AI Remote Monitoring and Operational Support System MaiDAS® for the Sustainability of Waste to Energy Plants

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Mitsubishi Heavy Industries Environmental & Chemical Engineering Co., Ltd. (MHIEC) has developed MaiDAS®, which is a next-generation AI-based remote monitoring and operational support system for Waste to Energy (WtE) plants. This system enables advanced automatic operation while maintaining the health of important equipment for plant operation and optimizing the amount of evaporation and the output of exhaust gas concentration while eliminating the effect of variable factors associated with individual operators. The use of this system can predict in real time values such as Low Heating Value (LHV), the amount of waste feed, and combustion conditions. The advanced automatic operation, which is controlled by the system, can considerably reduce manual intervention. The stabilization of the main steam flow rate has also been confirmed. Together with this system, the improvement of the already-developed waste pit mixing and feeding support system is considered to make it possible to realize both stable operation and cost reduction, while maximizing the sustainability of WtE plants.

1. Introduction

In recent years, one of the most important needs of WtE plants is the simultaneous realization of stable operation and cost reduction, while maximizing their sustainability. Furthermore, remote operational support is getting more indispensable than ever, when stable operation and cost reduction are also aimed to be achieved in relation to the shortage of experienced operators, the spread of infectious disease, and CO_2 emissions reduction to curb global warming. Given these circumstances, MHIEC has developed MaiDAS®, an AI-based remote monitoring and operational support system for the optimal management of WtE plants. This system enables advanced and efficient plant operation by aggregating the operational data from each plant using the cloud server and sharing the know-how obtained therefrom with other plants, with a view to centrally managing the operating conditions of multiple plants(1)(2). For better combustion stability, we are augmenting the already-developed waste pit mixing and feeding support system(3) with a crane automation system. This report presents the results we have obtained for these systems.

2. System overview

The remote monitoring and operational support system currently in operation was first introduced when we delivered a gasification and ash melting treatment facility in 2005, and afterward, it was installed mainly in the Design-Build-Operate (DBO) WtE plants. At this moment, we are operating the system in conjunction with eight plants across Japan. Since FY 2018, we have been working on the upgrade of the entire system, utilizing AI models implemented in the secure cloud server where we have built the MaiDAS® next-generation remote monitoring and operational support system (**Figure 1**). It is a fusion of AI technologies such as machine learning (especially deep learning) and network technologies such as IoT. As shown in **Figure 2**, MaiDAS® offers subsystem options to choose depending on the needs of each customer rather than always providing

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the whole set, while securing the commonality among the subsystems. The following chapters will present its main subsystems: MaiDAS® Dashboard, MaiDAS® Visualizer, and MaiDAS® Navigator. With these subsystems, we aim at advanced automatic operation that can almost eliminate the need for manual intervention. MaiDAS® is a registered trademark of MHIEC in Japan (Trademark Registration No. 6333918).

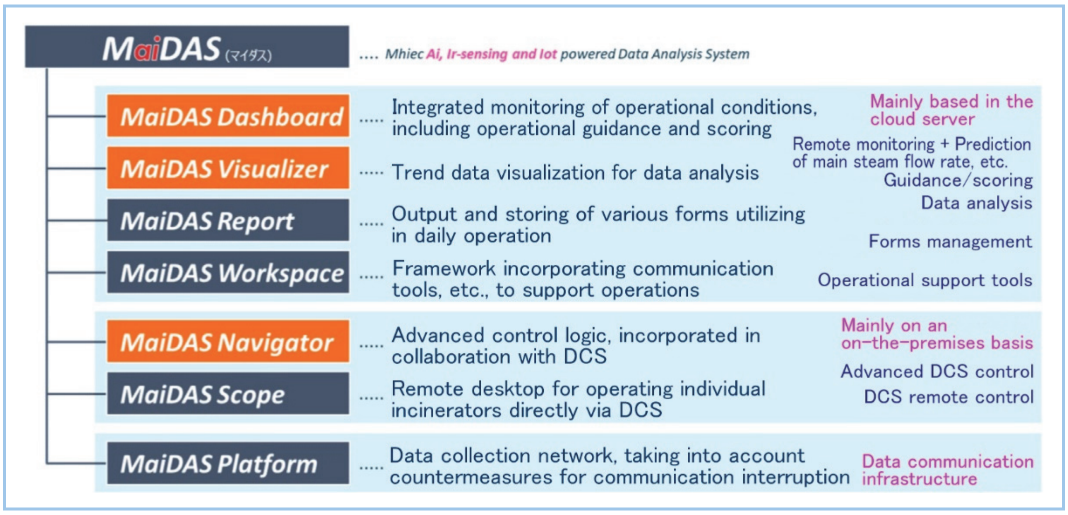

Figure 1 Configuration of MaiDAS® AI remote monitoring and operational support system MaiDAS®

