OpEx Shared Practice & Applied Practice

**ชื่อโครงการ** : CCR-2 furnaces optimization via excess O2 reducing

**บริษัท** : Thaioil PLC.

**คณะทำงาน**


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วันที่ 1 มกราคม 2561

1. Key Word (Taxonomy)

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|---|---|
| Project Type | Please select the 6 Key word from the attached file below. |
| Business Line | |
| Operational Function | |
| Operational Unit | |
| Equipment Type | |
| Product Group | |

## 2. Project Details

| No. | Title | Details |
|---|---|---|
| 1 | Project Name* | (English*) CCR-2 furnaces optimization via excess O2 reducing (after solving coke formation)<br>(Thai) การปรับปรุงประสิทธิภาพโดยการลดปริมาณออกซิเจนส่วนเกินของเตาเผาเพิ่มอุณหภูมิ CCR-2 ภายหลังการแก้ปัญหาเรื่องโค้กที่เกิดจากการใช้แก๊ส |
| 2 | Objective* | This activity is aimed to eliminate undesired coke formation from RFG firing which had been generated from insufficient combustion air at center of flame stabilizer plates. Moreover, the following benefit is to reduce excess O2 which increases furnace efficiency (reduce fuel consumption). |
| | Project Type<br>*(please select)* | ◉ Operation<br>[โครงการที่เกี่ยวข้องกับ core operation ของบริษัท ซึ่งส่งผลโดยตรงต่อประสิทธิภาพหรือประสิทธิผลของการผลิต]<br>○ Operation-support<br>[โครงงานที่สนับสนุนและส่งผลโดยตรงต่อการดำเนินงานของสายปฏิบัติการ/ธุรกิจหลัก อาทิ โครงการที่เป็นกิจกรรมในสายโซ่อุปทาน (supply chain) ซึ่งได้แก่ Procurement, Inventory, Logistic, Sale & Marketing] |
| 3 | Executive Summary* | Coke formation from RFG firing at burner flame stabilizers at CCR-2 furnaces had been found since October 2016 which was the cause of small fire at radiant wall of F-9720. Root cause of coke formation was insufficient combustion air at the center of flame stabilizers. Drilling holes to allow more combustion air through the plate was first mitigation by Thaioil. After modified flame stabilizers installation, flame stability test was done to confirm stability at absolute minimum test point (0.02 barg). Therefore, the current low-low fuel pressure trip of 0.05 barg is confirmed that has been still valid in accordance with the test. Moreover, for emission point of view, $NO_x$ increasing was key focus because of brighter and bluer color of flame pattern, but after measured the emission, the $NO_x$ concentration has not been significantly increased. With this modification the optimization activity on excess $O_2$ reduction was done, the benefit has been produced by 1.19 Tsrf/D. |

