APPLYING SIX SIGMA™ TO ENVIRONMENTAL MANAGEMENT SYSTEM DESIGN

by

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Abstract

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There is currently very little literature available that describes a defined method for designing an EMS. The thesis hypothesis was that the Six Sigma™ method could be applied to EMS design. The Six Sigma™ method was chosen because it has been successfully implemented in many large corporations in order to improve the quality of products and business processes.

Six Sigma™ provides a defined and structured method that allows a problem or opportunity to be defined, measured, analyzed, improved, and controlled. This results in a method that can be used over and over again to design or improve an EMS. This is a concept that not been thoroughly developed in EMS literature to date. However, it is the structured process of Six Sigma™ itself that is probably more beneficial in EMS design as opposed to focusing on which tools are used during the *DMAIC* process.

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List of Acronyms

AST	Aboveground Storage Tank
AP-42	Compilation of Air Pollutant Emission Factors
BB	Black Belt
BTU	British Thermal Unit
CAS No.	Chemistry Abstract Service Number
CEPA	Canadian Environmental Protection Act
C of A	Certificate of Approval
CTQ	Critical to Quality
DFSS	Design for Six Sigma
DMAIC	Define, Measure, Analyze, Improve and Control
DMADV	Define, Measure, Analyze, Design and Verify
DPMO	Defects Per Million Opportunities
DSL	Domestic Substances List
EHS	Environment, Health and Safety
EMS	Environmental Management Systems
EPA	Environmental Protection Act and Environmental Protection Agency
ESDM	Emission Summary and Dispersion Modelling
FMEA	Failure Mode and Effects Analysis
GB	Green Belt
HFC	Hydrofluorocarbon
HWIN	Hazardous Waste Information Network

IRS	Internal Responsibility System
Kg	Kilograms
MBB	Master Black Belt
MM	Million
MOE	Ministry of the Environment
NDSL	Non-Domestic Substances List
NGO	Non-Governmental Organization
NO	Nitric Oxide
NO_2	Oxides of Nitrogen
NPRI	National Pollutant Release Inventory
NSNR	New Substances Notification Regulation
O. Reg. 127	Airborne Contaminant Discharge – Monitoring and Reporting Regulation
P2	Pollution Prevention
PCB	Polychlorinated Biphenyl
PM	Particulate Matter or Preventative Maintenance
QFD	Quality Function Deployment
TDG	Transportation of Dangerous Goods
U.S.	United States
VOC	Volatile Organic Compound
VPI	Vacuum Pressure Impregnated

Chapter 1. Introduction and Study Information

1.1 Introduction

There are many different methods in place for Environmental Management System (EMS) design. However, "EMS work has focused on the identification and description of components and frameworks but has not addressed how to put them together" (Kirkland and Thompson, 1999: 128). Often time, personnel responsible for EMS design do it in isolation and end up recreating what other companies may have already done. "The current challenge in EMS work is...to take EMSs from the theoretical to the practical" (Kirkland and Thompson, 1999: 139). Therefore there is a need for a systematic and consistent process for EMS design. Lack of an EMS may result in decreased management efficiency, decreased operational efficiency, increased liability, and increased fines and compliance costs.

1.2 Study Background

There is currently very little literature available that describes a defined method for designing an EMS. The literature predominantly focuses on conducting pre-EMS development reviews, or gap analyses, auditing an EMS, and evaluating the effectiveness of an EMS to a limited extent[1] (Hagarty, 1998). However, there is a need for formal studies on the various ways to incorporate environmental policies into an EMS (Gabel and Sinclair-Desgagné, 1993).

1.3 Study Hypothesis and Objectives

The thesis hypothesis was that the Six Sigma™ method could be applied to EMS design. The Six Sigma™ method was chosen because it has been successfully implemented in many large corporations in order to improve the quality of various

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[1] See David Hagarty's thesis for a comprehensive study of designing a model for EMS effectiveness review.

business processes resulting in improved profits (Waxer, 2001). As a result, the objectives of this study where to determine:

- The applicability, benefits, strengths, weaknesses and limitations associated with using Six Sigma™ method for EMS design
- If a Roadmap[2] that includes problem-solving, measurement, and cost reduction tools could be developed for subsequent use in EMS design
- If Six Sigma™ provides a systematic and consistent method for organizations to design an EMS

1.4 Study Scope and Limitations

The principal research question of the study was as follows:

Can the Six Sigma™ method be used to design an EMS?

To answer the above question, the following sub-questions needed to be addressed:

1. Could the *Define*, *Measure*, *Analyze*, *Improve* and *Control (DMAIC)* phases of the Six Sigma™ method be applied to EMS design?
2. Is the Six Sigma™ method adaptable to EMS design in addition to its traditional use for quality improvement in manufacturing processes?

The study did not focus on topics such as: quality methods with no evidence of use in environmental management, the Environmental Management and Auditing Scheme (EMAS); the Commission for Environmental Cooperation; risk management systems; methods for including occupational health and safety in the EMS; what motivates employees in an organization to participate in EMS design; why organizations set environmental performance goals (Ransom and Lober, 1999); or why organizations adopt "beyond-compliance environmental policies" (Prakash, 2001). The study also did

[2] A Roadmap is a tool that outlines the steps and associated tools to use in EMS design

not include a review of the quality and statistical techniques and tools that can be used in Six Sigma™. Instead the report only discusses the tools used in the case study. Although a comprehensive review of quality and statistical tools could be beneficial, Six Sigma™ is different from other approaches because it focuses on extensive use of fewer tools that are linked and sequenced in a very methodical way (Horel and Snee, 2002). Moreover, Six Sigma™ includes a subset of tools that range from the basic to the advanced (Pyzdek, 2001).

1.5 Study Assumptions

There were a number of assumptions associated with the study as listed below:

- Several organizations are currently using the Six Sigma™ method to continually improve their business processes
- There is a senior management and employee commitment to environmental management needed in order to achieve business practices that are more environmentally sustainable (Yarnell, 1999)
- Many organizations are willing to use an EMS to manage their environmental risks
- Organizations currently using Six Sigma™ will consider using the method to design an EMS
- There are sufficient resources (financial and human resources) to design an EMS

1.6 Organization of the Report

The report begins with an outline of the method used to complete the study. Chapter three includes a comparative literature review that discusses quality methods used for improvements in environmental management. Chapters four to eight detail the work completed during each of the *Define*, *Measure*, *Analyze*, *Improve*, and *Control* phases of the case study.

Chapter nine provides a discussion regarding the applicability, benefits, strengths, weaknesses, and limitations associated with applying the Six Sigma^{TM} method to EMS design. The report then ends with conclusions regarding the application of the Six Sigma^{TM} to EMS design.

Chapter 2. Study Method

A case study was completed following the *DMAIC* process to design an EMS at "Company A"[3], which is a medium-sized electrical equipment repair facility located in the Ontario Golden Horseshoe area. This facility was chosen because it currently uses Six Sigma™ in its business processes, and it did not have an ISO 14000-based EMS in place. The *DMAIC* process included:

- *Define* – defining the stakeholder requirements, identifying the problem to resolve, and developing the team charter
- *Measure* – measuring how the current EMS process performed by identifying and collecting the key data to measure
- *Analyze* – analyzing the data collected as well as the process to determine the cause of the problems that are resulting in variation in the EMS process
- *Improve* – developing solutions based on data analysis to improve the EMS process
- *Control* – putting controls in place to ensure that improvements are maintained

(Adapted from Eckes, 2001; Green, 2000; Tayntor, 2003)

The study was conducted with the involvement of a team of Company A employees with included: the Service Centre Manager; Environmental, Health and Safety (EHS) Manager; Shop Lead Hand; facility EHS Representative; Purchaser; and the Shipper/Receiver. Each stage of the Six Sigma™ method was completed with this team,

[3] It was agreed that the company used in the research case study would remain anonymous.

with overall feedback from the project Champion (Service Centre Manager) through facility visits, meetings, telephone, and e-mail communication.

The study author was a participant observer, and participated as the Green Belt[4] in team exercises and meetings. Observations were recorded are documented in chapters four to ten including text, figures, tables, as well as in the appendices. Decisions made throughout the study were based on the *DMAIC* process.

[4] The term Green Belt will be defined in section 4.1.3 of the paper.

Chapter 3. Literature Review

The literature review starts with the history of management systems, quality systems, EMSs and their current uses, followed by a review of different quality methods used in EMS design or improvement in environmental management including the Plan-Do-Check-Act (PDCA) approach (ISO 14000) method, the Total Quality Management (TQM) method, the Baldrige Model method, the Kaizen method, the Systems method, and the Six Sigma™ method. A review was completed of each method's application to EMS design or improvement in environmental management, along with its associated strengths, benefits, weaknesses, and limitations.

Approximately two hundred companies that publicly claim to use Six Sigma™ in their business operations were also reviewed to see if any of them were currently applying the Six Sigma™ method to EMS design.

3.1 Management Systems

Many organizations today have implemented management systems in order to manage people, make quality products, track finances, or to minimize potential risk and liability. A system is defined as an organized set of components arranged such that they work together toward one or more goals (Dennis, 1997). Management systems include management functions such as planning, organizing, leading, and controlling the system which results in a system where its parts are related, ordered, arranged, and work together in order to achieve a purpose or goal[5] (Flood and Carson, 1995). One area where many organizations are using a management system is in the quality arena.

[5] See Flood and Carson "Dealing with Complexity: An Introduction to the Theory and Application of Systems Science" for a comprehensive study of systems theory.

3.2 Quality Management

Quality management has become a major part of many North American business operations. This occurred as a result of North American industries suffering quality problems in the 1960s and 1970s. In the 1970s and 1980s, North American businesses began to adopt Japanese quality techniques in an attempt to recover their competitive edge (Dennis, 1997).

There are four chronological periods that can be identified in the twentieth century. The first period could be called the "Taylor inspection period" (Keren, 2001). Frederick Taylor believed that every process could be broken down into minimal activities, and by distributing the activities to different workers, the probability that an error would occur would be reduced to a minimum (Keren, 2001). This approach was called "scientific management", where the "doing" and "thinking" parts of work were not connected (Dennis, 1997). The second period was identified as the quality control period. During the period, it was recognized that error was a systematic matter and not only an employee issue. The occurrence of a defect or error is not the employee's fault or the employer's fault. Instead, it is an error in the system that leads to an error or defect (Keren, 2001). The quality movement then entered the quality assurance period when businesses recognized that their responsibility for a product did not end once it went out the door (Keren, 2001). The last and current period is quality management. This period has taken place during the last twenty years approximately (Keren, 2001). In quality management, the focus is not just on the product produced, but also the processes, activities, and people involved making the product. Previous definitions of quality often overlooked the fact that a system rarely consisted of a single element conforming to a standard. Individual elements, when put together, may not work as a system. Quality management now means realizing value for both the customer and organization in every aspect of the business relationship (Harry, 2000).[6]

A number of quality principles have resulted from the different quality movement periods. First, quality is a philosophical movement that is driven by senior management (Dennis, 1997). Senior management has to believe that implementing quality techniques and methods will result in a better product and better organization. Quality involves everyone. It is not just a quality inspector who is responsible for quality, nor is it just the Quality Assurance Manager. Each person contributes to the organization's success through their work, and therefore is responsible for its results. This is an important concept since it allows capturing the insight of the people closest to the source of problems (Dennis, 1997). This idea is also similar to the Internal Responsibility System (IRS) principles found in occupational health and safety (OHS) systems and legislation. In the IRS philosophy, each person in an organization is responsible for identifying OHS problems and seeking solutions. Another important element is accountability, where everyone is accountable for his or her actions (Plummer *et al*, 2000).[7]

Quality focuses on continuously improving the system instead of placing blame, and promotes upstream prevention, as opposed to downstream inspection activities after an activity or step has been completed. This helps to reduce waste and rework activities that are not cost effective in terms of material and resources. Quality also uses data based decisions (Dennis, 1997). This is because what gets measured gets managed, particularly if the result is to reduce variation (errors or defects) in a product or process. Therefore,

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[6] This is evident with the change in the ISO 9001 International Standard. The 1994 version was very rigid and product focused, and companies had to fit their business into the 19 elements of the Standard. Therefore, a company could make square tires for a car as long as they consistently made them square even if it was useless for the customer. The ISO 9001:2000 Standard, however, begins with finding out your customers requirements first. It also focuses on ensuring consistent business processes, as oppose to just producing a product, to ensure that an organization gives the customer what they want.

[7] Dr. Peter Strahlendorf has also completed articles and teaching material regarding the concept of the Internal Responsibility System (IRS).

statistical analysis is often used to analyze data in order to design and implement solutions to reduce defect or error. This is important since reducing variation, error or defects minimizes dissatisfied customers and losses (Dennis, 1997).

These same principles can be applied to environmental management. For example, implementing upstream prevention activities such as pollution prevention activities can minimize or eliminate pollution at the emission point, and reduce or remove the need for end-of-pipe pollution abatement technologies. This reduces waste (or pollution) going into the environment. Measuring the amount of waste after the implementation of pollution reduction solutions can indicate whether they are effective in reducing the amount of pollution generated. A systematic approach to environmental management can organize activities to ensure that efficient steps are taken to reduce negative impact on the environment. Continuously seeking new and better ways for an organization to reduce its negative impact on the environment is an example of continuous improvement. Finally, involving everyone in the environmental management process removes the responsibility from one individual and clarifies organizational arrangements in environmental management (Dennis, 1997).

It is no wonder that EMS design is primarily based on quality principles. The very same elements are integral to a successful EMS. However, many quality methods used for environmental management are project-specific as oppose to addressing a management system. Quality techniques used for EMS design often define the end performance goal of the system, but do not include steps to design an EMS in order to reach the performance goals.

3.3 Environmental Management Systems (EMS)

The term "environmental management" does not mean that the environment can be managed, but instead that institutions and people that impact the environment can be managed (Krut and Gleckman, 1998). Environmental impact is a result of organizations doing business, and therefore organizations need a system to manage and minimize that impact. As such, an EMS is a "formal set of procedures and policies that define how a business will manage its potential impact on the natural environment and on the health and welfare of the people who depend on it" (Darnall *et al*, 2000: 1). The goal of the EMS is for organizations to successfully integrate environmental considerations into their operations and decision-making.

3.4 EMS Trends

3.4.1 Judicial Reliance on EMS

The use of EMSs is becoming more important for organizations. For example, as of late 2000 the judicial system began to use EMS as a benchmark for desirable behaviour from industry in terms of environmental management (CSA, 2001). The primary standard that has been used is the ISO 14001 International Standard created by the International Organization for Standardization located in Geneva, Switzerland.[8] However, in Canada prosecutors are likely to use elements of the ISO 14001 Standard to test a defendant's claim of due diligence in defence of a charge (CSA, 2001). For example, has the organization identified its applicable legal requirements? Has the organization audited its activities and processes and designed a formal compliance plan? (CSA, 2001).

[8] A more in-depth review of ISO 14001 will be discussed in the "Quality Methodologies for EMS Design" section of the paper.

EMS requirements have been built right into the sentencing structure of the *Canadian Environmental Protection Act, 1999* (CEPA, 1999). For example, it tells a judge to consider if any remedial or preventive action has been taken or proposed by or on behalf of the offender, including having an EMS in place that meets a recognized Canadian or International Standard. The sentencing judge can also include in the sentencing an order that directs the offender to implement an EMS that meets a recognized Canadian or International Standard (Environment Canada, 1999). There are many examples where companies have been sentenced to design and implement an EMS including Prospec Chemicals Ltd., Prototype Circuits Inc., Van Waters & Rogers Ltd., and the City of Calgary (CSA, 2001).[9]

Requirements for an EMS have also been included in Certificates of Approval (C of A) in Ontario. For example, Material Resource Recovery SRBP Inc. was seeking approval under the Ontario *Environmental Protection Act* to establish a hazardous waste processing facility for mercaptan wastes and fluorescent light ballasts. The Ontario Environmental Assessment Board included the requirement to design and implement an EMS in the terms and conditions of the C of A (CSA, 2001).

The requirement for an EMS has also been used "as part of administrative settlements in other countries" (CSA, 2001). For example, the US Department of Justice required Royal Caribbean Cruise Lines to implement an EMS after it was found to have dumped waste into the ocean. This requirement is expected to become the norm for cruise lines in the near future (CSA, 2001).

[9] For more information regarding these cases see the publication "ISO 14001 and Compliance in Canada" from the Canadian Standards Association, or Canadian case law.

3.4.2 Regulators' Use of EMSs

Both federal and provincial governments realize that an EMS is a good tool for a regulated industry to manage its environmental impact. Industry and the public have traditionally defined environmental protection as almost exclusively the government's responsibility (Executive Resource Group, 2001). However, governments are now recognizing the trend toward a shared responsibility by regulatory agencies, industry, non-governmental agencies and the scientific/technical community in managing the environment (Executive Resource Group, 2001). This leads to more performance-based regulations, and more of a partnership. The reasons for this shift are many. First, governments realize that they do not have the resources to fully regulate, inspect, charge and prosecute, and this approach has not been the most effective in environmental management (Executive Resource Group, 2001). Governments are also realizing that the "command and control" approach as a stand-alone approach does not adequately address the more emerging complex environmental challenges of today and in the future (Executive Resource Group, 2001). This is because there may be a lack of knowledge regarding such complex problems in the "command and control approach". However, a performance-based approach establishes the performance target for industry, but allows those with knowledge of the problem to work towards the performance goal. Therefore, there is the move to a more integrated approach of "compliance assurance"[10] where a number of regulatory and non-regulatory tools or instruments such as enforcement, abatement, cooperative agreements, compliance assistance and economic instruments are employed (Executive Research Group, 2001).

[10] This term "compliance assurance" refers to the different methods an environmental regulatory agency may use to ensure that a regulated community is complying with applicable environmental laws and regulations.

Table 3.1: Environmental Compliance Toolkit

Instrument	Definition	Example
Enforcement (procedural or performance-based)	A tool used by governments to gather evidence associated with potential violations, to undertake preparatory work for court actions and sanctions, and to follow up with associated responses to violations of the law.	Mandatory disclosure, investigations and prosecutions, civil liability, criminal, administrative and civil sanctions.
Abatement	Occurs where an environmental regulator negotiates or imposes an abatement strategy for facilities rather than "vigorously" prosecuting violations. However, failure to follow an abatement action can still lead to enforcement action.	Approvals, permitting, licensing, monitoring, inspections, remediation, warnings, occurrence reports, control, stop and remediation orders.
Compliance Assistance	The provision of information to help the regulated facility comply with environmental laws.	Education and training, technical advice, information, plain language legislation, hot lines, websites, community and business partnerships, codes of practice and guidelines.
Economic Instruments	A method of using market incentives and charges to motivate compliance and exemplary environmental performance (tradable emission permits, emission charges).	Tradable emission permits, emission charges, "feebates", financial assurance, subsidies and deposit-refund systems.
Cooperative Agreements	An agreement that requires parties to meet binding information disclosure and performance objectives in return for government incentives.	Unilateral industry commitments (Responsible Care), public disclosure schemes (ARET), recognition programs (P4 program – reduction and pollution prevention achievement), and negotiated agreements and covenants (REVA)

(Adapted from Executive Resources Group, 2001)

These tools go beyond the "command and control" approach where the regulatory body dictates what has to be done. Instead the tools are more performance-based where the regulated facility is given more flexibility to achieve the end goal, since it is the regulated facility that processes the most knowledge about the problem or areas that need to be improved. The basic premise is that the goal to be achieved will dictate what compliance assurance tool to use. However, there is still the challenge of finding the right tool to do the right job (Executive Research Group, 2001).

EMS requirements have been incorporated into a number of regulatory tools throughout Canada. For example, The *Nova Scotia Pipeline Regulations* require all operators to comply with ISO 14001 (CSA, 2001). New Brunswick's *Gas Distribution Act, 1999* also requires gas distributors to design an EMS (CSA, 2001). Finally, British Columbia's *Waste Management Act* requires applicable facilities to use a management system as part of their product stewardship programs, such as programs that take back residual product (such as paint) and containers from consumers (CSA, 2001).

Another tool in which EMS requirements have been incorporated is the cooperative agreement. Environmental cooperative or performance agreements include two parties that enter into an agreement to carry out specified activities on the other's behalf, or in order to agree to achieve some kind of "end". Sector associations, governments, and NGOs (sometimes) enter into a cooperative agreement as a voluntary initiative to support pollution prevention. For example, the MOE has created a cooperative agreement with the Automotive Parts Manufacturing Association (APMA) where one of the entry requirements is to have an ISO 14001-based EMS in place (Ministry of the Environment, 2003). A similar requirement is also included in Environment Canada's (EC) environmental performance agreement with the Automotive

Parts Manufacturing Association[11] (Environment Canada, 2002). Thus, an EMS has been identified as a major element in these cooperative agreements.

Canadian regulators have also incorporated EMS requirements into permit requirements. In Alberta, for example, EMS requirements were built right into Shell Canada Limited's operating approval for the Jumping Pond sour gas plant. In terms of tax credits, Nova Scotia regulators have offered a tax credit for the cost of obtaining ISO 14001 registration (CSA, 2001).

In the US, a number of state jurisdictions are allowing companies that have implemented an EMS to conduct their own routine monitoring, reporting, and auditing with clear accountability and verification requirements (Executive Resource Group, 2000). For example, in 1997 the Massachusetts Department of Environmental Protection (MDEP) launched the Environmental Results Program. The program requires companies in targeted sectors to submit an annual self-certification of compliance to the MDEP that is signed by the most senior corporate official in the company. If a facility is not in compliance with all applicable requirements, it has to identify deficiencies and complete a Return to Compliance (RTC) report that describes how and when it will achieve compliance. Failure to certify will result in a $1,000 per day fine. The program is also complemented with a compliance assistance program. The program currently applies to the dry-cleaning, photo processing, and printing industries (Executive Resources Group, 2000).

New Jersey implemented the Silver Track program in 1999. The program provides different degrees of regulatory flexibility and oversight for qualifying facilities (Executive Resources Group, 2000). The program requires accountability, measures

[11] Both the MOE and EC cooperative/performance agreements target reduction of criteria air contaminant (CAC) and greenhouse gas emissions from member companies of the APMA.

environmental performance, and provides operational flexibility. Furthermore, acceptance into the program indicates a demonstrable and measurable commitment to improved environmental performance, together with monitoring, reporting and oversight by the Department (Executive Resources Group, 2000).

3.4.3 Industry's Use of EMSs

Many organizations have adopted a formal EMS in order to systematically manage their environmental risk and impact performance (Darnall *et al*, 2000). It is widely recognized that by improving the environmental performance of organizations, the negative environmental effects of organizations within modern society can be reduced (Yarnell, 1999). Since the 1970s, many organizations have designed environmental management procedures, although environmental management has largely remained the responsibility of a single person within the organization (Darnall *et al*, 2000). One person assigned to environmental management is not going to be as effective as everyone in the organization doing it. More importantly, completing environmental management as an isolated, ancillary activity usually results in reactive management, as opposed to a naturally intrinsic consideration in all business activities. Inadequate environmental management may result if the EMS is not integrated with other systems within the organization (Kirkland and Thompson, 1999). Thus, environmental management should be "an organization-wide mission for which all managers would be held accountable" (Darnall *et al*, 2000: 1). However, many organizations today are adopting EMSs in order to better integrate environmental considerations throughout their operations in order to manage environmental impacts more effectively and efficiently (Darnall *et al*, 2000). As Yarnell states, "to achieve more environmentally friendly business practices, organizations must design internal management processes that integrate environmental objectives into their day-to-day operations" (Yarnell, 1999: 1). As a result, in the 1990s EMSs were developed in order to provide a framework for organizations that were trying to incorporate environmental objectives into their decision-making (Yarnell, 1999).

There are many other reasons why industry is adopting EMSs. Organizations may implement an EMS because their stakeholders want it. For example, judges, regulators, shareholders, non-governmental organizations (NGOs), ethical fund managers, lenders, clients, and the general public may want an organization to implement an EMS (Darnall *et al*, 2000; Yarnell, 1999). Internal customers such as enlightened employees and "legacy-minded" Chief Executive Officers may want it. There are a number of benefits associated with EMSs as well. An EMS allows organizations to use its experience, knowledge, insight and motivation to "answer" the problem of environmental protection. An EMS can ensure that organizations comply with applicable environmental legislation, as well as manage their environmental risks and liabilities. In theory, once a business implements an EMS, it will surpass specific procedural or regulatory standards for such regulated activities, and "may identify opportunities for reducing non-regulated environmental impacts…[and] may also lessen their environmental reporting burdens and the cost associated with them" (Darnall *et al*, 2000: 2). Other benefits include increased management efficiency, increased operational efficiency, reduced liability, regulatory benefits, improved community relationships, and improved customer/supplier relationships, cost savings due to activities such as reduced raw material usage, water usage, waste disposal costs, fines and compliance costs (University of North Carolina, 2003).

Industry wants to be competitive through lean production and quality, and now decision makers see environmental management as a means to efficiency and competitiveness as well.

3.5 Quality Methods for EMS Design

EMS studies have focused primarily on conducting EMS gap analyses, auditing an EMS, and the benefits of implementing an EMS. However, there is limited information available regarding actual methods used for designing an EMS (Yarnell, 1999). Although there is clearer guidance as to what is expected as part of the EMS (CSA, 2001), there is a lack of studies, examples and explanations of how to design an EMS (Kirkland and Thompson, 1999). Therefore, the current challenge in EMS work is to move from theory to application (Kirkland and Thompson, 1999).

Different quality methods have been used for EMS design or environmental management improvement. The discussion below highlights different quality methods that have been used for EMS design to varying degrees, including ISO standards, Total Quality Management (TQM), the Malcolm Baldrige Model, Kaizen, and the Systems Approach. Each approach is reviewed below as to evaluate its application to EMS, its benefits, and limitations. The discussion ends with a comparative review of the Six Sigma™ method, and why it can be applied to EMS design.

3.5.1 ISO 14000

ISO 14000 is a family of global, voluntary environmental management standards created and promoted by the International Organization for Standardization located in Geneva, Switzerland. ISO 14001 is the standard against which organizations may have their EMS audited and registered through a third party registrar (Corbett and Kirsch, 2000). ISO 14000 uses the quality Plan-Do-Check-Act approach to environmental management, which is a cycle of activities designed to drive continuous improvement in an organization. It was first designed by Walter Shewhart, and was popularized by W. Edward Deming.

The planning aspect includes the identification and significance ranking of an organization's environmental aspects and impacts respectively. An organization also identifies its applicable legal and other requirements during this stage. Objectives and targets that are consistent with the organization's policy and pollution prevention goals are then established, and environmental management programs are implemented to achieve the objectives and targets. The implementation aspect of the cycle involves defining the structure and responsibility of personnel involved in managing the EMS. This stage also includes training and awareness of employees, as well as communication, documentation, operational control, and emergency response. The monitoring and measurement stage of the cycle monitors and measures environmental objectives and targets, compliance with environmental regulations, and monitoring equipment. Nonconformance, corrective and preventive action, records and internal audits are all tools to assist with checking the status of the EMS. Finally, the "act" stage involves management review to ensure that the EMS is functioning, and may include changes for continual improvement. The key measurement is determining whether the EMS is achieving the commitments of the environmental policy (International Organization for Standardization, 1996).

