IMOA®

NEWSLETTER

JULY 2001

13th Annual General Meeting

At the kind invitation of AvestaPolarit, the AGM will be held in the Nordic Hotel, Stockholm with a provisional programme as follows:

Wednesday, 12 September
Cocktails and dinner in the hotel, hosted by IMOA

Thursday, 13 September
13th AGM. Dinner hosted by AvestaPolarit at a restaurant in the archipelago

Friday, 14 September
Work's visit to AvestaPolarit

Presentations at the AGM will include:

- updates on IMOA's activities (HSE work, market development, etc.)

- presentation by Stuart Pettifor, President of Coil Products and Deputy CEO, AvestaPolarit.

Topics he will cover will include:

- General industrial landscape
- State of stainless steel industry
- Our merger and potential synergies
- Outlook for the industry

Moly does the Job

This article is the latest in a series of case histories where the application of moly has helped companies to solve technical problems which have occurred. Nicole Kinsman of Technical Marketing Resources (Consultants to IMOA) is the author and she will continue to write similar articles for future issues of this Newsletter.

Edward Blessman of Trent Tube, East Troy, Wisconsin, contributed the information in this article and IMOA would like to thank him for his assistance.

Summary

Many aging US power plants have copper alloy condensers that are suffering from erosion or corrosion. Leaking tubes have to be plugged. This requires plant shut down and leads to reduced heat transfer and lower efficiency. Many power plants have solved the problem permanently by replacing the tube bundles with 4 to 6% molybdenum- containing stainless steels. The better thermal performance of stainless steel re-tubed units, and the lack of unscheduled outages due to leaking condenser tubes, more than compensate for the initial design and installation cost of the new tubing.

The Process

A critical part of any power plant is its condenser. It cools the steam from the turbine and condenses it to water that is recycled back to the boiler. The amount of power that is generated is correlated to the temperature difference between the steam temperatures at the inlet and outlet of the turbine. To minimize the condensate temperature, the condenser must maximize the heat transfer between the cooling water and the steam. Good thermal conductivity and large surface area of the tubing are the most important parameters for optimal heat transfer.

The Corrosion

Copper alloys have excellent thermal conductivity and, therefore, have been used traditionally as condenser tubing material. However, brass and copper-nickel alloys are susceptible to erosion, sulfur pitting corrosion, and both ammonia grooving and cracking from the steam side.

A leak in a condenser tube can lead to the contamination of the high purity boiler water. This contaminated water can damage the boiler and the turbines. For this reason a leaking condenser tube has to be plugged quickly and this may require an unscheduled shut down of the plant.

Another limitation of copper alloys is the copper contamination of the effluent water and the condensate. Environmental regulations strictly limit the release of copper into lakes and rivers. Often the only way to comply with these regulations is to eliminate all copper-containing

(Continued overleaf)

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alloys from the heat exchanger tubing. Copper in the condensate can also deposit in the boiler or the turbine and cause damage to the equipment.

The Solution

Stainless steel condenser tubing solves all of these problems. There have been more than 35 million meters (almost 115 million feet) of stainless steel (all grades) condenser tubing installed in the US in the last five years (an average condenser may use 100,000 meters, a large nuclear power plant condenser can use up to 1 million meters). Over 3.5 million meters (11.5 million feet) were high performance 4 to 6% molybdenum stainless steels. Traditionally the 6% Mo high performance austenitic grades were the most common, but in recent years an increasing number of plants have specified the 4% Mo super ferritic grades because of cost advantages. Six major plants have re-tubed with high performance ferritics in the last two years, and many more are in the planning stages for the next few years.

The ferritic stainless steels are especially well suited for re-tubing of copper alloy condensers due to their unique combination of properties. Copper tubing typically has a heavy wall thickness [0.049 inch (1.25 mm)] to compensate for its relatively low strength, low modulus of elasticity and its susceptibility to erosion. The better mechanical properties of high performance ferritic stainless steels allow the use of the same condenser designs with walls as thin as 0.028 inches (0.7 mm). The good heat transfer of the ferritics ensures that the thermal performance of the condenser remains high. Long-term thermal performance is enhanced compared to copper alloys, because the very smooth surface of stainless steel tubing minimizes fouling and remains cleaner.

