



Registrar

**National Electric Power Regulatory Authority**  
**Islamic Republic of Pakistan**

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No. NEPRA/Consultant(RE/Tech)/LAG-05/14722-14724  
August 4, 2022


Subject: **Order of the Authority in the matter of 3rd Party Heat Rate Test for 248 MW KCCPP of K-Electric Limited (KEL) on HSD Fuel**

Dear Sir,

Enclosed please find herewith the subject Order/Decision of the Authority (10 Pages) in the matter of 3rd Party Heat Rate Test for 248 MW KCCPP of K-Electric Limited (KEL) on HSD Fuel.

2. The Order/Decision is being intimated to the Federal Government for the purpose of notification in the official Gazette pursuant to Section 31(7) of the Regulation of Generation, Transmission and Distribution of Electric Power Act, 1997 within 30 days from the intimation of this Order/Decision. In the event the Federal Government fails to notify the subject Order/Decision or refer the matter to the Authority for reconsideration, within the time period specified in Section 31(7), then the Authority shall notify the same in the official Gazette pursuant to Section 31(7) of NEPRA Act.

Enclosure: As above

  
04 08 22  
( Syed Safer Hussain )

Secretary  
Ministry of Energy (Power Division)  
'A' Block, Pak Secretariat,  
Islamabad

CC:

1. Secretary, Cabinet Division, Cabinet Secretariat, Islamabad.
2. Secretary, Ministry of Finance, 'Q' Block, Pak Secretariat, Islamabad.

National Electric Power Regulatory Authority  
(NEPRA)

July 21, 2022

**'ORDER of the Authority in the matter of 3<sup>rd</sup> Party Heat Rate Test for 248 MW KCCPP  
OF K-Electric (KE) on HSD Fuel'**

**Introduction:**

Korangi Combined Cycle Power Plant (KCCPP) is a 248 MW combined cycle power Plant situated at Korangi Creek area of Karachi. It is part of the overall fleet of generating stations owned by K-Electric and commissioned in the year 2008. Plant comprises 04 Gas Turbines, 02 HRSGs and 02 Steam Turbines. Primary fuel for the Plant operation is natural gas, supplied by Sui Southern Gas Company Ltd (SSGC), while the HSD is backup fuel. Plant is connected to the K-Electric transmission system through 220 KV GIS.

**Background:**

**Multi-Year Tariff (MYT) Determination of K-Electric Ltd:**

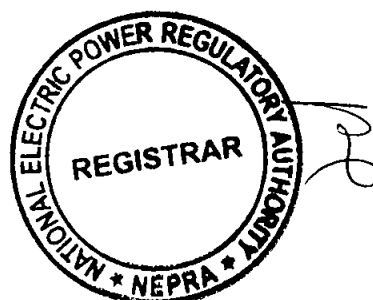
The Authority in the matter of reconsideration request filed by the Federal Government regarding Multi-Year Tariff (MYT) petition of K-Electric Ltd. for the period commencing from July 1, 2016 to June 30, 2023 [Case # NEPRATTRF-362/K-Electric-20161 dated July 5, 2018 decided as follows: (Paragraph 34 (viii)), Page 49)

*"...K-Electric is directed to conduct heat rate test of KCCP, SGTPS and KGTPS and submit the report to the Authority for approval. The adjustment in heat rates will be made based on the results of the performance (Heat Rate) test."*

In view of the above direction of the Authority for KCCP plant the tests on Gas fuel were conducted in June and July 2019<sup>6</sup>. Further, in April and May 2021, KE in view of gas constraints at the plant, had further sought Authority's directions / permission regarding HSD firing at KCCP Plant and the carrying out of Performance Tests on HSD fuel.

Pursuant to the directions of the Authority, Performance Test of KCCP plant was conducted on HSD fuel in June 2021 by NESPAK – in presence of NEPRA representatives as observers. Afterwards, KE submitted a report wherein KE sought approval of Heat Rate numbers for both HSD and Gas fuel as evaluated by IE.

