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Processed by RapidX: 5/10/2024 9:12:44 AM where $f(u)$ is the integrand in Eq. (4). Each integral in Eq. (5) is to be evaluated using a Romberg integration scheme[2] that has proven to be highly accurate for a wide variety of integrands including those that oscillate and/or are weakly singular. From experience the evaluation of the infinite series in Eq. (5), whose terms oscillate in sign, is best performed using an Euler transformation in order to accelerate convergence.[2]

The algorithm described above was tested for the case of a purely absorbing medium ($c = 0$) where the solution is

$$\psi(x) = \frac{1}{2} E_1(x) = \frac{1}{x\pi} \int_0^\infty du \cos u[\tan^{-1}(u/x)/(u/x)] \ , \quad (6)$$

where E_1 is the exponential integral. The infinite series was considered converged when the addition of each of three terms produced a relative error of less than a prescribed amount ϵ_s. The Romberg integration (relative error) accuracy was specified to be ϵ_R. For the test case, the results for $|x| \leq 20$ were invariably accurate to within the described relative error max (ϵ_s, ϵ_R).

Table I shows a comparison (to four places) with the flux results found in CdHP:

$$\epsilon = |\psi(x) - \psi_{\mathrm{CdHP}}(x)|/\psi_{\mathrm{CHdP}}(x) \quad (7)$$

and indicates, rather surprisingly, that a significant number of flux values are not accurate to the number of digits specified in CdHP. To confirm this finding, an independent verification based on an approach to steady state of a polynomial reconstruction[3] was found to be in complete agreement with the converged inverse transform solution. The flux results found in CdHP, therefore, do not qualify as a fourplace benchmark and should be used with caution if at all.

The example presented here on the development and testing of a basic benchmark, therefore, has brought the student in contact with

1. Fourier transforms
2. analytical continuation
3. manipulation of integrals (to generate a form convenient for numerical evaluation)
4. Romberg integration
5. Euler transformation
6. algorithmic verification.

Thus, benchmark development can provide significant experience in the applied mathematical side of nuclear engineering.

1. K. CASE, F. de HOFFMANN, G. PLACZEK, "Introduction to the Theory of Neutron Diffusion," Los Alamos National Lab. (1953).
2. P. J. DAVIS, P. RABINOWITZ, *Numerical Integration*, Blaisdell Publishing Co. (1967).
3. B. D. GANAPOL, *Trans. Am. Nucl. Soc.*, **52** (June 1986).

3. PWR Thermal Hydraulics Training Facility for Engineers and Operators, *J. R. Caves, B. W. Wehring, J. M. Doster, P. J. Turinsky (NCSU)*

The nuclear reactor program of the Nuclear Engineering Department at North Carolina State University has designed an operating model of a pressurized water reactor (PWR) nuclear steam supply system, referred to as the "PWR Loop." The PWR Loop will be used as a training facility in programs presented to utility reactor operators and engineers, as well as in undergraduate and graduate course work. The primary design criteria were: (a) maximize visualization of fluid flow regimes, (b) provide proper tracking of parameters of interest on specific transients, and (c) maintain the proper sequence of automatic protective actions, except when intentionally overridden.

The PWR Loop was first proposed in September 1984 to the Nuclear Engineering Department's industrial advisors group. The concept of the Loop as a training device for utility operators and engineers was well received, and a steering committee of training experts from utilities and vendors was formed to specify the functional design requirements. The input received from industrial representatives served to maximize the practicality of the PWR Loop, by establishing priorities used in the design process.

The Prairie Island facility, a two-loop Westinghouse system, was chosen to be the prototype for the PWR Loop model. Refrigerant R-11 was chosen as the working fluid, to allow operation of the Loop at reasonable temperature, pressure, and power, while keeping the ratio of vapor density to liquid density close to that of water. Electric heaters simulate the nuclear core. Primary system components are the reactor vessel, pressurizer, and two coolant loops, each with a pump and a steam generator. The secondary system includes feed and steam flow control valves, condenser, and feed pump (see Fig. 1).

