THE THAI-CANADIAN NUCLEAR HUMAN RESOURCES DEVELOPMENT LINKAGE PROJECT

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ABSTRACT

The Thai-Canadian Nuclear Human Resources Development Linkage Project (the "Project") was initiated in 1994 in order to develop the engineering and scientific expertise needed for Thailand to decide whether and how the country can best benefit from the establishment of a nuclear power program. The Project was designed to upgrade current academics and people in industry, and to develop an adequate supply of new technical personnel for academic, industry, utility, regulatory and other government institutions.

The key Project objectives included the establishment of a Chair in Nuclear Engineering at Chulalongkorn University, the upgrading of the current Masters level curriculum, the establishment of undergraduate and doctorate level curricula, development and delivery of an industrial training program for people in industry and government, exchanges of Thai and Canadian academics and industry experts to establish common research programs and teaching interests, and a public education program that was to test in Thailand some of the techniques that have been successfully used in Canada.

INTRODUCTION

Electricity demand in Thailand increased at an annual rate of 10.6% between 1991 and 1996. The peak power demand in May 1997 was 14,500 MW, and the installed generating capacity 16,900 MW. The increase in demand is expected to continue at an average rate of 9.8% of the current capacity in each of the next ten years, reaching a peak power demand of 29,000 MW by 2007.

The electricity supply plan issued in 1993 included nuclear units coming on line in 2005 and 2006, necessitating an accelerated program of nuclear human resources development. With the discovery of increasing amounts of natural gas and offers of IPP and hydraulic generation from Laos, the construction of nuclear units has been postponed and is currently part of the future potential generation mix.

Canada has had considerable experience in the successful transfer of nuclear technology to other countries, including irradiation equipment and CANDU (CANadian Deuterium Uranium) generating stations. Several unique aspects of the CANDU reactor technology make it ideally suited for high degree of localization in developing economies, since natural uranium fuel and pressure tubes are technologies that do not require the specialized manufacturing capabilities of countries with fuel enrichment and advanced metal fabrication facilities.

The Project was initiated in 1994 in order to develop the engineering and scientific expertise needed for Thailand to decide whether and how the country can best benefit from the establishment of a nuclear power program. The Project was designed to upgrade current academics and people in industry, and to develop an adequate supply of new technical personnel for academic, industry, utility, regulatory and other government institutions. The main sponsoring organizations were AECL, the Canadian

International Development Agency, CIDA and Thailand's national utility, EGAT, for the public education component. This paper describes the project's operation and achievements to date.

PROJECT AIMS AND PARTNERS

The Project was designed to develop the highly qualified personnel needed for utilities, regulators and government, as well as by engineering, manufacturing and construction companies. These people will have a key role in evaluating the nuclear power option for Thailand, and if such an option is chosen, to ensure that its construction, operation and maintenance meet international standards of safety and environmental impact. Within the overall project objective, the plan was to upgrade the current academics and industry people who were already involved in nuclear technology, as well as to establish the framework for developing new technical personnel through university education and professional development training programs.

The project aimed to provide the basis on which to develop the desired technical capability, and was planned to be conducted in such a way as to become self-sustaining after the proposed five years of funding by the main project partners. It was a key objective to conduct all tasks with a view to having them sustainable in the long term. The establishment of linkages between institutions and individuals with similar interests in the two countries was seen as a key mechanism to ensure that the exchange of information and collaborative work would be continued after the completion of the current project.

THAI PROJECT PARTNERS

The Thai institutions and companies that had a particular interest in such a project included Chulalongkorn University, the Electricity Generating Authority of Thailand (EGAT) and the Office of Atomic Energy for Peace (OAEP). There was also support expressed by various Ministries as well as the Federation of Thai Industries.

At the time the Project was initiated, the Nuclear Technology Department in the Engineering Faculty of Chulalongkorn University was the only institution of higher learning in Thailand to offer a course of studies in nuclear engineering. The program consisted of three Master's level programs: Graduate Diploma, Master of Science and Master of Engineering. The emphasis had been on the industrial applications of radiation and radioisotopes, with a limited number of courses offered in the area of nuclear power engineering. These programs have been offered since 1975, and over 200 students have graduated in that time.

