# Performance Verification of Hybrid Temperature Recorder Monitoring System

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**ABSTRACT –** Currently, the calibration process of burn-in chambers used in a HDD (Hard Disk Drive) production line requires an engineer to manually monitor temperatures at the hybrid temperature recorders throughout the calibration period. It is a time consuming and inefficient operation, due to a large number of burn-in chambers used in the production line comparing with a limited number of engineers to handle. Therefore, the hybrid temperature recorder monitoring system is developed and implemented to improve the monitoring procedure used in the current calibration process of burn-in chambers. There are two subsystems included, i.e., a temperature recording subsystem and a monitoring subsystem, which are connected through a wireless network. The temperature recording subsystem performs capturing temperatures from probes inside the burn-in chamber and sending the temperature data to the monitoring subsystem. The monitoring subsystem receives the temperature data to store in a central server before processing and displaying to the engineer for monitoring in real-time. The system performance is verified by deploying the system to operate in the actual environment of current calibration process. The operation results are verified and used to reflect the system performance in four sections. As the results obtained, the system yields accurate outcomes for the four sections and can reduce the operation time in the calibration process.

**KEYWORDS -** Process improvement, monitoring system, HDDs production line, burn-in chamber calibration process, and performance measurement

## 1. Introduction

In a current production line, the HDDs (Hard Disk Drives) are required to perform an operation test under high temperature in a burn-in chamber for several hours. After one year of operation, the burn-in chamber is needed to calibrate for assuring quality. The calibration process employs a hybrid temperature recorder to measure temperatures inside the burn-in chamber for a certain period. During the measurement period, an engineer has to manually monitor and to verify the temperatures printed out of the hybrid temperature recorder, in order to notify errors or failures that could occur during the calibration period. Due to a number of burn-in chambers located remotely at different locations in the production line, the engineer cannot stay at every hybrid temperature recorders to monitor and to verify the temperatures throughout the entire calibration period. Therefore, if the errors occur during the calibration interval, it is quite difficult for the engineer to notify and to handle, immediately. As the results, the completion of calibration process is delayed and the burn-in chambers might be damaged. Due to the current manual monitoring procedure, it is a time consuming and inefficient operation and requires to be improved.

The research work related to the burn-in chamber used in the HDD and other industries has long been started for several decades [1]-[4]. As in [1], there were experiments to determine the burn-in cycle of chamber that was controlled by a host computer. The result expressed that the shorter cycle precipitated many failures than the longer cycle. Also, the burn-in process could be made more powerful by reducing the time spent at the high temperature extreme. In [2], the testing system used for multiple HDDs in the burn-in chamber by employing a host controller was patented. The works in [3]-[4] presented the development of applied algorithms and relevant embedded software to the burn-in and binning processes. However, their work aimed to improve efficiency of burn-in process used in the IC (Integrated Circuit) industry. Also, there was no calibration process mentioned in those works. Furthermore, there are some research work applying the knowledge of information technology to the monitoring systems used in various industrial processes [5]-[7]. The work in [5] was a development of real-time monitoring system in ceramic tiles manufacturing by using the client/server architecture. The system was implemented by Microsoft Visual C++, Visual Basic, SQL database, and Windows NT. In [6], the internet based manufacturing process was introduced to allow multiple-user to monitor remote machines from different locations. The system used a Linux PC as the main server that acquired the data from remote machines through data acquisition control cards. The work in [7] proposed the concept of remote monitoring system for factory automation by using CORBA (Common Object Request Broker Architecture). The system was operated on a 10Base-T LAN (Local Area Network) under Windows OS environment. As can be observed, there is no monitoring system used in the calibration process of burn-in chamber for the HDD industry.

