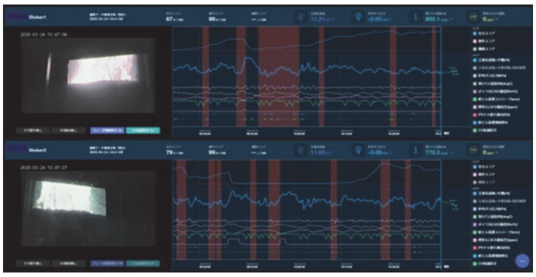
Introduction of Remote Monitoring and Operational Support Systems Aiming at Optimal Management of Waste to Energy Plants



TOMOMICHI EGUSA[*1] **YOSHINORI TERASAWA**[*1]

WATARU SUZUKI[*1] **SEIJI MASUYAMA**[*2]

KEIICHI HAYASHI[*3] **HITOSHI TAMURA**[*4]

Mitsubishi Heavy Industries Environmental & Chemical Engineering Co., Ltd. (MHIEC) develops designs, constructs and installs plants to treat waste such as municipal solid waste and sewage sludge. MHIEC also provides after-sales services and operational management of such plants.

MHIEC basic strategy of services and operations is to integrate efficiently a wide variety of our internal/external data and to utilize them appropriately for business, using the leading-edge technology of Artificial Intelligence (AI) and the Internet of Things (IoT). Since 2018, we have utilized AI and IoT technologies to handle data related to Waste-to-Energy (WtE) plant operation and power generation at the Tsuzuki WtE plant of the Resources and Waste Recycling Bureau, City of Yokohama, Japan. This joint research project sharing data with the city government is under way now.

This report summary the current applications of our remote monitoring and operational support systems, the situation surrounding the challenge of enhancing the systems, and the joint research project with the City of Yokohama in which these systems are utilized.

1. Introduction

MHIEC is mainly engaged in new construction and core component improvement, as well as life extension work for non-industrial WtE (e.g. municipal solid waste treatment), commercial plants for industrial waste treatment, sewage sludge dewatering/drying and incineration plants. We provide all-inclusive integrated engineering services ranging from domestic/overseas operation plans to after-sales services/operation management, including operation and maintenance management work in Design-Build-Operate (DBO) projects and Operation and Maintenance (O&M) of existing plants.

The recent needs of WtE plants are often the simultaneous realization of stable operation and cost reduction. An increasing number of WtE plants are now run by the private sector on a DBO basis as a result of administrative transitions from municipalities. Moreover, as the shortage of experienced operators is getting worse, it is getting important not only the availability of conventional on-site operation/management, but also remote support systems and its capabilities.

Under such circumstances, the number of projects in which we are in charge of not only WtE plant engineering, procurement and construction, but also long-term administration, is increasing. Therefore, to centrally manage the operating conditions of multiple waste-to-energy plants at MHIEC's Head Office (in Yokohama), we have established a combined remote monitoring and operational support system, by which the operation data from each plant are aggregated and analyzed. The obtained insights into one plant are applied to the other plants to realize more advanced and more efficient administration.

*1 Manager, New Product Development Unit, Engineering Division, Mitsubishi Heavy Industries Environmental & Chemical Engineering, Ltd.

*2 Group Manager, Design Unit, Engineering Division, Mitsubishi Heavy Industries Environmental & Chemical Engineering, Ltd.

*3 Group Manager, Special Purpose Company Management Promotion Unit, Domestic Division, Mitsubishi Heavy Industries Environmental & Chemical Engineering, Ltd.

*4 Manager, Growth Strategy Office, Mitsubishi Heavy Industries, Ltd.

Together with the City of Yokohama, we have also built an interconnected network between the WtE plant, the Yokohama City Government Office and MHIEC for the sharing of the operation data of the plant. The collected data are analyzed using AI and IoT technologies. We are thus conducting a joint research project to "introduce AI and IoT technologies in WtE plants through a public-private partnership" with the aim of achieving more advanced "stable operation of WtE plants."

This report summary the current applications of our remote monitoring and operational support systems, the situation surrounding the challenge of enhancing the systems, and the joint research project with the City of Yokohama in which these systems are utilized.