<sup>6</sup> An Order was issued in January 2022.



### **Objective of Performance (Capacity and Heat Rate) Test:**

The objective of the test was to perform Heat Rate and Capacity test on HSD fuel, as per ASME PTC-46 Standard, in the following plant loading conditions;

- Base Load operation of Plant in CC Mode (04 Gas Turbines, 02 HRSGs, 02 Steam Turbines referred to as Primary Test # 1)
- 85% Load operation of Plant in CC Mode (04 Gas Turbines, 02 HRSGs, 02 Steam Turbines referred to as Primary Test # 2)

### **Additional Scope:**

Following was the additional scope of the test:

- IE to include recoverable and non-recoverable degradation due to ageing of a Liquid Fuel gas turbine based combined cycle power plant and its impact on a tested Heat Rate and Capacity (for remaining life) along with the recommended degradation factors in detailed test report
- IE to include in report the comparison of HSD test results with Gas tested results (gross and net) along with impact of HSD on plants performance and maintenance interval
- IE to include detrimental impact of HSD firing on the life of gas turbine/HRSG.
- IE to give its opinion on requirement of regular testing of HSD to keep the system operational for HSD firing based upon the industrial best practices/OEM recommendation
- IE will comment on impact of HSD fuel quality on gas turbines
- IE to compare degradation of plant on gas and HSD operation

### **Test Standards:**

The guidelines of following applicable standards were followed while preparing test procedure, conducting and evaluating the Heat Rate and Capacity test:

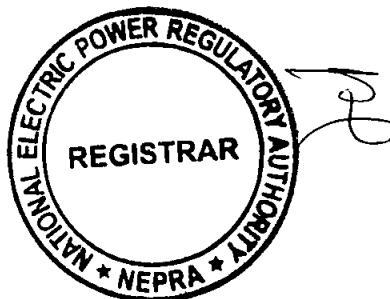
- |                                    |   |
|------------------------------------|---|
| • <b>ASME PTC 46-2015</b>          | Performance Test Codes on Overall Plant Performance             |
| • <b>ISO-2314-2014/PTC 22-2014</b> | Performance Test Codes on Gas Turbines                          |
| • <b>ASTM D240</b>                 | Standard Test method for Analysis of Natural Gas Chromatography |

### **Test Preparation:**

Test preparation mainly included following steps:

- i. Pre Test Meeting
- ii. Preparation Prior To Conducting the Test
- iii. Test Instrument Calibration
- iv. Isolation of Systems / Equipment
- v. Auxiliary Equipment Status
- vi. Stability Requirements before the Test

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**Performance (Capacity and Heat Rate) Tests (June 28, 2021):**

Pursuant to the performance test procedures formulated and submitted by the IE and thereafter approved by KE and agreed upon by NEPRA, the performance tests in different plant configuration were conducted on June 28, 2021.

In the performance test as per the test procedure one (01) Test Run of one (01) hour duration was performed for each Primary Test and all the required data was recorded and tabulated by IE personnel on the log sheets and shared in the Test report.

The Gross Capacity, Net Capacity, Gross Heat Rate (HHV), Net Heat Rate (HHV), Gross Heat Rate (LHV) and the Net Heat Rate (LHV) of the overall Plant (at base load-100% and part load-85%) were calculated using recorded parameters through station instrumentation/meters corrected to Reference Site Conditions using the independent third party correction curves provided to the IE by KE.

The report was submitted to NEPRA by KE vide dated Oct. 12, 2021.

