

REPORT  
OF  
ACTIVITIES

1992



Hydro-Québec



HYDRO-QUÉBEC'S VICE-PRÉSIDENCE TECHNOLOGIE ET IREQ (TECHNOLOGY AND IREQ) CONDUCTS RESEARCH, TESTING, DEVELOPMENT AND DEMONSTRATION IN CONNECTION WITH THE GENERATION, TRANSMISSION, DISTRIBUTION AND USE OF ELECTRICITY.

MOST OF ITS ACTIVITIES ARE DESIGNED TO MEET HYDRO-QUÉBEC'S SHORT-TERM OR MEDIUM-TERM NEEDS THAT ARE DIRECTLY RELATED TO CUSTOMER SATISFACTION. SOME OF ITS RESOURCES, HOWEVER, ARE DEVOTED TO TECHNOLOGY FORECASTING AND LONG-TERM PROJECTS. IN ADDITION, THE GROUP IS RESPONSIBLE FOR CHARTING THE COURSE OF HYDRO-QUÉBEC'S TECHNOLOGICAL DEVELOPMENT, AND PROMOTING THE PRODUCTS OF ITS RESEARCH. IT WORKS WITH MANY DIFFERENT ORGANIZATIONS IN CANADA AND ABROAD, INCLUDING RESEARCH CENTRES, UNIVERSITIES AND PRIVATE-SECTOR COMPANIES.

ITS HUMAN RESOURCES TOTAL ABOUT 800 PERSON-YEARS, 592 OF WHICH ARE PERMANENT POSITIONS. IN 1992, ITS OPERATING BUDGET WAS \$121 MILLION.

TECHNOLOGIE ET IREQ HAS IMPRESSIVE RESEARCH AND TESTING FACILITIES AT ITS DISPOSAL: TWO LARGE LABORATORIES (ONE HIGH-VOLTAGE, THE OTHER HIGH-POWER) FOR THE DEVELOPMENT AND TESTING OF TRANSMISSION AND DISTRIBUTION EQUIPMENT AND SYSTEMS; A POWER-SYSTEM SIMULATION CENTRE; AN ELECTROCHEMICAL AND ELECTRICAL TECHNOLOGIES LABORATORY; AND ABOUT 60 SMALL, SPECIALIZED LABORATORIES.

IN ADDITION TO THE WORK IT DOES FOR HYDRO-QUÉBEC, TECHNOLOGIE ET IREQ CONDUCTS RESEARCH AND DEVELOPMENT FOR OUTSIDE CLIENTS.

## VICE-PRÉSIDENCE TECHNOLOGIE ET IREQ

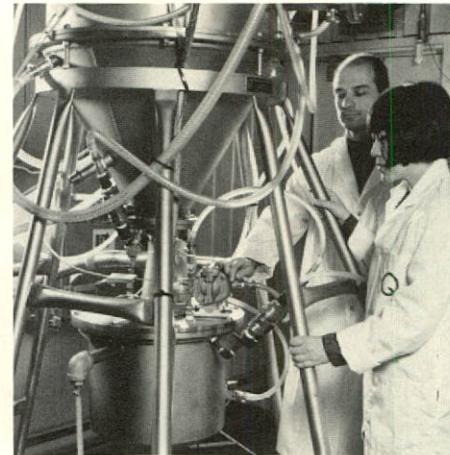
1. MARIE ROCHEFORT AND PIERRE GIROUX (POWER SYSTEM SIMULATION, IREQ)
2. MARIO PAQUIN AND LUC QUINTAL (HIGH-POWER LABORATORY, IREQ)
3. MY DUNG HANDFIELD AND FRANÇOIS ALLAIRE (INDUSTRIAL PLASMAS, LTEE)
4. CAROLE GEMME AND LINE PRÉVOST (HUMAN RESOURCES, SUPPLIES AND INFORMATION, IREQ).
5. DENISE DAUDELIN AND JEAN-JACQUES LEFEBVRE (DEVELOPMENT PROJECTS, FÉLIX-MARTIN)



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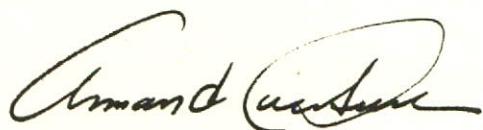


Cover  
MARIE-CLAUDE PÉTRIN  
AND RENÉ DUBUC  
(MATERIALS  
TECHNOLOGY, IREQ)

I AM PLEASED TO PRESENT THE 1992 REPORT OF ACTIVITIES OF THE VICE-PRÉSIDENCE TECHNOLOGIE ET IREQ. AS HYDRO-QUÉBEC'S NEW PRESIDENT AND CHIEF OPERATING OFFICER SINCE SEPTEMBER 1992, I HAVE HAD NUMEROUS OPPORTUNITIES TO WITNESS THE QUALITY OF THE WORK CARRIED OUT BY THE TECHNOLOGY AND IREQ STAFF, WHOM I CONGRATULATE FOR THEIR ACHIEVEMENTS AND PROFESSIONAL INTEGRITY.

BY MAKING R&D AND TECHNOLOGY-RELATED ACTIVITIES PART OF THE OPERATIONS GROUP, HYDRO-QUÉBEC WAS SEEKING TO INCREASE THE SYNERGY BETWEEN THE SUPPLIERS AND USERS OF TECHNOLOGICAL PRODUCTS. AS CAN BE SEEN BY THE RESULTS PRESENTED IN THIS REPORT, THE STAFF HAS MOST CERTAINLY RISEN TO THE CHALLENGE WITH UNQUESTIONABLE ENTHUSIASM. OUR R&D ACTIVITIES, WE ARE CONVINCED, WILL HELP US TO REDUCE OUR OPERATING COSTS AND INCREASE BOTH THE CONTINUITY AS WELL AS THE QUALITY OF SERVICE.

BETWEEN NOW AND THE YEAR 2000, HYDRO-QUÉBEC INTENDS TO DEVOTE 2% OF ITS REVENUE TO RESEARCH AND DEVELOPMENT, AN INCREASE FROM THE RATE OF 1.7% - 1.9% IT HAD BEEN MAINTAINING SINCE 1988. THIS COMMITMENT REFLECTS THE UTILITY'S DETERMINATION TO PURSUE ITS R&D ACTIVITIES, DESPITE THE CURRENT STATE OF THE ECONOMY. IN 1992, HYDRO-QUÉBEC RANKED SIXTH AMONG CANADIAN FIRMS IN TERMS OF R&D FUNDING AND COMPARED FAVORABLY WITH OTHER LARGE ELECTRICAL UTILITIES WORLDWIDE. HYDRO-QUÉBEC'S CONSIDERABLE R&D EFFORTS ARE JUSTIFIED NOT ONLY BY THE UNIQUE NATURE OF ITS POWER SYSTEM BUT ALSO BY THE UTILITY'S RESOLVE TO MAINTAIN ITS COMPETITIVENESS ALONG WITH THE QUALITY OF SERVICE WHICH ITS CUSTOMERS EXPECT.



ARMAND COUTURE  
PRESIDENT AND CHIEF OPERATING OFFICER  
HYDRO-QUÉBEC

## MESSAGE FROM THE PRESIDENT AND CHIEF OPERATING OFFICER



THE YEARLY PUBLICATION OF THE REPORT OF ACTIVITIES IS AN OPPORTUNITY TO REVIEW OUR STAFF'S WORK AND PRESENT THEIR MOST NOTEWORTHY ACHIEVEMENTS. I WOULD LIKE TO COMMEND THIS REMARKABLE GROUP OF MEN AND WOMEN WORKING ON HYDRO-QUÉBEC'S TECHNOLOGY OF THE FUTURE FOR THEIR EXPERTISE AND ENTHUSIASM IN CARRYING OUT A WIDE RANGE OF PROJECTS SUCH AS THE USE OF ELECTROSYNTHESIS IN THE DEVELOPMENT OF NEW INDUSTRIAL PRODUCTS, A STUDY ON REPAIR MATERIALS AND TECHNIQUES FOR CONCRETE STRUCTURES, THE USE OF ROBOTICS AND TELEROBOTICS IN LINE MAINTENANCE, THE DEVELOPMENT OF EXPERT SYSTEMS AND DISTRIBUTION SYSTEM PLANNING SOFTWARE, LABORATORY TESTING OF ELECTRICAL APPARATUS, A SIMULATION STUDY OF THE MULTITERMINAL DC NETWORK, MAGNETIC FUSION, EQUIPMENT CORROSION, THE DEVELOPMENT OF LITHIUM-POLYMER BATTERIES, ETC. I WOULD ALSO LIKE TO THANK THOSE WHO CONTRIBUTED TO THE ABOVE ACHIEVEMENTS, WHETHER THROUGH THE MANY SERVICES THEY PROVIDED OR THROUGH THEIR ROLE IN PLANNING AND PROMOTION.

HYDRO-QUÉBEC HAS CLEARLY STATED IN ITS PERFORMANCE CHALLENGE PROGRAM THAT IT INTENDS TO BE THE TOP CANADIAN ELECTRICAL UTILITY BY THE TURN OF THE CENTURY. I AM CONVINCED, ALONG WITH OUR STAFF, THAT RESEARCH AND DEVELOPMENT WILL BE INSTRUMENTAL IN ACHIEVING THIS GOAL WITH RESPECT TO SERVICE CONTINUITY, EQUIPMENT AVAILABILITY, AND A DECREASE IN OPERATING COSTS AND CAPITAL EXPENDITURE.

AT THE SAME TIME, WE WILL CONTINUE WORKING TOWARDS TOTAL QUALITY MANAGEMENT. WE HAVE SET MAJOR OBJECTIVES IN OUR QUALITY PROGRAM FOR 1993, ESPECIALLY IN TERMS OF STRENGTHENING OUR CLIENT-SUPPLIER APPROACH WITHIN THE VARIOUS DEPARTMENTS, THE TRANSFER OF TECHNOLOGY BETWEEN THE R&D AND OPERATIONAL UNITS, AND, OF COURSE, MANAGING OUR IMPROVEMENT TEAMS, WHICH WILL TOTAL 33 BY THE END OF 1993. OTHER MEASURES INVOLVE THE COMMISSIONING OF QUALITY ASSURANCE FACILITIES AND NETWORKING WITH OTHER FIRMS, RESEARCH CENTRES AND UNIVERSITIES IN R&D, DEMONSTRATION AND TESTING AS WELL AS PRODUCT PROMOTION WITH AN AIM TO APPLYING TOTAL QUALITY AT ALL LEVELS, WITHIN THE UTILITY AS THROUGHOUT QUÉBEC, THE REST OF CANADA AND ABROAD.

IN CONCLUSION, I WOULD LIKE TO SAY THAT, IN THE LIGHT OF THESE ACHIEVEMENTS OF OUR STAFF, I AM ALL THE MORE CONFIDENT OF EVEN GREATER ACCOMPLISHMENTS TO COME.

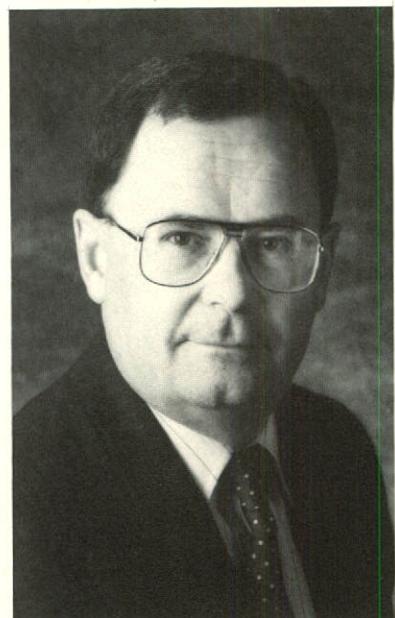


ALAIN BROSSEAU

VICE PRESIDENT

TECHNOLOGIE ET IREQ

## MESSAGE FROM THE VICE PRESIDENT



## TABLE OF CONTENTS

- 1 VICE-PRÉSIDENCE TECHNOLOGIE ET IREQ**
- 2 MESSAGE FROM THE PRESIDENT**
- AND CHIEF OPERATING OFFICER**
- 3 MESSAGE FROM THE VICE PRESIDENT**
- 6 TECHNOLOGY PLANNING**
- 10 GENERATION**
  - 11 Concrete-related projects
  - 11 Borehole inspection system
  - 12 Optimum generation planning
  - 12 The MATH project
  - 13 The Scompi robot
  - 14 SUPER: continuous monitoring for turbine-generators
  - 14 Wind turbine-diesel generator combinations with a high penetration level and no storage
- 15 TRANSMISSION**
  - 16 Testing at the high-voltage laboratory
  - 16 Transformer failure at LG-4
  - 17 Calculation of current in substation grounding systems
  - 17 Modeling of transformer windings
  - 18 Performance of HVDC wall bushings
  - 18 New gas mixtures for outdoor circuit breakers
  - 18 Dynamic tests on composite phase spacers
  - 19 Transformer and reactor tank resistance
  - 19 Naphthenic oils
  - 20 Main tests at the high-power laboratory
  - 21 Predicting geomagnetic storms by satellite
  - 22 Study of a DC link in India
  - 22 Automatic reactive compensation
  - 23 Real-time simulation of electromechanical phenomena
  - 23 Effect of series compensation on the stability of the MDCN control systems
  - 24 Hydrogen embrittlement of anchor bars
  - 24 Overhead-line vibration
  - 25 Evaluation of the structural integrity of a 69-kV line
  - 25 EHV underground cable testing
  - 26 Electromagnetic compatibility in substations
  - 27 Lightning-detection system
  - 28 Digital stabilizer
  - 28 Characterization of high-voltage cables on the underground transmission system
  - 29 Biological effects of electromagnetic fields on cattle
  - 30 Measurement of ground potential during geomagnetic storms
  - 30 On-line condition-monitoring system for double-pressure SF<sub>6</sub> circuit breakers
  - 31 Overhead ground wires incorporating optical fibres
  - 31 LOCADEF: a new fault-location system
- 32 DISTRIBUTION**
  - 33 Study of the stability of coating materials
  - 33 Tele-operated maintenance system
  - 34 Energy limit of distribution transformers
  - 34 Amorphous-steel-core transformers
  - 35 Lightning-current measurement
  - 36 Nondestructive testing of wood pole resistance
  - 36 Characterization of electrical connectors for the distribution system
  - 37 Multiple-electrode devices for nondestructive testing of electrical joints
  - 37 Chemical additives to replace PCP
  - 38 Testing gas detectors
  - 38 Main tests at the high-power laboratory
  - 40 Long-term distribution system planning
  - 40 Tests on water-saturated cables
  - 41 Power quality monitoring
  - 41 Limit conditions for use of Elastimold joints

**42 APPLICATIONS OF ELECTRICITY**

- 43 Organic electrosynthesis of anthraquinone
- 43 Oxidation by cerium
- 43 Electrocoagulation of proteins
- 44 Recycling of industrial acid waste
- 44 Aluminium recovery demonstration unit
- 45 Installation of an industrial unit for aluminum recovery
- 45 Production and forming of powders and ceramics
- 46 Graphite drying
- 46 Evaluation of the energy efficiency of electric motors
- 47 Alternatives to all-electric heating
- 47 High-frequency hardening of concrete

**48 LONG-TERM PROJECTS**

- 49 Superconductivity
- 49 New developments in lithium-polymer batteries
- 50 The hydrogen project
- 50 Magnetic fusion
- 52 Telerobotics
- 52 Electrochemical approach to the study of interfaces
- 53 Electrode materials for hydrogen research activities
- 53 Shape-memory alloys

**54 EXPERT SYSTEMS AND MEASUREMENT**

- 55 SESA: an intelligent design system for auxiliary services
- 55 Expert system for equipment diagnosis (SEDA)
- 55 Developments in expert systems
- 56 Leakage-current analyzer
- 56 High-performance measurement systems for the study of transients

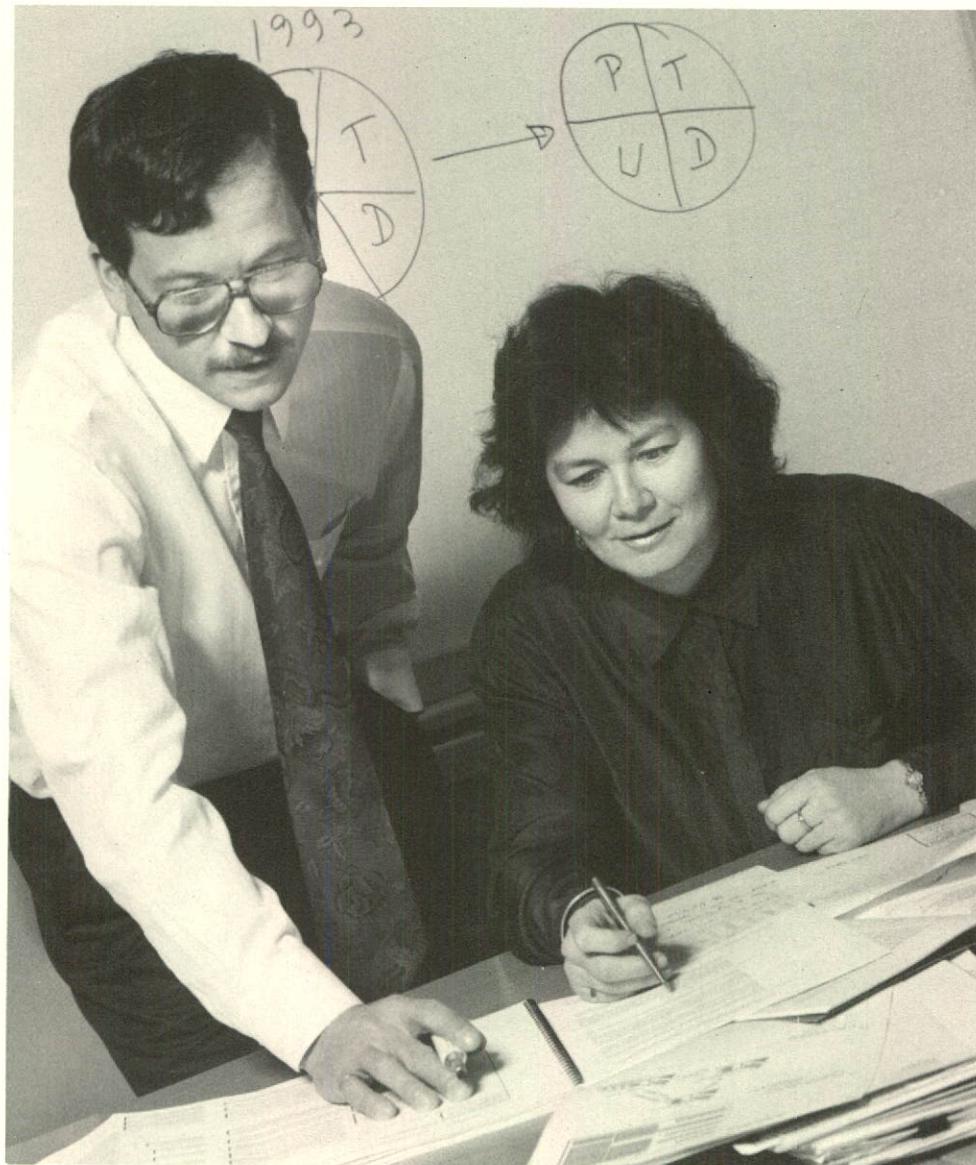
**57 NEW TEST FACILITIES**

- 58 Construction of an experimental line for mechanical tests
- 58 Battery testing facilities
- 59 Additional test areas for the power system simulator

**60 TECHNOLOGY PROMOTION****62 AWARDS AND DISTINCTIONS****63 SENIOR MANAGEMENT**

THE PAST YEAR SAW THE PUBLICATION OF THE 1993-1995 STRATEGIC PLAN FOR TECHNOLOGY-RELATED R&D, IN LINE WITH THE THREE-YEAR PLANNING TERM THAT HYDRO-QUÉBEC HAS RECENTLY UNDERTAKEN. THE PLAN STATES THAT HYDRO-QUÉBEC INTENDS TO DEVOTE 2% OF ITS TOTAL ANNUAL SALES IN ELECTRICITY TO TECHNOLOGICAL R&D BETWEEN NOW AND THE YEAR 2000. THE UTILITY THUS HOPES TO MEET ITS FUTURE OPERATING REQUIREMENTS AND MAINTAIN ITS TECHNOLOGICAL EDGE. IT WILL ALSO SEEK TO RETAIN ITS POSITION AS THE SIXTH LARGEST INVESTOR IN R&D IN CANADA AND STRENGTHEN ITS REPUTATION AS ONE OF THE TOP ELECTRICAL UTILITIES IN THE WORLD.

## TECHNOLOGY PLANNING



LYANE FRÉCHETTE  
AND OMER LEMAY  
ANALYZING DATA IN  
THE TECHNOLOGY  
PLAN (PLANS AND  
FOLLOW-UP,  
FÉLIX-MARTIN).

The strategy devised for technological R&D is based on the utility's new aims, themselves based on customers' needs and the concerns expressed by various public groups. Hydro-Québec has therefore decided to focus its efforts on achieving total customer satisfaction while assuming its social, environmental and financial responsibilities with respect to the public.

Considerable importance is allotted to activities involving power system expansion and development, as well as to those designed to meet changes in demand as a function of energy efficiency measures. While gradually integrating the province's unharnessed hydroelectric potential into its generating system, Hydro-Québec will have to prolong the service life of its existing facilities and make greater use of small rivers and co-generation.

However, several other options are available over the long term to ensure Québec's future energy needs, requiring that a certain portion of research be dedicated to the development of generation technologies. During the past year, research revolved mainly around studies on the efficiency of wind turbine-diesel generator combinations for isolated networks.

In terms of electricity demand, technology-related R&D is focused on developing consumption management tools and providing small and medium-sized businesses with high-performance industrial processes.

#### MAIN R&D INVESTORS IN CANADA IN 1991 (IN MILLIONS OF CURRENT DOLLARS)

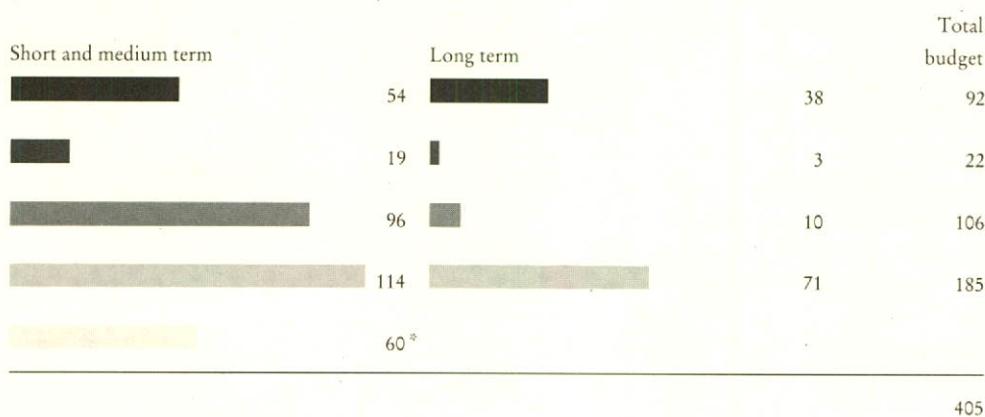
Rank	Companies	1991	1990	1989
1	Bell Canada Enterprises	1,019	1,000	1,008
2	Atomic Energy of Canada	293	256	248
3	Pratt & Whitney Canada	225	250	243
4	IBM Canada Ltd.	215	209	174
5	Ontario Hydro	165	164	122
6	Hydro-Québec	133	117	112
7	Imperial Oil Ltd.	109	95	82
8	Alcan Aluminum	95	96	97
9	Canadair	92	117	110
10	CAE Industries	80	70	63

In parallel with the above strategic-planning activities, the utility's commitment to performance will give way to R&D with the thrust of our efforts bearing on two facets: the ratio over electricity sales, and networking with universities and outside research centres based on the latter's participation in long-term research projects. These factors constitute the first step along the road to total quality in R&D.

A conference was held grouping about one hundred R&D clients and suppliers from various operational areas; the theme was R&D as a corporate strategy.

More comprehensive than Hydro-Québec's Performance Challenge program, the Operational Plan for R&D in Technology, an internal document, provides a detailed list of technology management objectives. The plan provides a series of concrete and quantifiable measures for the application of the Strategic Plan, evaluates anticipated results with respect to deliverables and the satisfaction of internal clients, and states the major measures to be implemented in terms of budgets, staff and facilities, as well as joint ventures set up with outside partners. By presenting a detailed list of the yearly objectives for the research staff as a whole, the Operational Plan constitutes a basis for following up on overall technology-related R&D.

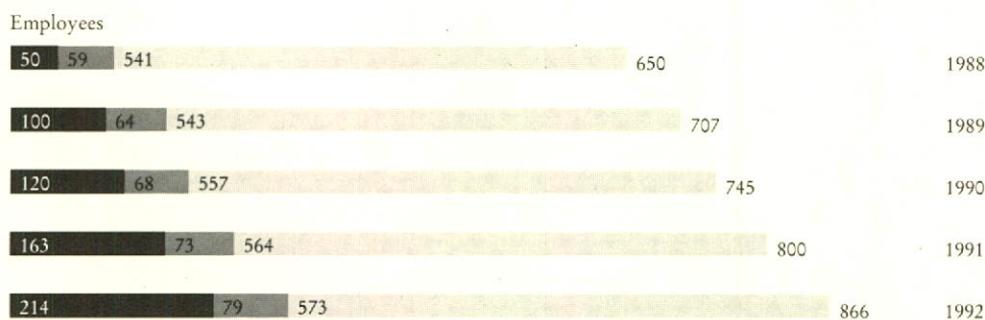
BREAKDOWN OF R&D EXPENSES BY TECHNOLOGICAL OBJECTIVE FOR 1993-1995  
(IN MILLIONS OF 1992 DOLLARS)



- Changes in demand
- Power system management
- Equipment availability
- Power system expansion and supply
- Knowledge of the environment and corrective measures

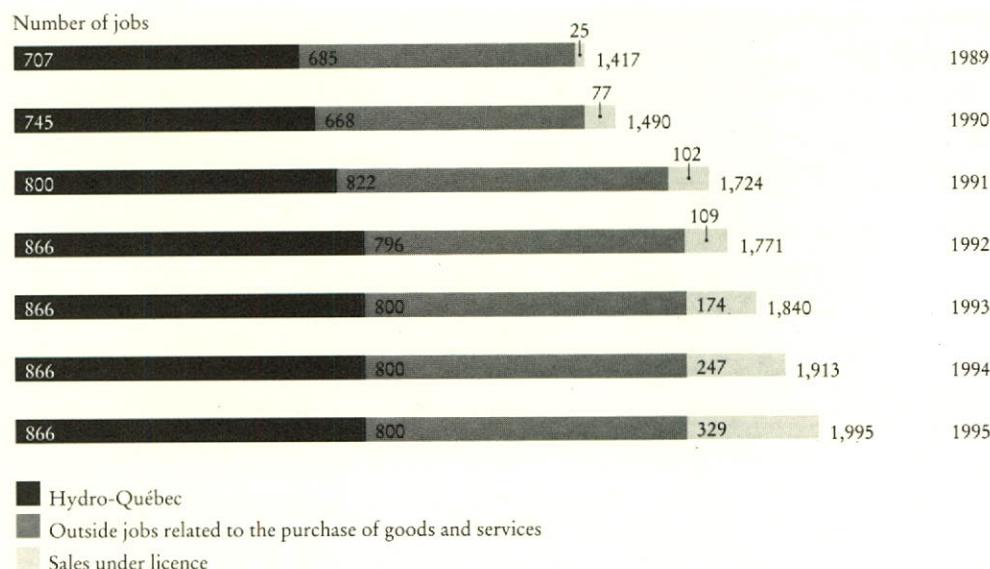
\* Budgets not related to technology

HUMAN RESOURCES ASSIGNED TO TECHNOLOGY-RELATED R&D FROM 1988 TO 1992



- Temporary positions
- Permanent HQ positions (representing 10% of total)
- Permanent R&D positions

NUMBER OF JOBS INVOLVED IN TECHNOLOGY-RELATED ACTIVITIES  
(1989-1995)



The consultation forum, consisting of the technology steering committee, sectorial discussion groups and task forces, has updated the four sectorial plans, in keeping with the aims of the Strategic Plan. Within the scope of the forum, strategy groups have been set up to help identify the needs of clients and the objectives set in generation, transmission, distribution and energy utilization. While targeting current concerns, these groups will also seek to provide a longer-term vision to the forum. The five-year planning term for R&D projects will benefit from a better structured framework, which will allow projects to be selected more efficiently. About a dozen strategy groups have been created, nine of which have already begun to work on their respective projects; a few preliminary reports have already been presented.