2. Overview of our remote monitoring and operational support systems and their basic functions

Of the two separate systems for remote monitoring and operational support, the former "remote monitoring system" is first addressed. The basic configuration is given in **Figure 1**. This system came into operation as part of our first DBO project, when we supplied a waste treatment plant with a gasification and ash melting system in 2005 and remote monitoring was introduced in the plant. Since then, the system has been included in the standard package for our WtE plants. At present, we are operating the system in conjunction with eight plants across Japan. By constantly collecting the plant data from each facility, we are taking on the challenge of enhancing our support with the help of AI. As shown in **Figure 2**, the system basically fulfills the following two functions ① and ②.

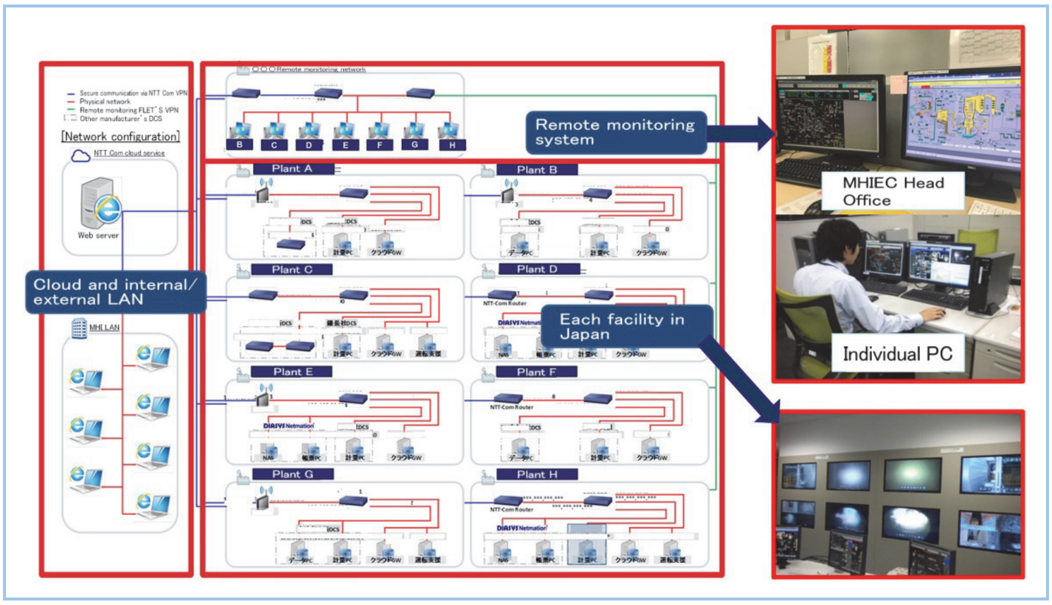


Figure 1 Network topology of remote monitoring system

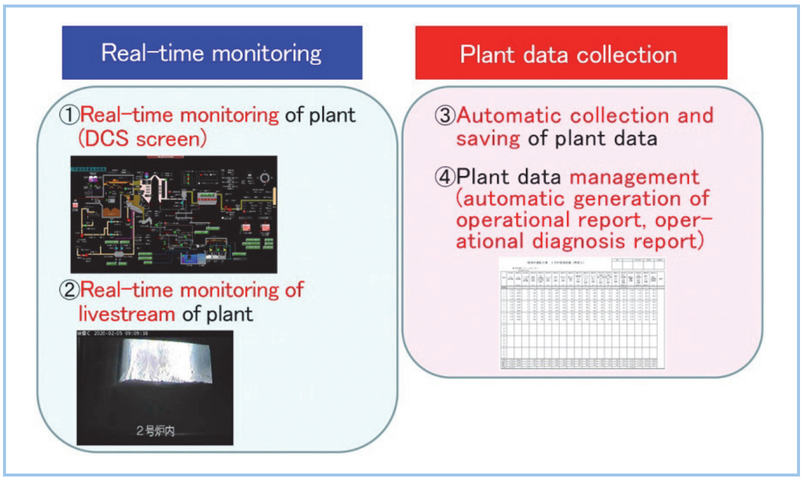


Figure 2 Basic functions of remote monitoring system

① Real-time monitoring

Remotely monitor in real time the screen and livestream of the on-site plant distributed control system (DCS).

② Plant data collection

Collect on-site plant data and create a database to automatically generate operation reports.