The high performance stainless steels are also resistant to erosion. When plant design will permit, it is advantageous to increase the cooling water flow velocity. The higher velocity increases heat transfer and improves the clean liness of the condenser.Higher flow rates are among the most economical methods to improve condenser performance.
Stainless steels easily tolerate velocities of 5 m/sec (16.4 feet/sec) without erosion.

Most of the units re-tubed with high performance ferritics and austenitics are cooled by brackish or sea-water. These grades were chosen because of their high chloride resistance. There are also many fresh water-cooled units that could be re-tubed with standard austenitic stainless steels such as Type 304 or 316. However, their plant owners selected high performance ferritics instead. This "over-design" ensures reliability in case of upset conditions or future changes in the water chemistry, and helps to insure against forced outages because of condenser leaks.

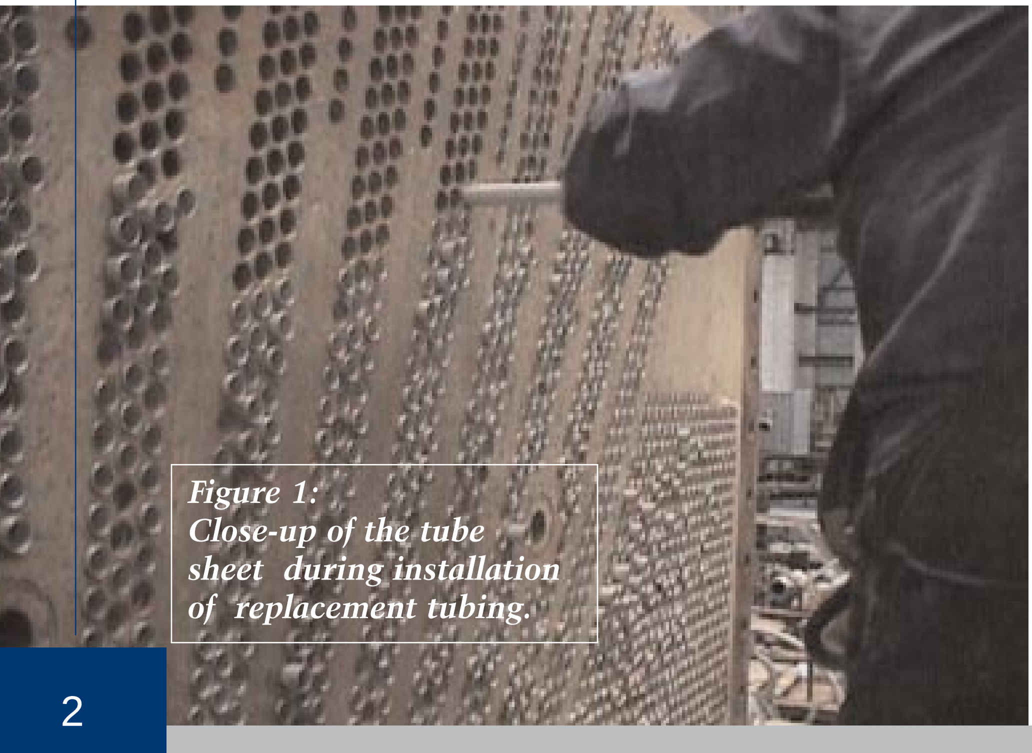


Figure 1: Close-up of the tube sheet during installation of replacement tubing.

The Cost Savings

The reasons driving power plants to upgrade condensers are improved reliability and profitability, and compliance with environmental regulations.

The trend toward high Mo stainless steels has accelerated with the transition toward an open electricity market in the US. Power plants now compete for business, and if their costs are low enough, they can sell all of the power that they can generate.

The most efficient power plants can generate power for less than $20 per MWhr. On the spot market, at times of peak demand, for example on a hot summer afternoon when air conditioners are running, power prices can be over $500 per MWhr. If a plant is off–line during a time of peak demand, it loses the opportunity to sell surplus power and it is forced to buy replacement power. For example, if a 300 MW plant shuts down for 10 hours to plug leaking tubes, it loses 3,000 MWhr of generation capacity. This power costs as little as $60,000 to generate, but, it may cost as much as $1,500,000 to purchase the replacement power from another plant.

