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WORLD ENVIRONMENT CENTER

WASTE MINIMIZATION DEMONSTRATION PROJECT

POLISH STEEL INDUSTRY

"CZESTOCHOWA" STEEL WORKS, CZESTOCHOWA

PLANT VISIT NO. 1

MARCH 9-14

World Environment Center
419 Park Avenue South, 18th Flr.
New York, N.Y. 10016

March 1995

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This report was prepared by Michael G. Weiss, P.E.

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I. EXECUTIVE SUMMARY

Background

Pursuant to the technical assistance program for Central and Eastern Europe countries funded by the United States Agency for International Development (USAID), the World Environment Center (WEC) team conducted a technical visit to the Czestochowa steel plant in Poland from March 9 through 14, 1995 to initiate a Waste Minimization Demonstration Project (WMDP) at this site.

The purpose of the visit was to introduce the WEC and its programs, and to observe the plant operations, and obtain information and data in order to establish feasible and economically beneficial waste minimization demonstration projects.

Activity

A presentation was made to key company directors, department managers and technical people on the WEC, and its successful programs established in Poland.

The WEC team visited the plant and discussed problem areas with personnel from the production and environmental departments.

Findings

Two departments, the blast furnace and the steel making, are interested in waste minimization programs. Key managers and technical support personnel from the two production departments and from the plant environmental departments had developed potential projects for discussion with the WEC.

Additional potential projects were developed through the discussions between Huta Czestochowa and the WEC team.

Blast furnace area projects include those related to improvements in cast house fume control and methods to improve productivity with little or no increase in energy.

Steel production projects include reduction of hazardous dust collected in electrostatic precipitators and reduction in NO_x generation.

Recommendations

The company should establish a plant wide Waste Minimization Committee (WMC) in addition to Working Teams in the production areas to coordinate a plant wide waste minimization program.

Future Action

The plant will establish the Waste Minimization Working Teams at production departments which will generate additional projects for discussion with the WEC. Where possible, cost and benefits for these projects will be developed.

During the next visit the WEC will begin a training program on waste minimization techniques.

The next visit will be scheduled for May 1995.

II. INTRODUCTION

During the period of March 9-14, 1995, the WEC Team visited the Huta Czestochowa steel plant in Poland. This facility is the third largest steel plant in Poland.

The WEC Team consisted of:

Mr. Romuald Michalek, WEC - Vice President

Mr. George Laszkiewicz, Ph.D., WEC - Project Manager

Mr. Stephen Muryn, Consulting Services Co. - Industry expert

Mr. Michael G. Weiss, P.E., Consulting Engineer, Consultant

Mr. Henryk Sojka, WEC - In-Country Coordinator

The purpose of the trip was to observe the plant operations, obtain information and data in order to establish feasible and economically beneficial waste minimization demonstration projects.

In the blast furnace and steel making departments, the WEC team and production and technical personnel and plant environmental specialists discussed current operations and problems that could be addressed in waste minimization demonstration projects.

Copies of a Waste Minimization Manual especially prepared for Huta Czestochowa were left with both departments to translate and to distribute to Waste Minimization Committee and working teams prior to the next WEC visit.

The company will establish a **Waste Minimization Committee** for the entire plant and select **Working Teams** for the two departments before the next WEC visit in May. The working teams will develop additional projects as potential waste minimization demonstration projects sponsored by the WEC.

The plant requested technical information from the WEC team, and this will be provided.

III. DISCUSSIONS

A. General

On Friday, March 10, a presentation was made to senior managers, department managers and technical support staff regarding the WEC Waste Minimization Program.

On Tuesday, March 14, a closing meeting was held.

Attending

WEC:
Romuald Michalek - WEC Vice President of Technical Programs (3/10)
George Laszkiewicz, Ph.D. - WEC Project Manager
Henryk Sojka - WEC In-Country Coordinator - Poland (3/10)
Stephen Muryn (Expert), Consulting Services Co.
Michael G. Weiss, P.E. (Consultant), Consulting Engineer

Huta Czestochowa:
Waclaw Korczak - Deputy Dir. for Production and First Deputy Plant Director (3/10)
Tomasz Trzeszczynski - Deputy Director for Technology
Kazimierz Gebka - Principal Process Engineer
Stanislaw Stachowicz - Department Head Steel Making (3/10)
Stanislaw Czornak - Assistant Dept. Head for Energy and Logistics
Henryk Szelag - Department Head for Steel Furnaces (3/10)
Jacek Groszczyniski - Chief Specialist for Process Technology (3/10)
Miroslaw Bojarski - Department Head Blast Furnaces
Jaroslaw Skalski - Technical Specialist Blast Furnace Dept.- Metallurgy (3/10)
Ryszard Lararski - Technical Specialist Blast Furnace Dept. - Agglomeration (3/10)
Wojciech Mikolajczyk - Process Engineer Blast Furnace Dept. (3/10)
Andrzej Ociepa - Representative of Director for Ecological Systems
Anna Rousseau - Environmental Protection Specialist (3/10)
Tadeusz Soja - Representative for Director for Waste Management

Discussion

The success of the WEC in the Polish chemical industry was described. The plants that have achieved the greatest level of success have had solid support from upper management as well as department managers.

Technical Director Trzeszczynski agreed that the WEC Team made several valuable suggestions that the plant will investigate further. A plant-wide Waste Minimization Committee and departmental Waste Minimization Teams in the steel making and blast furnace departments will be established. These teams will develop potential projects for discussion with the WEC at the next visit.

The WEC will begin training in waste minimization and relevant cost analysis techniques during the next visit.

Huta Czestochowa is interested in a special cost analysis training course for engineering and production staffs. The departmental managers expressed great interest in training in cost analysis for their managers related to their jobs in general. They would like a practical understanding of determining and using cost information, not merely an academic treatment. Huta Czestochowa asked WEC for technical support for this training. WEC will evaluate this request although it might be outside the scope of technical assistance which can be provided.

Waste Minimization Manuals were given to department heads for steel making and blast furnace departments. Huta Czestochowa will translate the manual before the next WEC visit and distribute copies to departmental Waste Minimization Teams.

In the closing discussions, the WEC consultant stated that Huta Czestochowa has a bright future if they work to fully utilize the facilities they have. He also suggested the plant develop a balanced plan for future capital installations and improvements that will consider all production facilities and not be a piece by piece approach. Each investment should represent a portion of the total plant plan so the entire facility improves on a step-by-step coordinated approach. This is particularly relevant now as Huta Czestochowa is considering a major upgrade in steel making technology.

B. Steel Making Department

Initial meetings with department personnel and a tour of the department were held on Thursday, March 9. Detail discussions were held on Saturday, March 11, and a closing meeting was held on Tuesday, March 14.

Attending

WEC:
George Laszkiewicz, Ph.D. - WEC Project Manager
Stephen Muryn (Expert), Consulting Services Co. (3/9,11)
Michael G. Weiss, P.E. (Consultant), Consulting Engineer

Huta Czestochowa:
Stanislaw Stachowicz - Department Head (3/9)
Stanislaw Czornak - Assistant Dept. Head for Energy and Logistics
Henryk Szelag - Department Head for Steel Furnaces (3/11)
Jacek Groszczyniski - Chief Specialist for Process Technology (3/11)
Andrzej Ociepa - Representative of Director for Ecological Systems (3/9,14)
Anna Rousseau - Environmental Protection Specialist (3/11)
Tadeusz Soja - Representative for Director for Waste Management (3/11)

General Background

Steel is produced in open hearth furnaces. Four are available, and three are run with one under repair or stand-by. Each furnaces produces a 200 ton heat in a tap-to-tap time of 5-1/2 hours. Furnaces are tapped into two 100 ton ladles.

Furnace charge is 40% hot iron from the blast furnace and 60% scrap. Furnace fuel is coke oven gas and tar from the coke plant. Oxygen-fuel burners are used to speed meltdown. Oxygen is injected through lances into the metal bath to speed carbon removal.