The standard is intended to "provide organizations with the elements of an effective environmental management system which can be integrated with other management requirements, to assist organizations to achieve environmental and economic goals" (International Organization for Standardization, 1996: v). However, ISO 14000 is not only about environmental management. According to Corbett and Kirsch it is "a broader business standard intended to help registered firms integrate, gain control over, and ultimately improve overall, company-wide environmental performance" (Corbett and Kirsch, 2000: 8). It is about an organization using quality techniques to effectively manage an aspect of its business.

There are many potential benefits associated with implementing an ISO 14000 EMS including the following:

- Demonstrating a standard of care with respect to due diligence
- Savings from reduced noncompliance with environmental regulations
- Satisfying investors, public and environmental groups
- Heightening employee satisfaction and morale
- Facilitating access to capital and insurance
- Streamlining and reducing environmental reporting requirements
- Increasing resource productivity (material savings and waste reduction)
- Accessing markets that design the standard as a "de facto" requirement in business relationships

(Adapted from Yarnell, 1999)

There are also a number of limitations associated with the ISO 14000 EMS framework. ISO 14000 EMS provides an organization with wide latitude in implementation, therefore facilitating adoption by different types of organizations (Davis, 2000). However, this wide latitude also results in a lack of a method to implement the EMS. As Kirkland and Thompson state, "while these models outline what should be introduced, they provide little guidance on how EMSs may be implemented" (Kirkland and Thompson, 1999: 128). Although the ISO 14004 guidance document does attempt to provide guidance on ISO 14001 implementation, some of the ambiguities of the standard such as methods of identifying and ranking significant aspects remain limitations to implementation (CSA, 2001). Moreover, the ISO 14000 framework focuses on the identification and description of components and frameworks "but has not addressed how to put the EMS elements together" (Kirkland and Thompson, 1999: 128).

There also tends to be a focus on top management commitment, and not employee involvement in the ISO 14000 EMS design process. The emphasis on top management commitment and not employee input into EMS policies, ISO outlines a top-down, hierarchical management approach, which contradicts current management trends (Yarnell, 1999). Therefore, EMS responsibilities are often delegated to a single manager or small team, and this is not exemplary of the IRS philosophy of everyone having a responsibility in environmental management.

Finally, most ISO 14000 work has focused on risk reduction, compliance and liability, and as a consequence the connection between environmental performance and business performance is not being made as well as it could (International Network for Environmental Management, 1998). Most of the benefit and cost attributes are intangible by their nature and are therefore difficult to measure, and the link between good environmental management and the benefit to the organization's bottom line is not being consistently made (Petroni, 2000).

ISO 14000 is gaining widespread acceptance as the tool to be used to design an EMS, due to its international applicability and more specifically because of supply chain pressure (International Network for Environmental Management, 1998). The main goal of creating ISO 14000 was to prevent the introduction of non-tariff trade barriers by standardizing the many national frameworks that were occurring (Yarnell, 1999). The overall result may be that ISO 14000 "is being sold and bought on the basis of its implied trade advantage, not its environmental benefits" (Krut and Gleckman, 1998: 90). Environmental performance improvement is not necessarily the goal of the investment as oppose to gaining access to business markets (Krut and Gleckman, 1998).

3.5.2 Total Quality Management

Total quality management (TQM) was first introduced in Japan by W. Edward Deming and Joseph M. Juran as part of a US-sponsored rebuilding program following World War II (Hagarty, 1998). TQM gained popularity by the mid-1980s, and since then has become a widely-adopted management philosophy in North America (Hagarty, 1998). TQM is "a set of tools, a philosophy and process whose outputs yield customer satisfaction and continuous improvement" (Hradesky, 1995: 2). A key element in the TQM philosophy, which is similar to Six Sigma™, is the change management focus, which includes processes like training and awareness programs (Yarnell, 1999). Other elements of the TQM philosophy that are very similar to Six Sigma™ include the following:

- The focus is on the customer, as he/she is the determiner of quality
- Quality is built into the product early (upstream) rather than being added on at the end (downstream)
- Preventing variability is the key to producing high quality
- Quality results from people working within systems, not individual efforts
- Quality requires continuous improvement of inputs and processes
- Quality improvement requires strong worker participation
- Quality requires total organizational commitment

(Adapted from Hagarty, 1998)

TQM, like Six Sigma™, purports that everyone in the company is involved in EMS design (Hradesky, 1995) as opposed to the top-down approach of ISO 14000. It also requires that top management is involved and committed, and that the focus is on implementation (Bhat, 1998; Hradesky, 1995). Finally, TQM encourages employee motivation by recognizing employee achievements (Padhi, 2002).

Total Quality Environmental Management (TQEM) is an extension of TQM, and was first introduced by the Global Environmental Management Initiative (GEMI) (Hagarty, 1998). GEMI is a non-profit organization whose mission is "Business helping business achieve environmental, health and safety excellence" (Hagarty, 1998: 64). The elements of TQEM are also similar to Six Sigma™, and include the following (Hagarty, 1998):

- Identifying customers – the customer (or stakeholder) environmental requirements must be identified and actions taken to ensure that these requirements are met
- Continuous improvement – there is a systematic on-going effort to improve business EMS processes
- Do the job right the first time – the organization has to detect and eliminate environmental problems before they occur
- The systems approach – every person and element of the organizational structure is part of the EMS, and therefore environmental concerns are included in all business decisions

While TQM and Six Sigma™ principles are pretty much the same, there are limitations associated with the TQM method. Unlike Six Sigma™, there is no roadmap provided to help decipher what statistical tools to use and when. TQM only provides very broad guidelines for management to follow resulting in an unsuccessful attempt by many business leaders to deploy a strategy for TQM (Pyzdek, 2001). TQM programs also focus on improvements in individual operations with unrelated processes as opposed to making improvements in all operations within a process (Harry, 2000; Pande *et al*, 2000). For example, TQM may focus on improving the design stage in making a light bulb, whereas Six Sigma™ will examine each process in making a light bulb including design, purchasing, manufacturing, and shipping/receiving. Finally, TQM does not capture cost implications and savings associated with its changes. Instead, TQM offered a soft set of philosophical guidelines and no way to prove that quality goals were achieved (Pyzdek, 2001).

3.5.3 The Malcolm Baldrige Model

The Malcolm Baldrige National Quality Award was established by US Congress in 1987 to recognize organizations for their quality and business performance achievements (Pojasek, 2000). "The award was designed to raise awareness about the importance of quality and performance excellence as a competitive edge" (Pojasek, 2000: 92). At the time that this award was established, it was believed that quality was no longer an option for organizations but instead that it was a necessity of doing business (Pojasek, 2000). The criteria are now regarded as an international standard for performance excellence. This differs from ISO Standards in that they only cover approximately ten percent of the scope of the Malcolm Baldrige criteria, and furthermore do not fully address any of the Malcolm Baldrige criteria (Hagarty, 1998).

The Malcolm Baldrige model provides a way to both measure progress and select continuous improvement projects to implement (Pojasek, 2000). It includes a rigorous scoring system that is used by highly trained examiners, and has a set of core values that must be integrated throughout the program (Pojasek, 2000). This model has been successfully adapted for achieving environmental excellence in the State of New Mexico under its New Mexico Green Zia Environmental Excellence Program (Pojasek, 2000). Environmental criteria include (Pojasek, 2000):

- Leadership – how senior management guides the organization and how the organization addresses its environmental responsibilities to the public
- Planning for continuous environmental improvement – how the organization sets strategic goals for continuous environmental improvement and how it determines key action plans
- Involvement of customers, suppliers and others – how the organization determines the requirements and expectation of stakeholders
- Information and analysis – how the organization manages, effectively uses, and analyzes data and information to support key environmental processes and the organization's performance in the EMS
- Employee involvement – how the organization enables its workforce to be actively engaged in the organization's environmental performance
- Process management – how key environmental processes are designed, managed and improved
- Results – examines the organization's environmental performance and improvement, and how it performs compared to competitors

Scoring is conducted by trained examiners and is initially based on applicant responses. The evaluation criteria fall under the categories of Approach/Deployment and Results. The rating scheme is a percentage-based score that determines how well the system is implemented and measured. Examiners come to a score by consensus in order to allow for consistency in scoring (Pojasek, 2000).

The Baldrige model does a nice job of requiring measurement and analysis in order to demonstrate improvement. Participants also benefit from a detailed feedback report that outlines all the strengths and weaknesses of the application. "The report can provide for continuous improvement by specifying opportunities for improvement that the organization should focus on during the upcoming year" (Pojasek, 2000: 95). Furthermore, the Baldrige model encourages organizations to strive for excellence instead of being satisfied with compliance (Pojasek, 2000).

Nonetheless, the Baldrige model does not describe how to design an EMS; it only provides a scoring mechanism to evaluate how well an organization has designed it. The scoring system is also somewhat subjective since it is based on examiners coming to a consensus. A review of the Malcolm Baldrige Award website did not indicate any winners for EMS design at this time.

3.5.4 Kaizen

The Kaizen approach advocates continual improvement through small steps. Kaizen is a Japanese word meaning gradual, orderly, continual improvement (Soltero and Waldrip, 2002). Like other quality approaches, Kaizen is based on post World War II business approaches that emphasized employee involvement, and fact-based decision making resulting in continuous improvement (Soltero and Waldrip, 2002). This method is similar to TQM and Six Sigma™, but Kaizen goes further by requiring that everyone in an organization work together to make incremental improvements in the EMS without large capital investments (Soltero and Waldrip, 2002). In short, Kaizen is an evolutionary approach. Kaizen also takes programs "that may be seen as having ownership in one department and makes them everyone's responsibility" (Soltero and Waldrip, 2002: 23). Once again, this exemplifies the IRS philosophy of everyone having responsibility for environmental management as opposed to the top down approach of ISO 14000.

The benefit of Kaizen is that it is a "low-cost, people-based, continual improvement strategy that is aimed at simplifying work methods in order to increase work flow" (Soltero and Waldrip, 2002: 26). However, Kaizen is more of a philosophy rather than a design tool as it provides a framework in which other quality methods can be employed to bring about change in increments. For example, Kaizen can be used as a framework to allow for: 1) standardization through an ISO-14000 EMS; 2) simplify processes; and 3) reduce variation through initiatives such as Six Sigma™ (Soltero and Waldrip, 2002). This type of approach is not only time consuming and long, but very costly in terms of training and resources.

3.5.5 Systems Approach

The systems approach originates from systems theory[12]. As previously stated, a system is defined as an organized set of components arranged such that they work together toward one or more goals (Dennis, 1997). Management systems include management functions such as planning, organizing, leading, and controlling into the system which results in a system where its parts are related, ordered, arranged, and work together in order to achieve a purpose or goal (Flood and Carson, 1995). The systems approach to EMS design "employs a team environment, using process characterization, problem-solving, and decision-making tools to identify opportunities for conserving resources, reducing wastes, and decreasing costs" (Wlodarczyk *et al*, 2000: 53).

[12] See Flood and Carson "Dealing with Complexity: An Introduction to the Theory and Application of Systems Science" for a comprehensive study of systems theory.

According to the systems approach, organizations need a problem-solving method that will enable them to seek solutions on their own (Wlodarczyk *et al*, 2000). The tools used in the systems approach are designed for use in teams. Tools include process mapping, identifying and rank ordering environmental problems, "Pareto charting"[13] to identify dollars lost, root cause analysis, designing and choosing the best solution, and creating an action plan. The tools used in the systems approach are similar to those used in TQM and Six Sigma™, and do a nice job of making the link between pollution and costs. Continuous improvement is also built into the method, as the steps the team will have completed are actually a collection of tools that the organization can use over and over to constantly improve and become more efficient (Wlodarczyk *et al*, 2000).

The systems approach does a nice job of problem solving, but unlike Six Sigma™, it lacks a consistent, methodical roadmap that can be used for EMS design.

3.5.6 Six Sigma™

Six Sigma™ as a measurement standard can be traced back to Carl Gauss who introduced the concept of the normal curve (isixsigma.com, 2002). Six Sigma™ as a measurement standard in product variation can be credited to Walter Shewhart who highlighted that three sigma from the mean is the point where a process requires correction (isixsigma.com, 2002). However, in 1979 Motorola designed Six Sigma™ as a methodical quality technique to provide more granularity by moving from the traditional quality measurement of errors per thousand opportunities to measure defects per million opportunities (isixsigma.com, 2002). In other words, the measurement indicator was moved from the traditional quality mark of 99% (or 3.8 sigma level) to the 99.99966% mark (6 sigma level). That means a difference 66, 807 defects per million

[13] A Pareto-chart is a tool used to focus on the problems that pose the greatest potential for improvement showing their relative frequency or size in a descending bar graph (Brassard and Ritter, 1994).

opportunities versus 3.4 defects per million opportunities. For example, that can mean the difference between having unsafe drinking water almost fifteen minutes each day versus one minute of unsafe drinking water every seven months. Hence the name Six Sigma™; it is a process that strives to reduce defects or errors to the point where only 3.4 defects per million opportunities will occur.

Six Sigma™ is a disciplined method of defining, measuring, analyzing, improving and controlling the quality of a process (Ramberg, 2000). It has also been defined in a number of other ways including:

- A statistical measure of the performance of a process or product
- A method used to reduce process cycle time
- A goal that reaches near perfection for performance improvement by reducing defects using facts and data to drive better solutions and
- A system of management to achieve lasting business leadership and world-class performance

(Adapted from Pande and Holpp, 2002; Pyzdek, 2001)

The quality principles and tools used in Six Sigma™ are not new. Like TQM, Six Sigma™ is a problem-solving process that focuses on improving stakeholder satisfaction. However, the difference is that a Six Sigma™ method provides a consistent roadmap for problem-solving. Six Sigma™ employs the *Define*, *Measure*, *Analyze*, *Improve* and *Control (DMAIC)* process. The steps are defined in the following table:

Table 3.2: The DMAIC Process

Phase	Description
Define:	Define customers, their requirements, the team charter and the key process that affects the customer, stakeholder-critical parameters, and the problem and identify what is important.

Measure:	Measure how the current process performs, identify key measures and data collection plan for process in question, and execute a plan for data collection.
Analyze:	Analyze data collected and the process to determine the cause of the problems that are causing the process not to perform as desired.
Improve:	Improve the process to reduce defects and variation by generating, determining and subsequently implementing potential solutions.
Control:	Control the process by designing, documenting and implementing a plan to ensure that changes are sustained.

(Adapted from Eckes, 2001; Green, 2000; Tayntor, 2003)

The key difference between the Six Sigma™ method and the Plan-Do-Check-Act method (ISO 14000) is that Six Sigma™ measures and analyzes a problem before implementing solutions, whereas ISO 14000 moves from the planning phase to the implementation phase without any measurement or analysis. Other characteristics that separate Six Sigma™ from other quality methods include producing major returns on investment, and changing how management operates (Pande and Holpp, 2002; Pyzdek, 2001).

There are many benefits associated with using Six Sigma™, including making improvements in all operations within a process, the ability to reach across the entire organization in a unified and focused manner, and the inclusion of a *Control* phase, which aims to keep process improvements from drifting back to old ways (Harry, 2000; Franco, 2001). Six Sigma™ provides a standard process and set of tools that prevents each team from designing its own problem-solving techniques thereby increasing consistency and decreasing time (Tayntor, 2003). Six Sigma™ also analyzes problems up front at the EMS design stage versus an ISO-14000 based EMS, which evaluates a problem through its corrective action tool after it has occurred. This promotes a proactive problem-solving approach as opposed to a reactive one. Often in the dash to show progress in solving a problem, companies fail to understand exactly what it is that they are changing before they begin to implement the modification (Tayntor, 2003). Furthermore, an ISO-14000 based EMS may begin with a gap analysis to highlight where an organization currently sits with respect to the standard. Six Sigma™, on the other hand, also analyzes why there is a gap in the first place. This promotes identification of root causes so that appropriate solutions can be implemented. Finally, Six Sigma™ can facilitate business justification and buy in because it quantifies the cost savings associated with changes.

Six Sigma™ has been criticized as being nothing new in defect prevention (Stamatis, 2000). Critics purport that Six Sigma™ is no different from TQM and systems methods, particularly in terms of its statistical tools, and this is true. Furthermore, critics state that Six Sigma™ is nothing new, just a repackaging of long-cherished quality techniques, or another quality trend that will come and go (Franco, 2001; Dalgleish, 2003). Others further say that Six Sigma™ is not necessarily suited for widespread business adoption (Tantham, 2003). However, Six Sigma™ is a business strategy for improvement; a vehicle to understand where you are in a process and where you want to be. It works to reduce process variation and should be based on the needs of a particular business (Mackertich, 2003). Hoerl and Snee further highlight the difference with Six Sigma™ in that it:

- Formulizes the use of statistical tools as oppose to having isolated individuals use them in a disconnected way
- Provides an overall "road map" or multi-step approach (i.e. DMAIC) to integrate tools appropriately
- Stresses the need to understand and reduce variation as oppose to estimating it

- Puts an emphasis on a data-based approach to management versus an intuition approach

(Adapted from Hoerl and Snee, 2002)

Six Sigma™ can also be criticized for the fact that it requires a lot of commitment, passion, and financial backing (Franco, 2001). However, if Six Sigma™ is already implemented in an organization, the commitment will already exist in terms of using Six Sigma™ to design an EMS.

Six Sigma™ has been used by many organizations to improve business practices and financial gain. A number of organizations have adopted and used Six Sigma™ to complete projects in a number of areas such as manufacturing, engineering, research and design, purchasing and pollution prevention (Dusharme, 2001 and 2003). However, many companies do not publicly state how they are using Six Sigma™ to improve their businesses. A review of approximately two hundred businesses, which profess to use Six Sigma™, was completed to determine whether they were applying this method to EMS design. There was no public information available stating that any company used Six Sigma™ to design an EMS. Instead, research indicated that companies that publicly declared using Six Sigma™ were using it for individual environmental, health and safety (EHS) program improvements such as reducing injuries in the workplace, waste reduction, and streamlining EHS policies and procedures (Table 3.3). However, General Electric has used Six Sigma™ for improving EHS management systems (Mukund, 2003).

Table 3.3: Companies Using Six Sigma™ for EHS Management

Company	Six Sigma™ Use
General Electric	Injury reduction and improving EHS Management Systems (General Electric, 2002 and 2003)
Goodyear Tire & Rubber Company	Oil disposal (Goodyear Tire & Rubber Company, 2002)
Raytheon	Injury reduction, waste reduction, and streamlining EHS policies and procedures (Raytheon, 2002)

TransCorp	Used as a working method in EHS department (TransCorp, 2002)
TRW	Increase productivity and efficiency of EHS programs, and implement cost determination and reduction program for EHS activities (TRW, 2003)

There are many reasons why companies may not publicize their application of the Six Sigma™ method to EMS design. First, the Six Sigma™ method is used in order to increase business competitiveness. If an organization publicly states how it applies the Six Sigma™ method to EMS design, competitors can easily leverage the information and use it to their advantage. Many organizations may already have an EMS in place, or may be using a customer-driven approach such as ISO 14001. Perhaps organizations have not made the connection of applying the Six Sigma™ method to EMS design like they have for other processes improvements. More importantly, organizations may not realize that the environmental management process can be improved. Another reason why organizations may not use the Six Sigma™ method to design an EMS is because there is no perceived cost savings, or the focus is to complete projects that result in direct cost savings.

Nonetheless, the Six Sigma™ method can be used to design an EMS because it can reduce defects or errors in the environmental management process by identifying and eliminating defects. All work is a process, all processes have variability, and all processes generate data that explains variability (Smith, 2003). Honeywell has said that it has seen dramatic results that equal or surpass those it has been in the manufacturing area when it applied the *DMAIC* method to nontraditional projects (Green, 2000). For example, the Six Sigma™ method can be used to address an invoicing process problem. The first step is to define the problem. The problem is that customers are receiving their invoices very late, and are therefore paying the late payment fee as well. The next step is to measure the problem in terms of how many times is this occurring, and how long the cycle is from shipping the product to invoicing the customer. Once the data are collected, the information is analyzed to identify any root causes resulting in late invoices. Once the root causes are identified, solutions are implemented to reduce the cycle time between product shipment and invoicing. Finally, controls can be put in place to ensure that customers do not receive late invoices again. Similarly, this study shows that the Six Sigma^{TM} method can be used to design an EMS.

Chapter 4. *Define* Phase

4.1 Introduction

The *Define* phase is a critical step in improving a process. However, when it comes to process improvement through other methods the step is often missed. This is because there is a tendency to rush through to the improvement stage in order to show progress, thereby failing to understand exactly what has to be improved before implementing the modification (Tayntor, 2003). For example, an organization using an ISO 14001 based EMS plans the EMS and then implements it. The Six Sigma™ method, on the other hand, will define EMS design as the opportunity, and then move on to measure how well the EMS is functioning if at all before moving to the implementation stage. This facilitates implementing solutions that will address any problems identified with environmental management as oppose to blindly implementing an EMS. There are a number of elements involved with the *Define* phase. This chapter begins with a more in-depth description of the facility used for the case study, including a discussion about Six Sigma™ use in the organization. Different Six Sigma™ roles are then discussed. Then the key elements of the *Define* phase including the Critical-to-Quality (CTQ) characteristics[14], team charter, project plan, and process map are discussed in detail.

4.1.1 Facility Information

The facility used for the research case study, which is called "Company A", provides customer support for many various electrical and mechanical machines and devices. Service provided follows the life cycle for equipment including installations, commissioning, maintenance, refurbishing, repair, and upgrades of all electrical and mechanical apparatus. Installation, commissioning and maintenance activities are

[14] The Critical-to-Quality characteristics (CTQs) are the key measurable characteristics of a process whose performance standards must be met in order to satisfy the customer.

performed by field technical personnel and sometimes by shop floor staff. Facility processes include transformer coil repair and refurbishing in Bay 1, electrical motor repair in Bay 2, transformer repair in Bay 3, babbit-bearing repair in the machine shop, and switchgear repair in the switchgear area. The facility map is included in Appendix 1. There are approximately 50 employees, including office and shop floor staff with 2 shifts. The facility was built approximately 30 years ago with 2-3 expansions, and is approximately 46,000 square feet. It is located in an industrial zone in Ontario's "Golden Horseshoe" area.

4.1.2 The Six Sigma™ Method in the Organization

Company A is part of a very large corporation that uses the Six Sigma™ method as a way of carrying on its business. The organization embraced the Six Sigma™ method approximately eight years ago. A large-scale transformation occurred with millions of dollars spent on Six Sigma™ training. There was also a challenge to each senior manager from the top of the corporation to implement the Six Sigma™ method. As a result, most employees completed Six Sigma™ training and completed projects as a part of their job[15]. The corporation has reportedly saved in excess of five billion dollars since implementing the Six Sigma™ method over six years (Table 4.1).

Table 4.1: Six Sigma™ Cost Savings

Year	Total Cost Savings (in Billions of Dollars)
1996	0.2
1997	1
1998	1.3
1999	2
2000	NA
2001	1.5

(Adapted from isixsigma.com, 2003)

[15] In fact, completion of Six Sigma™ projects was mandatory for career advancement in this organization.

At Company A, most if not all of the staff have completed Six Sigma™ training. Most salary staff completed a two-week training course delivered from within the organization. Hourly staff completed "on-the-job" training, which was a condensed version of the two-week course. The training typically included the *Define*, *Measure*, *Analyze*, *Improve* and *Control (DMAIC)* phases, although some individuals may have completed Design for Six Sigma™ (DFSS) training as well.

Working with a facility that used the Six Sigma™ method in its everyday business processes facilitated completion of the case study. Thus, using the Six Sigma™ method in an untrained organization would result in a large commitment of resources in terms of time and money, a commitment that would have to come from the most senior person in the organization.

4.1.3 Six Sigma™ Roles

In order to support the Six Sigma™ method in an organization, personnel may assume a number of Six Sigma™ roles in the process. The different roles include the Master Black Belt, Black Belt, Green Belt, and Champion/Sponsor.

The Master Black Belt role acts as a coach and mentor or consultant to Black Belts working on a variety of projects (Harry, 2000; Pande and Holpp, 2002). The person is also a "change agent", helping to promote Six Sigma™ solutions. Another role the Master Black Belt may play is Six Sigma™ trainer, as well as customer advocate (Pande and Holpp, 2002). Due to the nature of the Master Black Belt role, personnel who have this position are experts in the analytical tools used, and often have an engineering or science background with an advanced business degree (Pande and Holpp, 2002). Personnel also have to have intimate knowledge about how the business works. The Master Black Belt for Company A was located at the most senior business level in the corporation at a different location from Company A. This individual was a senior quality manager who served as a coach and mentor to the Black Belts as well as a customer advocate, and therefore was not involved in the day-to-day business at the facility level.

The Black Belt role is perhaps the most critical role in Six Sigma™. The individual who assumes this role must have a number of different skills including:

- Problem-solving
- Collecting and analyzing data
- Organizational diplomacy
- Leadership
- Coaching and mentoring
- Administration
- Project management

(Adapted from Harry, 2000; Pande and Holpp, 2002)

These skills are critical because it is usually the Black Belt who mobilizes the project team, promoting change opportunities and driving results. In short, the Black Belt is a change agent. Very often personnel who assume Black Belt roles have a high chance of promotion into other career opportunities as well. Company A had a Black Belt located at the business level. Because most if not all employees had Six Sigma™ training and experience, the Black Belt role in this case was more of a support role for Green Belts, and it provided an opportunity to work closely with customers on larger, long-range projects to improve business viability.

The Green Belt role is basically someone who is trained in Six Sigma™ skills, most often to the same level as the Black Belt. The key difference, however, is that the Green Belt continues to do his or her regular job, and completes Six Sigma™ projects as part of his or her job (Eckes 2001; Harry 2000; Pande and Holpp, 2002). The Green Belt role is crucial because it is personnel in this role who bring the Six Sigma™ method and tools to the day-to-day business activities. As previously mentioned, most if not all of the employees at Company A were Green Belts.

Another critical role in addition to the Master Belt and Black Belt is the Champion or Sponsor. This person is usually in a senior management role at the local level, and his or her participation sends a very strong message of commitment. The Champion/Sponsor has a very personal interest in the projects because this person is ultimately accountable. As Pande and Holpp state, the Champion/Sponsor has the following responsibilities:

- Ensure that projects stay aligned with overall business goals and provide direction when they do not
- Keep other members of the leadership team informed on the progress of projects
- Provide or cajole needed resources, such as time, money, and help from others, for the team
- Conduct the DMAIC tollgate reviews to ensure that each step in the DMAIC process is completed
- Negotiate conflicts, overlaps, and linkages with other Six Sigma™ projects

(Adapted from Pande and Holpp, 2002)

The Champion at Company A was the Service Centre Manager. This was beneficial because this person was involved with the whole EMS design process, which resulted in an increase in the Service Centre Manager's awareness of environmental management and issues, as well as his accountability in managing the environmental risks of the facility.

Defining the different Six Sigma^{TM} roles was important because a basic premise of Six Sigma^{TM} is that it is not one person who starts and manages the project once it is completed, but that project solutions are infused into day-to-day business operations for everyone's use.

4.2 *Define* Phase

4.2.1 Identifying the Project

One key component of Six Sigma^{TM} is the focus on the customer (Pande and Holpp, 2002). Therefore, the first question asked was who were Company A's customers or stakeholders with regards to environmental management. It was decided that there were a number of key stakeholders. The primary key stakeholders were the customers themselves. Environmental management was critical for Company A because it deals with a number of environmentally sensitive materials such as asbestos found in old motors to be repaired and polychlorinated biphenyls (PCBs) from transformer oil for example. Therefore, customers want to ensure that there are sound practices in place to prevent any environmental incidents from occurring, especially since it is their equipment that is being repaired. In fact, many of Company A's customers requested information on their health and safety program as part of the job bidding process.

