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BWR-LTAS: A Boiling Water Reactor Long-Term Accident Simulation Code

R. M. Harrington
L. C Fuller

Prepared for the U.S. Nuclear Regulatory Commission
Office of Nuclear Regulatory Research
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ABSTRACT

The BWR-LTAS code was developed by the SASA program at Oak Ridge National Laboratory for the detailed study of specific accident sequences at Browns Ferry Unit One: station blackout, small break LOCA outside primary containment, loss of decay heat removal, loss of vessel water injection, and anticipated transient without scram. The primary use of the code has been to estimate the effects of operator actions on the timing and course of events during the part of the sequence leading up to but not including severe fuel damage. This report documents the basis of the methods used to simulate the response of parameters in reactor vessel, primary coolant system, primary containment, and other reactor systems. Sample results are included in the appendix.

1. INTRODUCTION

BWR-LTAS is a digital computer code written to calculate the effects of operator actions on the general thermohydraulic behavior of the Browns Ferry Unit 1 boiling water reactor (BWR) following a hypothetical station blackout event. The code consists of the differential and algebraic equations of mass and energy conservation and equations of state for the reactor vessel and containment; it was originally written in the IBM CSMP-3 (Continuous System Modeling Program) (Ref. 1.1) language to minimize programming and debugging time.

The original CSMP language version was designated BWR-LACP (BWR-Loss of AC Power) for its initial use in the station blackout study. The BWR-LACP code was used for several years, and features were added as required for each accident studied. Recently a Fortran version, essentially the same in scope and structure, has been programmed. This version is designated BWR-LTAS (BWR-Long Term Accident Simulation) to correct the misimpression that the BWR-LACP code is applicable only to station blackout or loss of ac power events. It is the intent of this report to describe the basis and use of BWR-LTAS, the Fortran version.

Some of the important variables calculated by the BWR-LTAS code include:

1. Reactor vessel water levels (above the fuel as well as in the downcomer annulus),
2. Reactor vessel pressure,

3. Average fuel temperature,
4. Reactor vessel injection flow,
5. Safety-relief valve (SRV) flow,
6. Containment pressures and temperatures, and
7. Suppression pool water level and temperature.

These variables may be calculated for arbitrary time periods following initiation of the accident sequence—typically several hours for a sequence such as station blackout. Run specific input includes:

1. Injection flow vs time or an algorithm to represent operator control of reactor vessel water level,
2. SRV opening(s) vs time or an algorithm to represent operator control of reactor vessel pressure with the SRVs, and
3. Initialization parameters: initial time elapsed since reactor trip, initial reactor vessel pressure and level, and initial containment pressures, temperatures, and suppression pool level.

In order to understand the intended use of the BWR-LTAS code it is well to review the history of the development and use of its precursor, BWR-LACP at the Oak Ridge National Laboratory (ORNL). In 1980, the Severe Accident Sequence Analysis (SASA) program was formed under the sponsorship of the Containment Systems Research Branch of the Division of Accident Evaluation of the USNRC. Among the cooperating national laboratories, ORNL was assigned the task of performing realistic analyses of BWR severe accidents, including core degradation and fission product transport. The objective of the studies centered on a limited number of postulated reactor accidents that could lead to severe fuel damage.

It was decided to concentrate the ORNL SASA Program analyses on a specific representative plant, Browns Ferry Unit 1, because the Tennessee Valley Authority (TVA) had agreed to cooperate fully with the ORNL SASA program and because the Browns Ferry plant is typical of operating BWRs. Even now, 13 of the 29 operating BWRs in the United States are BWR 4 with Mark I containment (Ref. 1.7), as is Browns Ferry, and nine BWR 2 and BWR 3 plants also have the Mark I containment.

The first accident sequence for SASA analysis was a station blackout accident involving the long term loss of all ac power at the plant (Ref. 1.2). In order to do a realistic study, the effects of possible or likely operator actions had to be considered. For some accidents, it is possible to learn about plant and operator response using only hand calculations. This is especially true of BWR accidents, such as the station blackout, that do not involve major coolant leakage and during which the core generates only decay heat. At first, hand calculations were used to estimate things like time to core uncovery during a simple boil-off. The need for a mechanized calculational technique became evident as the focus of the analysis expanded from the primary coolant system into the primary containment and whenever different assumptions regarding operator action required additional calculation. Therefore, it was decided to use a computer-based method for the study of the part of the accident prior to severe fuel damage.

Two existing computer codes, MARCH and RELAP, were considered for this purpose. RELAP was not used because it did not model the primary containment and because it promised to use a lot of computer time for the slowly unfolding accident sequences being studied. MARCH was not used because, at the time, most of its programming was based on the pressurized water reactor (PWR) designs and because it did not have sufficient flexibility to model a variety of operator actions. Therefore, the previously used hand calculations were codified and developed into a single computer code, called BWR-LACP, from the subject of the first SASA study.

At the time of the station blackout analysis, BWR-LACP included the basic thermohydraulic models of primary coolant system and primary containment plus related systems that require no ac power: the reactor vessel safety relief valves (SRVs) and the steam turbine driven Reactor Core Isolation Cooling (RCIC) and High Pressure Coolant Injection (HPCI) injection systems. Questions investigated for the station blackout study using BWR-LACP included: (1) Should the operators depressurize the reactor vessel as soon as possible?; (2) Would a stuck open SRV compromise the operator's ability to provide the necessary vessel water injection using the RCIC or HPCI systems?; (3) How long would it take to uncover the core after failure of the station batteries (and the resulting failure of the HPCI and RCIC systems)?; and (4) How many times does the operator have to actuate an SRV during the period before core uncovery?

The second SASA study at ORNL was of a small break loss of coolant accident (LOCA) outside primary containment (Ref. 1.3). For this study, programming was added to BWR-LACP to simulate the leakage of saturated or subcooled water from the reactor vessel. In addition, models for the reactor vessel injection flow from the electric motor driven condensate booster pumps were added because it was found during practice sessions at the TVA Browns Ferry simulator that these pumps can be an important source of vessel injection even in the absence of operator action.

No additional modeling of primary containment cooling systems, such as drywell coolers and pressure suppression pool coolers, was added for the small break LOCA outside primary containment study because, even with the small break size assumed, most of the decay heat was deposited in the reactor building outside primary containment. Extensive modeling of the reactor building thermohydraulic response resulted in a reactor building model (described in Appendix A of Ref. 1.3) that could be run independently, utilizing as input the leakage vs time predicted by the BWR-LACP code. Questions investigated for this study using BWR-LACP included: (1) Based on indications available in the control room, how soon would the operators know of the existence of the break?; and (2) How fast would the reactor vessel flood after reactor vessel depressurization if the operators did not trip the condensate booster pumps?

The third accident study undertaken by the ORNL SASA team was the loss of decay heat removal accident (Ref. 1.4). In this accident, the operators are able to keep the core covered, but there is no suppression pool cooling. The link between the reactor and the ultimate heat sink, the river, is lost and containment pressure builds until the failure pressure is reached. For this study, programming to model the drywell coolers, the pressure suppression pool coolers, the net positive suction head (NPSH) of any of the pumping systems that might need to pump from the overheated suppression pool, leakage and vent flow from the pressurized primary containment, and heat transfer from the uninsulated wetwell torus to its surroundings was added. Questions investigated using the resulting version of BWR-LACP included: (1) How many pool coolers are necessary to prevent overheating of the suppression pool?; (2) Would there be adequate NPSH for the RHR pumps should pool cooling be recovered?; and (3) How long can the operators keep the core covered even though they cannot cool the primary containment?

The fourth ORNL SASA study investigated the effect of the small-capacity, high-pressure injection systems on the TQUV accident sequences (Ref. 1.5). For this study, programming was added to model the flow injected into the reactor vessel by the Control Rod Drive Hydraulic System (CRDHS) pumps as a function of reactor vessel pressure. Representation of injection flow from the Standby Liquid Control (SLC) system positive displacement pump was also added. BWR-LACP was used to determine injection flow necessary to prevent core uncovery, as well as time to core uncovery for various scenarios of operator action to control reactor vessel injected flow and pressure.

The fifth and most recent ORNL SASA study was the Anticipated Transient Without Scram (ATWS) accident (Ref. 1.6). For this study, a major effort was required to add an option to allow the code to calculate the reactor power after the failure of the control rods to insert into the core. Programming was also added to calculate the in-vessel mixing of the sodium pentaborate solution (including possible stratification of boron-rich solution in the lower plenum) after initiation of the SLC system, the flow injected into the reactor vessel by the LPCI and Core Spray systems, the effects of reactor vessel pressure and drywell temperature on the various reactor vessel water level indication systems in the control room, and to provide a more complete simulation of automatic and manual SRV actuation. The resulting version of LACP was used to investigate the effect of operator control of reactor vessel water level and pressure on the reactor power and to determine the rate of pressure buildup in the primary containment.

Since all Browns Ferry instrumentation is in English units, the BWR-LTAS code is written to understand input, to operate, and to deliver output in English units. This is not to deny the advantage of SI units for all future work on modern systems but to ensure that study results can be provided in the units that the operators of the existing plant can readily understand and can relate to the readings on their control room instruments.

BWR-LTAS is not a simple "USER-FRIENDLY" tool. Rather, it consists of a set of thermodynamic and physical calculations that can be and have been of great value to an analyst who understands BWR systems and who can use this system of mathematical calculations to advantage. For such a user, it offers great savings in time and money over conventional codes.

Presently the Fortran version, BWR-LTAS, and the CSMP version, BWR-LACP, are equivalent. However, future code modifications and improvements will be performed only on the Fortran version.

Chapters two through seven of this report describe the physical and mathmatical bases of the various parts of the simulation, starting, in

Chapt. 2, with the reactor vessel injection systems. Injection systems are considered first because they are of primary importance to the analysis of the initial phase of severe accident sequences (prior to permanent core uncovery and the resulting severe fuel damage). The BWR-LTAS code is designed solely for the study of the initial phase of severe accident sequences, while the vessel injection systems remain operational, and thus able to prevent permanent core uncovery.

Chapters 3 and 4 discuss the models used to simulate the primary coolant system thermohydraulics and SRVs. Chapter 5 outlines the modeling of the primary containment (drywell and wetwell). The simulation of the response of control room indication of reactor vessel water level instruments is presented in Chapt. 6. The modifications necessary for the calculation of prompt power during ATWS accidents are considered separately, in Chapter 7, because they are invoked only for ATWS accidents. The solution of system equations is discussed very briefly in Chapter 8 and Chapter 9 compares the results achieved with BWR-LACP to those obtained with other computer codes for certain test transients. Appendix A lists and defines the input parameters, Appendix B presents a sample use, both input and output, of the BWR-LTAS code, and Appendix C is a glossary of frequently used acronyms.

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2. REACTOR VESSEL INJECTION SYSTEMS

The functioning of the pumping systems that inject water into the reactor vessel is very important to any accident sequence. As long as the pumping systems continue to operate, there will be no permanent core uncovery or severe fuel damage. For this reason, the injection systems are presented in this chapter, ahead of the chapters dealing with the primary coolant system (Chapt. 3) or the primary containment (Chapt. 5).

The pumping systems that have been included in BWR-LTAS are the RCIC (Fig. 2.2) and HPCI (Fig. 2.3) systems, the CRD hydraulic system (CRDHS) (Fig. 2.4), the condensate/condensate booster pumps (Fig. 2.6), and the low pressure emergency core cooling systems [the LPCI mode of the RHR system (Fig. 2.10) and the Core Spray system (Fig. 2.9)]. The CRDHS and the RCIC and HPCI systems are capable of injecting adequate makeup flows against full reactor pressure; accordingly, they have been used most heavily in SASA studies to date. The steam-driven RCIC and HPCI systems are capable of running during station blackout. All the other pumps are driven by non-battery-backed electric motors that require a high voltage source of ac power.

Of the low pressure pumping systems, the operators would use the condensate/condensate booster pumps in preference to the Core Spray or the LPCI mode of the RHR systems. The Core Spray and RHR pumps are designed to inject very large flows (40,000 gpm nominal RHR system injection capacity and 12,500 gpm nominal Core Spray system capacity) into the depressurized reactor vessel after large break LOCA accidents. They can be utilized by the operators to provide low pressure injection when there is no line break, however, this would be inconvenient since the injection required to remove the core decay heat is on the order of only one percent of the nominal capacity of the systems.

Figure 2.1 shows how each of the injection systems is piped into the reactor vessel. The HPCI and RCIC systems tee into the main feedwater header inside the drywell; their injection is sprayed into the reactor vessel downcomer region through the 96 main feedwater sparger nozzles. The CRDHS, an integral part of the Control Rod Drive (CRD) system, injects coolant past the CRD mechanism assembly seals and into the interstitial region of the reactor vessel through the control rod guide tubes. The RHR system pumps through the recirculation system piping external to the reactor vessel into the throats of the jet pumps inside the reactor vessel. The Core Spray piping penetrates the reactor vessel, terminating in spray spargers directly above the top of the core. The SLC system is capable of pumping 50 gpm (Browns Ferry nominal rating) of either borated or unborated water through a pipe that terminates in a perforated section below the core plate.

The degree of detail in the BWR-LTAS simulation of each injection system is a reflection of the requirements of each of the six completed accident events studied by the ORNL SASA team. There has been no attempt to model all possible operating modes or each and every valve and control. Separate subroutines have been provided for the different injection systems so that the user may conveniently and selectively modify the programming for each system as needed for future studies.

2.1. RCIC/HPCI Systems

The RCIC and HPCI systems are steam-driven pumping systems that can be actuated either automatically or manually whenever necessary to supply cooling water to the reactor vessel. Figures 2.2 and 2.3 illustrate schematically the layout of the RCIC and HPCI systems. Table 2.1 is a list of the input parameters the model requires for the RCIC and HPCI systems. Both systems can pump from either the condensate storage tank (CST) or the pressure suppression pool; they are both normally aligned to the CST. The HPCI system has about ten times the capacity of the RCIC system; otherwise the systems are very similar. Appendices E and F of Ref. 2.1 provide a thorough description of the RCIC and HPCI systems.

The RCIC and HPCI systems are normally operated under automatic control whereby the speed of the turbine and the pump is adjusted to cause actual pumped water flow to equal the operator-set demand. Thus, the injected flows are proportional to the fractional demand:

$$Wrcic = (Rcicmx)\ (Rcicd)$$
$$Whpci = (Hpcimx)\ (Hpcid)$$

where

Wrcic = RCIC flow (lb/s) injected into reactor vessel,
Whpci = HPCI flow (lb/s) injected into reactor vessel,
Rcicmx = maximum RCIC flow at rated conditions,
Hpcimx = maximum HPCI flow at rated conditions,
Rcicd = operator-demanded fractional RCIC flow,
Hpcid = operator-demanded fractional HPCI flow.

It is assumed that operators would avoid very low flows due to the possible onset of controller instability; therefore, Rcicd and Hpcid are not allowed to assume non-zero values less than 0.2.

The injected flow does not vary with reactor vessel pressure because the automatic flow controller opens or closes the turbine inlet valve as required to deliver the demanded injection. The steam flow required to drive the turbine does vary with pressure. When reactor vessel pressure is reduced, the pumping power required to maintain constant injected flow decreases in proportion to the decrease in pressure. But, reduced reactor vessel pressure also means reduced turbine inlet pressure. The mechanical energy that can be extracted by isentropically expanding steam from some pressure to atmosphere pressure varies from 250 Btu/lb for an inlet pressure of 1125 psia, to 0 Btu/lb for an inlet pressure equal to atmospheric pressure. Therefore, as vessel pressure is reduced, a higher flow of steam is required to maintain constant production of mechanical energy. The two competing effects of reactor vessel pressure, when combined, yield an approximately linear relationship between vessel pressure and required steam flow:

$$Wte = Wte100\ (.1384 + 7.659E\text{-}4P)$$

where

Wte = turbine exhaust flow (lb/s),
Wte100 = turbine exhaust flow (lb/s) at rated injection flow with reactor vessel at a reference pressure of 1125 psia,
P = reactor vessel pressure (psia).

The turbine steam flow is a function not only of reactor vessel pressure but also of the rate at which flow is being injected into the reactor vessel. If vessel pressure is maintained constant, but the rate of injection is reduced, the turbine will require less steam. This effect is simulated by allowing the turbine steam flow to vary in direct proportion to demand.

The steam turbine flows for RCIC and HPCI systems are:

$$Wte,hpci = Hpcid\ (Wte100,hpci)(.1384 + 7.659E\text{-}4P)$$
$$Wte,rcic = Rcicd\ (Wte100,rcic)(.1384 + 7.659E\text{-}4P)$$

where

Wte,hpci = total HPCI turbine exhaust flow (lb/s),
Wte,rcic = total RCIC turbine exhaust flow (lb/s),
Hpcid and Rcicd = as defined previously, fractional injection demand,
Wte100, = turbine exhaust flow (lb/s) at rated 100% flow with reactor vessel at a reference pressure of 1125 psia.

The HPCI and RCIC turbine exhausts are piped to quenching spargers submerged in the suppression pool. These are vertical pipes, one for HPCI and one for RCIC, with many small holes to promote stable condensation of the turbine exhaust. The pressure suppression pool model (see Chapter 5) treats the turbine exhaust the same as the reactor vessel safety relief valve (SRV) exhaust. The turbine exhausts are at a lower enthalpy than SRV exhaust:

HSTE = 915 Btu/lb,

which is assumed to be constant.

In an actual accident, the demand for HPCI and/or RCIC injection would be influenced by a number of factors. Without any operator action, both systems will automatically start on low reactor vessel water level and run at 100% flow until the turbines are automatically tripped on high water level (after the vessel water level has increased by over 100 in). When water level again decreases to the initiation setpoint, the HPCI system would again initiate automatically and again refill the vessel. The RCIC will not actuate for a second injection cycle unless the operator resets the turbine trip signal. Of course, the operators need not wait for automatic initiation. They may start either the RCIC or HPCI system at almost any time, and throttle demand as necessary to effect the desired control of vessel water level. The demanded fractional HPCI flow is equal to the operator-set demand, as modified by the automatic trips or isolations:

Hpcid = (D,hpci)(B,hpci)
Rcicd = (D,rcic)(B,rcic)

where

D = operator-set fractional demand (function of indicated water level and desired water level),
B = 1 if trip or is lation is not in effect, = 0 after trip or isolation.

Table 2.1 lists the different conditions that can cause automatic HPCI or RCIC turbine trips or turbine steam supply isolations. Section 2.5 explains the simulation of the operator-set demand.

2.2. Control Rod Drive Hydraulic System (CRDHS)

The CRDHS continuously pumps from the CST into the reactor vessel (via the seals in the 185 CRD mechanisms) during normal operations. The CRDHS injection will continue after reactor scram even without intervention by the operators. In the event of loss of off-site power, the electric motor driven CRDHS pumps stop, and operator action is required to restore power to the pumps. In an emergency, the CRDHS injection flow can be increased considerably by operator intervention. Chapter 3 of Ref. 2.2 and Appendix E of Ref. 2.3 describe the operation and design of the CRDHS. Injection flow as a function of reactor vessel pressure, the number of running CRDHS pumps (1 or 2), and the flow resistance, is calculated as outlined below. Table 2.2 lists input parameters and gives typical values applicable to Browns Ferry Unit 1. Figure 2.4 is a schematic diagram of the layout of the Browns Ferry Unit 1 CRDHS.

Straightforward application of Bernoulli's law between the condensate storage tank (CST) and the reactor vessel (RV) yields the following equation:

$$h_p = 2.32\ P_{rv} + 35 + h_u$$

where

h_p = head developed by the CRDHS pump(s) (ft),
P_{rv} = reactor vessel pressure (psig),
2.32 = 144 in^2/ft^2 divided by the density of water at 90°F,
35 = elevation difference between the CST and RV injection point (ft),
h_u = total unrecoverable losses between the CST and RV (ft).

This equation is a simple statement that the CRDHS pump must develop sufficient head to pump against reactor pressure while offsetting the elevation difference and unrecoverable (i.e., frictional and shock) losses. Acceleration or deceleration losses are neglegible for this balance between the CST and the RV.

After expressing the h_p and h_u terms as quadratics in flow, the above equation can be rearranged as a single quadratic equation which can then be solved for the unknown, flow, using the familiar relationship for the largest root of a quadratic polynomial:*

$$B_i = (-b + \sqrt{b^2 - 4ac})/2a$$

where

B_i = flow injected into reactor vessel (gpm),
$a = (K_1 - h_2/N_p^2)$,
$b = -(h_1 + 2h_2 B_m/N_p$,
$c = 35 + 2.32\ P_{rv} - (h_o + h_1 B_m + h_2 B_m^2)$,
B_m = flow recirculated to pump suction (gpm per pump),
N_p = number of CRDHS pumps running,
K_1 = loss coefficient (ft/(gpm^2),
h_o, h_1, h_2 = coefficients developed from least squares pump curve fit.

The loss coefficient, K_1, relates the unrecoverable losses to the injected flow as follows

$$h_u = K_1 B_i^2$$

and the pump developed head is expressed as a quadratic function of B_p, the bulk flow per pump:

$$h_p = h_o + h_1 B_p + h_2 B_p^2$$

where

$$B_p = B_i/N_p + B_m \ .$$

The values for the coefficients were determined by a least squares fit to the TVA-supplied pump head vs capacity curve (Fig. 2.5) resulting in the following expression:

$$h_p = 3816 + 1.552 B_p - 0.02517 B_p^2 \ .$$

The calculation of loss coefficient, K_1, is more involved because two parallel flow paths were considered: (1) the normal post-scram flow

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*Actual values of system parameters lead to only one positive root.

path through the charging header and the open scram inlet valves, and (2) the pump test bypass flow path (which can only be opened by operator action) into the reactor vessel via valves 85-551 and 85-50. (see Fig. 2.4). Thus, the loss term Kl is a composite of the two parallel flow paths and also of a third, series resistance — the 85-527 throttling valve* through which all injection must flow before entering the charging header or the pump test bypass header:

$$K_l = 1/(1/\sqrt{K_{ch}} + 1/\sqrt{K_{ptb}})^2 + K_{tv} ,$$

where

K_l = overall loss coefficient,
K_{ch} = loss coefficient for flow through the charging header,
K_{ptb} = loss coefficient for flow through the pump test bypass, and
K_{tv} = loss coefficient for the 85-527 throttling valve.

Note that prior to operator action to enhance CRDHS flow, there is no flow through the pump test bypass, and K_{ptb} is effectively infinite, so the above expression reduces to $K_l = K_{ch} + K_{tv}$. The input parameters in Table 2.2 of this report utilize a value of $(K_{ch} + K_{tv})$ that was derived from Fig. 3.4.-10 of the Browns Ferry FSAR: $(K_{ch} + K_{tv}) = 0.0954$ ft/(gpm^2).

There is no FSAR data on flow through the pump test bypass, so a value was estimated by taking into account the known fittings and valves in each segment of piping of different diameter: $K_{ptb} = 0.01$ ft/(gpm^2).

The flow resistance of the 85-527 throttling valve was inferred from Browns Ferry OI-85, "Control Rod Drive Hydraulic System," which states that the valve has been set to maintain a 1500 psig control rod drive pump discharge pressure (i.e., as measured directly upstream from the valve) under normal conditions (before scram, with 60 gpm injection flow and 80 gpm total pump flow, considering the 20 gpm recirculation flow). This information is sufficient to allow the pressure drop across the throtting valve to be estimated because the pump developed head is available from the head capacity curve, and because the relative elevations of the CST and the pump discharge header are known. The calculated estimate of throtting valve flow coefficient is:

$$K_{tv} = 0.0507 \text{ ft/(gpm}^2).$$

For cases in which the 85-527 valve is fully opened as specified by Browns Ferry EOI-41, it is assumed that K_{tv} is reduced by factor of ten to 0.00507 ft/(gpm^2).

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*See Fig. 2.4.

As part of the CRDHS modeling, an expression was developed to calculate the pump suction pressure. This is necessary in order to determine at what flow the pump(s) would trip on low suction pressure (set at 18 in. mercury absolute, or 8.8 psia). The calculation proceeds from Bernoulli's Law:

$$P_{ps} = P_{atm} + \Delta P_{elev} - \Delta P_{l,a},$$

where

P_{ps} = pump suction pressure (psia),
ΔP_{elev} = 21.2 + 0.431(CST level) (psi),
$\Delta P_{l,a}$ = unrecoverable pressure losses plus acceleration pressure drop (psi).

The value of the loss term, $\Delta P_{l,a}$, was estimated from the calculated operating conditions provided in tabular form on Fig. 3.4-10 of the Browns Ferry FSAR:

$$\Delta P_{l,a} = 0.000516\ B_p^2\ ,$$

where B_p = flow per pump (gpm).

The method described above for calculating pump suction pressure was developed under the assumption that 100% of the pump suction pressure loss occurs in the pump suction piping that is specific to each pump. This assumption is reasonable since the section of piping between the CST and the CRD pumps that is common to both pumps is much larger, and since the pump-specific piping includes the suction strainer which is the largest single loss.

2.3. Condensate and Condensate Booster Pumps

Figure 2.6 shows schematically the relationship between the major parts of the feedwater and condensate systems. Table 2.3 lists required BWR-LTAS code input with typical Browns Ferry values. During normal power operation, the condensate pumps (CPs), condensate booster pumps (CBPs) and main feedwater pumps (MFPs) work in series to pump at a high rate (~30,000 gpm), from the main condenser hotwell into the reactor vessel. The BWR-LACP calculations performed for the SASA studies have invariably begun after closure of the main steam isolation valves (MSIVs), with the steam supply to the MFP turbines cut off, and the electric motor driven CPs and CBPs running but not able to inject into the pressurized reactor vessel. The combined shutoff head of the CPs and CBPs is only about 40% of the normal reactor vessel pressure. Figure 2.7 shows the head vs flow curves typical of Browns Ferry Unit 1.

Unless an accident sequence is initiated by loss of ac power, or unless the CPs and CBPs are tripped by an operator, the pumps will be running. If a depressurization of the reactor vessel occurs later in the accident they will then be able to inject water from the hotwell into the reactor vessel.

The calculation of injected flow as a function of reactor vessel pressure is based on interpolation of an input table (or, on evaluation of the polynomial equivalent) of flow vs reactor vessel pressure. The values for this table must be prepared beforehand by a separate calculation that balances the head developed by the pumps against the line losses, elevation change, and static head in the reactor vessel:

$$\Delta H_p = \Delta H_l + P_v(144/Rhoc) + \Delta H_e$$

where

ΔH_p = head developed by the pumps (ft),
ΔH_l = unrecoverable losses (ft),
ΔH_e = elevation of the reactor vessel injection point above the hotwell (=56 ft),
P_v = reactor vessel pressure (psig),
Rhoc = density of the condensate (lb/ft^3).

The ΔH_p term is calculated from the known performance curves (Fig. 2.7). The head loss term is proportional to loss coefficient times the square of flow. The loss coefficient is based on the approximation that the total unrecoverable loss (ΔP) between main condenser and reactor vessel is 212 psid for normal full power operation; the effective loss term at 100% flow is then increased to 250 psid to allow for the flow resistance of the idle MFPs. For each vessel pressure, P_v, there is an injected flow for which the above equation is satisfied. For the Browns Ferry input, this flow was calculated for a variety of vessel pressures. The resulting injected flow as a function of vessel pressure is plotted on Fig. 2.8. A table of condensate booster/condensate pump flow must be input by the user via data statements in function subprogram CBPF if a different injected flow versus vessel pressure relationship is desired.

2.4 Low Pressure Injection Systems

A schematic layout of the Core Spray (CS) system is shown on Fig. 2.9; that of the Residual Heat Removal (RHR) system is on Fig. 2.10. Table 2.4 specifies input parameters required by the simulation. The CS system and the Low Pressure Coolant Injection (LPCI) mode of the RHR system can inject into the reactor vessel at a high rate if the reactor vessel pressure is below about 300 psia. These systems have such large pumps because they are designed for rapid reflooding of the reactor vessel following large-break loss of coolant accidents. For each accident sequence investigated to date by the ORNL SASA team, the CS and RHR systems were found to have a capacity some 20 to 50 times greater than would be required to adequately cool the core. It should be noted that there is no high level trip of these pumps.

Normal suction for both CS and RHR systems is from the pressure suppression pool (PSP), but the operators can remote-manually shift the suction to the condensate storage tank (CST). The CS system introduces injection into the reactor vessel via spray headers located directly above the top of the core. The RHR system injects into the discharge piping of the main recirculation pumps, and enters the reactor vessel via the jet pump inlets. The entry point for low pressure injection does not make much difference for most non-LOCA sequences (at least before core damage or significant heatup). The reactor vessel thermo-hydraulic model (Chapt. 3) treats both injection paths similarly, with the exception that the core spray is assumed to combine directly with steam if the reactor vessel water level is below 380 in* (the level of the CS spray headers).

The operators can influence the flow injected by the CS or RHR systems after their automatic initiation by turning off one or more pumps or by throttling the flow by means of valves in the injection path. The following expressions for flow per pump were developed from hand calculations that considered the pump head vs flow curves and the unrecoverable losses in piping. (Ref. 2.4) The throttling of the injection valves is not simulated. Figure 2.11 shows the head vs flow curves typical for Browns Ferry.

$$\text{Blpci} = (10316)(1 - \text{Dpeccs}/331)^{0.5}$$

$$\text{Bcs} = (3879)(1 - \text{Dpeccs}/342)^{0.5}$$

where

Blpci = bulk flow (gpm) pumped from PSP into reactor vessel per RHR pump,
Bcs = bulk flow pumped from PSP into reactor vessel per CS pump,
Dpeccs = reactor vessel pressure minus PSP pressure (psid).

The corresponding mass flow equals the number of running pumps times the bulk flow per pump times the density of the PSP water.

2.5. Manual Control of RCIC and/or HPCI Injection

Operators prefer to use the RCIC system to supply reactor vessel injection requirements during the recovery period following a reactor scram with MSIV closure. The 600 gpm RCIC capacity is very close to the injection required to maintain constant water level immediately after a scram from full power. Of course, if there is a coolant leak, another

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*Normal reactor water level is 561 in. above vessel zero. The top of active fuel (TAF) is at 360 in.

pumping system, such as the HPCI system, would have to be started. About 1 h after a scram from full power, the decay heat has decreased such that the full RCIC capacity is about double that required to maintain constant water level.

ORNL investigators have observed at the Browns Ferry simulator that operators act to prevent the see-sawing up and down of reactor vessel water level and the abrupt start and stop cycles of the HPCI turbine that would occur if strictly automatic control were relied upon. They effect this smooth control of vessel water level by periodically making small adjustments to the flow demand at the RCIC control station. This section outlines how operator control of the RCIC system is simulated. Operator control of the larger but very similar HPCI system is simulated in the same way.

The basic assumption employed in the simulation is that the operator will periodically check the reactor vessel water level and make corrections to the RCIC flow demand that depend on how far the indicated water level is from the desired water level. The programming to simulate this behavior is straightforward. Table 2.5 summarizes required input and also serves to outline the program logic. Very low flows are avoided due to the possible onset of controller instability (i.e. the controller that automatically adjusts RCIC or HPCI turbine speed to achieve the flow demanded by the operator); therefore the demand fraction is not allowed to go below a minimum value, Dmin.

2.6. Net Positive Suction Head (NPSH) Requirements

NPSH is a measure, expressed in equivalent height of the water being pumped, of how close the water is to saturation as it enters the pump:

$$NPSH = (P_s + P_d - P_v)(144/Rho)$$

where

P_s = static pressure (psia),
P_d = dynamic pressure (i.e. velocity head (ft) times density/144),
P_v = vapor pressure (psia) evaluated at the temperature of the water as it enters the pump,
Rho = density (lb/ft^3) of the water being pumped.

Most pumps require a minimum NPSH in order to operate properly. If a pump is run without sufficient NPSH, a variety of consequences can result, from degradation of the pump developed head to cavitation and erosion of the pump impeller, and possibly to total failure of the pump or pump motor. Pump manufacturers typically publish a minimum recommended NPSH for each of their pumps. Operation at or above this minimum will assure smooth, cavitation-noise free operation with no more than a 3% degradation of the developed head.

Each of the pumps discussed in this chapter (excepting the condensate pumps for the main condenser hotwells, which are designed to pump saturated water) can be influenced by a low NPSH condition. Such a condition might be caused by excessive flow resistance (e.g. a plugged strainer) in the suction, or by excessive temperature of the pumped water. Excessive temperature of the pumped water was of concern for the ORNL SASA program study of the Loss of Decay Heat Removal (LDHR) accident. In this accident sequence, the pool cooling is lost, and very high pressure suppression pool (PSP) temperatures are reached. In order to predict whether the high pool temperature would cause a failure of the RHR pumps, the following expression was developed to calculate the NPSH of the RHR pumps:

$$Hsrhr = Hm + Dzrhr - (H1rht(Nrhrl^2) + H2rhr)\ (Brhr/10000)^2$$

$$Hm = (Ptspg - Pv)(144/Rho) + Dlpsp$$

where

Hsrhr = NPSH (ft) of RHR pump(s),
Hm = margin (ft) above saturation at the normal elevation of the surface of the PSP,
Dzrhr = normal elevation (ft) of the surface of the PSP above the RHR pumps,
H1rhr = head loss (ft) at 100% flow in the RHR suction piping common to both pumps in the loop,
Nrhrl = number of RHR pumps per loop (either 1 or 2),
H2rhr = head loss (ft) at 100% flow in the RHR suction piping particular to each individual pump,
Brhr = flow (gpm) per RHR pump (10,000 gpm is nominal 100% flow),
Ptspg = total pressure (psia) of PSP atmosphere,
Pv = vapor pressure (psia) of the water at the bottom of the PSP,
Dlpsp = change from normal of the PSP water level (ft).

Similar expressions were also developed for the NPSH of RCIC, HPCI, and Core Spray pumps. These expressions assume that each pump is pumping from the PSP; however, it should be emphasized that it is generally not necessary for these systems to pump from the PSP. Therefore the calculation of NPSH margin for the RCIC and HPCI systems is for information only, and no automatic failure on insufficient NPSH is programmed. If the PSP temperature were excessive (say, above 190°F) it would be much better to take suction on the condensate storage tank where the water is sufficiently cool so that inadequate NPSH is not of concern. Terms in the following expressions are defined similarly to those defined above for the RHR system:

$$Hscs = Hm + Dzcs - (Hlcs(Ncsl^2) + H2cs)(Bcs/3125)^2$$

$$Hshpci = Hm + Dzhpci - Hlhpci (Bhpci/5000)^2$$

$$Hsrcic = Hm + Dzrcic - Hlrcic (Brcic/600)^2 .$$

It should be mentioned that there is an additional failure mechanism for RCIC and HPCI if they should be used to pump hot water from the PSP. The lube oil of the RCIC and HPCI steam turbines is cooled by the pumped water. If the lube oil temperature exceeds 200°F, failure of the turbines is likely. Therefore, if an attempt were made to pump PSP water elevated to the neighborhood of 200°F, failure of the RCIC and HPCI turbines would result, even though the NPSH might be sufficient.

2.7 Sources of Water for Vessel Injection

Table 2.6 lists the sources of water available to each of the injection systems considered in this chapter. For most of the SASA investigations to date, the CST has been the primary source. The Browns Ferry Unit 1 CST normally holds about 362,000 gal of condensate — sufficient to cool the shutdown core for more than 24 h. Of course, in the event of a primary coolant line break, the reserve inventory can be depleted much faster.

If a condensate booster pump and condensate pump are providing injection to the reactor vessel, then the main condenser hotwell becomes the primary source of water. The makeup connection between the CST and hotwell is controlled by an automatic valve that opens to allow flow from CST to hotwell if the hotwell level falls about 6 inches below normal. During normal operations, the CST makeup flow to the hotwell, if actuated, is substantial because of the vacuum within the main condenser. During most long accident sequences the condenser vacuum is lost, so the CST to hotwell flow is driven only by gravity, at a much lower flow. The hotwell makeup pipe is connected to the CST by means of a standpipe (inside the CST) of a height sufficient to reserve 135,000 gal of coolant for the safety systems (HPCI, RCIC, and CRDHS).

For SASA investigations to date, it has been necessary to program the following mass balance equations to keep track of the coolant inventory in CST and hotwell. Not all the possible flow connections listed on Table 2.6 are programmed. For example, if a future sequence requires that the operator switch the Core Spray suction from PSP to CST, then an additional term would have to be added to the CST mass balance:

$$d/dt(Mcst) = -Shwmu(Whot) - Shpsuc(Whpci) - Srcsuc(Wrcsuc) - Wcrhy$$

$$d/dt(Mhw) = Shwmu(Whot) - Wcbp$$

where

Mcst = mass of coolant in CST (lb),
Shwmu = 0 if CST volume < 135000 gal or if hotwell water level > makeup point (= 1 otherwise),
Whot = automatically controlled makeup flow (lb/s) from CST to hotwell (calculated as indicated below),
Shpsuc = logic to switch the HPCI suction from CST to PSP when indicated PSP water level exceeds +7 in,
Srcsuc = logic to allow operator to switch RCIC suction,
Whpci = HPCI flow,
Wrcic = RCIC flow,
Wcrhy = CRDHS flow (injected into reactor vessel unless there is a line break),
Mhw = mass of water in the main condenser hotwell,
Wcbp = condensate flow pumped from hotwell by condensate and condensate booster pumps.

The gravity driven hotwell makeup flow is given by

$$\text{Whot} = .073 + 1.74(10)^{-7}(\text{Vcst}),$$

where Vcst is the coolant volume (cu. ft) in the CST. There is no provision for modeling the effect of condenser vacuum because it is expected that the condenser would be at atmospheric pressure during a severe accident sequence.

The temperature of water in the CST has generally been assumed to be 90°F, while the temperature of the PSP (initially 90°F) is a function of the amount of steam quenched in the PSP following accident initiation. Therefore, a steady flow energy balance is necessary to calculate the temperature of water injected into the reactor vessel if water from both the PSP and the CST is being injected.

REFERENCES FOR CHAPTER 2

2.1 S. A. Hodge et al., *Station Blackout at Browns Ferry Unit One — Accident Sequence Analysis*, NUREG/CR-2182 (ORNL/TM-455/V1), November 1981.

2.2 R. M. Harrington and L. J. Ott, *The Effect of Small-Capacity, High-Pressure Injection Systems on TQUV Sequences at Browns Ferry Unit One*, NUREG/CR-3179 (ORNL/TM-8635) August 1983.

2.3 S. A. Hodge et al., *SBLOCA Outside Containment at Browns Ferry Unit One — Accident Sequence Analysis*, NUREG/CR-2672, Vol. 1 (ORNL/TM-8119/V1), November 1982.

2.4 L. J. Ott, unpublished calculations, Oak Ridge National Laboratory, December 1983.

Table 2.1. Input parameters for HPCI and RCIC systems

Name	BFNP Value	Explanation
RCIC		
Rcicmx	83.3 lb/s	Rated reactor vessel injection with reactor at full pressure (equivalent to 600 gpm)
Wterc0	7.97 lb/s	Turbine steam flow when pumping full flow into fully pressurized reactor vessel
Lrcmt	582 in.	Reactor vessel water level (in above vessel zero) for manual turbine trip
Lrcmin	476.5 in.	Reactor vessel water level for manual initiation of RCIC flow
Orcman	150 s[a]	Time to begin manual RCIC control
Orct	7600 s[a]	Time for manual turbine trip
Orctr	10800 s[a]	Time for resetting manual turbine trip
Lrct	582 in.	Reactor vessel level for automatic turbine trip
Lrcin	476.5 in.	Vessel level for automatic initiation
Perct	40 psia	Turbine exhaust pressure (= suppression pool pressure) for automatic turbine trip
Prcis	65 psia	Reactor vessel steam pressure for automatic turbine steam supply isolation
Trcis	200 F	Turbine steam supply line space temperature for automatic turbine steam supply isolation
Trcf	190 F	PSP temp for RCIC/HPCI failure (only if suction has been shifted to suppression pool)
HPCI		
Hpcimx	694.1 lb/s	Rated reactor vessel injection with reactor vessel at full pressure (equivalent to 5000 gpm)
Wtehp0	51.15 lb/s	Turbine steam flow when pumping full flow into fully pressurized reactor vessel
Lhpmin	476.0 in.	Reactor vessel water level for manual initiation of HPCI flow
Lhpmt	540 in.	Reactor vessel water level for manual turbine trip

Table 2.1. (continued)

Name	BFNP Value	Explanation
Ohpt	600 s[a]	Time for manual turbine trip
Ohptr	10^6 s[a]	Time for reset of manual trip
Phpin	16.5 psia	Primary containment pressure for automatic HPCI initiation
Lhpin	476 in.	Reactor vessel water level for automatic HPCI initiation
Lhpt	582 in.	Vessel water level for automatic turbine trip
Phpis	115 psia	Vessel pressure for automatic turbine steam supply isolation
Pehpis	165 psia	Turbine exhaust pressure (= suppression pool pressure) for automatic isolation
Thpis	200°F	Turbine steam line space temperature for automatic isolation
Lspss	+7 in.	Indicated PSP level for automatic shift of HPCI suction from the CST to the PSP
Lcstss	0.0 in.	CST level for automatic shift of HPCI suction from the CST to the PSP
Ohpman	150.0 s	Time to begin manual HPCI control

[a]Very large values (e.g., 10^6) may be used to prevent the indicated operator action.

Table 2.2. Input parameters for the control rod drive hydraulic system

Parameter	Value	Definition
Dzv	35 ft	Elevation of the reactor vessel above the CST
Bm	20 gpm	Pump discharge to pump suction recirculation flow per pump
HO	3816 ft	Constant in the second order fit of the pump head vs flow curve
H1	1.552 ft/gpm	Coefficient of the first power of bulk flow (gpm) per pump in the pump head vs flow curve
H2	-0.02517 ft/(gpm^2)	Coefficient of the second power of bulk flow per pump in the pump head vs flow curve
Kcrdch	0.0447 ft/(gpm^2)	Loss coefficient for flow through the charging header (between the 85-527 throttling valve and the interior of the reactor vessel)
Kcrdtv	0.0507 ft/(gpm^2)	Normal loss coefficient for flow through the CRD pump discharge throttle valve (85-527 valve at Browns Ferry Unit 1)
Kptb	0.01 ft/(gpm^2)	Loss coefficient for flow through the pump test bypass line (from pump discharge to interior of reactor vessel)
Dzs	21.2 ft	Elevation of the bottom of the CST above the CRD pump centerline
Ksu	.000516 ft/(gpm^2)	Loss coefficient (unrecoverable plus acceleration) for bulk flow (per pump) between CST and CRD pump suction
Osscrd	10^6 s[a]	Time for the operator to start the second CRD pump
Ltcrd	582 in.	Indicated reactor vessel water level above which operator throttles the CRD pump discharge valve (triples flow resistance, Ktv)
Ootv	10^6 s[a]	Time for operator to open the CRD pump discharge valve (flow resistance, Ktv, reduced to 10% of normal value)
Ooptb	10^6 s[a]	Time for operator to open the pump test bypass valve

Table 2.2. (continued)

Parameter	Value	Definition
Otcrdp	10^6 s[a]	Time for operator to trip all CRD pumps (or for failure of CRD pumps)
Tslc	10^6 s[a]	Time at which the operator initiates injection of (non-borated) demineralized water by the SLC system to supplement the CRD pump injection.

[a]Very large values (e.g., 10^6) may be used to prevent the indicated operator action.

Table 2.3. Input parameters for CPs/CBPs

Parameter	Value	Definition
Ocbpc	60 s	Time interval between the periodic operator checks of vessel water level and adjustment of injected flow
Oocbp	10^6 s[a]	Time when operator control of condensate booster pump flow begins
Otcbp	0.0 s	Time when operator trips the condensate and condensate booster pump

[a]Very large values (e.g., 10^6) may be used to prevent the indicated operator action.

Table 2.4. Input data for low pressure injection systems

Parameter	Value	Definition
Hsrhrf	15.6 ft	Threshold net positive suction head for failure of RHR pump
Hscsf	16.2 ft	Threshold net positive suction head for failure of Core Spray pump
Llpi	413.5 in.	Reactor vessel water level for automatic start of CS and RHR pumps
Pvlpi	480 psia	Low vessel pressure (in conjunction with high drywell pressure) for automatic start of CS and RHR pumps
Pdlpi	16.95 psia	High drywell pressure (with low vessel pressure) for CS and RHR start
Pvlpiv	480 psia	Low vessel pressure which permits injection valves to open after the CS and/or RHR automatically initiate
Ncs	$0 \leq A \leq 4$ [a]	Number of operable core spray pumps
Nlpci	$0 \leq A \leq 4$ [a]	Number of operable RHR pumps
Oscs	10^6 s [b]	Time for operator to start core spray pumps
Oslpci	10^6 s [b]	Time for operator to start RHR pumps for LPCI
Odcs	0.0 s	Time for operator to disable the automatic operation of the CS system
Odlpci	0.0 s	Time for operator to disable the automatic operation of the LPCI mode of RHR
Llpit	587.0 in.	Reactor vessel water level at which the operator would discontinue low pressure injection in order to prevent overfilling the reactor vessel
Tcfail	30 s	Time that an RHR pump or core spray pump must operate below the threshold net positive suction head (Hsrhrf or Hscsf) in order to cause pump failure

[a] Refers to arbitrary user input.

[b] Very large values (e.g., 10^6) may be used to prevent the indicated operator action.

Table 2.5. Input parameters for simulation of manual control of HPCI and RCIC systems

Parameter	Value	Description
Opchrc	60 s	Time interval between operator checks of the reactor vessel water level
	Ldcset + 12	Water level (in.) above which the operator would run the system at minimum demand
	Ldcset + 8	Water level (in.) above which the operator would decrease the current flow demand setting by 10% of full scale
	Ldcset + 5	Water level (in.) above which the operator would decrease demand by 5% of full scale
Ldcset	560 in.	Desired indicated reactor vessel water level (setpoint for manual control)
	Ldcset - 5	Water level (in.) below which the operator would increase demand by 5% of full scale
	Ldcset - 20	Water level (in.) below which the operator would restore demand to 100% of full scale
Dmin	0.20	Minimum demanded flow (fraction of full flow) allowed for manual control (turbine control might be unstable below this demand)

Table 2.6. Sources of water for reactor vessel injection

Injection system	Normal suction	Alternate suction	Suction shift
HPCI	CST	PSP	Manual or automatic
RCIC	CST	PSP	Manual
LPCI (RHR)	PSP	CST	Manual
Core Spray	PSP	CST	Manual
CRDHS	CST	None	None
SLCS	SLC tank	Demin. water	Local manual
Condensate	Hotwell	None	None

Note: CST = condensate storage tank
PSP = pressure suppression pool

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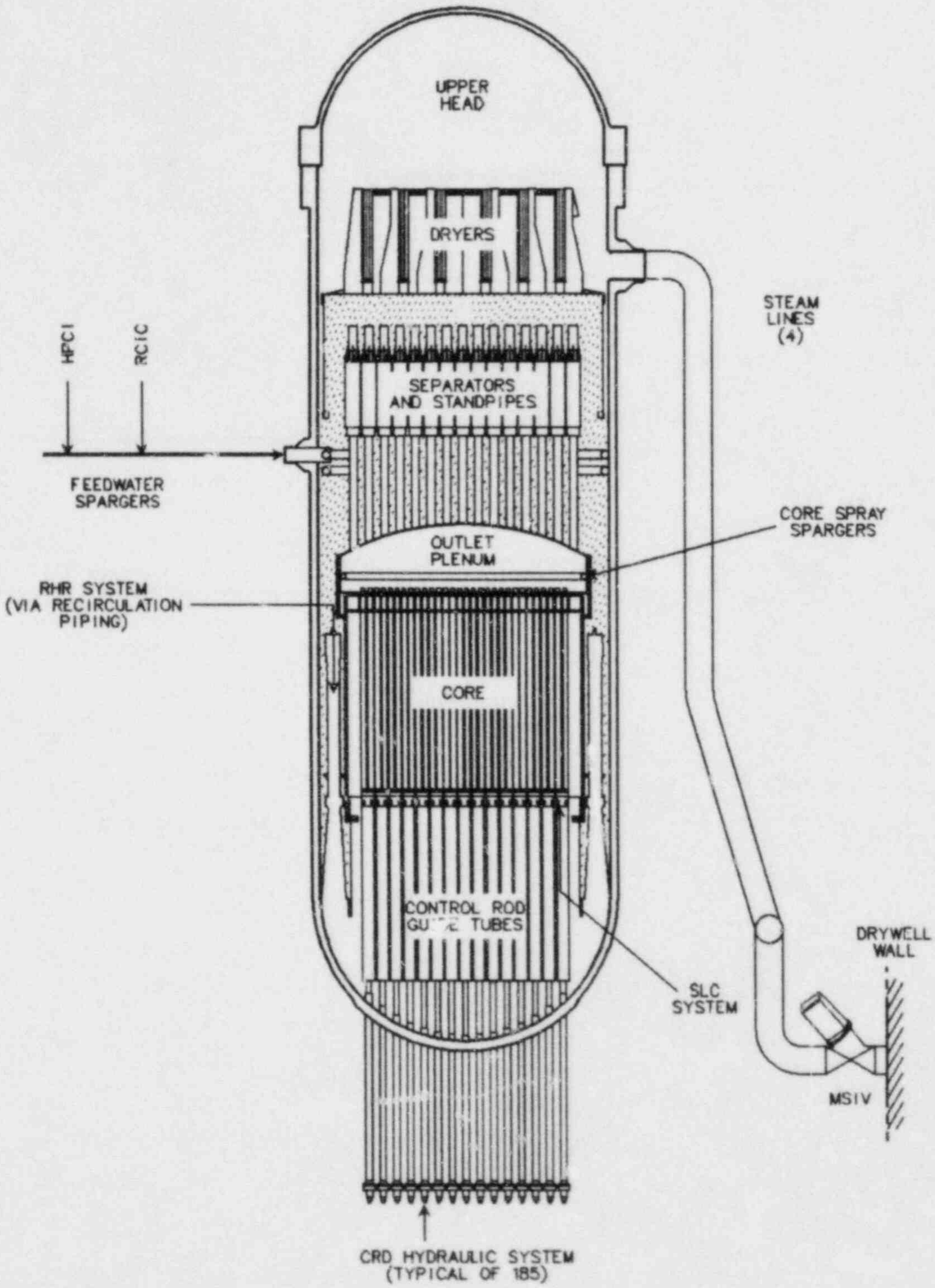

Fig. 2.1. Injection system connections to reactor vessel.