EGAT is responsible for the generation and transmission of electric power in the Kingdom, and it has maintained a varying level of interest and staff dedicated to the nuclear power plant field, depending on the policies of the various governments and its own assessment of the potential role of nuclear power in the electricity supply mix.

The Office of Atomic Energy for Peace (OAEP) is a multi-faceted Thai government agency responsible for research in various nuclear applications, the operation of research reactors and the production of radioisotopes, as well as regulating the application of all radioactive techniques.

CANADIAN PROJECT PARTNERS

The Canadian International Development Agency (CIDA) provides funding to developing countries in areas that are seen to be of mutual benefit to the recipient country as well as to Canada. Human resources development is a generic area supported by CIDA in many countries. Nuclear technology in general and the CANDU power plant in particular are Canadian exports with a potential in Thailand. Since it was recognized that a prerequisite for a nuclear power program in Thailand is the development of expertise in

this field, a Nuclear HRD Linkage Project met with CIDA's criteria for financial support. Although most of the Canadian participants were primarily experienced in the application of CANDU pressurized heavy water reactor technology, care was taken to ensure that the resulting programs would provide students with a grounding in all three currently commercial reactor technologies, including boiling water and pressurized water reactors.

Atomic Energy of Canada Limited (AECL) is a Crown Corporation of the Government of Canada employing over 3,600 people at sites in Canada and overseas. AECL is the designer of the CANDU reactor, and the corporation develops, markets and manages the construction of CANDU power reactors and MAPLE research reactors, as well as providing a wide variety of related services, such as above- and under-ground nuclear waste management technologies. An extensive research and development program and a wide variety of technical services continue to advance the CANDU technology and support the in-service units.

Canadian Universities have a history of accepting foreign students and have shown considerable interest in recent years to form partnerships with academic institutions in developing countries. Although no Canadian university offers an undergraduate degree in nuclear engineering, a number of faculties offer it as an option in mechanical, chemical or engineering physics. Several universities offer graduate programs in the nuclear engineering field. Expressions of interest were received from the University of Toronto, Royal Military College, University of Saskatchewan, McMaster University, Ecole Polytechnique and the University of New Brunswick. Because of the availability of staff and the matching of expertise of these staff to the needs for courses identified as the Project progressed, only the latter three of the above listed universities contributed lecturers to the Project.

