

Industry Safeguards and Standardized Process for Electrical Commissioning

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Abstract — *The main goal of this project was to develop a new process that would meet customer needs and help reduce human error by documenting a completed task. Early in 2021, Heatsinc was unable to submit the required documentation to Keys Energy to perform the commissioning process on the newly installed equipment, delaying the project for 60 days. To solve the problem, the improvement team decided to use the structured DMAIC model in combination with the 5S methodology for the development of a new process. As a result, new standardized procedures were established. These documents will be shared through SharePoint and must be reviewed and approved by company managers as a requirement of the new document control system. By following this new process, the company has minimized the lead time and guaranteed customers unsurpassed services, while increasing revenue.*

Key Terms — *5S Method, DMAIC Method, Electrical Commissioning, Lean Six Sigma.*

PROBLEM STATEMENT

Heatsinc is one of many US registered companies that provides some services including electrical testing and commissioning. Heatsinc was committed to presenting the client with documentation that included the testing process that was to be performed on newly installed equipment as a requirement of their contract during the final phase of a construction for Keys Energy. The client advised Heatsinc that the testing step could not be completed until the documents were reviewed and approved by them, as the company did not have a standardized documentation system. Because Heatsinc did not have the required documentation, each technician had employed independent techniques creating a non-uniform system that had

reflected inconveniences in the internal quality control process.

This situation had created a conflict at the time to present technical services to customers as there is no standard form, as previously mentioned, which represents the company's structural practice. The major difficulty reflecting the company is that each technician had created independent documentation on different occasions, resulting in a non-uniform system that does not meet the customer's requirements.

Research Description

This project involves creating a process that meets international standards established within the industry for power testing and energization of equipment designed for electrical distribution. The documentation process that will be generated must adhere to the Engineering Department's criteria, as well as the Manufacturer's instructions and the client's requirements. Another requirement for the documentation is that it may be submitted electronically so that it can be reviewed and edited without being altered by technicians. On the other hand, this document must be remained as a living document in the company library, where it can be easily accessed in any demographic location of the company for future revisions or use in accordance with the needs of the customers.

The main advantage for all companies is that having a document library minimizes the time a technician spends creating their own format, resulting in financial relief to the company. Furthermore, at the time of submitting bids, this document might be presented to the client for their approval and acceptance. Likewise, this guarantees that human errors will be minimized, ensuring that the steps are completed in accordance with the established standards.

Research Objectives

The main objective of this research is to develop a standard operating procedure that fulfills the needs of the customer and helps to reduce human error while documenting a task performed. The documents to be implemented are Equipment Data Sheets and Test Certification Sheets. Both documents will be combined in such a way that the validation procedure is guaranteed. Specifications for performing different tests on distinct equipment can be found in the documentation, including but not limited to:

- Cables
- Gas Circuit Breakers
- Protective Relays
- Power Transformers

These documents, in the same way, will be used for other electrical energy distribution and transmission devices.

Research Contributions

The documents created as part of this research will be distributed throughout the company in order for all employees to be self-aware trained and also acquire more knowledge. The implementation of these documents will allow the company to reduce human errors, save time, and revenue.

LITERATURE REVIEW

Company Background

The Heatsinc is one of many companies registered in the United States, founded by Roy Hilton in 2012 and its headquarters are located in the state of Georgia. This company provides high quality services in a safe and reliable manner. Throughout the years Heatsinc strives to evolve and grow improving up to date guidelines, procedures, and standards to meet clients demands and be the first choice as a provider in the Testing and Commissioning market as well as others. Periodically, Heatsinc performs internal audits to self-recognized levels of improvements within each

department and adopts layers of quality to better manage its structure and values.

In summary, while providing a full turnkey service on a brown field upgrade at Keys Energy sites, it was discovered that the quality certification documents in their library would not meet the client's requirements, and they needed to be reviewed and improved in order to better assess the different aspects of the commissioning phase at the near end of the project. A great opportunity was open, a lesson that will serve as a tool for the internal review committee to avoid similar issues in the future.

