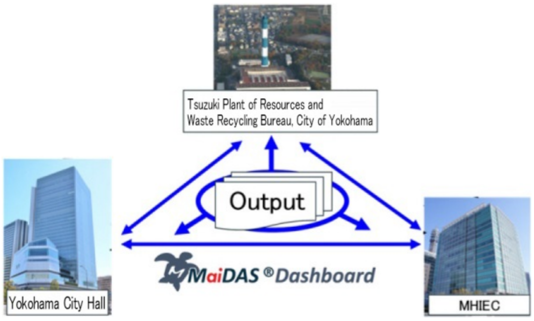
Approach to Highly Automated Operation Using AI Remote Monitoring and Operation Support System MaiDAS® in Joint Research with City of Yokohama



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Mitsubishi Heavy Industries Environmental & Chemical Engineering Co., Ltd. (MHIEC) has developed MaiDAS®, a next-generation AI-based remote monitoring and operation support system. For waste-to-energy plants, MaiDAS® optimizes the output values of evaporation rate and exhaust gas concentration while maintaining the integrity of critical equipment that controls their operation, and also enables highly automated operation with human-dependent factors eliminated. We are currently conducting joint research with the City of Yokohama on operation support using MaiDAS Dashboard, one of the subsystems of MaiDAS®, and are working on highly automated operation as a part of the research. This report describes the progress of the joint research and the results of a four-day verification of the highly automated operation.

1. Introduction

In recent years, there has been demand from waste-to-energy plants for both long-term stable operation in pursuit of the sustainability of the plant and cost reduction. In addition, the shortage of experienced operators and responses to unforeseen circumstances require further consideration. Under these circumstances, we have established operation support systems that utilize remote monitoring, AI (Artificial Intelligence), and cloud computing to centrally manage the operational status of multiple waste-to-energy plants, and we are working toward the advancement and efficiency improvement of waste-to-energy plant operations by consolidating these operational data and applying the know-how obtained to other plants [(1)]. This report describes the status of our efforts regarding the advancement of our systems and the progress of our joint research with the City of Yokohama that utilizes the systems.

2. System overview

Since 2018, MHIEC has been developing next-generation remote monitoring and operation support systems MaiDAS® using AI and IoT technologies. These systems were first introduced when we delivered a gasification and ash melting treatment facility in 2005, and afterward they were installed mainly in DBO (Design-Build-Operate) waste-to-energy plants. At this moment, we are operating the systems in conjunction with eleven plants across Japan. **Figure 1** and **Figure 2** show the configuration of MaiDAS®. Based on the basic functions of (1) data visualization, (2) data analysis, (3) AI prediction and (4) equipment abnormality diagnosis, MaiDAS® consists of seven subsystems. The main subsystems of the seven are Dashboard, which has operation scoring and guidance functions, Visualizer, which performs real-time visualization and analysis, and Navigator, which performs highly automated combustion control using AI. In particular, MaiDAS Dashboard is capable of predicting evaporation rate by machine learning, providing information to operators, and supporting operation by immediately detecting abnormalities in waste input and displaying guidance on how to deal with them.

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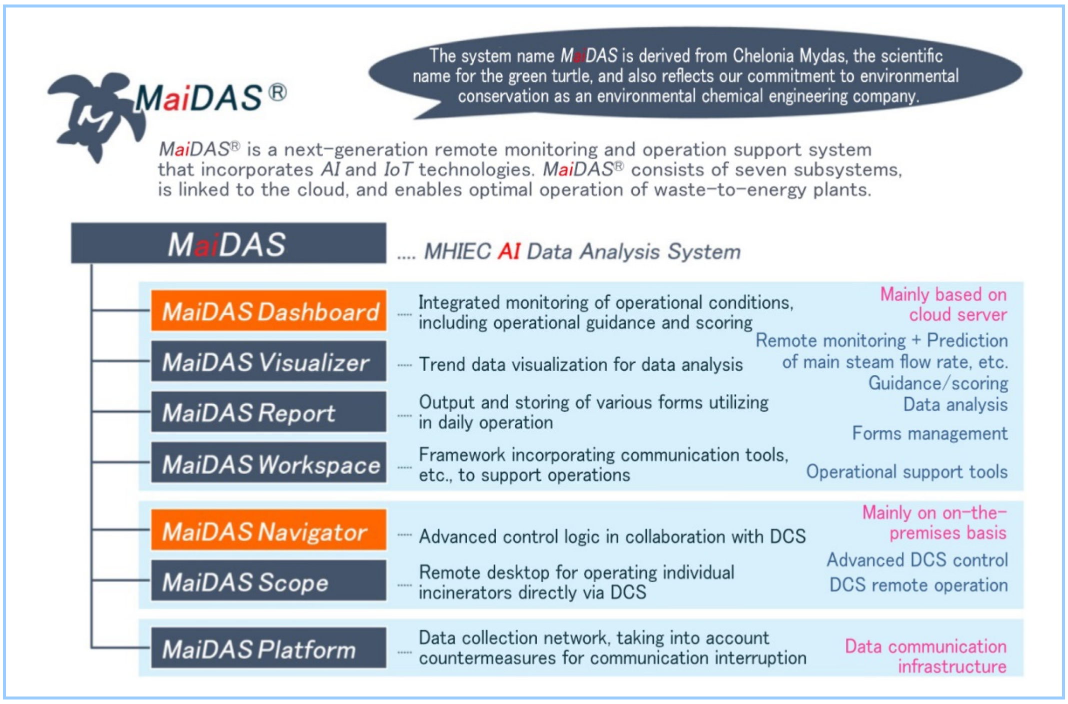