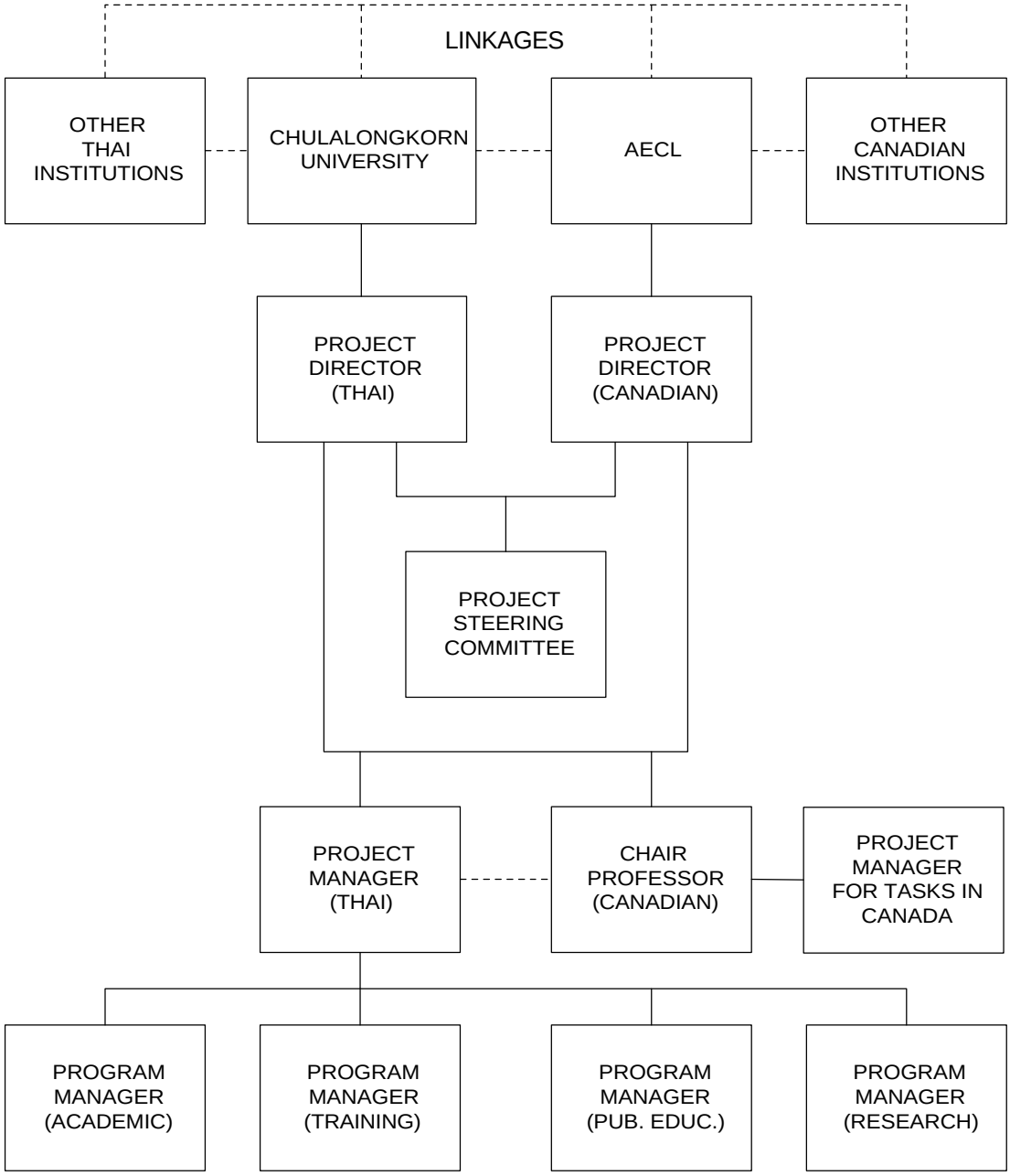
PROJECT ORGANIZATION

The project organization was set up as a combination of direct reports and linkages, as shown in Figure 1. Linkages are shown between the four groups of organizations participating in the project; in terms of program execution Chulalongkorn University represented all the Thai institutions and AECL all the Canadian institutions. Similarly, day-to-day project management tasks involving Thai faculty and other participants were handled by the Thai Project Manager, while decisions involving Canadian experts visiting in Thailand were the responsibility of the Canadian Chair Professor. Significant support was provided by AECL staff through a designated Project Manager for events taking place in Canada, such as organizing the programs for Thai visitors, administrative and accounting services, and handling all contractual matters for Canadians delivering courses, seminars and other consulting tasks.

The Thai and Canadian Project Directors provided overall direction to the Project. For example the broad outlines of the training program would be made by the Project Directors in consultation with the Project and Program Managers. The details of the courses and schedules would be established by the Project Manager in consultation with the Program Managers for Academics and Training. The Chair Professor would seek lecturers for the selected courses, and based on the availability of Canadian subject matter experts and their recommended course outlines, further consultations would take place in arriving at the final course content and delivery schedule.

