EAGLE COKE™

LOTUS WIRELESS
Connect with Innovation

Unmanned Efficiency
Streamlining Coke Machine Operations for Simplicity and Success

Unleashing Thermal Intelligence
Analyzing and Predicting Coke Oven Battery Operations with Unrivaled Expertise

Taking Charge of Emission Control
Ensuring Regulatory Compliance with Unyielding Accuracy

Safety at its Core
Unleashing SIL 2 Certified Systems for Unparalleled Protection

COKE OVEN
BATTERY SOLUTIONS

DIGITAL PLATFORM
FOR COKE OVEN BATTERIES

COKE OVEN BATTERY SOLUTIONS

SYSTEM OVERVIEW AND CASE STUDY

BEFORE AND AFTER IMPLEMENTING DIGITAL INSIGHT PLATFORM

IN

INDIAN INTEGRATED STEEL PLANT COKE OVEN BATTERY

EAGLE COKE™

Eagle Coke™ is designed for the Coke Oven Batteries. The basic foundation of this platform is on strong framework of predictive analytics assisting In effective decision making for better Coke making.

THE PLATFORM HAS FOLLOWING MAJOR MODULES :

- Predictive Modelling of Coking Process
- Constraint Based Dynamic Scheduling
- Heating Process Management

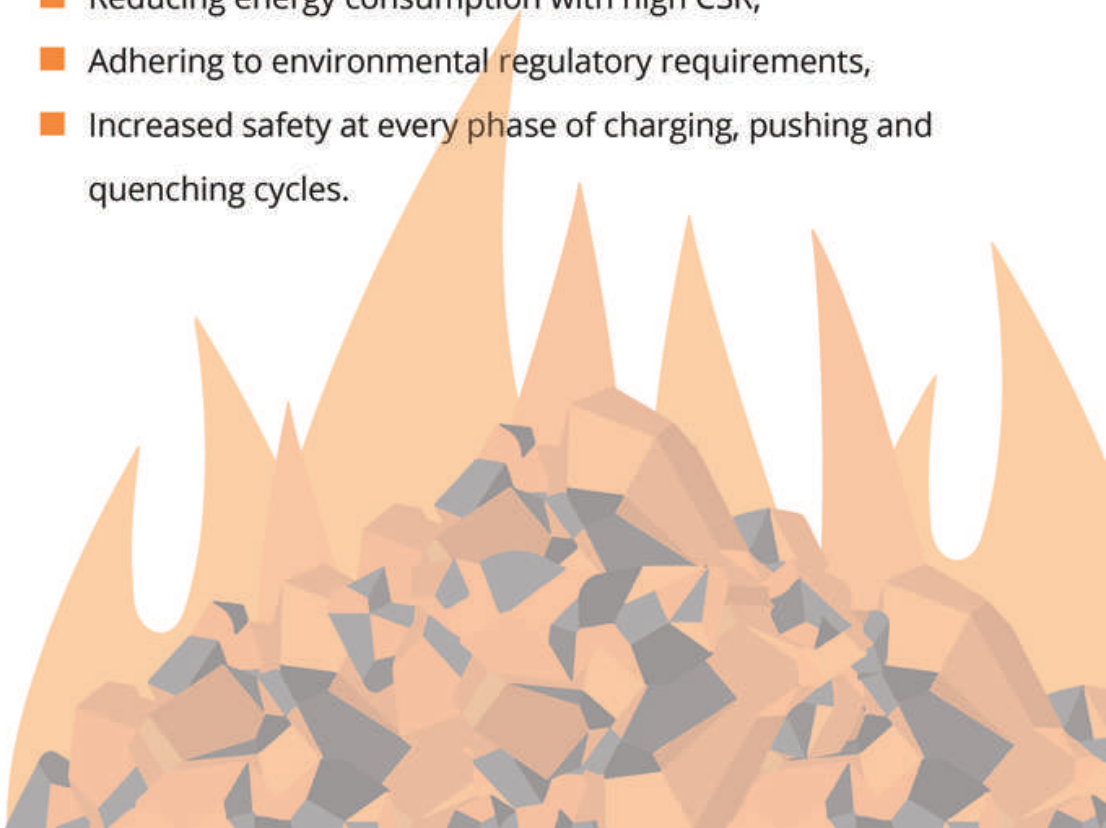
The Eagle Coke™ platform is based on Industry 4.0 which includes Cyber-Physical systems, the internet of things and cloud computing. The complete system is pivoted around the data analysis, which is not only the central repository of information but also takes care of all the data for control modules to meet the different functional aspects.

The 'Analytics' uses statistical tools for different decision making for major functions like:

- Coking Process Management
- Environmental Regulation
- Energy Management and Estimation
- Asset Management

Eagle Coke™ is an ideal platform to execute optimized energy balance, pollution accounting, high end coke quality with integrated asset management and safety controls. Above all with cloud-enabled platform user can opt for minimal IT infrastructure for an easy integration of IoT concept through smartphones and tablet. Modern coke making process involves the integration of oven battery with various machineries, IT hardware, software and multiple communication networks. Current Coke making process is facing new challenges like

