No. 29

Summer/*Été 98*

IEEE Canadian Review

- ***Membership Services from IEEE Canada***
- ***Get the lead out! Lead-free electronics come of age***
- ***Une nouvelte technologie d'interconnection qui tombe a plomb!***
- ***Nelson River HVDC Line failures***
- ***Interactive Multimedia Training - what is it really?***

Canada Post Postage Paid / Postes Canada Port payé
Bulk third class / En nombre troisième classe
F1468
MONTRÉAL, P.Q.

IEEE

The Institute of Electrical and Electronics Engineers Inc.

IEEE Canada

The National Library of Canada
ISSN 1481-2002

IEEE Canadian Review General Information

The ***IEEE Canadian Review*** is published three times per year as follows: Winter (to appear in March); Spring/Summer (to appear in July); Fall (to appear in November).The ***IEEE Canadian Review's*** principal objective is to project an **image** of the Canadian electrical, electronics, communications and computer engineering professions and their associated academic and business communities to :

(i) Canadian members of IEEE;
(ii) Canadian members of the profession and community who are non-members of IEEE;
(iii) the associated academic (i.e. universities, colleges, secondary schools), government and business communities in Canada.

To ensure that the ***IEEE Canadian Review*** has the desired breadth and depth, Associate Editors are responsible for identifying issues and screening articles submitted to the ***IEEE Canadian Review*** according to the following general themes :

1- National Affairs
2- International Affairs
3- Industry
4- Education
5- Power
6- Communications
7- Computers

Now IEEE related events and news of a topical nature may be published in the IEEE Canada E-mail/Fax newsletter. Submissions should be E-mailed to the IEEE Newsletter Editor, Jeff Marcellus, at j.marcellus@ieee.ca (Phone/Fax: (613) 823-6218).The Internet home page address of IEEE Canada is: "http://www.ieee.ca".

Advertising Policy

It is the policy of the ***IEEE Canadian Review*** to invite organizations to place corporate advertising in the review. For information regarding rates and copy requirements, please contact the Managing Editor, Vijay Sood at the address shown below.

Circulation

The circulation of the ***IEEE Canadian Review*** is the entire membership of IEEE in Canada, representing over 12,000 readers.

Information for Authors

Authors are invited to contribute to the ***IEEE Canadian Review***. Submissions in electronic form are especially welcomed. Please contact

IEEE Canadian Review is published three times per year by IEEE Canada. IEEE Canada is the Canadian Region of the Institute of Electrical and Electronics Engineers, Inc. **Address:** IREQ, 1800 boul. Lionel-Boulet, Varennes, Que, J3X 1S1, Tel.: (450) 652-8089. Fax.: (450) 652-8051. Responsibility for the contents rests upon the authors and not the IEEE, or its members. **Annual Subscription Price**: free of charge to all IEEE members in Canada. For IEEE members outside Canada: $15.00/year. Price for non-members: $24.00/year. Corporations and libraries: $30.00/year. Additional copies may be ordered at the cost of $5.00 each from the managing editor. **Change of address**: please send change of address directly to IEEE Service Center, 445 Hoes Lane, Box 1331, Piscataway (New Jersey) 0885, or by e-mail at "member.services@ieee.org". **Reprint Permission**: abstracting is permitted with credit to the source. Libraries are permitted to photocopy for private use of patrons. Instructors are permitted to photocopy isolated articles for non-commercial classroom use without fee. For other copying, reprint or republication, please write to the Managing Editor. Printed in Canada. Postage paid at Montréal, (Québec).

IEEE Canadian Review

Managing Editor
Rédacteur en chef

Vijay K. Sood
Institut de recherche d'Hydro-Québec (IREQ)
1800 boul. Lionel-Boulet
Varennes, Québec
tel: (450) 652-8089
fax: (450) 652-8051
email: sood.vijay@ireq.ca

Associate Editors
Adjoints à la rédaction

Paul Freedman
CRIM
Montréal, Québec, H3A 2N4
tel: (514) 398-1234
email: freedman@crim.ca

Brunilde Sanso,
Dept. of Mathematics & Ind. Eng.
Ecole Polytechnique de Montréal
C.P. 6079, Succ. Centre Ville
Montréal, Québec, H3C 3A7
tel: (514) 340-4949
fax: (514) 340-4463
email: bruni@crt.umontreal.ca

Terrance J. Malkinson
Faculty of Medicine
University of Calgary
Calgary, Alberta
Canada T2N 4N1
tel: (403)220-4497
fax: (403)283-8225
email: tjmalkin@acs.ucalgary.ca

Dr.C.S.Vaidyanathan
Senior Design Engineer
Terabit Fabric Development
Northern Telecom (NORTEL)
P.O.Box 3511, Station C
Mail Stop 622
Ottawa. ON
Tel: (613) 765-1920
Fax: (613)765 3552
email: csvaidy.nortel.ca

Cover picture
Photo de couverture

The Meridian 9316

In 1996, Nortel demonstrated the world's first lead-free Meridian 9316 business telephone set. Using 99.3 percent tin and 0.7 percent copper solder, replacing the current industry standard of 60 percent tin and 40 percent lead, Nortel successfully produced a lead-free Meridian 9316. Considered a breakthrough for the environment by eliminating toxic materials contained in the solder, this project was historic moment for Nortel and may prove to have potential positive impact on Meridian's market share. Initial market feedback has been extremely positive. Nortel's Enterprise Networks is expending its program in 1998 with higher speed applications and further research and development into lead-free interconnect technology.

CONTENTS / *SOMMAIRE*

Membership Services from IEEE Canada
Services offerts aux membres par l'IEEE Canada

To commence my two-year term as President of IEEE Canada and IEEE Region 7 Director, we conducted an Executive Committees strategic planning session in January. Eighteen workshops focused on goals with particular emphasis on service to members. Below are some of the current and planned services offered to members by IEEE and IEEE Canada.

1999 marks the 5th Anniversary of the *IEEE Financial Advantage Program* (FAP). Currently being investigated is the possibility of a *Canadian Retiree Medical and Dental Program*; this program would offer retiring members continuity of medical and dental benefits in cases where their employment had offered benefits in these areas. Worthy of note is the surplus generated by FAP which is sufficient to keep all IEEE membership dues $5.00 less than they would otherwise be.

A challenge for IEEE program administrators are the various provincial and country laws; these often prevent a program from being offered universally. IEEE Canada members currently receive benefits beyond those of members outside Canada:

- electronic services at the http://ieee.ca web site; Digital Library, member profile and the ability to revise same, conference listings, and much more;
- translation services; in 1997 IEEE Canada initiated a project to translate IEEE materials (see lead article in this issue);
- to enhance relations with industry a Professional Activities brochure is in development;
- an Educational Activities database catalogue has been developed and currently proposed to be piloted in the Toronto Section;
- two web based courseware products are in development: Neural Networks, and Programmable Logic Controllers;
- through membership in The Engineering Institute of Canada our members can also register continuing education and professional activities in the EIC registry, established to meet member reporting for provincial professional career upgrades;
- **Electronic Newsletter** (subscription instructions are on p. 2);
- **The Canadian Review**, sent to all IEEE Canada members, features articles on Canadian electrotechnology achievements;
- available by subscription, **The Canadian Journal of Electrical and Computer Engineering** features significant technical advances and contributions;
- this Fall will see the introduction of a new Leadership Development program for volunteers and members; this new IEEE program will be piloted in Canada;
- the annual **Canadian Conference on Computer and Electrical Engineering (CCECE)**.

Student Activities will be enhanced through the newly established Student Branch at the Mississauga DeVry Institute of Technology. Within IEEE worldwide, new programs for members include:

- the new Entrepreneurial Skills Workshop Video Series (this is available for loan to IEEE entities, Canadian entities should contact the IEEE Canada office);
- GOLD (Graduates of the Last Decade) programs for recent graduates and young professionals;
- Affinity Chapters for networking and program delivery in topic areas such as GOLD;
- Women in Engineering, and Consultants' Networks.

by/par Dave Kemp, President of IEEE Canada 1998

As part of the IEEE Internet Project, the following benefits are planned and in some cases currently available:

- electronic personal ieee.org mail alias with virus check features;
- Web hosting for IEEE entities such as Regions, Sections, and Societies:
- one authentication;
- member contact (profile) update;
- Electronic Catalogue (all 4700 single sale products);
- improved search;
- member renewal (full add, change, delete of all services);
- new member applications.

IEEE benefits and programs depend heavily on volunteers for their creativity and enthusiastic contributions. If you are interested in becoming involved, please contact me at d.kemp@ieee.org (V & F) 204-992-2494.

Version française

Pour débuter mon mandat de deux ans comme président de l'IEEE Canada et directeur de la région 7, nous avons tenu en janvier une séance de planification stratégique des comités exécutifs. Dix-huit ateliers furent axés sur des objectifs visant particulièrement le service aux membres. Plus bas, je vous ferai état de quelques-uns des services, autant actuels que prévus, offerts aux membres par l'IEEE en général et par l'IEEE Canada.

L'année 1999 marque le cinquième anniversaire du Programme d'Avantages Financiers (PAF) de l'IEEE. Il importe de mentionner que les surplus générés par le PAF sont suffisants pour réduire de 5.00 $ les cotisations de tous les membres.

De plus, nous étudions présentement la possibilité de lancer un programme canadien de soins médicaux et dentaires pour les retraités; ce programme donnerait la possibilité aux membres qui prennent leur retraite, de continuer à jouir des avantages qu'offrait leur employeur en ce qui concerne les soins médicaux et dentaires.

L'un des défis pour les administrateurs des programmes d'IEEE réside dans les diverses lois des provinces ou des pays; celles-ci nous empêchent souvent d'offrir un même programme sur une base universelle.

Les membres d'IEEE Canada jouissent à l'heure actuelle de certains avantages que n'ont pas les membres d'autres pays. On peut citer, entre autres:

- les services électroniques sur le site web « www.ieee.ca » : la Bibliothèque numérique, des renseignements sur les membres et la possibilité de les modifier, la liste des conférences à venir et bien d'autres;
- la traduction de documents: en 1997, IEEE Canada a lancé un projet en vue de traduire des documents de l'IEEE;

(continued on page 23 / *suite a la page 23*)

Get the lead out! Lead-free electronics come of age

Is it faster, smarter, or cheaper? These are the questions typically asked in our global search for high-tech breakthroughs. But what about safer for the environment?

Since the advent of electronic circuitry, printed circuit board (PCB) assembly has relied on tin-lead solder to interconnect components to the board substrate. Despite years of effort, implementing an alternative to the toxic combination has proven difficult. But last year Nortel (Northern Telecom) of Toronto, Canada, produced the first desktop telephone that was manufactured without lead solder. The Meridian telephone (**Figure 1**) uses a commercially-available tin-copper alloy that could be the beginning of a new--and environmentally safer--standard for PCB manufacture.

by Bill Trumble & Jane Brydges,
Environment and Sustainability, Nortel

The world is in a process of rapid transition. Political, economic, and societal values, are constantly being transformed. These changes are presenting potential beneficial opportunities as well as a growing concern to address problems that come with rapid development. The recognition of society to see the value of environmental initiatives and the integration of these initiatives will rely upon the allocation of resources and the willingness of individuals to move beyond compliance and champion the environment as good business sense.

Figure 1: The Meridian Telephone

The case against lead

The pressure to reduce the industrial use of lead is growing, particularly in Europe. Lead is a well-known hazard to human health. Small quantities of lead can cause brain, nervous system, liver and kidney damage. When disposed of in landfills, lead can leach into soils and pollute ground water. These concerns prompted the removal of lead from common consumer products such as gasoline, plumbing and paint products, and the strict management of lead-acid batteries to prevent disposal in the solid waste stream.

The global electronics industry uses about 20,000 tons of lead in solder each year -- less than five percent of the world's total annual lead production. No country has yet banned lead solder, but the pressure to remove or minimize lead use is steadily building. Some European countries have proposed a ban on the landfill disposal of electronic products containing leaded printed circuit boards, and the sale of products containing lead. The recent European Union proposals for recycling end-of-life electronic equipment and vehicles go one step further. They call for a phase-out in the use of lead (in addition to cadmium, mercury, and hexavalent chromium) in the design of new products.

Lead in electronics prompted the State of New Jersey to fund a municipal electronics recycling program. An analysis of the State's municipal incinerator ash revealed a high concentration of lead (as well as mercury and cadmium), resulting in the ash's classification as hazardous waste based on the U.S. Environmental Protection Agency's testing procedures. Consumer electronics were identified as the second largest source of lead (30 percent) in the municipal solid waste stream after lead-acid batteries (65 percent), which were already being separated from trash prior to disposal.

Tin-lead solder

Tin-lead is a "one-size fits all" solution that has been around for over 2,000 years. The Romans used lead solder in their aqueducts. Today, tin-lead solder is the material of choice for mounting components to a printed wire board to form a functional circuit. The manufacture of most printed circuit boards typically use a "60/40" tin-lead solder, that is, an alloy containing somewhere in the vicinity of 60 percent tin and 40 percent lead. Tin-lead solder also coats the copper surfaces on the board substrate and component leads to prevent oxidation of copper and improve solderability of components. (**Table 1**).

One characteristic of tin-lead solder is its broad application in electronic products-- it works well in everything from telephones and computers to more complex central office switches to electronics operating in harsh automotive and avionics environments. Its well-documented physical, mechanical and electrical performance characteristics (**Table 2**), combined with manufacturability and low material costs make it the material of choice for electronics circuitry.

