Ontario Hydro

1983 REVIEW AND 1984 PROGR

OH-- Report No 84-98-K

J.A. Chadha
Section Head
Applied Structural and
Solid Mechanics Sectic
Mechanical Research Depar

RESEARCH

ontario hydro
research division

APPLIED STRUCTURAL AND SOLID MECHANICS SECTION 1983 REVIEW AND 1984 PROGRAMS

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ABSTRACT

A review is made of the applied research and problem solving work carried out by the Applied Structural and Solid Mechanics Section of the Mechanical Research Department during 1983. The projects planned for 1984 are also described.

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740621-801-080	820.1	April 13, 1984	84-98-K

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EXECUTIVE SUMMARY

APPLIED STRUCTURAL AND SOLID MECHANICS SECTION 1983 REVIEW AND 1984 PROGRAMS

J.A. Chadha
Section Head
Applied Structural and Solid Mechanics Section
Mechanical Research Department

The purpose of this report is to briefly review the applied research and problem solving work carried out by the Applied Structural and Solid Mechanics (ASSM) Section during 1983. It is not simply a listing of activities; a moderate amount of detail is included.

Regarding 1983, a few highlights should be noted. There was a strong demand for services in the areas of theoretical and experimental stress analysis, heat transfer analysis, non-linear analysis, and general structural analyses related to nuclear and thermal power plant, and transmission line components. Development of capabilities in these areas progressed well. Details are included in the report. Proposed work programs for 1984 are also outlined in this report.

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To Mr. F.J. Kee
Director of Research

APPLIED STRUCTURAL AND SOLID MECHANICS SECTION
MECHANICAL RESEARCH DEPARTMENT
1983 REVIEW AND 1984 WORK PROGRAMS

1.0 INTRODUCTION

This report is a summary of progress and major achievements and work program plans of the Applied Structural and Solid Mechanics Section of the Mechanical Research Department. The Section is primarily responsible for research and services in the areas of theoretical stress analysis, experimental stress analysis, special projects related to structural mechanics, performance and behaviour of transmission lines and structures, and some heat transfer work. In 1983, the total budget of the Section was about $2.0 M. At present the Section is divided into 5 Units as follows:

1.	Unit Head - Transmission & Structures	Dr. D.G. Havard
2.	Unit Head - Theoretical Stress Analysis and Heat Transfer	Dr. T.P. Byrne
3.	Unit Head - Special Projects and Computing	Dr. J.D. Tulk
4.	Unit Head - Experimental Stress Analysis	M.T. Flaman
5.	Laboratory	R.W. Wolfendale

Full listing of the present staff in the Section is shown in Appendix IV of this report.

The text of this report has been organized to fit the new Research Division program areas such as Nuclear Generation, Thermal Generation, Nuclear Waste, and Transmission.

2.0 NUCLEAR GENERATION

2.1 CANDU Fuel Channel Integrity Programs

Following the failure of G16 Channel at PNGS-A, our section is getting more actively involved in studies related to fuel channel integrity. Most of the work programs are in their early stages. The following is a list of fuel channel integrity related work programs that our section is involved in.

1. Pressure tube blister growth analysis. Objective: To model growth of hydride blisters.
2. Measurement of axial loads on Pickering NGS-A pressure Tubes Objective: To assess influence of axial loads on sag of P/T and time before P/T and C/T contact.
3. C/T integrity analysis under shock loading of P/T break. Objective: To assess ability of a C/T to act as a containment boundary.
4. Perform accurate measurements and calculations of residual stresses in rolled joint area. Objective: To assess integrity of P/T near the end fittings.
5. CANDU P/T Dynamic analysis related to garter spring repositioning. Objective: To assist PED Section of Mechanical Research Department in their interpretation of experimental vibration data through finite element analysis of a fuel channel.
6. Provide input on stress related concerns in the study of P/T failure mechanisms. Objective: To assess integrity and life of P/T's.

2.2 Measurement of End Loads on Reactor Pressure Tubes - Douglas Point NGS

There is an uncertainty regarding the magnitudes of end loads imposed on Douglas Point NGS reactor pressure tubes. This concern relates to the growth tendency of these tubes under sustained high-intensity radiation. An exploratory project (as described in Report No 82-58-K) has been undertaken to investigate the use of strain gauged load washers to measure these end loads (on line) on selected pressure tubes on the Douglas Point reactor.

Recently, after some two years of uneventful on line monitoring, certain load readings began to increase in magnitude. Due to safety concerns of excessive pressure tube end loads, the reactor was shut down to determine the cause of high load readings during shutdown conditions. The function of the load washers was investigated and verified as correct. Therefore, adjustments were then made in end fitting hardware to cause a reduction in on line loads. This reduction was verified by the load washers when the reactor was restarted. Studies are now continuing to determine the initial cause of the high pressure tube end loads (and other phenomena) detected by the on line load washer measurements.

2.3 On-Line Measurements of Reactor End Shield Displacements at Pickering NGS A

The magnitudes of reactor end shield displacements have a direct impact on the continuing efficient operation of operating nuclear units, particularly as they age. The major concern regarding axial end shield movements is due to prolonged high intensity radiation effects on calandria tubes and pressure tubes.

A trial project has been undertaken to measure these end loads during unit operation by means of remotely monitored electronic displacement transducers. So far, after over a year of measurements, this on-line measurement approach has been verified as reliable and accurate.

2.4 Hydrogen Migration and Blister Control Growth in Pressure Tubes

The Zircaloy-2 pressure tube failure in Pickering A Unit 2 in August 1983 resulted from pressure tube/calandria tube contact leading to hydrogen migration and hydride blister formation. In view of the need for the examination of the implications of such pressure tube/calandria tube contact in reactors tubed with Zr-2.5 wt % Nb pressure tubes, a co-ordinated research team has been assembled to address the problem. A necessary part of this study is the analytical modelling of the temperature distribution and the hydrogen migration and precipitation resulting in the blister growth. The controlling equations have been assembled and a new unified model has been developed and demonstrated to work very well with the finite difference method. Work is proceeding on the formulation and coding for the finite element approach.

The objective for this study is to accurately predict the blister growth dynamics for various PT/CT contact scenarios. The blister growth dynamics will include the blister size and shape and the hydrogen/deuterium concentration as a function of time.

2.5 CANDU Pressure Tube Dynamic Analysis

Following the failure of a pressure tube in the Pickering NGS Unit 2 reactor, there has been considerable interest identifying tubes where the "garter springs" separating the pressure tubes from the calandria tubes are out of place. When these springs are out of place, the vibration characteristics of the tube assemblies change. A promising method of identifying tubes with out of place springs is to examine the dynamic characteristics of the tubes. ASSM personnel have been supporting efforts in this area through the development of mathematical models of the tube assemblies and the analysis of mode shapes and natural frequencies for a number of normal and abnormal garter spring configurations.

In 1984 this work will continue with the development of more accurate models of the tube assemblies. The objective will be to provide a theoretically sound basis for the rapid and reliable identification of faulty tubes.

2.6 On-Line Structural Integrity Monitoring for Nuclear Stations

The capability to evaluate and continuously monitor the on-line mechanical behaviour of critical nuclear plant components will become very important in the coming years with regard to structural integrity, safety and efficiency. A proposal to develop this capability was fully described in a report issued in early 1983 (No 83-39-K, M.T. Flaman) and interest in this on-line structural integrity monitoring approach has substantially increased as a result of the recent detection of high pressure tube end loads at DPNGS and as a result of the pressure tube failure at PNGS A.

Much of the required effort to develop an on-line structural integrity monitoring system cannot be "time-compressed". Therefore, if we are to be prepared for future demands in this area - which may be presently unforeseen but which may be urgent and of extremely high priority - substantial efforts must begin now.

In 1984, a presentation will be made to interested persons (based upon the 1983 proposal) to obtain specific financial support for the expeditions and comprehensive development of this needed capability.

2.7 Darlington and Pickering Nuclear Component Concerns: Proposed "Modifications" and Measurements

The prolonged operation of our nuclear stations has affected the ongoing mechanical behaviour of the reactors and associated nuclear components, particularly those subjected to sustained high radiation. This has become a very important concern and it especially involves the long term efficient operation of our nuclear generating stations.

It is very difficult to directly investigate various aspects of on-line structural performance of existing reactors and associated nuclear components becase of the very high radiation levels that prevail, particularly at the reactor site, even during shutdown conditions. As such, measurements on these reactors during shutdown conditions, or instrumenting these reactors during shutdown for subsequent on-line measurements, may be impossible to carry out in many cases due to the unacceptable radiation dose that would result to nuclear workers in the performance of these efforts.

Presently, with the construction of Darlington NGS A there exists an excellent opportunity - which may not be available again for the remainder of this century - to satisfy many of the difficulties in obtaining the required information. Specifically, an effort was begun by the Experimental Stress Analysis Group in 1982 (see Report No 83-52-K, February 1983) to promote the performance of certain measurements and modifications. This work would be

done during the design, construction and operation of Darlington NGS A to:

(1) Perform stress, strain, force, displacement, etc, measurements on reactors and other nuclear equipment during fabrication and installation. Such measurements would determine the residual and installation stresses on calandria tubes, fuel channels, feeder pipes, PHT pipes, reactor end shields, etc. Also several other types of "datum" or "benchmark" measurements regarding positions, dimensions, etc, of various components would be performed.