Figure 1

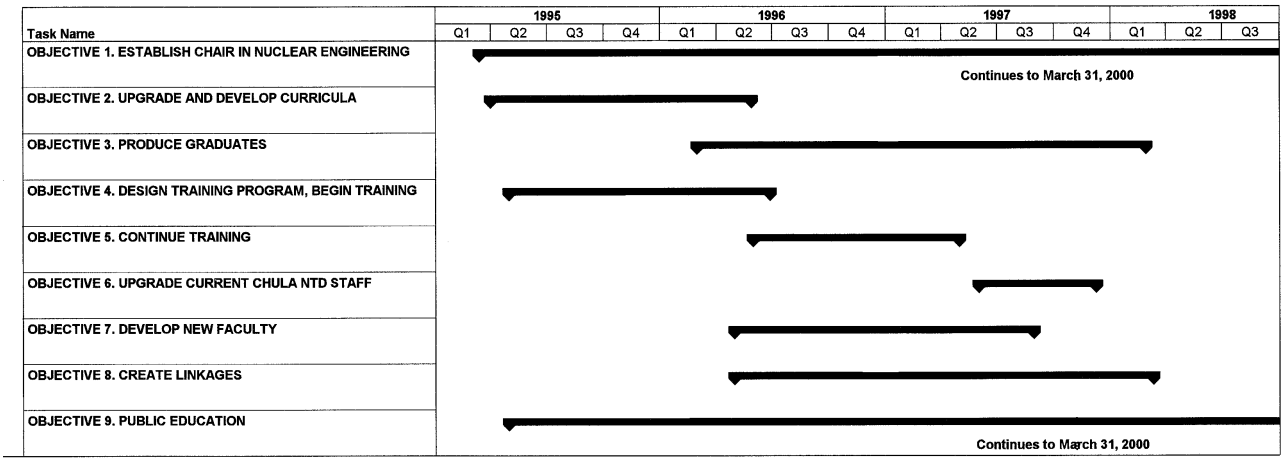
Project Organization Chart



PROJECT OBJECTIVES

The Project scope was organized under nine main objectives, described below, which are being delivered in accordance with the schedule set out in Figure 2.

Figure 2 Project Schedule



1) Chair in Nuclear Engineering

The HRD Project plans called for the establishment of a Senior Professor Chair and an Associate Professor Chair in the Nuclear Technology Department of Chulalongkorn University. The initial plan was for two Canadians to be appointed and located in Bangkok, the Senior Professor for two years and the Associate Professor for three years, with a one and a half year overlap. The main functions of the professors were the development and upgrading of the university curricula, planning and management of the professional development program and development and delivery of education and training courses.

The Senior Professor was appointed in March 1995. The appointment of the Associate Professor was at first postponed and subsequently canceled in favour of extending the Senior Professor position for five years. This change was brought about because of the delay in the Thai nuclear power program, and allowed the continued presence of a Canadian professor in Bangkok for the complete five year duration of the Project.

2) Curricula Upgrading and Development

The Project plan called for the upgrading of the current master's degree program, and the development of a doctorate level as well as an undergraduate degree program. The definition of the course content for these programs has been completed, and the detailed curricula described at the 10th PBNC (Ref. 1). The new and upgraded courses began integration into delivery of the master's degree program in 1996, and approximately half of the Master of Engineering courses in the 1997-98 academic year are being delivered with content developed under the Project.

The newly developed undergraduate curriculum has been approved in principle by the university authorities, but its implementation has been delayed because of a variety of changes being planned at the faculty level to all engineering curricula. The plan calls for the courses to be taught in Thai and/or in English, so as to allow foreign students to take these courses, to be able to use foreign professors in teaching some of the courses, and to provide Thai students with the opportunity to develop their English language skills without having to study at a foreign university. The latter aspect has become particularly important with the currency devaluation that took place since July 1997.

All tasks and deliverables have been completed for the masters and doctorate programs and curriculum definition completed for the undergraduate program. Detailed course development and implementation is awaiting Chulalongkorn University's decision.

3) Production of Graduates

The Project plan called for the production of 10 undergraduates by 1998, 10 Masters graduates in each of 1996, 1997 and 1998, and 4 doctoral graduates by 1998. Since the undergraduate program is yet to be approved, there are no such graduates for the time being. The number of Masters degrees granted were: 5 in 1996, 18 in 1997, and the projection is to have 13 in 1998, i.e. a total of 36 in the first three years of the Project . The first two doctoral students began their programs in 1997.

4) Training Program

The Project Plan provides for the development of 35 training courses, each delivered over a two week period of full time attendance. Present and future faculty, engineers and scientists working in industry, as well as graduate students were the intended targets for these courses. A combination of Canadian university professors and industry experts were to develop the courses and deliver them in Thailand. The planned list of courses is shown in Table 1. At the time of writing 25 of the planned 35 courses have been delivered.

An important aspect of engineering education and training is the need for practical work. Without access to a power plant, this is difficult to realize for power plant engineering, and particularly so for nuclear generating station technology. The approach used by utilities and increasingly by universities is to use computer simulation to provide the hands-on aspect of power plant design, analysis and operation. The need for simulation was identified in the Project proposal, and computers and simulation software were acquired to support the education and training courses (Ref. 2).

In order to ensure the sustainability of the education and training programs, a permanent record of the courses was established. Recognizing the benefit of electronic data retrieval and the expanding use of the Internet, as much as possible of the course documentation was produced in, or converted to, a consistent electronic format.