Figure 1 MaiDAS® subsystem configuration (1)
MaiDAS® consists of seven subsystems. This figure shows their details.

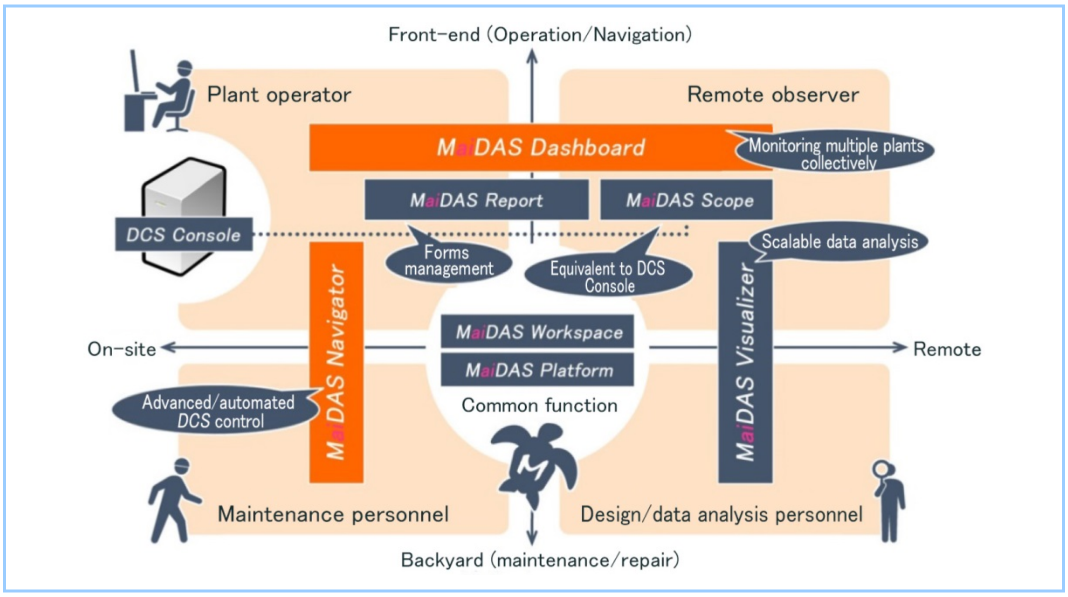

Figure 2 MaiDAS® subsystem configuration (2)
MaiDAS® consists of seven subsystems. This figure shows their relationship.

3. MaiDAS Dashboard and joint research with City of Yokohama

Currently, we are conducting a joint research project with the City of Yokohama on the "Application of AI and IoT Technologies to Waste-to-Energy Plants" using MaiDAS®, which has been ongoing since 2018. The ultimate goals of the joint research are highly automated operation of waste-to-energy plants (automated operation that maximizes performance while taking into account equipment life) and operation management that eliminates human-dependent factors (safe, high-quality, uniform operation and maintenance without error by anyone) by utilizing operational data and operation support know-how obtained via the system.

