
Development of Standardized Test Method & Calculation Protocol for Determining & Reporting Annual/Long-term Heat Rate & lbm-CO₂/MWh for Coal-Fueled Plants (EGU's)

DOE-NETL'S 2021 INTEGRATED PROJECT REVIEW MEETING

ASME Standards Technology, LLC

U.S. DOE-NETL Award #FE0031933

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Acknowledgment & Disclaimer

- Acknowledgment: "This material is based upon work supported by the Department of Energy Award Number DE-FE0031933"
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DOE Contract with ASME

- The US Department of Energy (DOE) has retained the services of ASME Standards Technology LLC (ASME ST-LLC) to conduct this study (U.S. DOE-NETL Award #FE0031933).
- The objective is to establish an industry-acceptable standard for long term heat rate test & CO₂ reporting methods for electric generating power plants EGUs. The first standard will be developed for coal-fired EGUs, other technologies such as nuclear & gas-fired plant will be developed later.
- Provide information for engineering studies, preventive or predictive maintenance, & planning purposes concerning equipment maintenance, replacements, or upgrades related to corrosion from changes in heat rate.

Project Structure/Team

- **ASME & ASME ST-LLC**
 - Project structure, communication system
 - Two PTC committees & staff to develop Code(s)/Standard
- **Licata Energy**
 - Lead technical investigator, expert in power plant operations
 - Project management, literature research, interview with stakeholders
 - Data gathering & preparation of interim & final reports
- **McHale & Associates**
 - Data analysis, expert in power plant testing, drafting of methodology
 - Coordination with subcontractors to draft inputs to ASME PTC committee
 - Remote evaluation of plant operating data
 - Thermodynamic modeling & analysis of potential methodologies for inclusion in the performance test code
- **Tennessee Technological University**
 - Recommend the procedure to assess the calculation of the instantaneous Gross Calorific Value (GVC) of coal
 - Prescribe method to evaluate (i) boiler efficiency, (ii) steam cycle heat rate, & (iii) unit heat rate, & recommend an approach for conducting a statistical analysis for the method of determining annual heat rate
- **Shakti Consultancy, LLC**
 - Provided overview of development of statistical data
 - Problem Identification for technical approaches & industry practices

Technical Approach to Project

- **Task 1 – Project Management & Planning**
 - Managing the project to meet all technical, schedule & budget objectives & requirements.
- **Task 2 – Problem Identification**
 - Problem will be defined, & problems/conflicts with current technology & test methods identified.
- **Task 3 – Summary Report**
 - Meet with various organizations & agencies that have a stake in measuring or reporting EGU heat rate & prepare summary report.
- **Task 4 – Code Language Development**
 - Develop a methodology to determine changes in heat rate on an annual basis with low uncertainty & based in established commercial standards that will increase acceptance of results.
 - Coordinate Performance Test Code with Codes & Standards.

Project Objective

- The intent of this study is to produce ASME Code language that provides heat rate ($\text{lbm-CO}_2/\text{MWh}$) measurement results with the lowest reasonably achievable uncertainty consistent with the best engineering knowledge & practice in the industry, by employing accurate instrumentation & best possible measurement techniques & data validation methods available to determine the continuous power output & heat rate, as applicable to a specific generating facility.
- In addition, the Code needs to provide procedures & techniques to design Relative Accuracy Test Audits (RATA) that ensure that the uncertainty reported is upheld.
- No consensus methodology exists.

Background

- Possible federally regulated electricity carbon pricing market.
 - \$/Ton CO₂ x Tons CO₂/MWh (Heat Rate is a direct conversion to CO₂/MWh)
 - FERC Carbon Pricing Conference (October 01, 2020)
 - Development of wholesale market rules that include a state-determined carbon price
 - PJM Studying ways to implement carbon pricing
 - NYISO carbon-pricing plan (Climate Leadership & Community Protection Act)
 - RGGI's Carbon-Trading Agreement
 - Social Cost of CO₂ \$51/ton (Biden administration)
 - Washington & California passed Cap & Trade (Price on Carbon Emissions)
- EPRI has working group.
- ASME formed two PTCs: Heat Rate & Data Validation.