All lectures are being video and sound tape recorded, and software is being developed that will facilitate the publication of the course material, including the overheads used in lectures synchronized with the spoken words and the highlights as they are being pointed out by the lecturer on the overhead, as well as the reference text material in an integrated Internet compatible (HTML) file format. This development is planned to allow the courses to be presented in a computer assisted self-paced learning format, with Thai subject matter experts from industry assisting the limited number of faculty members, as well as making it practicable to continue the development of the courses via the Internet and to obtain assistance from the Canadian authors of courses via e-mail and teleconferencing.

Table 1 Training Courses Delivered Under the Thai-Canadian HRD Project

1. Reactor Physics 1.1. Nuclear Theory I (Statics) 1.2. Nuclear Theory II (Kinetics) 1.3. CANDU Reactor Kinetics 1.4. Reactor Physics & Fuelling Strategies 1.5. Reactor Core Analysis 1.6. Monte Carlo Method for Particle Transport Simulation 1.7. Reactor Analysis Computational Methods 2. Reactor Thermalhydraulics 2.1. Introduction to Reactor Thermalhydraulics 2.2. Thermal Study of Nuclear Reactors 2.3. Reactor Thermalhydraulics Design 3. Nuclear Power Plant Engineering 3.1. Introduction to Nuclear Power Engineering 3.2. CANDU Overview 3.3. Reactor Simulation and Control 3.4. Nuclear Plant Control Design 3.5. Nuclear Reactor Containment Design 3.6. Reactor Mechanical Design 3.7. Nuclear Reactor Safety Analysis	4. Nuclear Power Plant Management 4.1. Radiation Protection 4.2. Operational Reactor Safety 4.3. Nuclear Plant Operation & Maintenance 4.4. Peer Evaluation Techniques 5. Nuclear Fuel Cycle 5.1. Reactor Siting & Licensing 5.2. Introduction to Radiation Waste Management 5.3. Radiation Waste Management Engineering 5.4. Radiation Waste Management Assessment 5.5. Radiation Waste Management Field Study 6. Other Nuclear Applications 6.1. Radiation Processing 6.2. Neutron Activation Analysis 7. General Industry 7.1. Quality Management 7.2. Non-Destructive Testing 7.3. Corrosion for Engineers 7.4. Instrumentation and Control 7.5. Welding Engineering 7.6. Public Education 7.7. Managing for Results

5) Training Program Participation

The Project target was to train 180 technical professionals during the three year training program. Table 2 summarizes the participation in the training program to date and the totals expected by the end of the three year program. On average, each participant attended two courses.

Table 2 Planned, actual and expected participation in the training courses

PARTICIPATION	PLANNED	ACTUAL TO DATE	FINAL EXPECTED
individual attendees	180	325	400
person-courses	200	573	800

Table 3 Participation statistics

TYPE OF INSTITUTION	NUMBER OF COMPANIES OR DEPARTMENTS	PARTICIPANTS		
		MALE	FEMALE	TOTAL
Utilities	2	106	13	119
Other Industry	26	41	13	54
Government	5	22	10	32
Research Institutions	8	29	20	49
University Faculty	7	12	7	19
Graduate Students	8	37	15	52
TOTAL	46	247	78	325

It should be noted that the participants included faculty members, engineers and scientists working at the electrical utilities, in industry, at various government departments and research institutions, as well as graduate students. Table 3 gives the breakdown of the participants to date based on their affiliations, and also shows the number of male and female participants:

Thirty nine of these participating companies and departments were from Bangkok and seven were from the Provinces.

6) Faculty Staff Development

Several of the existing faculty members made short visits to a Canadian university or institution specializing in a particular aspect of nuclear technology, as well as attending conferences in Canada.

7) New Faculty Staff Development

Several new Thai faculty members spent periods of up to several months on attachment at Canadian universities and nuclear institutions. In particular, the need for developing Thai expertise in the area of radioactive waste management was identified as an important area of staff development. Ten Thai faculty and industry experts received training in related subjects, through a combination of Canadian experts giving lectures in Thailand and visits to AECL's radioactive waste management research and development facilities in Canada. The initiation of a joint research program between Thai and Canadian experts in this area is currently under consideration.