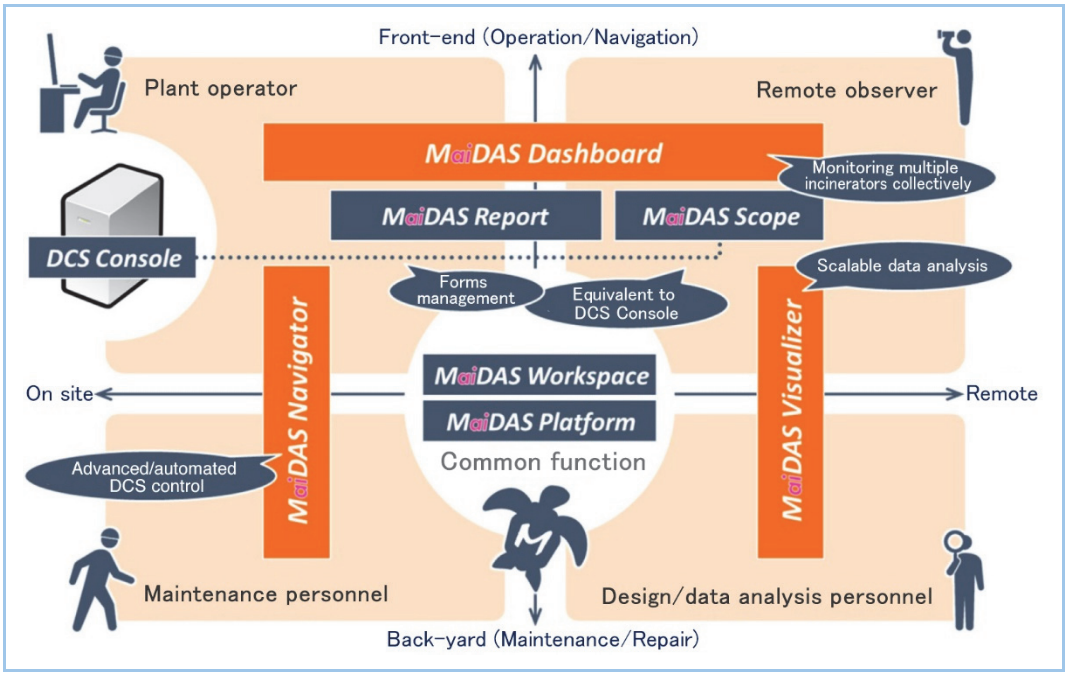

Figure 2 Positioning of MaiDAS® subsystems

3. MaiDAS® Dashboard and MaiDAS® Visualizer

Figure 3 is a conceptual diagram of advanced automatic operation with the system. In this operation, two approaches are taken: “stabilization” and “automation”. Either approach has two elements: “prediction of the main steam flow rate, etc., to accurately grasp the situation and take proactive measures” and “automatic detection of unexpected events” for the former, and “operational guidance to avoid delay in response” and “operational scoring to assess quantitatively” for the latter. Moreover, advanced automation to be realized by the system can be tailored to individual sites by linking the on-site subsystem (MaiDAS® Navigator, to be described later) and the one in the cloud server (MaiDAS® Dashboard) accordingly. With the use of the operational data obtained through the system and our support know-how, we aim to realize the advanced automatic operation of WtE plants (i.e., automatic operation with maximized performance while considering the service life of equipment) and operation management that is independent of variable factors associated with individual operators (i.e., consistent high-quality operation and maintenance that anyone can safely perform without errors). The data obtained on-site are visualized and analyzed in real time by MaiDAS® Visualizer, while MaiDAS® Dashboard (**Figure 4**) builds a model based on these data and provides three scores regarding the operating conditions (operational scoring). The three scores represent (1) operation, (2) output and (3) equipment, respectively. MaiDAS® Dashboard can also display the predicted amount of evaporation and automatically detect the occurrence of an unexpected event (such as feeding of large amounts of waste). A concept of operational scoring is shown in **Figure 5**, in which the integrity of the execution of operation is indicated by (1) operation score and (2) output score; the amount of evaporation and the output of exhaust gas concentration (3) equipment score; the health of important equipment for plant operation such as fans. The goal is to maintain operational stability by assessing the operating conditions while keeping a balance between these scores.