Benefits to Codifying Heat Rate & $\text{lbm-CO}_2/\text{MWh}$

- Provides consistency & transparency in reporting.
- Increases confidence in reporting results.
- Saves money by removing arguments.
- Stimulates solutions.
- Provides answers to policy issues.
- Puts everyone on an equal playing field.

Benefits to Proposed Heat Rate & Ibm-CO₂/MWh Techniques

- Method is rooted in ASME PTC 4 & ASME PTC 46. (How power plants are bought & sold)
- Results can be calculated & monitored real time.
- Improved uncertainty. (1-3% over current 3-14%)
- Methods relies on station instrumentation that is typically available & easily calibrated.
- Accounts for cycling & load following
- Allows for a Reference Test (Relative Accuracy Test Audits) for calibration. (performed at a low frequency)

Heat Rate Applications

- Heat rate, as a measure of operating performance, permits plant & fleet owner/operators to determine which units operate at the appropriate time to achieve the lowest total cost of generation.
- As the heat rate of a unit increases (worsens), that unit may drop lower on the dispatch order.
- Low load operation, cycling, on-and-off operation, & lower capacity factors increase heat rate, resulting in increased operating cost, corrosion, & potentially causing unit shutdown due to economics and/or damage to components & increased CO₂ emissions.

Heat Rate Increase & Corrosion

- Low load operation, cycling, & lower capacity factors.
 - “cold spots,” acid condensation, fouling
- On & Off operations.
 - Metal fatigue, deposits, corrosion
- Higher operating cost & fuel use.
- Change in materials of construction.
- Increased CO₂ & air emissions.

CO₂ Drives Heat Rate Measurements



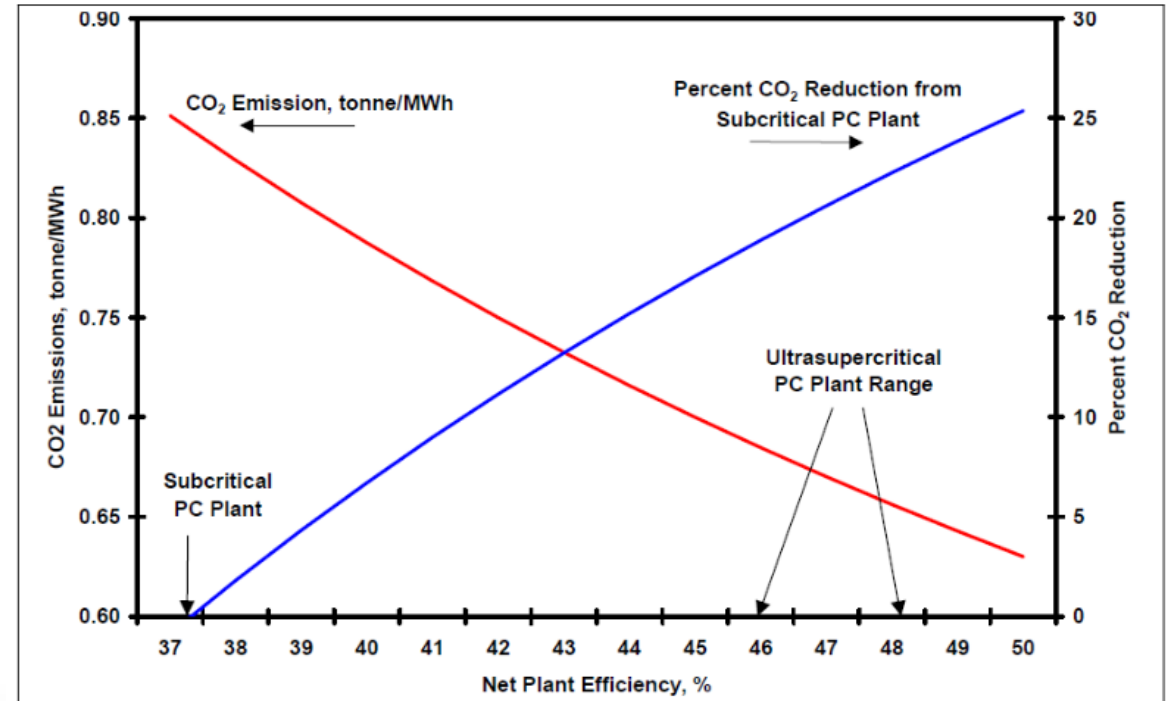
- Carbon dioxide emissions from world electricity production accounted for 30% of total emissions of the world, of which 40% is from coal.
- Accurate calculation of carbon emissions from coal-fired power plant is one of the prerequisites for the realization of carbon emission reduction.
- Industry needs a consistent codified method of reporting CO₂, there will be a uniform method that could be used by regulatory bodies & global policy makers in their efforts to improve global environmental goals.

