

# Canada-wide Standards for Dioxins and Furans

## Steel Manufacturing Electric Arc Furnace Pollution Prevention Strategy

### Context

The Canadian Council of Ministers of the Environment (CCME) signed the Canada-wide Standards (CWS) for emissions of Dioxins and Furans from Steel Manufacturing Electric Arc Furnaces in March 2003. An important provision of the CWS is a commitment to develop pollution prevention strategies, consistent with the principles outlined in the *Canada-wide Environmental Standards Sub-Agreement*, that is:

*Pollution prevention is the preferred approach to environmental protection. Governments will place emphasis on a pollution prevention approach when implementing standards under this Sub-Agreement.*

CCME's definition of pollution prevention is as follows:

*"The use of processes, practices, materials and energy that avoid or minimize the creation of pollutants and wastes at source."*

The following is the text of the commitment incorporated in the Steel EAF CWS for Dioxins and Furans:

### Pollution Prevention Strategy:

*In keeping with the Precautionary Principle as set out as guidance in the Canada-wide Standards sub-agreement, and in consideration of the CWS principles of sound science, technical feasibility and socio-economic impacts, efforts are to continue by steel manufacturing EAF operators to prevent, destroy or capture emissions of dioxins and furans. Emphasis should be placed on identifying and implementing opportunities to prevent the creation of dioxins and furans, and emissions of other pollutants generally. As an initial action with shared responsibility by all jurisdictions, strategies identifying opportunities to minimize emissions of air pollutants from the steel manufacturing EAF sector will be developed through a multi-stakeholder process by October 31, 2003.*

*The objective should be to provide a framework for continual progress toward the goal of virtual elimination of dioxins and furans and to take into account the Multi-pollutant Emissions Reduction Strategy specified by CCME Ministers.*

*Recognizing that opportunities and benefits for minimizing air pollutant emissions, and specifically avoiding the creation of dioxins and furans, fall beyond the exclusive influence of the operators of steel manufacturing EAFs, the preparation of this Strategy should and will engage a wide range of stakeholders and experts, recognizing and complimenting ongoing consultative processes on various issues.*

*Factors to be considered in developing the Strategy should include:*

- *Opportunities for improved control and release reductions of particulate matter;*
- *Combustion chemistry of the EAF process;*
- *The feasibility of applying existing and emerging pollution prevention and control techniques (e.g., catalytic oxidation, containment of fugitive emissions, best management practices for operations and maintenance, etc.);*
- *Reduction of mercury sources and emissions through the Mercury CWS development process;*
- *Cross-media transfers and management of pollutants;*
- *Emissions of greenhouse gases;*
- *Resource utilization; and*
- *Energy efficiency.*

The Steel Environmental Multistakeholder Advisory Group (SEMAG) was asked to provide advice and input on the development of a pollution prevention strategy for steel manufacturing electric arc furnaces. SEMAG is comprised of representatives of environmental non-government organizations, steel mill and industry association representatives, provincial environment departments, and federal government departments (Environment, Health and Industry).

As described above, the CWS pollution prevention strategy is to identify opportunities to minimize emissions of air pollutants from the steel EAF sector and provide a framework for continual progress toward the goal of virtual elimination of dioxins and furans. The Dioxins and Furans CWS Development Committee advised SEMAG that a pollution prevention strategy is considered as a tool or advice for jurisdictions to consider and use in whole or in part.

Members of SEMAG met regularly by teleconference and at a face-to-face meeting to discuss the range of issues. An extensive background paper entitled “*Research on Technical Pollution Prevention Options for Steel Manufacturing Electric Arc Furnaces*” was commissioned to address potential approaches and technical options. The report is a thorough collection and examination of the currently available information on dioxin and furan formation and dioxins/furans prevention and control technologies and practices for steel EAF operations. The consultant’s report considered the pollution prevention issues in the above list.

The report identifies a number of pollution prevention practices and techniques that may be useful to jurisdictions and EAF operators in reducing emissions of dioxins, furans and possibly other pollutants. Some practices and techniques will require further investigation, and not all identified practices will necessarily be applicable to all plants.

A successful pollution prevention approach necessitates the application of pollution prevention practices to upstream service providers of the steel industry and that, ultimately, the most effective pollution prevention is commitment from manufacturers to design for sustainability and to embrace product stewardship.