The reference site conditions for Primary Test to which the measured Capacity and Heat Rates have been corrected are given in the following table:

| Description                       | Units  | Parameters     |
|-----------------------------------|--------|----------------|
| Operation mode                    | -      | Base load      |
| Fuel                              | -      | HSD            |
| Ambient temperature               | °C     | 30°C           |
| Atmospheric pressure              | Mbar   | 1013.2 mbar    |
| Ambient humidity                  | %      | 60%            |
| Seawater cooling temperature      | °C     | 25°C           |
| Power factor                      | Ratio  | 0.85 (lagging) |
| Frequency                         | Hz     | 50 Hz          |
| HSD Oil Lower Heating Value (LHV) | BTU/Lb | 18400          |
| HSD Oil temperature               | °C     | 30             |

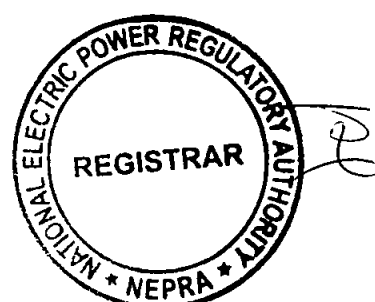
**Method of Data Collection:**

The data used for the performance test calculations was recorded manually on log sheets at the five (05) minutes intervals, by representatives of the IE present at the respective meter/data recording locations.

The main measuring parameters recorded during the test are described below.

- i. HSD Flow Rate Measurement
- ii. Ambient Conditions Measurement

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- iii. Power Output Measurement
- iv. Fuel Sampling

**Calculations of Calorific Values (LHV/HHV) of HSD fuel by IE:**

All necessary arrangements for collection of fuel samples and their subsequent tests/analysis from an accredited laboratory for determination of fuel composition including HHV/LHV were made. A fuel sampling point was jointly identified prior to the tests. It was ensured that the fuel sampling location was as far downstream of all filters as possible and closer to the Gas turbines, so that the samples were true representation of the fuel actually being consumed by the Gas turbines.

For each of Primary Test 1 & 2, three sets of HSD samples (each set of two samples) were taken at equal interval of 30 minutes, starting with the beginning, mid and end of each Primary Test 1 & 2. One set of each samples were sent to internationally recognized laboratory of SGS for analysis. For Primary Tests calculations, the average HHV and LHV of the three samples per test run was computed, and were used in the Heat Rate calculations for the respective Primary Test.

The summary of HHV/LHV calorific values of the samples as provided in IE report is as:

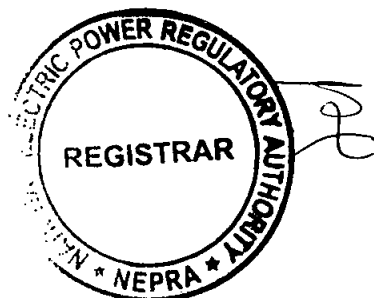
| <b>Primary Test # 1</b> |                   |                |               |                |                |                |                |                |                |
|-------------------------|-------------------|----------------|---------------|----------------|----------------|----------------|----------------|----------------|----------------|
| Samples                 | Sample Time (Hrs) | BTU/ US Gallon |               | BTU/lb         |                | BTU/liter      |                | KJ/Kg          |                |
|                         |                   | HHV            | LHV           | HHV            | LHV            | HHV            | LHV            | HHV            | LHV            |
| Sample 1                | 1030              | 137473         | 128761        | 19850          | 18592          | 36317          | 34015          | 46170          | 43245          |
| Sample 2                | 1100              | 137494         | 128775        | 19853          | 18594          | 36322          | 34019          | 46180          | 43250          |
| Sample 3                | 1130              | 137221         | 128579        | 19816          | 18568          | 36250          | 33967          | 46090          | 43190          |
| <b>Average</b>          |                   | <b>137396</b>  | <b>128705</b> | <b>19839.7</b> | <b>18584.7</b> | <b>36296.3</b> | <b>34000.3</b> | <b>46146.7</b> | <b>43228.3</b> |