(2) Explore the possibility (in conjunction with other groups) of slightly "modifying" one or two of the Darlington reactors during the construction stage to facilitate the gathering of on-line structural integrity information at some future date (perhaps as certain measurement transducers become perfected or as certain present concerns become critical).

(3) Comprehensive on-line structural integrity measurements be made continuously on one Darlington reactor right from the installation date and for the foreseeable future after initial unit startup to obtain complete information regarding certain concerns of ongoing mechanical behaviour.

The efforts described in this proposal (which to some extent might be applicable during the retubing at P1 and P2) must not only be considered in terms of present requirements but also in terms of those requirements which may become urgent only at some future time. This information could be extremely useful to not only Darlington NGS but also to existing Ontario Hydro nuclear plants.

2.8 Structural Behaviour Monitoring of Bruce NGS A Steam Drum/Steam Generator Structure

During the fall of 1980, the four steam generators connected to the west steam drum of Bruce NGS A were instrumented with thermocouples and capacitance strain gauges. On-line measurements of stresses and forces were performed at that time and were used to successfully enable the mechanical integrity of the structure to be demonstrated to AECB. This installed equipment has continued to be monitored periodically during the past three years. The results (as described in Report No 82-150-K) demonstrated that this steam drum/steam generator structure consistently performed in a stable and repeatable manner with regard to mechanical behaviour.

The main benefit of continuing these measurements, however, is to generate a history of successful long-term experience on the reliability of this type of measurement. This will be particularly

valuable for upcoming projects which may require a high degree of assurance in the measurement approach. As such, this ongoing project may provide very valuable input to future urgent concerns in this or other Ontario Hydro nuclear plants.

2.9 On-Line Crack Monitoring Development

The initiation and propagation of cracks or flaws during operation in electric power station structures is a well known phenomenon which can unduly limit service life. This phenomenon has particular significance to critical components in nuclear stations.

In order to accurately establish the state of flaw stability and thus possibly extend the remaining service life of the affected component, it may be very important to employ on-line crack monitoring techniques. Various surface and subsurface flaw monitoring approaches for on-line monitoring are being considered. This capability may be extremely important to have available for future nuclear plant concerns, which may be presently unforeseen or presently underestimated as to their importance to regulatory bodies.

2.10 Steam Generator Tube Integrity Burst Tests

An experimental program to evaluate the structural integrity of degraded steam generator tubing by performing laboratory tube burst tests has been initiated and will be performed in early 1984. The structural performance of steam generator tubes containing such degradation types as cracking, wastage, and denting are to be evaluated and compared to the performance of "defect-free" tubing. In addition, the defective tubes used in this program are to be inspected using the eddy current technique by station personnel before the burst tests. Structural integrity criteria based on both the burst test data and tube inspection interpretation would then be established. This information would be used to evaluate in-situ steam generator tubes during future inspections regarding continuing serviceability.

2.11 Residual Stress Measurements in a Simulated Temper Bead Weld Repair

Surface residual stress distributions for a simulated temper-bead weld repair in a SA516 Grade 70 steel plate have been investigated. This investigation was performed to determine the residual stresses present as a result of a thick-walled pressure vessel temper-bead weld repair. The surface residual stress measurements were performed using the ultra high speed hole drilling technique.

2.12 Investigations into Stress-Related Mechanisms Involved in Steam Generator Tube Failures

Occasional failures in steam generator tubes in Ontario Hydro nuclear stations have resulted in significant economic losses. Because of the large number of tubes in each steam generator and because the causes of the failures have not been confidently established, there exists a concern as to the possibility of continued tube failures.

The nature of past tube failures clearly implicates mechanical stresses as a contributing (and possibly primary) cause. As such, a proposal (No 83-228-K, June 20, 1983, M.T. Flaman) was made to comprehensively investigate stress-related mechanisms in steam generator tube failures.

2.13 Ice Plug Blocking of Nuclear Station Feeder Pipes

A routine station procedure of temporarily blocking water filled feeder pipes for repair and maintenance requirements in CANDU nuclear generating stations is based upon the use of a liquid nitrogen filled jacket. The cold fluid (-196°C) in this jacket which is put in direct contact with the outside pipe surface, causes ice to form within the pipe, thus temporarily forming a plug.

The performance of this procedure may cause unacceptably high stresses to occur which can be critically important with regard to the immediate and long-term integrity of the pipe.

A laboratory project to measure these stresses on a feeder pipe during ice plug blocking tests is being carried out by the Experimental Stress Analysis Group. Preliminary results from several ice plug tests in late 1983 have indicated that only "moderate" stresses arise on an unpressurized pipe when the ice plugging procedure is performed. Future tests in early 1984 are planned.

2.14 Safety Investigation of On-Line Leak Sealing Procedures

A brief investigation was performed (with CNS) into specific safety related aspects of a routine station procedure for sealing leaks in flanged joints of pressurized components. This on-line procedure involves the high pressure injection of a sealant between the flanges of the leaking connection.

Results of this study (performed on a test flange) indicated that this potentially hazardous procedure can readily be performed safely if certain precautions are taken. A recommendation was made to employ on-line stress monitoring approaches to ensure that flange bolt stress changes remained within predetermined limits during future performances of sealing operations.

2.15 Bruce NGS B Vacuum Building
16 PRv Blowthrough Test 1983

A comprehensive report has been prepared on the 16 PRv blowthrough test done on the Bruce NGS B vacuum building to confirm its structural integrity under an emergency situation. Measurements of pressure, air velocity and flow-induced force were made in the vacuum building to assess the response of its structural components to a postulated Loss of Coolant Accident. The data analysis shows that the measured pressures, air velocities and forces were below the design values. Nearly all the measuring instruments functioned satisfactorily during the tests leading to the conclusion that the vacuum building is suitably designed for its purpose.

2.16 Bruce NGS B Emergency Coolant
Injector Water Hammer Test

1983: The objective of the test program was to measure the loads on several pipe supports due to water hammer and pipe pressurization. Approximate instrumentation was installed on two selected supports to monitor dynamic strain, load and displacement. The analysis of data gathered from a series of tests indicates that the measured values were lower than the design specifications and hence the supports are adequately designed. A detailed report is expected to be issued in the beginning of 1984.

2.17 Development of Residual Stress Measurement Methods

As it becomes important to demonstrate the structural integrity of certain plant equipment, the capability of measuring residual stresses will be very useful. Presently, there are two general approaches for measuring residual stresses that are being investigated and developed at Research Division.

(1) Destructive (Sectioning) Methods such as ultra high speed machining, electrical discharge machining and chemical milling methods are being studied.

(2) X-ray Diffraction Methods and "Barkhausen" methods are being studied. These methods are completely non-destructive to the part being analyzed and, therefore, may have very important uses on operational nuclear plant equipment.

2.18 Rolled-Joint Residual Stress

A study was initiated during 1983 for the purpose of calculating rolled joint residual stresses. The objectives were to:

(a) investigate a potentially simple and inexpensive analytical method for evaluating rolled-joint residual stresses,
(b) determine the effect of various parameters,
(c) evaluate the strain gauge approach analytically,

(d) compare the calculated residual stresses with existing experimental results.

Some progress was made, however, higher priority work resulted in this project being temporarily shelved. If possible, this work will be re-initiated in 1984.

2.19 Hydrostatic Pressure Testing of a Blistered H_2S Absorber Tower

Stresses, strains and pressures were measured during a hydrostatic pressure test of a Bruce Heavy Water Plant (BHWP) H_2S Absorber Tower. This vessel had been removed from operating service as a safety precaution due to extensive inside surface hydrogen blistering and was to be scrapped. During this test, the vessel reached a maximum hydrostatic pressure of approximately 4340 kPa. At this test pressure, significant pressure vessel yielding was observed and the hydrostatic test was terminated. From the analysis of the stress and strain data collected during this test, no significant structural degradation was indicated to have occurred in the pressure vessel at the blistered locations compared to non-blistered locations.

2.20 BNPDS Steam Line Elbow Strain Gauge Measurements

A major water hammer occurrence at BNPD caused a large diameter steam line to be thrown from its support. Stress and strain measurements were performed on the energized steam line to investigate the extent of steam line material yielding while the line was being positioned back onto its support. Strain measurements indicated that some localized material yielding may have occurred at specific locations on the steam line elbows. It was, therefore, recommended that ultrasonic testing be performed during the next steam line outage to ensure that no significant defects exist at the concerned elbow locations.

2.21 Seismic Qualifications of Electrical Equipment

In 1983, work proceeded on the seismic qualification of a variety of electrical equipment for Bruce NGS 'B'. This included 4.16 kV switchgear and associated control relays for the emergency water and power supply system and unction boxes for the variable frequency supply equipment. Development work was carried out on methods and computer tools to enable the efficient qualification of equipment through a combination of testing and theoretical analysis.