Therefore, in our previous work [8], the development of hybrid temperature recorder monitoring system was proposed. The development process followed an object-oriented analysis and design methodology (OOADM). The system prototype was also implemented. The accuracy verification of system prototype was also investigated by simulation experiment in [9]. The simulation experiment used actual data acquiring from the current calibration process that reflected the results of actual operation mostly found in three cases, i.e., normal operation, loose probe, and broken probe. The results expressed that the system yields accurate outcomes and can be deployed in the monitoring procedure of current calibration process. This paper is the extension of our previous works. The system performance is investigated by deploying the system into the actual operation environment of current calibration process. The operation results are verified and used to reflect the system performance in four sections, i.e., communication, data verification, alarm module, and operation time. The paper is organized as follows: In section 2, the current calibration process and its problem are presented. Section 3 expresses the hybrid temperature recorder monitoring system implemented and its operation in details. Section 4 describes the performance verification methodology and result discussion. The conclusion is provided in section 5.

# 2. Current Process and Requirement Analysis

## 2.1 Burn-in Chamber Calibration Process

The processes of HDD production line that are found in most current HDD industries include a cleaning process, an assembly process, and a testing process, respectively. The cleaning process takes the HDD components from the stock to clean, e.g., screw, case, and other parts. In the assembly process, the clean components are assembled into a HDD unit before writing a servo track onto the platter (or disc). Then, the HDD unit is closed and sealed before testing leakage. After that, the PCBs (Printed Circuit Boards) are mounted onto the case of HDD unit in the testing process. Then, the HDDs are formatted and tested in various subjects, e.g., motor spinning, head stack movement, function, burn-in, and final tests. After passing the tests, the HDDs are sent to the QA (Quality Assurance) process. Finally, the HDDs are labeled and packed before shipping to customers.

As can be notified, the burn-in test of HDDs, called SRST (Self Running Stress Test), belongs to the testing process. In the SRST, the HDDs are operated under stress at high temperatures in the burn-in chamber for several hours. There is more than a thousand of burn-in chambers used in the SRST process, circularly. To ensure quality as specified in the preventive maintenance standard, the burin-in chambers have to be calibrated after one year of operation for temperature stabilization and adjustment. The calibration process employs the hybrid temperature recorder to probe the temperatures inside the burn-in chamber, while dummy operation. The temperatures from the probes (or sensors) are recorded and printed out at the hybrid temperature recorder throughout the period of calibration process, as showed in Figure 1.

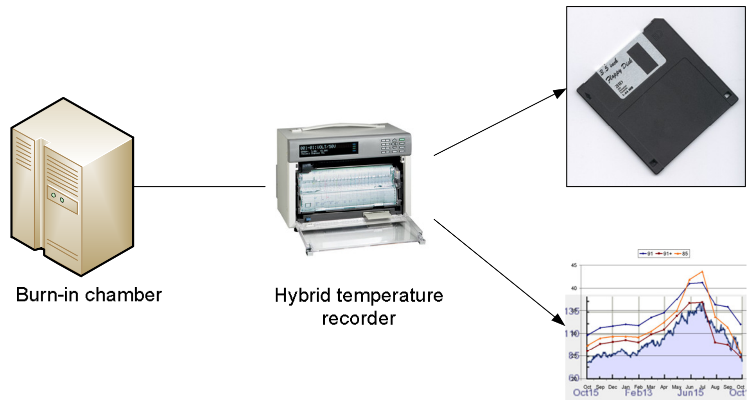


**Figure 1**. Burn-in chamber calibration process.

During the calibration period, the engineer has to manually monitor and verify the results at the hybrid temperature recorder periodically. Thus, when the errors occur during the calibration process, the engineer could notify and handle the problems immediately. This monitoring procedure is required to prevent not only the completion delay of calibration process, but also the damage that might occur to the burn-in chambers caused by failures, e.g., out of range temperatures. However, the current manual monitoring procedure used in the calibration process is a time consuming and inefficient operation, due to a large number of burn-in chambers used in the production line comparing with a limited number of engineers. Therefore, it requires to be improved by deploying a new monitoring system.