Table 1: Applications of Lead in Printed Circuit Boards

Application	Purpose	Prevalent Technology	Lead-free Alternatives
Surface Mount Assembly	Mechanical and electrical joining of components to board substrate to form functional circuits	"60/40" tin-lead solder	Adhesives, Tin Alloy Combined with other metals such as antimony, bismuth, copper, indium, silver, zinc
Component Finish	Improves solderability of components	"60-40" tin-lead solder	Tin, Silver, Palladium, Nickel
Final Surface Preparation	Prevents oxidation of exposed copper on PCB, ensuring a solderable surface for the mounting of components	Hot Air Solder Leveling (HASL)	Organic Solderability Preservatives (OSP's): Metallized Coatings (e.g. Ni/Au, immersion silver)

Table 2: Characteristics of Tin-Lead Solder

- Low material costs
- Low melting temperature (183° C)
- Excellent thermal fatigue resistance
- Good electrical and thermal conductivity
- Rapid and complete wetting ability
- Easy repairability
- Corrosion resistant
- Sufficient tensile, shear and creep strength
- Availability

Several performance characteristics required of solders are worth emphasizing. Any lead-free replacement would need to come close to matching the performance of lead solder in reliability and manufacturability. Thermal fatigue resistance is critical to the reliability of electronic circuits. As circuits are switched on and off, they go through heating and cooling cycles, resulting in the continual expansion and contraction of PCB materials and solder joints. This leads to fatigue and stress on the solder joint, and ultimately failure of the electronic circuit and impaired product function. Another important solder characteristic is solderability, also known as wettability, which is the ability and speed in which solder spreads over a metal surface. Spread is a factor in determining the ease of soldering, and hence the ease of manufacturing the board.

So much in the printed circuit board industry hinges on tin-lead solder. In many ways, electronic packaging and printed circuit boards assembly today is dictated by tin-lead solder and its physical properties. For example, current manufacturing processes and materials such as the resin base of a circuit board are based on the processing temperatures of the tin-lead solder system. Fluxes, which clean and protect the metal surfaces during processing, were designed for us in a tin-lead alloy system. Lead solder on component leads and the board finish are specifically added to improve interconnection performance of tin-lead solder.

As the industry searches for alternatives to lead solder, some of the processes developed to support the use of tin-lead solder are impeding progress. For example, conductive adhesives, a proven alternative in some applications, are not compatible with tin-lead-coated component leads or board surfaces. Simply put, the adhesive will not stick to tin-lead. In this example, application of conductive adhesives require a systems change, not just a solder substitution.

Lead-free alternatives

Alternatives to tin-lead solder fall into two categories: lead-free metallic solders and conductive polymers (**Table 3**). The options for no-lead solders systems rely on tin as the base metal with the addition of smaller amounts of other metals -- such as antimony, bismuth, copper, indium, silver or zinc -- to enhance performance. Tin, which is considered to be one of the least toxic metals, will most likely continue to serve as the base metal since it is relatively inexpensive and sufficiently available, in addition to possessing desirable physical properties. When considering alternatives, cost and availability of metals comes into play. Indeed, the limited availability and high costs will limit the widespread use of indium, bismuth, and silver-based alloy systems.

Interest in lead-free technologies seems to ebb and flow with political pressure. Several years back, there was a flurry of activity to find alternatives to tin-lead alloys among major U.S. electronics manufacturers including AT&T, Motorola, and IBM. To date, few companies have made a commitment.

The electronics industry is extremely competitive. There is little room for error, making reliability and manufacturability of solders critical to success. Using non-lead alloys may also pose difficulties for manufacturers. Some non-lead alloys will require costly changes to existing manufacturing processes.

Perceived performance and cost issues are likely to keep many companies away from alternatives to lead-free solders until their applications are proven. Similarly, despite mounting regulatory pressures, it is also unlikely that governments will strictly regulate this critical technology until alternative technologies are available.

But the real fix may be near, however. Extensive research programs undertaken by industry consortiums in the US and Europe have identified, evaluated and demonstrated several promising alternative technologies (**Table 4**). The UK-based International Tin Research Institute (ITRI) in conjunction with Nortel, Multicore Solders Limited and GEC (FULLNAME) conducted extensive metallurgy assessments of 200 alternatives to tin/lead solder. The field of suitable candidates was narrowed down to seven alloys, two of which were ultimately selected for detailed analysis -- a 99.3 percent tin/0.7 percent copper alloy and a 96.5 percent tin/3.5 percent silver alloy -- based on performance, cost and availability.

In the ITRI trials, a 99.3 percent tin/ 0.7 percent copper alloy demonstrated the best results, providing lead-free interconnection

Table 3 : Comparison of Tin-Lead Alloy and Selected Alternatives

Alloy	Melting Range (°C)	Metal Cost per Cubic Inch (as of 1/2/97)	Concerns	Identified as Promising Alternative
63Sn/37Pb (standard)	183	$0.85	Lead content	
42Sn/58Bi	138	$1.12	Availability of bismuth. Melting point too low for some applications.	NCMS
77.2Sn/20In/2.8Ag	179-189	$6.27	Indium availability and cost	
85Sn/10Bi/5Zn	168-190	$1.01	Poor wetting from zinc	
91Sn/9Zn	199	$0.95	Poor wetting from zinc	
90Sn/7.5Bi/2Ag/0.5Cu	186-212	$1.42	Increase manufacturing difficulties with four part alloy	
96.3Sn/3.2Ag/0.5Cu	217-218	$1.62		
95Sn/3.5Ag/1.5In	218	$2.01	Indium availability	
96.2Sn/2.5Ag/0.8Cu/0.5Sb	213-218	$1.48	Increase manufacturing difficulties with four part alloy	
96.5Sn/3.5Ag	221	$1.67		ITRI, NCMS
98Sn/2Ag	221-226	$1.40		
99.3Sn/0.7Cu	227	$1.03		ITRI
95Sn/5Sb	232-240	$1.00		
91.7Sn/3.5Ag/4.8Bi	205-210	N/A		NCMS

Data from Bastecki, Alpha Metals. 1997: NCMS, 1997.

comparable in quality to the standard industry solder containing 40 percent lead (**Table 5**). While the performance of the tin-silver alloy was not far behind tin-copper solder in performance, cost and availability issues make it less attractive than tin-copper alloys. A 96.5 percent tin/305 percent silver alloy costs approximately $1.70 per cubic inch compared to $1.00 per cubic inch for 99.3 percent tin/0.7 percent copper alloy. These two solutions were essentially "drop-in" replacements with one exception. The higher soldering temperatures of the tin-copper and tin-silver alloy systems required a nitrogen atmosphere, rather than air, in the solder machine to prevent the decomposition of plastic surfaces and corrosion of metal parts.

Encouraged by the success of these trials, in 1996 Nortel applied the tin-copper alloy in the assembly of printed circuit boards in a test group of two types of Meridian office telephones. Test results were encouraging. The company is planning a larger production run and market trials of the lead-free phone in the summer of 1998, and the corporation has expanded testing of this new technology to a wider range of products (See Box on page 9).

Not surprisingly, industry wants a one-size-fits-all replacement for tin-lead solder. This insistence seemed to be one road block to progress, particularly, since studies suggest that non-lead alloys may not be as reliable as tin-lead across the complete range of product operating conditions. One way to tackle this issue is through product segmentation.

In its demonstrations of replacements for tin-lead solder, Nortel is segmenting its product portfolio into three broad tiers characterized by progressively harsher operating conditions and board complexity. The company expects they might need different solutions for different applications. Tin-copper solder was successfully demonstrated on its business telephones which operate in a benign environment: phones sit on desks at room temperature (15-42°C) and are used on average for 10-15 minutes per hour. In contrast, a Digital Multiplex System (DMS) switch operates 24-hours each day handling high frequency signals -- a high temperature (45 - 125°C), high stress environment for solder joints. The latter application might be better suited to the tin-silver alloy which exhibits fatigue resistance at higher temperatures. The higher cost of tin-silver, compared to tin-copper, also will be more readily accepted for use in a high value item like the DMS switch.

Future Prognosis

Given the current political trend against toxics in the environment, it seems likely that lead in electronics will come under increased scrutiny in years to come. Perhaps this is no coincidence as industry is beginning to demonstrate the availability of replacements of equivalent performance and cost for some electronics applications.

We cannot expect the future of soldering to be as easy or as inexpensive as it is today, since no single, cost-effective substitute is expected to fill the shoes of the universal tin-lead solder. In order to make progress, the electronics industry must accept a series of alloys suitable to specific applications and operating conditions. The industry must also look beyond the solder to identify changes in the manufacturing system or design of components that will facilitate and optimize the transition to lead-free technology.

Table 4: Consortial Efforts for Lead-Free Alternatives

Organization	Program Objectives	Status
International Tin Lead Institute Consortium with GEC, Multicore and Nortel.	Evaluated 200 alternative alloys for performance and cost, as well as environmental impact. Laboratory assembly trials on 7 promising alloys; 2 selected for detailed analysis based on performance, cost and availability. Comparison of 2 alloys using various component and PCB finishes. Tin-copper alloy demonstrated best results, followed by tin-3.5% silver.	Consortial activities completed in 1995. Nortel continuing with product feasibility trails
National Center for Manufacturing Sciences Consortium with Ford, GM, AT&T/Lucent, Rockwell, Sandia National Lab, Texas Instruments.	$10 million consortial project to identify promising lead-free solders. Assessment of toxicology, economics & availability, manufacturability and reliability of 79 alloys. Assembly trails and extensive testing of 7 selected alloys. Most promising alloys for selected applications: tin-58% bismuth, tin-3.5% silver-4.8% bismuth, tin-3.5% silver	Final report published August, 1997
Swedish Institute of Production Engineering Research (IVF)	Research on currently available lead-free solders for volume electronics manufacturing. Assessment of manufacturability, reliability, solderability and reflow and wave soldering process and conditions. Failure mechanisms and design rules will be studied and fatigue data generated. Rare-earth metals will be added in small quantities to develop high strength, high performance lead-free solder	Expected completion April, 1999
US EPA Design for Environment Program PWB Surface Finishes Project	Evaluating lead-free alternative surface finishing technologies to the hot air solder leveling (HASL) process. Detailed data collection and analysis of performance, cost and environmental & health characteristics. Alternatives for evaluation include: thin and thin organic solder protectorates, immersion tin, immersion silver, electroless palladium directly over copper and electroless nickel/immersion gold.	Expected completion 1999.

To Probe Further

The National Center for Manufacturing Sciences (NCMS) just completed a report (No. 170502) that evaluates 79 lead-free solder alloys, and discusses 7 promising replacement candidates. Copies can be obtained from NCMS, Ann Arbor, Michigan, (313)-995-0300.

The International Tin Research Institute (ITRI) produces surveys of the technical literature on lead-free solder. Ordering information is available on their web site: http:\\www.itri.co.uk.

Several trade publications periodically publish articles on lead-free solders in printed circuit board assembly, including Circuits Assembly, Surface Mount Technology, Journal of Metallurgy, Metal Finishing, and Circuit World (UK).

Acknowledgments

The authors thank Patricia Dillon, Dillon Environmental Associates, for her valuable assistance in the preparation of this article.

Table 5: Comparison of Physical Properties and Manufacturability of Tin-Lead, Tin-Copper and Tin-Silver Alloys

	Melting Point (^{0}C)	Process Temperature. (Peak Reflow) (^{0}C)	Tensile Strength (N/mm^2)	% Elongation	Surface Tension (mN/m) Air----------Nitrogen		Electrical Conductivity (% LACS)	Thermal Conductivity (w/cm/^{0}C)
Tin-Lead	183	220	51	27	468	495	11.5	0.50
Tin-Copper	227	245	35	20	491	461	13.4	0.68
Tin-Silver	221	243	31	23	431	493	23	0.73

Getting the Lead-Free Telephone to Market

The goal of Nortel's Lead-Free Interconnect Technology Team was to demonstrate the assembly of printed circuit boards for Meridian 8009 and Meridian 9316 telephone sets using a "lead-free interconnection" technology. That meant eliminating lead from the solder; the board finish; and from the tips, or leads of components that are soldered to the board.

A key challenge was proving that the tin-copper alloy could be readily used on any standard manufacturing line, with industry-standard soldering processes. All three standard methods were demonstrated: solder reflow; solder wave; and hand soldering, using solder paste, bar or wire. Nortel selected the telephone as its first test case, in part, because its printed circuit board had the greatest variety of lead shapes (for example, j-lead, gullwing) used in a single product. The different geometric shapes of these joints require different material flow patterns and adhesion properties. By testing a variety of joints and solder methods, subsequent analytical and evaluative tests would be more easy to apply to other Nortel assemblies.

To eliminate any bias in testing, Nortel engaged outside contractors to assemble the phones. While suppliers were skeptical at first, within six months the first lead-free phones were complete. Nortel's Global Manufacturing Technology group in Calgary, Alberta, Canada, which manufactures the Meridian 9316, conducted extensive product integrity tests. In December 1996, Calgary gave the sets a "full-pass", citing their operational equivalence to their tin-lead counterparts.

Customer reaction to the prototype lead-free phone was positive, particularly in Europe, where concern over lead pollution from electronics is greater than in North America. British Telecom cited the development work of Nortel's lead-free program as an example of "best-in-class" environmental performance from telephone operating company (telco) suppliers. The next step is market trials. In 1998, Nortel will manufacture 5000 telephones for distribution to selected customers.

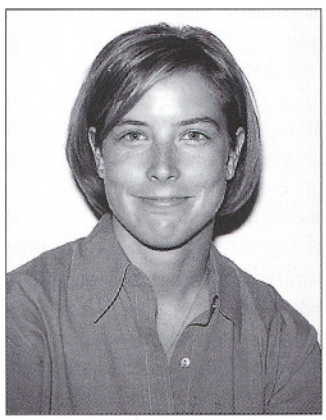
Overall, Nortel expects the switch to tin-copper to be cost neutral. While the raw material cost will increase (<5%), this should be offset by a reduction in other operating costs. As a hazardous waste and worker health and safety concern, lead required extra precautions. With tin-copper, Nortel will see a reduction in ventilation requirements and monitoring of worker health, as well as the elimination of its costly hazardous waste disposal bills.