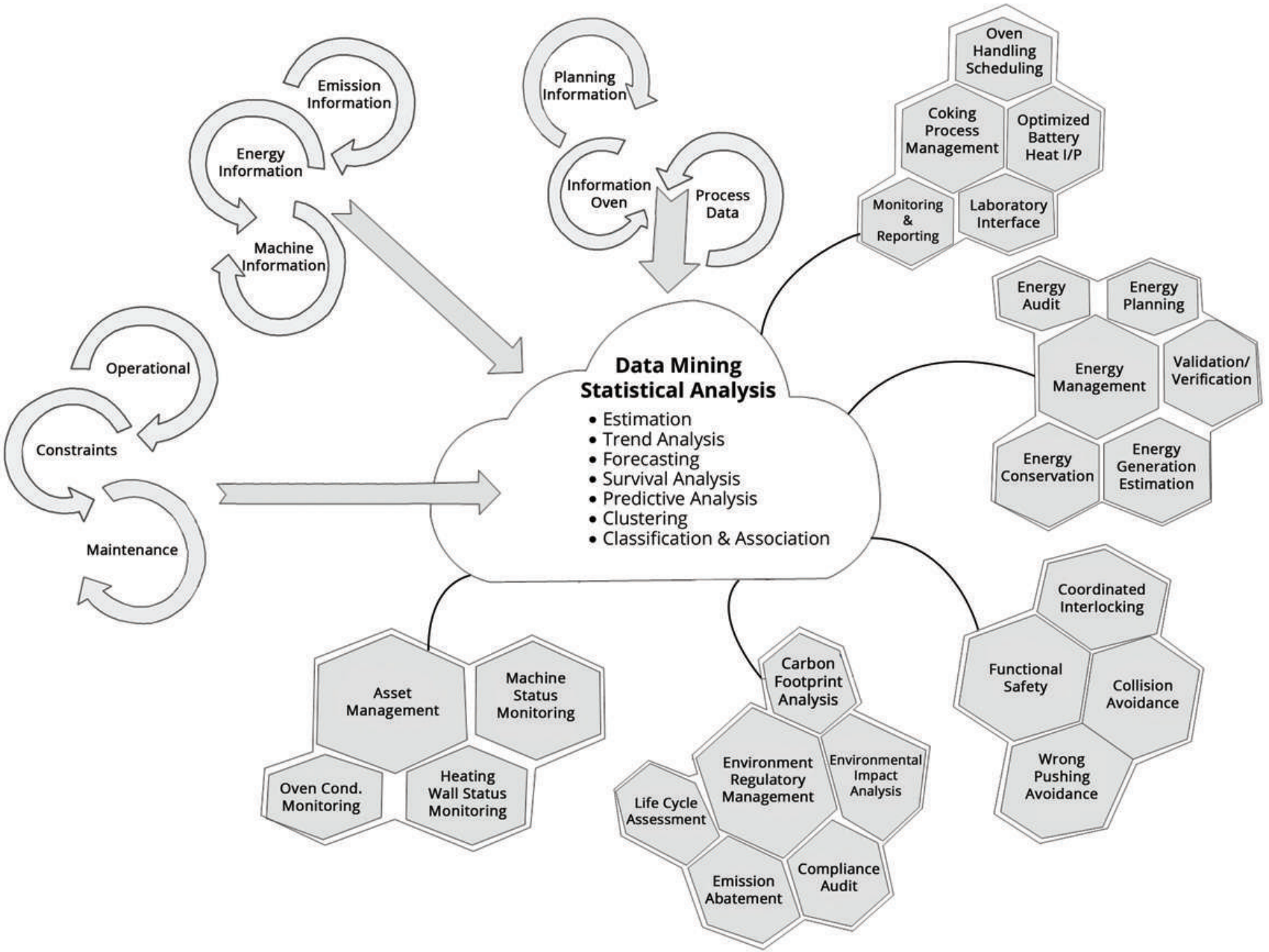
- Reducing energy consumption with high CSR,
- Adhering to environmental regulatory requirements,
- Increased safety at every phase of charging, pushing and quenching cycles.



EAGLE COKE™ CORE FUNCTIONS AND BENEFITS

FUNCTIONS		BENEFITS
POLLUTION	• Pragmatic approach towards emission monitoring • Environmental accounting • Environmental regulation compliance through PDCA	• Fulfillment of govt. regulations • Easy corporate decision making for practicing environmental management • Improve the performance of pollution control equipment
SAFETY	• Unsafe practice monitoring • Asset management • Oven/Machine condition-monitoring	• Pushing & charging interlocking • Avoidance of wrong pushing • Collision avoidance between machines • Measures against any outages
ENERGY	• Gas demand estimation • Power & Utility consumption care • Decision on autonomous activities	• Energy planning & conservation • Energy saving up to 5% • Energy management dashboard
PROCESS	• Process data monitoring and analysis • Oven Scheduling • Oven Identification & Positioning • Heat input control • Coke quality control • Reporting	• Consistency In Coke Quality • Improved CSR value up to 5% • Improved production efficiency • Stable operating conditions & web-based battery health assessment • Flue temperatures & damages • Pushing forces • Oven rankings • Overdue inspections • Refractory repair life /bracing

EAGLE COKE™ VARIOUS FUNCTIONAL MODULES



EAGLE COKE™ HEATING CONTROL TECHNOLOGY

Eagle Coke™ Machine learning engine has capability to learn the operations based on basic Coke Battery operational input and then accordingly complex dynamically formulated equation are generated over the time. The general algorithms engine has various constants which are based on the rich experience of the battery user and the designer. Our built-in artificial intelligence tool improvise the constants and factors based on the life and behavior of battery, and various inputs like coal, gas progressively. On sensing boundary condition violation the AI tool, finds most suitable control action preventing any abnormal operation. The platform kernel has various algorithms for heating models for decision-making with a combination of Mathematical model, rule based and Heuristic approach.

MATHEMATICAL MODEL MODULE BASED ON HEAT TRANSFER

Information fusion of desired inputs is achieved through data collation, filter, validation and data fusion technique is applied for extracting the useful information from the operational data. The technology deals with the synergistic combination of information at data level, feature level i.e. advancement of information level) or decision level or any combination. Mathematical model for computing the heat input to battery is Total Heat Energy demand = (Heat energy needed for coal carbonization + Heat Energy Loss though waste gas + Heat Energy Loss though surface of oven)

THE ACTUAL HEATING PERFORMANCE IS CORRECTED BASED ON ACTUAL TEMPERATURES OF

Heating Flue Temperature
Coke Mass Temperature

VARIOUS ALGORITHMS USED FOR HEATING MODELS ARE AS FOLLOWS

- Coking Time Calculation
- Heat Requirement
- Heating Flue Temperature
- Final Coke Temperature
- Heating Value of Under Firing Gas
- Air Demand For Combustion
- Waste Gas Volume & Waste Heat Losses

KNOWLEDGE BASED DECISION AUGMENTATION MODULE

This module works on forward reasoning technique and realises the real-time forecast of heat demand for required battery temperature, using case-based reasoning (CBR) neural network in conjunction with “Mathematical Model”. This model also continuously tunes the constants appearing in the equation.