Importance of Electrical Testing and Commissioning

Electrical testing has been employed as an important tool in all types of electrical installations and equipment over the years due to the high occurrence of accidents and human errors within the workplace. It plays a crucial role in electrical equipment and systems since this can identify any type of failure that could compromise personnel and electrical safety. "Beyond testing individual electrical equipment components, there is a need to verify that installed electrical systems match design documents, construction submittals, and owner's project requirements (OPR), and to document functional performance testing" [1]. Electrical commissioning is described as the systemic process of evaluating, documenting, and putting into operation newly installed or retrofitted electrical power equipment and systems under the Acceptance Testing Specifications for Electrical Power Systems (ANSI/NETA-ECS). All processes utilized to validate equipment for electrical systems should be well implemented with procedure adherence well defined while serving a commissioning process, whether placing into service new or retrofitted equipment. All new or retrofit installation projects require commissioning to confirm that the electrical system is operating safely and reliably according to the design intent [2]-[3]. Testing will ensure that the operation is as per the manufacturer specifications and that the

equipment is ready to be put in service assuring its reliability.

Since the globalization of trade has led to the emergence of complex supply chains impacting the product quality, the requirement for improved testing, and commissioning processes is increasing. Owing to the aforementioned factors, the global testing and commissioning market is expected to propel over the upcoming years. According to a report from the IMARC Group, a research and consulting firm, the global testing and commissioning market was worth US\$ 53.2 billion in 2018. The market value is expected to reach US\$ 72.7 billion by 2024, based on the projected Compound Annual Growth Rate (CAGR) of around 5.2% from 2019- 2024 analysis [4]. Companies engaged in the testing and commissioning services provide clients with certifications that reinforce the quality and compliance of utility companies.

Electronic Document and Record Management System Benefits

Beyond the implementation of a new documentation process to assist electronic document management, the fundamental objective is to allow the company to implement better practices and procedures that can be used throughout the life cycle of every project. For document management, an electronic document and records management system will be implemented; this will provide secure access to sensitive information as well as the version control and audit functionality required for better practice information management. An Electronic Document and Records Management System (EDRMS) is a system which enables organizations to manage unstructured information captured in paper and electronic formats, such as emails, word processing and spreadsheet contents [5]. This process will benefit the company significantly because, by keeping electronic communication, employees will be able to access and manage corporate documents with ease, both on paper and in digital format expediting the task with less effort into completion resulting in a cost-effective practice.

Lean Six Sigma

Lean Manufacturing is a tool used by many companies nowadays to improve their processes. The lean approach was developed in Japan by the automobile industry Toyota. This is how Kiichiro Toyoda and Taiichi Ohno created what is now known as Toyota Production System (TPS). The main approach of this ideology is to minimize costs, eliminate waste (muda) and improve the efficiency of processes. Lean fights against seven commonly recognized wastes [6]:

1. Over-production
2. Defects
3. Unnecessary inventory
4. Inappropriate processing
5. Excessive transportation
6. Waiting
7. Unnecessary motion

On the other hand, Six Sigma was developed at Motorola by an engineer named Bill Smith in the 1980s. This is another method used by organizations to improve their process capability. The term "Six Sigma" refers to a statistical measure of defects rate within a system [7]. This method focuses on reducing processes variation and improving control process using the methodology (DMAIC). By implementing this method, the improvement team can reduce all the defects defined by the customer. In this way the team can determine the root cause of the problem and find a solution.

The main objective of both methodologies is to provide a customer's good quality service and eliminate any impact on the cycle time and company expenses. Although both methods focus on process improvement, lean focuses on waste reduction, and six sigma is emphasized on reducing process variation. When both methods are integrated, improvement teams use the project management methodology which can help make a drastic improvement in company processes.

METHODOLOGY

For the implementation of a new process within the company, it is important that the teamwork follow a standardized model that helps to improve the deficiencies of the company significantly. Heatsinc improvement team determined to use the structured model DMAIC for the development of the new process. This model consists of 5 phases (Define, Measure, Analyze, Improve, Control) as illustrated on Figure 1. Each phase helps to establish a problem solution and develop an improvement process plan.