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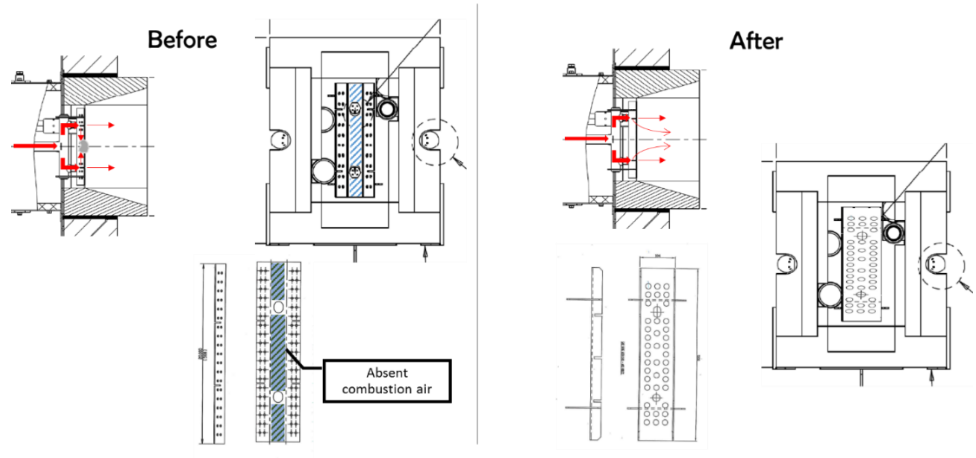
| 3.1 | Detail | The coke formed is located at center of flame stabilizer plate (called “wing plate”). The most possible cause is heavy component in RFG carried over to burners with lower temperature than dew point (66 degC). The lower temperature, around 40 deg at burners, introduces condensation of heavy components (heavier than propane) and eventually becomes liquid droplet. The liquid phase has lower rate of combustion than gaseous phase. After combustion reaction undergoes with gaseous phase, amount of oxygen continuously decreases and the oxidation reaction approaches pyrolysis reaction when coke is forms. Moreover, the center of wing plate seems that the combustion air is absent around the area.<br><br>Thaioil firstly modified wing plates with a lot of hole at the center to allow more combustion air through the insufficient air area. Increasing combustion air flow through burner leads increasing of $NO_x$. The new level of $NO_x$ was calculated and guaranteed that only few ppmv of $NO_x$ will be increased, therefore, it will be 40 ppmv after new wing plates are totally replaced (the existing $NO_x$ level is 37 ppmv).<br><br>To confirm flame stability and guarantee from burner vendor, he visited Thaioil to visual inspect current condition and advise same solution as Thaioil did. The new wing plates had been left in the environment of high heavier than propane content in RFG system for 3 months. Flame pattern and flame color was better than the existing one and there was no coke formation at any area of wing plate.<br><br>Flame stability test was performed at maximum combustion air flow rate and the lowest fuel pressure to check and validate flame pattern. The purposes of test are to ensure flame pattern at turn down condition and to validate current LL fuel pressure trip. The test result strongly confirmed that flame pattern at 0.02 barg of fuel gas pressure was still good and stable.<br><br>In addition, not only flame stability test was done but also emission measurement was performed to evaluate combustion performance. The emission was paid attention to $NO_x$ concentration which should be higher than neither regulation nor guarantee. The emission was measured and recorded at 3 conditions, (1) before wing plate replacement with excess $O_2$ level 2.0-2.5%vol, (2) after wing plate replacement with excess $O_2$ level 2.0-2.5%vol and (3) after wing plate replacement with excess $O_2$ level 1.5-2.0%vol. The result of emission is concluded that $NO_x$ has not been significantly changed, and CO has not been observed for every condition.<br><br>The benefit from reducing excess $O_2$ level from 2.0-2.5%vol to 1.5-2.0%vol is lower fuel consumption. Seeing that furnace efficiency of each furnace has been improved by 0.5% as excess $O_2$ reduced by 0.5%vol. By this improvement, the lower fuel consumption (of 4 furnaces) can be converted to energy saving around 0.56 MW or 1.19 Tsrf/D.<br><br><br><br>Figure 1 showing the conceptual of absent air area<br>comparing between original and new design |