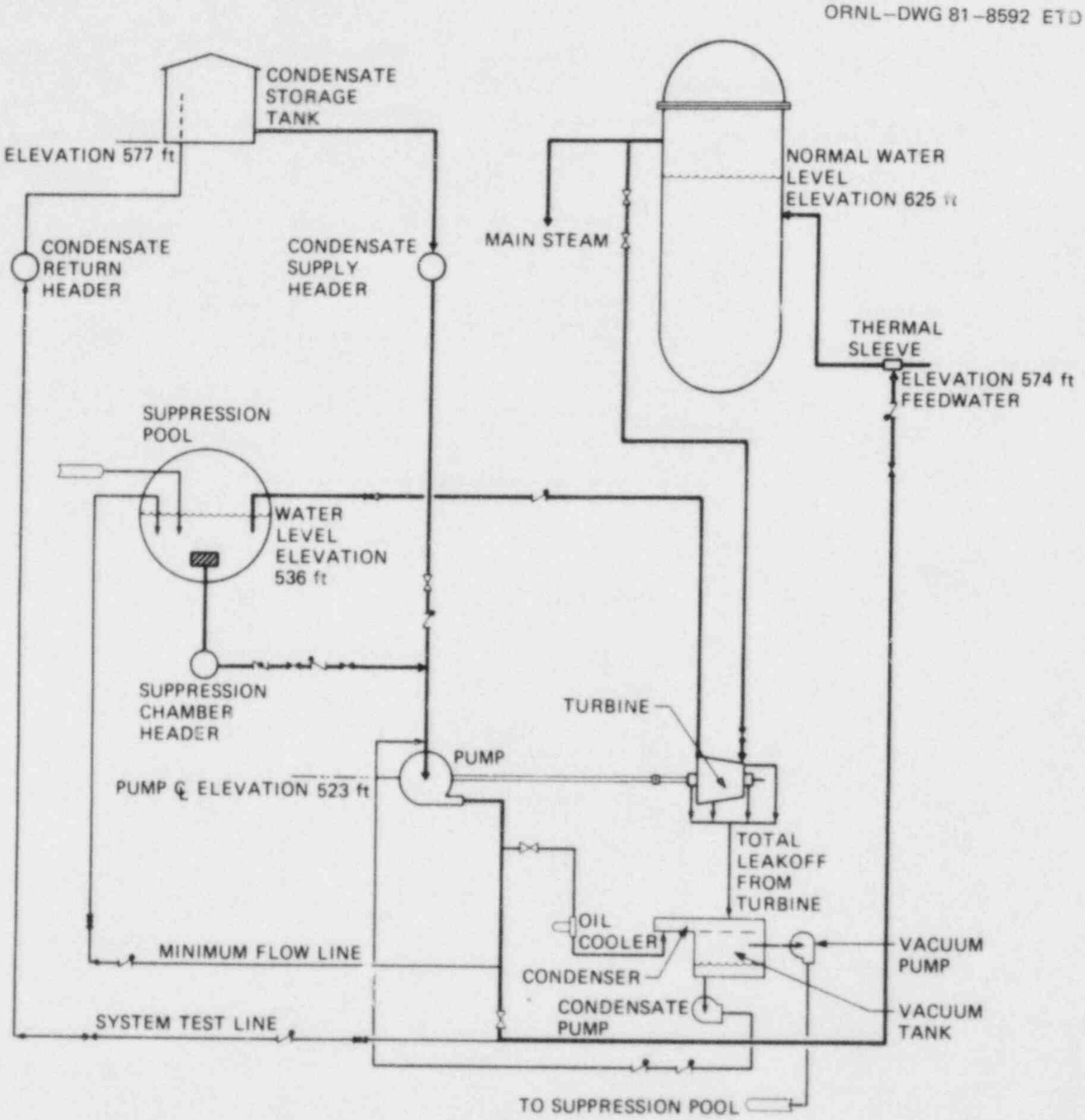

Fig. 2.2. Reactor core isolation cooling (RCIC) system.

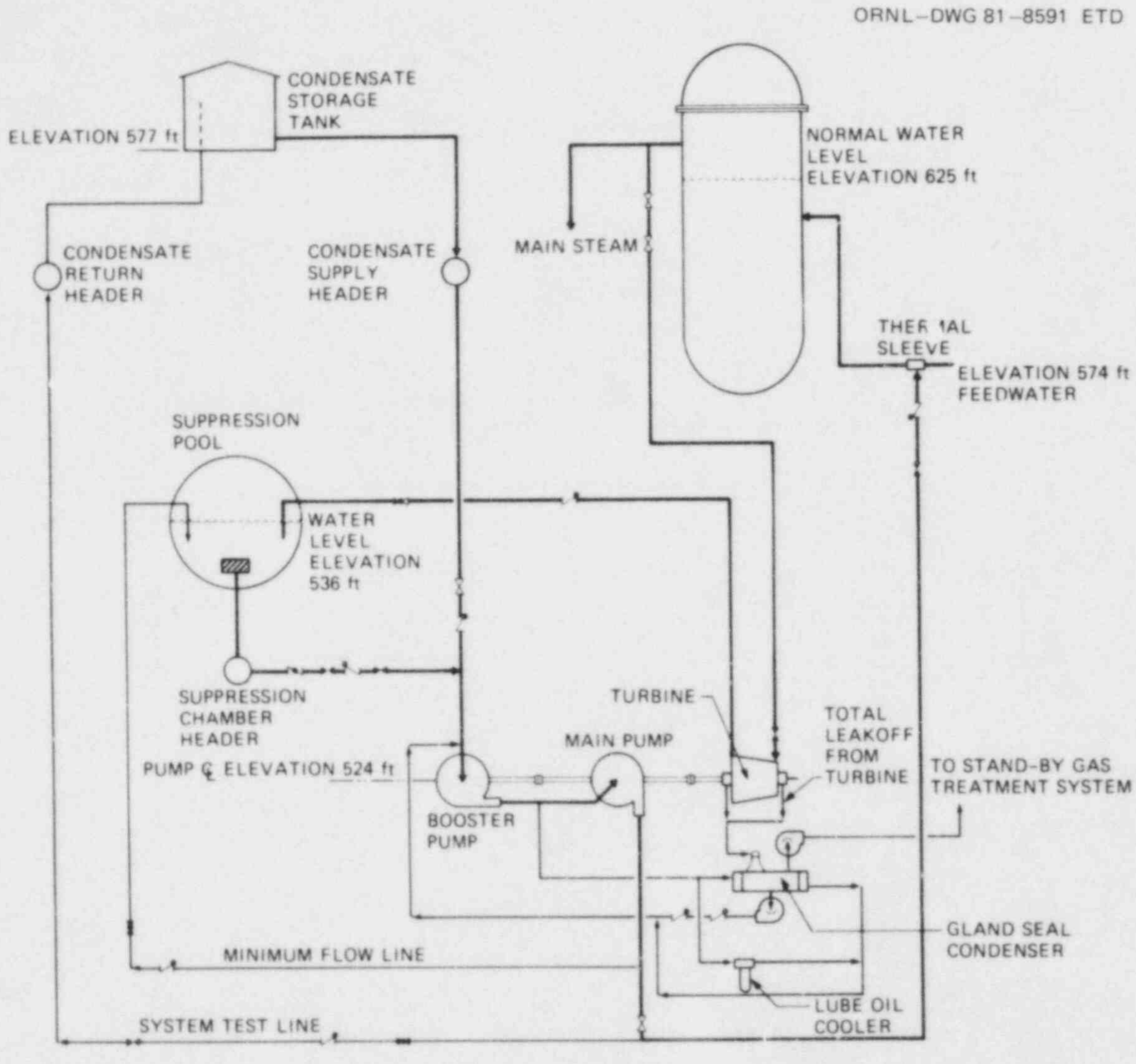

Fig. 2.3. High pressure coolant injection (HPCI) system.

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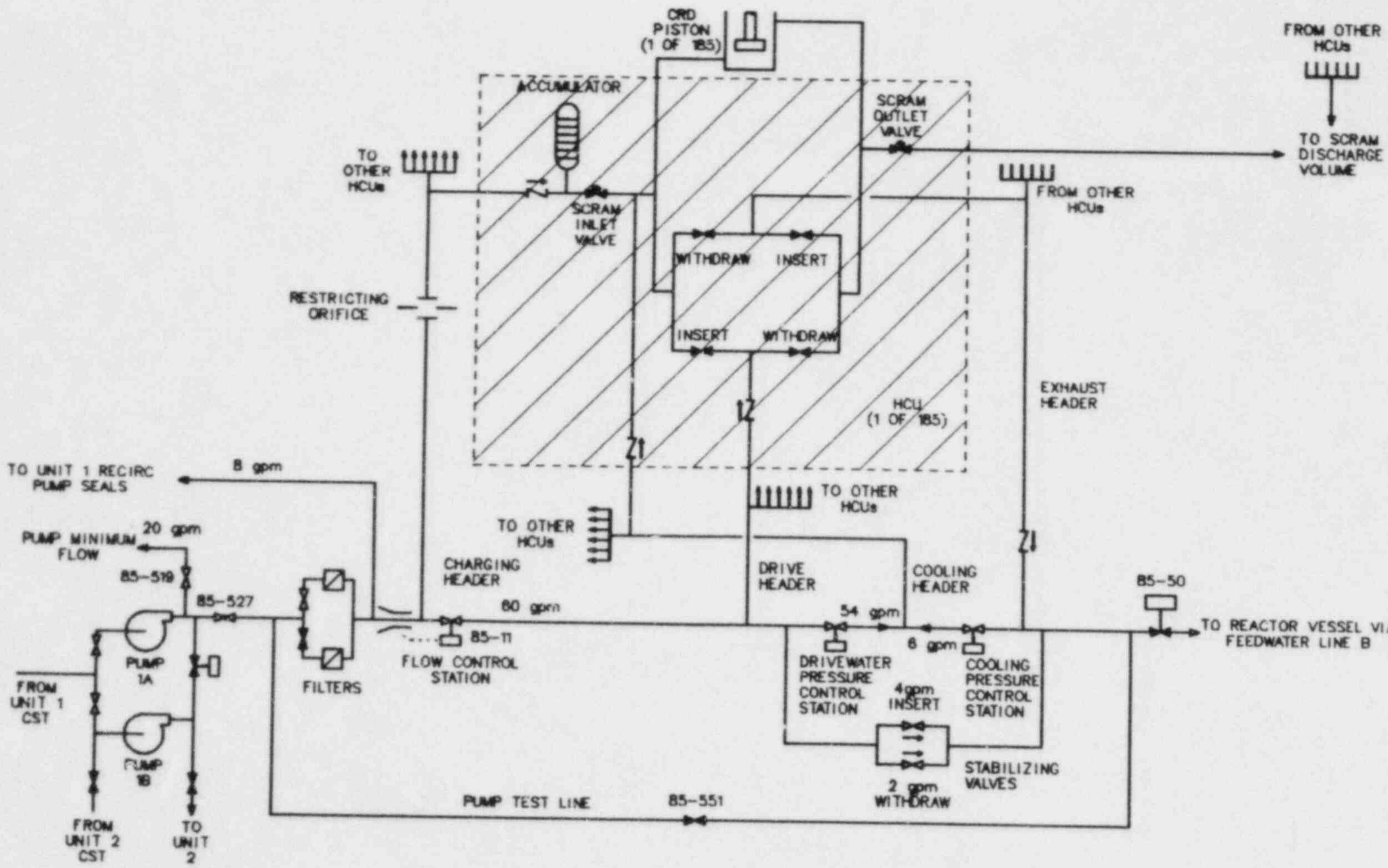

Fig. 2.4. Control rod drive hydraulic system (CRDHS).

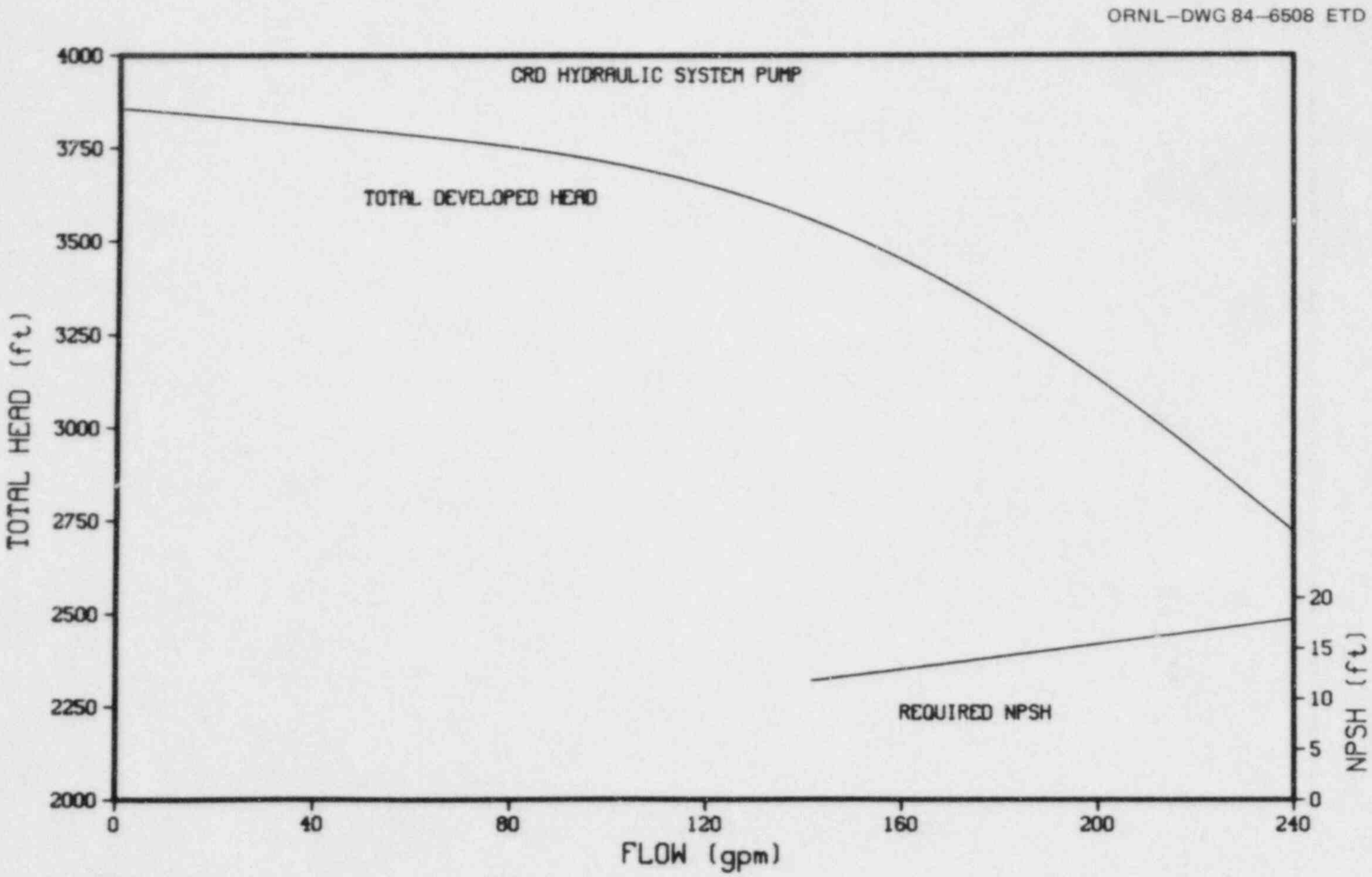

Fig. 2.5. Total developed head vs flow — CRDHS pump.

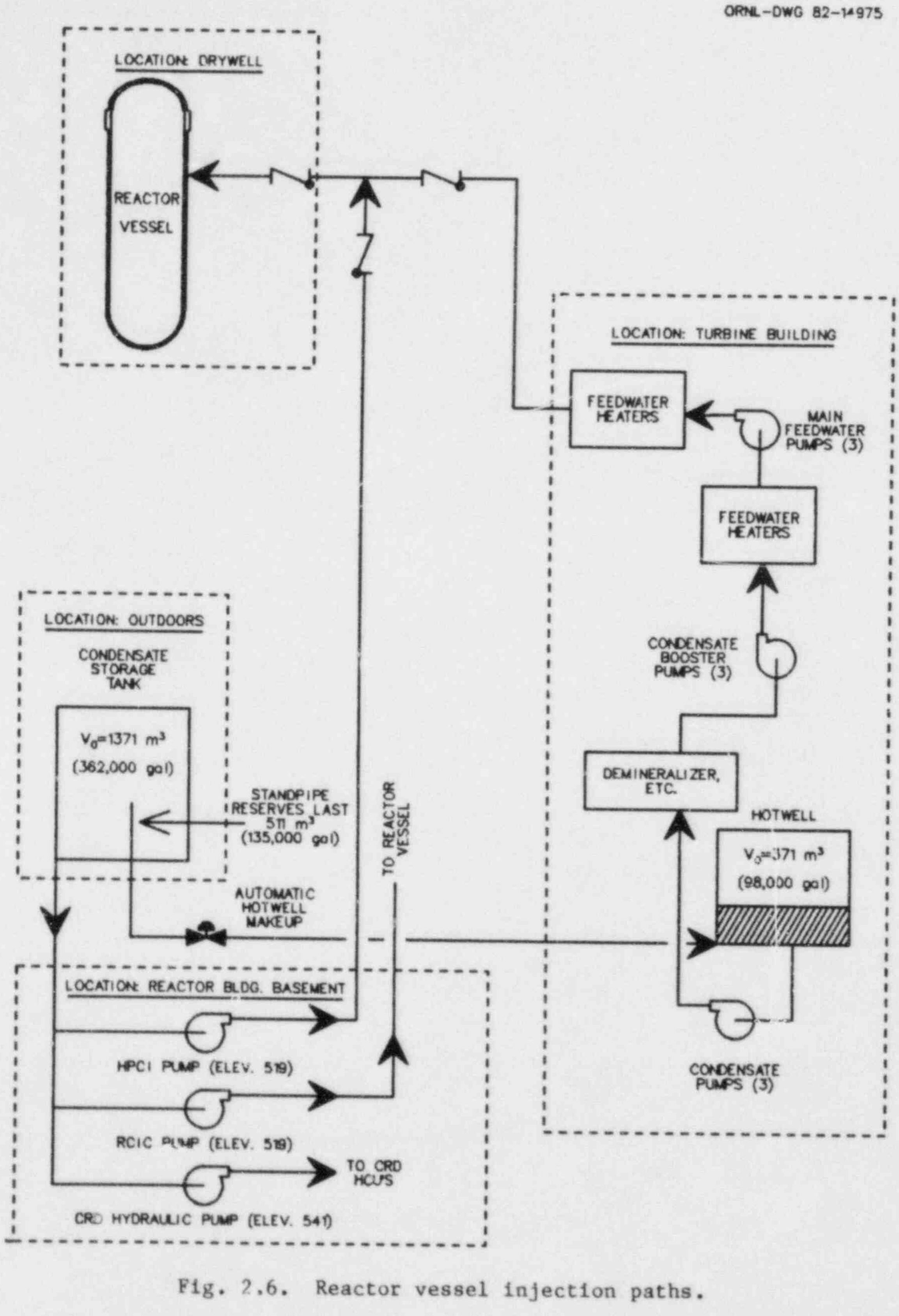

Fig. 2.6. Reactor vessel injection paths.

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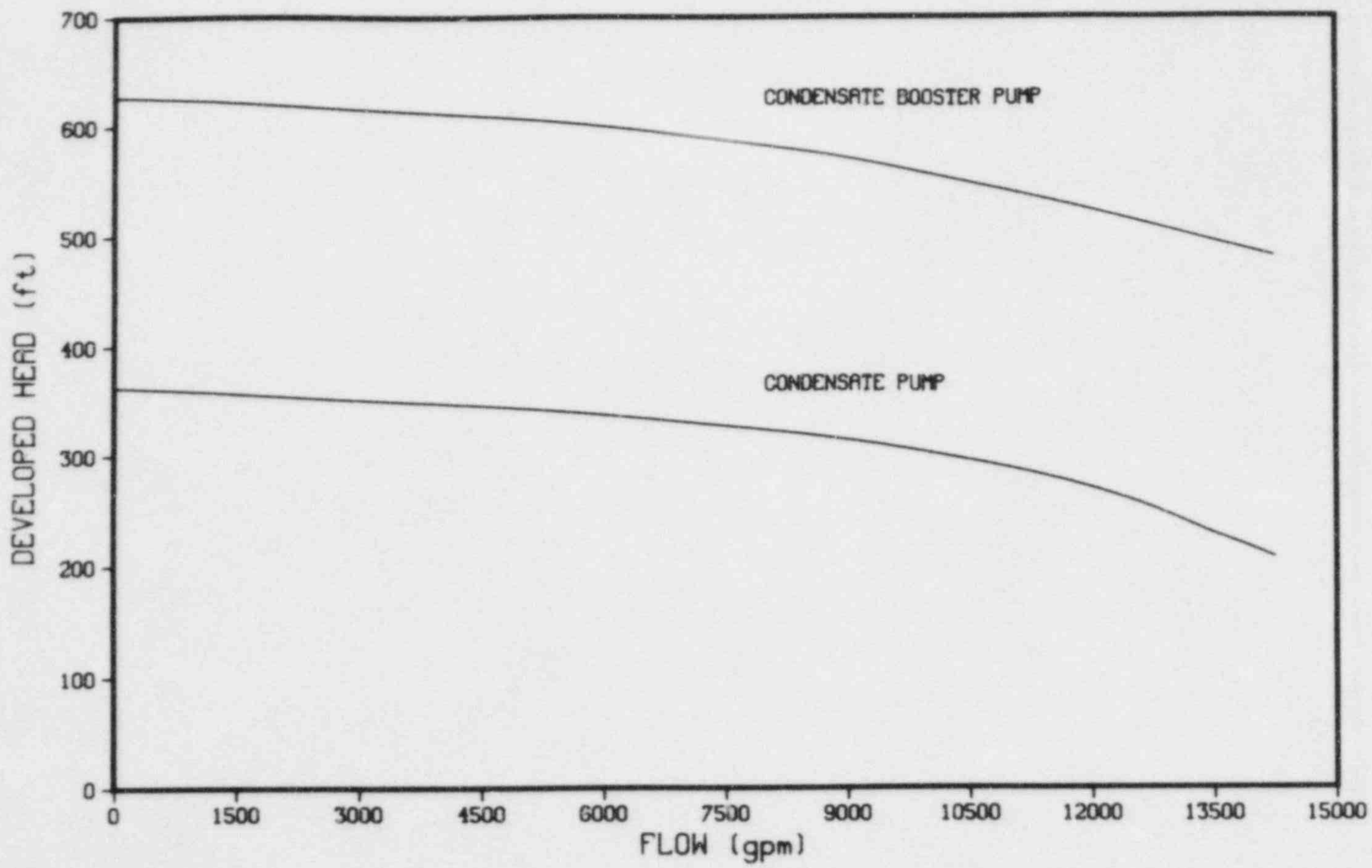

Fig. 2.7. Total developed head vs flow — condensate booster and condensate pumps.

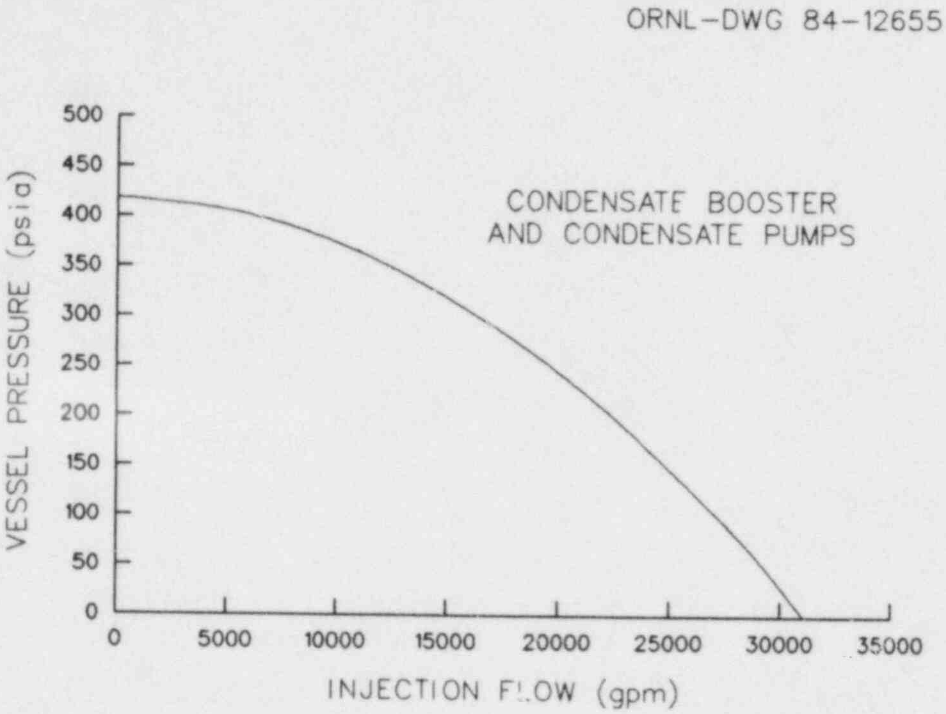

Fig. 2.8. Condensate system injected flow — three condensate booster and three condensate pumps running (main feedwater pumps idle).

ORNL-DWG 83-13719

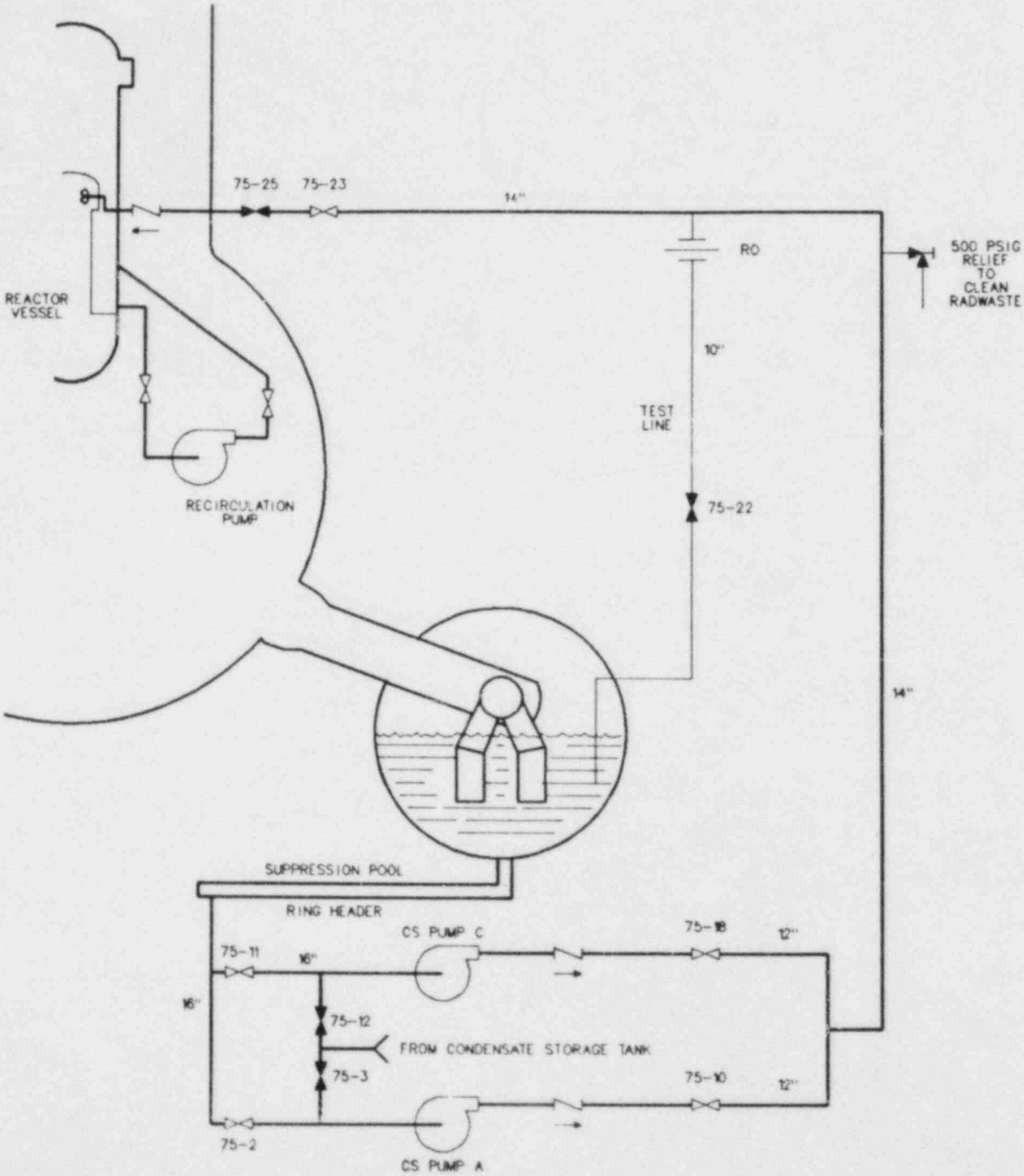

Fig. 2.9. One loop of the core spray system.

ORNL-DWG 82-19310

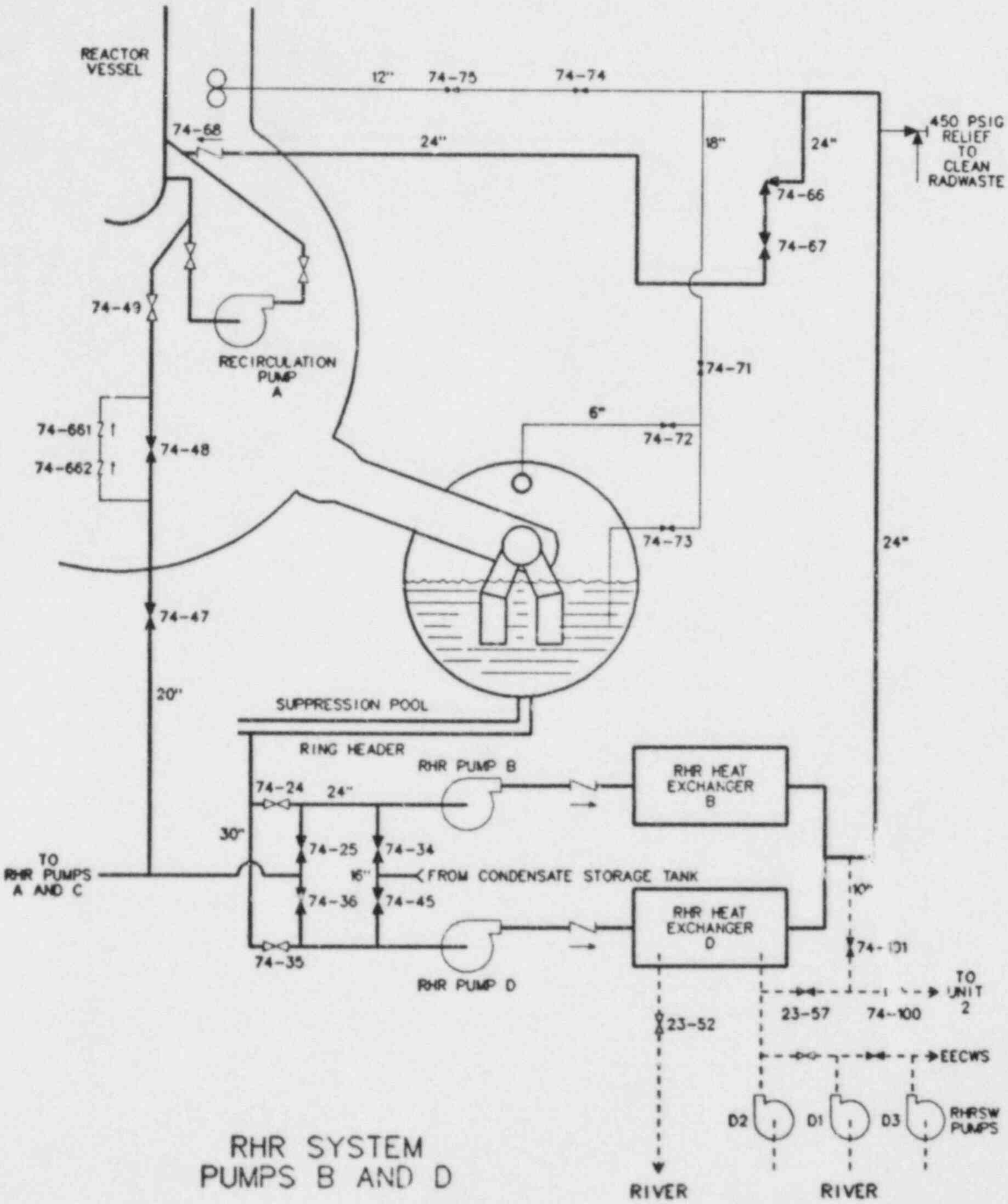

Fig. 2.10. One loop of the residual heat removal (RHR) system.

ORNL-DWG 84-6510 ETD

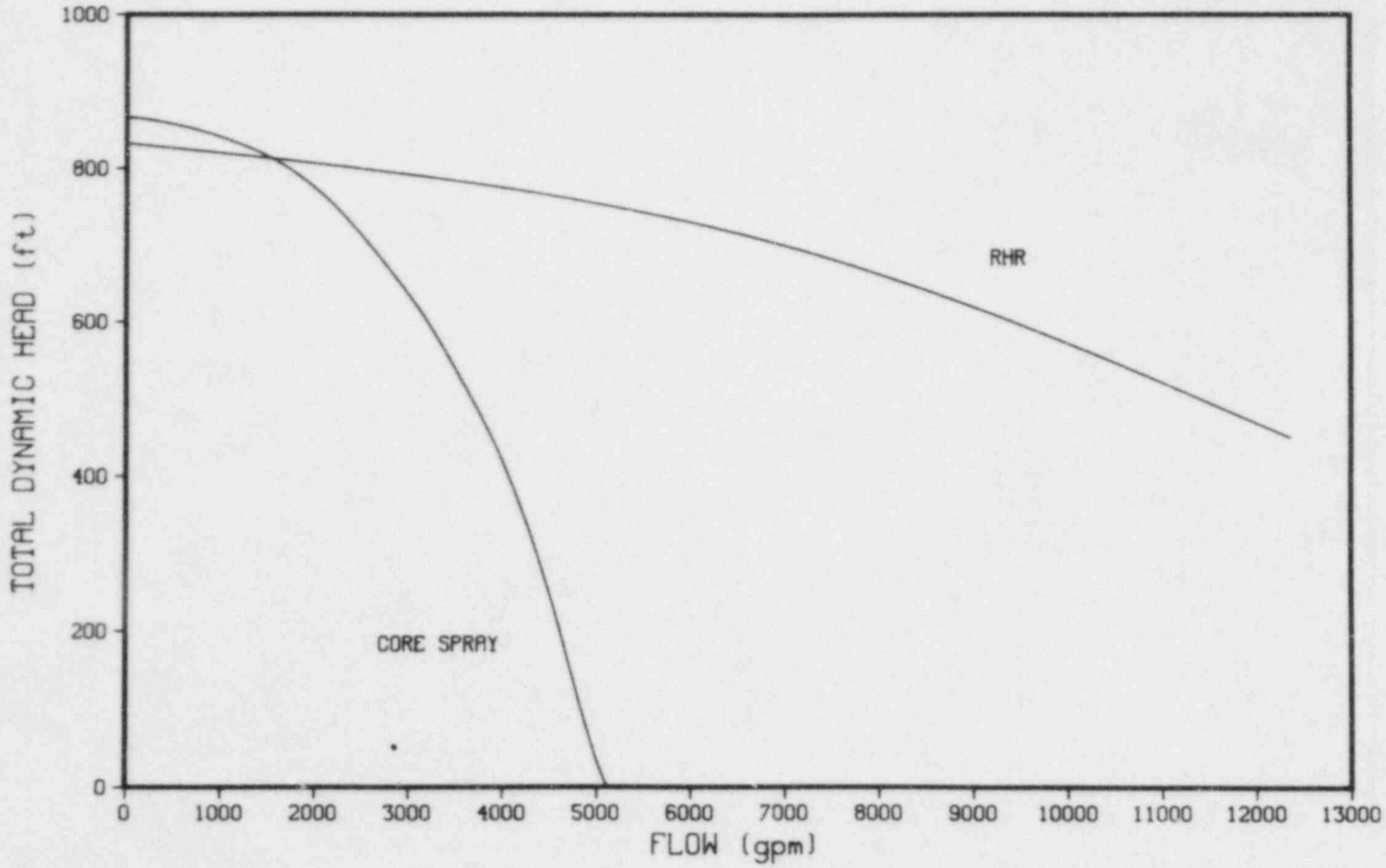

Fig. 2.11. Total developed head vs flow — RHR and core spray pumps.

3. PRIMARY COOLANT SYSTEM THERMOHYDRAULICS

This chapter describes the modeling of thermohydraulic processes within the reactor vessel and attached recirculation piping and main steam piping. The system variables calculated by this part of the model are among the most vital and basic to a BWR: core coverage, reactor vessel injection requirements, reactor vessel pressure, steam flow to the primary containment, and the transfer of heat from the surfaces of the reactor vessel and associated piping to the drywell atmosphere. The mathematical model is programmed to function at any reactor vessel pressure between atmospheric pressure and 1300 psia (well above the normal pressure of 1025 psia). The reactor vessel water inventory can range from nearly empty (water in the vessel lower plenum only) to nearly full. [For proper convergence the pressure calculation assumes that there is always a steam space of at least 500 ft^3 volume (about 2% of vessel free volume)].

The BWR-LTAS code is intended to be used to investigate that portion of accident sequences up to but not including permanent core uncovery and subsequent fuel damage. For this reason, no provision is made to calculate heatup of the fuel during periods of core uncovery. This has allowed considerable simplification of the programming, but has not prevented the use of BWR-LTAS for the applicable portions of all of the accidents investigated by the ORNL SASA team. For sequences involving no core uncovery, or even a brief core uncovery (e.g. $<$ 10 min) followed by recovery, the core does not heatup enough to reach damaging temperatures, and BWR-LTAS can be used to investigate the sequence. But, if there is a long term partial core uncovery, the core may heatup into the damage region (i.e. $>$ 2200°F) and the fuel temperature must therefore be calculated. In their investigation of the effect of small capacity, high pressure injection systems on TQUV accidents (Ref. 3.1), the ORNL SASA team used a special, modified version of the MARCH code to calculate the core heatup during prolonged partial core uncovery.

For modeling purposes in BWR-LTAS, the thermohydraulic processes within the reactor vessel are grouped into two regions: the steam-only region, which normally comprises approximately the top third of the reactor vessel; and the steam-water region, which includes water and steam/water regions and normally covers the reactor fuel. Given the injection flows and reactor vessel pressure, the steam/water region model calculates the reactor vessel water levels and the core steam production rate. The steam-only region calculation operates on the core steam production rate (and also on relief valve position information) to calculate reactor vessel pressure.

Certain simplifying assumptions are built into the reactor vessel thermohydraulic model. The justification for these assumptions is that BWR-LTAS is intended for use in the simulation of low power (e.g. decay heat) transients without any large liquid or steam line breaks: (1) The water in the reactor vessel downcomer and lower plenum regions contains no steam. In an actual reactor, it is known that there is carry-under of steam into the upper parts of the downcomer during full power operation, but with the reactor shut down and on decay heat, there should be very little carry-under. (2) Circulation of coolant within the reactor vessel is always in the normal direction; i.e., from downcomer to lower plenum, to core, to steam separators, with the steam separators allowing steam to pass into the vessel steam space while returning any liquid to the downcomers. This a reasonable assumption since the reactor vessel internals are designed to promote this natural circulation flow. (3) The steam separators, aided by the dryers, are assumed to be 100% effective in eliminating entrained water from the steam-only region. Moreover, flow from the steam space to the pressure suppression pool via the safety relief valves is similarly assumed to contain no entrained water.

3.1 Water/Steam Region

The water/steam region includes four subregions: water in the downcomer annulus, water in the lower plenum, water/steam in and above the core (inside the core shroud, extending from the core inlet to the steam separators), and the fuel within the core. Figure 3.1 shows each of these regions, and Fig. 3.2 provides a three dimensional view of the reactor vessel internals.

Mass and/or energy conservation relations are solved for each region. The energy conservation relations yield the enthalpy and water level for the liquid in the downcomer and lower plenum, the subcooled region length, and the boiling rate in the core. The total driving head for natural circulation and the corresponding natural circulation flow can then be calculated. The rate of recirculation of coolant from the steam separators back to the downcomer annulus is dependent upon the mixture level in the shroud as explained in Section 3.1.3. In steady-state, the rate of recirculation is equal to the core inlet flow less the boiling rate.

3.1.1 Core decay heat production

The rate of heat generation in the core, based on the 1979 ANS standard (Ref. 3.1), includes the heat released not only by decaying fission products but also by decay of the actinides and other activation products. Table 3.1 lists values of total fractional decay heat as a function of time after scram. The pre-scram period of full power operation is assumed to be long in comparison to the half-lives for decay of the significant fission products.

The nuclear heat generation of the core is added to the fuel and then transferred from the surface of the fuel rods to the coolant. To simulate the delay between the addition of heat to the fuel and the transfer of heat from the surface of the fuel rods, the following differential equation is solved:

$$(d/dt)\ T_f = (P_d - P_t)\ (Q_{fp}/MC_f)$$

where

T_f = whole core, volume averaged fuel temperature (°F),
P_d = decay heat power (fraction of full power),
P_t = heat transfer (thermal power) from the surface of the fuel rods (fraction of full power),
Q_{fp} = full power heat generation rate (Btu/s),
MC_f = mass times specific heat of the fuel and clad (Btu/°F).

The heat capacity of the clad is lumped with that of the fuel; this is adequate because the zirconium-water reaction is not modeled by BWR-LTAS and the clad temperature does not need to be known.

The thermal power fraction transferred to the coolant depends on the fuel temperature, T_f, and on the saturation temperature of the core coolant (T_s) as follows:

$$P_t = (T_f - T_s)/(T_f - T_s)_{fp}$$

where $(T_f - T_s)_{fp}$ is the difference between volume averaged fuel temperature and coolant saturation temperature during full power operation.

The relationships above are utilized primarily as means of simulating the delay between heat generation and heat transfer to the coolant. This means of calculating the average fuel temperature is correct in an approximate sense as long as the reactor vessel two-phase water level is high enough to keep the core fully immersed. The addition of the core's sensible heat content to the coolant in the event of reactor vessel depressurization is properly accounted for.

The axial power shape must be considered in order to properly allocate the core heat generation to the two regions of the core average hydraulic channel, the subcooled region and the boiling region (Fig. 3.1). Table 3.2 specifies values of the average core axial power generation profile representative of the equilibrium core to be utilized in all future ORNL SASA studies of accident sequences at the Browns Ferry Unit 1 reactor. The rate of heat transfer to each region is determined as a function of the region length and the average of the axial power profile over that region:

$$Q_{sc} = F_{sc}\, Q_{fp}\, P_t\, (L_{sc}/L_t)$$

$$Q_b = F_b\, Q_{fp}\, P_t\, (L_b/L_t)$$

where

Q_{sc} = rate of heat transfer to coolant in the subcooled region (Btu/s),
Q_b = rate of heat addition to boiling region coolant (Btu/s),
F_{sc} = normalized axial power, averaged between the core entrance (bottom) and the end of the subcooled region,

F_b = normalized axial power, averaged between the end of the subcooled region (beginning of the boiling region) and the end of the boiling region,
Q_{fp}, P_t = defined previously,
L_{sc}, L_b = subcooled and boiling region lengths (ft),
L_t = total active fuel length (ft).

3.1.2 Downcomer and lower plenum

The downcomer region extends from the surface of the water, wherever it may be in the downcomer annulus, to the bottom of the jet pump diffusers (see Figs. 3.1 and 3.2). The liquid portion of the lower plenum and downcomer regions is assumed not to have any entrained steam. The volume of water in the downcomer region is variable, whereas the lower plenum region contains a fixed volume (except in the very rare instances in which the downcomer region is entirely emptied). The downcomer region mass balance is:

$$d/dt\,(M_{dc}) = W_{rss} + W_{inj} + W_{injas} + W_{expc} + W_{ecc} + W_{cond} + W_{rpn} - W_{dclp} - W_{fldc}$$

where

W_{rss} = flow of water returning from the steam separators back to the downcomer (lb/s),
W_{inj} = total high pressure injection plus flow from the main feedwater system (i.e. pumped by condensate booster pumps) (lb/s)
W_{injas} = flow of steam condensed from the steam-only region by the high pressure injection, which enters via the main feedwater sparger nozzles (lb/s),
W_{expc} = flow of moisture condensing out of the steam-only region in the event of expansion (i.e. during a period of decreasing downcomer water level) (lb/s),
W_{ecc} = total low pressure ECCS flow, includes both core spray and RHR system LPCI mode injection (lb/s),
W_{dclp} = flow from the downcomer region to the lower plenum region (lb/s),
W_{rpn} = net flow from the recirculation piping to the downcomer region (lb/s),
W_{fldc} = rate of flashing of the water in the downcomer (lb/s),
W_{cond} = rate of condensation of steam onto the surface of the downcomer water (lb/s).

The flow W_{injas} is non-zero only when the downcomer water level is below the level of the feedwater sparger nozzles (below 500 inches for Browns Ferry). When the downcomer water level is below the sparger nozzles, the injected flow, W_{inj}, is heated as it falls through the steam atmosphere by the very rapid condensation of steam onto the surface of the falling droplets or jets. The final enthalpy of the injected flow is

$$h_{injf} = h_{inji} + (h_f - h_{inji})\, F_a$$

where

h_{inji} = enthalpy of injected flow as it enters the reactor vessel (Btu/lb),
h_{injf} = enthalpy of injected flow as it hits the surface of the downcomer region water (Btu/lb),
h_f = enthalpy of saturated fluid (Btu/lb),
F_a = fractional approach to saturation, limited between 0 and 1,
= (Lspa - Ldc)/Lsat,
L_{spa} = elevation of the feedwater sparger nozzles (ft),
L_{dc} = elevation of the surface of the downcomer water (i.e. water level) (ft),
L_{sat} = distance of fall through steam required for injected spray to become saturated (user input) (ft).

The flow (lb/s) induced in the recirculation piping W_{rp}, is proportional to the flow from the downcomer to the core (via the lower plenum), W_{ci}, times an input constant (FFREC, Table A.2); the residence time of coolant in the recirculation piping is:

$$\tau_{rp} = V_{rp}\, \rho_{rp}/W_{rp},$$

Heat transfer from the recirculation piping is assumed to be negligible, so, on the average, coolant in the recirculation piping has the same properties as the downcomer coolant delayed by a first order lag equal to τ_{rp}. For example, the average density ρ_{rp}, is determined by the solution of

$$d(\rho_{rp})/dt = (\rho_{dc} - \rho_{rp})/\tau_{rp},$$

where

ρ_{dc} = density of coolant in the downcomer (lb/ft^3).

The net mass flow (lb/s) of coolant from the downcomer is then

$$W_{rpm} = -\, V_{rp}\, d(\rho_{rp})/dt = V_{rp}\, (\rho_{rp} - \rho_{dc})/\tau_{rp}$$

where

V_{rp} = volume of piping associated with the recirculation pumps.

The flow from the downcomer region to the lower plenum region is calculated on the premise that the lower plenum must remain water filled. Thus the flow into the lower plenum from the downcomer must replace the mass flowing out of the lower plenum with an equal volume of water:

$$W_{dclp} = (W_{ci} + W_{fllp}) (\rho_{dc}/\rho_{lp})$$

where

W_{ci} = core inlet flow (flow from lower plenum into bottom of core) (lb/s),
W_{fllp} = rate of flashing of lower plenum water (e.g. during vessel depressurization) (lb/s),
ρ_{dc} = density of downcomer region water (lb/ft^3),
ρ_{lp} = density of lower plenum water (lb/ft^3).

If the enthalpy of the downcomer region water, h_{dc}, is near saturation and the reactor vessel pressure begins to decrease, part of the water will begin to flash to steam at the rate W_{fldc}. Since supersaturated water is very unstable, the flashing will continue until h_{dc} is reduced to below h_f, the saturated fluid enthalpy. Therefore, if $h_{dc} > h_f$:

$$W_{fldc} = M_{dc} (h_{dc} - h_f) F_{flash}$$

where

M_{dc} = mass of water in the downcomer region,
F_{flash} = fraction of water flashing per second per Btu/lb of supersaturation. (This is a user input constant; a small value of 0.001 lb/Btu s is typically used because of the substantial mass (~150,000 lb) normally in the downcomer.)

An expression of the same form is used to calculate the rate of flashing from the lower plenum, W_{fllp}.

The lower plenum mass balance is:

$$d/dt(M_{lp}) = W_{dclp} - W_{ci} - W_{fllp} ,$$

where each of the flows has been defined previously.

The energy balance for the downcomer is:

$$(d/dt)(M_{dc} h_{dc}) = h_f W_{rss} + h_{inj} W_{inj} + h_f W_{injas}$$

$$+ h_f W_{expc} + h_{ecc} W_{ecc} + h_{rp} W_{rpn} - h_{dc} W_{dclp} - h_g W_{fldc}$$

where

h_{dc} = downcomer water enthalpy (approximately equal to internal energy for water) (Btu/lb),
h_{ecc} = enthalpy of low pressure ECCS injection (systems that inject from PSP) (Btu/lb),
h_{inj} = enthalpy of high pressure system injection (HPCI, RCIC, CBP, CRDHS; systems that inject from CST) (Btu/lb),
h_{rp} = enthalpy of the induced circulation from the recirculation piping as it reenters the downcomer region (Btu/lb),
h_g = enthalpy of dry saturated steam (Btu/lb).

The enthalpy of water returning from the recirculation piping (Fig. 3.3), h_{rp}, is calculated by solving the equation of a first order delay that represents the residence time of fluid in the piping:

$$(d/dt)\ h_{rp} = (1/\tau_{rp})\ (h_{dc} - h_{rp}) \ .$$

The energy balance for the lower plenum is:

$$(d/dt)\ (M_{lp}\ h_{lp}) = h_{dc}\ W_{dclp} - h_{lp}\ W_{ci} - h_g\ W_{fllp} \ ,$$

where all terms have been defined previously. The lower plenum and downcomer enthalpies are found as follows:

$$h_{dc} = (Mh)_{dc}/M_{dc}$$
$$h_{lp} = (Mh)_{lp}/M_{lp}.$$

3.1.3 <u>In-shroud region</u>

This region extends from the bottom of the active fuel at the core inlet to the top of the steam separators. A mass balance for the whole region is solved:

$$(d/dt)\ M_{tot} = W_{ci} - W_{rss} - W_{tost} + W_{fllp} \ ,$$

where terms not previously defined include:

W_{tost} = total flow of steam to the reactor vessel steam space (includes W_{fllp}) (lb/s),

M_{tot} = total water/steam mass between core inlet and steam separator outlet (lb/s).

The flow of saturated water, W_{rss}, returned by the steam separators to the downcomer region depends on the location of the interface between the steam/water region above the core and the steam-only region which occupies the upper part of the reactor vessel. If the interface occurs below the elevation of the bottom of the steam separators, then phase separation is occurring in the standpipes, outlet plenum, or in the core itself, and there is no flow of saturated water back to the downcomer. The lower steaming rates associated with decay heat power make this phase separation possible. If the interface between the steam/water and steam-only regions occurs at or above a certain point within the steam separators, assumed here to be the vertical midpoint of the steam separators, all the saturated water flowing into the steam separators is returned to the downcomer. This behavior is simulated by the following relationship:

$$W_{rss} = (W_{ci} - W_{bo})\ (L_{int} - L_{bot})/(L_{mp} - L_{bot})$$

where

W_{ci} = flow into the core (lb/s),
W_{bo} = core boiling rate (lb/s),
L_{int} = elevation of the interface between the water/steam and steam-only regions (ft),
L_{bot} = elevation of the bottom of the steam separators (ft),
L_{mp} = reference elevation (halfway up the length of the steam separators) (ft).

The value of the ratio $(L_{int} - L_{bot})/(L_{rp} - L_{bot})$ is constrained between 0.0 and 1.0.

The key to determining the core boiling rate and the distribution of the water/steam region mass inventory, M_{tot}, between the subcooled and saturated subregions is the core subcooled region. Solution of the following equation yields the length of the subcooled region of an average channel, which is used by the model to represent the aggregate behavior of all core channels:

$$(d/dt)\ L_{sc} = -\ [L_{sc}\ Q_{fsc}\ P_{cor} - W_{ci}\ (h_f - h_{ci})]/[\rho_{ci}\ A_{cor}\ (h_f - h_{ci})]$$

where

L_{sc} = length of average channel subcooled region (ft),
Q_{fsc} = heat flux (Btu/s ft^2) averaged over the subcooled region (see also Section 3.1.1),
P_{cor} = heat transfer perimeter (heat transfer area divided by length) (ft^2),
h_{ci} = core inlet enthalpy (also equals h_{lp} as presented in 3.1.2) (Btu/lb),
ρ_{ci} = density of water entering the core (lb/ft^3),
A_{cor} = flow area of core (ft^2).

This equation was derived by combining the mass and energy conservation relations for the subcooled region.

The boiling region length, L_b, is equal to the total core active fuel length minus the subcooled length. The core boiling rate is:

$$W_{bo} = (Q_{fb}\ P_{cor}\ L_b)/(h_g - h_f)$$

where Q_{fb} is the heat flux averaged over the boiling length of the core. The density of the water/steam mixture in the core, core outlet plenum, and standpipes is calculated by means of a drift-flux formulation in which the void fraction is calculated as a function of total flow and steam flow:

$$\alpha = j_g/[C_o\ (j_f + j_g) + V_{gj}]$$

where

α = void fraction,
j_g = steam mass velocity (volumetric flow per unit area),
j_f = water mass velocity (volumetric flow per unit area),
C_o = distribution coefficient = 1.1,
V_{gj} = drift velocity = 1.15 ft/s.