In the latter "operational support system," as shown in **Figure 3**, when an alarm is issued by the DCS that controls each facility, the alarm data will be saved. This system can simultaneously infer the cause of the problem from the operational support system database that contains various collections of operational expertise. The on-site gauges can be photographed as needed, and the readings are then digitized before being imported as data. Meanwhile, the inferred causes and countermeasures are suggested to allow quick response and action. With this system, therefore, even inexperienced operators can promptly learn to operate the plant in a skillful way like experienced operators, which leads to a high-quality and standardized level of plant operation.

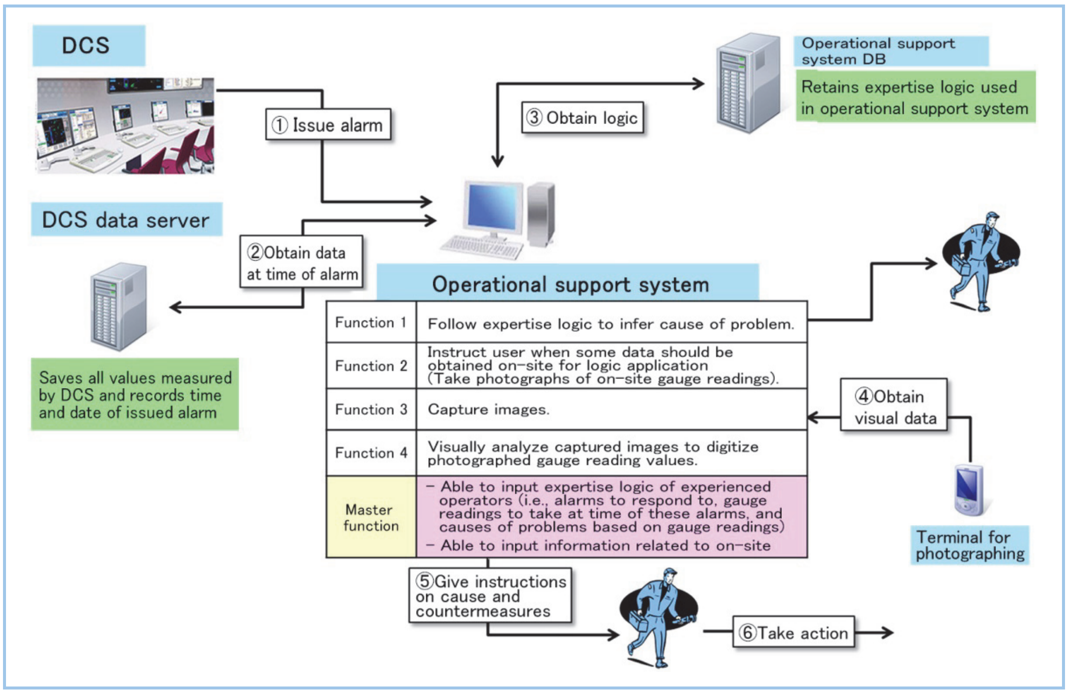


Figure 3 Operational support system configuration

3. Approach to realizing advanced automatic operation

MHIEC intends to enhance the appeal of this product through ICT enhancement, thereby working toward advanced automatic operation of WtE plants, that is, advanced automatic operation in which the performance is maximized in consideration of equipment life, and operational management with no involvement of factors specific to individual operators, by which high-quality and homogeneous operation and maintenance can be performed safely with no mistakes, irrespective of the operator in charge. We have therefore developed a tool to clearly visualize data obtained on-site and analyze them in real time (called Visualizer^{TM}).

Using Visualizer^{TM} to build an operational model through machine learning enables the AI prediction of process data such as the amount of evaporation, and calorific value of waste. The operator checks such predicted data-based operational guidance (i.e., presentation of information on operating method) and handles operations accordingly. The resulting outcomes will be applied to automatic operation (nearly no intervention by the operator). As such, we are taking on the challenge of realizing advanced automatic operation of WtE plants that are safe and economical and performing efficient management and operational control as shown in **Figure 4**.

3.1 Data analysis functions of Visualizer^{TM}

(1) Plant data visualization (Figure 4 ①)

Visualization of the abundant collected data, by zooming in or out freely through simple mouse manipulation, thereby enabling data to be displayed based on time ranges from macroscale (several years) to microscale (several seconds).

(2) Data analysis (to understand correlations, etc.) (Figure 4 ②)

Statistically process the collected data to understand correlations and extract characteristic quantities, which is performed automatically.