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| 4 | Best Practice Process / Procedures* | 1. Trialed to drill holes at center of flame stabilizers<br>2. Requested burner vendor visiting TOP to visually investigate root cause and find solution.<br>3. New flame stabilizers (solution), having configuration as same as Thaioi's trial, were proposed<br>4. The trial set had been left in the environment of high heavier than propane content in RFG system for 3 months.<br>5. Flame stability test was performed at maximum combustion air flow rate and the lowest fuel pressure to check and validate flame pattern.<br>6. The emission was paid attention to $NO_x$ concentration which should be higher than neither regulation nor guarantee.<br>7. Reduce excess $O_2$ from 2.0-2.5%vol back to 1.5-2.0%vol. |
| 5.1 | Operation Duration* | **start date**: 1 Jan 2017 **end date** : 14 Jan 2018 |
| 5.2 | Lifetime of Project* | 5 years |
| 6 | Application* | Can be applied for other furnace |
| 7 | Project Cost & Investment (Mil.Baht)* | 0.75 MB |
| 8 | Project Cost & Investment per year (Mil.Baht/ Yr)* | 0.15 MB per year |
| 9 | Benefit* | There is no coke formation at furnaces anymore. The solution increases furnace reliability and reduce operator's concern. |
| 10 | Benefit Value (Mil.Baht/ Yr)* | From optimization activity, the cost reduction is come from lower fuel consumption by 1.18 Tsrf/D. (5.13 milBht) |
| 11 | Benefit Value Calculation | See in attachement 2 |
| 12 | Apply From | TOP-0268: Optimize excess O2 at F-7201 |
| 13 | Company | Thaioil refinery PLC |
| 14 | Team member* | รายชื่อสมาชิกที่ร่วมในการจัดทำโครงการนี้<br>1. Santiwong Boonrueng<br>2. Yuttapun Jumphon<br>3. Thongchai Boonkittivasin<br>4. Watchara Tangcharoenkiat |

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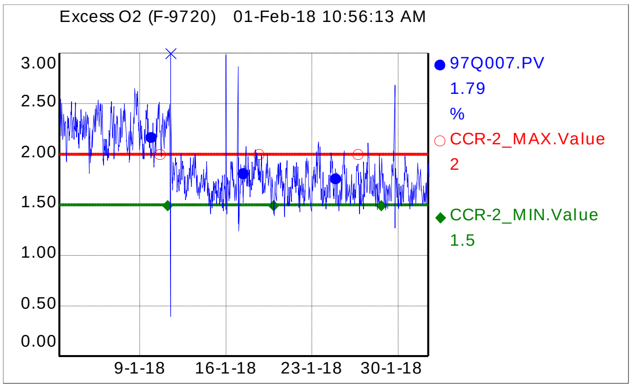
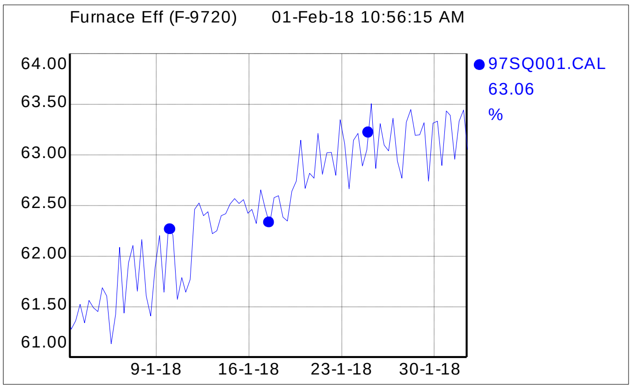
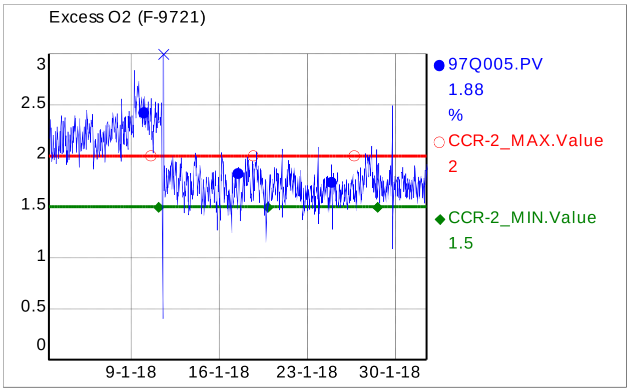
| 15 | Contact Person* | ชื่อตัวแทนของรายชื่อข้างบน 1 ท่านที่เป็นผู้รับผิดชอบและรู้รายละเอียดของโครงการนี้<br>Name : Santiwong Boonrueng<br>Phone: 2393<br>Email: santiwong@thaioilgroup.com |
| 16 | Year Contest | 2018 (System Default) |
| 17 | Project Type* | |
| 18 | Business Line* | Refinery |
| 19 | OEMS Element | - |
| 20 | Operational Function* | Process Egineering |
| 21 | Operational Unit* | Catalytic reforming (CCR) |
| 22 | Equipment Type* | Furnace |
| 23 | Product Group | High RON naphtha |
| 24 | Community of Practice | - |
| 25 | People Tag Account | - |
| 26 | People Tag Name | - |