For 1984, qualification work on electrical equipment for Bruce B and Darlington will continue. Work on the basic mechanics of seismic response is planned. This will encompass theoretical and experimental investigation. The long range objective of this work will be to develop simplified qualification procedures for equipment located in areas with low seismic loading.

2.22 Seismic Qualification of Cable Raceway at Bruce NGS B

The seismic withstand capability of conventional cable raceway systems have been extensively tested by Bechtel Power Corporation and ANCO Engineers in the US. On the basis of these tests, a procedure has been developed for the seismic qualification of safety related cable raceway systems at Bruce NGS'B'. On the basis of the Bechtel results and results of a series of experiments carried out by the personnel of the Mechanical Research Department, it is possible to show that all of the cable raceways at Bruce will require little or no bracing to survive the design basis earthquake (DBE) postulated for this site. This will result in a major saving of money and construction time for this project. A set of reports documenting the qualification procedure have been prepared. These describe the experimental and theoretical background to the procedures, outline methods for qualifying the various parts of the system and provide hardware assembly details.

For 1984, work on the Bruce 'B' cable raceway system will be completed. It is hoped that the principles developed for the qualification of the Bruce 'B' cable raceways will be applied to Darlington NGS.

2.23 Pipewhip Studies

This program, which is being developed in co-operation with the Mechanical Design Department, examines the response of a high-energy piping system to the large forces which would result from a major break in the pipe. Work in this project in 1983 has been limited by heavy commitments in other areas although literature surveys have continued and tests have been conducted to examine the crushing strength of pipe components under static and dynamic loading. As well, Dr. J. Tulk of this section has served as a technical advisor to a CEA funded project on this subject carried out at the AECL laboratories at Sheridan Park.

For 1984, work will include the development of an impact test rig with which impact loading on sample components in the 0-50 metres/second range can be tested at low cost. This equipment will be used to examine the effect of impacts on piping components and various targets.

2.24 Stability Studies - Bruce NGS B

The instrumentation program to install reference stations on all four units (5,6,7,8) at Bruce NGS 'B' will be completed in 1984. Only unit No 8 remains unfinished. Datum readings on the Trombik-Stadelmann design foundations were started in May 1982 and were completed in November 1983 for all units except unit 8. The installation report will be issued early in 1984.

This program will be taken over by the Civil Research Department upon completion of the Installation Report.

2.25 Pickering NGS B Moderator Temperature Measurements

In 1983 the ASSM Section was involved in a program to monitor and collect temperature data of the reactor moderator system of unit 5 at Pickering NGS 'B'. The purpose of this program was to obtain reliable temperature distribution measurements during reactor set-back experiments. These results are compared to a computer model to predict moderator temperatures during loss of coolant accidents.

A similar program is planned for 1984 using selected measurement locations of the unit 5 reactor and a high speed FM tape recording system for data collection. This program will hopefully meet the need for higher resolution measurements than were taken originally.

2.26 Pickering NGS B Reactor Physics

In 1983 the ASSM section was involved in a program to monitor the output of the safety shutdown detectors (SDS) of unit 6 during Phase C commissioning tests at Pickering NGS 'B'. The program which involves programming and operating a data acquisition system during reactor trip tests will conclude early in 1984.

2.27 Thermal Testing of a Simulated Fuel Bundle with Radial Power Depression

The evaluation of an electrically heated bundle to model conditions in a reactor channel has been carried out. A full scale model representing the centre section of a reactor channel has been tested under nonuniform heat input conditions (radial power depression). Temperature measurements have been made at three different planes across the bundle for channel powers in the range 0.5 to 3.5 kW. A comparison with previous experimental results obtained from a full scale channel simulation shows that the present results are 10% to 20% lower. It is recommended that the experimental bundle be used to model the thermal response of an actual fuel bundle accidentally stuck in a dry environment.

2.28 Nonlinear Structural Analysis

Work is continuing on the application of nonlinear techniques to calandria tube/pressure tube, CT/PT integrity and pipe whip problems. Preliminary analyses are performed to study the behaviour of CT/PT under external/internal pressures and pressure pulses. The ongoing study involves more detailed and accurate modelling to account for proper loading conditions and geometric effects. In pipe whip problems work is ongoing in refining the

nonlinear formulation of the problem and preliminary results have been obtained for straight pipe segments under impact loading.

3.0 NUCLEAR WASTE

3.1 Development of Thin-Wall, Particulate-Packed Container

The prototype of the thin-wall, particulate-packed container was designed and purchased by the Mechanical Design Department with the assistance from the ASSM Section. The container was assembled and hydrostatically tested by the Mechanical Research Department personnel. The assembly of the container, including particulate compaction was done on a specially designed shaker table, at the Dobson Labs. After assembly, the prototype was moved to the WNRE facilities in Whiteshell, Manitoba for the hydrostatic tests. The container survived three tests with only small amount of plastic deformation, as predicted by analysis which preceeded the tests.

During 1984, the prototype will be hydrostatically tested with induced voids. Subsequently, a series of destructive tests will be conducted at the Dobson Laboratories. Detailed stress analyses will follow the tests.

3.2 Integrated Metallic Container

The development work on the integrated metallic container has been continued. Significant consideration was given to the use of the container for storage and transportation of spent fuel bundles. A detailed closure system was proposed and it will be tested in 1984.

This program will continue in 1984.

3.3 Strain Gauge Development for Container Testing

Development work has been carried out to develop an economical and reliable strain gauge system for use in the container testing program. A method for protecting bonded strain gauges from high pressure (10 MPa), high temperature (150°C) water has been developed. This method was successfully used during the tests on the prototype thin wall, particulate packed container at WNRE. Because of this sytem, strain measurements were made at many more points on the container than would have been economically feasible with conventional high-temperature, high pressure strain gauge techniques.

For 1984, this method will be refined to make it simpler to use and more durable under prolonged exposure. This work is expected to benefit the container development program and other projects where strain measurements must be made in hot, high pressure environments.

3.4 Shipping and Storage Module

A prototype irradiated fuel shipping and storage module was analyzed and tested on behalf of its designers. The study was conducted to confirm that the module would withstand the loads anticipated during handling and storage at the plant and during transportation. Initial tests and analysis had indicated that local stresses in the module would exceed material yield and the module was subjected to overloads (2 times design lifting load, 1.5 times design stacking load) to demonstrate that there is an adequate margin of strength for service loadings. The strength and stiffness of the module under lateral loads (parallel to the tube axis) was also measured. This loading simulated the force on the module due to acceleration loads that might be experienced during transportation.

3.5 Fuel Sheath Structural Integrity

The structural integrity of fuel sheaths during interim day storage, before permanent disposal, is being studied. Specifically, the investigation is focussing on determining the maximum temperature at which the fuel sheathing can be expected to be resistant to rupture, for extended periods of time. The modes of failure that are being considered are: a) fast fracture of fuel sheaths with partial through-wall cracks, b) stress rupture, c) internal hydriding. The project is expected to be completed early in 1984.

3.6 Structural Integrity of a Modified Super Tiger Overpack

Ontario Hydro has two containers that are used for transporting low-level waste. These containers are known as Modified Super Tiger Overpacks (MSTO) and consist of an outer sheet metal shell measuring 8 ft x 8 ft x 8 1/2 ft and an inner shell, measuring 6 ft x 6 ft x 6 ft, separated by an energy-absorbing polyurethane foam. Following the discovery of the deterioration of some of the polyurethane foam, there were concerns over the reduced ability of the MSTO to survive the regulatory 9 m corner drop test. However, analysis showed that the MSTO will pass the 9 m corner drop test, even if all the energy-absorbing properties of the foam are neglected.

3.7 Thermal Analysis of an Irradiated Fuel Transportation Cask

The theoretical work for determining the maximum fuel sheath temperature within the cavity of a two-module cask under normal operating conditions has been carried out and the results of the study have been presented at the 7th International Symposium on Packaging and Transportation of Radioactive Materials. Further heat transfer analysis has been carried out to determine the effect of a protective cover on the maximum fuel sheath temperature.

The experimental work which started in 1983 in order to ensure that the maximum fuel sheath temperature during transportation will not exceed the desired limit of 200°C is almost complete. Thermal testing of a simulated cask is scheduled to commence in February 1984. Using the results of the tests the analytical tools will be verified and a specific cask design will be analyzed. Additional tests are also planned during 1984 to study the effect of a protective cover on the fuel temperatures.

3.8 Fire Accident Analysis of an Irradiated Fuel Transportation Cask

The purpose of the fire accident analysis is to prove that the design of a two-module transportation cask for irradiated fuel complies with AECB and IAEA regulatory fire accident requirements. The results of the analysis will be in terms of temperature distributions across the cask wall and within the cask cavity during fire accident conditions. This study will be conducted in 1984.

3.9 Thermal Analysis of Dry Vaults for Interim Storage of Irradiated Fuel

A heat transfer analysis of two dry vault configurations for interim storage of irradiated fuel has been performed to determine if the vaults are "coolable". The analysis was based on the numerical solution of the conservation equations of mess, momentum and energy. To account for the effects of the storage tubes on the flow field the fuel region was treated as a porous medium with uniform volumetric heat generation. The results of this study indicate that tube wall temperatures will be below the desired limit of 110°C and can therefore be considered "coolable".