## 2.2 Requirement Analysis

As previously mentioned, the new monitoring system is required to efficiently improve the monitoring procedure used in the current calibration process of burn-in chamber. Thus, the new monitoring system must provide the temperature data measured by the hybrid temperature recorders that can be simultaneously and centrally monitored at the engineering office. By taking the limitations and problems of current procedure into account, the new monitoring system requires a centralized control and client/server architecture to operate and replace the current monitoring procedure. Furthermore, the functional requirements of monitoring system are analyzed and can be defined as follows,

- The system should be able to connect to the hybrid temperature recorder for reading and recording the temperature data at the client.
- The system should be able to connect the client and the central server through the wireless network for transmitting and receiving temperature data.
- The system should be able to receive the temperature data from the client to record at the central server.
- The system should be able to display the temperature data for monitoring in real-time on the central server.
- The system should be able to display temperature data at the central server, as the same printout result on hybrid temperature recorder, during the calibration process.
- The system should be able to configure the calibration parameters and to manage the user data at the central server.
- The system should be able to verify the temperature data at the central server automatically, as specified in the measurement criteria.
- The system should be able to alert the engineer when the errors occur during the calibration period.

The nonfunctional requirements can also be specified as follows,

- The system should be able to install and operate on specified operating systems.
- The system should provide a user friendly interface through a web browser.
- The system should provide alert information to the user immediately.

# 3. System Design and Prototype Implementation

According to the requirements as specified, the hybrid temperature recorder monitoring system is proposed and developed by using the OOADM. The details of development process and the implementation of system prototype can be found in our previous work [8]. In the following sections, only the system design, operation, and architecture is reviewed in brief to realize how the system works before considering the performance verification methodology.

## 3.1 System Design

The design of hybrid temperature recorder monitoring system can be described by a usecase diagram that expresses the entire functions of hybrid temperature recorder monitoring system, as in Figure 2. There are two subsystems involved, i.e., the temperature recording subsystem and the monitoring subsystem. The temperature recording subsystem comprises seven main usecases, i.e., Login user, Select serial port, Connect hybrid recorder, Select test type, Set hybrid recorder, Start test, and Stop test. The Login user is used to verify the users before accessing the system. The Connect hybrid recorder provides connection between the client and the hybrid temperature recorder via a serial port. The Select test type is used to select the value of probing parameters. The Set hybrid recorder is used to configure the hybrid temperature recorder. The Start test includes the Get temperature, Return temperature and Record data to database. They are used to start the process, to receive temperature data from the hybrid temperature recorder, and to send the temperature data to the monitoring subsystem. The Stop test extends the Start test and is used to end the process. The temperature recording subsystem interacts with the hybrid temperature recorder, monitoring subsystem, and users, e.g., the engineers.