The lead-free telephone was just the beginning, Nortel is now rolling out lead-free technology across its product platform. Nortel's wireless joint venture in France, Matracom, demonstrated the application of lead-free technology to its high density wireless handset boards, and in Malaysia, Nortel is pursuing lead-free solder assembly for use in its power supply boards. The power supply boards require higher temperature solder assembly than the telephone, since the board is subsequently soldered to another board. The solder on the power supply board must maintain its assembly integrity when it is subjected to a second solder reflow process.

In its attempt to expand the lead-free interconnection technology program to a Private Branch Exchange (PBX), Nortel was faced with myriad new challenges for this technology. This application involves assembling more complicated printed circuit boards with a greater array of complex components than the desktop telephone. When replacing the lead solder, Nortel also found that the solder played an important secondary function not related to soldering. In addition to interconnection, lead solder provides lubrication and barrel protection for the compliant pin connection attached to the back panel. Replacing this lead solder requires technology development beyond interconnection. Since Nortel does not assemble these components, in order to move forward, suppliers need time to change over to lead-free solder assembly. Until then, the issue of the real integrity of the solder joints in a high density interconnect situation operating at a higher temperature environment remains unanswered.

About the Authors

William (Bill) Trumble is a Senior Scientist at Nortel (Northern Telecom) in the Materials and Environmental Sciences unit, located in Ottawa, Canada. He has led research efforts seeking alternatives to toxic heavy metals in product, including lead solder and chromate corrosion protection coatings. In addition to his role in Materials and Environmental Sciences, Bill holds senior positions on several product teams throughout Nortel. He holds forty-one patents.



Jane Brydges is a Program Manager with Environment and Sustainability unit at Nortel. Jane holds a B.A. degree in Political Science from Bishop's University and has extensive experience in project management, engineering, marketing and government affairs. The scope of the PLCM portfolio consists of eighteen innovative projects throughout Nortel, which provide environmental and business value. She is involved in product and technology innovations such as Nortel's lead-free interconnect technology and alternative chromate conversion coatings. She is currently a technical advisor for the IEEE Symposium on Electronics in the Environment. Jane has received several awards including Nortel's highest award - the Nortel Chairman's Award of Excellence for Environmental Protection.

Une nouvelle technologie d'interconnexion qui tombe à plomb!

par Bill Trumble & Jane Brydges,
Environnement et Sustainabilité, Nortel

Le monde connaît actuellement une période de transition rapide. Nos valeurs politiques, économiques et sociétales se transforment sans cesse. Ces changements ouvrent une fenêtre sur de nouvelles possibilités, tout en étant une source de préoccupations grandissantes à l'égard de notre capacité de faire face aux problèmes associés à un développement rapide. Or, la reconnaissance et l'intégration des initiatives environnementales reposent non seulement sur l'allocation des ressources nécessaires, mais aussi sur la volonté des gens d'en faire plus que se conformer aux normes et d'intégrer le respect de l'environnement à leurs principes de saine gestion commerciale.

Est-ce plus rapide, plus intelligent et plus économique? Voilà les questions qui se posent généralement lorsque l'on est à la recherche de nouvelles technologies. Mais ne devrait-on pas aussi se demander si c'est plus écologique?

Depuis l'avènement de l'électronique, l'interconnexion des composants électroniques au substrat des plaquettes de circuits imprimés se fait par soudage à l'étain-plomb. En dépit d'années d'efforts, on n'était pas encore parvenu à trouver un substitut à l'alliage toxique que constitue l'étain-plomb. Mais, l'an dernier, un premier combiné téléphonique ne comportant pas de soudures au plomb a été fabriqué par Nortel (Northern Telecom), à Toronto. Le téléphone Meridian (figure 1 au page 5), fabriqué d'un alliage d'étain-cuivre facilement disponible, représente un pas en avant vers une nouvelle norme de fabrication de plaquettes de circuits imprimés plus écologiques.

Le plomb au banc des accusés

Des pressions grandissantes sont exercées, particulièrement en Europe, pour qu'on réduise l'utilisation industrielle du plomb. Le plomb est un danger bien connu pour la santé humaine. Même de petites quantités de plomb peuvent causer des dommages au cerveau, au système nerveux, au foie et aux reins. Le plomb qu'on rejette dans les sites d'enfouissement peut s'infiltrer dans le sol et polluer les eaux souterraines. Ces préoccupations ont conduit non seulement à l'élimination du plomb dans des produits de consommation comme l'essence, la plomberie et la peinture, mais aussi à une gestion rigoureuse des accumulateurs au plomb afin d'empêcher leur rejet dans le flux des déchets solides.

À l'échelle mondiale, l'industrie de l'électronique utilise environ 20 000 tonnes de plomb par année pour les soudures - ce qui représente moins de 5 % de la production mondiale annuelle totale de plomb. Aucun pays n'a encore banni les soudures au plomb, mais les pressions pour que leur utilisation cesse ou diminue se font de plus en plus fortes. Certains pays européens ont proposé qu'on interdise l'enfouissement des produits électroniques contenant des plaquettes de circuits imprimés au plomb, et même la vente de produits contenant du plomb. De récentes propositions de l'Union européenne concernant le recyclage en fin de vie utile de pièces d'équipement électronique et de véhicules vont encore plus loin en suggérant l'élimination progressive du plomb (en plus du cadmium, du mercure et du chrome hexavalent) dans la conception de nouveaux produits.

La présence de plomb dans les circuits électroniques a incité l'État de New-Jersey à financer un programme municipal de recyclage des produits électroniques. Une analyse des cendres produites par les incinérateurs municipaux de l'État a révélé que celles-ci présentaient de fortes concentrations de plomb (ainsi que de mercure et de cadmium). On a donc classé les cendres dans la catégorie des déchets dangereux, conformément aux protocoles d'analyse de la U.S. Environmental Protection Agency. Les produits électroniques de consommation ont été identifiés comme la deuxième plus grande source de plomb (30 %) dans le flux de déchets solides municipaux, la première étant les accumulateurs au plomb (65 %), que l'on séparait déjà des déchets avant leur élimination.

Soudures à l'étain-plomb

L'alliage d'étain-plomb est employé « à toutes les sauces » pour les travaux de soudage depuis plus de 2 000 ans. Les Romains s'en servait dans leurs aqueducs. Aujourd'hui, l'étain-plomb est un matériau de choix pour l'interconnexion des composants électroniques aux plaquettes de circuits imprimés. Dans la plupart des plaquettes de circuits imprimés, on emploie un alliage 60/40 , qui contient environ 60 % d'étain et 40 % de plomb. Le soudage à l'étain-plomb est aussi employé pour recouvrir les surfaces en cuivre des conducteurs et du substrat des plaquettes, ce qui empêche l'oxydation du cuivre et améliore la soudabilité des composants (tableau 1).

L'un des avantages des soudures à l'étain-plomb, c'est qu'on peut les employer dans un large éventail de produits électroniques - depuis les téléphones et les ordinateurs jusqu'aux équipements centraux de commutation très complexes, en passant par les composants électroniques plus robustes utilisés dans l'industrie de l'automobile et de l'aviation. Le rendement physique, mécanique et électrique du plomb (tableau 2), de même que sa manufacturabilité et son faible coût, en font un matériau de choix pour les circuits électroniques.

Plusieurs des caractéristiques de rendement des soudures méritent d'être soulignées. Tout substitut au plomb devrait posséder des caractéristiques de fiabilité et de manufacturabilité semblables à celles que possède le plomb. La résistance à la fatigue thermique est essentielle à la fiabilité des circuits électroniques. En effet, les mises en circuit et hors circuit produisent des cycles de réchauffement et de refroidissement qui résultent en une expansion et une contraction constantes des composants électroniques et des joints de soudure. Ces cycles entraînent une fatigue et un stress qui peu-

Tableau 1: Utilisation du plomb dans les plaquettes de circuits imprimés

Utilisation	But	Technologie actuellement employée	Substituts sans plomb
Montage en surface	Assemblage mécanique et électrique des composants au subtrat des plaquettes pour créer des circuits fonctionnels	Soudure à l'étain- plomb 60/40	Adhésifs, alliage d'étain et d'autres métaux tels que l'antimoine, le bismuth, le cuivre, l'indium, l'argent, le zinc
Fini des composants	Améliore la soudabilité des composants	Soudure à l'étain- plomb 60/40	Étain, argent, palladium, nickel
Apprêt final de la surface	Prévient l'oxydation des surfaces en cuivre des plaquettes; assure une soudabilité pour le montage des composants	Procédé d'étalement à l'air chaud (HASL)	Revêtement protecteurs organiques (OSP); Enduits métallisés (p. ex. Ni/Au, argent pour placage par immersion)

vent éventuellement provoquer une défaillance des circuits électroniques et un mauvais fonctionnement des produits. Une autre caractéristique importante des soudures est la soudabilité, qu'on appelle aussi la mouillabilité, soit la facilité et la vitesse avec lesquelles la soudure s'étale sur les surfaces métalliques. L'étalement contribue à faciliter l'application des soudures et, par le fait même, la fabrication des plaquettes.

Dans l'industrie de l'électronique, beaucoup repose sur l'utilisation de soudures à l'étain-plomb. En effet, ce sont les propriétés physiques des soudures à l'étain-plomb qui dictent souvent les techniques employées pour le conditionnement électronique et le montage des plaquettes de circuits imprimés. Ainsi, les procédés et les matériaux actuellement utilisés pour la fabrication des plaquettes (dont la base de résine) sont conçus en fonction des températures de traitement du système de soudage à l'étain-plomb. De plus, le nettoyage et la protection des surfaces métalliques en cours de traitement s'effectuent au moyen de fondants spécialement adaptés au système de soudage à l'étain-plomb. Enfin, les conducteurs et les surfaces des plaquettes sont revêtus de plomb dans le but d'améliorer les caractéristiques d'interconnexion des soudures à l'étain-plomb.

Tableau 2: Caractéristiques de la soudure à l'étain-plomb

- Coûts peu élevés des matériaux
- Basse température de fusion (183 °C)
- Excellente résistance à la fatigue thermique
- Bonne conductivité électrique et thermique
- Capacité de mouillage rapide et complet
- Réparation facile
- Résistance à la corrosion
- Résistance à la rupture, au cisaillement et au fluage
- Disponibilité

Malheureusement, certains procédés conçus spécialement pour permettre l'emploi des soudures à l'étain-plomb viennent ralentir les progrès réalisés par l'industrie dans sa recherche de substituts au plomb. Ainsi, les adhésifs conducteurs, un substitut au plomb éprouvé pour certaines applications, ne sont pas compatibles avec les conducteurs ou les surfaces des plaquettes revêtus d'étain-plomb. Ces adhésifs ne collent tout simplement pas à l'étain-plomb. Il faudrait modifier en profondeur le système, pas uniquement remplacer le type de soudures, pour que les adhésifs conducteurs puissent être utilisés.

Substituts au plomb

Les substituts à l'étain-plomb tombent dans deux catégories: les soudures métalliques sans plomb et les polymères conducteurs (tableau 3). Les systèmes de soudage sans plomb utilisent de l'étain comme métal de base, celui-ci étant additionné de plus petites quantités d'autres métaux - tels que l'antimoine, le bismuth, le cuivre, l'indium, l'argent ou le zinc - pour en améliorer le rendement. L'étain, qui est considéré comme étant l'un des métaux les moins toxiques, continuera vraisemblablement de servir de métal de base, car il est relativement peu dispendieux et suffisamment disponible, sans compter qu'il possède les propriétés physiques souhaitées. Lorsque l'on examine les possibilités d'utilisation des divers substituts, le coût et la disponibilité des métaux sont des facteurs importants à considérer. Ces facteurs, en fait, expliquent l'utilisation limitée qui est faite des alliages à base d'indium, de bismuth et d'argent.

L'intérêt à l'égard des technologies sans plomb semble augmenter et diminuer au gré des pressions politiques. Il y a quelques années, une multitude d'activités avaient été entreprises pour trouver des substituts aux alliages d'étain-plomb par les principaux fabricants de produits électroniques des États-Unis, y compris AT&T, Motorola et IBM. Jusqu'à présent, peu de sociétés en pris des engagements en ce sens.

La concurrence est très forte au sein de l'industrie de l'électronique. Comme l'erreur ne pardonne pas, la fiabilité et la manufacturabilité des soudures sont des facteurs essentiels à la réussite. L'emploi de soudures sans plomb peut aussi se révéler un casse-tête pour le fabricant. En effet, certains alliages sans plomb nécessiteront la modification coûteuse des procédés de fabrication existants.

Des considérations de rendement et de coût pourraient dissuader de nombreuses sociétés d'utiliser des soudures sans plomb tant que la fiabilité de celles-ci n'aura pas été éprouvée. De façon similaire, malgré les pressions grandissantes exercées, il est fort peu probable que les gouvernements imposent une réglementation stricte dans ce domaine tant que des substituts ne seront pas disponibles.

Cependant, une solution pointe à l'horizon. D'importants programmes de recherche entrepris aux États-Unis et en Europe par des consortiums industriels ont permis d'identifier, d'évaluer et d'éprouver plusieurs substituts prometteurs (figure 4). L'International Tin Research Institute (ITRI), établi au Royaume-Uni, en collaboration avec Nortel, Multicore Solders Limited et GEC, a évalué 200 substituts aux soudures à l'étain-plomb. Le nombre des substituts a été réduit à sept alliages et deux d'entre eux ont été soumis à une analyse approfondie - un alliage constitué à 99,3 % d'étain et à 0,7 % de cuivre et un alliage constitué à 96,5 % d'étain et à 3,5 d'argent - en fonction du rendement, du coût et de la disponibilité.