| <b>Primary Test # 2</b> |                   |                |               |                |                |                |                |                |              |
|-------------------------|-------------------|----------------|---------------|----------------|----------------|----------------|----------------|----------------|--------------|
| Samples                 | Sample Time (Hrs) | BTU/ US Gallon |               | BTU/lb         |                | BTU/liter      |                | KJ/Kg          |              |
|                         |                   | HHV            | LHV           | HHV            | LHV            | HHV            | LHV            | HHV            | LHV          |
| Sample 1                | 1230              | 137415         | 128718        | 19844          | 18588          | 36301          | 34004          | 46155          | 43235        |
| Sample 2                | 1300              | 137616         | 128863        | 19873          | 18609          | 36354          | 34042          | 46225          | 43285        |
| Sample-3                | 1330              | 137283         | 128607        | 19822          | 18572          | 36261          | 33974          | 46105          | 43200        |
| <b>Average</b>          |                   | <b>137431</b>  | <b>128729</b> | <b>19846.3</b> | <b>18589.7</b> | <b>36305.3</b> | <b>34006.7</b> | <b>46161.7</b> | <b>43240</b> |

**Test Results:**

Following are the detailed results of the test regarding capacity and heat rate of KCCPP as prepared by the IE and forwarded by KE to NEPRA vide dated October 12, 2021.

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**Results (Output) of Performance Test:**

| Performance parameters      | Units | Primary Test # 1<br>(PT-1) | Primary Test # 2<br>(PT-2) | Difference<br>(PT-2 – PT-1) |
|-----------------------------|-------|----------------------------|----------------------------|-----------------------------|
|                             |       | 4+2+2<br>(100% Base Load)  | 4+2+2<br>(85% Part Load)   |                             |
| Gross Power (U-C)           | MW    | 219.498                    | 188.234                    | -31.264                     |
| Gross Power (C)             | MW    | 228.704                    | 195.559                    | -33.145                     |
| Net Power (U-C)             | MW    | 210.787                    | 179.479                    | -31.308                     |
| Net Power (C)               | MW    | 220.018                    | 186.825                    | -33.193                     |
| Auxiliary Consumption       | MW    | 8.711                      | 8.755                      | 0.044                       |
| Auxiliary Consumption Ratio | %     | 3.969                      | 4.651                      | 0.682                       |

**Results (Heat Rates) of Performance Test:**

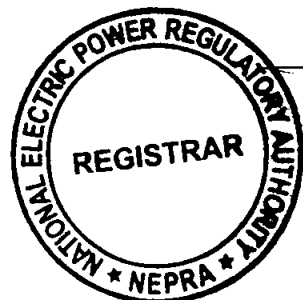
| Performance parameters               | Units   | Primary Test # 1<br>(PT-1) | Primary Test # 2<br>(PT-2) | Difference<br>(PT-2 – PT-1) |
|--------------------------------------|---------|----------------------------|----------------------------|-----------------------------|
|                                      |         | 4+2+2<br>(100% Base Load)  | 4+2+2<br>(85% Part Load)   |                             |
| Gross Plant Heat Rate (U-C)          | BTU/kWh | 7607.147                   | 7708.022                   | 100.875                     |
| Gross Plant Thermal Efficiency (U-C) | %       | 44.854                     | 44.267                     | -0.587                      |
| Gross Plant Heat Rate (C)            | BTU/kWh | 7611.121                   | 7704.839                   | 93.718                      |
| Gross Plant Thermal Efficiency (C)   | %       | 44.831                     | 44.286                     | -0.545                      |
| Net Plant Heat Rate (U-C)            | BTU/kWh | 7921.521                   | 8084.020                   | 162.499                     |
| Net Plant Thermal Efficiency (U-C)   | %       | 43.074                     | 42.208                     | -0.866                      |
| Net Plant Heat Rate (C)              | BTU/kWh | 7911.771                   | 8065.219                   | 153.448                     |
| Net Plant Thermal Efficiency (C)     | %       | 43.127                     | 42.307                     | -0.820                      |

**Conclusions of the Test Results as per IE:**

The conclusions of the test results as per IE are summarized below;

- i. Base Load Corrected (RSC) Net Output is 220.018 MW.
- ii. Part Load (85%) Corrected Net Output is 186.825 MW.
- iii. Base Load Corrected (RSC) Net Heat rate (HHV) is 7911.771 Btu/kWh.
- iv. The Part load (85%) Corrected (RSC) Net Heat rate (HHV) is 8065.219 BTU/kWh.
- v. For Primary Test # 1, the Corrected Net Efficiency (HHV) is increased by 1.405 % point as compared to Corrected Net Efficiency on Gas Fuel.
- vi. For Primary Test # 2, the Corrected Net Efficiency is (HHV) increased by 1.531 % point as compared to Corrected Net Efficiency on Gas Fuel.