The report also advances a number of recommendations for consideration by jurisdictions. Elements advanced for consideration include:

- Development and implementation of facility pollution prevention plans with objectives to prevent or minimize the formation of dioxins/furans in the EAF steelmaking process, to prevent or minimize the release of dioxins/furans to the atmosphere, and to provide good environmental management of the handling, storage and disposal of material containing dioxins/furans. Factors for consideration in developing the pollution prevention plans could include:
  - Emission limits in the Canada-wide Standards for Dioxins and Furans from Steel Manufacturing EAFs, March 2003;
  - The ultimate goal of virtual elimination of dioxins and furans;
  - Best environmental practices identified in this study and through industry experience; and
  - Recommendation RN 123 (Pollution Prevention Planning) of the CEPA Environmental Code of Practice for Non-integrated Steel Mills, March 2001.
- Industry should draw on the experience of plants that have achieved low emission concentration levels of dioxins and furans, to further identify and compile the most effective pollution prevention practices; and
- Operating practices and conditions should be recorded and included as part of emission testing programs and reports to better assist facilities in identifying pollution prevention opportunities and assessing effectiveness of avoiding/minimizing the formation and release of dioxins and furans.

The members of SEMAG reached agreement on the following:

- options for a CWS pollution prevention strategy were captured effectively in the consultant's report;
- a recommendation be made to the Dioxins and Furans CWS Development Committee that the consultant's report should form the CWS pollution prevention strategy;
- consideration should be given to the development and implementation of facility pollution prevention plans;
- pollution prevention plans should consider the CWS emission limits, the goal of virtual elimination, and the pollution prevention practices and techniques identified in the consultant's report and through industry experience;
- a summary of the consultant's report be posted on the CCME website in both official languages, along with this context note and the text of the original report or a link to the original report; and
- SEMAG should continue to meet, as a forum to support progress towards virtual elimination of dioxins and furans from steel EAF operations, through sharing of new information between members and progress made by EAF operators in achieving emission reductions.

**Research on Technical Pollution Prevention Options  
for  
Steel Manufacturing Electric Arc Furnaces**

**Prepared for:**

**The Canadian Council of Ministers of the Environment (CCME)**

**Prepared by:**

**William Lemmon and Associates Ltd.  
Peachland, BC**

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## **Abstract**

This report provides a review of technical information on the formation, prevention, and reduction of dioxin/furan emissions from electric arc furnace steelmaking. The contents include an overview of the electric arc furnace steelmaking process, review of the theory and research for dioxin/furan formation, review of electric arc furnace combustion chemistry, emission control and pollution prevention techniques, other environmental issues associated with electric arc furnace steelmaking, and recommendations for further action.

## Summary

### *S.1 Introduction*

In 1998 the Canadian Council of Ministers of the Environment (CCME) established dioxins and furans as a priority substance for Canada-Wide Standards (CWS) development. The objective of the CWS process is to make significant strides in reducing anthropogenic releases of dioxins and furans to the atmosphere and soil.

A Multi-stakeholder Advisory Group (MAG) led by Environment Canada (EC) submitted recommendations to the Development Committee (DC) during the development of the CWSs for dioxins and furans. Environment Canada's technical contribution was based largely on its earlier work during the Strategic Options Process (SOP), background technical research, and consultations with the steel sector. The background technical research included paper research on the formation, prevention, and emission control of dioxin/furan emissions, collaborative emission testing with the industry to develop insights into the formation of dioxins/furans in the electric arc furnace (EAF) steelmaking process, and review of emission test reports. Recommendations for the standard were submitted to the DC by EC on behalf of the Electric Arc Furnace MAG in June 2001. The proposed CWS was received by the CCME Ministers in September 2001 and was endorsed by the Ministers of all jurisdictions in March 2003 with the exception of Quebec.

The CWS sets out numerical emission limits for dioxins and furans and timelines for achievement. Development of CWSs for dioxins and furans has taken into consideration environmental benefits, available technologies, socio-economic impacts, opportunities for pollution prevention, and collateral benefits from reductions in other pollutants. The dioxin/furan emission limits and schedules are contained in Table T.1. The actions specified in the CWS represent significant steps towards the goal of virtual elimination as expressed by achieving concentrations less than the Level of Quantification (LOQ) of 32 pg ITEQ/Nm<sup>3</sup>.

**Table T.1: CWS Dioxin/Furan Emission Limits and Schedules for EAF Steelmaking**

Facility	Dioxin/furan emission limit (pg ITEQ/ Rm <sup>3</sup> )	Scheduled date
Existing	150	2006
	100	2010
New or expanding	100	CWS effective date

In addition the CWSs make it clear that the ultimate goal of virtual elimination be kept in mind. Accordingly, CCME Ministers asked that pollution prevention strategies be developed for all source categories identified in the CWS including steel manufacturing, which is among the most significant source categories of atmospheric emissions of these substances. These strategies would set out clear, verifiable goals within a framework that accommodates continual improvement over time. In setting out the goals for these substances, CCME Ministers also emphasized the importance of a multi-pollutant approach and to consider that reduction measures have multiple benefits.