Tableau 3: Comparaison entre d'étain-plomb et certauns substituts

Alliage	Plage de fusion (°C)	Coût du métal par pouce cube (2/1/97)	Problémes	Considéré comme étant un substitut prometteur par
63 Sn/37 Pb (standard)	183	0,85 $	Contenu en plomb	
42 Sn/58 Bi	138	1,12 $	Disponibilité du bismuth. Point de fusion trop bas pour certaines applications	NCMS
77,2 Sn/20 In/2,8 Ag	179-189	6,27 $	Disponibilité et coût de l'indium	
85 Sn/10 Bi/5 Zn	168-190	1,01 $	Faible mouillage du zinc	
91 Sn/9 Zn	199	0.95 $	Faible mouillage du zinc	
90 Sn/7,5 Bi/2 Ag/0,5 Cu	186-212	1,42 $	Difficultés de fabrication accrues par l'emploi d'un alliage de quatre métaux	
96,3 Sn/3,2 Ag/0,5 Cu	217-218	1.62 $		
95 Sn/3,5 Ag/1,5 In	218	2,01 $	Disponibilité de l'indium	
96,2 Sn/2,5 Ag/0,8 Cu/0,5 Sb	213-218	1,48 $	Difficultés de fabrication accrues par l'emploi d'un alliage de quatre métaux	
96,5 Sn/3,5 Ag	221	1,67 $		ITRI, NCMS
98 Sn/2 Ag	221-226	1,40 $		
99,3 Sn/0,7 Cu	227	1,03 $		ITRI
95 Sn/5 Sb	232-240	1,00 $		
91,7 Sn/3,5 Ag/4,8 Bi	205-210	S/O		NCMS

Données provenant de Bastecki, Alpha Metals, 1997; NCMS, 1997.

Les essais menés par l'ITRI ont révélé que l'alliage constitué à 99,3 % d'étain et à 0,7 % de cuivre était supérieur, l'interconnexion sans plomb réalisée grâce à l'alliage d'étain-cuivre étant comparable à celle des soudures contenant 40 % de plomb couramment employées dans l'industrie (tableau 5). Quoique le rendement de l'alliage d'étain-argent ne soit pas de beaucoup inférieur à celui de l'alliage d'étain-cuivre, des considérations liées au coût et à la disponibilité le rendent moins attrayant que l'alliage d'étain-cuivre. L'alliage constitué à 96,5 % d'étain et à 3,5 d'argent coûte environ 1,70 $ le pouce cube, tandis que l'alliage constitué à 99,3 % d'étain et à 0,7 % de cuivre revient à 1,00 $ le pouce cube. Ces deux solutions s'intègrent facilement aux procédés existants, sauf que les températures élevées requises par les systèmes de soudage à l'étain-cuivre et à l'étain-argent exigent l'emploi, dans la machine à souder, d'une atmosphère d'azote, au lieu d'air, afin de prévenir la décomposition des surfaces en plastique et la corrosion des parties métalliques.

Encouragée par la réussite de ces essais, Nortel a appliqué, en 1996, l'alliage d'étain-cuivre au montage de plaquettes de circuits imprimés dans un groupe d'essai comprenant deux types de téléphone d'affaires Meredian. Les résultats des essais se sont révélés encourageants. Nortel prévoit une production à plus grande échelle et la réalisation d'essais de mise en marché pour des postes téléphoniques sans plomb au cours de l'été 1998. La Société entend également étendre les essais de cette nouvelle technologie à une plus vaste gamme de produits (voir l'encadré au page 14).

Il n'est pas surprenant que l'industrie tienne mordicus à un substitut « universel » aux soudures à l'étain-plomb. Une telle attitude pourrait faire obstacle au progrès, car les études démontrent clairement que la fiabilité des alliages sans plomb varie selon leurs conditions d'utilisation. L'une des façons de résoudre cette question consiste à segmenter la production.

Dans une étude portant sur les possibilités d'application des substituts aux soudures à l'étain-plomb, Nortel a segmenté ses produits en trois grandes catégories en fonction de leur robustesse et de leur complexité. La Société prévoit peut-être recourir à différentes solutions pour différentes applications. Les soudures à l'étain-cuivre ont donné de bons résultats pour les téléphones d'affaires exigeant une faible robustesse : ces combinés restent sur un bureau à la température ambiante (de 15 à 42 °C) et ne sont employés que de 10 à 15 minutes par jour. En revanche, une grande robustesse est exigée d'un système multiplex numérique (DMS), car il est employé 24 h par jour, achemine des signaux à haute fréquence et fonctionne à une température élevée (de 45 à 125 °C). Cette dernière application pourrait convenir davantage à l'alliage d'étain-argent puisque celui-ci peut résister à la fatigue à de hautes températures. Le coût plus élevé de l'alliage d'étain-argent, comparativement à celui de l'alliage d'étain-cuivre, sera plus facilement accepté pour un appareil dispendieux comme le DMS.

Pronostic

Compte tenu de la tendance politique actuelle s'opposant à l'emploi de produits toxiques pour l'environnement, il semble probable que l'utilisation du plomb dans les produits électroniques sera soumise à un examen de plus en plus minutieux au cours des prochaines années. Cela explique sans doute pourquoi l'industrie a commencé à concevoir, pour certaines applications électroniques, des produits de remplacement dont le rendement et le coût sont équivalents.

Il est certain que, dans l'avenir, le soudage ne sera jamais aussi facile ou aussi peu dispendieux qu'il peut l'être aujourd'hui. Aucun substitut rentable ne peut remplir à lui seul le rôle de la soudure universelle à l'étain-plomb. Pour progresser, l'industrie de l'électronique devra accepter de recourir à une série d'alliages con-

Tableau 4: Efforts conjoints déployés pour la recherche de substituts sans plomb

Organisme	Objectifs du programme	État d'avancement
International Tin Lead Institute Consortium avec GEC, Multicore et Nortel.	200 alliages ont fait l'objet d'etudes portant sur le rendement, le coût et les répercussions environnementales. 7 alliages prometteurs ont été soumis à des essais d'assemblage en laboratoire. 2 ont été choisis et soumis à une analyse approfondie portant sur le rendement, le coût et la disponibilité. Lacomparaison de ces 2 alliages a été effectuée en utilisant divers composants et finis de plaquettes de circuits imprimés. L'alliage d'étain-cuivre a donné les meilleurs résultats; l'alliage d'étain-3,5% argent est arrivé au second rang.	Activités conjointes terminées en 1995. Nortel continue à effectuer des essais de faisabilité
National Center for Manufacturing Sciences Consortium avec Ford GM, AT&T/Lucent, Rockwell, Sandia National Lab, Texas Instruments	Un projet conjoint 10 millions $ a été mis sur pied en vue d'identifier des alliages sans plomb prometteurs. 79 alliages ont fait l'object d'etudes axées sur la toxicologie, la rentabilité, la disponibilité, la manufacturabilité et la fiabilité. 7 alliages ont été soumis à des essais d'assemblage et à des analyses plus poussées. Les alliages les plus prometteurs pour les applications choisies sont les suivants: étain-58% bismuth, étain-3,5% argent-4,8% bismuth, étain-3,5% argent.	Rapport final publié en 1997
Swedish Institute of Production Engineering Research (IVF)	Réalisation de recherches sur les techniques de soudage sans plomb applicables à la production de masse de produits électroniques. Évaluation de la manufacturabilité, de la fiabilité, de la soudabilité ainsi que des procédés et des conditions de soudage par refusion et de brasage tendre à la vague. Etude des mécanismes de défaillance et des régles de conception; production de données sur la résistance à la fatigue. Ajout de métaux des terres rares en petites quantités en vue de la mise au point de soudures sans plomb de haute résistance et de haut rendement.	Achèvement prévu pour 1999
US EPA Design for Environment Program Projet de recherche sur les finis de surface pour plaquettes de circuits imprimés	Évaluation de technologies sans plomb applicables à la finition de surface qui pourraient être substituées au procédé HASL. Collecte de données et analyse du rendement, du coût ainsi que des effets sur l'environnement et la santé. Parmi les substituts évalués figurent les revêtements protecteurs organiques en couches minces et épaisses, l'étain pour placage par immersion, l'argent pour placage par immersion, le palladium autocatalytique applique directement sur le cuivre, le nickel autocatalytique/l'or pour placage par immersion.	Achèvement prévu pour 1999

venant à des applications et à des conditions d'exploitation spécifiques. L'industrie devra aussi examiner des considérations autres que le soudage proprement dit, afin de cerner les changements à apporter à la fabrication ou à la conception des composants pour faciliter et optimiser la transition vers les technologies sans plomb.

Pour en savoir plus

Le National Center for Manufacturing Sciences (NCMS) vient juste de compléter un rapport (No 170502) sur 79 alliages sans plomb et sept substituts prometteurs. Pour en obtenir un exemplaire, il suffit de communiquer avec Ann Arbor (Michigan), au (313)-995-0300.

L'International Tin Research Institute (ITRI) effectue le recensement de la documentation portant sur les soudures sans plomb. On peut passer des commandes par l'entremise de leur site web: http:\\www.itri.co.uk.

Plusieurs publications spécialisées présentent périodiquement des articles sur l'emploi de soudures sans plomb pour l'assemblage des plaquettes de circuits imprimés: Circuits Assembly, Surface Mount Technology, Journal of Metallurgy, Metal Finishing et Circuit World (UK).

Remerciements

L'auteurs aimerait remercier Patricia Dillon, de Dillon Environmental Associates, pour leur précieuse contribution à la préparation de cet article.

Tableau 5: Comparaison des propriétés physiques et de la manufacturabilité des alliages d'étain-plomb, d'etain-cuivre et d'etain-argent

	Pointe de fusion (^{0}C)	Température du procédé. (refusion maximale (^{0}C)	Résistance à la rupture (N/mm^2)	% étirement	Tension de surface (mN/m) Air----------	----------Azote	Conductivité électrique (% L.A.C.S.)	Conductivité thermale (w/cm/^{0}C)
Étain-plomb	183	220	51	27	468	495	11.5	0.50
Étain-cuivre	227	245	35	20	491	461	13.4	0.68
Étain-argent	221	243	31	23	431	493	23	0.73

À quand la commercialisation du téléphone sans plomb?

Le but de l'Équipe de technologie d'interconnexion sans plomb de Nortel [photo] était de démontrer la faisabilité de l'application de la technologie d'interconnexion sans plomb au montage des plaquettes de circuits imprimés dans les téléphones Meridian 8009 et Meridian 9316. Il s'agissait donc d'éliminer le plomb des soudures, du fini de la plaquette ou des conducteurs soudés à la plaquette.

Un défi important était de démontrer que l'alliage d'étain-cuivre pouvait être facilement utilisé sur une chaîne de fabrication ordinaire, en employant des procédés de soudage habituels. Trois méthodes de soudage standard ont été mises à l'épreuve : le soudage par refusion, le brasage tendre à la vague et le soudage à la main, en utilisant de la soudure en pâte, en baguette et en fil. Nortel a choisi le téléphone comme banc d'essai en partie parce que ses plaquettes de circuits imprimés utilisent la plus grande variété de formes de joints (en J, en M, p. ex.) pour un seul produit. Les diverses formes géométriques de ces joints exigent différents patrons de fusion et différentes propriétés d'adhérence. Comme on a mis à l'essai une grande variété de joints et de méthodes de soudage, il serait plus facile de réaliser d'autres analyses et évaluations sur les autres lignes d'assemblage de Nortel.

Pour éliminer toute partialité lors des essais, Nortel a donné à contrat le montage des téléphones. En dépit du scepticisme initial des fournisseurs, les premiers téléphones sans plomb étaient terminés en dedans de six mois. À Calgary, le Groupe de technologie de fabrication à l'échelle mondiale de Nortel qui fabrique le Meridian 9316 a soumis le produit à des essais intensifs d'intégrité. En décembre 1996, le produit obtenait une note parfaite et on jugeait que ses interconnexions sans plomb étaient d'une qualité comparable aux soudures à l'étain-plomb.

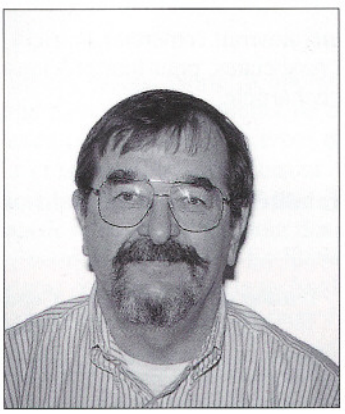
La réaction des consommateurs à l'égard du prototype de téléphone sans plomb a été positive, tout particulièrement en Europe, où l'inquiétude à l'égard de la pollution au plomb due aux produits électroniques est plus grande qu'en Amérique du Nord. British Telecom a cité en exemple le travail accompli par Nortel dans le domaine des interconnexions sans plomb en vue de réduire les effets nocifs de ses produits sur l'environnement. Il reste à effectuer les essais de mise en marché. En 1998, Nortel fabriquera 5 000 téléphones destinés à ses clients privilégiés.

Dans l'ensemble, Nortel s'attend à ce que le virage étain-cuivre n'entraîne pas de coûts supplémentaires. Le coût du matériel en vrac augmentera (<5 %), mais cette augmentation sera compensée par une réduction des autres coûts d'exploitation. En tant que déchet dangereux et produit nocif pour la santé des travailleurs, le plomb nécessite des précautions supplémentaires. Avec l'étain-cuivre, Nortel verra diminuer ses besoins en matière de ventilation et de suivi de la santé des travailleurs et pourra également réduire ses coûts élevés d'élimination de produits dangereux.