When a particular vault design is proposed, a parametric heat transfer analysis will be carried out to optimize the final vault configuration.

3.10 Analysis of Dry Storage Bays

This study deals with the thermal analysis of the primary fuel bays at Bruce, Pickering and Darlington under loss of coolant accident conditions using the finite difference method. The temperature distribution throughout the bay will be determined by treating the fuel region as a porous medium. Due to the high heat output from the fuel the temperatures are expected to be relatively high and therefore a radiation model is being developed to incorporate into the finite difference procedure.

The analysis for the three bays is expected to be completed by Spring 1984.

3.11 Development of a Heat Transfer Finite Element Code

This study deals with the development of a two dimensional finite element code for convective heat transfer. The generality of the finite element method appears to be an attractive choice in solving heat transfer problems particularly those with complicated geometries. The code will be used by Nuclear Materials Management Department to perform the thermal analysis of irradiated fuel during storage and transportation. This work is expected to be completed by the end of 1984.

4.0 THERMAL GENERATION

4.1 CLE Curves for Turbine Rotors at Lakeview & Lambton TGS

Cyclic life expenditure curves (CLE) have been constructed for both AEI (GEC) and NEI Parsons turbines on Lakeview Units 1 to 8 and Nanticoke Units 1 to 8. These curves allow the fatigue damage per startup/shutdown cycle to be calculated for the high temperature rotors. Also, they can be used to set temperature ramp rate limits on rotors during startup to control the rate of damage accumulation.

The General Electric method of assessing damage using the CLE curves is criticized and an alternative procedure is presented. Examples of applying the alternative damage assessment procedure, utilizing the CLE curves, are provided.

4.2 Cyclic Life Expenditure Curves

An in-house software system (NONFE) is used to analyze the Lambton GS secondary super heater outlet header Tee-junction. The analysis is composed of a nonlinear heat transfer conduction followed by a linear thermal stress analysis. The results will be used to develop cyclic life expenditure curves for the Lambton GS secondary superheater outlet header Tee-junction. These curves are necessary to assess present start-up procedures and also to provide life assessment for the two-shifting mode of operation.

4.3 Nanticoke - LP2 Turbine Blade Analysis

This study will carry out finite element stress analyses on the Nanticoke LP2 turbine rotor blades (stages 5 and 6) for the purpose of determining the cause of failure on stage 5. The effects of various proposed design modifications will also be studied in order to help determine the proper corrective action.

4.4 Corrosion Fatigue

Stress analyses have been initiated as part of a program to determine the root cause of corrosion fatigue failures of boiler water-wall tubes at pressure/nonpressure part attachments. The stresses are thoguht to have been caused by the temperatures and temperature gradients that exist in the waterwalls. Therefore, temperature monitoring of critical locations is necessary to provide the required data for the stress analyses. This project was initiated in 1983 and will be ongoing in 1984.

4.5 Lambton TGS Boiler Gas Discharge Coupling

On Unit 3, six new hanger rods at the inlet to the boiler gas discharge elbow were straingauged in May following repairs to the inlet coupling and thermal insulation of struts in the inlet truss as previously recommended. The total cold load which was 106 kips before startup increased to 140 kips after operation at 375 MW, leading to the conclusions that some of the cold load existing before the start of repairs was lost during repairs and that in future repairs (units 1 and 2 in 1984) the cold load should be increased before the start of repairs and be maintained throughout. Load reductions measured during operation confirmed that in the presence of adequate initial total cold load there was no likelihood of theduct lifting ie during firing, and damaging the flexible coupling at the inlet.

4.6 Nanticoke TGS Investigation of Turbine Throttle Valve Spindle Failures

The problem consists of fatigue failures of the valve spindle at the root of the lowest thread where the spindle exits the valve body. During the first 8 years the maximum valve opening was 70% and there were 2 failures. Subsequently the maximum opening was 100% and there were 3 failures in 1 month. In an exploratory investigation to determine possible causes of failure, during July strains were measured on the external linkages which operate one of the valves on unit 2. Based on forces and moments computed from the measured strains, maximum and minimum stresses in the spindle were determined and from these and material properties and operating practice, it was concluded that the failures were due to low cycle fatigue due to stresses incurred mainly during startups, the computed fatigue life being less than 12 to 150 years. A report will be issued early in 1984.

4.7 R.L. Hearn GS Loads on Chimney Hanger Rods

Loads on 16 lower and 16 upper rods were measured on May 3rd as part of a routine plant inspection performed every 3 years. The minimum and maximum loads expressed as a percentage of ideal load were 71 and 152 percent respectively. The higher of the two loads is only 10 percent of yield and is therefore no cause for concern. Report B83-40-H "R.L. Hearn GS Load Measurements on Chimney Liner Hanger Rods August 17, 1983" was issued.

4.8 Thunder Bay Coal Bunker Impact Stresses

The purpose of the investigation is to determine the possibility of structural fatigue due to relocated impact stresses resulting from coal hangup and dropping and the use of air blasters during freezing weather. Strain gauges were installed on the cone, straight section, and support beams of bunker 2A, and strains due to filling and emptying the bunker were measured in November to determine static stresses and to determine the most significant locations for measuring dynamic stresses. Dynamic stresses were to be measured early in 1984.

4.9 Computation of Fatigue Life

During the investigation of the cause of the Nanticoke TGS throttle valve fatigue failures, it was found that textbook data (sets of curves) were available for estimation of fatigue life but that in that form it could not be optimally used. Accordingly the curves were incorporated into a computer program which makes it possible to input ultimate strength, stress concentration factor, sample period, number of stress ranges, and for each stress range, maximum stress, minimum stress and number of cycles per sample period. The program then outputs percentage fatigue life expended in one sample period of each stress range, and total fatigue life. Report B83-87-K "Program for Computing Fatigue Life" was issued.

4.10 Evaluation of Ailtech SG425 Strain Gauges for Thermal Plant Applications

Ailtech SG425 Strain Gauges were investigated for long-term stability at high temperature and zero shift during cyclic thermal loading. It has been found that these gauges may prove suitable to continuously monitor strains on critical thermal plant components during the two-shift mode of operation. Further strain gauge qualification tests for specific thermal plant component monitoring applications may be required. Successful testing of these gauges at temperatures in excess of 800°C were performed.

5.0 TRANSMISSION

5.1 365 kV Niagara River Crossings

A program of monitoring wind induced vibration of the six phases of vertical twin conductor bundle that comprises the 345 kV crossing of the Niagara River at Sir Adam Beck No 2 was carried out during 1983. Due to the local topography wind effects along the Niagara Gorge were expected to be atypical which coupled with the importance of this tie line, necessitated careful design of spacer dampers and alsc the use of galloping controls.

The monitoring program used Ontario Hydro Live Line recorders on each phase from May 24 till October 31st, during which time one circuit was completed as designed and the other was unspacered. Both circuits were unenergized. The vibration records showed that only modest motions (up to 0.003 inch peak to peak) were present in this period. The line has been fully equipped with spacers and detuning pendulums for galloping control and is now energized. An equipped crew from the Beamsville area office has been selected and trained for observation of galloping at this crossing through the winter.

This location will continue to be monitored for galloping performance through icing conditions during 1984. The results of the monitoring program will be reported.

5.2 Testing of Emergency Restoration Structures

The Transmission Lines Department is developing an Emergency Restoration Structure (ERS) for use in the by-pass line in the event of catastrophic failure of a vital transmission line. The ERS being considered is a modular aluminum gauged tower. Mechanical testing of the tower was carried out simulating the anticipated field conditions. Measurement of member loads, consultation on overall instrumentation and a complete data analysis were done by ASSM. The results of the tests will be used in preparing the emergency restoration plan.

5.3 Probability Techniques Applied to Transmission Lines

Work on the application of probability techniques to overhead power lines has been continued. The technique has been used for calculating the change in security level of overhead transmission lines to be uprated. A somewhat simplified case study on the economic benefit of uprating a section of an existing transmission line, using probability-based methods, shows that at the end of ten years, the present value of net increase in income after allowing for the uprating cost is approximately $68 million.

A more detailed uprating study will be carried out in 1984 on an important line to calculate the economic benefits of uprating lines using probability methods. The objective of the full scale study will be to highlight the immediate return on the investment to uprate existing lines by using the probability method.

5.4 Galloping Field Trials (Ontario)

There were six recorded and reported observations of galloping in Canada in the last part of 1982 and the first part of 1983. Five of the six occurrences were on Ontario Hydro lines, and one was from Newfoundland Light and Power.

On January 31, 1983, an ice storm near Orangeville, Ontario produced galloping on the Bruce-Milton 500 kV bundle line and the Orangeville-Fergus 230 kV line. Control devices are not installed on either of these lines.

On February 2, 1983, observations of galloping were made on the four circuit transmission lines between Ottawa Junction TS and Merivale SS. Detuning pendulums and inertial detuners are installed at this location. The phases with pendulums were still while the untreated phases galloped.