The current study was commissioned to help develop a Pollution Prevention Strategy. This report provides background technical information on the formation and reduction of dioxin/furan emissions from electric arc furnace (EAF) steelmaking, identified pollution prevention techniques for dioxins/furans, and discusses associated environmental issues in support of the development of the Pollution Prevention Strategy. CCME requested that as an initial action strategies identifying opportunities to minimize emissions of air pollutants from the steel manufacturing EAF sector be developed through a multi-stakeholder process by October 31, 2003.

The CWS identified the following factors to be considered in developing the Strategy:

- *Opportunities for improved control and release reductions of particulate matter;*
- *Combustion chemistry of the EAF process;*
- *The feasibility of applying existing and emerging pollution prevention and control techniques (e.g., catalytic oxidation, containment of fugitive emissions, best management practices for operations and maintenance, etc.);*
- *Reduction of mercury sources and emissions through the Mercury CWS development process;*
- *Cross-media transfers and management of pollutants;*
- *Emissions of greenhouse gases;*
- *Resource utilization; and*
- *Energy efficiency.*

The DC asked that the full scope of technical options be considered. In broad terms the options include pollution prevention measures (e.g., process modifications) that would avoid the formation of dioxins/furans and control measures that mitigate the environmental releases of these substances. The introduction of alternative steel manufacturing processes to replace the conventional EAF steelmaking process would be an example of a preventative measure.

The objective of this research is to assemble information that will provide the DC with an understanding of the technical options available for preventing emissions of air pollutants from steelmaking EAFs as described above.

### S.1.1.1 Environmental Releases from EAF Steelmaking

The releases of dioxins/furans reported to NPRI in 2000, 2001, and 2002 (preliminary) from steelmaking EAF facilities are shown in Table T.2.

The most recent data for releases of dioxins/furans to the atmosphere from EAF steelmaking are summarized in Table T.3. Note that the releases are ranked in order of decreasing dioxin/furan concentration and that the 2002 releases to air are preliminary NPRI data. Generally there is a significant variation in emission concentration between the emission test runs. Factors which may influence the variations include scrap composition, furnace delays, variations in furnace operating practices and gas conditioning parameters, and baghouse operating efficiency and

parameters. Note that Slater Steel Inc. is idling the Atlas Specialty Steels and winding down the operations at the Atlas Stainless Steel and Hamilton Specialty Bar Division.

**Table T.2: Reported Releases and Transfers of Dioxins/Furans from Steelmaking EAFs in 2000, 2001 and 2002**

Year	Releases and Transfers (g I-TEQ)			
	Air	Water	Land Disposal	Off-site Transfers
2000	9.36	0	32.08	0.51
2001	3.21	0	24.99	3.54
2002 *	6.48	0	19.54	4.18
Note: * Preliminary				

**Table T.3: Dioxins and Furans Emission Testing and Annual Release Data for Canadian Steelmaking Electric Arc Furnaces**

Facility	Location	Most Recent Emission Test		Releases to Air	
		Result (pg I-TEQ/Nm <sup>3</sup> )	Date of test	1999 Estimate (1)	2002 NPRI <sup>(2)</sup>
				(grams I-TEQ)	
IPSCO Inc.	Regina, SK	291	2001	1.40	3.65
Gerdau Ameristeel Cambridge Inc.	Cambridge, ON	111	2002	0.36	0.42
Norambar Ltée	Contrecoeur, QC	101	2003	1.13	0.42
Atlas Specialty Steels (4)	Welland, ON	66.1	2000	0.27	0.14
Dofasco Inc.	Hamilton, ON	45.3	2002	0.50	0.68
Aciers Inoxydables Atlas Stainless Steels (5)	Tracy, QC	44	2000	0.09	0.15
Gerdau Ameristeel Whitby	Whitby, ON	40	2001	0.79	0.13
Gerdau Ameristeel (MRM)	Selkirk, MB	35	2002	0.63	0.15
Ivaco Rolling Mills Inc. (6)	L'Original, ON	34.8	2002	0.92	0.07
Slater Steels – Hamilton Specialty Steel Bar Div. (5)	Hamilton, ON	32.6	2001	0.82	0.18
Ispat-Sidbec Inc.	Contrecoeur, QC	28	2002	3.69	0.31
AltaSteel Ltd.	Edmonton, AB	12.5	2003	0.15	0.18
Sydney Steel Corp. (3)	Sydney, NS	n/a		0.40	-
<b>Totals</b>				<b>11.15</b>	<b>6.48</b>

Notes: n/a = not available (never tested, or results not received by Environment Canada)  
 NPTI = National Pollutant Release Inventory  
 TEQ = Toxic Equivalency Quotient  
 (1) Environment Canada's PCDD/PCDF Inventory of Releases, Updated Edition of February 2001.  
 (2) Preliminary data provided by NPRI (retrieved January 12, 2004).  
 (3) Facility closed in 2000.  
 (4) Facility being closed.  
 (5) Facility operations to be wound down, in bankruptcy protection.  
 (6) Facility in bankruptcy protection.