The coefficient values for C_o and V_{gj} were taken from Lahey and Kamath, (Ref. 3.2) and were selected to give void fractions in agreement with experimental data for water/steam at low (decay heat) steaming rates. The density of the water/steam mixture is:

$$\rho = \alpha\ \rho_g + (1 - \alpha)\ \rho_f$$

where

ρ_g = density of saturated dry steam (lb/ft^3),
ρ_f = density of saturated water (lb/ft^3).

The density for each of the in-shroud two-phase regions (core boiling region, core outlet plenum, and standpipes) is calculated. In the core boiling region, the steam flow increases and density decreases with distance up the channel, so the density must be calculated at several points and an average utilized to represent the whole core boiling region. The total two phase mixture height inside the shroud is then calculated from the known quantities: the density in each subregion, the subcooled region length, and the total in-shroud mass.

At decay heat steaming rates, the densities of the water/steam mixture in the core boiling region, outlet plenum, and standpipes can be relatively high, consistent with a significant inventory of saturated water. During periods of changing reactor vessel pressure, this inventory of saturated water would have a transient influence on the net steaming rate that would be dependent on the mass of saturated water present:

$$\Delta W_{sr} = M_{poo}\,(dh_f/dt)/(h_g - h_f)$$

where

ΔW_{sr} = change to boiling rate,
M_{poo} = total in-shroud inventory of saturated water,
h_f, h_g = saturation properties.

3.1.4 In-vessel natural circulation

The circulation of water from the downcomer and lower plenum into the core occurs because the density of the two phase mixture inside the shroud is lower than the density of the single phase water in the downcomer region. The amount of flow is determined by a balance between the density-difference driving head and the unrecoverable pressure drops incurred by the coolant flowing in the natural circulation path. The driving head is:

$$\Delta P_g = (L_{dc}\,\rho_{dc} - L_{sc}\,\rho_{sc} - L_b\,\rho_b - L_{op}\,\rho_{op} - L_{sp}\,\rho_{sp})/144$$

where

ΔP_g = density difference driving head (psi),
L_{dc} = height of water in downcomer, referenced to the bottom of active fuel,
L_{sc} = core subcooled length,
L_b = core boiling length,
L_{op} = length of core outlet plenum,
L_{sp} = length of standpipes.

In the steady state, the driving head will be exactly counter balanced by the unrecoverable losses associated with the circulation flow:

$$\Delta P_{ur} = K_\ell\,(\rho_r/\rho_b)\,W_{ci}^2$$

where

ΔP_{ur} = unrecoverable pressure drop throughout the circulation path,
K_ℓ = loss coefficient (determined from reference conditions),
ρ_b = average boiling region water/steam density,
ρ_r = average boiling region water/steam density for reference conditions.

The "reference conditions" above must be taken from a steady-state, natural circulation (recirculation pumps off) operating condition for which reactor power, reactor vessel pressure, water level, and natural circulation flow are known. The density ratio (ρ_r/ρ_b) is included in this expression because most of the unrecoverable pressure losses will occur in the water/steam regions, especially the core; and the two-phase losses are, very roughly, inversely proportional to the density. The flow is found by equating ΔP_{ur} and ΔP_g, and solving for W_{ci}.

3.2 Steam-Only Region (Reactor Vessel Pressure)

The reactor vessel steam-only space extends from the top of the downcomer water region to the top of the reactor vessel and includes the volume of the main steam lines out to the Main Steam Isolation valves (MSIVs). (In all SASA studies to date, the MSIVs have been shut very early in the accident sequence.) The mass inventory of the steam space is assumed to consist only of steam, with no entrained water droplets, and the flow from the steam space via the safety relief valves (SRVs) or the RCIC and HPCI turbines consists of dry steam.

To solve for the pressure, it is necessary first to compute the specific volume and enthalpy of the steam. These two properties uniquely determine the pressure via a steam-table look-up routine.

The mass balance for the steam space is

$$d/dt\ (M_{st}) = W_{tost} + W_{fldc} - W_{expc} - W_{cond} - W_{injas} - W_{srv} - W_{ste}$$

where

M_{st} = total steam mass (lb),
W_{tost} = net steam flow from in-shroud region (lb/s),
W_{fldc} = rate of flashing of downcomer water (lb/s),
W_{expc} = condensation due to expansion of steam space (lb/s),
W_{cond} = rate of condensation from steam space onto surface of downcomer water (lb/s),
W_{injas} = rate of condensation from steam space onto injected spray (lb/s),
W_{srv} = total SRV flow (lb/s),
W_{ste} = total flow to HPCI, RCIC steam turbines.

The volume of the steam space is

$$V_{st} = V_{free} - V_{water} - V_s$$

where

V_{free} = total vessel + main steam lines free volume (ft^3),
V_{water} = free volume occupied by water in downcomer and lower plenum regions (ft^3),
V_s = volume within core shroud (ft^3).

The specific volume of the steam space steam is $v_{sv} = V_{st}/M_{st}$.

The energy balance for the steam space is

$$d/dt\,(u_s M_{st}) = h_g\,W_{tost} + h_g\,W_{fldc} - h_f\,W_{expc}$$

$$- h_s\,(W_{cond} + W_{injas} + W_{srv} + W_{ste}) - P\,(dVst/dt)\,(144/778)$$

where

u_s = average specific internal energy of steam throughout the steam space (Btu/lb),

h_s = average specific enthalpy of steam throughout steam space (Btu/lb),

h_g, h_f = saturation properties,

P = steam space pressure (psia).

The enthalpy is:

$$h_s = (u_s M_{st})/M_{st} + Pv_{sv}\,(144/778)$$

and total pressure is uniquely determined:

$$P = f(v_{sv}, h_s)\ .$$

REFERENCES FOR CHAPTER 3

3.1 R. M. Harrington and L. J. Ott, *The Effect of Small-Capacity, High-Pressure Injection Systems on TQUV Sequences at Browns Ferry Unit One*, NUREG/CR-3179, ORNL/TM-8635 (September 1983).

3.2 P. S. Kamath and R. T. Lahey, "The Analysis of Boiling Water Reactor Long-Term Cooling," *Nuclear Technology*, Vol. 49, June, 1980.

Table 3.1. Decay heat after shutdown
(% of pre-scram operating power)

Time after shutdown (h)	Decay heat (%)
$8.33(10)^{-3}$ (30s)	4.36
1	1.38
2	1.13
3	1.01
5	0.88
8	0.78
24	0.59
36	0.53

Table 3.2. Axial power shape
(average channel)

Distance from core inlet fraction of active fuel length	Relative power
0.0000	0.61
0.0833	1.04
0.1666	1.16
0.2500	1.19
0.3333	1.16
0.4166	1.11
0.5000	1.09
0.5833	1.07
0.6666	1.05
0.7500	1.03
0.8333	0.92
0.9166	0.72
1.0000	0.33

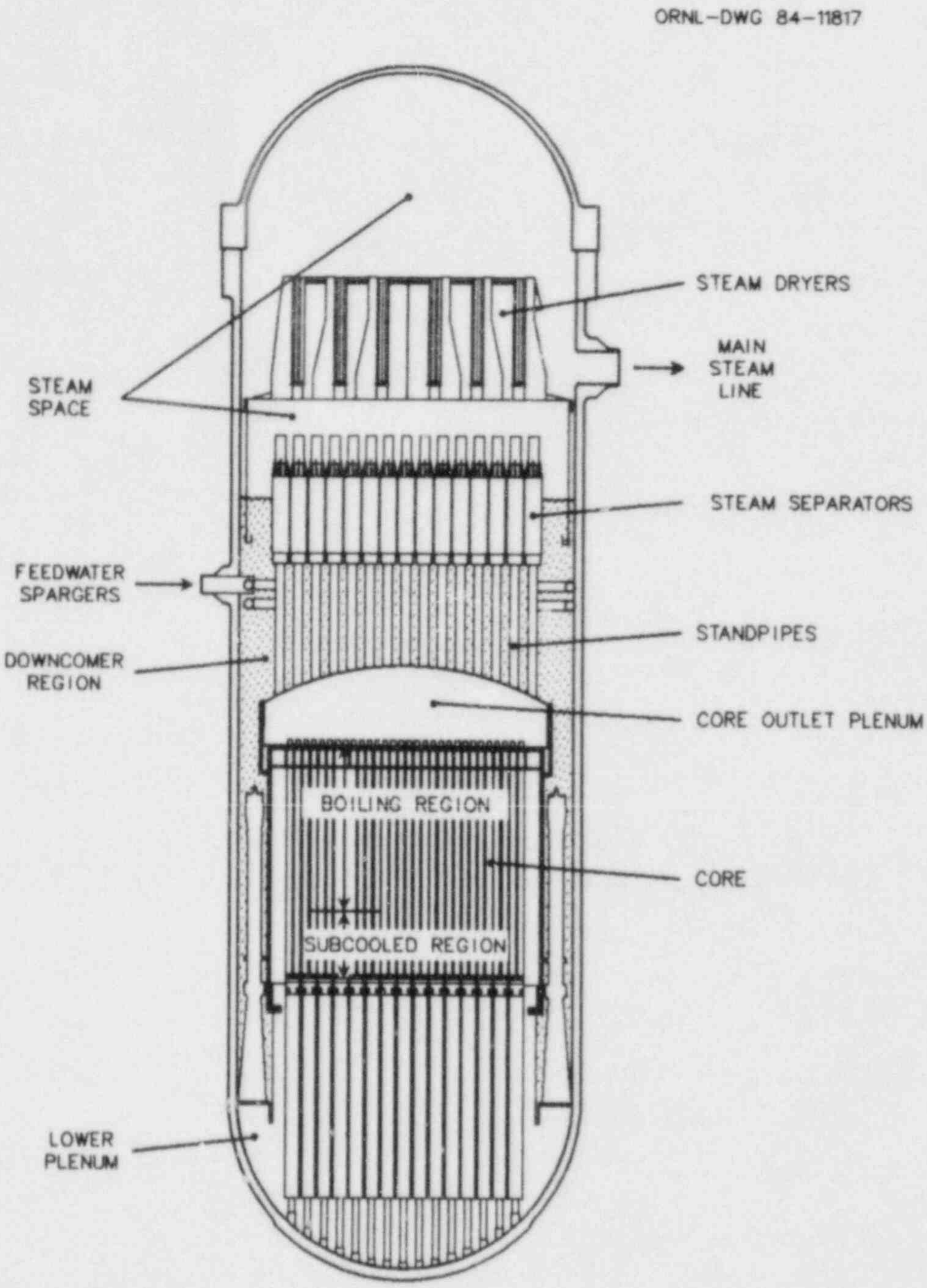

Fig. 3.1. Regions within the reactor vessel.

ORNL-DWG 80-5840A ETD

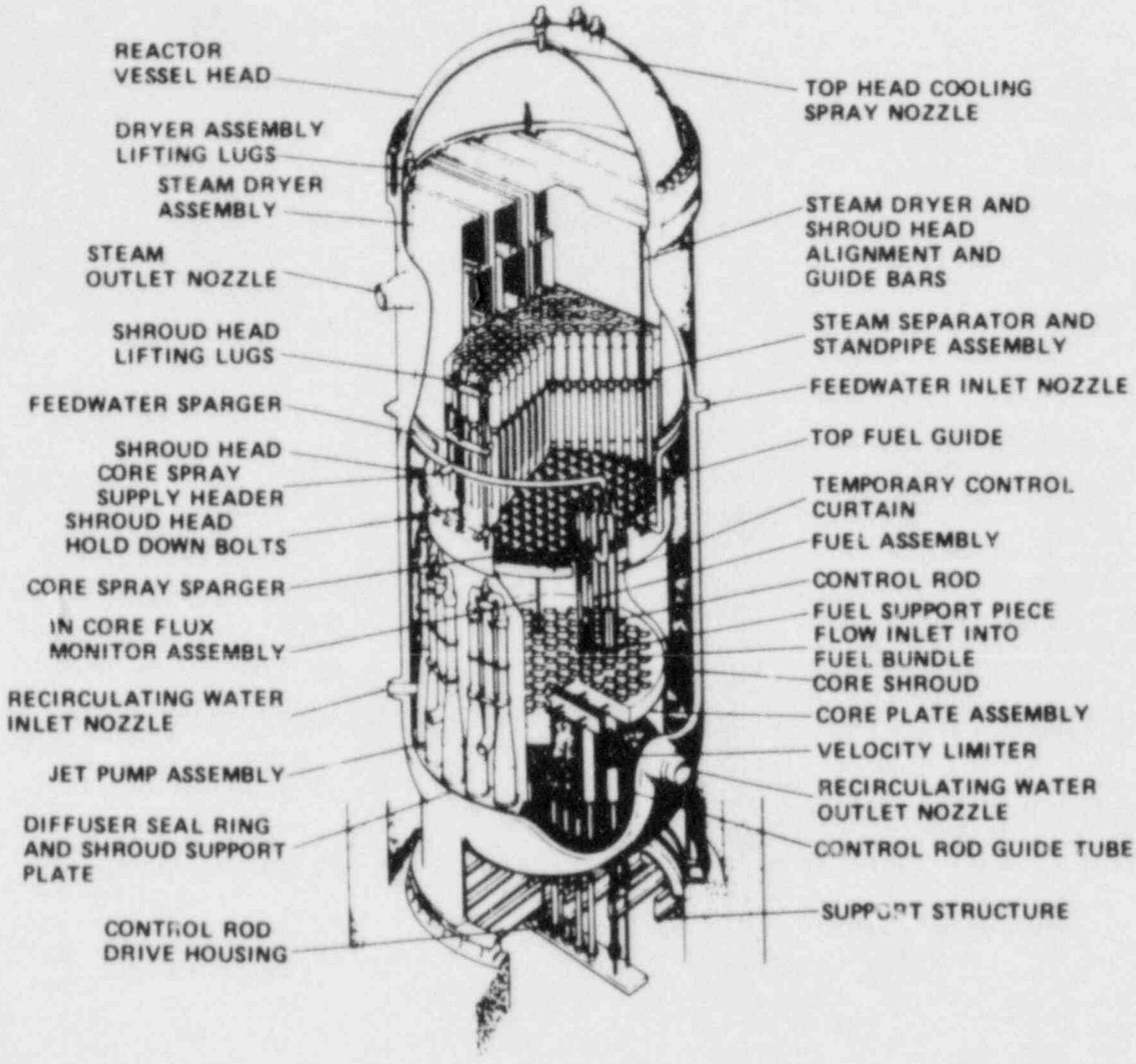

Fig. 3.2. BWR reactor vessel internals.

ORNL-DWG 80-5843A ETD

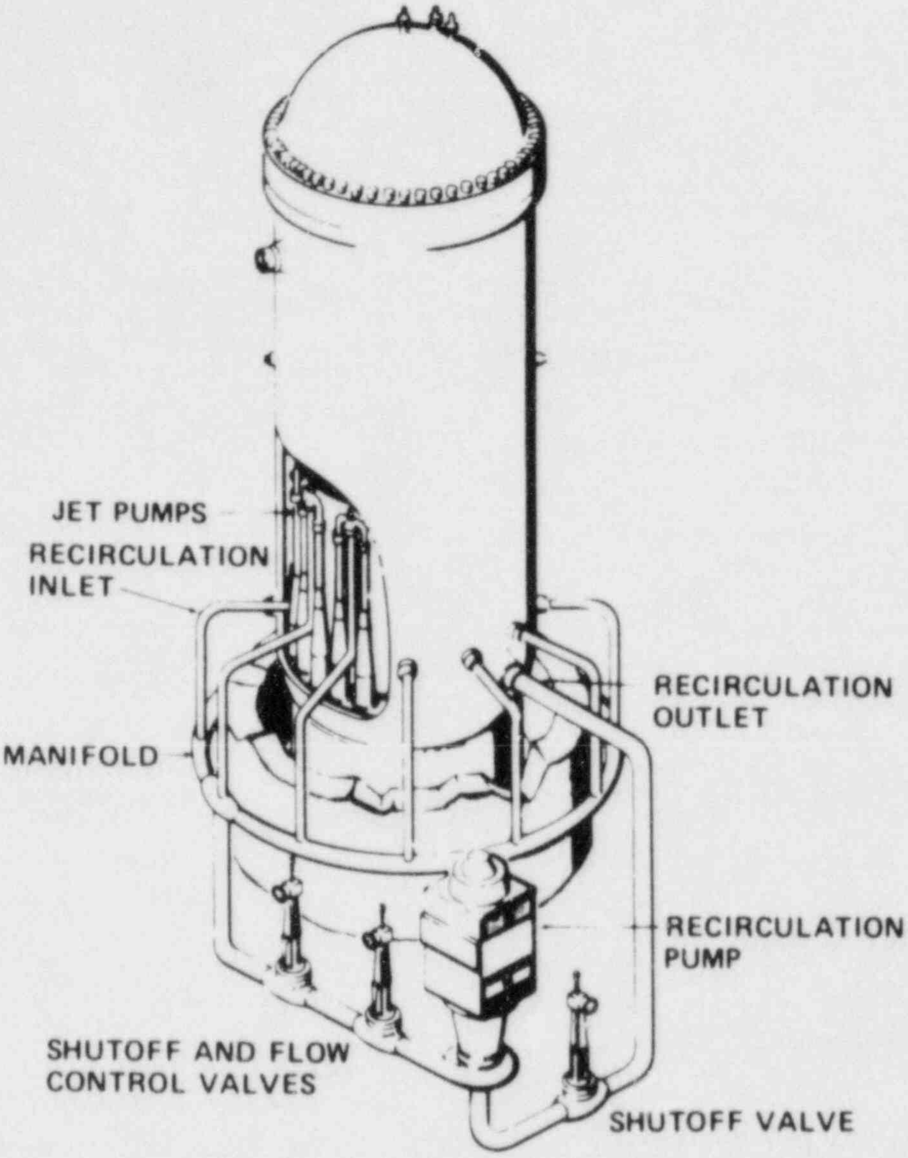

Fig. 3.3. BWR reactor vessel and recirculation piping.

4. SAFETY RELIEF VALVES (SRVs)

The SRVs (13 for each unit at Browns Ferry) are connected to the main steamlines inside the drywell. They protect the reactor vessel from overpressurization by automatically controlling reactor vessel pressure when the Main Steam Isolation Valves (MSIVs) are closed. When the MSIVs are closed, the SRVs provide the only path for relief of steam produced in the reactor vessel, except for the RCIC and HPCI turbines which accept relatively small steam flows when the turbines are running.

The SRVs are either open or closed — there are no intermediate valve positions. The two-stage Target Rock valves currently in use at Browns Ferry (see Fig. 4.1) are pilot operated. The pilot (i.e., first "stage") valve can be opened by either differential between upstream-side steam pressure (≈ reactor vessel pressure) and downstream pressure (≈ wetwell pressure) or by the action of control air pressure on the air actuator. When the pilot valve opens,* it vents the above-piston chamber of the main valve (second "stage"), creating a pressure difference† that pops the main valve open against the force of the main valve preload spring. When the pilot valve closes, the above-piston chamber of the main stage repressurizes (to upstream pressure) and the main valve is forced shut by the main valve preload spring.

Steam operation of the pilot valve is associated with automatic SRV actuation. The SRV opens when the differential between reactor vessel pressure and containment pressure exceeds the set differential pressure of 1105 psi or higher and then closes when reactor vessel pressure has been reduced by about 5% (~50 to 60 psi) and the pilot valve repositions. However, as noted previously, it is the pressure differential across the main valve piston that actually holds the valve open. Therefore, even with the pilot valve positioned for SRV opening, the SRV will close if and when reactor vessel pressure is reduced to within 20 psi of wetwell pressure‡; if this happens, the valve will reopen if reactor vessel pressure subsequently increases to 50 psi above wetwell pressure.

Control air operation of the pilot valve is necessary for operator initiated remote-manual actuation of any of the 13 SRVs, or for Automatic Depressurization System (ADS) actuation of the six ADS SRVs. Control air must act across the valve air actuator in opposition to the

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*For the valve configuration shown on Fig. 4.1, the pilot valve opens by being moved to the right. This requires compression of the setpoint adjustment spring.

†The below-piston chamber of the main valve is always connected to the upstream pressure.

‡SRV exhaust is piped to T-quencher discharge devices submerged within the suppression pool. Therefore, the back pressure which is seen by the above-piston chamber of the main valve when the pilot valve is open is the wetwell pressure.

drywell pressure in order to open the pilot valve. Drywell control air pressure (normally about 115 psia) must exceed drywell pressure by at least 25 psi to permit the opening of a closed SRV, and must continue to exceed drywell pressure by at least 5 psi in order to maintain the pilot valve positioned for SRV opening. Therefore, if drywell pressure exceeds 110 psia in an accident sequence, any remote-manually or ADS-opened SRV will shut and stay shut until the reactor vessel pressure reaches the setpoint necessary for automatic steam actuation of the pilot valve.

The SRVs discharge to the suppression pool, whose pressure is normally close to atmospheric pressure and much lower than the reactor vessel pressure. Therefore, sonic flow normally prevails in the throat of an open valve, and flow is calculated as follows

$$W_{srv} = W_{rated} [\rho P/(\rho_r P_r)]^{0.5}$$

where

W_{srv} = flow through the SRV if reactor vessel pressure is P and reactor vessel steam density is ρ, and
W_{rated} = flow through the SRV under rated conditions, when vessel pressure is P_r and vessel steam density is ρ_r.

If the suppression pool pressure is greater than 44% of the reactor vessel pressure, then the flow calculated by the formula above must be reduced since sonic flow conditions no longer prevail. When this is true, the flow is corrected as follows:

$$W_{srv} = W_{srvs} [2.22 (1 - P_{sp}/P)]^{0.5}$$

where

W_{srv} = flow through the SRV,
W_{srvs} = flow through the SRV for sonic flow,
P_{sp} = suppression pool pressure, and
P = reactor vessel pressure.

4.1 Automatic Actuation

The purpose of automatic SRV actuation is to prevent excessive pressurization of the reactor vessel. The ASME code for nuclear pressure vessels specifies performance requirements for safety valves: (1) at least some of the SRVs must be set to open at or below the reactor vessel design pressure, (2) each SRV must "pop" open (to $\geq$97% of its full flow) at a pressure within 1% of its pre-set opening pressure, and (3) each SRV must, unless specifically exempted, reclose after the pressure has been reduced by no more than 5%.

At Browns Ferry, there are three designated banks of SRVs. The four valves of the first bank are set to open at 1105 psig; the four valves of the second bank are set to open at 1115 psig; and the five valves of the third bank are set to open at 1125 psig. Even though the valves in a given bank have the same setpoint, they do not open or close in concert. The setpoint for automatic SRV opening is set individually at each SRV by adjustment of the pilot valve setpoint adjustment spring. Therefore, as provided for by the ASME code, each of the valves in a bank might open anywhere within $\pm 1\%$ of the nominal opening pressure. For example, the valves in the first bank, nominally set at 1105 psig, may open anywhere between 1094 and 1116 psig. This effect may be simulated in BWR-LTAS by properly staggering the user-provided input for the SRV automatic opening pressure setpoints.

Experience with the SRVs at Browns Ferry has shown that, after opening automatically, an SRV will remain open until pressure has been reduced by between about 6% and 11%. The realistic closing pressures can be simulated by staggering the user-provided input for automatic closing pressures between the maximum and minimum expected closing pressures.

4.2 Automatic Depressurization

Six of the 13 SRVs at Browns Ferry are associated with the Automatic Depressurization System (ADS). These valves are like the other seven SRVs, in that they respond identically to automatic actuation and to operator-initiated, remote-manual actuation. They are unlike the other seven in that the pilot-stage solenoid of each of the six ADS valves can respond to the ADS actuation signal (by admitting air to the inlet of the air actuator) and in that each of the six is equipped with its own compressed air accumulator; thus, even in the event of the loss of both the drywell air compressor and the station control air, the ADS could still actuate to depressurize the reactor vessel.

At Browns Ferry, all the following indications are required for ADS actuation: (1) high drywell pressure (>2.45 psig), (2) low reactor vessel water level (<413.5 in.), (3) confirmatory low reactor vessel water level (<546 in.), and (4) the expiration of the ADS two-minute timer. These features are built into the BWR-LTAS simulation and the setpoints may be changed by changing user-provided input.

4.3 Manual Actuation

An operator can open any one of the 13 SRVs by moving the handswitch for that valve to the "on" position; the valve will not close until the operator returns the handswitch to the "off" position. When the reactor vessel is isolated, the plant emergency procedures instruct the operator to control reactor vessel pressure in the neighborhood of 900 psig by manual actuation of the SRVs. Operator control is not absolutely necessary since automatic SRV actuation will, without any help from the operator, control the reactor vessel pressure between about

1100 and 1000 psig. Operator control is preferred because SRV actuations are less frequent under manual control, and this minimizes wear on the valves and also the chance that an SRV will stick in the open position. Operator control also allows the operator to selectively alternate the SRVs in such a manner as to distribute the heat load associated with SRV discharge more evenly around the circumference of the pressure suppression pool.

BWR-LTAS simulates operator control by opening one SRV when pressure exceeds the reactor vessel pressure setpoint* by about 100 psi, and by closing the opened SRV when reactor vessel pressure has been reduced to about 50 psi below the vessel pressure setpoint. Operator initiated depressurization is simulated by ramping down the setpoint for vessel pressure i.e., the user input desired reactor vessel pressure; the start and end time, and final pressure reached are also specified by the user.

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*The code is programmed with a setpoint of 950 psia; this is consistent with typical Browns Ferry emergency operating instructions and with operator performance observed at the Browns Ferry training simulator.

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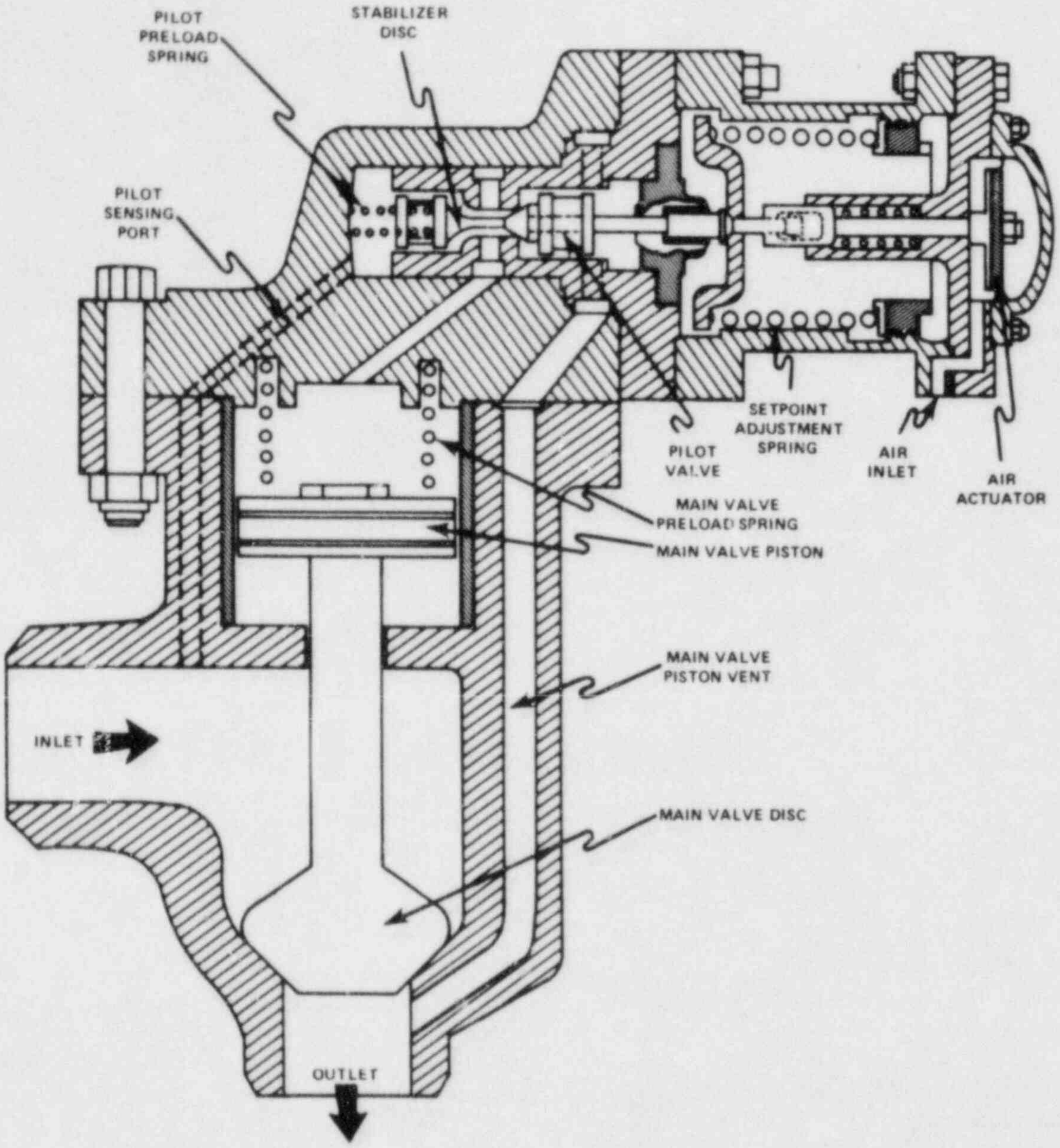

Fig. 4.1. Two-stage target rock safety/relief valve.

5. PRIMARY CONTAINMENT THERMOHYDRAULICS

5.1 Introduction

The primary containment thermohydraulic model is designed to predict pressures and temperatures over a wide range of conditions for a large, but not all inclusive, number of accidents. For example, the model is not intended to be adequate for the case of a large break LOCA accident; however, it has been applied to the study of loss of decay heat removal accidents and Anticipated Transient Without Scram (ATWS) accident sequences in which there would be a relatively slow pressurization of the primary containment to 132 psia, the analytically predicted overpressure failure pressure of the Mark I containment drywell. The model calculates average temperatures and pressures for specified control volumes. No attempt is made to calculate localized phenomena such as the pool swell that occurs in the locality of a discharging PSP T-quencher.

Figure 5.1 shows the Browns Ferry primary containment. The inerted light bulb — shaped drywell is a 1-1/8 in. average thickness pressure vessel which is separated by several inches of foam insulation from the closely surrounding concrete structure. The Browns Ferry drywell liner weighs about 850,000 lbs and, as a heat sink, has a significant effect on the temperature of the drywell atmosphere. The drywell houses the reactor vessel and associated primary coolant system (PCS) piping, including reactor vessel, reactor coolant recirculation pumps, steam lines, and safety relief valves, and is inerted during reactor operation. The primary containment is surrounded by the reactor building (Fig. 5.2.).

The drywell atmosphere temperature and pressure can be affected by the primary coolant system (PCS) by direct heat transfer from the hot PCS outer surfaces and by direct leakage of primary coolant. During normal operation, there are other heat sources in the drywell such as the recirculation pump motors. The drywell atmosphere coolers run during normal operation and maintain drywell temperature in the neighborhood of 135 F.

The wetwell (Fig. 5.3) is a 31 ft minor diameter by 111.5 ft major diameter torus made of 0.76 in thick steel, and located in the concrete-walled torus chamber in the basement of the reactor building. The wetwell is approximately half-filled with water. This water, known as the pressure suppression pool (PSP), is designed to serve as a heat sink for condensation of steam discharged from the reactor coolant system under accident or transient conditions. During a LOCA, steam would enter the drywell atmosphere and then flow into the suppression pool through the 96 downcomer pipes distributed around the circumference of the PSP. Under transient conditions, excess steam pressure within the reactor vessel is relieved by SRVs whose discharge is piped directly into the PSP through T-quencher devices located about 5 ft off the bottom of the 15 ft deep pool. The T-quencher shown in Fig. 5.3 is rotated 90° from its normal tangential alignment, for illustrative purposes. The residual heat removal (RHR) system can be aligned to provide PSP cooling adequate to prevent excessive PSP temperatures even if all of the decay heat is being dissipated within the PSP.

The drywell and wetwell atmospheres communicate through the 96 drywell-to-wetwell vent downcomers and the 8 wetwell-to-drywell vacuum breakers. If drywell atmosphere pressure exceeds the wetwell atmosphere pressure by about 1.75 psi, the water is forced from the interior of the downcomers and the drywell atmosphere bubbles up through the PSP into the wetwell atmosphere (most of the water vapor will be condensed). If the pressure in the wetwell atmosphere exceeds the drywell pressure by more than 0.5 psi, the wetwell-to-drywell vacuum breakers would open and allow flow from the wetwell atmosphere to the drywell until the pressure is equalized. These vacuum breakers are check valves, which can be tested by means of compressed air actuators. For all but brief periods during severe transients such as large break LOCA accidents, these mechanisms keep the wetwell and drywell atmosphere pressures within about 2 psi of each other.

The BWR-LTAS primary containment model performs energy and mass balances on three regions: the drywell atmosphere, the wetwell atmosphere, and the PSP. For the atmosphere regions, there is a separate mass balance for each of the two gaseous components, nitrogen (since the atmosphere is inerted) and water vapor. The assumption is made that these gases behave as perfect gases. This allows the computation of temperature from internal energy, and the calculation of pressure from temperature and the component masses.

5.1.1 Primary containment atmosphere mass balances

Four equations describe the conservation of mass for the drywell and wetwell atmospheres:

$$(d/dt)\ Mnspg = Wndwsp - Wnspl - Wnspdw$$

$$(d/dt)\ Mndwg = -Wndwsp - Wndwl + Wnspdw$$

$$(d/dt)\ Msspg = Wssvnq + Wsdwsp\ (Fnq) + Wstenq + Wtespw - Wsspdw - Wsspl - Wcspg$$

$$(d/dt)\ Msdwg = Wsdwr - Wsdwsp - Wcdwc + Wsspdw - Wsdwl - Wcdwg$$

where

Mnspg = mass of N_2 in wetwell atmosphere (lb),
Msspg = mass of steam in wetwell atmosphere (lb),
Mrdwg = mass of N_2 in drywell atmosphere (lb),
Msdwg = mass of steam in drywell atmosphere (lb),
Wndwsp = flow of N_2 from drywell to wetwell atmosphere (lb/s),
Wsdwsp = flow of steam from drywell to wetwell (lb/s),
Fnq = fraction of steam flowing to the downcomers that does not condense before reaching the surface of the PSP,
Wnspdw = flow of N_2 from wetwell to drywell atmosphere (lb/s),
Wsspdw = flow of steam from wetwell to drywell atmosphere (lb/s),
Wnspl = leakage flow of N_2 from wetwell atmosphere (lb/s),
Wsspl = leakage flow of steam from wetwell atmosphere (lb/s),
Wndwl = leakage flow of N_2 from drywell atmosphere (lb/s),
Wsdwl = leakage flow of steam from drywell atmosphere (lb/s),

Wssvnq = flow of steam from SRVs discharged into PSP but not quenched (lb/s),
Wstenq = flow of steam from steam turbines (HPCI or RCIC) discharged into PSP but not quenched (lb/s),
Wtespw = rate of evaporation from the surface of the suppression pool (lb/s),
Wcspg = flow of steam condensed from the wetwell atmosphere (lb/s),
Wcdwg = flow of steam condensed from the drywell atmosphere (lb/s),
Wsdwr = flow of steam released directly to drywell atmosphere (lb/s),
Wcdwc = flow of steam condensed in the drywell coolers (lb/s).

5.1.2 Intercompartment mass flows and compartment leakage

The density of each component is calculated by dividing its mass by the compartment (i.e., drywell or wetwell atmosphere) free volume. The mass rate of flow of N_2 or steam between compartments or the compartment leakage flow is then calculated by multiplying an input or calculated bulk flow rate by the component density.

The compartment leakages are taken to be a constant input fraction of the compartment volume per unit time. This simulates the increased mass flow rate of leakage that occurs as primary containment pressure increases. For primary containment pressure over two atmospheres the calculated leakage flow approximates choked flow through a restrictive orifice. As a practical matter, the demonstrated leak rate of the Browns Ferry primary containment is so low that its effect would be significant only in a days-long accident sequence. The equations for leakage flow are,

Bspl = (Vgsp) (Flspg)
Wsspl = (Bspl) (Msspg/Vgsp)
Wnspl = (Bspl) (Mnspg/Vgsp)
Bdwl = (Vgdw) (Fldwg) + Bdwvl
Wndwl = (Bdwl) (Mndwg/Vgdw)
Wsdwl = (Bdwl) (Msdwg/Vgdw)

where

Vgsp = volume of wetwell atmosphere (ft^3),
Vgdw = volume of drywell atmosphere (ft^3),
Bspl = bulk flow (volume/time) leaking from the wetwell atmosphere to the surrounding reactor building (ft^3/s),
Bdwl = bulk flow leaking from drywell atmosphere (ft^3/s),
Fldwg = drywell leakage fraction per unit time (1/s), (user input),
Flspg = wetwell leakage fraction per unit time (1/s), (user input),
Bdwvl = bulk flow from the drywell through the drywell vent line (discharges to the plant stack via the Standby Gas Treatment System) (defined below) (ft^3/s).

Venting of the drywell (bulk flow = Bdwvl), if initiated by the operators, can have a greater effect on containment pressure than does the small leakage flow. Therefore, the vent flow is calculated with more accuracy. If the flow is choked, bulk flow is:

$$Bdwvl = FFdvc \sqrt{Tgdwr/Mwgdw}$$

where

Bdwvl = bulk flow (ft^3/s) through drywell vent,

Ffdvc = flow factor $[(ft^3/s)\ (lb/mole\ R)^{0.5}]$ for choked flow through drywell vent line,

Tgdwr = average temperature of drywell atmosphere (R),

Mwgdw = average molecular weight (lb/mole) of drywell atmosphere.

If the flow is not choked, the bulk flow is:

$$Bdwvl = Ffdvuc \sqrt{(Ptdwg - Pa)\ (Tgdwr)/[Mwgdw\ (Ptdwg + Pa)]}$$

where

Ffdvuc = flow factor $[(ft^3/s)\ (lb/mole\ R)^{0.5}]$ for unchoked flow through drywell vent line,

Ptdwg = total pressure (psia) of drywell atmosphere,

Pa = ambient pressure (psia) of the reactor building surrounding the drywell

The bulk flow from the drywell to the wetwell atmosphere is zero if there is not enough pressure difference to force the water down and out of the 96 downcomer pipes. If the pressure difference is great enough the bulk flow from drywell to wetwell is:

$$Bdwsp = Bdwsp0\ (Ptdwg - Ptspg - Pdcvp)$$

where

Bdwsp0 = user-input bulk flow from drywell to wetwell per unit pressure difference ($ft^3/s/psi$),

Ptspg = total pressure of wetwell atmosphere (psia),

Pdcvp = user input pressure difference necessary to clear the downcomer vent pipes (~1.75 psi).

The bulk flow from the wetwell airspace above the suppression pool to the drywell consists of vacuum breaker flow and the wetwell-to-drywell compressor flow if the compressor is running. If the total pressure of the wetwell atmosphere is less than 0.5 psi above the drywell pressure, there is no vacuum breaker flow; when the wetwell pressure increases to >0.5 psi above the drywell pressure, the vacuum breaker flow is:

$$Bvspdw = BspdwO\ (Ptspg - Ptdwg - Pdovb)$$

where,

Bvspdw = bulk flow from wetwell to drywell through the vacuum breakers (ft^3/s),
BspdwO = user-input total vacuum breaker bulk flow per unit pressure drop ($ft^3/s/psia$),
Pdovb = pressure difference required to open the vacuum breakers (psi).

If the suppression pool-to-drywell delta P compressor is running, the bulk flow is a user-input constant, Brdpc. If the drywell atmosphere pressure exceeds wetwell pressure by more than a user-input differential pressure Pmxdpc, the compressor is cut off; it may be restarted if the drywell pressure sinks to below Pmndpc. The purpose of this system is to maintain the drywell pressure above wetwell pressure to minimize the columns of water on the insides of the 96 drywell-to-wetwell downcomers. In the event of a large break LOCA, the slug of water inside each of the downcomers would be accelerated rapidly downward with the possibility of damage to PSP internals or pressure boundary.

5.1.3 Drywell and wetwell steam flows

To complete the mass balances, the steam flow rates must be specified. The condensation flows, Wcspg and Wcdwg, which consist primarily of condensation on the metal walls surrounding the wetwell and drywell

$$W_c = Q_c/(h_g - h_f)$$

where

Q_c = condensation heat transfer (Btu/s),
h_g = saturated steam enthalpy (Btu/lb),
h_f = saturated fluid enthalpy (Btu/lb).

The drywell cooler program calculates the rate of condensation inside the coolers, Wcdwc. The flow of steam from the suppression pool by evaporation (Wtespw) or direct bubble-through of non-quenched SRV or steam turbine exhaust (Wssvnq or Wstenq) are calculated by the PSP model. The flow of steam released directly to the drywell, Wsdwr, is the flash fraction of liquid coolant leakage from the primary coolant system. The input constant Wdleak allows the user to specify a constant leakage of saturated water from the primary coolant system to the drywell.

5.2 Calculations

5.2.1 Drywell and wetwell atmosphere energy balances

The drywell and wetwell atmosphere energy balance equations are:

d/dt(Udwg) = EPsdw + EPndw + Qrvhl - Qldwg
d/dt(Uspg) = EPssp + EPnsp + Qsspg - Qlspg + Mwork

where

Udwg = total internal energy [(mass) (specific internal energy)] of all gases in the drywell atmosphere (Btu)
Uspg = total internal energy of gases in the wetwell atmosphere (Btu),
EPsdw = product of enthalpy and mass flow for all flows of steam entering or leaving the drywell atmosphere (positive sign for flow into drywell, negative for out-flow) (Btu/s),
EPssp = same as above but for the wetwell atmosphere (Btu/s),
EPndw = product of enthalpy and mass flow for all N_2 flows to or from the drywell atmosphere (Btu/s),
EPnsp = product of enthalpy and mass flow for all N_2 flows to or from the wetwell atmosphere (Btu/s),
Qrvhl = heat transfer from outer surfaces of reactor vessel and associated piping (Btu/s),
Qldwg = heat loss from the drywell atmosphere to heat sinks within the drywell (primarily the 1 1/8 in. thick steel drywell wall) (Btu/s),
Qlspg = same as above for the wetwell atmosphere (Btu/s),
Qsspg = heat transfer from the surface of the suppression pool to the wetwell atmosphere (Btu/s),
Mwork = work done on the wetwell atmosphere by change in the suppression pool water level (Btu/s).

The enthalpy products include each mass stream to or from the atmosphere. Since perfect gas behavior is assumed for N_2 and water vapor, the specific enthalpy of each is a function only of temperature:

$$h_s = 0.45\ T - 4.89$$

$$h_n = 0.2475\ T$$

where

h_s = specific enthalpy of water vapor (Btu/lb),
T = temperature of water vapor (degrees Rankine),
h_n = specific enthalpy of nitrogen gas (Btu/lb).

In order to properly interface with other parts of the model, which use the ASME steam tables, it is necessary to subtract 854.5 Btu/lb from the

ASME steam table enthalpy before forming the product of enthalpy and mass flow rate for use in the energy balances above. This applies whenever steam is released from the primary coolant system to the primary containment.

5.2.2 Drywell atmosphere heat sources

The drywell heat source term, Qrvhl, consists primarily of heat transfer from the warm outer surfaces of the reactor vessel and associated piping. This heat transfer rate is proportional to the difference between the temperature of the water or steam within the reactor vessel and the temperature of the drywell atmosphere. A second, transient, term is included in Qrvhl to simulate the heat load (mainly associated with the recirculation pumps) that lingers after reactor scram:

$$Qrvhl = UAorv\ (Tsat - Tgdw) + Qophl$$

where

- UAorv = product of heat transfer coefficient and the area of contact between hot reactor coolant and the cooler drywell atmosphere (Btu/s °F),
- Tsat = temperature of reactor coolant, equal to saturation temperature at reactor vessel pressure (°F),
- Tgdw = temperature of drywell atmosphere (°F),
- Qophl = transient heat load after reactor scram (Btu/s).

The product of heat transfer coefficient and area, UAorv, in the above expression is determined primarily by the relatively small effective conductance through the reactor vessel and piping insulation. Other conductances such as the exterior surface to air film coefficient, are relatively so great that they have practically no effect on the overall conductance. UAorv is calculated from plant data and/or from detailed design calculations of the drywell heat loads. The transient operating heat load is calculated by solving the following equation

$$d/dt\ (Qophl) = -\ (Qophl)/TAUophl$$

where TAUophl is the time constant for decay of the operating heat load. The initial value for solution of this equation is a code input based on detailed calculation or operational knowledge. A time constant of 600 s was assumed for Browns Ferry Unit 1.

5.2.3 Convective and condensation heat transfer from atmosphere to heat sinks

The 1 1/8 in. average thickness steel drywell liner is the major heat sink in the drywell. The heat loss term, Qldwg, includes all heat loss from the atmosphere to the drywell liner by natural convection heat transfer and by condensation:

$$Qldwg = Qdmdry + Qdmwet$$

where

Qdmdry = convective heat transfer rate,
Qdmwet = condensation heat transfer rate.

The convective heat transfer rate depends on the temperature difference between the liner temperature, Tdmet, and the atmosphere temperature Tgdw:

$$Qdmdry = Admet\ 5.3(10)^{-5}\ (Tgdw - Tdmet)^{0.33}\ (Tgdw - Tdmet)$$

where Admet is the heat transfer area of the drywell metal (liner), and the units of Qdmdry are Btu/s. This equation is based on the following natural circulation heat transfer correlation:[5.1]

$$Nu = 0.13\ (Gr_L\ Pr)^{0.333}$$

where

Nu = Nusselt number = hL/k
Gr_L = Grashoff number = $\rho^2 g\beta(T - T_a)\ L^3/\mu^2$
Pr = Prandtl number = $\mu C_p/k$.

and the length parameter, L, cancels. This correlation is good for vertical or nearly vertical surfaces and also for hot horizontal surfaces facing upward (or cool horizontal surfaces facing downward).

The condensation heat transfer is zero unless the heat sink temperature, Tdmet, is below the dewpoint. When condensation does occur, the rate is dependent on the relative amount of nitrogen present:[5.2]

$$Qdmwet = Admet\ 0.0185\ (Msdwg/Mndwg)^{0.707}\ (Tdewdw - Tdmet)$$

where

Msdwg = mass of steam in drywell atmosphere (lb),
Mndwg = mass of N2 in drywell atmosphere (lb),
Tdewdw = dewpoint of drywell atmosphere (°F).

During normal operation, the drywell coolers constantly remove moisture from the drywell atmosphere, so that the dewpoint is well below the atmosphere temperature. The dewpoint temperature is determined from the steam tables: it is the saturation temperature evaluated at the specific volume of the drywell atmosphere steam (Vgdw/Msdwg).

An energy balance is utilized to solve for the drywell liner temperature, Tdmet:

$$(d/dt)\ \text{Tdmet} = (\text{Qdmdry} + \text{Qdmwet})/\text{Cdmet}$$

where Cdmet equals the mass times the specific heat of the 1-1/8 inch thick steel drywell liner. There is no heat loss term in the calculation of drywell liner temperature because the drywell liner is insulated on the outside; the calculation assumes this insulation stops all heat loss.

The natural circulation convective heat transfer and the condensation heat transfer for the wetwell are calculated in a manner similar to that explained above for the drywell. The chief heat sink considered for the wetwell atmosphere is the 3/4-in. thick steel wall of the upper half of the torus, which is in contact with the atmosphere. The temperature of this steel shell is calculated by integration of the following energy balance:

$$(d/dt)\ \text{Tpmet} = (\text{Qpmdry} + \text{Qpmwet} - \text{Qpgair} - \text{Qrpgc})/\text{Cpmet}$$

where

Qpmdry = natural circulation convective heat transfer from wetwell atmosphere to the torus wall (Btu/s),
Qpmwet = condensation heat transfer from wetwell atmosphere to the torus wall (Btu/s),
Qpgair = natural circulation convective heat transfer from the outside surface of the torus to the air of the torus chamber (Btu/s),
Qrpgc = radiant heat transfer from the torus wall to the concrete walls of the torus chamber (Btu/s),
Cpmet = product of mass and specific heat of the torus shell (Btu/°F).

5.2.4 Torus room temperature

For many accident sequences, the temperature of the concrete torus room walls does not change; however, for an accident sequence such as the loss of decay heat removal (DHR) accident, the surface temperature of these walls can increase enough to significantly affect the torus heat loss. In an unmitigated loss of DHR accident sequence, the surface temperature of the uninsulated torus can exceed 300°F. The greatest heat loss from the surface of the torus at this temperature is by radiant heat transfer directly to the 3 ft thick concrete walls (also to the floor and ceiling) of the torus room. This heat transfer rate is evaluated using an assumed emissivity of 0.9 for both torus and concrete surfaces:[5.1]

$$Q_r = SA_t(T_t^4 - T_c^4)/[1/e_t + (A_t/A_c)(1/e_c - 1)]$$

where

Q_r = total radiant heat transfer rate (Btu/s),
S = Stefan-Boltzman constant (Btu/ft^{2}s °R^4),
A_t = surface area of torus (ft^2),
A_c = surface area of concrete (ft^2),
T_t = surface temperature of the torus (°R),
T_c = surface temperature of the concrete (°R),
e_t = surface emissivity of the torus,
e_c = surface emissivity of the concrete.

The rate of natural circulation convective heat transfer between the torus and the torus room air is as follows:

$$Q_c = A_t h \ (T_t - T_a)$$

$$h = 5.3(10)^{-5} \ (T_t - T_a)^{0.33}$$

where the units of h are Btu/(ft^2 s°F). A similar expression is employed for calculation of heat transfer between torus room air and torus room concrete surfaces.

A differential energy equation is solved for each of the following temperatures: torus surface, torus room air, and torus room concrete. The 3 ft thick concrete walls are divided into five parallel, slab-geometry, regions to insure accurate computation of the temperature distribution within the concrete. The surface slab is 1 in. thick, the adjacent slab 2 in. thick, and so on, with slab thickness increasing with penetration into the concrete. A typical concrete differential energy balance is:

$$dT_i/dt = [2 \ K_c/(DX_i C_{pc})][(T_{i-1} - T_i)/(DX_{i-1} + DX_i)$$

$$- (T_i - T_{i+1})/(DX_i + DX_{i+1})]$$

where

T_i = temperature of the i-th concrete slab (°F),
K_c = concrete thermal conductivity (Btu/s ft °F),
DX_i = thickness of i-th concrete slab (ft),
C_{pc} = product of specific heat and density of concrete (Btu/lb °F).

The expression for natural circulation of air from the reactor building basement corner rooms into the torus room and out through sleeves in the ceiling of the torus room is based on the discussion in Sect. 5.2.6.3 of the Browns Ferry FSAR that gives the circulation rate for a specific set of conditions. In adapting the circulation rate given by the FSAR to other conditions, it was assumed that the rate of natural circulation is proportional to the square root of the density difference (i.e., density of reactor building basement air outside the torus room vs the density of the air inside the torus room) and, therefore, also proportional to the square root of the temperature difference. The basement air outside the torus room is assumed to remain close to 90°F throughout the loss of DHR sequence.

5.2.5 Wetwell atmosphere heat sources

In an accident sequence with MSIVs closed, the pressure suppression pool is heated as it condenses the steam discharged by the SRV T-quenchers. The atmosphere above the hotter pool is heated in two ways: by natural circulation convective heat transfer and by evaporation of water from the surface of the pool. The convective heat transfer coefficient is calculated by means of the same relation given in Sect. 5.2.3 that is used for heat transfer from the atmosphere to heat sinks,

$$Nu = 0.13\,(Gr_L\,Pr)^{0.333} \quad .$$

Evaporation of water vapor from the surface of the suppression pool to the wetwell atmosphere can be the dominating mechanism for pressurization of the primary containment during accidents such as the Loss of DHR sequences.[5.3] If the pool is slowly heated, evaporation can cause the containment pressure to rise fast enough such that the suppression pool remains subcooled and there is no direct bubble-through of SRV discharge from the T-quenchers to the wetwell atmosphere even at elevated pool temperatures.

The wetwell atmosphere is initially a mixture of nitrogen and a small amount of water vapor, and remains a binary mixture throughout most of the accident sequences. If the wetwell atmosphere were pure water vapor, then it would be correct to assume that the partial pressure of water vapor in the wetwell atmosphere is identical to the saturation pressure evaluated at the temperature of the water at the surface of the pool. Since the wetwell atmosphere is a binary mixture, this assumption is not correct because the rate of transfer of water vapor from the pool is limited by diffusion and convection through the air.