Heat Rate Relation to $\text{lbm-CO}_2/\text{MWh}$

It is estimated that 1% to 2% increase in heat rate improvements, leading to efficiency improvement, will result in 1% to 2% decrease in emissions per unit of electricity.
(USAID/TVA/NTPC 2000)

Figure 5. Carbon Dioxide Emissions vs. Net Plant Efficiency

Based on Burning Pittsburgh #8 (Bituminous) Coal



Source: Booras, G. and N. Holt, Pulverized Coal and IGCC plant Cost and Performance Estimates, Gasification Technologies Conference Washington D.C. 2004.

Notes:

- 1) One tonne (also known as a metric ton) is a unit of mass equaling 1,000 kilograms.
- 2) This chart assumes subcritical plants (using bituminous coal) would be near the top of the range for efficiency. Improvements at the higher end of the range are now considered to be based on advanced ultrasupercritical technology, which while technologically possible, is unlikely to be implemented in the next few years.

Heat Rate & $\text{lbm-CO}_2/\text{MWh}$ Applications

- To measure overall thermal/electric efficiency & $\text{lbm-CO}_2/\text{MWh}$.
- As a key metric for dispatch to the electricity grid (key to ISOs & Grid Operators).
- To measure & monitor fuel use.
- To measure & monitor operating economics.
- To support reporting of air pollution emission rates & CO_2 emissions.
- To verify if changes or improvements in operating procedures are beneficial.
- To verify if changes or improvements to equipment & systems are beneficial.
- Evaluation of life of an asset.
- Provide a verifiable standard for reporting CO_2 emissions for trading or carbon tax credits.
- Identify any performance trends to help identify the cause of the adverse trends.

Preliminary Results

- Two ASME PTC Code Committees Operating
 - ASME RAP/PTC Joint Subcommittee on Heat Rate
 - ASME PTC Committee on Control & Quality Improvement of Process Data (DVR)
- Power Generating Facilities: Continuous Power Output & Heat Rate
 - The objective of this effort is to establish an industry-acceptable standard heat rate test method & annual heat rate calculation protocol for coal-fired electricity generating units.
 - DOE participation
- Committee on Control & Quality Improvement of Process Data
 - Develop procedures & guidelines for using techniques such as data validation & reconciliation to assure determine the quality of measurements, quantify reduce the uncertainties, & assess reconciled results.