Four Thai faculty undertook assignments of an average of three months duration in Canada, and fourteen other Thai faculty and technical experts received development through a combination of Canadians visiting Bangkok and Thai participants visiting Canada.

8) Linkage Creation

To develop long term sustainable working relationships between Thai and Canadian faculty and other experts, a total of 30 short term visits to each other's institutions was planned. The establishment of the means for video and teleconferencing was also planned to facilitate long term collaboration.

As noted above, the number of long term (6 to 12 months) visits by Thai experts to work at Canadian universities and institutions did not materialize, and much of the funding was reassigned to provide additional training courses in Thailand. Considering the linkage aspect of these assignments, one would like

to measure the extent of the working contacts that would have been formed between Thai and Canadian experts under the originally planned long term assignments, and what has been achieved by the larger number of shorter term visits, seminars and courses that were delivered. The number and duration of the visits is easily determined, but the extent of human linkages formed during these visits is more difficult to quantify. The number of contact-days was chosen as the measure to enable a quantitative comparison of the original plans and what was actually accomplished. Discussions with university and research institute staff indicated that a typical long term assignment usually involves at most one day of contact per week between the host and the visitor. Using this measure Table 4 gives the comparison of planned and actual visits and contact-days between Thai and Canadian project participants:

Table 4 Planned and actual number of visits and resultant contact-days

	Planned	Actual
Number of Visits	86	107
Number of Contact-days	2915	7658

During implementation of these exchanges it was found that while the Thai staff going to Canada would participate in conferences, workshops and individual study assignments, several of the visits by Canadians could be arranged to include the delivery of additional training courses, which in turn resulted in far more contacts between Thai and Canadian experts than was originally anticipated.

At this stage of the project, video conferencing has not been used, in part because the facilities at Chulalongkorn University have only recently become operational, and also because the 12 hour time difference and high telephone charges make connections in the order of an hour uneconomic. However, the video tapes being made of all the course lectures and the software development that will allow the lectures to be presented in a computer assisted self-paced learning format via the Internet as described under item 4 above, is expected to provide an effective form of distant education, and will contribute to the goals of sustainable long distance two way education between Canada and Thailand.

9) Public Education Program

It was recognized at the outset of the Project that improving the technical capability of Thai experts was not sufficient to allow the introduction of nuclear plants in Thailand. An equally important aspect is to gain a level of public acceptance that would allow the government to proceed with a nuclear power program. The Project scope included development of educational modules directed towards high school students. This target audience was selected in part because they are the population segment which will be most affected by the expected introduction of nuclear power in Thailand, as well as their ability to influence their peers, family members and others in their community. This program was planned as a pilot for subsequent country wide programs that would address the needs of the total population.

The Public Education Program was planned to develop written material in the form of booklets and videos that described four topics of major relevance to nuclear power:

- the nature of radiation
- the uses of radiation in health care, agriculture and other areas
- the need for energy and the environmental impact of electricity generation
- the role of nuclear energy in electricity generation.

This information was distributed to all participating schools in Thailand, and was used as the basis of essay contests by students of these schools, as well as being displayed and distributed at various science fairs and

exhibitions. The first three phases of the program have now been completed and the response has been very positive, with the majority of eligible schools participating in the program. Further details of the Public Education component of the Project are given in the paper by Mr. Walter Keyes (Ref. 3).

CONCLUSION

At the half-way point of the Thai-Canadian Human Resources Development Project, a solid foundation has been established that will enable Chulalongkorn University to continue the education and training of engineers and scientists in the nuclear field in preparation for consideration of a nuclear power program in Thailand. For implementation of a nuclear power program, this foundation needs to be built on by establishing an undergraduate program in nuclear engineering, or as an option in some of the established engineering programs, such as mechanical and chemical engineering.

The training courses that have been developed and have had their initial delivery, should form the basis of a continuing education post-graduate diploma or degree program. The continued development of these courses in conjunction with the graduate courses at Thai as well as Canadian universities will help to expand and improve the breadth and depth of the subjects available for the students.

The production and distribution of the course material in electronic form will enable the sharing of this material throughout Thailand as well as in Canada, and may be extended through international collaboration to produce a comprehensive set of nuclear power plant reference material.

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