Many older plants have a significant number of plugged condenser tubes. The leaks often stem from old 'accidents' and upsets. This reduction in heat transfer surface area may have a small effect on plant profitability during a time of low demand. However, any loss of heat transfer will hurt generating capacity most during hot weather, when the cooling water is warmer and does not have the same cooling capacity. Unfortunately, this is exactly when demand for power and its price are the highest.

Table 1: Typical Composition of High Performance Stainless Steels in Weight Percent

		UNS No.	Cr	Mo	Ni
Ferritics	SEA-CURE®	S44660	27	4	2
	AL 29-4C®	S44735	29	4	0
	FS 10®	S44800	29	4	2
Austenitics	AL-6XN®	N08367	21	6.5	24
	254 SMO®	S31254	20	6	18

Table 2: Typical Properties of High Performance Stainless Steels

		UNS	Thermal Conductivity [Btu/ft hr °F (W/M °C)]	Modulus [10^6 psi (GPa)]	Yield Strength [ksi (MPa)]
Ferritics	SEA-CURE®	S44660	9.5 (15.9)	31 (213)	75 (517)
	AL 29-4C®	S44735	9.5 (15.9)	31 (213)	80 (552)
	FS 10®	S44800	9.5 (15.9)	31 (213)	85 (586)
Austenitics	AL-6XN®	N08367	7.5 (13)	28 (193)	55 (379)
	254 SMO®	S31254	7.9 (13.7)	29 (200)	50 (345)

Protected trademarks:

SEA-CURE:	Crucible Materials Corp.
AL 29-4C and AL-6XN	ATI Properties,Inc.
FS-10:	Sumitomo
254 SMO:	AvestaPolarit

The 4% Mo ferritic and the 6% Mo austenitic high performance stainless steels are playing a significant role in improving the availability, reliability, capacity and economics of power plants in the US.

Readers with similar experiences, where moly has assisted in solving problems, are invited to contact the Secretariat.

Congratulations to our Consultants, Technical Marketing Resources of Pittsburgh! The firm has been hired by the Johnson Space Centre to assist in the selection of materials (stainless steel) and surface finish for the tools and enclosures to hold the Mars rock and soil samples which will be brought to Earth as part of the Mars Surveyor 2005 project.

IMOA's Duplex Training Seminars – Success in the UK and Italy

The Association's appreciation and gratitude are due to all the sponsors, speakers, participants and planners who made the seminars so valuable in educational terms. Particular thanks, however, are due to Duncan Munro (Director of BSSA) and Fausto Capelli (Director of Centro Inox) for the fine planning, promotion and organisation of these highly successful events.

These seminars are one-day workshops on the fabrication of duplex stainless steels which are increasingly regarded as at the leading edge of stainless steel applications development, due to their enhanced strengths and corrosion resistance. They offer a prime market opportunity for fabricators in the chemical, petro-chemical and pharmaceutical sectors, as well as in structural applications, such as reinforcement for bridges.

Like all stainless steels, the duplex family is different, but not difficult to fabricate, once the basic principles of the material are understood. The workshops are designed to familiarise the audience with these basic principles and the advantages of fabricating duplex stainless steels.

The workshops are primarily aimed at fabricators and sheet metalworkers, who have basic experience with working in stainless steels, and would like to familiarise themselves with duplex grades. The programme is also suitable for engineers, contractors, designers and specifiers, who are interested in the properties and application of duplex stainless steels.

The workshops include the opportunity for discussion of case histories and for participants to ask questions, give comments and share their experience. Handouts, which include supplementary information as well as the material presented, are provided to each delegate.

IMOA's programme began in the USA in 2000 and has continued to be a hit this year amongst European audiences in Germany, Italy and the UK; plans are already under review for venues in Asia.

The latest seminars, conducted as usual by Nicole Kinsman (Technical Marketing Resources) and Heike Helfen (Climax Molybdenum) on IMOA's behalf, began with a series of eight in the UK, spread during March and April this year and organized in cooperation with the British Stainless Steel Association (BSSA) with sponsorship from the Department of Trade and Industry and several local companies.

Each seminar consisted of a brief introduction to the BSSA by its Director, Duncan Munro; an introduction to IMOA and discussion on why users choose duplex stainless steels by Heike Helfen; and the metallurgical basics of duplex stainless steels by Nicole Kinsman. After lunch, which was typically offered by the local sponsor, the presentations on welding and cutting, forming and machining were given by either a representative of the host or Nicole Kinsman.