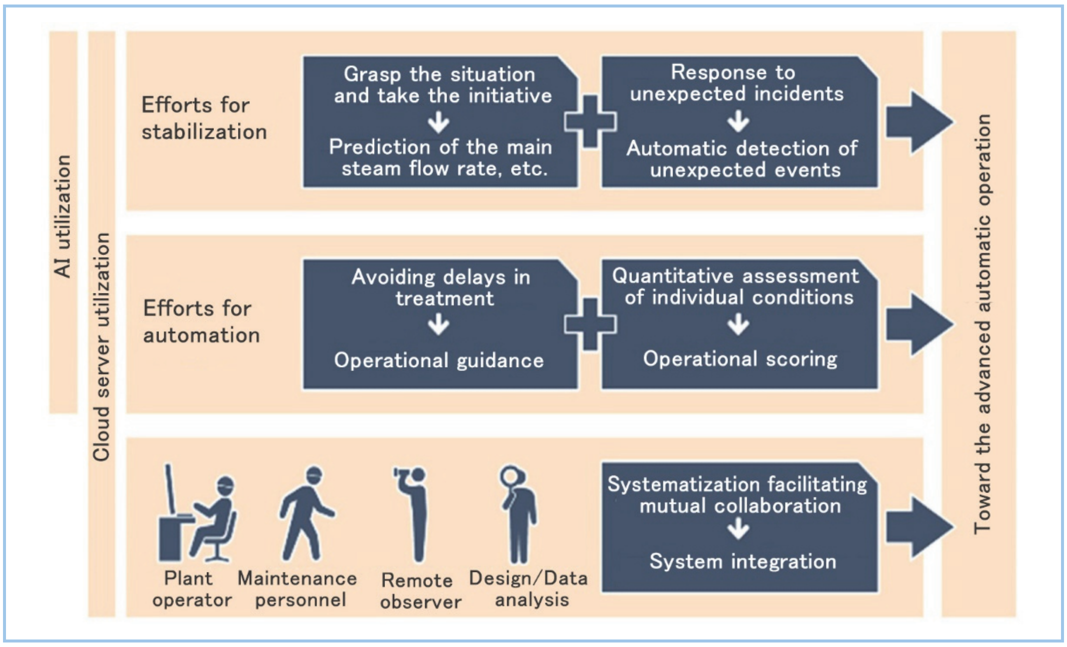

Figure 3 Concept of advanced automatic operation

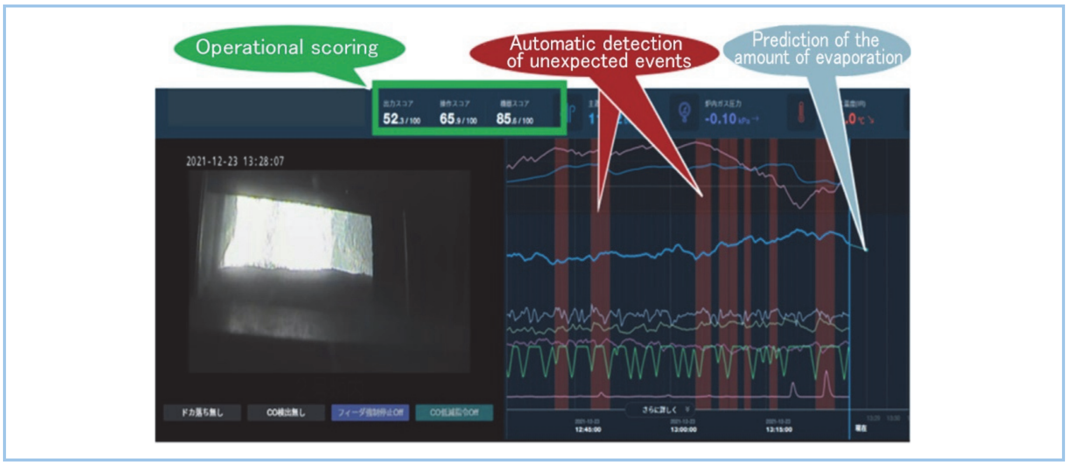

Figure 4 MaiDAS® Dashboard

With these subsystems, machine learning-based prediction of process data (e.g., main steam flow rate, and heating value of waste) becomes possible, whereby the operator can be informed of the situation a few minutes in advance. The deep learning-based anomaly detection models are used to promptly detect events such as anomalous feeding of waste. A prediction example of the main steam flow rate is shown in **Figure 6**. As these models are kept in the cloud server, their upgrading and maintenance can be performed while the incinerator is in operation. By checking such operational guidance with the results of actual operations based thereon, the guidance model is continuously improved. In this way, it becomes possible to realize advanced automatic operation of

WtE plants and their efficient operation and management, while securing both operational stability and economic performance with maximized sustainability.