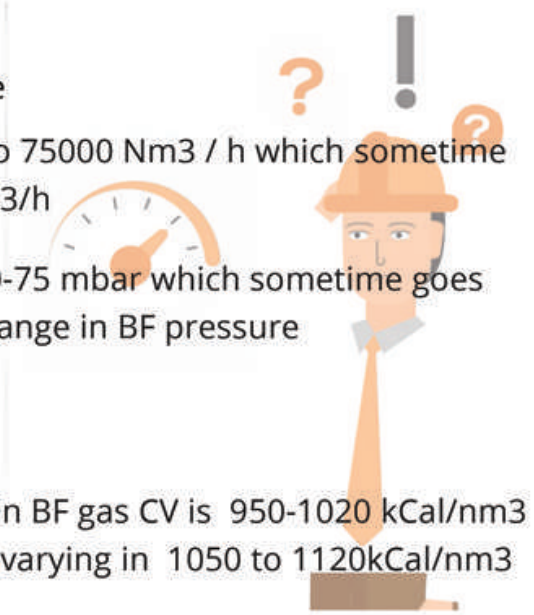
RULE BASED DECISION AUGMENTATION MODULE

The heating module kernel has decision-making logic as rules that are processed by an Inference Engine. The rules are “Heuristics” - If/then rules that are the individual steps that adds up the overall decision. It has the backward chaining of reasons (conventionally which can be considered as feedback loop) and forward chaining of reasons (conventionally which can be considered as feed forward loop) helping to make the suitable decision

CORRECTIONS ARE MADE WHEN THESE TEMPERATURES ARE OUTSIDE THE TARGET RANGE AND ARE EXECUTED BY

Changing The Heating Pause Time
Changing The Gas Flow or Pressure
Changing The Heating Value Of The U-gas

ARE THESE THE CHALLENGES IN YOUR COKE BATTERY



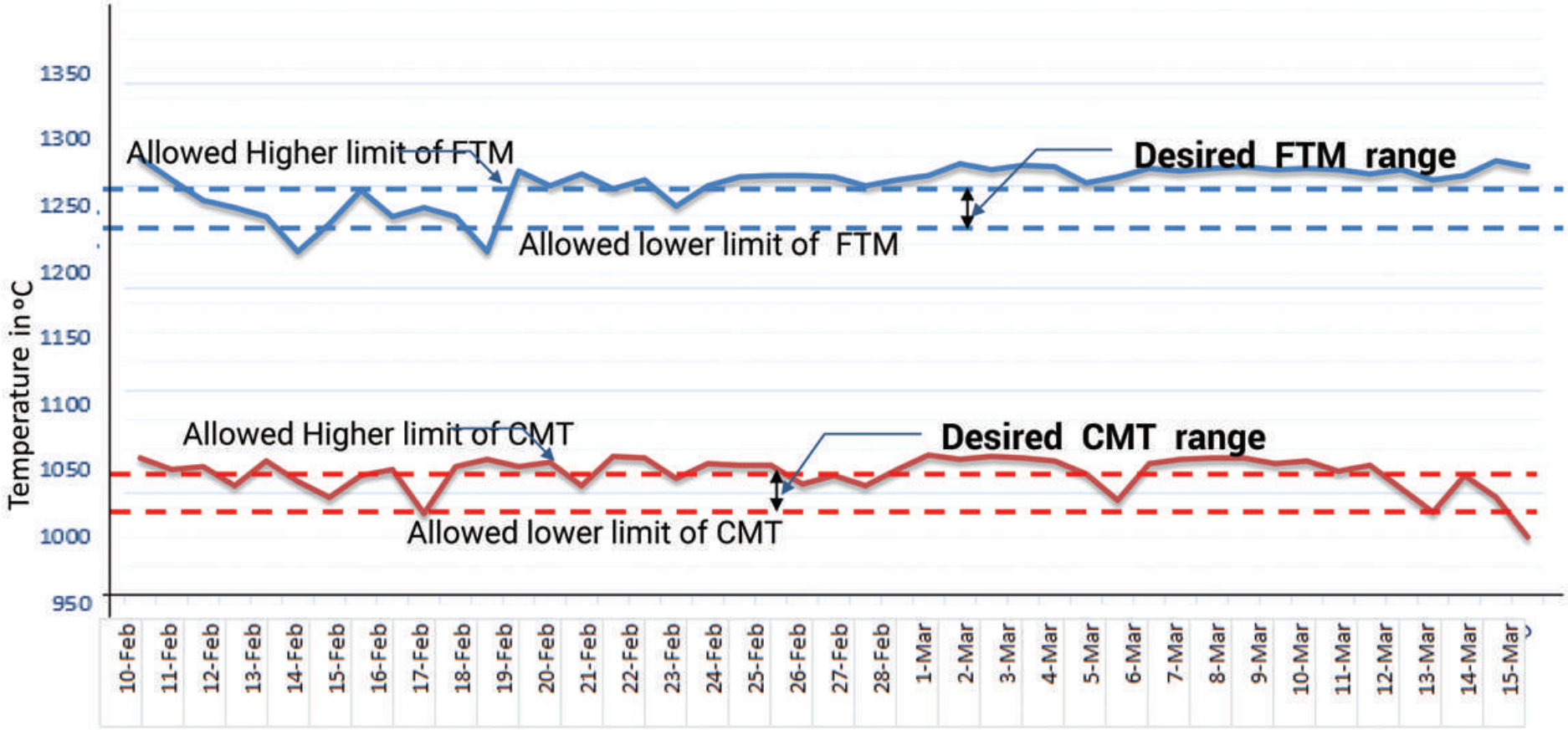
- Fluctuation in gas flow/pressure
  - Normal flow rate is 67000 to 75000 Nm3 / h which sometime goes as low up to 60000 Nm3/h
  - Normal Pressure range is 50-75 mbar which sometime goes as low as 35 mbar due to change in BF pressure
- Fluctuation in CV
  - General range of operation in BF gas CV is 950-1020 kCal/nm3 but in our case it is typically varying in 1050 to 1120kCal/nm3 range
  - CV has to be maintained consistently is challenge as BF gas flow is also varying randomly
- Wide change in pushing schedule

Normal	90-93(with drop-out ovens 1 or 2 oven)
Demand change	+/-5 oven in day plan
Gas changeover	+ /- 7 oven