In terms of prospecting, 1992 was more a year of laying the groundwork. Hydro-Québec joined the Business Intelligence Program and Techmonitoring at the Stanford Research Institute (SRI), an organization whose reputation is well established in the field of research. The topics were chosen in consultation with R&D clients and suppliers, the latter agreeing to make the results more accessible to clients. The topics of greatest interest to Hydro-Québec, in addition to individual prospecting conducted within the various departments, are computer-assisted engineering, conducting polymers, fuel cells, parallel processing, photovoltaic energy, membrane separation and robotics.

Begun in 1991, the analysis of the various fields of expertise has continued this year in order to bring them into line with the future needs of the utility. A series of recommendations, based on observations of the performance of other top business enterprises, focus on the need to foster and systematize the acquisition of additional know-how and on the importance of improving the efficiency of manpower planning over the medium term.

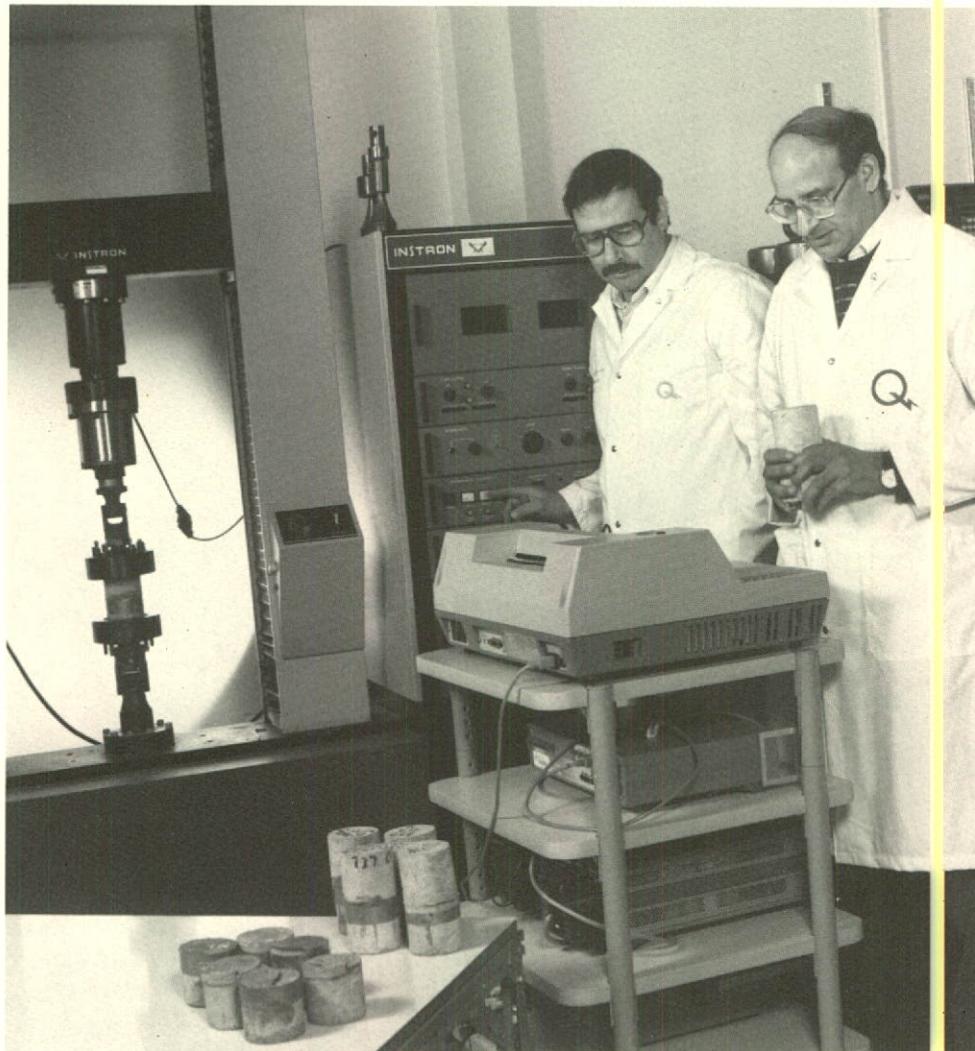
The chair in technology management, created at Université du Québec à Montréal (UQAM) with the support of the federal government, has continued its activities. Well-known European and American researchers have held conferences on the innovation strategies set up in various industrial fields. These conferences have attracted about 80 representatives from world-class Canadian universities and firms. The UQAM chair has also published a major study on approaches in quality and technology transfers used in research management, the result of two projects that had been granted to the chair as part of Hydro-Québec's Performance Challenge program.

THIS YEAR WE CONDUCTED A WIDE VARIETY OF TESTS ON THE BEHAVIOR OF CONCRETE IN NORTHERN CLIMATES, ESPECIALLY WITH RESPECT TO SURFACE REPAIR MORTARS, THE INJECTION OF MICROFINE CEMENTS, AND JOINT SEALANTS. WE ALSO DEVELOPED AN ADVANCED BOREHOLE INSPECTION SYSTEM FOR GENERATING STATIONS AND CONTINUED TO WORK ON SAPHYI, AN OPTIMUM GENERATION PLANNING MODEL FOR HYDROELECTRIC POWER SYSTEMS.

IN TERMS OF THE MATH PROJECT, WE DEVELOPED TWO-DIMENSIONAL ANALYSIS SOFTWARE AND STARTED WORK ON 3D SOFTWARE FOR HYDRAULIC TURBINE MODELING. RESEARCH ON THE SUPER PROJECT, DEALING WITH THE PERMANENT MONITORING OF GENERATING UNITS, INVOLVED THE MANUFACTURE OF A DIAGNOSTIC MODULE BASED ON EXPERT SYSTEMS. IN THE AREA OF WIND ENERGY, WE STARTED A PROJECT ON THE EFFICIENCY OF WIND TURBINE-DIESEL GENERATOR COMBINATIONS IN SUPPLYING ELECTRICITY TO ISOLATED NETWORKS.

LASTLY, TWO SCOMPI ROBOTS WERE USED FOR ON-SITE REPAIR OF CAVITATION-DAMAGED TURBINES, AND WE WERE AWARDED A CONTRACT BY A TURBINE MANUFACTURER FOR ROBOTIZING THE OVERLAY OF THE BLADES OF TURBINE RUNNERS.

## GENERATION



ANDRÉ WATIER (L.)  
AND JAHANGIR  
MIRZA MONITOR  
A TENSILE-STRENGTH  
TEST ON CONCRETE  
SPECIMENS (MATERIALS  
TECHNOLOGY, IREQ).

## CONCRETE-RELATED PROJECTS

Five major projects are under way as part of a far-reaching study on repair materials for concrete structures exposed to extremely low temperatures.

- The first, for Hydro-Québec's Manicouagan Region and the Canadian Electrical Association (CEA), deals with mortars used to repair surfaces damaged by abrasion-erosion. It has now reached its third and final stage, large-scale field evaluation of products selected in light of the results of laboratory tests (stage I) and then subjected to small-scale field tests (stage II).
- Also undertaken for the Manicouagan Region, the second project concerns the injection of cement into cracks. The focus is currently on microfine cements, which should be easier to inject into narrow cracks than ordinary Portland cement.
- The third project, on joint sealants for hydraulic structures in cold climatic conditions, has been completed and is now at the technology transfer stage. This work was conducted for the Mauricie Region and CEA.
- In the fourth project, also for the Mauricie Region, we have identified the properties of different types of concrete mixes and drawn up technical standards for applying high-quality shotcrete with good freeze-thaw durability.
- Lastly, a study for Equipment Maintenance and Dam Safety, which had asked us to examine the products to be used for repairing the Bersimis 1 intake tunnel, allowed us to trace the exact cause of the problem identified. This task involved a thorough review of international expertise related to head loss due to the accumulation of sediments or organic substances on tunnel walls.

A seminar on dams and concrete was held at IREQ in November. The aim of this event, organized jointly with Equipment Maintenance and Dam Safety personnel, was to update engineers and technicians about the latest technologies in the field of dam monitoring and maintenance and the repair of concrete structures. The presence of some 200 participants bore witness to the keen interest in this topic at Hydro-Québec.

TECHNOLOGIE DES MATERIAUX  
(MATERIALS TECHNOLOGY)

## BOREHOLE INSPECTION SYSTEM

The inspection cameras used until very recently in boreholes did not allow accurate diagnosis of anomalies. Their black and white images did not have the required resolution, the probe diameter was too large, it was impossible to know the probe position, the depth of field obtained was limited and adjustment lacked precision. In addition, it was very difficult to store and archive useful data.

To solve this problem, we have developed a sophisticated system based essentially on two color cameras coupled to a gyroscope. The probe is only 50 mm in diameter so that the same quality of images can be obtained at depths of up to 50 m. The first camera, with a short focal length, is mounted in front to take a general view of the hole, while the second takes a reduced-field radial view using a 45-degree mirror. The latter camera and the mirror rotate together a full 360 degrees, which means that the image does not require any further rotation. The lighting system is adjustable so that the contrast can be modified to accentuate the surface flaws. The cameras are both CCD type, which offers such advantages as high definition and sensitivity, low glare, reduced size and more robust construction.

The other objective of this work for the Manicouagan Region was to incorporate a device that would give the probe position and orientation with respect to the end of the borehole. We therefore added the gyroscope together with sensors that measure the length of cable fed into the hole and the angle of the radial sighting camera. The absolute position of this probe is determined by computer as it progresses along the hole. A variety of data such as the triaxial angle of the gyroscope, the radial angle of sight, the depth, the hole number, the site reference and the date are incrustated on the image as well as recorded on S-VHS magnetic tape. If necessary, the most significant images may be digitized and stored on hard disk to conserve their maximum resolution. It is also possible to compare the images of a crack taken at different moments in time in order to monitor any development. To determine the crack size and orientation, an incrustator produces mobile spider lines that the operator superimposes on the screen. Printouts of color images and two- or three-dimensional graphics of the probe travel can be obtained if required.

The system has already been used during inspections at Bersimis 2 generating station and La Tuque dam and the quality of the records it produced has exceeded all expectations.

ELECTRONIQUE  
(ELECTRONICS)



ALAIN SPÉNARD  
CHECKS THE  
TELEGEOCAMERA  
USED TO INSPECT  
BOREHOLES  
(ELECTRONICS, IREQ).

## OPTIMUM GENERATION PLANNING

SAPHYR, an optimum generation planning model for hydroelectric power systems, has been adapted to meet new needs expressed by Hydro-Québec's System Operations Directorate. Among other modifications, we have added a simplified modeling function for optimum loading of the units at each generating station, which will be used for short-term scheduling.

SAPHYR includes not only a mathematical model but also a database and a graphical user interface. We have now begun to implement it on a network of microcomputers operating under OS/2 so that it can be put into service early in the new year. A more powerful central microcomputer acting as the database and computation server is connected to each microcomputer, all of which are equipped with the graphical interface allowing the user to access the database and initiate the different stages in the optimization process.

Validation tests provided an opportunity to better define the utility's needs with respect to its future production scheduling system, SPEX, which will combine several functions, e.g., optimization of generation on all the different horizons of concern to the System Operations Directorate, on the same leading-edge computer platform. Work will begin some time in the new year on the development of this system by an outside firm in collaboration with Hydro-Québec. It is expected to go into service by the end of 1994.

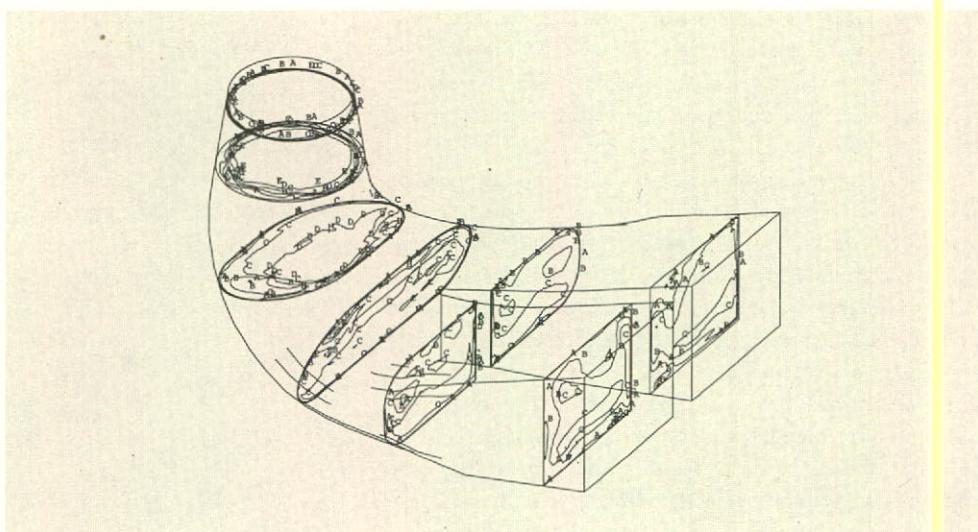
## MÉTHODES NUMÉRIQUES

(NUMERICAL METHODS)

## THE MATH PROJECT

With almost 96% of its production based on hydroelectric resources, Hydro-Québec is very interested in hydraulic turbines. Recent advances in numerical analysis have brought about substantial developments in turbine design. In light of the present tendency to increase the unit power and operating speed of these machines, the current focus of the MATH project is to develop our expertise in the field of numerical simulation with a view to reducing the margin of uncertainty and, in the long term, enhancing plant reliability. Applications of numerical simulation range from analysis of problems peculiar to hydraulic machines, estimation of the margin of manoeuvre of turbines in operation, correction of design flaws and design validation to technical assistance for planners, designers and operators.

The MATH project, which comprises four three-year phases, is a joint undertaking with two turbine manufacturers (GE Canada and GEC Alsthom Électromécanique), École Polytechnique de Montréal, Université de Sherbrooke and, more recently, the Centre de Recherche en Calcul Appliqué (CERCA) whose activities are largely related to hydraulic turbines.



CONTOUR PLOTS  
OF THE WATER  
VELOCITY IN THE  
DRAFT TUBE OF A  
GENERATING STATION,  
AS DETERMINED BY  
FINITE-ELEMENT  
CALCULATIONS UNDER  
THE MATH PROJECT  
(MECHANICAL  
ENGINEERING, IREQ).

The first phase came to a close this year with the development of numerical models for the analysis of hydraulic turbines. The results submitted to the Electrical and Mechanical Engineering Department, which funded the project, included two-dimensional fluid-flow and stress analysis software as well as experimental data obtained from geometric measurements of turbine runners and measurements of the stresses and different types of pressure to which the blades are subjected in service. These results furnish essential information for validating numerical models.

Initiated in March, Phase 2 is aimed at creating three-dimensional analysis software. Significant progress has already been achieved in the geometric modeling of scroll cases, runners and draft tubes and we have performed flow computations for the latter. As far as this second phase is concerned, the technology transfer will involve a detailed analysis of the turbines at Hydro-Québec's new Brisay generating station and flow analyses for Manic 5 PA.

MÉCANIQUE  
(MECHANICAL ENGINEERING)

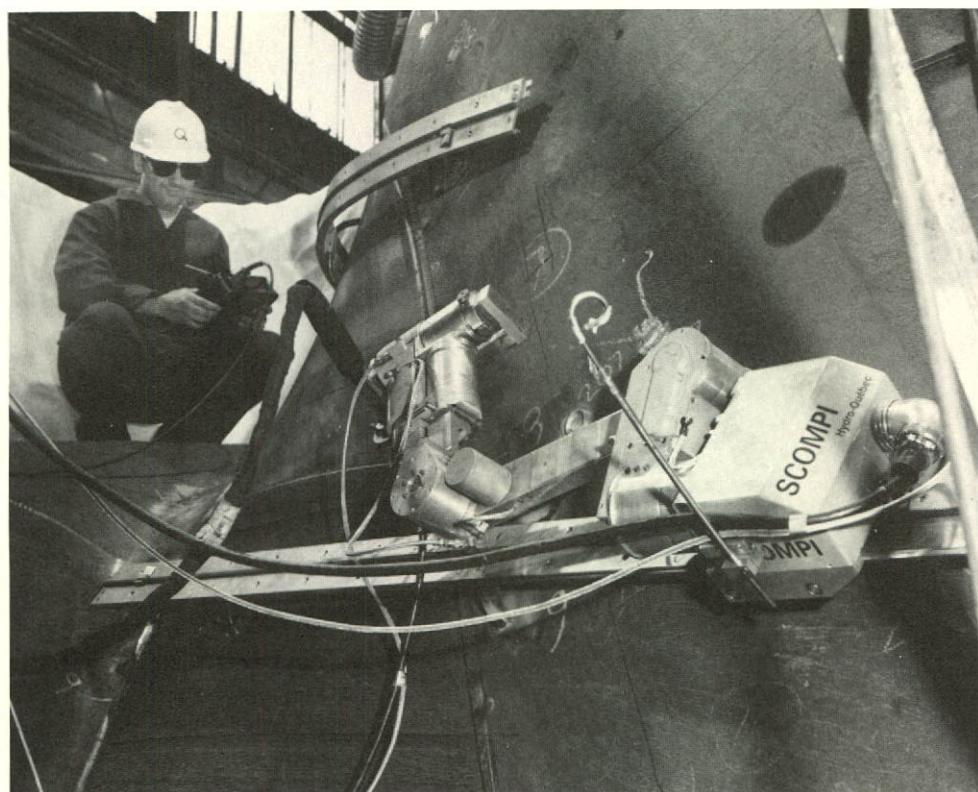
#### THE SCOMPI ROBOT

Two new Scompi robots developed at the request of the Generating Facilities Department passed a first major test at Beauharnois generating station at the end of the year. The test consisted in repairing cavitation-damaged surfaces in situ. The two robots and a team of four welders and two grinders managed to apply some 400 kg of weld to the turbine runner of unit 24 in just 28 days.

This confirmed the reliability and simplicity of using Scompi. After only two days' training, the welders had mastered the rapid programming technique. The robots carried out the work in more or less the same time that the welders would have taken but the latter were spared the more unpleasant aspects of the task. Other tests will be conducted during the coming year in particular to verify the reliability of robotized grinding. Meanwhile, the Generating Facilities Department will draw up an implementation plan by the end of 1993.

In addition, Scompi has found its first application at the factory: GEC Alsthom Électromécanique has awarded us a contract for robotizing the overlay of the blades of turbine runners. For the first time, Hydroloy steel will be used at the manufacturing stage to overlay the blades of the four turbine runners built at GEC's Tracy plant for installation at La Grande-1 generating station. This opens the door to new in-plant applications for Scompi.

TECHNOLOGIE DES MATERIAUX  
(MATERIALS TECHNOLOGY)



YVAN LAROCHE  
PROGRAMS THE  
SCOMPI ROBOT  
TO APPLY AN  
ANTICAVITATION  
COATING TO A  
TURBINE RUNNER  
(MATERIALS  
TECHNOLOGY,  
IREQ).

## **SUPER: CONTINUOUS MONITORING FOR TURBINE-GENERATORS**

The SUPER project was initiated several years ago in an effort to reduce the number of service interruptions due to the need to inspect turbine-generator units. The project has involved various studies of computer-based systems that would carry out continuous monitoring of these units. The first phase of the work led to the development of a system comprising 64 transducers, one acquisition unit, and a computer for processing and storing data and producing reports on the measurements performed. After successful testing on two turbine-generator units, the system is now ready for installation on 79 units at different Hydro-Québec generating stations.

In parallel, the last three years have seen the development of a diagnostic module based on expert-system technology to help station personnel interpret the data produced by SUPER as accurately and swiftly as possible. We have already completed a first version of the diagnostic which is based on LEVEL 5 expert-system software. Although this version is already highly sophisticated and covers most cases of turbine-generator diagnostics, it is nevertheless a preliminary one and, before it goes into service, we shall have to perfect the design by increasing its knowledge base, validating its diagnostics with SUPER data and creating an interface with the latter's database. This stage of the project, now under way, is being performed for the Generating Facilities Department.

MÉCANIQUE  
(MECHANICAL ENGINEERING)

## **WIND TURBINE-DIESEL GENERATOR COMBINATIONS WITH A HIGH PENETRATION LEVEL AND NO STORAGE**

On the heels of many projects in the last few years on supplying electricity to isolated networks using wind turbine-diesel generator combinations, we are now involved in a joint undertaking with the Atlantic Wind Test Site in Prince Edward Island. The aim of this project is to demonstrate the efficiency of wind turbine-diesel generator combinations with a high penetration level and no storage, using an installation similar in size to that of a typical remote village.

The installation comprises four wind turbines with a total capacity of 200 kW, two diesel generating units (each rated 50 kW) and two synchronous compensators totaling 150 kvar to supply the reactive power for operating the asynchronous machines of the wind turbines when the diesel generators are shut down. The system also includes a 190-kW smoothing load and a 150-kW load simulating the village power demand.

Once we had completed the design of the system, selected the components and performed dynamic characterization tests on the existing site equipment, we installed the complete system and put it into operation. The results obtained from the first series of tests are very conclusive.

One of the highlights of this work undertaken for the Refurbishing and Generation Department was to operate the system for over 90 min by simulating the situation of a village supplied only from the wind turbines, with all the diesel generators shut down. The compensators were supplying reactive power and the power system frequency was steady at 60 Hz.

MÉCANIQUE  
(MECHANICAL ENGINEERING)

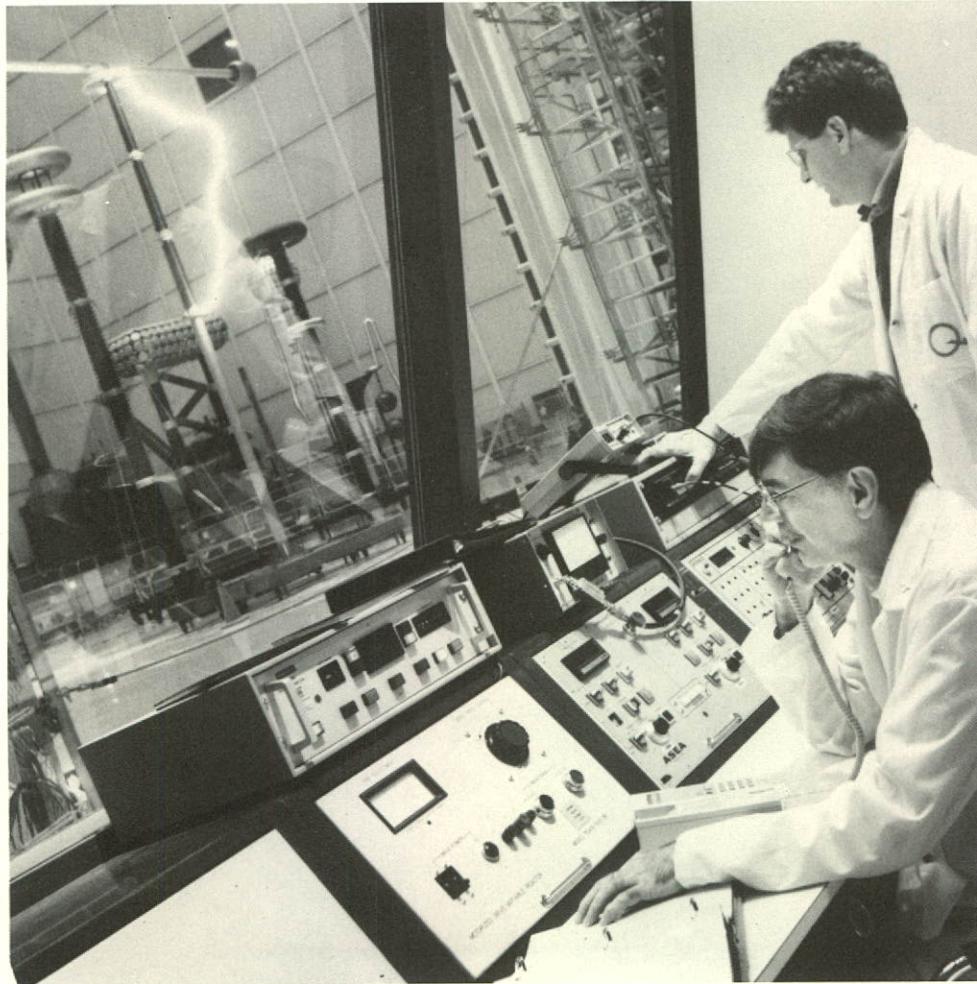
A NUMBER OF MAJOR PROJECTS WERE CONDUCTED THIS YEAR IN R&D AND TESTING.

OUR ELECTRICAL APPARATUS SPECIALISTS DEVELOPED A COMPUTATION PROGRAM FOR THE MODELING OF TRANSFORMER WINDINGS, STUDIED THE PRESENCE OF ALUMINUM PARTICLES IN TRANSFORMER OIL, AND ANALYZED TRANSFORMER AND REACTOR TANK RESISTANCE. RESEARCHERS WORKED ON DEVELOPING A COMPUTER PROGRAM DESIGNED TO CALCULATE THE CURRENT INJECTED INTO THE GROUNDING SYSTEM DURING FAULT CONDITIONS, STUDIED THE PERFORMANCE OF HVDC WALL BUSHINGS, ASSESSED THE PROPERTIES OF NEW GAS MIXTURES FOR OUTDOOR CIRCUIT BREAKERS, AND CONTINUED TO STUDY THE OXIDATION RESISTANCE OF NAPHTHENIC OILS.

WE ARE CURRENTLY CONDUCTING STUDIES ON GEOMAGNETIC DISTURBANCES INCLUDING REMOTE AND SATELLITE DETECTION, AS WELL AS THE EFFECT OF SERIES COMPENSATION ON THE STABILITY OF CONTROL SYSTEMS. WE CARRIED OUT A STUDY OF A DC LINK IN INDIA AND SIGNED AN AGREEMENT WITH ÉLECTRICITÉ DE FRANCE REGARDING A JOINT STUDY OF THE VIBRATION OF BUNDLED CONDUCTORS USED ON OVERHEAD LINES EXPOSED TO WIND.

DURING THE PAST YEAR, RESEARCHERS WERE ALSO BUSY STUDYING THE HYDROGEN EMBRITTLEMENT OF ANCHOR BARS AND PURSUED THEIR WORK ON THE CERTIFICATION OF AN 800-kV AC UNDERGROUND CABLE. A MAJOR SERIES OF TESTS WAS ALSO COMPLETED ON ELECTROMAGNETIC COMPATIBILITY IN SUBSTATIONS AND RESEARCH CONTINUED ON THE BIOLOGICAL EFFECTS OF ELECTROMAGNETIC FIELDS ON CATTLE. LASTLY, OUR EXPERTS DEVELOPED A NEW CONCEPT OF DIGITAL STABILIZER FOR AC GENERATORS, FURTHERED THEIR WORK ON THE DEVELOPMENT OF A FAULT-LOCATION SYSTEM, AND TESTED A LIGHTNING-DETECTION SYSTEM.