## S.2 *Review of the Theory of Dioxin and Furan Formation for EAF Steelmaking*

A recent (2003) United Nations Environment Programme (UNEP) document, *Formation of PCDD/PCDF – An Overview*, provides an overview of the formation of dioxins/furans. The findings from this document that are pertinent to EAF steelmaking are as follows:

- The processes by which dioxins/furans are formed are not completely understood nor agreed upon. Most information about these substances in combustion processes has been obtained from laboratory experiments, pilot-scale systems, and municipal waste incinerators.
- Dioxins/furans appear to be formed in the EAF steelmaking process via *de novo* synthesis from chemically unrelated compounds such as polyvinyl chloride (PVC) and other chlorocarbons or more likely by the combustion of non-chlorinated organic matter such as polystyrene, coal, and particulate carbon in the presence of chlorine donors. Many of these substances are contained in trace concentrations in the steel scrap or are process raw materials such as injected carbon.
- Dioxins/furans are also produced from related chlorinated precursors such as polychlorinated biphenyls (PCB), chlorinated phenols, and chlorinated benzenes. Trace concentrations of these substances may be contained in some steel scrap.
- It may be possible to have formation of dioxins/furans in one area of the EAF while de-chlorination is taking place in another area depending on the furnace conditions in the two areas. In general, de-chlorination of dioxins/furans appears to take place at temperatures above 750°C in the presence of oxygen. As the temperature increases above 750°C, the rate of de-chlorination increases and the required residence time decreases.
- Increasing the oxygen concentrations promotes dioxin/furan formation. Under pyrolytic conditions (oxygen deficiency) de-chlorination of dioxins/furans occurs at temperatures above 300°C.
- Some metals act as catalysts in the formation of dioxins/furans. Copper is a strong catalyst and iron is a weaker one.

- Condensation starts in the 125-60 °C range with the higher chlorinated dioxins and increases very rapidly as the temperature drops. The lower chlorinated furans are the last to condense, which explains why the tetra and penta furans constitute the majority of the dioxins/furans congeners observed in EAF emission tests.

### S.2.1 EAF Operational Research

Most of the research on dioxin/furan formation and control has been carried out for EAFs in Europe. The earliest reported work was by Badische Stahlwerke GmbH (BSW) in Kehl/Rhein, Germany, in the early 1990s. Other European steel companies followed BSW's lead under regulatory pressure from national environmental agencies. Consequently most of the information on dioxin/furan formation mechanisms and emission control for steelmaking EAFs originated in Europe.

Environment Canada commissioned technical studies to review research on dioxin/furan formation mechanisms and emission control for EAFs in the late 1990s following the identification of dioxin/furan emissions as an environmental issue by the Strategic Options Process.

A summary of the EAF operational findings follows:

- The Badische Stahlwerke GmbH research project confirmed that a high concentration of hydrocarbon material in the steel scrap significantly increased the VOC and dioxin/furan emissions.
- Emission test results from the Badische Stahlwerke GmbH, ProfilARBED, Differdange, and Gerdau Ameristeel Cambridge emission testing programs had higher dioxin/furan emission concentrations when the gas temperature exiting the gas conditioning system gas cooling device was consistently above 225 °C indicating that *de novo* synthesis had taken place in the gas conditioning system.
- Furans consistently accounted for 60 to 90 percent of the dioxin/furan I-TEQ concentration in the Canadian EAF emission tests. Similar results have been reported in European emission tests of EAFs.
- Two furan congeners, 2378-T4CDF and 23478-T5CDF, consistently accounted for 60 to 75 percent of the dioxin/furan I-TEQ concentration in the Canadian EAF emission tests. Similar results have been reported in European emission tests of EAFs. These results are comparable to the theoretical condensation calculations for dioxins/furans since these two congeners would be the last to condense as the gas temperature decreases.
- The congener I-TEQ concentration distributions in the Canadian EAF emission tests were similar regardless of the total dioxin/furan I-TEQ concentrations.
- The findings indicate that *de novo* synthesis is the predominant dioxin/furan formation mechanism for the EAF steelmaking process.
- It appears likely that variations in the dioxin/furan emission fingerprint for the EAF steelmaking process are due to variations in the constituents of the scrap charge, varying conditions in the EAF resulting from changes in EAF operating practices from heat to heat and plant to plant, varying conditions in the gas conditioning and cleaning system,

and differences in baghouse collection efficiencies. There is insufficient publicly available information to determine the relative importance of these factors.