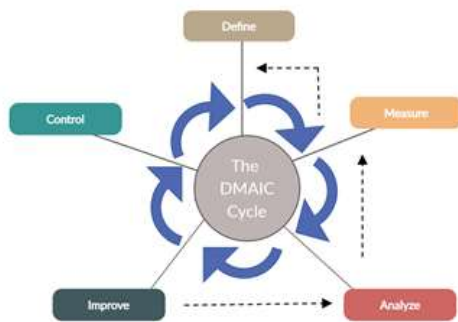


Figure 1
DMAIC Cycle

Define

The first phase of the DMAIC methodology is Project definition. This phase consists of identifying the possible improvement projects within the company. At this stage it is important to establish an improvement team that helps to define properly the problem that the company is facing. Here is where the team establishes the project design alongside its objectives. The key deliverables to be completed in this phase are:

- Established Design Project
- Project Charter: Mission Statement and Objectives
- Project Plan
- Initial Business Case

Measure

Measure phase involves identifying the client's needs and determining which tools are adequate to design a successful process. After identifying

customer's needs, the problem is quantified through data collection and analytics. From these variables, the way that the process capability will be measured is determined, so it is necessary to seek for an appropriate tool that can help to collect information about the current process. Among the tools commonly used in this phase are:

- Prioritized list of customer needs
- Value Stream Map
- Pareto Chart

Analyze

This stage aims to analyze all obtained data in the measure phase, determine the root cause and thus select a high-level design that can solve the problem. In measure phase, data analysis tools are commonly used in conjunction with a structured improvement plan that will be applied in the next phase. In this phase, a brainstorming is an excellent tool that will be used to determine what factors are critical to process performance. Among the tools commonly used in this phase are:

- Cause-and-Effect Diagram
- Flow Chart
- 5 Why

Improve

In the improve phase, the improvement team have the responsibility to find creative solutions that can be implemented and measured within the DMAIC process. It is in this phase where the team develops a detailed functional design that meets the client's requirements and also will help improve business process. To do this, the 5S method will be used, which is based on five principles to achieve an organized, cleaner, orderly and productive workplace.

Control

To guarantee the maintenance of the solution and its results, it is important that the company implements a control plan. In addition, the company must ensure that all employees maintain compliance with the established standards within the company. In this way, employees will create an

organizational culture which will generate long-term success if the established process is followed.

RESULTS AND DISCUSSION

Many companies today have successfully implemented Six Sigma methodology in their projects in order to better establish procedures and gain clients satisfaction. This is the main reason that the DMAIC methodology was chosen as a solution to the company issues. In the next sections a brief description is provided of how the methodology was applied during the improvement proposal of the company.

Definition Phase

On March 6, 2021, the project schedule in Primavera P6 Software showed the commencing of the testing and commissioning process with a 7-day window to complete. Because of the lack of organization and previous compromise in multiple contracts the company assets were tied to other projects and because of the Covid19 regulations the schedule was affected and shifted two more weeks in calendar to mitigate the problem. To fill the void other post construction activities were performed. It wasn't until May that the company had the resources and manpower to fall back into the commissioning phase. Heatsinc asked the technicians to present their test process and documents, but they noticed that these documents lacked client's specifications and uniformity. This misunderstanding further delayed the process for another two calendar weeks. At that time Heatsinc and Keys Energy started a discussion on how and what type of testing was going to take place and how was it going to be documented. Finally, the decision was made to utilize Six Sigma methodology to solve the company's problem. This provides business with the tools to improve the capability of their business processes [8]. Heatsinc wasn't prepared and a lesson or opportunity to overcome this situation was presented. Then, the company reached out to their managers and organized a meeting to help create a standardized

solution that will serve as the permanent solution to this matter to give birth to a well-established and control process.

To define the problem, an improvement team was established. This team of planners developed a project charter to achieve company's objectives. The project charter is an effective planning tool that is used in the project initiation phase and is a communication tool that can be used continually [9]. The main purpose of this letter is for top management and stakeholders to share their common ideas and establish the project's mission, scope, responsibilities, and deliverables timeframe. The following are included in this Project Charter:

- Project Improvement Team
- Purpose, Objectives, Deliverables
- Roles, Responsibilities, Activities
- Management Commitments
- Stakeholders and Partners
- Customer Success Criteria

In the project charter, the company's objective was formulated, where the main goal is implementing a standard operating procedure for system commissioning testing. This document must be electronically submitted through a system that can be accessible in any demographic region where the company is located. The charter was presented to top management and stakeholders for their approval. It is critical that this document be presented to top management for approval before any changes to the company's procedures are finalized. This ensures that the necessary resources are gathered in order to complete the project successfully.