Another key stakeholder was the parent company or corporation itself because there was an expressed commitment to meet environmental regulatory requirements through its environmental, health and safety (EHS) policy, demonstrate due diligence, and avoid negative media publicity should it be subject to regulatory action.

The government was also identified as a key stakeholder since it establishes the requirements and criteria by which industrial facilities have to comply.

Another identified stakeholder group was comprised of non-governmental organizations (NGOs) as they have a primary interest in protecting the environment for all citizens.

Neighbours, including industrial, commercial and residential, were also identified as stakeholders, as any environmental upset could have impacted on their health, use and enjoyment of property[16].

Shareholders were also identified as stakeholders as negative events or publicity could result in a drop in share price (Bosch *et al*, 1996).[17]

Finally, Company A employees were identified as stakeholders as many were residents of the community, and employees did not want harm the environment.

Once the key stakeholders were identified, the next step was to determine who in the company represented the voice of the customer. It was decided that the Service Centre Manager represented the voice of the customer because he was ultimately accountable for meeting both business and customer requirements. The Service Centre Manager also felt that he was ultimately responsible for the company's environmental performance and therefore became the Champion/Sponsor of the research project. One important comment from the Champion was that he saw an EMS as part of the overall business management system.

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[16] The idea of impact on health and use and enjoyment of property comes from the definition of an adverse effect in the Ontario *Environmental Protection Act* (EPA). Sections 6 and 14 of the EPA include general prohibitions against creating an adverse effect in the natural environment.

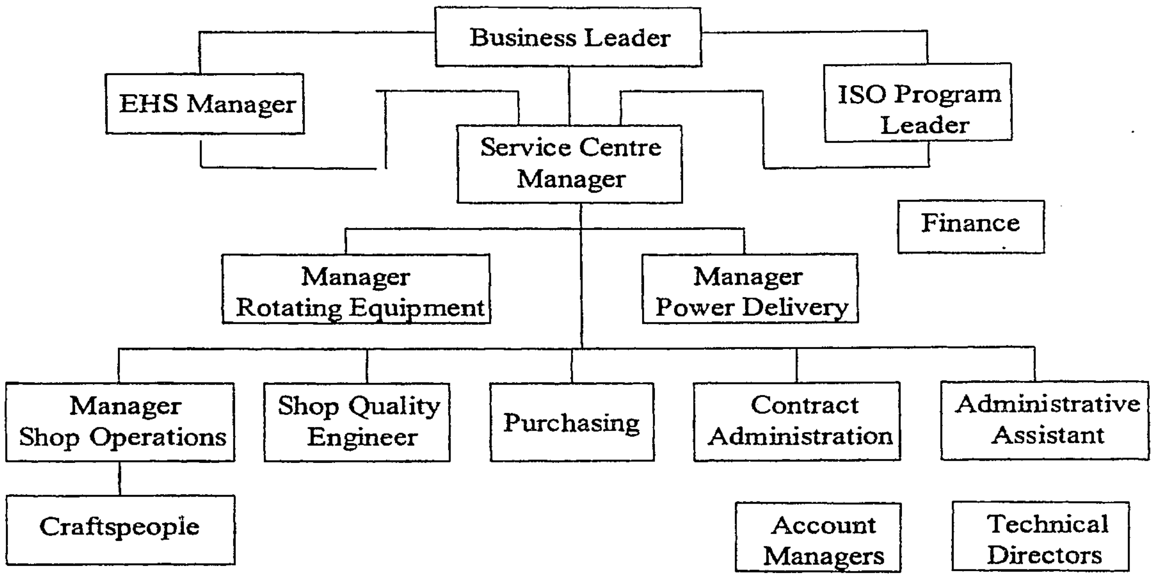
[17] Company A is part of publicly traded U.S. Corporation. Bosch *et al* completed a study that concluded that there is a definite negative market response to the announcement that an organization has attracted the attention of the U.S. EPA (Bosch *et al*, 1996).

The next question was whether there was anyone else who had a stake in ensuring effective environmental management. Senior managers, Business Leaders, Executives, Directors and Officers were identified[18]. Once the Champion was identified for the project, he was asked what he believed was critical to environmental management. Responses included spill prevention, proper storage of chemicals, legacy issues, monitoring of discharges, air emissions, metal recycling, and hazardous chemical substitution. He also stated that he would like to see an EMS save the company money.

It was also important to see who else in the company was able to define environmental issues. A review of the company's organizational chart (Figure 4.1) and discussions with company personnel indicated that people knowledgeable about facility processes such as the Lead Hand and experienced employees could provide valuable information. Personnel who completed environmental activities on a day-to-day basis were also identified as important contacts. This included the company EHS representative and the business level EHS Manager. Support functions such as the Shipper/Receiver and the Purchaser were identified as important contacts as they worked and managed a lot of paperwork that fell under the environmental regulatory area such waste manifests, bills of lading for dangerous goods, and service records for refrigerated equipment.

[18] Directors and Officers can be directly charged for any contravention of environmental requirements (Torys LLP, 2003).

Figure 4.1: Organizational Chart



The next step was to identify what the current environmental management business strategy was for Company A. When asked whether the company had an EMS, the Champion did not know. Therefore, it was also important to determine what existing environmental data was on-site. It was at the *Define* phase that the team had to determine whether there was an existing process to be improved or the absence of a process altogether. If it were a process that needed to be improved, the *Define*, *Measure*, *Analyze*, *Improve,* and *Control (DMAIC)* process would be used. If there was no process, the *Define*, *Measure*, *Analyze*, *Design* and *Verify (DMADV)* process from the Design for Six Sigma (DFSS)[19] method would have to be used.

A preliminary review of company data revealed the following information:

- Monthly EHS communication took place through employee meetings and postings on employee bulletin boards
- Employees completed EHS Culture training

[19] Design for Six Sigma™ (DFSS) is used when a process does not exist and needs to be designed, or when an existing process has been optimized and cannot be improved any further without re-designing the process (Chowdhury, 2003).

- An EHS Scorecard evaluation was completed in 1999
- On-line monitoring and reminder tools such as an EHS compliance calendar were available
- An EHS Manual existed
- A Certificate of approval (Air) had been issued
- Waste manifests were routinely filled out
- Groundwater monitoring reports were available
- PCB storage facility inspection checklists and correspondence with the Ontario Ministry of the Environment (MOE) were available
- EHS business goals including zero notices of violation were available
- Corporate environmental audits had been done

Based on data obtained during the preliminary review, it was agreed that there was some evidence of an EHS system. Therefore the team agreed that the DMAIC process would be used to improve upon the company's EMS. Closer review of the data, however, indicated that it primarily focused on health and safety requirements with a minimal focus on environmental management. For example, the information posted on the employee board was related to accident prevention. Business goals posted on the shop floor just indicated, "zero accidents". Therefore, another factor to determine through the study was whether environmental management was a priority or if there was just a lack of knowledge regarding environmental requirements. The *DMAIC* approach facilitated answering this question.

4.2.2 Team Charter

The next step was to complete the team charter, which is shown in Table 4.2 below.

Table 4.2: Team Charter

Project: Using Six Sigma™ to Design an Environmental Management System (EMS)	
Team Charter Components	
Business Case:	• Increase market competitiveness by demonstrating to stakeholders a proactive approach in managing environmental activities • Determine if regulatory and corporate environmental requirements are being met • Meet business goal of "zero" notices of violations (NOV) • Avoid consequences of not doing the project including potential environmental orders, fines, and corporate scrutiny • Design an Environmental Management System (EMS) as a business tool for environmental management
Opportunity Statement:	Applying Six Sigma™ to EMS design
Project Scope:	• Work processes in company A's facility • Non-inclusion of field work activities • Non-inclusion of different companies located in the building including an installation and field services company and an oil testing lab • Focus on environmental management only and not occupational health and safety management
Goal:	To determine whether Six Sigma™ method could be used to design an EMS.
Objectives:	• Determining the applicability, benefits, strengths, weaknesses and limitations associated with applying the Six Sigma™ method to EMS design • Determining if a Roadmap can be developed that includes problem-solving, cost measurement and reduction tools for use in EMS design • Determine if Six Sigma™ provides a systematic and consistent method for organizations to design an EMS • Determining what improvements, if any, need to be made to the EMS to meet environmental regulatory and corporate requirements
Project Constraints:	• Project work has to take place through a series of facility visits, e-mail and phone communication • Project steps have to be completed in an organized and planned fashion as all team members have their own regular full-time jobs to do with not much time to spare
Required Resources:	• A workspace is required for the author when completing facility visits

	• Access to existing on-line resources and tools in order to identify current tools that the company is using • Potential for some expenses in order to make improvements
Project Milestones:	• *Define* Phase – February 6 – 28, 2003 • *Measure* Phase – March 1 – March 28, 2003 • *Analyze* Phase – March 29 – April 11, 2003 • *Improve* Phase – April 12 – May 16, 2003 • *Control* Phase – May 17 – May 31, 2003
Roles:	• Champion/Sponsor – Service Centre Manager • Study Author – Green Belt • Black Belt – Existing Company A Black Belt • Team Members – Company EHS Representative, business level EHS Manager, Lead Hand, Shipper/Receiver, and Purchaser
Responsibilities:	• Champion/Sponsor – facilitate project completion, provide access to all necessary information, and ensure improvement solutions are implemented • Green Belt – facilitate operationalization of designed solutions, and recommendations • Black Belt – answer any analytical questions that the team may have • Team Members – provide company specific information as required throughout the project

The team charter was a critical tool in the *Define* phase because it included information such as the business case for the project, the problem/opportunity statement, project scope, goals and objectives of the project, project constraints, required resources, project milestones, and roles and responsibilities of the team members (Eckes, 2001; Pande and Holpp, 2002).

The business case described what impact the project would have on the business. For example, why was the project worth doing? What were the consequences of not doing the project? How did it fit in with business initiatives and targets? This tied back to the identified stakeholders and why it was important to meet their requirements. In the case of Company A, completion of the project would increase market competitiveness by demonstrating to stakeholders a proactive approach in managing environmental activities. The project was also worth completing in order to determine if regulatory and corporate environmental requirements were being met. Consequences of not doing the project were identified as potential environmental orders, fines, and corporate scrutiny. Finally, the project fitted into the business goal of "zero" notices of violations. Designing an EMS was a business tool completed to help meet this goal.

Once the business case was completed, the Opportunity Statement was developed. The word "opportunity" was used instead of "problem" since it was not known at the time if there was an existing problem. The opportunity statement described what needed to be improved. The opportunity statement was the research study question applying Six Sigma™ to EMS design.

The project scope established the project boundaries. This was an important step because it served as a reference point for the project to ensure that the project was not moving out of its established boundaries. The project boundaries were as follows:

- Work processes in Company A's facility
- Non-inclusion of field work activities
- Non-inclusion of different companies located in the same building including an installation and field services company and an oil testing lab
- Focus on environmental management only and not occupational health and safety management

The goal and objectives of the project were then designed. The study purpose and objectives were used as the project goals and objectives with some additional objective of determining what improvements, if any, need to be made to the EMS to meet environmental regulatory and corporate requirements. The goal of the project was to determine whether the Six Sigma™ method could be applied to EMS design. Objectives of the project included:

- The applicability, benefits, strengths, weaknesses and limitations associated with using Six Sigma™ method for EMS design
- If a Roadmap that includes problem-solving, measurement, and cost reduction tools could be developed for subsequent use in EMS design
- If Six Sigma™ provides a systematic and consistent method for organizations to design an EMS

It was important to define at the start what the project constraints were and the resources required. This served two purposes. First, identifying project constraints forced a realistic view of how and when the project could be completed. Second, it allowed for the identification of resources, which included human resources, electronic resources, workspace, time, and money. Project work had to take place through a series of facility visits, e-mail and phone communication. Also, project steps had to be completed in an organized and planned fashion as all team members had their own regular full-time jobs to do and not much time to spare. A workspace was required and established for the author when facility visits were completed. Access to existing on-line resources and tools was necessary to identify current tools that the corporation was using. Finally, it was acknowledged that there might be some expenses in order to make improvements.

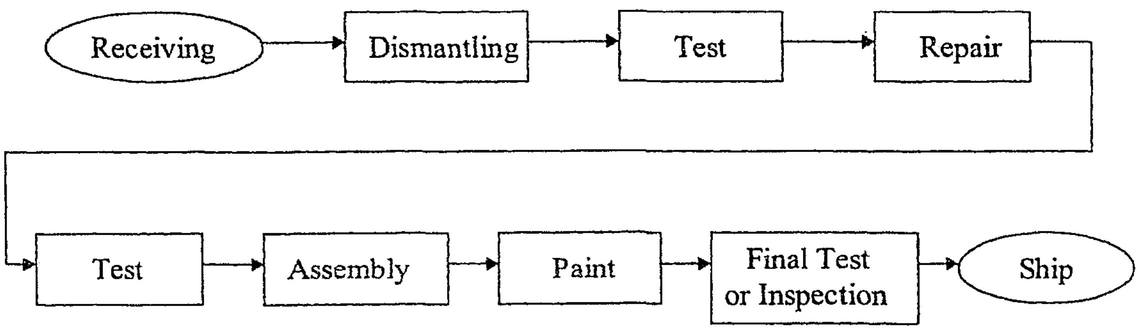
Project milestones were then completed. A basic principle of Six Sigma™ is not to address broad issue. Therefore, the project had to be scoped to enable completion within four to six months, with half of the time spent on the *Define* and *Measure* phases and the other half spent on completing the *Analyze*, *Improve* and *Control* phases (Eckes, 2001; Pande and Holpp, 2002). Furthermore, the *Control* phase often takes place after the team has disbanded since solutions should be operationalized at this point (Eckes, 2001). Therefore, a project plan was designed identifying what steps in the *DMAIC* process would be completed and when.

Finally, roles and responsibilities were defined for the team members. It was important to include people who would have the most impact on the project (Eckes, 2001). Therefore, the Champion/Sponsor of the project was the Service Centre Manager, who was responsible for facilitating project completion and ensuring that solutions for areas of improvements were implemented. The Champion was also responsible to ensure that all the necessary information for project completion was available such as access to environmental documents, personnel, and on-line information. The author of the study assumed the role of Green Belt and/or team leader. This facilitated operationalization of project solutions such as the development of tools to assist with day-to-day environmental management activities. This also resulted in the Green Belt assuming the role of recommendation versus implementation. Company personnel were tasked with implementation responsibilities. The Black Belt was the company's existing Black Belt, and was only consulted when any analytical-type questions arose. Other members of the team included the company EHS representative, who provided environmental documentation, explained the role of the company EHS representative, and was responsible for ensuring that the solutions designed would be implemented. The business level EHS Manager was also a member of the team, and provided information regarding environmental corporate requirements. The Lead hand provided detailed process information, and the Shipper/Receiver and Purchaser provided requested information.

4.2.3 High Level Process Mapping

Once the existing environmental management process was reviewed and the project team was established, it was agreed that the team had to gain a basic understanding of the facility's processes. Therefore, a high-level process map was completed (Figure 4.2). This enabled team members to have the same picture of the process and to work from the same assumptions (Pande and Holpp, 2002). This also allowed the team to connect stakeholders to the process, which occurred at all stages of the process, namely the input, process and outputs stages for the reasons previously described in section 4.2.1 above.

Figure 4.2: High-Level Process Map



The general work process at the facility starts with receipt of the piece of equipment that needs to be repaired. The equipment is then dismantled, tested and repaired. The equipment is re-tested after the repair, assembled, and painted (where applicable). A final test and/or inspection are completed, and the equipment is then shipped back to the customer.

4.2.4 *Define* Phase Tollgate Checklist

Completion of the environmental management process review and the high level process map also set the stage for the next phase, the *Measure* phase, by giving the team an idea of where to collect information (Pande and Holpp, 2002). Once facility process information was documented, a *Define* Phase Tollgate Checklist[20] was completed as outlined in Table 4.3 below.

Table 4.3: *Define* Phase Tollgate Checklist

Steps	Date Completed
Team Readiness	
Team sponsored by a Champion/Sponsor	February 6, 2003
Team Leader Assigned	February 6, 2003
Team Formed	February 6, 2003
Team equipped with available and reliable resources	February 21, 2003
Stakeholders (and CTQs)	
Stakeholders identified and segmented according to the different needs and requirements	February 21, 2003
Data collected and displayed to better understand stakeholders critical needs and requirements	February 21, 2003
Team Charter	
Project Management Charter established including business case, opportunity statement, goals and objectives, project scope, milestones, roles, and responsibilities	February 21, 2003
Business Process Mapping	
Completed, verified, and validated high-level "as is" business process map	February 21, 2003

The purpose of the tollgate checklist was to ensure that all the steps in the *Define* phase were covered and adequately completed. The project then moved to the *Measure* phase.

[20] *DMAIC* Tollgate Checklists ensure that each step in the DMAIC process is completed. There is a Tollgate for each of the *Define*, *Measure*, *Analyze*, *Improve*, and *Control* phases in the study.

Chapter 5. *Measure* Phase

5.1 Introduction

The purpose of the *Measure* phase was to determine current process performance, and to quantify process defects (Waddick, 2003). The *Measure* phase is where a practical problem is converted into a statistical problem. As Pande and Holpp assert, the *Measure* phase has two main objectives:

1. To gather data to validate and to quantify the problem/opportunity.
2. To begin teasing out facts and numbers that offer clues about the causes of the problem.

(Adapted from Pande and Holpp, 2002)

This chapter starts with a review of the CTQ characteristic for the project, and then follows with a review of the detailed process maps for the facility. The discussion then covers process performance standards, the type of data to collect to determine process capability, the data collection process, measurement system analysis, and measurement system results.

5.2 Project CTQ Selection

The purpose of the selecting a project CTQ was to allow the team to focus on what to *Measure*, *Analyze*, *Improve* and *Control*. Sometimes tools such as the Quality Function Deployment (QFD)[21] could be used to accomplish this task. The purpose of the QFD was to take customer requirements and translate them into detailed company requirements to ensure that customer requirements were met (Pyzdek, 2002). However, this tool was not used for this determination because the team was able to determine what

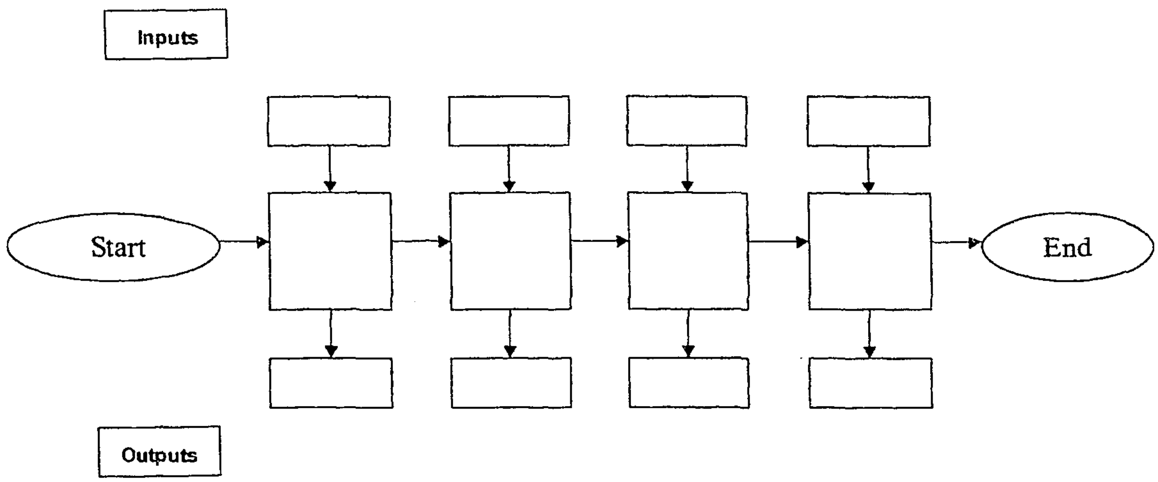
[21] The Quality Function Deployment (QFD) tool is used to identify and quantify customers' requirements, and translate them into key critical parameters. It is used to prioritize actions to improve a process in order to meet customers' expectations.

the project CTQ was with the information provided from the *Define* phase, and the detailed process mapping exercise described below. It was determined that the single criterion project CTQ was whether the facility was meeting all of its environmental regulatory and corporate requirements. This was chosen as a starting point in order to ensure that the company was meeting all its basic requirements before considering any improvement initiatives. Developing an EMS was a way to manage increasingly complex environmental issues (University of North Carolina, 2003). A company must have environmental compliance under control before it can focus on a higher level of environmental performance (Ibbotson and Phyper, 1996). This decision was especially important for the Champion, as he was accountable for the facility being the Service Centre Manager.

5.3 Detailed Process Mapping

In order to effectively make a positive change, the team needed to understand how processes worked at the facility. It was also important to see at which stages there was interaction with the environment and how stakeholders were connected to or affected by these processes. Therefore, the team agreed that the best tool to use to obtain details regarding environmental interactions were detailed process maps for each work area based on the high-level facility process map designed in the *Define* phase. Shop and area Lead hand personnel were important in completing this step as they had intimate knowledge about the processes. A process map was designed for the transformer winding area (Bay 1), the electric motor repair area (Bay 2), the transformer repair area (Bay 3), the machine shop area, and the switchgear area. Once the steps of each work process were documented, all the inputs and outputs of the steps were added. Due to the numerous details obtained throughout the process map exercise, inputs and outputs are described below and each process is illustrated with a process map below. Figure 5.1 demonstrates the model process map used to obtain the information.

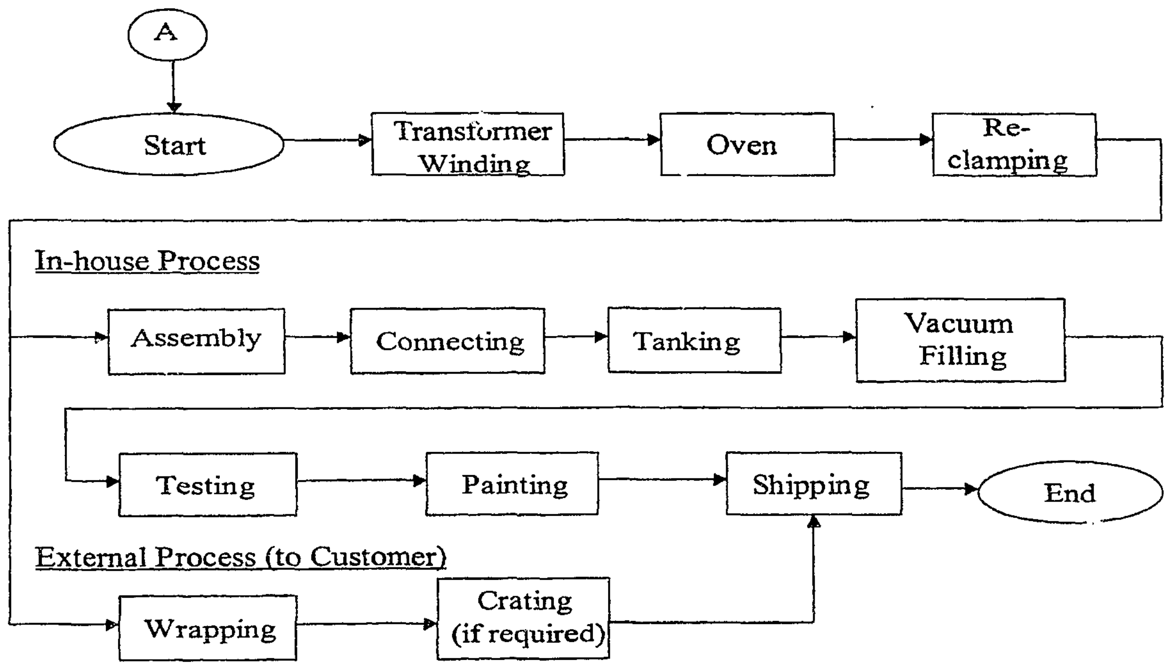
Figure 5.1: Model Detailed Process Map



Bay 1 – Transformer Winding Area

The process begins with transformer coil cylinders. An insulation package, which consists of paper or enamel and copper wire, is applied using a key splicer and pressboard. Electricity, compressed air, glue and tape are also used to complete the installation. The coil is then either wound horizontally or vertically by gravity. The coil can also be "reversed engineered" in order to determine the correct wind pattern. Once winding is completed, the coil is removed from the winding equipment and clamped. Scrap copper and excess insulation are generated. Scrap copper is sent to a scrap metal dealer, and the insulation is reused or recycled. The coil is then unclamped and put into the oven for drying. If it is a coil patch or repair then oil mist may be emitted from the oven as an emission. After the coil has dried, it is removed from the oven after cooling and re-clamped. If the coil is to be put back into the transformer at the customer site, the coil is wrapped with kraft paper, crated if required, and sent out for on-site installation. This process generates excess paper that is reused or recycled, and wood that is reused for other crating operations. If the transformer is on-site, coil installation takes place in-house. For in-house installations, the coil is assembled in the transformer after re-clamping. This process involves using PF degreaser and rags to remove any excess oil precipitate. The used rags are then collected and disposed of as hazardous waste. The coil connections are then completed using new cables, which consist of copper wire and paper or enamel insulation. Fifteen percent silver solder is used to complete minor welds to form the connections. PF degreaser and rags are also used to remove any excess oil precipitate. Waste copper wire is recycled, and excess insulation is either reused or recycled. Used rags are collected and disposed of as hazardous waste. Any excess solder is reused, and welding fumes are emitted as fugitive emissions. The unit is then tanked, and if this is a repair there might be oil mist air emissions due to oil being present in the transformer. If it is a new installation, the vacuum filling process or hot oil fill process is completed where new transformer oil or recycled transformer oil, from five outdoor double-walled aboveground storage tanks (ASTs), is put into the transformer assembly. Any excess oil is sent for recycling for later use. This process has the potential for oil spills during line hook up changes. Spent oil absorbent and/or oil-soaked rags are also disposed of as hazardous waste. Once vacuum filling is completed, the transformer unit goes through high-voltage electrical testing. Once completed, the unit is painted at the paint booth area. This process generates air emissions of volatile organic compounds and waste paint, which is shipped off-site as hazardous waste. Spent paint booth filters are disposed of as hazardous waste. Plastic, wood, steel and threaded rods are used to prepare the unit for shipment. The welding process generates fugitive emissions. The transformer unit is then shipped back to the customer (Figure 5.2).

Figure 5.2: Bay 1 – Transformer Winding Area Process Map



Bay 2 – Electric Motor Repair

Electric motors are typically received in plastic and on wooden skidding. The wood is reused for packaging and the plastic is discarded in the regular garbage. An oxy-acetylene torch method is then used to dismantle the motor. Heated grease from the dismantling process is cooled and disposed of in the regular garbage. The motor is then subject to electrical testing. The dismantled housing is then cleaned with a number of varying techniques that include blasting with frozen carbon dioxide ("dry ice") and water, or acetone and rags, or PF degreaser and rags, or varsol in a parts washer for smaller parts. This step generates wastewater that is discharged to the sanitary sewer, as well as noise, hazardous waste including waste acetone, PF degreaser or varsol, dust collector material, and small pieces of paint chips, grease and dirt that are swept and disposed of in the regular garbage. Sanitary effluent is treated through a three-stage oil/water interceptor water treatment process before discharging to the sanitary sewer.

