Methodologies for efficiency improvement of HOB and CHP through JCM scheme

Advisory committee on 7th October in 2013

Kunihiro Ueno
Current state of developing methodology for JCM HOB project in Mongolia
JCM HOB project in Mongolia
(Expected 1st project of JCM scheme in the world)

Project Name
Upgrading and Installation of Centralized Control System of High-Efficiency Heat Only Boiler in Mongolia

Project site
• Bornuur sum
• 18th school of Ulaanbaatar City”)

Employed HOB
EKOEFFECT

Outline of Heat Supply
JCM HOB project implementation structure in Mongolia

MOE,J

Subsidization

Report

International consortium of companies

Consultation

SUURI-KEIKAKU CO., LTD

Construction supervisory

Anu-Service CO., LTD

Construction supervisory

Report

Site workers

Parties concerned for municipality on the project site
Outline of MRV activities for HOB project in Mongolia

Joint Committee
- Submitting the proposed methodology (finalized version)
- Approval or Non-approval (Reintroduction requirement)

MOE,J
- Supervising for development of methodology
- Developing the proposed methodology for HOB

Anu-Service
- Reporting

SUURI-KEIKAKU with JQA /Climate Experts
- Supporting for MRV activities
- Preparing PDD and Monitoring report

EEC
- Management commission of monitoring data

JQA
- Supporting for accreditation of ISO14065

NREC
- Check whether Monitoring plan and monitoring report meets requirement by Verification

Operation management
Equation of Emission Reductions

This parameter is measured actually by heat meter with verification in accordance with MNS for the purpose of securing accurate measurement (up to PP).

These default values are provided by the methodology (up to JCM scheme owner (=JC)).

By provision of default value, measuring coal consumption by the project HOB is not needed.

\[ \text{ER}_p = \text{PH}_p \left( \frac{1}{\eta_{RE \ BM}} - \frac{1}{\eta_{PJ \ HOB}} \right) \eta \ EF_{CO2, coal} - \ EF_{CO2, grid} \]

Net heat quantity supplied by the Project HOB during the monitoring period p [GJ/p]

Benchmark value for boiler efficiency of reference HOB [-]

Default value for boiler efficiency of reference HOM [-]

CO₂ Emission Factor of the consumed coal [tCO₂/GJ]

Electricity consumption of the project HOB during the monitoring period p [MWh/p]

CO₂ Emission Factor of electricity consumed by the project HOB [tCO₂/MWh]

\[= 0.101 \ tCO₂/GJ \ (Default \ value) \ according \ to \ “Lignite” \ from \ 2006 \ IPCC \ Guidelines \ for \ National \ Greenhouse \ ← \ This \ value \ will \ be \ confirmed \ by \ actual \ laboratory \ analysis \ of \ the \ used \ coal.\]

\[= 1.103 \ tCO₂/MWh \ (Default \ value) \ according \ to \ “Combined \ margin \ CO₂ \ emission \ factor \ for \ central \ energy \ system \ in \ Mongolia \ (According \ to \ CDM \ National \ Bureau \ of \ Mongolia)\]

\[= \text{Max MW value for specification} \ Θ \ \text{Total operating hours of the project HOB} \]
BaU and Reference emissions in JCM scheme

General case of JCM

CO$_2$ emission level

- BaU emissions
- Reference emissions
- Project emissions

Emission reductions by JCM project

(Historical status) JCM project start (In the near future) time

In case of JCM HOB project in Mongolia

Boiler efficiency

- (Actual) Project HOB level
- Default value for Project HOB
- Default value for Reference HOB
- (Estimated) Average Reference level
- BaU level

(Historical status) JCM project start (In the near future) time
What is project HOB?

Boiler type which coal is continuously fed into conveyor type fire grate from stoker.

Type: CARBOROBOT, EKOEFFECT

Eligibility criteria for Project HOB

(1) The built-in sensors of Project HOB control the autonomous operation while there is fuel in the container.

(2) The project HOBs have the boiler efficiency equal to or higher than 80% as the manufacturer’s specification value.

(3) The project HOBs obtain the international certification.

   ← Catalog value for boiler efficiency is generally free-wheeling one by the maker

(4) The project HOBs have dust collectors.
How to set default value for boiler efficiency of project HOB ($\eta_{PJ\ HOB}$)?