## TRANSMISSION



PIERRE MORRIER  
(SEATED) AND  
JEAN CHOQUETTE  
CONDUCT A SERIES  
OF TESTS ON HIGH-  
VOLTAGE SUPPORT  
INSULATORS  
(HIGH-VOLTAGE  
LABORATORY, IREQ).

## TESTING AT THE HIGH-VOLTAGE LABORATORY

The high-voltage laboratory had 12 months' nonstop activity in 1992, as may be seen from the following list of major tests performed for our many external clients, including ABB, GEC, Alsthom Énergie, Jeumont-Schneider, Northern Telecom, Sumitomo, Trench Electric, Conrac and GE Canada.

- Tests on 34 transformers and 44 shunt reactors
- Tests on blocking capacitors
- Tests on 88 current transformers rated 765 kV
- Dielectric tests on series blocking capacitors
- Demonstration tests on an underground 800-kV AC cable
- Tests on disconnecting switches rated 245, 330 and 765 kV
- Tests on a protection spark gap for blocking capacitors
- Wet switching-overvoltage tests at 1550 kV on disconnecting switches and current transformers
- Tests on support insulators rated 330 and 765 kV
- Tests on surge arresters rated 108, 144, 192, 258 and 612 kV
- Current-impulse tests on distribution arresters and measurement of the leakage current on hot sticks, safety belts and insulating ropes
- Dielectric tests on a remote manipulator
- Tests on 69-kV composite insulators
- Certification tests on distribution insulators
- Tests on a suspension insulator
- Leakage-current tests on an insulator polluted with smoke
- Certification tests on line hardware
- Tests on insulating panels
- Accelerated-aging tests on distribution cables
- Tests on communication cables
- Study of electric fields

LABORATOIRE HAUTE TENSION  
(HIGH-VOLTAGE LABORATORY)

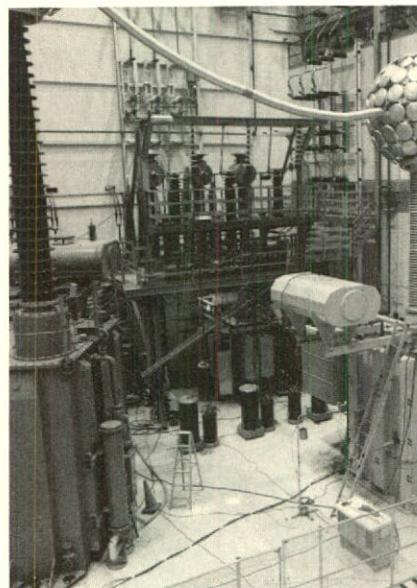
## TRANSFORMER FAILURE AT LG-4

A task force set up by the Power System Studies Department has been tracing the cause of failure of six transformers at Hydro-Québec's LG-4 generating station in order to recommend suitable corrective measures. The failures all coincided with dynamic overvoltages measuring approximately 1.5 p.u. following system separation. The main internal insulation was involved every time. This type of failure is as rare as its consequences are serious. Several items of equipment have exploded in fact and could have jeopardized the safety of personnel as well as deprive the system of power from the generating station for considerable periods of time.

The study included a review of the equipment design, oil analysis of all the transformers at LG-2, LG-3 and LG-4, characterization of the effect of particles on the dielectric withstand, and a special program of overexcitation tests. The personnel of the high-voltage and high-power laboratories as well as the Cables and Insulation Group contributed to this work.

The results show that the cause of the transformer failures was the presence of aluminum particles produced by the vibration of steel turbulators in the aluminum tubes of the cooling circuit. Laboratory tests have revealed that a particle concentration as high as that suspected at the time of the failures reduces the dielectric strength of the oil by up to 30%. The task force therefore recommended that, in order to ensure the other transformers at LG-4 are reliable, the oil should be carefully filtered and an induced voltage test at 1.6 p.u. be performed in situ.

APPAREILLAGE ÉLECTRIQUE  
(ELECTRICAL APPARATUS)



TESTING APPARATUS  
IN THE 60-HZ TEST  
AREA (HIGH-VOLTAGE  
LABORATORY, IREQ).

## CALCULATION OF CURRENT IN SUBSTATION GROUNDING SYSTEMS

EPMALTEL is a computer program designed to calculate the current injected into the grounding system of a substation under fault conditions as well as the impedance of the lines entering and leaving the station. This information is essential input for designing grounding systems that will guarantee the safety of workers and the integrity of the communication circuits.

We were requested by the Power System Studies Department to develop a new version of this software which runs on IBM-PC type computers operating under DOS. The main features of this new version are summarized below:

- A new input-output module developed with the help of the Premier Pas software designed by IREQ's mechanical engineering experts has been added to facilitate data input and the production of reports.
- A database created by a Power System Studies group has been coupled to this input-output module for recording new studies and accessing previous ones.
- The computation module uses new algorithms which improve the accuracy and offer new user options.

Initiated in 1990, the project came to a close in December this year with the publication of a guide explaining all the characteristics of the new software.

APPAREILLAGE ÉLECTRIQUE  
(ELECTRICAL APPARATUS)

## MODELING OF TRANSFORMER WINDINGS

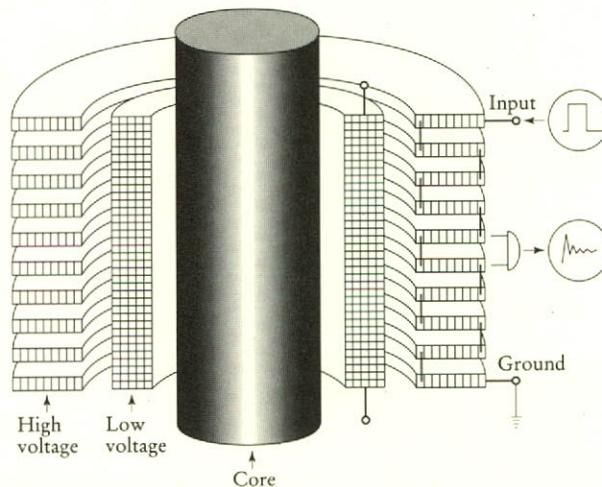
Power transformer manufacturers are turning more and more to sophisticated computation programs for evaluating the electrical behavior of windings subjected to high-frequency surges. In order to assess the safety margins at design review time and trace the cause of failures when analyzing faults, Hydro-Québec is therefore obliged to have a thorough understanding of how these tools work.

At the request of the Substation Engineering Department, we carried out an investigation of the modeling methods used by 735-kV transformer manufacturers and new methods still on the drawing boards. The one most frequently employed consists of an equivalent RLC circuit for each disk which allows internal oscillations to be analyzed in terms of their frequency or duration. We also examined the methods used to take account of variations in dielectric losses as a function of the frequency and nonlinearity of parameters such as the core permeability and the resistance of the varistors protecting the regulating winding.

Carried out in conjunction with IREQ's Measurement and Data Processing Group, this study revealed that the various methods differ quite substantially from one manufacturer to another, with a frequency resolution varying from 30 to 800 kHz. It also brought to light the fact that an EMTP-type program is unable to provide an effective solution to all problems and that close collaboration with the manufacturer is essential. Consequently, we worked beside ABB in a recent joint project involving a series of measurements on typical windings in an aim to characterize the disk-to-disk resonance modes. The software used for that project will serve in future design reviews and fault analyses.

APPAREILLAGE ÉLECTRIQUE  
(ELECTRICAL APPARATUS)

Schematic  
of a 735-kV  
transformer



## PERFORMANCE OF HVDC WALL BUSHINGS

Work was pursued on a project initiated in 1990 in an aim to study the performance of HVDC wall bushings under nonuniform rain conditions throughout the world. The long term objectives of this work are to optimize the design of the auxiliary sheds used on such equipment and to hone the techniques for testing conventional and composite bushings. The project is a follow-up to a study on the same topic sponsored primarily by the Canadian Electrical Association (CEA) which has maintained its support. Work is progressing according to plan.

The multitude of tests performed this year in the high-voltage laboratory under nonuniform rain and artificial pollution focused on a conventional wall bushing with a porcelain housing and, in turn, various designs of booster sheds. In order to better characterize their behavior, we carried out a series of successful measurements of the voltage at the terminals of the dry band using an in-house voltmeter specially designed for this purpose. We have also developed an electrical probe to determine the distribution of the electric field along the length of the bushing. A probe designed by IREQ's electronics specialists now allows us to position this probe along the bushing during the tests and comprises a camera so that we can see the type and location of the electrical arcs.

With regard to the performance of composite bushings equipped with rubber sheds, we discovered that not only is it affected by the pollution deposits on the sheds but also by the technique chosen to apply these deposits as well as the time that elapses before the test starts. Tests are now under way on smaller rubber insulators in an attempt to improve our test techniques before testing the 600-kV composite bushing.

This project involves the cooperation of many partners including Manitoba Hydro, the German company Felten & Guilleaume (HSP) and the American utility Bonneville Power Administration (BPA). Its objective is to determine whether the use of different designs of porcelain sheds could improve the bushing performance. The study will involve tests at Dorsey substation in Manitoba and at BPA's test station in Oregon on a conventional bushing coated with silicon rubber and fitted with booster sheds designed at IREQ.

LIGNES AÉRIENNES  
(OVERHEAD LINES)

## NEW GAS MIXTURES FOR OUTDOOR CIRCUIT BREAKERS

Outdoor circuit breakers on Hydro-Québec's transmission system use SF<sub>6</sub>/N<sub>2</sub> mixtures as their insulating and interrupting medium in order to be able to function at low temperatures. However, with this type of gas mixture parallel capacitors must be installed between the breaker terminals where the capacitance reaches such a high level that it causes excessive residual voltages as well as risks of ferroresonance.

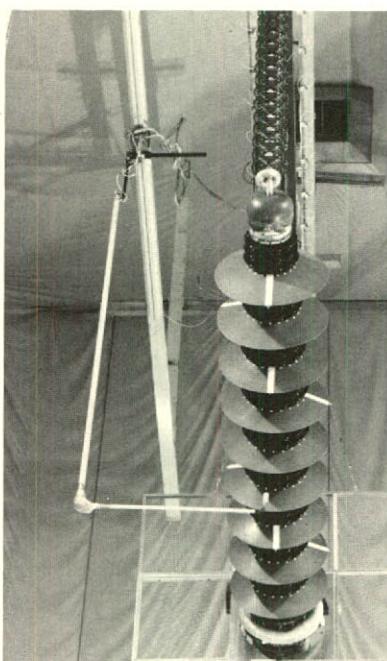
An interesting solution has been proposed by a circuit-breaker manufacturer in the form of a new gas mixture, SF<sub>6</sub>/CF<sub>4</sub>, and our group has been asked by the Studies and Standardization Department to assess the properties of this mixture to determine how efficient it would be in this application.

Our study was based on an integrated approach which allowed us to analyze the insulating and interrupting properties of the mixture in detail as a function of the various requirements for outdoor use at low temperatures. The findings show that the new gas mixture has a far better performance than the conventional SF<sub>6</sub>/N<sub>2</sub> in many ways, with no major drawbacks. It thus represents an exciting breakthrough which opens up a whole new field of research in gas insulating systems. Work is expected to resume on this project in the near future.

CÂBLES ET ISOLANTS  
(CABLES AND INSULATION)

## DYNAMIC TESTS ON COMPOSITE PHASE SPACERS

Many transmission lines will have to be more compact in the future in order to meet eight-way requirements or to allow the use of multi-circuit towers. This means that the distance between the conductors, i.e. the spacing, will have to be reduced. To maintain system reliability, however, the spacing must remain sufficient to avoid electrical breakdown, which can occur if the conductors have too much freedom of movement. Phase spacers have proven to be an effective means of holding conductors in place but only composite insulators have the appropriate properties for withstanding the strong dynamic stresses to which transmission lines are exposed, particularly compressive stresses which can cause the insulator to buckle.



POLLUTION TESTS  
ON WALL BUSHINGS  
(HIGH-VOLTAGE  
LABORATORY, IREQ).

Earlier studies on composite suspension insulators revealed a marked decrease in performance when they are subjected to dynamic tensile and bending stresses. For this particular investigation, we therefore subjected composite insulators to cycles of tension and compression loads at a frequency of 0.5 Hz. In the first part of the cycle we applied a tension load, in the second a compression load that led to buckling of the insulator, and so on until the rod broke. The tests were performed on composite insulators designed by two different manufacturers. Three tension levels were combined with three compression levels, each of the latter producing a given deflection value for the buckling.

The tests showed that the two makes of insulator had a similar behavior and confirmed that their performance decreased in the presence of dynamic stresses. Lastly, the phase spacers seem to be particularly affected by a particular set of compression values. Further testing is now necessary for detailed validation of these results.

LIGNES AÉRIENNES  
(OVERHEAD LINES)

#### TRANSFORMER AND REACTOR TANK RESISTANCE

The irruption of an electric fault arc in a 735-kV transformer or reactor creates a pressure surge that can cause the tank to burst, spilling oil which could start off a fire. Although such occurrences are rare, we were asked by the Studies and Standardization Department to define new specifications that would guarantee the best possible protection for the public, utility personnel and the environment.

We therefore undertook a series of case studies to determine the tank's arc-confinement capacity and identify tank design flaws. Our theoretical studies allowed us to trace and find an explanation for the mechanical phenomena involved and to establish their main governing parameters. Modeling tests were then performed to confirm these assumptions and evaluate the results. We were assisted in this work by members of the Electrical Apparatus Group.

It is clear from the findings of these studies that future tank designs will have to meet far more rigorous requirements, especially with respect to the relationship between the arc parameters and the tank properties, especially its mechanical resistance. Manufacturers will have to gradually modify their design criteria to take account of the internal-arc resistance factor.

MÉCANIQUE  
(MECHANICAL ENGINEERING)

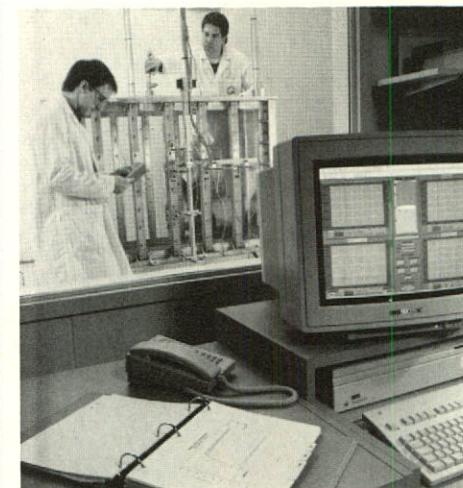
#### NAPHTHENIC OILS

Supply difficulties with naphthenic mineral oil and the increasingly unreliable quality of the Voltesso 35 oils used in Hydro-Québec's electrical apparatus over the last ten years have led the utility to envisage the use of other formulas.

In order to have a substitute accepted or simply to ascertain the quality of new Voltesso 35 oils, however, it is necessary to analyze some of their physicochemical and electrical properties, especially their oxidation resistance.

The procedure used thus far to assess the oxidation resistance of an insulating oil was time-consuming, complicated and costly. At the request of the Standards and Studies Department, we therefore decided to adapt a test setup that had served for a study of the rancidity of vegetable oils. This new setup was subjected to validation tests and proved highly efficient. It is both simple to use and fully automatic, requiring only one tenth of the time that the technician used to take. Furthermore, it provides an accurate evaluation of the induction period, which is the key criterion in assessing the oil's oxidation resistance.

CÂBLES ET ISOLANTS  
(CABLES AND INSULATION)



JEAN-YVES PAQUIN  
(R.) AND RÉAL  
BEAUCHEMIN  
PREPARE A FAULT  
SIMULATION TEST ON  
THE TRANSFORMER  
TANK MODEL  
(MECHANICAL  
ENGINEERING, IREQ).

## MAIN TESTS AT THE HIGH-POWER LABORATORY

### ELECTRICAL TESTS

#### • *Induced-current making and breaking tests by grounding switches*

On multi-circuit overhead lines, induced currents may flow in nonenergized lines as a result of electrostatic and electromagnetic coupling with adjacent live circuits. The grounding switches on these lines must therefore be designed to perform the following functions:

- make and break a capacitive current when they are switched at the end of a circuit whose other end is open;
- make and break an inductive current when they are switched at the end of a circuit whose other end is grounded.

Making and breaking tests on inductive currents ranging from 60 A at 1.6 kV up to 520 A at 40 kV and on capacitive currents ranging from 2 A at 8 kV to 25 A at 33 kV were performed on 145-kV grounding switches equipped with arcing whips, arcing horns or an arcing spring mechanism, as well as on 330-kV grounding switches equipped with an interrupting chamber.

#### • *Short-circuit-current withstand tests on grounding devices*

- Tests at 125 kA<sub>peak</sub> 80 kA<sub>rms</sub>, asymmetrical, for 1 s on a telescoping single-phase 130-kV grounding switch equipped with an interrupting chamber;
- tests at 216 kA<sub>peak</sub> asymmetrical/80 kA<sub>rms</sub> for 1 s on a telescoping single-phase 130-kV grounding switch equipped with an interrupting chamber;
- tests at 270 kA<sub>peak</sub> asymmetrical/100 kA<sub>rms</sub> for 1 s on a telescoping 550-kV grounding switch.

We also tested a wide variety of portable and temporary grounding devices used to protect workers during the maintenance, repair or refurbishing of Hydro-Québec generating stations, substations and transmission lines. Some 270 acceptance tests were performed on a score of such devices rated 20, 30 and 40 kA for periods lasting 0.25 s. These devices usually consisted of a fixed point or conductor, a clamp, an extra-flexible cable, a grounding clamp and a conductor.

#### • *Tests of mechanical resistance to electric arcs caused by an internal fault*

- in an SF<sub>6</sub>-insulated 550-kV bushing-busbar combination at 80 kA for 0.3 s and in a similar combination rated 250 kV at 50 kA for 0.48 s;
- in metal-oxide surge arresters rated 78, 98 and 123 kV at 12.5, 25, 50 and 80 kA for 0.2 s;
- in varistors protecting series-compensation capacitors at a discharge of 290 kA or 190 kA peak, 2.5 kHz, simultaneously with a 31.5-kA 60-Hz fault.

The purpose of these tests was to verify the resistance of the metallic, porcelain or other type of housing and to assess the performance of the pressure-limiting or overpressure-relief device. Another objective was to establish a correlation between the internal pressure and the arc energy.

#### • *Temperature rise tests*

Temperature rise tests on a telescoping 13.8-kV metal-enclosed, insulated-phase switch at 7 kA; on 13.8-kV metal-enclosed, insulated-phase busbars at 6.3 kA; on a 26.4-kV metal-enclosed, insulated-phase bus at 4 kA.

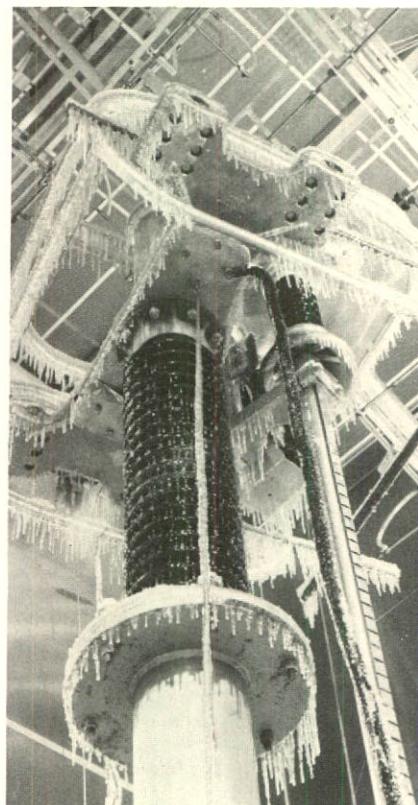
### MECHANICAL TESTS

- Acceptance tests on the characteristics of overhead ground wires incorporating optical fibres, and their mechanical behavior at low temperatures (-30°C).
- Tests on the thermomechanical behavior of 230-kV and 315-kV cables in a duct bank.
- Compression, mechanical strength, torsional strength and cantilever strength tests on porcelain insulators.
- Study of the behavior of caisson foundations protected by deep tubes.

### MAJOR CLIENTS

GEC Alsthom Énergie, Haefely, Ohio Brass, General Electric, Siemens, GE Canada and Hydro-Québec

LABORATOIRE GRANDE PUISSANCE  
(HIGH-POWER LABORATORY)



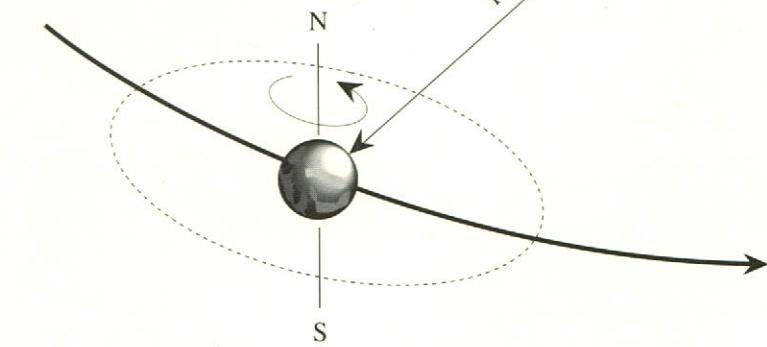
ICING TESTS  
ON A GROUNDING  
SWITCH  
(HIGH-POWER  
LABORATORY, IREQ).

## PREDICTING GEOMAGNETIC STORMS BY SATELLITE

The geomagnetic storm of March 13, 1989, which resulted in a province-wide blackout in Québec and countless problems on power systems throughout the world, revived the scientific community's interest in the use of satellites for forecasting such phenomena. This accounts for the Transmission System and Interconnections Directorate being asked to help finance the launching of a satellite at libration point L1, a zero apparent gravity point located 1.4 million kilometres from the earth in the direction of the sun. Studies of solar winds should eventually make it possible for this satellite to provide a warning about one hour before the onset of a geomagnetic storm so that utilities can take the necessary safety measures to avoid damage to the power system.

We were therefore given a mandate to verify this assumption with the assistance of an expert on solar winds by analyzing the bank of data recorded by the ISEE-3 satellite, which was actually in orbit itself around L1 from 1978 to 1982, and comparing it to the geomagnetic disturbances that occurred in Québec during the same period.

The main findings of this study were as follows: at least one interplanetary field component must be oriented toward the south ( $B_s$ ) for the solar plasma to penetrate the terrestrial envi-



ronment; the larger  $B_s$ , the greater the risk of strong geomagnetic disturbances; the warning time is longer than 30 min; and, lastly, the local time is critical as far as the extent of the disturbance at a given geographic location is concerned.

So far, however, the probability calculations are too different from 0 or 1 to be able to confirm the capacity of the new satellite to trigger a warning that gives a sufficiently accurate idea of the intensity, duration and location of a geomagnetic disturbance.

In order to calculate the energy likely to penetrate the terrestrial environment with an interplanetary field oriented toward the south, the ISEE data will have to be studied in greater detail. If, in addition, the dissipation time of this energy is calculated using geomagnetic data, there seems to be a possibility of improving the prediction of major storms using an algorithm based on solar wind parameters measured by the satellite.

APPAREILLAGE ÉLECTRIQUE  
(ELECTRICAL APPARATUS)

## STUDY OF A DC LINK IN INDIA

The Maharashtra State Electricity Board (MSEB) in India is planning to build a 1500-MW  $\pm 500$ -kV bipolar DC transmission line of 737 km between Chandrapur and Padghe. MSEB engaged a consortium of consultants consisting of the National Thermal Power Corporation Limited of India (NTPC), SNC-Lavalin Inc. and Hydro-Québec International to assist it with the DC project.

At Chandrapur, about 20 km from the bipole converter station, Power Grid Corporation of India plans to construct a 1000-MW back-to-back HVDC line between the western and southern regional systems. The two DC links would be tied by a 20-km stretch of 400-kV double-circuit line.

At the request of Hydro-Québec International, the Power System Simulation Department studied the system in 1992. The work involved verifying the DC system's recovery capability and analyzing the interactions between the two stations during power system disturbances. The simulation involved a 400-kV AC system, an HVDC link, a DC tie and a thermal generating station located at the Chandrapur bus. The study considered the following configuration variant:

- DC power flow of 1500, 1000 and -500 MW on the DC line;
- DC power flow of 1000, 600 and -500 MW on the back-to-back line;
- installation of the back-to-back interconnection at Chandrapur or at Ramagundem.

These simulations allowed us to analyze the behavior of two rectifiers, two inverters and three rectifier-inverter combinations at Chandrapur.

Each configuration underwent 12 tests, which revealed the presence of commutation problems at Padghe during single- and three-phase faults at Chandrapur. Faults on the DC line were not covered by the study.

We completed the simulator setup in July and conducted preliminary tests throughout the following month. The tests were performed in the presence of the client's representative from August 22 – October 9. The final report on this study is due in April 1993.

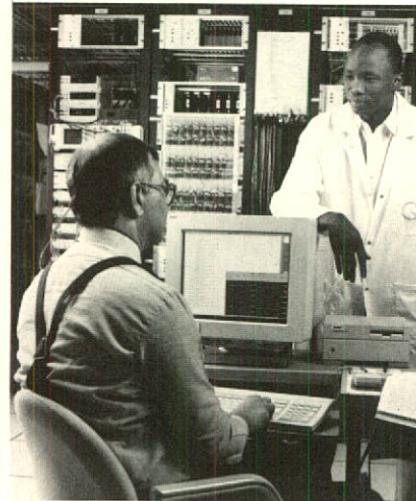
SIMULATION DE RÉSEAUX  
(POWER SYSTEM SIMULATION)

## AUTOMATIC REACTIVE COMPENSATION

Load flow studies call for an accurate profile of the voltage as a function of the power system configuration and the load. This profile is maintained by adjusting the voltage settings and the reactive-power output at the compensators and generating stations, and by connecting or disconnecting the shunt elements according to the number of capacitors and reactors available at the different substations of the system. Regulating the reactive output of compensators involves repeated application of the utility's load flow program.

The automatic reactive-compensation module integrated into the RP 600 software this year has made it possible to automate this process according to criteria predetermined by the user. With this modified version of the software, the user can therefore switch shunt elements automatically to match given discrete values. Another module, already at the prototype stage in this version, automatically adjusts the voltage settings at the capacitor terminals so that the user can increase or lower the total capacitive output of the system as needed. The automatic reactive-compensation data relating to each case investigated are stored and may be modified or entered directly during a work session with the RP 600 or at an earlier stage, in a modifications file. Control boards are provided for the user to define the main reactive-compensation parameters required. On request, the software will generate a full report on the data and on the solution obtained.

MÉTHODES NUMÉRIQUES  
(NUMERICAL METHODS)



VIJAY K. SOOD  
(AT THE KEYBOARD)  
AND ALPHA O. BARRY  
CARRYING OUT A  
SIMULATOR STUDY  
ON A DIRECT-  
CURRENT LINK IN  
INDIA (POWER  
SYSTEM SIMULATION,  
IREQ).

## REAL-TIME SIMULATION OF ELECTROMECHANICAL PHENOMENA

We have significantly improved IREQ's power system simulator by adding sophisticated load models and subsystem equivalents designed at the request of the Power System Department.

As part of the multiterminal DC system project, we had planned to conduct real-time simulation of both electromagnetic transient phenomena as well as electromechanical phenomena. The system low-frequency dynamics on the simulator had to be comparable to the results obtained for the ST600 transient stability program. We therefore developed three new real-time numerical models: one for generating units, a simplified model for synchronous machines, and a third for dynamic loads. All operate on DSPs (digital signal processors) and are directly connected to the power system simulator. The design and validation reports for these models were produced in December.