Exhaust gases pass through a recuperator for heat recovery, then to a Lurgi electrostatic precipitator for dust removal.

Metal is taken to a ladle furnace, or ladle metallurgy furnace (LMF) for adjustment of temperature and composition. The average heating rate at the LMF is 4°C per minute.

Huta Czestochowa has the first continuous caster in Poland, a slab/bloom caster manufactured by Voest-Alpine. The caster was started in December, and now 80% of production is continuously cast. Slabs up to 2 meters wide can be cast. Typical widths are 1350 mm (53 inches), 1500 mm (59 inches) and 1600 mm (63 inches). Slabs are 150-200 mm thick (6-8 inches).

In about three months blooms 250 mm (10 inches) square and 280 mm (11 inches) square will be cast. These are used in seamless tube production.

The major areas of concern in the steel production department are hazardous dust from the electrostatic precipitator (ESP), nitrogen oxides and increasing sulfur levels in steel.

ESP Dust

The ESP dust has a zinc content of 4% to 7% which makes the dust unsuitable for recycling to the blast furnace because the zinc will attack the furnace refractory lining. The zinc value is not high enough for economical recovery of the metal units.

Steve Muryn observed that most of the scrap fed to the furnace during the visit seemed to be high quality. He suggested that Huta Czestochowa should categorize the scrap into two classifications: uncoated scrap and coated scrap. The uncoated scrap should be charged for at least 50% of the heats on a continuous basis in all furnaces. The most critical grades of steel should be produced during this campaign on uncoated scrap. Upon completion of this campaign, the coated scrap, which would contain zinc, can be charged in a campaign.

Two types of ESP dust would be produced in this manner. A zinc free dust would be suitable for recycle to the blast furnace, and a zinc containing dust for disposal. If the zinc in the dust for disposal was increased to 15% or greater, there might be a market for the material. This would eliminate the current waste disposal problem.

It is important that the electrostatic precipitator and ducts be cleaned prior to the campaigns of uncoated scrap steel to prevent contamination of zinc free dust by the residual material in the ESP. Vacuum cleaning of the ducts and ESP might be necessary to ensure removal of all zinc bearing dust.

The Huta Czestochowa people were concerned about recycling the dust to the blast furnace sinter since sodium and potassium sulfates, which total about 30% in the dust, could also adversely affect the refractory lining. They stated the dust production was 12 tons/day, which would be a small portion of the blast furnace burden of 1500 tons/day. Both Steve Muryn and Michael Weiss felt that the alkali compounds would have little effect at these levels. Most of the sodium and potassium would be removed in the blast slag, but some would reflux and be contained in the sludge from the blast furnace dust collection system. This sludge would have to be checked periodically to ensure the alkalis did not accumulate to levels that could cause a problem.

Michael Weiss suggested that Huta Czestochowa try to have scrap vendors sort the material. Different prices for different grades with penalties or downgrading of contaminated scrap should be considered.

There are industry standards in the U.S. for scrap metal, and steel mills inspect scrap upon receipt to ensure they receive what they purchased. If lower grades of scrap are mixed in a load, the entire load is downgraded or rejected.

Steve Muryn asked if there were instances of short heats, or heats that yielded less than calculations indicated. Short heats had occurred in the past, and Mr. Muryn pointed out

that they were an indication that the scrap quality was probably the cause of the problem. He pointed out that the plant has a standard for the blast furnace metal, but this is only 40% of the furnace charge. They should also have standards for the 60% that is scrap metal.

Huta Czestochowa asked if there was equipment to assist a field inspector in sorting metals. Michael Weiss said he would check to see what procedures or instruments were used by U.S. scrap dealers or steel mills.

During the visit, ESP stack emissions of varying amounts were noticed. The Huta Czestochowa personnel also indicated that zinc in the stack emissions was as high as 16%, much greater than the 7% zinc in captured dust. These two facts indicate a problem with either the unit operations and maintenance or the size of the unit.

NO_x

Since the plant started using a oxy-fuel burner to melt scrap and oxygen injection into the bath, levels of nitrogen oxides, or NO_x, have increased beyond allowable limits.

Huta Czestochowa will send information on the regulatory limits and what they are getting. Michael Weiss will find out what standards U.S. steel producers must meet, and how they control NO_x.

Sulfur

Sulfur content in the furnace steel has been an increasing problem. Sulfur must be removed at the ladle furnace ahead of the continuous caster.

Steve Muryn said that U.S. companies are increasingly removing sulfur from the molten iron after the blast furnace before the metal is sent to the steel furnaces. This has two advantages—a reduction in limestone fed to the blast furnace with a resultant increase in iron production and adjustment of sulfur to levels required for the steel being produced, minimizing subsequent treatment in the steel furnace or ladle metallurgy facility. This is discussed in the section for the blast furnace.

C. Blast Furnace Department

Initial meetings with department personnel and a tour of the department were held on Thursday, March 9. Detail discussions were held on Monday, March 13, and a closing meeting was held on Tuesday, March 14.

Attending

WEC:
George Laszkiewicz, Ph.D. - WEC Project Manager
Stephen Muryn (Expert), Consulting Services Co. (3/9,13)
Michael G. Weiss, P.E. (Consultant), Consulting Engineer

Huta Czestochowa:
Miroslaw Bojarski - Department Head
Jaroslaw Skalski - Technical Specialist - Metallurgy (3/9)
Ryszard Lararski - Technical Specialist - Agglomeration (3/9,13)
Wojciech Mikolajczyk - Process Engineer (3/13,14)
Andrzej Ociepa - Representative of Director for Ecological Systems (3/9,14)
Anna Rousseau - Environmental Protection Specialist (3/13)
Tadeusz Soja - Representative for Director for Waste Management (3/13,14)

General Background

Huta Czestochowa provided data on the blast furnace. Key items are summarized in the table below and compared to data on the furnace number 5 at Wheeling-Pittsburgh Steel furnished by Stephen Muryn. In order to better compare the furnaces, units of measurement are expressed in both metric and English units.

Exact comparison of furnaces of different sizes is difficult, so the ratio of tones produced per 100 cubic feet of working volume is used in the United States.

Item of Comparison	Huta Czestochowa	Wheeling Pittsburgh
Volume	1,030 cubic meters 36,374 cubic feet	1,001 cubic meters 35,365 cubic feet
Production per Day	1,200 metric tons 1,320 short tons	2,178 metric tons 2,400 short tons
Blast Capacity	84,000 m^3/hr 49,440 cfm	144,416 m^3/hr 85,000 cfm
Hot Blast Temperature	840°C 1544°F	927°C 1700°F
Coke Rate	595 Kg/Tonne 1190 Lb/Ton	440 Kg/Tonne 880 Lb/Ton
Tons/100 Cu. Ft. Volume	3.63	6.78

Huta Czestochowa feels that one of the limits to furnace operation is the limited blast blower. Stephen Muryn suggested they consider a used blower and offered to locate one in the U.S.

Huta Czestochowa has made some efforts to minimize waste. **Slag generation has been reduced from 600 kg/tonne a few years ago to 400 kg/tonne currently**.

The blast furnace produces iron to meet the demands of the steel plant. If the steel plant does not require iron, the furnace is idled. There is a pig caster at the plant, but it has not been installed.

There is no oxygen enrichment in the hot blast. Tar from the coke plant is not available for injection into the blast furnace as it is all used at the steel furnaces.

A major concern of the Huta Czestochowa personnel is cast house emissions. Discussions of potential changes to reduce emissions led to suggestions on improving productivity, some with little to no expense. The issue of sulfur removal was discussed as a method to increase productivity, but is summarized separately below as this topic also concerns the steel production department.

Cast House Emissions

Major emissions during tapping occur at the tap hole and wherever the metal takes a sharp change in elevation such as where it drops into a ladle.

In the taphole area the existing hood is not efficient in capturing fumes as the hood must be elevated to clear the mud gun and tapping drill mechanisms which swing into and away from the taphole.