The scaling laws of Ishii and Kataoka[1,2] were used in the design; they required that the dimensionless groups, Richardson number, heat source number, and friction/orifice number, have the same value in the model and the prototype. This criterion fixed the relationships between length, power, temperature, and time ratios for any given fluid. The desire to keep the time behavior of the model close to real time on the prototype led to a selection of a length ratio of 10 (lengths parallel to the direction of flow in the model are $\frac{1}{10}$ that of the prototype) and operating power of 61.8 kW. The cross-sectional-flow-area ratio was chosen to be 100, yielding geometric similarity between plant and model for simple components (such as pipes) and a close approximation to geometric similarity for components such as the reactor and steam generator.

The reactor vessel is 1.22 m tall and 0.381 m in diameter,

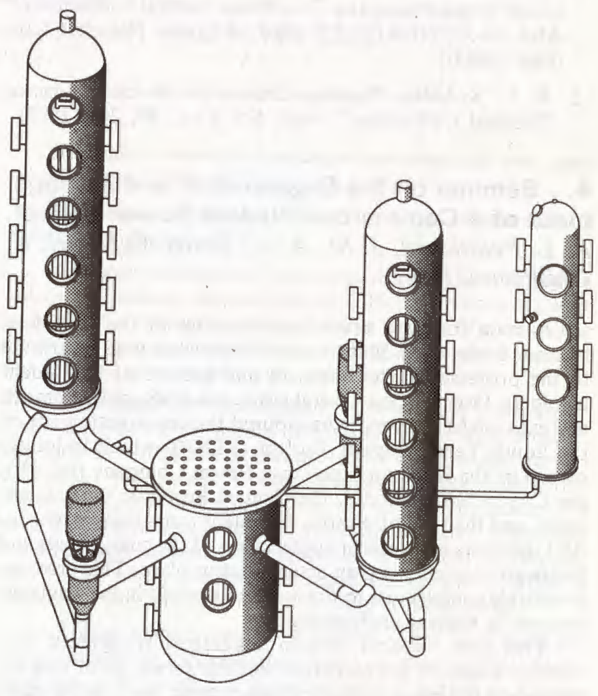

Fig. 1. Perspective view of the PWR Loop. Shown are the reactor vessel, steam generators, reactor coolant pumps, and pressurizer (far right). Glass windows provide visual access to component internals.

with 52 heater rods, each 0.366 m long and 0.019 m in diameter. The steam generator was designed to provide the appropriate primary-to-secondary heat transfer and to keep the same loss coefficient for fluid friction in the prototype and the model. Each steam generator has 84 U tubes, which provide 7.71 m^2 of heat transfer area. The tube bundle is 1.22 m tall and 0.305 m in diameter. Primary system pressure is controlled by an electrically heated pressurizer. The heat sink is a refrigeration unit used in air conditioning systems.

The instrumentation system monitors 30 channels of temperatures, pressures, flows, and levels, as well as various valve positions and motor status signals. Parameters of interest must be displayed to the students, recorded for subsequent analysis, and used to generate control functions for the heat source, flow control valves, pressure control, and safety systems. This is accomplished by the use of two personal computers (PCs) with hardware for data acquisition (DAS) and control, linked via a parallel interface bus. Software controls the DAS, provides safety functions, performs control calculations, and generates the graphic display of operating parameters.

The first PC acquires data, writes data to disk for playback and analysis, and sends required data to the second PC. The second updates the graphic display of operating parameters. Four different screens are kept updated and available for display on request. Several others can be called from the disk if needed. This computer also generates control signals utilizing a point reactor kinetics algorithm for heat source power control, and three-element PID controllers for flow control to the steam generators.

The PWR Loop will provide the opportunity for operators and engineers to investigate and study situations beyond normal, steady-state, full-power operating conditions, where the ability to interpret plant instrumentation properly is important in mitigating core damage. The \$150 000 capital cost of the PWR Loop has been provided by nuclear utilities that will send engineers and operating personnel to our facility for training. Construction is scheduled to begin in July 1986.

1. M. ISHII, I. KATAOKA, "Scaling Criteria for LWR's Under Single-Phase and Two-Phase Natural Circulation," ANL-83-32, NUREG/CR-3267, Argonne National Lab. (Mar. 1983).