The models currently in use on Hydro-Québec's simulation network (weak load configuration) include nine generating-unit models, six simplified synchronous-machine models, and seven dynamic-load models. Simulation tests for electromechanical phenomena are proceeding as planned. The new models constitute a major technological breakthrough considering that no manufacturer has yet been able to simulate the real-time dynamic behavior of a large power system.

SIMULATION DES RÉSEAUX  
(POWER SYSTEM SIMULATION)

## EFFECT OF SERIES COMPENSATION ON THE STABILITY OF THE MDCN CONTROL SYSTEMS

At the request of Hydro-Québec's transmission system studies experts, a study was conducted on the effect of series compensation on the stability of the multiterminal DC network (MDCN) control systems. This concern has arisen in connection with the addition of series compensation to the AC network, which modifies its impedance characteristics and introduces new modes of oscillation. The combination of shunt reactors and series compensation leads to parallel resonances with high impedance peaks in the range of 5 to 10 Hz, while the combination of series capacitors with the line inductance results in series resonances in the neighborhood of 20 Hz. During disturbances, these new modes of oscillation can impact the voltage and current waveforms monitored by the control systems for synchronization purposes.

Under the direction of the Transmission System Directorate, a preliminary numerical study was carried out by the General Electric Company utilizing modal-analysis techniques with a simple equivalent representation of the AC network and a simplified model of the DC controls. The results at the time did not indicate any detrimental effect on the behavior of the MDCN.

For the study at IREQ, the Hydro-Québec AC network was simulated in detail and replicas of the actual DC controls were used in order, first, to verify the conclusions of GE's study and, then, to analyze in greater depth the effect of small and large disturbances on particular control modes. The behavior of the DC controls with the series compensators in service was studied both for steady-state conditions, which result in the converter commutating buses being subjected to low-frequency voltage distortion, and for large disturbances.

This study will establish more clearly whether series compensation of the AC network could degrade the operation of the controls of the Radisson-Nicolet DC link.

SIMULATION DE RÉSEAUX  
(POWER SYSTEM SIMULATION)



(SEATED, L. TO R.)  
RAVI B. KASHNYAP,  
DANIEL PARÉ,  
MICHAEL ÉNÉ,  
NICKIE MENEMENIS,  
(STANDING, L. TO R.)  
LEWIS VAUGHAN,  
ANDRÉ VENNE AND  
SILVANO CASONI  
DURING A STUDY OF  
THE MULTITERMINAL  
DIRECT-CURRENT  
NETWORK (POWER  
SYSTEM SIMULATION,  
IREQ).

## HYDROGEN EMBRITTLEMENT OF ANCHOR BARS

The failure of an anchor bar can lead to the collapse of a guyed tower and interruption of an entire transmission line. Recognizing that embrittlement by hydrogen plays an important role in this phenomenon, the Studies and Standardization Department requested us to launch a research program to identify the source of the hydrogen.

The study focused first on the effect of chemical pickling processes used by some manufacturers. The results showed that these processes had no long-term impact on high-strength steels because hydrogen tends to diffuse. Our findings also revealed that the presence of a coating applied by hot galvanization did not prevent hydrogen escaping from previously stripped bars.

The study continued with an investigation of corrosion problems affecting galvanized bars embedded in Portland cement. We found that the electrochemical conditions that exist in service lead to hydrogen generation, especially when a defect or crack in the sheath exposes the steel surface. Combined with a sufficiently high level of tensile stresses, this phenomenon results in embrittlement of the steel.

Based on these findings, we can now recommend various solutions for future generations of guyed towers. For example, the equipment lifetime could be extended by modifying the galvanization process so as to prevent hydrogen generation. Alternatively, more resistant steels could be selected.

TECHNOLOGIE DES MATERIAUX  
(MATERIALS TECHNOLOGY)

## OVERHEAD-LINE VIBRATION

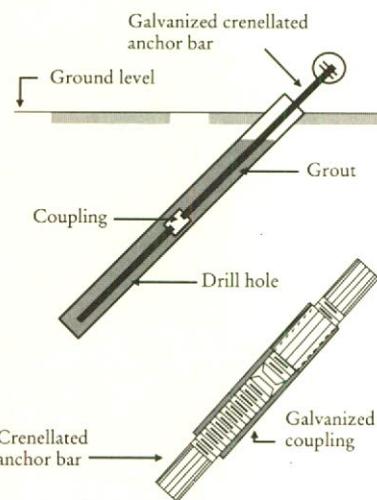
An agreement has been signed with Électricité de France to conduct a joint study of the vibration of bundled conductors used on overhead lines exposed to wind. The principal objective of this study is to determine the role played by parameters such as the conductor tension and composition (AAAC or ACSR), the type of antivibration device used, the bundle characteristics and the tension differentials in the same bundle. To do this, we plan to perform tests over a period of around 12 months on the mechanical test line recently erected near IREQ in Varennes.

We also made significant progress in the development of user-friendly software for the design of eolian-vibration attenuation measures on single-conductor lines. In 1992, the emphasis in this work for the Canadian Electrical Association was on formulating the calculations and devising damper characterization modes.

Several other studies for the Studies and Standardization Department have helped us to further our knowledge, especially about wind tunnel measurement of the energy imparted to each subconductor of a bundle under eolian vibration conditions (in cooperation with Université de Sherbrooke); modeling of the self-damping capability of multilayer stranded cables based on microslips at the points of contact between wires (jointly with Université Laval); study of the equivalence between simple and complex models of the eolian vibration of cables (also in conjunction with Université Laval); and, lastly, measurement of the self-damping capability of overhead ground wires incorporating optical fibres (in conjunction with IREQ's high-power laboratory personnel).

LIGNES AÉRIENNES  
(OVERHEAD LINES)

## Configuration of anchor bar in service



## EVALUATION OF THE STRUCTURAL INTEGRITY OF A 69-kV LINE

The degradation of transmission line hardware reduces their reliability and resistance, creating serious operating and maintenance problems. This has happened on the 69-kV line in the Magdalen Islands, which has experienced numerous current interruptions in recent years. The Generation, Transmission and Telecommunications Branch therefore turned to us for an assessment of the structural integrity of the line. Our work consisted in analyzing the present condition of the line components compared to their original state.

The samples used for this analysis were taken from sections of the line that were particularly exposed to the local environmental conditions in the form of strong winds and a harsh coastal climate. The hardware studied comprised conductors, insulators, overhead ground wires and guy wires.

The test results revealed that the insulators had lost some 17% of their mechanical capacity, with a reduction in their failure load from 135 kN to 112 kN. This, combined with the marked signs of degradation, creates a strong risk of reduced insulator integrity in the short term. The conductors were assessed on the basis of their ductility; tests showed a loss in the ductility of the strands, particularly those in the first layer. In addition, the lines had been damaged by wear at the points of contact between the suspension clamp and the strands, as well as between the strands themselves, which in the short run could cause many strands to break. Judging from the many cracks observed in the strands analyzed, this probability is fairly strong.

We recommended that, for greater reliability, the insulators and conductors currently used on this line be replaced, at least in the section exposed to the worst environmental conditions.

This work completed a general evaluation of this 69-kV line and provided data that will be used in a future project involving an assessment of the residual life of transmission line components. The latter will be carried out in cooperation with several other Hydro-Québec departments for the utility's transmission equipment experts.

TECHNOLOGIE DES MÉTÉRIAUX  
(MATERIALS TECHNOLOGY)

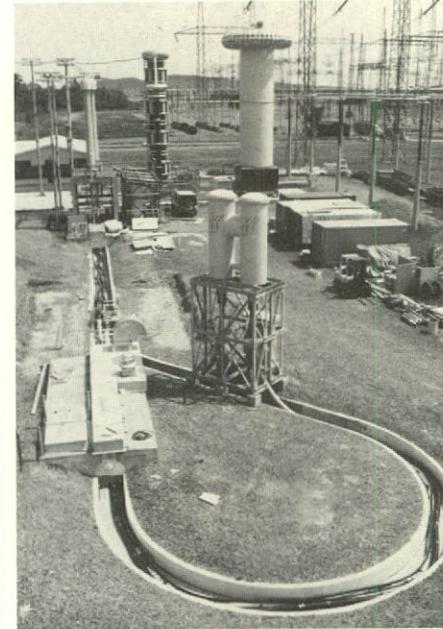
## EHV UNDERGROUND CABLE TESTING

In view of the possible installation of 735-kV under-river crossings in the not too distant future, we have performed prototype tests on a 800-kV cable. The prototype selected for these tests was an oil-filled cable manufactured by the Japanese company Sumitomo Electric with the following characteristics: rated ( $U_o$ ) and maximum ( $U_m$ ) operating voltages of 765 kV and 800 kV, respectively; copper conductor with a cross section of 2000 mm<sup>2</sup>; 30-mm-thick PPLP (polypropylene laminated paper) insulation; overall diameter of 156 mm; and 60 kg/m in weight. The withstand levels for the insulation design were 865 kV AC (for 24 h) between conductor and shield, 1980 kV crest under lightning impulses and 1550 kV crest under switching impulses. The testing was performed in conjunction with high-voltage laboratory personnel.

In August, following up on the very conclusive type tests at IREQ in 1991, we initiated a 12-month demonstration test at the EHV cable testing facility. The 130-m cable was installed in a concrete-covered duct together with accessories similar to the five it had during the previous tests, namely two external terminations, two internal oil/SF<sub>6</sub> terminations, and one insulated straight joint. We intend to raise the voltages and temperatures to a maximum of 1.3  $U_m$  and 100°C respectively in order to subject the cable to accelerated aging. Periods of weekly temperature cycling will be alternated with periods at constant temperature. This aging program is designed to simulate some 30 years of aging. Other measurements and analyses (tg, dissolved gas) will be performed to monitor the aging of the insulation. So far, work has gone according to plan, with no abnormal behavior detected in either the cable or its accessories. The future stages of this project will consist in increasing the conductor temperature from 90 to 100°C at the beginning of January 1993 and, at the end of the aging period, conducting a lightning impulse test up to breakdown. A detailed analysis of the cable components and accessories will then be undertaken to complete the validation of the PPLP technology.

It should be mentioned, lastly, that the test program on 500-kV DC cables for the Grondines-Lotbinière under-river crossing came to an end with the completion of six months of acceptance tests on the Hitachi repair joint. The six cables installed in the tunnel, each 5.1 km long, went into service in the fall.

CÂBLES ET ISOLANTS  
(CABLES AND INSULATION)



INSTALLING AN OIL-  
INSULATED AC 800-kV  
CABLE IN A DUCT  
AT THE UNDER-  
GROUND CABLE  
TESTING FACILITY  
(HIGH-VOLTAGE  
LABORATORY;  
CABLES AND  
INSULATION,IREQ).

## ELECTROMAGNETIC COMPATIBILITY IN SUBSTATIONS

This year brought to an end a series of studies and tests aimed at characterizing the electromagnetic immunity of communications systems in contiguous electrical and telecommunications stations forming part of the Hydro-Québec power system under strong electromagnetic disturbances. Our two main objectives in this work for the Telecommunications Directorate were to identify the characteristics of transient electromagnetic and radioelectric disturbances in substations equipped with telecommunications facilities and to determine the degree of immunity of the analog and digital telecommunications systems used to protect the power grid.

The study called for active participation by several Hydro-Québec departments. Since the lightning-fault simulation tests were to take place on the real power and communications system, all these departments, including the Systems Operations Branch, had a part to play. In view of the scope of the test program, the tight schedule for installing series compensation, and the short time allowed for preparing the tests, we made great efforts to coordinate the tasks and all the concerned. Our efforts proved worthwhile: by May 1991, a full series of tests had already been completed at Radisson while studies and tests of transient and short-circuit faults on 315 and 735-kV systems at Lévis substation came to a close at the end of June.

We succeeded in carrying out three measurement campaigns, two at Radisson and one at Lévis, and also installed a typical digital teleprotection unit which uses the present transmission and telecommunications system. It is employed primarily for the installation of series compensation. This work provided an opportunity to apply four solid faults to the 735-kV system at Lévis, two "fugitive" faults to both the 735-kV and the 315-kV systems at Lévis, as well as countless opening and closing operations on disconnecting switches and circuit breakers. During the year we completed our analysis of the results and presented the final report.

Various types of digital (LFCB) and analog (SPCU) teleprotection systems were assessed during real transient electromagnetic disturbances. The behavior of the telecommunications systems was evaluated as a function of their response to these disturbances, taking into account their time response as well as their signal-to-noise ratio during the different faults applied. These tests allowed us to determine some of the critical nerve points in the teleprotection system.

Another aspect of our work involved a study of the characteristics of the electromagnetic environment in the telecommunications rooms in 315- and 735-kV substations for frequencies ranging up to 30 MHz. This data could be used to determine the immunity criteria for new digital and analog equipment to be installed in future substations located next to a telecommunications station.

Analysis of the various signals reveals a generally high susceptibility to electromagnetic noise which varies with the type of couplings and the frequency of the disturbances. This study cannot fail to have a substantial impact on the safety aspects of power system operation and protection.

LIGNES AÉRIENNES  
(OVERHEAD LINES)

## LIGHTNING-DETECTION SYSTEM

Lightning is a natural phenomenon that gives rise to many failures on the Hydro-Québec power system. The Power Systems Branch has therefore acquired a protective device in the form of a lightning tracking and positioning system (LPATS) and submitted it to us for appraisal and suggestions regarding possible improvement. The study began this year and is scheduled to continue until 1995.

The LPATS comprises six antennas which detect lightning strokes and send the data to the central analyzer which can then calculate the position of the storm. The data is subsequently transmitted via a telephone line to the peripheral units, one of which is located at IREQ. These units are designed to continuously record the lightning-related data and display a list of all the strokes that occur. A computerized map of Québec can be displayed with the lightning strokes superposed. The LPATS determines the position, exact time, polarity and intensity of each stroke.

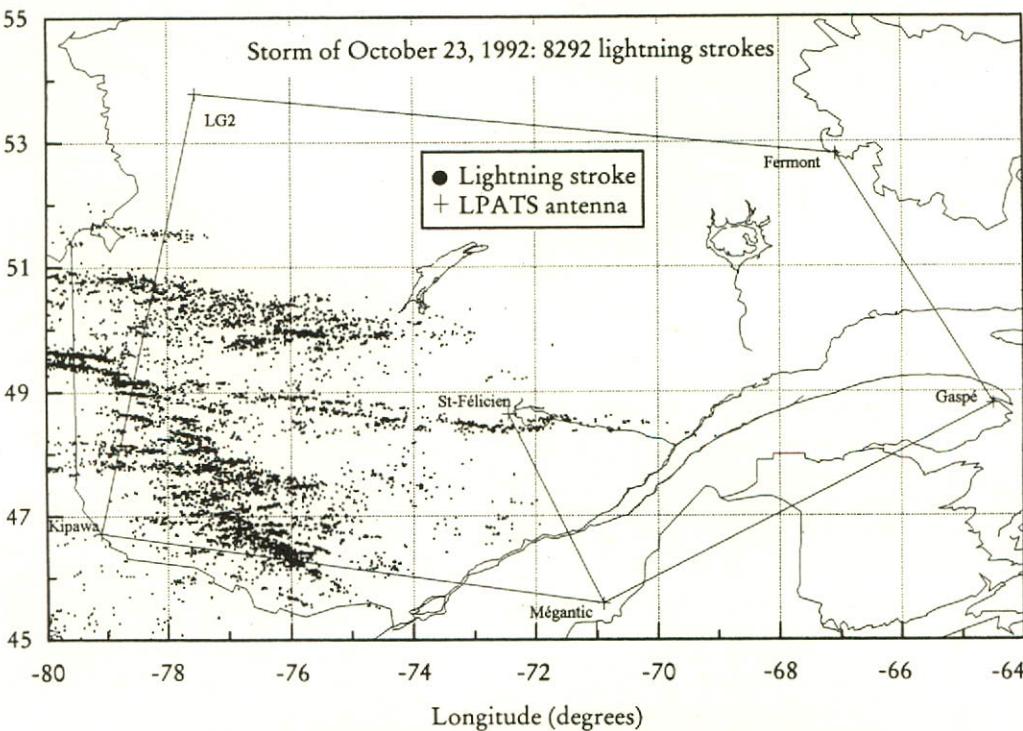
Preliminary results from our study indicate that, although the system shows room for improvement with regard to tracking, it works sufficiently well to be used in other studies under way on lightning to investigate its impact on transmission hardware and measure the levels it can reach on the power distribution system.

Our appraisal of the LPATS will include a comparison of line trips and lightning strokes occurring near high-voltage lines ranging from 120-kV to 735-kV in order to validate the system's tracking capacity in terms of location and time of the strokes. We also intend to establish a lightning density map to identify the most vulnerable areas of the province. Another task will be to analyze the data recorded by CEA lightning counters compared to the LPATS data and to repeat this for lightning-current measurements recorded by distribution surge arresters. In a word, if used to its full potential, the system could find a useful application in the fields of power system operation, as well as transmission and distribution equipment design and maintenance.

LIGNES AÉRIENNES  
(OVERHEAD LINES)

55

Storm of October 23, 1992: 8292 lightning strokes



Position of LPATS antennas and lightning strokes in Québec

## DIGITAL STABILIZER

For several years now, we have been involved in the development of a new concept of digital stabilizer for AC generators that would help to enhance the dynamic and transient stability of the transmission system. The project was initiated at the request of the Power System Planning Department and carried out in cooperation with its personnel.

Work on this three-phase project (research, development and demonstration) came to a close this year with a test at LG-2 generating station. The first phase led to the development of a multi-band stabilizer for more efficient processing of the different modes of natural power system oscillations. The underlying algorithms, including the algorithm for measuring the rotor speed from the electrical variables of voltage and current at the rotor terminals, were also developed at that stage.

The second phase consisted in developing the laboratory prototype of the digital stabilizer, which is based on the use of two redundant microcomputers to take the measurements, calculate the speed, and evaluate the stability signal 80 times per second. The transfer functions are equipped with differential filters, which make it easier to adjust the gains and phases of the damping loops.

The test performed in the third and last phase of the project, in conjunction with the Automatic Controls Department and the La Grande Region, provided an opportunity to compare the currently used stabilizer with the prototype installed in open loop on one of the units at LG-2. A few adjustments had to be made to the dynamic ranges of the input voltage and current signals, but on the whole the prototype efficiency proved satisfactory and had a far better response to the different types of oscillation. Discussions are due to begin soon on implementing this concept on a system-wide basis.

MÉTHODES NUMÉRIQUES  
(NUMERICAL METHODS)

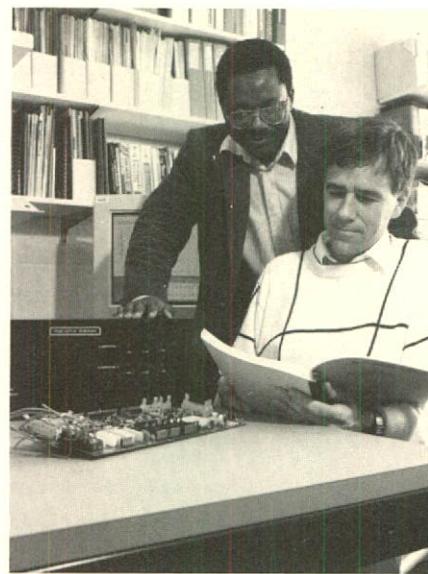
## CHARACTERIZATION OF HIGH-VOLTAGE CABLES ON THE UNDERGROUND TRANSMISSION SYSTEM

New data acquisition and control software has been designed and developed by IREQ's measurement specialists for mechanical performance tests on high-voltage cables in underground ducts. The objective is to study the cable behavior in detail in order to improve the design of the various related installations: manholes, connection hardware, etc.

The software allows the user to control two current sources by means of two variac motors which regulate the temperature of the core and sheath of the cable according to the curve plotted by the user on the screen. The data is gathered by 200 sensors located along the length of the cable, recorded and converted into engineering units for real-time analysis of the cable displacement and temperature together with the forces produced inside the cable. The results are displayed in the form of graphs illustrating the signals and the changes therein. The new software was specifically designed to meet certain requirements that had never been met: it thus features three-dimensional graphics representing cable displacement, alarm management at several levels on each sensor or group of sensors, smart automatic restart according to the stage reached in the test procedure, and automatic or manual save of the daily file kept on the test, etc. The software operates on a user-friendly Macintosh platform.

The project was initiated in March 1991 at the request of the Engineering and Mechanical Testing Division and has benefited from the assistance of the Montréal consulting firm, Information. Tests have since been performed on 315- and 230-kV cables.

MESURE ET INFORMATIQUE  
(MEASUREMENT AND DATA PROCESSING)



INNOCENT KAMWA  
(STANDING) AND  
ROBERT GRONDIN,  
LEADERS OF THE  
PROJECT ON THE  
DEVELOPMENT OF A  
DIGITAL STABILIZER  
FOR AC GENER-  
ATORS (NUMERICAL  
METHODS, IREQ).

## BIOLOGICAL EFFECTS OF ELECTROMAGNETIC FIELDS ON CATTLE

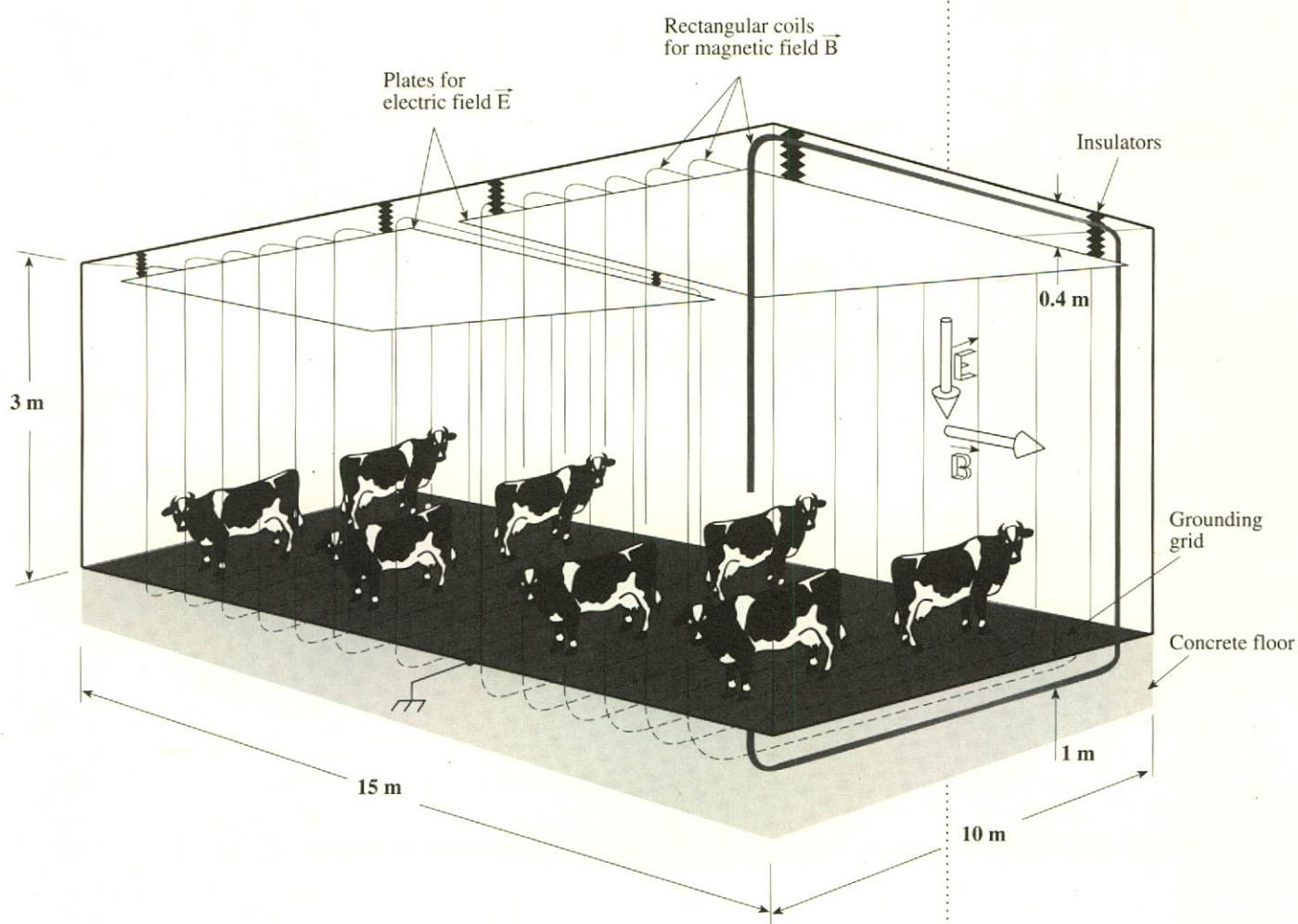
A special room has been constructed in a stable at McGill University's Macdonald College to study the biological effects that electromagnetic fields generated by 735-kV AC power lines may have on dairy cattle. This room is equipped with two plates suspended from the ceiling by synthetic insulators to generate an electric field, while the magnetic field is generated by two rectangular coils buried 1 m deep in the earth inside the building. Precautions have been taken to ensure field uniformity.

The size of the room (15 x 10 m by 3 m high) was designed to accommodate eight cows at the same time for exposure to the electromagnetic fields. Each test program consists of a session of three weeks' exposure to a magnetic field of 30  $\mu$ T and an electric field of 10 kV/m, preceded and followed by a session of the same duration but without exposure. The first stage of this study, which began at the end of 1991, has already been completed and has involved six full exposure sessions so far. The project is scheduled to terminate in March 1993.

In order to assess the extent to which the cows are affected by electromagnetic fields, we will examine various parameters during the exposure: milk production, amount of feed absorbed, digestion and blood condition (frequent blood samples). This data will enable us to analyze the cows' stress, reproductive hormones and any other health-related factor.

The utmost care has been taken to protect personnel. The programming of the test sessions and data acquisition are fully automatic while all high-voltage apparatus is insulated by optical links. All control operations can be performed by telephone link from the control station at the college or from IREQ. Lastly, the test room is equipped to meet the requirements for further studies at higher frequencies and higher field levels.

LIGNES AÉRIENNES  
(OVERHEAD LINES)



## MEASUREMENT OF GROUND POTENTIAL DURING GEOMAGNETIC STORMS

In an effort to gain a better understanding of geomagnetic storms, we have designed five stand-alone data acquisition systems intended to measure the ground potential and have installed them in the Abitibi region of Québec. They are located at roughly 60-km intervals along a telephone and power distribution network stretching some 300 km. Each system is equipped with a magnetometer which measures the earth's magnetic field in the three axes. Two short dipoles of 100 m measure the electric field in the soil in the north-south and east-west directions while a third measures the voltage between their point of contact and the acquisition system. The principal ground potential measurements are made by two electrodes buried 3 m deep, some 30 m on either side of each system; copper wires leased from the local telephone company provide the connection. The direct current induced in the neutral of the distribution feeder that supplies the system is also measured. The systems are all synchronized and equipped with a data transmission circuit which sends ten readings every 10 s to a computer at the Rouyn regional control centre. Every night, the entire 1 Mbyte of data are sent automatically to a computer at IREQ via Hydro-Québec's Ethernet network.

The project began in 1991 with the selection of the sites, the conception of the measuring approach, an environmental study and negotiation of the participation agreements. The second stage consisted mainly in manufacturing, installing and putting into operation the measuring, acquisition and telecommunication units. In addition, the necessary modifications were made to the electrical and telephone networks and the data control, acquisition, transmission and processing software was designed. The present (third) stage, already quite well advanced, comprises follow-up, maintenance, data analysis and processing, and the drafting of reports. The project is due for completion at the end of 1994.