Galloping was observed on March 11, 1983 on the 500 kV and 230 kV lines from Claireville TS to Milton TS. This was an unusual occurrence for this area because the lines run east-west.

Observations of galloping were made at the Burlington-Hamilton Beach test site by untrained Ontario Hydro observers. No written records or movie films were taken of this occurrence. The observers stated that untreated phases were galloping significantly, the phases with detuning pendulums and modified drag dampers were galloping slightly and the phases with interphase spacers were galloping moderately.

On March 21, 1983, conductor galloping was observed on two of four single conductor circuits which connect Nanticoke GS to Middleport TS. The phases treated with modified drag dampers remained quiet while the untreated phases galloped.

Galloping was observed on March 15-16, 1983 on a 66 kV double circuit line near St. John's, Newfoundland. The first day showed galloping occurring on the untreated phases with the detuned phases still. The second day showed the opposite happening.

A new test site for detuning pendulums has been established at Queenston on the 345 kV vertical twin conductor bundle crossing of the Niagara River. A new site is designed and hardware being manufactured for the 4-conductor bundle 500 kV line running north from Darlington. Interphase spacers and detuning pendulums will be installed.

Observations of galloping will continude during 1984 with an increasing emphasis on bundle conductor line test sites. New sites will be established near Darlington and Middleport and an existing site near Streetsville will be extended.

5.5 EPRI Galloping Field Trials

The EPRI field trials of galloping controls produced two reports as follows:

On December 8, 1982, galloping was observed on a 69 kV single conductor line in Omaha. Air Flow Spoilers (a product of Preformed Line Products) were installed on some phases and were still while the untreated phases were galloping.

Galloping was observed on January 10, 1983 on a 138 kV double circuit single conductor line in Pennsylvania. Detuning pendulums were installed on one circuit and were still while the other untreated circuit was galloping.

There were no changes to installations of detuning pendulums during the year and there may have been a reduction of commitment to make these observations in some utilities. A paper on progress during the first five years of this program was presented at the IEEE Summer meeting in Los Angeles which was well received. Four one-day workshops were also given to describe the program and its results, primarily to staff of the US utilities that participated in the program and that support EPRI. The key conclusions reached at this stage are that the pendulums are effective at controlling galloping when properly applied to single conductors between 1 and 2 inches in diameter on spans between 300 and 1200 ft long, and more data are required for evaluation of pendulums on other single conductor spans and on bundle conductor spans. An agreement between Ontario Hydro and EPRI to license manufacturers has been clarified and is in the finalization stage.

The field observations will continue during 1984 but under a new manager from EPRI. A one-day workshop similar to those above will be given at the CEA's Spring Meeting in Toronto to inform Canadian utility staff of the present status of the research on galloping.

5.6 CORECH Galloping Studies

Input was provided in absentia to the annual meeting of the CORECH working group on conductor galloping which was held in Kyoto, Japan. Reports of galloping experiences during the 1982-83 winter, progress with development of the automatic movie camera monitoring system, installation of detuning pendulums on the Niagara River crossing, studies of aeolian entrapment between pendulums with different types of conductor attachment, and the initiation of CEA sponsored field trials of galloping control devices for distribution lines and for bundle conductor lines, were reported to the group. Many of this group advocate use of spacer removal for control of galloping on

bundle lines, thereby making each subconductor act as a single conductor. Three observations recorded in Ontario were reported which showed single conductors galloping more severely than bundle conductors on the same right of way which conflicts with this European approach. A contribution, which reviewed the status of galloping research in Canada, was made to a working group paper for inclusion in a Unipede conference in 1985.

In 1984 CORECH activities will continue to be supported through comments and inputs from the members and through reports of progress in Ontario, and in the CEA and EPRI sponsored field trials.

5.7 Aeolian Vibration Entrapment Tests

A full measuring and data acquisition system was completed during 1983. It was tested and calibrated successfully at the Research Laboratory. There were some problems with installation of the system at Kleinburg. They were traced to a pair of defective accelerometers which caused one of the power supplies to act up. New accelerometers have been ordered and when received the system will be operational.

The program of monitoring the aeolian vibration in six spans using different methods of support for detuning pendulums will be carried out during 1984 and recommendations for future hardware choices will be made.

5.8 Automatic Movie Camera to Monitor Galloping

The automatic movie camera system was installed on a 500 kV line near Nanticoke in January 1983. There were no galloping occurrences on the 500 kV line to trigger the camera. Galloping was, however recorded on the adjacent 230 kV lines. Movie films showed no galloping on the 500 kV lines. The camera was manually triggered from the ground to ensure the system was operational. The system was removed during the Summer and Fall of 1983 for maintenance and refinements. Improvements are being made to facilitate the installation, calibration and adjustment of the trigger switch.

A movie film was produced to show the development of the camera system from laboratory construction and testing to final installation. It has been shown to some members of the EPRI RP-1095 galloping project and HG&C Division.

The camera system will be reinstalled in early 1984, and a second system is planned which is to be installed in the Manby TS and later in the year.

5.9 Interphase Spacers

The continued development of the interphase spacer as a galloping control device has been endorsed by various Head Office Divisions. Spacers are felt needed as a back-up control system to detuning pendulums. Although 230 kV spacer work has continued, new 500 kV line applications have received top priority. The major activities completed in 1983 are:

1. Three sites were identified for 500 kV interphase spacer installations in Southern Ontario.

2. The Rebosio insulators at the Burlington-Hamilton Beach site were inspected for electrical performance. Two of the spacers have been replaced as a result of the inspection.

3. Corona inception tests were done on the present 500 kV spacer design. The tests showed that the design was vulnerable to corona discharge. The design has been changed to reduce corona and new spacers have been built using a modified design.

4. A new design for 230 kV and 500 kV articulated spacers was developed. It is much lighter and less costly than the present version. Material for prototypes of each has been ordered and is expected early in 1984.

Electrical and mechanical tests on the new designs will be done in 1984. Installation of spacers and other control devices are planned at the three proposed sites.

5.10 CEA Conductor Dynamics Working Group

CEA's Transmission Research and Development Committee has been supported through representation on the Conductor Dynamics Working Group. This group evaluates new research topics and prepares requests for proposals in its area of expertise. It also coordinates ongoing CEA sponsored research programs in conductor vibration, damping and control.

Support will be continued during 1984. Proposals for research in bundle stability and suspension damp design will be fostered, seeking agreement for processing requests for proposals.

5.11 Participation in CEA Sponsored Projects

Participation has been maintained by providing technical assistance to two CEA projects related to wind and ice loading on overhead transmission lines. The ice free anemometer developed by CEA was laboratory tested prior to field installation and found to be defective. The testing efforts by B.C. Hydro and Newfoundland and Labrador Hydro were coordinated. Since the ice-free anemometer was found to be defective, it was recommended to CEA that another prototype independently developed by a Toronto-based company should be tested for its suitability.

The wind and ice load monitoring instrument package being developed by Saskatchewan Power is nearing completion and will be installed for field tests.

Technical assistance will be continued during 1984 for choosing a suitable anemometer for operating under icing conditions. The field performance of the load monitoring package will be monitored for its suitability.

5.12 Participation in EPRI Sponsored Projects

Participation has been maintained by providing technical guidance to a EPRI funded project on probability techniques applied to transmission lines. The work, originally intended for wood pole lines, has now been extended to lattice structures as well. An outline for a proposed guide has been completed. A data base on wood pole strength has been established.

The work on selected parts of the proposed guide will be completed. Our participation in the guide preparation will be to provide technical assistance and consultation on wind and ice load models and to review and critique the guide.

5.13 Skywire Replacement Program

Assistance was provided in reviewing the current Skywire replacement procedures for possible improvements. The probability-based technique was suggested as one of the means of improving the current program.

A literature review will be carried out on the availability of data on load and strength for the Skywire replacement program. A feasibility study will be done to assess whether or not the probability-based method could be applied to solve the problem.

5.14 Wind and Ice Loads on Transmission Lines

Detailed procedures have been developed for deriving probabilistic distribution models for wind load, ice load and wind-on-ice load on overhead transmission line conductors. The models are derived from basic meteorological data on wind and ice and transmission line details. A numerical example is used to illustrate the application of these procedures to real situations. The results of this study were presented to an IEEE Panel Discussion on Reliability Based Design of Transmission Lines. The load distributions, in conjunction with appropriate structural strength distributions, can be used in the probability-based design of overhead transmission lines.

The models will be expanded during 1984 to include in more detail the terrain effect on wind loading and also direct loading on the tower itself. A digital computer program will be developed to perform all the calculations.

5.15 Ice Accretion Model - An Environment Canada Project

A joint contract has been awarded to Ontario Hydro and Meteorological and Environmental Planning Limited, by Environment Canada for identifying a suitable ice accretion and wind model.

The role of the Applied Structural and Solid Mechanics Section in this project during 1984 will be to provide consulting services in the following areas: a) interpreting ice load data, b) ice accretion information for transmission design purposes, and c) evaluation procedure for ice accretion models. The outcome of the project would be a suitable ice accretion and wind model for transmission line design.