Stephen Muryn suggested installing a flexible curtain formed by hanging 1½ inch (38 mm) pipes along the edges of the hood. These pipes, installed so each touches the adjacent pipes, form a wall to capture the fumes and limit the excess air drawn in. This wall is flexible, however, and will not restrict access of equipment as the pipes will merely swing out of the way as equipment contacts them.

Mr. Muryn also suggested a burner be installed at the taphole area as much of the fumes are carbon monoxide and fine carbon particles which readily burn.

Molten metal flows from the furnace into a launder then to a system of runners at Huta Czestochowa. Instead of the launder, some U.S. companies tap into an iron trough which remains full of molten iron between taps. Since there is less surface agitation of the stream surface during tapping, emissions are reduced. This trough also does not have to be relined as often as the launder, so save maintenance time costs are reduced, and production time increases. The iron trough at Wheeling Pittsburgh Steel requires a 24 hour outage for reline every 7 to 11 months versus a weekly reline of 8 hours at Huta Czestochowa.

Stephen Muryn will provide drawings of an iron trough for Huta Czestochowa.

Hoods are required where the metal falls from the runner into the ladles. These hoods may capture sufficient fume so control of the minimal emissions from the metal flowing in the runners may not have to be considered. Huta Czestochowa is currently looking at a German patented method of hooding the runners and conveying fumes to a capture device with a neutral gas. The plant has nitrogen available so is looking at this method instead of a burner to combust the fumes under a tunnel hood.

Production Improvements to Minimize Waste

Cost of iron at Huta Czestochowa is high, about $170/T versus a $130/T in the U.S. One reason for the high cost is the lower furnace productivity (see the earlier chart). Both Mr. Muryn and Mr. Weiss felt strongly that Huta Czestochowa should maximize production on the blast furnace which would reduce iron costs.

The furnace is presently producing only to meet the demands of the steel furnaces, and the blast furnace is idled if the steel furnaces cannot take the metal. Idling the blast furnace causes operational and cost problems. Furnace lining life is reduced because the protective shell of metal and slag that forms over the lining during operation is melted off when the furnace is idled. Abrasion of the lining occurs until a new crust or shell is formed. Coke usage increases when the furnace is idled since the column must be kept full, and coke is used to replace iron bearing material.

Low hot blast temperature is a problem for Huta Czestochowa. One cause of this is small stoves which were installed originally on a smaller furnace. Mr. Muryn suggested increasing the checkerwork area by installing brick at the top of the stove. This additional brick can be installed on one stove at a time, allowing continued furnace operation with the remaining three stoves. He will furnish a drawing for the plant.

Mr. Muryn also suggested a plant periodic check of the open area in the stove brick by shoving rods up through the holes. If more than 25% of the openings are blocked, the stove will need to be rebuilt.

The stoves are placed on heating cycle for an hour at Huta Czestochowa versus thirty minutes at Wheeling-Pittsburgh. This longer cycle results in lowered hot blast temperatures and extended stove reheat time. Mr. Muryn and Mr. Weiss suggested decreasing the cycle gradually to increase hot blast temperature without increasing energy consumption.

Since the blast furnace is very large (the Polish term of "wielki piec" or great furnace is an apt description), it has large inertia on both mass and energy. All changes must be graduai with time allowed for restoration of equilibrium in order to prevent operational upsets. Reduction in stove cycle time should be made gradually, with changes of no more than five minutes at a time, with one to two weeks allowed for stabilization. Huta Czestochowa will work out a schedule for trying reduced stove cycles.

The available pig caster should be installed so pig iron can be produced when the steel plant cannot take molten iron. There is a great shortage of iron in the U.S., and quality pig iron could be exported. Solid iron could also be used in-house as a replacement for scrap. This would reduce problems of scrap quality and ESP dust discussed above.

An energy balance should be done on the plant to optimize fuel usage at the blast furnace and steel furnaces. Injecting coke plant tar in the blast furnace would reduce coke rate and help increase furnace production. Increasing the percentage of liquid iron in the steel furnaces would provide energy from the oxidation of carbon in the steel making process, and this energy may be a replacement for the coke tar presently used in the open hearths.

Sulfur

As mentioned in the steel making section, sulfur in steel is a problem. Huta Czestochowa removes sulfur in the blast furnace with limestone. In the United States, more common practice is to remove sulfur from the iron after the blast furnace, either in the torpedo car or ladle. Dolomitic lime ((MgO + CaO) is injected into the ladle, and removes the sulfur into a slag. This slag is scrapped off the metal which is taken to the steel furnaces. Some plants react the lime in the torpedo car and pour the metal out from under the floating slag. The ladle slag is mixed with the blast furnace slag for disposal.

Sulfur removal in this manner will allow an increase in blast furnace production. Since limestone is not required for sulfur control in the furnace, iron bearing material, such as sinter or pellets, will replace the limestone in the burden. Coke required to melt the limestone will be utilized to reduce and melt the iron, so the coke rate per ton of production will fall.

The level of sulfur in each tap can be adjusted to the requirements of the steel furnace. Sulfur in iron can be reduced to levels with allowance for sulfur pick-up in the steel furnace from scrap and fuels, so final sulfur will be within specification without further treatment.

APPENDIX A: AGENDA

Thursday, March 9

General visit to two selected production/process departments for the Waste Minimization Demonstration Project - Steel Making Department and Blast Furnace Department

Preliminary discussions about the production processes

Friday, March 10

Meetings and discussions with plant's senior management and production staff from the two departments.

Saturday, March 11

Steel Making Department production process evaluation, discussions with production, technical and environmental staffs, waste minimization possibility assessment.

Monday, March 13

Blast Furnace Department production process evaluation, discussions with production technical and environmental staffs, waste minimization possibility assessment

Tuesday, March 14

Closing discussions with Steel Making and Blast Furnace Departments to establish action items by Huta Czestochowa and WEC.

Meet with plant/production management to prepare one year Waste Minimization Demonstration Program implementation plan.

APPENDIX B: BUSINESS CARDS

APPENDIX B: BUSINESS CARDS

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APPENDIX C: WASTE MINIMIZATION MANUAL

Waste Minimization Manual
for

Czestochowa Steelworks
Czestochowa, Poland

Prepared Exclusively for

World Environment Center
Suite 1800
419 Park Avenue South
New York, New York 10016

by Michael G. Weiss, P.E.

March, 1995

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Waste Minimization Manual
for
Czestochowa Steelworks

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I. INTRODUCTION

Waste minimization and pollution prevention are simply the use of materials, processes and practices that reduce or eliminate the creation of pollutants at the source. The two general methods of source reduction are product changes and process changes to reduce the volume and hazards of production wastes. This manual considers only process changes as they are most applicable to the Czestochowa Steelworks operations.

Increasing disposal costs, potential liabilities and more stringent regulations are causing industry to look at reducing the generation of waste instead of the "end of the pipe" approach of waste control, capture and treatment. Companies in the U.S. are taking proactive roles to implement successful waste minimization and pollution prevention programs, and many companies consider "zero discharge" as the ultimate goal of their programs.

Although publicity is often given to the innovative technologies which have been developed in part to reduce the environmental impact of production processes, waste minimization does not always require new technology. Many companies have realized success by applying existing technology. Often improvements are achieved through a series of small changes. These can cost little money and require only minor modifications to practices or procedures.

This manual has been developed as a guide for those responsible for planning, organizing and implementing waste minimization and pollution prevention programs at operating units. Step-by-step procedures, flow charts and check lists are provided to assist in the implementation of a successful waste minimization or pollution prevention program.

Pollution often refers to hazardous materials, while waste is a more general term. Since waste minimization and pollution prevention refer to programs or practices that are similar in goals and approaches, this manual will use the terms somewhat interchangeably.

Much of the material in this manual has been excerpted from publications of the U.S. Environmental Protection Agency (EPA).