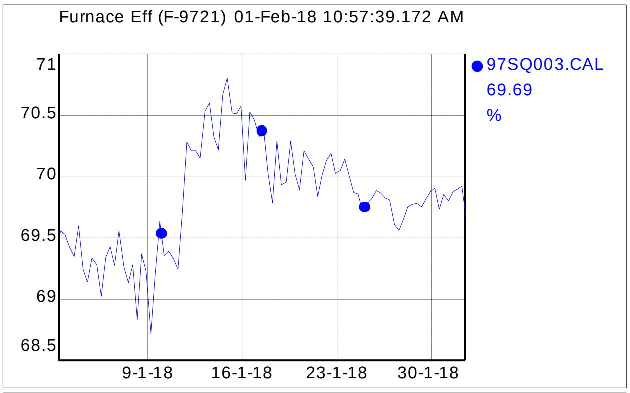
## 5. Support Information

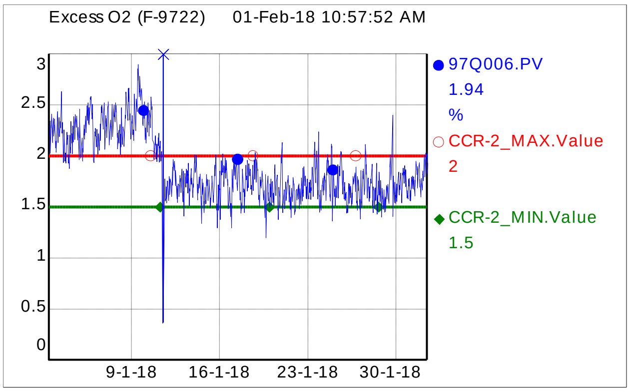
Attachment 1 Excess $O_2$ and furnaces efficiency improvement after implementation

