTOR

	Period Aug - Dec/95	Period Aug - Dec/96	Period Aug-Dec/97
ENGINE Nº 1 :			
total downtime	126	128	123
beyond-control downtime	87	59	81
attributable downtime	39	69	42
Total Service factor	95.57 %	96.51 %	96.65 %
Service factor attrib.	**98.94 %**	**98.12 %**	**98.86 %**
ENGINE Nº 2 :			
total downtime	116	108	173
beyond-control downtime	66	58	118
attributable downtime	50	50	55
Total Service factor	96.84 %	97.06 %	95.29 %
Service factor attrib.	**98.64 %**	**98.64 %**	**98.50 %**
Average ENGINES Nº 1 and 2 :			
total downtime	242	236	296
beyond-control downtime	153	117	199
attributable downtime	89	119	97
Total Service factor	96.70 %	96.79 %	95.97 %
Service factor attrib.	**98.79 %**	**98.38 %**	**98.68 %**

* It can be observed that the service factor obtained during the period of the test, considering planned downtime, that is to say, discounting the downtime for foreign motives (see list on following page), is identical, in both engines, to that which was obtained in the same period of previous years , in spite of the fuel change .

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So that the results would be homogeneous and comparative, unplanned down-time has been considered as consequence of:

- Engine overhaul
- Excess of production or valley hours
- Relevant Electric Company cuts
- Tree repair levies in 1997
- Storms in 1997

Consequently, the attributable downtime, used for the calculation of the service factor, is the difference between the total downtime and that which is considered as foreign .

In all the cases, the Service Factor has been calculated according to the following formula:

$$\text{Service Factor (\%)} = \frac{(\text{Total hours} - \text{downtime}) \times 100}{\text{Total hours}}$$

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4 - 3 CORROSION OF EXHAUST VALVES

The compared data are those currently available, which correspond to the data registered for engine No. 2 in the overhauls effected before beginning the test and upon ending it.

Initial review : effected 14-7-97 , at 21,083 total working hours
Final review : effected 19-1-98 , at 25,324 total working hours
TBO of the test : 4,241 hours

The comparison between the two reviews is accomplished by analyzing, for each exhaust valve, the following parameters:

- Weight of residues adhered to the stems
- Corrosion level in the spindles, which includes:
  - Corrosion pitting
  - Beginning of corrosion
  - Corrosion
- Level of leakage in the spindles, which includes:
  - Beginning of leakage
  - Blown completely
- Corrosion level in the baskets, which includes:
  - Corrosion pitting
  - Beginning of corrosion
  - Corrosion
- Level of leakage in the baskets, which includes:
  - Beginning of leakage
  - Blown completely

A) WEIGHT OF ADHERED RESIDUES
(Attached sheets of results valve by valve)

* In the Initial review (1997) : 4.57 gr per valve , of average
* In the Final review (1998) : 2.85 gr per valve , of average

*** Result: decrease of residues of 37.6% in spite of using a fuel oil of lower quality.**

B) CONDITION OF EXHAUST VALVES

C = Corrosion
S = Blown
HU = Valve stem
CAN = Valve basket

Valve	Initial Review	Final Review
A 1 A	C in HU and CAN	C in HU
A 1 B	C in HU and CAN	without corrosion
A 2 A	C in HU and CAN	without corrosion
A 2 B	C in HU	without corrosion
A 3 A	C in HU and CAN	without corrosion
A 3 B	C in HU and CAN	without corrosion
A 4 A	C in HU	without corrosion
A 4 B	C in CAN , S in HU	without corrosion
A 5 A	C in CAN , S in HU	without corrosion
A 5 B	S in HU	C in HU
A 6 A	C in HU	C in HU
A 6 B	C in HU	S in HU
A 7 A	C in HU	without corrosion
A 7 B	C in HU and CAN	S in HU
A 8 A	C in HU	C in HU
A 8 B	C in HU and CAN	S in HU
A 9 A	without corrosion	without corrosion
A 9 B	C in HU	without corrosion
B 1 A	C in HU and CAN	without corrosion
B 1 B	C in HU and CAN	without corrosion
B 2 A	C in HU	C in HU
B 2 B	C in HU	without corrosion
B 3 A	C in HU and CAN	without corrosion
B 3 B	C in HU and CAN	without corrosion
B 4 A	S in HU	without corrosion
B 4 B	C in HU	S in HU
B 5 A	C in HU	without corrosion
B 5 B	C in HU	C in HU
B 6 A	C in HU	without corrosion
B 6 B	C in HU	C in HU
B 7 A	C in HU	without corrosion
B 7 B	C in HU and CAN	without corrosion
B 8 A	C in HU and CAN	S in HU
B 8 B	C in HU	C in HU
B 9 A	C in HU	without corrosion
B 9 B	C in HU	without corrosion

	(A) Initial Review	(B) FinalReview	(B) - (A) Difference %
No. Stems with corrosion	31	8	- 74
No. Basket with corrosion	15	0	- 100
No. Stems with leakage	4	5	+ 25
No. Baskets blown	0	0	0
Total No. of anomalies in Stems	**35**	**13**	**- 63**
Total No. of anomalies in Baskets	**15**	**0**	**- 100**

*** Result : Decrease of the deterioration of Engine exhaust valves (Spindles and Baskets) at 63% and 100%, respectively, in spite of the fuel change, which contains almost the double the potentially corrosive impurities than the fuel previously used .**

Note :

In the final review compactions in the seats of the valves have been detected which can be put down to the increase in residual solids (sulfates) in the combustion process because of the higher quantity of Sulphur that the fuel contains.