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II. BENEFITS OF WASTE MINIMIZATION AND POLLUTION PREVENTION

The following are some of the benefits that result from a waste minimization program:

Financial Benefits

Both direct and indirect savings will result from a successful waste minimization program. Direct savings often include reduction in energy, materials, waste disposal costs, operating permit fees, and improvements in product yield and quality. Indirect savings include less waste storage space and reduced paperwork and record-keeping requirements.

Reduced Liability

Environmental regulations are becoming ever more stringent. Many new or proposed laws require companies to pay for clean up or damage caused by past emissions. A successful waste minimization program will reduce future liability by eliminating the volume and potential hazards of the solid, liquid and gaseous discharges.

Better Employee and Community Relations

Employees will feel more positive toward the company when they realize the company is committed to providing an improved workplace environment and to reducing hazardous emissions to the environment. Participation by employees in a waste minimization program requires them to look at their jobs and possible ways to improve operating procedures and practices.

The neighboring community will be more willing to support plants that are actively working to minimize the environmental impact of their operations. Support of the community is very important when a plant faces government opposition to plans for expansion or even continued operation.

III. DEVELOPING A WASTE MINIMIZATION PROGRAM

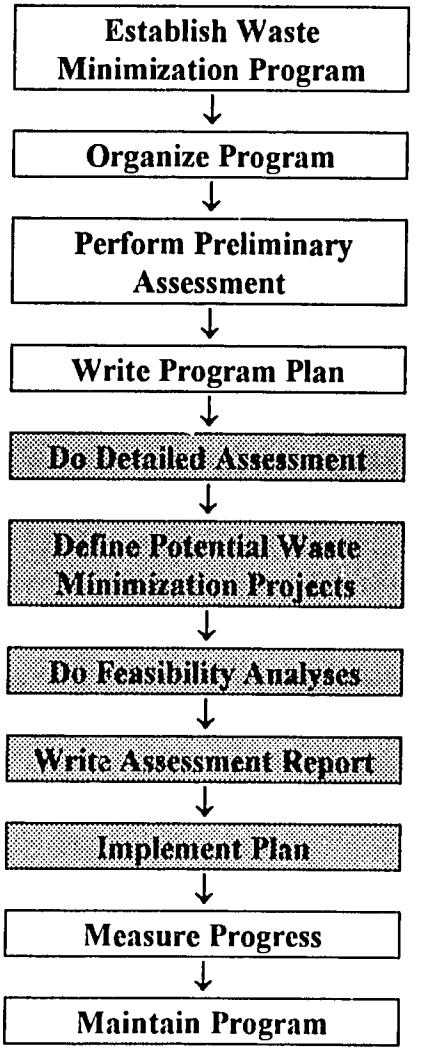
A waste minimization program is a comprehensive and continuing process of evaluating the way a company operates. The steps that make up a program are illustrated in Figure III-1. Individual elements are discussed in greater detail in following sections.

In actual practice, some steps may be combined and feedback occurs as more information becomes available which can lead to plan modification.

Figure III-1

Waste Minimization Program Overview

(Shaded Areas Represent Project Steps)



IV. ESTABLISHING THE PROGRAM

Whether the idea for a waste minimization program comes from the top or from the rank and file, management makes the decision whether to proceed with a waste minimization program.

Management commitment is necessary if the program is to succeed. If line and staff workers do not sense a true commitment by management, they will not make the commitment to the program. Management must encourage total employee participation and must provide the necessary personnel and financial resources to organize and implement the program.

A successful program develops from a consensus throughout the organization. Management must be committed since company resources will be involved, and production level workers must be committed since it is their activities that generate wastes.

Some of the major steps to be taken by management in organizing and implementing a successful waste minimization program are:

1. Issue a formal policy statement from the highest ranking officer to all employees indicating the company's interest, support and total commitment to waste minimization and pollution prevention.

2. Hold employee meetings with the highest level officers to highlight excerpts of the policy statement and to solicit suggestions for the waste minimization program.

3. Designate a Program Team to direct the program. Members of this group should possess business, technical and communications skills and have a thorough knowledge of the company, its products and processes.

4. Designate a Team Leader. This person should have authority and influence necessary to maintain support for the program.

5. Establish a positive atmosphere and continued emphasis of company commitment to the waste minimization program. Slogans, posters and other promotional material can be used to provide continual awareness for waste minimization. Awards for suggestions and achievements in waste minimization will further encourage employee participation.

V. ORGANIZE PROGRAM

A. Name Program Team

A waste minimization program is directed by a program team. Members of the team are assembled from various disciplines in the company, and sometimes from outside the company. It is important that team members have a good understanding of both the production process being examined and the procedures for a successful waste minimization program.

Depending on the complexity of the issue and the personnel available, a small core team can be formed, and they will involve other people as required. Typical team members are listed in Table V-1.

Table V-1

Typical Program Team Members

The *core group* is composed of individuals familiar with the process:

- An operations supervisor or operator involved in the process on a daily basis with a thorough knowledge of startup, shutdown, regular operations, emergency shutdown, and batch operations that may generate wastes or off-specification product
- A process engineer familiar with process chemistry, process interconnections, flow rates, procedures, design practices and environmental discharges
- A research and development person with thorough knowledge of the fundamental basis of the operation
- A quality control person familiar with customer requirements on the product
- A maintenance engineer or worker familiar with maintenance procedures for the equipment, including waste streams generated during maintenance
- An environmental staff person who knows the regulations affecting the process and waste streams

A *resource group* can assist the core group in specialized areas:

- An outside consultant familiar with the industry and improvements in product or process technology
- Purchasing, sales and accounting people who can advise on cost and availability of materials and equipment, customer demands and costs associated with the operation.

Separate individuals are not needed for each area listed. In some cases one person may provide required skills and knowledge in more than one area. The important issue is that all skills and knowledge should be represented.

The team leader is crucial to the success of the program. The role of this person is to maintain the flow of information among all levels of the company, so this person should have the personal qualities to ensure support from employees throughout the company.

This leader should hold frequent employee meetings and report the progress of the a waste minimization program, highlighting success stories. Table V-2 summarizes some of the major responsibilities of the program leader.

Table V-2

Responsibilities of the Team Leader

- Coordinate and monitor all program activities.
- Provide proper resources for waste minimization projects.
- Provide guidance in identifying waste minimization opportunities.
- Arrange for training and increased awareness for waste minimization.
- Hold frequent progress review meetings.
- Issue progress reports.

B. State Goals

One of the first tasks of the team is to establish goals that will give a long term direction to the program. These goals should be consistent with the company waste minimization policy, and may be specific statements of the policy general statements.

Goals need to be well defined, meaningful to all employees, challenging yet achievable and flexible.

Goals can be qualitative or quantitative. Quantitative goals require more effort to develop, but they do detail the waste minimization commitment and do provide a means of measuring progress for participants and observers.

It is important to recognize that goals are flexible. Things change in actual practice, and goals can be refined to reflect these changes. Goals can be adjusted up or down to reflect lessons learned during the program. Periodic review and adjustment of goals with

suggestions from all employees will keep the program active and maintain the interest of employees.

VI. PRELIMINARY ASSESSMENT AND PROGRAM PLAN

A. Preliminary Assessment

Although some initial work was necessary for the decision to establish the waste minimization program, it is frequently useful to perform additional preliminary assessments to collect data, visit the physical process site and to establish priorities.

Data for this assessment can come from a variety of reports and information that should be readily available such as reports filed with regulatory agencies, production reports and process information and accounting records. Typical data sources are listed in Table VI-1.

Remember that the goal of the program is to minimize waste, not collect data. Data not useful to the project should be ignored.

Site visits will help members of the task force understand any site specific constraints that must be considered. These visits will also help in establishing priorities that will be considered in the plan.

Assigning priorities will focus the remainder of the waste minimization plan development. Priorities will help determine areas for detailed assessments. Some criteria for prioritizing waste for further study are listed in Table VI-2.