EAGLE COKE™ SOLUTION OVERCOMING THE CHALLENGES

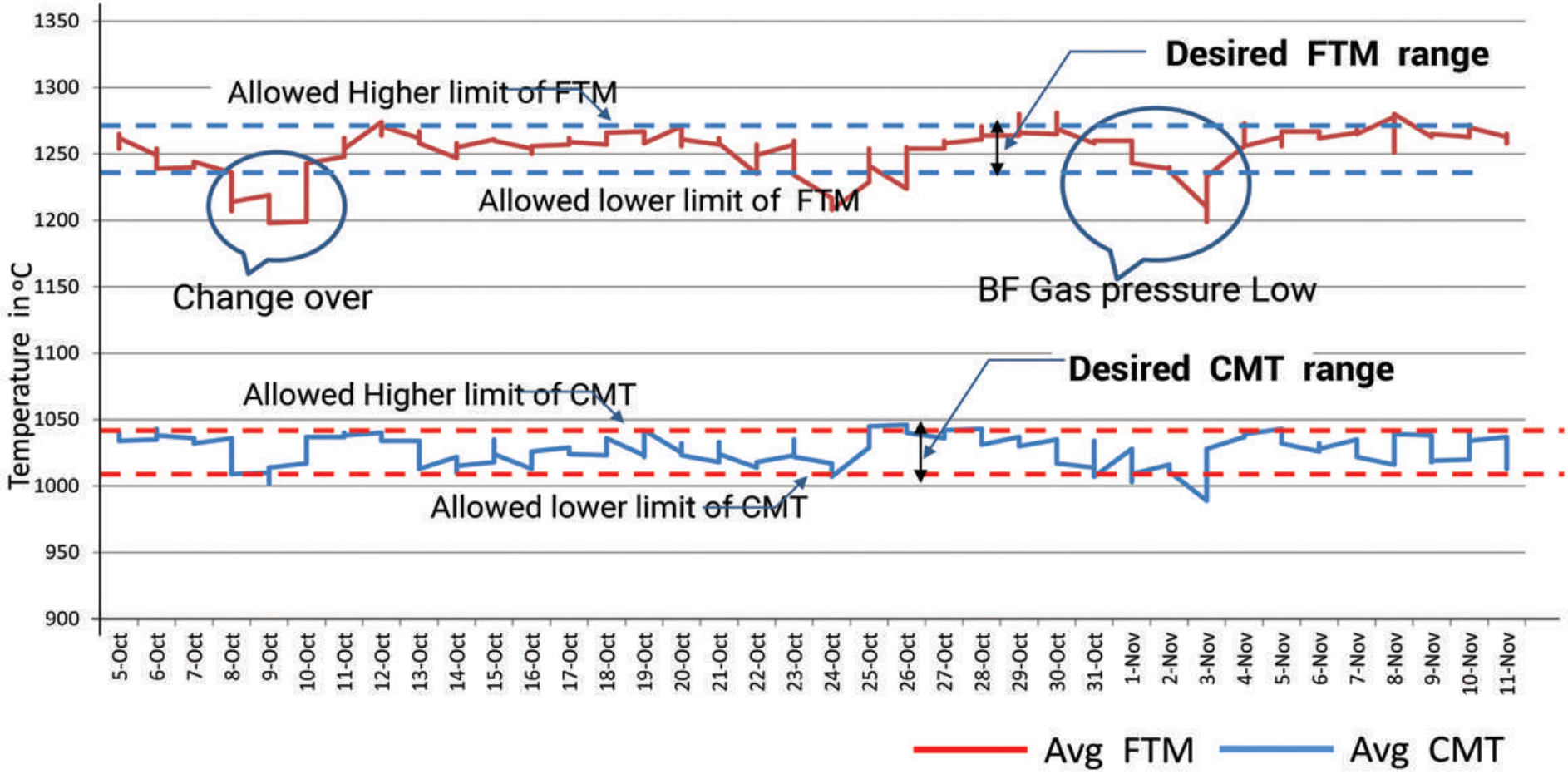
1. Control of COG flow to attain the desired mixed gas CV value
2. Based on the wide variation of pushing schedule, system is able to increase and decrease the heat input
3. Auto sequencing of Pushing schedule in case of out of sequence of oven charging.
4. Attaining consistent CMT and battery temperature range

PERFORMANCE OF FTM AND CMT WITHOUT PLATFORM



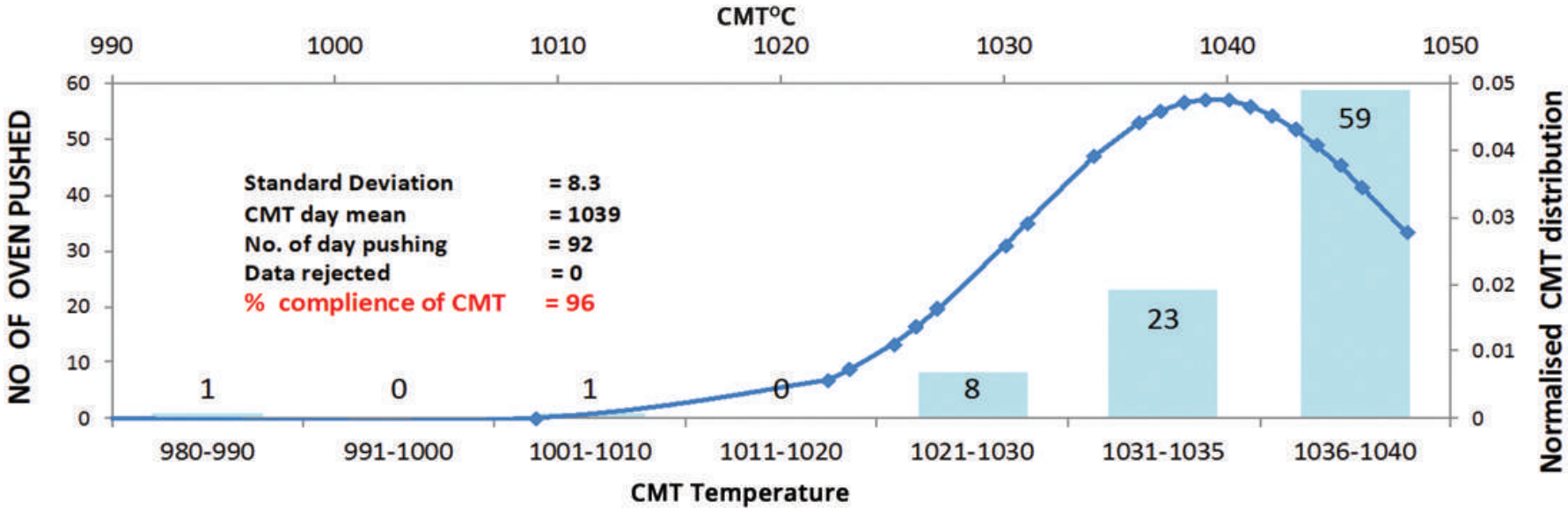
The blue dotted line indicates the "allowed FTM temperature range". When the battery heat input was controlled manually; it was not possible to keep battery temperature within desired band. Either battery was cooling OR it was overheating. Same way CMT also remains at higher side i.e. towards higher limit of CMT (red dotted line). This is mainly because of higher battery temperature. It has been observed that it was vary difficult to keep the battery temperature within band due to uncontrolled variation of U-gas flow as well as CV value. Since, it was not possible by battery operator to decide upon the heat input requirement under such changes.