In this joint research, first, to acquire operational data, power generation data, image data, etc., of waste-to-energy plants of the City of Yokohama in real time, we established a remote monitoring network between the City Hall, the Tsuzuki Plant of the Resources and Waste Recycling Bureau, City of Yokohama (hereinafter "Tsuzuki Plant") and our company (**Figure 3**). Next, we accumulated and visualized the operation data, and constructed a prediction model of the main steam flow rate (hereinafter "boiler evaporation rate") by machine learning to enable real-time display of the data. Currently, as mentioned above, we are currently working on highly automated operation. Many waste-to-energy plants maintain stable combustion using ACC (Automation Combustion Controller) that automatically controls the amount of waste feed and combustion air. However, when the waste feed rate fluctuates beyond the control range of the ACC, the plant operators check the combustion status from the operation data displayed on the monitoring screen of DCS (Distributed Control System) or from ITV (Industrial Television) images, and perform manual intervention operations. We are working to replace the manual intervention operations with machine learning that uses process data, flame data, etc. In other words, we aim to realize the further improvement of the accuracy of automatic control by ACC (i.e., highly automated operation) by directly inputting signals of optimal manual intervention operations (recommended values) calculated by machine learning into DCS.

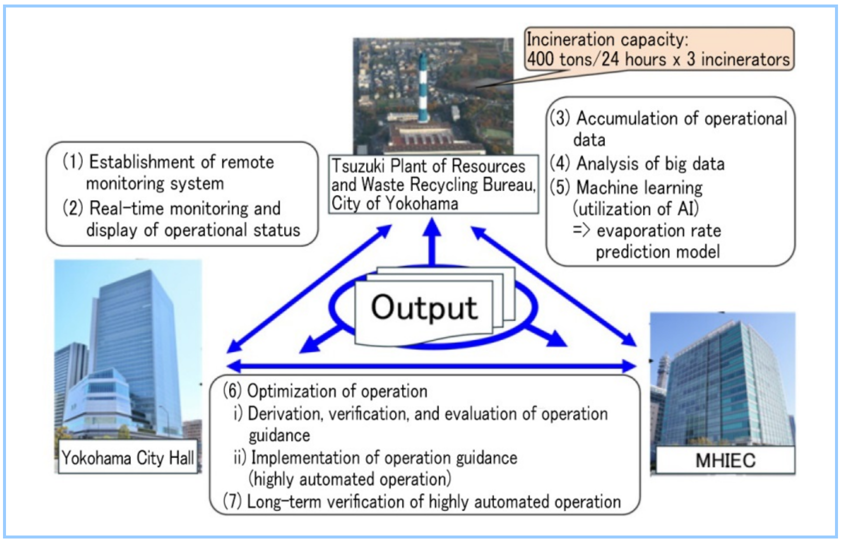

Figure 3 Details of joint research efforts with City of Yokohama
This figure shows the network diagram between the related sites in the joint research with the City of Yokohama and the details of the efforts made using the network.

First, as shown in **Figure 4**, we used MaiDAS Dashboard to indicate the recommended values on the screen as guidance and performed the operation according to the guidance to evaluate the recommended values calculated by machine learning and improve the machine learning model. The operation according to the guidance was evaluated by comparing the manual intervention (the number of times the operator made decisions and performed operations other than those based on the guidance), the stability of boiler evaporation rate, the stability of carbon monoxide (CO) concentration, and the stability of nitrogen oxide (NOx) concentration with those in normal operation. Sulfur oxides (SOx), hydrogen chloride (HCl), soot and dust, etc., are suppressed by the exhaust gas treatment system installed in the latter stage of the incinerator, and therefore they were excluded from the evaluation items this time. However, NOx, the concentration of which is also suppressed by chemicals, etc., is subject to this evaluation because it can increase significantly when conditions in the incinerator become unstable. The recommended values were issued for (1) combustion control, (2) feeder speed, (3) primary combustion air, and (4) secondary combustion air. We verified the possibility of highly automated operation incorporating prediction methods based on machine learning of these four items into the control.

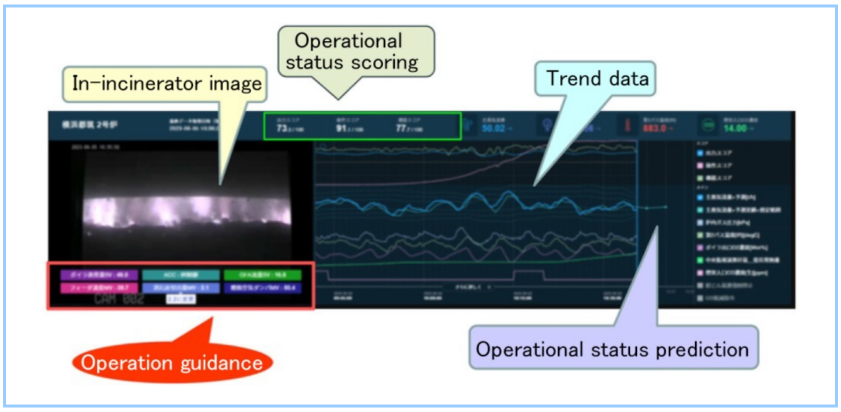

Figure 4 MaiDAS Dashboard
This figure shows the display screen of the MaiDAS Dashboard used in the verification of guidance operation and automated operation.