Measure Phase

A value stream map was created to analyze the time required by all activities carried out by the Heatsinc teamwork from the start of their task to the end of the project. Figure 2 shows the generated value stream map for the electrical utilities service provider. This flowchart shows the real time of each stage carried out indicating the time lost as a result of the lack of documentation and resources

for it. The dissatisfied client has questioned the capacity of the company and demands a prompt solution of the problem since it deviates from the agreements in the contract, delaying the project for 60 days with an efficiency of 40%. It is important that the company eliminate or reduce this waiting time in its process and thus increase their value-added percent to the customer. Doing this would prevent Keys Energy from running the risk of not corresponding to hundreds of subscribers with the due demand for electricity distribution, which will benefit from these improvements to the system, guaranteeing the integrity in summer times when demand is higher.



Figure 2
Electrical Utilities VSM

Analyze Phase

Cause-and-Effect Diagram - A cause-and-affect diagram was designed in order to determine the potential causes of the company's problem (Figure 3). By applying this method, a common denominator of the problem was obtained by adding all elements identified and their relationship to potential causes that led to a single effect: Dissatisfied Customer. This tool helped the company dig deeper into the initial incident, in which, as previously stated, the customer was dissatisfied with the company's documentation procedures. The root causes of the low satisfaction were:

- There is no procedure in place including a planned approach or road map of what should be done in order to verify and document the proper system installation. (Each technician had employed independent techniques creating a non-uniform system.)

There is no electronic document and records management system process created by the

company to ensure better a communication between employees and partners. It can help save time and money, decrease human documentation error, and ensure documentation uniformity.



Figure 3
Cause-and-Effect Diagram

Five Why Diagram - Another essential tool used in the analyze phase was the 5 Whys analysis. This diagram was used to identify the root cause of the problem in order to eliminate it. After identifying the main root cause of the problem (see Figure 4), the improvement team held a meeting to discuss the most effective technique that should be adapted to improve the company's documentation system and further prevent the recurrence of the problem.

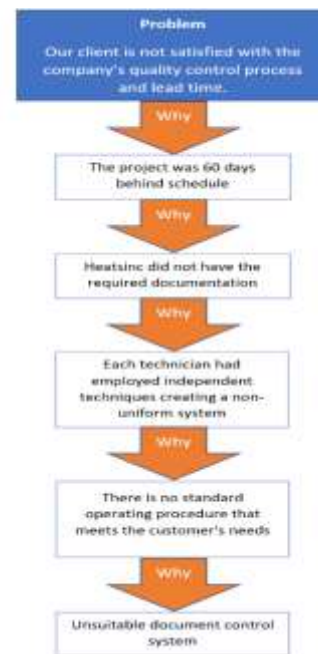


Figure 4
Five Why Diagram

Improvement Phase

Based on the analysis that has been performed, the improvement team decided to implement the 5S technique to achieve an organized workplace in order to avoid future misunderstandings, minimize of time wasted during electrical commissioning tests documentation, and prevent human error.

1. Sort

In the first step, the improvement team performed an interview with the customer in order to understand client's needs. Clients were asked to rate their needs in order of importance from 1 to 20. The results are shown in Table 1. Then, using a Pareto chart they identified and prioritized the customer's needs. Figure 5 shows the Pareto chart results including the top three needs that were total electronic data entry, test certification sheets and electrical tests documents. Using this data, the team was able to devise which were the better option to implement a new standard operation procedure for electrical system commissioning.

Table 1
Customer Needs

Category	Total
No Conflicting Instructions	15
Total Data Entry	19
Readability	8
Electrical Tests	17
Visual Inspection	13
Test Certification Sheets	19

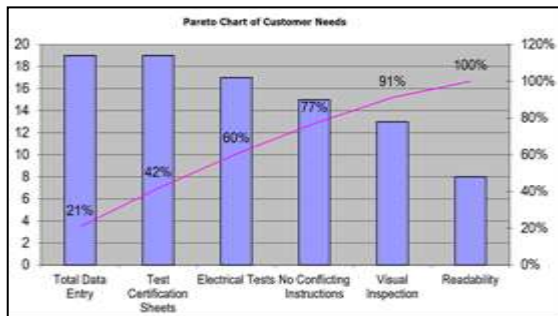


Figure 5
Pareto Chart

2. Set in Order

In this phase the project manager has aligned customers and set priorities for the design of the new standard operation procedures. Specific test procedures should be developed for each commissioning test referencing the equipment to be used, also step by step procedures with readings to be recorded and forms for the results.