The repair process is then divided into a major or minor repair. For major repairs, the next step is a more intense and detailed cleaning of the unit. The unit is stripped with a ceramic fiber, and sent to the burn-off oven. Air emissions are generated from the burning of the grease, and stripping chemicals used in the previous step. After the burn-off oven, various parts may be subject to further water blasting, carbon dioxide blasting ("dry ice"), sandblasting, glass bead blasting, or grinding, as well as sawing. Again, these steps generate wastewater that contain small amounts of particulate including sand and glass that is discharged to the sanitary sewer, as well as noise, hazardous waste including waste acetone, PF degreaser or varsol, dust collector material, and small pieces of paint chips, grease and dirt that are swept and disposed of in the regular garbage.

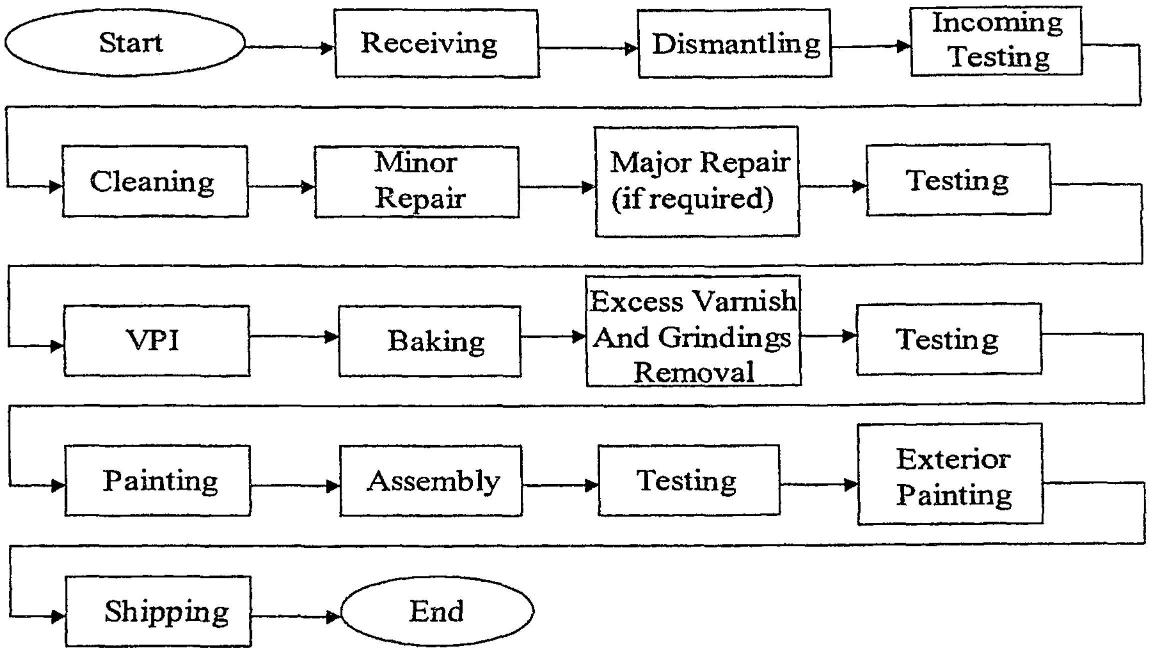
Asbestos may be stripped from the windings, and removal is completed in a controlled way as per the facility's asbestos program. Waste asbestos is placed in a rigid, impermeable, sealed container, labeled and disposed of by an approved waste hauler. Copper-mica dust and copper grind waste are generated from cleaning the armature. Copper-mica dust and glass dust is disposed of in the regular garbage. Copper grinds are also recycled. The unit is then repaired using an epoxy resin mixture, and copper/fiberglass cable connections are made and connected to the armature by silver solder. The waste epoxy resin mixture is disposed as hazardous waste. Scrap copper is recycled, and fugitive emissions are generated from the welding solder.

The unit then undergoes electrical testing, and is put into a vacuum pressure impregnated (VPI) tank with varnish. Opening the lid of the tank releases varnish fumes as fugitive emissions. The VPI step ensures that varnish reaches all the crevices of the motor unit, as it acts as an insulation barrier and therefore increases electrical conductivity of the unit. Once the VPI step is completed, a large plastic sheet is placed on the ground to capture any varnish drippings when the motor unit is removed from the tank. Varnish fumes are again released as fugitive emissions in the shop. The plastic sheet is then disposed of in the garbage. Varnish is changed out on a periodic basis and disposed of as hazardous waste.

The motor is then placed in an electrical oven for baking. The baking process generates air emissions that include varnish and resiglass from the insulation. Once cooled, the excess varnish is removed by light grinding, and varnish chips are disposed of in the regular garbage. The unit is then electrically tested, and parts of the motor unit are painted at the paint booth. Waste paint and waste xylene from cleaning the paint gun are generated and disposed of as hazardous waste. Used paint filters are disposed of as hazardous waste. Parts from the unit are then assembled using grease or motor oil, and polished using carbon sandpaper. Waste grease and used sandpaper are disposed of in the regular garbage, and oil-soaked rags are disposed of as hazardous waste. The unit is then electrically tested again, and its exterior painted. Again, waste paint and waste xylene from cleaning the paint gun are generated and disposed of as hazardous waste. Used paint filters are disposed of as hazardous waste. Vapour barrier paper, wood crates, and stock are placed around the motor, and it is shipped to the customer. Excess paper and wood is reused as packaging material, and scrap pieces of paper are disposed of in the regular garbage.

With a minor repair, the unit is stripped using abrasive disks, and used abrasive disks; paint chips, and dust are swept up and disposed in the regular garbage. The minor repair process then follows the same testing, VPI, baking, painting, assembly, testing, and shipping steps as outlined above (Figure 5.3).

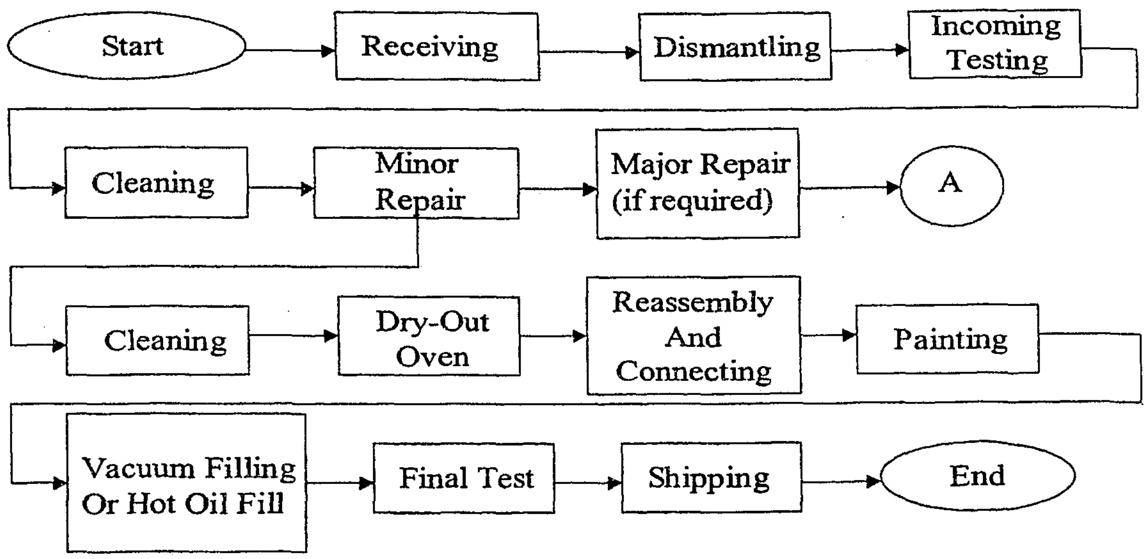
Figure 5.3: Bay 2 – Electric Motor Repair Area Process Map



<u>Bay 3 – Transformer Repair Area</u>

Transformers that come into the shop for repair follow the same initial flow as electric motors in that they are received, dismantled, tested and cleaned. Once the transformer is received, transformer oil and rags are used to dismantle and evacuating the unit. This step also poses the risk of spill. Fugitive emissions such as oil fumes are generated from disconnecting and evacuating the unit. Waste oil is also generated and sent out for recycling. This oil is then put back into the transformer. Finally, oil-soaked rags, gloves and absorbent are disposed of as hazardous waste. The transformer is then electrically tested, and cleaned with solvents and/or thinners as such PF degreaser, and sandpaper. Waste solvent and rags are disposed of as hazardous waste, and used sandpaper is reused if possible or discarded in the regular garbage. The process then splits into a major or minor repair. Major repairs tie into the transformer coil winding process as previously discussed in the Bay 1 area. For minor repairs, the next step is to put the unit into the dry-out oven. This step generates oil vapour that is emitted to the outside air. The unit is then re-assembled and silver solder is used to complete minor welds to form the connections. Any excess solder is reused, and welding fumes are emitted as fugitive emissions. The unit is then painted at the paint booth area. This process generates air emissions such as volatile organic compounds as well as waste paint, which is shipped off-site as hazardous waste. Spent paint booth filters are disposed of as hazardous waste. Vacuum oil filling or hot oil fill is then completed where new transformer oil or recycled transformer oil, from five outdoor double-walled ASTs, is put into the transformer assembly. Any excess oil is recycled for later use. This process has the potential for oil spills during line hook up changes. There is also the potential for a spill when an outside contractor is refilling the ASTs. Spent oil absorbent and/or oil-soaked rags are also disposed of as hazardous waste. Once vacuum filling is completed, the transformer unit goes through high-voltage electrical testing. Plastic, wood, steel and threaded rods are used to prepare the unit for shipment. The welding process generates fugitive emissions. Once completed, the transformer unit is then sent back to the customer (Figure 5.4).

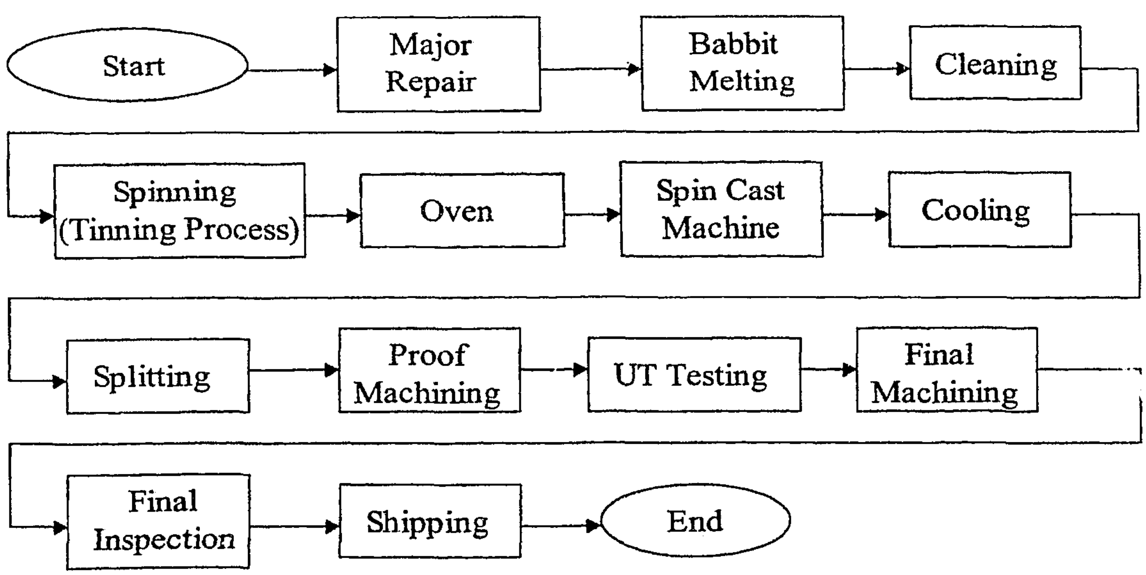
Figure 5.4: Bay 3 – Transformer Repair Area Process Map



<u>Babbit Bearing Machine Shop Area</u>

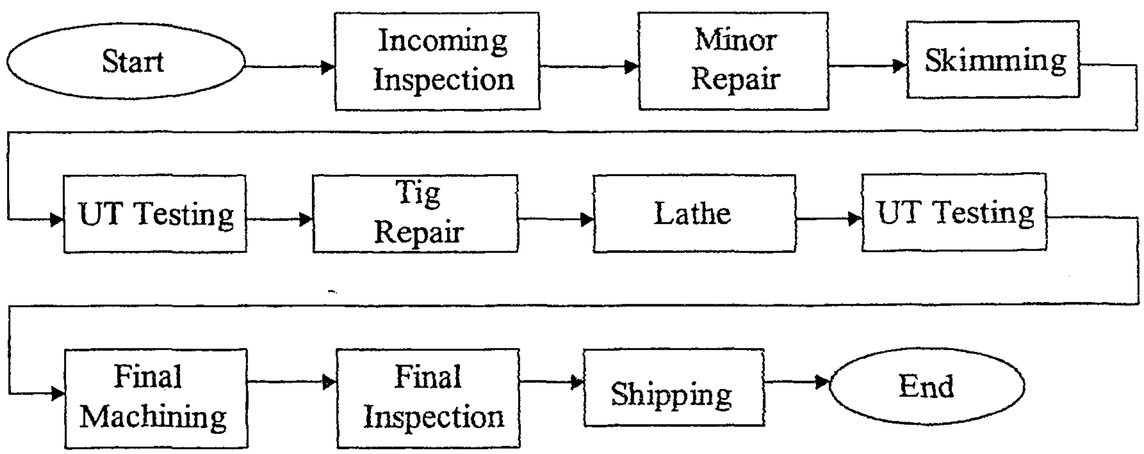
The incoming inspection step determines whether a major or minor repair is needed for the babbit bearing. If a major repair is required (Figure 5.5), the next step is to melt the bearing using an oxy-acetylene torque process. This step generates scrap metal, pieces of resiglass and fugitive emissions from the welding process. The scrap metal is recycled, and the resiglass is disposed of in the garbage. Next the bearing is placed in the Kolene salt bath machine, and is further cleaned with steel shot in the Vibra Finish machine or with glass bead blasting. Wastewater from the Kolene machine is discharged to the sanitary sewer. The steel shot and glass bead are reused. The bearing then goes through the spinning or "tinning" process. First, Hydro-Perm is used to plug any holes then Fiber Fax and Garlock (non-asbestos high temperature insulation) is applied to the bearing. Tin-Rite or tin sticks are heated and then applied to the bearing through spinning. Fugitive emissions result from the tin being heated. Waste Hydro-Perm and Fiber Fax dust are swept up and disposed of in the regular garbage. The bearing is then dipped into the babbit pot oven, which consists of liquid tin babbit at 900 degrees Celsius. Again, fugitive emissions are generated from the heated tin. The bearing is then spun into shape on the Spin Cast machine and simultaneously cooled with water. Smoke is released as a fugitive emission and water leaks flow to an area drain and are discharged to the sanitary sewer. The bearing goes through the splitting process where the bearing is split into two. Once again, Hydro-Perm is used to plug any holes then Fiber Fax and Garlock (non-asbestos high temperature insulation) is applied to the bearing. Tin-Rite or tin sticks are heated and then applied to the bearing. Fugitive emissions from the tin being heated are generated. Waste Hydro-Perm and Fiber Fax dust are swept up and disposed of in the regular garbage. The bearing then goes through the "proof" machining stage where babbit scrap is generated and collected for recycling. The bearing is then tested with an ultrasound machine. The bearing then undergoes final machining, final inspection, and is then shipped to the customer. Final machining generates babbit scrap that is collected for recycling. The bearings are shipped in wooden crates with Styrofoam packing. Waste Styrofoam is disposed of in the regular garbage.

Figure 5.5: Babbit Bearing Machine Shop Area (Major Repair) Process Map



If the bearing undergoes a minor repair, the first step is to skim the bearing. This results in the removal of scrap lead or tin babbit that is collected and recycled. The bearing is then tested with an ultrasound machine. The next step is to complete a Tig repair. This is where lead or tin babbit is applied to the bearing by welding with oxy-acetylene or argon. Welding fumes are generated as a fugitive emission as a result. The bearing is then put on a machine lathe where cutting oil is used to shape it. Scrap metal is collected and recycled, and spent cutting oil is disposed of as hazardous waste. The bearing is then tested again with an ultrasound machine. The bearing then undergoes final machining, final inspection, and is then shipped to the customer. Final machining generates babbit scrap that is collected for recycling. The bearings are shipped in wooden crates with Styrofoam packing. Waste Styrofoam is disposed of in the regular garbage (Figure 5.6).

Figure 5.6: Babbit Bearing Machine Shop Area (Minor Repair) Process Map

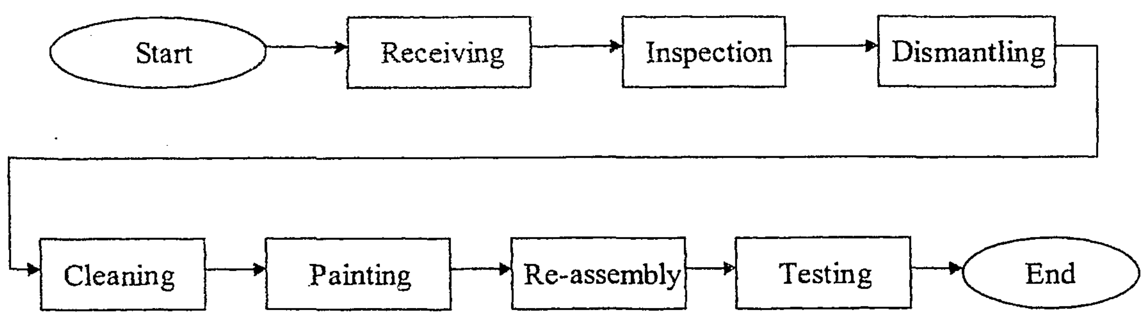


Switchgear Repair Area

The switchgear repair area is the final process area. Here, switchgear is received in crates that are reused when packing repaired switchgear for shipment to the customer. Once received, switchgear is inspected and then *dismantled with hand tools. Asbestos* may be present in the switchgear unit depending on its age. The asbestos is stripped from the windings, and is completed in a controlled way as per the facility's asbestos program. Waste asbestos is placed in a rigid, impermeable, sealed container, labeled and disposed of by an approved waste hauler. Soap, water and Scotch Rite pads are then used to clean the unit. Used pads and waste Fiber Finish are disposed of in the regular garbage. Wastewater is discharged to the sanitary sewer. The unit is then spray painted, reassembled and electrically tested. Volatile organic compounds are emitted as fugitive emissions, and waste paint residue from the spray cans is shipped off-site as hazardous waste. The spray cans are then recycled.

Re-assembly may involve installing insulation that contains asbestos. The asbestos-containing insulation is applied in a controlled way as per the facility's asbestos program. Waste asbestos is placed in a rigid, impermeable, sealed container, labeled and disposed of by an approved waste hauler. The switchgear unit is then packaged in wooden crates and shipped to the customer (Figure 5.7).

Figure 5.7: Switchgear Repair Area Process Map



Outside Area

Equipment such as oil-filled or non-filled transformer bushings is stored in the outdoor storage area. Oil-filled or non-filled transformer tanks are also stored outdoors. Sandblasting and water blasting of large pieces of equipment are occasionally completed outdoors on an asphalt and/or concrete pad surface. These activities result in the generation of waste paint chips, sand, rust, copper, and insulation, which are swept up and disposed of in the garbage. Scrap copper is recycled. Wastewater discharge is discharged to the storm sewer, and small particles of waste debris remain on the pavement, blow away, or are washed into the storm sewer.

There is also an empty PCB storage facility that is registered with the Ontario Ministry of the Environment (MOE). The storage facility housed PCB-contaminated soils and transformer tanks at one time, but an approved company removed them for destruction over a ten-year period approximately. The storage facility is still listed as active in the MOE records.

5.4 Process Performance Standard

Once the detailed process maps were completed it was important to define the performance standard of the current EMS process. As previously stated, the project CTQ was defined as ensuring that Company A was meeting all applicable regulatory and corporate environmental requirements. By doing this, the company was maintaining market competitiveness by ensuring that it was meeting its stakeholder requirements.

The next term that was defined was a "defect". A defect is defined as any event that does not meet a stakeholder requirement (Eckes, 2001). The purpose of the defect definition was to remove ambiguity so that all team members had the same understanding, as well as identifying what to measure and how to measure a defect characteristic. In terms of the study, a defect was defined as any environmental requirements that were not being met. This definition was important as it helped to determine the type of data to collect, and how to go about collecting those data.

5.5 Types of Data to Measure Process Capability

One of the most important concepts for data collection was the type of data to collect namely continuous or discrete data. Each type of data serves different purposes and allows different results to be obtained. A measurement scale represents continuous data where data can be continuously divided into finer and finer increments of precision (Pyzdek, 2002). This is the type of data needed to apply the concept of normal distribution, and therefore is the preferred data to collect in order to reach Six Sigma™ in a process.

Discrete data, on the other hand, represent an attribute or variable type of measurement and can be used with limitations (Pyzdek, 2002). The biggest limitation is that discrete data can only be used to reach a three or four sigma level. Continuous data are required to obtain a higher sigma score. Regardless of the limitations with discrete data, the team decided that it would collect discrete data in the form of count data.

As the name suggests, count data are obtained through counting. Count data were selected to determine whether environmental requirements were being met at this point as opposed to determining the extent to which environmental requirements were being met. For example when measuring a process, discrete data would represent the presence or absence of a requirement, whereas continuous data would measure the percentage that something is complete (Pyzdek, 2002). A logical next step in assessing the company's EMS would be to collect continuous data in the form of the percent completion of environmental requirements.

5.6 Data Collection Process

Once the types of data to collect was determined, the team had to determine how to collect count data from the information obtained about the company's environmental aspects and existing documentation, as well as refine the defect definition and other definitions. The team decided to design a checklist that contained applicable regulatory and corporate environmental requirements, as this was seen as the most logical way to obtain data (Table 5.1). Therefore the project Green Belt, with the assistance of business EHS resources, completed a review of all federal, provincial, municipal environmental laws and by-laws, and corporate requirements in order to determine applicable laws and requirements based on the environmental aspects identified through the detailed process map exercise. Access to federal and provincial environmental acts and regulations was obtained through the company's subscription to the Canadian Centre for Occupational Health and Safety's (CCOHS) website of environmental, health and safety legislation. Municipal by-law requirements were obtained from the Halton Region and City of Burlington websites. Corporate requirements were obtained from the company's internal website, as well as from the Champion and the business level EHS Manager.

The definition of a defect was then further refined to be any checklist question that resulted in a "no" answer. A "no" answer could result from not having a process in place or from not having any evidence to demonstrate that a process was in place to address an environmental requirement. In order to determine the total number of defects, other definitions had to be designed. The main definitions involved with discrete data include defect, unit and opportunity. The definition of a defect was previously determined. A unit is any item that can be measured or evaluated against predetermined criteria or standards. Therefore, for the purposes of the study a unit was defined as each question from the checklist. An opportunity is defined as any step in a process where a defect can be produced. Hence, an opportunity was defined as any question from the checklist where the answer could indicate that an environmental requirement was not being met. Having the defect, unit and opportunity terms defined helped to determine a current sigma score for the existing EMS process later on in the project.

5.7 Measurement System Analysis

Once the measurement system was selected, it was analyzed to determine its effectiveness since decisions would be based on data obtained from the measurement system. Therefore, the measurement system analysis stage was critical to the project. There are two ways a measurement system can be biased. First, a measurement system can result in data that are precise but not accurate. For example, the data collected from the checklist could be precise in that the person completing the checklist can answer all the questions from the information provided, but if the questions did not include applicable regulations, or included non-applicable questions the data collected would not be accurate. Additionally, the data would not be accurate if questions were not worded in such a way as to clearly determine whether or not a requirement had been met. Therefore, it was imperative for the team to design a checklist that would minimize collecting inaccurate or imprecise information. Taking all requirements and putting them into a question format, as well as having the project Green Belt complete the checklist helped to achieve this. For example, if the requirement was to have an up-to-date documented air emissions inventory maintained on file, then the question was worded "is an up-to-date documented air emissions inventory maintained on file?" Checklist questions were grouped by media, namely air, water, waste, emergency response, and chemical reporting.

Once the measurement analysis was completed, the project Green Belt visited the facility in order to complete the *Measure* Phase Checklist. Table 5.1 below shows the completed *Measure* Phase Checklist.