- Therefore it appears that the identification and implementation of pollution prevention practices and techniques will be a significant factor in further reductions of dioxin/furan emissions from the EAF.

### ***S.3 Review of Electric Arc Furnace Combustion Chemistry***

A review of the relationship of EAF combustion chemistry with dioxin/furan formation in the EAF is provided.

A summary of the EAF combustion chemistry findings and assessment follows:

- Dioxins/furans can be formed from related chlorinated precursors such as polychlorinated biphenyls (PCB), chlorinated phenols, and chlorinated benzenes.
- The environment inside a steelmaking EAF is very complex and is constantly varying. The combustion chemistry produces conditions that are amenable to dioxin/furan formation. The hydrocarbons entering the EAF in the scrap may be vaporized, cracked, partially combusted, or completely combusted depending on the conditions in the furnace or parts of the furnace during or after charging. Other sources of carbon include injected carbon and the graphite electrodes. The dual processes of dioxin/furan formation and de-chlorination may be proceeding at the same time if the oxygen concentration and temperature are such that some dioxin or furan congeners are being formed while other congeners are being de-chlorinated.
- The research on optimization of internal post-combustion indicates that under normal steelmaking operations conditions – oxygen-rich atmosphere, reactive carbon particles, and temperatures under 800°C - are present in parts of the furnace during the meltdown phase and possibly for some time afterwards. Given that metals that act as catalysts are present and that trace amounts of chlorine may be present in some of the charge materials and fluxes, the conditions appear to be present for *de novo* synthesis to occur. Since ideal mixing conditions are not present, it appears that a portion of the dioxins/furans that are formed will leave the EAF in the off-gas without encountering sufficiently high temperatures for de-chlorination to take place.
- Most of the research on combustion chemistry and internal post-combustion in EAF steelmaking has been to increase EAF productivity by taking advantage of fuels within the EAF - such as hydrocarbons, carbon monoxide, and hydrogen - to replace electric energy with chemical energy thus reducing the total energy input, which results in lower production costs per tonne of product.
- Indications are that internal post-combustion may be a more attractive option than external post-combustion for dioxin/furan formation prevention.

#### ***S.4 Pollution Control Techniques***

EAF steelmaking is a high temperature metallurgical process which generates particulate matter that contains a fine fume of metal and metal oxides. High efficiency pollution control systems are required to remove the fine particulate matter in the off-gases.

Note that dioxin/furan emissions from EAF steelmaking were raised as an environmental concern in Europe in the early 1990s, so most of the early EAF dioxin/furan emission control technologies were developed in Europe and retrofitted to European EAF steelmaking plants.

Brief reviews of current dioxin/furan pollution control techniques follow:

##### Fabric filter baghouses:

Some of the dioxins/furans in the EAF off gases adsorb onto fine particulate matter. As the gas temperature decreases through the dioxin/furan condensation temperature of the various congeners more of the dioxins/furans either adsorb onto the fine particulate matter or condense and form fine particulate matter. Fabric filters are widely used to remove fine particulate matter and are used as the total particulate matter (TPM) emission control technique for all the EAFs in the Canadian iron and steel sector and most of the steelmaking EAFs worldwide. Modern fabric filter baghouses have achieved TPM reductions to under  $2 \text{ mg/Nm}^3$  for EAF steelmaking applications thereby reducing dioxin/furan emissions as part of the collection of fine particulate matter.

##### External post-combustion system coupled with a rapid water quench:

This technique was the early dioxin/furan emission control technique applied to EAF steelmaking. External post-combustion systems were originally developed to combust CO and H<sub>2</sub> in the EAF off-gas in a refractory-lined combustion chamber, usually with supplementary fuel. Subsequently a number of European EAF steelmaking plants adopted the external post-combustion technology to de-chlorinate dioxin/furan emissions by maintaining the post-combustion temperature above 800°C. This emission control technique is not able to consistently meet the CWS standard of  $100 \text{ pg/Nm}^3$ .