PERFORMANCE OF FTM AND CMT WITH PLATFORM

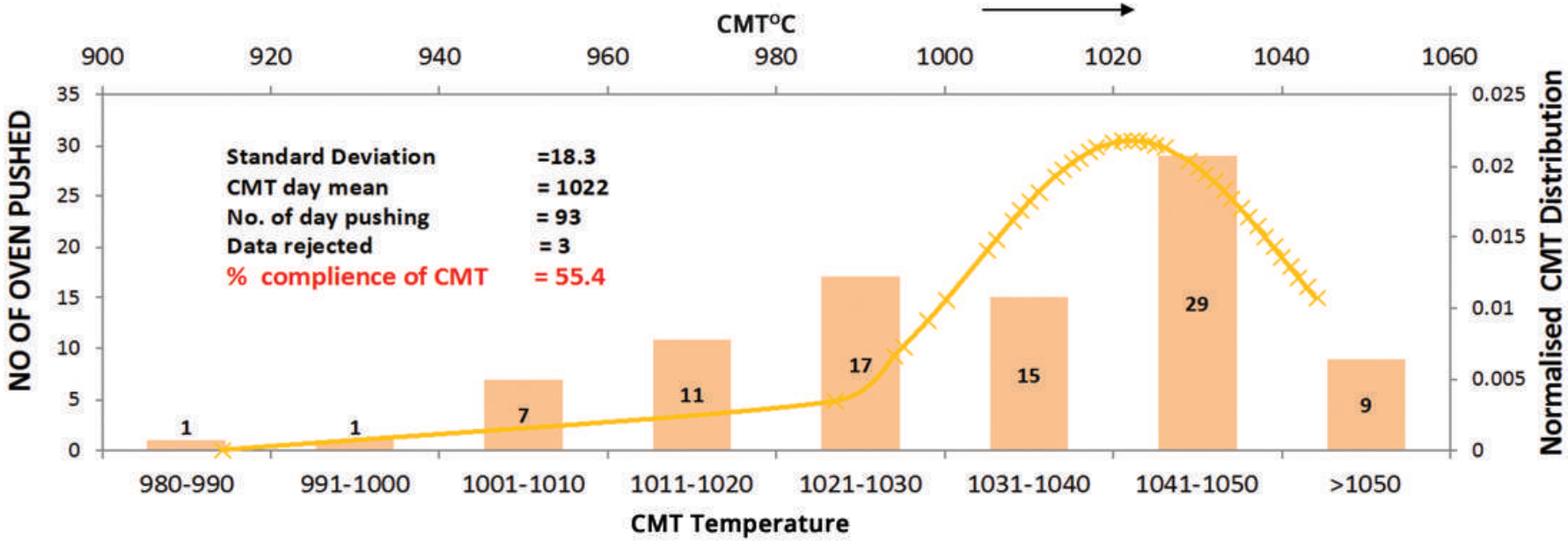


In **EAGLE COKE™** heating control mode, the over all battery performance was found smooth and takes care the typical operating conditions. In this slide a typical FTM & CMT data under **EAGLE COKE™** control mode' are analyzed and presented In the period Oct-Nov 2018, there was change over from BF gas to CO gas due to less availability of BF gas. Battery was CO mode for ~1 day (from mid of A-shift on 7th oct to late C-shift of 7th Oct). Due to change over the pushing target reduced, accordingly battery was taken into 'neutral' and the battery temp (FTM) reduced as shown in diagram. But, **EAGLE COKE™** takes over the control by adjusting the coking time and pause control and as soon as the BF gas availability restores back quickly the battery temperature is boosted up and the coking time starts reducing (not shown in graph) to reach the normal pushing demand (93 ovens/day). There after the battery temperature maintained HIGHLY within limit. On 2nd Nov (in B shift) there was pressure fall causing the gas restriction ~10hrs. The system readjust the pushing target during gas restriction and restoring it to the normal pushing target (coking time) once gas restriction is over. Most important point to be noted that in either case the CMT is maintained (except few pushing [4 nos] on 2nd Nov C shift) well within the limit. (ref CMT graph) The comparison of previous slide and this slide shows the superiority of battery controllability within close tolerance with **EAGLE COKE™** over manual control. It also confirms that the un-predicted battery abnormal operating conditions are controllable with the **EAGLE COKE™**