Table 5.1: Completed *Measure* Phase Checklist

Question	Comments	NA	Yes	No
Air Emissions Management				
1. Is an up-to-date documented air emissions inventory maintained on file?	An up-to-date documented air emissions inventory dated September 2002 is maintained on-file. There have reportedly been no changes since that time.		X	
2. Is an up-to-date Certificate of Approval (C of A) (Air) maintained on file? (EPA, s.9)	A copy of an up-to-date C of A (Air) was not available for review.			X
3. Are exempt sources documented with an explanation for the exemption?	Exempt sources are included with the air emissions summary information.		X	
4. Are all terms and conditions associated with the C of A (Air) being met?	A copy of the C of A (Air) could not be located during the review.			X
5. Is a process in place to notify the Director of the MOE in writing of changes relating to an existing C of A (Air) where it is impractical to first obtain an amendment (provided the change does not result in increasing the potential of a discharge into the environment)? (EPA, s.9)	A review of documentation including procedures, records, and interviews with personnel did not indicate that there is a process in place.			X
6. Is there equipment on-site that contains refrigerant?	A review of refrigerated equipment including air conditioning equipment, compressor air dryers, and a process chiller.	X		
7. Does the facility have a refrigerated equipment inventory?	An inventory form was available, but it was not completed.			X

8. Are copies of proof of technician's qualifications maintained on file?	Copies of technician's qualifications are not maintained on file.			X
9. Are service records for refrigerated equipment maintained on file for two years?	Greater than 2 years worth of service records for refrigerated equipment are maintained on file.		X	
10. Has a notice been affixed to equipment after a leak or test?	A notice has been affixed to refrigerated equipment where required (e.g. air dryers)		X	
11. Is there a process to flag changes or additions to site activities that could impact air emissions compliance?	There is a Change Control procedure that addresses air emissions in the EHS manual.		X	
Wastewater Management				
1. Is an up-to-date documented list and map of wastewater sources, treatment systems and discharge points maintained on file?	An up-to-date list and map of wastewater sources, treatment systems and discharge points are maintained on file.		X	
2. Is an up-to-date Waste Survey Report maintained on file? (By-Law No. 2-03)	A Waste Survey Report was reportedly completed, but could not be located during the review.			X
3. Are exempt sources documented with an explanation for the exemption?	There are no exempt wastewater sources for the facility.	X		
4. Is water sampling completed on a regular basis?	Wastewater sampling is completed on an annual basis by an outside consultant. Records were available for review.		X	
5. Is a process in place to investigate, mitigate, and complete corrective actions if sampling analysis indicates an exceedance?	There is a corrective action process through the ISO 9002 system, but it does not include environmental non-conformances (e.g. sampling exceedances).			X
6. Is a process in place to notify the Region and/or City of sampling exceedances (where required)?	There is a process in place that involves consultation with the legal department and the business EHS Manager for guidance.		X	

7. Is there a process to flag changes or additions to site activities that could impact water discharge compliance?	There is a Change Control procedure that addresses wastewater discharge in the EHS manual.		X	
Waste Management				
1. Is an up-to-date documented inventory of waste characterizations maintained on file?	A documented inventory of waste characterizations was last revised in 1998. There is no evidence of any review since that time.			X
2. Is a waste generator identification number maintained on file? (O. Reg. 347, s. 18)	The facility's waste generator identification number is maintained on file.		X	
3. Is subject waste registered on the Hazardous Waste Inventory Network (HWIN)? (O. Reg. 347, s. 18)	Subject waste classes are registered on the HWIN system. Reviewed subject waste classes on-line, and all registered classes corresponded with subject waste generated.		X	
4. Is a process in place to ensure that HWIN registration is completed by February 15th of each year? (O. Reg. 347, s.18)	There was no evidence that the HWIN system was updated since 2002. Interviews with the Shipper/Receiver and Purchaser confirmed this.			X
5. Is copy #1 of waste manifests sent to the Ministry of the Environment (MOE) within 3 workings days of shipment? (Reg. 347, s. 18)	Reviewed waste manifest file and found no copy #1 on file. The receptionist also indicated that copy #1 is sent to the MOE immediately once received. The Shipper/Receiver confirmed this also.		X	
6. Is copy #2 of waste manifests maintained on file for at least two years? (O. Reg. 347, s. 18)	Reviewed waste manifest file and copies were maintained on file.		X	
7. Is copy #6 of waste manifests maintained on file for at least two years? (O. Reg. 347, s. 18)	Reviewed waste manifest file and copies were maintained on file.		X	
8. Is a process in place to ensure that subject waste is not stored on-site longer than 90 days? (O. Reg. 347, s. 18)	There was no evidence of a process to ensure that waste is not stored on-site longer than 90 days.			X

9. Is the disposal of non-normal wastes such as asbestos or PCB's documented?	Procedures for PCB disposal and MOE notification requirements documented in the EHS files. Asbestos procedures are documented in the EHS Manual.		X	
10. Do personnel shipping subject waste/dangerous goods or receiving dangerous goods have up-to-date Transportation of Dangerous Goods training (SOR/2001-286, Pt. 6)?	The Shipper/Receiver and Purchaser have up-to-date TDG training. Reviewed training certificates and wallet cards.		X	
11. Is a process in place to ensure that waste manifests and shipping/receiving documents for dangerous goods are completed correctly?	Process is controlled through signing control and use of templates from training session.		X	
12. Are copies of waste carrier's C of A (Waste) maintained on file?	A list of waste carriers is maintained on file, but a copy of their C of A is not.			X
13. Are copies of waste receiver's C of A (Waste) maintained on file?	A list of waste receivers is maintained on file, but a copy of their C of A is not.			X
14. Is an up-to-date Waste Audit and summary maintained on file for 5 years? (O. Reg. 102, s. 5)	The facility has less than 100 employees, and is therefore exempt from this requirement.	X		
15. Is an up-to-date Waste Reduction Workplan and summary maintained on file for 5 years? (O. Reg. 102, s. 5)	The facility has less than 100 employees, and is therefore exempt from this requirement.	X		
16. Is a recycling program in place? (O. Reg. 103, s. 15)	The facility has less than 100 employees, and is therefore exempt from this requirement. However, the facility does recycle metal, used oil, cardboard, paper, aluminum cans, and glass bottles.	X		
17. Is there a process to flag changes or additions to site activities that could impact waste management compliance?	There is a Change Control procedure that addresses waste generation and disposal in the EHS manual.		X	

Chemical Management and Reporting				
1. Is an up-to-date documented inventory of chemicals maintained on file?	A documented inventory of chemicals was last revised in 1998. There is no evidence of any review since that time.			X
2. Is there a material approval process that includes an environmental regulatory review and sign-off?	There is a Material Approval process, but it does not include a review for environmental requirements.			X
3. Is the purchasing department included in the material approval process?	The Purchaser indicated that she is involved in the material approval process.		X	
4. Are aboveground storage tanks (ASTs) inspected on a regular basis?	There was no evidence that ASTs are inspected on a monthly basis.			X
5. Are ASTs equipped with secondary containment? (O. Reg. 388/97, s. 4.3.7)	All ASTs are double-walled, and enclosed with a secondary containment system.		X	
6. Are ASTs equipped with an overfill protection device? (O. Reg. 388/97, s. 4.3.1.8)	All ASTs are equipped with an automated spring mechanism to prevent overfill.		X	
7. Are the ASTs equipped with leak protection? (O. Reg. 388/97, s. 4.3.7.7)	All ASTs are double-walled, and enclosed with a secondary containment system. Dispensing occurs within the facility, and secondary containment and spill materials are used.		X	
8. Is the distance between each AST at least 1 metre? (O. Reg. 388/97, s. 4.3.3.2)	All ASTs are located 1.5 metres apart.		X	
9. Are the ASTs labeled as to their contents? (O. Reg. 388/97, s. 4.3.1.7)	All ASTs are labeled "Oil".		X	
10. Is a process in place to review the List of Toxic Substances for potential pollution prevention plan requirements, reporting requirements, and prohibited substances? (CEPA, Pt. 4, s. 95 and s. 212)	There is no evidence of a process in place to review the List of Toxic Substances.			X

11. Is a process in place to review the Domestic Substances List (DSL) and the Non-Domestic Substances List (NDSL) for use and reporting requirements? (CEPA, Pt. 5)	There is no evidence of a process in place to review the DSL and NDSL.			X
12. Is a process in place to review the Export Control List for reporting requirements? (CEPA, s. 101)	There is no evidence of a process in place to review the Export Control List.			X
13. Is a process in place to review new substances for reporting requirements? (SOR/94-260)	There is no evidence of a process in place to review new substance for reporting requirements.			X
14. Is a process in place to ensure that electrical equipment containing PCBs (>50 ppm) is not introduced into the facility? (SOR/91-152)	There is a procedure to test oil in electrical equipment for PCB content prior to arriving at the facility. A Certificate of Analysis is also sent to the facility before the electrical equipment arrives.		X	
15. Is a process in place to annually evaluate whether National Pollutant Release Inventory (NPRI) reporting is required? (CEPA, Pt. 3)	There is no evidence of a process in place to evaluate whether NPRI reporting is required.			X
16. Is a process in place to annually evaluate whether Air Contaminant Discharge and Reporting is required? (O. Reg. 127)	There is no evidence of a process in place to evaluate whether O. Reg. 127 reporting is required.			X
17. Is there a process to flag changes or additions to site activities that could impact chemical management compliance?	There is a Change Control procedure that addresses chemical management and reporting in the EHS manual.		X	
Pollution Prevention				
1. Is a process in place to review operations and processes for pollution prevention (P2) opportunities including:	There is a P2 procedure in the EHS manual.		X	
a) material substitution?	Included in the P2 procedure.		X	
b) service design or reformulation?	Included in the P2 procedure.		X	

c) equipment or process modifications?	Included in the P2 procedure.		X	
d) spill and leak prevention?	Included in the P2 procedure.		X	
e) on-site reuse, recycling or recovery?	Included in the P2 procedure.		X	
f) Improved inventory management or purchasing techniques?	Included in the P2 procedure.		X	
g) good operating practices or training?	Included in the P2 procedure.		X	
Emergency Spill/Release Response				
1. Is there an up-to-date inventory of potential and actual hazards that require prevention, preparedness and mitigation procedures?	There is no evidence of an up-to-date inventory of potential and actual hazards for the facility.			X
2. Is a process in place to review environmental emergency plan and notification requirements? (CEPA, Pt. 8)	There is no evidence of a process in place to review environmental emergency plan and notification requirements.			X
3. Is a spill control procedure in place including (O. Reg. 388/97, s. 4.1.6.4):	There is a spill/release response procedure in the EHS Manual.		X	
a) approval by the Fire Department?	There is no evidence that the spill/release response procedure was approved by the local fire department.			X
b) operating procedures to prevent leaks and spills from piping, pumps, storage tanks and process vessels?	Included in ISO 9002 work instructions, but not referenced in the procedure.			X
c) procedures for ventilation?	Not included in the procedure.			X
d) spill containment and clean up?	Included in procedure.		X	
e) protective clothing and PPE?	Included in procedure.		X	
f) handling and disposal of waste?	Not included in procedure.			X
g) chain of command including notification of applicable agencies and management?	Included in procedure.		X	
h) preventative maintenance program?	In place, but not referenced in procedure.			X

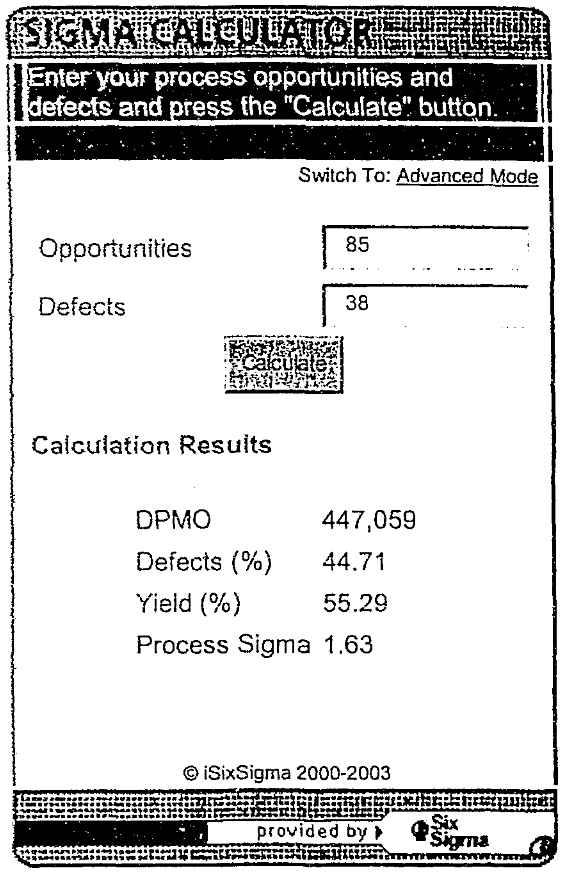
i) posting and maintenance of the procedure?	Procedure is posted in work cell areas, and included in EHS Manual. There is an annual requirement (minimum) to review the procedure.		X	
j) training of new employees within 3 months of hire and every 6 months for experienced employees?	There is no evidence of completion of spill response training.			X
4. Is a process in place to immediately notify the Ministry of Environment (MOE), followed by written particulars as soon as practicable, of a discharge in excess of a limit, causing an adverse effect, or resulting in visible emissions that exceed standards? (Reg. 346, s.9)	There is no evidence of a process in place to notify the MOE of a discharge in excess of a limit, causing an adverse effect, or resulting in visible emissions that exceed standards.			X
5. Is a process in place to report discharges of 100 kg or more of refrigerant to the MOE? (EPA, Pt. X)	There is no evidence of a process in place to report refrigerant releases of 100 kg or more.			X
6. Is a process in place to notify the MOE and Region of spills/releases that have the potential cause an adverse effect? (EPA, Pt. X and By-Law No. 2-03)	The MOE and the local municipality are included in the notification requirements of the procedure.		X	
7. Is a process in place to document spill/release investigations that includes the following information (O. Reg. 675, s. 12):	There is a spill investigation form as part of the procedure.		X	
a) date, time, location, and duration of the release?	The duration of the release is not included on the form.			X
b) material and quantity released?	Not included in the form.			X
c) circumstances and cause of spill?	Not included in the form.			X
d) details of containment and clean-up efforts?	Not included in the form.			X
e) an assessment of the success of the containment and clean-up efforts?	Not included in the form.			X

f) how waste from the spill clean up was handled and disposed of?	Not included in the form.			X
g) any adverse effects as a result of the spill?	Not included in the form.			X
8. Is there a process to flag changes or additions to site activities that could impact emergency response and hazard identification?	There is a Change Control procedure that addresses emergency spill/release response in the EHS manual.		X	
Total Defects: 38 **Total Number of Questions: 85**				

5.8 Measurement Results

Once the *Measure* Phase Checklist was completed, the total number of defects was determined. All defects were rated at the same value. Defects were not weighted based on a comparison with different environmental media, since the *Analyze* phase of the project would be used to determine causes of defects, as well as prioritizing those causes in order to implement solutions. The sigma value for the existing EMS process was calculated using a Process Sigma Calculator from the *isixsigma.com* website as listed in Figure 5.8 below.

Figure 5.8: Process Sigma Calculator – *Measure* Phase



(Courtesy of isixsigma.com)

The calculation was completed by taking the number of defects, which totaled thirty-eight, and dividing that number by the total number of opportunities, or total number of questions, which totalled eighty-five. The resulting number was 0.4471. This indicated that 44.71% of all opportunities were defects. The corresponding yield was 55.39% meaning that the facility was complying with 55.39% of the environmental requirements listed on the checklist. Since the Six Sigma^{TM} method looks at defects per one million opportunities, the resulting number of defects per million opportunities was 447,059. This resulted in a process sigma score of 1.63. The Sigma Capability Conversion Table (Pande *et al*, 2002; Pande and Holpp, 2002; Tayntor, 2003) listed in Table 5.2 below can also be used to determine process sigma score.

Table 5.2: Sigma Capability Conversion Table

Yield (%)	Defects per Million Opportunities (DPMO)	Sigma
6.68	933200	0
8.455	915450	0.125
10.56	894400	0.25
13.03	869700	0.375
15.87	841300	0.5
19.08	809200	0.625
22.66	773400	0.75
26.595	734050	0.875
30.85	**691500**	**1**
35.435	645650	1.125
40.13	598700	1.25
45.025	549750	1.375
50	500000	1.5
54.975	450250	1.625
59.87	401300	1.75
64.565	354350	1.875
69.15	**308500**	**2**
73.405	265950	2.125
77.34	226600	2.25
80.92	190800	2.375
84.13	158700	2.5
86.97	130300	2.625
89.44	105600	2.75
91.545	84550	2.875
93.32	**66800**	**3**
94.79	52100	3.125
95.99	40100	3.25
96.96	30400	3.375
97.73	22700	3.5
98.32	16800	3.625
98.78	12200	3.75
99.12	8800	3.875
99.38	**6200**	**4**
99.795	2050	4.375
99.87	1300	4.5
99.91	900	4.625
99.94	600	4.75
99.96	400	4.875
99.977	**230**	**5**
99.982	180	5.125
99.987	130	5.25
99.992	80	5.375
99.997	30	5.5
99.99767	23.25	5.625

99.99833	16.7	5.75
99.999	10.05	5.875
99.99960	**3.4**	**6**

(Adapted from Pande and Holpp, 2002)

The EMS process did not achieve a six sigma level, which can also be expressed as a 99.99966% compliance rate with environmental requirements. Therefore, the EMS process needed to be improved.

It is important to note that the *Measure* Phase Checklist was used as a tool to determine how effective the EMS system was prior to making any improvements. The tool itself was not an improvement tool at this point of the study.

5.9 *Measure* Phase Tollgate Checklist

After determining the environmental requirements and the process sigma score, a *Measure* Phase Tollgate Checklist (Table 5.3) was completed. This was to ensure that all steps in the *Measure* phase were completed, before moving to the *Analyze* phase.

Table 5.3: *Measure* Phase Tollgate Checklist

Steps	Date Completed
Project CTQ Selection	
Project CTQ identified and defined	March 5, 2003
Process Variation Displayed/Communicated	
Detail process maps completed identifying environmental inputs and outputs	February 21, 2003
Long term and short term variability accounted for	March 10, 2003
Process Performance Standard	
Key measures identified and agreed upon	March 10, 2003
High impact defects defined and identified in the business process	March 10, 2003
Data Collection Planned and Executed	
Data collection plan established that includes measurement systems analysis	April 5, 2003
Data collected on key measures that were identified	April 10, 2003
Performance Baseline/Sigma Calculation	
Measure baseline process performance (capability, yield, sigma level)	April 10, 2003

Adapted from Waddick, 2003

Chapter 6. *Analyze* Phase

6.1 Introduction

The *Analyze* phase is often overlooked in the attempt to quickly implement a solution once a gap has been identified. Using the Six Sigma™ method forces teams to analyze why a defect has occurred before identifying and implementing any solutions (Trayntor, 2003). This helps to ensure that the appropriate solutions are implemented, solutions that will address the cause(s) of defects. Therefore, the purpose of the *Analyze* phase was for the team to determine the root causes of effects, and to prioritize them. This chapter reviews the analysis of measurement results, performance improvement goals, hypothesis testing, as well as a discussion of tools used in this phase including graphs, a Pareto chart, the Cause and Effect Diagram[22], and the Payoff Matrix[23].

6.2 Analysis of Measurement Results

A number of tools were used in order to analyze the results from the measurement phase of the project. The first tool that was used was a bar graph (Figure 6.1).

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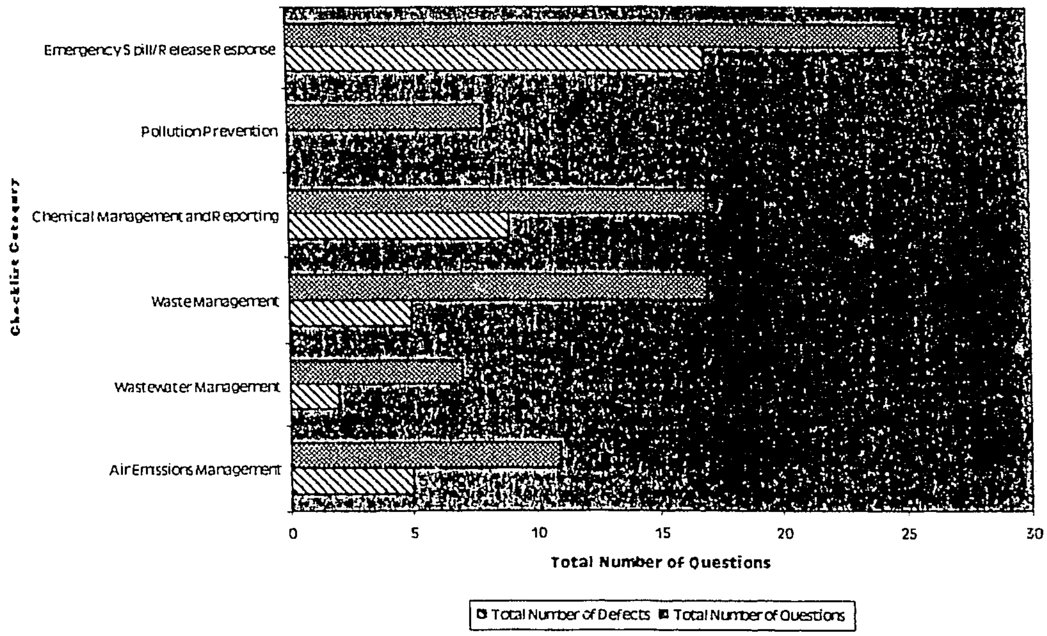
[22] The Cause and Effect diagram allows a team to identify and graphically display all of the possible causes related to a problem or condition in order to determine its root cause(s) (Brassard and Ritter, 1994).
[23] The Payoff Matrix is a tool used to narrow down options using a systematic approach to compare choices by selecting and weighting selected criteria (Brassard and Ritter, 1994),

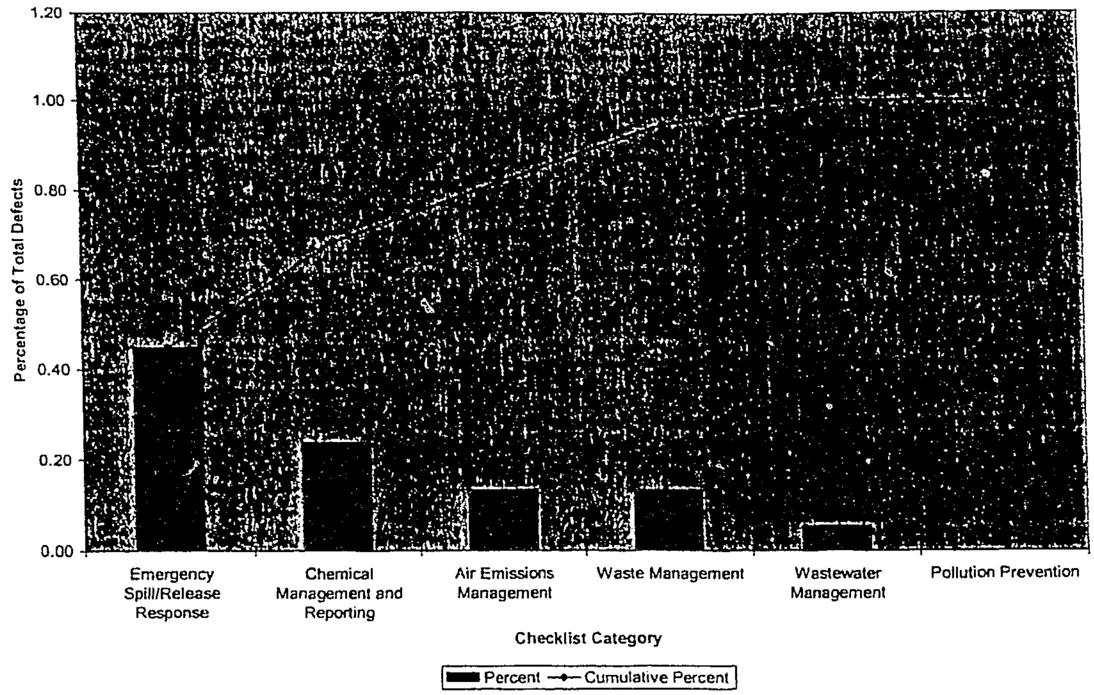
Figure 6.1: Summary of Defects and Questions by Checklist Category



The bar graph was completed in order to illustrate the number of questions by media, as well as the number of defects for each medium. This gave a preliminary indication of the number of defects per category, so that the team could see where efforts would have to be focused.

The team then decided to complete a Pareto chart (Figure 6.2) since this tool highlighted the biggest contributors to a cause (George 2002; Pande and Holpp, 2002). In other words, the Pareto chart would allow the team to focus efforts on the checklist category areas that offered the greatest potential for improvement by showing their relative frequency or size in a descending bar graph (Brassard and Ritter, 1994).

Figure 6.2: Pareto Chart for Checklist Defects



The Pareto analysis revealed that most of the findings were from the emergency spill/response category, followed by chemical management and reporting. This was helpful in order to determine which of the environmental media had the most impact on not meeting environmental requirements so that solutions could be focused on those media. The Pareto chart capitalizes on the'80-20 Rule' where most of the problems (80%) arise from relatively few causes (20%) (Pande and Holpp, 2002). However, completion of the Pareto chart did not indicate the severity of the defects (environmental impact), nor did it emphasize why the defects occurred. Therefore, the team decided to complete a Cause and Effect diagram.

A Cause and Effect diagram is a beneficial tool because good *DMAIC* problem solving includes considering many types of causes, so that biases or past experience do not interfere with the team's judgment (Pande and Holpp, 2002). Furthermore, the Cause and Effect Diagram forced the team to look at many possible causes of not meeting environmental requirements instead of simply acting on the first cause identified (Wlodarczyk *et al*, 2000). The Cause and Effect Diagram was structured using the categories material, methods, machines, and people (Pande and Holpp, 2002). Each category is defined in Table 6.1 below.

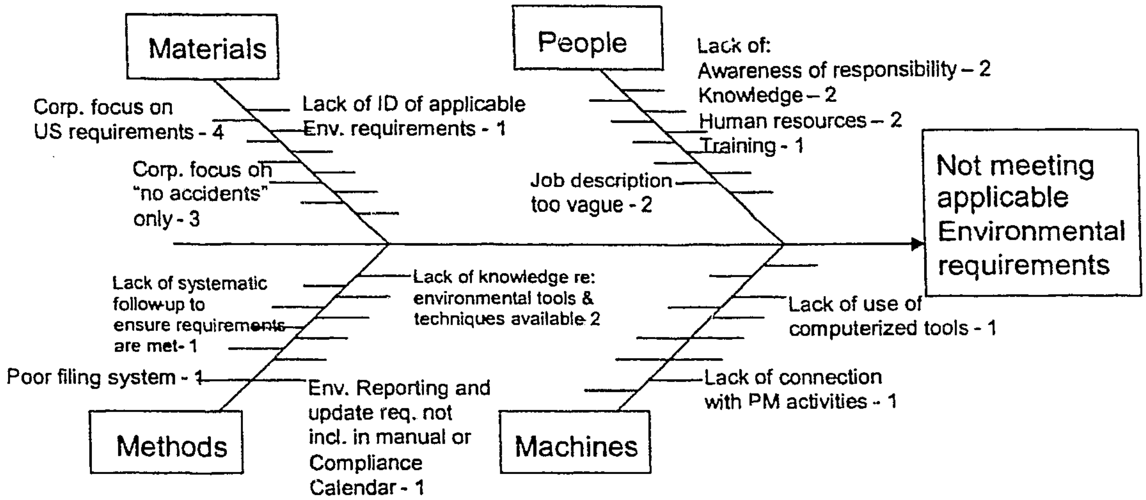
Table 6.1: Cause and Effect Diagram Categories

Materials:	The data, instructions, numbers or facts, forms, and files that, if flawed, will have a negative impact on the output (or the environment)
Methods:	The procedures or techniques used in doing the work (or maintaining the EMS system)
Machines:	The technology, such as computers, copier, or manufacturing equipment, used in a work process
People:	A key variable in how all these other elements combine to produce business results (or EMS results)

A review of the data from the *Define* and *Measure* phases, as well as the brainstorming technique[24] were used to list causes on the Cause and Effect diagram. The brainstorming technique is a lateral thinking process that is designed to help break out of current thinking patterns and into new ways of looking at things (Brassard and Ritter, 1994). Brainstorming allowed a number of potential root causes to be identified under each of the categories on the Cause and Effect diagram listed in Figure 6.3 below. Group brainstorming was beneficial as it allowed for the development of ideas with more depth than achieved by individual brainstorming. A broad range of ideas was also generated as the team represented a wide range of disciplines including EHS, senior management, shop floor process and supervision, purchasing, and shipping/receiving. A number of root causes were identified using the Cause and Effect diagram.

[24] The brainstorming technique is a common method for a team to generate a number of ideas on any topic by creating a process that is free of criticism and judgement (Brassard and Ritter, 1994).

Figure 6.3: Cause and Effect Diagram



Under the materials category, the team stated that one of the reasons the facility was not meeting environmental requirements was because they were not clearly identified. This may have been a result of the corporate EHS office focusing on U.S. environmental requirements since it was a U.S. based company. Instead of understanding applicable Canadian requirements, corporate EHS personnel just reportedly imposed U.S. requirements on the facility. This did not help in meeting specific Canadian and Ontario environmental requirements to which the facility is subject. Finally, the team determined that the current focus of EHS metrics on health and safety criteria led to the omission of environmental criteria.

In terms of the methods category, the team highlighted that there was a lack of knowledge regarding different environmental tools and techniques available to maintain the EMS such as charts and tables. Furthermore, the team stated that there was a lack of systematic follow-up to ensure that activities listed in procedures, for example, were completed. Another weak area identified was the lack of environmental reporting and update requirements included in the EHS manual or other tools like the facility's EHS

Compliance Calendar. Finally, the team identified the poor filing system for EMS documentation. For example, some team members were absolutely sure that some documents requested during the *Measure* phase assessment were completed, but some of the questions in the *Measure* Phase Checklist were marked "No" because the records could not be located.

The team indicated that current and available computerized tools in the facility were not being utilized to incorporate environmental requirements, such as the EHS Compliance Calendar previously mentioned. The lack of connection between preventative maintenance (PM) activities and regulatory required activities was identified.