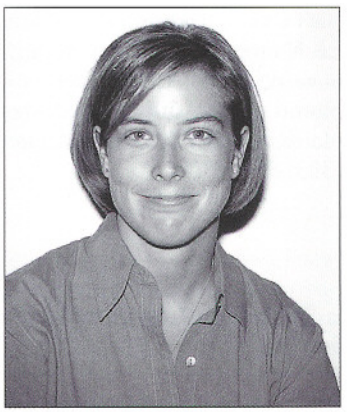
Le téléphone sans plomb n'était qu'un début. Nortel est en voie d'étendre la technologie d'interconnexion sans plomb à toute sa gamme de produits. En France, la société Matracom, une entreprise conjointe de Nortel, applique la technologie d'interconnexion sans plomb au montage de plaquettes de haute densité pour téléphones sans fil. En Malaisie, Nortel applique la technologie d'interconnexion sans plomb au montage de plaquettes pour blocs d'alimentation. Une plaquette pour blocs d'alimentation est ultérieurement soudée à une autre plaquette et nécessite, par conséquent, un soudage à une température plus élevée qu'une plaquette de combiné téléphonique. La soudure appliquée à une plaquette de bloc d'alimentation doit conserver son intégrité d'assemblage au cours du deuxième processus de refusion.

Dans ses tentatives visant à étendre son programme d'interconnexion sans plomb au commutateur privé (PBX), Nortel a été confrontée à une myriade de nouveaux défis. Le PBX nécessite l'assemblage de plaquettes de circuits imprimés plus complexes à l'aide de composants plus variés que ceux exigés pour le téléphone de bureau. En remplaçant les soudures au plomb, Nortel s'est aperçue que celles-ci jouaient une importante fonction secondaire. En plus d'assurer une interconnexion, les soudures au plomb lubrifient et protègent les broches de connexion souples fixées au support arrière de la plaquette. Remplacer ces soudures au plomb nécessite la modification des composants existants. Puisque Nortel n'assemble pas ces composants, il faudra que ses fournisseurs adaptent leurs produits à la nouvelle technologie d'interconnexion sans plomb. En attendant, la question de l'intégrité réelle des joints de soudure dans une situation d'interconnexion à haute densité et à haute température reste sans réponse.

À propos de l'auteurs



William (Bill) Trumble est chercheur principal chez Nortel (Northern Telecom), à l'Unité des sciences environnementales et des matières située à Ottawa. Il a dirigé des recherches visant à trouver des substituts aux métaux lourds toxiques que contiennent des produits tels que les soudures au plomb et les revêtements au chromate anti-corrosion. Bill exerce également des fonctions de supervision au sein de plusieurs équipes chargées de la conception de produits pour le compte de Nortel. Il détient 41 brevets.



Jane Brydges est une Gestionnaire de Portefeuille dans l'unité 'Environment and Sustainability' à Nortel. Diplômée (Bac.Adm.) en Science Politique de l'Université de Bishop, Jane a une vaste expérience dans les domaines de la gestion des projets, de l'ingénierie, du marketing et des affaires gouvernementales. Leur champ d'activités du portefeuille 'PLCM 'consiste en dix huit projets d'innovation partout au sein de Nortel: ce qui lui procure une maîtrise dans le domaine environnemental et des affaires administratives. Elle est engagée dans la production et dans les innovations technologiques telles la technologie de l'interconnexion sans plomb de Nortel et la 'conversion alternative des couches chromatiques'. Elle est présentement conseillère technique pour le 'IEEE Symposium on Electronics in the Environment'. Jane a reçu plusieurs prix notamment le prix d'Excellence du Président de Nortel en matière de protection de l'Environnement.

Nelson River HVDC Line Failures

by M. Rashwan, Manitoba Hydro

On September 5, 1996 a severe windstorm destroyed 19 HVDC transmission line towers on the two bipolar Nelson River system. The storm also destroyed several wooden poles on both electrode lines. The event was the first of it's kind on the Nelson River HVDC System in its 25 years of commercial operation. This paper describes the event and discusses the design criteria of the dc lines as well as the repairs and the impact on Manitoba Hydro's system following an event of this magnitude.

Le 5 septembre 1996, une violente tempête de vent a détruit 19 pylônes de la double liaison bipolaire CCHT de Nelson River. La tempête a aussi endommagé plusieurs poteaux électriques en bois sur les deux électrodes de la liaison. Cet événement fut le premier du genre sur la liaison CCHT de Nelson River depuis ses 25 années de mise en exploitation. Cet article décrit cet événement et examine aussi bien les critères de conception/design de la liaison que les travaux de réparation et l'impact sur le réseau de Manitoba-Hydro, suite à un événement de cette ampleur.

Introduction

The Nelson River HVDC system is a two bipolar system with a total transmission capacity of 3800 MW. Two bipolar HVDC lines connect the two rectifiers Radisson and Henday located in Northern Manitoba near the Generating Stations to the inverter at Dorsey Converter Station in Southern Manitoba near Winnipeg as shown in **Figure 1**. The total transmission distance is 930 km. The HVDC system supplies 75% of the power requirements in Manitoba.

The normal mode of operation of the system is shown in **Figure 2**.

HVDC Lines Design Criteria

Bipoles 1 and 2 HVDC lines are designed to survive lateral and down burst winds of 150 km/hr which is classified as level F1 on the Fujita Scale (this scale classifies these events in 6 categories of increasing intensities from F0 to F5, F1 being the second lowest). The lines are designed to standards that are currently in use and considered quite appropriate for lines of comparable importance. The transmission lines design parameters are:

1. 75 kg/m^2 wind pressure on a wind span of 490m with no longitudinal loads on the suspension points of the conductors.

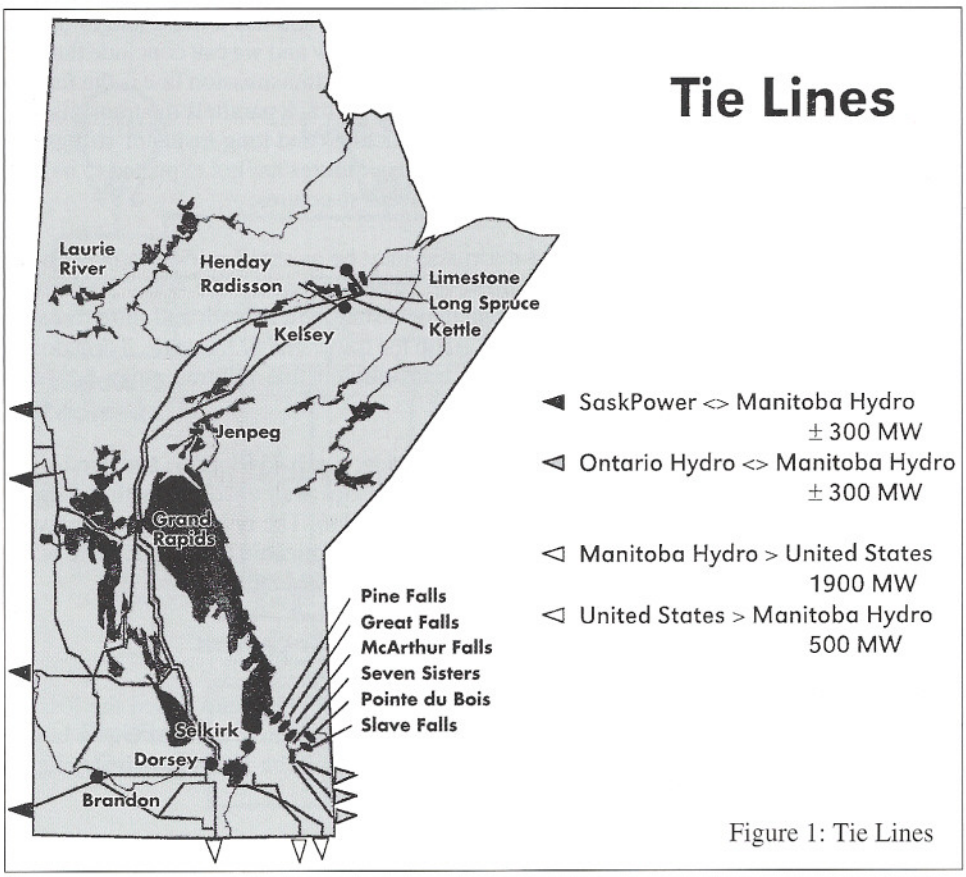


Figure 1: Tie Lines

2. 40 kg/m^2 wind pressure on 12.7mm ice covered conductor and a span of 535m with no longitudinal loads on the suspension points of the conductors.
3. No wind pressure and 25.4mm thick ice on the conductor on a span of 535m.

The above parameters translate into:

1. 120 km/hr steady wind with gusts up to 150 km/hr and no ice loads.
2. 90 km/hr steady wind with gust up to 120 km/hr with a 12.7mm ice load on a 535 m span.
3. 25.4mm ice load on a span of 535m.

The lines are designed to the above loads with safety factors of 1.3, assuming that the winds are acting exclusively in horizontal planes without any vertical components, and all ice/wind loads are uniformly constant in time and space.

The Thunder Storm Features

On September 5, 1996 a thunderstorm about 3-5 km wide with wind gusts of 115-180 km/hr was over the southwest portion of Manitoba. The storm destroyed 19 steel

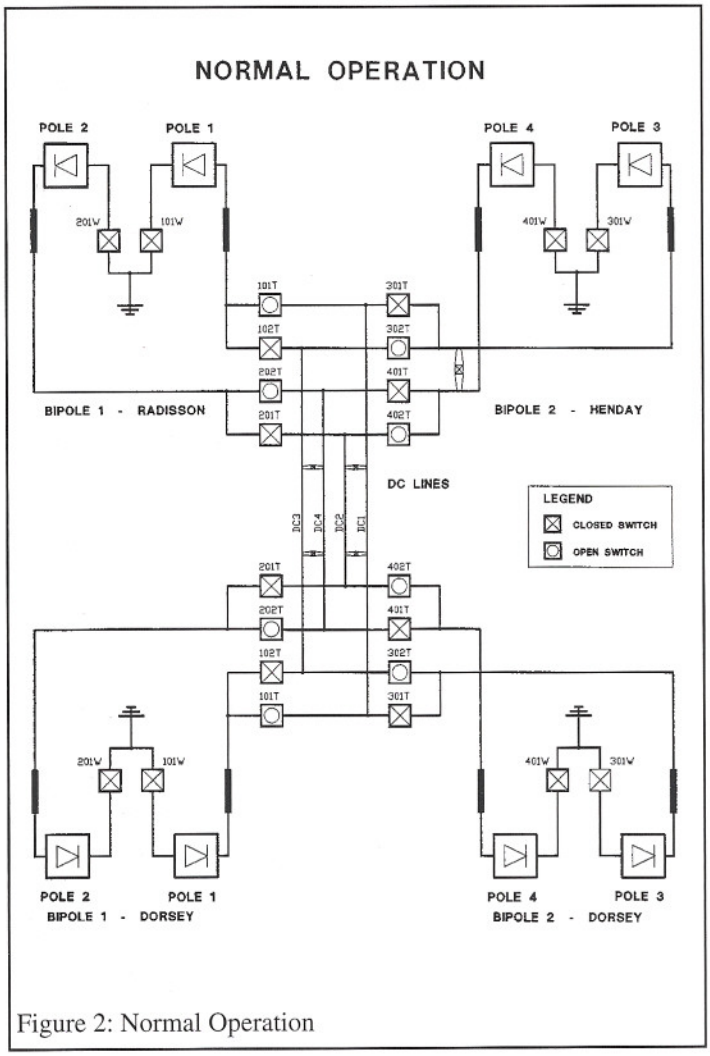


Figure 2: Normal Operation

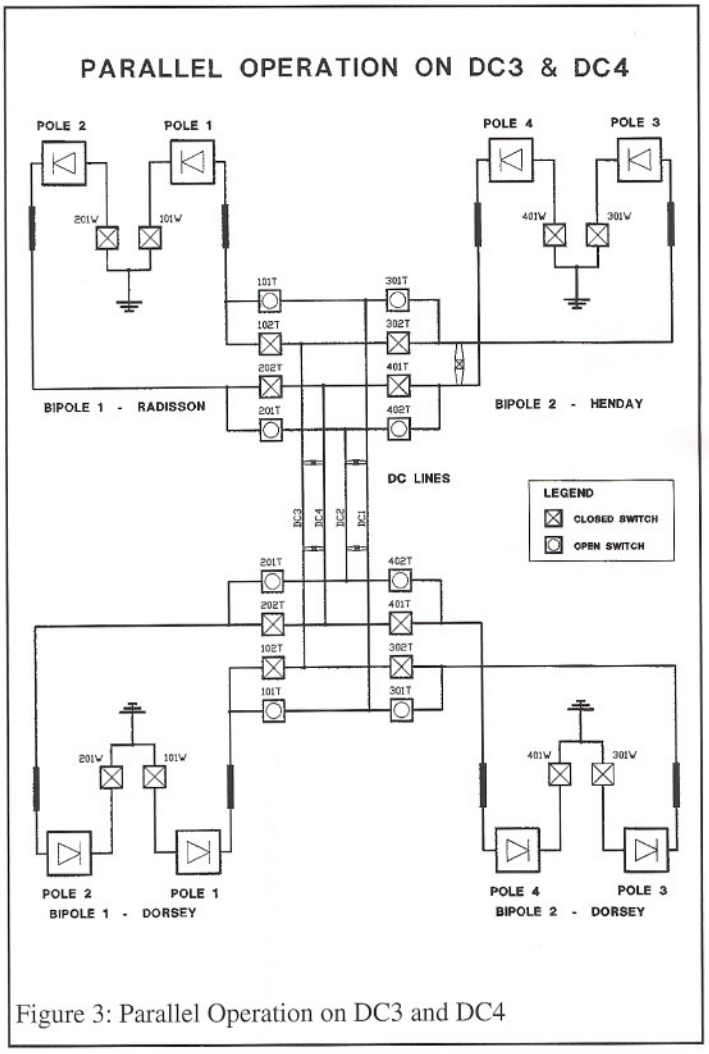


Figure 3: Parallel Operation on DC3 and DC4

transmission line towers on the two HVDC bipolar lines. This resulted in the HVDC conductors falling to the ground. The storm also destroyed the two electrode lines which are located on the east and west side of the main HVDC lines.