5.16 Bruce 4-Conductor Bundle Short Circuit Forces

A request was received from Bruce Engineering to determine 4-conductor bundle collapse and swingout forces within the 500 kV station at Bruce NGS 'B'. Existing computer programs STBUS3 and SWINGT3 were reviewed and modified as needed to do the study. A Research report was issued to document the findings. While conductor swingout tensions were within acceptable limits, tension increases due to bundle collapse were significant. Phase tensions increased from about 4,000 lbs to over 30,000 lbs (ice covered conductors). It was concluded that double insulator strings were required.

5.17 Twin Conductor Collapse Forces in Stations

Work in this area continued over from 1982 with focus on refining and verifying the BUNDL1 computer program (formerly STBUS1) for predicting peak tensions and forces on support structures during short circuits on twin conductors. Insulator string assembly elasticity tests were performed to determine a representative static spring constant of an insulator string. As a result, an average measured value of 30,000 lb/in was input into the program to represent the effect of the insulators. A report to verify and to establish a confidence level for calculated peak tensions versus measured peak tensions was issued.

A research proposal was submitted to Head Office Divisions to conduct full scale short circuit tests on Item 39 station structures. No decision on the proposal was made during 1983.

Impulse testing of insulator strings were done to determine the impact withstand capability of typical station insulators and to further refine the spring constant measured in the static tests. The data has not yet been analyzed but a report is forthcoming early in 1984.

The BUNDL1 program has been verified and confidence levels established for time to peak tensions and equivalent static loads. Reports on these verifications will be issued early in 1984.

In 1984, plans are to continue to expand the BUNDL1 program to cover a broader range of fault conditions.

5.18 Rigid Bus Dynamics due to Short-Circuit Forces

During short-circuits, transient electromagnetic forces are exerted on rigid bus in stations sometimes resulting in large bus stresses as well as high reaction forces at the support points or insulators. The finite element method was utilized to calculate the transient dynamic response of a Bruce NGS A bus-insulator assembly. Dynamic bus stresses and insulator forces were calculated and compared with the existing simplified methods being used for the same analysis.

5.19 Nanticoke GS Down Drop Leads

Wind-induced vibration of down drop leads in the station yard at Nanticoke GS has led to several failures of conductors and misalignment of switches. In cooperation with Electrical Design Department, alternative control methods have been proposed to alleviate the problem. These include use of interphase spacers between leads, use of stockbridge dampers and also use of stiffeners adjacent to the switches.

Hardware for these alternatives will be installed during 1984 and the effects monitored. The solution which is most effective may also be applied at Bruce GS where similar problems exist.

5.20 Conductor Vibration Test Facility

Construction has commenced on the new Mechanical Testing and Development Complex to the south of the Research Laboratory. The design of the building includes space for a conductor vibration test facility (span room) for use by the Applied Structural and Solid Mechanics Section. The room is being designed to accommodate a 91.44 m (300 ft) and a 42.67 m (140 ft) conductor test span. These choices of span lengths will allow close simulation of normal transmission line subspan lengths.

Test programs during 1984 will include studies of aeolian vibration, conductor self-damping, wake induced vibration, and testing of new dampers for single and bundle lines.

The expected completion date for the building is the summer of 1984 and initial activities will be to equip the test span with a suitable shaker and monitoring instrumentation to perform a check on the two IEEE standard procedures for measuring conductor internal damping.

6.0 DISTRIBUTION SYSTEMS

6.1 Probability Techniques Applied to Distribution Systems

A state-of-the-art report "Overview and Recommendations on Probabilistic Distribution System Design" has been prepared for the CEA R&D Committee on Distribution. This report provides a fairly comprehensive account of the probabilistic method as applied to distribution systems along with recommendations on selected distribution system problems for further study. The following problems are recommended for possible research and development projects: a) Mechanical Design of Overhead Lines, b) Transformer Loading, c) Conductor Loss Optimization, and d) Statistical Data Bases for Projects a) to c).

If the above recommendations are accepted by CEA R&D Committee on Distribution then a detailed Request for Proposals will be prepared for issue during 1984.

6.2 Wind and Ice Load Monitoring System on a Distribution Line

A proposal was submitted to Distribution Systems Planning and Design for establishing a test site for monitoring wind and ice loads on distribution lines. The project is to be cofunded by Distribution Systems and Research Division.

If the plan is approved a mutually agreed test site will be instrumented for monitoring wind speed and direction, wind and ice loads, temperature and pole movement at ground line during 1984.

6.3 Probability Techniques Applied to Wood Distribution Poles

Work has been continued on the application of probability-based methods to the design of wood distribution poles. A comprehensive computer program is being developed to analyze wood pole structures under various loading conditions and to calculate the probability of failure. The program, which is a cooperative effort with Distribution Systems Division, will consider the effect of vertical load on deflected pole (P-Δ effect), wind loading, ice loading and wind-on-ice loading in calculating the probability of failure.

The analysis program will be used during 1984 to develop a comprehensive design load for wood pole structures. Necessary data bases will be developed for applying the design tool to real situations.

6.4 CEA Distribution Line Galloping

This project was undertaken as a result of Ontario Hydro's proposal to carry out Research and Development work on control of galloping of overhead distribution lines. The objectives of the overall project include: a) determining the extent of distribution line galloping problems in Canada, b) exposing promising control devices to galloping conditions across Canada by establishing a network of field sites on operating distribution lines, c) obtaining reliable observations of performance of promising control devices during galloping occurrences, d) determining the overall effectiveness of the control devices under natural galloping conditions, and e) providing recommendations on the application of these devices on existing and new distribution lines.

The work began by identifying those Canadian Utilities with distribution lines in their system. A questionnaire was set to 34 provincial and municipal utilities across Canada. Of the 34 utilities surveyed, 30 completed and returned the questionnaire. Some highlights of the results are:

1. Twenty-two utilities experience galloping at least once every two years. Six utilities indicated that galloping never occurs on their lines.

2. Eighteen utilities stated that galloping causes outages on their distribution system at least once every two years.

3. Twenty-eight of thirty-four utilities expressed at least some interest in the galloping problem.

4. Sixteen of thirty-four utilities would support CEA studies aimed at controlling galloping.

5. Fourteen utilities estimated costs of damage due to galloping totalling about $400,000.

6. Nine utilities across Canada have offered a total of 39 possible test sites.

Design and establishment of 17 test sites is well underway and will occupy much of the time on this project in 1984. Observers will be trained for each site using techniques developed in Ontario Hydro for parallel studies of transmission line galloping.

6.5 TVI/Galloping Distribution Test Line

In cooperation with Electric Research Department, a proposal was presented to CEA to establish a distribution line in the Kleinburg test site area which could be used to evaluate various sources of television interference (TVI) and also permit evaluation of the control devices being exposed in the CEA field trials of galloping controls for distribution lines. This test line will permit the four promising control devices (interphase spacers, Russian tea foils, air flow spacers and detuning pendulums) to be supported on three span lengths (100, 160, 250 feet) of two conductor sizes (556.5 kcmil acar and 4/0 acsr) thereby effectively simulating six different test conditions. The contract was approved in part. The line will be built to serve both purposes and the TVI research has been funded. Approval for the galloping studies is deferred.

The test line will be built early in 1984 and some galloping hardware is available. Due to the strong support of the technical advisors it is expected that CEA will fund the galloping studies at this site.

6.6 CEA Proposal on the Application of Robotics to Distribution Systems

A proposal was prepared in conjunction with staff from Metallurgical and Electrical Research Departments, Distribution Systems Division and Spar Aerospace Ltd in Downsview, Ontario. The research program is divided into three stages.

Stage I is to completely document and analyze the range of potential applications for the robotic device to distribution systems based on input from most Canadian utilities. Stage II deals with the formulation of the design requirements of the device in order to perform a list of specific tasks, chosen to be most beneficial. Stage III deals with the conceptual layout, operational concept and design of the system.

An expert tool manufacturer will also be subcontracted to perform the development of the specialized tools needed to perform the tasks. Ontario Hydro will then demonstrate the feasibility of the conceptual design using the existing in-house Unimate PUMA 560 robot. The project will be completed within 18 months at a total cost of $160,000, $35,000 of which will be contributed by Ontario Hydro 1984. CEA will choose the winning applicant in mid February 1984.

7.0 MISCELLANEOUS

7.1 Building Joint Displacement Measurements

Changes in joint widths of exterior structural panels on an IBM Building (Victoria Park and Steeles, Toronto, Ontario) were continuously monitored for 12 days under various weather conditions. These brief measurements were performed for TREMCO Engineering Services to investigate the cause of recent joint caulking failures in which panel movements were suspected to have been greater than design specifications. It is anticipated that TREMCO Engineering Services will use the joint displacement data obtained in this measurement program to predict joint displacements for various postulated extreme weather conditions.

7.2 Development of Specialized Structural Integrity Monitoring Equipment

Capacitance strain gauges and displacement transducers (which consist entirely of inert materials such as ceramics and non-corrosive metals) have been demonstrated to be very useful for long term on-line monitoring of components in high temperature/high radiation environments.