A number of root causes were identified under the people category, but most appeared to be related. For example, there was the lack of knowledge regarding regulatory environmental requirements because there was a lack of training regarding them. Also, activities and duties required to meet environmental requirements were not identified in job descriptions. It was determined that there was a lack of human resources available to meet environmental requirements, but the underlying root cause appeared to be the lack of awareness in terms of who was responsible to ensure that environmental requirements were met. Table 6.2 below summarizes the root causes identified.

Table 6.2: Summary of Identified Root Causes

Materials:
• Lack of identification of applicable environmental regulatory and corporate requirements • Corporate focus on U.S. environmental requirements instead of Canadian, Ontario, and municipal environmental requirements • Corporate focus on "no accidents" only, and no focus on environmental metrics

Methods:
• Lack of knowledge regarding environmental tools and techniques available to maintain the EMS • Lack of systematic follow-up to ensure environmental requirements are being met • Environmental reporting and update requirements not included in the EHS manual or Compliance Calendar • Poor filing system for EMS documentation
Machines:
• Lack of use of computerized tools to incorporate environmental requirements (e.g. EHS Compliance Calendar) • Lack of connection between preventative maintenance (PM) activities and regulatory required PM activities
People:
• Lack of knowledge regarding regulatory environmental requirements • Lack of human resources to maintain the EMS • Lack of awareness in terms of who is responsible to ensure that environmental requirements are met • Lack of training on regulatory environmental requirements • Job description too vague regarding environmental responsibilities

Once the Cause and Effect diagram was completed, the Payoff Matrix tool was used to prioritize the root causes. This tool was borrowed from the Work-Out™ method[25], which is a powerful team problem-solving technique (Bertels, 2003; Ulrich *et al*, 2002; Schaninger and Niebuhr, 1999; Waddick, 2003). The purpose of the Payoff Matrix was to identify which root causes the team felt could be addressed easily and which root causes would be more difficult to address. This tool allowed the team "to narrow down options through a systematic approach of comparing choices by selecting, weighting, and applying criteria" (Brassard and Ritter, 1994: 105). The tool also forced the team "to focus on the best thing(s) to do, and not everything they could do, dramatically increasing the chances of implementation success" (Brassard and Ritter, 1994: 105). Table 6.3 highlights the scoring method used, which essentially compared

[25] The Work-Out™ method is an intense problem-solving approach involving facilitation tools and techniques in order to develop and evaluate solutions for improvement.

the effort it would take to address a root cause compared with the degree of impact addressing the root cause would have.

Table 6.3: Payoff Matrix Definitions

Block Number	Impact	Effort
1:	Big	Easy
2:	Big	Hard
3:	Little	Easy
4:	Little	Hard

(Adapted from Bertels, 2003; Ulrich *et al* 2002; Waddick, 2003)

Using the scoring method listed above, the team went back to the Cause and Effect Diagram and together scored each of the root causes identified.

The team felt that a number of the root causes identified could be easily addressed and could produce a big impact in terms of meeting environmental requirements including: clear identification of environmental requirements; systematic follow-up to ensure that environmental requirements were met; inclusion of environmental reporting and update requirements in the EHS manual; improving current filing methods; using current electronic tools available to incorporate environmental requirements; connecting PM activities with applicable environmental requirements; and training personnel regarding environmental requirements. The team decided that root causes identified such as lack of knowledge regarding environmental tools and techniques available to maintain the EMS, lack of knowledge regarding regulatory environmental requirements, lack of human resources to maintain the EMS, lack of awareness regarding responsibility, and vague job descriptions would be a little harder to address but still felt that the resulting impact would be big. Finally for the purposes of the study, the team decided that trying to change the view of the corporate EHS department would not be easy, nor would it have a big impact for the facility. Instead, it was felt that the responsibility to meet environmental requirements was at the facility level, and in turn the team determined that it would focus on solutions to help the facility meet its environmental requirements. Table 6.4 summarizes the results of the priority ranking below.

Table 6.4: Summary of Root Cause Priority Ranking

Cause and Effect Diagram Category	Payoff Matrix Rating
Materials:	
• Lack of identification of applicable environmental regulatory and corporate requirements	1
• Corporate focus on U.S. environmental requirements instead of Canadian, Ontario, and municipal environmental requirements	4
• Corporate focus on "no accidents" only, and no focus on environmental metrics	3
Methods:	
• Lack of knowledge regarding environmental tools and techniques available to maintain the EMS	2
• Lack of systematic follow-up to ensure environmental requirements are being met	1
• Environmental reporting and update requirements not included in the EHS manual or Compliance Calendar	1
• Poor filing system for EMS documentation	1
Machines:	
• Lack of use of computerized tools to incorporate environmental requirements (e.g. EHS Compliance Calendar)	1
• Lack of connection between preventative maintenance (PM) activities and regulatory required PM activities	1
People:	
• Lack of knowledge regarding regulatory environmental requirements	2
• Lack of human resources to maintain the EMS	2
• Lack of awareness in terms of who is responsible to ensure that environmental requirements are met	2
• Lack of training on regulatory environmental requirements	1
• Job description too vague regarding environmental responsibilities	2

The Payoff Matrix was an excellent tool to assist the team in determining where it should spend its energy in designing and implementing solutions to address the root causes identified. Thus, the tool also helped to prioritize improvement ideas as well. It also helped to further define the project goal as is evident in the process performance improvement section below.

6.3 Process Performance Improvement

Once the EMS process was measured and analyzed, the next step was to narrow the definition of the project goal in order to clearly define what defects would be addressed within the time allotted to complete the study. The team decided that the project goal was to reduce the number of defects identified in the *Measure* phase by at least 75%. Seventy-five percent was chosen for two reasons. First, the corporate mandate for a Six Sigma™ project to be considered successful was a 75% defect reduction. Second, it became apparent that not all of the identified root causes could be addressed through the research project either because of company organizational issues (e.g. human resources, job descriptions, etc.) or the time it would take to implement the solution. Nonetheless, it was decided that the necessary tools would be designed where applicable even if they could not be implemented during the research study, since the original purpose of the research study was to design an EMS.

One technique that is commonly used during the *Analyze* phase is hypothesis testing. Hypothesis testing is an objective or statistical way to determine whether variations detected during the *Measure* phase are attributed to true defects or random effects (Brue, 2002; Pyzdek, 2002). This test allows two or more sets of data to be compared against using a null and alternative hypothesis. The null hypothesis represents no difference in data sets, while the alternative hypothesis represents a statistically significant difference in data sets. However based on discussions with the company Black Belt, hypothesis testing was not used for the project because there was only one set of data generated during the *Measure* phase. Therefore, it was not known whether the defects identified were valid or if they were due to random variation. Furthermore, the team was not able to demonstrate graphically or statistically if defects identified were valid. This resulted in subjective versus objective improvement measures.

6.4 *Analyze* Phase Tollgate Checklist

After completion of the process performance improvement step an *Analyze* Phase Tollgate Checklist (Table 6.5) was completed to ensure that all the steps in the *Analyze* phase were completed. Once this was confirmed, the project moved to the *Improve* phase.

Table 6.5: *Analyze* Phase Tollgate Checklist

Steps	Date Completed
Data and Process Analysis	
Identify gaps between current performance and the goal performance	April 10, 2003
Quantifying the Gap/Opportunity	
Determine the performance gap	April 10, 2003
Communicate the gap	April 10, 2003
Root Cause Analysis	
Generate list of possible causes (sources of variation)	April 20, 2003
Prioritize list of "vital few" causes (key sources of variation)	April 20, 2003
Verify and quantify the root causes of variation	April 20, 2003

(Adapted from Waddick, 2003)

Chapter 7 – *Improve* Phase

7.1 Introduction

The *Improve* phase is where many teams are tempted to jump to once a problem has been identified. However once the team saw the value of asking questions, checking assumptions, and using data, team members realized the benefit of the Six Sigma™ method (Pande and Holpp, 2002). The *Improve* phase involves improving a process by eliminating defects (Waddick, 2003). Potential solutions are designed and assessed, and then validated through implementation case studies. Changes based on the case study results are made, and the process sigma is recalculated to determine if any improvement was made. This chapter discusses the brainstorming, the action plan matrix, and the Failure Mode and Effects Analysis tools.

7.2 Development of Proposed Solutions

The team reviewed the results of the *Analyze* phase to determine what solutions could be implemented and tested to address identified root causes. The team then discussed what root causes could realistically be addressed through the research study, and which root causes would have to be addressed between the Champion and the corporate EHS department. Therefore, it was decided that the team would focus on designing practical and simple solutions to address the root causes that impacted Company A's ability to meet environmental requirements.

The brainstorming technique was used again, along with a review of the *Measure* Phase Checklist, to identify potential solutions to implement to address the root causes. A number of solutions were identified including designing a records filing list, tables to summarize requirements such as C of A (Air) terms and conditions and chemical reporting requirements, completing and/or obtaining required documents, and revising various procedures and forms to include environmental requirements. Actual copies of revised procedures were not included in the paper because Company A wanted to remain anonymous. Instead a procedure revision summary table was completed in order to highlight the changes (Table 7.1), and copies of generic tables such as the C of A (Air) Requirement table, applicable legislation table, substances with key reporting requirements table, etc. were included in Appendices 3 to 6 of the research paper.

Table 7.1: Procedure Revision Summary Table

New Procedure or Procedure to be Revised	Summary of Revisions to be Made
EHS-0.2: EHS System Organization and Review	• Add an applicable legislation table and file organization (records) table
EHS-13.2 (new): C of A (Air) Requirements Table	• Design C of A (Air) requirements table including the type of requirement, facility action/task, reference document, personnel responsible, frequency of tasks, and compliance dates
EHS-13.0: Air Emissions Management	• Add requirement to notify MOE Director in writing of changes in existing C of A (Air) where impractical to first obtain an amendment
EHS-14.3: Ozone Depleting Chemicals Management	• Add requirement to obtain copy of technician's qualifications and ozone depletion prevention (ODP) information • Add recordkeeping requirements
EHS-15.0: Wastewater Management	• Reference ISO 9002 procedure in the wastewater management procedure for investigating, mitigating, and completing corrective action if sampling exceedances
EHS-12.1: Waste Inventory Log	• Include requirement to annually review (as a minimum) the waste inventory log to ensure that it is up-to-date
EHS-12.0: Waste Management	• Add requirement to ensure that HWIN registration is completed by February 15th each year • Add requirement to date label drums when waste starts to accumulate to ensure it is not stored greater than 90 days • Add requirement to obtain copies of C of As for waste carriers and waste receivers • Add recordkeeping requirements for waste manifests
EHS-11.0: Chemical Management and Handling	• Add word reporting to title of procedure • Include requirement to annually review (as a minimum) the chemical inventory to ensure that it

	is up-to-date • Include section for ASTs and added the inspection requirement • Add a chemical review and reporting section to the procedure for the List of Toxic Substances, DSL, NDSL, Export Control List, NPRI, O. Reg. 127, and new substances
EHS-11.1: Material Approval Request Form	• Add environmental media air, waste, water, emergency spill/release response, and chemical reporting requirements to the form
EHS-11.0A (new): Substances with Key Reporting Requirements Table	• Design a summary table in order to list chemicals in the facility with reporting and/or review requirements
EHS-11.0B (new): NPRI Reporting Determination Worksheets	• Design worksheets in order to complete threshold calculations to determine if reporting is required
EHS-11.0C (new): O. Reg. 127 Reporting Determination Worksheets	• Design worksheets in order to complete threshold and reporting calculations to determine if reporting is required
EHS-16.2: Emergency Response Plan	• Add requirement to have an up-to-date inventory of potential and actual hazards for the facility • Add requirement to review environmental emergency plan and notification requirements
EHS-16.7: Spill/Release Response	• Add requirement to obtain approval from local fire department • Reference ISO 9002 work instructions for ASTs, VPI, and dip tank • Include procedure for ventilation • Include steps to handle and dispose of waste and reference waste management procedure • Reference PM program • Revise training frequency requirement • Include MOE notification for releases that are in excess of a limit, causing an adverse effect, or resulting in visible emissions that exceed standards • Include refrigerant release reporting requirement

EHS-16.8: Emergency Incident Report	Include the following information on the form: • Duration of spill/release • Material and quantity released • Circumstances and cause of spill • Details of containment and clean-up efforts • Assessment of success of containment and clean-up efforts • How waste from spill was cleaned up, handled and disposed • Any adverse effects as a result of the spill

The team also decided that once the above improvements were made, an awareness session would be completed for affected employees so that they would be familiar with the new requirements in the procedures. In order to capture all the *Improve* recommendations, the team completed an *Improve* Matrix Action Plan. The *Improve* Matrix Action Plan outlined the issue, proposed solutions, timelines, and responsibilities, as well as the benefits, and impacts of the proposed solutions (Appendix 2). Once the *Improve* Phase Action Plan was completed however, it became apparent that the team did not think of any cost reduction benefits associated with the study, and therefore just listed potential cost avoidance benefits. Although, cost avoidance is a recognized benefit under the Six Sigma™ method, it was determined that it was not as tangible as a cost reduction benefit. This may have occurred was because the project focused on meeting environmental requirements, as oppose to specific environmental projects or pollution prevention projects such as waste reduction where cost reduction benefits could be better defined. The cost of implementation was also not representative because the project Green Belt facilitated the solutions, and was not an employee of the facility.

Another tool that is commonly used to mistake-proof proposed solutions is the Failure Mode and Effects Analysis (FMEA) tool[26]. However, this tool was not used during the *Improve* phase to evaluate potential solutions, as the team felt that any failure in the potential solutions would result in the facility not meeting environmental requirements.

7.3 Solution Implementation

The next step for the team was to implement the proposed solutions. After the proposed solutions were designed, an awareness session was completed outlining the additional environmental requirements for the EHS manual procedures (Table 7.1) to assist in meeting requirements. The team also reviewed how to use the checklist tool that was used in the *Measure* phase of the study.

The implementation period was approximately one month, and appeared to be relatively short for a number of reasons. First, the project timeline completion as defined in the project charter was four to six months. Secondly, the facility agreed to permit the study to last for a four month period. Third, and most importantly, the *Control* phase was put in place to address any defects that may arise once the project was completed. It was in this phase that monitoring and measuring solutions were addressed.

7.4 Process Sigma Recalculation

Once the solutions were implemented, the checklist from the *Measure* phase, now called the *Improve* Phase Checklist, was completed again to evaluate the effectiveness of the *Improve* phase. Table 7.2 shows the completed *Improve* Phase Checklist below.

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[26] The Failure Modes and Effects Analysis (FMEA) tool is used to rank and prioritize the possible causes of failures of potential solutions in order to include preventative actions to prevent the failures from occurring (Pande and Holpp, 2002).

Table 7.2: Completed *Improve* Phase Checklist

Question	Comments	NA	Yes	No
Air Emissions Management				
1. Is an up-to-date documented air emissions inventory maintained on file?	An up-to-date documented air emissions inventory dated September 2002 is maintained on-file. There have reportedly been no changes since that time.		X	
2. Is an up-to-date Certificate of Approval (C of A) (Air) maintained on file? (EPA, s.9)	A copy of an up-to-date C of A (Air) was maintained in the air emissions file.		X	
3. Are exempt sources documented with an explanation for the exemption?	Exempt sources are included with the air emissions summary information.		X	
4. Are all terms and conditions associated with the C of A (Air) being met?	A review of the C of A (Air) requirement table and supporting documentation indicated terms and conditions were being met for all affected equipment except for the lab fume hoods. This was because the fume hoods are part of another business operating out of the same building.			X
5. Is a process in place to notify the Director of the MOE in writing of changes relating to an existing C of A (Air) where it is impractical to first obtain an amendment (provided the change does not result in increasing the potential of a discharge into the environment)? (EPA, s.9)	The process is included in the air emissions management procedure.		X	
6. Is there equipment on-site that contains refrigerant?	A review of refrigerated equipment including air conditioning equipment, compressor air dryers, and a process chiller.	X		
7. Does the facility have a refrigerated equipment inventory?	A completed inventory form is on file in the Ozone Depleting Substances (ODS) file.		X	

8. Are copies of proof of technician's qualifications maintained on file?	Copies of technician's qualifications are maintained in the ODS file.		X	
9. Are service records for refrigerated equipment maintained on file for two years?	Greater than 2 years worth of service records for refrigerated equipment are maintained on file.		X	
10. Has a notice been affixed to equipment after a leak or test?	A notice has been affixed to refrigerated equipment where required (e.g. air dryers)		X	
11. Is there a process to flag changes or additions to site activities that could impact air emissions compliance?	There is a Change Control procedure that addresses air emissions in the EHS manual.		X	
Wastewater Management				
1. Is an up-to-date documented list and map of wastewater sources, treatment systems and discharge points maintained on file?	An up-to-date list and map of wastewater sources, treatment systems and discharge points are maintained on file.		X	
2. Is an up-to-date Waste Survey Report maintained on file? (By-Law No. 2-03)	A Waste Survey Report is maintained in the Wastewater file.		X	
3. Are exempt sources documented with an explanation for the exemption?	There are no exempt wastewater sources for the facility.	X		
4. Is water sampling completed on a regular basis?	Wastewater sampling is completed on an annual basis by an outside consultant. Records were available for review.		X	
5. Is a process in place to investigate, mitigate, and complete corrective actions if sampling analysis indicates an exceedance?	Wastewater management procedure references ISO 9002 corrective action procedure.		X	
6. Is a process in place to notify the Region and/or City of sampling exceedances (where required)?	There is a process in place that involves consultation with the legal department and the business EHS Manager for guidance.		X	
7. Is there a process to flag changes or additions to site activities that could impact water discharge compliance?	There is a Change Control procedure that addresses wastewater discharge in the EHS manual.		X	

Waste Management				
1. Is an up-to-date documented inventory of waste characterizations maintained on file?	Annual review requirement is included in the waste management procedure, but there is no evidence of the review being completed.			X
2. Is a waste generator identification number maintained on file? (O. Reg. 347, s. 18)	The facility's waste generator identification number is maintained on file.		X	
3. Is subject waste registered on the Hazardous Waste Inventory Network (HWIN)? (O. Reg. 347, s. 18)	Subject waste classes are registered on the HWIN system. Reviewed subject waste classes on-line, and all registered classes corresponded with subject waste generated.		X	
4. Is a process in place to ensure that HWIN registration is completed by February 15th of each year? (O. Reg. 347, s.18)	The waste management procedure includes the annual HWIN registration requirement.		X	
5. Is copy #1 of waste manifests sent to the Ministry of the Environment (MOE) within 3 workings days of shipment? (Reg. 347, s. 18)	Reviewed waste manifest file and found no copy #1 on file. The receptionist also indicated that copy #1 is sent to the MOE immediately once received. The Shipper/Receiver confirmed this also.		X	
6. Is copy #2 of waste manifests maintained on file for at least two years? (O. Reg. 347, s. 18)	Reviewed waste manifest file and copies were maintained on file.		X	
7. Is copy #6 of waste manifests maintained on file for at least two years? (O. Reg. 347, s. 18)	Reviewed waste manifest file and copies were maintained on file.		X	
8. Is a process in place to ensure that subject waste is not stored on-site longer than 90 days? (O. Reg. 347, s. 18)	90-day storage requirements are included in the waste management procedure.		X	

9. Is the disposal of non-normal wastes such as asbestos or PCB's documented?	Procedures for PCB disposal and MOE notification requirements documented in the EHS files. Asbestos procedures are documented in the EHS Manual.		X	
10. Do personnel shipping subject waste/dangerous goods or receiving dangerous goods have up-to-date Transportation of Dangerous Goods training (SOR/2001-286, Pt. 6)?	The Shipper/Receiver and Purchaser have up-to-date TDG training. Reviewed training certificates and wallet cards.		X	
11. Is a process in place to ensure that waste manifests and shipping/receiving documents for dangerous goods are completed correctly?	Process is controlled through signing control and use of templates from training session.		X	
12. Are copies of waste carrier's C of A (Waste) maintained on file?	C of As for waste carriers are maintained in the waste management file.		X	
13. Are copies of waste receiver's C of A (Waste) maintained on file?	C of As for waste receivers are maintained in the waste management file.		X	
14. Is an up-to-date Waste Audit and summary maintained on file for 5 years? (O. Reg. 102, s. 5)	The facility has less than 100 employees, and is therefore exempt from this requirement.	X		
15. Is an up-to-date Waste Reduction Workplan and summary maintained on file for 5 years? (O. Reg. 102, s. 5)	The facility has less than 100 employees, and is therefore exempt from this requirement.	X		
16. Is a recycling program in place? (O. Reg. 103, s. 15)	The facility has less than 100 employees, and is therefore exempt from this requirement. However, the facility does recycle metal, used oil, cardboard, paper, aluminum cans, and glass bottles.	X		
17. Is there a process to flag changes or additions to site activities that could impact waste management compliance?	There is a Change Control procedure that addresses waste generation and disposal in the EHS manual.		X	

Chemical Management and Reporting				
1. Is an up-to-date documented inventory of chemicals maintained on file?	Annual review requirement is included in the chemical management procedure, but there is no evidence of the review being completed.			X
2. Is there a material approval process that includes an environmental regulatory review and sign-off?	The Material Approval procedure includes a review for environmental requirements.		X	
3. Is the purchasing department included in the material approval process?	The Purchaser indicated that she is involved in the material approval process.		X	
4. Are aboveground storage tanks (ASTs) inspected on a regular basis?	Inspection requirements are included in the chemical management procedure, but there is no evidence that inspections are completed.			X
5. Are ASTs equipped with secondary containment? (O. Reg. 388/97, s. 4.3.7)	All ASTs are double-walled, and enclosed with a secondary containment system.		X	
6. Are ASTs equipped with an overfill protection device? (O. Reg. 388/97, s. 4.3.1.8)	All ASTs are equipped with an automated spring mechanism to prevent overfill.		X	
7. Are the ASTs equipped with leak protection? (O. Reg. 388/97, s. 4.3.7.7)	All ASTs are double-walled, and enclosed with a secondary containment system. Dispensing occurs within the facility, and secondary containment and spill materials are used.		X	
8. Is the distance between each AST at least 1 metre? (O. Reg. 388/97, s. 4.3.3.2)	All ASTs are located 1.5 metres apart.		X	
9. Are the ASTs labeled as to their contents? (O. Reg. 388/97, s. 4.3.1.7)	All ASTs are labeled "Oil".		X	

10. Is a process in place to review the List of Toxic Substances for potential pollution prevention plan requirements, reporting requirements, and prohibited substances? (CEPA, Pt. 4, s. 95 and s. 212)	The chemical management procedure includes a requirement to review the List of Toxic Substances.		X	
11. Is a process in place to review the Domestic Substances List (DSL) and the Non-Domestic Substances List (NDSL) for use and reporting requirements? (CEPA, Pt. 5)	The chemical management procedure includes a requirement to review the DSL and NDSL.		X	
12. Is a process in place to review the Export Control List for reporting requirements? (CEPA, s. 101)	The chemical management procedure includes a requirement to review the Export Control List.		X	
13. Is a process in place to review new substances for reporting requirements? (SOR/94-260)	The chemical management procedure includes a requirement to review new substances for reporting requirements.		X	
14. Is a process in place to ensure that electrical equipment containing PCBs (>50 ppm) is not introduced into the facility? (SOR/91-152)	There is a procedure to test oil in electrical equipment for PCB content prior to arriving at the facility. A Certificate of Analysis is also sent to the facility before the electrical equipment arrives.		X	
15. Is a process in place to annually evaluate whether National Pollutant Release Inventory (NPRI) reporting is required? (CEPA, Pt. 3	The chemical management procedure includes a requirement to review NPRI reporting requirements.		X	
16. Is a process in place to annually evaluate whether Air Contaminant Discharge and Reporting is required? (O. Reg. 127)	The chemical management procedure includes a requirement to review O. Reg. 127 reporting requirements.		X	
17. Is there a process to flag changes or additions to site activities that could impact chemical management compliance?	There is a Change Control procedure that addresses chemical management and reporting in the EHS manual.		X	

Pollution Prevention				
1. Is a process in place to review operations and processes for pollution prevention (P2) opportunities including:	There is a P2 procedure in the EHS manual.		X	
a) material substitution?	Included in the P2 procedure.		X	
b) service design or reformulation?	Included in the P2 procedure.		X	
c) equipment or process modifications?	Included in the P2 procedure.		X	
d) spill and leak prevention?	Included in the P2 procedure.		X	
e) on-site reuse, recycling or recovery?	Included in the P2 procedure.		X	
f) Improved inventory management or purchasing techniques?	Included in the P2 procedure.		X	
g) good operating practices or training?	Included in the P2 procedure.		X	
Emergency Spill/Release Response				
1. Is there an up-to-date inventory of potential and actual hazards that require prevention, preparedness and mitigation procedures?	The requirement for an up-to-date inventory is included in the emergency response plan, but there is no evidence of a completed inventory.			X
2. Is a process in place to review environmental emergency plan and notification requirements? (CEPA, Pt. 8)	Requirement is included in the emergency response plan.		X	
3. Is a spill control procedure in place including (O. Reg. 388/97, s. 4.1.6.4):	There is a spill/release response procedure in the EHS Manual.		X	
a) approval by the Fire Department?	The requirement is included in the spill/release response procedure, but there is no evidence that the spill/release response procedure was approved by the local fire department.			X
b) operating procedures to prevent leaks and spills from piping, pumps, storage tanks and process vessels?	Included in ISO 9002 work instructions, and referenced in the spill/release response procedure.		X	
c) procedures for ventilation?	Included in the procedure.		X	

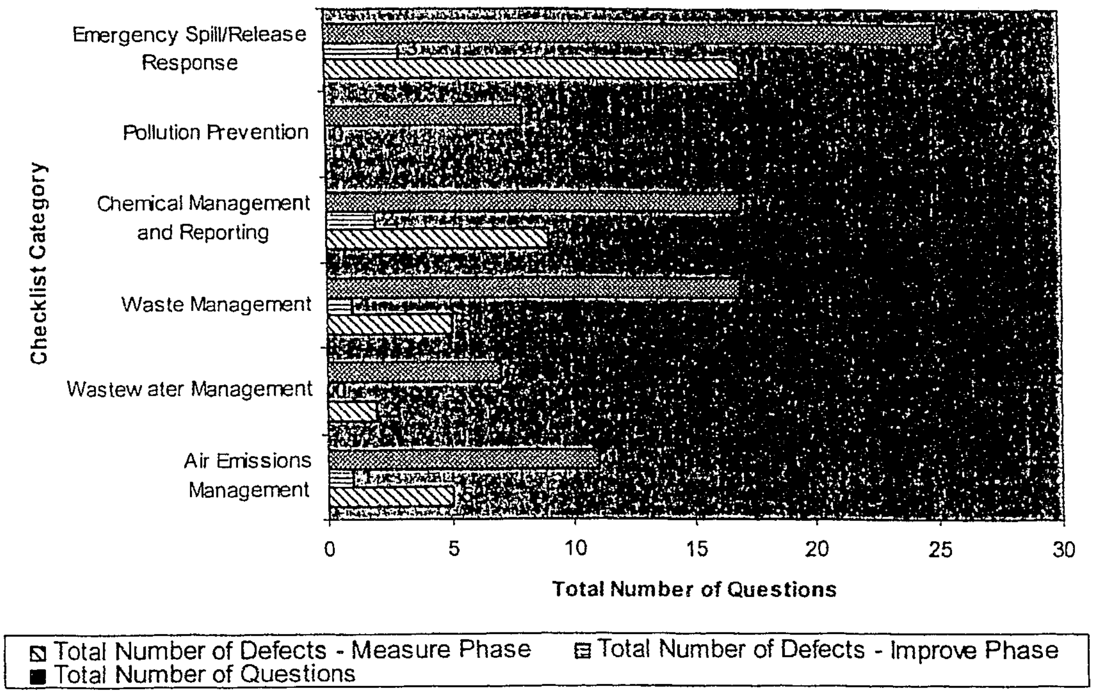
d) spill containment and clean-up?	Included in procedure.		X	
e) protective clothing and PPE?	Included in procedure.		X	
f) handling and disposal of waste?	Included in procedure.		X	
g) chain of command including notification of applicable agencies and management?	Included in procedure.		X	
h) preventative maintenance program?	In place, and referenced in procedure.		X	
i) posting and maintenance of the procedure?	Procedure is posted in work cell areas, and included in EHS Manual. There is an annual requirement (minimum) to review the procedure.		X	
j) training of new employees within 3 months of hire and every 6 months for experienced employees?	Training requirements are listed in the spill/release response plan, but there is no evidence of completion of spill response training.			X
4. Is a process in place to immediately notify the Ministry of Environment (MOE), followed by written particulars as soon as practicable, of a discharge in excess of a limit, causing an adverse effect, or resulting in visible emissions that exceed standards? (Reg. 346, s.9)	Notification requirement included in the spill/release response procedure.		X	
5. Is a process in place to report discharges of 100 kg or more of refrigerant to the MOE? (EPA, Pt. X)	Reporting requirement is included in the spill/release response procedure.		X	
6. Is a process in place to notify the MOE and Region of spills/releases that have the potential cause an adverse effect? (EPA, Pt. X and By-Law No. 2-03)	The MOE and the local municipality are included in the notification requirements of the procedure.		X	

7. Is a process in place to document spill/release investigations that includes the following information (O. Reg. 675, s. 12):	There is a spill investigation form as part of the procedure.		X	
a) date, time, location, and duration of the release?	Included on the form.		X	
b) material and quantity released?	Included on the form.		X	
c) circumstances and cause of spill?	Included on the form.		X	
d) details of containment and clean-up efforts?	Included on the form.		X	
e) an assessment of the success of the containment and clean-up efforts?	Included on the form.		X	
f) how waste from the spill clean up was handled and disposed of?	Included on the form.		X	
g) any adverse effects as a result of the spill?	Included on the form.		X	
8. Is there a process to flag changes or additions to site activities that could impact emergency response and hazard identification?	There is a Change Control procedure that addresses emergency spill/release response in the EHS manual.		X	
Total Defects: 7 **Total Number of Questions: 85**				

At this point in the study the checklist was used as a tool to determine whether or not there was a reduction in the number of defects in the EMS process. This demonstrated that the same tool could be used for different purposes within the Six Sigma™ method.