The downed steel towers spanned a total of 4 km, indicating that the thunderstorm winds were at the upper end of the specified gusts and they destroyed virtually all the steel towers in their path. On the electrode lines 18 wood poles snapped, this is out of a total of 70 poles.

Analysis Of The Storm

Manitoba has an average of 9 reported tornados, mostly in the south (2-3 times as many go unreported).

The surface area of Manitoba is 650, 000 km^2, while the right-of-way of the transmission lines is 110 km^2. If we assume the total number of tornados to be 36, the likelihood of a tornado strike on the Bipole lines is 1 strike in 164 years. This estimate is valid regardless of the distribution density of the tornados along the north - south centerline of Manitoba as the Bipole lines also are built in the north - south direction. If the 36 tornados are assumed to be concentrated exclusively in the southern half of Manitoba then only half of the Bipole lines could be struck by a tornado and the risk of such an event would remain 1 strike in 164 years. This one tornado strike in 164 years may or may not result in tower failures, depending on the intensity of the tornado, as discussed below.

A typical tornado is 40-150m wide and has a track length of 2-9 km. This width is sufficiently narrow and we can conclude that the likely effect of a tornado strike on a transmission line is the failure of relatively few towers, unless its track parallels the transmission line. In the case of guyed structures and long insulator strings associated with EHV lines, these failures are not expected to be followed by cascading of adjacent structures.

The intensity of a tornado may be as small as 64 km/hr with no real upper limit; however, when it reaches the 400 - 500 km/hr range it causes complete devastation in its path and little remains intact. Most tornados are in the lower end of the scale. Tornado intensities that result in transmission line failures range between 115 km/hr and 180 km/hr.

Down bursts may be 4 km wide, reach 216 km/hr, and persist for 5-30 minutes. These characteristics are consistent with the damage sustained on September 5, 1996. The only statistical analysis of wind microburst intensities is applicable to the US; there is no comparable analysis for Canada and Manitoba.

Impact Of The Failure On The System

On September 5, 1996, when the HVDC lines failed the loss of generation on the Manitoba Hydro system of 2020 MW was larger than the operating reserve that Manitoba Hydro was carrying at the time.

When the Manitoba Hydro system lost the 2020 MW of generation, the Manitoba/USA tie lines and the Manitoba/Saskpower tie lines instantaneously made up the generation deficiency on the Manitoba system. Manitoba Hydro's system control started taking actions to balance its generation with the load. Under this disturbance the 1544 MW of exports were interruptible and were curtailed 225 MW of operating reserve was automatically picked up by the southern system hydraulic stations. Purchases of 100 MW from Saskpower, 50 MW from Ontario Hydro and 100 MW from the USA were established.

In addition 30 MW of shutdown hydraulic generation was started. This action balanced the Manitoba Hydro load and generation.

It is important to note that there was no interruption of service to any of the Manitoba customers due to the HVDC lines failure. Some local outages in some parts of the province did occur. However, these were mainly due to local distribution system problems.

Once it was confirmed that all HVDC lines would not be available for several days, the System Control Department took steps to meet Manitoba's load demands without the HVDC system.

1) All available thermal generation was put in service.
2) All southern hydraulic generation out for maintenance was returned to service as soon as possible.
3) Imports of up to 985 MW were arranged with Canadian and USA utilities.

Since the majority of the imports that were arranged were interruptible, a contingency plan was established should Manitoba Hydro lose a generation source on an import at anytime. This contingency plan consisted of identifying four 200 MW blocks of load that could be curtailed and operated on a rotational basis of one block "off" for 0.5 hour and three blocks "on" for 1.5 hours. Should more than 200 MW been needed, these four blocks would have been operated two blocks "off" for 0.5 hour and two blocks "on" for 0.5 hour allowing 400 MW to be controlled.

HVDC Lines Repairs

On the morning of September 5, 1996, crews were assembled to assess the damage and start the repair of the HVDC lines. The number of staff involved in the restoration process at the peak of the activity was 225. The decision was made early in this restoration process to proceed with repairing DC lines 1 and 2 using wooden structures as well as the two electrode lines. At the same time steel towers to complete the repair of DC lines 3 and 4 and to replace the wooden structures on DC lines 1 and 2 were ordered.

By September 9, DC lines 1 and 2 were available for service and the transmission was restored as described in Section 7. By September 14, DC lines 3 and 4 were available and hence the full transmission capability was available.

Between October 11 and October 27, permanent repairs were performed on the HVDC lines. The repairs included the replacement of the wood pole structures on DC lines 1 and 2 as well as reconductring of approximately 5 km of the HVDC lines north of Dorsey Station.

Parallel Operation

The Nelson River HVDC System was the first system planned and designed with high speed paralleling of the two bipoles on one transmission line.
The basic requirement for paralleling is to maintain full Nelson River generation output for a DC line tower failure. With this objective in mind a number of key decisions were made to accommodate parallel operation:

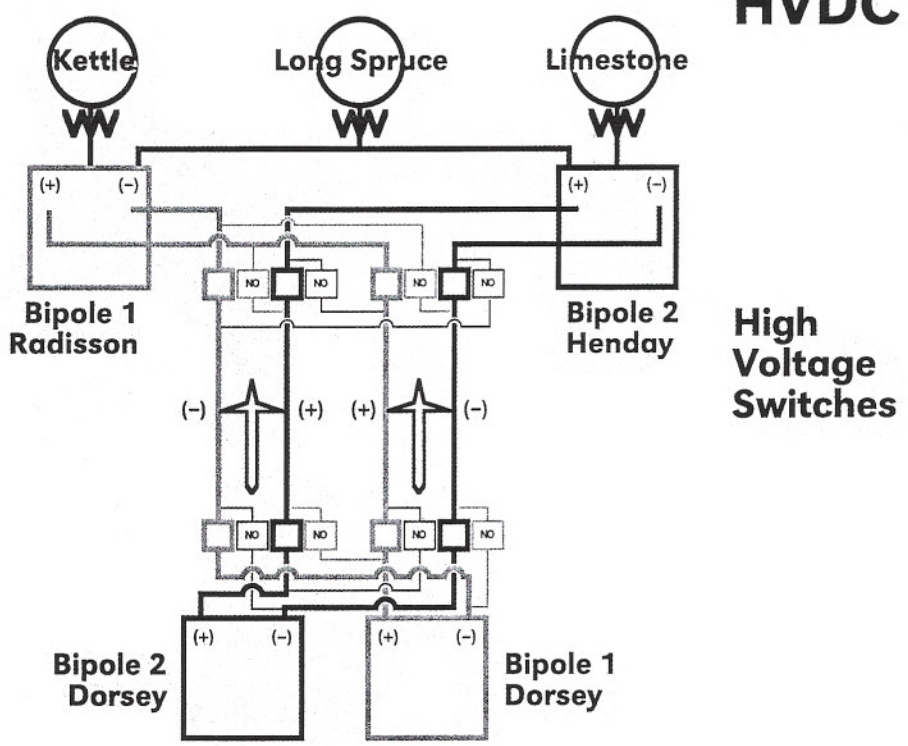


Figure 4: Parallel Operation on two Bipoles

1. The DC lines were built with a conductor capacity of 3 600 A for parallel operation.
2. Bipole 1 which is rated at +/- 463.5 kV and completed in 1977 was specified for parallel operation in the future, although no paralleling controls were incorporated.
3. Bipole 2 which is rated at +/- 500 kV was specified and designed to operate in parallel with Bipole 1.
4. High speed paralleling required high voltage high speed switches (HVHS) with no DC current interruption capability to be supplied for both bipoles.
5. Bipoles 1 and 2 paralleling controls require a substantial number of telecommunications signals.

Therefore, a reliable communications system was incorporated between the two bipoles for the exchange of signals. Manitoba Hydro specified and tailored the system for its need starting from the signal processing equipment to the digital microwave link.

The paralleling controls for Bipole 2 were supplied as an integral part of the contract.

However, the paralleling controls for Bipole 1 were designed and implemented in house. Several unique solutions were adopted to facilitate the paralleling of the converters of two different technologies.

The paralleling scheme was tested and optimized by simulator studies. This was followed by low voltage paralleling tests in 1982 and the final high voltage tests in 1985.

1 DC Circuit

The normal allocation of the converter poles to the DC lines is as shown in **Figure 2**. Pole 1 is on DC line 3, pole 2 is on DC line 2, pole 3 is on DC line 1 and pole 4 is on DC line 4.

Parallel operation is the operation of the two converter poles of the same polarity on one common DC line. Converter poles 1 and 3 (negative poles) can operate in parallel on DC lines 1 or 3, and converter poles 2 and 4 (positive poles) can operate in parallel on DC lines 2 or 4.

2 Paralleling Sequence

To parallel a converter pole to another, a command is initiated automatically from the DC line protection or manually from the Dorsey Control Room operator's desk.

The sequence commands the isolation of the converter pole from its normal DC line by reducing the pole voltage and current to zero followed by opening the appropriate HVHS. The sequence will proceed to connect the converter pole in parallel with the same polarity pole by closing the appropriate HVHS. The sequence does not require the shutdown of any pole to get into parallel operation.

Parallel operation can be discontinued using a manual de-paralleling sequence.

In the event of a fault during parallel operation a fault de-paralleling sequence is initiated. During this sequence the power from the two parallel poles is zero. The faulted pole is isolated from the DC line and the healthy pole can restart following the isolation.

To demonstrate the paralleling sequence, if we consider pole 2 to be paralleled to pole 4 on DC line 4.

1. Pole 2 is isolated from DC line 2 by setting its voltage and current to zero by the control system. This is followed by opening HVHS 201T at Dorsey and Radisson.
2. Pole 2 is parallel connected to pole 4 on DC line 4 by closing HVHS 202T at Dorsey and Radisson.
3. Several specific control functions are only enabled after the two poles are in parallel operation.

The final operating condition is shown in **Figure 3**.

3 Paralleling following the repair of the DC lines

On September 9, following the temporary repairs of DC lines 1 and 2 and the two electrode lines, the availability of converter poles was:

1. Pole 1 (Thyristor Valves) was fully available at (-463.5 kV).
2. Pole 2 (Mercury Arc Valves) was fully available at (+463.5 kV).
3. Pole 3 (Thyristor Valves) was only available at (-250 kV) because one converter transformer at Dorsey was out of service for inspection and bushings replacement prior to the DC line tower failure.
4. Pole 4 (Thyristor Valves) was fully available at (+500 kV).

The maximum transmission capacity of the HVDC system on DC lines 1 and 2 and without parallel operation would be 1 920 MW. This capacity can be obtained by operating pole 1 on DC line 1 and pole 4 on DC line 2. However, using parallel operation of poles 2 and 4 on DC line 2 and operating pole 1 separately on DC line 1 would increase the HVDC transmission capacity by 670 MW to 2 590 MW.

On September 9, at 23:45 hrs. pole 1 was placed in service on DC line 1 at -463.5 kV and on September 10, at 05:43 hrs. poles 2 and 4 were placed in service in parallel on DC line 2. Pole 3 was left out of service. This mode of operation continued until September 14, when DC lines 3 and 4 were available.

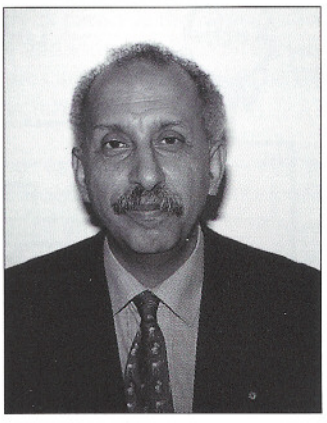
During the period of September 9 to September 14, parallel operation was interrupted only twice due to Mercury Arc Valves problems.

During the reconstruction of the DC lines between October 11 and October 27, the two bipoles operated in parallel as shown in **Figure 4**. The transmission capacity under this condition is 3 420 MW.

During that period the following availability statistics were produced:

1. The overall availability of the HVDC system was 93.14%.
2. The availability of poles 1 and 3 in parallel was 100%.
3. The availability of poles 2 and 4 in parallel was 73.18%.

About the Author



Mohamed Rashwan obtained his B.Sc. in Electrical Engineering from Alexandria University in Egypt in 1966, M.Sc. and Ph.D. from the University of Manitoba in 1971 and 1974 respectively. Dr. Rashwan has been involved with the Nelson River HVDC Transmission in Manitoba Hydro for 25 years. He was involved in Nelson River HVDC transmission as a plant engineer, senior plant engineer at Dorsey station, Dorsey station superintendent, manager of the HVDC transmission operation department, and manager of the HVDC engineering department. Dr. Rashwan is very active in IEEE, CIGRE and IEC. He is an adjunct professor in the department of Electrical Engineering at the University of Manitoba. Dr. Rashwan is currently working with Siemens Power Transmission & Distribution in HVDC. Dr. Rashwan is a Fellow of the IEEE.

Interactive Multimedia Training - What is it really?

by Stéphane Daigle
BGW Multimédia Inc.