Actual measurement data of project HOB

Boiler efficiency (%) vs. Road rate (%)

Catalog value
How to set default value for boiler efficiency of project HOB ($\eta_{PJ\ HOB}$)?

$$\eta_{PJ\ HOB} = \eta_{SP\ PJ} \odot DR_{PJ\ SP}$$

Boiler efficiency of the project HOB as the manufacturer’s specification value [Fraction] = 0.8

Difference rate between specification value and actual measurement one in boiler efficiency of project HOB [fraction]

Graph: Difference rate between specification value and actual measurement one in boiler
### What is BaU HOB?

*Boiler type which coal is fed into fixed fire grate by the hand?*

### What is Reference HOB?

<table>
<thead>
<tr>
<th>Portrait style</th>
<th>Catalog value</th>
<th>Actual measurement data</th>
</tr>
</thead>
</table>

#### Old type prevailed in past days
- **BZUI** 45-60
- **HP18/54** 55-60

#### Other types
- **MDZ**
- **DZL** 74-83
- **MUHT 0.4-1.2** 75-78
- **KB3-06**
- **М↑↑ 3-1500**
- **VIADRUS** 45-60
- **MWB, МОНГОЛ**
- **Китурами** 65-75
- **Others**

<table>
<thead>
<tr>
<th>Boiler type</th>
<th>Catalog value</th>
<th>Actual measurement data</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLSG</td>
<td>75</td>
<td>53.4 42.8 40.1 40.6 49.6</td>
</tr>
<tr>
<td>HP10-60</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>HP18/27</td>
<td>75</td>
<td>40.7 43.6</td>
</tr>
<tr>
<td>BZUI</td>
<td>45-60</td>
<td></td>
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</table>
Brick construction type HOB

Old type of candidates for reference HOB.

Although this type was major HOB type in past days, recently, the occupancy has been decreasing.

Can we say that this falls under the category of reference HOB?

HP 18/54

BZUI
Portrait style HOB

This type has kept high occupancy until now.

Maybe we can that this is typical type of reference HOB....

CLSG

HP 10-60
Advanced type HOB

High-efficient type of candidates for reference HOB? However, these types were often subsidized by foreign assistances (e.g. millennium challenge projects by Word Bank).

Although these types may be project HOB rather than reference HOB…. should we include these types in the category of reference HOB?

DZL

MUHT
How to set default value for boiler efficiency of reference HOB ($\eta_{PJ\ HOB}$)?

$\eta_{RE\ BM} = \eta_{RE\ ST} \emptyset DR_{RE\ SP}$

Boiler efficiency (for specification value base) recommended by MNS[Fraction] = 0.75

Difference rate between specification value and actual measurement one in boiler efficiency of reference HOB [fraction]

MNS5043:2001 "Total specification regarding heat boiler from 0.1MW to 3.15MW in rating capacity"
How to quantify emission reductions by heat-retention wearing project at CHP in Mongolia?

Pyrogel XT
Summary of the e‘ - AIM Method of Maintenance (Patent of NICHIASU CO.)

Easy installation just by wrapping around piping or equipments.

(Increase thermal insulation method of maintenance)
Candidate areas for heat-retention wearing

- Boiler
- Main steam duct
- Turbine
- Extraction steam duct
Outline drawing of process flow at thermal power plant in Mongolia

- Unburnt combustible content loss through fly ash and bottom ash
- Heat loss through exhaust gas
- Radiation heat loss
- Energy loss for startup
- Radiation heat loss
- Radiation heat loss
- Radiation heat loss
- Radiation heat loss
- Radiation heat loss

Outline:

1. **Coal**
   - Overheated boiler supply water
   - Main steam from duct
   - Overheated boiler supply water
   - Direct heat supply ducts
   - Heat exchanger
   - Coal weight

2. **Boiler**
   - High pressure water supply heater
   - Into boiler
   - Into heat supply for factories
   - High pressure water supply heater
   - Measuring point
     - Temperature (T)
     - Pressure (P)
     - Flow rate (F)
     - Condenser (V)
     - Vacuum (V)

3. **Turbine**
   - Terminal steam
   - Into boiler
   - Into low pressure water supply heater
   - Into high pressure water supply heater

4. **Generator**
   - Transduction loss into electricity energy
   - Into high pressure water supply heater
   - Into low pressure water supply heater
   - From condenser
   - Condenser vacuum