A. Commissioning of Cables- Tests should be performed in accordance with ANSI/IEEE standards.

- Cable information (Proper Data and Labeling)
- Electrical Tests (Insulation Resistance Test and Dielectric Withstand Test)
- Visual Inspection and Maintenance
- Commissioning Engineer Signature

B. Inspection and Test Plan for Gas Circuit Breaker- Inspection for SF6 or vacuum leaks should be performed by train technicians who perform services on par with NETA standards.

- Circuit Breaker Nameplate
- Electrical Tests (Contact Resistance, SF6 Moisture and Purity Test, Insulation Resistance Test, and Min Voltage Pick Up)
- Visual Inspection and Maintenance
- Commissioning Engineer Signature

C. Protective relays- In accordance with industry standards, protection relays are to be tested before they are put in service and also periodically to assure reliability.

- Relay Nameplate/ Info
- Electrical/ Functional Test
- Physical/ Mechanical Test
- Test Certification Sheet
- Commissioning Engineer Signature

D. Power Transformer- Physical inspection of power transformers should be performed when transformers are transferred to the location where it will be installed, assembled, tested, and put in service to identify any noticeable damage. Most transformers are set up with devices that monitor

and records their every movement and excessive forces or impact if they occur.

- Transformer Nameplate
- Electrical Tests (Insulation Resistance, Winding Resistance, Temperature Device, Nitrogen Pressure, Oil level, Core Insulation and Core to Ground Resistance)
- Visual Inspection and Maintenance
- Commissioning Engineer Signature

3. Shine

The third phase of 5S is Shine. The team created a template in Microsoft Words which includes all the necessary tests requested by the client, including Equipment Data Sheets and Test Certification Sheets for testing and commissioning. Figure 6 and Figure 7 show an example of the new Equipment Data Sheet and Test Certification Sheet developed for protective relay. Additionally, in order to reduce the carbon footprint in the environment, the company decided to create this document in digital form. By reducing paper and ink cartridges usage, not only helps the environment, but it can also have a direct impact on reducing company's expenses. Likewise, a digital document will help minimize human error by providing clear, standardized, and structured instructions to ensure that the commissioning test technician can take the necessary steps. On the other hand, the company has adopted Microsoft SharePoint to store and share its documents electronically. SharePoint implementation will allow the company to store all its digital files and share them with coworkers and clients. Another advantage of this platform is the ability to exchange documents via any device around the world.

EQUIPMENT DATA SHEET DS-22
PROTECTIVE RELAY

GENERAL INFORMATION

Customer:	Date:
Equipment Location:	Job #:
Equipment ID:	Tested By:

RELAY NAMEPLATE / INFO

Manufacturer:	Rated Voltage:
Function:	System Voltage:
Serial Number:	Part Number:
Form:	Date of Manufacture:

ELECTRICAL / FUNCTIONAL TESTS

Code Legend: A - Acceptable C - Corrected R - Needs Repair N/A Not Applicable

CT Ratio:	Metering:
PT Ratio:	Protective Elements:
Trip Duration:	Custom Logic:
Panel Scheme:	Communications:

PHYSICAL / MECHANICAL TESTS

Code Legend: A - Acceptable C - Corrected R - Needs Repair N/A Not Applicable

Physical Condition:	Wiring Connections:
Output Contact Operation:	Input Pickup Operation:
Indicators:	Alarm Rate:
Verify all LED and Pushbutton labels installed:	Functional test of IFR0 # input signal:

COMMENTS

Figure 6
Protective Relay Equipment Data Sheet

TEST CERTIFICATION SHEET TC-20
PROTECTIVE RELAY

Site: _____
Panel No: _____
Line/Equipment: _____
Manufacturer/Model: _____
Serial Number: _____

Test	Completed by	Date
1. All settings present in relay verified against basis documents	_____	_____
2. CT and PT ratios verified against basis documents and design	_____	_____
3. All relay inputs and outputs functionally tested (including spares)	_____	_____
4. Metering tests completed and documented	_____	_____
5. Protective element tests completed and documented	_____	_____
6. All custom logic tests completed and documented	_____	_____
7. SCADA/communications functional testing completed	_____	_____
8. Full functional testing completed as applicable (e.g., reclosing)	_____	_____
9. As-lett settings recorded and comparisons completed	_____	_____
10. All logs cleared	_____	_____

FORM TO BE FILLED IN WITH BLACK OR BLUE INK. HANDWRITTEN ONLY

Figure 7
Protective Relay Test Certification Sheet

4. Standardized

The fourth step is the standardization of the process. New standards have been archived as a living document in the virtual library. These documents show step by step the testing processes

for cable, gas circuit breaker, protective relays, power transformer and others. These documents should be evaluated by commissioning engineers to determine that the instructions are clear and detailed. Once the company operating procedures and guidelines are created, evaluated, and accepted the team must be introduced to the newly established. Employees must receive orientation and training on the use of these documents and the handling SharePoint software. Once the implementation is complete, periodic checks should be performed in the event of a change.