The U.S. Environmental Protection Agency (EPA) has developed a method for developing priorities called the Weighted Sum Method. A detailed description of this method is provided in Appendix A.

B. Write Program Plan

The program plan will define objectives, identify potential obstacles and develop a schedule. The plan should be in agreement with the company policy statement

Objectives are the specific tasks necessary to achieve goals. For example, objectives to achieve a goal of decreased energy consumption might be to monitor air and gas flows to burners and analyze oxygen in flue gases.

Objectives should be quantitative and should have target dates.

Obstacles are factors which might hinder the waste minimization program. If everyone recognizes the obstacles ahead of time, the means for overcoming them can be addressed.

Obstacles generally fall into 4 categories:

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1. Economic Obstacles— All companies have limited financial resources, even the largest corporations. Costs incurred in waste minimization may be for new equipment, different raw materials or supplies. A cost-benefit analysis is one method of evaluating the value of the program.

2. Technical Obstacles — There may be problems associated with the nature of the process itself. As examples: a)modifying existing equipment or installing new equipment may require a production shutdown, and this may be difficult to schedule, and b) the process under consideration may be physically arranged so that space is not available for new equipment.

   Information on techniques applicable to the problem may not be available in the company. Often outside resources can help in these situations.

   Concerns about quality or customer acceptance may make a company reluctant to make changes. If possible, laboratory and pilot runs to determine the effect of process changes and customer evaluation of products made in the modified process should be done before permanent changes are made.

3. Regulatory Obstacles — Early contact with agencies to inform them of the program and plans will often eliminate potential delays and problems if the work affects permits.

4. Institutional Obstacles — Change is often resisted, particularly when the reasons for change are not understood. Good communication and education regarding the program and its goals will reduce resistance at all levels of the organization.

Schedules that will help control the project include a progress chart listing key tasks from planning through implementation with necessary dates for accomplishing these tasks to maintain the planned schedule. Two useful charts of this sort are Critical Path Method (CPM) or Program Evaluation and Review Technique (PERT) charts.

A cash flow schedule showing expected expenditures and the time they will occur will assist in controlling project costs. The projected cash flow will allow the company to examine the program with other known expenditure schedules to determine if the proposed total project schedule is acceptable.

Table VI-1

Sources for Facility Information

Regulatory Reports:
- Permits or Permit Applications
- Analyses of Solid Waste and Air and Water Emissions
- Regular Reports to Agencies

Process Information:
- Process Flow Diagrams
- Material and Energy Balances - Design and Actual
- Plot Plans and Elevations
- Piping and Instrumentation Diagrams
- Equipment Lists, Specifications, Data Sheets
- Operating Manuals
- Equipment Layout/Work Flow Diagrams

Production Information:
- Operating Procedures
- Operator Data Logs
- Equipment Downtime Reports
- Production and Inventory Records

Accounting Records:
- Water and Sewer Costs
- Energy Costs
- Permit Fees
- Discharge Fees and Penalties
- Waste Handling and Disposal Fees
- Operating and Maintenance Costs
- Department Cost Accounting Reports

Table VI-2

Example Criteria for Prioritizing Waste Streams

- Increase compliance with current and anticipated regulations
- Reduce cost of waste management (pollution control, treatment, disposal)
- Reduce potential liability — environmental and safety
- Reduce quantity of waste
- Reduce hazardous properties (toxicity, flammability, corrosivity, reactivity)
- Reduce safety hazards to employees
- Ease of implementation
- Low capital and operating costs
- Remove bottlenecks in production or waste treatment
- Recovery of valuable by-products
- Previous successful use in company/industry
- Minimizing waste water discharges
- Reduce energy use

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VII. PROJECT DEVELOPMENT AND IMPLEMENTATION

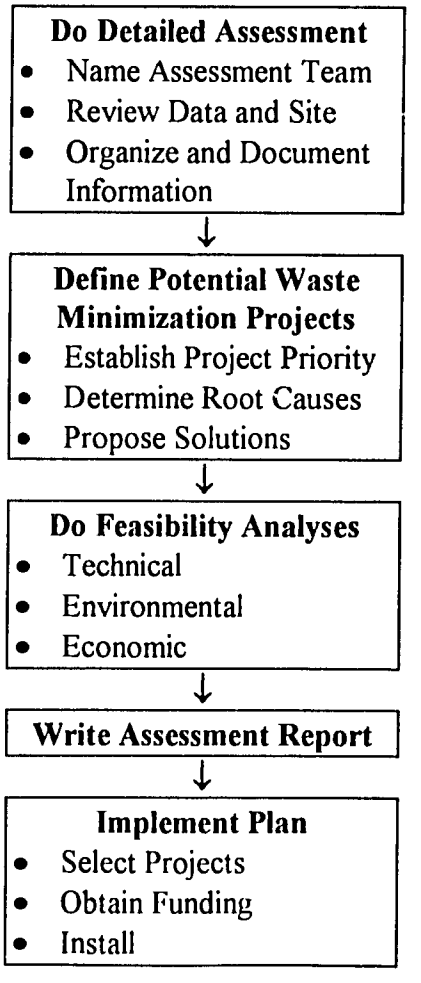
Waste minimization projects are the heart of the waste minimization program. Once it has been established and proven to be successful, a program should be continuous and dynamic. Projects will be proposed, examined and implemented throughout the company.

Production departments are not the only generators of waste. All departments such as maintenance, laboratory, shipping and receiving, and office areas consume energy and generate waste. A successful program will include waste minimization projects in all these areas, see Appendix C. Although this manual is written principally for projects in production areas, the methods of analysis are applicable throughout the organization.

Figure VII-1 lists the project steps from Figure III-1 in greater detail.

Figure VII-1

Waste Minimization Project Overview



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A. Detailed Assessment

The purpose of the detailed assessment is to answer the questions of what, where, why, how much, and how the waste is generated.

Depending on the scope of the waste minimization program, the program team may not be able to handle the detailed examination of all potential projects. In that case, an ***assessment team*** will be necessary for each area of the company that was identified in the preliminary assessments.

An assessment team will have a specific focus. It may be smaller than the program team, but should include at least one member of the program team to ensure good communication and coordination with that group.

The ***data review*** will review the same written material mentioned under preliminary assessment, but in possible greater detail. In addition to written records and material used in the preliminary assessment, the team may interview workers in the particular department or area under consideration. Again, the goal is not to collect data, but to minimize waste.

The ***site visit*** is to provide a better understanding of how waste is being generated. If possible, photographs or videotape should be taken during site visits to illustrate particular problems or equipment for which drawings are not available. Table VII-1 shows key factors regarding site visits.

Typical questions that should be answered by the detailed assessment are:

- What is quantity and composition of waste streams generated?
- Which processes or treatments generate the waste?
- Which emissions are regulated?
- What are fees or penalties associated with the emissions?
- What is recovery of material through various process steps?
- What raw materials contribute to the waste stream?
- What process controls are in use?
- What are causes of operational upsets?.
- What additional instrumentation/controls would enhance the process?
- Are there potential markets for materials currently considered wastes?
- Are unnecessary wastes or emissions generated by mixing materials?

Table VII-1

Factors to Consider for Site Visits

- Plan the site visit: Prepare an agenda to cover all points needing clarification; advise workers in the area of the visit in advance, and inform them that team members may ask questions.
- Monitor the operation at different times over all shifts: Observe operations as they are performed under different circumstances. Observe portions of the operating cycle that may generate significant wastes, such as furnace tapping.
- General cleanliness and housekeeping: Look for evidence of spills, leaks, general trash.
- Process controls: Are instruments and controls in working order? Are charts changed on schedule?
- Actual operating and maintenance procedures: Are they the same as the written procedures, or is the manual out of date?
- Cooperation among workers: Do workers coordinate their efforts and follow company work and safety rules?

Organize and document the process information to illustrate causes and extent of waste generation.