During this series, the format was modified to increase interaction between the presenters and the delegates. Discussions were conducted in small work-groups to give the participants more opportunity to think about what had been presented; to apply some of the theory to practical examples; and to raise concerns or questions regarding duplex stainless steel.

The first seminar week was March 26th to March 30th
Leeds (hosted by AvestaPolarit)
Birmingham (hosted by Sandvik)
Pontypool, South Wales (hosted by AvestaPolarit)
London (hosted by The Institute of Materials and NiDI).

The second seminar week was April 23th to April 27th
Middlesborough (hosted by AvestaPolarit)
Glasgow (hosted by TWI, Joining Forces North East)
Belfast (no local host)
Manchester (hosted by Weir Materials)

The total number of participants in the two weeks of workshops was about 140 and special thanks are due to Chris Baxter of AvestaPolarit, Rex Withers of Sandvik Coromant, Dr. Liane Smith of the Nickel Development Institute (NiDI), Dr. Andrew Leonard of the Welding Institute (TWI), and Dr. Roger Francis of Weir Materials.

The participants filled out feedback sheets and from these it seems that most people were very happy with the event and what they learned. IMOA and BSSA think that these workshops have made more people familiar with molybdenum-containing duplex stainless steels and, in the long run, this will lead to increased specification and use of these grades.

After a short respite, Heike and Nicole returned to Italy (a seminar had been given at the Duplex 2000 Conference in Venice).

Inspired by IMOA's previous duplex seminars, Centro Inox (the Italian Stainless Steel Development Association) asked IMOA to co-operate in a joint seminar in Milan.
The considerable increase in the use of stainless steel recorded in Italy, particularly in recent years, in all areas of applications, has led to extreme specialisation of end uses with increasingly advanced machining technologies and the search for materials with more specifications and high performances. To answer the needs of the various applications, new steels have been developed and among them duplex stainless steels.

IMOA's previous experience and the Centro Inox contacts with Italian specialists and its mailing list of fabricators, end-users and producers of stainless steel made for a great event with an excellent turnout. The all-day seminar took place on 29 May 2001 in the Centro Congressi Fondazione Stelline and featured speakers from various countries, all specialists in their respective fields. The Centro Inox promotional efforts attracted 140 participants, of whom one-third were fabricators, one- third were stainless steel producers and the rest end-users, distributors and academics.

Dr. Ing. Fausto Capelli, Director of Centro Inox, was the Chairman of the seminar. Heike Helfen introduced IMOA and covered the history and evolution of duplex stainless steels, whilst Nicole Kinsman talked about their metallurgy.

Subsequent presentations related to machining, welding behaviour, resistance to corrosion and standards. Speakers included the following specialists: Giuliano Melotti (Acciaierie Valbruna) discussed fabrication; Giovanni Carratino (Italian Welding Institute) talked about welding; Professor Marco Boniardi (Technical University in Milan) covered corrosion resistance; Jan Olsson (AvestaPolarit) addressed standards and cost savings; and Omar Molinari (Ilta Inox), Robecco d'Oglio (CR), Mario Celant (MaC Materials and Corrosion) and Vizzolo Predabissi (MI) finished the proceedings with a discussion on their practical experiences.

There was simultaneous translation in Italian and English and, at the end of the morning and afternoon sessions, the speakers answered questions in a podium discussion.

The good turnout and the variety and quality of the questions indicate that the Italian market in general, and the attending audience in particular, are highly interested in using molybdenum-containing duplex stainless steels.

LIFE CYCLE INVENTORY FOR MOLYBDENUM PRODUCTS

Introduction

Over the past 15 years, environmental issues have assumed an increasing priority for both government and industry alike. In North America as well as in Europe, the emphasis has gradually broadened from a site specific focus to include product attributes. Several regulations and schemes have been progressively implemented which address environmental issues regarding products. Similarly, product related environmental information is an increasing part of many companies' decision-making process and is often shared with these companies' customers.

Life Cycle Assessment (LCA), and especially its most developed component, Life Cycle Inventory analysis (LCI), is a tool that provides quantitative and scientific analyses of the environmental impacts of products and their associated industrial systems. By providing an unbiased analysis of entire industrial systems, LCA has shown that the reality behind widely held beliefs regarding "green" issues is often more complex than expected.