3.2 Approach to realizing advanced automatic operation

(1) AI predictions (e.g., the amount of evaporation, and calorific value of waste.) (Figure 4 ③)

To achieve advanced automatic control, we have built AI prediction models for the amount of evaporation, amount of calorific value of waste (i.e. LHV (lower heating value)), CO generation at high concentrations within a short period of time, etc. In terms of the major indicators such as the amount of evaporation and calorific value of waste the big data collected in the past, specifically various types of process data such as process variables (PV) and flame image data (ITV: Industrial Television), are used to predict the amount of evaporation. The predicted data are displayed on the dashboard screen in real time. In the case of predicting the amount of evaporation in 3 minutes from a given moment, the predicted values are highly accurate compared with the measured values, as shown in **Figure 5**. Good following capabilities have also been confirmed in respect to not only the amount of evaporation, but also other indicators such as LHV of waste. We aim to further improve the prediction precision toward the realization of advanced automatic operation.

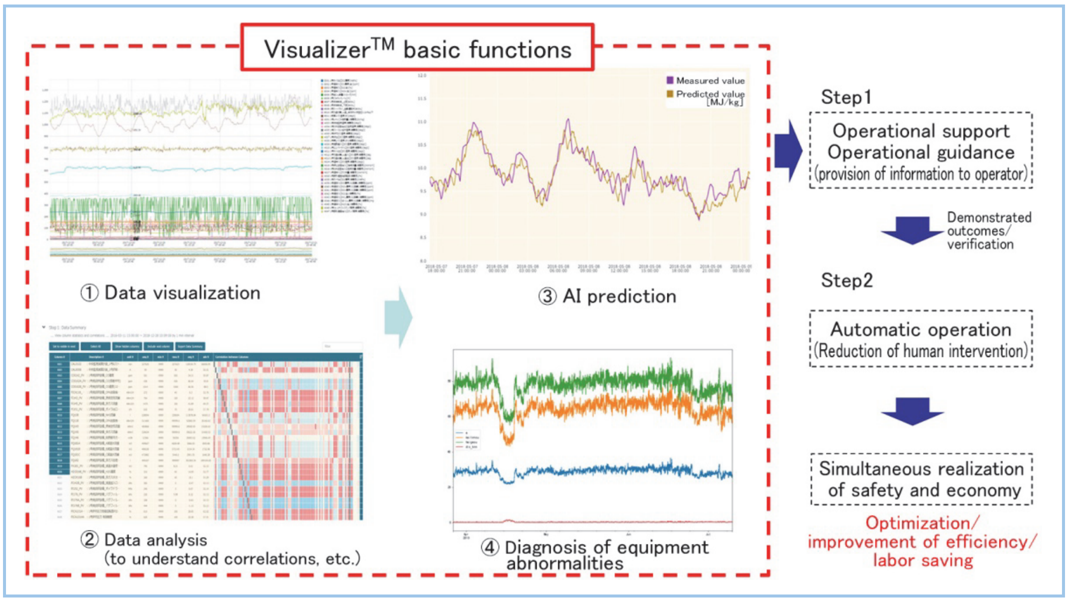


Figure 4 Approach to realizing advanced automatic operation

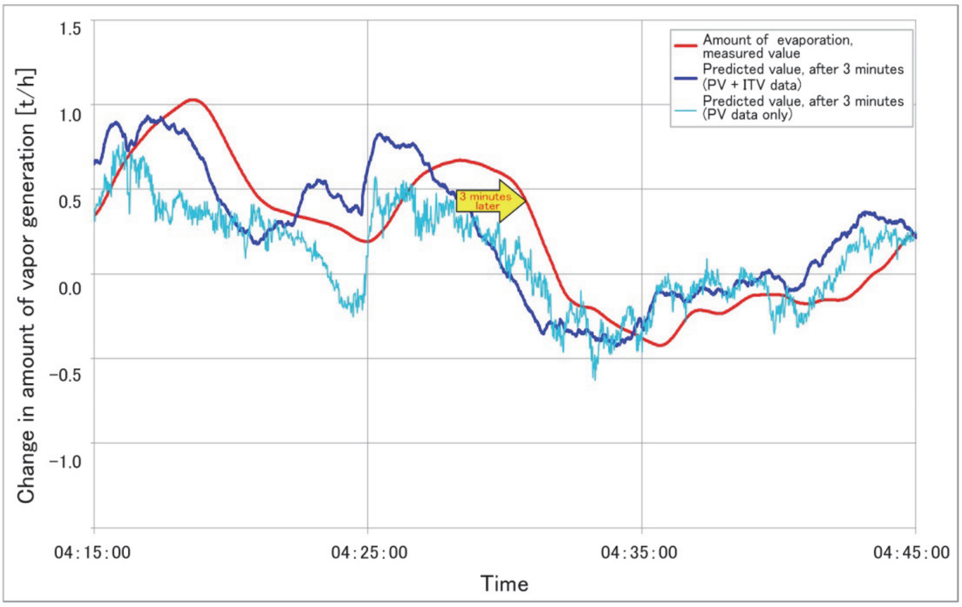


Figure 5 Results of predicted amounts of evaporation

(2) Diagnosis of equipment abnormalities (Figure 4 ④)

Using the process data including electric current applied to equipment, abnormalities are diagnosed based on the degree of abnormality estimated by the k nearest neighbor algorithm (k-NN method). As k-NN method is a supervised learning classification algorithm, the k-NN method can classify newly collected data as normal or abnormal by majority decision according to the distance from the k sets of data that have been collected.

(3) Approach to realizing advanced automatic operation