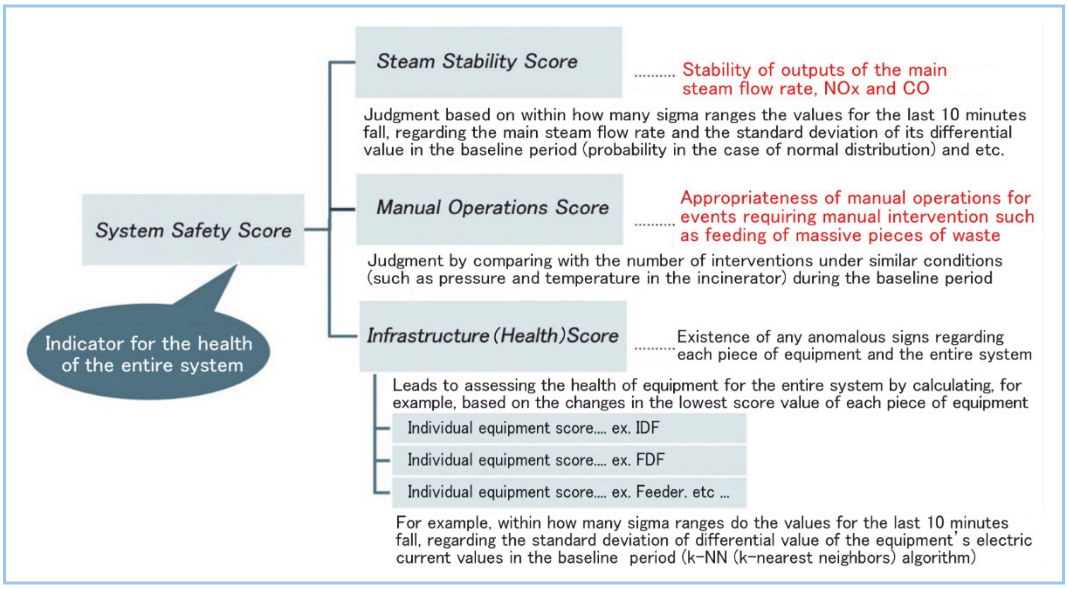

Figure 5 Concept of operational scoring

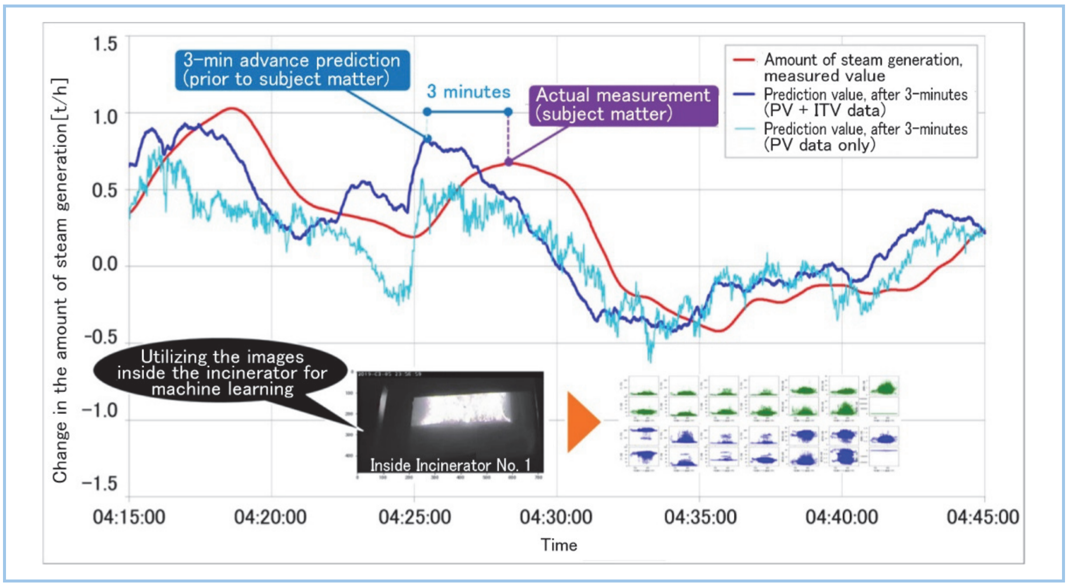

Figure 6 Prediction of the main steam flow rate by MaiDAS® Visualizer

4. MaiDAS® Navigator

In order to carry out stable waste treatment and power generation at WtE plants, it is necessary to maintain stable combustion despite varying properties of waste or varying amounts of waste fed to the combustion zone. Usually, the automatic combustion control (ACC) in use achieves stable power generation by waste combustion. When the waste properties or fluctuations of waste feed amounts go outside the ACC range, experienced operators can manually handle the situation to retain stable plant operation. The newly developed MaiDAS® Navigator is, as shown in **Figure 7**, a combustion control and operational support subsystem by which such manual handling can be automated based on the waste quality and waste feeding conditions indicated by special measurement data (i.e., waste water content, waste layer image, and combustion flame image) and plant data, coupled with the advanced distributed control system (DCS). For combustion stabilization, the waste feeding and combustion conditions are assessed in a quick and appropriate manner, and are controlled in accordance with the assessment results. It is possible for the operator to grasp the operating conditions at a glance during automatic operation. Further linking with the MaiDAS® system via the cloud server can improve the accuracy of advanced automatic operation.