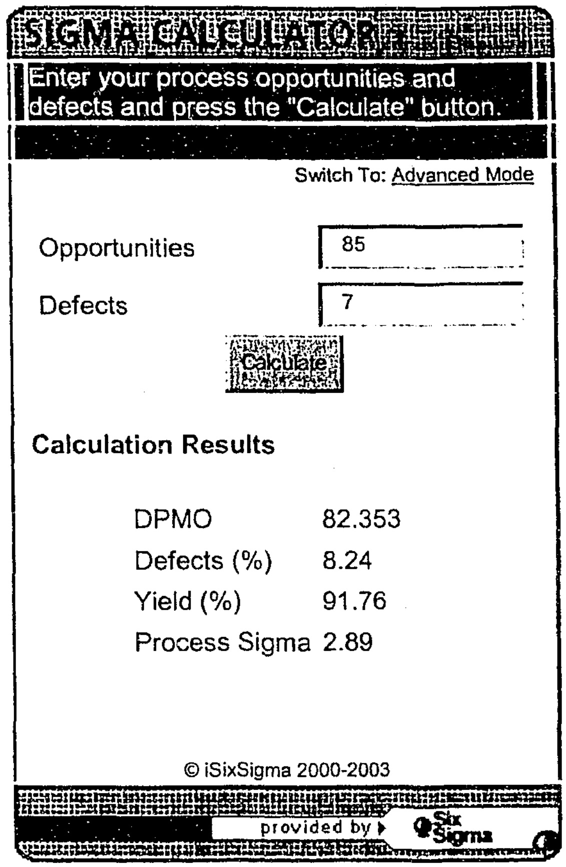
The total number of defects identified from the *Improve* phase checklist was seven. Figure 7.1 below was completed in order to graphically compare the difference in the number of defects between the *Measure* and *Improve* phase.

Figure 7.1: Summary of Defects in *Measure* vs. *Improve* Phase



Once the defect changes were summarized, the process sigma calculator was used again to determine the sigma score for the EMS process after improvements were made. Figure 7.2 below shows the calculated results.

Figure 7.2: Process Sigma Calculator – *Improve* Phase



(Courtesy of isixsigma.com)

The calculation was completed by taking the number of defects, which totaled seven, and dividing that number by the total number of opportunities, or total number of questions, which totalled eighty-five. The resulting number was 0.0824. This indicated that 8.24% of all opportunities were defects. The corresponding yield was 91.76% meaning that the facility was complying with 91.76% of the environmental requirements listed on the checklist. Since the Six Sigma™ method examines defects per one million opportunities, the resulting number of defects per million opportunities was 82,353. This resulted in a process sigma score of 2.89. The defect reduction was equal to 82%. Therefore, the research study met Company A's corporate definition of a successful project. However, the resulting process sigma score of 2.89 validated the limitation of using discrete data in the Six Sigma™ method. When discrete data are used, process entitlement will only reach a three to four sigma level.

7.5 Process Performance Improvement

Although the process sigma score improved tremendously, the team wanted to confirm that defect reduction was due to the improvements made by the team, as opposed to random effects. This step was completed with the help of the company Black Belt. The test was completed in the *Improve* phase because there were now two sets of defect data, one from the *Measure* phase, and one from the *Improve* phase. Therefore, statistical arguments were established in order to test the data. The null hypothesis was defined as no statistical difference in the data sets, and the alternative hypothesis was defined as a statistically significant difference in data sets. In other words the null hypothesis was defined as *Improve* phase solutions not having an effect on defect reduction, and the alternative hypothesis was defined as *Improve* phase solutions having an effect on defect reduction. Once the hypotheses were defined, statistical analysis was used to test the hypotheses. The type of statistical analysis had to be defined in order to use the correct test. Use of attribute data limited the applicable tests to the one sample proportion, two sample proportion, and chi square test. The number of factors had to be determined in order to narrow down test choices. The study had one factor, and that was meeting environmental requirements. Next, the number of samples had to be determined. There were two sets of data so it was decided that there were two samples available for the test. Finally, the purpose of the statistical test had to be confirmed. Once again, the purpose of the statistical test was to determine if the *Improve* phase solutions had an impact on the defect reduction (i.e. independence test). Based on the information gathered, the chi-square test (Weiss, 1997) was used to test the null and alternative hypotheses.

Once the type of statistical test to be used was determined, a statistical software program called Minitab® was used to complete the test. This software was available for use at the facility. The data was inputted and the chi-square test was completed (Table 7.3). The P-value was used in order to calculate the probability of being wrong if the alternative hypothesis was accepted. The P-value used for comparison purposes was P=0.05, or a significance level of 95%. If the calculated P-value was more than 0.05, the significance level was less than 95% and the null hypothesis was accepted (i.e. *Improve* phase solutions did not affect defect reduction). If the calculated P-value was less than 0.05, the significance level was greater than 95% and the alternative hypothesis was accepted (i.e. *Improve* phase solutions did affect defect reduction). The resulting P-value was P<0.05, so the alternative hypothesis was accepted. Hence, *Improve* phase solutions did affect defect reduction.

Table 7.3: Minitab® Chi Square Test Results

	Measure Phase	Improve Phase	
Defects	38	7	
Opportunities	85	85	
	97.26	72.74	
	1.544	2.065	
Total	123	92	215
Chi-Sq = 17.244, DF = 1, P-Value = 0.000			

7.6 *Improve* Phase Tollgate Checklist

Once the steps in the *Improve* Phase were completed, an *Improve* Phase Tollgate Checklist (Table 7.4) was completed to ensure that all the steps in the *Improve* phase were completed. The project then moved to the *Control* phase.

Table 7.4: *Improve* Phase Tollgate Checklist

Steps	Date Completed
Generating Possible Solutions	
Possible solutions generated	April 22, 2003
Process Standardization	
New process steps, standards, and documentation are integrated into normal operations	April 28, 2003
Documented Procedures	
Operating procedures are consistent	April 28, 2003
Knowledge gained on process is shared and institutionalized	April 28, 2003
Designing Implementation Plan	
Solution implementation plan established	April 22, 2003
Project impact on utilizing the best solutions	April 22, 2003
Small-scale case for proposed improvements	May 16, 2003
Performance Sigma Recalculation	
Case data collected and analyzed	May 16, 2003
Process sigma score recalculated	May 16, 2003

(Adapted from Waddick, 2003)

Chapter 8. *Control* Phase

8.1 Introduction

The *Control* phase is a very important step in the *DMAIC* process because its purpose is to prevent processes from reverting back to old ways. It also has a long-term impact on the way people work and ensuring that it lasts is as much about persuading people as it is about measuring and monitoring results (Pande and Holpp, 2002). Key steps involved with the *Control* phase include:

- Designing a monitoring process to keep track of changes as they occur
- Handing off project responsibilities to those responsible for the day-to-day activities
- Creating a response plan to address any problems that may arise
- Helping focus management's attention on a few critical measures that give them current information on the outcomes (Y) and key process measures (X)
- Ensuring support from management for the long-term goals of the project
- Educating the rest of the employees in terms of the project subject

(Adapted from Pande and Holpp, 2002)

8.2 Monitoring and Measurement

One step in the *Control* phase was to include a regular assessment step to verify that environmental requirements were consistently being met. Therefore, the team decided to modify the *Improve* Phase Checklist (now called the Assessment Checklist) to include a column to identify whether or not the task was completed. This linked the Assessment Checklist to the EHS Compliance Calendar tool to ensure completion. Finally, there had to be a mechanism to communicate new regulatory or corporate environmental requirement[illegible] [illegible]erefore, a question was added to the assessment checklist, and a task was ac[illegible] to the EHS Compliance Calendar. Table 8.1 shows the revised Assessment Checklist.

Table 8.1: Assessment Checklist

Question	Comments	NA	Yes	No	Compliance Calendar Task Completed (Y/N/NA)
Is a process in place to obtain and review legislative updates?					
Air Emissions Management					
1. Is an up-to-date documented air emissions inventory maintained on file?					
2. Is an up-to-date C of A (Air) maintained on file? (EPA, s.9)					
3. Are exempt sources documented with an explanation for the exemption?					
4. Are all terms and conditions associated with the C of A (Air) being met?					
5. Is a process in place to notify the Director of the MOE in writing of changes relating to an existing C of A (Air) where it is impractical to first obtain an amendment (provided the change does not result in increasing the potential of a discharge into the environment)? (EPA, s.9)					
6. Is there equipment on-site that contains refrigerant?					
7. Does the facility have a refrigerated equipment					

inventory?					
8. Are copies of proof of technician's qualifications maintained on file?					
9. Are service records for refrigerated equipment maintained on file for two years?					
10. Has a notice been affixed to equipment after a leak or test?					
11. Is there a process to flag changes or additions to site activities that could impact air emissions compliance?					
Wastewater Management					
1. Is an up-to-date documented list and map of wastewater sources, treatment systems and discharge points maintained on file?					
2. Is an up-to-date Waste Survey Report maintained on file? (By-Law No. 2-03)					
3. Are exempt sources documented with an explanation for the exemption?					
4. Is water sampling completed on a regular basis?					
5. Is a process in place to investigate, mitigate, and complete corrective actions if sampling analysis indicates an exceedance?					
6. Is a process in place to notify the Region and/or City of sampling exceedances (where required)?					
7. Is there a process to flag changes or additions to site activities that could					

impact water discharge compliance?					
Waste Management					
1. Is an up-to-date documented inventory of waste characterizations maintained on file?					
2. Is a waste generator identification number maintained on file? (Reg. 347, s.18)					
3. Is subject waste registered on the Hazardous Waste Inventory Network (HWIN)? (Reg. 347, s.18)					
4. Is a process in place to ensure that HWIN registration is completed by February 15th of each year? (Reg. 347, s.18)					
5. Is copy #1 of waste manifests sent to the Ministry of the Environment (MOE) within 3 workings days of shipment? (Reg. 347, s.18)					
6. Is copy #2 of waste manifests maintained on file for at least two years? (O. Reg. 347, s.18)					
7. Is copy #6 of waste manifests maintained on file for at least two years? (O. Reg. 347, s.18)					
8. Is a process in place to ensure that subject waste is not stored on-site longer than 90 days? (O. Reg. 347, s.18)					
9. Is the disposal of non-normal wastes such as asbestos or PCB's documented?					
10. Do personnel shipping subject waste/dangerous goods or receiving dangerous goods have up-					

to-date Transportation of Dangerous Goods training? (SOR/2001-286, Pt. 6)					
11. Is a process in place to ensure that waste manifests and shipping/receiving documents for dangerous goods are completed correctly?					
12. Are copies of waste carrier's C of A (Waste) maintained on file?					
13. Are copies of waste receiver's C of A (Waste) maintained on file?					
14. Is an up-to-date Waste Audit and summary maintained on file for 5 years? (O. Reg. 102, s.5)					
15. Is an up-to-date Waste Reduction Workplan and summary maintained on file for 5 years? (O. Reg. 102, s.5)					
16. Is a recycling program in place? (O. Reg. 103, s. 15)					
17. Is there a process to flag changes or additions to site activities that could impact waste management compliance?					
Chemical Management and Reporting					
1. Is an up-to-date documented inventory of chemicals maintained on file?					
2. Is there a material approval process that includes an environmental regulatory review and sign-off?					
3. Is the purchasing department included in the material approval process?					

4. Are aboveground storage tanks (ASTs) inspected on a regular basis?					
5. Are ASTs equipped with secondary containment? (O. Reg. 388/97, s. 4.3.7)					
6. Are ASTs equipped with an overfill protection device? (O. Reg. 388/97, s. 4.3.1.8)					
7. Are the ASTs equipped with leak protection? (O. Reg. 388/97, s. 4.3.7.7)					
8. Is the distance between each AST at least 1 metre? (O. Reg. 388/97, s. 4.3.3.2)					
9. Are the ASTs labeled as to their contents? (O. Reg. 388/97, s. 4.3.1.7)					
10. Is a process in place to review the List of Toxic Substances for potential pollution prevention plan requirements, reporting requirements, and prohibited substances? (CEPA, Pt. 4, s. 95 and s. 212)					
11. Is a process in place to review the Domestic Substances List (DSL) and the Non-Domestic Substances List (NDSL) for use and reporting requirements? (CEPA, Pt. 5)					
12. Is a process in place to review the Export Control List for reporting requirements? (CEPA, s. 101)					
13. Is a process in place to review new substances for reporting requirements? (SOR/94-260)					

14. Is a process in place to ensure that electrical equipment containing PCBs (>50 ppm) are not introduced into the facility? (SOR/91-152)					
15. Is a process in place to annually evaluate whether National Pollutant Release Inventory (NPRI) reporting is required? (CEPA, Pt. 3)					
16. Is a process in place to annually evaluate whether Air Contaminant Discharge and Reporting is required? (O. Reg. 127)					
17. Is there a process to flag changes or additions to site activities that could impact chemical management compliance?					
Pollution Prevention					
1. Is a process in place to review operations and processes for pollution prevention (P2) opportunities including:					
a) material substitution?					
b) service design or reformulation?					
c) equipment or process modifications?					
d) spill and leak prevention?					
e) on-site reuse, recycling or recovery?					
f) Improved inventory management or purchasing techniques?					
g) good operating practices or training?					

Emergency Response					
1. Is there an up-to-date inventory of potential and actual hazards that require prevention, preparedness and mitigation procedures?					
2. Is a process in place to review environmental emergency plan and notification requirements? (CEPA, Pt. 8)					
3. Is a spill control procedure in place including (O. Reg. 388/97, s. 4.1.6.4):					
a) approval by the Fire Department?					
b) operating procedures to prevent leaks and spills from piping, pumps, storage tanks and process vessels?					
c) procedures for ventilation?					
d) spill containment and clean-up?					
e) protective clothing and PPE?					
f) handling and disposal of waste?					
g) chain of command including notification of applicable agencies and management?					
h) preventative maintenance program?					
i) posting and maintenance of the procedure?					
j) training of new employees within 3 months of hire and every 6 months for experienced employees?					

4. Is a process in place to immediately notify the Ministry of Environment (MOE), followed by written particulars as soon as practicable, of a discharge in excess of a limit, causing an adverse effect, or resulting in visible emissions that exceed standards? (Reg. 346, s.9)					
5. Is a process in place to report discharges of 100 kg or more of refrigerant to the MOE? (EPA, Pt. X)					
6. Is a process in place to notify the MOE and/or Region of spills/releases that have the potential cause an adverse effect? (EPA, Pt. X and By-Law No. 2-03)					
7. Is a process in place to document spill/release investigations that includes the following information (O. Reg. 675, s. 12):					
a) date, time, location, and duration of the release?					
b) material and quantity released?					
c) circumstances and cause of spill?					
d) details of containment and clean-up efforts?					
e) an assessment of the success of the containment and clean-up efforts?					
f) how waste from the spill clean up was handled and disposed of?					
g) any adverse effects as a result of the spill?					

8. Is there a process to flag changes or additions to site activities that could impact emergency response and hazard identification?					

Monitoring the completion of required activities was another key point that was raised by the team. The *Measure* tool primarily focused on ensuring that a process was in place, but did not necessarily indicate if a required activity was completed. Therefore, the team had to decide how to make that connection. As previously mentioned, Company A already had a monitoring tool in place for health and safety activities called the EHS Compliance Calendar. The tool listed the activity to be completed, the frequency, and had a feature to indicate if the activity has been completed. Other features included reminder e-mails to responsible parties, as well as measurement of task completion. The team decided to leverage this existing tool in order to identify environmental management tasks to be completed, by whom, and by when. Tasks were identified using the *Improve* Phase Checklist, categorized by checklist categories, and inputted into the calendar. Table 8.2 summarizes the tasks added to the EHS Compliance Calendar.

Table 8.2: EHS Compliance Calendar Tasks

Task	Frequency	Compliance Due Date	Personnel Responsible
Review legislation for new or changing requirements.	Quarterly	NA	Business EHS Manager
Complete assessment checklist.	Quarterly	NA	EHS Rep. or designate

Review inventories for: • Air emissions • Wastewater discharges • Waste generation • Chemical management • Refrigerated equipment • Emergency response	Annual (minimum)	NA	EHS Rep. Shipper/Receiver Purchaser
Review chemical inventory for possible reporting requirements including: • List of Toxic Substances • DSL • NDSL • Export Control List • New Substances	Annual (minimum)	NA	EHS Rep. Shipper/Receiver Purchaser
Review chemical inventory for possible reporting determination calculations including: • NPRI • O. Reg. 127	Annual (minimum)	June 1st	EHS Rep. Shipper/Receiver Purchaser
Complete PM work on paint booths, and lab fume hoods.	Monthly	NA	Lead Hands or designates
Complete sanitary and storm sewer sampling.	Annual	NA	Service Centre Manager
HWIN registration.	Annual	February 15th	Purchaser
90 waste storage limit.	Quarterly	NA	Shipper/Receiver
Calculate employee hours.	Monthly	NA	Receptionist
AST inspections.	Monthly	NA	Transformer Area Lead Hand or designate

8.3 Response Plan to Address Areas for Improvement

The team then had to decide how to identify areas for improvement, and actions to take to make any necessary improvements. Once again, it was indicated that Company A was an ISO 9002 registered company and could therefore use its existing corrective action process to address this issue. As such, the corresponding procedure was revised to include environmental requirements, but to exclude any potential environmental non-conformances from ISO 9002 third party audit activities.

8.4 Project Completion and Report-Out

The final step for the team was completion of the *Control* Phase Tollgate Checklist as outlined in Table 8.3 below.

Table 8.3: *Control* Phase Tollgate Checklist

Steps	Date Completed
Monitoring Plan	
Control plan in place for sustaining improvements (short and long-term)	May 5, 2003
Response Plan	
Response plans established, understood, and deployed	May 5, 2003
Transfer of Ownership (Project Closure)	
Transfer of ownership and knowledge to process owner and process team tasked with responsibilities	May 23, 2003
Company Wide Communication	
Summary 4-blocker completed and communicated to employees	May 23, 2003
Dashboard communication tool designed and posted	May 23, 2003

(Adapted from Waddick, 2003)

The project Green Belt and the Champion also completed a project review in order to formally "close" the project. A Four-Blocker Project Summary tool[27] (Figure 8.1) was used for the close-out meeting. The Four-Blocker Project Summary categorized information into the *Define/Measure*, *Analyze*, *Improve*, and *Control* phases of the project. The *Define/Measure* section included information such as the opportunity statement, project goal, definitions of defect unit and opportunity, and the process sigma score. The *Analyze* section of the summary highlighted the vital X's identified throughout the project. The *Improve* section outlined the benefits of the project, as well as the re-calculated process sigma score. Finally, the *Control* section of the summary included the monitoring plan.

[27] The Four-Blocker Summary tool highlights the key findings from each of the steps in the *DMAIC* process.

Figure 8.1: Four-Blocker Project Summary

Define/Measure

Opportunity Statement: Using Six Sigma to Develop an Environmental Management System (EMS)
Project Goal: To determine whether Six Sigma can be used for EMS development
Opportunity: Number of checklist questions
Unit: Each checklist question
Defect: Any checklist question answered as "No"

Current Process Sigma Calculation: 1.63

Analyze

Vital X's:
- Applicable environmental requirements not clearly identified or known
- Poor filing system for EMS documentation
- No follow-up mechanism to ensure that required tasks are completed
- Required reporting and maintenance activities not incorporated into current procedures

Improve

Benefits: Avoidance of fines and penalties, facility ownership of EMS, improved recordkeeping, leverage existing tools for follow-up activities, better understanding of environmental impact of processes and environmental requirements, and development of a roadmap for potential future use

Improved Process Sigma Calculation: 2.89

Control

Monitoring Plan:
- Quarterly completion of assessment checklist
- Tie-in with ISO 9002 corrective action process
- Monitoring and tracking completion of tasks using the EHS Compliance Calendar

Once the project was considered closed, the Champion (Service Centre Manager) expressed a commitment to ensuring that environmental requirements would be met. The Service Centre Manager also gained more awareness and appreciation for the work involved in meeting environmental requirements through the Six Sigma^{TM} method.

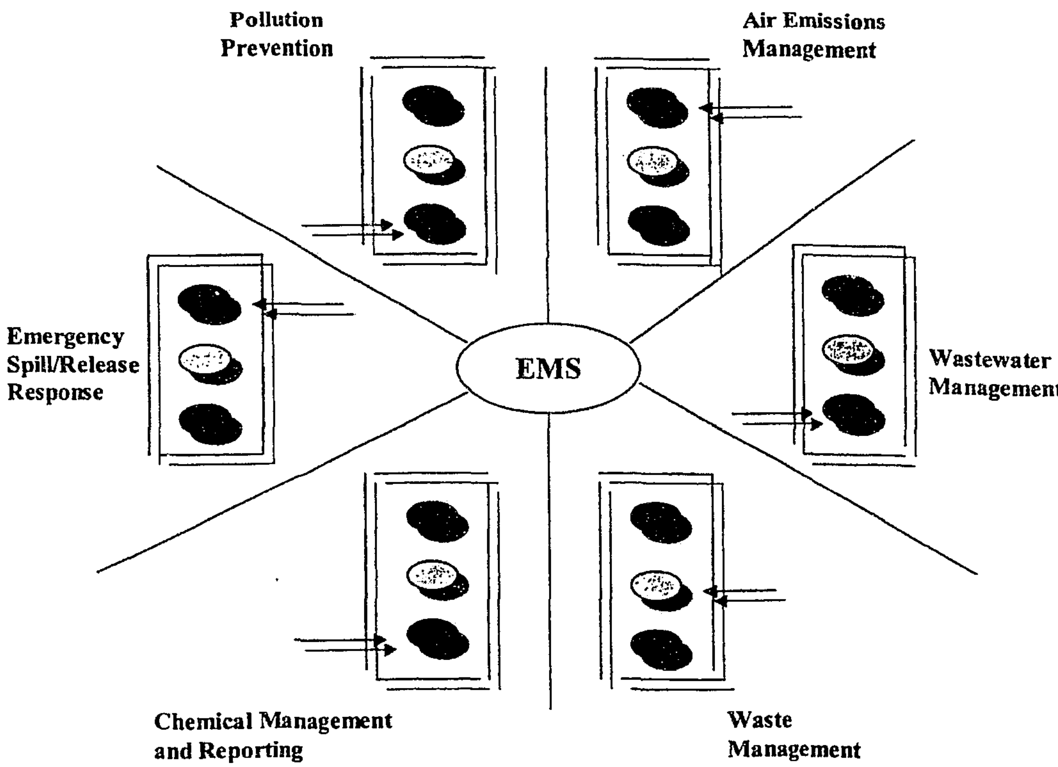
8.5 Employee Communication and Management Commitment

Employees were also provided with a review of the Four-Blocker Project Summary tool, in order to make them aware of what the project was about, what changes Company A made to assist in meeting environmental requirements, and what their role was in helping Company A meet those requirements. A pictorial EMS Dashboard tool[28] was also created (Bertels, 2003; Eckes, 2003) in order to visually demonstrate how

[28] The EMS Dashboard tool is used for collecting and reporting information about the organization's performance against environmental requirements. It provides a quick summary of EMS process performance.

Company A was doing in meeting environmental requirements on an on-going basis (Figure 8.2).

Figure 8.2: EMS Dashboard



The EMS dashboard was categorized by environmental media including air emissions management, wastewater management, waste management, chemical management and reporting, emergency spill/release response, and pollution prevention. The scoring system was defined as follows:

- Green – all regulatory and corporate environmental requirements were being met
- Yellow – all regulatory environmental requirements were being met, but not all corporate environmental requirements
- Red – any regulatory environmental requirements were not being met

Chapter 9. Discussion

9.1 Six Sigma™ Applicability in EMS Design

Completion of the project demonstrated that the Six Sigma™ method could be applied to EMS design. In order to optimize an organization's performance, all processes should be improved with the *DMAIC* process (Wheat *et al*, 2003). There is the potential for multiple uses of Six Sigma™ in the environmental management field, including EMS design or projects to address specific environmental issues. Managing the environment is a process just as is designing products, invoicing customers, and making a widget, and Six Sigma™ can be equally applied to both products and processes. A true Six Sigma™ organization does not only produce excellent product, but also maintains highly efficient production and administrative systems (Perez-Wilson, 1997).