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**Request of K-Electric:**

Through its letter dated October 12, 2021 KE requested following heat rates for approval:

**Annexure A**  
to the letter KE/BPR/NEPRA/2021/2371 dated Oct 12, 2021

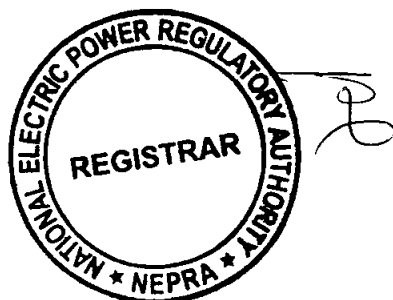
**K-Electric Limited**  
**KCCP Heat Rates**

| Year    | Corrected RSC 85% Part Load Degraded Net Heat Rate (HSD) | Corrected RSC 85% Part Load Degraded Net Heat Rate (Gas) |
|---------|--|--|
| FY 2021 | 8065.219   | 8466.665   |
| FY 2022 | 8104.376   | 8507.770   |
| FY 2023 | 8075.370   | 8477.320   |

The relevant excerpt from the report is as hereunder.

| Annualized Degraded Net Heat Rate |  |  |                                  |   |  |                    |  |  |  |  |          |
|-----------------------------------|--|--|----------------------------------|---|--|--------------------|--|--|--|--|----------|
| Year                              | Actual Fired Hours on Gas and HSDO (Annual 65.20% Load factor) | Actual Fired Hours for Degradation Factors Calculation (Annually 5274.3 Hrs on Gas and 438 Hrs on HSD) | Net Heat Rate Degradation Factor | Cumulative Net Heat Rate Degradation Factor | Cumulative Incremental Degradation w.r.t IE Performance Test Results |                    | Corrected RSC Base Load Degraded Net Heat Rate (HSD) | Corrected RSC 85% Part Load Degraded Net Heat Rate (HSD) | Corrected RSC Base Load Degraded Net Heat Rate (GAS) | Corrected RSC 85% Part Load Degraded Net Heat Rate (GAS) |          |
|                                   |  |  |                                  |   | %  | Multiplying Factor |  |  |  |  | BTU/KWH  |
| 2021                              | Base Year (Till June 30, 2021)                                 | 68,349.76  | 0 - 68152.6                      | 2.463                                       | 2.49   | 0.00               | 1.0000   | 7911.771   | 8065.219   | 8274.714   | 8466.665 |
|                                   |  |  | 68152.6 - 68349.76               | 0.091                                       |  |                    |  |  |  |  |          |
| 2022                              | 1  | 74,062.06  | 68349.76 - 73624.06              | 2.930                                       | 2.98   | 0.49               | 1.0049   | 7950.183   | 8104.376   | 8314.888   | 8507.770 |
|                                   |  |  | 73624.06 - 74062.06              | 0.049                                       |  |                    |  |  |  |  |          |
| 2023                              | 2  | 79,774.36  | 74062.06 - 79336.36              | 2.519                                       | 2.62   | 0.13               | 1.0013   | 7921.728   | 8075.370   | 8285.128   | 8477.320 |
|                                   |  |  | 79336.36 - 79774.36              | 0.101                                       |  |                    |  |  |  |  |          |

| Legend |  |
|--------|--|
|        | Actual Fired Hours/Degradation Factors on Gas  |
|        | Actual Fired Hours/Degradation Factors on HSDO |