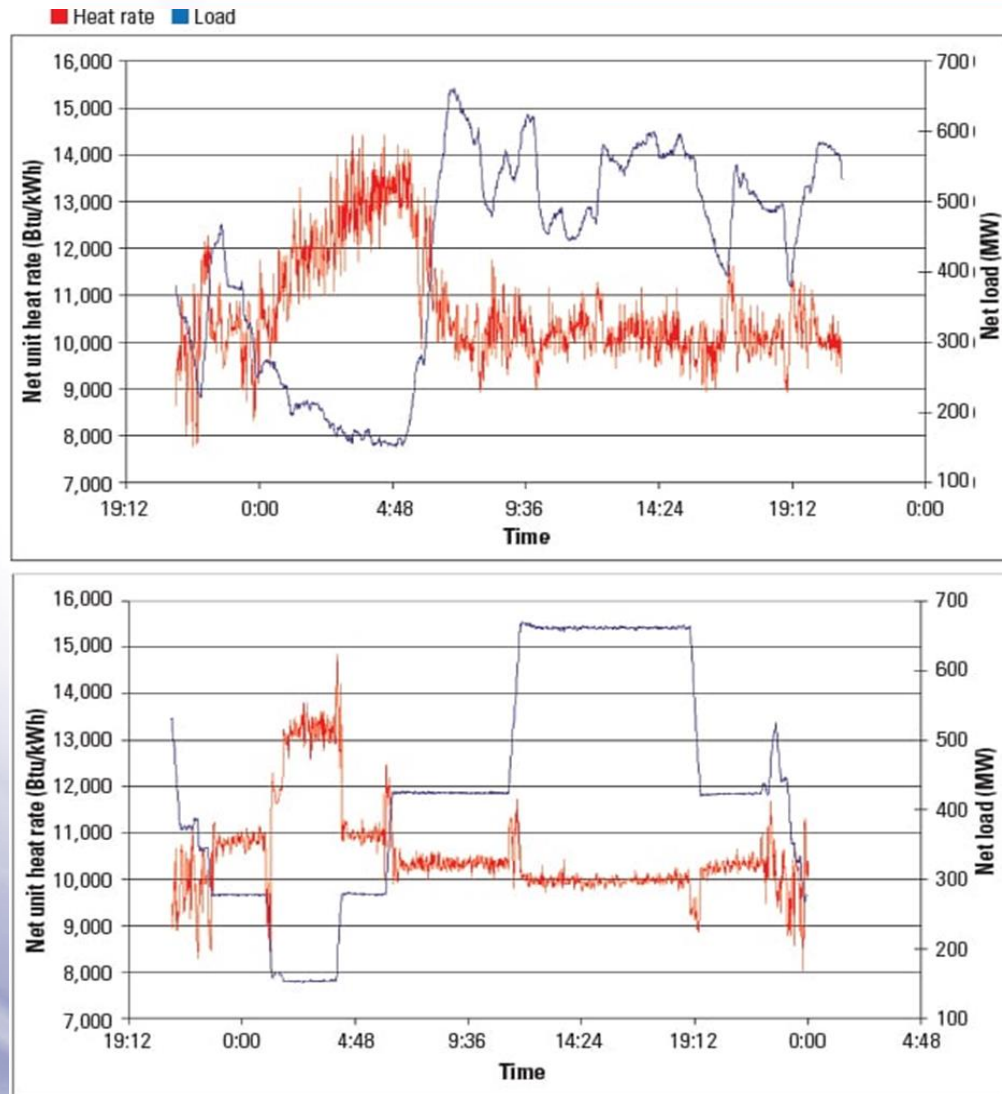
Preliminary Results

- McHale has identified three potential concepts / methodologies / procedures that may be used in developing a Performance Test Code to determine annual heat rate (lbm-CO₂/MWh) for power plants that can achieve more consistent uncertainties of +/-1.5% to +/-3%.
- Each of the methods can evaluate measuring heat rate on an annual basis & on a rolling average basis.
 - One can readily be adopted to an online continuous basis
- An approach for uncertainty analysis for the proposed method of annual heat rate will be recommended.
- Have ID sources for plant data.
- Methods underdevelopment will be applicable to other generation technologies.

Factors Impacting Heat Rate

- One of the primary issues when evaluating heat rate performance from year to year or baseline are:
 - Ambient temperature, an analysis of CAMD found that day-to-day variance in load profile, operating & ambient conditions, exceed the 2% & the 4.5% targeted HRI profiled by EPA.
 - Plant capacity
 - Plant cycling loads
 - “Not all Heat Rates Reported are created equal”. Heat rate reporting must consider ambient conditions, loads, electric grid causes, or how the plant is dispatched.