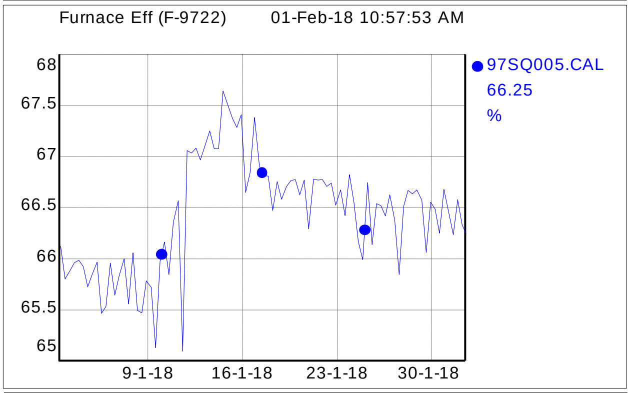


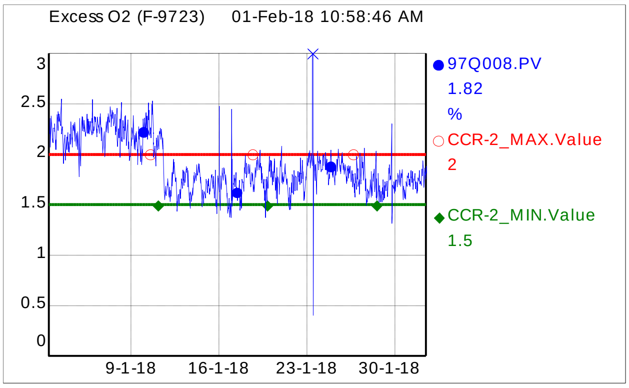



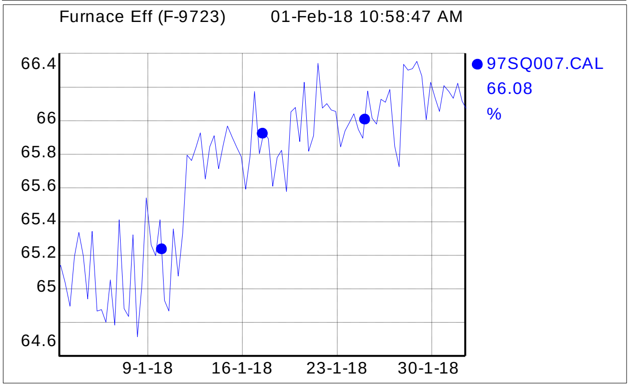



Attachment 2 Benefit calculation from optimization activity

The basis of benefit calculation is overall energy balance at boundary of furnaces (exclude air preheater; E-9735 and waste heat boiler; F-9791). Table 2 states steady state process operating conditions between before and after excess $O_2$ optimization. The example of calculation of benefit evaluation is presented by using F-9720 as model.

**Table 1** Process operating condition comparing between before and after optimization

| Furnaces | UOM | F-9720 | | F-9721 | | F-9722 | | F-9723 | |
|---|---|---|---|---|---|---|---|---|---|
| | | Before | After | Before | After | Before | After | Before | After |
| NAPH feed | T/D | 3,150 | 3,150 | 3,150 | 3,150 | 3,150 | 3,150 | 3,150 | 3,150 |
| RG feed | T/D | 630 | 630 | 630 | 630 | 630 | 630 | 630 | 630 |
| Total feed | T/D | 3,780 | 3,780 | 3,780 | 3,780 | 3,780 | 3,780 | 3,780 | 3,780 |
| HIT | degC | 448 | 448 | 409 | 408 | 456 | 456 | 476 | 476 |
| HOT | degC | 524 | 524 | 527 | 527 | 518 | 518 | 516 | 516 |
| Excess $O_2$ | %vol | 2.36 | 1.79 | 2.63 | 1.79 | 2.44 | 1.71 | 2.16 | 1.65 |
| Firing rate | MW | 27.2 | 26.6 | 29.5 | 29.0 | 11.7 | 11.8 | 7.55 | 7.54 |
| Air flow | T/D | 904 | 856 | 1,060 | 995 | 403 | 398 | 250 | 241 |
| Air temp | degC | 129 | 131 | 129 | 131 | 129 | 131 | 129 | 131 |
| BWT | degC | 893 | 895 | 709 | 708 | 787 | 786 | 816 | 817 |
| RON | - | 102.2 | 102.2 | 102.2 | 102.2 | 102.2 | 102.2 | 102.2 | 102.2 |

**Note:** Before condition had been retrieved for 0.5 day

After condition had been retrieved for 0.5 day

The assumptions of calculation are

- Ambient air temperature: 30 degC
- Specific heat capacity of air: 1.024 kJ/kg$^o$C
- Enthalpy of flue gas[1]: 0.6 x ($Temp^{1.1}$) kJ/kg, where UOM of temp is degC
- Radiant heat loss: 2% of total heat input
- Heat inputs are declared in term of heat release from fuel gas and enthalpy from combustion air
- Heat outputs are declared in term of radiant heat loss, heat left to waste heat boiler and process absorbed duty

[1] Solomon correlation

Calculation step

(1) Calculate enthalpy of air as one of heat input

$$Q\ (MW) = Mass_{air}\left(\frac{kg}{s}\right) \times 1.02\left(\frac{kJ}{kg℃}\right) \times \left(T_{air\ to\ B/N} - 30\right) \quad (1)$$

$$Q_{air,before} = \frac{904}{24 \times 3600} \times 1.024 \times (129 - 30) = 1.06\ MW$$

$$Q_{air,after} = \frac{856}{24 \times 3600} \times 1.024 \times (131 - 30) = 1.00\ MW$$