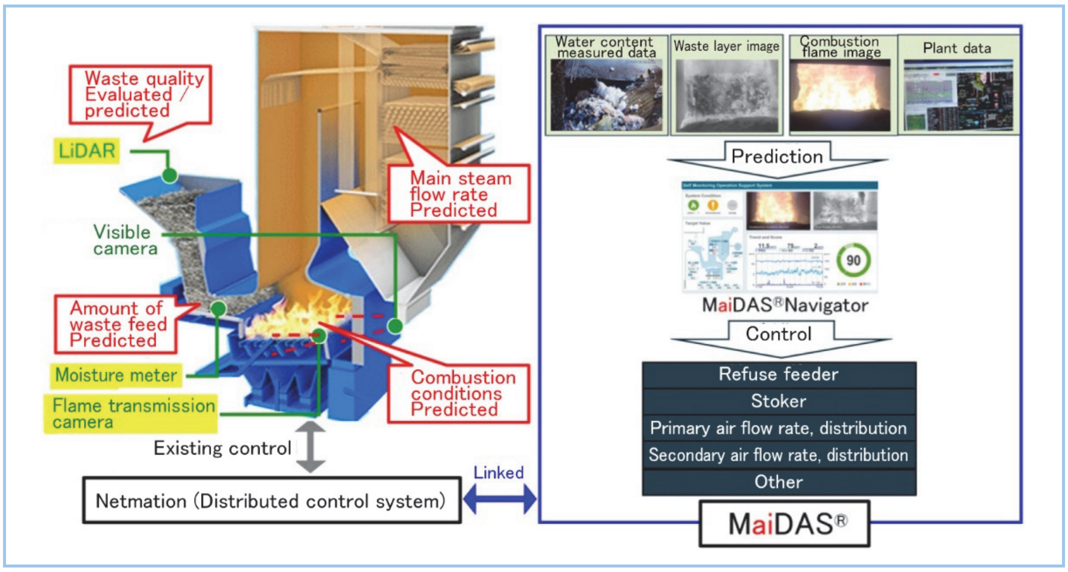

Figure 7 Configuration of MaiDAS® Navigator

The special measurement results of MaiDAS® Navigator are given in **Figure 8**. Figure 8-1 shows a moisture meter attached to the side of the hopper chute, whereby the water content and LHV of waste passing through the hopper chute can be measured based on the attenuation rate of electromagnetic waves to which the passing waste is exposed. Figure 8-2 shows images of waste layers on the feeder, based on which the scale of the falling of waste from the feeder is estimated to predict the amount of waste to be fed. For the utilization of combustion flame images, machine learning is used to extract features from the images. The images features are then related to the corresponding plant data and combustion conditions through machine learning, whereby the combustion conditions can be predicted in real time. The prediction results are given in Figure 8-3. As shown in Figure 8-4, the interrelationship of the obtained data (i.e., LHV in the hopper, combustion conditions data, plant data, combustion flame image, waste layer image, and main steam flow rate) is to be machine-learned, so that the main steam flow rate can be predicted in real time. The advanced automatic operation in which these predicted values are added to correct the control variables can reduce the manual intervention by 90%, as shown in **Figure 9**. The stabilization of main steam flow rate has also been confirmed.