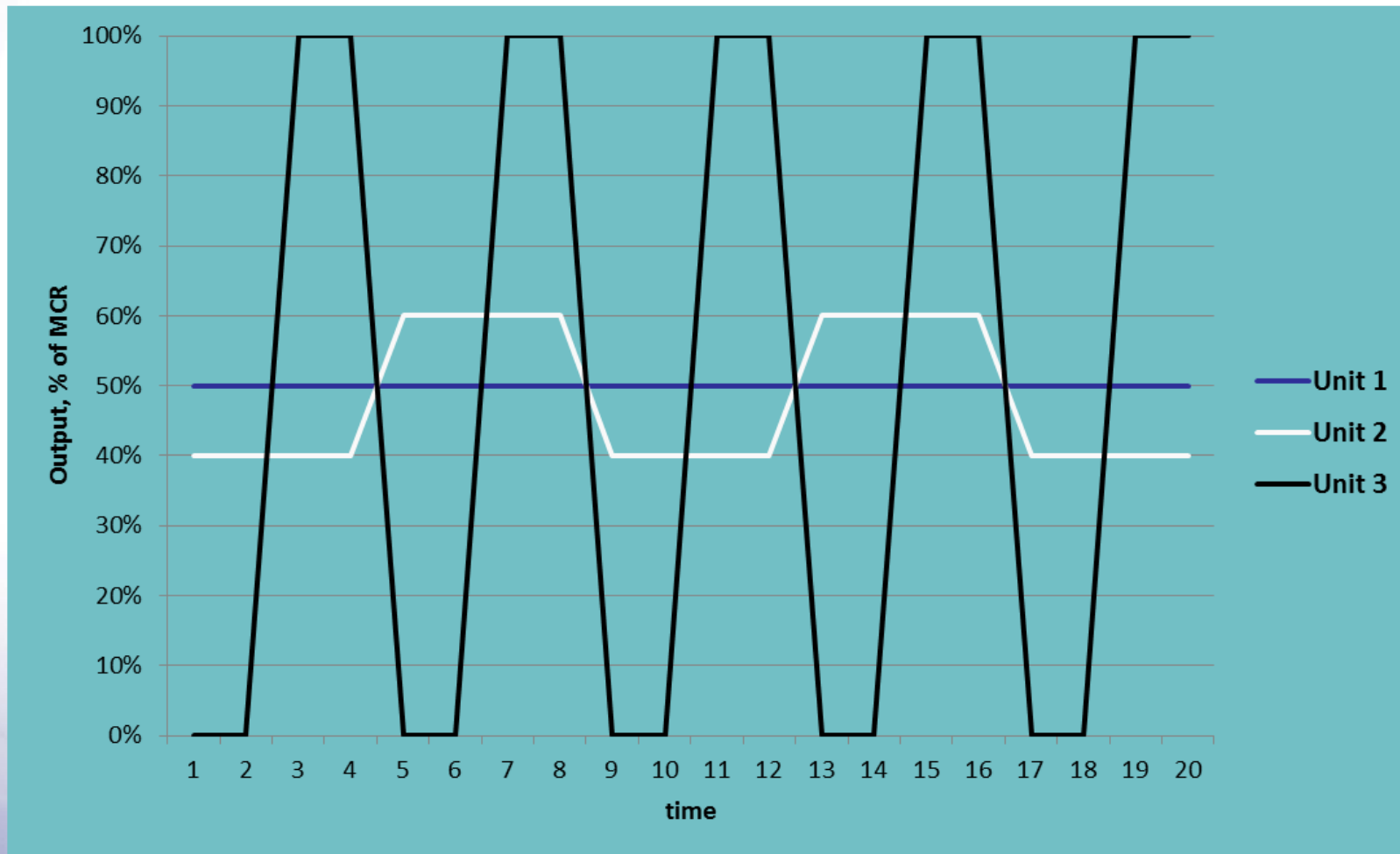
Load Change Impacts



EPRI Data Power Magazine

“Operating conditions under flexible operation can result in reductions in plant efficiency and increased degradation and maintenance requirements on components due to constant swings in operating temperature and pressure”.

Units 1, 2, & 3 all have 50% capacity factor although their operation is very different.