In 1998, the International Molybdenum Association (IMOA) commissioned Ecobalance to perform a Life Cycle Inventory (LCI) on three molybdenum products used in the metallurgical industry.

Goal

The aim of this study was to provide the Molybdenum Industry with a current LCI of three molybdenum products, using current, robust data on molybdenum production. The three products studied include:

a. technical grade molybdic oxide (referred hereinafter as "tech oxide") in powder form;

b.tech oxide in briquette form;

c.ferromolybdenum in chip form.

The LCI is "cradle to gate", i.e. from the point of extracting resources from the earth to the point where the molybdenum products are ready for shipment to customers. This LCI is based on current data on process technologies, energy and materials consumed, and environmental outputs. The LCI results may later be used by the molybdenum industry in the evaluation of the potential environmental impacts of molybdenum products and their applications. This data used with appropriate methodologies such as the ISO 14000 standards can be the basis of industry benchmarking and management of environmental improvement programmes.

The aim of this study is also to provide the stainless steel industry with LCI data for use in other LCI studies.

The geographical scope of the study is worldwide production of molybdenum excluding China, Mongolia, and CIS (former USSR).

This project adheres to the LCA guidelines summarised by ISO, which are widely acknowledged among the main practitioners in the US and in Europe. The requirements of this study are summarised in the following:

- ISO 14040:1997(E), the International Standard of the International Standardisation Organisation, Environmental management - Life cycle assessment - Principles and framework.

■ ISO 14041:1998(E), the International Standard of the International Standardisation Organisation, Environmental management - Life cycle assessment - Goal and scope definition and inventory analysis.

The study aims to meet the essential requirements formalised by these ISO standards. Specifically,

■ The project aims at taking an inventory of the environmental inflows and outflows associated with the cradle-to-gate production of a product;

■ The goal and scope of the project are precisely defined at the beginning of the project;

■ Assumptions are clearly stated, and the methodology is as transparent as allowed with the protection of confidential data. System boundaries, functional unit, and allocation rules are rigorously defined and described;

■ Pertinent data are collected, and their quality is rigorously assessed;

■ Reporting requirements are stated.

Ecobalance worked to ensure that the major LCI-related methodological decisions (allocation rules, etc.) were consistent with the EUROFER and other stainless steel-related LCI studies to the extent that the confidentiality of all studies has been respected.

This LCI will be the most comprehensive, current record of environmental inflows and outflows associated with molybdenum production. However, it should be borne in mind that this LCI, like any other scientific/quantitative study, is not completely free of some margin of error due to various limitations such as unavailability of some relevant data.

Scope & Methodology

Life Cycle Assessment (LCA) is an analytical tool used to comprehensively quantify and interpret the environmental flows (to and from the environment, including air emissions, water effluents, solid waste, and the consumption/depletion of energy and other resources), over the entire life cycle of a product or process. The life cycle assessment is a comprehensive study of a product which includes the production and extraction of raw materials, the manufacture of intermediate products, transportation, distribution, use, and a final "end-of-life" stage which often includes multiple parallel paths such as recycling, incineration, landfilling, etc.

The three products included in the study are technical grade oxide in powder form and in briquette form; and ferromolybdenum. Nineteen sites including primary and by-product mines, and conversion facilities, participated in the study. Technical grade oxide and ferromolybdenum production represent some 67% and 53% respectively of total Western world production.

Companies in Europe and the Americas were well represented and a typical range of operating configurations included. This level of coverage makes IMOA's LCI study one of the most representative LCI studies ever carried out for a material and this provides a sound basis for LCA studies relating to molybdenum.

An LCA involves three main phases:

1 .Life Cycle Inventory Analysis is the "phase of the LCA involving the compilation and quantification of inputs and outputs, for a given product system throughout its life cycle." (ISO 14040:1997(E), Section 3). This phase includes:

■ defining the project system boundaries (i.e. defining which steps are included in the system and which are not) as specified by the goal and scope of the project;

■ collecting data required for each step included in the system;

■ calculating the final inventory.

The compiled flows result in an inventory which is classified into five main categories: raw material consumption, energy consumption, air emissions, water effluents and solid waste.