Due to the incredible IT developments, the application of interactive multimedia to employee training has become a reality. But for neophytes, the various multimedia applications, and the terminology involved, remain confusing. This article demystifies computer-based training and describes a solution which permits subject matter experts, with no computer programming skills, to create effective interactive multimedia courses, in-house, without having to depend on a plethora of outside specialists.

Grâce aux développements impressionnants des TI, l'application du multimédia à la formation en entreprise est maintenant devenue réalité. Par contre, pour un néophyte, les différentes applications multimédia ainsi que la terminologie qui s'y rattache demeurent parfois déconcertantes. Cet article démystifie la formation assistée par ordinateur et donne une solution qui permet aux experts en contenu de créer des cours interactifs multimédia efficaces à l'interne, et ce sans avoir à détenir des compétences en programmation informatique ou à avoir recours à une panoplie d'experts à l'externe.

BGW Multimédia Inc. (BGW) is active in the corporate training sector. With the rapid developments in information technologies (IT) over the past few years, there is a myriad of new applications and new buzz words in this sector, from CBT, IMT to EPSS. As a follow-up to the article entitled: "Robotics Training for Space Station: Overcoming Limitations" which appeared in the Winter 1998 Edition of the IEEE Canadian Review, this article will discuss these new IT training applications and their strengths and weaknesses as well as their appropriateness given the specific training problem to be solved. Ironically enough, especially given the training industry rhetoric, traditional "stand-up" training still has its place!

New Information Technologies

SMEs, or Subject Matter Experts, possess specific, specialized knowledge. In most organizations, they are frequently called upon to train new employees, or, when equipment or business processes change, they are the ones responsible for bringing the others up-to-date.

"Stand up" or conventional training is the traditional knowledge transfer method. However, this method obliges the SME to juggle the schedules of groups of employees and then spend hours delivering the course to each group, thereby costing the company valuable employee productivity time.

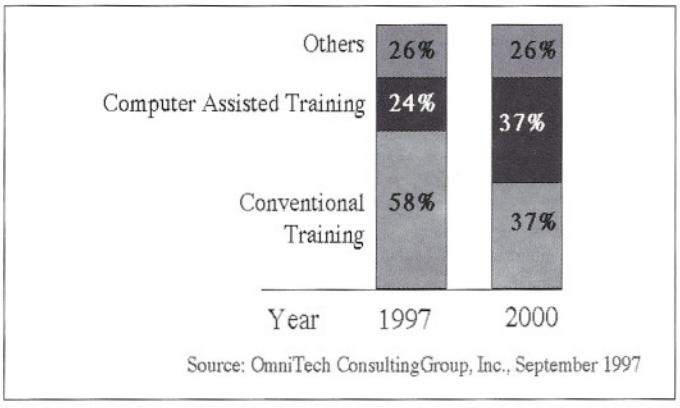
However, today, new information technologies allow SMEs to consider new approaches to transfer their knowledge. The following are amongst the most popular:

- **Electronic Information Systems:** A Web site is a good example of such a system. The SME can structure his/her knowledge on different Web pages. By doing so, peers can directly access this knowledge, virtually, from anywhere in the world. In addition, modifications and updates are instantaneously available to others. However, information systems, whether paper-based or electronic, lack the guidance and student tracking mechanisms found in training systems.
- **CBT (Computer-Based Training) Systems**: These systems are based on the material found in information systems. A course structure and learning scenarios are added which the student can use as a guide through the material. Also, there are "check points" in the course (i.e. interactive exercises) that allow the system and Course Administrator to verify the student's level of comprehension. CBT systems are typically distributed on CD-ROMs or LANs (Local Area Networks).
- **WBT (Web-Based Training) Systems:** These systems are just like their CBT counterparts, except that they are delivered using Web, or more generally speaking, Internet technologies. They normally take advantage of the widespread accessibility of the Internet to re-create virtual classrooms. For bandwidth reasons, the use of multimedia elements is not normally emphasized here. Rather, course developers and administrators use e-mail, chats, white-boards and news-groups to create environments where students and instructors can interact to stimulate learning. Also, specialized systems are now available to allow student tracking and evaluation. These systems allow Course Designers to create quiz banks that can be accessed by students to verify their level of comprehension.
- **EPSS (Electronic Performance Support Systems):** These systems permit individuals direct access to structured expert knowledge "just-in-time" when it is required. EPSS is also a very promising avenue in the use of computers to help employees do their job more efficiently. An EPSS can take various forms. One of the simplest consists of adding a search engine to an existing information system. A more sophisticated approach is to use rule-based, or expert, systems to allow employees to interact with the computer in order to solve a problem encountered on the job.

It is important to note, however, that not ALL training material is suited to computer-based delivery. In order to determine which is the most appropriate method, it is important to focus on the goals to be achieved by the training. Training about company policies and culture are typically good examples of subjects which are better delivered in the traditional manner. In fact, it is very common to use a hybrid approach, mixing elements of both CBT and stand-up delivery methods. An effective combination of the two approaches allows the instructor to concentrate on the essential points to be taught, knowing that the basics have been covered by a CBT and reviewed and understood by all students before the traditional training takes place.

The Advantages Of Interactive Multimedia Training

Studies show that the use of computer-based training will increase significantly in the next few years as shown in the following figure:



Source: OmniTech ConsultingGroup, Inc., September 1997

But why is this so? The answer lies in the major advantages of what we call interactive multimedia training (IMT) which includes both CBT and WBT. These advantages have already been proven in concrete training circumstances:

- **Early Delivery:** Through the use of IMT, corporations don't have to wait until a group of employees needs training before training individuals. Rather, since training does not require an instructor, it can be delivered to anyone, as soon as it is needed.
- **Self Paced:** Since training is based on the interaction between an individual and a computer, the individual can send as much time as needed on any subject. Material already understood can be skipped or quickly reviewed thus allowing to spend more time on new material. Learners are not are not slowed down nor left behind by a group.
- **Easy Updates:** Traditional course delivery normally requires printed material which is often complicated to keep up-to-date because of delays imposed by the printing process. IMT delivered through a network makes any update immediately available to all learners.
- **Consistent Training Quality:** The quality of traditional training often relies upon the competence of individual trainers. It is not rare to see different levels of competence in a corporation simply because learners had a different trainer for the same course. With the use of IMT, each course can be reviewed by a set of experts and thus be guaranteed to contain accurate information, and pertinent exercises.
- **Significant ROI:** The single most important reason why IMT is becoming so popular is because of the return on investment (ROI) factor. Even if IMT-based course creation is more expensive, it has been repeatedly demonstrated that course delivery is much more cost effective. This is because employees can be trained on-site, and in a shorter period of time. Expenses related to travel and lost employee productivity are thus eliminated. Also, through IMT, it is possible to train employees in less critical periods of their work shifts.

All of these advantages translate into a better and more efficient training environment which is directly in line with the total quality trend currently sweeping the competitive international business scene.

Transferring A Traditional Course To IMT Format Is Not Free

If IMT has all the advantages listed above, then why isn't it already widespread? Well, the reason is technology. We are just arriving at a point in technology and software development where it is possible to create efficient IMT at a reasonable cost. For example, based on our professional experience:

- One hour of a professional course can take up to 200 to 300 person hours to create. With new technologies and new software, the development of one hour of an "internal course" (i.e. a course to be viewed by employees rather than by clients) can be reduced to 50 person hours.
- It is more difficult to create a CBT than traditional stand-up training because the instructor is not "there" when the students take the course and thus it cannot compensate for any minor problems with content packaging or delivery which are perceived as the course is being delivered.

For professional course development, there will always be a significant amount of media production (i.e. narration, sound effects, photography and video production) which require efforts that contribute to increasing the associated course development time. However, it is becoming easier every day to create "internal" IMT because of the following reasons:

- **Media creation is simpler:** Today, almost all new PCs sold are multimedia-ready. This means that they have an integrated sound card with relatively simple audio sound recording capabilities. Second, not so long ago, the only way to use photographs in multimedia presentations or courses was to digitize them with a scanner. Now, digital cameras can record images directly in, for example, JPEG format. Kodak has also developed the Photo-CD standard which develops traditional 35 mm film directly on a CD-ROM. Finally, video grabbing is becoming very affordable with video cards below the $1,000 bracket. As well, there now exist video cameras which record directly in MPEG format which can be downloaded to a computer using a serial connection or even a PC memory card.
- **Media editing tools are easier to use:** A few years ago, only professionals and very determined hobbyists could consider using media editing tools. The reason was that the market focus was on the development of increasingly powerful tools such as Adobe's PhotoShop and Avid's MediaSuitePro. While this is still the case today, more simple derivatives of these tools, aimed at the general market are now available. This new generation of tools, while less powerful than their professional counterparts, are very easy to use and effectively bring media editing within range of the average literate computer user.
- **Authoring tools are becoming more focused:** In essence, an authoring tool is a simplified programming environment used to create multimedia software. As for the editing tools, authoring tools, where all the media are put together to form an application, used to be very complicated to use. Why? These tools were "general purpose" tools, for the development of any type multimedia application, from information kiosks to full fledged simulators. Today, a new generation of tools, specifically aimed at interactive multimedia course development, is emerging. Focused on the training sector, these tools offer specialized functions and templates useful for the Course Designer, at the cost of removed fancy "bell and whistles" which are normally used for marketing applications.

Tactic!™, aimed at helping SME's develop IMT, is just such a tool and one of the first of its kind to appear in the marketplace. In the next part of this article, Tactic!™ will be described in some detail.

Tactic! Is More Than An Authoring Tool

Tactic!™ is a multimedia course development tool developed by BGW Multimédia to allow SME's, who are not programmers or multimedia experts, to easily create effective multimedia courseware. With Tactic!™, SME's don't have to depend upon a full team of experts to transfer their knowledge to employees or to their peers. The underlying philosophy behind Tactic! is that the Course Developer should concentrate on developing and structuring content for the target audience, rather than fiddling with a complicated multimedia application development tool. Thus, Tactic!™ comes with the pre-built Tactic!™ Viewer that already handles standard navigation within a course and the playback of interactive multimedia documents.

Tactic!™, is based on a proven multimedia course development methodology. It is a lot more than a standard authoring tool because it accompanies the SME through all phases of the course development process:

- **Needs Assessment**: During this phase, the SME must analyze all aspects of the training context. The Tactic!™ methodology explains how to thoroughly complete this type of analysis. It also offers a set of pre-defined questionnaire templates which can be adapted to the specific needs of any organization. With the help of these questionnaires, the SME can gather and structure all relevant information concerning the learning context, the learners, and the items to be learned.
- **Design:** The design phase begins with the creation of a course structure. This is a hierarchical structure composed of learning units and multimedia documents created directly using the Tactic!™ Editor. For each item in the course structure, the designer can enter specific information in pre-defined fields. This information is then used by Tactic!™ to create reports and/or help the designer in the upcoming phases of the course development process. Some of this information, such as "learning objectives," is even directly presented to the learner. Also, Tactic! comes with a complete set of multimedia document templates that also help the course designer to structure the course information.
- **Production:** After the design phase is competed, media "shells" or media place holders are put inside documents by the Course Designer. Every time the designer adds a media element to a document, Tactic!™ keeps a record of it in its Media List. Once all of the documents are created, the Course Designer can move into the Tactic!™ Media Manager to work with the Media List. Within this tool, the Designer can sort, filter and perform search operations for any media element. He/she can also create different reports which can be used, if needed, as work orders for media production professionals. Once the media elements are produced, they then can be dropped directly into the Tactic!™ Media Manager which will automatically associate each one with its corresponding media "place holder" in all of the course's documents.
- **Integration:** Once all of the media elements have been created and imported, the Course Designer can finalize the page layout and, where needed, synchronize the media in each document. Media synchronization allows the user to create multimedia and even interactive slide shows.

It is important to note that when using traditional authoring tools, this is where final programming and debugging would be done. Since Tactic!™ contains pre-programmed objects such as different kinds of exercises, such programming is not required from the user.

- **Publishing:** Once the course is complete, it is ready to be packaged for distribution to learners. This is done in the publishing phase. With Tactic!™, publishing is straightforward thanks to the Publishing Wizard which guides the Course Designer through all the necessary steps. It is possible to create a course package, including an installation program ready to be put on a CD-ROM, or a publish the course as part of a course list on a LAN. It is also possible to create "update" packages which only include modifications of the course made since the last "full package" was published.

What About Validation?

Validation is one of the most important parts of creating a valuable interactive multimedia course. The Tactic!™ Methodology proposes specific times when validation should occur within the process. In Tactic!™, validation is supported at three different levels:

- **Validation through reports:** Tactic!™ may be used to generate storyboards and design reports which can be reviewed by clients or peers.
- **Validation of prototypes:** Tactic!™ supports a rapid prototyping course development approach. This means that at anytime during the course development process, it is possible to see the course in the Tactic!™ Viewer and thus get a feeling of what the learner will experience. In prototypes, missing media elements are presented in their shell form which contain a written description of the intended contents.
- **Validation of the final course:** Once the course (or a part of the course) is complete and has been revised, it should be validated by a group of learners representative of course's target audience. This validation allows the Course Designer to confirm that the course is well adapted to the learners' needs.

Don't Forget Student Tracking

When developing IMT, student tracking should always considered. Only through effective tracking is it possible to verify that students are actually learning and also calculate the return on investment (ROI) for the organization. This is the basis needed to effectively know that training is efficient and worth the organization's investment.

Tactic!™ supports the AICC (Aviation Industry CBT Committee) standard for student performance tracking. This means that it can be linked to any AICC compliant CMI (Computer Managed Instruction) tool, such as Manager's Edge from Allen Communications, and exchange information with it.

The CMI tool allows the training manager to enroll students in any course from a list of available courses (developed by Tactic! or by any other means). Once a student has completed a given course, he/she can move on to the next one. The Training Manager can track the results obtained by the learner in all AICC compliant courses. These results can then be compiled and assembled in different comparative reports to analyze the efficiency of the training program.