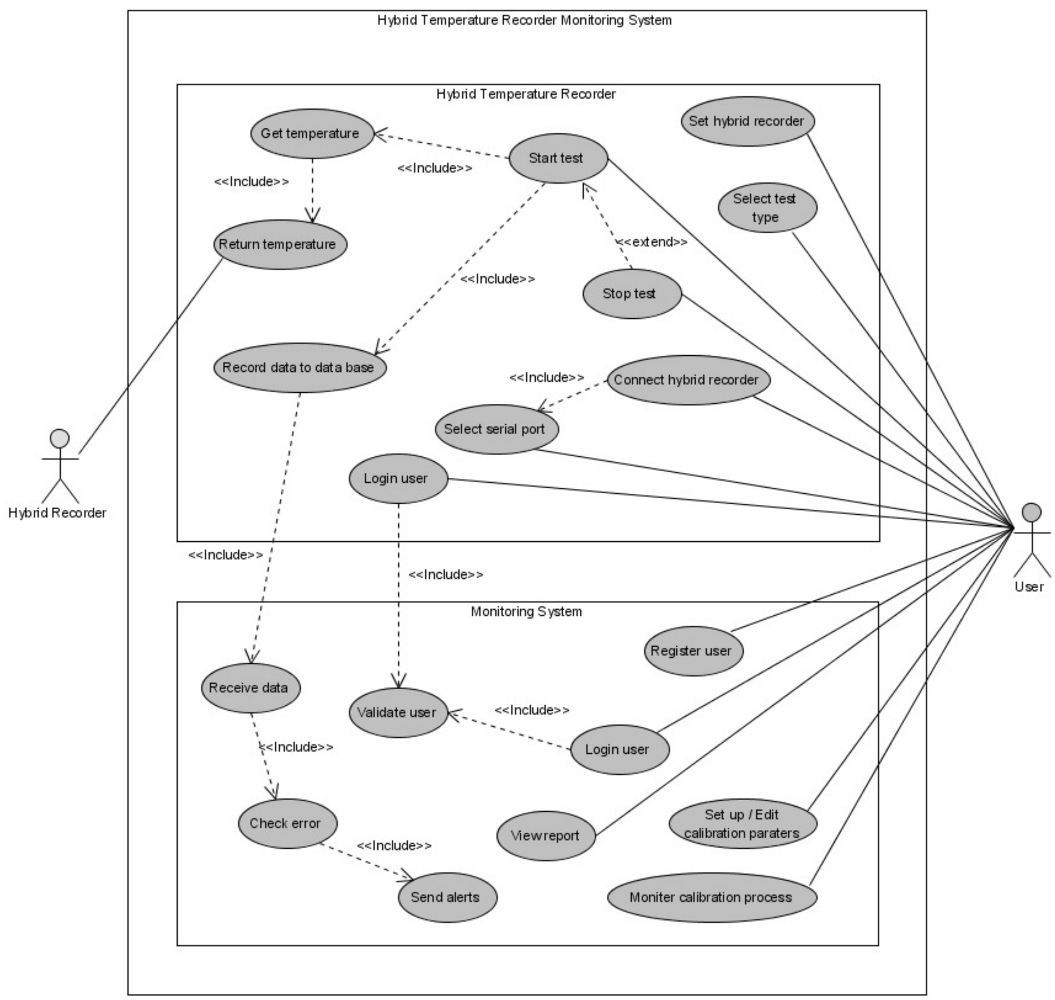


**Figure 2**. Usecase diagram of hybrid temperature recorder monitoring system.

The monitoring subsystem comprises six main usecases, i.e., Register user, Login user, Receive data, Monitor calibration process, Setup/Edit calibration parameters, and View report. The Register user is used for user registration. The Login user includes the Validate user used for user verification before allowing access to the system. The Receive data includes the Check error and Send alert. They are employed to verify the received data from the temperature recording subsystem through the wireless network and to send the alert signal to the engineer when the errors occur, respectively. The Monitor calibration process performs displaying the results to user for monitoring. The Setup/Edit calibration parameters allow the user to modify the value of probing parameters. The View report is used to display the summary of calibration process. The monitoring system also interacts with the temperature recording subsystem and the user.

## 3.2 System Architecture

The hybrid temperature recorder monitoring system is design by deploying the centralized control approach and the client/server architecture. As showed in Figure 3, there are two main subsystems as mentioned, i.e., the temperature recording subsystem and the monitoring subsystem. The temperature recording subsystem is located remotely at the testing process in the production line. The monitoring subsystem is located centrally at the engineering office. The two subsystems are interconnected through the wireless network, i.e., WiFi (IEEE802.11), for transmitting and receiving temperature data.

The temperature recording subsystem performs capturing temperatures periodically from the probes inside burn-in chamber through the hybrid temperature recorder that is connected to the client via the RS-232 port. The client performs reading, recording, and transmitting the temperature data to the central server for monitoring in real-time. The central server is located at the monitoring subsystem and used to store and process the temperature data receiving from the client for monitoring. The central server is also connected to other computers and the access point through a wired network (LAN). During the calibration period, the temperature data from hybrid temperature recorders are displayed on the server screen and can be monitored by the engineer in real-time. The web browser is used for displaying the result, which is similar to the printout plot on the hybrid temperature recorders. As the application is operated through the web browser, the engineer can access the system and monitor the results anywhere in the plant via any clients connected to the network. When the errors occur during the calibration period, the monitoring subsystem can send the alarm signal to alert the engineer via an e-mail and SMS (Short Message Service). In addition, the temperature data are stored in the database of central server for easier verification and reference in the future.