**Facts of the Case & Analysis:**

It is stated that Authority in MYT determination of KE directed KE to conduct Heat Rate test of KCCP Plant. The Authority further decided that

*"...The adjustment in heat rates will be made based on the results of the performance (Heat Rate) test."*

Pursuant to above directions of the Authority in MYT, a Heat Rate test of KCCP plant on Gas fuel was earlier conducted in June 2019 by NESPAK-SGS. Afterwards, KE submitted the report to the Authority and requested Heat Rate for period FY 2017~FY 2023. It is further highlighted that during the review motion proceedings (Gas fuel), KE submitted Heat Rate test report on HSD fuel and requested Heat Rate numbers on both Gas and HSD fuels for the period FY 2021 – FY 2023. Therefore, the Authority in matter of review motion (Gas fuel) issued an Order in January 2022 for the period FY 2017 to FY 2020 (prior to HSD operation) and decided to consider Heat Rate for FY 2021 onwards on Gas & HSD fuel at the time consideration of Heat Rate report on HSD fuel.

Keeping above in view, the Authority noted that the Heat Rate number for KCCP plant needs to be determined for the remaining period of MYT i.e. FY 2021-FY 2023 for both Gas and HSD fuel.

**Submission and Review of the Report:**

KE has submitted the report along with its request vide letter dated Oct. 12, 2021.

KE has carried out a Performance test on HSD fuel by the same Independent Engineer i.e. NESPAK-SGS, who carried out Performance test on Gas fuel. Prior to the test, the test procedures were made by IE & KE and were submitted to the Authority by KE for approval. As per the test procedures, the test were conducted in two configurations i.e. at Base load and at 85% loading. KE subsequently sought Heat Rate numbers on annual basis for either of the fuels.

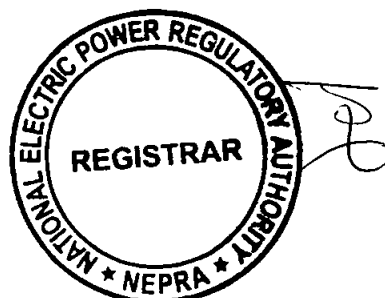
The Authority noted that HSD operation of KCCP falls in the period FY 2021, consequently IE's recommended numbers on gas fuels, as given in the current Heat Rate report, had slightly changed vis-à-vis earlier Heat Rate report due to consideration of impact of HSD fuel.

**Consideration of Load Factor for Degradation in FY 2022 and FY 2023:**

The Authority has noted that IE in its report has considered an annual load factor of 65.2% for KCCP plant<sup>7</sup>. IE has further considered 5274.3 hours of operation on Gas fuel and 438 hours on HSD. The approach is deemed as satisfactory and scientific by the Authority.

<sup>7</sup> In view of Authority's directions sent to KE dated July 2021

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Comparison of Degradation of Plant on Gas and HSD:

The Authority has noted that IE in the report has discussed at length the detrimental impact of HSD on life of Gas turbines and has produced OEM's response. (Section 13.3 of the report – an excerpt pasted for ready reference).

For severity factor of HSD fuel, KE approached OEM (GE), their response is reproduced below for ready reference;

*"When operating with liquid fuel (compliant of course with MID-TD-0000-2) the expected life of HS is reduced to half (~12.5 khrs vs ~25 khrs)."*

The IE in its report has further stated:

... it is obvious that the degradations on HSD as compared to Gas fuel are significantly higher. It is worth mentioning that the severity factor with HSD operation is two (1 OH=2 FFH) i.e. double to the severity factor as on gas (1 OH = 1 FFH). (Section 13.6 of the report).

The Authority has observed that IE has incorporated the impact of the degradation in its reported numbers.

Impact of Part Load:

The Performance Test (Heat rate and Capacity test) has been carried out at both 85% loading and at base load. KE vide its letter had requested Heat rate at 85% loading, in line with the decision of the Authority for Heat rate of KCCP at Gas fuel.