2. R. L. KIANG, "Scaling Criteria for Nuclear Reactor Thermal Hydraulics," *Nucl. Sci. Eng.*, **89**, 207 (1985).

4. Seminar on the Organization and Management of a Commercial Nuclear Power Project, *K. L. Peddicord, J. M. Alvis (Texas A&M), K. K. Chitkara (HL&P).*

A main function of student branches of the American Nuclear Society (ANS) is to identify activities that contribute to the professional development and growth of its student members. Over the past several years, the ANS student branch at Texas A&M University has toured the construction site of the South Texas Nuclear Project (STNP), which is jointly owned by the Houston Lighting & Power Company (HL&P), the City of San Antonio, the Central Power & Light Company, and the City of Austin. The plant tours have given student members an excellent appreciation of the components and hardware that make up an actual nuclear plant. This provides a valuable complement to the material covered in the academic courses in nuclear engineering.

This year, student branch organizers recognized that another aspect of a commercial nuclear power plant was not being covered either in the academic course work or the plant tours. This facet includes the organization and management required to undertake a major nuclear power project. To fill this gap, HL&P sponsored a one-day seminar that covered the various managerial functions for STNP. Unit 1 of STNP is targeted for commercial operation in 1987. Unit 2 operation will follow 18 months later.

The seminar consisted of short 20-min presentations by 12 officers and managers at every level of the project. The various speakers and their topics are summarized in Table I (see next page).

Following the seminar, a short tour of ~1.5 h was made through the plant. The main features of the nuclear steam supply system, turbo-generator deck, condensor, feedwater system, and safety systems were observed. The brief tour was a valuable capstone for the day's events.

This seminar provided valuable insight into organizational and managerial activities that are not usually covered in academic curriculum for nuclear engineering students. Furthermore, students were able to see how the expertise and background they will have gained as bachelor of science degree holders in nuclear engineering fit in both for the technical activities and for higher levels in the organizational management. In addition, the speakers stressed the needs for both a solid technical education and communication skills.

The seminar on the "Organization and Management at a Commercial Nuclear Power Project" was very interesting and beneficial. Other ANS branches and utilities may find this to be a useful model for future activities.

5. Contamination Awareness at the Dresden Nuclear Power Station, *D. J. Pagel (CECO, Wilmington), W. C. Rath (CECO, Morris)*

Dresden Nuclear Power Station, which is located ~60 miles southwest of Chicago near Morris, Illinois, has been generating electricity since 1960. Owned by Commonwealth Edison, Dresden was the nation's first privately financed nuclear station. On its site are three boiling water reactors (BWRs). The station helps supply electricity to the 11 525-mile^2 territory of northern Illinois. While the company's primary goal is the generation of electricity, it also has a commitment to the proper and safe operation of the plant in order to protect the well-being of the public, plant personnel, and the environment. Thus the station is dedicated to containing and limiting all radioactive contamination.

Radioactive contamination has a special association with reactors. Water, as the reactor coolant, boils by the heat produced in the nuclear fuel. Radioactive steam formed in the reactor vessel passes to the turbine, which rotates a generator. It is here where electricity is produced. In a BWR, radioactive contamination due to fission and activation products may occur throughout the primary piping system and in the turbine. The products include ^{60}Co, ^{58}Co, ^{134}Cs, and ^{54}Mn.

Due to the contamination potential inherent with a reactor, a contamination trending program was created at the station. Studies had indicated a rise in contamination events during refueling outages. Further increases were due to specific work projects such as hydrolyzing operations. The investigations suggested that contract personnel also increased the number of events.

The early contamination trending program consisted of documenting all contamination cases. Clothing events were reported in a log book. Skin cases were placed on an external contamination record. The information logged included name, social security number, work group, reason for the contamination, and survey results. Health physics management reviewed the records weekly. From these records, skin and clothing events were tabulated. Dresden personnel/contractor events were trended. Finally, weekly totals were correlated to specific jobs and events were investigated for root causes.

Investigations further revealed that a retraining policy was necessary. The policy included a reevaluation and redesign of various areas. It also included a review of radiation practices and procedures.

In 1983, a contamination awareness program was created.