(2) Calculate enthalpy of flue gas to waste heat boiler (F-9791) as heat output

$$Q(MW) = \left(Mass_{air} + Mass_{fuel}\right)\frac{kg}{s} \times 0.6 \times T_{BWT}^{1.1}(℃) \quad (2)$$

$$Q_{left,before} = \frac{904 + 50.7}{24 \times 3600} \times 0.6 \times 893^{1.1} = 11.7\ MW$$

$$Q_{left,after} = \frac{856 + 49.5}{24 \times 3600} \times 0.6 \times 895^{1.1} = 11.1\ MW$$

(3) Calculate furnace radiant thermal efficiency

$$\eta\ (\%) = 100 - RL - 0.0375 \times \frac{21}{21 - excess\ O_2} \times \left(T_{flue} - T_{amb}\right) \quad (3)$$

$$\eta_{before} = 100 - 2.00 - 0.0375 \times \frac{21.0}{21.0 - 2.36} \times (893 - 30) = 61.7\%$$

$$\eta_{after} = 100 - 2.00 - 0.0375 \times \frac{21.0}{21.0 - 1.79} \times (895 - 30) = 62.3\%$$

(4) Calculate process absorbed duty as heat output

$$Q_{process}(MW) = \eta \times \left(Q_{fuel} + Q_{air}\right) \quad (4)$$

$$Q_{process,before} = 0.617 \times (27.2 + 1.06) = 17.5\ MW$$

$$Q_{process,after} = 0.623 \times (26.6 + 1.00) = 17.2\ MW$$

(5) Calculate fuel consumption when the efficiency is improved (called “fuel compensated”) in order to estimate fuel consumption with the same feed property and HIT/HOT and compare with actual fuel flow rate reading from flow transmitters

$$Q_{fuel,compensated}\ (MW) = \frac{Q_{process}}{efficiency} - Q_{air} \quad (5)$$

$$Q_{fuel,compensated} = \frac{17.5}{0.623} - 1.00 = 27.0\ MW$$

(6) Calculate fuel saving

$$Fuel\ saving\ \left(\frac{Tsrf}{D}\right) = (Q_{actual} - Q_{fuel,compensated}) \times \frac{40{,}500}{24 \times 3600} \quad (6)$$

$$Fuel\ saving = (27.2 - 27.0) \times \frac{40{,}500}{24 \times 3600} = 0.436\frac{Tsrf}{D}$$

The benefit calculation methodology is applied for the other 3 furnaces. The result of energy balance and benefit calculation of CCR-2 furnaces is individually presented in table 3. As mention on very short period of retrieved data between before and after optimization, the feed property and HIT/HOT could be assumed to be constant and changeless. Hence, the compensated fuel consumption (in step 5) might represent fuel consumption after furnace efficiency was improved. In addition, the compensated and actual fuel consumption were not significant different. It would be implied that it was reasonable. The total saving is 1.19 Tsrf/D. If fuel gas price is assumed to be $358 per ton standard fuel, the benefit will be 5.13 MB/year.

**Table 2** Summary of energy balance calculation in accordance with the mentioned methodology and total benefit calculation

| Furnaces | UOM | F-9720 | | F-9721 | | F-9722 | | F-9723 | |
|---|---|---|---|---|---|---|---|---|---|
| | | Before | After | Before | After | Before | After | Before | After |
| Firing rate | MW | 27.2 | 26.6 | 29.5 | 29.1 | 11.7 | 11.8 | 7.55 | 7.55 |
| Enthalpy air | MW | 1.06 | 1.00 | 1.24 | 1.16 | 0.47 | 0.47 | 0.29 | 0.28 |
| Heat left to WHB | MW | 11.7 | 11.1 | 10.6 | 9.94 | 4.52 | 4.46 | 2.92 | 2.83 |
| Process duty | MW | 17.5 | 17.2 | 21.3 | 21.2 | 8.07 | 8.16 | 5.12 | 5.14 |
| Efficiency | % | 61.7 | 62.3 | 69.4 | 70.1 | 66.1 | 66.5 | 65.2 | 65.7 |
| Fuel compensated | MW | 27.0 | - | 29.3 | - | 11.7 | - | 7.51 | - |
| Fuel saving | MW | 0.205 | | 0.235 | | 0.071 | | 0.046 | |
| | Tsrf/D | 0.436 | | 0.501 | | 0.152 | | 0.099 | |