COMPARATIVE PUSHING WITH PLATFORM

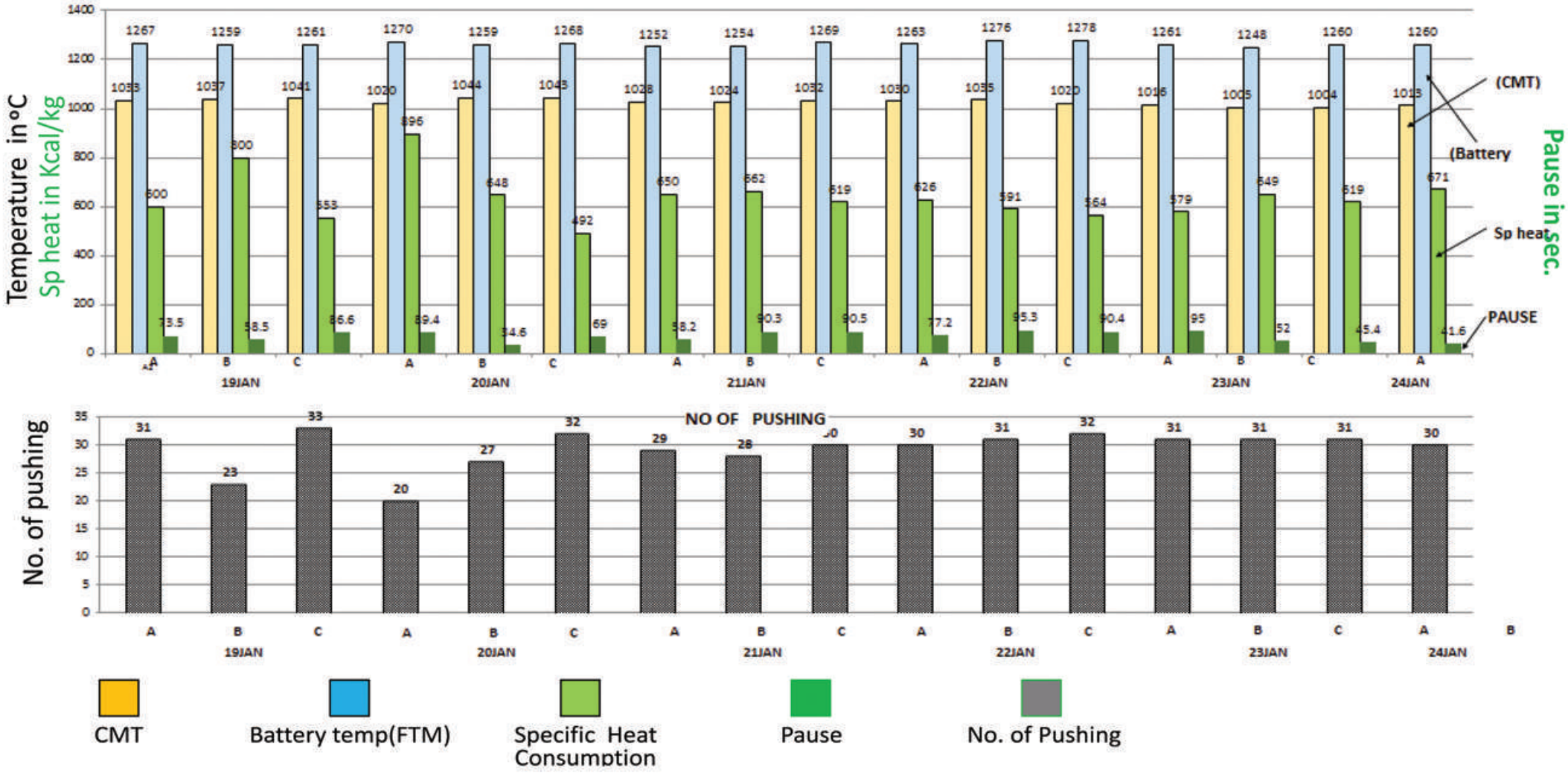


COMPARATIVE PUSHING WITHOUT PLATFORM



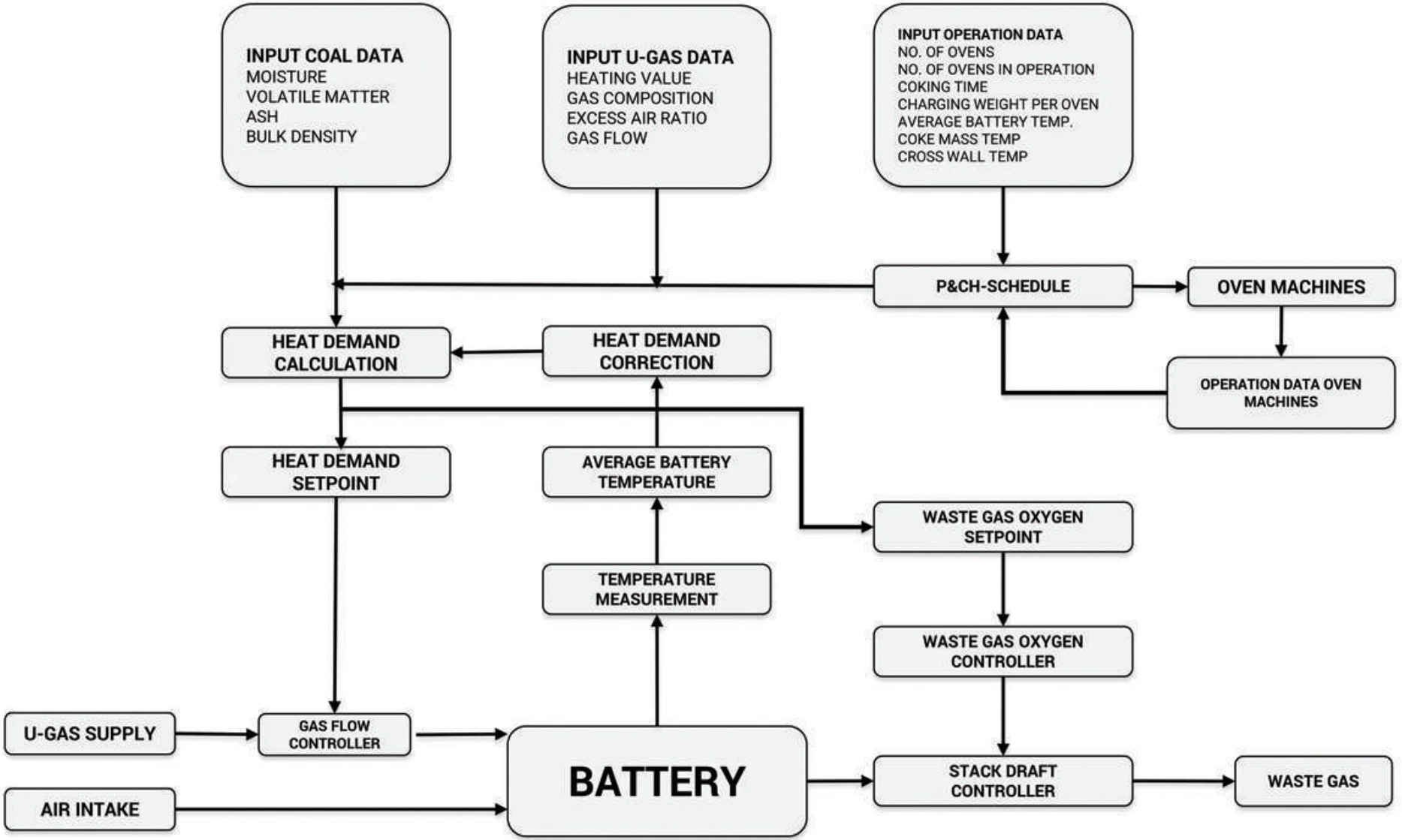
Desired range of CMT by user is 1020 -1040 °C and the best range desired is 1030 +/- 5 °C. With platform total 88 nos. of pushing are in 1020 -1040°C Range. Without platform 38 nos. of pushing are within desired range, 38 nos. over the range and undertake desired range is 20 number of pushing. Standard deviation desired by customer is +/- 12 and achieved is 8.3 when battery is controlled with Platform.

