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ÉNERGIE ATOMIQUE DU CANADA LIMITÉE

INCENTIVES FOR IMPROVEMENT OF CANDU

BONNES RAISONS POUR AMÉLIORER CANDU

R.S. HART, J.T. DUNN and R.B. FINLAY

Presented at the IAEA Technical Committee Meeting on
Progress in Heavy Water Reactor Design and Technology
Montreal, Quebec, Canada, 1988 December 6-9

CANDU Operations

Opérations CANDU

Mississauga, Ontario

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RÉSUMÉ

CANDU est une technique relativement jeune qui a été couronnée de beaucoup de succès en tant que filière de production d'énergie électrique. Parmi ces succès, il faut citer une tradition de sécurité non surpassée, un facteur d'utilisation élevé annuel et de durée de vie, un prix de revient d'électricité faible ainsi que beaucoup d'autres qualités diverses en matière de performances, lesquels indiquent que la technique CANDU est fondamentalement bonne.

Les possibilités connues non encore complètement exploitées, telles que les possibilités de cycle du combustible avançé, indiquent que la technique CANDU continuera d'être très efficace pour la recherche, le développement et la conception consacrés. Elles donnent de fortes raisons pour améliorer CANDU de façon permanente.

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ABSTRACT

CANDU is a relatively young technology which has demonstrated many achievements as an electrical power generation system. These achievements include an unsurpassed safety record, high annual and lifetime capacity factors, low electricity cost and a broad range of other performance strengths which together indicate that the CANDU technology is fundamentally sound.

Known capabilities not yet fully exploited, such as advanced fuel cycle options, indicate that CANDU technology will continue to pay strong dividends on research, development and design investment. This provides a strong incentive for the improvement of CANDU on a continuing basis.

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1. INTRODUCTION

Most energy forecasts predict that the world demand for electricity will increase steadily through the next century. Prime factors in these forecasts are the increase in population and predicted greater use of electricity to increase output per capita.

Because of its flexibility of use, cleanliness, safety, and efficiency in so many applications, electricity is a highly favoured energy source. This has encouraged, and will continue to encourage, the development of new electro-technologies which will help make the production of goods and services less energy-consuming.

Reliable low-cost electricity, plant site flexibility, high-technology employment opportunities and fuel cost savings are among the economic benefits which put nuclear power in an advantageous position. When these factors are combined with an assessment of the full impact of the alternatives, it is clear that nuclear-generated electricity is poised to make an ever-increasing contribution to the world's energy needs through the next century.

Beyond the production of low-cost reliable electricity, nuclear power technology will likely be widely used for district heating and for the production of process heat suitable, for example, for the in-situ production of oil from tar sands deposits. Indeed, in the future, nuclear power may be called upon to provide the process heat required for gasification of coal and to generate the electricity required for the hydrogenation of coal gas to supplement declining oil resources.

2. WHY IMPROVE CANDU?

No product stands still and CANDU is a relatively young technology which has demonstrated many achievements as an electrical power generation system. These achievements include an unsurpassed safety record, high annual and lifetime capacity factors, low electricity cost and a broad range of other performance strengths which together indicate that the CANDU technology is fundamentally sound. Known capabilities not yet fully exploited, such as advanced fuel cycle options, and identified potential breakthroughs, indicate that CANDU technology will continue to pay strong dividends on research, development and design investment. This provides a strong incentive for the improvement of CANDU on a continuing basis.

Progress in all branches of technology, including other nuclear technologies, provides an imperative to drive the CANDU development program. Technologies are sustained in practical use by this continuing drive from research, development and design to remain abreast of competing technologies.

Electricity production is one of the key factors in a competitive economy and there is constant pressure to reduce electricity cost. CANDU nuclear power is in the vanguard of the lowest cost sources of electricity production, and it relies on aggressive, forward looking research, development and design initiatives for greater achievement in all of the factors which contribute to safe operation and low electricity cost over a long, useful life.

A unique feature of the CANDU system is its ability to accommodate a wide range of fuels, in order to achieve economic or strategic aims. While CANDU reactors currently use natural uranium fuel, the use of slightly enriched uranium fuel would result in a significant improvement in fuel cycle costs and uranium utilization. Plutonium and/or uranium from spent light water reactor (LWR) fuel can also be efficiently burned in existing CANDU reactor designs, offering a unique synergism between CANDU and the LWR. Long-term energy security is assured through the use of thorium in a "thermal breeder" CANDU, which has the potential to reduce dependency on uranium to essentially zero in the long term. This is the CANDU equivalent to the fast breeder reactor and it can be achieved with no new major reactor development.