##### Adsorbent Injection:

This control technique was originally developed to control dioxin/furan emissions from waste incinerators. Sized lignite coke (activated carbon is a similar adsorbent) injection technology is used in a number of European EAF steelmaking plants to supplement the fabric filter baghouse technology to achieve low dioxin/furan emission concentrations consistently. Reported emission test results from EAF steelmaking plants in Europe indicate that this technique in combination with a high efficiency fabric filter baghouse achieves dioxin/furan emission concentrations of less than  $100 \text{ pg/Nm}^3$  consistently

## ***S.5 Pollution Prevention Techniques and Practices***

### Raw Material Quality:

The major raw material used in the EAF steelmaking process is steel scrap. Contaminants including oil, plastics, other hydrocarbons, and mercury contained in automotive switches are often present in the scrap. Pollution prevention practices to prevent or minimize the entry of contaminants into EAF steelmaking include changes in material specifications, improved quality control programs, changes in the types of raw materials (such as avoidance of oily scrap), and programs to prevent the entry of contaminants.

### EAF Operation:

Recent changes in EAF operational practices that have been adopted to improve operational and energy efficiency appear to have collateral benefits to reduce dioxins/furans or in certain conditions to de-chlorinate dioxins/furans. Pollution prevention practices which appear to reduce dioxin/furan emissions include minimizing the duration of the roof being open for charging, reduction of air infiltration into the EAF, and avoiding or minimizing operational delays.

Off-gas conditioning system design: Off-gas conditioning includes the collection, cooling, and ducting of EAF off-gases prior to cleaning in a baghouse. Off-gas conditioning system conditions may be conducive to *de novo* synthesis formation of dioxins/furans unless care is taken to avoid conditions leading to *de novo* synthesis. Pollution prevention techniques include maximization of off-gas mixing and development and implementation of good operating and maintenance practices.

Fabric filter operations: A fabric filter baghouse is the best emission control technology for TPM emission control of EAF off-gases. Since some dioxins/furans adsorb onto particulate matter or are cooled and form fine particulate, they are removed with the fine particulate. Pollution prevention practices or techniques include the installation and operation of bag leak detectors, off-gas entry temperature monitoring, preventive maintenance of the baghouse, and continual improvement of fabric filter design and material, baghouse operation, and baghouse improvements.

Management of collected dust: Management of baghouse collected material is important to avoid the inadvertent release of dust containing dioxins/furans. Pollution prevention practices include enclosure of the collection and discharge of the baghouse dust, transfer in enclosed containers, and best environmental practices for the disposal of the collected dust.

## ***S.6 Advances in Steelmaking***

Feed process material modification: is a pollution prevention technique to prevent the entry of contaminants to the plant. An example is the removal of automotive mercury switches before the automobile is shredded.

Advances in the EAF steelmaking process: often has collateral benefits including the reduction of particulate matter and dioxin/furan emissions. Usually the objective of advanced operating practices is improved operational and energy efficiency to increase productivity and thus increase production and reduce operating costs.

Research and development for EAF steelmaking, especially in Europe, is focused on EAF design improvements to increase productivity and energy efficiency, and to reduce steelmaking costs.

### ***S.7 Other Environmental Issues***

This section summarizes pollution prevention opportunities identified and discussed in earlier sections and addresses supplementary environmental issues. Factors that should be considered for the identification of pollution prevention opportunities include:

- materials in the feed material that may be involved in the formation of dioxins/furans or the emission of other contaminants;
- process considerations and operating practices that may increase or reduce the formation of dioxins/furans;
- operating characteristics of the gas conditioning system and emission control technology that affect the emissions of dioxins/furans;
- cross media transfer of pollutants;
- energy efficiency considerations;
- resource utilization; and
- reduction of greenhouse gas emissions.

Opportunities for improved control and release reductions of particulate matter are linked to pollution prevention techniques and practices and EAF operational improvements. Pollution prevention techniques and practices including reduction of extraneous material in the scrap and baghouse pollution prevention techniques and practices will reduce particulate matter releases.

Feasibility of applying existing and emerging pollution prevention and control techniques was reviewed. Implementation of some or all of the pollution prevention practices that have been identified should be technically feasible. Some plants may have to replace their baghouses. It may not be feasible for some plants to install external post-combustion and improvements to gas conditioning systems due to site-specific space considerations. It should be feasible for all plants to install an activated carbon injection system. There may be site-specific constraints such as lack of available space, configuration of existing emission control systems, and financial costs.

It is beyond the scope of this study to forecast the feasibility of applying emerging emission reduction or control techniques.

Minimization and management of cross-media transfers and pollutants would be improved by application of the identified pollution prevention practices and techniques. Two examples are the removal of mercury switches from the steel recycling stream and the prevention of dioxin/furan formation.

Opportunities for reduction of mercury sources and emissions have been identified and pollution prevention techniques have been suggested.