9.2 Benefits of Applying Six Sigma™ to EMS Design

There were a number of benefits and strengths associated with applying the Six Sigma™ method EMS design. The first benefit was the use of relatively simple quality tools in a structured process to improve Company A's EMS without having to recreate what may have already been done. More importantly, the Six Sigma™ method provided a defined method that still allowed for creativity (Bertels, 2003). The Six Sigma™ method allowed for the examination of what was in place and working in other functions or departments of Company A, as well as leveraging best practices from other companies. For example, existing tools used in other departments such as the EHS Compliance Calendar, corrective action process, and the dashboard tool were used to assist with Company A's EMS. As well, the use of tables, charts, and simple procedures assisted in this regard. In fact, the use of simplified tools both to identify requirements and to design tasks led to the operationalization of environmental requirements and the EMS in

Company A. Instead of one person completing all the tasks, tasks were delegated to different individuals. The development of tools, particularly during the *Improve* phase, also enabled Company A to generate records and improve its record management. It also allowed Company A to design and implement measurement and tracking tools that aided in monitoring the EMS. Finally, the tools served as an educational resource, particularly the *Measure*/Assessment checklist and applicable regulatory summary.

Another benefit of the Six Sigma™ method was in indicating the financial implications of completing the project. This was important for identifying as well as educating personnel as to the costs involved in EMS design and cost avoidance.

The use of process maps was extremely beneficial in a number of ways. First, use of the process map allowed for the identification of facility process inputs and outputs, and allowed Company A employees to gain a better understanding of the various processes in the facility. It also demonstrated how and where facility processes interacted with the environment such as air emissions, water intake and discharge, raw material and chemical use, and waste generation points. This ultimately led to the identification of applicable environmental legislation for Company A that further permitted the development of a framework in which to design the EMS, as well as identify where stakeholders were connected to Company A's processes.

Completion of the process maps could have been used for identification of potential Six Sigma™ projects to improve environmental performance, pollution prevention opportunities, and well as hazard analysis techniques. Although it was not the scope of the case study, an examination of potential pollution prevention opportunities could have been completed including material substitution, product design or reformulation, equipment or process modifications, spill and leak prevention, on-site reuse, recycling or recovery, improved inventory management or purchasing techniques, good operating practices, and training (Environment Canada, 2003). The Six Sigma™ *DMAIC* process could also be used in completing specific environmental projects.

Hazard analysis techniques could have also been used once the process maps were completed. For example, a hazard analysis could have been used to evaluate the nature of an accidental release for spill/release response plan development or revisions. Steps would include the review of chemical inventory and storage conditions, chemical properties, dispersion modeling, and consequence analysis (Dowsett, 2003). Once this was completed, spill/release response plans could be designed or revised.

The *Measure/Improve* checklist tool was also beneficial in a number of ways including identifying defects in the EMS process, identifying gaps in the EMS that needed to be addressed, as well as serving as an assessment tool during the *Control* phase.

Perhaps the most important benefit of applying the Six Sigma™ method to EMS design was the development of a Roadmap as outlined in Table 9.1 below.

Table 9.1: Six Sigma™ Roadmap for EMS Design

Six Sigma™ Phase	Tools
Organizing Ideas and Information	
Define Phase	• Team Charter • Project Plan • High Level Process Map • Tollgate Checklist
Data Gathering	
Measure Phase	• Detailed Process Maps • *Measure* Phase Checklist • Measurement Tool Analysis • Process Sigma Calculator/Six Sigma™ Conversion Chart • Tollgate Checklist
Process and Data Analysis	
Analyze Phase	• Bar Graph • Pareto Chart

	• Cause and Effect Diagram • Brainstorming • Payoff Matrix • Tollgate Checklist
Implementation and Process Management	
Improve Phase	• Bar Graph • Brainstorming • *Improve* Action Plan Matrix • Applicable Legislation Table with File Setup • C of A (Air) Requirements Table • Substances with Key Reporting Requirements Table • NPRI/O. Reg. 127 Reporting Determination Worksheets • Procedure Revision Summary Table • Training • *Improve* Phase Checklist • Process Sigma Calculator/Six Sigma™ Conversion Chart • Tollgate Checklist
Monitoring and Maintaining Process Changes	
Control Phase	• EHS Compliance Calendar Schedule • Assessment Checklist • 4-Blocker Project Summary • EMS Dashboard • Tollgate Checklist

(Sub-titles adapted from Pande and Holpp, 2002)

Development of this tool provides a consistent, structured, and rigorous process that can be used over and over again by Company A to constantly improve the EMS, and allow it to become more efficient (Wlodarczyk *et al*, 2000). It provided instructions for company personnel in order to move from identifying the problem/opportunity to addressing it. It also prevented the team from jumping directly from problem/opportunity identification to solution implementation.

9.3 Limitations Associated with Six Sigma™ Use for EMS Design

Limitations in the Six Sigma™ method occurred primarily in the *Measure* and *Analyze* phases. First, discrete data were used in the project, and this type of data has limitations in that sigma improvement could only reach a four sigma. Continuous data would be required in order to reach five and six sigma levels. Decisions made in the Six Sigma™ project were only as good as the measurement system used. One way to address this weakness would be for Company A to change the measurement tool so that it could measure the percent completion of the EMS. The data collected could then be treated as continuous data, and could be used to provide further defect reduction and process sigma improvement.

The measurement system analysis was also a weak area. A statistically-based analysis could not be carried out because only one set of data was obtained during the *Measure* phase. In order to improve this area, a number of assessments could be completed over a defined period of time, thereby generating a number of data sets. A more comprehensive measurement system analysis could then be completed to determine if any measurement system bias or flaws exist.

A similar type of weakness was also identified during the *Analyze* phase. As previously highlighted, the team could not determine whether the defects identified were statistically significant, or whether they were due to a random effect. This was because only one set of data was collected during the *Measure* phase. Hypothesis testing could have been completed if more than one set of data were collected. This would have allowed improvement decisions to be based on objective information as oppose to subjective information.

Identification of applicable environmental requirements was facilitated because the project Green Belt worked as a specialist in the environmental management field. Therefore, identification of environmental requirements could have been problematic if none of the team members had an environmental background. However, such an obstacle could be overcome by ensuring more involvement of the business level EHS Manager to assist with identifying applicable environmental regulations. An environmental consultant would have to be used for smaller companies with no in-house environmental expertise.

The biggest potential limitation in applying the Six Sigma™ method for EMS design was commitment. This project was completed because Company A has already embraced Six Sigma™ as a way to do business. This, however, came after eight years of aggressive implementation efforts (Hoerl, 2002). This may not be the case in an organization that does not use Six Sigma™. Six Sigma™ acceptance is often an ignored element when attempting to implement it in organizations (Eckes, 2001). Even if Six Sigma™ was implemented in Company A, team dynamics were critical in order to complete the project. In particular, the Champion had a crucial role throughout the whole process, and therefore management commitment was imperative in order for Six Sigma™ to work (Dusharme, 2003; Eckes, 2003; Waxer, 2001).

9.4 Further Research

More research is needed to examine how Six Sigma™ is being applied to pollution prevention projects, and to projects that focus on improving environmental performance. There is also an opportunity to examine the use of Six Sigma™ in implementing an ISO 14001-based EMS, since ISO 14001 is an internationally recognized Standard. Although there has been some preliminary work in this area

(Keren, 2001), the idea needs to be tested for its effectiveness. Further research is also needed in order to determine how companies are currently using Six Sigma^{TM} in the environmental management field. This is especially true in discovering how companies are capturing financial benefits associated with Six Sigma^{TM} use in the environmental field. Finally, there is a need for more studies regarding how to implement an EMS. Once this information becomes available, more companies will truly begin to integrate environmental management into their businesses.

Chapter 10. Conclusions

Some Six Sigma™ tools may not be appropriate to apply to EMS design. However, Six Sigma™ does provide a defined and structured method that allows a problem or opportunity to be defined, measured, analyzed, improved, and controlled. This results in a method that can be used over and over again to design or improve an EMS. This is a concept that not been thoroughly developed in EMS literature to date.

At this point, the structured process of Six Sigma™ itself is probably more beneficial in EMS design as opposed to focusing on which tools are used during the *DMAIC* process. The Six Sigma™ method also promoted team involvement from a number of people with varying backgrounds. This especially helped during brainstorming and identification of activities in order to have a more comprehensive analysis of an issue.

Although a structured method was used, there was still room for creative thinking, as well as flexibility in selecting the tools used during the *DMAIC* process (Dusharme, 2003). However, it was important to ensure that the appropriate tools were selected in order to effect meaningful change.

In conclusion, Six Sigma™ can be applied as a structured and consistent method in EMS design.

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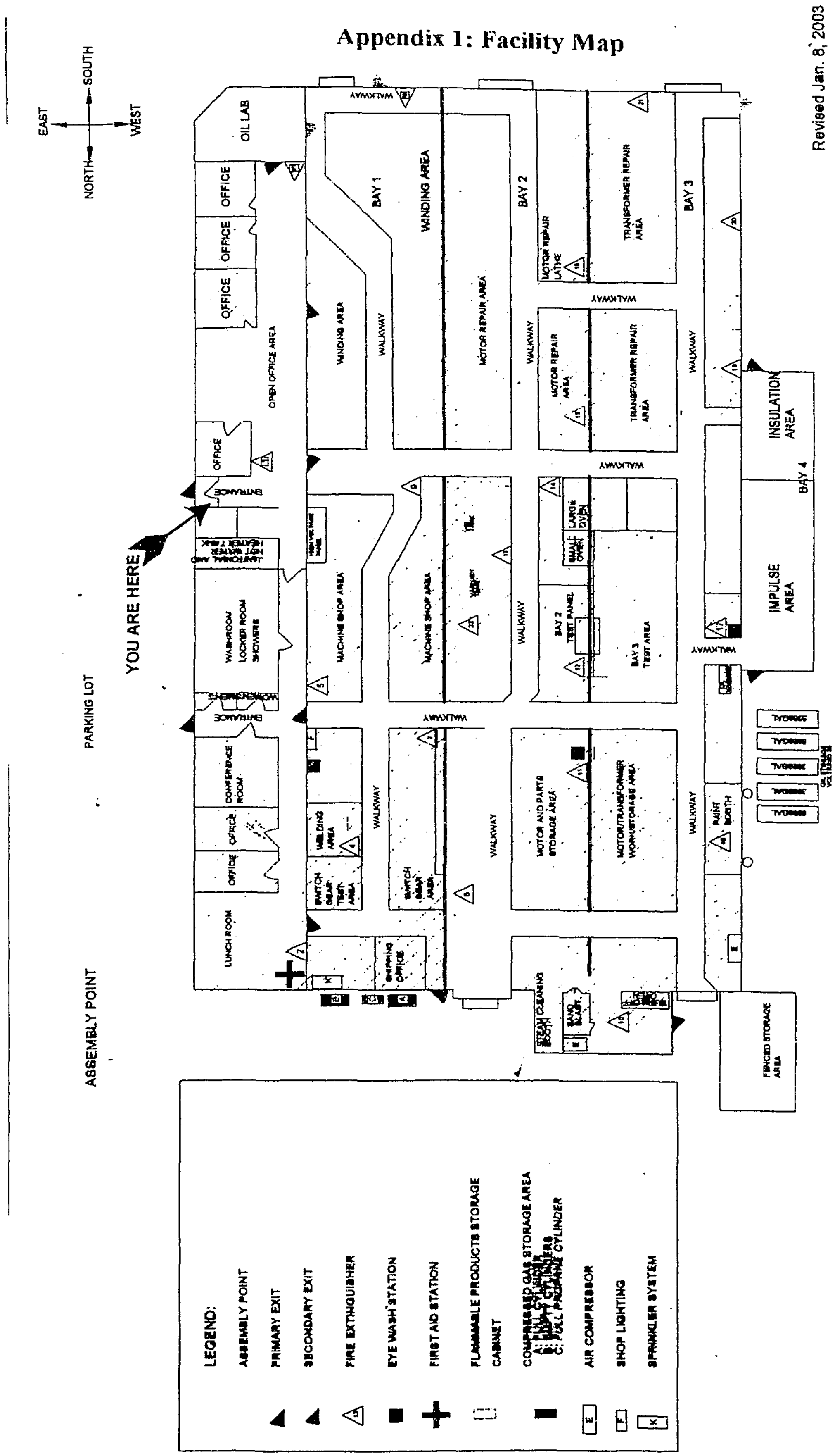
Appendix 1: Facility Map



Appendix 2: *Improve* Matrix Action Plan

Issue	Solution	Costs		Benefits		Impact			
		Cost to Implement	Time to Implement	Cost Reduction	Cost Avoidance	Employees	Stakeholders	Procedures	Training
Applicable environmental regulatory and corporate requirements are not clearly identified.	Include summary table of applicable environmental legislation in the EHS system organization and review procedure, and revise procedures to include environmental requirements and summarize changes made for easy reference.	$0*	3 weeks	$0	Maximum regulatory fines under the EPA: 4 million for individual; 6 million for company**	X	X	X	X
No systematic follow-up to ensure environmental requirements are being met.	Implement a monitoring plan using the EHS Compliance Calendar to include required tasks.	$0*	3 weeks	$0	Regulatory (See above)	X	X		
Environmental reporting and update requirements not included in the EHS manual or Compliance Calendar.	Revise EHS procedures (summarize changes also), and add tasks to the EHS Compliance Calendar.	$0	3 weeks	$0	Regulatory (See above)	X		X	X
Poor filing system for EMS documentation.	Include record requirements with applicable legislation summary table, and in control phase checklist.	$0	3 weeks	$0	$0	X		X	
Not using computerized tools to incorporate environmental requirements (e.g. EHS Compliance Calendar).	Implement a monitoring plan using the EHS Compliance Calendar to include required tasks.	$0	3 weeks	$0	$0	X	X		
No connection between preventative maintenance (PM) activities and regulatory required PM activities.	Develop C of A (Air) requirements table and reference PM program in spill/release response procedure.	$0	3 weeks	$0	Regulatory (See above)	X	X	X	X
No training on regulatory environmental requirements.	Train affected personnel on procedure changes and applicable legislation summary table.	$0	3 weeks	$0	Regulatory (See above)	X		X	X
No knowledge of environmental tools and techniques available to maintain the EMS.	Develop tables such as chemical reporting tables to include in the EHS manual.	$0	3 weeks	$0	$0	X		X	X

Appendix 2: *Improve* Matrix Action Plan

No knowledge of regulatory environmental requirements.	Include summary table of applicable environmental legislation in the EHS system organization and review procedure.	$0	3 weeks	$0	$0	X		X	X
Not aware of who is responsible to ensure that environmental requirements are met.	Review responsibility section of each environmental procedure in training sessions.	$0	3 weeks	$0	$0	X		X	X

* There was no cost because the changes were made by the project Green Belt who was not employed by the facility

** Potential maximum regulatory fines were used for cost avoidance numbers

Appendix 3: Applicable Legislation Table

Air Contaminant Discharge Monitoring and Reporting Regulation (O. Reg. 127)	Requires subject industry sectors to determine reporting requirements, and if required report air releases of contaminants.	Chemical Inventory; O. Reg. 127 Reporting Determination Worksheets.
Emergency Spill/Release Response		
CEPA, 1999	Part 8 covers environmental emergency plan and notification requirements.	Completed Emergency Incident Reports.
TDGA (SOR/2001-286)	Transportation requirements for dangerous goods including training, waste manifests, notification procedures, container labelling, marking and packaging, classification, safety standards, and emergency response plans (as applicable).	Completed Emergency Incident Reports.
EPA, 1990	Part X covers the duty to report, duty to respond/act, MOE responses to spills, compensation and distribution of costs, and exempt spills; also includes refrigerant release reporting requirement of 100 kg or more.	
Ontario Fire Code (O. Reg. 388/97)	Includes a number of requirements to be included in the spill control procedure.	
General - Air Pollution Regulation (O. Reg. 346)	S. 9 deals with release notification requirements where it is in excess of a limit, causing an adverse effect, or resulting in visible emissions that exceed standards.	Completed Emergency Incident Reports.
Spills (O. Reg. 360)	Deals with compensation associated with spill clean up from the MOE where applicable.	
Halton Sewer Use By-Law (By-Law No. 2-03)	Includes a duty to notify the Region of any spills into its sewer system.	Completed Emergency Incident Reports.
City of Burlington Storm Sewer Discharge By-Law (By-Law 86-2002)	Includes a duty to notify the City of any spills into its storm sewer system.	Completed Emergency Incident Reports.
Classification and Exemption of Spills (O. Reg. 675)	Includes the required information to include on a spill incident form.	Completed Emergency Incident Reports.

Appendix 3: Applicable Legislation Table

Industrial, Commercial and Institutional Source Separation Programs (O. Reg. 103/94)	Defines categories for source separated materials based on industry sector and employee hours.	
City of Burlington Dumping and Disposal of Waste By-Law (By-Law 117-1976)	Prohibits and regulates the dumping or disposing of garbage on any grounds, yards, or vacant lots.	
Chemical Management and Reporting		
Ontario Fire Code (O. Reg. 388/97)	Provides requirements for ASTs containing flammable or combustible materials including secondary containment, overfill protection, leak protection, inspections, distance requirements, and labelling requirements.	Completed AST inspections.
Canadian Environmental Protection Act (CEPA), 1999	Part 4 deals with the List of Toxic Substances review, reporting, and prohibitions requirements (as applicable); also covers potential pollution prevention plan requirements. Part 5 deals with DSL and NDSL reporting requirements. S. 101 covers Export Control List reporting requirements, and Part 3 covers NPRI review and reporting requirements.	Chemical Inventory; Substances with Key Reporting Requirements Table; NPRI Reporting Determination Worksheets.
New Substances Notification Regulations (SOR/94-260)	Reporting requirements for new substances (as listed).	Chemical Inventory; Substances with Key Reporting Requirements Table.
Chlorobiphenyl Regulations (SOR/91-152)	Limits concentrations of PCBs in oil in electrical equipment that are imported, manufactured or offered for sale.	Certificate of Analysis for Oil Tests.
Transportation of Dangerous Goods Act (TDGA) (SOR/2001-286)	Transportation requirements for dangerous goods including training, waste manifests, notification procedures, container labelling, marking and packaging, classification, safety standards, and emergency response plans (as applicable).	Training certificates and wallet cards; Bills of Lading.

Appendix 3: Applicable Legislation Table

Halton Sewer Use By-Law (By-Law No. 2-03)	Prohibits and/or restricts the discharge of contaminants into the Region's sanitary and storm sewer system.	Waste Survey Report; sanitary and storm sewer sampling results
City of Burlington Storm Sewer Discharge By-Law (By-Law 86-2002)	Prohibits and/or restricts the discharge of contaminants into the City's storm sewer system.	Storm sewer sampling results
Waste Management		
Environmental Protection Act (EPA), 1990	Part 5 addresses ownership of waste and prohibitions with respect to deposition of waste.	Waste Characterization Inventory
General - Waste Management Regulation (O. Reg. 347)	Covers waste generator registration and responsibilities regarding waste classification, waste collection, storage, transport, handling and disposal, as well as recordkeeping requirements; includes disposal requirements for asbestos waste.	HWIN system and printout; waste manifests; Waste Characterization Inventory; Completed Report on The Storage of Subject Waste; copies of waste carrier and receiver C of As.
Waste Management - PCB Wastes (O. Reg. 362)	Covers recordkeeping requirements, safe and secure storage, and safe and secure disposal of equipment, liquid or material containing oils with PCB concentrations > 50 ppm.	Correspondence re: PCB disposal site; Storage facility inspection log.
Transportation of Dangerous Goods Act (SOR/2001-286)	Transportation requirements for hazardous and liquid industrial waste including training, waste manifests, notification procedures, container labelling, marking and packaging, classification, safety standards, and emergency response plans (as applicable).	Training certificates and wallet cards.
Waste Audits and Waste Reduction Workplans (O. Reg. 102/94)	Requirement to complete annual waste audit and waste reduction workplans if there equivalent of 100 employees working per month in the prior two calendar years; post waste audit and waste reduction workplan summaries; maintain reports on file for 5 years.	Waste Audit and Waste Reduction Workplan and summaries.

Appendix 3: Applicable Legislation Table

Legislation	Applicability	Record to Maintain on File
Air Emissions Management		
Environmental Protection Act (EPA), 1990	S. 5 addresses control of air contaminants; S. 6 provides general prohibitions related to emission of a contaminant into the environment; S. 9 requires a C of A (Air) to construct, alter, extend, replace anything, alter a process or rate of production that may discharge a contaminant into the natural environment; S. 14 provides additional prohibitions for discharges of a contaminant that is likely or will cause an adverse effect.	Certificate of Approval (Air)
General - Air Pollution Regulation (O. Reg. 346)	Addresses control of air contaminants and lists maximum amounts of concentration of a contaminant of the point of impingement (POI).	C of A (Air) Requirements Table
Certificate of Approval Exemptions - Air (O. Reg. 524/98)	Lists exempt emission sources that do not require a C of A (Air).	List of exempt air emissions sources.
City of Burlington Noise By-Law (By-Law No. 19-2003)	Purpose is to prohibit and regulate certain public nuisances, including time and place prohibitions.	
Refrigerants Regulation (O. Reg. 189)	Covers certification and servicing programs, use and recovery of refrigerants, equipment tagging, and documentation requirements for service work including leak tests and recharging.	Technician's qualifications and ODP information; service work orders for refrigerated equipment; Refrigerated Equipment Inventory.
Wastewater Management		
Environmental Protection Act (EPA), 1990	S. 6 and 14 provide general prohibitions on discharges into the natural environment.	Wastewater Source Inventory; sewer diagram map.

Appendix 4: C of A (Air) Requirements Table

Certificate of Approval (Air) Requirements Table						
C of A (Air) Requirement	Type of Requirement	Facility Action/Task	Reference Document	Personnel Responsible	Frequency of Task	Compliance Dates

Appendix 5: Substances with Key Reporting Requirements Table

Substance	CAS No.	DSL	NDSL	Toxic Substances List	Export Control List	New Substances Notification	NPRI	O. Reg. 127

NPRI/O. Reg. 127 Reporting Determination Worksheets

O. REG 127 THRESHOLD DETERMINATION for NATURAL GAS COMBUSTION (TABLE 2A)

Table 2A

Determine total MMBTU/hr for screening criteria

Screening Criteria outlined in Section 2.2 of Step-By-Step Guidance Document

Criteria	Criteria Met?
The facility can reasonable be expected to use coal, refuse, wood or waste oil as fuel at any time during the year?	
The facility can reasonably be expected to have, at any time during the year, a name plate capacity of greater than 3 million BTU/hr?	
The facility can reasonalby be expected to use 3,000 kilograms or more of solvents during the year?	
The facility can reasonably be expected to use 3,000 kilograms or more of printing ink during the year?	
The facility can reasonalby be expected to use 5,000 kilograms or more of welding rods during the year?	

Results –

Table 2A Threshold Determination

Step 1 - Determine total natural gas consumption and convert to million cubic feet (1 cubic meter = 35.31467 cubic feet)

Step 2 - Determine if contaminants exceed reporting threshold

Emission = Consumption * Emission Factor (AP-42)

Contaminants for Natural Gas Combustion from Appendix B of Step-by-Step Guidance Document with Table 2A Thresholds

Contaminant	Emission Factor (lb/million cu feet) from AP-42	Calculated Emission (lbs)	Calculated Emissions (kg)	Threshold (kg) Table 2A
Carbon Dioxide				100000000
Carbon Monoxide				20000
Methane				5000000
Nitrous Oxide				2700
Oxides of Nitrogen (as NO2)				
Oxides of Nitrogen (converted to NO) = NO2*0.6522	N/A			14000
PM (includes PM10 & PM2.5)				20000
PM10 (includes PM2.5)				500
PM2.5				300
Sulphur Dioxide				20000
HFC-134A				10
VOC				10000

Results =

NPRI THRESHOLD DETERMINATION for NATURAL GAS COMBUSTION

Step 1 - Determine if an exemption applies
Reporting Criteria for Parts 1A through to 3 substances:

Screening Criteria outlined in Figure 1 of NPRI Guidance Document

Criteria	Criteria Met?
Was the facility exclusively used for an activity which only requires reporting of CAC emissions from stationary combustion equipment?	
Did the facility operate any stationary combustion equipment	

Proceed to Case 2?

Case 2
Did the facility meet **all** of the following requirements:

Only releases to air occurred from stationary **external** combustion equipment?		
The cumulative nameplate capacity of the equipment is < 10 MMBTU/hr?		
The only type of fuel combusted in that equipment is commercial grade natural gas, liquefied petroleum gas, Number 1 or 2 fuel oil or any combination thereof?		*Results* =

<u>**Threshold Determination**</u>
Step 1 - Determine total natural gas consumption and convert to million cubic feet (1 cubic meter = 35.31467 cubic feet)

Step 2 - Determine if contaminants exceed reporting threshold
Contaminants for Natural Gas Combustion from Figure 1 of the NPRI Guidance Document

Contaminant	Emission Factor (lb/million cu feet) from AP-42	Calculated Emission (lbs)	Calculated Emissions (kg)	NPRI Threshold (kg)	
Carbon Monoxide				20000	
Oxides of Nitrogen (as NO2)				20000	
PM (includes PM10 & PM2.5)				20000	
PM10 (includes PM2.5)				500	
PM2.5				300	
Sulphur Dioxide				20000	
VOC				10000	*Results* =

O. REG 127 THRESHOLD DETERMINATION for TABLE 2A & 2B

Step A - Screening Criteria

Table 2A

Screening Criteria outlined in Section 2.2 of Step-By-Step Guidance Document

Criteria	Criteria Met?
The facility can reasonable be expected to use coal, refuse, wood or waste oil as fuel at any time during the year?	
The facility can reasonably be expected to have, at any time during the year, a name plate capacity of greater than 3 million BTU/hr?	
The facility can reasonably be expected to use 3,000 kilograms or more of solvents during the year?	
The facility can reasonably be expected to use 3,000 kilograms or more of printing ink during the year?	
The facility can reasonably be expected to use 5,000 kilograms or more of welding rods during the year?	

Results =

Table 2B

Screening Criteria outlined in Section 2.3 of Step-By-Step Guidance Document

Criteria	Criteria Met?
The facility can reasonably be expected to employ or engage persons who will together work a total of 20,000 hours or more during the year?	
The contaminant can reasonably be expected to be manufactured, processed or otherwise used at the facility during the year in am amount equal to or greater than the threshold amount for the contaminant set out in Table 2B of the guideline?	

O. REG 127 & NPRI THRESHOLD DETERMINATION

Worksheet to Identify Reg 127 Table 2B & NPRI Chemicals in Products Used in Facility

Products Used in Facility	Reg 127 Chemicals Present	NPRI Chemicals Present	CAS Number	% Concentration of Chemical	Applicable Exemption from Threshold Determination?

O. REG 127 & NPRI THRESHOLD DETERMINATION

Table to Identify Weight of Reg 127 Table 2B & NPRI Chemicals in Products Used in Facility

Facility Name ______________________
Substance ______________________
CAS Number ______________________
Reporting Year ______________________

Material Containing Substance	Information Source	A Purity (%)	B Total Weight of Material (tonnes)	(A/100) x B Calculated Weight of Substance (tonnes)
			Total Weight of Substance	

Facility Name ______________________
Substance ______________________
CAS Number ______________________
Reporting Year ______________________

Material Containing Substance	Information Source	A Purity (%)	B Total Weight of Material (tonnes)	(A/100) x B Calculated Weight of Substance (tonnes)
			Total Weight of Substance	

The threshold calculations are not to be reported to the MOE or Env't Canada. Their purpose is to determine for which substance(s) the facility is required to report for. Keep this information in your files.