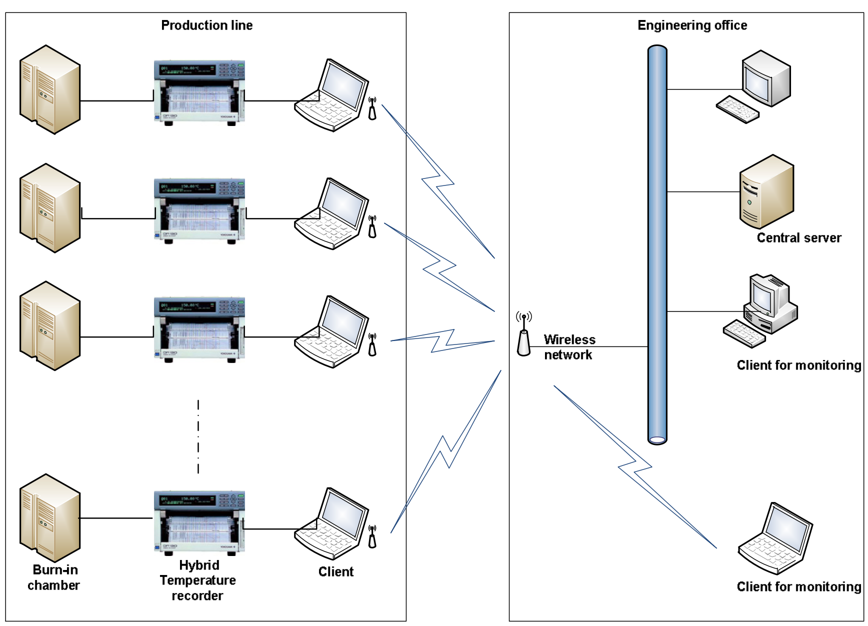


**Figure 3**. An architecture of hybrid temperature recorder monitoring system.

## 3.3 System Prototype

The temperature recording subsystem is implemented on the client machine by using Java language running on Linux operating system. The monitoring subsystem is implemented on the server machine by using C# language on Microsoft .NET platform. The database server employs the SQL server Express edition. Figure 4 expresses the application prototype on the client machine. As can be seen, the engineer can also setup calibration parameters on the client machine for measurement, e.g., tester type, tester number, hybrid temperature recorder number, and test date-time. The application can display the instance of temperature data captured from the probes inside burn-in chamber, as well as the measurement status.