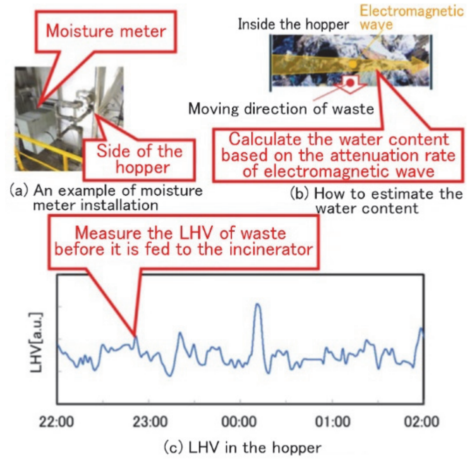

Figure 8-1 Prediction of the water content and LHV in the hopper chute

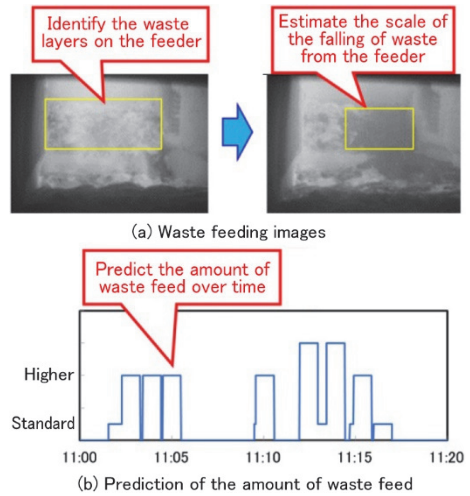

Figure 8-2 Prediction of the amount of waste feed

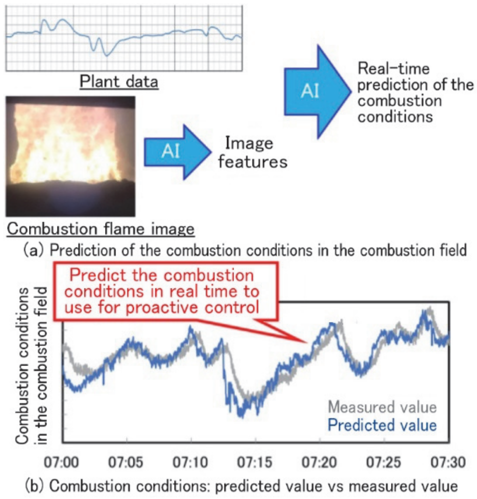

Figure 8-3 Prediction of combustion conditions

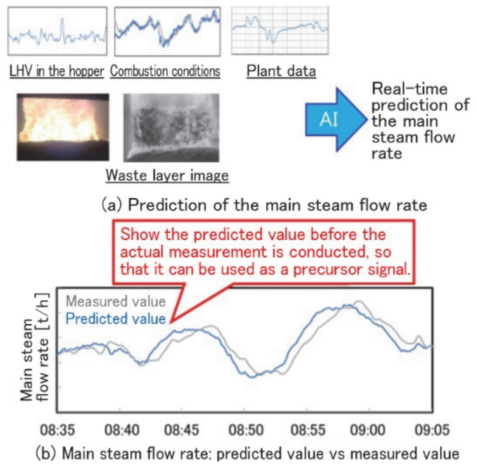

Figure 8-4 Prediction of the main steam flow rate

Figure 8 Special measurement results

Item	Outcome
Automated manual operations	23
Manual intervention	90% reduction

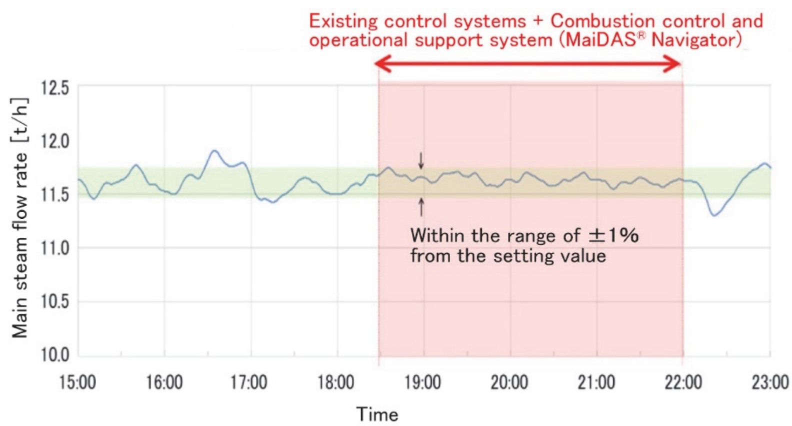

Figure 9 Stabilization of the main steam flow rate with advanced automatic operation

5. Improvement of the waste pit mixing and feeding support system

In developing this system, we first analyzed how cranes were operated in order to visualize the work load over time, and made a request to complete the questionnaires about waste crane operation. Using the results, the waste mixing conditions were numerically evaluated from the three perspectives of "the number of mixings", "apparent specific gravity" and "retention time". Each of the three was then weighted. We thus developed a method to assess the mixing conditions using, as an indicator, the comprehensive evaluation point (= K1 × the number-of-mixing evaluation point + K2 × the apparent-specific-gravity evaluation point + K3 × the retention-time evaluation point)[3]. **Figure 10** shows the waste pit mixing and feeding support system. The logic was built for crane automatic operation in accordance with the waste being received, together with the logic for automatic mixing based on the above-mentioned waste quality evaluation method using the frequency of waste mixing. It has thus become possible for automatically operated cranes to receive waste, mix the pit, and provide waste feed. **Figure 11** shows the results of system verification. It indicates smaller LHV variation than the conventional operation, leading to the improved stability of waste quality. As a result, the accuracy of combustion control is improved, which in turn enhances the stability of advanced automatic operation.