The CANDU reactor design is unique among the major reactor designs in that the main nuclear pressure vessels are the fuel channels, which are easily replaced. Thus, the life of a CANDU generating station can be extended almost indefinitely.

The longevity features of CANDU reactors, coupled with the world's considerable reserves of uranium and thorium fuel, ensure that CANDU reactors can provide low-cost electricity for at least 200 years.

3. DEVELOPMENT OBJECTIVES

There have been two phases in CANDU's evolution to date. The first, spanning two decades from 1942 to 1963, was the concept development and demonstration phase. The second, spanning the years from 1964, when Pickering 1 and 2 were committed, to 1987, was the first step in the commercialization of CANDU reactors.

The next 30 years will be the second step in CANDU commercialization. This period will have as its focus consolidation of gains made to date and an increase in CANDU's share of the market.

The competitive challenges are to reduce the capital cost of CANDU nuclear power plants while maintaining advantages in high nuclear safety, low electricity generating costs and good performance. The relatively simple oil- and coal-burning generating stations set the capital investment standard for large thermal plants. Capital cost reduction in combination with simplification is identified as the most effective improvement strategy for competing with oil or coal.

Rapid advances in computer software capability and in low-cost computing power provide opportunities to reduce initial cost, by improved productivity in all of the activities needed to bring a CANDU project from concept design to full-power operation. CANDU plants have had 17 years' experience with computerized plant control. Building on this, advanced computing techniques provide the opportunity to substantially improve the plant control center and the decision support provided to the operator. These new techniques promise to improve the quality of the plants and the effectiveness of all plant operating staff.

Practical improvement in safety, with emphasis on inherent and passive safety features, is a major aspect of CANDU improvement and a primary consideration in operability and maintainability improvements.

One important objective is the development and demonstration of an advanced CANDU fuel bundle which will allow greater flexibility in operation. With this bundle, element ratings can be significantly reduced, which would facilitate the achievement of higher burnups, and improve operating and safety margins. This advanced fuel bundle will also improve the good load-following capability of CANDU plants.

CANDU equipment manufacturers have been traditionally selected on the basis of competitive tender. Since the basic design of this equipment is independent of manufacture, CANDU equipment design simplification can be vigorously pursued to facilitate quality manufacture by the most cost-effective methods.

Interest during construction and construction labour cost are significant components of nuclear power reactor cost. Significant savings can be realized by both cost and schedule by simplifying systems and designing the system installations as large modules for manufacture within industrial environments instead of the less efficient and more costly construction environment. Another major reduction in project schedule can come from the pre-licensing of reactor designs. This is being accomplished by involving the licensing authority during the conceptual design and detail design stages of all new reactor programs.

The CANDU development program has set challenging targets for advanced designs to achieve higher capacity factors, longer periods of operation between planned shutdowns and short outages for the replacement of major equipment. CANDU improvement places priority on progressive improvement in operability and maintainability to further enhance reliability, capacity factor and safety and to reduce costs. Enhancement of the man-machine interface and provision of diagnostic aids for plant upsets and incidents are objectives which will improve reliability and productivity and reduce manpower requirements. Expanded capability for on-power inspection and maintenance is another objective which will deliver similar benefits.

CANDU plants are world leaders in low radiation exposure to operating staff and in the small annual quantities of solid and liquid waste produced. Nevertheless, development will continue in this area to further reduce emissions of all kinds, to minimize the quantities of wastes and to assure safe storage and ultimate isolation in disposal.

4. SUMMARY

The world will experience a continuing growth in demand for electricity through the next century. Having understood the full impact of the alternative options, the world will likely experience a continuing growth in nuclear-generated electricity through the next century.

CANDU is a relatively young technology which has demonstrated many achievements as an electrical power generation system. These achievements include an unsurpassed safety record with high annual and lifetime capacity factors. Known capabilities not yet fully exploited, such as advanced fuel cycle options, will ensure that CANDU reactors will have a viable place in the generation of low-cost electricity well into the next century and beyond.

CANDU improvement is guided by the principle of evolutionary progress building on strengths with introduction of new technology once it is proven. Improvement covers the complete cycle from research, development and design to provision for life extension and eventual decommissioning and dismantling.

Public confidence in advanced CANDU designs, as with past designs, will be earned by showing that safety and environmental concerns have been given priority attention. Investor confidence in advanced CANDU designs will be earned by similar demonstration that economic, operational and safety performance is based on experience, proven technologies and conclusive research and development.

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