The relationship used to calculate the rate of evaporation from the pool is based on the heat transfer/mass transfer analog discussed in Chap. 13 of Ref. 5.1:

$$W = (12.3\,A_p R_m)(P_{vs} - P_{va})h/\overline{P}_n$$

where

W = evaporation rate (lb/s),
12.3 = constant of proportionality $[lb_m^2\ {}^\circ R^2/(Btu\ psia\ ft^3)]$

A_p = surface area of pool (ft^2),
R_m = suppression pool bulk atmosphere mole-fraction-weighted (i.e. between nitrogen and water vapor) perfect gas constant [psia ft^3/lb_m °R)]
P_{vs} = vapor pressure (psia) of water, evaluated at the pool surface temperature,
P_{va} = partial pressure of water vapor in wetwell atmosphere,
$\overline{P}_n$ = average nitrogen pressure in the convective boundary layer (psia),
h = coefficient of natural circulation heat transfer between the surface of the pool and the pool atmosphere [Btu/(s °F ft^2)]
$= 5.85 \times 10^{-5} \ (T_p - T_a)^{0.333}$,
T_p = pool surface temperature (°F),
T_a = wetwell atmosphere temperature (°F).

5.2.6 Drywell coolers

The drywell coolers transfer heat from the drywell atmosphere to the reactor building closed cooling water (RBCCW) system. The RBCCW system pumps water through the inside of the heat exchanger tubes; the cooler's blowers draw the drywell air (i.e. nitrogen and water vapor) across the exterior of the tubes. Air-side heat transfer is enhanced by the many closely spaced parallel copper sheets attached to the outside of the tubes.

The calculation of heat transfer within the drywell coolers is similar to that for the RHR heat exchangers in that the effectiveness formulation is used; however, an iterative solution is employed because the heat transfer properties of the air-side are radically altered when the water vapor fraction becomes significant (after 8 h, or more, into the loss of DHR accident sequence, for example).

The equation for counterflow heat exchanger cooling effectiveness* is:[5.1]

$$E = (1 - e^{-x})/(1 - C_r e^{-x})$$

where

$C_r = C_{min}/C_{max}$,
C_{min} = smaller of the air-side mass flow times specific heat product and RBCCW-side mass flow times specific heat product (Btu/s °F),

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*Heat exchanger effectiveness is defined as the ratio of the actual heat transfer rate to the rate that would be obtained if the heat exchanger surface were unlimited.

C_{max} = larger of the air-side and RBCCW-side mass flow times specific heat products (Btu/s °F),

$x = (1 - C_r)UA/C_{min}$,

UA = product of overall air-to-water heat transfer coefficient and effective heat transfer area (Btu/s °F).

The iteration proceeds as follows:

1. A value of air-side C_a is assumed (mass flow * specific heat),
2. E is calculated, along with the resulting heat transfer rate, air-side ΔT, and air-side exit temperature,
3. The air-side condensation rate is then calculated from the results of step 2, combined with the known saturation pressure of steam as a function of temperature (i.e. the air side exit temperature determines the maximum concentration of water that can exit as vapor and the rest must condense),
4. The condensation rate is then divided by the heat of vaporization and used to calculate the total heat transfer rate (latent + sensible), and a corrected value for C_a,

   $C_a' = \frac{Q}{\Delta T}$, is calculated.

5. If $C_a' \cong C_a$, the iteration is terminated. If not, then steps 1 through 4 are repeated until convergence is achieved.

Major assumptions of the drywell cooler model include:

1. constant volumetric flow maintained by the drywell cooler blowers,
2. constant RBCCW system inlet temperature and flow,
3. constant overall air-to-RBCCW heat transfer coefficient * effective heat transfer area.

Input parameters for the drywell coolers include the setpoints for automatic trip of the blowers that occurs upon coincident high drywell pressure and low reactor vessel pressure if a loss of off-site power has occurred. This trip is a part of the automatic load shedding that follows a core spray initiation when the emergency diesels are providing power. The operator may restart the blowers unless off-site power is not available.

5.2.7 Calculation of drywell and wetwell atmosphere pressures and temperatures

By integration of the mass and energy balance equations discussed in the previous sections, the component masses and the total internal energies are known, and therefore the specific internal energy of the mixture is uniquely determined:

$$u = UM/M$$

where

u = specific internal energy of the atmosphere mixture (Btu/lb),
UM = total internal energy of the atmosphere (Btu),
M = total mass of the atmosphere (steam + N_2) (lb).

Since for ideal gases, the internal energy is a function of temperature only, the temperature of the mixture can be calculated by solving the following equation:

$$u = u_s(T)\, M_s/M + u_n(T)\, M_n/M$$

where

u = the known specific internal energy of the atmosphere mixture (Btu/lb),
$u_s(T)$ = internal energy of steam as a function of temperature (Btu/lb),
M_s = mass of steam in the atmosphere (lb),
$u_n(T)$ = internal energy of N_2 as a function of the temperature (Btu/lb),
M_n = mass of N_2 in the atmosphere (lb).

Having calculated mixture temperature, the partial pressure of each component can now be calculated:

$$P_n = (M_n/V)R_nT$$

$$P_s = (M_s/V)R_sT$$

$$P_t = P_n + P_s$$

where

P_n = partial pressure of N_2,
M_n = mass of nitrogen,
V = total free volume of the compartment,
R_n = ideal gas constant for N_2,
P_s = partial pressure of steam,
M_s = mass of steam,
R_s = ideal gas constant for steam,
P_t = total pressure of the atmosphere.

The atmosphere pressure and temperature calculations are done independently for the drywell and wetwell atmospheres.

5.3 Pressure Suppression Pool (PSP) Mass and Energy Balances

Mass and energy balances are solved for a single-region control volume, resulting in the calculation of the PSP water level and a single average water temperature for the whole PSP. If it is desired to calculate the top-to-bottom or the circumferential temperature distributions in the PSP, it is possible to replace this single-region model with a much more detailed one developed at ORNL.[5.4] The single-region model is described below. The mass balance equation for the PSP is:

$$(d/dt)\ M = F_q(Wssv + Wste) + Wc - Ws - We + Wsdwsp\ (1 - Fnq)$$

where

- M = total mass of PSP water (lb),
- F_q = fraction of the SRV or steam turbine exhaust that is condensed in the PSP (the non-condensed part would bubble up into the wetwell atmosphere),
- Wssv = SRV discharge flow to PSP (lb/s),
- Wste = HPCI or RCIC steam turbine discharge to PSP (lb/s),
- Wc = rate of steam conduensation in the wetwell atmosphere (lb/s),
- Ws = total flow to suction of pumping systems other than pool cooling (e.g. Core Spray, LPCI, or HPCI if the suction shift has occurred — the water circulation provided by the pool cooling mode of the RHR system is assumed to effect no net mass transfer) (lb/s),
- We = rate of evaporation from the suppression pool surface into the wetwell atmosphere (lb/s),
- Wsdwsp,Fnq = defined in Section 5.1.1.

The condensation of steam from SRV exhaust or from the HPCI and RCIC turbine exhausts is assumed to be complete (i.e. F_q = 1.0) if the saturation temperature evaluated at the quenching depth (i.e. Tsat at wetwell atmosphere pressure plus hydrostatic pressure equivalent to the height of water above the quencher) is at least 10°F greater than bulk pool temperature (input parameter TSQUEN, Table A-4); there is no condensation (F_q = 0.0) if the bulk pool temperature exceeds saturation temperature. Between these limits, F_q is linearly ramped from 1.0 to 0.0 as subcooling decreases from 10.0 to 0.0°F. This treatment is considered to be a reasonable approximation for the expected performance of the currently installed "T-quencher" quenching devices. The T-quenchers are constructed with many small holes to promote stable condensation and prevent the condensation oscillations that could occur with the formerly employed "rams head" quenchers. A more detailed discussion of the physics of condensation is provided in Ref. 5.4.

The PSP energy balance is:

$$d/dt(MH) = F_q[Wssv\ (hst) + Wste\ (hste)] + Wc(h_f)$$

$$- hpsp\ (Ws) - We\ (hg) + hsdw\ (Wsdwsp)\ (1 - Fnq)$$

where

MH = product of total mass and enthalpy for PSP water (for water h=u, so this is also total internal energy) (Btu),
hst = enthalpy of steam discharged by the SRVs (Btu/lb),
hste = enthalpy of steam discharged by the steam turbines (Btu/lb),
h_f = saturated fluid enthalpy evaluated at PSP atmosphere temperature (Btu/lb),
hpsp = enthalpy of PSP water (Btu/lb),
h_g = saturated dry steam enthalpy evaluated at PSP temperature (Btu/lb),
hsdw = enthalpy of steam (Btu/lb) evaluated at drywell atmosphere temperature.

Having integrated the mass and energy balances, the program next calculates the pool temperature, T_{psp}, from the specific enthalpy

$$T_{psp} = (MH/M) + 32 .$$

The PSP water level is a function of total water volume:

$$L_{sp} = f\ [M/\rho(T)]$$

where

f[ ] = water level as function of volume
M = PSP water mass
$\rho(T)$ = PSP water density as a function of water temperature.

REFERENCES FOR CHAPTER 5

5.1 Frank Kreith, *Principles of Heat Transfer*, International Textbook Company, Scranton, Pennsylvania (January 1966).

5.2 R. O. Wooton and H. I. Avci, *MARCH Code Description and Users Manual*, NUREG/CR-1711, BMI-2064 (October 1980).

5.3 D. H. Cook et al., *Loss of DHR Sequences at Browns Ferry Unit One - Accident Sequence Analysis*, NUREG/CR-2973, ORNL/TM-8532 (May 1983).

5.4 D. H. Cook, *Pressure Suppression Pool Thermal Mixing*, NUREG/CR-3471, ORNL/TM-8906 (October 1984).

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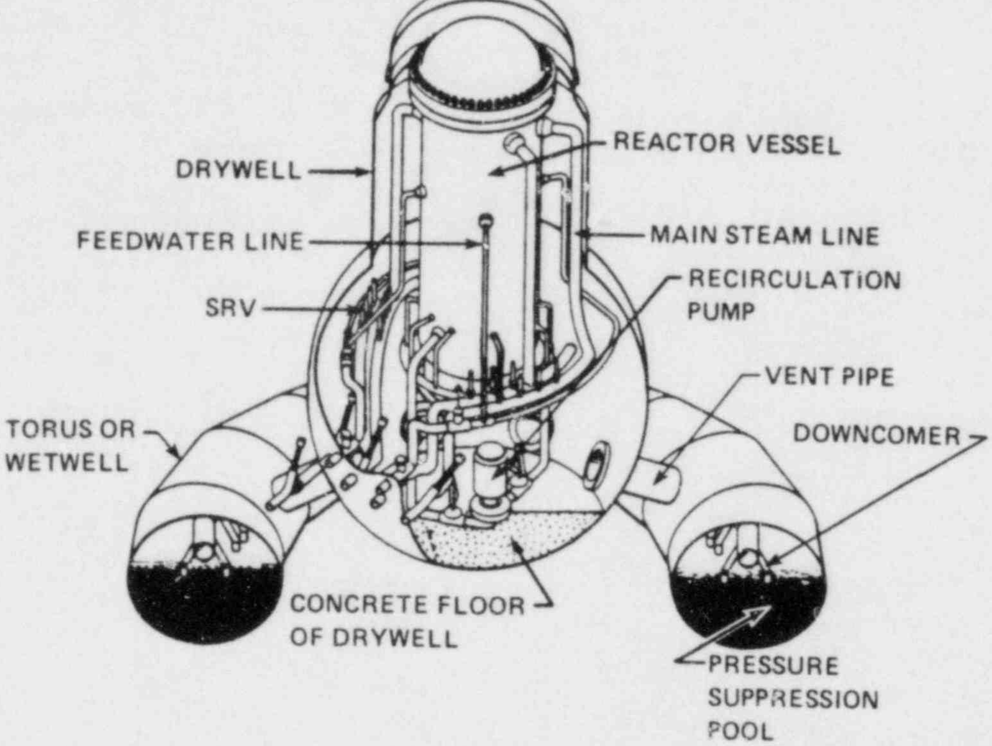

Fig. 5.1. BWR Mark I primary containment system.

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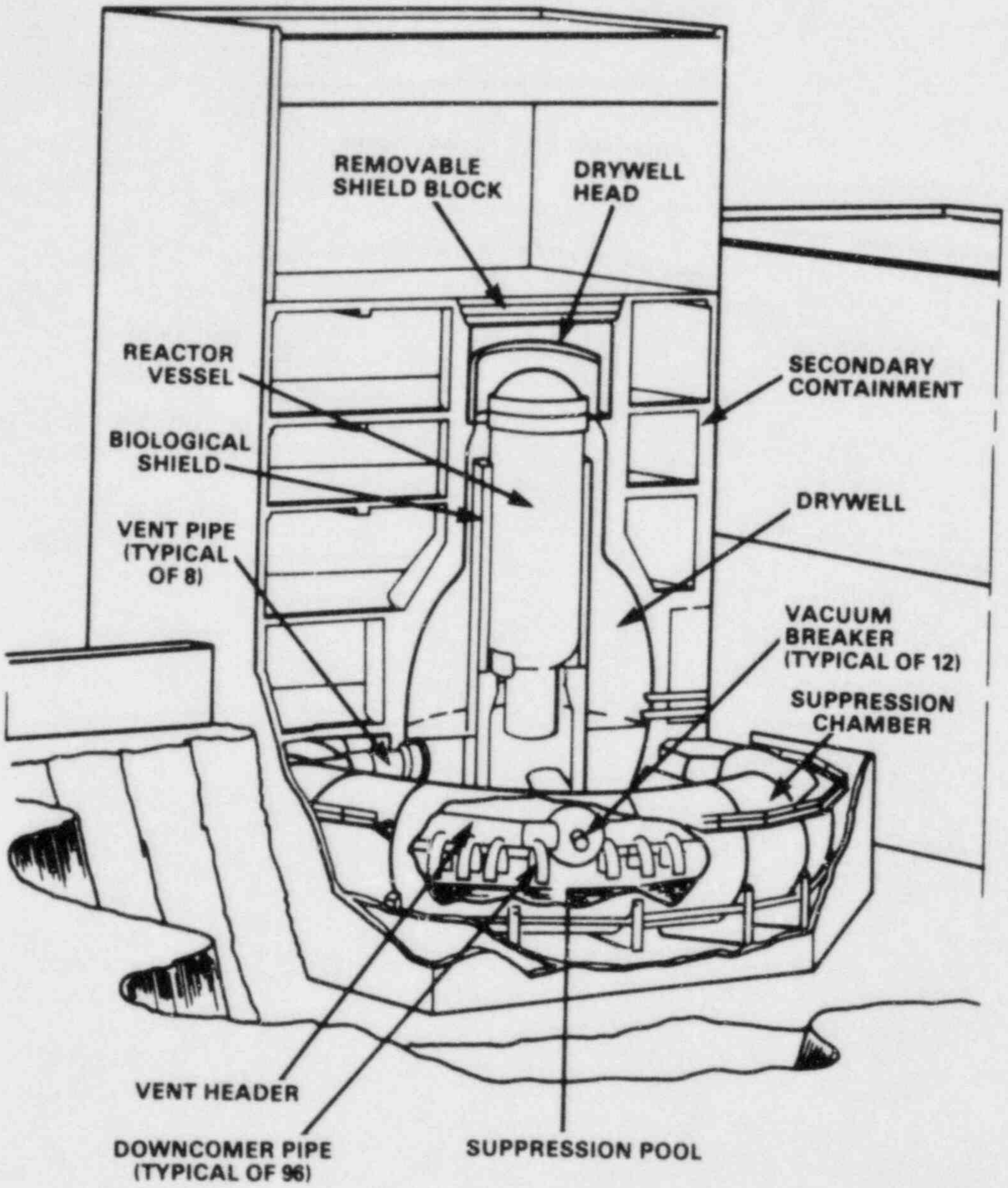

Fig. 5.2. Mark I primary and secondary containment.

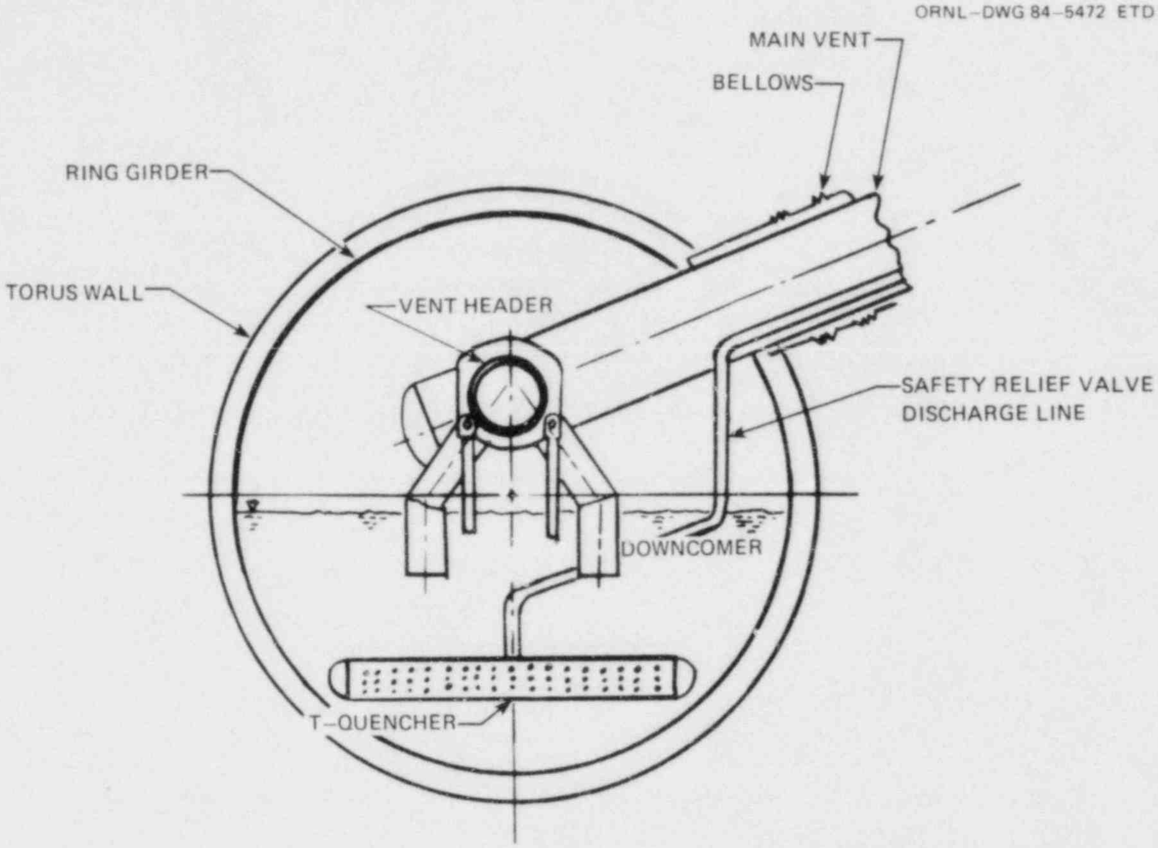

Fig. 5.3. Browns Ferry Mark I pressure suppression pool.

6. CONTROL ROOM INSTRUMENTATION

In general, the response of control room instrumentation is not simulated in BWR-LTAS. However, due to the relative importance of the indicated reactor vessel water level in determining the actions that the operator might take, it was decided to simulate the response of the two most safety-related water level instruments. The calculated instrument responses are used within the code where appropriate for the automatic or manual control of injection systems and SRVs. The simulation calculates the effect of drywell temperature and of reactor coolant temperature on the indicated water level.

There are two vessel water level instruments considered in this report: the Emergency Systems range indicator and the Post-Accident Flooding range indicator. Their ranges in relation to the Browns Ferry reactor vessel and internals are shown on Fig. 6.1. Zero on the Emergency Systems range corresponds to the bottom of the dryer skirt, 528 inches above vessel zero. Zero on the Post-Accident Flooding range corresponds to the top of the active fuel in the core, 360 inches above vessel zero. Both of these instruments measure the collapsed water level in the downcomer annulus of the reactor vessel.

The Emergency Systems indication covers the range from above normal water level down to about 1 ft above the top of active fuel (TAF). This indication is calibrated to read correctly when the reactor coolant is hot and at full pressure. The Yarway system of reference leg compensation minimizes the error when the reactor coolant is cooled to below operating temperature. The variable leg is outside the reactor vessel and is clamped physically and thermally to the reference leg (see Fig. 6.2). Steam from the reactor vessel condenses in the constant head condensing chamber and circulates back to the reactor vessel through the variable leg, transferring enough heat to maintain the reference leg temperature about 50% of the way between the drywell air temperature and the reactor coolant temperature.

The Post-Accident Flooding range indicator covers the range from 100 in. below the TAF to 200 in. above the TAF. The indication is calibrated to read correctly when the reactor vessel is depressurized and the reactor coolant is at about 212°F. The variable leg is inside the reactor vessel (it is the vessel downcomer annulus), and the reference leg is not heated (see Fig. 6.3). The reference leg temperature will therefore remain close to the temperature of the drywell atmosphere.

Both of the level indication systems under consideration here consist of a ΔP sensing element, an electronic circuit to transform the ΔP signal to a level signal, and an indicating meter. The ΔP element measures the difference between the pressure at the bottom of the reference leg and the pressure at the bottom of the variable leg. The reference leg is (or should be) always water-filled*; the amount of water and/or steam in the variable leg depends on the actual water level inside the vessel downcomer.

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*During rapid reactor vessel depressurization the heated reference leg of the Yarway instrument can flash, causing a temporary full-to-the-top level indication. This effect is not simulated in BWR-LTAS.

The potential for error addressed here is in the circuitry that transforms the pressure difference into a water level. This circuitry is designed to always give the same level indication for the same measured pressure difference. Suppose that the vessel water level stays the same, but that the density of the water either in the reference leg or in the variable leg changes; the measured pressure difference would change and thus the indicated water level would change when, in fact, there was no change in actual water level.

The following equations are used to compute the effect on indicated level of reference leg or variable leg conditions that differ from calibration conditions:

$$L_{ind} = L_{max} - (\Delta P - \Delta P_t^*)(\Delta L_i)/(\Delta P_b^* - \Delta P_t^*)$$

where,

L_{ind} = indicated height of water in the downcomer annulus (ft),
L_{max} = height of the upper end of the indication range (ft),
ΔP = measured pressure difference (psi),
ΔP_t^* = pressure difference that would be measured at calibration conditions if the vessel water level were at the top end of the indication range (psi),
ΔL_i = length of the indication range (ft), and
ΔP_b^* = pressure difference that would be measured at calibration conditions if the reactor vessel water level were at the bottom end of the indication range (ft).

The measured ΔP is a function of the actual vessel water level and the reference leg and variable leg water densities:

$$\Delta P = (\Delta L)\rho_r - (\Delta L_\ell)\rho_\ell - (\Delta L - \Delta L_\ell)\rho_g$$

where

ΔL = distance between the upper and lower ΔP taps,
ρ_r = water density of the reference leg,
ΔL_ℓ = reactor vessel downcomer liquid level above the lower ΔP tap,
ρ_ℓ = density of variable leg water (i.e., reactor coolant in the downcomer annulus),
ρ_g = density of the reactor vessel steam.

The calculation makes the assumption that ρ_ℓ is equal to the density of saturated fluid evaluated at reactor vessel pressure. The steam density is set equal to the density of dry saturated vapor at vessel pressure. The reference leg density is evaluated at reference leg temperature T_r

and vessel pressure:

$$\rho_r = \rho_r(T_r, P_v)$$

where

$T_r = 0.4\ T_{sat} + 0.6\ T_{dw}$ for the Emergency System range,
$T_r = T_{dw}$ for the Post-Accident Monitoring range,
P_v = reactor vessel pressure,
T_{sat} = saturation temperature at P_v, and
T_{dw} = drywell atmosphere temperature.

The remaining terms in the expression for L_{ind} are given by the following

$$\Delta P_t^* = \Delta L_i\ (\rho_r^* - \rho_\ell^*)$$

$$\Delta P_b^* = \Delta L_i\ (\rho_r^* - \rho_g^*)$$

These expressions (programmed into the current version of BWR-LTAS) imply the assumption that the indiction range is the same as the distance between the ΔP taps. If this were not the case, then a slightly more complicated expression (obtained by substituting the appropriate dimensions and densities into the expression for ΔP given on the previous page) would have to be used.

For the Emergency Systems level indication, the reference leg calibration density, ρ_r^*, is evaluated at 290°F and ρ_ℓ^* and ρ_g^* are evaluated at a 1000 psia saturation condition.

For the Post-Accident Monitoring level indication, the reference leg calibration density, ρ_r^* , is evaluated at 135°F, and ρ_ℓ^* and ρ_g^* are evaluated at a 14.7 psia saturation condition.

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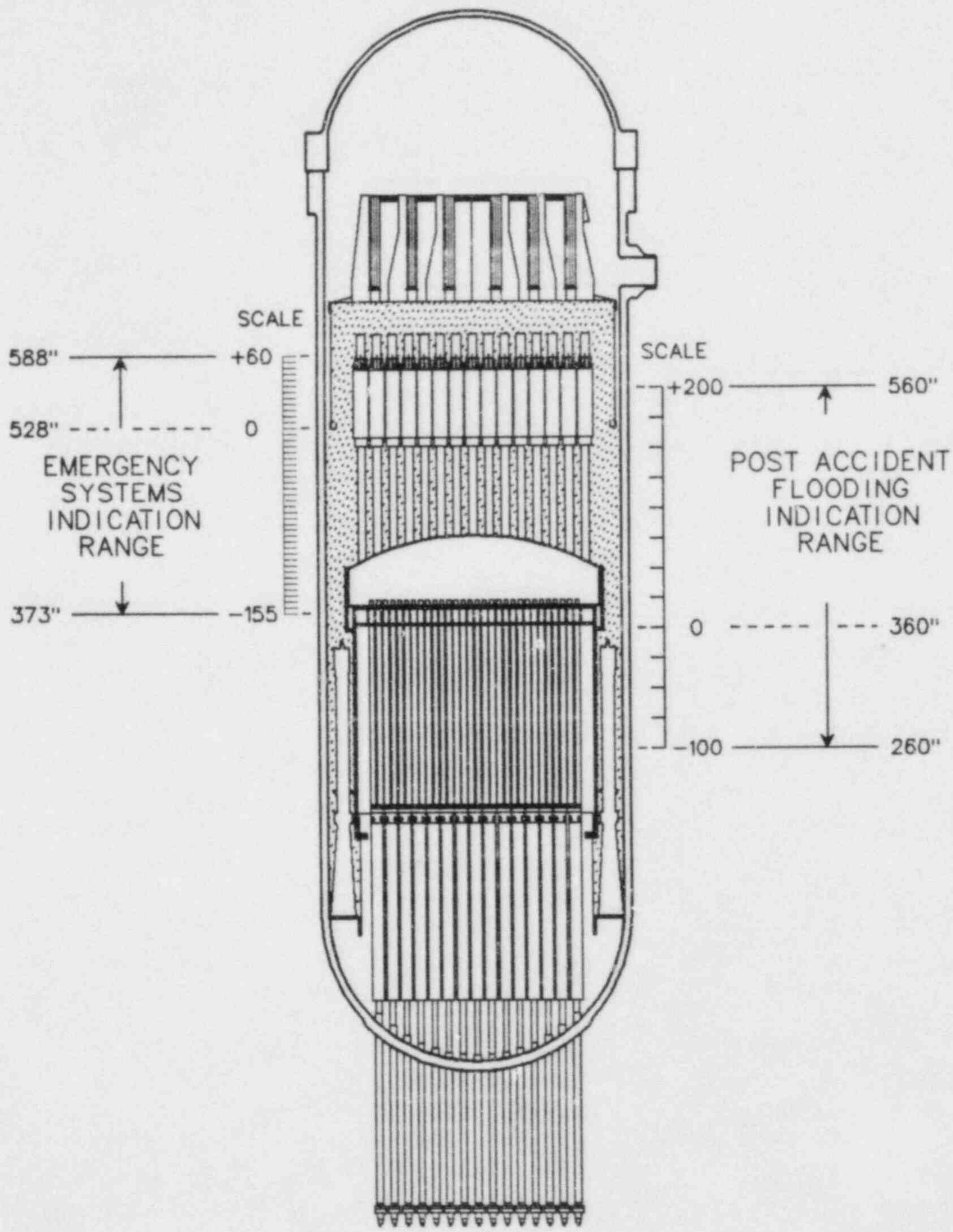

Fig. 6.1. Reactor vessel water level indication ranges.

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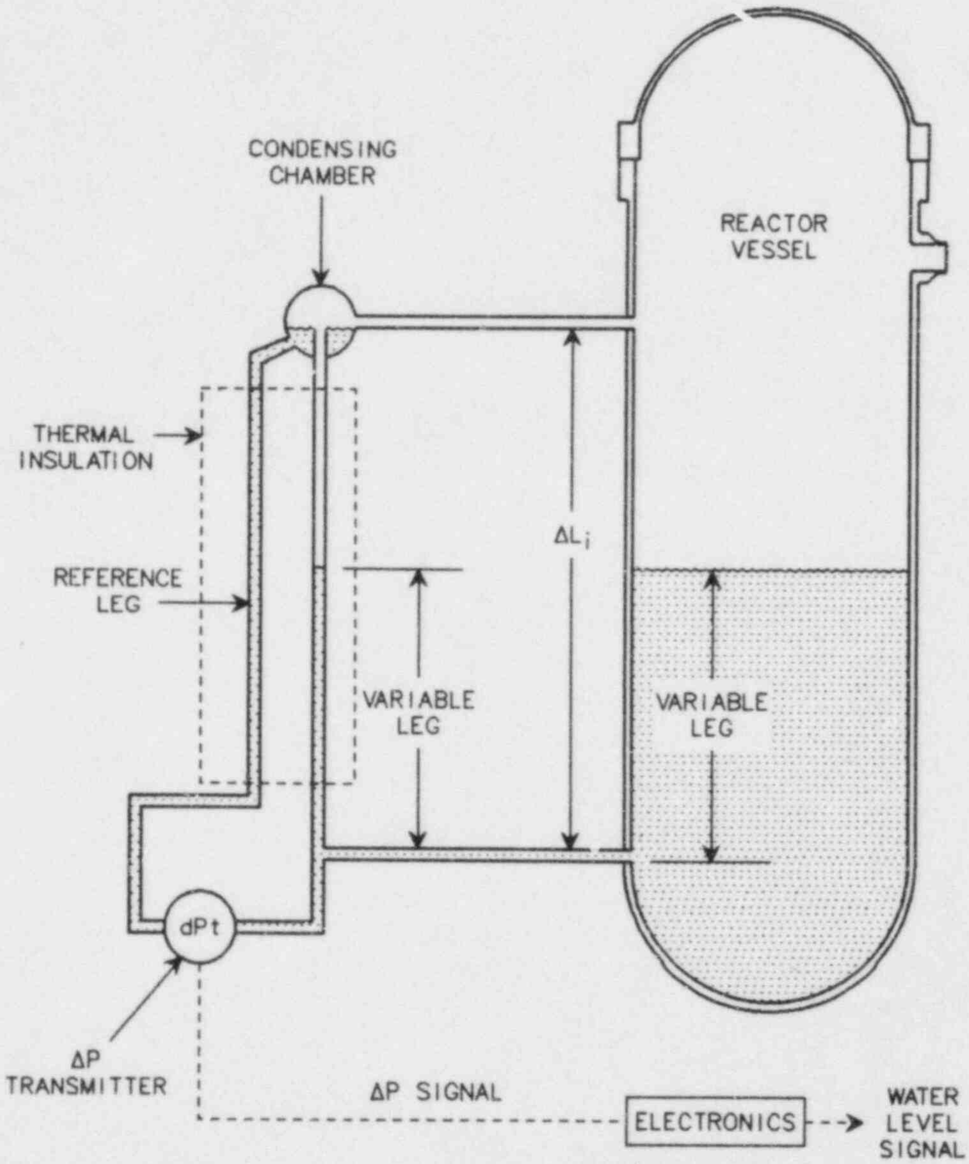

Fig. 6.2. Heated reference leg water level indication.

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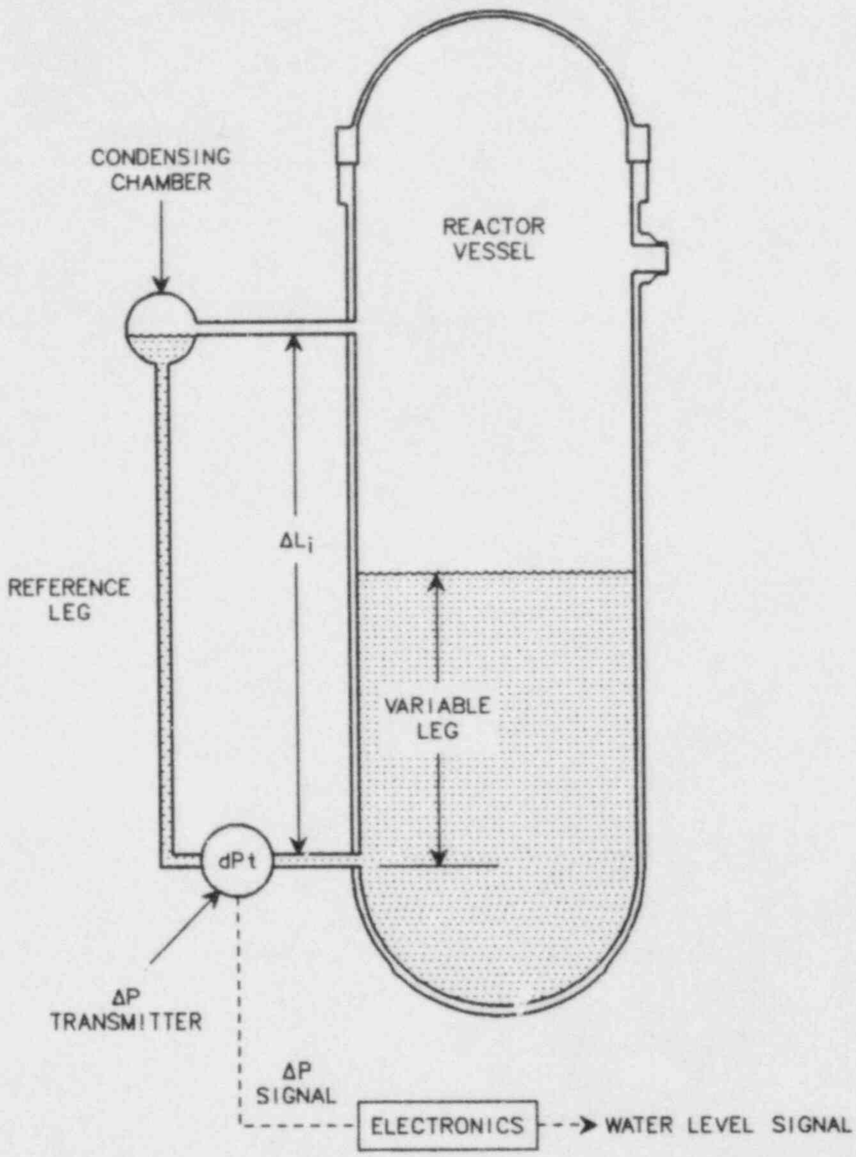

Fig. 6.3. Unheated reference leg water level indication.

7. CALCULATION OF REACTOR POWER FOR MSIV-CLOSURE-INITIATED ATWS SEQUENCES

This chapter provides details of modifications to the BWR-LTAS code made specifically for the ATWS study. The models used in BWR-LTAS to calculate core voiding and fission power are considerably simplified in comparison to the detailed, first principles models used in codes such as RAMONA, RELAP, or TRAC. To assess what differences might exist between results predicted by BWR-LTAS and the more complex codes, a comparison is presented in Appendix A of the ORNL SASA study of BWR ATWS (NUREG/CR-3470). The comparison is made between RELAP5 results (provided by the SASA team at INEL) and BWR-LACP results for the same test ATWS transient. In general, BWR-LACP is shown to be a very useful scoping tool for ATWS analyses, but it is the opinion of the authors that any major findings derived from BWR-LTAS results should be confirmed by calculations using the more sophisticated codes, i.e., TRAC, RELAP, or RAMONA, as applicable.

The models described in this chapter are active only when the user specifically selects the ATWS option.

7.1 Point Kinetics

In an ATWS accident, the reactor power is the sum of decay heat power plus fission power. The fission power is a transient function of the reactivity of the core; decay heat power is a function of the elapsed time since the attempted but unsuccessful reactor shutdown. Whenever the negative reactivity insertion brings the core subcritical, the total power in BWR-LACP is set equal to the decay heat power as soon as the calculated fission power is negligible.

The decay heat function is calculated in accordance with the ANS 5.1-1979 standard decay heat curve (with actinides). This calculation for decay heat is exactly correct only for the case of a full successful scram; however, it is a reasonable approximation for most of the ATWS studies because reactor power is quickly reduced to low levels by recirculation pump trip, reduction in reactor vessel injection, and the effect of operator actions.

$$P_{dk} = f(t, P_o)$$

where

P_{dk} = decay heat power (fraction of full power),
t = elapsed time since the scram or accident initiation (s),
P_o = initial reactor power (=100% for all cases).

The prompt-jump approximation to the point kinetics prompt neutron balance and the six delayed neutron equations are solved for fission power. These equations can be found in any nuclear analysis textbook and are not discussed here. The code input for delayed neutron properties is listed on Table 7.1. These parameters are embedded in data statements in function subprogram "PK" in the BWR-LTAS code. Four sources of reactivity are considered: fuel temperature change (via doppler coefficient), coolant void fraction change (via void coefficient), control rod insertion, and boration of reactor coolant. Each of these sources of reactivity is discussed in the following subsections.

7.1.1 Fuel temperature and reactivity feedback

A single average fuel temperature is calculated by solving the following equation

$$\frac{dT_f}{dt} = 108\ P_t - .1624\ (T_f - T_{sat})$$

where

T_f = volumetric average fuel temperature (°F),
P_t = fission plus decay heat power (fraction of full power),
T_{sat} = saturation temperature (°F), of the coolant in the core.

The numerical coefficients in the above equation take into account the fuel heat capacity and the average fuel-to-coolant heat transfer coefficient.* The coefficient of P_t is the thermal equivalent of full power, divided by the fuel heat capacity. The coefficient of $(T_f - T_{sat})$ is the effective heat transfer coefficient between the volumetric average fuel temperature and the coolant average temperature, divided by the fuel heat capacity.

The net reactivity due to a change in average fuel temperature is a function of the doppler coefficient which is corrected for change in coolant void fraction:

$$\Delta\rho_d = (T_f - 1210)\ \alpha\ (D_o + D_1 V)$$

where

$\Delta\rho_d$ = the change in total doppler reactivity ($\Delta k/k$),
T_f = average fuel temperature (°F),

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*See Section 3 of Browns Ferry FSAR for fuel weights, steady state volumetric average temperatures, and average heat flux. A value of 0.08 Btu/lb F was used for UO_2 specific heat (Nuclear Engineering Handbook, H. Etherington, Editor).

1210 = average fuel temperature (°F) at full power,
α = doppler coefficient
= $-1.58(10)^{-5}$ ($\Delta k/k/°F$),
D_o = doppler correction factor with 0% core average void
= .83,
D_1 = rate of change of doppler coefficient with core average void ($\Delta\alpha/\%$)
= $4.4(10)^{-3}$,
V = core coolant average % void (=38% at full power).

Numerical values given above for the doppler coefficient, including the effect of coolant void fraction, are from to the Browns Ferry FSAR, Figs. 3.6-5 and 3.6-6. The doppler coefficient, above, includes a weighting factor of 1.33, as recommended by NFDO-20964. This 1.33 factor accounts for the greater temperature changes in the more important parts of the fuel.

If the reactor is brought from full power to hot shutdown at 1000 psia, the fuel, on average, cools by about 660°F since the fuel temperature is very close to the coolant saturation temperature at hot shutdown. By the above formula, a negative reactivity of 0.00865 Δk/k would have to be added to compensate for the increased reactivity of the cooler fuel.

7.1.2 Void reactivity

The calculation of void reactivity is based on the average void fraction in the average channel. As explained in Sect. 7.2, the void fraction is calculated at 1 ft axial intervals up the average channel. The calculation of average void fraction weights the void in each 1 ft section with the square of the normalized axial power distribution over that section. Table 7.2 gives the axial power distribution used for the weighting. The use of flux squared weighting accounts for the greater reactivity of a given void when it is in a higher worth axial location.

The equation for void reactivity change accounts for the change in void reactivity coefficient with void fraction (void coefficient becomes more negative as void increases):

$$\Delta\rho_v = C_o(V - V_{100}) + C_1(V^2 - V_{100}^2)/2$$

where

$\Delta\rho_v$ = the change in total void reactivity ($\Delta k/k$),
V = average void fraction (%),
V_{100} = average void fraction at 100% power (%)
= 38%,
C_o = void coefficient with no voids present ($\Delta k/k/\%$)
= $-5.3(10)^{-4}$,
C_1 = derivative of void coefficient with respect to void ($\Delta k/k/(\%)^2$)
= $-.1138(10)^{-4}$.

As the reactor is brought from full power to hot shutdown, the core average void changes from 38% to 0%. By the above formula, a negative reactivity of 0.0283 Δk/k would have to be added to compensate for the increased reactivity of the core without any voids. By adding this void reactivity change to the doppler reactivity change (see subsection 7.1.1), one can estimate that a total negative reactivity of 0.0369 would bring the reactor from full power to hot shutdown. This estimate does not consider the relatively slowly changing xenon reactivity which would, during the first ~8 h after accident initiation, help to shut down the reactor. In a period of only one or two hours, the buildup of xenon would not provide a substantial fraction of the reactivity required to reach hot shutdown. Therefore, in the relatively short-term ATWS transients examined by BWR-LTAS, either the control rods or coolant boration must supply a negative reactivity of at least 0.0369 Δk/k to bring the reactor to hot shutdown.

7.1.3. Control rod reactivity

The reactivity due to manual control rod insertion in an ATWS accident would be a function not only of the physics and configuration of the reactor core, but also would depend on the reactor operators. Exercises conducted at the TVA Browns Ferry simulator showed that the proclivity of operators to perform all the manipulations necessary to maintain continuous control rod insertion during an ATWS would depend heavily on characteristics of the individual operator. Since constant attention is required to maintain continuous control rod insertion, it is assumed here that an operator could easily be diverted from the manual rod insertion task 50% of the time. Therefore, the reactivity insertion rate is based on an effective average control rod speed of 1.5 in./s instead of the nominal rod speed of 3.0 in./s. The assumption of faster sustained control rod insertion can not be assumed at present because the training of operators to the EPG procedures for ATWS is still in an early stage.

$$t_i = 144 \text{ in.}/1.5 \text{ in./s} = 96 \text{ s}$$

where

t_i = time consumed for each rod inserted (s),
144 in. = distance traveled by rod for full core insertion.

Section 3.6.5.6 of the Browns Ferry FSAR explains that a control rod worth of 10^{-3} Δk/k would be very weak. Using this to represent average rod worth, the rate of reactivity addition during periods of manual rod insertion would be

$$\dot{\rho} = -10^{-3}(\Delta k/k)/t_i \cong -10^{-5} \ \Delta k/k/s$$

where $\dot{\rho}$ is the average rate of reactivity insertion after the initiation of manual rod insertion.

7.1.4 Boron concentration and reactivity

The boron concentration in the reactor coolant depends on the rate at which the sodium pentaborate solution is pumped into the reactor vessel, the total volume of coolant in the reactor vessel, and the mixing of the boron solution within the reactor coolant. It is stated in the lesson plan for the Standby Liquid Control System provided in Volume 4 of the Browns Ferry Hot License Training Manual that there is 990 lb of boron in a volume of 4550 gal in the SLCS storage tank, and that, upon SLCS actuation, this solution is pumped into the reactor vessel at a rate of 50 gpm. Therefore, the rate of injection of boron into the reactor vessel is:

$$W_{binj} = \frac{990 \text{ lb B}}{4550 \text{ gal}} \frac{50 \text{ gal}}{\text{min}} \frac{1 \text{ min}}{60 \text{ s}} = 0.181 \text{ lb B/s} .$$

If the boron mixes perfectly within the reactor vessel, the boron concentration after SLC initiation is

$$C_b = t_i(0.181 \text{ lb B/s})/V_t$$

where

C_b = boron concentration (lb B/ft^3),
t_i = elapsed time since SLCS initiation (s),
V_t = total volume of water within the reactor vessel (ft^3).

According to TVA operations analysis engineers, a boron fraction in the coolant of 320 ppm would bring the reactor from full power to hot shutdown. Using a coolant volume of 14785 ft^3 at the normal reactor water level of 561 in., the mass of boron within the reactor vessel would be:

$$M_b = 14785 \text{ ft}^3 \frac{45.4 \text{ lb } H_2O}{\text{ft}^3} \frac{320 \text{ lb B}}{10^6 \text{ lb } H_2O} = 215 \text{ lb B.}$$

Therefore, with perfect mixing, hot shutdown could be reached after only 19.8 min of SLC injection at 50 gpm.

When the Browns Ferry specific EPGs are written, they will probably reflect a slightly more conservative hot shutdown mass of 265 lbs B, based on a boron fraction of 395 ppm boron in reactor coolant required to reach hot shutdown with a margin of 0.02 $\Delta k/k$. The corresponding SLCS injection time would be 24.4 min.

For ATWS transients with boron injection, it is necessary to calculate the boron reactivity at each instant during the transient. The method used for this is based on the TVA estimate of the hot shutdown ppm boration requirement and the boron mixing information presented in the GE BWR owners group report "Power Suppression and Boron Remixing Mechanism for General Electric Boiling Water Reactor Emergency Procedures," DAC 261, NEDC-22166, August 1983 (prepared by L. Chu).

Boron concentration is calculated for two subvolumes within the reactor vessel: (1) the volume of coolant at the bottom of the vessel lower plenum, and (2) all other coolant within the vessel. As explained in NEDC-22166, if the core inlet flow is less than 5% of its full power value, 100% of the injected boron solution sinks into the bottom of the lower plenum (i.e., the initial mixing efficiency is 0%). At 25% flow, the initial mixing efficiency climbs to 75% and it is 100% at full flow. The residence time of the heavier boron solution in the lower plenum is also dependent on the reactor coolant flow. If primary coolant flow is 4% or less, the residence time is infinite but when primary coolant flow is above about 15%, the residence time is only about 22 s. In the BWR-LACP model, the mass of boron in each of the two control volumes is calculated using the following set of equations

$$d(M_{blp})/dt = (1 - E_{im})\, W_{binj} - M_{blp}/T_{rm}$$

$$d(M_{bg})/dt = E_{im} W_{binj} + M_{blp}/T_{rm}$$

where

M_{blp} = mass of boron stratified in the bottom of the lower plenum (lb),
M_{bg} = mass of boron in general circulation, in the balance of the coolant (lb),
E_{im} = initial mixing efficiency (lb B mix/lb B injected),
T_{rm} = residence time(s) of stratified boron in the bottom of the lower plenum.

The concentration of boron in general circulation, also assumed to be the boron concentration of the coolant in the core, is

$$C_{bg} = M_{bg}/V_t$$

where

C_{bg} = boron concentration (lb/ft^3) in reactor coolant,
V_t = total coolant volume (ft^3) in the vessel.

The net boron reactivity is then

$$\rho_b = \Delta k_{hsd}\, C_{bg}/C_{bhsd}$$

where

ρ_b = total boron reactivity,
Δk_{hsd} = total reactivity that must be supplied to reach hot shutdown
= −0.0369 $\Delta k/k$ (per Sect. 7.1.2),
C_{bhsd} = boron concentration corresponding to the TVA estimate of 320 ppm B required to reach hot shutdown
= 0.0145 lb B/ft^3.

7.2. Calculation of Core Void Fraction

The ATWS routine in BWR-LTAS calculates the void fraction profile at 1 ft intervals over the length of an average fuel assembly channel. Each time the void fraction routine is called, it is given the core thermal power, the vessel pressure, the and downcomer water level and enthalpy. The core inlet flow must also be known to allow calculation of the core void profile. The void fraction routine calculates the core inlet flow by means of an iterative procedure that assumes steady-state thermohydraulic conditions over each time step.

At the beginning of the iteration, a primary coolant flow is assumed and the core void profile of the average channel is calculated at 1 ft intervals from the inlet to the outlet. Since the core is 12 ft long, this amounts to 13 node points. The average channel is a representative fuel assembly (one of a total of 764) that is assumed to generate (1/764)-th of the total core thermal power and to receive the same fraction of the total core inlet flow. The axial power distribution assumed for the average channel is specified by Table 7.2.

The conservation of energy is applied across each 1 ft axial segment to calculate the steam generation rate. If the bulk coolant temperature is below saturation, a void fraction of zero is assigned. After the coolant reaches saturation, the void fraction is calculated from the steam and water flows by the drift flux equations:

$$V = J_g/(C_o J + V_{gj})$$

$$J_g = XG/\rho_g$$

$$J = G[X/\rho_g + (1 - X)/\rho_f]$$

where

G = mass flux,
V = void fraction,

J_g = steam mass velocity,
C_o = concentration parameter = 1.0,
J = total mass velocity,
V_{gj} = drift velocity = 1.0 ft/s,
X = flow quality (steam flow/total flow),
ρ_g = saturated vapor density,
ρ_f = saturated fluid density.

The values used for the C_o and V_{gj} parameters were taken from the report "BWR Low Flow Bundle Uncovery Test and Analysis," NUREG/CR-2232, EPRI NP-1781, GEAP-24964, by D. S. Seeley and R. Muralidharan (April 1962).

After the core void profile is calculated, the unrecoverable pressure drops around the primary coolant loop are calculated. These unrecoverable losses include friction and/or form losses in the average channel unheated and heated portions, core outlet plenum, standpipes, steam separators, and jet pumps. The equations used to calculate these losses, and typical coefficients for each loss term, were taken from the EPRI report, "NATBWR; A Steady-State Model for Natural Circulation in Boiling Water Reactors," EPRI NP-2856-CCM, by J. M. Healzer and D. Abdollahian, S. Levi, Inc. (February 1983).

The only major difference between the natural circulation calculations in NATBWR and BWR-LTAS is that the natural circulation through the core bypass path (mainly the interstitial region between fuel assemblies into which the control rods insert) is neglected in BWR-LTAS. At full power conditions, about 10% of the core inlet flow bypasses the active fuel, flows up through the bypass paths, and rejoins the main flow in the core outlet plenum. Under natural circulation conditions, the direction of bypass flow can reverse, with coolant from the core outlet plenum flowing downward through the bypass paths to join with the majority of the core flow into the active fuel. The core bypass flow path was left out of BWR-LTAS because it was felt that its relatively high flow resistance would limit the bypass flow to a small fraction of the total natural circulation flow. If this circulation path were included in BWR-LTAS, the additional core flow under conditions of low vessel water level (i.e., downcomer water level near the top of the active fuel) would decrease the in-core coolant voiding and therefore lead to the prediction of higher core power. The effect would be negligible for a normal vessel water level (i.e., 12 to 18 ft above the top of active fuel) because the change in core flow would be small compared to the already substantial natural circulation.

Elevation pressure drops (gains) around the reactor vessel primary coolant natural circulation flow path are also calculated after the void fractions are calculated. At the end of each iteration, the net elevation head (elevation pressure increases minus drops) around the loop is compared to the total unrecoverable losses around the loop. The value of flow for use in the next iteration is determined by the formula:

$$W_{new} = W_{old} \sqrt{\Delta P_{te} / \Delta P_{tu\ell}}$$

where

W_{new} = total natural circulation flow to be used on the next iteration,

W_{old} = current iteration value of flow,

ΔP_{te} = net elevation pressure gain around the loop in the direction of natural circulation,

$\Delta P_{tu\ell}$ = total unrecoverable pressure losses around the natural circulation loop.

If the new flow iteration is within 0.5% of the current flow iteration, further iteration is unnecessary and control is returned to the main program.