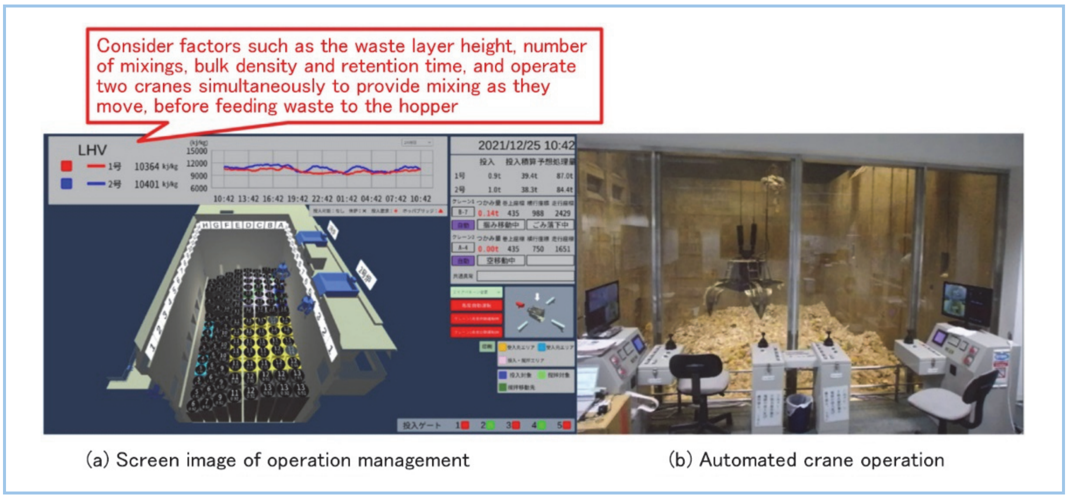

Figure 10 Waste pit mixing and feeding support system

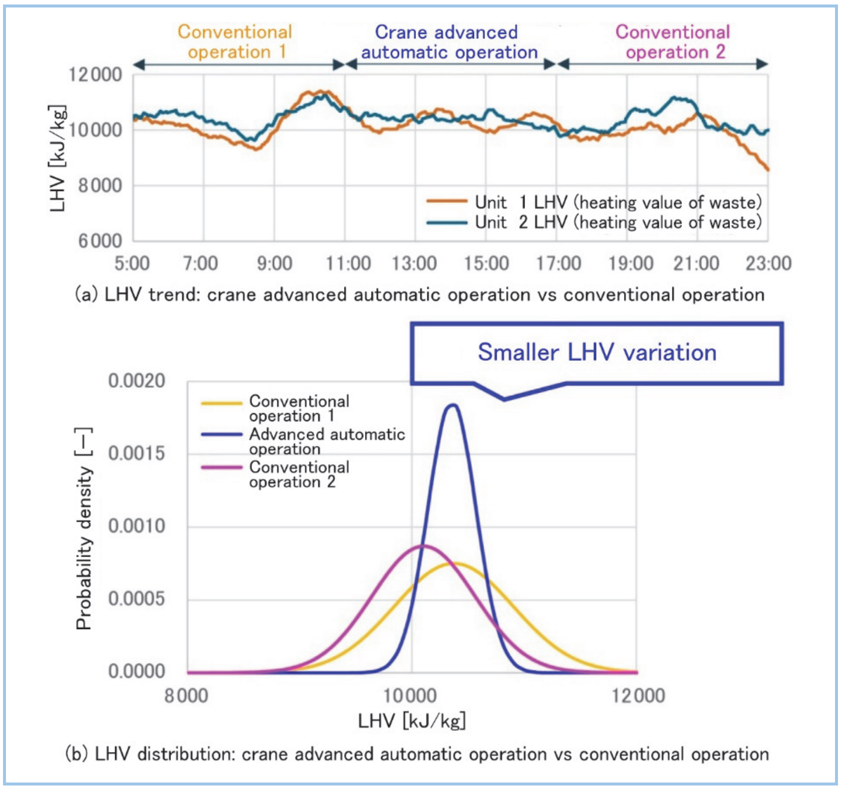

Figure 11 Results of system effect verification

6. Conclusion

MaiDAS® is a next-generation AI-based remote monitoring and operational support system developed by MHI Group. It mainly consists of the three subsystems: MaiDAS® Dashboard that performs operational scoring, MaiDAS® Visualizer for real-time visualization and analysis, and MaiDAS® Navigator enabling advanced automatic combustion control using AI. With the waste pit mixing and feeding support system, which has been improved, the waste quality can be stabilized and the accuracy of combustion control can be enhanced. As the application of these systems enables advanced automatic operation that can eliminate the effect of variable factors associated with individual operators, we consider that the sustainability of WtE plants can be bettered in terms of plant management sophistication and efficiency in times of uncertainty.

References

(1) Shu Pang et. al, Application of AI/IoT Technology in the Incinerator Facilities, Proceedings of The 32nd Annual Conference of Japan Society of Material Cycles and Waste Management 2021, (2021-10) p.287

(2) Nobuharu Iwashita et. al, Creating Customer Value Through Advanced Driving Automation Using Remote Monitoring and Driving Support Systems, Proceedings of The 32nd Annual Conference of Japan Society of Material Cycles and Waste Management 2021, (2021-10) p.265

(3) Yoshinori Goto et. al, Development of a Waste Mixing and Feeding Support System, Proceedings of The 41nd Waste Management Research Symposium, (2020-1) p.212