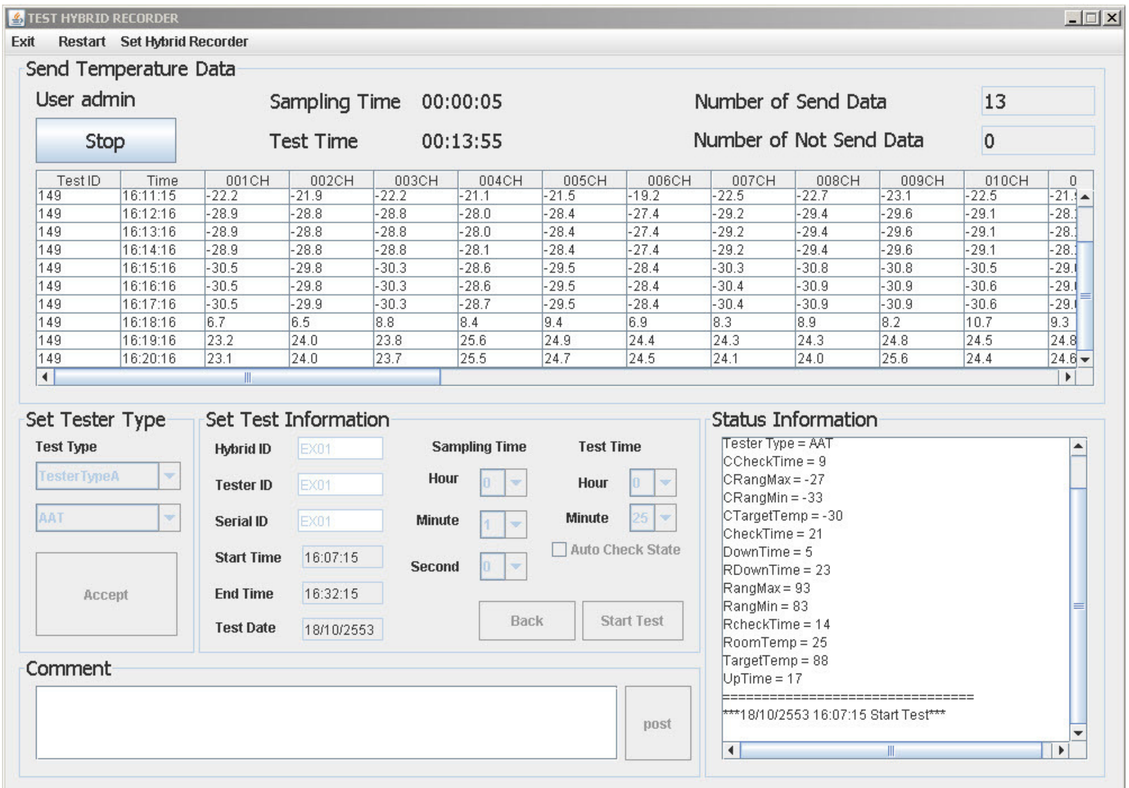


**Figure 4**. The main page of temperature recording subsystem.

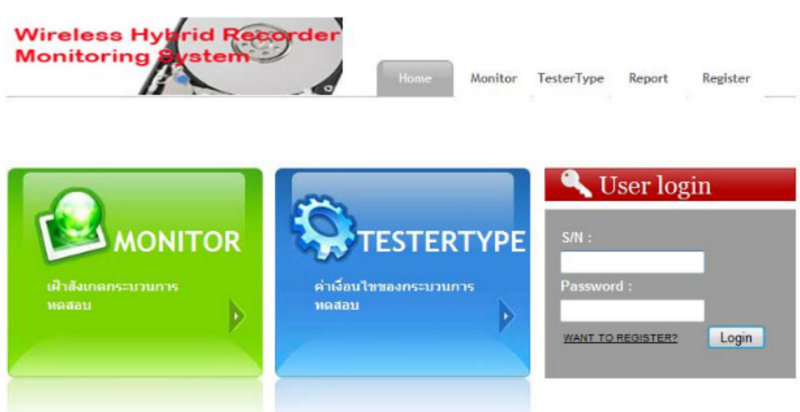


**Figure 5**. The main page of monitoring subsystem.

The monitoring subsystem running on the server machine is composed of three main menus, i.e., Monitor, Set up, and User login, as in Figure 5. The engineer can configure the calibration parameters used in the process via the set up page, e.g., Testertype, Max/Min temperatures, Rise up time, and Check time (or calibration period). Figure 6 displays the plotting results of temperature data obtaining from the hybrid temperature recorders for monitoring during the calibration process via the monitor menu. The plotting results can also be extended in a full screen mode to verify the measurement result in detail. The results showed in Figure 6 uses dummy data for demonstration purpose.