The work was undertaken at the request of the Power System Studies Department following a recommendation by a task force set up pursuant to the system-wide power failure on March 13, 1989 caused by a major geomagnetic storm. It involves the collaboration of the scientific data processing specialists of the Measurement and Data Processing Department, five other Hydro-Québec units, and partners such as Télécédex, École Polytechnique de Montréal and the Geological Survey of Canada.

MESURE ET INFORMATIQUE  
(MEASUREMENT AND DATA PROCESSING)  
APPAREILLAGE ÉLECTRIQUE  
(ELECTRICAL APPARATUS)

## ON-LINE CONDITION-MONITORING SYSTEM FOR DOUBLE-PRESSURE SF<sub>6</sub> CIRCUIT BREAKERS

With the recent advances that have taken place in transducer technology, microprocessor-based control systems and programming techniques, we can now contemplate the possibility of developing reasonably priced on-line monitoring systems for high-voltage circuit breakers in the near future.

A project aimed at creating such a system is under way for the New York Power Authority, the Consolidated Edison Company of New York and the Empire State Electric Energy Research Corporation. The project is now in its third stage which involves performance tests and field installation. The fourth and final stage will be to assess the new system in the field over a 12-month period.

The system was specially designed to monitor the critical parameters of the breaker, flag irregularities and, in this way, predict any degradation in the components before they reach the point of failure. Monitoring of this nature allows a utility to schedule maintenance appropriately and to eliminate preventive maintenance in favor of just-in-time maintenance, which considers the actual condition of the equipment.

Both electrical and mechanical parameters are monitored. The former comprise the vertical control rod displacement to track the breaker contact travel and the pressure drop in the high-pressure gas system to monitor the operation of the blast valve. The electrical parameters include the high and low SF<sub>6</sub> gas pressure, contact wear, the electrical continuity of the tripping and closing coils, the condition of the heaters, the AC and DC auxiliary and control voltages, and the moisture level in the SF<sub>6</sub> gas.

ONE OF THE DATA ACQUISITION SITES FOR THE GROUND-POTENTIAL MEASURING SYSTEM DURING A GEOMAGNETIC STORM (ELECTRICAL APPARATUS; MEASUREMENT AND DATA PROCESSING, IREQ).



A first prototype will be installed on an 800-kV circuit breaker at New York Power Authority's Massena substation. If the anticipated results are obtained, a second will then be installed on a 362-kV breaker at a substation belonging to Consolidated Edison.

It is worth mentioning, lastly, that we are also assessing the feasibility of applying the new monitoring system to Hydro-Québec's air-blast circuit breakers.

APPAREILLAGE ÉLECTRIQUE  
(ELECTRICAL APPARATUS)

**OVERHEAD GROUND WIRES INCORPORATING OPTICAL FIBRES**

Work has continued on a joint project with the Telecommunications Directorate which involves continuous monitoring of 1300-nm and 1500-nm optical links incorporated into the overhead ground wires protecting the transmission lines between the Trois-Rivières regional control centre and Mauricie and Cap-de-la-Madeleine substations.

We have also, for the same department, determined the characteristics of the optical and mechanical-optical behavior of the dispersion-shifted fibre-optic ground wires to be used on Hydro-Québec's twelfth transmission line, linking James Bay to Québec City. In addition, a study was performed on the use of patch cords with standard and dispersion-shifted fibres.

A major project on fibre optics has been initiated in cooperation with the Telecommunications Directorate. Due for completion in 1994, this project is aimed at developing new mechanical-optical modeling and remote inspection techniques for fibre-optic ground wires and includes a study of their aging characteristics and the impact of high-optical-power transmission. This year's effort consisted largely in planning the project and purchasing the equipment needed.

ÉLECTRONIQUE  
(ELECTRONICS)

**LOCADEF: A NEW FAULT-LOCATION SYSTEM**

In view of the installation of series compensators on Hydro-Québec's 735-kV transmission system in the near future, the Control and Protection Department has asked us to develop a fault-location system based on wave fronts. Bearing in mind that a short circuit on a line generates a wave front which propagates toward both ends, we can locate the fault if we know the propagation speed and length of the line and measure the difference in the time of wave front arrival, applying a simple rule of three. The accuracy of the measurements is a determining factor in the calculation, however, because a slight deviation of only 1 s will introduce an error of about 300 m in the fault position.

The past year saw development of the local measuring unit and initial work on the central unit. In the first case, the final version of the main printed circuit is now completed and prototypes of the auxiliary circuits have been built. The system of synchronization with the GPS satellites that use these circuits is now in operation.

We have already purchased the central unit and examined several approaches for displaying the data obtained. We have also acquired the libraries needed for developing programs and selected a suitable protocol for communicating with local units.

ÉLECTRONIQUE  
(ELECTRONICS)

IN THE AREA OF DISTRIBUTION, RESEARCHERS WERE HARD AT WORK, AS CAN BE SEEN FROM THE FOLLOWING SUMMARY OF OUR ACTIVITY IN R&D AND TESTING.

## DISTRIBUTION

WE UNDERTOOK A STUDY TO ASSESS THE EFFICIENCY OF ANTICORROSION PAINTS USED TO COAT OVERHEAD AND BASE-MOUNTED HARDWARE. USING LABORATORY TESTS AND COMPUTER SIMULATIONS, WE WERE ABLE TO DETERMINE THE MAXIMUM MECHANICAL RESISTANCE OF TRANSFORMER TANKS. WE ALSO HELPED DEVELOP A TELE-OPERATED SYSTEM FOR LINE MAINTENANCE AND CONTINUED OUR WORK ON AMORPHOUS-STEEL-CORE TRANSFORMERS, OF WHICH FIVE PROTOTYPES ARE NOW INSTALLED ON THE HYDRO-QUÉBEC DISTRIBUTION SYSTEM AND UNDERGOING ACCEPTANCE TESTS. FURTHERMORE, WE COMPLETED THE DEVELOPMENT OF A STAND-ALONE LIGHTNING-CURRENT RECORDING SYSTEM.

WE UNDERTOOK A STUDY OF THE LATEST NONDESTRUCTIVE MEASURING TECHNIQUES WHICH ENABLED US TO DETERMINE THE LOAD-BEARING CAPACITY OF WOOD POLES. WE ALSO ANALYZED A VARIETY OF CHEMICAL ADDITIVES THAT COULD POTENTIALLY REPLACE PCPs FOR THE TREATMENT OF WOOD POLES. IN THE AREA OF ELECTRICAL CONNECTORS, OUR EXPERTS DEVELOPED A COMPLETELY NEW METHOD WHICH INCREASES THE EFFICIENCY OF TEST PROGRAMS USED TO CHARACTERIZE ELECTRICAL CONNECTORS. ANOTHER STUDY DEALT WITH THE USE OF MULTIPLE-ELECTRODE DEVICES FOR NONDESTRUCTIVE TESTING OF COMPRESSED JOINTS ON UNDERGROUND LINES, AND STILL ANOTHER ON GAS DETECTORS USED IN UNDERGROUND DUCTS. WATER SATURATION IN CABLES AND JOINTS WAS ALSO STUDIED.

LASTLY, OUR EXPERTS DEVISED LONG-TERM DISTRIBUTION SYSTEM PLANNING SOFTWARE, LORD, AS WELL AS A POWER QUALITY MONITORING SYSTEM TO RECORD AND ANALYZE VARIOUS TYPES OF DISTURBANCES.



ESTELLE POTVIN USES ELECTROCHEMICAL IMPEDANCE SPECTROSCOPY TO TEST THE PAINT ON A STEEL SPECIMEN (MATERIALS CHEMISTRY, IREQ).

## STUDY OF THE STABILITY OF COATING MATERIALS

The corrosion of overhead and base-mounted hardware is strongly affected by climatic conditions and has a direct impact on the reliability, safety and, eventually, the useful service life of various types of distribution system equipment. At the request of Hydro-Québec's Distribution Department, we therefore carried out a study in collaboration with the Saint-Laurent and Matapedia Regions to assess the efficiency of the latest anticorrosive paints on the market.

Several series of samples were first subjected to the salt fog test for a period varying from 1500 to 3000 hours and, subsequently, to impact, abrasion, adherence and other tests. The paints were also exposed to ultraviolet rays so that we could measure their gloss decrease. A test bench was set up in the Magdalen Islands in June to expose the samples to a harsh climate, salt fogs and the corrosive action of sand.

Meanwhile, we have improved the Impedance Spectroscopy Method (ISM), an advanced electrochemical technique with a host of advantages. For example, it has revealed that, despite the lack of visible traces, it is able to detect the initiation of corrosion of mild steels below a polyester coating.

CHIMIE DES MATERIAUX  
(MATERIALS CHEMISTRY)

## TELE-OPERATED MAINTENANCE SYSTEM

A tele-operated maintenance system for the distribution system has been developed by Hydro-Québec's Distribution Directorate in conjunction with the robotics laboratory personnel. Scheduled to go into service in the course of 1993, this development represents an interesting breakthrough which should enhance service continuity and reduce the risks associated with live-line work.

The laboratory personnel's contribution consisted mainly in assessing the latest remote-controlled systems on the market. Among other things, its study of joysticks led to the development of a cartesian control to increase the boom manoeuvrability for the Hydro-Québec auxiliary arm. A prototype insulated boom was incorporated into the system prior to dielectric tests.

IREQ's overhead-lines specialists lent their assistance in the development of the insulation for the maintenance system. They designed special insulators and fibre optic communication links and performed a series of measurements to ensure equipotential space in the control cabin. A first series of dry tests gave excellent results, while standard wet tests confirmed the safety of the new system in this respect.

Development of the prototype involved two outside firms. One was responsible for the design and manufacture of the prototype itself while the other made the required modifications to the boom truck. During the year, the tele-operated maintenance system successfully underwent various tests and was the focus of several demonstrations.

Optimization of the system will continue under a joint agreement with Électricité de France with a view to developing a preproduction prototype that meets the requirements of both ÉdF and Hydro-Québec. The agreement raises hopes that this system has an excellent market potential.

As far as telepresence is concerned, a study now under way on stereoscopic vision will include an evaluation of the efficiency of a lineperson working in remote-operated mode, i.e. without a direct view of the work place. We will therefore explore the possibility of eliminating the control cabin and allowing the lineperson to remain on the ground while the maintenance work is done on the line. A first test bench equipped with a sophisticated stereo camera and auxiliary cameras has just been set up in the laboratory.

ÉLECTRONIQUE  
(ELECTRONICS)  
VALORISATION DE LA TECHNOLOGIE  
(TECHNOLOGY PROMOTION)

TESTS AT THE  
HIGH-VOLTAGE  
LABORATORY ON THE  
TELEMANIPULATOR  
UNIT DESIGNED FOR  
DISTRIBUTION LINE  
MAINTENANCE  
(ELECTRONICS, IREQ)



## **ENERGY LIMIT OF DISTRIBUTION TRANSFORMERS**

Hydro-Québec's distribution system comprises over 500,000 oil-filled transformers. Any fault in the insulation of such equipment could generate an electric arc inside the tank and cause pressure to build up in the transformer itself. If this pressure exceeds the mechanical resistance of the tank, the latter may explode, spewing pieces of hardware, hot gases and burning oil, and jeopardizing the environment as well as the safety of anyone in the vicinity.

In an attempt to fully understand the problem, we have performed a series of laboratory tests and computer simulations for the Distribution Directorate. According to our findings, the maximum relative pressure that a transformer tank can withstand is 100 kPa, which corresponds to an electric arc of about 25 kJ. It is therefore possible to confine the energy of arcs liable to occur in transformers to within these energy limits, using adequate electrical protection.

There are two ways that the pressure on transformer tanks could be substantially reduced in future. One is to increase the tank height and diameter, the other is to lower the oil level, although not below the core. In addition, more efficient means could be found for attaching the cover to the tank to attenuate the repercussions of any faults that might occur.

This work will ensure better protection against transformer explosions both for personnel and for the environment. Moreover, the utility will be in a position to define more stringent purchasing specifications and thus obtain more resistant equipment.

APPAREILLAGE ÉLECTRIQUE  
(ELECTRICAL APPARATUS)  
MÉCANIQUE  
(MECHANICAL ENGINEERING)

## **AMORPHOUS-STEEL-CORE TRANSFORMERS**

Work on our joint project with Ferranti-Packard to develop a distribution transformer with an amorphous-steel magnetic circuit continued throughout the year. Using this new steel, we have managed to reduce the core losses by a factor of 4. Conventional transformers made of the best grain-oriented steels usually have core losses of 210 W for a 100-kVA unit but the losses of the six prototypes of the same rating that we have produced do not exceed 50 to 55 W per transformer.

Five of these prototypes are now installed on the Hydro-Québec distribution system where they are undergoing acceptance tests. Their main feature is the design of the magnetic circuit, which is composed of toroidal segments. This design has now been patented by Hydro-Québec, which has awarded the manufacturer a licence to produce and sell the new transformers.

It should be pointed out that the use of amorphous steel in the production of distribution transformers has a major obstacle to overcome before cores can be made: the steels require a thermomagnetic treatment. We therefore plan to develop new methods of processing steel ribbons in an aim to reduce the magnetic-circuit production costs and minimize eddy current and hysteresis losses.

TECHNOLOGIE DES MATERIAUX  
(MATERIALS TECHNOLOGY)

## LIGHTNING-CURRENT MEASUREMENT

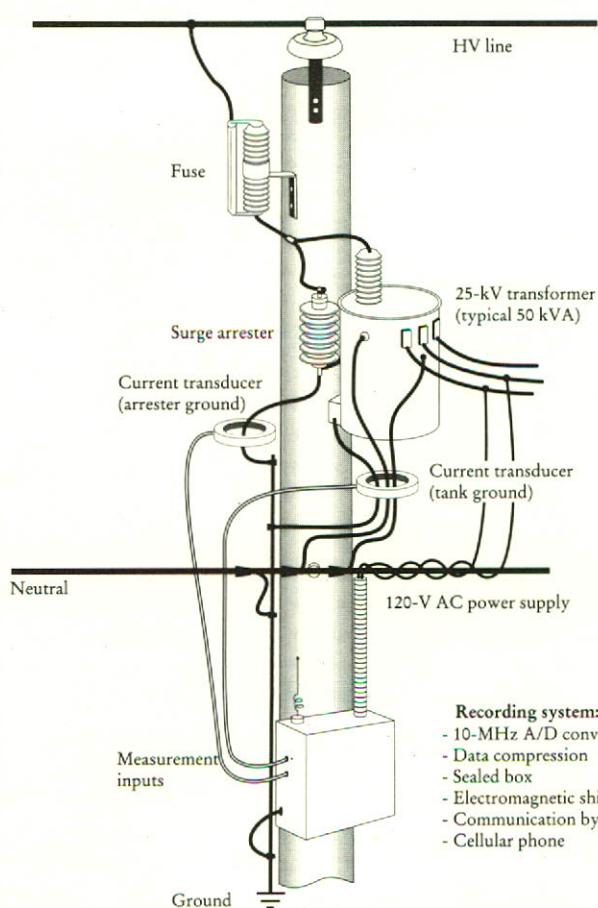
A final series of tests has been performed on the stand-alone lightning-current recording system developed for the distribution system. This measurement system comprises current transducers located on the neutral side of the electrical installation and an electronic box which records the signals at the very time they are generated. A first current transducer records the surge current in the transformer neutral on the primary side (slow part) while a second records the lightning current in the arrester (fast part). The advantage of this method is that the overvoltage at the terminals of the installation can be assessed without using energized sensors.

Four prototypes of a first version of the electronic circuitry were tested during the 1991 lightning season and, on the strength of the results, we were able to develop a more efficient method, particularly with regard to the remote control aspect. Measurement systems based on this approach offer substantial flexibility because their measuring functions can be controlled and stored data can be retrieved using a cellular telephone located inside the electronic box fixed to the pole, near the electrical installation. From a computer in the laboratory, the user can monitor 20 or so installations via a modem and a standard telephone line.

This joint project with personnel from different sectors of the distribution system also identified the areas in the province most vulnerable to lightning based on earlier Hydro-Québec studies on surge arresters. All the installations concerned have surge arresters with polymer envelopes so that monitoring overvoltages will provide an opportunity to determine the real stresses that occur during field acceptance tests.

The project benefited from the expertise of the Québec City firm CPU Design which designed and built the circuitry. The unique characteristics of the newly developed system give rise to hopes that it can be used for other equipment monitoring applications at both the distribution and transmission levels. Studies of these possibilities are already under way.

LIGNES AÉRIENNES  
(OVERHEAD LINES)



Recording system:

- 10-MHz A/D converter
- Data compression
- Sealed box
- Electromagnetic shield
- Communication by modem
- Cellular phone

## NONDESTRUCTIVE TESTING OF WOOD POLE RESISTANCE

Wood poles deteriorate over time as a result of various factors, mainly bacteria, and utilities are obliged to verify their loading capacity after a number of years in service. However, no non-destructive measuring technique exists for accurately determining the residual loading capacity of such poles.

At the request of the Plant Maintenance Directorate, we therefore undertook a study of the latest measuring techniques in light of two criteria: measuring precision and the specific needs of Hydro-Québec's power system. The study led to the selection of two devices, one based on wave propagation in the wood, the other, a gamma-ray density indicator, based on attenuation of radiation.

This preliminary study was conducted with the support of the Distribution Directorate and the participation of Bell Canada. The aim of the project under way is to assess the two devices in terms of the specific characteristics of Hydro-Québec's poles (wood species, treatments used, inspection procedure) so that a correlation can be established between the measurements taken by each instrument and the loading-capacity values obtained from laboratory tests.

Meanwhile, we are exploring a new stratigraphic technique for evaluating the resistance of wood using an instrumented drilling technique. Our objective is to develop an alternative technique that would give a more reliable quantitative measurement of the pole loading capacity.

LIGNES AÉRIENNES  
(OVERHEAD LINES)

## CHARACTERIZATION OF ELECTRICAL CONNECTORS FOR THE DISTRIBUTION SYSTEM

The degradation mechanisms of electrical connectors used on power distribution systems are still beyond the limits of current knowledge. The adverse consequences of this situation are reflected in the materials specifications for electrical joints, their usage and maintenance and, in general, the reliability of the entire power system. To resolve this problem and simultaneously enhance system reliability, it is essential to determine the in-service connector degradation rate, revise the applications accordingly, and optimize maintenance schedules.

Existing standard tests used by utilities to evaluate electrical joints (ANSI C119.4 and CSA C57) are based on current cycling involving 500 cycles on several connectors with a temperature-cycling history representing a lifetime of performances. The main parameter is a temperature rise of 100°C on the control conductor rather than the connector. Practice has shown that most connectors tested according to these standards easily meet the requirements, yet fail when exposed to real field operating conditions. The reason is that the performance criteria of the standards are not based on the theories of electrical contacts and possible degradation mechanisms, but rather on arbitrarily selected testing conditions designed to simulate field conditions.

In order to examine the performance of different types of connectors under diverse operating conditions, we have developed a new accelerated test, radically different from the ANSI test. The main aim of this current-cycling test is acceleration of joint degradation by rapid heating of a connector to 130°C with currents several times higher than rated, followed by air cooling to room temperature. The purpose of rapid heating was to produce large micromotions (fretting), increase the current density and contact force, and consequently rupture the conducting bridges at the contact interface, thus accelerating its deterioration. Continuous monitoring of the connector resistance and temperature during the heat/cool cycle provides a much better indication of the state of deterioration of the conductor/connector interface, which ultimately determines the overall performance of a connection.

We made use of this novel approach for assessing the performance of connectors from different manufacturers in a saline environment. The results show that wedge-type connectors offer the best stability, with their resistance and temperature remaining steady throughout the cycling tests. Parallel-groove connectors, by contrast, reveal rapid deterioration, showing the worst performance of all. These results provided a better reflection of service conditions and confirmed the validity and efficiency of the newly developed method.

TECHNOLOGIE DES MATERIAUX  
(MATERIALS TECHNOLOGY)



JACQUES CHEVALIER  
MEASURES THE  
DEGRADATION OF  
WOOD POLES  
(OVERHEAD LINES,  
IREQ).

## **MULTIPLE-ELECTRODE DEVICES FOR NONDESTRUCTIVE TESTING OF ELECTRICAL JOINTS**

No safe and reliable technique has yet been invented for nondestructive testing of compressed joints on underground lines. The electrical resistance method can be used quite successfully for this purpose but it is difficult to attach the measuring electrodes to the cables. With the multiple-electrode approach, however, the injected current can be measured more accurately and a single reading of the mean resistance value can be obtained. The electrode assemblies must be easy to use and adaptable to a wide range of cables. They must also fit into position with a precision of the order of one microohm.

We therefore carried out a study of the voltage distribution in joints to determine the position that would yield the most accurate measurements without increasing the portion of bare cable. So far we have tested two different devices based on the same moulding fabrication technique. Performed in conjunction with UltraOptec for the Distribution Directorate, this project should provide more conclusive results in the next 12 months, especially with regard to the best jig model to use for the nondestructive testing of compressed joints.

UltraOptec has just completed a new version of the portable microohmmeter designed for measuring very low resistances; the company is licensed by Hydro-Québec to manufacture this instrument. The new microohmmeter, due to be launched officially in 1993, is especially suitable for nondestructive testing in the field and will be used together with the electrode assemblies for testing joints on underground lines.

CHIMIE DES MATERIAUX  
(MATERIALS CHEMISTRY)

### **CHEMICAL ADDITIVES TO REPLACE PCP**

At the request of the Distribution Directorate, we have begun to assess chemical additives that could replace the pentachlorophenol (PCP) currently used for treating wood poles. The five formulas studied were CCA-PEG (chromated copper arsenate mixed with polyethylene glycol), CCA-ET (identical to the first but mixed with oil rather than PEG), ammoniacal copper-quaternary ammonium compound (ACQ), copper naphthenate dissolved with oil, and the standard formula, pentachlorophenol dissolved with oil. Treating wood poles with chemicals results in a five- to tenfold increase in their useful service life.

The aim of our study of PCP substitutes was to determine the additives' long-term efficiency under different experimental conditions, in particular accelerated aging and real conditions. The aging tests comprise two parts: exposure of the pole surface to leaching to simulate strong precipitation and laboratory tests in a climatic chamber. A facility has been set up at IREQ which can hold up to about 40 pole sections in the upright position so that we can study the retention of active agents as a function of the temperature and humidity levels.



WOOD POLE  
TESTING TAKES PLACE  
UNDER REAL CLIMATIC  
CONDITIONS  
(MATERIALS CHEMISTRY,  
IREQ).

The tests under real conditions also involve two aspects. The first is an analysis of the amount of additives lost during ground storage between the time the poles are delivered and the time they go into service, while the second consists in simulating the operating conditions of the poles installed upright at an outdoor test area. This new test facility holds 45 jack pine and red pine poles treated with the five selected additives. We plan to measure their efficiency as well as their effect on the hardness of the two wood species so that we can compare them to PCP-treated poles. Measurements of the retention of active agents and the hardness will be taken at the foot, middle and top of each pole at regular intervals to monitor changes in these parameters with time.

CHIMIE DES MÉTÉRIAUX  
(MATERIALS CHEMISTRY)

### TESTING GAS DETECTORS

Hydro-Québec's distribution system comprises extensive networks of underground ducts where workers have to carry out tasks such as installing or repairing equipment. Parts of these underground duct networks are located in hazardous areas, near oil refineries, for example, or waste dumps. These sources of pollution could expose workers to tainted, dangerous (explosive) or even toxic environments. For a number of years now, Hydro-Québec has been using special devices to assess the quality of the air before workers enter the ducts and thereby reduce the risks.

Its first study dates back about ten years. The objective was to assess commercially available devices, most of which were designed to measure only the combustible gas (explosive) and oxygen content. Subsequent advances in the field of detection cells and microcomputers have increased the functions of these devices to include, among others, measurement of the combustible gas (explosimeter), oxygen, carbon dioxide and hydrogen sulphide content. Integrated electronics and improved display facilities have helped to reduce the size and weight of the detectors and allow them to operate for up to eight hours at a time without the batteries having to be recharged.

At the request of the Saint-Laurent Region, five of these devices were studied in the laboratory where we analyzed their main parameters in order to establish their strong and weak points: calibration procedure, accuracy and reproducibility of the measurements, calibration stability over time, absence of interference and low-temperature operation. The study was performed in the context of Hydro-Québec's upgrade of its facilities, which calls for the replacement of several hundreds of these detectors in the next few years.

CHIMIE DES MÉTÉRIAUX  
(MATERIALS CHEMISTRY)

### MAIN TESTS AT THE HIGH-POWER LABORATORY

#### ELECTRICAL TESTS

- *Tests on 27-kV 600-A three-phase SF<sub>6</sub> interrupter switches, according to ANSI standard C37.71-1984*  
Breaking tests on a mainly active load current at 600, 300 and 75 A, 21-A magnetizing current, 25-A capacitive current; 14-kA short-circuit withstand tests; 14-, 20- or 25-kA short-circuit current making tests at 27 kV; dry, 60-Hz voltage withstand tests for 1 min at 40 kV; and temperature rise tests at 600 A.
- *Tests on a 26.4-kV, 12-kA SF<sub>6</sub>-insulated three-phase circuit breaker-recloser*
  - Electrical endurance tests at 2, 6 and 12 kA, at approximately 23°C, with an opening-closing sequence of 0/2 s/CO/10 s/CO/20 s/CO, according to ANSI Std. C37.60-1981;
  - Terminal fault breaking tests at 1.2, 3.6, and 7.2 kA at -40°C, according to IEC 56.
- *Tests on a modified circuit breaker*  
Terminal fault breaking tests at 30, 18, 9 and 3 kA (according to C37.09-1991) on a modified bulk-oil 30-kA three-phase circuit breaker where the oil interrupting chamber was replaced by a 29-kV vacuum interrupting chamber.

- Short-circuit current withstand tests on grounding devices
  - Tests at 33.8 kA<sub>peak</sub> asymmetrical / 12.5 kA<sub>rms</sub> symmetrical for 1 s on indoor and outdoor (used) 15- and 25-kV single-phase grounding switches, and on different portable grounding components;
  - Tests at 15 kA for 5 s and at 45 kA for 0.2 s on two-position, oil-insulated 34-kV three-phase grounding switches for transformers.
- Mechanical resistance to electric arcs caused by an internal fault
  - in 13.8-kV and 25-kV metal-clad apparatus: at 5, 12.5, 23, 37, 40 or 48 kA three-phase, for 0.17 or 1.0 s;
  - in 26.4-kV metal-enclosed bus compartments: at 12.5 kA, three-phase, for 1.0 s;
  - in insulated enclosures for underground 25-kV cable splices located in manholes: at 8 and 12 kA for 0.2 s;
  - in a 25-kV SF<sub>6</sub> circuit breaker: at 8 and 12 kA for 0.25 s.