Table 7.1 Neutron kinetics data[a]

Delayed Neutron Group	Fraction	Decay Constant (s^{-1})
1	$0.207(10)^{-3}$	0.0127
2	$0.1163(10)^{-2}$	0.0317
3	$0.1027(10)^{-2}$	0.115
4	$0.222(10)^{-2}$	0.311
5	$0.699(10)^{-3}$	1.4
6	$0.142(10)^{-3}$	3.87

[a]From "RAMONA Analysis of the Peach Bottom-2 Turbine Trip Transients," by Scandpower, Inc., EPRI Report No. NP-1869, June 1981

Table 7.2 Assumed[a] full power steady state axial power distribution

Distance from bottom of active fuel (Fraction of active fuel length)	Relative power
0.0000	0.61
0.0833	1.04
0.1666	1.16
0.2500	1.19
0.3333	1.16
0.4166	1.11
0.5000	1.09
0.5833	1.07
0.6666	1.05
0.7500	1.03
0.8333	0.92
0.9166	0.72
1.0000	0.33

[a]Applicable to end-of-cycle, equilibrium xenon full power operation.

8. SOLUTION OF SYSTEM EQUATIONS

The solution of the system equations is based on the straightforward solution of simple Euler steps. Once during each 0.5 s time step, the derivative is calculated for each variable whose value depends on the solution of a differential equation. The time step size is fixed and may not be changed by the user. The change in each such variable is the product of the time step size times the derivative, and the variable is updated each time step:

$$X_{t+0.5} = X_t + (0.5\ s) * (dX/dt)_t$$

Since the computer time used by the program is not excessive, no attempt has been made to improve upon this scheme.

9. COMPARISON TO RESULTS OF OTHER CODES

BWR-LTAS is a FORTRAN language version of its simulation language-based progenitor, BWR-LACP. Throughout the task of converting from simulation language to FORTRAN, there were no changes to the mathematical models employed to simulate the plant or plant systems, and frequent checks were made to assure that the conversion to FORTRAN did not change calculational results. Therefore, code comparison and other verification activities conducted over the four-year period of development and use of BWR-LACP are applicable to BWR-LTAS.

The use of BWR-LACP by the ORNL SASA program for detailed study of five severe accident sequences (see Chapter 1 for more historical detail) constituted a period of extensive use and testing. Various verification activities were pursued to establish the validity of conclusions based on BWR-LACP results. Comparison to hand calculations, results published in the Browns Ferry FSAR, data obtained at the Browns Ferry training simulator, and RELAP calculations have all proven useful in this respect. Experimental data has been unavailable for the long, drawn-out, beyond-design-basis accidents typically studied with BWR-LACP. The most powerful means for validation of BWR-LACP results has been that of comparison to RELAP calculations performed at INEL for the SASA program. Such comparisons were performed and documented for three of the accident sequences: Station Blackout (Ref. 9.1), Small Break LOCA Outside Primary Containment (Ref. 9.2), and ATWS (Ref. 9.3). The comparison cases were run with either identical or similar input assumptions. The closeness of comparison has ranged from surprisingly good to only approximate. In all cases, both codes predicted the same basic sequence of events. It must be kept in mind that the BWR-LACP code is intended to be a scoping tool and therefore is not required to match the RELAP results to an extremely close tolerance. The results of each comparison are summarized below.

For the Station Blackout investigation, a boil-off transient was selected for comparison of RELAP-IV and BWR-LACP predictions. This comparison is discussed in detail in Chapter 4 of Ref. 9.1. The RELAP-4/MOD7 calculation started at nominal full power plant conditions. During the first several seconds, the reactor tripped and the main steam isolation valves closed. Initially, several SRVs were required to control vessel pressure, but after about 40 seconds, one SRV was sufficient. Injection flow was zero throughout. The BWR-LACP calculation was initialized at 30 seconds because it was, at that time, programmed only for decay heat operation. The steam/water level above the core was calculated by each code. Results for vessel water level are very similar, with RELAP predicting an elapsed time of 33 minutes and BWR-LACP predicting 30 minutes prior to the initial uncovering of active fuel. Results for reactor vessel pressure control are similar although RELAP predicts a longer SRV cycle (about 60 s) than BWR-LACP (about 38 s).

For the small break LOCA outside containment investigation, a small break accident without operator action was selected for comparison of RELAP-5 and BWR-LACP results. The comparison is discussed in detail in Appendix G of Ref. 9.2. The essential features of this accident sequence, as predicted by BWR-LACP, include a gradual downward trend in vessel pressure that is overshadowed by the wide swings in pressure associated with automatic HPCI actuation cycles. After about four hours, the vessel pressure dips low enough to allow the condensate booster pumps to inject from the main condenser hotwell. Without operator control, the booster pumps quickly flood the reactor vessel and main steam lines out to the main steam isolation valves and continue to pump with the vessel pressurized almost to the pump shutoff head. Failure of all vessel water injection occurs when the hotwell becomes exhausted at five hours (water in the steamlines prevents further successful automatic HPCI operation, and all of the necessary conditions for automatic LPECCS actuations are not met). The five hour RELAP-5/MOD1-(Cycle 13) calculation verifies this behavior in every respect, including both the gradual and the short-term vessel pressure swings, and the timing and mode of the eventual failure of vessel water injection.

For the ATWS investigation, the comparison to RELAP results was done for an MSIV-closure-initiated ATWS accident. Operator actions to reduce the power level by reducing the reactor vessel water level and to depressurize the reactor vessel were allowed, but operator action to initiate the injection of sodium pentaborate solution and to manually drive in the control rods was assumed not to take place. The comparison is discussed in detail in Appendix A of Ref. 9.3.

Essential features predicted by BWR-LACP for this accident include the successful reactor power reduction by lowering of the vessel water level, followed by a fairly smooth depressurization of the reactor vessel (from about 1000 psia to about 100 psia); however, even with operator pressure/level control, BWR-LACP predicted spontaneous repressurization of the reactor vessel accompanied by power excursions.

The RELAP-5/MOD 1.6 run verified the essential features of this accident sequence, but with a slower time scale for most of the major events. For example, the RELAP calculation predicts that the first power excursion after depressurization would occur after 40 min instead of after 24 min. The difference in timing is due to the lower power levels calculated by RELAP after completion of the vessel water level reduction maneuver. Differences between RELAP and BWR-LACP in the prediction of this power level are acceptable because of the considerable uncertainty in the current knowledge of what the actual power level would be.

The RELAP/BWR-LACP comparisons have validated the use of BWR-LACP as a scoping tool to establish the essential features of BWR accident sequences. The quantitative differences noted above show that BWR-LACP is a complement to, and not a replacement for, sophisticated codes such as RELAP. Major new findings obtained by use of BWR-LACP should in the future continue to be validated by comparison to applicable results calculated by another code such as RELAP.

REFERENCES FOR CHAPTER 9

9.1 R. M. Harrington et al., *Station Blackout at Browns Ferry Unit One-Accident Sequence Analysis*, NUREG/CR-2182, ORNL/NUREG/TM-455/VI (November 1981).

9.2 S. R. Greene et al., *SBLOCA Outside Containment at Browns Ferry Unit One — Accident Sequence Analysis*, NUREG/CR-2672 (Vol. 1), ORNL/TM-8119/VI (November 1982).

9.3 S. A. Hodge and R. M. Harrington, *ATWS at Browns Ferry Unit One-Accident Sequence Analysis*, NUREG/CR-3470, ORNL/TM-8902 (July 1984).

Appendix A

REACTOR VESSEL AND PRIMARY CONTAINMENT INPUT PARAMETERS

As discussed in Chapt. 1, BWR-LTAS is intended to be used for investigation of accident sequences on a shutdown BWR 4 with Mark I containment (Browns Ferry style BWR), up to but not including permanent core uncovery and/or severe fuel damage. Accident sequences to which BWR-LTAS has been applied are discussed in Chapt. 1. For all of these accidents except ATWS, the reactor is scrammed and the MSIVs are shut. For the ATWS accident the MSIVs are shut but the reactor is not scrammed.

Tables A.1 through A.6 list input data requirements for the simulation of reactor vessel and primary containment. Tables A.1 and A.3 contain parameters that may need to be changed for each run, whereas Tables A.2 and A.4 contain parameters that will be changed less frequently. Table A.5 lists input parameters for the calculation of drywell cooler operation. Table A.6 lists parameters necessary for the simulation of reactor vessel pressure control via the SRVs. Tables 2.1 through 2.5 list input parameters for the reactor vessel injection systems.

The numbers given in Tables A.1 through A.6 and 2.1 through 2.5 comprise the default data set and will be utilized by the code unless modified by the user. All input data parameters are listed in alphabetical order in Table A.7, with their default values and indication of the table in which they are explained. Appendix B explains how to modify the input data.

Overall control parameters for the optional ATWS calculation have been included among the other input variables listed in Tables A.1 and A.2. Physical input parameters such as the doppler or void coefficients for the ATWS routines are, in general, specified by data statements in each routine; these parameters may be altered by recompiling the applicable subroutine.

Table A.1. Run Specific Parameters — Reactor Vessel

Parameter Name	Value	Units	Definition
ALEAKO	A[a]	ft^2	Initial liquid break size (=0.007 ft^2 for SDV break). (Model assumes leak outside primary containment.)
ATWSF	0.0		Set to 1.0 to signify an ATWS condition is in effect
DALEAK	A[a]	ft^2	Amount by which area of liquid line break outside primary containment increases, beginning at Tblein and ending at Tslein (=.016 ft^2 for SDV break)
FINTIM	A[a]	s	End time for the BWR-LTAS run
FTSTAB	$1(10)^6$	s	Failure time of station batteries during extended station blackout (causes failure of RCIC, HPCI, and manual mode of SRV control)
HCIO	539.0	Btu/lb	Initial core inlet enthalpy
HCST	58.0	Btu/lb	Enthalpy of condensate storage tank water
LDCO	23.67	ft	Initial downcomer water level (ft above the bottom of active fuel) (note: the BOAF is 18 ft above vessel zero)
IFLAG	0, 1, or 2		This flag may be set to 0 for a no-operator-action run, to 1 for a run with expected operator action, and to 2 for the default operator action parameters (see Table B-2)
OSBOR	250.0	s	In an ATWS event, the time elapsed before the operators initiate SLC system injection of sodium pentaborate solution.
OSCRI	250.0	s	In an ATWS event, the time elapsed before the operators initiate manual insertion of control rods.
OSDLEV	250.0	s	In an ATWS event, the time elapsed before the operators begin the vessel water level reduction maneuver.
PO	1025.0	psia	Initial reactor vessel pressure

Table A.1. (continued)

Parameter Name	Value	Units	Definition
SBOFLG	0.0 or 1.0		Set to 1.0 to signify a station blackout condition.
SDVFLG[b]	0.0 or 1.0		Set to 1.0 to signify a scram discharge volume break is in effect.
TBLEIN	A[a]	s	Elapsed time prior to beginning of the increase in liquid line break area (initial area = ALEAKO)
TSLEIN	A[a]	s	Elapsed time prior to the ending of the increase in liquid line break area
TDIESL	A[a]	s	Emergency diesel start time after station blackout
TO	30.0[c]	s	Initial time after reactor scram
WGUESS	3578.0	lb/s	Guess for initial core inlet flow

[a]A = arbitrary user input, may be set to very high (or low, if appropriate) values to entirely disable.

[b]This flag to be used in conjunction with parameters DALEAK, TBLEIN, and TSLEIN.

[c]TO = 50.0 s used for ATWS accident sequence. Time zero is defined as the time of recirculation pump trip for ATWS sequences.

Table A.2. Plant Specific Parameters — Reactor Vessel

Parameter Name	Value	Units	Definition
ACOP	234.0	ft^2	Cross-sectional free area of core outlet plenum
ACOR	137.0	ft^2	Cross-sectional free area of core in active fuel region
ART	42.3	ft^2	Total cross-sectional free area of standpipes
CPO	3293.0	MW	100% reactor power
CPREF	3293.0	MW	Core full power for reference* conditions
CPST	0.1	Btu/lb°F	Specific heat of steel (in reactor vessel internals)
DKDTCR	$-1.0\ (10)^{-5}$	(ΔK/K)/s	Reactivity insertion rate for manual control rod insertion (must be negative)
DTRVHL	404.0	°F	Overall temperature difference associated with initial reactor vessel external heat losses input parameter QRVHLO
FFLASH	0.001	(lb/Btu s)	Fraction of supersaturated water (i.e. in downcomer or lower plenum) flashed per second per Btu/lb of enthalpy in excess of saturated fluid enthalpy at the applicable pressure
FFREC	0.02	NA	Fraction of total natural circulation flow that flows into the recirculation piping
HREF	522.0	Btu/lb	Core inlet enthalpy for reference* condition
JETPMP	0.0	lb/s	Extra core flow added by recirculation pumps running 20% speed
LBOT	24.85	ft	Elevation (above the BOAF) of the bottom of the steam separators
LDCR	27.58	ft	Downcomer water level (above BOAF) for reference* condition
LHEDER	23.4	ft	Elevation of the (upper) feedwater sparger ring above the BOAF

Table A.2. (continued)

Parameter Name	Value	Units	Definition
LOP	5.58	ft	Effective length of the core outlet plenum (= volume ÷ cross-sectional area)
LRT	10.0	ft	Average length of the standpipes (from the core outlet plenum to the mid-height of the steam separators)
LTRJP	490.0	in.	Indicated vessel water level below which the recirculation pumps are automatically tripped.
MINT	$4.77(10)^5$	lbs	Mass of steel in the reactor vessel internals (includes everything inside reactor vessel except the core)
MRVST	$1.5(10)^6$	lbs	Mass of the reactor vessel
PCOR	5518.0	ft	Total core heat transfer perimeter (total heat transfer area/length of active fuel)
PRATED	1120.0	psia	Steam pressure at which the rated safety relief valve flow (WRATED) is specified
PRELR	0.32		Relative fractional power for reference* condition
PRR	1020.0	psia	Reactor vessel steam pressure for reference* condition
QRVHLO	948.0	Btu/s	Initial heat transfer rate between surface of reactor vessel (and associated piping) and the drywell (atmosphere and or walls or other equipment) when the temperature difference is DTRVHL
UAIRV	33.0	Btu/°F/s	Product of heat transfer coefficient and area for heat transfer from reactor coolant to reactor vessel
VANN	1044.0	ft^3	Free volume of downcomer annulus (i.e. outside the core shroud) between the jet pump suction and the top of the core outlet plenum (between XL2 and XL3)
VDIFF	192.0	ft^3	Total free volume of jet-pumps and diffusers below the BOAF

Table A.2. (continued)

Parameter Name	Value	Units	Definition
VFREE	13000.0	ft^3	Free volume of reactor vessel, not including: in-shroud free volume or lower plenum free volume
VJET	58.4	ft^3	Total free volume of jetpumps between the jet pump suction and the BOAF (i.e. between XL1 and XL2, defined below)
VOLP	2325.0	ft^3	Volume of the reactor vessel lower plenum outside the CRD guide and stub tubes
VREC	1150.0	ft^3	Free volume of reactor vessel recirculation piping
VSL	1811.0	ft^3	Free volume of reactor vessel between the top and bottom of the main steam line penetration (between XL5 and XL6) plus the volume of the main steam lines out to the inner main steam isolation valve
VSSOP	4435.0	ft^3	Free volume of downcomer annulus between top of the core outlet plenum and the top of the steam separators (between XL3 and XL4)
VUV1	1063.0	ft^3	Free volume of reactor vessel between the top of the steam separators and the bottom of the main steam line penetration (between XL4 and XL5)
VUV2	2031.0	ft^3	Free volume of reactor vessel between the top of the main steam penetration and the bottom of the vessel upper head (between XL6 and XL7)
WRATED	240.0	lb/s	Steam flow through fully open safety relief valve when pressure is PRATED (value given above)
WREF	9111.0	lb/s	Core inlet flow for reference* condition

Table A.2. (continued)

Parameter Name	Value	Units	Definition
WBSLC	0.183	lb/s	Boron injection rate after initiation of the SLC system
XL1	0.0	ft	Height of bottom of active fuel
XL2	8.0	ft	Height of jet pump suction inlet
XL3	17.5	ft	Height of top of core outlet plenum
XL4	32.63	ft	Height of the top of the steam separators
XL5	35.88	ft	Height of the bottom of the main steam line penetrations
XL6	37.88	ft	Height of the top of the main steam line penetrations
XL7	44.09	ft	Height of the bottom of the vessel upper head
XREF	0.133		Core outlet quality for reference* conditions

*The reference condition referred to here is a low power steady state condition used by the code during initialization to normalize the reactor vessel natural circulation calculation.

Table A.3. Run Specific Parameters — Primary Containment

Parameter Name	Value	Units	Definition
DM	29000.0	lbs	Mass of steam condensed in the suppression pool between event initiation and the beginning of the calculation
FLDWG	$3.12(10)^{-8}$	s^{-1}	Fractional leakage rate of drywell (volume fraction per unit time of the drywell atmosphere leaking to the reactor building atmosphere)
FLSPG	$1(10)^{-8}$	s^{-1}	Fractional leakage of suppression pool atmosphere
HUMDWO	20.0	%	Initial humidity of drywell atmosphere
HUMSPO	100.0	%	Initial humidity of suppression pool atmosphere
LBASE	-4.0	in.	Initial suppression pool water level (in above instrument zero)
NTRHR	4		Number of RHR coolers/pumps utilized for suppression pool cooling
OSDPC	10^{6}[a]	s	Time at which the operator starts the wetwell-to-drywell differential pressure compressor
PIDWV	10^{6}[a]	psia	Drywell pressure at which operators would initiate venting through the 2.5 in. lines leading to the SGT system
PTDWGO	15.7	psia	Initial drywell atmosphere pressure
PTSPGO	14.5	psia	Initial suppression pool atmosphere pressure
TBASE	90.0	°F	Initial suppression pool temperature
TBGRHR	14400.0	s	Elapsed time at which the operators begin pool cooling
TDMETO	145.0	°F	Initial drywell metallic heat sink temperature (primarily the ~1 in. thick drywell liner)

Table A.3. (continued)

Parameter Name	Value	Units	Definition
TPMETO	90.0	°F	Initial suppression pool metallic heat sink temperature (primarily the ~0.75 in. thick suppression pool shell).
TGDWO	145.0	°F	Initial drywell atmosphere temperature
TGSPO	90.0	°F	Initial suppression pool atmosphere temperature
WDLEAK	0.68	lb/s	Leakage flow of saturated water from the reactor vessel to the drywell

[a]Very large values (e.g., 10^6) may be used to prevent the indicated operator action.

Table A.4. Plant Specific Parameters — Primary Containment

Parameter Name	Value	Units	Definition
ADMET	18700.0	ft^2	Area for heat transfer between drywell atmosphere and metallic heat sinks (i.e. the ~1 in. thick steel drywell liner)
APMET	17000.0	ft^2	Area for heat transfer between suppression pool atmosphere and metallic heat sinks (i.e. the ~0.75 in. thick steel pool shell).
ASSPW	10860.0	ft^2	Surface area of suppression pool water
BDWSPO	2500.0	$(ft^3/s/psi)$	Coefficient for flow between drywell and suppression pool atmosphere after the vent pipe is cleared
BRDPC	2.5	ft^3/s	Bulk flow from suppression pool atmosphere to drywell atmosphere when the suppression-pool-to-drywell differential compressor is operating
BRHRP	22.2	ft^3/s	Bulk flow per RHR pump in the pool cooling mode
BSPDWO	2000.0	$(ft^3/s/psi)$	Flow coefficient for flow between the suppression pool atmosphere and the drywell atmosphere when the vacuum breakers are open
BSUMP	50.0	gpm	Reactor building basement drain sump pump flow (relevant only to accident with liquid line break outside primary containment).
CDMET	97100.0	Btu/°F	Product of mass and specific heat of metallic heat sink in contact with the drywell atmosphere (primarily the 1 in. thick steel drywell liner)
CPMET	55300.0	Btu/°F	Product of mass and specific heat of metallic heat sink in contact with the suppression pool atmosphere
DTRVHL	404.0	°F	Temperature difference corresponding to reactor vessel-to-drywell heat loss QRVHLO

A.4. (continued)

Parameter Name	Value	Units	Definition
ERHRR	0.433		Effectiveness of RHR heat exchangers for reference conditions (see parameters WSWR, WRHRR): reference heat transfer rate divided by the product of minimum mass flow, specific heat, and temperature difference (between cold and hot side inlet temperatures)
FFDVC	1.252	$(ft^3/s)(lb/mole\ R)^{0.5}$	Flow factor for choked drywell venting
FFDVUC	3.01	$(ft^3/s)(lb/mole\ R)^{0.5}$	Flow factor for unchoked drywell venting
HUDWCI	20.0	%	Humidity of the drywell consistent with the specification of reference drywell cooler performance (see also parameters TWDWCI, TADWCI, BDWCO, QDWCR)
PDCVP	1.75	psi	Pressure difference (drywell pressure - suppression pool atmosphere pressure) necessary to clear all the water from inside the drywell vent pipes and allow a flow from the drywell atmosphere to bubble through the suppression pool into the suppression pool atmosphere
PMNDPC	1.1	psid	Pressure differential below which the wetwell to drywell differential compressor will start if operating in automatic
PMXDPC	1.35	psid	Pressure differential above which the wetwell to drywell compressor will shut off if operating in automatic
QOPHLO	452.0	Btu/s	Drywell heat load (in addition to QRVHL) present during normal operation but which diminishes to zero after reactor scram
QRVHLO	948.0	Btu/s	Reference reactor vessel-to-drywell heat loss corresponding to temperature difference DTRVHL
TAUOHL	600.0	s	Time constant for decay of operating heat load QOPHLO after reactor scram

A.4. (continued)

Parameter Name	Value	Units	Definition
TSQUEN	10.0	°F	Subcooling required for the complete condensation of SRV discharge in the suppression pool (saturation temperature evaluated at T-quencher submergence depth — pool temperature)
TSTRAT	0.0	°F	Difference between bulk pool temperature and the suppression pool temperature in the neighborhood of a discharging T-quencher
TSW	95.0	°F	Temperature of the service water that circulates through the RHR coolers:
VGDW	$1.59(10)^5$	ft^3	Volume of drywell atmosphere
VTSP	$2.67(10)^5$	ft^3	Total free volume (water plus atmosphere) of the wetwell torus
WSWR	625.0	lb/s	Reference service water flow per RHR cooler (see also parameters ERHRR, WRHRR)
WRHRR	1389.0	lb/s	Reference RHR pumped flow per RHR cooler (see also parameters ERHRR and WSWR)
WRHRSW	625.0	lb/s	RHR service water flow per RHR cooler.

Table A.5. Input parameters for drywell coolers

Name	BFNP value	Explaination
Bdwc0	2800 ft^3/s	Total drywell cooler air flow
Ltrdwc	99.0 in.	Low reactor vessel water level that will cause trip of the drywell cooler blowers providing that a loss of off-site power is in effect (SBOFLG = 1.0 in Table A.1, but time > TDIESL)
Otdwc	600.0 s	Time of operator trip (if any) of drywell coolers
Ordwc	14400.0 s	Time of operator restart (if any) of drywell coolers
Ptrdwc	16.95 psia	High drywell pressure that in conjunction with low reactor vessel pressure, Pvtdwc, will cause automatic trip of the drywell cooler blowers providing that a loss of off-site power is in effect (SBOFLG = 1.0 in Table A.1, but time > TDIESL)
Pvtdwc	465 psia	Low reactor vessel pressure for trip of drywell coolers as explained above
Qdwcr	1389 Btu/s	Heat removal by drywell coolers under rated conditions: Tadwci, Twdwci, Wwdwc, and Bldwc0
Tadwci	145 F	Drywell cooler air temperature under rated conditions
Twdwci	100 F	Temperature of cooling water circulating through the drywell coolers
Tfdwc	200 F	Drywell atmosphere temperature sufficiently high to cause failure of the drywell cooler blowers
Wwdwc	143.4 lb/s	Flow of cooling water circulated through the drywell coolers by the RBCCW system

Table A.6. Input parameters for SRVs

Parameter name	Value	Units	Definition
ADSOVR	1.0 or 0.0	NA[a]	Flag set equal to 1.0 by user to override automatic ADS
LRVADS	413.5	in.	Indicated low reactor vessel water level required for ADS initiation
NSORV	0.0	NA[a]	Number of SRVs that stick open at time TSORV
OBRVD	A[b]	s	Time at which operator begins manual depressurization of the reactor vessel (accident sequence dependent)
OERVD	A[b]	s	Time at which operator ends manual depressurization of the reactor vessel
OPCHSV	60.0	s	Elapsed time between operator checks of reactor vessel pressure
OSVMAN	100.0[c]	s	Time at which operator begins manual control of SRVs
PC(1)	1052	psia	Closing pressure for automatic actuation of SRV No. 1
PC(2)	1030	psia	Closing pressure for automatic actuation of SRV No. 2
PC(3)	1042	psia	Closing pressure for automatic actuation of SRV No. 3
PC(4)	1014	psia	Closing pressure for automatic actuation of SRV No. 4
PC(5)	1023	psia	Closing pressure for automatic actuation of SRV No. 5
PC(6)	1062	psia	Closing pressure for automatic actuation of SRV No. 6
PC(7)	1042	psia	Closing pressure for automatic actuation of SRV No. 7
PC(8)	1051	psia	Closing pressure for automatic actuation of SRV No. 8
PC(9)	1072	psia	Closing pressure for automatic actuation of SRV No. 9
PC(10)	1032	psia	Closing pressure for automatic actuation of SRV No. 10

Table A.6. (continued)

Parameter name	Value	Units	Definition
PC(11)	1060	psia	Closing pressure for automatic actuation of SRV No. 11
PC(12)	1053	psia	Closing pressure for automatic actuation of SRV No. 12
PC(13)	1015	psia	Closing pressure for automatic actuation of SRV No. 13
PFODP	100.0	psia	Final target pressure for the manual depressurization initiated at time OBRVD
PO(1)	1115	psia	Opening pressure for automatic actuation of SRV No. 1
PO(2)	1118	psia	Opening pressure for automatic actuation of SRV No. 2
PO(3)	1120	psia	Opening pressure for automatic actuation of SRV No. 3
PO(4)	1125	psia	Opening pressure for automatic actuation of SRV No. 4
PO(5)	1126	psia	Opening pressure for automatic actuation of SRV No. 5
PO(6)	1130	psia	Opening pressure for automatic actuation of SRV No. 6
PO(7)	1131	psia	Opening pressure for automatic actuation of SRV No. 7
PO(8)	1135	psia	Opening pressure for automatic actuation of SRV No. 8
PO(9)	1138	psia	Opening pressure for automatic actuation of SRV No. 9
PO(10)	1140	psia	Opening pressure for automatic actuation of SRV No. 10
PO(11)	1141	psia	Opening pressure for automatic actuation of SRV No. 11
PO(12)	1145	psia	Opening pressure for automatic actuation of SRV No. 12
PO(13)	1147	psia	Opening pressure for automatic actuation of SRV No. 13
PDHOSV	20	psi	Pressure difference, (reactor vessel pressure — drywell pressure), required to hold open an SRV under ADS or manual actuation

Table A.6. (continued)

Parameter name	Value	Units	Definition
PDOCSV	50.0	psi	Pressure difference, (reactor vessel pressure — drywell pressure), required for a closed SRV to open in response to a manual or ADS SRV actuation
PDWADS	16.95	psia	High drywell pressure for automatic ADS actuation (logic seals in and will not automatically reset)
PFMOSV	110.	psia	Drywell pressure above which a manually opened SRV or one opened by ADS will fail closed due to drywell pressure approaching the control air pressure
TSORV	$1(10)^6$	s	Time at which one or more SRVs stick open

[a]NA = not applicable.

[b]A = arbitrary user input.

[c]Expected value specified for operator action.

Table A.7. Alphabetical listing of all input parameters

Parameter Name	Default value	Units	Table where defined
ACOP	234.0	ft^2	A.2
ACOR	137.0	ft^2	A.2
ADMET	18700.0	ft^2	A.4
ADSOVR	1.0	NA	A.6
ALEAKO	0.0	ft^2	A.1
APMET	17000.0	ft^2	A.4
ART	42.3	ft^2	A.2
ASSPW	10860.0	ft^2	A.4
ATWSF	0.0	NA	A.1
BDWCO	2800.0	ft^3/s	A.5
BDWSPO	2500.0	$ft^3/s/psi$	A.4
BM	20.0	gpm	2.2
BRDPC	2.5	ft^3/s	A.4
BRHRP	22.2	ft^3/s	A.4
BSPDWO	2000.0	$ft^3/s/psi$	A.4
BSUMP	50.0	gpm	A.4
CDMET	97100.0	Btu/F	A.4
CPMET	55300.0	Btu/F	A.4
CPREF	3293.0	MW	A.2
CPST	0.1	Btu/lb°F	A.2
CPO	3293.0	MW	A.2
DALEAK	0.0	ft^2	A.1
DM	29000.0	lbs	A.3
DMIN	0.2	NA	2.5
DKDTCR	$-1.0\ (10)^{-5}$	$(\Delta K/K)/s$	A.2
DTRVHL	404.0	F	A.2
DZS	21.2	ft	2.2
DZV	35.0	ft	2.2
ERHRR	0.433	NA	A.4
FFDVC	1.252	$(ft^3/s)(lb/mole\ R)^{1/2}$	A.4
FFDVUC	3.01	$(ft^3/s)(lb/mole\ R)^{1/2}$	A.4

Table A.7. (continued)

Parameter Name	Default value	Units	Table where defined
FFLASH	0.001	lb/Btu s	A.2
FFREC	0.02	NA	A.2
FINTIM	18000.0	s	A.1
FLDWG	3.12×10^{-8}	s^{-1}	A.3
FLSPG	1.0×10^{-8}	s^{-1}	A.3
FTSTAB	1.0×10^{6}	s	A.1
HCIO	539.0	Btu/lb	A.1
HCST	58.0	Btu/lb	A.1
HPCIMX	694.1	lb/s	2.1
HREF	522.0	Btu/lb	A.2
HSCSF	16.2	ft	2.4
HSRHRF	15.6	ft	2.4
HUDWCI	20.0	%	A.4
HUMDWO	20.0	%	A.3
HUMSPO	100.0	%	A.3
HO	3816.0	ft	2.2
H1	1.552	ft/gpm	2.2
H2	-0.02517	ft/gpm^2	2.2
JETPMP	0.0	lb/s	A.2
KCRDCH	0.0447	ft/gpm^2	2.2
KCRDTV	0.0507	ft/gpm^2	2.2
KPTB	0.01	ft/gpm^2	2.2
KSU	0.000516	ft/gpm^2	2.2
LBASE	-4.00	in.	A.3
LBOT	24.85	ft	A.2
LCSTSS	0.0	in.	2.1
LDCR	27.58	ft	A.2
LDCSET	560.0	in.	2.5
LDCO	23.67	ft	A.1
LHEDER	23.4	ft	A.2

Table A.7. (continued)

Parameter Name	Default value	Units	Table where defined
LHPIN	476.0	in.	2.1
LHPMIN	476.0	in.	2.1
LHPMT	540.0	in.	2.1
LHPT	582.0	in.	2.1
LLPI	413.5	in.	2.4
LLPIT	587.0	in.	2.4
LOP	5.58	ft	A.2
LRCIN	476.5	in.	2.1
LRCMIN	476.5	in.	2.1
LRCMT	582.0	in.	2.1
LRCT	582.0	in.	2.1
LRT	10.0	ft	A.2
LRVADS	413.5	in.	A.6
LSPSS	7.0	in.	2.1
LTCRD	582.0	in.	2.2
LTRDWC	99.0	in.	A.5
LTRJP	490.0	in.	A.2
MINT	477000.0	lbs	A.2
MRVST	$1.5\ (10)^6$	lbs	A.2
NCS	4.0	NA	2.4
NLPCI	4.0	NA	2.4
NSORV	0.0	NA	A.6
NTRHR	4.0	NA	A.3
OBRVD	1800.0	s	A.6
OCBPC	60.0	s	2.3
ODCS	0.0	s	2.4
ODLPCI	0.0	s	2.4
OERVD	2400.0	s	A.6

Table A.7. (continued)

Parameter Name	Default value	Units	Table where defined
OHPMAN	150.0	s	2.1
OHPT	600.0	s	2.1
OHPTR	$1 (10)^6$	s	2.1
OOCBP	$1 (10)^6$	s	2.3
OOPTB	$1 (10)^6$	s	2.2
OOTV	$1 (10)^6$	s	2.2
OPCHRC	60.0	s	2.5
OPCHSV	60.0	s	A.6
ORCMAN	150.0	s	2.1
ORCT	7600.0	s	2.1
ORCTR	10800.0	s	2.1
ORDWC	14400.0	s	A.5
OSBOR	250.0	s	A.1
OSCRI	250.0	s	A.1
OSCS	$1 (10)^6$	s	2.4
OSDLEV	250.0	s	A.1
OSDPC	$1 (10)^6$	s	A.3
OSLPCI	$1 (10)^6$	s	2.4
OSSCRD	$1 (10)^6$	s	2.2
OSVMAN	100.0	s	A.6
OTCBP	0.0	s	2.3
OTCRDP	$1 (10)^6$	s	2.2
OTDWC	600.0	s	A.5
PC	Various	psia	A.6
PCOR	5518.0	ft	A.2
PDCVP	1.75	psi	A.4
PDHOSV	20.0	psi	A.6
PDOCSV	50.0	psi	A.6
PDLPI	16.95	psia	2.4
PDWADS	16.95	psia	A.6

Table A.7. (continued)

Parameter Name	Default value	Units	Table where defined
PEHPIS	165.0	psia	2.1
PERCT	40.0	psia	2.1
PFMOSV	110.0	psia	A.6
PHPIN	16.5	psia	2.1
PHPIS	115.0	psia	2.1
PIDWV	$1\ (10)^6$	psia	A.3
PMNDPC	1.1	psi	A.4
PMXDPC	1.35	psi	A.4
PO	Several	psia	A.6
PRATED	1120.0	psia	A.2
PRCIS	65.0	psia	2.1
PRELR	0.32	NA	A.2
PRR	1020.0	psia	A.2
PTDWGO	15.7	psia	A.3
PTRDWC	16.95	psia	A.5
PTSPGO	14.5	psia	A.3
PVLPI	480.0	psia	2.4
PVLPIV	430.0	psia	2.4
PVTDWC	465.0	psia	A.5
PO	1025.0	psi	A.1
QDWCR	1389.0	Btu/s	A.5
QOPHLO	452.0	Btu/s	A.4
QRVHLO	948.0	Btu/s	A.2
RCICMX	83.3	lb/s	2.1
SBOFLG	0.0	NA	A.1
SDVFLG	0.0	NA	A.1
TADWCI	145.0	°F	A.5
TAUOHL	600.0	s	A.4
TBASE	90.0	°F	A.3
TBGRHR	14400.0	s	A.3
TBLEIN	0.0	s	A.1
TCFAIL	30.0	s	2.4

Table A.7. (continued)

Parameter Name	Default value	Units	Table where defined
TDIESL	$1\ (10)^6$	s	A.1
TDMETO	145.0	°F	A.3
TFDWC	200.0	°F	A.5
TGDWO	145.0	°F	A.3
TGSPO	90.0	°F	A.3
THPIS	200.0	°F	2.1
TPMETO	90.0	°F	A.3
TRCF	190.0	°F	2.1
TRCIS	200.0	°F	2.1
TSLC	$1\ (10)^6$	s	2.2
TSLEIN	$1\ (10)^6$	s	A.1
TSQUEN	10.0	°F	A.4
TSORV	$1\ (10)^6$	s	A.6
TSTRAT	0.0	°F	A.4
TSW	95.0	°F	A.4
TWDWCI	100.0	°F	A.5
TO	30.0	s	A.1
UAIRV	33.0	Btu/°F/s	A.2
VANN	1044.0	ft^3	A.2
VDIFF	192.0	ft^3	A.2
VFREE	13000.0	ft^3	A.2
VGDW	$1.59\ (10)^5$	ft^3	A.4
VJET	58.4	ft^3	A.2
VOLP	2325.0	ft^3	A.2
VREC	1150.0	ft^3	A.2
VSL	1811.0	ft^3	A.2
VSSOP	4435.0	ft^3	A.2
VTSP	$2.67\ (10)^5$	ft^3	A.4
VUV1	1063.0	ft^3	A.2
VUV2	2031.0	ft^3	A.2

Table A.7. (continued)

Parameter Name	Default value	Units	Table where defined
WBSLC	0.183	lb/s	A.2
WDLEAK	0.68	lb/s	A.3
WGUESS	3578.0	lb/s	A.1
WRATED	240.0	lb/s	A.2
WREF	9111.0	lb/s	A.2
WRHRR	1389.0	lb/s	A.4
WRHRSW	625.0	lb/s	A.5
WSWR	625.0	lb/s	A.4
WTEHPO	51.15	lb/s	2.1
WTERCO	7.97	lb/s	2.1
WWDWC	143.4	lb/s	A.5
XL1	0.0	ft	A.2
XL2	8.0	ft	A.2
XL3	17.5	ft	A.2
XL4	32.63	ft	A.2
XL5	35.88	ft	A.2
XL6	37.88	ft	A.2
XL7	44.09	ft	A.2
XREF	0.133	NA	A.2

Appendix B

SAMPLE INPUT AND OUTPUT

The purpose of this appendix is not only to present the input and output from a sample use of BWR-LTAS, but also to instruct potential users how to run the code. It is assumed that the user is acquainted with FORTRAN in general and the use of BLOCK DATA in particular.

In order to modify input parameters for a BWR-LTAS run, it is necessary to recompile at least the INOUT subroutine. All the input parameters are initialized with default values in a single alphabetically arranged BLOCK DATA subprogram; INOUT obtains access to these parameters via labeled commons. Any or all of the input parameters may be changed by adding assignment statements to INOUT. In addition, by setting the flag variable, IFLAG, to 0, 1, or 2 the user may initialize a subset of the input data for, respectively, no operator action, expected operator action, or operator action for the demonstration transient that was used for code checkout. INOUT prints a namelist of all the input parameters both before (default) and after the input data changes. In addition, it prints a subset of the input data in a system summary of parameters (listed on Table B-2) that control the injection systems, the SRVs, and the containment cooling systems.

Table B-1 outlines the major steps in the operation of the MAIN program and INOUT. Besides the selection of preselected subsets of input data by IFLAG, the user may set flags ATWSF, SBOFLG, and SDVFLG to invoke three preselected accidents (see Table B-3). Random failure of individual systems may be simulated by including an assignment statement in INOUT to change the appropriate variable. For example, to fail the RCIC system, the input parameter ORCT can be used to cause the RCIC system to be tripped after ORCT elapsed seconds.

The end time of the run, FINTIM, and the output print interval, PINTVL, can be modified by assignment statements in INOUT.

During execution, the program updates the value of all program variables after each 0.5 s time step. After PINTVL seconds have elapsed, a preselected list of key variables is written to Unit 6, for hard copy, and, if desired, to Unit 20, which may be designated by site-specific job control language to be either punch cards or magnetic disc storage. Table B-4 defines the output variables that are typically written to Unit 6 and/or Unit 20. The data stored by writing to Unit 20 would typically be used separately for plotting purposes. Another output feature is available to give a very detailed picture of the calculation at a specific instant. Whenever the DEBUG flag is set to 1.0 in MAIN, the NURV, POOL, and CONT subroutines will each print a detailed namelist of variables. The user may control the number and time of DEBUG printouts by "if" statements starting three lines after statement number 600 in MAIN. For example, the statement "IF (TIME.EQ.1000.) DEBUG = 1.0" will produce a DEBUG printout after 1000 s.

A hypothetical Station Blackout case was chosen for the sample transient. The output is included as Table B.5; it includes both the normal column output printed every 10 s, as well as a DEBUG print at 3600 s. To run this case it was necessary to add the following assignment statements to the INOUT subroutine:

```
   IFLAG = 1.0      (Select best-estimate operator actions)
  SBOFLG = 1.0      (Station Blackout Flag)
 FTSTAB = 5400.0    (Time of station battery failure)
  OBRVD = 3600.0    (Begin time for reactor vessel depressurization)
  OERVD = 9000.0    (End time for reactor vessel depressurization)
FINTIM = 10800.0    (Desired end time of run)
```

Use of the Station Blackout Flag SBOFLG automatically changes the value of the parameters LHPMIN, LRCMIN, LTCRD, ODCS, ODLPCI, OHPT, ORCMAN, ORCT, ORCTR, ORDWC, OTCBP, and TBGRHR. The values used for the Station Blackout calculations are listed in the "Modified Input Data" section of the output (Table B.5). The DEBUG variable list was selected for printing by inserting the following statement three lines after Statement 600 in MAIN: "IF (TIME.EQ.3600.) DEBUG = 1.0".

This case is not intended to represent a realistic station blackout accident sequence. The battery failure time of 1.5 h (5400 s) was in this case chosen to minimize the number of pages of printed output. The battery failure time for Browns Ferry has been estimated by TVA to exceed 6 h.

The manual depressurization initiated at OBRVD = 3600 s is a typical and desirable operator action. The normal shutdown depressurization rate of 100°F/h was chosen by setting OERVD = 9000 s. The target final pressure for the depressurization, 100 psia, was determined by choosing IFLAG = 1.0 (best estimate operator actions). The program then automatically assumes that the target low pressure is 100 psia.

Due to the battery failure at 1.5 h, the RCIC and HPCI systems and manual control of the SRVs fail; the reactor vessel repressurizes, and vessel water level begins to steadily decrease. At the end of the run the downcomer water level is within inches of the level of the top of the active fuel.

Table B.1. Outline of BWR-LTAS execution sequence

MAIN Program

M.1 Call subroutine INOUT

Subroutine INOUT

I.1 Print the default input data
Call to NAMOUT provides a namelist print of all parameters

I.2 Option to modify subset of default input data applicable to plant injection, cooling systems (see Table B-2).
IFLAG = 0: No operator action, automatic control only
IFLAG = 1: Best estimate operator actions and control setpoints
IFLAG = 2: Values used for demonstration transient

I.3 Select Accident Flags (Default = 0.0) (see Table B-3)
ATWSF = 1.0: MSIV-closure-initiated ATWS
SBOFLG = 1.0: Station blackout
SDVFLG = 1.0: Scram discharge volume break

I.4 Modify other parameters, if desired
FINTIM, PINTVL, any other block data parameter

I.5 Print modified input data
System summary for each injection system, the SRVs, and containment cooling system. Call to NAMOUT for namelist print of all input parameters.

I.6 Return to MAIN

M.2 Initialize all transient variables

M.3 (Begin transient calculation)

M.4 Set parameter DEBU to 1.0 at selected time(s) (=0 otherwise) to cause subroutines NURV, POOL, and CONT to print detailed namelists

M.5 Calculate value of all system variables at the end of the 0.5 s time step by calling subroutines REALG2, XLIND, XSRV, RIKSEY, HIPSEY, LPECCS, NURV, CRODHY, CBOOST, WELL, POOL, and CONT

M.6 Write output variables (Table B-4) to UNITS 6 and 20
if PINTVL seconds have elapsed

M.7 Return to step M.3 unless elapsed time exceeds FINTIM

Table B.2. Summary of parameters that control automatic and manual control actions, and system failures for injection systems, SRVs, and containment cooling systems

System	Parameter name	Standard Parameter Values			Units
		IFLAG=0	IFLAG=1	IFLAG=2	
HPCI	LHPMIN	0*	490	476	in.
HPCI	LHPMT	1.E6*	540	540	in.
HPCI	OHPT	1.E6	1.E6	600	s
HPCI	OHPR	1.E6	1.E6	1.E6	s
HPCI	OHPMAN	1.E6	150	150	s
HPCI	PHPIN	16.5	16.5	16.5	psia
HPCI	LHPIN	476	476	476	in.
HPCI	LHPT	582	582	582	in.
HPCI	PHPIS	115	115	115	psia
HPCI	PEHPIS	165	165	165	psia
HPCI	THPIS	200	200	200	°F
HPCI	LSPSS	7	7	7	in.
HPCI	LCSTSS	0	0	0	ft
RCIC	LRCMT	1.E6	570	582	in.
RCIC	LRCMIN	0	520	476.5	in.
RCIC	ORCT	1.E6	1.E6	7600	s
RCIC	ORCTR	1.E6	1.E6	10800	s
RCIC	ORCMAN	1.E6	150	150	s
RCIC	LDCSET	560	560	560	in.
RCIC	OPCHRC	60	60	60	s
RCIC	DMIN	0.2	0.2	0.2	
RCIC	LRCT	582	582	582	in.
RCIC	LRCIN	476.5	476.5	476.5	in.
RCIC	PERCT	40	40	40	psia
RCIC	PRCIS	65	65	65	psia
RCIC	TRCIS	200	200	200	°F
RCIC	TRCF	190	190	190	°F
CRDHS	OSSCRD	1.E6	1.E6	1.E6	s
CRDHS	LTCRD	1.E6	582	582	in.
CRDHS	OOTV	1.E6	1.E6	1.E6	s
CRDHS	OOPTB	1.E6	1.E6	1.E6	s
CRDHS	OTCRDP	1.E6	1.E6	1.E6	s
CP/CBP	OCBPC	60	1.E6	60	s
CP/CBP	OOCBP	1.E6	1.E6	1.E6	s
CP/CBP	OTCBP	1.E6	120	1.E6	s
LPECCS	OSCS	1.E6	1.E6	1.E6	s
LPECCS	OSLPCI	1.E6	1.E6	1.E6	s
LPECCS	ODCS	1.E6	1.E6	0	s
LPECCS	ODLPCI	1.E6	1.E6	0	s
LPECCS	LLPIT	1.E6	587	587	in.
LPECCS	LLPI	413.5	413.5	413.5	in.

Table B.2. (continued)

System	Parameter name	Standard Parameter Values			Units
		IFLAG=0	IFLAG=1	IFLAG=2	
LPECCS	PVLPI	480	480	480	psia
LPECCS	PDLPI	16.95	16.95	16.95	psia
LPECCS	PVLPIV	480	480	480	psia
LPECCS	HSRHRF	15.6	15.6	15.6	ft
LPECCS	HSCSF	16.2	16.2	16.2	ft
LPECCS	NCS	4	4	4	
LPECCS	NLPCI	4	4	4	
LPECCS	TCFAIL	30	30	30	s
SRV	ADSOVR	0	1	1	
SRV	OBRVD	1.E6	1800	1800	s
SRV	OERVD	1.E6	10800	2400	s
SRV	OPCHSV	60	60	60	s
SRV	OSVMAN	1.E6	100	100	s
SRV	LRVADS	414	414	414	in.
SRV	PDWADS	17	17	17	psia
SRV	NSORV	0	0	0	
SRV	PDHOSV	20	20	20	psid
SRV	PDOCSV	50	50	50	psid
SRV	PFMOSV	110	110	110	psia
SRV	TSORV	1.E6	1.E6	150	s
Primary	PIDWV	1.E6	16.5	1.E6	psia
containment	TBGRHR	1.E6	1800	14400	s
	OTDWC	1.E6	1.E6	600	s
	ORDWC	1.E6	1.E6	14400	s

Note: These parameters are defined in the body of the report in Tables 2.1-2.5, and Tables A.1—A.6, and also in the "system summary" part of a typical code output (Table B.5, this appendix).

*Values of 1.E6 or 0.0, as appropriate, may be used to prevent a potential operator action.

Table B.3. Outline of accident flags and their associated system effects

Flag	Definition	Effects
ATWSF	ATWS	(1) Initialize reactor at 28% power (2) Calculate prompt power, add to decay heat power (3) Select X = 1.0 in subroutine XSRV (decreased operator sensitivity to RV pressure fluctuations) (4) Lower LDCSET from 560 in. to 380 in. at time > OSDLEV (5) Begin control rod insertion at time > OSCRI (6) Begin boration at time > OSBOR
SBOFLG	Station blackout	(1) Fail all pumps and blowers that depend on AC power, until time TDIESL
SDVFLG	Scram discharge volume break	(1) Begin leak from reactor vessel to reactor building at time 0.0 (2) Leak area increases to ALEAKO + DALEAK between times TBLEIN and TSLEIN (3) CRD hydraulic system injection zeroed.

Table B.4. Definition of typical output variables

Variable	Definition
TIME	Time elapsed (s) since T0 (T0 = the initial time after reactor scram that calculations begin)
PREL	Reactor thermal power: heat transfer from the fuel to coolant as fraction of full power (3293.0 MW)
LDCVZ	Actual collapsed reactor vessel water level (in. > vessel zero)
LYAR[a]	Reactor vessel water level, as measured via the Emergency Systems instrument (in > vessel zero)
LSHRD[a]	Reactor vessel water level, as measured via the Post-Accident Flooding instrument (in > vessel zero)
WINJ	Total reactor vessel injection from RCIC, HPCI, CRD hydraulic system, and condensate/condensate booster pumps (lb/s)
P	Reactor vessel pressure (psia)
WTOST	Total steam flow from reactor vessel liquid and two-phase regions to the reactor vessel steam space
WSTC	Total steam flow (SRV + HPCI, RCIC turbine exhaust) from reactor vessel to suppression pool (lb/s)
LOGREL	The number of open SRVs
TGDW	Temperature (°F) of the drywell atmosphere
PTDWG	Total pressure (psia) of drywell atmosphere
LWSPAV	Suppression pool water level (inches above instrument zero)
TWSPAV	Suppression pool bulk temperature (°F)
WECC	Total reactor vessel injection from the Core Spray and LPCI systems

[a]LDCVZ is used for internal code calculations. LYAR differs from LDCVZ when the reactor vessel is depressurized because of instrument calibration and has maximum value of 588 in., minimum value of 373 in. LSHRD differs from LDCVZ when the reactor vessel is pressurized and has maximum value of 560 in., minimum value of 260 in. (see Chap. 6).