4 - 4 OTHER NON COMPARATIVE RESULTS

4-4-1 Operation of Fuel Purifier

Even though we have not been able to obtain quantifiable operation data previous to or during the test, the opinion that has been communicated to us by the personnel of the plant is that, with the use of the additive:

- Greater decantation of water from the fuel
- Lower quantity of sludge generated in the fuel purifier
- Fuel purifier cleaner and easier to clean
- The sludge removed is more fluid and better handling

4-4-2 Evolution of the working temperature of the Engines at constant load

From the beginning of the test , the working temperatures of both Engines, taken at constant load and almost constant ambient temperature , have practically not varied , which means that blocking of the exhaust gases circuit is not produced, mainly in the collectors, in spite of the increase in impurities in the fuel . There is no comparative data for previous periods .

4-4-3 Engine oil consumption (Gr. Oil / Kwhe)

	Period Aug - Dec/95	Period Aug - Dec/96	Period Aug - Dec/97
Engine No. 1+2	0.59	0.52	0.82

The increase in oil consumption has not been taken into consideration because according to information from the company, it is due to a change in the type of oil in the engine, daily renovation of 50 l. unnecessary in the other engine, and a loss of oil in the purifier.

5 - ECONOMIC EVALUATION OF THE RESULTS

The economic valuation is made only from the point of view of fuel and additive consumption in 1996 and 1997, for the following reasons :

a) Calorific Power data of fuel No. 1 BIA consumed in the year 1995 is not available, as has been commented previously.

b) The service factor obtained in the period of the test is practically the same as was obtained in the same period from the two previous years .

c) Comparative data of other parameters could have had an influence on the cost, such as the generation and elimination of sludge, cleaning costs of fuel purifier, valve costs and other parts of the engines, etc.

Considering only the energy saving in Kcal. of the 1.56 % detected (see 4.1) , that is to say , without taking into account the saving due to fuel change , the economic balance of the additive , for the same current production of 100 M Kwhe per year would be :

- Mean Calorific Power of the fuel = 9,631 Kcal /Kg or 9,631,000 Kcal / T

- Annual consumption of fuel with additive :
  100,000,000 x 2,144.24 / 9,631,000 T = 22,263.94 T.

- Annual consumption of fuel without additive :
  100,000,000 x 2,178.30 / 9,631,000 T = 22.617.59 T.

- Saving of fuel with additive :
  22,617.59 - 22,263.94 **= 353.65 T / year (1.56 %)**

6 - FINAL CONCLUSIONS IN 1998

Considering the difficulties that always exist at the time of establishing conclusions after accomplishing tests, above all in this case in which does not have a series of comparative data (previously mentioned) and in which the test has been made coinciding with a fuel change (which happens to be a type that causes much more problems than the type used previously), we think that in the light of the results, the main final conclusions are the following :

A) The use of the additive " rb bertomeu" beco F1/ ASF , has made possible the change of fuel No. 1 BIA to fuel No. 1 without causing operative difficulties in the Engines or reducing the service factor .

B) The saving in fuel cost due to lower energy consumption and to a lower fuel price has been 8.43 %.

C) Though conservation of exhaust valves has been improved, the results obtained are not homogeneous because:
- The quality of the fuel oil has been much worse during the test
- Some of the valve stems of engine No. 2 were installed for the test in Nymonic instead of Estelite, as has been used before.

D) Other savings derived from what is detailed in paragraph 4-4, have been produced, although we are not in a position to quantify them (as of January 1998).
In the next section, you can read the updated results.

Pol. Ind. Fondo de Llitera, Par. 82-83 - E-22520 Fraga, Huesca (Spain)
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7 - JANUARY 2017 UPDATE

In January 2017, we acknowledge achieving the following savings, widely demonstrated and endorsed by our customers:

1-1	Increase in normal TBO for maintenance of exhaust valves	+ 50 % minimum
1-2	Increase in the normal operational life of valves due to corrosion	+ 100 % minimum
1-3	Reduction of valve blowouts in normal	80 % average
1-4	Increase in normal TBO for cleaning turbos	+ 50 % minimum
1-5	Increase in the normal operational life of turbos due to corrosion	+ 100 % minimum
1-6	Reduction of fuel consumption per kWhe , due to better combustion	1,56 % average
1-7-1	Reduction of fuel consumption per kWhe , due to lower erosion of injection equipment	0,9 % average
1-7-2	Reduction of fuel consumption per kWhe , due to fuel sludge reduction	0,45 % average
1-7-3	Reduction of fuel consumption per kWhe , due to lesser incrustations in the turbo compressors	0,19 % average
1-8-1	Reduction of fuel oil sludge to be treated or handled	70 % average
1-8-2	Reduction of fuel oil sludge Reduction of lubricating oil sludge	54,8 % 26,8 %
1-8-3	Reduction of consumed fuel oil due to lesser sludge production (Kg/T)	5,80 Kg.
1-8-4	Savings due to a lower volume of sludge to be recycled (sludge recycling cost: 110 €/T)	0,638 €/T of consumed fuel oil
1-9	Reduction in downtime for maintenance	30 % minimum
1-10	Increase of the Service Factor as a result of less downtime due to breakdowns and scheduled maintenance.	To be calculated by each engine or plant

After assessing the influence of the above-mentioned points, the achieved **Profit is 2.19 Euros/MWhe produced** (the calculations have been made with an average fuel oil consumption of 210 Kg/MWhe and a fuel oil price of 364 €/T as of January/2017)

PROFIT = SAVINGS – COST OF ADDITIVE “rb bertomeu” beco F1/ASF
MINIMUM PROFIT = 2.19 Euro/MWhe

You can find more information in our Technical document “RB-1 Profitability study in power plants after using additive “rb bertomeu” beco F1/ASF in diesel engines running on heavy fuel oil”

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