An excellent way to show this information is with material and energy flowsheets. It is recognized that many flowsheets are incomplete or approximate due to factors such as the inability to determine the exact flow, composition and temperature of many streams, the changing nature of feed materials and product mix, difficulty in measuring heat losses, etc. Nevertheless, well prepared flowsheets and balances with actual measurements and estimations based on good engineering practices and data from outside sources should answer most of the what, where, why, how much, and how of waste generation.

B. Define Waste Minimization Projects

Once the opportunities for waste minimization have been identified, the assessment team should identify potential projects.

The first step in the process is to ***prioritize*** the opportunities to determine which projects offer the greatest total potential for improvement. Much of this may already have been done under the preliminary assessment step, but it should be reviewed with the knowledge gained from the more detailed study. The criteria listed earlier can be used to develop the ranking, and the Weighted Sum Method may be useful in establishing the priority of the projects to be examined further.

Next, ***determine root cause*** of the waste generation. This may not always be obvious, so all possibilities must be examined, even remote or unusual ones. For example, a problem might be fume generation from a furnace in excess of the capacity of the pollution control device. A cause might seem to be periodic surges in emissions, but the root cause is wet feed material which causes the surges in emissions when the water vaporizes as the material enters the hot furnace. Table VII-2 list typical categories of causes of waste generation.

The technique of brainstorming encourages creative thought among the group and is a good method for generating a wide range of possible causes.

Table VII-2

Typical Categories of Waste Generation Causes

- Poor/improper equipment design
- Poor raw material quality
- Poor equipment conditions
- Poor yield
- Non-optimized processing conditions
- Inadequate operating procedures
- Inadequate process instrumentation and control
- Inadequately trained operators
- No in-process recovery/recycle
- Poor housekeeping
- Poor materials/inventory management
- Improper package size/materials for raw materials

Once the root cause(s) is (are) determined, ***propose solutions*** . This is another occasion where creative thinking is required to include all possibilities. In the example mentioned above, solutions for wet feed may include: install covers to keep rain and snow off the material, install a dryer, place a moisture penalty if the wet feed is a purchased material, change the operation generating the wet feed if it is produced within the company.

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Examples of process changes that can be considered as potential solutions as listed in Table V11-3.

Table VII-3

Process Changes

Input Material Changes	Technology Changes	Improved Operating Practices
• Material Quality • Substitution of Less-Toxic Materials	• Layout Changes • Increased Automation • Improved Operating Conditions • Improved Equipment • New Technology	• Operating and Maintenance Procedures • Management Practices • Material Handling Improvements • Waste Segregation • Production Scheduling • Inventory Control • Training

A method of analyzing a process for waste minimization opportunities is listed in Appendix C.

C. Feasibility Analysis

Once the potential solutions to the causes of waste generation have been determined, they must be checked to see if they are ***feasible or practical.***

The solutions should be screened to answer the following questions:

- Which solution will best achieve the goal of waste minimization?
- What are main benefits of this solution?
- Does the technology exist for the solution?
- Does it appear to be cost effective, or does it merit further economic analysis?
- Can solution be implemented in reasonable time with minimal disruption to production?
- Does the solution appear to stand a good chance of success?
- What other areas in the company will be affected?

A first step in screening the solutions is a preliminary quick review by the team so those with no cost or risk can be implemented immediately and those that are impractical or have little chance of success can be discarded.

Remaining possibilities are further screened by informal discussion and consensus among the group or, in more complicated cases, by more formalized techniques such as the Weighted Sum Method.

When the solutions have been screened, detailed examination should be done to determine if the final candidates are technically, environmentally, and economically feasible, and the list can be ranked for implementation.

The ***technical evaluation*** is to determine whether a proposed solution will work in the specific case. Many of the questions addressed in this stage are more detailed examination of those asked in the preliminary screening. Some sample criteria used for technical evaluation are listed in Table VII-3.

The technical evaluation should include all groups in the company who will be affected by the proposed solution. In addition to production, concerned groups might include purchasing, maintenance, laboratory, quality control, purchasing and sales. As well as identifying factors that should be considered, these groups will more likely cooperate with any changes if they have been involved prior to implementation.

Table VII-3

Typical Questions for Technical Evaluation

- Will proposed solution reduce waste?
- Are the changes safe for workers?
- Will product quality be maintained or improved?
- Is space available for proposed changes?
- Are new procedures, equipment and materials compatible with rest of plant operations?
- Will additional labor be required?
- Will special skills be needed for operation and maintenance?
- Are utilities — water, fuel, electricity, steam, compressed air — available?
- What production outage is required for new equipment installation?

The ***environmental evaluation*** considers the advantages and disadvantages of proposed solutions with regard to the environmental impact. In some cases these are not so obvious. For example a flux might allow a reduction in metal in dross removed from a furnace, but the flux itself might create problems in further treatment or disposal of the waste.

The environmental evaluation should also examine whether plant operating permits include restrictions in types or amount of supplies or materials the plant can use.

Energy is also an environmental as well as an economic consideration. If a proposed solution requires more fuel, for example, increases in amounts or type of emissions may be a negative factor.

The ***economic evaluation*** can be complex. Among the many factors to be considered are capital costs, operating cost changes, increased profits if a salable by-product is created, decreased environmental fees and penalties and decreased waste handling and disposal costs. Typical costs are listed in Table VII-4.

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Table VII-4

Economic Evaluation Considerations

Direct Costs:

Capital Expenditures
- Buildings
- Equipment, including Installation
- Utility Connections
- Project Engineering and Management

Operating/Maintenance Expenses and Revenues
- Raw Material
- Operating/Maintenance Supplies and Material
- Labor
- Utilities: Water, Fuel Electricity, Compressed Air, Steam
- Waste Disposal
- Value of Recovered Material

Indirect Costs:
- Administrative Costs
- Compliance Costs
  - Fees
  - Monitoring, Record keeping, Reporting
- Payroll Benefits
- Insurance - Workers' Compensation
- Insurance - Liability
- Pollution Control Equipment Operation
- On-Site Waste Management

Liability Costs:
- Penalties
- Fines
- Property Damage
- Personal Injury
- Clean-up

Less-Tangible Benefits:
- Increased Productivity Due to Improved Employee Relations
- Improved Relations with Regulators
- Improved Community Relations

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Many companies distribute indirect and overhead costs to production in a manner which does not reflect the true dependency between these overhead charges and the department which incurs them. It may be necessary to try to establish the allocation based upon a proper relationship.

The economic evaluation must often look at the project over an period of time, and therefore the time value of money must be considered. There are several methods for performing an analysis of this type, but the net present value (NPV) method has the advantages of being easily understood and requiring few assumptions.

If there is uncertainty regarding some aspects of the project, such as the market for a by-product or the expected production levels or utility costs or, the economic evaluation can look at more than one possibility, such as optimistic, pessimistic and most likely case.

D. Write Assessment Report

After all possibilities have been examined, screened and evaluated, an ***assessment report*** should be written summarizing the results of the work.

The project team can write an overall report with the assessment teams providing reports covering the results of their studies with a list of potential projects evaluated.

Report on each proposed project should discuss the following:

- Project waste minimization potential
- Overall project economics — present multiple cases if analyzed
- Required resources — manpower, equipment, financial — and how they will be obtained
- Technology employed and successful applications
- Time for installation and startup
- Performance measures for project evaluation after implementation

Before the report is issued, it should be reviewed with managers and other key people in the particular production units. This be one more opportunity to look at the feasibility of the projects, and, once again this involvement will help to gain support of those who will be involved with the changes on a day-to-day basis.

E. Implement Plan

At this stage, you are ready to ***select projects***, ***obtain funding*** and ***install the project***.

Project selection and implementation schedules may be done by the project team, but more likely plant or company management will make the final decisions with recommendations from the project team.

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If capital funding is necessary it must be arranged. Funding may come from internal sources such as the company capital budget, or from external sources including loans and grants from government or other agencies.

Project installation includes more than equipment installation of modification. Operating and maintenance manuals, policies and procedures will have to be written or revised to reflect changes. New materials specifications may have to be written for purchasing. Employees on the production line and in support roles will have to be trained.