4. Verification results of guidance and automated operation

Figure 5 shows the guidance operation-derived changes in standard deviation of evaporation rate (PV-SV)/SV, CO average value, NOx average value, and number of manual interventions due to the guidance operation. Here, the verification was conducted using operation data from 9:00 to 17:00 during the daytime when waste is being delivered, in which the operation comparatively needs to be focused on. In this verification of the guidance operation, the number of manual interventions for the four guidance items on the verification day was 1.75 times/8 hours on average, a 95% reduction compared to normal operation. In addition, the evaporation rate deviation, CO, and NOx values were almost the same as those in the normal operation. This confirmed the validity of the recommended values calculated by machine learning.

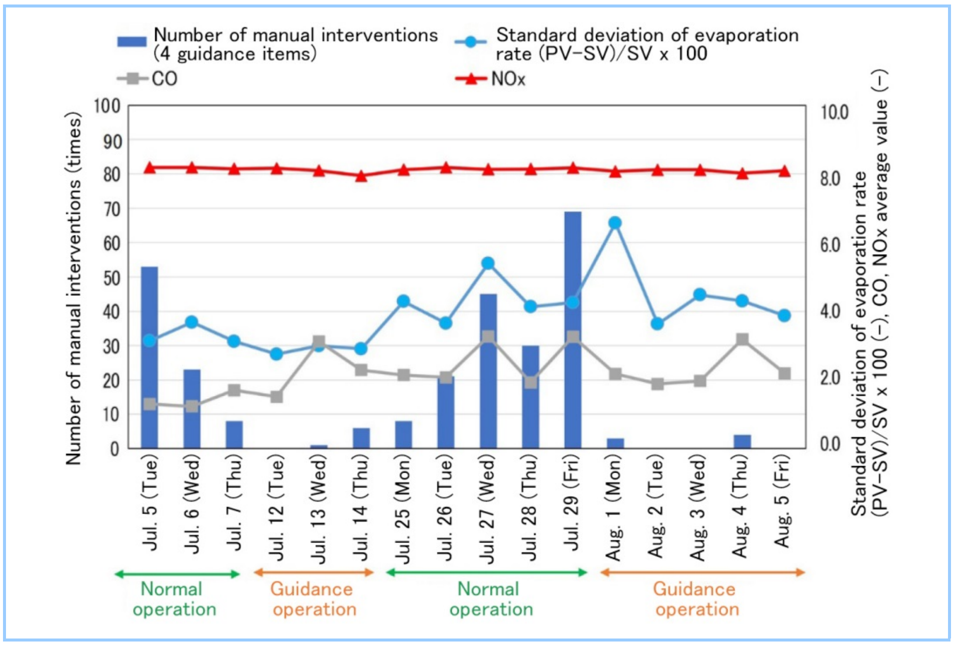

Figure 5 Verification results of guidance operation
This figure shows the number of manual interventions and the stability of evaporation rate, CO, and NOx during normal operations and guidance operations.

In addition, we conducted a 5-day verification of highly automated operation in which the logic of guidance operation was incorporated into the control. **Figure 6** shows the verification results of the highly automated operation. On June 13 and 14, manual intervention had to be conducted due to insufficient tuning of the machine learning model at the time of irregular treatment of the processing of long-term stored waste, but after that, manual intervention for the four automated operation items was reduced to zero. In that case, the values of evaporation rate, CO, and NOx values were almost the same as those in normal operation, and the values complied with the operation control standard values for all five days of the verification.