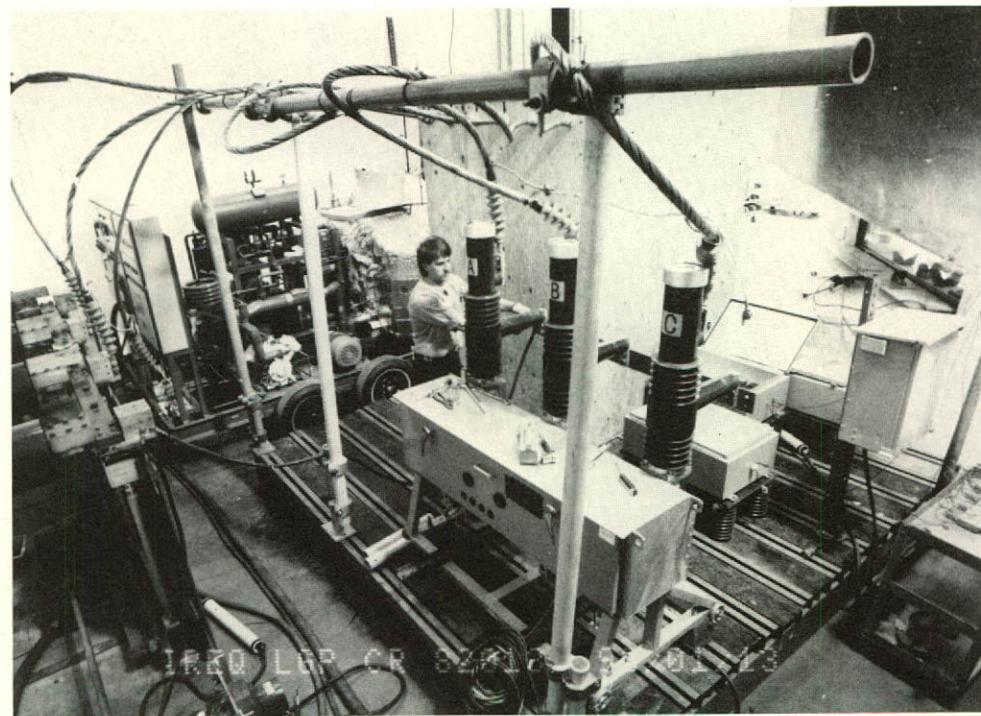
#### MECHANICAL TESTS

- mechanical strength, torsional strength and cantilever strength tests on porcelain insulators
- tests of mechanical resistance to creep, buckling and rupture in composite insulators
- acceptance tests on electrical connectors
- tests on surge arresters, fuses and voltage indicators
- mechanical/climatic tests on various types of equipment including circuit breaker-reclosers, autodisconnecting switches, load-break switches, SF<sub>6</sub> overhead interrupter switches, 25-kV transformers, grounding switches, porcelain insulators and switches.

#### MAJOR CLIENTS

ABB Power T & D, Electrical Equipment, Powell-Esco, Joslyn Power Product, Ontario Hydro, Federal Pioneer, BG Automatec, Westinghouse Canada, Toshiba International, Conrac, Brush, A.B. Chance, Cooper, Joslyn Canada, ABB Canada, Alsthom Énergie, Bell Canada, S & C Electric Canada and Hydro-Québec.

#### LABORATOIRE GRANDE PUISSANCE (HIGH-POWER LABORATORY)



TESTS ON A 26.4-KV  
SF<sub>6</sub> CIRCUIT BREAKER-  
RECLOSER AT -40°C  
(HIGH-POWER  
LABORATORY, IREQ).

## LONG-TERM DISTRIBUTION SYSTEM PLANNING

Long-term distribution system planning software has been developed which covers all of Hydro-Québec's major projects to be implemented in the next 15 years. LORD (*logiciel d'optimisation des réseaux de distribution*), as this software is known, can propose the construction of new substations, an increase in the capacity of existing facilities, and the replacement of certain line sections or the installation of new ones.

The software is based on a mathematical model that determines not only the work to be done according to the list of projects proposed by the planners but also the best year for carrying it out, considering the cost and technical constraints involved. The program is capable of swiftly identifying the best solution among the many possibilities submitted, whereas planners were previously able to analyze only two or three scenarios at a time and their studies could take up to several weeks.

LORD takes into account capital outlay, maintenance and operating costs, power and energy losses, and the residual value of the constructions at the end of the planning period; it uses actual costs computed by an integrated module. Furthermore, in contrast with all other software on the market, LORD also considers the reliability factor, proposing shorter lines when the load is heavy.

Its user-friendliness and original features make LORD particularly apt to increase planning efficiency. In the light of our experience over the last 12 months in the Laurentides Region, we can also look forward to approximately 10% savings on investments and on the cost of power and energy losses, which represents some \$60 million per year. Considering that the results obtained so far have shown gains of the order of 25 to 30%, these figures are a very cautious estimate. For example, one solution proposed by LORD cut the cost of a \$20-million project involving the Gatineau municipal network by \$5 million.

The development of LORD, a joint project with the Laurentides Region, was initiated in 1989 at the request of the Distribution Directorate. Implementation in all Hydro-Québec's regions is expected to get under way in the next 12 months and negotiations are already in progress with a view to marketing this software. LORD is sufficiently flexible to be adapted to other power systems and was shown by a recent survey to meet all the requirements of many utilities in the U.S. The next step will be to test the software at two different electricity companies to demonstrate its advantages over the methods currently in use.

## MÉTHODES NUMÉRIQUES (NUMERICAL METHODS)

### TESTS ON WATER-SATURATED CABLES

Underground distribution cables are constantly in contact with damp, with the result that water trees are formed in the cable insulation, generating an electric field which leads to cable breakdown. This problem, which came to light in an earlier project performed in Hydro-Québec's Richelieu Region, has not yet been thoroughly examined, especially for extreme cases when the insulation is saturated, as can happen under service conditions.

Two years ago, we initiated a study of this phenomenon for the Distribution Directorate. We began by soaking samples of field-aged cables for over 10,000 hours in water at 80°C. Each sample was then subjected to a dielectric breakdown test to determine its state of aging as well as the water content of the insulation. The findings showed a marked decrease in dielectric strength as the water content of the insulation increases. The tests also allowed us to observe that the water trees easily changed into electrical trees, in the step immediately preceding breakdown. Since this has the effect of accelerating the aging rate of cables in service, we have recommended that the presence of water in underground distribution lines be kept to a strict minimum.

## CÂBLES ET ISOLANTS (CABLES AND INSULATION)

## POWER QUALITY MONITORING

Power quality has an essential role to play in the service offered to electrical utility customers and, in its Service Quality Enhancement Program, Hydro-Québec is therefore making substantial efforts to equip itself with the necessary tools to obtain an ideal, i.e. perfectly sinusoidal and steady, voltage waveform. However, the waveform is vulnerable to distortion by several types of disturbance, natural disturbances as well as those caused by fluctuations in industrial, commercial and residential loads. When these disturbances reach the distribution system, they are liable to interfere with the operation of electrical appliances or cause flicker. It is consequently important for the utility to have some means of detecting such disturbances and tracing their origin.

At the request of the Customers and Distribution Branch, we have developed a system which allows the utility to respond swiftly and efficiently to customer complaints. The power quality monitoring system is a portable device designed to record, analyze and assess different types of disturbance such as flicker, undervoltages, overvoltages, phase unbalance harmonics and impulses. It also determines the location from which they originate, which helps us to find appropriate solutions to the problems identified. The new monitoring system, now in its final stage of development, is the only device capable of verifying customers' compliance to Hydro-Québec By-law 411 regarding flicker.

TECHNOLOGIE DES MATERIAUX  
(MATERIALS TECHNOLOGY)

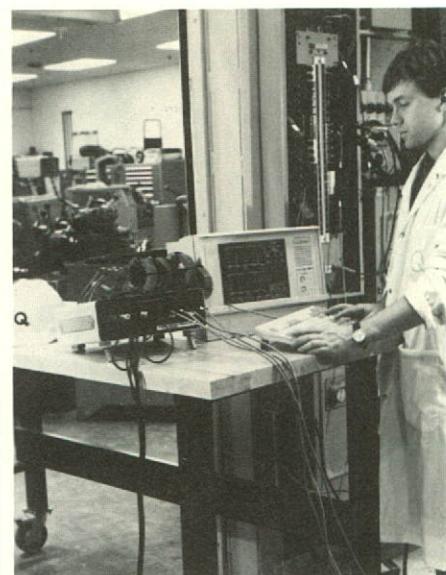
## LIMIT CONDITIONS FOR USE OF ELASTIMOLD JOINTS

At the request of the Distribution Directorate, we have carried out a modeling study of the thermal behavior of Elastimold joints in order to determine their limit conditions for field use. This task involved the development of a computation model that would enable us to simulate the temperature distributions in a joint based on the load currents and electrical resistance of the sleeve. The results obtained showed marked differences in the thermal behavior of K65OS and PCJ type Elastimold joints at high values of the linear resistance of the sleeve. From this we concluded that the type of joint must be known in order to correctly diagnose its state of degradation.

We used the results of these calculations to establish two types of relation: between the temperature rise and the load current, and between the internal and external temperatures of a joint. By measuring the external temperature of the joints, which poses no difficulty from the point of view of accessibility, we can thus determine the real temperature of their sleeve very simply and rapidly. On the basis of these findings, we proposed a diagnostic technique for preventive maintenance based on measurement of the external temperature of the joint and the load current.

Finally, it is worth mentioning that the model we have developed can be used equally well to simulate the operating conditions of other types of joint from different manufacturers. The report describing this study also includes recommendations about the application of the results and an outline of future work.

CÂBLES ET ISOLANTS  
(CABLES AND INSULATION)



CLAUDE LAFOND  
TESTS THE NEW  
POWER QUALITY  
MONITORING  
SYSTEM (NUMERICAL  
METHODS, IREQ).

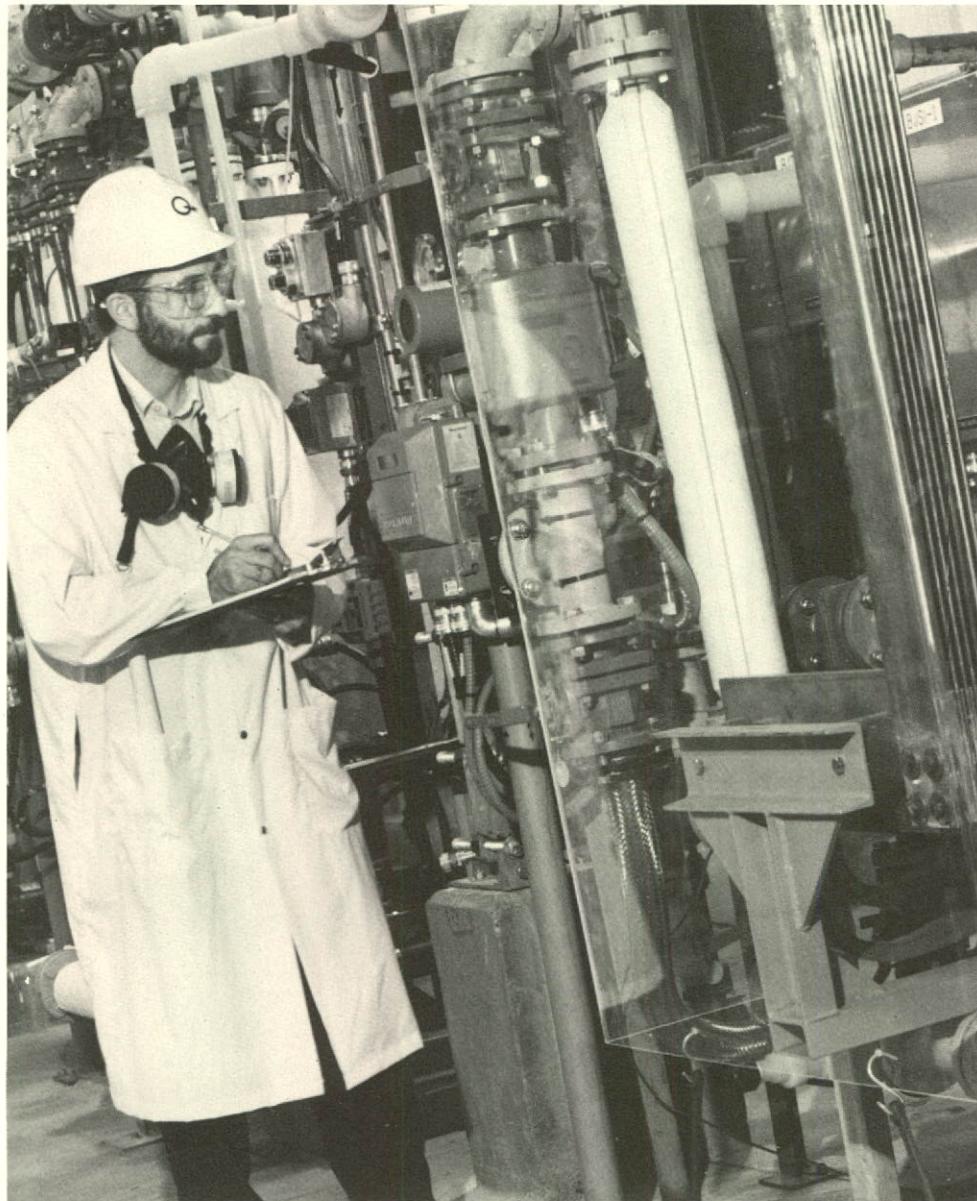
AS IN THE PAST, 1992 SAW A BURGEONING OF ACTIVITY IN ENERGY EFFICIENCY AND IN THE INDUSTRIAL AND COMMERCIAL APPLICATIONS OF ELECTRICITY. TOGETHER WITH AN INDUSTRIAL FIRM, WE DEVELOPED AN ELECTROCHEMICAL PROCESS FOR MANUFACTURING ANTHRAQUINONE AND INAUGURATED A NEW ELECTROSYNTHESIS PILOT PLANT WHICH WILL BE USED FOR THE VALIDATION OF NUMEROUS ELECTROCHEMICAL PROCESSES.

OVER THE PAST YEAR, OUR RESEARCHERS HAVE BEEN STUDYING VARIOUS OXIDATION PROCESSES BASED ON CERIUM, A TECHNOLOGY USED IN THE MANUFACTURE OF A WIDE RANGE OF CHEMICAL AND PHARMACEUTICAL PRODUCTS. RESEARCH ALSO CENTERED ON THE ELECTROCOAGULATION OF PROTEINS AND THE RECYCLING OF INDUSTRIAL ACID WASTE USING MEMBRANE SEPARATION TECHNOLOGIES.

OUR RESEARCHERS DEVELOPED A 650-KW ROTATING FURNACE FOR THE RECOVERY OF ALUMINUM CONTAINED IN SLAG AND SIGNED A LICENSING AGREEMENT FOR THE INDUSTRIAL USE OF THE PROCESS. WE ALSO BEGAN WORK ON THE PRODUCTION AND FORMING OF HIGH-PERFORMANCE MATERIALS USING PLASMAS.

LASTLY, WE INSTALLED A TEST PLATFORM TO ASSESS THE ENERGY EFFICIENCY OF ELECTRIC MOTORS, STUDIED THE HIGH-FREQUENCY HARDENING OF CONCRETE AND GRAPHITE DRYING, AND ASSESSED ALTERNATIVES TO ALL-ELECTRIC HEATING.

## APPLICATIONS OF ELECTRICITY



ALAIN ANGEL  
GATHERS DATA  
AT THE NEW  
ELECTROSYNTHESIS  
PILOT PLANT  
(INDUSTRIAL  
CHEMISTRY AND  
ELECTROCHEMISTRY,  
LTEE).

## ORGANIC ELECTROSYNTHESIS OF ANTHRAQUINONE

Anthraquinone is one of the basic chemicals used in the manufacture of dyes and is also found in the paper industry where it serves to improve the productivity and energy efficiency of chemical pulping processes and to mitigate certain environmental problems.

A three-year project involving the design and development of an electrochemical process for manufacturing anthraquinone was recently completed for Hydro-Québec's Major Customer Accounts Branch. As a result of this joint project with W.R. Grace & Co., we have filed five patent applications for this technology, which equals the number of patents already obtained by the American company.

Prior to commercial development, the new process must undergo the ultimate test: validation. This test will last six months and take place in a new electrosynthesis pilot plant with an annual capacity of 100 tonnes. In October, Mr. Richard Drouin, President and Chief Executive Officer of Hydro-Québec, officially inaugurated this world-class pilot plant, the only one of its kind in North America. It was built at a cost of \$5 million, of which \$2.8 million were provided under the Canada-Québec Agreement on Technological Development. Lastly, it is worth mentioning that Hydro-Québec has signed three industrial licensing agreements for the commercial use of this new process.

CHIMIE ET ÉLECTROCHIMIE INDUSTRIELLES  
(INDUSTRIAL CHEMISTRY AND ELECTROCHEMISTRY)

## OXIDATION BY CERIUM

The electrochemical process of oxidation using cerium is a generic technology in that it opens the door to selective manufacture of a broad range of high-value-added chemicals and pharmaceuticals. The process is the outcome of a joint development project with the American multinational W.R. Grace & Co. A preliminary market survey was conducted by the British firm Synprotech which identified products with a commercial potential as well as the companies liable to be interested in acquiring this technology.

On the basis of the results, we drew up a study program in cooperation with a group of electrochemistry specialists in Shawinigan, Québec, to optimize manufacturing processes for high-value-added products. The study focused on the three most promising, namely p-methoxybenzaldehyde, p-t-butylbenzaldehyde, and 5-nitro-1,4 naphtoquinone, which are used respectively in the aromatics, perfume and pharmaceuticals industries and for the manufacture of dyes. Already substantial improvements have been made to the method of producing these quinones and aromatic aldehydes, and negotiations are under way with various companies seeking a licensing agreement.

Lastly, mention should be made of a major breakthrough in the field of organic electrosynthesis: the discovery of an original chemical reaction mechanism by cerium, which allows lactones to be produced. This optimization work for the Major Customer Accounts Branch was carried out jointly with a team of electrochemists at Université de Sherbrooke, Québec.

CHIMIE INDUSTRIELLE  
(INDUSTRIAL CHEMISTRY)

## ELECTROCOAGULATION OF PROTEINS

The agro-food industry is producing more and more high-value-added proteins, several of which are already being used to enrich a wide range of foods, including milk formula. Some of these proteins are derived from soya meal, a particularly abundant source.

A study was performed at LTEE in an aim to improve a protein extraction method used thus far. The new process, known as electrocoagulation, forces the precipitation of the proteins contained in aqueous solutions by means of an electric field and a set of membranes.

Unlike conventional methods, this process requires neither heating nor chemicals. Furthermore it uses relatively little electricity, which is a distinct advantage in terms of energy efficiency, while effluents into the environment are reduced to a minimum. Most important, in-depth analysis of the proteins obtained by this process revealed that they keep all their food value, which means that the electric field has absolutely no macroscopic effect on their quality.

Undertaken for Hydro-Québec's Industrial Chemistry and Pulp and Paper Department, this project benefitted from the contribution of the Food Research and Development Centre (Agriculture Canada).

CHIMIE ET ÉLECTROCHIMIE INDUSTRIELLES  
(INDUSTRIAL CHEMISTRY AND ELECTROCHEMISTRY)

## RECYCLING OF INDUSTRIAL ACID WASTE

Recycling of acids contaminated by heavy metals is one of the main aspects of our R&D program on membrane separation technologies. Not only is this work of significance to Québec industry but it corresponds to a major environmental concern of industrialized countries throughout the world: how to dispose of acid waste? In an attempt to answer this thorny question, we are currently studying two membrane electrotechnologies, namely electrodialysis and membrane electrolysis, both representing efficient applications of electrical energy.

Electrodialysis studies have revealed that, if the appropriate membranes are selected, it is possible to recover up to 80% of the acid value of contaminated solutions and eliminate as much as 90% of their heavy-metal content. Moreover, the recovery of one kilogram of acid requires only 0.3 to 0.5 kWh of electricity. Our study, which focused on contaminated sulphuric acid solutions, leads us to believe that electrodialysis could be used for recycling diluted solutions commonly encountered in the chemical industry.

Membrane electrolysis, meanwhile, is a particularly effective means to achieve high-level purity of the recovered acid, provided this is economically justified. Work under way on the development of a cerium-based technology has shown that this type of electrolysis allows up to 96% of the acid value of contaminated solutions of methane sulphonate acid to be recovered and over 99% of the heavy-metal content to be eliminated. This cannot fail to spur development of the cerium technology, since such a high degree of purification suggests that a more stable operation of electrolysis units could be attained and the production of hazardous wastes reduced.

CHIMIE ET ÉLECTROCHIMIE INDUSTRIELLES  
(INDUSTRIAL CHEMISTRY AND ELECTROCHEMISTRY)

## ALUMINUM RECOVERY DEMONSTRATION UNIT

A 650-kW demonstration unit has been built according to the Droschar process patented by Hydro-Québec for the recovery of metallic aluminum contained in the slag produced at smelting plants. The unit comprises a rotary furnace revolving a full 360° round two horizontal graphite electrodes supporting an electric arc which heats the charge to 800°C. As it melts, the oxides and other products contained in the slag are separated from the aluminum which then forms a bath of molten metal that is poured through a tap hole at the end of the treatment. The solid residue is tipped out by tilting the furnace.

The furnace has been made thoroughly airtight to prevent oxidation of the aluminum and electrodes. The Droschar process does not require any gas or fluxing salt for treating the slag. Furthermore, none of the parts has water-cooling so that there is no risk of explosion caused by water flowing into the metallic bath. The furnace is expected to go into service at the beginning of 1993.

Hydro-Québec's Mines and Metallurgy Department funded the development of the demonstration unit and has launched a market study of potential buyers. Two Québec companies, Recyclage Mingan and Recyclage d'aluminium du Québec, have already acquired an operating licence for this technology for their plants in the Sept-Îles and Bécancour regions respectively.

PLASMAS INDUSTRIELS  
(INDUSTRIAL PLASMAS)

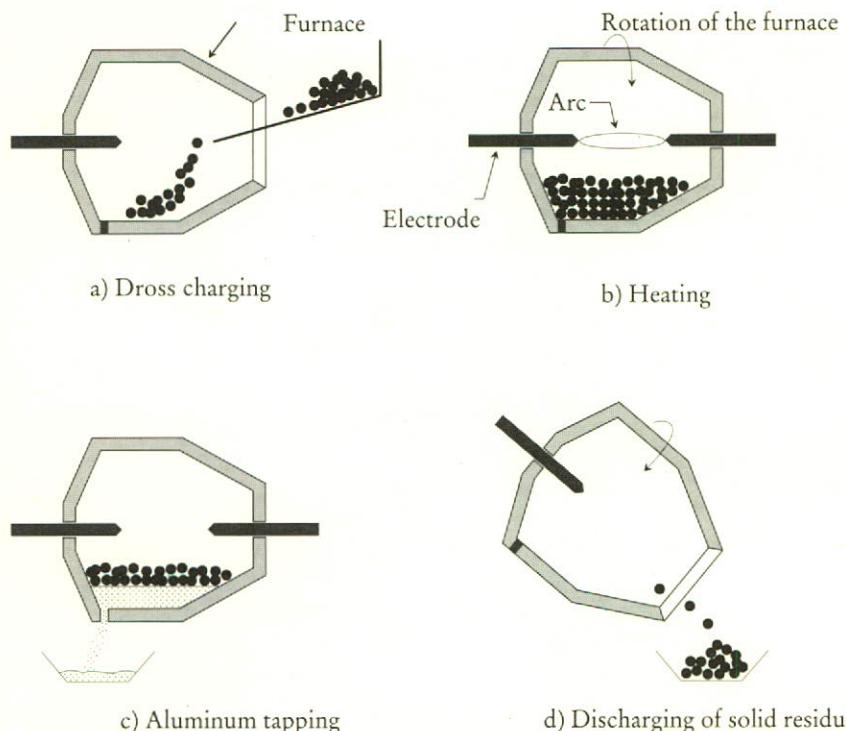
## INSTALLATION OF AN INDUSTRIAL UNIT FOR ALUMINUM RECOVERY

The Québec firm Recyclage d'aluminium du Québec (RAQ) has been granted a licence by Hydro-Québec to use the Droskar technology at its processing plants in Baie-Comeau and Bécancour. This licence gives the company the exclusive right to build a 1.5-MW industrial unit for aluminum recycling in Bécancour in 1993. The company will thus switch from natural gas to electricity for heating its rotary furnaces in order to eliminate the use of salts and gas, which currently hinders processing.

RAQ will bear all the conversion costs and has undertaken to perform tests, with Hydro-Québec's support, at power levels of over 500 kW. Once the tests are completed, the company will run the process at 1.5 MW and pay the utility royalties for each tonne of aluminum slag processed.

PLASMAS INDUSTRIELS  
(INDUSTRIAL PLASMAS)

### Aluminum Recovery Process



## PRODUCTION AND FORMING OF POWDERS AND CERAMICS

The sphere of activity of the industrial plasma specialists at LTEE encompasses all technologies involved in the production and forming of high-performance materials such as ceramics, intermetallics, composites, etc. Two projects stand out as particularly promising. The first, a joint endeavor with Pegasus Refractory Materials (PERMA), is aimed at producing powders with the aid of plasmas, while the second consists in forming oxide and non-oxide ceramics using a sophisticated prototype plasma torch.

Work on the first project was initiated last June. Thus far, a laboratory has been built and a reactor equipped with three plasma torches, and an induction furnace has been installed and put into service.

With regard to the second project, not only has a test bench been designed but, more importantly, a prototype plasma torch has been developed and tested. The major feature of this prototype is that it allows particles to be injected directly into the plasma, which means that their residence time in the hot region can be prolonged. The advantage of this new concept over conventional torches is that particles can be melted and thick deposits produced as well as parts with a considerably higher density. The project is funded in part by the Canadian Electrical Association and a patent application has been filed for this technology.

(PLASMAS INDUSTRIELS)  
(INDUSTRIAL PLASMAS)

## GRAPHITE DRYING

The wide variety of facilities at LTEE and the new test benches recently put into service inspired a host of studies in the industrial, residential, commercial and institutional sectors in the last 12 months. Some 50 reports have been issued in relation to these studies.

One of our major successes was the testing of graphite drying at the Stratmin mine in Mont-Laurier, Québec, using an Archimedes' screw 1.94 m long and 150 mm in diameter heated by magnetic induction. The aim of these 60-hour-long tests was to demonstrate the potential of this process for speeding up the drying process.

With a power consumption of 65 kW, the screw allowed 200 kg of anhydrous graphite to be processed every hour, which corresponds to 0.3 kWh/kg. In terms of energy efficiency, the results therefore exceeded the value 0.9.

These tests provided an opportunity to improve productivity and establish the energy savings and economic advantages of using industrial screws of different sizes.

ÉLECTROTECHNOLOGIES INDUSTRIELLES  
(INDUSTRIAL ELECTROTECHNOLOGIES)

## EVALUATION OF THE ENERGY EFFICIENCY OF ELECTRIC MOTORS

Tests are under way on a platform comprising three test benches covering power ranges of 1 - 15 HP, 10 - 150 HP and 100 - 500 HP, respectively, in an aim to assess the energy efficiency of electric motors. The facility was specially designed for studying three-phase induction motors rated up to 600 V AC.

All the tests are fully controlled by computer so that the operator's role is limited to positioning the motor and connecting it to the power supply. The test program was drawn up with a view to protecting the installations as much as the motor under test.

Testing is entirely in conformity with the procedure described in CSA Standard C-390 which specifies the measurements to be taken at the different load and voltage points. The control software allows standard tests to be performed in accordance with NEMA MG-1 and IEEE 112 as well as custom-designed tests such as assessment of the effects of voltage unbalance on motor efficiency.

The calibration of the instruments conforms to all national standards and allows a measuring accuracy of the order of  $\pm 0.2\%$  to be achieved.

The test results will provide valuable information not only to Hydro-Québec's Energy Efficiency Branch, which administers the financial-assistance program for would-be buyers of high-efficiency electric motors, but also to the electrical industry at large.

ÉLECTROTECHNOLOGIES INDUSTRIELLES  
(INDUSTRIAL ELECTROTECHNOLOGIES)



PIERRE ANGERS  
ASSESSES THE  
ENERGY EFFICIENCY  
OF ELECTRIC  
MOTORS (INDUSTRIAL  
ELECTROTECH-  
NOLOGIES, LTEE).