After the program is implemented it should be followed to measure performance against the technical, environmental and economic claims made in the analysis. Some modifications may have to be made to equipment or procedures as experience is gained with the changes.

VIII. MEASURE RESULTS

A waste minimization project is not completed when equipment, process or procedure changes have been placed in service. The results of the changes must be measured and evaluated to determine the effectiveness of the program.

Data used in the assessment portion of the project development can serve as baseline information. Obviously the issues that must be measured are those that the project was designed to change, for example the amount of waste generated. Additional measurements should be made to determine if unanticipated effects, good or bad, have occurred as a result of the project. Typical factors to consider when measuring results are listed in Table VIII-1.

Cost information should be included in the measurement for comparison of actual against projected economic benefit.

It may be difficult to correct for factors not related to the changes made as part of the waste minimization project. In many cases, measuring generation rates based on time and units of production as well total generation will help indicate changes resulting from the waste minimization project and from other causes.

The project team leader should issue progress status reports comparing the expected and actual results of the project. Depending on the scope of the project, these can be a one time presentation of results, or periodic reports showing progress on a monthly, bimonthly or quarterly basis as changes are implemented and employees become accustomed to new procedures.

Information obtained by measuring results can form the basis for adjustments to the chugs implemented or for additional changes to the process.

The measurement of results reveals the successes and failures that will assist in planning future projects. Techniques that work well and those that do not can be identified.

Table VIII-1

Factors to Consider in Measuring Project Results

- Waste generation or emission rate per hour and per unit of output
- Total waste generation or emissions
- Change in hazardous or toxic nature of wastes generated
- Process on-line reliability, or actual vs. scheduled operating hours
- Fuel and electricity usage in total and per unit of output
- Water usage in total and per unit of output
- Labor requirement in total man-hours and man-hour per unit of output
- Changes in processes connected to the modified process
- Production rate (units/hr) and total production
- Product quality
- Raw material yield (%)

IX. MAINTAINING THE WASTE MINIMIZATION PROGRAM

As mentioned earlier, the waste minimization program should be a continuing program. Publicizing the project results, recognizing employee suggestions and participation and informing employees of specific environmental issues will help maintain awareness of, and participation in, the program.

Important factors to maintain and improve the waste minimization program are:

Integrating a waste minimization program into the total company operating plan

Key factors here are: a) assigning accountability for wastes so employees become aware of waste generated in their department and the cost of controlling and disposing of this waste, b) tracking and reporting the status of the company wide waste minimization program and c) annually evaluating the company program to determine its effectiveness.

Staff education and training

New employees should receive training in waste minimization as part of their orientation to become aware of the program. Current employees will need training to understand how and why procedures are being changed. Additional training will be necessary as further changes are made in policies and procedures.

Maintaining internal communication

Communications must be two-way, not only the management suggestions and reporting of project results. Employees should be encouraged to offer suggestions. Management should promptly evaluate these suggestions and inform the employees if their suggestions will be implemented or the reasons they will not be used.

Rewarding personnel for success in waste minimization

Rewards can range from special recognition to material awards. Employees who suggest waste minimization projects or methods that are feasible and scheduled for implementation should be publicized in company newsletters or on bulletin boards. Money or merchandise can be awarded to individuals or groups of employees as further recognition of their efforts. In some cases the size of the award is based upon the annual cost savings realized through the suggested project.

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APPENDIX A: WEIGHTED SUM METHOD

The Weighted Sum Method is a quantitative method for screening and ranking waste streams and waste minimization/pollution prevention options such as the potential projects and ways to minimize waste. It provides a means of quantifying the important criteria the affect waste management in a facility. This method involves four steps.

1) Determine important criteria in terms of program goals and constraints and corporate goals and constraints. Example criteria listed in table VI-2 in the report are repeated here:

Increase compliance with current and anticipated regulations
Reduce cost of waste management (pollution control, treatment, disposal)
Reduce potential liability — environmental and safety
Reduce quantity of waste
Reduce hazardous properties (toxicity, flammability, corrosivity, reactivity)
Reduce safety hazards to employees
Ease of implementation
Low capital and operating costs
Remove bottlenecks in production or waste treatment
Recovery of valuable by-products
Previous successful use in company/industry
Minimizing waste water discharges
Reduce energy use

2) Assign a weight to each criterion ranging from a low of 0 to a high of 10. As examples, if reducing the quantity of waste were very important, it would be given a value of 10, and if ease if implementation and low costs were somewhat important, they might be given values around 6 to 8; if previous successful use is not important, it might be given a value of 1 or 2.

3) Each project or option is rated on each criteria, also on a scale of 0 to 10.

4) Determine "weighted" sum each option by multiplying each criterion weight by the rating for that option. The option with the highest weighted sum should receive the most follow-up.

Example: The following criteria are given the weights shown:

Increase compliance with regulations	10
Reduce quantity of waste	8
Low capital and operating costs	8
Ease of implementation	6
Reduce safety hazards	6
Reduce energy use	4

Three options are being considered. They are given the following ratings:

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Rating Criteria	Option 1	Option 2	Option 3
Increase compliance with regulations	8	6	4
Reduce quantity of waste	4	6	8
Low capital and operating costs	2	6	6
Ease of implementation	5	2	8
Reduce safety hazards	4	4	5
Reduce energy use	2	3	9

The final weighted sum for each option is computed by multiplying criteria weight by option rate:

		Weight X Ratings		
Rating Criteria	Weight	Option 1	Option 2	Option 3
Increase compliance with regulations	10	80	60	40
Reduce quantity of waste	8	32	48	64
Low capital and operating costs	8	16	48	48
Ease of implementation	6	30	12	48
Reduce safety hazards	6	24	24	30
Reduce energy use	4	8	12	36
Total		190	204	266

Even though Option 3 has the lowest rating in the most important criterion, increased compliance with regulations, it has the highest rating weighted sum and is the option that should be given top priority for further consideration.

Worksheet

A worksheet to assist in a weighted sum rating analysis for either waste streams or project options is included in the section of forms.

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APPENDIX B: CONSIDERATIONS FOR MINIMIZING WASTE

Processes should be developed, designed and run on the principles of "zero discharge" and "do it right the first time". Attempts should be made to maximize yield and eliminate generation of by-products and wastes. Some methods to consider for minimizing waste are summarized below:

A. Raw Materials Quality and Process Yield Improvement

Processes should be run with the best quality raw materials available to maximize yields and eliminate or minimize formation of undesirable by-products and effluents.

Sometimes a close investigation of the cause of poor yield can be attributed to a very low level (ppm range) of impurities in the feed material. Once the impurities have been identified, a program to eliminate them can be developed by working closely with the supplier.

Programs for continual raw material quality improvement are highly recommended for an effective waste minimization process.

B. Substitution/Elimination of Hazardous Materials

Attempts should be made to minimize or eliminate the use of hazardous materials. It is not uncommon to find that old processes were developed using hazardous supplies or raw materials which can now be replaced by newer non-hazardous materials. Examples include use of newer non-flammable hydraulic fluids and use of water base paints.

C. Optimization of Processing Conditions

Improper processing conditions such as temperature, pressure, reducing conditions, etc. can make the process inefficient and result in generation of excess waste. It is important to evaluate all process parameters and operate based on the optimized values to maximize yield and minimize waste.

Typical process parameters are:

- Temperature
- Pressure
- Atmosphere
- Residence time
- Feed or addition rate
- Slag thickness
- Burner firing rate

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Burner air/gas ratio

Oxygen enrichment

D. Equipment Debottlenecking/Efficiency

Equipment must be designed for the specific process or operation. Often equipment no longer needed in another operation is placed in service without proper modifications to meet the requirements of the new operation.

If equipment is too small it may form a bottleneck, preventing the process from achieving designed throughput. If equipment is too large, it may operate inefficiently, wasting fuel and power.