In order to more effectively utilize these sensors for future nuclear station requirements, an external contract has been awarded to a small Canadian electronics company to develop advanced capacitance measurement equipment. The development of this completely solid-state, micro-processor controlled equipment is nearing completion and initial evaluation shows it to be significantly superior to presently-used foreign equipment.

7.3 Modified "Extended Shim" Resistance Strain Gauge

Resistance-type strain gauges to investigate the structural integrity of critical components could have important applications in nuclear plants. A limitation with commercially-available strain gauges is due to their unpredictable behaviour with regard to their thermal response when attached to the station structure.

A development study is now being done whereby resistance strain gauges are to be individually calibrated before attachment to the station structure. In this study, commercially-available strain gauges are bonded to an "extended shim" to form a "calibratable" strain transducer. If this procedure proves to be workable, our capabilities to verify the structural integrity of nuclear components will be significantly enhanced.

7.4 Thermal Expansion Measurements

The exact thermal expansion of operating plant equipment has a very important impact on the accuracy of stress measurements on operating station equipment. It is often very difficult to determine the exact coefficient of thermal expansion of any material from handbook data. In order to overcome this difficulty, two studies are proposed:

1. A theoretical development to measure this data in situ has been made and will be qualified for use on operating equipment.

2. Investigations to the variability of different samples of any one type or grade of metal are to establish the suitability of using "reference" materials to predict the thermal characteristics of station equipment material are to be undertaken.

7.5 Structural Mechanics Test Pit/Burst Test Facility

The structural integrity of various nuclear and thermal power plant components is evaluated for the most part by mathematical modelling combined with material test data. Although this approach provides useful information, certain significant deficiencies may exist in the assumptions and approximations used in the modelling process. A full-scale testing facility to be used for studying the performance of power plant structural components, under normal operating and postulated loading conditions, is a required additional step for those components that are fundamental to the continuing operation and safety of the station.

A large test pit is to be incorporated into the new Mechanical Test Building and will enable future potentially hazardous tests to be safely performed.

7.6 Software System Development

The first phase of the development of software system for linear and nonlinear structural analysis has been completed. This includes linear static analysis, linear and nonlinear heat transfer analysis. A number of modular processors were developed, tested and applied to the Lambton GS secondary superheater outlet header Tee-junction. These processors are: input/output processor for three-dimensional data manipulation and checking; element characteristic processor for 6 to 20 noded three-dimensional elements; a frontal solution package processor; plotting processor; linear and nonlinear heat transfer conduction analysis processor; and, finally, a linear static analysis processor. It is shown that the accuracy of the developed system is the same as that of other commercial packages whereas the cost of the latter is at least 200% higher. Future developments of the system include convection heat transfer analysis, diffusion analysis, nonlinear and dynamic analysis.

7.7 Research Program Advisory Committees

The section has active representation on Research Program Advisory Committees on Nuclear Generation, Nuclear Waste, Thermal Generation, Transmission Systems and Distribution Systems during the next RPAC cycle (1984).

8.0 CONCLUSIONS

1983 was a very successful year for our section. We worked on a number of important projects; our services were in constant demand; we enhanced our section's capabilities in a number of areas and we expect 1984 to be another busy and successful year.

Approved

for G.J. Clarke
Manager
Mechanical Research Dept

Submitted:

J.A. Chadha
Section Head
Applied Structural and
Solid Mechanics Section

JAC:rdm

APPENDIX I

List of Reports Issued in 1983

Date Issued	Report No	Title	Author
Jan 11	82-515-K	Structural Integrity Burst Test of a Blistered BHWP H_2S Recovery Compressor Surge Drum	J.M. Boag
Jan 11	B82-77-K	Environmental Qualification at Ontario Hydro Research Division	J.D. Tulk
Feb 3	B83-3-K	Status Report Waste Fuel Management Strain Gauge Development	J.H. Russell
Feb 9	83-61-K	Pickering NGS 'A' Units 1,2,3 and 4 Turbo-Generator Foundations Stability Studies	R.W. Wolfendale
Feb 11	83-52-K	Applied Structural and Solid Mechanics Section 1982 Review and 1983 Programs	J.A. Chadha
Feb 22	B83-5-K	Electric Power Research Institute Research Project (RP-1352) on Reliability Based Design of Overhead Transmission Lines December 20-22, 1982, Palo Alto, CA (Attendance at the Project Advisory Committee Meeting)	S. Krishnasamy
Feb 23	83-70-K	Seismic Qualification of Bruce NGS 'B' EWPSB Junction Boxes	J.D. Tulk
Mar 8	82-446-K	User Manual for the BUNDL1 Program on the Univac Computer System	G.J. Sullivan C.J. Pon
Mar 10	83-1-K	Development of a Movie Camera System to Automatically Record Conductor Galloping of Transmission Lines	C.J. Pon
Mar 28	83-101-K	Measurement of End Shield Axial Displacement on Unit 3, Pickering GS 'A'	J.A. Herring M.T. Flaman W.K. Chan

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List of Reports Issued in 1983

Date Issued	Report No	Title	Author
Apr 19	B83-21-K	Seismic Testing of Aged Nuclear Generating Station Batteries	J.D. Tulk
Apr 28	83-134-H	Stability of Bundle Conductors Under High Currents	D.G. Havard
May 19	83-205-K	Insulator String Assembly Elasticity Tests	C.J. Pon
May 27	83-221-K	Thermal Analysis for the Design of an Irradiated Fuel Transportation Cask under Normal Operating Conditions	D. Taralis
June 2	B83-26-K	BNPDS Steam Line Elbow Strain Gauge Measurements	J.M. Boag O.C. Sonstenes
June 10	B83-33-K	Verification and Confidence Level of the Bundle Collapse Computer Program Against Measured Test Results	C.J. Pon
June 20	83-228-K	Proposed Approach to Investigate Stress-Related Mechanisms in Steam Generator Tube Failures	M.T. Flaman
June 23	B83-35-K	Interim Report No 16 - R.L. Hearn GS 700 Ft Stack and Building Stability Study	R.W. Wolfendale
June 24	83-279-K	Nonlinear Structural Analysis Survey of Formulation and Solution Methods	M.S. Gadala
June 28	83-39-K	On-Line Structural Integrity Monitoring for Nuclear Plants	M.T. Flaman
June 29	B83-37-K	X-Ray Diffractometers for Stress Measurement - Visit to Siemens Corp, Chicago, Ill and Technology for Energy Corp, Knoxville, Tenn	J.M. Boag

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List of Reports Issued in 1983

Date Issued	Report No	Title	Author
July 19	B83-21-K Revised	Seismic Testing of Aged Nuclear Generating Station Batteries	J.D. Tulk
July 27	B83-38-K	Trip Report - PATRAM'83 - New Orleans, Louisiana, May 15-20, 1983	B. Teper
Aug 4	83-340-K	NONFE: A Programming System for Finite Element Analysis	M.S. Gadala
Aug 9	B83-42-K	Trip Report - Visit to Stevenson and Associates Consulting Engineering Firm, June 23-24,1983	B. Teper
Aug 9	B83-48-K	Pickering NGS B - Unit 8 Turbo-Generator Foundation Settlement Interim Report No 1	R.W.Wolfendale
Aug 16	83-321-K	Irradiated Fuel Shipping Module Transportation Tests	G.M. Smrke J.D. Tulk
Aug 18	B83-50-P	Residual Stress Measurement Results on a Subway Car Component	M.T. Flaman B.E. Mills
Aug 25	83-360-K	Hydrostatic Pressure Testing of a Blistered H_2S Absorber Tower	J.M. Boag N.N. Shah
Aug 30	B83-40-H	R.L. Hearn GS Load Measurements on Chimney Liner Hanger Rods Aug 17, 1983	J.G. Willmot R.W.Wolfendale
Sept 2	B83-39-K	Performance Features of an Upgraded Data Logger	J.G. Willmot
Sept 13	B83-52-K	Trip Report Attendance at 21st National Heat Transfer Conference Seattle, Washington, July 24-27/83	D. Taralis
Sept 21	83-291-K	Investigation of the Safety of On-Line Steam Leak Sealing Procedures	B.E. Mills M.T. Flaman

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List of Reports Issued in 1983

Date Issued	Report No	Title	Author
Sept 23	83-365-K	Thermal Analysis for the Design of a Protective Cover of an Irradiated Fuel Transportation Cask Under Normal Operating Conditions	D. Taralis
Sept 23	82-387-K	Thermal Analysis of Dry Vaults for Interim Storage of Irradiated Fuel	D. Taralis
Sept 27	B83-61-K	Tension Increase in 4-Conductor Bundles at Bruce GS 'B' due to Bundle Collapse and Phase Swing-out under Short-Circuit Forces	C.J. Pon J.R. Meale
Sept 28	B83-65-K	Thermal Testing of a Simulated Fuel Bundle with Radial Power Depression	D. Taralis
Oct 6	B83-63-K	Description of Proposed Steam Generator Tube Integrity Burst Tests	J.M. Boag
Nov 3	83-396-CON	Basis for Seismic Qualification of the Cable Raceway System for Bruce NGS 'B' Part 2 - Background Information	B. Teper
Nov 10	B83-75-K	IBM Building Joint Displacement Measurements	J.M. Boag
Nov 14	83-461-K	Performance of Galloping Control Devices on Ontario Hydro Lines 1982-83 Winter	C.J. Pon
Nov 16	83-411-K	Weather Induced Transmission Line Loads on a Probabilistic Basis	S. Krishnasamy
Nov 16	B83-78-K	Structural Mechanics in Reactor Technology 7th SMIRTH Conference Chicago, Ill - Aug 22-26/83	M.S. Gadala
Nov 21	83-492-K	Bruce NGS 'A' - Short Circuit Forces on Rigid Bus Bends and Insulators	M.S. Gadala