5. Sustain

The final step is Sustain. Procedure adherence has been established, implemented, and followed to maintain quality control when the testing and commissioning process takes effect, guaranteeing customer satisfaction and ensuring reliability standards. In this step managers must ensure that the procedures are implemented well and continuously. The processes were successfully implemented and utilized on the Keys Energy projects and all the testing and commissioning services exceeded the client's expectations. In the event that the commissioning engineer notices an issue in the documentation, an initiative should be taken as soon as possible to fix the problem. To promote continuous improvement, it is important that all technicians create the same workplace culture. These must include communication methods, auditing, good documentation practices and kaizen.

Control Phase

A procedure is a document that describes how the activities will be performed. The company had no defined written procedures, so the commissioning technicians performed independent techniques that created a non-uniform system. For this reason, it was decided to create a document that includes all the procedures that must be performed by the technicians. In this way, documentation ambiguity will be eliminated, thus guaranteeing uniformity. These documents will be shared,

reviewed, edited, and signed electronically by the technicians and the company's top management. Electronic documentation has been used by many businesses because it reduces costs, saves time, and improves the efficiency of the process.

Figure 8 shows the complete processes performed by Heatsinc's employees but this time with the new implementation processes using Microsoft SharePoint. After completing installation in a substation in the Key West area, the company opted to implement this new format, which allowed the company to decrease non-value-added time to one day in order to test the equipment's. On the other hand, being an electronic document in just two days, all the tests were completed along with its documentation, increasing processes efficiency to 68%. A study was shown that manual documentation is time consuming [10]. For this reason, the company has opted for paperless documentation as it is a simple process, minimizes errors and reduces administrative expenses. This guarantees a clean work area since it can reduce storage of documents and records.



Figure 8
New Electrical Utilities Process VSM

A document management system is a way to organize, approve and complete processes using digital documents from the company. This system makes document searching and organization easier. The company adapted this method so that the technicians could quickly access the documents they need during the tests. On the other hand, company's main problem was poor document control system, so they decided to establish a new process to control all documentations. Figure 9 shows the document control system established by de company. All documentation will be shared through SharePoint and will have to be reviewed

and approved by company managers before finishing the project and prior to the energization. Having a document control system promotes minimization of documentation errors and eases the automation of tasks and processes. In the future, if any document is being obsolete or needs changes, any technician may recommend a new procedure or a revision to the existing document. Any new document or revision will need pass through the approval procedure again before its implementation.

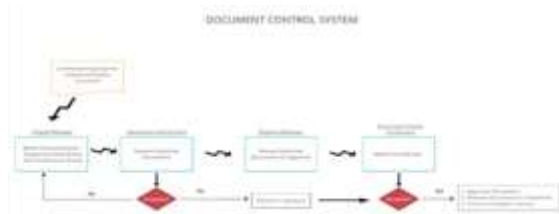


Figure 9
Document Control System

CONCLUSION

The main objective of this proposal was to develop a standard process that would help commissioning engineers to document their tests and create uniformity in the company. It is important to recognize that Heatsinc understood the differences and challenges that the company needed to improve to serve better when providing testing & commissioning services, while ensuring quality and time management regardless of work overloads and technicians performances. The principle of continuous improvement using DMAIC tool in conjunction with Six Sigma methodology was presented. Likewise, 5S methodology helped organize client's ideas to develop a standard document that would be shared electronically via SharePoint. All these quality tools helped the improvement team in decision process and in the development of a new document control system. With the new documentation process shared, reviewed and storage digitally by the quality control system, the company improved its process and decreased the non-value-added time from 60 days to 1 day increasing the efficiency to 68%. Now Heatsinc clients can benefit from industry-

established operating practices that will deliver second to none services and at the same time, increase in profits.

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