All items of equipment must be evaluated to ensure they meet design criteria of the process they are used on.

E. Improved Housekeeping, Material Handling and Storage

Most of the time poor housekeeping, materials handling and storage generate unnecessary waste. Common causes for waste are materials becoming unusable because they are old, get wet, freeze, are spilled, or get damaged in handling.

Proper training and planning in material storage and handling must be developed and implemented to reduce wastes.

Properly designed and sized equipment such as pumps, bins, hoppers and chutes will minimize spillage and waste.

F. Inventory Control and Scheduling

Proper scheduling and inventory control of supplies and materials are essential to minimize waste caused by spoilage and obsolescence.

Changeovers in alloy production can result in off-grade material, so proper sequencing of production should be planned to minimize these occurrences.

G. Packaging - Raw Material, Supplies and Finished Products

Disposal of packaging material is a major concern for industries, so effort should be made to purchase material in containers of suitable size and material to minimize waste.

Returnable containers are possible solutions to some packaging problems. Suppliers and customers should be contacted to see if returnable containers fit their operations.

H. Segregation of Waste Streams

Often different waste streams are mixed at the source, making subsequent recovery, treatment or disposal difficult. A waste of consistent quality and composition often has market value, but contamination by other wastes can reduce or eliminate the value and may even cause the material to be disposed of at a cost to the company. This is a particular problem when a relatively large amount of non-hazardous waste is contaminated by mixing with a small amount of hazardous waste.

Isolation of effluents at the point of generation is recommended. This allows for better planning for recovery, treatment and final disposal. Small, local dedicated control or recovery equipment might be more suitable than larger central units to maintain segregation of wastes.

Employee training is important regarding the need to prevent mixing waste streams.

I. Recycle and Recovery

This is one of the better ways to minimize wastes with the potential for increasing productivity and profitability. Much of the metals industry is based on upgrading scrap or off-grade material, so the in-house reprocessing of certain by-products is a standard practice.

Other materials such as used motor oil, hydraulic fluid and cutting oil, scrap plastic and metal containers and paper can be sold to processors.

J. Sale of By-Products

In addition to the items mention above, by-products that cannot be treated within the company may be sold. Examples are drosses, skimmings and baghouse dusts to smelters or chemical producers, and slags for aggregate in concrete.

K. Detoxification of Wastes

After other techniques of minimizing wastes have been applied, the remaining waste material should be evaluated for toxic hazardous characteristics. If the material is hazardous, often techniques can be applied to stabilize or fixate the hazardous constituents so the material can be disposed of under less stringent regulation at lower costs.

APPENDIX C: USING KEY WORDS TO IDENTIFY WASTE MINIMIZATION OPPORTUNITIES

(Reference: "Identifying Pollution Prevention Opportunities: A Tool to Help Industry", William W. Doerr, *The National Environmental Journal*, May/June 1994)

One method to develop opportunities for waste minimization from an entire plant operation to an individual process is to use guidewords or key words to stimulate the team's analytical thinking.

The guideword method consists of three steps:

1) Obtain background information and segment the process or work flow
2) Ask the "What if?" questions in a group discus sion and brainstorming session
3) Document response for follow-up

Step 1): After information is gathered during the assessment stage, the group should divide the process flow diagram into segments based upon a sequential division of key processes or operations. Each segment should contain a small number of waste streams and all pieces of equipment that contribute to the generation of wastes.

Step 2): Each segment is studied with "What if" analysis of waste handling, process changes and operational frequency. Some key words for the analysis of each group are listed below:

WASTE HANDLING

What if the waste is:	Guidewords for discussion
Recycled?	Internal, off-line, offsite
Reused?	reused as feed or product; alternate use
Changed by equipment modification?	Chemical, physical, phase forms
Isolated or contained?	Fugitive emissions; closed vents or vessels
Managed differently?	Consolidated, purified, different package
Segregated by constituent?	Different containers, lines
Recovered?	Capture maintenance or transient wastes; reduce yield loss

PROCESS CHANGE

What if process is changed by:	Guidewords for discussion
Physical treatment?	Drying, agglomeration, size reduction
Feed material substitution?	Fewer problem components, less waste
Construction materials?	Resistance to heat, chemical attack; reduced

	maintenance outages
Equipment modification?	Fewer upsets, reduced maintenance
Thermodynamic considerations?	Pressure, temperature, concentration, phase; yield improvements
Secondary recirculation of utilities?	Heat recovery, water reuse, avoid once-through systems

FREQUENCY CHANGE

What if the frequency is modified for:	Guidewords for discussion
Operation, cleaning, use, release	More or less often
Sequence of operation	Change order of steps

Step 3) Results of the discussion should be recorded on a standard form and indicating the participants, date and time of review, the process or operating segment evaluated, guide word question, response to the question, needed follow-up, potential for waste minimization, and other useful remarks.

For clarity, the forms may be attached to the process flow diagram.

A typical form is attached in Appendix E.

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APPENDIX D: WASTE MINIMIZATION GUIDE FOR SUPPORT GROUPS

Most of this manual has discussed waste minimization techniques that affect the operating or production departments. However, all areas within the company structure generate waste and can contribute to the total waste minimization program.

The following are suggestions for some of the support groups to contribute to the company waste minimization effort.

Purchasing

- Become familiar with the waste minimization concepts discussed in this manual.
- Coordinate closely with Production Scheduling, Maintenance and other departments before ordering materials and supplies.
- Become familiar with various hazardous materials lists.
- Investigate possibilities of purchasing better quality raw materials.
- Look for substitutes for hazardous materials.
- Avoid buying excess materials.
- Follow Just-In-Time (JIT) and First-In-First-Out (FIFO) principles when ordering materials.
- Give attention to package size and type, for example returnable bulk containers.
- Maintain close contact with other groups such as Production, Research & Development, Scheduling, Shipping, Receiving and Maintenance to stay aware of their activities, needs and concerns.

Research and Development

- Become familiar with the waste minimization concepts discussed in this manual.
- Become familiar with various hazardous materials lists.
- Avoid developing processes or products that use hazardous materials or produce hazardous by-products.

- Optimize processing conditions.
- Improve yields of existing processes.
- Develop processes with recycle and recovery capabilities.
- Develop applications and uses of by-product streams.
- Work with Production and Engineering to improve operating instrumentation and controls.
- Maintain close contact with other groups such as Production, Environmental and Marketing to stay aware of their activities, needs and concerns.

Engineering

- Become familiar with the waste minimization concepts discussed in this manual.
- Become familiar with various hazardous materials lists.
- Design equipment and processes with zero discharge goals in mind.
- Base equipment selection on Maximum Achievable Control Technology (MACT).
- Keep fugitive emissions to a minimum.
- Perform process risk and hazard analysis to avoid catastrophic failures.
- Become familiar with present and proposed relevant environmental, health and safety regulations.
- Maintain close contact with other groups such as Production, R&D, Environmental and Maintenance to stay aware of their activities, needs and concerns.

Maintenance

- Become familiar with the waste minimization concepts discussed in this manual.

- Become familiar with various hazardous materials lists.
- Look for substitutes for hazardous materials.
- Establish plans to recover and recycle lubricating and cooling oils, and so forth.
- Sell scrap materials and equipment to recyclers..
- Calibrate and maintain process and pollution control equipment and instruments.
- Become familiar with appropriate safety, health and environmental regulatory requirements affecting plant activities.
- Maintain close contact with Production, Engineering and Purchasing to stay aware of their activities, needs and concerns.

Marketing

- Become familiar with the waste minimization concepts discussed in this manual.
- Maintain close contact with customers to determine their needs for product quality, packaging size and materials.
- Communicate customer needs to Production and Research & Development.
- Identify customers who could use by-product streams.

APPENDIX E: USEFUL FORMS

The following worksheets are provided as tools to aid in the waste minimization effort:

1) Weighted Sum Method

2) Process Information Review

3) Guideword Review Summary Form

4) Option Generation

5) Option Description

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