OVERVIEW OF BATTERY PERFORMANCE

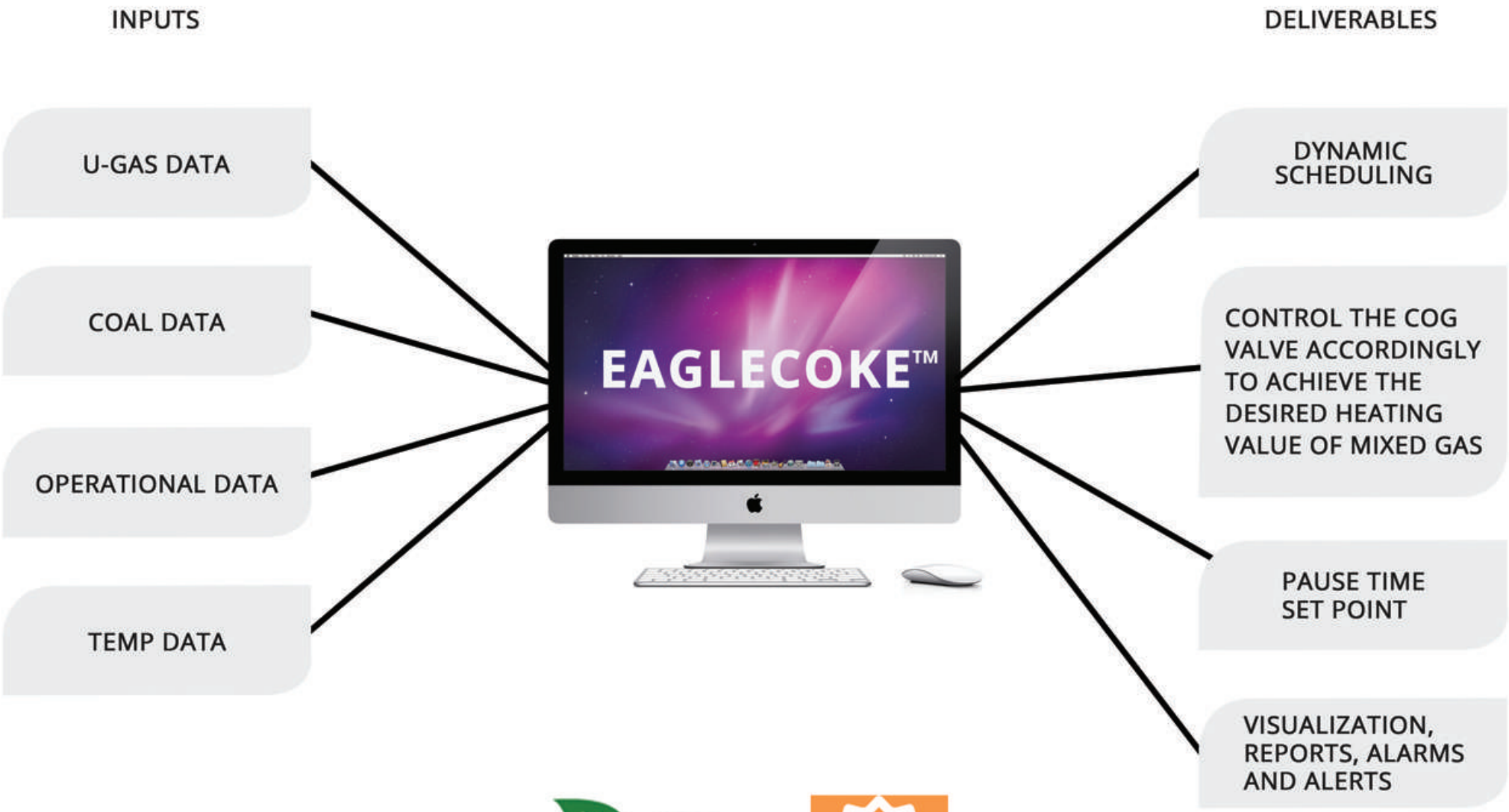


This slide illustrates a comparative overview of battery operation under different pushing irregularities. It may be observed that on 19th A shift their was 31 pushings,B shift there was reduced pushing and accordingly system has identified this operating condition (abnormally reduced pushing) and had taken action to reduce the heat input and maintained the battery temperature at 1259°C (in 19th B shift) and 1261°C (in 19th Cshift). It may also be noted that in C shift there was 33 pushing and system tried to increase the heat input which got reflected on 20th Jan FTM. On can observe that temperature has gone to 1270°C (little above limit). This is mainly because of less (11 nos) pushing than the target (31 oven planned). However, based on battery temperature feed back the EAGLE COKETM has taken action to bring back temperature within range. It is also vary important to note that average CMT was within limit (1020°C-1040°C) during these pushing irregularities period (19th – 20th Jan). This confirms that the MODEL is robust enough to take care these types of abnormalities.

HEATING CONTROL MODEL



EAGLE COKE™ INPUTS AND DELIVERABLES



FUNCTIONAL ACHIEVEMENTS BY IMPLEMENTING EAGLE COKE™

IMPROVING COKE QUALITY STEADILY:

EAGLE COKE™ stabilizes the coke oven heating temperature, the vertical flue temperature and effectively reduces the vertical flue temperature variation and put under control within ±10°C; inturn provides a guarantee for improving the coke quality effectively.

INCREASING GAS UTILIZATION RATE AND SAVING ENERGY:

EAGLE COKE™ establishes a coke oven heating control model and controls the best heat supply to achieve the purpose of saving heating gas and adjusting oxygen content in waste gas (that is, controls to have a suitable excess air coefficient) to realize the best combustion. Energy balances reduces the carbon footprint by ensuring there is no waste or energy leakage.

REDUCING EMISSIONS AND POLLUTION:

EAGLE COKE™ significantly reduce exhaust pollution, smoke and dust pollution from coke pushing and realizing environmentally friendly production of coke oven.

INCREASING SAFETY ASPECTS OF BATTERY OPERATION:

EAGLE COKE™ increases the safety aspect of battery operation with Mathematical modelling, Closed looped systems and artificial intervention, increasing the work place safety.