## ALTERNATIVES TO ALL-ELECTRIC HEATING

Most homes in Québec are heated by electricity, with baseboard heaters installed in each room. In the housing sector, this type of heating is used in over 70% of new homes built, which has a strong impact on peak demand. Hydro-Québec is therefore developing two alternatives, both dual-energy methods, in an attempt to reduce peak load and at the same time increase the comfort level.

The first approach combines a dual-energy system with a central heating or air-conditioning system which allows customers to take advantage of the dual-energy rate. High-speed air pipes and virtually silent vents are installed and equipped with settings so that the user can regulate the ambient temperature and control the quality of the air (humidity, odors, etc.). In order to conduct experiments on this method, LTEE has built a test bench simulating a typical room of a Québec home so that it can optimize the network of main and secondary air pipes. Studies will focus on hydraulic aspects, mechanical components, insulation and insulating materials, air distribution and stratification, and aerodynamic noise abatement.

The second method under study comprises a hot-water system which would replace the electrical baseboards. Based on a compact, straightforward distribution system, this approach is ultra-safe and offers temperate, comfortable heating. Furthermore, it can be adapted to a gas-fired boiler or co-generator. LTEE's test bench will be used to develop new combinations of heating elements and to validate the concept of heating water by a second source when the outdoor temperature drops below -12°C.

**ÉLECTROTECHNOLOGIES INDUSTRIELLES**  
(INDUSTRIAL ELECTROTECHNOLOGIES)

## HIGH-FREQUENCY HARDENING OF CONCRETE

The Bromont (Québec) company Enduits Unifix produces concrete panels for the construction industry which are used primarily for wall lining. In the current process, the concrete hardens as the panels are passed through a long tunnel where the temperature is kept at about 65°C.

To improve productivity, researchers propose to accelerate the hardening process by pre-heating the concrete panels before they enter the tunnel. Dielectric heating seemed particularly attractive for this purpose because it allows high power densities to be transferred uniformly through the thickness of the material. The preheating unit could therefore be very compact and would not call for a longer production chain.

An initial study revealed that concrete is a suitable material for radio-frequency heating. Extrapolating the results of tests on small samples, we concluded that production could be increased twofold by adding a preheating section measuring only one tenth the length of the tunnel.

A radio-frequency heating unit designed to fit into the production chain has been developed for an industrial-scale demonstration of this concept. Factory tests have yielded the expected results, corroborating our predictions based on laboratory experiments.

**ÉLECTROTECHNOLOGIES INDUSTRIELLES**  
(INDUSTRIAL ELECTROTECHNOLOGIES)



MONICA MINÉA AND  
LOUIS HANDFIELD  
ADJUST MEASURING  
INSTRUMENTS IN  
THE NEW DUAL-  
CLIMATE CHAMBER  
(INDUSTRIAL  
ELECTROTECH-  
NOLOGIES, LTEE).

OUR R&D ACTIVITIES IN THE AREA OF LITHIUM POLYMER BATTERIES GAINED CONSIDERABLE MOMENTUM OVER THE PAST YEAR. WORK IN SUPERCONDUCTIVITY FOCUSED ON PRODUCING SUPERCONDUCTING WIRES WITH A HIGH CRITICAL TEMPERATURE AND HIGH CURRENT DENSITY AND DEVELOPING VARIOUS TECHNOLOGIES RELATED TO THE COATING AND TEXTURING OF CERAMICS. RESEARCH ALSO CENTERED ON VARIOUS APPLICATIONS OF SUPERCONDUCTIVITY SUCH AS FAULT-CURRENT LIMITERS AND A SUPERCONDUCTING AC REGULATOR. WE ALSO COORDINATED A NUMBER OF PROJECTS INVOLVING THE USE OF HYDROGEN.

IN THE AREA OF MAGNETIC FUSION, WORK CONTINUED ON UPGRADING OUR EXPERIMENTAL TOKAMAK DEVICE, TDeV, ESPECIALLY IN TERMS OF THE POLARIZATION OF MAGNETIC DIVERTOR PLATES AND THE ELIMINATION OF PLASMA IMPURITIES. IN TELEROBOTICS, WE PURSUED OUR PROGRAM INVOLVING THE DEVELOPMENT AND EXPERIMENTATION OF VARIOUS TECHNOLOGIES OF POTENTIAL USE IN THE DESIGN OF HYBRID SYSTEMS FOR EQUIPMENT MAINTENANCE. LASTLY, WE CONDUCTED A STUDY ON ELECTROCHEMICAL INTERFACES, WORKED ON THE DEVELOPMENT AND CHARACTERIZATION OF ELECTRODE MATERIALS FOR HYDROGEN PRODUCTION THROUGH WATER ELECTROLYSIS, AND UNDERTOOK A STUDY ON SHAPE-MEMORY ALLOYS AND THEIR APPLICATIONS.

## LONG-TERM PROJECTS



JULIE CLOUTIER AND  
ROGER BELLEMARE  
EXAMINE A  
COMPONENT OF  
A LITHIUM-POLYMER  
BATTERY (MATERIALS  
CHEMISTRY, IREQ).

## **SUPERCONDUCTIVITY**

In line with our objectives, the work this year focused on two distinct aspects of superconductivity: materials and applications.

As far as materials are concerned, we pursued the activities initiated by the Superconducting Technology Consortium and, as planned, produced superconducting wires with a critical temperature close to 105 K and a critical current density of over 10,000 A/cm<sup>2</sup> at 77 K. We also developed a technology for eliminating unwanted reactions between the superconducting ceramic and its coating. This development represents a breakthrough which should lead to industrial manufacture of more reliable and, at the same time, more efficient wires. A patent has been obtained on the method we developed for the texturing of the ceramic, an essential step if the required high current densities are to be achieved.

Two applications were investigated: a fault-current limiter and a superconducting AC regulator. The first involved inventing a limiter that would prevent the peak current from exceeding a value no more than three times the rated current when an 800-A fault occurs on a 25-kV distribution feeder. This calls for a rapid transition from the superconducting state to the resistive state at the moment the current exceeds the critical value. Simulations of inductive and hybrid (inductive-resistive) models revealed the advantages of this current limiter of which two prototypes were built and validated in the laboratory. This project was performed in cooperation with IREQ's electrical apparatus specialists.

The second application concerns the SMES, a device designed to enable exchanges of active and reactive energy between the power system and a superconducting energy storage coil. The aim is to enhance power system stability by regulating the voltage (reactive-power exchange) as static compensators do, and by efficiently damping power oscillations (active-power exchange) after a fault. Simulations on the 1996 configuration of Hydro-Québec's power system revealed that, ideally, for energy exchanges of 650 MVA the SMES should have a storage capacity of 1000 MJ.

TECHNOLOGIE DES MATERIAUX  
(MATERIALS TECHNOLOGY)

## **NEW DEVELOPMENTS IN LITHIUM-POLYMER BATTERIES**

Research and development work in lithium-polymer batteries saw much progress this past year. The objective for this project was to devise high-performance rechargeable batteries, which would be both light-weight and environmentally friendly. The focus was on developing two types of products, i.e. small, thin batteries for electronics applications, and larger batteries for vehicle traction, such as golf carts and electric wheelchairs.

With respect to the first product – small batteries – the Japanese firm Yuasa Battery, with whom Hydro-Québec had signed a partnership agreement in 1990, pursued its R&D activities. Yuasa and Hydro-Québec should reach a decision by the end of 1993 as to whether a pilot plant will be built in 1994. At present, Hydro-Québec's participation in the project mainly involves the production of ultra-thin lithium film.

As to the second product – large batteries – we have started to produce small 10-Wh rolled batteries as well as a 100-Wh model; these will serve as the basis for a 2-kWh battery which researchers are planning to produce by 1994.

PROJET DE DEVELOPPEMENT - ACEP  
(ACEP DEVELOPMENT PROJECT)  
CHIMIE DES MATERIAUX  
(MATERIALS CHEMISTRY)  
CHIMIE ET ELECTROCHIMIE INDUSTRIELLES  
(INDUSTRIAL CHEMISTRY AND ELECTROCHEMISTRY)



## THE HYDROGEN PROJECT

Until 1991, the thrust of the Hydrogen Project was on production but 1992 heralded a new phase which concerns the utilization of this gas. A consortium has therefore been created which has agreed to develop hydrogen products in the areas of aeronautics, urban transportation, reservoirs, shipping and safety.

No less than 60 different companies and organizations will contribute to the project, most of them from Germany and Québec. Their readiness to cooperate is founded on a dynamic industrial vision shared by industry, the European Economic Community and the Québec government which are all determined to promote an environmentally friendly form of energy and to develop the areas of technology concerned.

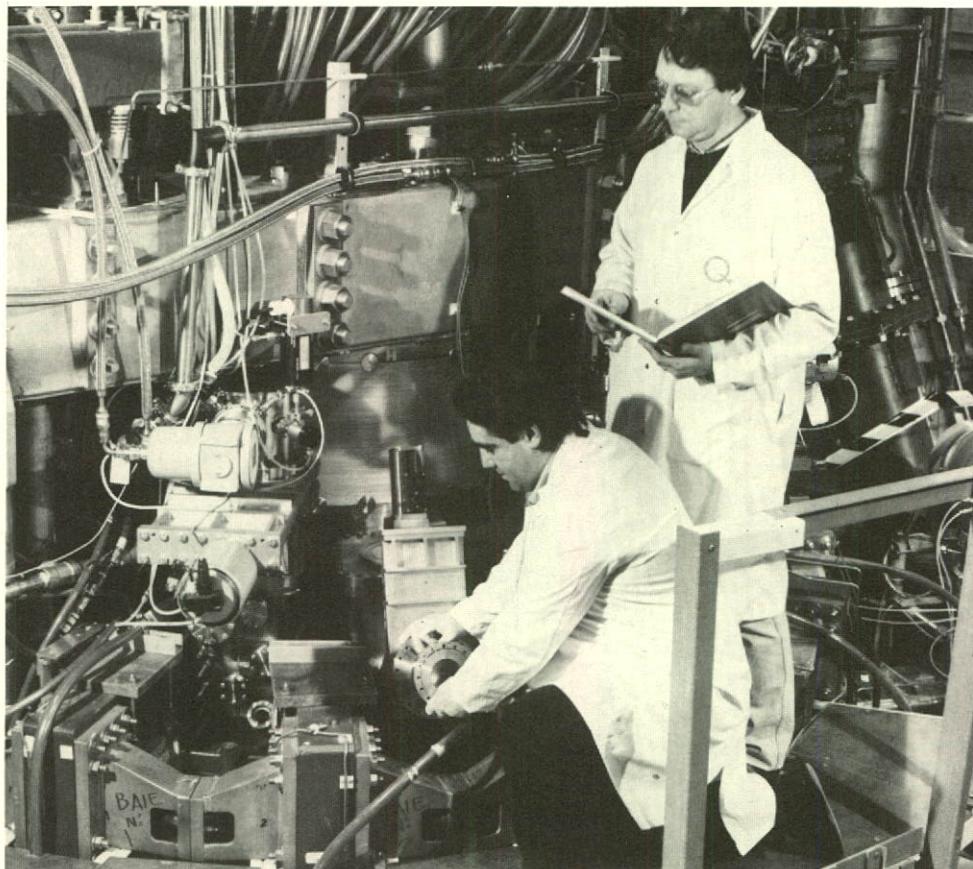
Hydro-Québec has been authorized by the provincial government to draw up a new strategy and to administer the industrial and commercial projects that ensue. The German companies Lüdwing-Bolkow-Stiftung and Conoc, for their part, will be in charge of managing projects carried out in cooperation with the EEC.

VALORISATION DE LA TECHNOLOGIE  
(TECHNOLOGY PROMOTION)

## MAGNETIC FUSION

Our research activities in the area of magnetic fusion, a source of energy which is as promising as it is environmentally friendly, continued to focus on operation of our experimental tokamak device known as TdeV. This work is performed under the auspices of the Centre canadien de fusion magnétique (CCFM). Hydro-Québec's partners in CCFM are Atomic Energy of Canada Limited (AECL) and Institut national de la recherche scientifique (INRS). CCFM now has approximately 100 employees drawn from Hydro-Québec, INRS and private companies such as MPB Technologies and Canatom.

Since 1987, when it was first launched, operation of the TdeV has undergone numerous scientific and technical developments which have confirmed its place as a leading-edge device in the area of magnetic fusion. A major factor contributing to this reputation is the ability to apply bias voltages to the magnetic divertor plates. All agree that a divertor will be an essential feature of the next generation of fusion reactors, yet that the design of this divertor represents an enormous scientific challenge. TdeV, one of the few tokamaks in the world designed to study this configuration, is by far the most suitable for studies of such biasing and of pumping of the fuel particles (ash) and impurities that the divertor extracts from the confinement area.



PIERRE NOËL  
(STANDING) AND  
ANDRÉ ROBERT  
CHECK ONE OF  
THE PARTS OF THE  
TOKAMAK DE  
VARENNE (FUSION  
PROJECT, IREQ).

## SCIENTIFIC EXPERIMENTS

The thrust of the work in the last 12 months has been on analyzing the behavior of the plasma and the divertor when the divertor plates are biased at voltages of up to 200 V in both polarities. We found that applying a negative voltage produces a distinct improvement in TdeV confinement and a significant increase in the divertor's impurity extraction capability. Very encouraging results have also been obtained by adding pumping to the divertor chamber and demonstrating the extraction of helium, considered to be the "ash" of fusion reactions, from the central zone.

In other studies, we compared discharges produced in deuterium, which were tried for the first time this year, with those produced in hydrogen. Boronization of the vessel walls, a major aspect of our research in 1991, is now routinely used to eliminate impurities. This highly effective method allowed us to achieve record axial densities (up to  $6 \times 10^{19} \text{ m}^{-3}$ ). We have also succeeded in performing preliminary measurements of the plasma current profile with the submillimetre polarimeter. Lastly, a joint project with the University of Texas at Austin provided an opportunity to measure the properties of the plasma edge using a retractable electrostatic probe.

## THEORETICAL STUDIES

While experiments were under way on TdeV, we were busy carrying out a program of theoretical interpretation and simulation studies. One of these studies, which was conducted jointly with the Massachusetts Institute of Technology and Princeton Plasma Physics Laboratory, was aimed at simulating the effect of lower hybrid frequency waves on tokamak plasmas. These simulations will help us to analyze the results of installing 1 MW of high-frequency power for driving the plasma current and plasma heating, which is planned for 1993. A final report on the use of such high-frequency waves in fusion reactors was issued during the year, completing a study contract for the NET (Next European Torus) program.

## MODIFICATIONS TO TdeV

Among many modifications to TdeV, mention should be made of the addition of a very complex power supply for controlling the vertical position of the plasma. This system was designed and manufactured in the Montréal area. Two other experiments are nearing completion. One is a compact torus injector, which is the outcome of a joint endeavor by CCFM, the Ontario fusion research program (CFFTP), the University of Saskatchewan and the University of California at Davis. The other is a diagnostic which uses a thallium beam to measure the edge plasma characteristics; this development work was performed in cooperation with the Interscience Corp. of Schenectady, New York. We also modified the divertor plate insulation to permit higher bias voltages. Operation of TdeV is due to resume in February 1993.

Meanwhile, the high-frequency wave injection system to be used for current drive will shortly be subjected to its first power tests. The two klystrons and the electrical power supply are already operational.

This year again, the CCFM had two researchers in Germany as part of the NET/ITER team which is currently working on the design of the next generation of fusion reactors. CCFM's Comprehensive Facility Plan was completely revamped in the spring and the new version subsequently approved by the International Advisory Committee.

The administrative highlight of the year was the federal government's confirmation that it would contribute \$7.2 million, i.e. half the CCFM's budget, over the next five years. Hydro-Québec and the INRS also confirmed their support, to the tune of approximately 40% and 10% respectively.

PROJET FUSION  
(FUSION PROJECT)

## TELEROBOTICS

The goal in IREQ's telerobotics research activities is to develop and experiment technologies likely to be of use in the design of hybrid systems for hardware maintenance. A joint project with CRIM (Centre de recherche en informatique de Montréal - Montréal Computer Research Centre) and McGill University drew to a close this year with many demonstrations on a test bench in our robotics laboratory. The aim was to coordinate the operator's manoeuvres and the use of a computer with a view to carrying out certain types of task, such as locating a conductor and a faulty porcelain, grasping a conductor with a tool or closing a disconnecting switch. The operator guided the robot with the aid of a joystick while the computer used an effort sensor and a 3D laser camera. These tests forms part of the TDS project, which also involves robotized boring of a hole and unwinding of a tie wire. Work was also completed on the infrastructure needed for installing a Sarcos remote manipulator arm with 10 degrees of freedom, which is outstanding mainly for its great dexterity and sophisticated programming capability.

Our links with local universities have led to the marketing of the AMETIST vision system, which can be used for analyzing and segmenting surface images, developing the algorithms necessary for analysis of the workspace, for collision avoidance, and for simulations. A research contract has been awarded to an outside firm to develop a Kali controller for the Sarcos arm and we also took part in an airborne vision experience using a miniature helicopter.

Robotized cells like the tele-operated system used for distribution line maintenance call for great dexterity on the part of the operator who has to handle a collection of joysticks. We are therefore interested in voice-operated control for some types of equipment. One experiment under way uses a series of simple words to control a swiveling camera base. This joint experiment with CRIM will allow us to compare the efficiency of a commercial voice-recognition system with that of more sophisticated software.

PROJETS DE DÉVELOPPEMENT  
(DEVELOPMENT PROJECTS)

## ELECTROCHEMICAL APPROACH TO THE STUDY OF INTERFACES

Work continued on an internal project initiated three years ago on an electrochemical approach to the study of interfaces, i.e. places where two different phases (e.g. solid-liquid, solid-gas) meet and interact with each other. The aims of this project are to develop our expertise by updating our knowledge in this field and to propose theoretical analyses of phenomena affecting various aspects of electrical apparatus.

Several different interfaces were examined. In the case of gas-insulated apparatus, for example, we focused on metal-gas (air, SF<sub>6</sub>, etc.) interactions. However, we also looked at metal-vacuum and metal-gas interfaces at reduced pressure levels, as found in plasma discharges or power switches, and analyzed the metal-polymer interface, with the polymer acting as an electrochemical medium with a highly diluted electrolyte. For all three of these interfaces, the charge transfer mechanisms characterizing the most common media, such as water with a strong salt concentration, were found to be quite analogous.

Our work consisted of a theoretical analysis of these interfaces and the interpretation of existing data on new lines bringing out a new understanding, at the molecular level, of the phenomena involved. One has combined the notions of solid-state physics and/or plasma physics with electrochemical concepts to elucidate the nature of interfaces involved in electrical apparatus. This work opened the way to new avenues of research which our researchers have already investigated and which have given rise to a number of publications in international scientific journals.

CHIMIE DES MATERIAUX  
(MATERIALS CHEMISTRY)

## **ELECTRODE MATERIALS FOR HYDROGEN RESEARCH ACTIVITIES**

Work was performed on two projects being carried out in joint ventures with the Hydrogen Industry Council. Both reflect the orientations spelled out in 1989 for Hydro-Québec's hydrogen research activities.

Each project concerned a particular aspect of the electrochemical approach to hydrogen production. The aim of the first was to develop and characterize electrode materials that would give off oxygen during water electrolysis. To that end, we determined the electrochemical and physical characteristics of a material capable of withstanding current densities over 500 mA/cm<sup>2</sup> sustaining overvoltages equal to or less than 350 mV. The other important criterion was the cost of the electrode material, which had to be the lowest possible. During the two years that the work was in progress, we tested various compositions which were all different but shared the same synthesis mode, i.e. electrodeposition, so that at least the cost criterion was respected. The electrodes were therefore created by depositing cobalt on nickel, cobalt on iron and nickel on iron. The most promising electrode material, obtained by the deposition of cobalt on a nickel substrate in an alkaline medium, is now undergoing more thorough analysis in a new project that the HIC has agreed to sponsor. The results are expected in March 1994.

The second project deals with the development of suitable materials for water electrolysis and the inverse, i.e. the production of electricity by an electrochemical reaction between hydrogen and oxygen in a fuel cell. To achieve this objective, we chose a technology based on oxygen ion conduction electrolytes, which meant using ceramics and operating the electrochemical system at temperatures near 1000°C. We therefore separated the work into two parts: development of the production techniques and physical characterization of the materials. The technique selected is based on the cathodic sputtering of oxides on ceramic substrates. Our efforts consisted mainly in setting up the necessary facilities and producing the large-size targets required. The work over the last 12 months focused on the characterization of deposits obtained by various surface analysis techniques and the production of very fine powders from materials that seem suitable for sputtering. The results have been sufficiently promising for the HIC to renew its participation in this project for another two years.

CHIMIE DES MATERIAUX  
(MATERIALS CHEMISTRY)

## **SHAPE-MEMORY ALLOYS**

Shape-memory alloys represent one of the most promising technologies in the field of electrical engineering. Their most attractive feature is their versatility, since they can be used equally well for temperature sensing as for mechanical action and shock absorption. We therefore initiated a project consisting of a study of the SMA industry throughout the world, an evaluation of their metallurgical properties and an exhaustive analysis of their potential applications, especially to the power industry.

The outstanding feature of SMAs is their ability to undergo a reversible solid-state phase transformation during cooling, when the crystalline structure of a material passes from the original, i.e. austenitic, state to the martensitic phase. This transformation occurs over a temperature range from -200°C to +200°C and endows SMAs with physical, mechanical and thermal properties that no other material possesses in terms of elasticity, damping capacity and memory.

They can also produce a mechanical action during heating, before they resume their original shape. For example, an SMA with a section of 1 cm<sup>2</sup> is quite capable of moving an object weighing 4650 kg.

Shape-memory alloys are basically functional devices: they are more important for what they can do, rather than for what they are. SMA materials have been used successfully in the power industry as well as the space, robotics, nuclear, medical and automobile industries among others.

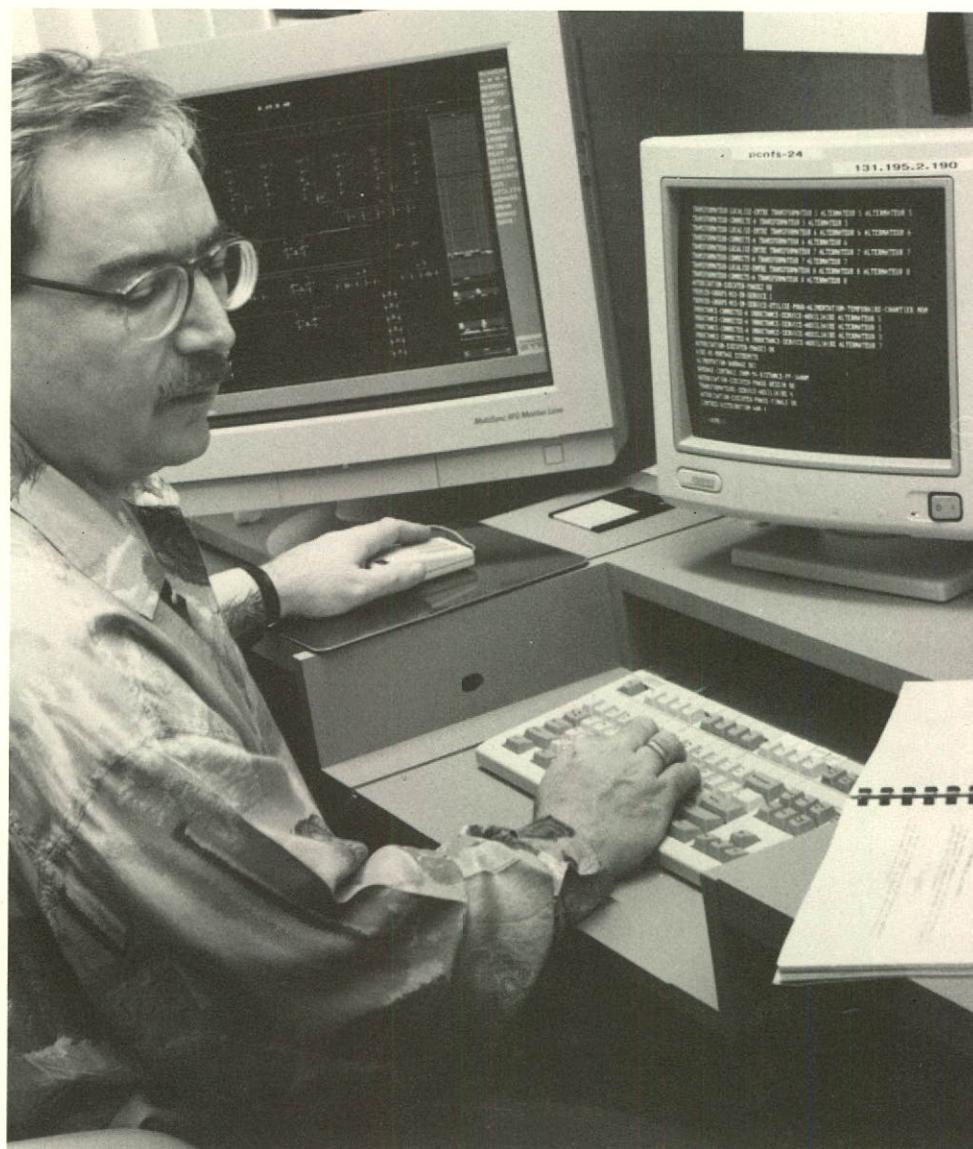
In light of the results obtained so far, we recommend that the thrust of future research be oriented toward three areas: interruption systems (circuit breakers, fuses), safety systems (heat sensing and monitoring) and maintenance (mechanical integrity). We are now in the process of forming a consortium between Hydro-Québec, Imago Canada and X-PER-X in order to pursue research, development and testing in the SMA field.

TECHNOLOGIE DES MATERIAUX  
(MATERIALS TECHNOLOGY)

OUR SPECIALISTS HAVE BEEN WORKING HARD OVER THE PAST YEAR ON VARIOUS EXPERT-SYSTEM PROJECTS. EXAMPLES INCLUDE THE DESIGN OF AUXILIARY EQUIPMENT FOR GENERATING STATIONS AND TRANSMISSION SYSTEMS, EQUIPMENT DIAGNOSIS, ALARM MANAGEMENT IN CONTROL CENTRES, DETERMINING THE LOCATION OF SPILLWAYS, AND DAM MONITORING.

WE HAVE ALSO DEVELOPED HIGH-PERFORMANCE MEASUREMENT SYSTEMS FOR THE STUDY OF HIGH-FREQUENCY PHENOMENA AS WELL AS A LEAKAGE-CURRENT ANALYZER.

## EXPERT SYSTEMS AND MEASUREMENT



JEAN-MARC PELLETIER PURSUES THE DEVELOPMENT OF THE SESA EXPERT SYSTEM (ELECTRONICS, IREQ).

## **SESA: AN INTELLIGENT DESIGN SYSTEM FOR AUXILIARY SERVICES**

SESA is an integrated set of software packages used to design auxiliary equipment for generating stations. These complementary packages are controlled by an expert system which combines the methods laid out in the design guidelines for auxiliary services with the knowledge of experts in this field. The software was conceived for the Electricity and Mechanics Department.

The software comprises two main modules, i.e. the design expert system as such and the AutoCAD drawing environment adapted to the design of auxiliaries. The originality of this combination is the way the two modules dovetail perfectly. The system uses an IBM-PC micro-computer operating under DOS and comprises two screens: as the designer, with the aid of the expert system, expresses his or her choices on one screen, the drawing is updated on the second.

Additional modules are currently under development: one consists of a bill of materials and the cost of the auxiliary equipment, while two others are related to busbar capacity and the capacity of reactors and transformers, respectively.

The development of the first version of the two main modules, which began in April 1991, was completed by June this year and the system has since been installed for the client. The final version, together with the additional modules, will be delivered in 1993.