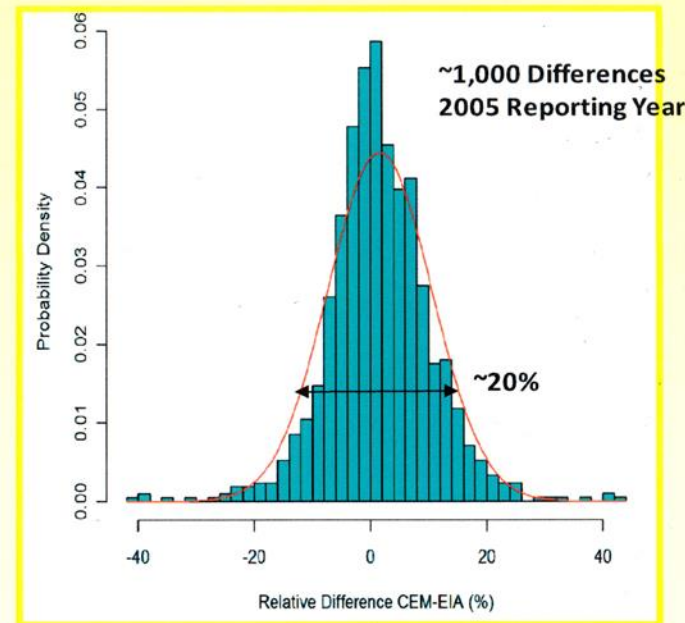
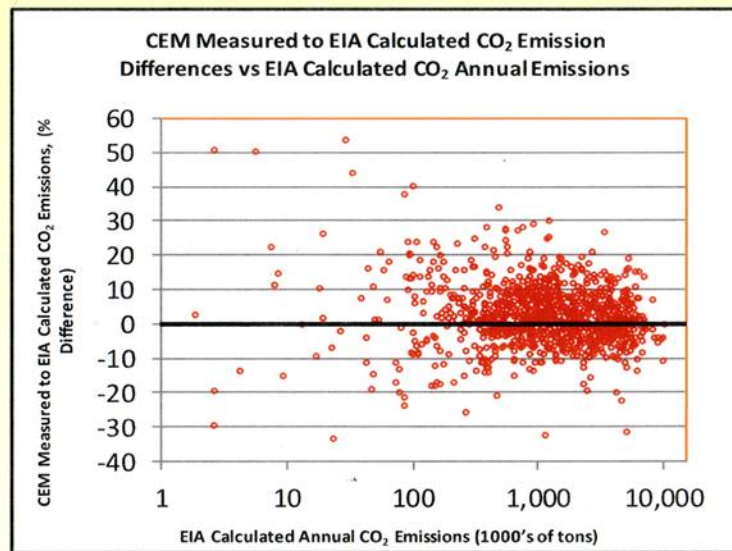


NIST Presentation June 2017

5) Stationary/Point Source Metrology

Agreement between 2 methods of CO₂ emissions reporting?

- 1) Pre-Combustion – Fuel Calculation Method
- 2) Post-Combustion – CO₂ Measurement via CEMS (flow x mole fraction)



Measurement challenges: 1) carbon content of coal, 2) flow measurement in stacks, 3) Pitot velocity measurements, 4) better methods, 5) composition, 5) other?

Challenges to Measuring Annual Heat Rate

- Vast amounts of data to be utilized.
 - Uncertainty of data, need data validation & reconciliation (DVR). Some programs are available but need to be adopted into code.
- Measurement issues.
 - Feedwater flow & steam flow to turbine
 - Coal mass flow to boiler
 - Flue gas volume
 - Continuous flue gas moisture

Conclusions

- CO₂ & Heat Rate are related & need to be reported minimizing uncertainty.
- Drive to improve heat rate & decrease CO₂.
- Domestic & world-wide need for reporting.
- EGUs will continue to operate in low load & cycling modes increasing corrosion, metal fatigue & a need for enhanced materials used to maintain unit availability & economics.

The logo features the company name in a blue serif font, with a large, thin blue arc on the left side that curves around the text. The background is a light blue gradient with abstract, flowing white lines.

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