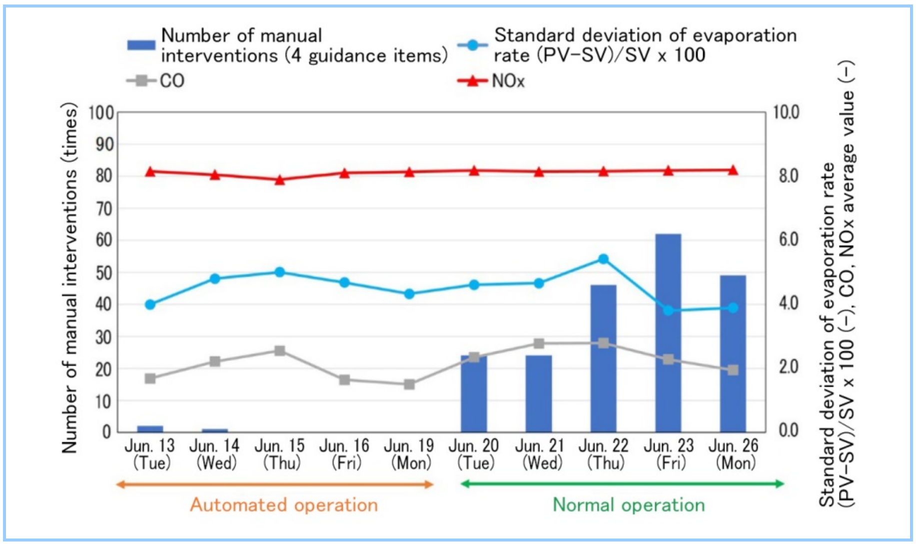

Figure 6　Verification results of automated operation
This figure shows the number of manual interventions and the stability of evaporation rate, CO, and NOx during normal operation and automated operation.

The emission concentration and total amount of HCl, SOx, NOx, dioxins, etc., contained in the exhaust gas generated during waste incineration are regulated by law, and acidic gases such as HCl and SOx are removed by neutralization reaction with slaked lime, and NOx by denitration reaction with ammonia. In the case of the incinerator in which highly automated operation was performed with the data showing the highest operational stability, the waste feed fluctuation (O_2 fluctuation) was reduced compared to the case of normal operation (**Figure 7**), and as a result, the amount of slaked lime and ammonia used was reduced. In the future, we will work on improving the accuracy of the highly automated operation, reducing the amount of extra chemical injection that could not follow the exhaust gas fluctuations, and actively reducing utilities in consideration of the prediction of exhaust gas concentrations and the control methods by applying machine learning.

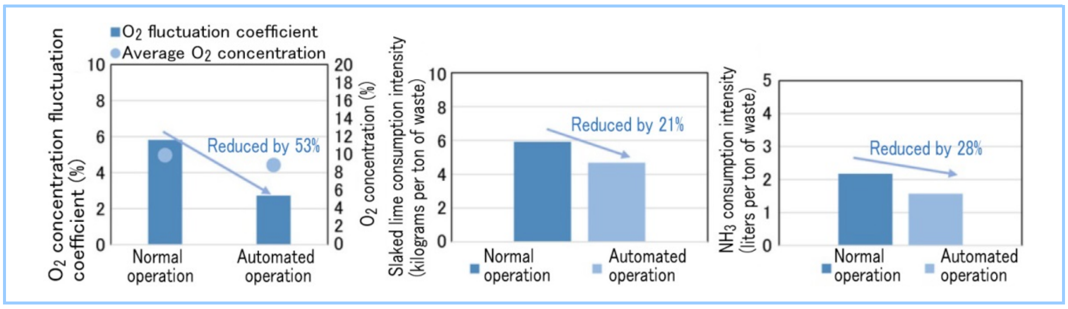

Figure 7　Comparison of O_2 concentration stability, slaked lime usage, and NH_3 usage between normal operation and automated operation

5. Conclusion

Aiming for highly automated operation of waste-to-energy plants, we have developed MaiDAS®, a system that can perform real-time data visualization based on operational data acquired from the field and derive recommended operations. As a result of verifying the highly automated operation, which derives control recommended values by machine learning and introduces the signals directly into the combustion control system, it was confirmed that the number of manual interventions can be significantly reduced while maintaining the same performance as in normal operation. Going forward, aiming for further improvement of accuracy and reduction of the number of manual interventions considering the fluctuation in waste quality due to seasonal changes etc., we plan to conduct long-term verification. In addition, we will work on constructing a highly automated operation system that optimizes plant operation by reducing the use of chemicals and monitoring the condition of critical equipment that leads to CBM (Condition-Based Maintenance).

At the end of this report, we would like to thank the Resources and Waste Recycling Bureau, City of Yokohama, for agreeing to conduct the joint research.

MaiDAS® is a registered trademark of Mitsubishi Heavy Industries Environmental & Chemical Engineering Co., Ltd. in Japan (Trademark Registration No. 6333918).

References

(1) Tomohiro Harada et. al, Application of AI/IoT technology in the waste incinerator facilities (2^{nd} Report), The 44^{th}Japan Waste Management Association research symposium proceedings, (2022)