Table B.5. Listing of BWR-LTAS output for a sample case

```
                 DEFAULT INPUT DATA
                 ------------------
&NAM1
ACOP=  234.000000    ,ACUR=  137.000000    ,ADMET=  18700.0000    ,ADSOVR=  1.00000000    ,ALEAKO= 0.000000000E+00,APMET=
  17000.0000    ,ART=  42.3000031    ,ASSPW=  10860.0000    ,ATWSF= 0.000000000E+00,BDWCO=  2800.00000    ,BDWSPC=  2500.00000    ,
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DM=  29000.0000    ,DMIA= 0.199999988    ,DTRVHL=  404.000000    ,DZS=  21.1599969    ,DZV=  35.0000000    ,ERHRR= 0.433000028    ,
FFLASH= 0.399999931E-03,FFREC= 0.199999996E-01,FINTIM=  18000.0000    ,FLDWG= 0.311999990E-07,FLSPG= 0.100000008E-07,FTSTAB=
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NTRHR=  4.00000000    ,OBRVD=  1800.00000    ,OCBPC=  60.0000000    ,ODCS= 0.000000000E+00,ODLPCI= 0.000000000E+00,CERVD=
  2400.00000    ,OHPMAN=  150.000000    ,OHPT=  600.000000    ,OHPTR=  1000000.00    ,OOCRP=  1000000.00    ,OOPTB=  1000000.00    ,
OOIV=  1000000.00    ,OPCHRC=  60.0000000    ,OPCHSV=  60.0000000    ,ORCMAN=  150.000000    ,ORCT=  7600.00000    ,ORCTR=
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  16.9499969    ,PFCDP=  100.000000    ,FFDVC=  1.25199986    ,FFDVUC=  3.01000023    ,PMXDPC=  1.35000038    ,PMNDPC=
  1.10000038    ,TAUCHL=  500.000000
&END
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Table B.5 (continued)

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                         MODIFIED INPUT DATA
                         -------------------
STATION BLACKOUT IN EFFECT UNTIL 1000000. ELAPSED SECONDS.  BATTERIES FAIL AFTER    5400. ELAPSED SECONDS.
THIS IS A TYPICAL OPERATOR ACTION RUN.

                         RCIC SYSTEM SUMMARY
OPERATOR ACTIONS:
                LRCMT       570.00  RV WATER LEVEL (IN. ABOVE VESSEL ZERO) FOR MANUAL TURBINE TRIP
                LRCMIN      520.00  RV WATER LEVEL FOR MANUAL INITIATION OF RCIC FLOW
                ORCT       1000000. TIME FOR MANUAL TURBINE TRIP
                ORCTR      1000000. TIME FOR RESETTING MANUAL TURBINE TRIP
                ORCMAN          30. TIME TO BEGIN MANUAL INCREMENTAL RCIC CONTROL
                LOCSET         560. SETPOINT FOR INCREMENTAL MANUAL CONTROL OF RCIC FLOW
                OPCHRC          60. TIME INTERVAL BETWEEN OPER. CHECKS OF THE RV WATER LEVEL FOR INCREMENTAL FLOW CONTROL
                CMIN           0.2  MIN. DEMANDED FLOW FRACTION ALLOWED FOR MANUAL CONTROL
AUTOMATIC CONTROL:
                LRCT           582. RV LEVEL (INCHES) FOR AUTO. TURBINE TRIP
                LRCIN        476.5  RV LEVEL FOR AUTO. INITIATION
                PERCT           40. TURBINE EXHAUST PRESSURE (= PSP PRESSURE) FOR AUTO. TURBINE TRIP
                PRCIS           65. RV PRESSURE FOR AUTO. TURBINE STEAM SUPPLY ISOLATION
                TRCIS          200. TURBINE STEAM SUPPLY LINE SPACE TEMP. FOR AUTO. TURBINE STEAM SUPPLY ISOLATION
SYSTEM FAILURES:
                TRCF           190. PSP TEMP FOR RCIC/HPCI FAILURE

                         HPCI SYSTEM SUMMARY
OPERATOR ACTIONS:
                LHPMIN      490.00  RV WATER LEVEL FOR MANUAL INITIATION OF HPCI FLOW
                LHPMT       540.00  RV WATER LEVEL FOR MANUAL TURBINE TRIP
                OHPT           400. TIME FOR MANUAL TURBINE TRIP
                OHPTR      1000000. TIME FOR RESET OF MANUAL TRIP
                OHPMAN         150. TIME TO BEGIN MANUAL HPCI CONTROL
AUTOMATIC CONTROL:
                PHPIN         16.5  PRIMARY CONTAINMENT PRESS. FOR AUTO. HPCI INITIATION
                LHPIN          476. RV WATER LEVEL FOR AUTO. HPCI START
                LHPT           582. RV WATER LEVEL FOR AUTO. TURBINE TRIP
                PHPIS          115. RV PRESSURE FOR AUTO. TURBINE STEAM SUPPLY ISOLATION
                PEHPIS         165. TURBINE EXHAUST PRESSURE (=PSP PRESSURE) FOR AUTO. ISOLATION
                THPIS          200. TURBINE STEAM LINE SPACE TEMP. FOR AUTO. ISOLATION
                LSPSS            7. INDICATED PSP LEVEL FOR AUTO. SHIFT OF HPCI SUCTION FROM THE CST TO THE PSP
                LCSTSS           0. CST LEVEL FOR AUTO. SHIFT OF HPCI SUCTION FROM THE CST TO THE PSP
SYSTEM FAILURES:
                TRCF           190. PSP TEMP. FOR RCIC/HPCI FAILURE

                         CRD HYDRAULIC SYSTEM SUMMARY
OPERATOR ACTIONS:
                OSSCRD     1000000. TIME FOR OPERATOR TO START SECOND CRD PUMP
                LTCRD          581. INDICATED RV WATER LEVEL ABOVE WHICH OPERATORS THROTTLE THE CRD PUMP DISCH. VALVE
                OCTV       1000000. TIME FOR OPERATOR TO OPEN CRD PUMP DISCH. VALVE
                OOPTV      1000000. TIME FOR OPERATOR TO OPEN THE PUMP TEST BYPASS VALVE
                OTCRDP     1000000. TIME FOR OPERATOR TO TRIP ALL CRD PUMPS

                         CP/CBP SUMMARY
OPERATOR ACTIONS:
                OCBPC           60. TIME INTERVAL BETWEEN THE PERIODIC OPERATOR CHECKS OF RV WATER LEVEL FOR FLOW CONTROL
                OOCBP      1000000. TIME WHEN OPERATOR CONTROL OF CBP FLOW BEGINS
                OTCBP          120. TIME WHEN OPERATORS TRIP THE CPS AND CBPS

                         LP INJECTION SYSTEM SUMMARY
OPERATOR ACTIONS:
                OSCS       1000000. TIME FOR OPERATOR TO START CORE SPRAY PUMPS
                OSLPCI     1000000. TIME FOR OPERATOR TO START RHR PUMPS FOR LPCI
                ODCS       1000000. TIME FOR OPERATOR TO DISABLE AUTO. OPER. OF CS SYSTEM
                ODLPCI     1000000. TIME FOR OPERATOR TO DISABLE THE AUTO. OPERATION OF THE LPCI MODE OF RHR
                LCPIT        587.0  RV WATER LEVEL ABOVE WHICH THE OPERATOR WOULD DISCONTINUELPI TO PREVENT OVERFILLING RV
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Table B.5 (continued)

AUTOMATIC CONTROL:			
	LLPI	413.5	RV WATER LEVEL FOR AUTO. START OF CS AND RHR PUMPS
	PVLPI	480.	LOW PV PRESS. (WITH HI DW PRESS) FOR AUTO START OF CS AND RHR PUMPS
	PDLPI	16.95	HI DRYWELL PRESS. (WITH LO PV PRESS.) FOR CS AND RHR START
	PVLPIV	480.	LOW PV PRESS. PERMITS INJ. VALVES TO OPEN AFTER CS AND/OR RHR AUTO. START
SYSTEM FAILURES:			
	HSRHRF	15.6	THRESHOLD NPSH FOR FAILURE OF RHR PUMP
	HSCSF	16.2	THRESHOLD NPSH FOR FAILURE OF CORE SPRAY PUMP
	NCS	4.	NUMBER OF OPERABLE CORE SPRAY PUMPS
	NLPCI	4.	NUMBER OF OPERABLE RHR PUMPS
	TCFAIL	30.	TIME AN RHR PUMP OR CS PUMP MUST OPERATE BELOW THE THRESHOLD NPSH TO CAUSE PUMP FAILURE
	SRV SUMMARY		
OPERATOR ACTIONS:			
	ADSOVR	1.	FLAG SET EQUAL TO 1.0 BY USER TO OVERRIDE AUTO. ADS
	OBRVD	3600.	TIME OPER. BEGINS MANUAL DEPRESS. OF RV
	OERVD	9000.	TIME OPER. ENDS MANUAL DEPRESS. OF RV
	OPCHSV	60.	ELAPSED TIME BETWEEN OPER. CHECKS OF RV PRESSURE
	OSVMAN	100.	TIME AT WHICH OPER. BEGINS MANUAL CONTROL OF SRVS
	PDCOP	100.	TARGET RV PRESS AFTER DEPRESS. (AT TIME OERVD)
AUTOMATIC CONTROL:			
	LRVADS	414.	INDICATED LOW RV WATER LEVEL REQD. FOR ADS INITIATION
	PDWADS	16.95	HIGH DW PRESS FOR AUTO. ADS ACTUATION (NO AUTO. RESET)
	PC(1)	1052.	CLOSING PRESSURE FOR AUTO. ACTUATION OF SRV NO. 1
	PC(2)	1030.	CLOSING PRESSURE FOR AUTO. ACTUATION OF SRV NO. 2
	PC(3)	1042.	CLOSING PRESSURE FOR AUTO. ACTUATION OF SRV NO. 3
	PC(4)	1014.	CLOSING PRESSURE FOR AUTO. ACTUATION OF SRV NO. 4
	PC(5)	1023.	CLOSING PRESSURE FOR AUTO. ACTUATION OF SRV NO. 5
	PC(6)	1062.	CLOSING PRESSURE FOR AUTO. ACTUATION OF SRV NO. 6
	PC(7)	1042.	CLOSING PRESSURE FOR AUTO. ACTUATION OF SRV NO. 7
	PC(8)	1051.	CLOSING PRESSURE FOR AUTO. ACTUATION OF SRV NO. 8
	PC(9)	1072.	CLOSING PRESSURE FOR AUTO. ACTUATION OF SRV NO. 9
	PC(10)	1032.	CLOSING PRESSURE FOR AUTO. ACTUATION OF SRV NO. 10
	PC(11)	1060.	CLOSING PRESSURE FOR AUTO. ACTUATION OF SRV NO. 11
	PC(12)	1053.	CLOSING PRESSURE FOR AUTO. ACTUATION OF SRV NO. 12
	PC(13)	1015.	CLOSING PRESSURE FOR AUTO. ACTUATION OF SRV NO. 13
	PO(1)	1115.	OPENING PRESSURE FOR AUTO. ACTUATION OF SRV NO. 1
	PO(2)	1118.	OPENING PRESSURE FOR AUTO. ACTUATION OF SRV NO. 2
	PO(3)	1120.	OPENING PRESSURE FOR AUTO. ACTUATION OF SRV NO. 3
	PO(4)	1125.	OPENING PRESSURE FOR AUTO. ACTUATION OF SRV NO. 4
	PO(5)	1126.	OPENING PRESSURE FOR AUTO. ACTUATION OF SRV NO. 5
	PO(6)	1130.	OPENING PRESSURE FOR AUTO. ACTUATION OF SRV NO. 6
	PO(7)	1131.	OPENING PRESSURE FOR AUTO. ACTUATION OF SRV NO. 7
	PO(8)	1135.	OPENING PRESSURE FOR AUTO. ACTUATION OF SRV NO. 8
	PO(9)	1138.	OPENING PRESSURE FOR AUTO. ACTUATION OF SRV NO. 9
	PO(10)	1140.	OPENING PRESSURE FOR AUTO. ACTUATION OF SRV NO. 10
	PO(11)	1141.	OPENING PRESSURE FOR AUTO. ACTUATION OF SRV NO. 11
	PO(12)	1145.	OPENING PRESSURE FOR AUTO. ACTUATION OF SRV NO. 12
	PO(13)	1147.	OPENING PRESSURE FOR AUTO. ACTUATION OF SRV NO. 13
SYSTEM FAILURES:			
	NSORV	0.	NO. SRVS THAT STICK OPEN AT TIME TSORV
	PDHOSV	20.	DELTA P (RV - DW PRESS.) REQD. TO HOLD SRV OPEN
	PDCCSV	50.	DELTA P (RV - DW PRESS.) REQD. FOR CLOSED SRV TO OPEN
	PFMOSV	110.	DW PRESS ABOVE WHICH A MANUALLY OPENED SRV OR ONE OPENED BY ADS WILL FAIL CLOSED
	TSORV	1000000.	TIME AT WHICH ONE OR MORE SRVS STICK OPEN
	PRIMARY CONTAINMENT SYSTEM SUMMARY		
OPERATOR ACTIONS:			
	PIDWV	1000000.0	DW PRESS. AT WHICH OPER. INIT. VENTING TO SGT SYS.
	TBGRHR	1800.	TIME AT WHICH OPERATORS BEGIN POOL COOLING
	OTDWC	1000000.	TIME OPERATOR TRIP DRYWELL COOLERS
	ORDWC	1000000.	TIME OPERATOR RESTART DRYWELL COOLERS

Table B.5 (continued)

```
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ACOP=  234.000000    ,ACOR=  137.000000    ,ACMET=  18700.0000    ,ADSOVR=  1.00000000    ,ALEAKC= 0.000000000E+00,APMET=
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BM=  20.0000000    ,BRCPC=  2.50000000    ,BRFRP=  22.1999969    ,BSPDWC=  2000.00000    ,BSUMF=  50.0000000    ,CCMET=
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DM=  29000.0000    ,DMIN= 0.199999988    ,DTRVHL=  404.000000    ,DZS=  21.1999969    ,DZV=  35.0000000    ,ERHRR= 0.433000028    ,
FFLASH= 0.999999931E-03,FFREC= 0.199999996E-01,FINTIM=  10800.0000    ,FLDWG= 0.311999990E-07,FLSPG= 0.100000008E-07,FTSTAB=
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HSRHRF=  15.6000004    ,HUDWCI=  20.0000000    ,HUMDWO=  20.0000000    ,HUMSPO=  100.000000    ,HO=  3816.00000    ,H1=
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VGDW=  159000.000    ,VJET=  58.3999939    ,VCLP=  2325.00000    ,VREC=  1150.00000    ,VSL=  1811.00000    ,VSSOP=  4434.69922    ,
VTSP=  267600.000    ,VUV1=  1063.00000    ,VUV2=  2031.00000    ,WDLEAK= 0.680000007    ,WGUESS=  3578.00000    ,WBSLC=
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WTEMPO=  51.1499939    ,WTERCO=  7.97000027    ,WWDWC=  143.399994    ,XL1= 0.000000000E+00,XL2=  8.00000000    ,XL3=
  17.5000000    ,XL4=  32.6300049    ,XL5=  35.8800049    ,XL6=  37.8800049    ,XL7=  44.0899963    ,XREF= 0.133000016    ,DKDTCR=
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  1.10000038    ,TAUOHL=  600.000000
&END
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Table B.5 (continued)

TIME	PREL	LDCVZ	LYAR	LSHRD	WINJ	P	WTCST	WSTC	LOGREL	TGCW	PTCWG	LWSPAV	TWSPAV	WECC
0.00	0.037	500.0	501.3	426.3	0.0	1025.0	168.	0.0	0.	145.0	15.70	-3.322	94.2	0.0
10.00	0.039	498.8	499.9	424.0	0.0	1061.3	60.	0.0	0.	145.4	15.72	-3.322	94.2	0.0
20.00	0.038	497.4	498.4	421.9	0.0	1089.3	55.	0.0	0.	146.8	15.76	-3.322	94.2	0.0
30.00	0.037	496.6	497.6	420.6	83.3	1115.7	50.	7.9	0.	149.1	15.82	-3.322	94.2	0.0
40.00	0.040	496.4	498.0	422.2	83.3	1080.4	197.	236.9	1.	152.3	15.91	-3.268	94.5	0.0
50.00	0.040	496.2	498.4	423.7	83.3	1056.5	198.	232.3	1.	156.2	16.02	-3.212	94.8	0.0
60.00	0.035	495.3	497.9	423.0	83.3	1076.4	59.	7.7	0.	160.6	16.14	-3.195	94.9	0.0
70.00	0.034	494.7	497.6	422.4	83.3	1099.3	57.	7.8	0.	165.3	16.27	-3.193	94.9	0.0
80.00	0.035	494.3	497.7	422.6	83.3	1101.4	182.	241.2	1.	169.7	16.35	-3.180	95.0	0.0
90.00	0.037	494.3	498.3	424.6	83.3	1071.0	196.	235.4	1.	174.3	16.43	-3.124	95.3	0.0
100.00	0.035	494.3	498.8	425.8	777.5	1060.2	99.	56.2	0.	178.9	16.51	-3.078	95.6	0.0
110.00	0.033	496.0	501.0	427.7	777.5	1067.5	90.	56.5	0.	183.4	16.59	-3.065	95.7	0.0
120.00	0.032	496.9	502.3	428.7	777.5	1078.0	70.	286.2	1.	188.0	16.66	-3.053	95.7	0.0
130.00	0.036	498.2	504.5	432.4	777.5	1031.7	184.	274.8	1.	192.4	16.74	-2.987	96.1	0.0
140.00	0.036	499.5	506.5	435.7	777.5	995.9	180.	265.1	1.	196.9	16.82	-2.924	96.5	0.0
150.00	0.036	500.8	508.6	439.0	777.5	959.3	171.	255.3	1.	201.2	16.89	-2.863	96.8	0.0
160.00	0.036	502.3	511.0	442.6	777.5	922.8	162.	245.5	1.	205.4	16.96	-2.804	97.2	0.0
170.00	0.035	504.1	513.6	446.4	777.5	886.6	154.	235.8	1.	209.5	17.03	-2.748	97.5	0.0
180.00	0.035	506.1	516.4	450.4	777.5	851.0	146.	226.4	1.	213.5	17.10	-2.694	97.8	0.0
190.00	0.035	508.2	519.4	454.5	777.5	816.0	139.	217.1	1.	217.3	17.16	-2.642	98.1	0.0
200.00	0.034	510.6	522.6	458.8	777.5	781.9	132.	43.7	0.	220.9	17.22	-2.592	98.4	0.0
210.00	0.030	512.8	525.3	461.1	777.5	787.1	34.	43.8	0.	224.4	17.28	-2.582	98.4	0.0
220.00	0.030	515.5	528.5	463.9	777.5	785.4	27.	43.7	0.	227.7	17.33	-2.572	98.5	0.0
230.00	0.030	518.4	532.0	467.1	777.5	782.2	25.	43.6	0.	230.9	17.38	-2.563	98.5	0.0
240.00	0.029	522.1	536.1	470.7	777.5	778.6	19.	43.4	0.	233.9	17.43	-2.553	98.6	0.0
250.00	0.029	525.0	539.5	473.9	777.5	773.0	15.	43.2	0.	236.8	17.48	-2.543	98.6	0.0
260.00	0.028	525.8	540.8	475.2	83.3	773.1	2.	5.8	0.	239.6	17.52	-2.541	98.6	0.0
270.00	0.028	527.1	542.5	476.8	83.3	773.8	3.	5.8	0.	242.2	17.56	-2.540	98.6	0.0
280.00	0.028	528.0	543.8	478.1	83.3	774.1	2.	5.8	0.	244.7	17.60	-2.539	98.7	0.0
290.00	0.028	529.0	545.0	479.3	83.3	774.4	2.	5.8	0.	247.0	17.64	-2.537	98.7	0.0
300.00	0.027	529.9	546.3	480.5	83.3	774.5	2.	5.8	0.	249.3	17.68	-2.536	98.7	0.0
310.00	0.027	530.8	547.5	481.8	83.3	774.6	2.	5.8	0.	251.5	17.71	-2.535	98.7	0.0
320.00	0.027	531.8	548.7	483.0	83.3	774.6	2.	5.8	0.	253.5	17.74	-2.533	98.7	0.0
330.00	0.027	532.7	549.9	484.1	83.3	774.5	2.	5.8	0.	255.4	17.77	-2.532	98.7	0.0
340.00	0.026	533.6	551.1	485.3	83.3	774.3	2.	5.8	0.	257.3	17.80	-2.531	98.7	0.0
350.00	0.026	534.6	552.3	486.4	83.3	774.0	1.	5.8	0.	259.0	17.83	-2.530	98.7	0.0
360.00	0.026	535.5	553.5	487.6	83.3	773.6	1.	5.8	0.	260.7	17.85	-2.528	98.7	0.0
370.00	0.026	536.4	554.7	488.7	83.3	773.2	0.	5.8	0.	262.3	17.88	-2.527	98.7	0.0
380.00	0.026	537.4	555.9	489.8	83.3	772.3	0.	5.8	0.	263.8	17.90	-2.526	98.7	0.0
390.00	0.026	538.3	557.0	491.0	83.3	771.2	0.	5.8	0.	265.2	17.92	-2.524	98.7	0.0
400.00	0.026	539.3	558.2	492.1	83.3	770.2	0.	5.8	0.	266.5	17.94	-2.523	98.7	0.0
410.00	0.025	540.3	559.4	493.2	83.3	769.2	0.	5.8	0.	267.8	17.96	-2.522	98.7	0.0
420.00	0.025	541.3	560.6	494.3	83.3	768.2	0.	5.8	0.	269.0	17.98	-2.521	98.7	0.0
430.00	0.025	542.3	561.8	495.5	83.3	767.3	0.	5.8	0.	270.1	17.99	-2.519	98.7	0.0
440.00	0.025	543.3	563.1	496.6	83.3	766.4	0.	5.8	0.	271.1	18.01	-2.518	98.7	0.0
450.00	0.025	544.3	564.3	497.7	83.3	765.5	0.	5.8	0.	272.1	18.03	-2.517	98.8	0.0
460.00	0.025	545.4	565.5	498.8	79.1	764.7	0.	5.5	0.	273.1	18.04	-2.515	98.8	0.0
470.00	0.024	546.4	566.8	499.9	79.1	764.0	0.	5.5	0.	274.0	18.05	-2.514	98.8	0.0
480.00	0.024	547.5	568.0	501.0	79.1	763.4	0.	5.5	0.	274.8	18.07	-2.513	98.8	0.0
490.00	0.024	548.7	569.4	502.1	79.1	763.0	0.	5.5	0.	275.6	18.08	-2.512	98.8	0.0
500.00	0.024	549.7	570.5	503.1	0.0	763.7	0.	0.0	0.	276.3	18.09	-2.511	98.8	0.0
510.00	0.024	550.5	571.4	503.7	0.0	765.8	0.	0.0	0.	277.0	18.10	-2.511	98.8	0.0
520.00	0.023	551.3	572.2	504.4	0.0	767.8	0.	0.0	0.	277.7	18.11	-2.511	98.8	0.0
530.00	0.023	552.0	573.0	505.0	0.0	769.9	0.	0.0	0.	278.3	18.12	-2.511	98.8	0.0
540.00	0.023	552.8	573.8	505.6	0.0	771.9	0.	0.0	0.	278.9	18.13	-2.511	98.8	0.0
550.00	0.023	553.5	574.6	506.2	0.0	773.8	0.	0.0	0.	279.4	18.13	-2.511	98.8	0.0
560.00	0.023	554.2	575.4	506.8	0.0	775.8	0.	0.0	0.	279.9	18.14	-2.511	98.8	0.0
570.00	0.023	554.9	576.1	507.3	0.0	777.6	0.	0.0	0.	280.4	18.15	-2.511	98.8	0.0
580.00	0.023	555.4	576.7	507.8	0.0	779.1	0.	0.0	0.	280.8	18.16	-2.511	98.8	0.0

Table B.5 (continued)

TIME	PREL	LDCVZ	LYAR	LSHRD	WINJ	P	WTOST	WSTC	LOGREL	TGDW	PTDWG	LWSPAV	TWSPAV	WECC
590.00	0.023	556.3	577.6	508.4	0.0	781.6	0.	0.0	0.	281.2	18.16	-2.511	98.8	0.0
600.00	0.023	557.1	578.5	509.0	0.0	783.9	0.	0.0	0.	281.6	18.17	-2.511	98.8	0.0
610.00	0.022	557.9	579.3	509.6	0.0	786.1	0.	0.0	0.	281.9	18.17	-2.511	98.8	0.0
620.00	0.022	558.7	580.1	510.2	0.0	788.4	0.	0.0	0.	282.2	18.18	-2.511	98.8	0.0
630.00	0.022	559.5	580.9	510.7	0.0	790.8	0.	0.0	0.	282.5	18.18	-2.511	98.8	0.0
640.00	0.022	560.4	581.8	511.3	0.0	793.5	1.	0.0	0.	282.8	18.19	-2.511	98.8	0.0
650.00	0.022	561.2	582.6	511.8	0.0	796.5	1.	0.0	0.	283.1	18.19	-2.511	98.8	0.0
660.00	0.022	562.0	583.4	512.3	0.0	799.8	2.	0.0	0.	283.3	18.20	-2.511	98.8	0.0
670.00	0.022	562.8	584.2	512.8	0.0	80[illegible].6	2.	0.0	0.	283.5	18.20	-2.511	98.8	0.0
680.00	0.022	563.6	584.9	513.2	0.0	807.5	3.	0.0	0.	283.7	18.20	-2.511	98.8	0.0
690.00	0.021	564.3	585.6	513.6	0.0	811.9	3.	0.0	0.	283.9	18.21	-2.511	98.8	0.0
700.00	0.021	565.0	586.3	513.9	0.0	816.4	4.	0.0	0.	284.0	18.21	-2.511	98.8	0.0
710.00	0.021	565.7	586.9	514.2	0.0	821.2	4.	0.0	0.	284.2	18.21	-2.511	98.8	0.0
720.00	0.021	566.4	587.4	514.4	0.0	826.3	5.	0.0	0.	284.3	18.22	-2.511	98.8	0.0
730.00	0.021	567.0	588.0	514.6	0.0	831.5	5.	0.0	0.	284.4	18.22	-2.511	98.8	0.0
740.00	0.021	567.6	588.0	514.8	0.0	836.9	5.	0.0	0.	284.5	18.22	-2.511	98.8	0.0
750.00	0.021	568.1	588.0	515.0	0.0	842.5	6.	0.0	0.	284.6	18.22	-2.511	98.8	0.0
760.00	0.021	568.7	588.0	515.1	0.0	848.1	6.	0.0	0.	284.7	18.22	-2.511	98.8	0.0
770.00	0.021	569.2	588.0	515.1	0.0	853.9	6.	0.0	0.	284.8	18.23	-2.511	98.8	0.0
780.00	0.021	569.7	588.0	515.2	0.0	859.7	6.	0.0	0.	284.8	18.23	-2.511	98.8	0.0
790.00	0.021	570.1	588.0	515.2	0.0	865.6	6.	0.0	0.	284.9	18.23	-2.511	98.8	0.0
800.00	0.020	570.6	588.0	515.3	0.0	871.5	6.	0.0	0.	284.9	18.23	-2.511	98.8	0.0
810.00	0.020	571.1	588.0	515.3	0.0	877.4	6.	0.0	0.	284.9	18.23	-2.512	98.8	0.0
820.00	0.020	571.5	588.0	515.3	0.0	883.4	6.	0.0	0.	285.0	18.23	-2.512	98.8	0.0
830.00	0.020	571.9	588.0	515.3	0.0	889.4	7.	0.0	0.	285.0	18.24	-2.512	98.8	0.0
840.00	0.020	572.4	588.0	515.2	0.0	895.4	7.	0.0	0.	285.0	18.24	-2.512	98.8	0.0
850.00	0.020	572.8	588.0	515.2	0.0	901.4	7.	0.0	0.	285.0	18.24	-2.512	98.8	0.0
860.00	0.020	573.2	588.0	515.2	0.0	907.5	7.	0.0	0.	285.0	18.24	-2.512	98.8	0.0
870.00	0.020	573.7	588.0	515.2	0.0	913.5	7.	0.0	0.	285.0	18.24	-2.512	98.8	0.0
880.00	0.020	574.1	588.0	515.1	0.0	919.5	6.	0.0	0.	285.0	18.24	-2.512	98.8	0.0
890.00	0.020	574.5	588.0	515.1	0.0	925.5	6.	0.0	0.	284.9	18.24	-2.512	98.8	0.0
900.00	0.020	574.9	588.0	515.1	0.0	931.5	6.	0.0	0.	284.9	18.25	-2.512	98.8	0.0
910.00	0.020	575.3	588.0	515.0	0.0	937.6	6.	0.0	0.	284.9	18.25	-2.512	98.8	0.0
920.00	0.020	575.7	588.0	515.0	0.0	943.6	6.	0.0	0.	284.9	18.25	-2.512	98.8	0.0
930.00	0.020	576.2	588.0	514.9	0.0	949.6	6.	0.0	0.	284.8	18.25	-2.512	98.8	0.0
940.00	0.020	576.6	588.0	514.9	0.0	955.6	6.	0.0	0.	284.8	18.25	-2.512	98.8	0.0
950.00	0.020	577.0	588.0	514.9	0.0	961.5	6.	0.0	0.	284.8	18.25	-2.512	98.8	0.0
960.00	0.019	577.4	588.0	514.8	0.0	967.5	6.	0.0	0.	284.7	18.25	-2.512	98.8	0.0
970.00	0.019	577.8	588.0	514.8	0.0	973.5	6.	0.0	0.	284.7	18.25	-2.512	98.8	0.0
980.00	0.019	578.2	588.0	514.7	0.0	979.5	6.	0.0	0.	284.6	18.25	-2.512	98.8	0.0
990.00	0.019	578.7	588.0	514.7	0.0	985.4	6.	0.0	0.	284.6	18.26	-2.512	98.8	0.0
1000.00	0.019	579.1	588.0	514.6	0.0	991.4	6.	0.0	0.	284.5	18.26	-2.512	98.8	0.0
1010.00	0.019	579.5	588.0	514.6	0.0	997.3	6.	0.0	0.	284.5	18.26	-2.512	98.8	0.0
1020.00	0.019	579.9	588.0	514.6	0.0	1003.3	6.	0.0	0.	284.4	18.26	-2.512	98.8	0.0
1030.00	0.019	580.3	588.0	514.5	0.0	1009.2	6.	0.0	0.	284.4	18.26	-2.512	98.8	0.0
1040.00	0.019	580.8	588.0	514.5	0.0	1015.2	6.	0.0	0.	284.3	18.26	-2.512	98.8	0.0
1050.00	0.019	581.2	588.0	514.4	0.0	1021.1	6.	0.0	0.	284.2	18.26	-2.512	98.8	0.0
1060.00	0.019	581.6	588.0	514.4	0.0	1027.0	6.	0.0	0.	284.2	18.26	-2.512	98.8	0.0
1070.00	0.019	582.0	588.0	514.4	0.0	1032.9	6.	0.0	0.	284.1	18.27	-2.512	98.8	0.0
1080.00	0.019	582.4	588.0	514.3	0.0	1038.8	6.	0.0	0.	284.1	18.27	-2.512	98.8	0.0
1090.00	0.019	582.9	588.0	514.3	0.0	1044.7	6.	0.0	0.	284.0	18.27	-2.512	98.8	0.0
1100.00	0.019	583.3	588.0	514.2	0.0	1050.6	6.	0.0	0.	283.9	18.27	-2.512	98.8	0.0
1110.00	0.019	583.7	588.0	514.2	0.0	1056.5	6.	0.0	0.	283.9	18.27	-2.512	98.8	0.0
1120.00	0.019	584.1	588.0	514.2	0.0	1062.4	6.	216.7	1.	283.8	18.27	-2.512	98.8	0.0
1130.00	0.024	584.7	588.0	518.0	0.0	1000.0	153.	205.9	1.	283.8	18.28	-2.461	99.1	0.0
1140.00	0.021	586.3	588.0	520.2	0.0	984.4	97.	203.7	1.	283.8	18.28	-2.413	99.4	0.0
1150.00	0.020	586.2	588.0	520.7	0.0	975.8	125.	202.7	1.	283.7	18.29	-2.364	99.7	0.0
1160.00	0.020	585.0	588.0	520.3	0.0	968.5	120.	201.8	1.	283.7	18.29	-2.316	100.0	0.0

Table B.5 (continued)

TIME	PREL	LDCVZ	LYAR	LSHRD	WINJ	P	WTDST	WSTC	LOGREL	TGDW	PTDWG	LWSPAV	TWSPAV	WECC
1170.00	0.020	583.2	588.0	519.4	0.0	961.4	104.	200.9	1.	283.7	18.30	-2.268	100.2	0.0
1180.00	0.020	581.1	588.0	518.3	0.0	953.5	106.	199.8	1.	283.7	18.30	-2.220	100.5	0.0
1190.00	0.020	578.9	588.0	517.1	0.0	945.8	106.	198.6	1.	283.6	18.30	-2.173	100.8	0.0
1200.00	0.020	576.7	588.0	515.9	0.0	938.3	106.	197.4	1.	283.6	18.31	-2.126	101.1	0.0
1210.00	0.020	574.6	588.0	514.7	0.0	930.9	105.	196.2	1.	283.6	18.31	-2.079	101.4	0.0
1220.00	0.020	572.4	588.0	513.4	0.0	923.6	104.	194.9	1.	283.5	18.32	-2.033	101.7	0.0
1230.00	0.020	570.3	588.0	512.2	0.0	916.4	104.	193.6	1.	283.5	18.32	-1.987	101.9	0.0
1240.00	0.020	568.2	587.4	511.0	0.0	909.4	103.	192.3	1.	283.5	18.33	-1.941	102.2	0.0
1250.00	0.020	566.1	585.4	509.8	0.0	902.9	98.	191.0	1.	283.4	18.33	-1.895	102.5	0.0
1260.00	0.020	564.1	583.5	508.6	0.0	896.2	99.	0.0	0.	283.4	18.34	-1.850	102.7	0.0
1270.00	0.017	562.5	581.4	506.2	0.0	914.7	28.	0.0	0.	283.3	18.34	-1.850	102.7	0.0
1280.00	0.017	560.6	579.3	504.1	0.0	927.5	27.	0.0	0.	283.3	18.34	-1.850	102.7	0.0
1290.00	0.017	558.9	577.3	502.1	0.0	938.4	22.	0.0	0.	283.2	18.34	-1.850	102.7	0.0
1300.00	0.017	557.8	575.9	500.7	0.0	948.0	18.	0.0	0.	283.1	18.34	-1.850	102.7	0.0
1310.00	0.018	557.1	575.0	499.7	0.0	956.7	15.	0.0	0.	283.1	18.35	-1.850	102.7	0.0
1320.00	0.018	556.7	574.4	498.9	0.0	964.6	13.	0.0	0.	283.0	18.35	-1.850	102.7	0.0
1330.00	0.018	556.5	574.1	498.4	0.0	972.1	12.	0.0	0.	282.9	18.35	-1.850	102.7	0.0
1340.00	0.018	556.5	573.9	497.9	0.0	979.1	10.	0.0	0.	282.9	18.35	-1.850	102.7	0.0
1350.00	0.018	556.5	573.8	497.6	0.0	985.9	10.	0.0	0.	282.8	18.35	-1.850	102.7	0.0
1360.00	0.018	556.7	573.8	497.3	0.0	992.4	9.	0.0	0.	282.8	18.36	-1.850	102.7	0.0
1370.00	0.018	556.8	573.8	497.1	0.0	998.8	8.	0.0	0.	282.7	18.36	-1.850	102.7	0.0
1380.00	0.018	557.1	573.9	496.9	0.0	1005.0	8.	0.0	0.	282.6	18.36	-1.850	102.7	0.0
1390.00	0.018	557.3	574.0	496.8	0.0	1011.1	8.	0.0	0.	282.6	18.36	-1.850	102.7	0.0
1400.00	0.017	557.6	574.2	496.7	0.0	1017.1	7.	0.0	0.	282.5	18.36	-1.850	102.7	0.0
1410.00	0.017	557.9	574.3	496.6	0.0	1023.1	7.	0.0	0.	282.5	18.36	-1.850	102.7	0.0
1420.00	0.017	558.3	574.5	496.5	0.0	1029.0	7.	0.0	0.	282.4	18.37	-1.850	102.7	0.0
1430.00	0.017	558.6	574.7	496.4	0.0	1034.8	7.	0.0	0.	282.4	18.37	-1.850	102.7	0.0
1440.00	0.017	558.9	574.9	496.3	0.0	1040.6	7.	0.0	0.	282.3	18.37	-1.850	102.7	0.0
1450.00	0.017	559.3	575.1	496.3	0.0	1046.4	7.	0.0	0.	282.3	18.37	-1.850	102.7	0.0
1460.00	0.017	559.6	575.4	[illegible]	0.0	1052.1	7.	219.4	1.	282.2	18.38	-1.850	102.7	0.0
1470.00	0.022	[illegible]	577.0	[illegible]	0.0	994.2	147.	208.7	1.	282.2	18.38	-1.799	103.0	0.0
1480.00	0.020	561.3	578.6	501.3	0.0	980.6	95.	206.4	1.	282.2	18.39	-1.750	103.3	0.0
1490.00	0.019	561.2	578.7	501.7	0.0	971.9	123.	204.9	1.	282.2	18.39	-1.701	103.6	0.0
1500.00	0.019	559.9	577.6	[illegible]	0.0	963.8	131.	203.5	1.	282.2	18.40	-1.653	103.9	0.0
1510.00	0.019	558.1	576.0	500.3	0.0	955.7	134.	202.1	1.	282.2	18.40	-1.604	104.2	0.0
1520.00	0.019	556.1	574.1	499.2	0.0	947.6	135.	200.6	1.	282.2	18.41	-1.557	104.5	0.0
1530.00	0.019	554.0	572.7	498.1	0.0	939.6	135.	199.1	1.	282.2	18.41	-1.509	104.8	0.0
1540.00	0.018	551.9	570.2	496.9	0.0	931.9	132.	197.5	1.	282.2	18.42	-1.462	105.0	0.0
1550.00	0.018	549.8	568.3	495.7	0.0	924.3	130.	195.8	1.	282.2	18.43	-1.415	105.3	0.0
1560.00	0.018	547.7	566.3	494.6	0.0	916.7	129.	194.1	1.	282.2	18.43	-1.369	105.6	0.0
1570.00	0.018	545.7	564.4	493.4	0.0	909.2	128.	192.4	1.	282.2	18.44	-1.323	105.9	0.0
1580.00	0.018	543.8	562.6	492.3	0.0	901.9	127.	190.8	1.	282.1	18.44	-1.277	106.1	0.0
1590.00	0.018	541.9	560.8	491.3	0.0	894.6	127.	189.2	1.	282.1	18.45	-1.232	106.4	0.0
1600.00	0.018	540.0	559.0	490.2	0.0	887.5	126.	0.0	0.	282.1	18.45	-1.187	106.7	0.0
1610.00	0.016	538.6	557.2	488.1	0.0	905.7	27.	0.0	0.	282.1	18.46	-1.187	106.7	0.0
1620.00	0.016	537.1	555.5	486.4	0.0	918.0	26.	0.0	0.	282.1	18.46	-1.187	106.7	0.0
1630.00	0.016	535.8	554.0	484.6	16.7	928.6	23.	1.4	0.	282.0	18.46	-1.187	106.7	0.0
1640.00	0.016	534.9	552.9	483.6	16.7	938.2	20.	1.4	0.	282.0	18.47	-1.187	106.7	0.0
1650.00	0.016	534.4	552.3	482.7	16.7	947.0	17.	1.4	0.	281.9	18.47	-1.187	106.7	0.0
1660.00	0.016	534.1	551.8	482.1	16.7	955.3	16.	1.4	0.	281.9	18.47	-1.186	106.7	0.0
1670.00	0.016	533.9	551.5	481.5	16.7	963.2	14.	1.4	0.	281.9	18.47	-1.186	106.7	0.0
1680.00	0.016	533.9	551.3	481.1	16.7	970.7	13.	1.4	0.	281.8	18.48	-1.186	106.7	0.0
1690.00	0.016	533.9	551.2	480.8	20.8	977.8	13.	1.8	0.	281.8	18.48	-1.186	106.7	0.0
1700.00	0.016	534.0	551.2	480.5	20.8	984.6	12.	1.8	0.	281.8	18.48	-1.185	106.7	0.0
1710.00	0.016	534.1	551.2	480.2	20.8	991.1	12.	1.8	0.	281.8	18.49	-1.185	106.7	0.0
1720.00	0.016	534.2	551.2	480.0	20.8	997.5	11.	1.8	0.	281.7	18.49	-1.184	106.7	0.0
1730.00	0.016	534.4	551.3	479.8	20.8	1003.6	11.	1.8	0.	281.7	18.49	-1.184	106.7	0.0
1740.00	0.016	534.6	551.4	479.7	20.8	1009.5	10.	1.8	0.	281.7	18.50	-1.184	106.7	0.0

Table 8.5 (continued)

TIME	PREL	LDCVZ	LYAR	LSHRC	WINJ	P	WTOST	WSTC	LOGREL	TGDW	PTCWG	LWSPAV	TWSPAV	WECC
1750.00	0.016	534.9	551.6	479.6	25.0	1015.2	10.	2.2	0.	281.7	18.50	-1.183	106.7	0.0
1760.00	0.016	535.1	551.7	479.5	25.0	1020.7	10.	2.2	0.	281.6	18.50	-1.183	106.7	0.0
1770.00	0.016	535.4	[illegible]	479.4	25.0	1026.1	9.	2.2	0.	281.6	18.51	-1.182	106.7	0.0
1780.00	0.016	535.7	552.1	479.4	25.0	1031.3	9.	2.2	0.	281.6	18.51	-1.182	106.7	0.0
1790.00	0.016	536.0	552.3	479.3	25.0	1036.4	9.	2.2	0.	281.6	18.51	-1.181	106.7	0.0
1800.00	0.016	536.3	552.5	479.3	25.0	1041.3	8.	2.2	0.	281.6	18.52	-1.181	106.7	0.0
1810.00	0.016	536.6	552.8	479.3	29.2	1046.0	8.	2.6	0.	281.6	18.52	-1.180	106.7	0.0
1820.00	0.016	537.0	553.1	479.3	29.2	1050.6	8.	2.6	0.	281.5	18.52	-1.180	106.7	0.0
1830.00	0.016	537.3	553.3	479.4	29.2	1055.0	8.	2.6	0.	281.5	18.53	-1.179	106.7	0.0
1840.00	0.016	537.7	553.6	479.4	29.2	1059.4	8.	2.6	0.	281.5	18.53	-1.179	106.7	0.0
1850.00	0.016	538.0	553.9	479.5	29.2	1063.6	7.	2.7	0.	281.5	18.53	-1.178	106.7	0.0
1860.00	0.016	538.4	554.2	479.6	29.2	1067.6	7.	224.8	1.	281.5	18.54	-1.178	106.7	0.0
1870.00	0.021	538.5	555.2	482.6	33.3	1006.0	145.	213.8	1.	281.5	18.54	-1.125	107.0	0.0
1880.00	0.021	540.0	557.3	485.6	33.3	967.5	149.	206.6	1.	281.6	18.55	-1.075	107.3	0.0
1890.00	0.018	540.2	557.8	486.5	33.3	956.1	100.	204.5	1.	281.6	18.56	-1.027	107.6	0.0
1900.00	0.018	539.8	557.7	486.8	33.3	946.7	128.	202.8	1.	281.6	18.56	-0.978	107.9	0.0
1910.00	0.018	538.7	556.7	486.4	33.3	937.2	135.	201.0	1.	281.6	18.57	-0.930	108.2	0.0
1920.00	0.018	537.2	555.4	485.8	33.3	927.7	137.	199.2	1.	281.7	18.58	-0.883	108.5	0.0
1930.00	0.018	535.6	554.0	485.1	37.5	918.3	138.	197.5	1.	281.7	18.58	-0.835	108.7	0.0
1940.00	0.018	534.0	552.5	484.4	37.5	908.7	139.	195.3	1.	281.7	18.59	-0.789	109.0	0.0
1950.00	0.01[illegible]	532.4	551.0	483.6	37.5	899.3	138.	193.2	1.	281.8	18.60	-0.743	109.3	0.0
1960.00	0.017	530.8	549.5	482.9	37.5	890.0	137.	191.1	1.	281.8	18.60	-0.697	109.5	0.0
1970.00	0.017	529.2	548.1	482.1	37.5	880.9	136.	189.1	1.	281.8	18.61	-0.652	109.8	0.0
1980.00	0.017	527.7	546.6	481.4	37.5	871.9	136.	187.1	1.	281.8	18.62	-0.607	110.1	0.0
1990.00	0.017	526.2	545.2	480.7	41.6	863.0	135.	185.4	1.	281.9	18.62	-0.563	110.3	0.0
2000.00	0.017	524.7	543.8	480.0	41.6	854.1	134.	3.2	0.	281.9	18.63	-0.519	110.6	0.0
2010.00	0.015	523.5	542.3	478.2	41.6	870.7	26.	3.2	0.	281.9	18.64	-0.518	110.6	0.0
2020.00	0.015	522.5	541.1	476.9	41.6	882.0	26.	3.2	0.	281.9	18.64	-0.518	110.6	0.0
2030.00	0.015	521.5	539.9	475.6	41.6	892.0	23.	3.3	0.	281.9	18.64	-0.517	110.6	0.0
2040.00	0.015	520.8	539.1	474.6	41.6	901.3	21.	3.3	0.	281.9	18.65	-0.516	110.6	0.0
2050.00	0.015	520.6	538.8	474.0	83.3	909.6	21.	6.7	0.	281.9	18.65	-0.515	110.6	0.0
2060.00	0.015	520.5	538.6	473.6	83.3	917.4	19.	6.7	0.	281.9	18.66	-0.514	110.6	0.0
2070.00	0.015	520.5	538.5	473.2	83.3	924.7	18.	6.7	0.	281.8	18.66	-0.512	110.6	0.0
2080.00	0.015	520.6	538.5	473.0	83.3	931.6	18.	6.8	0.	281.8	18.66	-0.511	110.6	0.0
2090.00	0.015	520.7	538.6	472.7	83.3	938.1	17.	6.8	0.	281.8	18.67	-0.509	110.6	0.0
2100.00	0.015	520.9	538.7	472.6	83.3	944.3	16.	6.9	0.	281.8	18.67	-0.508	110.6	0.0
2110.00	0.015	521.1	538.8	472.5	83.3	950.3	15.	6.9	0.	281.8	18.67	-0.506	110.6	0.0
2120.00	0.015	521.4	539.0	472.4	83.3	955.9	15.	6.9	0.	281.8	18.68	-0.505	110.6	0.0
2130.00	0.015	521.7	539.2	472.3	83.3	961.3	14.	7.0	0.	281.8	18.68	-0.503	110.6	0.0
2140.00	0.015	522.0	539.5	472.3	83.3	966.4	14.	7.0	0.	281.8	18.69	-0.501	110.7	0.0
2150.00	0.015	522.3	539.7	472.4	83.3	971.3	13.	7.0	0.	281.9	18.69	-0.500	110.7	0.0
2160.00	0.015	522.7	540.0	472.4	83.3	976.0	13.	7.1	0.	281.9	18.70	-0.498	110.7	0.0
2170.00	0.015	523.1	540.3	472.5	83.3	980.4	13.	7.1	0.	281.9	18.70	-0.497	110.7	0.0
2180.00	0.015	523.4	540.7	472.5	83.3	984.7	12.	7.1	0.	281.9	18.70	-0.495	110.7	0.0
2190.00	0.015	523.8	541.0	472.6	83.3	988.7	12.	7.1	0.	281.9	18.71	-0.494	110.7	0.0
2200.00	0.015	524.3	541.4	472.8	83.3	992.5	11.	7.2	0.	281.9	18.71	-0.492	110.7	0.0
2210.00	0.015	524.7	541.7	472.9	83.3	996.1	11.	7.2	0.	281.9	18.72	-0.491	110.7	0.0
2220.00	0.015	525.1	542.1	473.1	83.3	999.6	11.	7.2	0.	281.9	18.72	-0.489	110.7	0.0
2230.00	0.015	525.6	542.5	473.3	83.3	1002.8	10.	7.2	0.	281.9	18.72	-0.487	110.7	0.0
2240.00	0.015	526.0	543.0	473.5	83.3	1005.9	10.	7.2	0.	281.9	18.73	-0.486	110.7	0.0
2250.00	0.015	526.5	543.4	473.7	83.3	1008.7	10.	7.3	0.	281.9	18.73	-0.484	110.7	0.0
2260.00	0.015	527.0	543.8	473.9	83.3	1011.4	9.	7.3	0.	281.9	18.74	-0.483	110.7	0.0
2270.00	0.015	527.5	544.3	474.2	83.3	1013.9	9.	7.3	0.	282.0	18.74	-0.481	110.8	0.0
2280.00	0.015	528.0	544.7	474.4	83.3	1016.2	9.	7.3	0.	282.0	18.74	-0.479	110.8	0.0
2290.00	0.015	528.5	545.2	474.7	83.3	1018.4	8.	7.3	0.	282.0	18.75	-0.478	110.8	0.0
2300.00	0.015	529.0	545.7	475.0	83.3	1020.3	8.	7.3	0.	282.0	18.75	-0.476	110.8	0.0
2310.00	0.015	529.5	546.2	475.3	83.3	1022.1	8.	7.3	0.	282.0	18.76	-0.475	110.8	0.0
2320.00	0.015	530.0	546.7	475.6	83.3	1023.7	7.	7.4	0.	282.0	18.76	-0.473	110.8	0.0

Table B.5 (continued)

TIME	PREL	LUCVZ	LYAR	LSHRL	WINJ	P	WTOST	WSTC	LOGREL	TGDW	PTCWG	LWSPAV	TWSPAV	WECC
2330.00	0.015	530.6	547.2	476.0	83.3	1025.2	7.	7.4	0.	282.0	18.77	-0.471	110.8	0.0
2340.00	0.015	531.1	547.7	476.3	83.3	1026.4	7.	7.4	0.	282.1	18.77	-0.470	110.8	0.0
2350.00	0.015	531.7	548.3	476.7	83.3	1027.5	6.	7.4	0.	282.1	18.77	-0.468	110.8	0.0
2360.00	0.015	532.2	548.8	477.0	83.3	1028.4	6.	7.4	0.	282.1	18.78	-0.467	110.8	0.0
2370.00	0.015	532.8	549.4	477.5	83.3	1029.1	6.	7.4	0.	282.1	18.78	-0.465	110.8	0.0
2380.00	0.015	533.4	549.9	477.9	83.3	1029.7	5.	7.4	0.	282.1	18.79	-0.463	110.8	0.0
2390.00	0.015	534.0	550.5	478.3	83.3	1030.2	5.	7.4	0.	282.2	18.79	-0.462	110.8	0.0
2400.00	0.015	534.6	551.1	478.7	83.3	1030.4	5.	7.4	0.	282.2	18.80	-0.460	110.8	0.0
2410.00	0.015	535.2	551.7	479.2	83.3	1030.6	4.	7.4	0.	282.2	18.80	-0.458	110.9	0.0
2420.00	0.015	535.8	552.3	479.6	83.3	1030.6	4.	7.4	0.	282.2	18.80	-0.457	110.9	0.0
2430.00	0.015	536.5	553.0	480.1	83.3	1030.4	4.	7.4	0.	282.2	18.81	-0.455	110.9	0.0
2440.00	0.015	537.1	553.6	480.6	83.3	1030.1	3.	7.4	0.	282.3	18.81	-0.454	110.9	0.0
2450.00	0.015	537.7	554.2	481.1	83.3	1029.6	3.	7.4	0.	282.3	18.82	-0.452	110.9	0.0
2460.00	0.015	538.4	554.9	481.6	83.3	1028.9	3.	7.4	0.	282.3	18.82	-0.450	110.9	0.0
2470.00	0.015	539.0	555.5	482.1	83.3	1028.2	3.	7.4	0.	282.3	18.82	-0.449	110.9	0.0
2480.00	0.015	539.7	556.2	482.7	83.3	1027.3	3.	7.4	0.	282.4	18.83	-0.447	110.9	0.0
2490.00	0.015	540.3	556.8	483.2	83.3	1026.3	2.	7.4	0.	282.4	18.83	-0.446	110.9	0.0
2500.00	0.015	541.0	557.5	483.8	83.3	1024.6	0.	7.4	0.	282.4	18.84	-0.444	110.9	0.0
2510.00	0.016	541.7	558.3	484.5	83.3	1022.3	0.	7.3	0.	282.4	18.84	-0.442	110.9	0.0
2520.00	0.016	542.4	559.0	485.1	83.3	1020.0	0.	7.3	0.	282.5	18.85	-0.441	110.9	0.0
2530.00	0.015	543.2	559.8	485.8	83.3	1017.8	0.	7.3	0.	282.5	18.85	-0.439	110.9	0.0
2540.00	0.015	543.9	560.6	486.5	83.3	1015.6	0.	7.3	0.	282.5	18.85	-0.438	111.0	0.0
2550.00	0.015	544.7	561.4	487.2	83.3	1013.5	0.	7.3	0.	282.5	18.86	-0.436	111.0	0.0
2560.00	0.015	545.5	562.2	487.9	83.3	1011.4	0.	7.3	0.	282.6	18.86	-0.434	111.0	0.0
2570.00	0.015	546.3	563.1	488.6	83.3	1009.4	0.	7.3	0.	282.6	18.87	-0.433	111.0	0.0
2580.00	0.015	547.1	563.9	489.3	83.3	1007.4	0.	7.3	0.	282.6	18.87	-0.431	111.0	0.0
2590.00	0.015	548.0	564.8	490.0	83.3	1005.6	0.	7.2	0.	282.6	18.88	-0.430	111.0	0.0
2600.00	0.015	548.8	565.7	490.8	79.1	1004.0	0.	6.9	0.	282.7	18.88	-0.428	111.0	0.0
2610.00	0.015	549.7	566.6	491.5	79.1	1002.4	0.	6.9	0.	282.7	18.88	-0.427	111.0	0.0
2620.00	0.015	550.5	567.4	492.2	79.1	1000.8	0.	6.9	0.	282.7	18.89	-0.425	111.0	0.0
2630.00	0.015	551.3	568.3	493.0	79.1	999.1	0.	6.8	0.	282.8	18.89	-0.424	111.0	0.0
2640.00	0.015	552.2	569.2	493.7	79.1	997.4	0.	6.8	0.	282.8	18.90	-0.422	111.0	0.0
2650.00	0.015	553.0	570.0	494.4	79.1	995.6	0.	6.8	0.	282.8	18.90	-0.420	111.0	0.0
2660.00	0.015	553.5	570.5	494.7	0.0	997.2	0.	0.0	0.	282.9	18.90	-0.420	111.0	0.0
2670.00	0.015	554.0	571.0	495.0	0.0	999.0	0.	0.0	0.	282.9	18.91	-0.420	111.0	0.0
2680.00	0.015	554.5	571.4	495.3	0.0	1000.9	0.	0.0	0.	282.9	18.91	-0.421	111.0	0.0
2690.00	0.015	555.0	571.9	495.6	0.0	1002.7	0.	0.0	0.	282.9	18.92	-0.421	111.0	0.0
2700.00	0.015	555.4	572.3	495.8	0.0	1004.2	0.	0.0	0.	283.0	18.92	-0.421	111.0	0.0
2710.00	0.015	555.9	572.8	496.1	0.0	1005.9	0.	0.0	0.	283.0	18.92	-0.421	111.0	0.0
2720.00	0.015	556.5	573.3	496.5	0.0	1008.1	0.	0.0	0.	283.0	18.93	-0.421	111.0	0.0
2730.00	0.015	557.1	573.9	496.8	0.0	1010.2	0.	0.0	0.	283.1	18.93	-0.421	111.0	0.0
2740.00	0.015	557.7	574.4	497.1	0.0	1012.2	0.	0.0	0.	283.1	18.94	-0.421	111.0	0.0
2750.00	0.015	558.2	574.9	497.4	0.0	1014.2	0.	0.0	0.	283.1	18.94	-0.421	111.0	0.0
2760.00	0.015	558.8	575.4	497.7	0.0	1016.3	0.	0.0	0.	283.2	18.95	-0.421	111.0	0.0
2770.00	0.015	559.3	575.9	498.0	0.0	1018.5	1.	0.0	0.	283.2	18.95	-0.421	111.0	0.0
2780.00	0.015	559.8	576.4	498.3	0.0	1021.0	1.	0.0	0.	283.2	18.95	-0.421	111.0	0.0
2790.00	0.015	560.4	576.8	498.5	0.0	1023.6	1.	0.0	0.	283.3	18.96	-0.421	111.0	0.0
2800.00	0.015	561.0	577.4	498.8	0.0	1026.6	2.	0.0	0.	283.3	18.96	-0.421	111.0	0.0
2810.00	0.014	561.4	577.8	499.0	0.0	1029.7	2.	0.0	0.	283.3	18.97	-0.421	111.0	0.0
2820.00	0.014	561.9	578.2	499.2	0.0	1032.9	2.	0.0	0.	283.4	18.97	-0.421	111.0	0.0
2830.00	0.014	562.4	578.6	499.4	0.0	1036.4	3.	0.0	0.	283.4	18.97	-0.421	111.0	0.0
2840.00	0.014	562.9	579.0	499.6	0.0	1040.0	3.	0.0	0.	283.4	18.98	-0.421	111.0	0.0
2850.00	0.014	563.3	579.4	499.7	0.0	1043.7	3.	0.0	0.	283.5	18.98	-0.421	111.0	0.0
2860.00	0.014	563.8	579.7	499.9	0.0	1047.6	3.	0.0	0.	283.5	18.99	-0.421	111.0	0.0
2870.00	0.014	564.2	580.0	500.0	0.0	1051.5	4.	0.0	0.	283.5	18.99	-0.421	111.0	0.0
2880.00	0.014	564.6	580.4	500.1	0.0	1055.6	4.	0.0	0.	283.6	18.99	-0.421	111.0	0.0
2890.00	0.014	565.0	580.7	500.1	0.0	1059.8	4.	0.0	0.	283.6	19.00	-0.421	111.0	0.0
2900.00	0.014	565.4	581.0	500.2	0.0	1064.0	4.	0.0	0.	283.6	19.00	-0.421	111.0	0.0