Regarding selection of 85% loading number for KCCP on gas fuel, the Authority noted its earlier decision dated October 9, 2017, reproduced here for clarity.

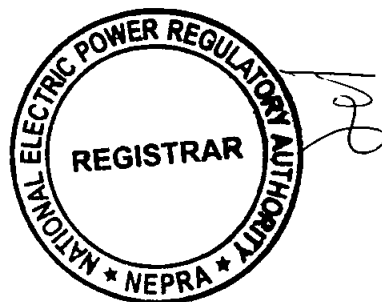
Various benchmarks recognizing the concept of a normative plant operation<sup>8</sup> have also been reviewed and for combined cycle power plants, a normative loading level of 85% is recommended. K-Electric also has requested for NPL of 85% for KCCPP. The Authority considers that the claimed value of 85% (of rated capacity) due to load variation seems reasonable and thus approved the same. In the absence of part load curves, the Authority considers the adjustments factors allowed to other IPPs, as mentioned above, as reasonable.... (para 8.2.16)

Further, the Authority also noted that it has already allowed a Heat Rate number corresponding to 85% loading (regardless of actual hourly loading position) to KCCP plant on Gas fuel<sup>9</sup>.

<sup>8</sup> Reasoning for taking a normative number for part load adjustment is given in MYT decisions of the Authority and Order on KCCP dated September 2020.

<sup>9</sup> Order of Authority on KCCP dated September 2020 and January 2022.

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However, the Authority has noted that HSD being relatively an expensive fuel the Authority has already directed to K-Electric that...in general power generation on costlier fuel needs to be avoided, therefore Power Generation through HSD, if any, shall be justified by KE.

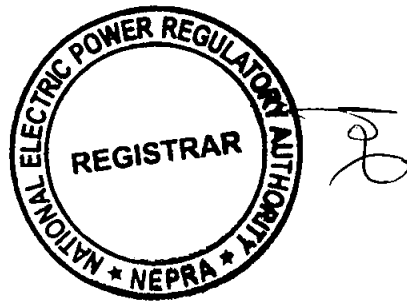
Keeping above in view, the Authority believes that 85% loading for HSD should not be directly allowed to KE for KCCP Plant as allowed in case of Gas/RLNG fuel. Rather, the Authority in the instant matter allows Heat Rate number reflecting base load operation on HSD. It is further highlighted that KE is allowed part load adjustment of 85% on gas fuel<sup>10</sup> however, the overall loading of KCCP plant would further improve as a result of diesel operations as seen through operational data of KE.

**Summary Table: Net Heat Rate for KCCP:**

| Year    | Corrected RSC 85% Part Load Degraded Net Heat Rate (Gas) HHV-Btu/kWh | Corrected RSC Base Load Degraded Net Heat Rate (HSD) HHV-Btu/kWh |
|---------|--|--|
| FY 2021 | 8466.665   | 7911.771   |
| FY 2022 | 8507.770   | 7950.183   |
| FY 2023 | 8477.32  | 7921.728   |

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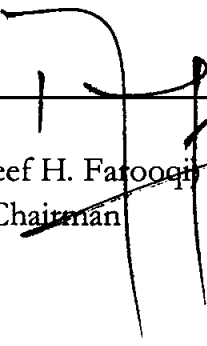
<sup>10</sup> In MYT determination as well as through later decisions i.e. Sep 2020, Jan. 2022.

**Decision of the Authority:**

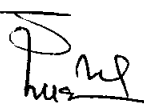
Based on the Heat Rate and Capacity tests conducted by the Independent Engineer for KCCP, the Authority approves the net Heat Rate numbers for KCCP plant as given in Summary Table.

  
\_\_\_\_\_  
(Engr. Maqsood Anwar Khan)  
Member

  
\_\_\_\_\_  
(Rafique Ahmed Shaikh)  
Member

  
\_\_\_\_\_  
(Tauseef H. Farooqi)  
Chairman



  
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