Moreover, longer historical data (10 days between before and after optimization) had been retrieved in order to confirm benefit from the activity. The summary of furnace operating condition and thermal energy calculation are shown in table 4 and 5, respectively. The benefit calculated from operating condition in this period is 2.07 Tsrf/D.

**Table 3** Process operating condition comparing between before and after optimization (20 days of data)

| Furnaces | UOM | F-9720 | | F-9721 | | F-9722 | | F-9723 | |
|---|---|---|---|---|---|---|---|---|---|
| | | Before | After | Before | After | Before | After | Before | After |
| NAPH feed | T/D | 3,150 | 3,150 | 3,150 | 3,150 | 3,150 | 3,150 | 3,150 | 3,150 |
| GC feed | T/D | 643 | 601 | 643 | 601 | 643 | 601 | 643 | 601 |
| CCR-2 feed | T/D | 3,793 | 3,752 | 3,793 | 3,752 | 3,793 | 3,752 | 3,793 | 3,752 |
| HIT | degC | 450 | 449 | 409 | 410 | 457 | 458 | 478 | 479 |
| HOT | degC | 524 | 524 | 529 | 531 | 520 | 522 | 517 | 518 |
| Excess $O_2$ | %vol | 2.27 | 1.72 | 2.23 | 1.70 | 2.32 | 1.72 | 2.24 | 1.73 |
| FG flow | Tsrf/D | 56.4 | 55.0 | 65.4 | 62.9 | 27.7 | 26.8 | 16.6 | 16.1 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Firing rate | MW | 26.4 | 25.8 | 30.7 | 29.5 | 13.0 | 12.5 | 7.79 | 7.56 |
| Air flow | T/D | 857 | 809 | 1,078 | 999 | 471 | 426 | 261 | 242 |
| Air temp | degC | 129 | 131 | 129 | 131 | 129 | 131 | 129 | 131 |
| BWT | degC | 895 | 895 | 713 | 710 | 794 | 791 | 815 | 815 |
| RON | - | 102 | 102 | 102 | 102 | 102 | 102 | 102 | 102 |

**Table 4** Summary of energy balance calculation in accordance with the mentioned methodology and total benefit calculation (20 days of data)

| Furnaces | UOM | F-9720 | | F-9721 | | F-9722 | | F-9723 | |
|---|---|---|---|---|---|---|---|---|---|
| | | Before | After | Before | After | Before | After | Before | After |
| Firing rate | MW | 26.4 | 25.8 | 30.7 | 29.5 | 13.0 | 12.5 | 7.79 | 7.56 |
| Enthalpy air | MW | 1.01 | 0.95 | 1.27 | 1.17 | 0.55 | 0.50 | 0.31 | 0.28 |
| Heat left to WHB | MW | 11.1 | 10.5 | 10.8 | 10.0 | 5.31 | 4.81 | 3.04 | 2.83 |
| Process duty | MW | 16.9 | 16.7 | 22.1 | 21.6 | 8.90 | 8.73 | 5.27 | 5.17 |
| Efficiency | % | 61.6 | 62.6 | 69.3 | 70.2 | 65.8 | 66.9 | 65.1 | 65.9 |
| Fuel compensated | MW | 26.0 | - | 30.4 | - | 12.8 | - | 7.71 | - |
| Fuel saving | MW | 0.389 | | 0.321 | | 0.177 | | 0.081 | |
| | Tsrf/D | 0.829 | | 0.685 | | 0.379 | | 0.173 | |