2 . The Life Cycle Impact Assessment is the part of the LCA "aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts of a product system" (ISO 14040:1997(E), Section 3). Examples of potential environmental impacts include natural resources depletion, global warming potential, and eutrophication potential.

3 .The Life Cycle Interpretation is the LCA step in which the "findings of either the inventory analysis or the impact assessment, or both, are combined in line with the defined goal and scope in order to reach conclusions and recommendations" (ISO 14040:1997(E), Section 3). With the exception of discussion of the results, that portion of an LCA was not performed.

ISO's representation of LCA actually indicates a four stage process, with Goal and Scope Definition preceding the Inventory Analysis phase. Individualising Goal and Scope Definition as a separate stage is not a key methodological issue, but was specially intended as a reminder that the key project objective parameters should be carefully established and clearly stated at the outset of an LCA, and that they guide the subsequent stages. All stages of an LCA should be scoped by the particular use or uses for which the study is intended, and that use of the results may entail some results interpretation.

Results

The LCI results provide average cradle- to- gate data for all the energy and material inputs, air emissions, water effluents and solid wastes for each of the three molybdenum products studied.

Data from facilities around the world were collected to represent the molybdenum industry. The molybdenum data included in the study represents 56% of the total molybdenum produced in the world and 72% of production excluding China, Mongolia and CIS.

Additional information available includes the geographical location and number of sites contributing to the average, minimum, maximum and standard deviation for each LCI flow monitored.

IMOA proposes to review and update the LCI data on a regular basis, to take account of expanding and improved monitoring procedures. Where possible this review will include the broadening of the geographical coverage and the number of participating companies.

Availability of Data

Applications for LCI data are to be made through IMOA which will designate an LCI manager from one of the participating companies, according to geographical location, to liaise with the applicant.

The normal procedure is to complete a questionnaire describing the intended application of the data and to discuss this with that LCI Manager. This will help to ensure that the IMOA methodology and results can be applied appropriately and will be compatible with the goals of the study.

Conclusions

The IMOA LCI study has generated a large, rigorous and representative database. The results can be used reliably to assist decision-making and for evaluating the performance of molybdenum products in the context of sustainable development.

The results also provide the opportunity for companies to benchmark and evaluate improvement measures to their processes and product systems.

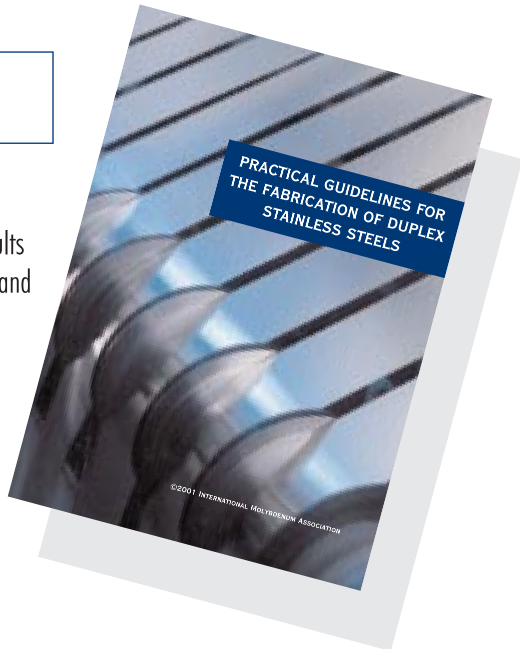
Industry expertise has been enhanced by involvement in the study and the industry is now better equipped to provide technical support to customers and users of molybdenum on LCA issues.

A programme has been launched to keep the database up to date and further enhance the methodology and understanding of the study. Recommendations for improvement concerning both the documentation and the data will be welcome.

For LCA to be used as a reliable tool for decision-making, high quality data, sound methodology and transparent reporting are essential. This study is a major step towards enhancement of these standards and the molybdenum industry intends to continue and encourage this trend in its future programme of work.

Acknowledgement

IMOA wishes to acknowledge with thanks the help of the International Iron & Steel Institute (IISI). This summary, the policy and communication guidelines, and the questionnaire are based on the format of the IISI's own LCI for the steel industry; their permission to take advantage of their expertise is greatly appreciated.



The second edition of this brochure is ready to go to the printers. Readers wanting copies of the revised brochure are invited to email the Secretariat, specifying numbers and full mailing address.

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