In Step 1, as shown in **Figure 6**, based on the process data predicted by AI (such as the amount of evaporation), operational guidance containing "recommended set values" is formulated to present the information to the operator. The operator then checks the recommended set values displayed on the operational control indicator guidance screen and handles it accordingly to demonstrate the stable operation of WtE plants. In Step 2, operational guidance (operational guidelines), the validity of which has been demonstrated, is applied to the automatic control of WtE plants, thereby enabling the reduction of intervention by the operator. As a result, advanced automatic operation will eventually be made possible. It will also become viable to perform stable operation, increase the amount of power generated, reduce the maintenance costs, etc., while ensuring the equipment life.

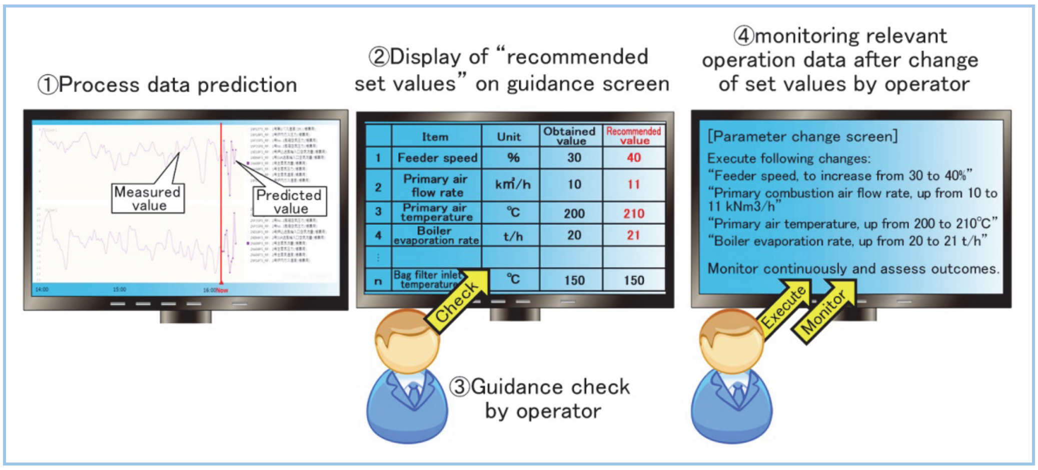


Figure 6 Conceptual diagram for introduction of operational guidance

4. Summary of joint research project with City of Yokohama

Together with the City of Yokohama, we have undertaken a "study on information sharing of a WtE plant in Yokohama through the use of AI and IoT technologies," and are monitoring operations in real time at the remote-monitoring and operational support center established within the premises of our company (**Figure 7**). By optimizing operations through the sharing of information related to the waste-to-energy plants using AI and IoT technologies, we aim to realize the stable operation of waste-to-energy plants and reduce operation costs.

Figure 7 Remote-monitoring and operational support center

4.1 Building interconnected network between Tsuzuki Plant, City Government Office and MHIEC

To obtain the relevant data including various types of operation data, power generation data and image data related to the WtE plant (Tsuzuki Plant) in Yokohama in real time, we have built a remote monitoring network connecting the three sites—City Government Office, Tsuzuki Plant and MHIEC—with each other (**Figure 8**). In this joint research, we aim to enable visualization through remote monitoring and analyze the collected big data using AI technology, with the goal of realizing more advanced "stable operation of waste-to-energy plant."