SESA could prove useful in various related fields, especially refurbishing and design (electrical, civil, mechanical, etc.), in fact in any area where the end-product involves drawing or drafting.

ÉLECTRONIQUE  
(ELECTRONICS)

## **EXPERT SYSTEM FOR EQUIPMENT DIAGNOSIS (SEDA)**

SEDA comprises a set of four expert systems designed for transformer and circuit-breaker diagnosis and maintenance. Since these expert systems complement each other, we are able both to diagnose the status of power system equipment and to control its functions.

The development of the different modules forming part of SEDA dates back to 1989 when we first received the mandate from the Electrical Apparatus Directorate. Work was completed this year with the production of a users' technical manual. Other modules will be implemented next year in three Hydro-Québec sectors to validate their performance.

The flexible architecture of SEDA allows new modules to be added as needed. A transformer-aging module, for example, could be incorporated to simulate the changes that affect the lifetime of these units. Furthermore, modules for other types of power system equipment such as reactors, disconnecting switches, compensators, etc. could be added to the four basic modules. This set of expert systems, which operates on an IBM personal computer under DOS, has very user-friendly person-machine interfaces and can produce high-quality diagnostics.

ÉLECTRONIQUE  
(ELECTRONICS)

## **DEVELOPMENTS IN EXPERT SYSTEMS**

Several expert systems were developed during the past year for internal Hydro-Québec clients. They consist of:

- **Transect**, an expert system for the preliminary design of transmission systems, was delivered in February to the Power Systems Branch.
- **Langage**, an expert system for real-time alarm management in control centres, was delivered to three regional control centres for verification and validation, after which it will be implemented in six others.
- **Hydram**, an expert system prototype used to determine the location of spillways, was delivered to the Generating Plant and Buildings Branch, which then proceeded to test it. We are currently working on developing a final product.
- The "refund calculation" module of the **Confrère** system was developed and implemented in 1992 by the department in charge of sales and the quality of electric power (Customer Services Branch). This is the first module of a comprehensive system designed to analyze the connection requirements of Hydro-Québec clients. Work on other modules will continue in 1993.

We have also undertaken, in conjunction with CRIM (Centre de recherche en informatique de Montréal – Montréal Computer Research Centre), the development of an expert system called **Subarex** for the purpose of monitoring earthfill and rockfill dams. Delivery of the product to the Equipment Maintenance and Dam Safety Directorate is slated for 1994.

Lastly, in 1992 Hydro-Québec acquired from Coopers & Lybrand the methodology for the development of knowledge-based systems, called **Summit-Dk<sup>o</sup>**. In 1993, we will be studying, along with potential users within the utility, how this methodology can best be implemented.

PROJET SYSTÈMES EXPERTS  
(EXPERT-SYSTEMS PROJECT)

### **LEAKAGE-CURRENT ANALYZER**

Analysis of leakage currents plays an important role in the assessment of the insulating properties of contaminated insulators during tests in the pollution chamber at IREQ's high-voltage laboratory. We have therefore developed a new device, the leakage-current analyzer, which will allow us to study and interpret the leakage current and the voltage measurements in real time. This multi-channel device measures the peak current values, establishes a histogram of these values as a function of their cumulative number, calculates the derivative, determines the number of flashovers, and measures the minimum and maximum values of the voltage. It also records the last 100 cycles of each current and voltage channel prior to flashover and sends this data every ten seconds to a computer which stores the results and displays them in graphic form. Lastly, the results of each test series are transferred to a spreadsheet for later statistical study.

MESURE ET INFORMATIQUE  
(MEASUREMENT AND DATA PROCESSING)

### **HIGH-PERFORMANCE MEASUREMENT SYSTEMS FOR THE STUDY OF TRANSIENTS**

Twelve high-performance measurement systems have been delivered to the testing and technical appraisals specialists of the Maisonneuve Region who will incorporate them into the SMART (*système mobile d'acquisition en régime transitoire*) mobile laboratory they are using to study high-frequency phenomena on the power system.

These modular, extremely flexible, systems have a number of advantages. They operate efficiently in a highly disturbed environment, where measurements are difficult to perform, and are equipped with a 13-scale voltage divider at the input, which ensures the measurements are very accurate up to 1000 V<sub>dc</sub> or 707 V<sub>rms</sub>. Lastly, they require little supervision and can be operated remotely by computer. The latter is a valuable asset indeed, considering the access problems encountered when taking measurements at certain locations on Hydro-Québec's power system.

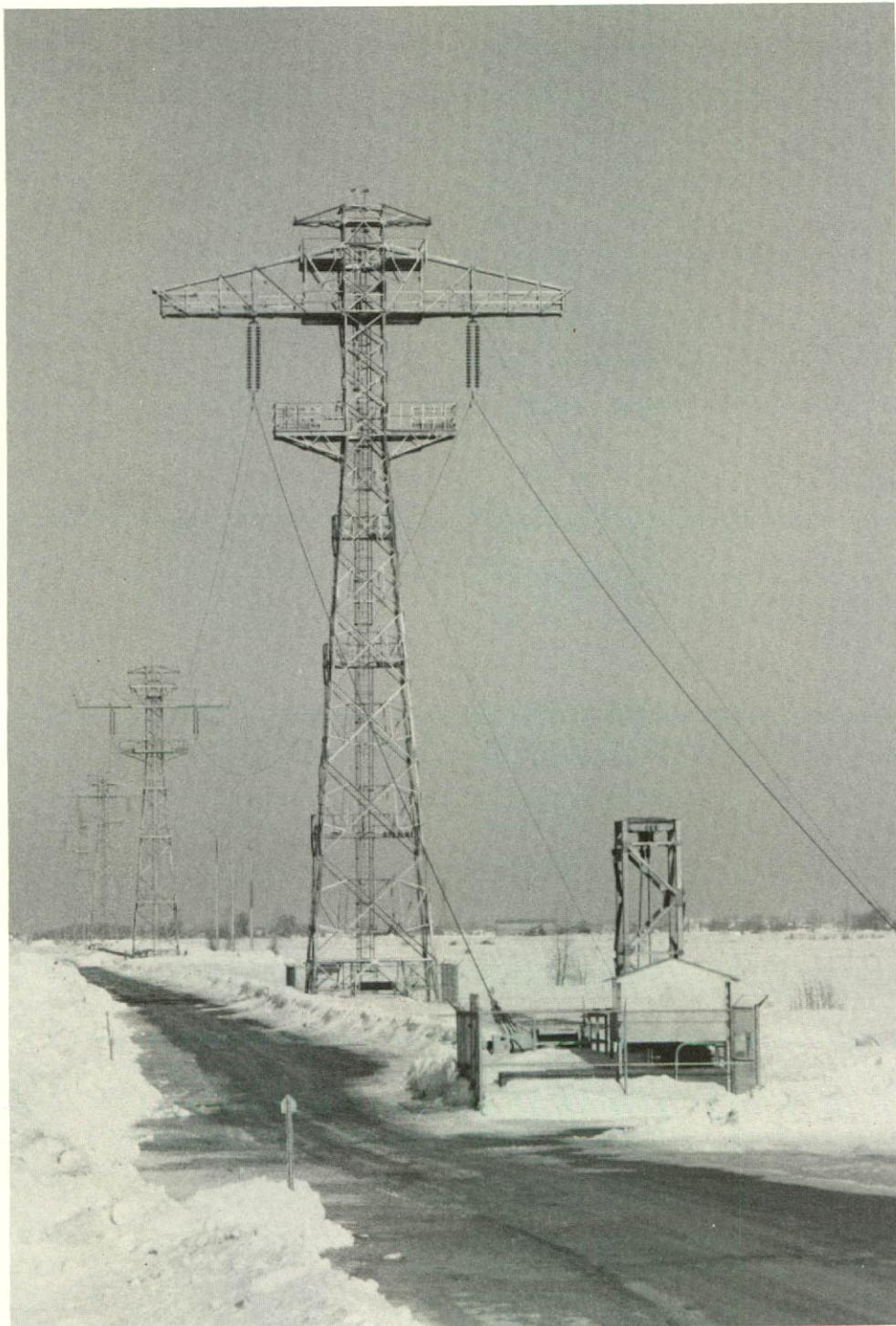
The measurement systems have already proven very effective at Nicolet substation for short-circuit tests at the terminals of the smoothing reactor and, also, in the Lanaudière Region for overvoltage tests on the distribution network. Several other tests are planned in the coming months.

Specially designed for IREQ's high-power laboratory, the new instruments form a key part of an entire new measurement system now being implemented there.

MESURE ET INFORMATIQUE  
(MEASUREMENT AND DATA PROCESSING)

DURING THE PAST YEAR, A 1.6-KM MECHANICAL TEST LINE WAS BUILT IN VARENNES WHICH WILL BE USED FOR THE STUDIES AND TESTS NEEDED TO DEVELOP SAG PARAMETERS FOR NEW CONDUCTOR SYSTEMS AND SELECT APPROPRIATE ANTIVIBRATION DEVICES. WE ALSO SET UP A FACILITY TO CONDUCT ACCELERATED-AGING TESTS ON BATTERIES. TWO RECENTLY ADDED TEST AREAS FOR THE POWER SYSTEM SIMULATOR WILL BE USED FOR ACCEPTANCE TESTS ON AUTOMATIC CONTROL DEVICES AS WELL AS ON PROTECTION AND CONTROL SYSTEMS FOR STATIC COMPENSATORS.

## NEW TEST FACILITIES



THE MECHANICAL TEST LINE ERECTED AT VARENNES, NOT FAR FROM IREQ (HIGH-POWER LABORATORY, IREQ).

## **CONSTRUCTION OF AN EXPERIMENTAL LINE FOR MECHANICAL TESTS**

A new mechanical test line went into operation this year. The facility is located at a site in Varennes near IREQ where it is exposed to low-intensity, low-turbulence winds. It will be used for the studies and tests needed to develop sag parameters for new conductor systems and select appropriate antivibration devices. Another objective of these studies is to make it easier to choose the best conductor technology in terms of increasing the power transmission capacity of lines and reducing the tower height. Thus, in future, one may expect that fewer lines will need to be built while greater respect for the environment will be achieved.

The 1.6-km line, which is not energized, comprises four towers and three suspension spans of 400, 425 and 450 m together with two end spans of 150 m.

LABORATOIRE GRANDE PUISSANCE  
(HIGH-POWER LABORATORY)

## **BATTERY TESTING FACILITIES**

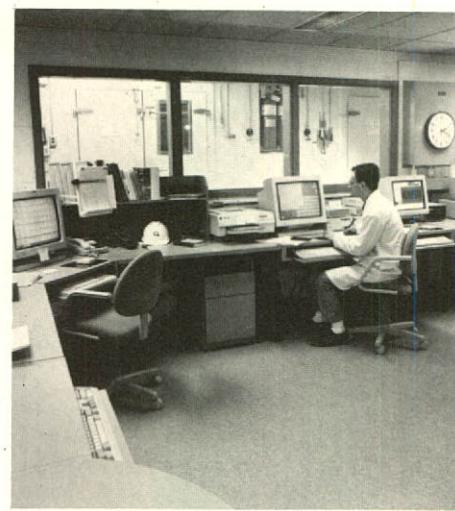
Work will commence soon on accelerated-aging tests on valve-regulated lead-sealed 2-V 625-Ah batteries, at the request of Hydro-Québec's Studies and Standardization Department. These so-called "maintenance-free" batteries will be subjected to ambient temperatures of 25, 40, 50, 60 and 70°C since, according to a logarithmic rule, the battery lifetime is inversely proportional to the temperature rise.

The tests will be performed in floating-voltage mode, in other words, when the batteries are connected to compensate for self-discharge, and in self-discharge mode, i.e. when they are not connected. Constant-current discharge cycles and constant-voltage charge cycles are regularly performed on batteries to estimate their condition while measurements are taken of their residual capacity (ampere-hours). After exposure to different temperatures over varying periods of time, the batteries will be tested at high-current discharges and constant-voltage overloads.

To be able to perform these tests, we had to build three thermally insulated enclosures designed to keep the temperature at 80°C. One of these enclosures can be set at a relative humidity of 65% while another is kept at 25°C and 55% relative humidity for the residual-capacity measurements.

The cycling equipment used to apply the charges and discharges is controlled by a computer which records and processes the accumulated data. Specially designed regulators are used to set the floating voltages, while the in-house developed software LISAC handles the aging and residual-capacity data.

LABORATOIRE GRANDE PUISSANCE  
(HIGH-POWER LABORATORY)



NEW BATTERY  
TESTING FACILITY  
AT THE HIGH-POWER  
LABORATORY.

## ADDITIONAL TEST AREAS FOR THE POWER SYSTEM SIMULATOR

Two additional test areas have been set up and commissioned, thereby enhancing the capacity of the power system simulator. The existing dedicated test areas have been used since February 1990 for conducting several studies at the same time; they are put into service as the need arises, depending on the availability of operating personnel.

The new facilities will be used for acceptance tests on automatic control devices as well as on protection and control systems for static compensators. In addition to specific equipment for the tests for which they are intended, these two test areas share a number of common features:

- a test control and monitoring centre comprising network interconnection panels for the system components and measurement transducers, an oscilloscope, multimeters and real-time controllers and for the system component models;
- a user-friendly data acquisition system offering 128 acquisition channels with a 1-MHz sampling-rate capability;
- current and voltage measurement transducers;
- a file server comprising the data acquisition software and test data base;
- two workstations for preparation and selection of the tests, measurements and mathematical processing applied to the test results.

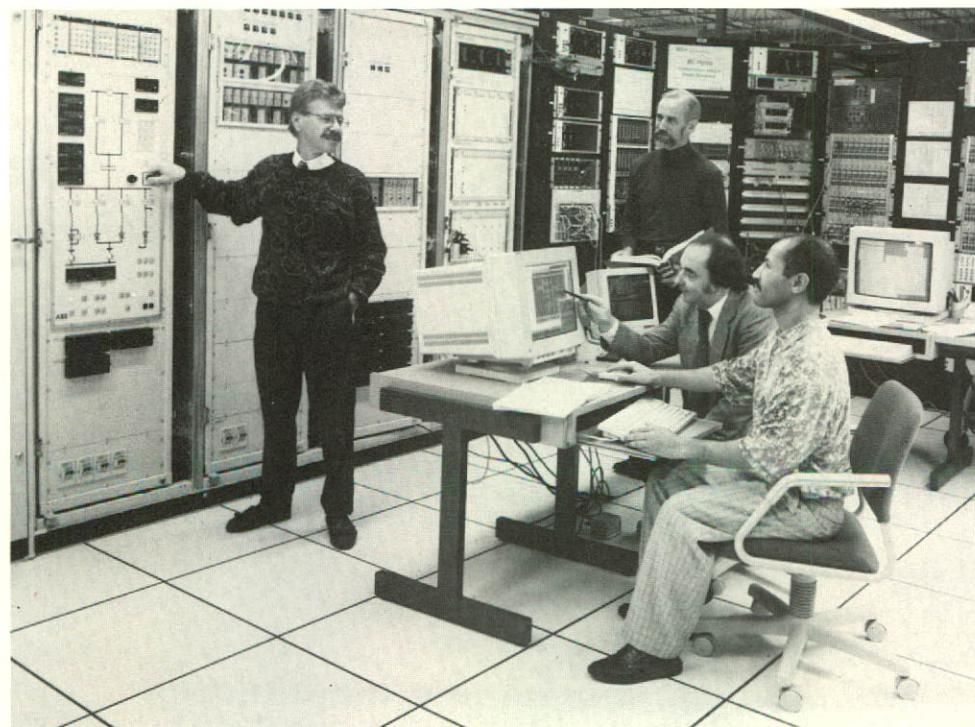
In addition, the protection system test area is equipped with:

- a generic model power system comprising six equivalent sources, transformers and various flexible transmission line models;
- 24 voltage and current amplifiers for applying waveforms of the simulated power system to protection relays;
- a waveform playback system for re-applying to relays the waveforms recorded during previous fault tests, and stored on optical disk.

The control system acceptance test area, for its part, comprises a typical power system comprising a system-equivalent source, hardware for simulating switching operations and usual power system faults, a coupling transformer generally used with static compensators, power components of a compensator with one thyristor-controlled reactor branch (TCR) and three thyristor-controlled capacitive branches (TSC). The latter area has been operational since September and is now being used for a study for BC Hydro.

These new facilities will allow a wider variety of studies to be performed, especially for the acceptance of protection and control systems. Moreover they will eliminate one of the inconveniences of the present simulator by reducing the test preparation time and, in so doing, will improve the quality of service we offer our clients.

SIMULATION DE RÉSEAUX  
(POWER SYSTEM SIMULATION)



(STANDING, L. TO R.)  
MICHEL TOUPIN,  
PIERRE MERCIER,  
(SEATED, L. TO R.)  
JEAN BÉLANGER AND  
YASSINE MAHARI,  
IN THE NEW STATIC-  
COMPENSATOR  
TEST AREA (POWER  
SYSTEM SIMULATION,  
IREQ).

IT WAS AN EXCELLENT YEAR FOR MARKETING LICENCES AND ROYALTIES. IN ADDITION, ANOTHER NEW COMPANY HAS JOINED THE GROUP OF TECHNOLOGICAL SUBSIDIARIES FORMING PART OF NOUVELER, A HYDRO-QUÉBEC HOLDING. IN ALL, EIGHT LICENCES WERE SIGNED, TWO WITH SUBSIDIARIES, BRINGING THE NUMBER OF ACTIVE LICENCES AT THE PRESENT TIME TO 40. AS FOR ROYALTIES, THEY EXCEEDED THE \$1.27 MILLION MARK FOR THE FIRST TIME, WHICH REPRESENTS A 100% INCREASE OVER 1991.

## TECHNOLOGY PROMOTION



LUCIE FILTEAU  
AND DANIEL  
SIMONEAU FROM  
HYDRO-QUÉBEC'S  
CUSTOMER SERVICES  
DISCUSS THE  
COMMERCIAL  
PROSPECTS OF A  
NEW PRODUCT  
WITH BERNARD  
LAITHIER (PLANNING  
AND TECHNOLOGY  
PROMOTION,  
FÉLIX-MARTIN)

## COMMERCIAL DEVELOPMENT OF THE SAMDI REMOTE ACCESS AND MEASUREMENT SYSTEM

The size of the Québec power system makes it difficult to perform maintenance on telecommunication links because some of the more distant components are practically inaccessible. In an attempt to remedy this situation, personnel in the Saguenay Region have designed a new system, SAMDI, for carrying out a full gamut of tests on communication circuits.

A licensing agreement has been signed with the Chicoutimi firm, Troniq, to manufacture and market SAMDI, and a patent application has been filed. This system represents a technological breakthrough which should give rise to a whole new range of products for monitoring the parameters of data and voice transmission circuits. Through Nouveler, Hydro-Québec has also acquired shares in Troniq.

## LICENSING AGREEMENT WITH RAQ FOR AN ALUMINUM DROSS RECOVERY PROCESS

Aluminum dross that forms at the surface of metallic baths in reaction to oxygen in the ambient air can contain up to 75% metallic aluminum. Various technologies are used to recover this metal, including the plasma torch-based approach which was first demonstrated in 1987. A second generation of this technology recently developed at LTEE offers a much greater efficiency.

The Québec company RAQ operates aluminum dross processing plants at Baie-Comeau and Bécancour, using gas and fuel oil to heat the rotating furnaces. However, the company is interested in gradually converting to electric arc heating using a technology patented by Hydro-Québec and has acquired an exclusive licence allowing it to apply this technology within a 200-km radius from Bécancour. The agreement also provides for a joint demonstration project.

## COMMERCIAL DEVELOPMENT OF ELECTROCHEMICAL PROCESSES

In 1989, LTEE's Industrial Electrochemistry and Chemistry Department initiated the development of an electrochemical technology known as cerium-based oxidation, which was first pursued by the major American company, W. G. Grace. By agreement with the latter, Hydro-Québec and its beneficiaries now have exclusive use of the cerium technology and related patents.

The technology developed at LTEE is generic in that it can be used for synthesizing various chemical compounds. Two specific processes have resulted from this work so far. The first concerns the synthesis of tetrahydroanthraquinone (THAQ) which is used in the pulp and paper industry. An agreement has been signed with an American chemicals company giving the latter an exclusive option on a licence to use the LTEE technology for the production of THAQ.

The second process is related to the synthesis of a different compound, belonging to the quinone family. An agreement has been signed with an Asian chemicals company which is helping to finance the R&D activities. If LTEE'S work is conclusive, the company could be granted a licence to build an electrolysis plant with an annual capacity of 3300 tonnes, representing an investment of over \$30 million.

## GRANTING OF A LICENCE FOR THE RUPA AND DIGLO GENERATOR PROTECTION RELAYS

The combination of RUPA, a universal protection relay, and DIGLO, a global differential relay, provides full digital protection for AC generators. Developed at IREQ for the utility's Generating Plant and Buildings Branch, this product is now replacing the electromechanical and static relays currently used on the Québec power system.

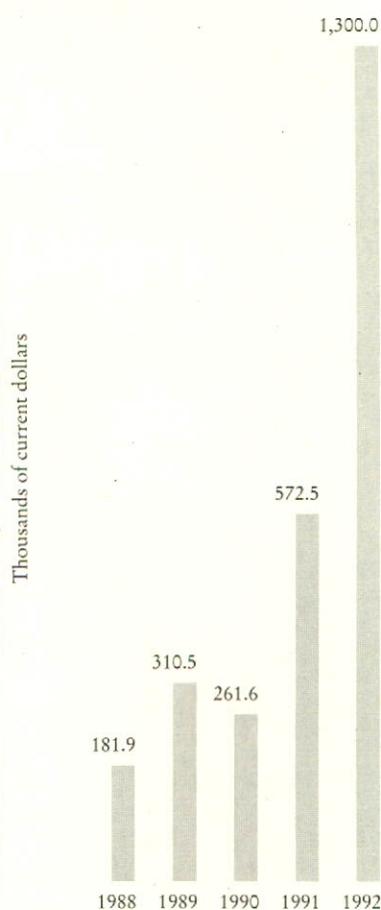
Protection is one of the essential functions of a power utility and the promotion of relays calls for a partner with a wide distribution system and market. General Electric was therefore awarded an exclusive licence for the manufacture and marketing of the RUPA-DIGLO technology. The licence's field of application includes AC generators, motor-generators and transformers.

## THREE OTHER LICENCES AWARDED

A licensing agreement signed with Cyme International, another subsidiary of Nouveler, involves three new software packages for power line analysis. Developed for the Transmission Equipment Branch, one of these packages is for the analysis and dimensioning of lattice towers, the second for calculating cable tension and sag, and the third for tower repair.

A manufacturing and marketing licence concerning fireproof clothing has been awarded to Camoplast and another, for aluminum dross processing, to Recyclage Mingan.

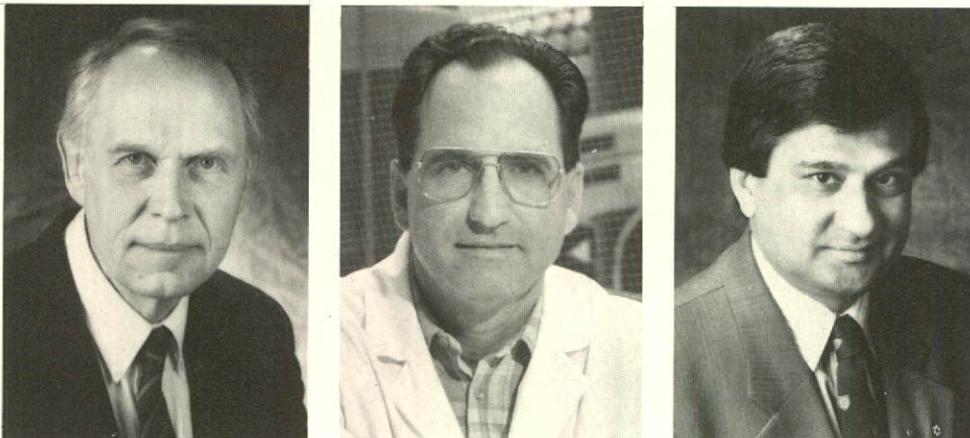
## GROWTH IN REVENUE FROM LICENCES 1988-1992



Raymond Bartnikas, distinguished senior scientist, has won the Standards Council of Canada's 1992 Jean-P. Carrière Award, the highest honour in the area of standardization in Canada.

Georges Vaillancourt, senior researcher, Service Mesure et Informatique, was awarded two prizes by the Institute of Electrical and Electronics Engineers (IEEE) for his contribution to the development of a standard for partial-discharge measurement applicable to transformer and reactor acceptance tests.

Ashok Kumar Vlijh, distinguished senior scientist, has received the medal commemorating the 125th anniversary of the Canadian Confederation in acknowledgment of his outstanding contribution to the well-being of his compatriots and his community. He has also been made a Knight Commander of the Merit of the Sovereign Military Order of St. John of Jerusalem.



#### BEST TEAM OF THE YEAR

The anthraquinone research team in LTEE's Service Chimie et Électrochimie industrielles won the Best Team of the Year prize. This team is developing manufacturing processes for anthraquinone, one of the basic products used in the dyeing industry. Since it offers a means of reducing pollution and energy consumption, anthraquinone is also useful as a delignifying agent in the pulp and paper industry. Various technical and economic studies have revealed that the electrochemical process developed at LTEE has a strong competitive edge and negotiations are under way to award operating licences.



## AWARDS AND DISTINCTIONS

(FROM L. TO R.)  
ROGER RICARD,  
BERNARD GUIRAL,  
MICHEL PETITCLERC,  
JACQUES HAMELIN,  
ANNA VÉLIN, ALAIN  
BROSSEAU, ANTOINE  
THÉORET, BERNARD  
SAINT-Louis, PIERRE  
ÉLIE, STEPHEN  
HARRISON, CLAUDE  
DUMAS, RAYNALD  
LABRECQUE AND  
ALAIN ANGEL. NOT  
APPEARING IN THIS  
PHOTOGRAPH ARE  
JACQUES CONTANT  
AND ROBERT NAULT.

**TECHNOLOGY AND IREQ  
(INSTITUT DE RECHERCHE  
D'HYDRO-QUÉBEC)**

*Alain Brosseau*

**SENIOR  
MANAGEMENT**

CENTRE D'INNOVATION EN TRANSPORT D'ÉNERGIE  
DU QUÉBEC (CITEQ)  
CENTRE CANADIEN DE FUSION MAGNÉTIQUE  
(CCFM)

**EQUIPMENT TECHNOLOGY AND TESTING**

*Clément Ouellet*

Cables and Insulation  
Electrical Apparatus  
High-Power Laboratory  
High-Voltage Laboratory  
Overhead Lines

**GENERATION TECHNOLOGY AND MATERIALS**

*Yvan Couture (interim)*

Fusion  
Materials Chemistry  
Materials Technology  
Mechanical Engineering

**POWER SYSTEM TECHNOLOGY**

*Marc Hung*

Electronics  
Expert Systems Project  
Measurement and Data Processing  
Numerical Methods  
Power System Simulation

**APPLICATION TECHNOLOGY AND LTEE  
(ELECTROCHEMICAL AND ELECTRICAL  
TECHNOLOGY LABORATORIES)**

*Louis-F. Monier*

Industrial Chemistry and Electrochemistry  
Industrial Electrotechnologies  
Industrial Plasmas

**TECHNOLOGY PLANNING AND PROMOTION**

*Yves Langhame (interim)*

ACEP Development Project  
Engine Development Project  
Plans and Follow-Up  
Promotion – Customers and Distribution  
Promotion – Generation  
Promotion – Transmission  
Promotion – Utilization and Environment

**RESOURCES AND SERVICES**

*Gilles Lacoste*

Human Resources, Procurement and Information  
Technical Services





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