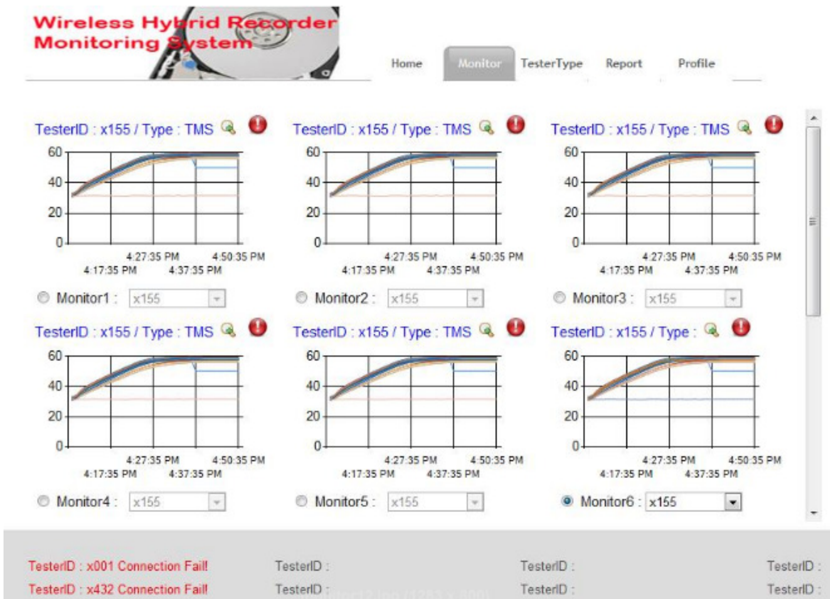


**Figure 6**. Plotting results of monitoring subsystem.

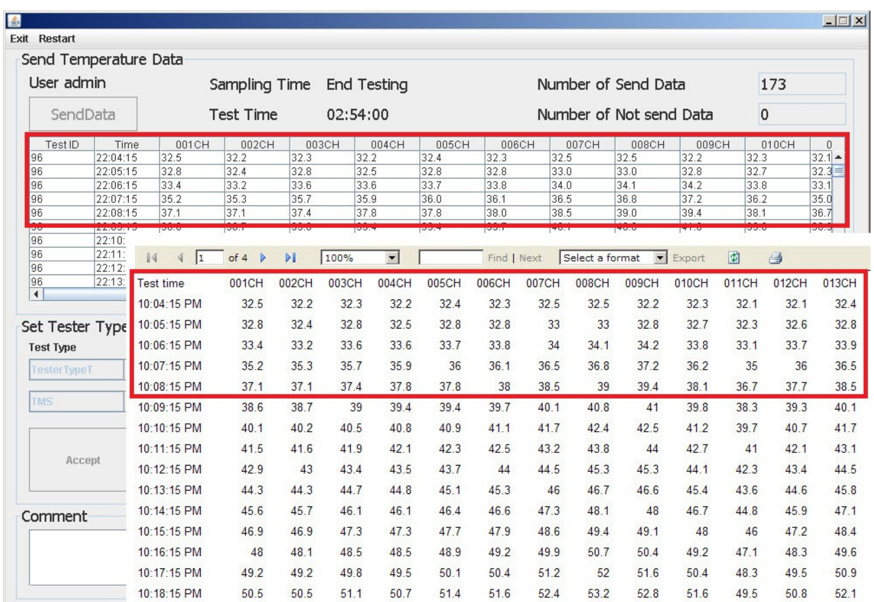


**Figure 7**. Temperature data on the temperature recording subsystem and the monitoring subsystem.

# 4. Performance Verification

In this section, the performance of hybrid temperature recorder monitoring system is investigated to verify how the system can operate. The verification is performed by deploying the system to operate under the actual environment of current calibration process. The system performance is verified in four sections, i.e., communication, data verification, alarm module, and operation time. The operation results are used to compare with the results of current calibration process for verification.

The performance of communication section is measured by verifying the transmitted and received temperature data between the temperature recording subsystem and the monitoring subsystem during the calibration process. Figure 7 shows the results when comparing the temperature data on both sides in the square boxes. The probe numbers are represented by CHs on the screen. The results yield the same temperature data on both the client of temperature recording subsystem and the server of monitoring subsystem. Thus, the communication module is performed correctly.

The performance of data verification section is verified by comparing the temperature data between the hybrid temperature recorder and the monitoring subsystem. Every samples capturing from the probes are used, i.e., 8700 sample data. The temperature data are analyzed by Minitab program in two-sample test form, i.e., comparing two independent data. Figure 8 expresses the comparing result at 95% confidential interval. The P-value is 0.979 which is higher than 0.05, thus the comparing data on both sides are not different. Also, when observing the boxplot, the mean values of two sides are the same at 49.1. Therefore, the hybrid temperature recorder monitoring system provides the results correctly.