Opportunities for reduction of greenhouse gases have been identified and can be achieved through continual improvement programs for EAF operating practices.

Resource utilization can be improved through continual improvement programs for EAF operating practices. Also the EAF steelmaking process is a recycling process. Some pollution prevention and emission control techniques may require additional resources such as water for rapid quenching of EAF off-gases.

Opportunities for improvement of energy efficiency have been identified. Improvement of energy efficiency is a driving force in EAF steelmaking and most of the opportunities for energy efficiency require improvements and changes in EAF operating practices. Some pollution prevention and emission control techniques may require additional energy such as external post combustion, rapid quenching of EAF off-gases, and higher efficiency particulate matter collection.

## ***S.8 Conclusions and Recommendations***

### ***S8.1 Conclusions***

The following conclusions are based on the data and information presented in the main body of this report.

#### **S8.1.1 Dioxin/furan Emission Formation in EAF Steelmaking**

- Research findings suggest that *de novo* synthesis is the predominant dioxin/furan formation mechanism in the EAF. The formation and de-chlorination mechanisms both occur within the furnace depending on the various constituents and temperature present in the various areas of the furnace atmosphere. The dioxin/furan emission fingerprint varies in accordance with the net results of the formation and de-chlorination mechanisms.
- The research and findings indicate that *de novo* synthesis occurs in the gas conditioning system unless the entry temperature is above approximately 800°C, the exit temperature is below approximately 225°C, and the gas temperature transit time is very short.
- It appears likely that variations in the dioxin/furan emission concentrations and fingerprint result from factors including contaminants in the steel scrap, variations in EAF operating practices and the furnace atmosphere, the use of post combustion, EAF combustion efficiency, design and operating conditions of the gas conditioning system, and furnace off-gas temperature entering the baghouse. There is insufficient publicly available information to determine the relative importance of these factors.

### S8.1.2 Best Available Emission Control Technology for Dioxins/Furans

- High efficiency fabric filter baghouses are an essential component of the emission control system for dioxin/furan emission control. Minimizing TPM emissions also minimizes dioxin/furan emissions. Emission tests of Canadian EAFs have reported TPM emissions as low as two mg/Nm<sup>3</sup>.
- Injection of activated carbon or similar adsorptive material into the off-gas upstream of high efficiency baghouses in European EAF steelmaking plants has consistently reduced dioxin/furan emissions to significantly less than 100 pg I-TEQ/Nm<sup>3</sup> according to emission test data.
- Selective catalytic reduction (SCR) technology used for NO<sub>x</sub> removal in other industrial sectors has been shown to reduce dioxin/furan emissions to significantly less than 100 pg I-TEQ/Nm<sup>3</sup>. This technology has not been applied to steelmaking EAFs but may be in the future.

### S8.1.3 Pollution Prevention Techniques for Dioxins/Furans

Pollution prevention techniques were identified that avoid, suppress, or minimize the formation of dioxins and furans or de-chlorinate dioxins and furans in the EAF steelmaking process including (Note that these are a range of options, some may not be applicable to all plants, and some may require further investigation):

- avoidance or removal of substances in the steel scrap that contribute to the formation of dioxins/furans;
- improvement of combustion efficiency in the EAF through the optimum use of internal post combustion to minimize the *de novo* synthesis formation of dioxins/furans and maximize the de-chlorination of dioxins/furans including the use of continuous parameter monitoring systems;
- design and operation of the gas conditioning system to minimize the *de novo* synthesis formation of dioxins/furans in the gas conditioning system;
- control of off-gas entry temperature to the baghouse to avoid vapourization of dioxins/furans, maximizing baghouse collection efficiency and reliability, and use of fabric bag leak detection technology;
- environmentally-sound management of the collected dust; and
- development, documentation, and implementation of pollution prevention techniques coupled with efficient fabric filter baghouse technology and operation to reduce dioxin/furan emissions to below the CWS emission limits and as a goal to achieve virtual elimination through continuous improvement over time (i.e., the dioxin/furan limit of

quantification (LOQ) of 32 pg I-TEQ/Nm<sup>3</sup>). This could include identification of parameters or operating practices in emission testing programs that may lead to reduced dioxin/furan emissions.

#### S8.1.4 Opportunities for Reduction of Mercury Sources and Emissions

Pollution prevention practices were identified for the removal of automotive mercury switches from the steel recycling process. Some voluntary mercury switch programs, such as the Switch Out program, have been initiated. The State of Maine requires mandatory removal of mercury switches from scrap motor vehicles before recycling and prohibits sales of new motor vehicles containing mercury switches.