VALUE DELIVERY RECOMMENDATION BY EAGLE COKE™

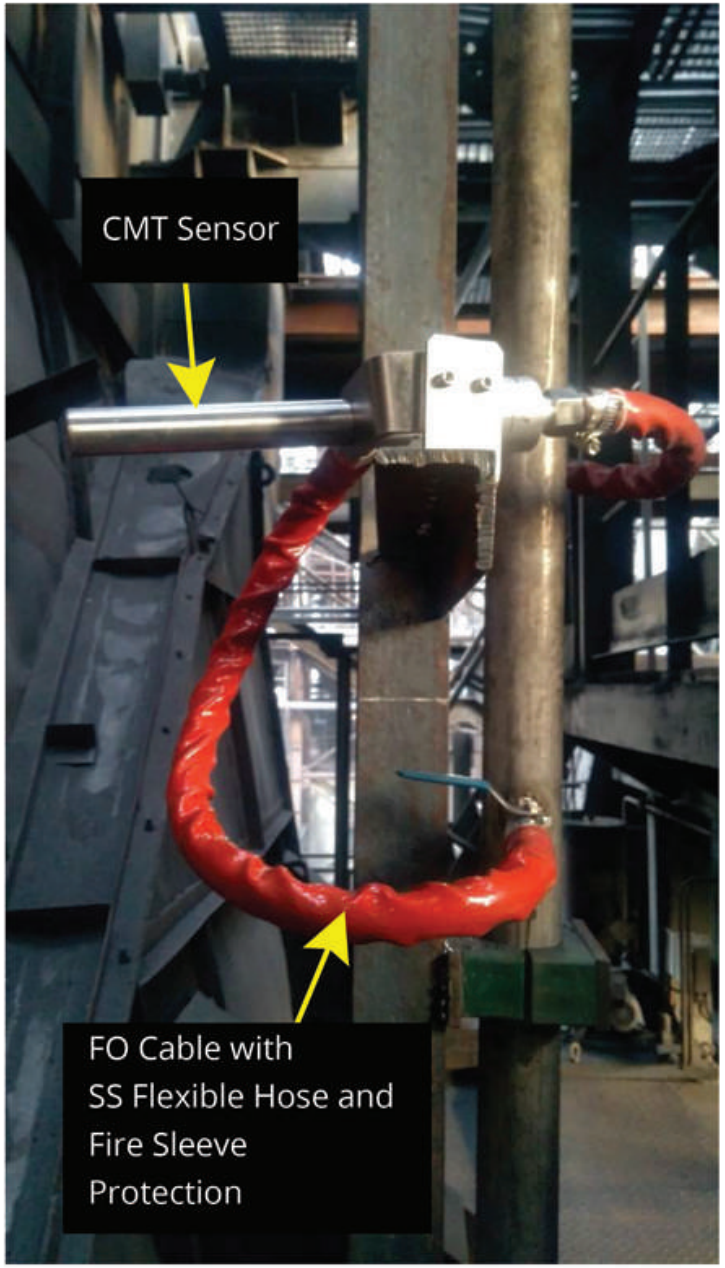
CSR improvement up to 5% as system will maintain the battery temperature in the desired limits. 1% CSR improvement will causes 3kg reduction in coke consumption for 1ton hot metal (THM) production.

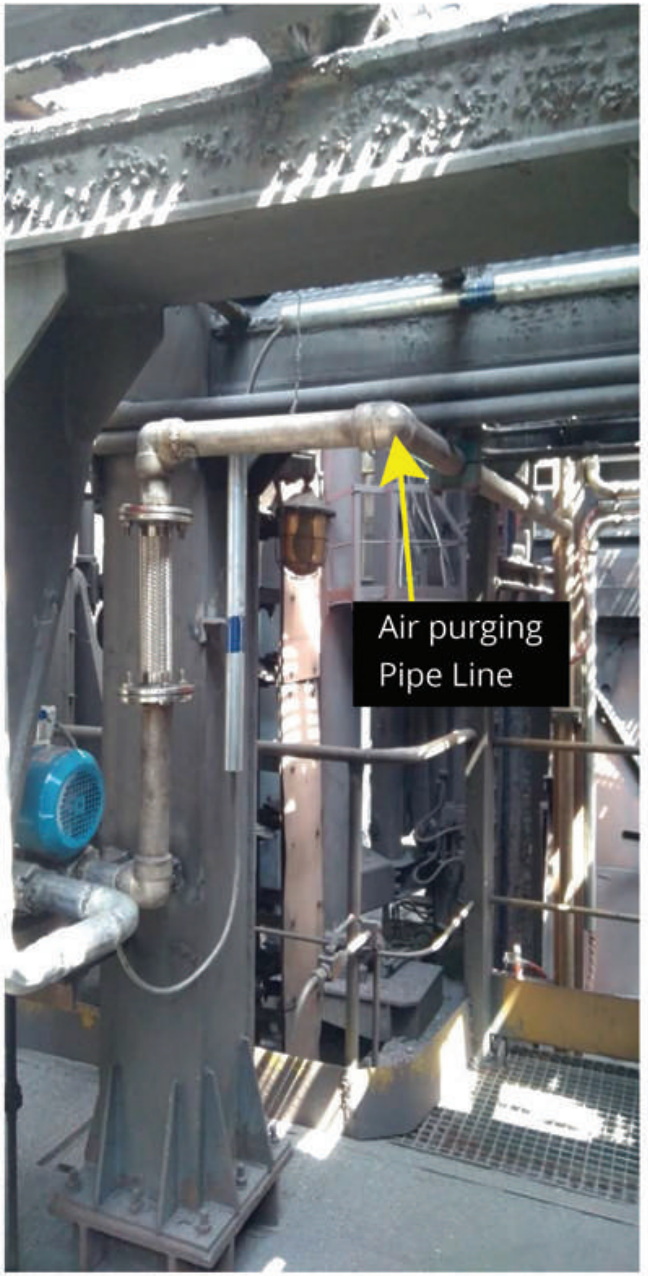
CO emission / Tons of Coke Production will further reduce due to maximize combustion of gases as system will ensure maximize combustion of gas.

Consistency of Coke Quality will remain same even with irregular pushing's also as system will take care of running the battery in the limits

Dynamic scheduling for Smooth transition from low pushing to high number of pushing or vice versa will optimize production to maximum level.

ENGINEERED CMT MEASUREMENT SYSTEM IN GUIDE CAR





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