Table B.5 (continued)

TIME	PREL	LDCVZ	LYAR	LSHRD	WINJ	P	WTOST	WSTC	LOGREL	TGDW	PTCWG	LWSPAV	TWSPAV	WECC
2910.00	0.014	565.8	581.2	500.3	0.0	1068.3	4.	0.0	0.	283.7	19.01	-0.421	111.0	0.0
2920.00	0.014	566.2	581.5	500.3	0.0	1072.7	4.	222.4	1.	283.7	19.01	-0.421	111.0	0.0
2930.00	0.019	566.3	583.0	503.7	0.0	1009.8	149.	211.0	1.	283.8	19.02	-0.370	111.3	0.0
2940.00	0.016	566.8	583.8	504.8	0.0	999.1	87.	209.4	1.	283.9	19.03	-0.320	111.6	0.0
2950.00	0.016	566.2	583.5	505.0	0.0	989.6	116.	207.9	1.	283.9	19.03	-0.270	111.9	0.0
2960.00	0.016	564.7	582.3	504.4	0.0	980.2	123.	206.4	1.	284.0	19.04	-0.221	112.2	0.0
2970.00	0.016	562.8	580.6	503.5	0.0	970.8	125.	204.8	1.	284.1	19.05	-0.172	112.5	0.0
2980.00	0.016	560.7	578.7	502.4	0.0	961.6	126.	203.1	1.	284.2	19.06	-0.123	112.8	0.0
2990.00	0.016	558.5	576.7	501.3	0.0	952.4	126.	201.5	1.	284.2	19.06	-0.075	113.1	0.0
3000.00	0.015	556.3	574.7	500.1	0.0	943.5	126.	199.8	1.	284.3	19.07	-0.027	113.3	0.0
3010.00	0.015	554.1	572.7	499.0	0.0	934.8	123.	198.1	1.	284.4	19.08	0.020	113.6	0.0
3020.00	0.015	552.0	570.7	497.8	0.0	926.3	123.	196.2	1.	284.4	19.09	0.067	113.9	0.0
3030.00	0.015	549.9	568.8	496.7	0.0	917.9	121.	194.3	1.	284.5	19.10	0.113	114.1	0.0
3040.00	0.015	547.8	566.8	495.6	0.0	909.6	115.	192.5	1.	284.6	19.10	0.159	114.4	0.0
3050.00	0.015	545.8	564.9	494.5	0.0	901.4	118.	190.7	1.	284.6	19.11	0.205	114.7	0.0
3060.00	0.015	543.8	563.1	493.4	0.0	893.4	117.	0.0	0.	284.7	19.12	0.249	114.9	0.0
3070.00	0.013	542.5	561.5	491.6	0.0	908.9	22.	0.0	0.	284.7	19.12	0.249	114.9	0.0
3080.00	0.013	541.4	560.2	490.2	0.0	919.3	21.	0.0	0.	284.8	19.13	0.249	114.9	0.0
3090.00	0.013	540.3	558.8	488.9	0.0	928.4	19.	0.0	0.	284.8	19.13	0.249	114.9	0.0
3100.00	0.013	539.4	557.8	487.8	0.0	936.7	16.	0.0	0.	284.8	19.14	0.249	114.9	0.0
3110.00	0.014	538.8	557.1	486.9	0.0	944.3	14.	0.0	0.	284.9	19.14	0.249	114.9	0.0
3120.00	0.014	538.5	556.6	486.3	0.0	951.5	13.	0.0	0.	284.9	19.15	0.249	114.9	0.0
3130.00	0.014	538.3	556.3	485.8	0.0	958.3	11.	0.0	0.	284.9	19.15	0.249	114.9	0.0
3140.00	0.014	538.2	556.1	485.4	0.0	964.8	11.	0.0	0.	284.9	19.16	0.249	114.9	0.0
3150.00	0.014	538.1	555.9	485.0	0.0	971.1	10.	0.0	0.	285.0	19.16	0.249	114.9	0.0
3160.00	0.014	538.1	555.8	484.7	0.0	977.2	9.	0.0	0.	285.0	19.17	0.249	114.9	0.0
3170.00	0.014	538.2	555.8	484.5	0.0	983.1	9.	0.0	0.	285.0	19.17	0.249	114.9	0.0
3180.00	0.014	538.3	555.8	484.3	0.0	988.8	9.	0.0	0.	285.1	19.17	0.249	114.9	0.0
3190.00	0.014	538.4	555.8	484.1	0.0	994.4	8.	0.0	0.	285.1	19.18	0.249	114.9	0.0
3200.00	0.014	538.5	555.8	483.9	0.0	999.9	8.	0.0	0.	285.1	19.18	0.249	114.9	0.0
3210.00	0.014	538.6	555.9	483.7	0.0	1005.2	8.	0.0	0.	285.2	19.19	0.249	114.9	0.0
3220.00	0.014	538.8	556.0	483.6	0.0	1010.5	7.	0.0	0.	285.2	19.19	0.249	114.9	0.0
3230.00	0.014	539.0	556.1	483.5	0.0	1015.7	7.	0.0	0.	285.2	19.20	0.249	114.9	0.0
3240.00	0.014	539.1	556.2	483.4	0.0	1020.7	7.	0.0	0.	285.2	19.20	0.249	114.9	0.0
3250.00	0.014	539.3	556.3	483.3	0.0	1025.8	7.	0.0	0.	285.3	19.21	0.249	114.9	0.0
3260.00	0.014	539.5	556.4	483.2	0.0	1030.7	7.	0.0	0.	285.3	19.21	0.249	114.9	0.0
3270.00	0.014	539.7	556.5	483.1	0.0	1035.6	7.	0.0	0.	285.3	19.21	0.249	114.9	0.0
3280.00	0.014	539.9	556.7	483.0	0.0	1040.4	6.	0.0	0.	285.4	19.22	0.249	114.9	0.0
3290.00	0.014	540.2	556.8	482.9	0.0	1045.1	6.	0.0	0.	285.4	19.22	0.249	114.9	0.0
3300.00	0.014	540.4	556.9	482.9	0.0	1049.8	6.	0.0	0.	285.4	19.23	0.249	114.9	0.0
3310.00	0.014	540.6	557.1	482.8	0.0	1054.5	6.	0.0	0.	285.5	19.23	0.249	114.9	0.0
3320.00	0.014	540.9	557.3	482.8	0.0	1059.1	6.	220.7	1.	285.5	19.24	0.249	114.9	0.0
3330.00	0.018	540.9	558.2	485.6	0.0	999.9	145.	209.8	1.	285.6	19.24	0.299	115.2	0.0
3340.00	0.016	541.2	558.9	486.9	0.0	981.7	87.	206.6	1.	285.7	19.25	0.349	115.5	0.0
3350.00	0.015	540.7	558.6	487.1	0.0	971.4	112.	204.8	1.	285.7	19.26	0.398	115.8	0.0
3360.00	0.015	539.5	557.6	486.7	0.0	962.0	119.	203.2	1.	285.8	19.27	0.446	116.1	0.0
3370.00	0.015	537.8	556.1	486.0	0.0	952.7	122.	201.5	1.	285.9	19.28	0.494	116.4	0.0
3380.00	0.015	535.9	554.4	485.1	16.7	943.2	127.	201.1	1.	286.0	19.29	0.542	116.6	0.0
3390.00	0.015	534.1	552.8	484.2	16.7	933.4	127.	199.2	1.	286.0	19.29	0.589	116.9	0.0
3400.00	0.015	532.3	551.1	483.4	16.7	923.8	127.	197.0	1.	286.1	19.30	0.636	117.2	0.0
3410.00	0.015	530.5	549.4	482.5	16.7	914.2	127.	194.9	1.	286.2	19.31	0.682	117.5	0.0
3420.00	0.015	528.7	547.7	481.6	16.7	904.8	126.	192.8	1.	286.2	19.32	0.728	117.7	0.0
3430.00	0.015	527.0	546.1	480.7	16.7	895.6	125.	190.7	1.	286.3	19.33	0.774	118.0	0.0
3440.00	0.015	525.2	544.5	479.9	20.8	886.5	125.	189.0	1.	286.4	19.33	0.819	118.2	0.0
3450.00	0.015	523.6	542.9	479.0	20.8	877.3	124.	187.0	1.	286.4	19.34	0.863	118.5	0.0
3460.00	0.015	521.9	541.3	478.2	20.8	868.4	123.	1.6	0.	286.5	19.35	0.908	118.8	0.0
3470.00	0.013	520.8	539.9	476.7	20.8	883.0	22.	1.6	0.	286.5	19.36	0.908	118.8	0.0
3480.00	0.013	520.1	539.1	475.7	20.8	893.2	21.	1.6	0.	286.5	19.36	0.908	118.8	0.0

Table B.5 (continued)

TIME	PREL	LDCVZ	LYAR	LSHRC	WINJ	?	WTOST	WSTC	LOGREL	TGDW	PTDWG	LWSPAV	TWSPAV	WECC
3490.00	0.013	519.4	538.3	474.6	20.8	902.6	20.	1.7	0.	286.6	19.37	0.909	118.8	0.0
3500.00	0.013	518.9	537.7	473.9	83.3	911.0	21.	6.7	0.	286.6	19.37	0.909	118.8	0.0
3510.00	0.013	518.8	537.4	473.4	83.3	918.5	20.	6.7	0.	286.6	19.38	0.911	118.8	0.0
3520.00	0.013	518.7	537.3	473.0	83.3	925.7	19.	6.8	0.	286.7	19.38	0.912	118.8	0.0
3530.00	0.013	518.7	537.2	472.7	83.3	932.5	18.	6.8	0.	286.7	19.39	0.914	118.8	0.0
3540.00	0.013	518.7	537.2	472.4	83.3	938.9	17.	6.8	0.	286.7	19.39	0.915	118.8	0.0
3550.00	0.013	518.9	537.2	472.2	83.3	945.0	16.	6.9	0.	286.7	19.40	0.917	118.8	0.0
3560.00	0.013	519.0	537.3	472.0	83.3	950.9	16.	6.9	0.	286.8	19.40	0.918	118.8	0.0
3570.00	0.013	519.2	537.4	471.9	83.3	956.5	15.	6.9	0.	286.8	19.40	0.920	118.8	0.0
3580.00	0.013	519.4	537.5	471.8	83.3	961.8	15.	7.0	0.	286.8	19.41	0.921	118.8	0.0
3590.00	0.013	519.6	537.7	471.7	83.3	966.9	14.	7.0	0.	286.9	19.41	0.923	118.8	0.0

```
------------DEBUG PRINTOUT------------TIME= 3600.00
&NURV1
B1=  1.00000000    ,CAV= 0.313457847E-01,CAVE= 0.626915693E-01,CAVO= 0.108703494    ,CMDC=  29423.3320    ,CMHDC=  9448041.00    ,
CMHLP= -5934938.00    ,CMLP= -6857.11328    ,CMST= -2964.98242    ,CMTCT=  17433.9414    ,CUMTC= -3080276.00    ,DELF1=
 20.9279785    ,DHF= 0.759277344E-01,DMST=  6.80279064    ,DPO= 0.470464706    ,DUMTO=  8149.98828    ,DVST=-0.638020813    ,EQX=
 0.000000000E+00,FRECIR= 0.984998286    ,HF=  538.069336    ,HFD=  537.879395    ,HG=  1192.88281    ,HINJIN=  57.9999695    ,HLP=
 517.141357    ,HREC=  527.451904    ,HRECIR=  533.708496    ,HST=  1204.21460    ,HWECC= 0.000000000E+00,KLOSSU= 0.546821823E-07,
LB=  5.54489326    ,LBD=  5.58616829    ,LBC=  9.52650166    ,LDC=  25.3238831    ,LDCVZ=  519.886475    ,LINT=  27.5390472    ,
LOGREL= 0.000000000E+00,LOSSIN= 0.514554977E-01,LSC=  6.50552845    ,LSCD=  6.46519089    ,LSCX=  6.51541996    ,LSCO=
 2.47349834    ,MB=  34301.2187    ,MCPINT=  47700.0078    ,MCPRV=  150000.000    ,MDC=  247382.250    ,MCCO=  217981.750    ,
MHDC=  126935232.    ,MHDCO=  117492160.    ,MHLP=  52400000.0    ,MHLPO=  58333308.0    ,MLP=  101326.250    ,MLPO=
 108226.000    ,MPCC=  109497.437    ,MSC=  41681.5469    ,MST=  19866.8555    ,MSTC=  22835.2422    ,MTOST=  176764.937    ,MTOT=
 151995.562    ,MTOTC=  134570.750    ,OPVC= 0.160855830    ,P=  971.834229    ,PREL= 0.132393092E-01,PRELO= 0.399999991E-01,
PTSPG=  17.6682281    ,RHOB=  45.1539612    ,RHCBR=  28.2675781    ,RHCDC=  47.8715057    ,RHOF=  46.5447998    ,RHOG=
 2.17409229    ,RHCLP=  47.6679687    ,RHOREC=  47.1428680    ,RTVO= 0.331022859    ,TAUREC=  2133.43970    ,TGCW=  286.893311    ,
TINT=  540.704102    ,TMIX=  61.4174957    ,TRV=  519.153809    ,TRVO=  518.885742    ,TSAT=  541.151611    ,UACRV=  2.52616215    ,
UCSRV=  4.48990726    ,UMTC=  22231312.0    ,VDC=  5167.62891    ,VOLPW=  2125.66724    ,VST=  9412.37109    ,VSTD=  9413.96484    ,
VSTO=  9897.14062    ,VSVST= 0.473772526    ,WBO=  26.5728149    ,WBOO=  153.753616    ,WCI=  1226.01709    ,WCIC=  1268.35596    ,
WCIG=  1235.70337    ,WCIO=  3548.44019    ,WCCNC= 0.395771004E-01,WCRD= 0.000000000E+00,WECC= 0.000000000E+00,WEXPC=
 0.000000000E+00,WFLDC= 0.000000000E+00,WFLLP= 0.000000000E+00,WINJ=  83.3000031    ,WINJAS= 0.000000000E+00,WPUC=  12.6965780    ,
WRECIR=  1193.95630    ,WSSV= 0.000000000E+00,WSTC=  7.03386879    ,WSTE=  7.03386879    ,WTOST=  13.8762369    ,XO=
 0.432913564E-01
&END
&POOL1
CMHW=  210397184.    ,CMINR=  625.000000    ,CMW=  179650.187    ,ERHR= 0.432576358    ,HSI= 0.124316590E-03,LWSPAV=
 0.924108565    ,MBASE=  7865027.00    ,MW=  8073671.00    ,PVAP=  1.63854980    ,QPC= -133.813919    ,QPCNET= 0.000000000E+00,
QRHR= 0.000000000E+00,TPOCOD=  118.834778    ,TRING=  118.834778    ,TWSPAV=  118.834778    ,UAR=  411.430176    ,VGSP=
 136623.500    ,VGSPO=  140504.500    ,VW=  130976.500    ,VWC=  127295.500    ,WCSPG= 0.110670567    ,WPCCCC=  5473.82422    ,
XNQ= 0.000000000E+00
&END
&PRAT1
QPAIR=  44.0504761    ,QPGAIR= -5.85168171    ,CPWAIR=  49.9021606    ,QRPGC=  12.5381203    ,CRPWC=  133.813416    ,TCCN1=
 91.7521210    ,TCON2=  90.4180756    ,TCCN3=  90.0000000    ,TCCN4=  90.0000000    ,TCON5=  90.0000000    ,TPAIR=  98.5324097
&END
&CONT1
BCSPDW= 0.000000000E+00,BDWC= 0.280000150    ,BDWL= 0.496079773E-02,BDWSP=  2.60317516    ,BDWSPX=  2.59399414    ,BDWVL=
 0.000000000E+00,BSPDW= 0.000000000E+00,BSPDWX= 0.000000000E+00,BSPL= 0.136623508E-02,CHCWC= 0.477011874E-02,CMINO=  47.8025665    ,
CGOINI= 0.000000000E+00,COCTRP= 0.000000000E+00,CUMDWG=  313473.625    ,CUMSPG=  176189.375    ,CWDWC=  143.399994    ,DUMCWG=
 46.7795410    ,DELSPG=  30.7166595    ,EFFO= 0.645711482    ,FFRACT= 0.357393086    ,HUMDW=  5.90600586    ,HLMSP=
 72.6599731    ,MNDWG=  8995.45312    ,MNDWGC=  10325.5352    ,MNSPG=  10511.2617    ,MNSPGO=  9208.23828    ,MSDWG=
 1158.25342    ,MSDWGO=  289.616943    ,MSSPG=  364.054199    ,MSSPGO=  299.537354    ,PNDWG=  16.1798401    ,PNDWGO=
 15.0437571    ,PNSPG=  16.7654419    ,PNSPGO=  13.8017588    ,PSDWG=  3.23968220    ,PSDWGO= 0.656242132    ,FSSPG=
 0.903036892    ,PSSPGO= 0.698241055    ,PTDWG=  19.4195099    ,PTSPG=  17.6684723    ,QDM=  586.945557    ,QDMDRY=  586.945557    ,
QDMWET= 0.000000000E+00,QLDWG=  586.945557    ,QLSPG=  131.939133    ,QCPHL=  1.11544514    ,QPMDRY=  32.3162231    ,QPMWET=
 99.6229095    ,QRVHL=  587.838135    ,QSSPG=  11.8416796    ,QVDWG= 0.000000000E+00,QVSPG= 0.000000000E+00,SPDWO=  3.28121090    ,
TDEWDW=  135.290665    ,TDEWSP=  97.9768311    ,TDMET=  166.834549    ,TCWCE=  286.895508    ,TFLO=  135.290665    ,TGDW=
 286.895508    ,TGSP=  109.119629    ,TPMET=  94.4635468    ,UACWC=  57.0243683    ,UMDWG=  1474937.00    ,UMDWGO=  1161487.00    ,
UMSPG=  1125274.00    ,UMSPGO=  949035.187    ,VGSPO=  136624.062    ,WCDWC= 0.000000000E+00,WCDWG= 0.000000000E+00,WCSPC=
 0.110692084    ,WNDWC= 0.198755004E-01,WSCWCR= 0.255888095E-02,WSDWCS= 0.255888095E-02,WSDWR= 0.243027270    ,WTESPW=
 0.145262539    ,WVCDWG= 0.000000000E+00,WVCSPG= 0.000000000E+00,WWCDWG= 0.000000000E+00,WWCSPG= 0.110692084
&END
```

Table B.5 (continued)

3600.00	0.013	519.9	537.9	471.7	83.3	971.8	14.	7.0	0.	286.9	19.42	0.924	118.8	0.0
3610.00	0.013	520.2	538.1	471.7	83.3	976.5	13.	7.1	0.	286.9	19.42	0.926	118.8	0.0
3620.00	0.013	520.5	538.4	471.7	83.3	981.0	13.	7.1	0.	287.0	19.43	0.927	118.8	0.0
3630.00	0.013	520.8	538.6	471.8	83.3	985.3	13.	7.1	0.	287.0	19.43	0.929	118.9	0.0
3640.00	0.013	521.1	538.9	471.8	83.3	989.4	12.	7.1	0.	287.0	19.44	0.930	118.9	0.0
3650.00	0.013	521.4	539.2	471.9	83.3	993.4	12.	7.2	0.	287.1	19.44	0.932	118.9	0.0
3660.00	0.013	521.8	539.5	472.0	83.3	997.1	12.	7.2	0.	287.1	19.45	0.933	118.9	0.0
3670.00	0.013	522.1	539.8	472.1	83.3	1000.7	11.	7.2	0.	287.1	19.45	0.935	118.9	0.0
3680.00	0.013	522.5	540.2	472.2	83.3	1004.1	11.	7.2	0.	287.2	19.46	0.937	118.9	0.0
3690.00	0.013	522.9	540.5	472.4	83.3	1007.3	11.	7.3	0.	287.2	19.46	0.938	118.9	0.0
3700.00	0.013	523.3	540.9	472.5	83.3	1010.3	10.	7.3	0.	287.2	19.47	0.940	118.9	0.0
3710.00	0.013	523.7	541.2	472.7	83.3	1013.2	10.	7.3	0.	287.3	19.47	0.941	118.9	0.0
3720.00	0.013	524.1	541.6	472.9	83.3	1015.9	10.	7.3	0.	287.3	19.48	0.943	118.9	0.0
3730.00	0.013	524.5	542.0	473.1	83.3	1018.4	9.	7.3	0.	287.3	19.48	0.944	118.9	0.0
3740.00	0.013	525.0	542.4	473.3	83.3	1020.8	9.	7.3	0.	287.4	19.49	0.946	118.9	0.0
3750.00	0.013	525.4	542.8	473.5	83.3	1023.0	9.	7.3	0.	287.4	19.49	0.948	118.9	0.0
3760.00	0.013	525.8	543.2	473.8	83.3	1025.1	8.	7.4	0.	287.4	19.50	0.949	118.9	0.0
3770.00	0.013	526.3	543.6	474.0	83.3	1027.0	8.	7.4	0.	287.5	19.50	0.951	119.0	0.0
3780.00	0.013	526.8	544.1	474.3	83.3	1028.7	8.	221.8	1.	287.5	19.51	0.952	119.0	0.0
3790.00	0.018	526.3	544.5	476.9	83.3	965.7	135.	209.7	1.	287.6	19.51	1.004	119.3	0.0
3800.00	0.018	526.2	545.0	479.1	83.3	919.7	132.	200.8	1.	287.6	19.52	1.052	119.5	0.0
3810.00	0.018	526.4	545.7	481.1	83.3	882.5	120.	193.0	1.	287.7	19.53	1.099	119.8	0.0
3820.00	0.017	526.7	546.6	483.1	83.3	849.5	123.	185.5	1.	287.8	19.54	1.144	120.1	0.0
3830.00	0.017	527.5	547.7	485.2	83.3	820.6	125.	179.0	1.	287.9	19.55	1.187	120.3	0.0
3840.00	0.016	528.5	549.2	487.2	83.3	800.6	96.	174.5	1.	287.9	19.55	1.229	120.5	0.0
3850.00	0.015	528.6	549.3	487.6	83.3	792.7	109.	172.7	1.	288.0	19.56	1.270	120.8	0.0
3860.00	0.015	528.2	549.1	487.8	83.3	784.2	119.	5.9	0.	288.0	19.57	1.310	121.0	0.0
3870.00	0.013	527.7	548.4	486.8	83.3	797.0	21.	6.0	0.	288.1	19.58	1.312	121.0	0.0
3880.00	0.012	527.4	548.0	486.1	83.3	805.4	21.	6.0	0.	288.1	19.58	1.313	121.0	0.0
3890.00	0.013	526.9	547.3	485.3	83.3	812.9	20.	6.1	0.	288.1	19.58	1.314	121.0	0.0
3900.00	0.013	526.4	546.7	484.6	83.3	819.6	18.	6.1	0.	288.2	19.59	1.316	121.0	0.0
3910.00	0.013	526.1	546.3	484.1	83.3	825.7	17.	6.1	0.	288.2	19.59	1.317	121.0	0.0
3920.00	0.013	526.0	546.2	483.7	83.3	831.3	15.	6.2	0.	288.2	19.60	1.318	121.1	0.0
3930.00	0.013	526.0	546.1	483.5	83.3	836.5	14.	6.2	0.	288.3	19.60	1.320	121.1	0.0
3940.00	0.013	526.1	546.2	483.3	83.3	841.4	13.	6.2	0.	288.3	19.61	1.321	121.1	0.0
3950.00	0.013	526.3	546.3	483.2	83.3	845.9	13.	6.3	0.	288.3	19.61	1.322	121.1	0.0
3960.00	0.013	526.5	546.4	483.2	83.3	850.2	12.	6.3	0.	288.3	19.62	1.324	121.1	0.0
3970.00	0.013	526.8	546.7	483.2	83.3	854.3	12.	6.3	0.	288.4	19.62	1.325	121.1	0.0
3980.00	0.013	527.1	546.9	483.2	83.3	858.1	11.	6.3	0.	288.4	19.63	1.326	121.1	0.0
3990.00	0.013	527.4	547.2	483.3	83.3	861.7	11.	6.4	0.	288.4	19.63	1.328	121.1	0.0
4000.00	0.013	527.7	547.5	483.4	83.3	865.1	10.	6.4	0.	288.5	19.64	1.329	121.1	0.0
4010.00	0.013	528.1	547.8	483.5	83.3	868.3	10.	6.4	0.	288.5	19.64	1.330	121.1	0.0
4020.00	0.013	528.5	548.1	483.6	83.3	871.3	10.	6.4	0.	288.5	19.64	1.332	121.1	0.0
4030.00	0.013	528.8	548.5	483.8	83.3	874.1	9.	6.4	0.	288.5	19.65	1.333	121.1	0.0
4040.00	0.013	529.2	548.9	483.9	83.3	876.7	9.	6.5	0.	288.6	19.65	1.335	121.1	0.0
4050.00	0.013	529.7	549.2	484.1	83.3	879.2	9.	6.5	0.	288.6	19.66	1.336	121.1	0.0
4060.00	0.013	530.1	549.6	484.4	83.3	881.5	8.	6.5	0.	288.6	19.66	1.338	121.1	0.0

Table B.5 (continued)

TIME	PREL	LDCVZ	LYAR	LSHRG	WINJ	P	WTCST	WSTC	LOGREL	TGCW	PTCWG	LWSPAV	TWSPAV	WECC
4070.00	0.013	530.5	550.1	484.6	83.3	883.7	8.	6.5	0.	288.7	19.67	1.339	121.1	0.0
4080.00	0.013	531.0	550.5	484.8	83.3	885.7	8.	6.5	0.	288.7	19.67	1.340	121.1	0.0
4090.00	0.013	531.4	550.9	485.1	83.3	887.5	7.	6.5	0.	288.7	19.68	1.342	121.2	0.0
4100.00	0.013	531.9	551.4	485.4	83.3	889.2	7.	6.5	0.	288.8	19.68	1.343	121.2	0.0
4110.00	0.013	532.3	551.8	485.7	83.3	890.7	7.	6.5	0.	288.8	19.69	1.345	121.2	0.0
4120.00	0.013	532.8	552.3	486.0	83.3	892.1	6.	6.5	0.	288.8	19.69	1.346	121.2	0.0
4130.00	0.013	533.3	552.8	486.3	83.3	893.3	6.	6.6	0.	288.8	19.69	1.347	121.2	0.0
4140.00	0.013	533.8	553.3	486.6	83.3	894.4	6.	6.6	0.	288.9	19.70	1.349	121.2	0.0
4150.00	0.013	534.3	553.8	487.0	83.3	895.3	6.	6.6	0.	288.9	19.70	1.350	121.2	0.0
4160.00	0.013	534.8	554.3	487.3	83.3	896.1	5.	6.6	0.	288.9	19.71	1.352	121.2	0.0
4170.00	0.013	535.3	554.8	487.7	83.3	896.6	5.	6.6	0.	289.0	19.71	1.353	121.2	0.0
4180.00	0.013	535.9	555.3	488.1	83.3	897.2	5.	6.6	0.	289.0	19.72	1.355	121.2	0.0
4190.00	0.013	536.4	555.9	488.5	83.3	897.6	5.	6.6	0.	289.0	19.72	1.356	121.2	0.0
4200.00	0.013	537.0	556.4	488.9	83.3	897.8	4.	6.6	0.	289.1	19.73	1.357	121.2	0.0
4210.00	0.013	537.5	557.0	489.3	83.3	897.9	4.	6.6	0.	289.1	19.73	1.359	121.2	0.0
4220.00	0.013	538.1	557.6	489.8	83.3	897.9	4.	6.6	0.	289.1	19.73	1.360	121.2	0.0
4230.00	0.013	538.6	558.2	490.2	83.3	897.7	4.	6.6	0.	289.2	19.74	1.362	121.2	0.0
4240.00	0.013	539.2	558.8	490.7	83.3	897.4	3.	6.6	0.	289.2	19.74	1.363	121.2	0.0
4250.00	0.013	539.8	559.4	491.2	83.3	897.0	3.	6.6	0.	289.2	19.75	1.365	121.3	0.0
4260.00	0.013	540.4	560.0	491.6	83.3	896.5	3.	6.6	0.	289.3	19.75	1.366	121.3	0.0
4270.00	0.013	541.0	560.6	492.1	83.3	895.8	3.	6.6	0.	289.3	19.76	1.367	121.3	0.0
4280.00	0.013	541.6	561.2	492.6	83.3	895.1	3.	6.6	0.	289.3	19.76	1.369	121.3	0.0
4290.00	0.013	542.2	561.8	493.2	83.3	894.2	2.	6.6	0.	289.4	19.77	1.370	121.3	0.0
4300.00	0.013	542.8	562.5	493.7	83.3	893.2	2.	6.6	0.	289.4	19.77	1.372	121.3	0.0
4310.00	0.013	543.4	563.2	494.3	83.3	891.3	0.	6.5	0.	289.4	19.77	1.373	121.3	0.0
4320.00	0.013	544.1	563.9	494.9	83.3	889.1	0.	6.5	0.	289.5	19.78	1.375	121.3	0.0
4330.00	0.013	544.8	564.6	495.6	83.3	886.8	0.	6.5	0.	289.5	19.78	1.376	121.3	0.0
4340.00	0.013	545.4	565.4	496.2	79.1	884.7	0.	6.2	0.	289.5	19.79	1.377	121.3	0.0
4350.00	0.013	546.1	566.1	496.9	79.1	882.7	0.	6.2	0.	289.6	19.79	1.379	121.3	0.0
4360.00	0.013	546.8	566.9	497.5	79.1	880.8	0.	6.2	0.	289.6	19.80	1.380	121.3	0.0
4370.00	0.013	547.6	567.7	498.2	79.1	879.0	0.	6.1	0.	289.6	19.80	1.381	121.3	0.0
4380.00	0.013	548.4	568.5	498.9	79.1	877.3	0.	6.1	0.	289.7	19.81	1.383	121.3	0.0
4390.00	0.013	549.2	569.4	499.6	79.1	875.6	0.	6.1	0.	289.7	19.81	1.384	121.3	0.0
4400.00	0.013	549.9	570.1	500.2	0.0	874.6	0.	0.0	0.	289.7	19.81	1.385	121.3	0.0
4410.00	0.013	550.3	570.5	500.5	0.0	875.9	0.	0.0	0.	289.8	19.82	1.385	121.3	0.0
4420.00	0.013	550.7	571.0	500.8	0.0	877.3	0.	0.0	0.	289.8	19.82	1.385	121.3	0.0
4430.00	0.013	551.2	571.4	501.0	0.0	878.7	0.	0.0	0.	289.8	19.83	1.385	121.3	0.0
4440.00	0.013	551.6	571.8	501.3	0.0	880.0	0.	0.0	0.	289.9	19.83	1.385	121.3	0.0
4450.00	0.013	551.9	572.1	501.5	0.0	881.1	0.	0.0	0.	289.9	19.83	1.385	121.3	0.0
4460.00	0.013	552.4	572.6	501.8	0.0	882.5	0.	0.0	0.	289.9	19.84	1.385	121.3	0.0
4470.00	0.013	552.9	573.1	502.1	0.0	884.2	0.	0.0	0.	290.0	19.84	1.385	121.3	0.0
4480.00	0.013	553.4	573.5	502.4	0.0	885.7	0.	0.0	0.	290.0	19.85	1.385	121.3	0.0
4490.00	0.013	553.9	574.0	502.7	0.0	887.2	0.	0.0	0.	290.0	19.85	1.385	121.3	0.0
4500.00	0.013	554.4	574.5	503.0	0.0	888.7	0.	0.0	0.	290.1	19.86	1.385	121.3	0.0
4510.00	0.013	554.8	574.9	503.3	0.0	890.3	0.	0.0	0.	290.1	19.86	1.385	121.3	0.0
4520.00	0.013	555.3	575.4	503.6	0.0	892.1	1.	0.0	0.	290.1	19.86	1.385	121.3	0.0
4530.00	0.013	555.8	575.8	503.8	0.0	894.1	1.	0.0	0.	290.2	19.87	1.385	121.3	0.0
4540.00	0.013	556.2	576.2	504.1	0.0	896.2	1.	0.0	0.	290.2	19.87	1.384	121.3	0.0
4550.00	0.013	556.7	576.7	504.3	0.0	898.6	2.	0.0	0.	290.2	19.88	1.384	121.3	0.0
4560.00	0.013	557.2	577.1	504.5	0.0	901.1	2.	0.0	0.	290.3	19.88	1.384	121.3	0.0
4570.00	0.013	557.6	577.5	504.7	0.0	903.8	2.	0.0	0.	290.3	19.88	1.384	121.3	0.0
4580.00	0.013	558.0	577.9	504.9	0.0	906.6	2.	0.0	0.	290.3	19.89	1.384	121.3	0.0
4590.00	0.012	558.4	578.2	505.1	0.0	909.5	2.	0.0	0.	290.4	19.89	1.364	121.3	0.0
4600.00	0.012	558.8	578.6	505.2	0.0	912.6	3.	189.7	1.	290.4	19.90	1.384	121.3	0.0
4610.00	0.017	559.2	579.9	508.2	0.0	861.2	125.	180.2	1.	290.5	19.90	1.428	121.6	0.0
4620.00	0.014	559.9	580.9	509.4	0.0	852.8	69.	178.8	1.	290.5	19.91	1.471	121.8	0.0
4630.00	0.014	559.8	581.1	509.8	0.0	845.2	92.	177.5	1.	290.6	19.92	1.513	122.1	0.0
4640.00	0.014	559.0	580.5	509.6	0.0	838.1	96.	176.2	1.	290.7	19.93	1.555	122.3	0.0

Table B.5 (continued)

TIME	PREL	LDCVZ	LVAR	LSHRD	WINJ	P	WTOST	WSTC	LCGREL	TGCW	PTCWG	LWSPAV	TWSPAV	WECC
4650.00	0.014	557.[illegible]	[illegible].2	509.1	0.0	831.4	82.	175.0	1.	290.7	19.93	1.597	122.6	0.0
4660.00	0.014	556[illegible]	[illegible]7.7	508.3	0.0	824.9	69.	173.8	1.	290.8	19.94	1.638	122.8	0.0
4670.00	0.014	554.[illegible]	[illegible]6.1	507.3	0.0	818.4	66.	172.4	1.	290.8	19.95	1.679	123.[illegible]	0.0
4680.00	0.014	552.6	574.4	506.4	0.0	811.5	66.	170.9	1.	290.9	19.96	1.720	123.3	0.0
4690.00	0.014	550.8	572.8	505.4	0.0	804.7	67.	169.4	1.	291.0	19.96	1.760	123.5	0.0
4700.00	0.014	549.1	571.1	504.4	0.0	798.0	6[illegible].	168.0	1.	291.0	19.97	1.800	123.7	0.0
4710.00	0.014	547.3	569.4	503.4	0.0	791.4	67.	166.5	1.	291.1	19.98	1.840	124.0	0.0
4720.00	0.014	545.7	567.8	502.5	0.0	784.9	66.	165.1	1.	291.2	19.99	1.879	124.2	0.0
4730.00	0.014	544.0	566.2	501.5	0.0	778.5	66.	163.7	1.	291.2	19.99	1.918	124.4	0.0
4740.00	0.014	542.4	564.6	500.6	0.0	772.2	67.	162.3	1.	291.3	20.00	1.957	124.6	0.0
4750.00	0.014	540.8	563.1	499.7	0.0	766.0	66.	161.0	1.	291.3	20.01	1.995	124.8	0.0
4760.00	0.014	539.3	561.6	498.8	0.0	759.9	66.	159.7	1.	291.4	20.02	2.033	125.1	0.0
4770.00	0.014	537.7	560.0	498.0	0.0	753.9	66.	158.4	1.	291.4	20.02	2.071	125.3	0.0
4780.00	0.014	536.2	558.5	497.1	0.0	748.0	66.	157.1	1.	291.5	20.03	2.108	125.5	0.0
4790.00	0.014	534.7	557.0	496.2	0.0	742.1	66.	155.8	1.	291.5	20.04	2.145	125.7	0.0
4800.00	0.014	533.2	555.6	495.4	0.0	736.4	66.	154.[illegible]	1.	291.6	20.05	2.182	125.9	0.0
4810.00	0.014	531.8	554.2	494.6	16.7	730.3	68.	154.4	1.	291.6	20.05	2.219	126.1	0.0
4820.00	0.014	530.5	552.9	493.9	16.7	724.1	69.	153.0	1.	291.7	20.06	2.255	126.3	0.0
4830.00	0.014	529.1	551.6	493.2	16.7	718.0	68.	151.7	1.	291.7	20.07	2.292	126.5	0.0
4840.00	0.014	527.8	550.3	492.4	16.7	712.0	68.	150.4	1.	291.8	20.07	2.327	126.7	0.0
4850.00	0.014	526.5	549.0	491.7	16.7	706.1	68.	149.1	1.	291.8	20.08	2.363	126.9	0.0
4860.00	0.014	525.2	547.7	491.0	16.7	700.3	67.	1.1	0.	291.9	20.09	2.398	127.1	0.0
4870.00	0.012	524.1	546.4	489.5	20.8	711.0	17.	1.4	0.	291.9	20.10	2.398	127.1	0.0
4880.00	0.012	523.4	545.5	488.5	20.8	719.1	17.	1.4	0.	291.9	20.10	2.399	127.1	0.0
4890.00	0.012	522.6	544.5	487.5	20.8	726.6	16.	1.4	0.	291.9	20.11	2.399	127.1	0.0
4900.00	0.012	521.9	543.7	486.6	20.8	733.5	14.	1.4	0.	292.0	20.11	2.399	127.1	0.0
4910.00	0.012	521.5	543.2	485.9	20.8	740.0	13.	1.4	0.	292.0	20.12	2.399	127.2	0.0
4920.00	0.012	521.2	542.8	485.3	20.8	746.3	12.	1.[illegible]	0.	292.0	20.12	2.400	127.2	0.0
4930.00	0.012	521.1	542.6	484.9	25.0	752.3	12.	1.7	0.	292.0	20.13	2.400	127.2	0.0
4940.00	0.012	521.1	542.5	484.6	25.0	758.1	11.	1.7	0.	292.0	20.13	2.400	127.2	0.0
4950.00	0.012	521.0	542.4	484.3	25.0	763.7	11.	1.7	0.	292.1	20.14	2.400	127.2	0.0
4960.00	0.012	521.1	542.3	484.0	25.0	769.2	11.	1.7	0.	292.1	20.14	2.401	127.2	0.0
4970.00	0.012	521.1	542.3	483.8	25.0	774.6	10.	1.7	0.	292.1	20.15	2.401	127.2	[illegible].0
4980.00	0.012	521.2	542.3	483.6	25.0	779.9	10.	1.8	0.	292.1	20.15	2.401	127.2	0.0
4990.00	0.012	521.3	542.4	483.4	29.2	785.0	10.	2.1	0.	292.1	20.15	2.402	127.2	0.0
5000.00	0.012	521.4	542.4	483.2	29.2	790.0	10.	2.1	0.	292.2	20.16	2.402	127.2	0.0
5010.00	0.012	521.5	542.5	483.1	29.2	794.9	10.	2.1	0.	292.2	20.16	2.403	127.2	0.0
5020.00	0.012	521.7	542.6	482.9	29.2	799.8	9.	2.1	0.	292.2	20.17	2.403	127.2	0.0
5030.00	0.012	521.8	542.7	482.8	29.2	804.5	9.	2.1	0.	292.2	20.17	2.403	127.2	0.0
5040.00	0.012	522.0	542.8	482.7	29.2	809.2	9.	2.1	0.	292.3	20.18	2.404	127.2	0.0
5050.00	0.012	522.2	542.9	482.6	33.3	813.7	9.	2.4	0.	292.3	20.18	2.404	127.2	0.0
5060.00	0.012	522.4	543.1	482.5	33.3	818.1	9.	171.5	1.	292.3	20.19	2.405	127.2	0.0
5070.00	0.016	522.2	543.5	484.5	33.3	778.0	119.	164.1	1.	292.3	20.19	2.445	127.4	0.0
5080.00	0.016	522.3	543.9	486.0	33.3	749.4	117.	158.8	1.	292.4	20.20	2.483	127.6	0.0
5090.00	0.016	522.8	544.7	487.7	33.3	725.1	117.	154.3	1.	292.4	20.21	2.520	127.8	0.0
5100.00	0.014	522.9	545.1	488.5	33.3	714.0	75.	151.9	1.	292.5	20.22	2.556	128.0	0.0
5110.00	0.013	522.7	545.0	486.7	37.5	707.9	89.	150.9	1.	292.5	20.22	2.592	128.2	0.0
5120.00	0.013	522.2	544.5	488.7	37.5	702.6	64.	149.7	1.	292.6	20.23	2.628	128.4	0.0
5130.00	0.013	521.4	543.8	488.4	37.5	696.3	67.	148.3	1.	292.6	20.24	2.663	128.6	0.0
5140.00	0.013	520.5	542.9	488.0	37.5	690.0	68.	147.0	1.	292.6	20.24	2.698	128.8	0.0
5150.00	0.013	519.6	542.0	487.6	37.5	683.7	69.	145.6	1.	292.7	20.25	2.733	129.0	0.0
5160.00	0.013	518.6	541.0	487.1	37.5	677.4	69.	144.2	1.	292.7	20.26	2.768	129.2	0.0
5170.00	0.013	517.6	540.0	486.7	41.6	671.1	70.	143.1	1.	292.8	20.26	2.802	129.4	0.0
5180.00	0.013	516.6	539.1	486.2	41.6	664.9	70.	141.8	1.	292.8	20.27	2.835	129.6	0.0
5190.00	0.013	515.6	538.1	485.8	41.6	658.7	70.	140.4	1.	292.8	20.28	2.869	129.8	0.0
5200.00	0.013	514.7	537.1	485.3	41.6	652.7	70.	2.5	0.	292.9	20.28	2.902	130.0	0.0
5210.00	0.011	513.7	535.9	483.9	41.6	662.8	17.	2.6	0.	292.9	20.29	2.902	130.0	0.0
5220.00	0.011	513.2	535.3	483.2	41.6	670.5	17.	2.6	0.	292.9	20.30	2.903	130.0	0.0

Table B.5 (continued)

TIME	PREL	LOCVZ	LYAR	LSHRD	WINJ	P	WTOST	WSTC	LCGREL	TGCW	PTCWG	LWSPAV	TWSPAV	WECC
5230.00	0.011	512.[illegible]	534.7	482.4	83.3	677.4	18.	5.2	0.	293.0	20.30	2.904	130.0	0.0
5240.00	0.011	512.3	534.3	481.8	83.3	683.7	16.	5.3	0.	293.0	20.31	2.905	130.0	0.0
5250.00	0.012	512.2	534.0	481.3	83.3	689.7	15.	5.3	0.	293.0	20.32	2.906	130.0	0.0
5260.00	0.012	512.1	533.9	481.0	83.3	695.4	15.	5.3	0.	293.0	20.32	2.907	130.0	0.0
5270.00	0.012	512.2	533.9	480.8	83.3	700.8	14.	5.4	0.	293.0	20.33	2.908	130.0	0.0
5280.00	0.012	512.3	534.0	480.6	83.3	706.1	13.	5.4	0.	293.1	20.33	2.909	130.0	0.0
5290.00	0.012	512.5	534.1	480.5	83.3	711.2	13.	5.4	0.	293.1	20.34	2.911	130.0	0.0
5300.00	0.012	512.7	534.3	480.4	83.3	716.1	13.	5.5	0.	293.1	20.34	2.912	130.0	0.0
5310.00	0.012	512.9	534.5	480.3	83.3	720.8	12.	5.5	0.	293.1	20.34	2.913	130.0	0.0
5320.00	0.012	513.2	534.7	480.3	83.3	725.4	12.	5.5	0.	293.1	20.35	2.914	130.0	0.0
5330.00	0.012	513.4	534.9	480.2	83.3	729.9	12.	5.6	0.	293.1	20.35	2.915	130.0	0.0
5340.00	0.012	513.7	535.1	480.2	83.3	734.2	12.	5.6	0.	293.2	20.36	2.916	130.0	0.0
5350.00	0.012	514.0	535.4	480.3	83.3	738.4	11.	5.6	0.	293.2	20.36	2.918	130.0	0.0
5360.00	0.012	514.3	535.7	480.3	83.3	742.5	11.	5.6	0.	293.2	20.37	2.919	130.1	0.0
5370.00	0.012	514.6	536.0	480.3	83.3	746.4	11.	5.7	0.	293.2	20.37	2.920	130.1	0.0
5380.00	0.012	514.9	536.3	480.4	83.3	750.3	11.	5.7	0.	293.2	20.38	2.921	130.1	0.0
5390.00	0.012	515.3	536.6	480.5	83.3	754.0	11.	5.7	0.	293.2	20.38	2.922	130.1	0.0
5400.00	0.012	515.6	536.9	480.6	0.0	757.6	10.	156.5	1.	293.3	20.39	2.924	130.1	0.0
5410.00	0.012	515.6	536.8	480.4	0.0	760.5	7.	0.0	0.	293.3	20.39	2.926	130.1	0.0
5420.00	0.012	515.7	536.9	480.3	0.0	765.1	7.	0.0	0.	293.3	20.40	2.925	130.1	0.0
5430.00	0.012	515.8	537.0	480.1	0.0	769.7	7.	0.0	0.	293.3	20.40	2.925	130.1	0.0
5440.00	0.012	516.0	537.1	480.0	0.0	774.3	7.	0.0	0.	293.3	20.41	2.925	130.1	0.0
5450.00	0.012	516.1	537.2	479.9	0.0	778.8	7.	0.0	0.	293.3	20.41	2.925	130.1	0.0
5460.00	0.012	516.2	537.2	479.8	0.0	783.3	7.	0.0	0.	293.4	20.41	2.925	130.1	0.0
5470.00	0.012	516.4	537.3	479.6	0.0	787.9	7.	0.0	0.	293.4	20.42	2.925	130.1	0.0
5480.00	0.012	516.5	537.4	479.5	0.0	792.4	7.	0.0	0.	293.4	20.42	2.925	130.1	0.0
5490.00	0.012	516.6	537.5	479.4	0.0	796.9	7.	0.0	0.	293.4	20.43	2.925	130.1	0.0
5500.00	0.012	516.7	537.6	479.3	0.0	801.4	7.	0.0	0.	293.4	20.43	2.925	130.1	0.0
5510.00	0.012	516.9	537.7	479.2	0.0	805.8	7.	0.0	0.	293.5	20.44	2.925	130.1	0.0
5520.00	0.012	517.0	537.8	479.0	0.0	810.3	7.	0.0	0.	293.5	20.44	2.925	130.1	0.0
5530.00	0.012	517.1	537.8	478.9	0.0	814.7	7.	0.0	0.	293.5	20.45	2.925	130.1	0.0
5540.00	0.012	517.3	537.9	478.8	0.0	819.2	7.	0.0	0.	293.5	20.45	2.925	130.1	0.0
5550.00	0.012	517.4	538.0	478.7	0.0	823.6	7.	0.0	0.	293.5	20.46	2.925	130.1	0.0
5560.00	0.012	517.5	538.1	478.6	0.0	828.0	7.	0.0	0.	293.6	20.46	2.925	130.1	0.0
5570.00	0.012	517.7	538.2	478.5	0.0	832.4	7.	0.0	0.	293.6	20.46	2.925	130.1	0.0
5580.00	0.012	517.8	538.3	478.4	0.0	836.8	7.	0.0	0.	293.6	20.47	2.925	130.1	0.0
5590.00	0.012	518.0	538.4	478.3	0.0	841.2	7.	0.0	0.	293.6	20.47	2.925	130.1	0.0
5600.00	0.012	518.1	538.5	478.2	0.0	845.5	7.	0.0	0.	293.7	20.48	2.925	130.1	0.0
5610.00	0.012	518.2	538.6	478.1	0.0	849.9	7.	0.0	0.	293.7	20.48	2.925	130.1	0.0
5620.00	0.012	518.4	538.7	478.0	0.0	854.2	7.	0.0	0.	293.7	20.49	2.925	130.1	0.0
5630.00	0.012	518.5	538.8	477.9	0.0	858.6	7.	0.0	0.	293.7	20.49	2.924	130.1	0.0
5640.00	0.012	518.7	538.9	477.8	0.0	862.9	7.	0.0	0.	293.7	20.50	2.924	130.1	0.0
5650.00	0.012	518.8	539.0	477.7	0.0	867.2	7.	0.0	0.	293.8	20.50	2.924	130.1	0.0
5660.00	0.012	518.9	539.1	477.6	0.0	871.4	6.	0.0	0.	293.8	20.50	2.924	130.1	0.0
5670.00	0.012	519.1	539.2	477.5	0.0	875.7	6.	0.0	0.	293.8	20.51	2.924	130.1	0.0
5680.00	0.012	519.2	539.3	477.4	0.0	879.9	6.	0.0	0.	293.8	20.51	2.924	130.1	0.0
5690.00	0.012	519.4	539.4	477.3	0.0	884.2	6.	0.0	0.	293.9	20.52	2.924	130.1	0.0
5700.00	0.012	519.5	539.5	477.2	0.0	888.4	6.	0.0	0.	293.9	20.52	2.924	130.1	0.0
5710.00	0.012	519.7	539.6	477.1	0.0	892.6	6.	0.0	0.	293.9	20.53	2.924	130.1	0.0
5720.00	0.012	519.8	539.7	477.0	0.0	896.8	6.	0.0	0.	294.0	20.53	2.924	130.1	0.0
5730.00	0.012	520.0	539.8	477.0	0.0	901.0	6.	0.0	0.	294.0	20.54	2.924	130.1	0.
5740.00	0.012	520.1	539.9	476.9	0.0	905.1	6.	0.0	0.	294.0	20.54	2.924	130.1	0.0
5750.00	0.012	520.3	540.0	476.8	0.0	909.2	6.	0.0	0.	294.0	20.55	2.924	130.1	0.0
5760.00	0.012	520.4	540.1	476.7	0.0	913.4	6.	0.0	0.	294.1	20.55	2.924	130.1	0.0
5770.00	0.012	520.6	540.2	476.7	0.0	917.5	6.	0.0	0.	294.1	20.55	2.924	130.1	0.0
5780.00	0.012	520.7	540.3	476.6	0.0	921.5	6.	0.0	0.	294.1	20.56	2.924	130.1	0.0
5790.00	0.012	520.9	540.4	476.5	0.0	925.6	6.	0.0	0.	294.2	20.56	2.924	130.1	0.0
5800.00	0.012	521.0	540.5	476.4	0.0	929.7	6.	0.0	0.	294.2	20.57	2.924	130.1	0.0