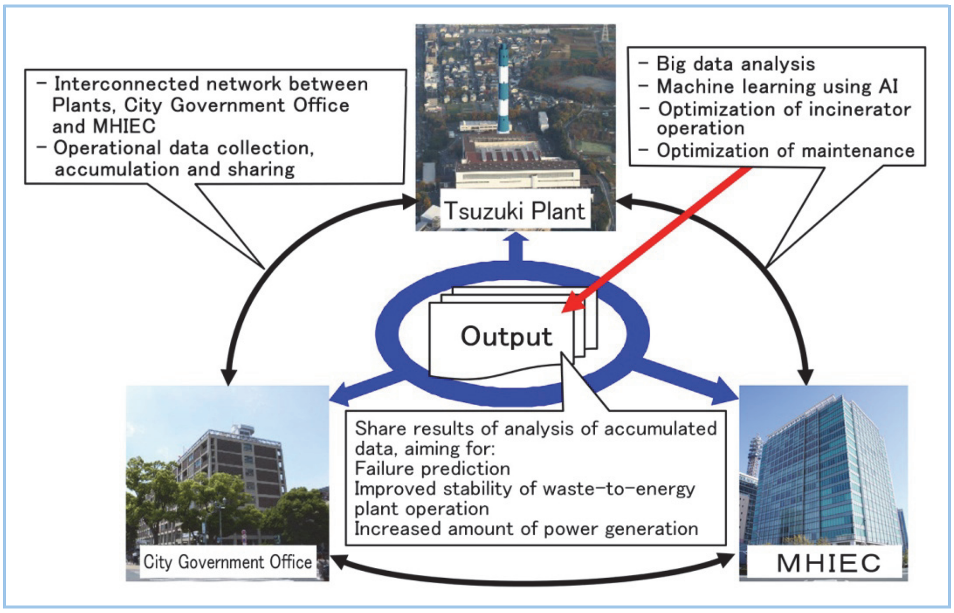


Figure 8 Conceptual diagram of network with Yokohama City

4.2 Use of AI technology to predict operating process values and realize stable operation

In this study, IoT technology has enabled the City Government Office and MHIEC to check the operating conditions of the WtE plant and collect its operation data in real time. By collecting and accumulating images and operation data as big data, therefore, it becomes possible to perform various analyses. The big data are then analyzed using AI technology, which enables predictions for the amount of evaporation, calorific value of waste, etc. (**Figure 9**). The stability of WtE plant operation can be further improved. We will eventually incorporate such prediction methods into the control system, aiming for the realization of automatic operation.

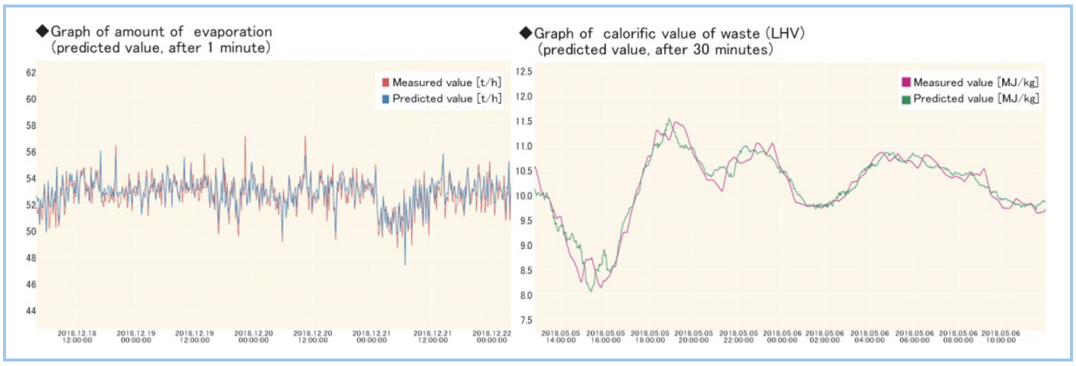


Figure 9 Results of predictions for amount of evaporation and calorific value of waste

4.3 Introduction of cybersecurity system

In the remote monitoring of waste-to-energy plants, it is necessary to consider the risk of cyberattacks via networks, etc. To reduce such cyberattack risk, we have tentatively introduced a cybersecurity system called "InteRSePT®" which was jointly developed by Mitsubishi Heavy Industries, Ltd. (MHI) and NTT.