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List of Reports Issued in 1983

Date Issued	Report No	Title	Author
Nov 28	83-447-K	Cyclic Life Expenditure Curves at AEI (GEC) Turbine Rotors at Lakeview TGS	T.P. Byrne D. Sidey
Nov 30	84-401-CON	Basis for Seismic Qualification of the Cable Raceway System for Bruce NGS 'B' Part 7 - Conduit System	B. Teper
Dec 1	B83-84-K	Seminar Highlights - Temperature Measurements Nov 15-17/83 National Research Council, Ottawa, Ontario	R.W.Wolfendale
Dec 5	83-414-K	Uprating of Transmission Lines by Probability-Based Methods A Case Study	S.Krishnasamy M.S. Nashid
Dec 6	B83-87-K	Program for Computing Fatigue Life	J.G. Willmot
Dec 22	83-398-CON	Basis for Seismic Qualification of the Cable Raceway System for Bruce NGS 'B' Part 4 - Qualification by Proof Test	B. Teper
Dec 22	83-470-K	Holography as an Option for Study of the Ice Blocking Procedure	D.L. Mader M.T. Flaman
Dec 23	83-397-CON	Basis for Seismic Qualification of the Cable Raceway System for Bruce NGS 'B' Part 3 - Hardware	B. Teper
Dec 23	83-481-K	Protection of Bondable Strain Gauges Under Severe Conditions (10 MPa Water 150°C) Using the Sealed Cap Method	J.H. Russell
Dec 23	B83-82-K	Residual Stress Measurements in a Simulated Temper-Bead Weld Repair	J.M. Boag

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List of Reports Issued in 1983

Date Issued	Report No	Title	Author
Dec 23	B83-93-K	Pickering NGS 'B' - Units 5&6 Turbo-Generator Foundation Settlement Interim Report No 2	R.W.Wolfendale
Dec 30	83-204-K	Structural Integrity of the Vacuum Building for the Bruce Nuclear Generating Station (Sixteen Valve Blowthrough Test)	S.Krishnasamy
Dec 30	83-446-K	Cyclic Life Expenditure Curves for NEI Parsons Turbine Rotors at Lakeview TGS and Nanticoke TGS	T.P. Byrne D. Sidey
Dec 30	83-545-K	Scenarios for Research Planning	T.P. Byrne W.G. Hanson W. Watson

APPENDIX II

Publications and Presentations - 1983

Date	Title	Author
Jan 18	EPRI Sponsored Workshop "Galloping Conductors - Causes and Cures" Tucson	D.G. Havard J.C. Pohlman
Jan 28	Seminar - "Basis for Seismic Qualification of the Cable Raceway System for Bruce "B" NGS"	B. Teper
April 4	EPRI Sponsored Workshop "Galloping Conductors - Causes and Cures" Kansas City, Missouri	D.G. Havard J.C. Pohlman
May	"Integrated Metal Container as a Part of an Integrated System for Back End of Irradiated Fuel Management" Patram 1983 Symposium, New Orleans, Louisiana	B. Teper
May 15-20	"Thermal Analysis for the Design of a CANDU Irradiated Fuel Transportation Cask", presented at the 7th International Symposium on Packaging and Transportation of Radioactive Materials, New Orleans	D. Taralis K.E. Nash
July	"Five Years' Field Trails of Detuning Pendulums for Galloping Control" IEEE Paper No 83 SM 470-2, presented at the IEEE Summer Meeting in Los Angeles	D.G. Havard J.C. Pohlman
Oct 3	"Survey of Canadian Utilities on Distribution Line Galloping", CEA E&O Division Section Meetings in Calgary	C. Pon
Oct 4	EPRI Sponsored Workshop "Galloping Conductors - Causes and Cures" Chicago, Illinois	D.G. Havard J.C. Pohlman
Nov 15	EPRI Sponsored Workshop "Galloping Conductors - Causes and Cures" Pittsburgh, Pennsylvania	D.G. Havard J.C. Pohlman
Nov 25	Departmental Seminar - "The Numerical Solution and Application of Nonlinear Structural Problems	M.S. Gadala

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Publications and Presentations - 1983

Date	Title	Author
	"A Consistent Formulation for Nonlinear Problems with Application to Calandria Tube Collapse", 7th Int Conf on Struct Mech in Reactor Tech - SMIRT, Chicago, Ill.	M.S. Gadala T.P. Byrne
	"A Comparative Numerical Study of Nonlinear Finite Element Formulations, 9th Cndn Cong of Appl Mech - CANCAM, Saskatchewan.	M.S. Gadala T.P. Byrne
	"A Consistent Eulerian Formulation of Large Deformation Problems in Statics and Dynamics", Int J. Nonlinear Mechanics	M.S. Gadala G.A.E. Oravas M.A. Dokainish
May	"Cyclic Operation of Large Coal-Fired Steam Boilers", Proceedings of the Symposium on Thermal Utilities Boiler Reliability, McMaster University,	D. Sidey R.B. Dooley T.P. Byrne J. Westwood

APPENDIX III

Planned Publications and Presentations - 1984

Title	Author
"The Application of a Programming System to Transient-Thermal Stress Analysis", Int Conf on Num Methods for Transient and Coupled Problems, Venice, Italy	M.S. Gadala T.P. Byrne M.A. Dokainish
"Numerical and Analytical Comparisons of Formulation Methods in Nonlinear Structural Analysis", 4th World Congress on FEM, Switzerland	M.S. Gadala T.P. Byrne
"Re-Qualification of Switchgear Equipment Following Field Modification" - to be presented at ASME Pressure Vessel and Piping Conference, San Antonio, Texas, June 1984	J. Tulk M. Elbestawi
"Combining Metal Analysis and Finite Element Modelling for Seismic Qualification of Electrical Equipment" to be presented at the Seventh Symposium on Engineering Applications of Mechanics, Toronto, June 1984	M. Elbestawi J. Tulk
"Weather Induced Transmission Line Loads on a Probabilistic Basis" - IEEE	S. Krishnasamy
"Field Measurement of Wind and Ice Loads on Transmission Lines" - IEEE	S. Krishnasamy
"Design of Wood Pole Distribution Lines by Probabilistic Method", Modelling and Simulation Conference, Pittsburgh, April 1984	S. Krishnasamy
"Analysis of Overhead Power Lines by Probabilistic Method" - ASCE Specialty Conference, Berkeley, California, Jan 1984	S. Krishnasamy
"Structural Integrity of CANDU Reacter's Negative Containment System" - 5th International Conference on Thermal Reactor Safety, Karlsruhe, Germany, Sept 1984	S. Krishnasamy
"Structuring of the Vacuum Building for Ontario Hydro Bruce Nuclear Generating Station (Sixteen Valve Blowthrough Test)" - International Conference on Containment Design, Toronto, June 1984	S. Krishnasamy
"Effects of Short Circuits in Twin and Quad Flexible Station Bus" for IEEE Summer Meeting, Seattle, July	D.G. Havard C.J. Pon J.R. Meale

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Planned Publications and Presentations - 1984

Title	Author
"Progress in Field Research on Control of Galloping of Lead Conductors" - 2nd International Workshop on Atmospheric Icing of Structures, June 1984, Trandheim, Norway	D.G. Havard J.C. Pohlman
"Galloping of Conductors - Causes and Cures" Workshop to be presented to CEA Transmission and Distribution Sections, March 29, 1984, Toronto	D.G. Havard J.C. Pohlman
Department Seminar on the Development of Thin-Wall, Particulate-Packed Container	B. Teper
"Comparison of Experimental and Analytical Results from the Time History Analysis of Multiple Relay Panels", 8th World Conference on Earthquake Engineering, San Francisco, California, July 1984	B. Teper
"Continuum Bases and Consistent Numerical Formulations of Nonlinear Continuum Mechanics Problems", Solid Mechanics Archives (1983)	M.S. Gadala G.A.E. Oravas
"Formulation Methods of Geometric and Material Nonlinearity Problems", Int. J. Num. Meth. Engng, (1983)	M.S. Galada G.A.E. Oravas
"Ontario Hydro Experience with Dissimilar Metal Welds in Boiler Tubing", EPRI Technology Transfer Seminar: Solutions to Problems with Dissimilar Metal Weldments in Fossil-Fired Power Plants, New Orleans, Louisiana, February 1984	J.D. Parker T.P. Byrne R.B. Dooley