#### S8.1.5 Implementation of Pollution Prevention Opportunities

A number of pollution prevention opportunities have been identified in this study. Most if not all of the plants will have identified these and others and will have implemented some of the opportunities identified in this study or that they have identified. It is important to note that some of the plants have achieved dioxin/furan emissions below the CWS 2010 emission limit and a few to near or even below the limit of quantification (LOQ) of 32 pg I-TEQ/Nm<sup>3</sup>. Therefore most of the plants should be able to achieve the CCME emission limit of 100 pg I-TEQ/Nm<sup>3</sup> by 2010 through the development and implementation of a pollution prevention plan. For those plants that cannot achieve this emission limit through the implementation of a pollution prevention plan, emission control technology has been identified. This technology is capable of reducing dioxin/furan emissions well under the 2010 emission limit. Some of the identified pollution prevention techniques require further investigation before they can be implemented and in some cases they may be applicable only to some plants.

#### S8.1.6 Impact of Best Operating Practices

Research data and information have shown that the implementation of best operating practices to improve productivity and reduce energy intensity have collateral benefits including suppression and/or reduction of dioxin/furan, particulate matter, greenhouse gas emissions, and other pollutants.

#### S8.1.7 Future of EAF Steelmaking

Change has been a fact of life for EAF steelmaking for some time and is forecast to continue into the future. In many cases EAF steelmaking changes will be carried out on a site-specific basis to take into consideration the site-specific requirements, operating conditions and constraints, and economic situation. It is beyond the scope of this study to forecast the future of EAF steelmaking for new or improved EAF facilities or for changes in operating practices. However, no process technology was identified that would replace the EAF for steelmaking.

### S8.1.8 Information Limitations

- The effectiveness of EAF emission control varies from plant to plant but limited information is available on site-specific technical details of the operating parameters of the environmental control systems in place. Without more information it is not feasible to correlate the operating parameters with dioxin/furan emission minimization/reduction.
- Environmental, pollution prevention, and operating practices used by Canadian EAF steelmaking plants vary from plant to plant. There is limited available information on many of these practices, therefore it is not feasible to correlate the practices with dioxin/furan emission minimization/reduction.
- Detailed results and technical details are not available for those EAF emission tests for which reports have not been provided.
- Information is not publicly available regarding the costs of implementation of best environmental practices and pollution prevention techniques for the EAF steelmaking process.
- Limited information on dioxin/furan formation and emissions from scrap preheating or alternative EAF steelmaking processes was located.

The study assessment of pollution prevention technique implementation feasibility, estimate of dioxin/furan reductions resulting from implementation of pollution prevention techniques, and estimates of the cost of implementation have been limited by the above information deficiencies.

### S8.2 *Recommendations*

The following pollution prevention elements are based on the findings and pollution prevention practices identified in this study and are presented as considerations for the development of a pollution prevention strategy:

Development and implementation of facility pollution prevention plans with objectives to prevent or minimize the formation of dioxins/furans in the EAF steelmaking process, to prevent or minimize the release of dioxins/furans to the atmosphere, and to provide good environmental management of the handling, storage, and disposal of material containing dioxins/furans. Factors for consideration in developing the pollution prevention plans could include:

- Emission limits in the Canada-wide Standards for Dioxins and Furans from Steel Manufacturing EAFs, March 2003;
- The ultimate goal of virtual elimination of dioxins and furans;
- Best environmental practices identified in this study and through industry experience;

- Recommendation RN 123 (Pollution Prevention Planning) of the CEPA Environmental Code of Practice for Non-integrated Steel Mills, March 2001.

Development and implementation of best environmental practices to prevent or minimize the amount of mercury in scrap, as discussed in Section 5.2.2 in the full report.

To assist with the above, it is recommended that:

- The industry draws on the experience of the plants which have been able to achieve significant emissions reductions. It is noted that some of the Canadian plants have successfully achieved dioxins/furans emission concentration levels close to or below the dioxin/furan stack emission LOQ. Encourage the industry to identify and compile the most effective pollution prevention practices and share the information to assist those remaining facilities faced with elevated dioxins/furans emissions and to government.
- Adequate operating practice and operating conditions be included in emission test reports to provide information that would assist mills in assessing the effectiveness of the dioxin/furan emission avoidance or minimization and identify potential pollution prevention opportunities. This information could include the scrap mix and oil concentration, charging delays, furnace delays, furnace outlet off-gas data, operating parameters and off-gas data at key points in the gas conditioning system, baghouse off-gas entry temperature, dioxin/furan and particulate emission test results before dilution air or secondary emissions are mixed with the primary emissions, baghouse entry, and stack, and dioxin/furan concentration in the baghouse collected dust.