"InteRSePT®" is a cybersecurity technology for control systems such as important social infrastructure. It can detect abnormalities caused by unknown cyberattacks in real time and counteract them, allowing control systems to be operated safely and securely. At present, MHI is introducing its application into the fields with private-sector demand such as thermal power generation plants and chemical plants. As another trial application, we have tentatively introduced “InteRSePT®” to the Tsuzuki Plant. The initial stage of testing has been completed, and confirmed the appropriate functioning of this cybersecurity system. With a view to its full-scale introduction in the future, we will examine the performance of the system to further enhance its functions.

5. Approach to homogenizing the properties of waste

Jukan Operation Co., Ltd., an MHIEC Group company, uses machine learning in the operation of publicly-built and publicly-run waste treatment plants to build the following two systems: “AI hybrid system®”, by which calorific value of waste (LHV) is predicted, and with the help of a knowledge system, operational guidance is provided [1], and the “waste pit mixing support system,” by which the properties of waste can be made uniform. In the waste pit mixing support system, the mixing conditions of waste can be quantitatively assessed based on three parameters: “number of mixing”, “apparent specific gravity” and “retention time”. By developing a method in which waste is efficiently mixed/homogenized before being fed to the WtE plant with minimized variations (standard deviation) of calorific value of waste (LHV) [2],[3], we are contributing to stable combustion in the WtE plant shown in **Figure 10**.

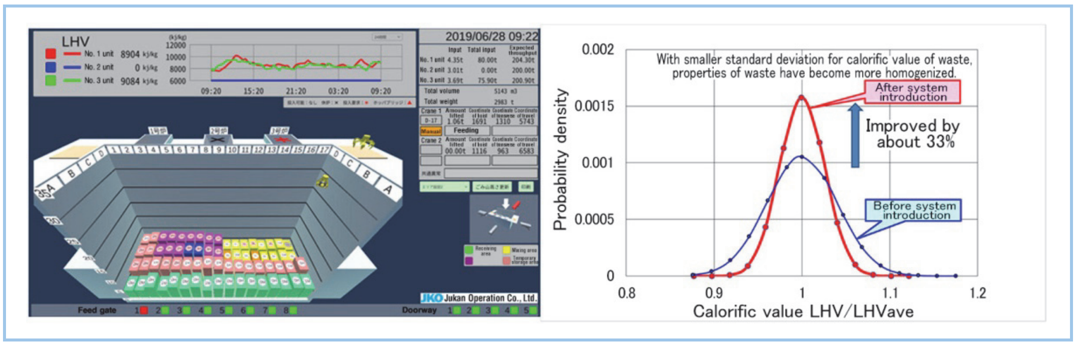


Figure 10 Overview of waste pit mixing support system

6. Conclusion

Toward advanced automatic operation of WtE plants, we have developed a tool to clearly visualize data obtained on-site and analyze them in real time (called Visualizer™). The realization of advanced automatic operation using AI technology makes it viable to perform stable operation, increase the amount of power generated, reduce the maintenance costs, etc., while ensuring the equipment life.

In addition to waste-to-energy plants, we will work on the enhancement of ICT with a view to application to other products such as industrial waste plants, sludge treatment/incineration plants, and biomass power generation/sludge regeneration plants.

InteRSePT® is a registered trademark of Mitsubishi Hitachi Power Systems, Ltd. in Japan.

AI Hybrid System® is a registered trademark of Mitsubishi Heavy Industries Environmental & Chemical Engineering Co., Ltd. and Jukan Operation Co., Ltd. in Japan.

References

(1) Yudai Kato et al., One Stop Solution from Understanding Facts, Setting Goals, to Optimization AI Support for Plant Operation, Mitsubishi Heavy Industries Technical Review Vol. 55 No. 4 (December 2018)

(2) Yoshinori Goto et al., Development of Waste Mixing and Supply Support System, the 41th Waste Management Research Symposium proceedings, and Ⅱ-3-69 (2020), p.211-213

(3) Jukan Operation Co., Ltd., Waste Pit Mixing Support System, http://www.jko.co.jp/operation/index.html