5. **Condenser**
   - Heat loss through condensing
   - Into heat supply for factories
   - (Adjusted) Extraction steam duct
   - (Non-adjusted) Extraction steam duct
   - Heat loss
Main steam ductwork and measuring points of steam heat energy at CHP4

No. 1 Boiler 420t/h
No. 2 Boiler 420t/h
No. 3 Boiler 420t/h
No. 4 Boiler 420t/h
No. 5 Boiler 420t/h
No. 6 Boiler 420t/h
No. 7 Boiler 420t/h
No. 8 Boiler 420t/h

TPF TPF TPF TPF TPF TPF TPF TPF

Steam header

TPF TPF TPF TPF TPF TPF TPF TPF

Heat exchanger

Direct Heat supply system

Overheated steam temperature measuring point
Overheated steam pressure measuring point
Overheated steam flow measuring point
Quantification of adiabatic effect by heat-retention on the surfaces of main steam ducts

Before wearing of insulation materials

Inlet heat quantity of main steam

QMSD_{in_{BP}} [GJ/h] (T_{in_{BP}}, P_{in_{BP}}, V_{in_{BP}})

Depleted part

Outlet heat quantity of main steam

QMSD_{out_{BP}}[GJ/h] (T_{out_{BP}}, P_{out_{BP}}, V_{out_{BP}})

After wearing of insulation materials

Inlet heat quantity of main steam

QMSD_{in_{AP}} [GJ/h] (T_{in_{AP}}, P_{in_{AP}}, V_{in_{AP}})

Non-wearing part of heat insulation material

Wearing part of heat insulation material

AHE_{msd}[m^2]

Outlet heat quantity of main steam

QMSD_{out_{AP}}[GJ/h] (T_{out_{AP}}, P_{out_{AP}}, V_{out_{AP}})

Heat quantity saved by heat-retention [GJ/h] = qRMSD_{BP}[GJ/h] − qRMSD_{AP}[GJ/h]

Specific adiabatic effect by heat-retention [GJ/m^2/h] = (qRMSD_{BP}[GJ/h] − qRMSD_{AP}[GJ/h]) / AHE_{msd}[m^2]
Emission Reductions by heat-retention on the surfaces of main steam ducts

Heat quantity saved by heat-retention in main steam ducts [GJ/h]

\[ \text{ER}_{msd,y} = \sum (q_{RMSD_{BP}} - q_{RMSD_{AP}}) / \eta_{boiler} \]

Yearly value of heat quantity saved by heat-retention [GJ/y]

Boiler efficiency of the CHP [Fraction]

CO₂ Emission factor of coal consumed by the CHP [tCO₂/GJ]

1.0 (Default value) is applied in conservative manner, although this value is actually lower than 0.9.
For simplification and avoiding monitoring works for coal consumption

=0.101 tCO₂/GJ (Default value) according to “Lignite” from 2006 IPCC Guidelines for National Greenhouse
This value will be confirmed by actual laboratory analysis of the used coal.

Although 0.101 tCO₂/GJ (for EF_{CO₂, coal}) may not be conservative, conservativeness will be secured through 2 default values of EF_{CO₂, coal} and \( \eta_{boiler} \). Because 1.0 of \( \eta_{boiler} \) is conservative value by a large margin.
How to identify adiabatic effect by heat-retention on boiler, turbine and extraction steam duct?

*Using thermo-viewer owned by CHP4, do difficult task by the following procedure*

Implement sampling measurement of temperatures on 4 surfaces of facilities such as main steam ducts, boiler, turbine and extraction steam ducts by thermo-viewer before and after wearing of insulation materials and estimate radiation heat quantity from these facilities.

For main steam ducts, comparing the adiabatic effect for heat-retention identified by actual measuring data of stem heat quantity and the one estimated by surface temperatures measured by thermo-viewer, identify correlation (difference co-efficient) between both results.