Conclusion

Thus, conventional stand-up training, CBT, WBT and EPSS, and the spectrum of training solutions in between, all have their place in the professional environment of today. Thanks to IT developments, training professionals, as well as subject matter experts (SMEs) who are increasingly called upon to develop effective courseware, have a myriad of options from which to choose, depending on which is the most appropriate to the specific training situation.

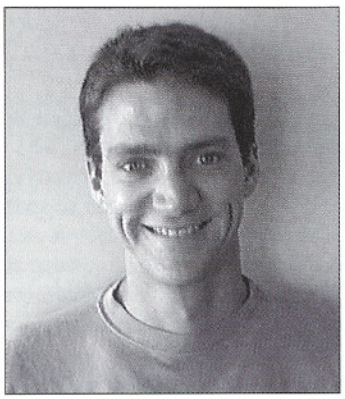
If CBT is deemed to be the most appropriate training method, multimedia course design solutions such as Tactic!™ simplify the whole multimedia course creation process, from needs assessment to final publishing and update. Supported by a proven computer-based training methodology, Tactic!™ is part of a new generation of more targeted authoring tools which offer specialized functions to help the SME (non-programmer) quickly create effective CBT.

References

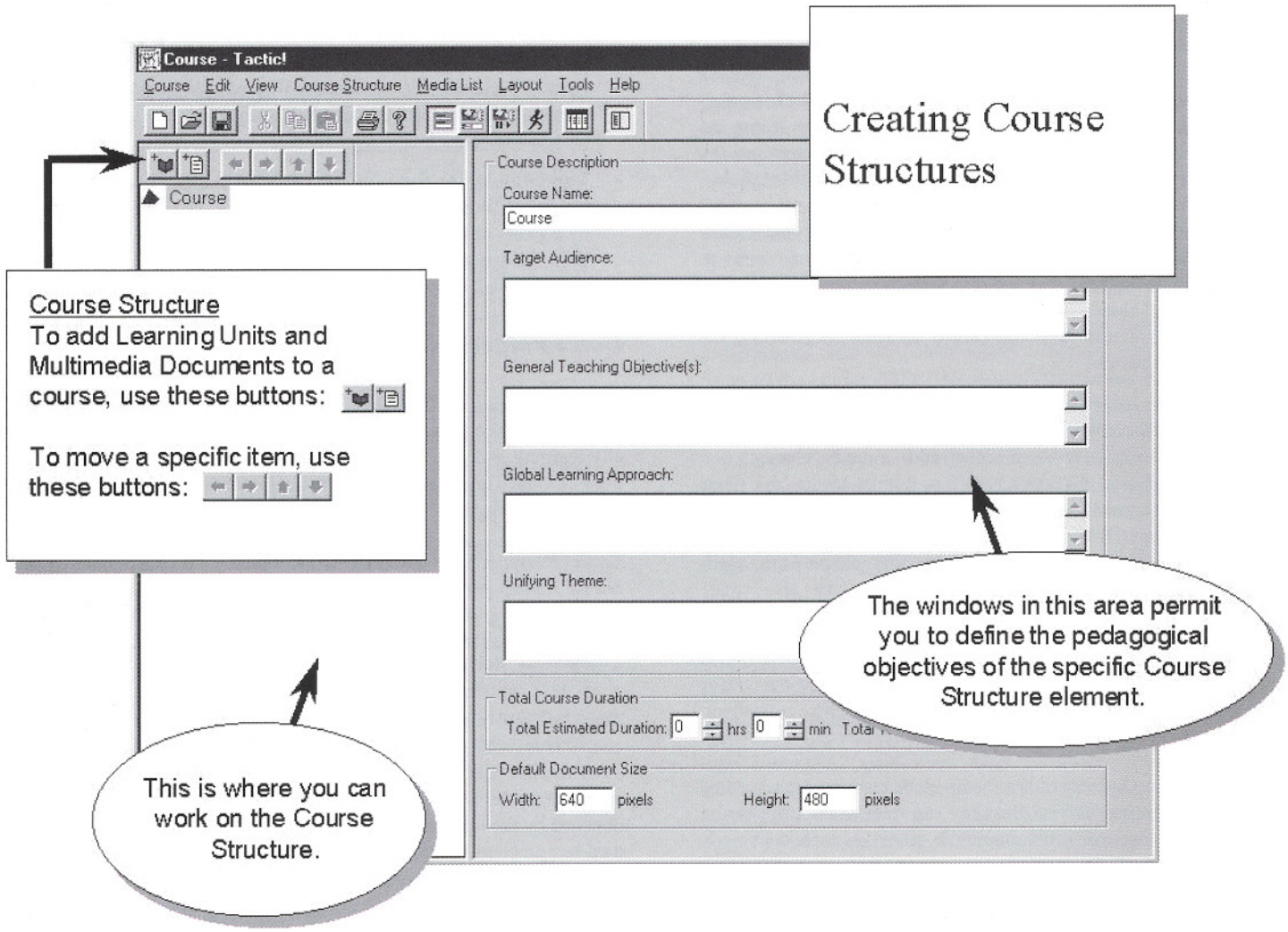
E. Greenberg, "Robotics Training for Space Station: Overcoming Limitations", IEEE Canadian Review, Winter 1998.

S. Bergstrom, "CMI Guidelines for Interoperability", AICC CMI Subcommittee (Document CMI001), Revision 1.9 July 1997.

About the Author



Stephane Daigle has been with BGW Multimédia Inc. since the company's inception in the early 1990's. With a Bachelor's Degree in Computer Science from the University of Sherbrooke, he also completed Masters level studies at McGill University. Stephane has extensive experience in multimedia application development, due to his involvement in a variety of multimedia projects where he played various roles, ranging from Applications Specialist to Project Director. Currently, Stephane is the Director, Software Development, at BGW Multimédia, and is responsible for the development of Tactic!.



(continued from page 4 / *suite de la page 4*)

- nous sommes à préparer une brochure sur les activités professionnelles afin de promouvoir les relations avec l'industrie;
- un catalogue informatisé des activités de formation a été réalisé et nous le proposons présentement comme projet pilote dans la section de Toronto;
- deux didacticiels aménagés en fonction du web sont en préparation : l'un sur les réseaux neuronaux et l'autre sur les automates programmables;
- en appartenant à l'Institut Canadien des Ingénieurs (ICI), nos membres peuvent aussi inscrire leurs activités professionnelles et de formation continue dans le registre de l'ICI, mis sur pied afin que les membres puissent mettre à jour leur dossier professionnel provincial;
- les bulletins électroniques;
- le périodique Canadian Review, envoyé à tous les membres d'IEEE Canada, contient des articles sur des réalisations canadiennes en électrotechnologie;
- le Canadian Journal of Electrical and Computer Engineering, disponible par abonnement, présente les contributions et développements techniques d'importance;
- l'automne prochain verra le jour d'un nouveau programme de développement du leadership pour les bénévoles et les membres; ce nouveau programme de l'IEEE sera mis à l'essai au Canada;
- la conférence annuelle canadienne sur le génie informatique et électrique.

Les activités étudiantes se verront promues par le tout nouveau secteur d'activités étudiantes du Mississauga DeVry Institute of Technology.

Au niveau mondial, l'IEEE offre les nouveaux services suivants aux membres:

- une nouvelle série de documents vidéo Entrepreneurial Skills Workshop (Ateliers de compétences en gestion d'entreprise) que les unités de l'IEEE peuvent emprunter; pour ce faire, les unités canadiennes doivent contacter le bureau d'IEEE Canada;
- les programmes DDD (diplômés de la dernière décennie) [ce qu'on appelle en anglais les programmes GOLD (Graduates of the Last Decade)] à l'intention des nouveaux diplômés et des jeunes professionnels;
- des groupes de liaison pour le maillage et la mise en œuvre de programmes sur les sujets comme DDD, les femmes en génie et les réseaux de consultants.

Dans le cadre du projet Internet de l'IEEE, les services suivants sont prévus ou, dans certains cas, sont déjà disponibles :

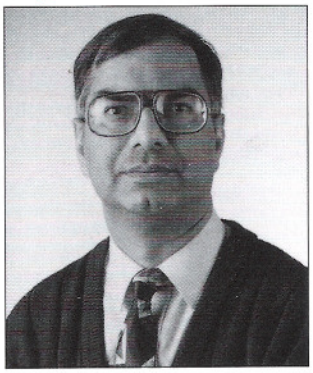
- le courrier électronique personnel par pseudonyme (mail alias) dans le domaine ieee.org, avec la fonction de détection de virus;
- l'hébergement de sites web pour les unités de l'IEEE comme les Régions, les Sections et les Sociétés;
- l'authentification unique;
- la mise à jour des dossiers des membres;
- le catalogue électronique de tous les 4700 produits disponibles;
- la recherche améliorée du contenu du site;
- les renouvellements d'adhésion (la possibilité d'ajout, de modification et de suppression pour tous les services);
- les demandes d'adhésion de nouveaux membres.

Les services et les programmes offerts par l'IEEE dépendent en grande partie de l'esprit de créativité et de l'enthousiasme des membres bénévoles. Si vous désirez vous impliquer dans notre organisation, veuillez me contacter à l'adresse « d.kemp@ieee.org » ou au (204) 992-2494 (téléphone et télécopieur).

Quelque mots du redacteur en chef

By / *par Vijay K. Sood*

Researcher / chercheur
Hydro-Québec (IREQ)
1800 boul. Lionel-Boulet
Varennes, Québec. J3X 1S1
Phone: (450) 652-8089
Fax: (450) 652-8051
e-mail: sood.vijay@ireq.ca



Le présent numéro constitue une étape importante de l'évolution de Canadian Review. Nous sommes à tenter une nouvelle expérience et voulons prendre le pouls de nos membres au sujet d'une publication comportant plus de textes en français. En effet, nous ajoutons la traduction complète de l'article principal aux courts résumés en français des articles les plus importants. Nous suivrons de près, bien sûr, les coûts supplémentaires engendrés par ce projet, mais si nos membres le souhaitent et que le nombre de membres qui en bénéficieront est suffisant, nous ferons en sorte de répondre à ce besoin. Je tiens à remercier Marc Provencher, membre de la section Saint-Maurice (Trois-Rivières), qui s'occupe de faire traduire les textes. Nous aimerions avoir vos commentaires en ce qui concerne la qualité de ces traductions.

L'IEEE poursuit son objectif de mieux répondre aux attentes de ses membres. Le rapport de notre président, Dave Kemp, reflète d'ailleurs les efforts déployés par IEEE Canada en vue de tenir compte de l'évolution du monde du travail.

De plus, le présent numéro de Canadian Review est publié, pour la première fois, de manière indépendante. Nous y avons donc mis beaucoup d'effort personnel et nous souhaitons que la qualité ne soit pas en reste. L'apport bénévole des corédacteurs fut précieux. J'aimerais également souligner l'appui que j'ai reçu de la part de mon épouse Vinay, qui a réalisé le traitement de texte et participé à la composition de la revue.

Les recettes publicitaires rentrent lentement, ce qui nous aiderait à défrayer les coûts de publication. Nous aimerions toutefois faire paraître plus d'annonces dans la Canadian Review. Si vous ou votre entreprise aimeriez en faire paraître une, n'hésitez donc pas à communiquer avec moi. Le coin des consultants est bien parti et nous vous invitons à y insérer vos cartes d'affaires.

En terminant, nous avons été profondément attristés par la nouvelle de la tragédie aérienne à Mirabel qui a coûté la vie à neuf ingénieurs travaillant de la Générale Électrique du Canada ainsi qu'à deux membres d'équipage. Cet accident m'a touché personnellement, car j'y ai perdu un bon ami. Je voudrais transmettre mes plus sincères condoléances à tous les parents et amis des personnes qui ont péri dans cet accident.

A few words from the Managing Editor

This issue marks another milestone for the Review. We are now embarking into a new experiment to test the waters about a more bilingual Review. Instead of just a short abstract in French for the principal articles, we are adding a full translation of the lead article. Of course, we will be keeping track of the added expense that this will entail, but if the readership wants it and warrants it, then we will try to fulfil that need. The assistance of Marc Provencher from the Saint Maurice section (Trois Rivières) for getting the translation done is gratefully acknowledged. Your assistance in evaluating the quality of the translation is sought.

The move towards a more membership-oriented IEEE continues and the report by President Dave Kemp shows the effort that has been put in by IEEE Canada to meet the demands of members and a changing business environment.

This issue also marks the first independently produced Review following my re-location to the Electrical Equipment Department at IREQ (my new address is above). It is a lot of personal effort and I hope that the quality is not compromised. The voluntary contributions of the associate editors are a big help and I acknowledge their efforts. I acknowledge also the appreciable support provided by my wife Vinay for entering the data and assisting with the typesetting.

Note also that the Associate Editor from Saskatoon has recently relocated to Ottawa; I expect that the high-tech industry in Ottawa will take advantage of this and provide further articles for the Review.

Advertising revenue is slowly trickling in and helps to defray the costs of publication. We would like to see more advertisements in the Review, and if you or your company would like to use this vehicle, please do not hesitate to contact me. The *Consultant's Corner* is in place, and any business card placements are welcome (see below).

Finally, on a sad note, the recent aeroplane disaster at Mirabel caused the untimely death of nine engineers from General Electric Canada and two crew members from the airline. I lost a close friend in that accident. My sincerest condolences to all the families and friends of the people who perished in that accident.

Consultants Corner

Consultants are invited to publish their business cards and services offered in the **IEEE Canadian Review**. Please contact the Editor for information regarding publishing dates and rules. The rates are 300.00 dollars for one issue or 750.00 dollars for a series of three issues.

Consultants Inc.
Address

Services Offered