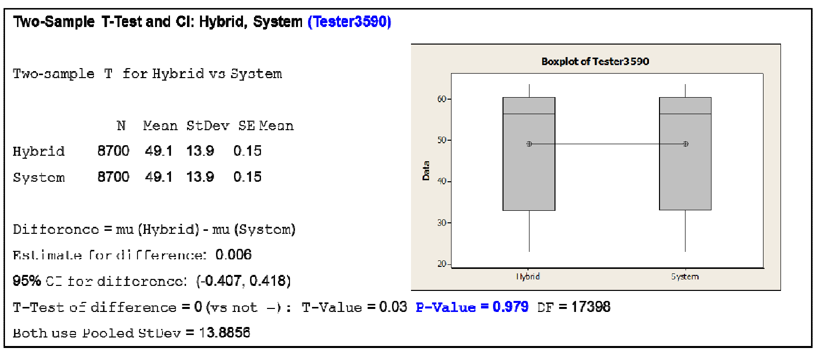


**Figure 8**. Data verification by using the two-sample test.

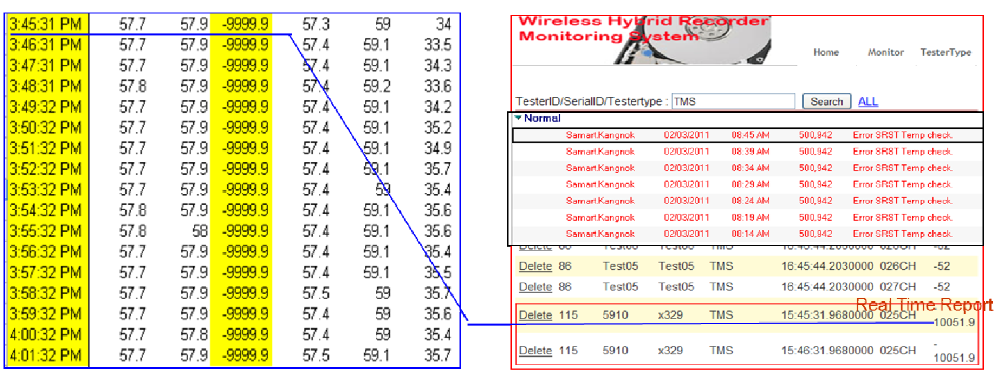


**Figure 9**. Real-time error data report.

The performance of alarm module section is verified by comparing the error data between the hybrid temperature recorder and the monitoring subsystem. The error data used to represent the broken probe case is -9999.9. Figure 9 expresses the result getting from the hybrid temperature recorder and the monitoring subsystem. As can be observed, the monitoring subsystem can report the error in real-time and the alert message is sent immediately at 3.45:31 p.m.

As the hybrid temperature recorder monitoring system yields the results correctly and can notify the engineer immediately, the operation time is reduced in the case of temperature out criteria (or when the errors occur). Without the hybrid temperature recorder monitoring system, the calibration process will be delayed until the end of idle time. Table 1 expresses the idle time that can be reduced on the test samples.

**Table 1**. Reduced idle time

| Test type sample | Idle time (min.) |
|---|---|
| Triton Mobile SRST | 180 |
| V3 SRST SATA | 180 |
| V8 SRST | 180 |
| Triton Automotive Tester | 220 |
| Ariel Automotive Tester | 840 |

# 5. Conclusion

This paper expressed the performance verification of hybrid temperature recorder monitoring system used in the burn-in chamber calibration process of HDD production line. The problem of monitoring procedure used in the current calibration process was introduced. The requirements of new monitoring system were defined by taking the limitations and problems of current process to consider. The hybrid temperature recorder monitoring system was developed and the system prototype was implemented for improvement. The system operation and architecture was also described to realize how the system works in the paper.

The system performance was investigated and verified in this work. There were four sections that are verified, i.e., communication, data verification, alarm module, and operation time. The results were used to compare with the current calibration process to reflect the performance. As the results obtained, the system yielded accurate outcomes for the four sections and could reduce the idle time in the calibration process. Moreover, the system could provide real-time monitoring for several hybrid temperature recorders simultaneously and centrally at the engineering office. The temperature data were also recorded in the system database. This leaded to reduce the printout paper and to find the history data easily for verification and reference in the future. Thus, the system can be used to replace the monitoring procedure in current calibration process for improvement.

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