Apply correlation (difference co-efficient) between the adiabatic effect identified by actual measurement data and the estimated by thermo-viewer to estimation equations of the adiabatic effect on boilers, turbines and extraction steam ducts. In such case, for securing conservativeness (avoiding overestimation of emission reductions), discount rate are considered.
Thermal imagery by thermo-viewer

(On main steam duct at inlet of No.2 turbine in CHP4)

Steam temperature: 556°C
Steam pressure: 130kgf/cm²
Steam flow: 400-406 ton/h according to monitoring screen in control room
Before wearing of insulation materials

Inlet heat quantity of main steam

\[ \text{QMSD}_{\text{in BP}} \ [\text{GJ/h}] \]

Outlet heat quantity of main steam

\[ \text{QMSD}_{\text{out BP}} \ [\text{GJ/h}] \]

Outlet heat quantity of main steam

\[ \text{QMSD}_{\text{out AP}} \ [\text{GJ/h}] \]

Wearing part of heat insulation material

\[ \text{AHE}_{\text{msd}} \ [\text{m}^2] \]

Radiated heat quantity estimated by surface temperature per wearing area [GJ/m²/h]

\[ q_{\text{RMSD}} \ [\text{GJ/h}] \]

\[ q_{\text{RMSD}} \ [\text{GJ/h}] \]

\[ \frac{(\text{Surface temperature})^4 - (\text{Surrounding temperature})^4}{\text{Unit [K]}} \times \delta \times \epsilon \times 3.6 \times 10^{-6} \]

\[ \text{Emissivity from surface [Fraction]} \]

\[ \text{Stefan-Boltzmann constant} = 5.67 \times 10^{-8} \ [\text{W/m²K}^4] \]

In case of flat surface

Compare with radiated heat quantity identified by actual measurement value of steam heat quantity (\(q_{\text{RMSD}}_{\text{BP}}/q_{\text{RMSD}}_{\text{BP}}\))
# Quantification flow of adiabatic effects on boiler, turbine and extraction steam duct

<table>
<thead>
<tr>
<th>Main steam duct</th>
<th>Adiabatic effect identified by actual measurement of steam heat quantity [GJ/m²/h]</th>
<th>Adiabatic effect estimated by thermo-viewer [GJ/m²/h]</th>
<th>Adjustment factor for completing difference between actual measurement and thermo-viewer [Fraction]</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAE&lt;sub&gt;msd&lt;/sub&gt;</td>
<td>qRE&lt;sub&gt;EmB&lt;/sub&gt;–qRE&lt;sub&gt;EmA&lt;/sub&gt;</td>
<td>AF&lt;sub&gt;msd&lt;/sub&gt;=S&lt;sub&gt;msd&lt;/sub&gt;/ (qRE&lt;sub&gt;msdB&lt;/sub&gt;–qRE&lt;sub&gt;msdA&lt;/sub&gt;)</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Boiler</th>
<th>Adiabatic effect transferred into actual measurement base</th>
<th>Adiabatic effect estimated by thermo-viewer [GJ/m²/h]</th>
<th>Setting adjustment factor for completing difference between actual measurement and thermo-viewer [Fraction]</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAE&lt;sub&gt;boiler&lt;/sub&gt; = AF&lt;sub&gt;boiler&lt;/sub&gt;*(qRE&lt;sub&gt;bB&lt;/sub&gt;–qRE&lt;sub&gt;bA&lt;/sub&gt;)</td>
<td>qRE&lt;sub&gt;bB&lt;/sub&gt;–qRE&lt;sub&gt;bA&lt;/sub&gt;</td>
<td>AF&lt;sub&gt;boiler&lt;/sub&gt; = (1–DR&lt;sub&gt;boiler&lt;/sub&gt;) 0 AF&lt;sub&gt;msd&lt;/sub&gt;</td>
<td></td>
</tr>
<tr>
<td>Turbine</td>
<td>SAE&lt;sub&gt;turbine&lt;/sub&gt; = AF&lt;sub&gt;turbine&lt;/sub&gt;*(qRE&lt;sub&gt;tB&lt;/sub&gt;–qRE&lt;sub&gt;tA&lt;/sub&gt;)</td>
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</tr>
<tr>
<td>Extraction steam duct</td>
<td>SAE&lt;sub&gt;esd&lt;/sub&gt; = AF&lt;sub&gt;esd&lt;/sub&gt;*(qRE&lt;sub&gt;eB&lt;/sub&gt;–qRE&lt;sub&gt;eA&lt;/sub&gt;)</td>
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</table>

Discount rate for the purpose of create creditable emission reductions
Some homework to do with challenge

(1) **To what extent** we should consider conservativeness to set values of **discount rates** in order to **create creditable emission reductions**?

   Especially there are a **discrepancy (for surface shape)** between main steam duct and boiler/turbine. So, we are needed to **consider conservative adjustment factor by this discrepancy for setting discount rates**

(2) How to set $\varepsilon$ (**Emissivity from surface**)?

   Because existing surfaces of 4 facilities are composed of a number of materials?

(3) We shall justify that surface heat **transfer coefficient by convection flow is not considered** for simplification because of measuring in-house at the thermal power plant
Improvement of efficiency through condenser tube cleaning work during overhaul period at CHP in Mongolia

Work Situation by Rakuchin Gun Use

The load of the workers was reduced by gripping mechanism.

Because there is no remaining water in the tube, the upper and lower work can be performed, work efficiency is improved.
Reference emissions

\[ R_{E_x} = \sum_{i=1}^{m} E_{C_{RE,i}} \times E_{F_{CO2,grid}} \]

Where:

| \( R_{E_x} \) | Reference emissions during the \( x^{th} \) overhaul period after the project starts | tCO2/t |
| EC_{RE,i} | Reference electricity consumption for condenser tube cleaning work of No.i turbine | MWh/t |
| EF_{CO2,grid} | CO2 Emission factor of the net electricity supplied to the electricity grid by the thermal power plant | tCO2/MWh |

Identification of \( E_{C_{RE,i}} \)

Project participants shall measure electricity consumption (of cleaning water pump) for condenser tube cleaning by conventional method during overhaul period before the project starts. Measuring value of electricity consumption shall be identified for each turbine. As the following equation, \( E_{C_{RE,i}} \) is set as the minimum value of measured ones of all turbines for the project in conservative manner.

\[ E_{C_{RE,i}} = \text{Minimum}(E_{CCM_{BP,1}}, E_{CCM_{BP,2}}, \ldots, E_{CCM_{BP,m}}) \]

\((i=1,m)\)
### Project emissions

\[ P_{E_x} = \sum_{i=1}^{m} EC_{x,i} \times EF_{CO2,grid} \]

\[ EC_{x,i} = ECWP_{x,i} + ECAC_{x,i} \]

**Where:**

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>( P_{E_x} )</td>
<td>Project emissions during the ( x^{th} ) overhaul period after the project starts</td>
<td>tCO₂/t</td>
</tr>
<tr>
<td>( EC_{x,i} )</td>
<td>Electricity consumption for condenser tube cleaning work of No.( i ) turbine by project method during the ( x^{th} ) overhaul period after the project starts</td>
<td>MWh/t</td>
</tr>
<tr>
<td>( EF_{CO2,grid} )</td>
<td>CO₂ Emission factor of the net electricity supplied to the electricity grid by the thermal power plant</td>
<td>tCO₂/MWh</td>
</tr>
<tr>
<td>( ECWP_{x,i} )</td>
<td>Electricity consumption of cleaning water pump for condenser tube cleaning work of No.( i ) turbine by project method during the ( x^{th} ) overhaul period after the project starts</td>
<td>MWh/t</td>
</tr>
<tr>
<td>( ECAC_{x,i} )</td>
<td>Electricity consumption of air compressor for condenser tube cleaning work of No.( i ) turbine by project method during the ( x^{th} ) overhaul period after the project starts</td>
<td>MWh/t</td>
</tr>
</tbody>
</table>
Reduction effect of CO$_2$ emission by use of “Rachchin Gun”

(1) Electricity consumption for cleaning water pump can be reduced by reduction of cleaning water consumption.

(2) Electricity consumption for effluent processing for ash pond can be reduced by reduction of cleaning water consumption.

(3) Power generation efficiency can be increased by improvement effect of condenser vacuum

For now, it is impossible to identify creditable emission reductions.
Adherence of impurities in condenser tube

Condenser tube is clogged by adherence of impurities because of hard water.

(At Darkhan thermal power plant)

At thermal power plants of Darkhan and Erdenet, condenser tubes have been cleaned by hydrochloric acid, because german cleaning method has no effect.

However, this acid cleaning method makes the lifetime of tube short.
Improvement effect of by increase of condenser vacuum

(In control room of CHP3)

Coal consumption of 2.7-3.6 g/kWh is saved by 1% increase of condenser vacuum.
Photography of Milky Way starfields in Mongolia by Mr. Yamamoto, JQA

Thank you for your attention!

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