Table B.5 (continued)

TIME	PREL	LOCVZ	LYAR	LSHRD	WINJ	P	WTCST	WSTC	LOGREL	TGDW	PTDWG	LWSPAV	TWSPAV	WECC
5810.00	0.012	521.2	540.6	476.4	0.0	933.7	6.	0.0	0.	294.2	20.57	2.924	130.1	0.0
5820.00	0.012	521.4	540.8	476.3	0.0	937.7	6.	0.0	0.	294.3	20.58	2.923	130.1	0.0
5830.00	0.012	521.5	540.9	476.2	0.0	941.7	6.	0.0	0.	294.3	20.58	2.923	130.1	0.0
5840.00	0.012	521.7	541.0	476.2	0.0	945.7	6.	0.0	0.	294.3	20.59	2.923	130.1	0.0
5850.00	0.012	521.8	541.1	476.1	0.0	949.6	6.	0.0	0.	294.3	20.59	2.923	130.1	0.0
5860.00	0.012	522.0	541.2	476.1	0.0	953.5	6.	0.0	0.	294.4	20.60	2.923	130.1	0.0
5870.00	0.012	522.2	541.4	476.0	0.0	957.5	6.	0.0	0.	294.4	20.60	2.923	130.1	0.0
5880.00	0.012	522.3	541.5	476.0	0.0	961.3	6.	0.0	0.	294.4	20.61	2.923	130.1	0.0
5890.00	0.012	522.5	541.6	475.9	0.0	965.2	6.	0.0	0.	294.5	20.61	2.923	130.1	0.0
5900.00	0.012	522.7	541.7	475.9	0.0	969.1	6.	0.0	0.	294.5	20.61	2.923	130.1	0.0
5910.00	0.012	522.9	541.8	475.8	0.0	972.9	5.	0.0	0.	294.5	20.62	2.923	130.1	0.0
5920.00	0.012	523.0	542.0	475.8	0.0	976.7	5.	0.0	0.	294.6	20.62	2.923	130.1	0.0
5930.00	0.012	523.2	542.1	475.7	0.0	980.5	5.	0.0	0.	294.6	20.63	2.923	130.0	0.0
5940.00	0.012	523.4	542.2	475.7	0.0	984.3	5.	0.0	0.	294.6	20.63	2.923	130.0	0.0
5950.00	0.012	523.5	542.4	475.6	0.0	988.0	5.	0.0	0.	294.7	20.64	2.923	130.0	0.0
5960.00	0.012	523.7	542.5	475.6	0.0	991.7	5.	0.0	0.	294.7	20.64	2.923	130.0	0.0
5970.00	0.012	523.9	542.6	475.6	0.0	995.4	5.	0.0	0.	294.8	20.65	2.923	130.0	0.0
5980.00	0.012	524.1	542.8	475.5	0.0	999.1	5.	0.0	0.	294.8	20.65	2.923	130.0	0.0
5990.00	0.012	524.3	542.9	475.5	0.0	1002.8	5.	0.0	0.	294.8	20.66	2.923	130.0	0.0
6000.00	0.012	524.4	543.0	475.5	0.0	1006.4	5.	0.0	0.	294.9	20.66	2.923	130.0	0.0
6010.00	0.012	524.6	543.2	475.5	0.0	1010.0	5.	0.0	0.	294.9	20.67	2.923	130.0	0.0
6020.00	0.012	524.8	543.3	475.4	0.0	1013.6	5.	0.0	0.	294.9	20.67	2.922	130.0	0.0
6030.00	0.011	525.0	543.5	475.4	0.0	1017.2	5.	0.0	0.	295.0	20.67	2.922	130.0	0.0
6040.00	0.011	525.2	543.6	475.4	0.0	1020.7	5.	0.0	0.	295.0	20.68	2.922	130.0	0.0
6050.00	0.011	525.4	543.8	475.4	0.0	1024.2	5.	0.0	0.	295.1	20.68	2.922	130.0	0.0
6060.00	0.011	525.6	543.9	475.4	0.0	1027.7	5.	0.0	0.	295.1	20.69	2.922	130.0	0.0
6070.00	0.011	525.8	544.1	475.4	0.0	1031.2	5.	0.0	0.	295.1	20.69	2.922	130.0	0.0
6080.00	0.011	526.0	544.2	475.3	0.0	1034.6	5.	0.0	0.	295.2	20.70	2.922	130.0	0.0
6090.00	0.011	526.2	544.4	475.3	0.0	1038.0	5.	0.0	0.	295.2	20.70	2.922	130.0	0.0
6100.00	0.011	526.4	544.5	475.3	0.0	1041.4	5.	0.0	0.	295.3	20.71	2.922	130.0	0.0
6110.00	0.011	526.6	544.7	475.3	0.0	1044.8	4.	0.0	0.	295.3	20.71	2.922	130.0	0.0
6120.00	0.011	526.8	544.8	475.3	0.0	1048.1	4.	0.0	0.	295.3	20.72	2.922	130.0	0.0
6130.00	0.011	527.0	545.0	475.3	0.0	1051.4	4.	0.0	0.	295.4	20.72	2.922	130.0	0.0
6140.00	0.011	527.2	545.2	475.3	0.0	1054.7	4.	0.0	0.	295.4	20.73	2.922	130.0	0.0
6150.00	0.011	527.4	545.3	475.3	0.0	1058.0	4.	0.0	0.	295.5	20.73	2.922	130.0	0.0
6160.00	0.011	527.6	545.5	475.4	0.0	1061.2	4.	0.0	0.	295.5	20.74	2.922	130.0	0.0
6170.00	0.011	527.8	545.7	475.4	0.0	1064.4	4.	0.0	0.	295.6	20.74	2.922	130.0	0.0
6180.00	0.011	528.0	545.8	475.4	0.0	1067.6	4.	0.0	0.	295.6	20.75	2.922	130.0	0.0
6190.00	0.011	528.2	546.0	475.4	0.0	1070.8	4.	0.0	0.	295.6	20.75	2.922	130.0	0.0
6200.00	0.011	528.4	546.2	475.4	0.0	1073.9	4.	0.0	0.	295.7	20.75	2.922	130.0	0.0
6210.00	0.011	528.7	546.3	475.4	0.0	1077.0	4.	0.0	0.	295.7	20.76	2.922	130.0	0.0
6220.00	0.011	528.9	546.5	475.5	0.0	1080.1	4.	0.0	0.	295.8	20.76	2.922	130.0	0.0
6230.00	0.011	529.1	546.7	475.5	0.0	1083.1	4.	0.0	0.	295.8	20.77	2.921	130.0	0.0
6240.00	0.011	529.3	546.9	475.5	0.0	1086.1	4.	0.0	0.	295.9	20.77	2.921	130.0	0.0
6250.00	0.011	529.5	547.1	475.6	0.0	1089.1	4.	0.0	0.	295.9	20.78	2.921	130.0	0.0
6260.00	0.011	529.8	547.2	475.6	0.0	1092.1	4.	0.0	0.	296.0	20.78	2.921	130.0	0.0
6270.00	0.011	530.0	547.4	475.6	0.0	1095.0	3.	0.0	0.	296.0	20.79	2.921	130.0	0.0
6280.00	0.011	530.2	547.6	475.7	0.0	1097.9	3.	0.0	0.	296.0	20.79	2.921	130.0	0.0
6290.00	0.011	530.4	547.8	475.7	0.0	1100.8	3.	0.0	0.	296.1	20.80	2.921	130.0	0.0
6300.00	0.011	530.7	548.0	475.8	0.0	1103.6	3.	0.0	0.	296.1	20.80	2.921	130.0	0.0
6310.00	0.011	530.9	548.2	475.8	0.0	1106.5	3.	0.0	0.	296.2	20.81	2.921	130.0	0.0
6320.00	0.011	531.2	548.4	475.9	0.0	1109.2	3.	0.0	0.	296.2	20.81	2.921	130.0	0.0
6330.00	0.011	531.4	548.6	475.9	0.0	1112.0	3.	0.0	0.	296.3	20.82	2.921	130.0	0.0
6340.00	0.011	531.6	548.8	476.0	0.0	1114.7	3.	0.0	0.	296.3	20.82	2.921	130.0	0.0
6350.00	0.017	530.9	549.0	478.4	0.0	1051.1	148.	212.7	1.	296.4	20.83	2.965	130.3	0.0
6360.00	0.012	531.1	549.0	478.1	0.0	1062.6	4.	0.0	0.	296.5	20.83	2.968	130.3	0.0
6370.00	0.011	531.3	549.2	478.1	0.0	1066.3	5.	0.0	0.	296.5	20.84	2.968	130.3	0.0
6380.00	0.011	531.6	549.4	478.1	0.0	1070.0	4.	0.0	0.	296.5	20.84	2.968	130.3	0.0

Table B.5 (continued)

TIME	PREL	LDCVZ	LYAR	LSHRC	WINJ	P	WTOST	WSTC	LOGREL	TGDW	PTCWG	LWSPAV	TWSPAV	WECC
6390.00	0.C11	531.8	549.6	478.2	C.C	1C73.6	4.	0.0	0.	296.6	20.85	2.968	13C.3	C.C
6400.00	0.C11	532.1	549.8	478.2	0.C	1077.2	4.	C.0	0.	296.6	20.85	2.968	130.3	0.0
6410.00	C.C11	532.3	550.0	478.2	0.0	1080.7	4.	C.0	C.	296.7	20.86	2.968	13C.3	0.0
6420.00	0.011	532.6	550.2	478.2	0.0	1084.3	4.	0.0	0.	296.7	20.86	2.967	13C.3	C.C
6430.00	0.011	532.8	550.4	478.3	C.C	1C87.7	4.	C.0	0.	296.8	20.87	2.967	130.3	0.C
6440.00	0.011	533.1	550.6	478.3	0.0	1091.2	4.	0.0	C.	296.8	20.87	2.967	130.3	0.0
6450.00	0.C11	533.3	550.8	478.3	0.0	1094.6	4.	0.0	0.	296.9	20.88	2.967	13C.3	C.C
6460.00	0.011	533.5	550.9	478.3	C.C	1C98.0	4.	0.0	0.	296.9	20.88	2.967	130.3	0.C
6470.00	0.011	533.8	551.1	478.4	0.C	11C1.3	4.	C.0	C.	297.C	20.89	2.967	130.3	0.0
6480.00	0.C11	534.0	551.3	478.4	0.0	1104.6	4.	0.0	0.	297.0	20.89	2.967	13C.3	0.C
6490.00	0.011	534.2	551.5	478.4	C.C	11C7.9	4.	0.0	0.	297.1	20.90	2.967	13C.3	C.C
6500.00	0.011	534.5	551.7	478.4	0.C	1111.2	4.	C.0	0.	297.1	20.90	2.967	130.3	0.0
6510.00	C.C11	534.7	551.9	478.5	0.0	1114.4	4.	C.0	C.	297.2	2C.91	2.967	13C.3	0.0
6520.00	0.016	534.2	552.2	480.7	0.C	1058.7	151.	215.2	1.	297.2	20.91	3.C06	13C.5	C.C
6530.00	0.012	534.4	552.4	480.8	C.C	1C62.6	6.	C.0	0.	297.3	20.92	3.017	130.6	C.C
6540.00	0.011	534.6	552.5	480.7	0.0	1067.2	6.	0.0	C.	297.4	20.93	3.017	130.6	0.0
6550.00	0.C11	534.8	552.7	480.7	0.0	1071.7	6.	0.0	0.	297.4	2C.93	3.C17	13C.6	C.C
6560.00	0.011	535.1	552.8	480.6	C.C	1C76.3	6.	0.0	0.	297.5	20.94	3.017	130.6	0.C
6570.00	0.011	535.3	553.0	480.6	0.C	1080.7	6.	C.0	C.	297.5	20.94	3.016	130.6	0.0
6580.00	0.C11	535.5	553.1	480.6	0.0	1085.2	6.	0.0	0.	297.6	20.94	3.016	13C.6	0.0
6590.00	0.C11	535.7	553.3	480.5	C.C	1C89.6	6.	0.0	0.	297.6	20.95	3.016	13C.6	C.C
6600.00	0.011	535.9	553.4	480.5	0.C	1094.C	6.	0.0	0.	297.6	20.95	3.016	130.6	0.0
6610.00	0.C11	536.1	553.5	480.4	0.0	1098.3	6.	C.0	C.	297.7	2C.96	3.016	13C.6	0.0
6620.00	0.011	536.3	553.7	480.3	0.0	1102.6	6.	0.0	0.	297.7	20.96	3.C16	13C.6	0.C
6630.00	0.011	536.5	553.8	480.3	C.C	11C6.8	6.	C.0	0.	297.8	20.97	3.016	130.6	0.C
6640.00	0.011	536.7	553.9	480.2	0.0	1111.0	6.	0.0	0.	297.8	20.97	3.016	130.6	0.0
6650.00	0.C11	536.9	554.C	480.2	0.0	1115.2	6.	0.0	0.	297.9	2C.98	3.C16	13C.6	C.C
6660.00	0.016	536.5	554.6	482.5	C.C	1C52.0	156.	215.3	1.	298.0	20.99	3.066	13C.9	0.C
6670.00	0.012	536.9	554.9	482.8	0.0	1064.2	9.	C.0	C.	298.C	20.99	3.071	130.9	0.0
6680.00	0.C11	537.2	555.1	482.6	0.0	1071.0	10.	0.0	0.	298.1	21.CC	3.071	13C.9	0.0
6690.00	0.011	537.3	555.1	482.4	C.C	1C77.5	10.	0.0	0.	298.1	21.C0	3.C71	13C.9	C.C
6700.00	0.011	537.3	555.0	482.1	0.C	1083.9	1C.	C.0	0.	298.2	21.01	3.071	130.9	0.0
6710.00	0.C11	537.4	555.0	481.9	0.0	1090.1	10.	C.0	C.	298.2	21.C1	3.C71	13C.9	0.0
6720.00	0.011	537.4	554.9	481.6	0.C	1096.1	10.	0.0	0.	298.3	21.02	3.C71	13C.9	C.C
6730.00	0.011	537.4	554.8	481.3	C.C	1102.0	9.	C.0	0.	298.3	21.02	3.071	13C.9	C.C
6740.00	0.011	537.4	554.8	481.1	0.0	1107.7	9.	0.0	C.	298.4	21.03	3.071	130.9	0.0
6750.00	0.C11	537.5	554.7	480.8	0.0	1113.2	9.	0.0	0.	298.4	21.C3	3.071	13C.9	C.C
6760.00	0.015	537.3	555.1	482.6	C.C	1C73.3	162.	220.1	1.	298.5	21.04	3.103	131.1	C.C
6770.00	0.012	536.8	555.[illegible]	483.1	C.0	1059.9	11.	[illegible]	C.	298.6	21.05	3.144	131.3	0.0
6780.00	0.C11	537.1	555.1	482.8	0.0	1068.7	13.	0.0	0.	298.6	21.C5	3.144	131.3	0.0
6790.00	0.011	537.1	555.0	482.4	C.C	1C77.3	[illegible]	0.0	0.	298.7	21.06	3.144	131.3	C.C
6800.00	0.011	536.9	554.7	481.9	0.C	1085.3	14.	C.0	0.	298.7	21.06	3.144	131.3	0.0
6810.00	0.C11	536.6	554.3	481.3	0.0	1092.9	14.	C.0	C.	298.8	21.07	3.144	131.3	0.0
6820.00	0.011	536.3	553.9	480.8	0.0	1100.0	13.	0.0	0.	298.8	21.07	3.144	131.3	C.C
6830.00	0.011	536.1	553.6	480.3	C.C	1106.7	12.	C.0	0.	298.9	21.08	3.144	131.3	0.C
6840.00	0.011	535.9	553.3	479.9	0.0	1113.2	11.	C.0	C.	298.9	21.08	3.144	131.3	0.0
6850.00	0.C15	535.7	553.7	481.6	0.0	1073.2	166.	221.5	1.	299.C	21.C9	3.179	131.5	C.C
6860.00	0.014	534.6	553.0	481.9	0.0	1052.8	122.	218.4	1.	299.1	21.10	3.231	131.8	0.0
6870.00	0.C11	534.3	552.5	481.1	0.0	1064.7	15.	0.0	0.	299.1	21.1C	3.239	131.8	0.C
6880.00	0.011	534.2	552.3	480.6	0.0	1073.8	15.	0.0	0.	299.2	21.11	3.239	131.8	C.C
6890.00	0.011	533.9	551.9	480.0	0.C	1082.3	16.	C.0	0.	299.2	21.11	3.239	131.8	0.0
6900.00	0.C11	533.5	551.4	479.3	0.0	1090.3	15.	C.0	C.	299.3	21.12	3.239	131.8	0.0
6910.00	0.C11	533.2	551.C	478.7	0.0	1097.8	14.	0.0	0.	299.3	21.12	3.239	131.8	0.C
6920.00	0.011	532.9	550.6	478.2	C.C	1104.9	13.	C.0	0.	299.4	21.13	3.239	131.8	C.C
6930.00	0.011	532.7	550.3	477.7	0.C	1111.7	12.	C.0	0.	299.4	21.13	3.239	131.8	0.0
6940.00	0.C14	532.5	550.5	478.8	0.0	1083.7	164.	224.8	1.	299.5	21.14	3.263	132.C	0.C
6950.00	0.014	531.6	550.1	479.7	C.C	1054.9	125.	220.0	1.	299.6	21.15	3.316	132.3	0.C
6960.00	0.011	531.0	549.3	478.8	0.0	1063.4	15.	C.0	0.	299.7	21.16	3.332	132.4	0.0

Table B.5 (continued)

TIME	PREL	LDCVZ	LYAR	LSHRD	WINJ	P	WTDST	WSTC	LOGREL	TGDW	PTCWG	LWSPAV	TWSPAV	WECC
6970.00	0.011	530.9	549.1	478.4	C.C	1C72.6	16.	0.0	0.	299.7	21.16	3.332	132.4	0.C
6980.00	0.011	530.7	548.8	477.8	0.0	1081.3	16.	0.0	0.	299.7	21.17	3.332	132.4	0.0
6990.00	0.C11	530.4	548.4	477.2	0.0	1089.5	15.	C.0	0.	299.8	21.17	3.331	132.4	0.0
7000.00	0.011	530.0	548.C	476.6	0.0	1097.3	14.	0.0	0.	299.8	21.18	3.331	132.4	C.C
7010.00	0.011	529.8	547.6	476.C	0.0	11C4.7	13.	C.0	0.	299.9	21.18	3.331	132.4	C.C
7020.00	0.011	529.6	547.3	475.6	0.0	1111.6	13.	C.0	C.	299.9	21.19	3.331	132.4	0.0
7030.00	0.014	529.5	547.6	476.6	0.0	1084.9	164.	226.2	1.	3CC.C	21.19	3.356	132.5	C.C
7040.00	0.014	528.5	547.2	477.5	C.C	1C55.1	126.	221.0	1.	300.1	21.20	3.409	132.8	C.C
7050.00	0.011	527.7	546.2	476.5	0.0	1063.6	16.	0.0	C.	3C0.2	21.21	3.425	132.9	0.0
7060.00	0.C11	527.6	546.0	476.1	0.0	1072.7	16.	0.0	0.	3C0.2	21.22	3.425	132.9	0.C
7070.00	0.011	527.4	545.7	475.5	C.C	1081.5	16.	0.0	0.	300.2	21.22	3.425	132.9	0.C
7080.00	0.011	527.2	545.3	474.9	0.0	1C89.9	15.	C.0	0.	300.3	21.23	3.425	1?2.9	0.0
7090.00	0.C11	526.9	544.9	474.3	0.0	1097.9	15.	C.0	0.	300.3	21.23	3.425	132.9	0.0
7100.00	0.011	526.6	544.6	473.8	0.0	1105.6	14.	0.0	0.	300.4	21.24	3.424	132.9	0.C
7110.00	0.011	526.4	544.3	473.3	C.C	1113.C	13.	C.0	0.	300.4	21.24	3.424	132.9	C.C
7120.00	0.014	526.3	544.7	474.8	0.0	1076.8	167.	225.7	1.	3C0.5	21.25	3.460	133.1	0.0
7130.00	0.014	525.0	543.8	475.2	0.0	1052.3	128.	221.4	1.	3C0.6	21.26	3.513	133.4	C.C
7140.00	0.011	524.4	543.0	474.2	C.C	C65.3	16.	0.0	0.	300.7	21.26	3.518	133.4	0.C
7150.00	0.010	524.3	542.8	473.7	0.0	1C74.5	16.	0.0	C.	3C0.7	21.27	3.518	133.4	0.0
7160.00	0.C1C	524.1	542.5	473.1	0.C	1083.3	16.	0.0	0.	3C0.7	21.27	3.518	133.4	0.0
7170.00	0.C10	523.9	542.2	472.6	C.C	1C91.8	16.	0.0	0.	300.8	21.28	3.518	133.4	0.C
7180.00	0.011	523.6	541.9	472.0	0.C	1C99.9	15.	[illegible]	C.	3C0.8	21.29	3.518	133.4	0.0
7190.00	0.C11	523.4	541.6	471.5	0.0	1107.8	14.	C.C	0.	3C0.9	21.29	3.518	133.4	0.0
7200.00	0.011	523.3	541.3	471.C	0.0	1115.5	14.	233.6	1.	300.9	21.30	3.518	133.4	C.C
7210.00	0.015	522.9	541.6	473.1	0.0	1C63.4	168.	224.C	1.	301.0	21.30	3.572	133.7	C.C
7220.00	0.012	521.4	540.3	472.4	0.0	1059.1	19.	C.0	C.	3C1.1	21.31	3.612	133.9	0.0
7230.00	0.011	521.1	539.8	471.7	0.0	1068.3	16.	0.0	0.	3C1.1	21.32	3.612	133.9	C.C
7240.00	0.010	521.0	539.6	471.2	C.C	1C77.5	16.	0.0	0.	301.2	21.32	3.612	133.9	C.C
7250.00	0.010	520.8	539.3	470.7	0.C	1C86.3	16.	C.0	C.	3C1.2	21.33	3.612	133.9	0.0
7260.00	0.C1C	52C.6	539.C	470.1	0.0	1094.8	16.	0.0	0.	3C1.3	21.33	3.612	133.9	0.0
7270.00	0.010	520.4	538.7	469.6	C.C	11C3.1	15.	0.0	0.	301.3	21.34	3.612	133.9	C.C
7280.00	0.010	520.2	538.5	469.1	0.0	1111.2	15.	C.0	0.	301.4	21.35	3.612	133.9	0.0
7290.00	0.C14	52C.2	538.7	470.1	0.0	1087.0	166.	229.0	1.	3C1.4	21.35	3.636	134.1	0.0
7300.00	0.014	519.1	538.2	471.C	0.0	1054.4	125.	223.0	1.	301.5	21.36	3.69C	134.4	C.C
7310.00	0.011	518.0	536.9	469.7	0.0	1064.1	17.	C.0	0.	301.6	21.37	3.703	134.4	0.C
7320.00	0.010	517.9	536.7	469.2	0.0	1073.4	16.	0.0	C.	3C1.6	21.37	3.703	134.4	0.0
7330.00	0.010	517.8	536.5	468.8	0.0	1082.5	16.	0.0	0.	301.7	21.38	3.703	134.4	C.C
7340.00	0.010	517.6	536.2	468.2	C.C	1C91.3	16.	0.0	0.	301.7	21.38	3.703	134.4	0.C
7350.00	0.010	517.4	535.9	467.7	0.C	11C0.C	16.	0.0	0.	3C1.8	21.39	3.703	134.4	0.0
7360.00	0.C1C	517.3	535.7	467.2	0.0	1108.4	15.	0.0	0.	3C1.8	21.39	3.703	134.4	0.C
7370.00	0.011	517.1	535.5	467.C	C.C	11C5.5	114.	232.8	1.	301.8	21.40	3.708	134.5	0.C
7380.00	0.015	516.6	535.6	468.8	0.C	1062.C	169.	224.8	1.	301.9	21.41	3.763	134.8	0.0
7390.00	0.C11	514.9	534.0	467.7	0.0	1060.6	24.	0.0	0.	3C2.C	21.42	3.795	135.C	0.0
7400.00	0.010	514.8	533.8	467.2	0.0	1C70.3	17.	0.0	0.	302.1	21.42	3.795	135.C	C.C
7410.00	0.010	514.7	533.6	466.7	0.C	1C79.6	16.	0.0	0.	302.1	21.43	3.795	135.C	0.0
7420.00	0.C1C	514.6	533.4	466.2	0.0	1088.6	16.	0.0	C.	3C2.1	21.43	3.795	135.C	0.0
7430.00	0.C10	514.4	533.1	465.7	0.0	1097.5	16.	0.0	0.	302.2	21.44	3.795	135.C	C.C
7440.00	0.010	514.3	532.9	465.2	C.C	11C6.2	16.	C.0	0.	302.2	21.44	3.794	135.0	0.0
7450.00	0.010	514.1	532.7	464.8	0.C	1114.7	16.	C.0	C.	3C2.3	21.45	3.794	135.0	0.0
7460.00	0.C14	513.7	532.8	466.4	0.0	1070.4	171.	226.8	1.	3C2.3	21.46	3.844	135.2	C.C
7470.00	0.012	512.2	531.5	465.9	C.C	1060.2	22.	0.0	0.	302.4	21.47	3.884	135.5	C.C
7480.00	0.011	511.8	530.9	465.1	0.C	1C69.5	17.	C.0	C.	3C2.5	21.47	3.884	135.5	0.0
7490.00	0.C1C	511.7	530.7	464.7	0.0	1078.8	17.	0.0	0.	3C2.5	21.48	3.884	135.5	0.0
7500.00	0.C10	511.6	530.5	464.7	C.C	1C88.C	17.	0.0	0.	302.6	21.48	3.884	135.4	C.C
7510.00	0.010	511.5	530.3	463.7	0.0	1097.1	17.	C.0	C.	302.6	21.49	3.884	135.4	0.0
7520.00	C.C1C	511.3	530.1	463.2	0.0	1106.0	16.	C.0	C.	3C2.7	21.5C	3.884	135.4	0.0
7530.00	0.010	511.2	529.9	462.7	0.0	1114.8	16.	0.0	0.	302.7	21.50	3.883	135.4	C.C
7540.00	0.014	510.8	529.9	464.3	C.C	1C71.3	171.	227.3	1.	302.8	21.51	3.933	135.7	C.C

Table B.5 (continued)

TIME	PREL	LOCVZ	LYAR	LSHRD	WINJ	P	WTCST	WSTC	LCCREL	TGDW	PTCWG	LWSPAV	TWSPAV	WECC
7550.00	0.012	509.2	528.7	463.9	0.0	1060.2	23.	0.0	0.	302.8	21.52	3.973	135.9	0.0
7560.00	0.010	508.8	528.0	463.0	0.0	1069.6	17.	0.0	0.	302.9	21.52	3.973	135.9	0.0
7570.00	0.010	508.7	527.8	462.6	0.0	1079.0	17.	0.0	0.	303.0	21.53	3.973	135.9	0.0
7580.00	0.010	508.6	527.7	462.1	0.0	1088.3	17.	0.0	0.	303.0	21.54	3.973	135.9	0.0
7590.00	0.010	508.5	527.5	461.6	0.0	1097.5	17.	0.0	0.	303.0	21.54	3.973	135.9	0.0
7600.00	0.010	508.4	527.3	461.1	0.0	1106.7	17.	0.0	0.	303.1	21.55	3.973	135.9	0.0
7610.00	0.010	508.3	527.1	460.7	0.0	1115.7	17.	236.0	1.	303.1	21.55	3.973	135.9	0.0
7620.00	0.014	507.7	527.0	462.3	0.0	1068.3	172.	227.0	1.	303.2	21.56	4.028	136.2	0.0
7630.00	0.012	505.9	525.4	461.5	0.0	1060.4	28.	0.0	0.	303.3	21.57	4.062	136.4	0.0
7640.00	0.010	505.8	525.1	460.8	0.0	1070.3	17.	0.0	0.	303.3	21.57	4.062	136.4	0.0
7650.00	0.010	505.7	524.9	460.4	0.0	1079.8	17.	0.0	0.	303.4	21.58	4.062	136.4	0.0
7660.00	0.010	505.6	524.8	459.9	0.0	1089.2	17.	0.0	0.	303.4	21.59	4.062	136.4	0.0
7670.00	0.010	505.5	524.6	459.5	0.0	1098.6	17.	0.0	0.	303.5	21.59	4.062	136.4	0.0
7680.00	0.010	505.4	524.4	459.0	0.0	1107.9	17.	0.0	0.	303.5	21.60	4.062	136.4	0.0
7690.00	0.012	505.2	524.3	459.0	0.0	1102.1	148.	233.6	1.	303.5	21.60	4.070	136.5	0.0
7700.00	0.014	504.5	524.0	460.2	0.0	1063.8	172.	226.4	1.	303.6	21.61	4.125	136.8	0.0
7710.00	0.011	502.9	522.4	459.1	0.0	1063.5	21.	0.0	0.	303.7	21.62	4.149	136.9	0.0
7720.00	0.010	502.9	522.3	458.7	0.0	1073.3	17.	0.0	0.	303.7	21.63	4.149	136.9	0.0
7730.00	0.010	502.9	522.2	458.3	0.0	1082.8	17.	0.0	0.	303.8	21.63	4.149	136.9	0.0
7740.00	0.010	502.8	522.0	457.8	0.0	1092.3	17.	0.0	0.	303.8	21.64	4.149	136.9	0.0
7750.00	0.010	502.7	521.9	457.4	0.0	1101.9	17.	0.0	0.	303.9	21.64	4.149	136.9	0.0
7760.00	0.010	502.6	521.7	456.9	0.0	1111.3	18.	0.0	0.	303.9	21.65	4.149	136.9	0.0
7770.00	0.013	502.4	521.7	457.8	0.0	1086.1	173.	230.8	1.	304.0	21.65	4.179	137.1	0.0
7780.00	0.014	501.1	520.8	458.4	0.0	1051.2	163.	224.2	1.	304.0	21.66	4.233	137.4	0.0
7790.00	0.011	500.0	519.5	456.9	0.0	1067.6	18.	0.0	0.	304.1	21.67	4.236	137.4	0.0
7800.00	0.010	499.9	519.4	456.5	0.0	1077.2	17.	0.0	0.	304.2	21.68	4.236	137.4	0.0
7810.00	0.010	499.9	519.3	456.0	0.0	1086.8	18.	0.0	0.	304.2	21.68	4.236	137.4	0.0
7820.00	0.010	499.8	519.2	455.6	0.0	1096.4	18.	0.0	0.	304.2	21.69	4.236	137.4	0.0
7830.00	0.010	499.6	519.1	455.2	0.0	1106.1	18.	0.0	0.	304.3	21.69	4.236	137.4	0.0
7840.00	0.010	499.7	518.9	454.7	0.0	1115.7	18.	236.6	1.	304.3	21.70	4.236	137.4	0.0
7850.00	0.014	499.0	518.6	456.0	0.0	1070.7	173.	228.1	1.	304.4	21.71	4.291	137.7	0.0
7860.00	0.012	497.1	516.9	455.2	0.0	1061.7	32.	0.0	0.	304.5	21.72	4.323	137.9	0.0
7870.00	0.010	497.1	516.7	454.7	0.0	1072.1	18.	0.0	0.	304.5	21.72	4.323	137.9	0.0
7880.00	0.010	497.1	516.6	454.3	0.0	1081.8	18.	0.0	0.	304.6	21.73	4.323	137.9	0.0
7890.00	0.010	497.0	516.5	453.8	0.0	1091.5	18.	0.0	0.	304.6	21.73	4.323	137.9	0.0
7900.00	0.010	497.0	516.5	453.4	0.0	1101.2	18.	0.0	0.	304.6	21.74	4.323	137.9	0.0
7910.00	0.010	496.9	516.3	453.0	0.0	1110.9	18.	0.0	0.	304.7	21.75	4.323	137.9	0.0
7920.00	0.013	496.6	516.2	453.6	0.0	1088.9	175.	231.7	1.	304.7	21.75	4.351	138.0	0.0
7930.00	0.014	495.4	515.3	454.2	0.0	1055.0	166.	225.1	1.	304.8	21.76	4.405	138.3	0.0
7940.00	0.011	494.1	513.9	452.9	0.0	1064.0	19.	0.0	0.	304.9	21.77	4.415	138.4	0.0
7950.00	0.010	493.9	513.6	452.4	0.0	1073.6	18.	0.0	0.	304.9	21.77	4.415	138.4	0.0
7960.00	0.010	493.8	513.5	451.9	0.0	1083.2	18.	0.0	0.	305.0	21.78	4.415	138.4	0.0
7970.00	0.010	493.8	513.4	451.5	0.0	1092.8	18.	0.0	0.	305.0	21.79	4.415	138.4	0.0
7980.00	0.010	493.7	513.3	451.1	0.0	1102.5	18.	0.0	0.	305.1	21.79	4.415	138.4	0.0
7990.00	0.010	493.7	513.2	450.7	0.0	1112.3	18.	0.0	0.	305.1	21.80	4.415	138.4	0.0
8000.00	0.013	493.2	512.9	451.4	0.0	1083.7	175.	230.7	1.	305.1	21.80	4.451	138.6	0.0
8010.00	0.014	492.0	512.0	451.9	0.0	1051.6	159.	224.4	1.	305.2	21.81	4.505	138.9	0.0
8020.00	0.011	490.8	510.7	450.5	0.0	1065.8	20.	0.0	0.	305.3	21.82	4.508	138.9	0.0
8030.00	0.010	490.6	510.5	450.0	0.0	1075.3	18.	0.0	0.	305.3	21.83	4.508	138.9	0.0
8040.00	0.010	490.5	510.4	449.6	0.0	1084.9	18.	0.0	0.	305.4	21.83	4.508	138.9	0.0
8050.00	0.010	490.5	510.3	449.1	0.0	1094.6	18.	0.0	0.	305.4	21.84	4.508	138.9	0.0
8060.00	0.010	490.4	510.2	448.7	0.0	1104.2	18.	0.0	0.	305.5	21.84	4.508	138.9	0.0
8070.00	0.010	490.4	510.1	448.3	0.0	1114.0	18.	0.0	0.	305.5	21.85	4.508	138.9	0.0
8080.00	0.014	490.0	509.9	449.4	0.0	1079.3	172.	230.0	1.	305.6	21.86	4.552	139.1	0.0
8090.00	0.014	488.8	509.0	449.9	0.0	1052.1	117.	0.0	0.	305.6	21.87	4.603	139.4	0.0
8100.00	0.010	487.5	507.5	448.2	0.0	1065.6	19.	0.0	0.	305.7	21.88	4.603	139.4	0.0
8110.00	0.010	487.3	507.3	447.6	0.0	1075.1	18.	0.0	0.	305.7	21.88	4.603	139.4	0.0
8120.00	0.010	487.2	507.2	447.2	0.0	1084.7	18.	0.0	0.	305.8	21.89	4.603	139.4	0.0

Table B.5 (continued)

TIME	PREL	LOCVZ	LYAR	LSHRC	WINJ	P	WTOST	WSTC	LOGREL	TGDW	PTCWG	LWSPAV	TWSPAV	WECC
8130.00	0.010	487.1	507.1	446.8	0.0	1094.3	18.	0.0	0.	305.8	21.89	4.603	139.4	0.0
8140.00	0.010	487.0	507.0	446.4	0.0	1104.0	19.	0.0	0.	305.9	21.90	4.603	139.4	0.0
8150.00	0.010	487.0	506.9	445.9	0.0	1113.7	18.	0.0	0.	305.9	21.90	4.603	139.4	0.0
8160.00	0.014	486.6	506.7	447.0	0.0	1079.1	173.	229.9	1.	306.0	21.91	4.647	139.7	0.0
8170.00	0.014	485.5	505.8	447.5	0.0	1052.3	117.	0.0	0.	306.0	21.92	4.698	140.0	0.0
8180.00	0.010	484.1	504.3	445.8	0.0	1065.7	20.	0.0	0.	306.1	21.93	4.698	140.0	0.0
8190.00	0.010	483.9	504.1	445.3	0.0	1075.2	18.	0.0	0.	306.2	21.93	4.698	140.0	0.0
8200.00	0.010	483.8	503.9	444.8	0.0	1084.8	18.	0.0	0.	306.2	21.94	4.698	140.0	0.0
8210.00	0.010	483.7	503.8	444.4	0.0	1094.3	19.	0.0	0.	306.2	21.95	4.698	140.0	0.0
8220.00	0.010	483.7	503.7	444.0	0.0	1104.0	19.	0.0	0.	306.3	21.95	4.698	140.0	0.0
8230.00	0.010	483.6	503.7	443.6	0.0	1113.6	19.	0.0	0.	306.3	21.96	4.698	140.0	0.0
8240.00	0.013	483.4	503.6	444.7	0.0	1079.4	171.	230.0	1.	306.4	21.96	4.742	140.2	0.0
8250.00	0.014	482.2	502.6	445.2	0.0	1052.6	115.	0.0	0.	306.4	21.97	4.794	140.5	0.0
8260.00	0.010	480.7	501.1	443.4	0.0	1065.7	21.	0.0	0.	306.5	21.98	4.794	140.5	0.0
8270.00	0.010	480.5	500.8	442.9	0.0	1075.2	18.	0.0	0.	306.6	21.99	4.794	140.5	0.0
8280.00	0.010	480.4	500.6	442.4	0.0	1084.7	19.	0.0	0.	306.6	21.99	4.794	140.5	0.0
8290.00	0.010	480.3	500.6	442.0	0.0	1094.3	18.	0.0	0.	306.6	22.00	4.793	140.5	0.0
8300.00	0.010	480.2	500.5	441.6	0.0	1103.9	19.	0.0	0.	306.7	22.00	4.793	140.5	0.0
8310.00	0.010	480.2	500.4	441.2	0.0	1113.6	19.	0.0	0.	306.7	22.01	4.793	140.5	0.0
8320.00	0.013	480.0	500.3	442.3	0.0	1081.4	170.	230.4	1.	306.8	22.02	4.835	140.7	0.0
8330.00	0.014	478.9	499.4	442.8	0.0	1050.1	160.	0.0	0.	306.8	22.03	4.889	141.0	0.0
8340.00	0.010	477.4	497.8	441.0	0.0	1065.6	20.	0.0	0.	306.9	22.04	4.889	141.0	0.0
8350.00	0.010	477.1	497.5	440.5	0.0	1075.0	19.	0.0	0.	307.0	22.04	4.889	141.0	0.0
8360.00	0.010	477.0	497.4	440.0	0.0	1084.5	18.	0.0	0.	307.0	22.05	4.889	141.0	0.0
8370.00	0.010	476.9	497.3	439.6	0.0	1094.1	18.	0.0	0.	307.0	22.05	4.889	141.0	0.0
8380.00	0.010	476.8	497.2	439.2	0.0	1103.6	19.	0.0	0.	307.1	22.06	4.889	141.0	0.0
8390.00	0.010	476.8	497.1	438.8	0.0	1113.2	19.	0.0	0.	307.1	22.06	4.889	141.0	0.0
8400.00	0.013	476.6	497.0	439.8	0.0	1081.1	170.	230.4	1.	307.2	22.07	4.930	141.2	0.0
8410.00	0.014	475.5	496.2	440.4	0.0	1050.0	160.	0.0	0.	307.2	22.08	4.984	141.5	0.0
8420.00	0.010	474.0	494.5	438.7	0.0	1065.3	20.	0.0	0.	307.3	22.09	4.984	141.5	0.0
8430.00	0.010	473.7	494.2	438.1	0.0	1074.7	18.	0.0	0.	307.3	22.09	4.984	141.5	0.0
8440.00	0.010	473.6	494.1	437.6	0.0	1084.1	19.	0.0	0.	307.4	22.10	4.984	141.5	0.0
8450.00	0.010	473.5	494.0	437.2	0.0	1093.6	19.	0.0	0.	307.4	22.11	4.984	141.5	0.0
8460.00	0.010	473.4	494.0	436.8	0.0	1103.2	19.	0.0	0.	307.5	22.11	4.984	141.5	0.0
8470.00	0.010	473.4	493.9	436.5	0.0	1112.8	19.	0.0	0.	307.5	22.12	4.984	141.5	0.0
8480.00	0.013	473.2	493.8	437.4	0.0	1082.8	170.	230.7	1.	307.6	22.12	5.023	141.7	0.0
8490.00	0.014	472.2	493.0	438.0	0.0	1051.4	161.	224.3	1.	307.6	22.13	5.077	142.0	0.0
8500.00	0.010	470.6	491.3	436.3	0.0	1064.9	21.	0.0	0.	307.7	22.14	5.079	142.0	0.0
8510.00	0.010	470.3	490.9	435.7	0.0	1074.1	20.	0.0	0.	307.7	22.15	5.079	142.0	0.0
8520.00	0.010	470.2	490.8	435.3	0.0	1083.6	19.	0.0	0.	307.8	22.16	5.079	142.0	0.0
8530.00	0.010	470.1	490.8	434.9	0.0	1093.1	19.	0.0	0.	307.8	22.16	5.079	142.0	0.0
8540.00	0.010	470.0	490.7	434.5	0.0	1102.6	19.	0.0	0.	307.9	22.17	5.079	142.0	0.0
8550.00	0.010	470.0	490.7	434.1	0.0	1112.2	19.	0.0	0.	307.9	22.17	5.079	142.0	0.0
8560.00	0.013	469.8	490.5	434.8	0.0	1086.5	170.	231.4	1.	308.0	22.18	5.112	142.2	0.0
8570.00	0.014	469.1	489.8	435.5	0.0	1054.9	158.	225.1	1.	308.0	22.19	5.166	142.5	0.0
8580.00	0.010	467.2	488.1	433.9	0.0	1064.0	23.	0.0	0.	308.1	22.20	5.174	142.6	0.0
8590.00	0.010	466.9	487.7	433.3	0.0	1073.5	19.	0.0	0.	308.1	22.20	5.174	142.6	0.0
8600.00	0.010	466.8	487.6	432.9	0.0	1082.9	19.	0.0	0.	308.2	22.21	5.174	142.6	0.0
8610.00	0.010	466.7	487.5	432.5	0.0	1092.3	19.	0.0	0.	308.2	22.22	5.174	142.6	0.0
8620.00	0.010	466.6	487.5	432.1	0.0	1101.8	19.	0.0	0.	308.3	22.22	5.174	142.6	0.0
8630.00	0.010	466.5	487.4	431.7	0.0	1111.2	20.	0.0	0.	308.3	22.23	5.174	142.6	0.0
8640.00	0.013	466.3	487.2	432.3	0.0	1087.8	169.	231.6	1.	308.4	22.23	5.205	142.7	0.0
8650.00	0.014	465.8	486.6	433.2	0.0	1056.1	157.	225.4	1.	308.4	22.24	5.259	143.0	0.0
8660.00	0.011	463.9	484.8	431.6	0.0	1063.3	22.	0.0	0.	308.5	22.25	5.270	143.1	0.0
8670.00	0.010	463.5	484.4	431.0	0.0	1072.6	19.	0.0	0.	308.5	22.26	5.269	143.1	0.0
8680.00	0.010	463.4	484.3	430.5	0.0	1081.9	19.	0.0	0.	308.6	22.26	5.269	143.1	0.0
8690.00	0.010	463.3	484.3	430.2	0.0	1091.4	19.	0.0	0.	308.6	22.27	5.269	143.1	0.0
8700.00	0.010	463.2	484.2	429.8	0.0	1100.8	19.	0.0	0.	308.7	22.28	5.269	143.1	0.0

Table B.5 (continued)

TIME	PREL	LCCVZ	LYAR	LSHRD	WINJ	P	WTOST	WSTC	LOGREL	TGCW	PTCWG	LWSPAV	TWSPAV	WECC
8710.00	0.010	463.1	484.2	429.4	0.0	1110.3	19.	0.0	0.	308.7	22.28	5.269	143.1	0.0
8720.00	0.013	463.0	484.0	429.8	0.0	1093.3	170.	232.6	1.	308.7	22.29	5.291	143.2	0.0
8730.00	0.014	462.5	483.7	430.8	0.0	1060.1	169.	226.3	1.	308.8	22.30	5.345	143.5	0.0
8740.00	[illegible]	460.5	481.6	429.3	0.0	1060.1	25.	0.0	0.	308.9	22.31	5.367	143.6	0.0
8750.00	0.010	460.1	481.1	428.7	0.0	1069.5	19.	0.0	0.	308.9	22.31	5.367	143.6	0.0
8760.00	0.010	459.9	481.0	428.2	0.0	1078.8	19.	0.0	0.	309.0	22.32	5.367	143.6	0.0
8770.00	0.010	459.8	481.0	427.8	0.0	1088.0	20.	0.0	0.	309.0	22.33	5.367	143.6	0.0
8780.00	0.010	459.7	480.9	427.4	0.0	1097.5	19.	0.0	0.	309.0	22.33	5.367	143.6	0.0
8790.00	0.010	459.7	480.9	427.1	0.0	1106.9	20.	0.0	0.	309.1	22.34	5.367	143.6	0.0
8800.00	0.010	459.6	480.8	426.7	0.0	1111.6	68.	236.0	1.	309.1	22.34	5.370	143.6	0.0
8810.00	0.013	459.4	480.5	428.1	0.0	1071.8	166.	228.6	1.	309.2	22.35	5.425	143.9	0.0
8820.00	0.012	457.5	478.7	427.3	0.0	1057.8	46.	0.0	0.	309.3	22.36	5.463	144.1	0.0
8830.00	0.010	[illegible]	[illegible]	426.3	0.0	1068.1	20.	0.0	0.	309.3	22.37	5.462	144.1	0.0
8840.00	0.010	456.5	477.7	425.9	0.0	1077.4	19.	0.0	0.	309.4	22.37	5.462	144.1	0.0
8850.00	0.010	456.4	477.7	425.5	0.0	1086.7	19.	0.0	0.	309.4	22.38	5.462	144.1	0.0
8860.00	0.010	456.3	477.6	425.1	0.0	1096.1	19.	0.0	0.	309.4	22.39	5.462	144.1	0.0
8870.00	0.010	456.2	477.6	424.7	0.0	1105.4	20.	0.0	0.	309.5	22.39	5.462	144.1	0.0
8880.00	0.010	456.2	477.6	424.4	0.0	1114.9	20.	0.0	0.	309.5	22.40	5.462	144.1	0.0
8890.00	0.013	456.0	477.2	425.5	0.0	1076.6	166.	229.5	1.	309.6	22.41	5.512	144.4	0.0
8900.00	0.012	454.9	476.1	425.5	0.0	1056.3	66.	0.0	0.	309.6	22.41	5.558	144.6	0.0
8910.00	0.010	453.4	474.7	[illegible]	0.0	1066.6	20.	0.0	0.	309.7	22.42	5.558	144.6	0.0
8920.00	0.010	453.1	474.5	423.5	0.0	1075.9	19.	0.0	0.	309.7	22.43	5.558	144.6	0.0
8930.00	0.010	453.0	474.4	423.2	0.0	1085.2	19.	0.0	0.	309.8	22.44	5.557	144.6	0.0
8940.00	0.010	452.9	474.4	422.8	0.0	1094.4	19.	0.0	0.	309.8	22.44	5.557	144.6	0.0
8950.00	0.010	452.9	474.4	422.4	0.0	1103.8	19.	0.0	0.	309.9	22.45	5.557	144.6	0.0
8960.00	0.010	452.8	474.3	422.0	0.0	1113.2	19.	0.0	0.	309.9	22.45	5.557	144.6	0.0
8970.00	0.013	452.6	474.0	422.9	0.0	1081.3	166.	230.4	1.	310.0	22.46	5.599	144.9	0.0
8980.00	0.014	451.6	473.0	423.3	0.0	1050.3	154.	0.0	0.	310.0	22.47	5.653	145.2	0.0
8990.00	0.010	450.0	471.5	421.7	0.0	1065.0	21.	0.0	0.	310.1	22.48	5.653	145.2	0.0
9000.00	0.010	449.8	471.2	421.2	0.0	1074.2	19.	0.0	0.	310.1	22.49	5.653	145.2	0.0
9010.00	0.010	449.7	471.2	420.8	0.0	1083.4	19.	0.0	0.	310.2	22.49	5.653	145.1	0.0
9020.00	0.010	449.6	471.1	420.5	0.0	1092.7	19.	0.0	0.	310.2	22.50	5.653	145.1	0.0
9030.00	0.010	449.5	471.1	420.1	0.0	1102.0	19.	0.0	0.	310.3	22.50	5.652	145.1	0.0
9040.00	0.010	449.4	471.1	419.7	0.0	1111.4	20.	0.0	0.	310.3	22.51	5.652	145.1	0.0
9050.00	0.013	449.2	470.8	420.3	0.0	1088.0	167.	231.6	1.	310.3	22.52	5.683	145.3	0.0
9060.00	0.014	448.7	470.1	421.0	0.0	1056.3	155.	225.4	1.	310.4	22.52	5.737	145.6	0.0
9070.00	0.010	446.8	468.3	419.5	0.0	1063.2	22.	0.0	0.	310.5	22.53	5.748	145.7	0.0
9080.00	0.010	446.4	467.9	418.9	0.0	1072.2	20.	0.0	0.	310.5	22.54	5.748	145.7	0.0
9090.00	0.010	446.3	467.9	418.5	0.0	1081.5	19.	0.0	0.	310.6	22.55	5.748	145.7	0.0
9100.00	0.010	446.2	467.9	418.1	0.0	1090.8	19.	0.0	0.	310.6	22.55	5.748	145.7	0.0
9110.00	0.010	446.1	467.9	417.8	0.0	1100.0	19.	0.0	0.	310.6	22.56	5.748	145.7	0.0
9120.00	0.010	446.0	467.8	417.4	0.0	1109.3	20.	0.0	0.	310.7	22.56	5.748	145.7	0.0
9130.00	0.012	445.8	467.6	417.6	0.0	1096.9	165.	233.3	1.	310.7	22.57	5.764	145.8	0.0
9140.00	0.014	445.6	467.2	418.6	0.0	1063.5	166.	227.0	1.	310.8	22.58	5.819	146.0	0.0
9150.00	0.011	443.5	465.2	417.3	0.0	1060.9	27.	0.0	0.	310.8	22.59	5.843	146.2	0.0
9160.00	0.010	443.0	464.7	416.6	0.0	1070.1	20.	0.0	0.	310.9	22.60	5.843	146.2	0.0
9170.00	0.010	442.9	464.6	416.2	0.0	1079.3	20.	0.0	0.	310.9	22.60	5.843	146.2	0.0
9180.00	0.010	442.8	464.6	415.8	0.0	1088.6	19.	0.0	0.	311.0	22.61	5.843	146.2	0.0
9190.00	0.010	442.7	464.6	415.5	0.0	1097.8	19.	0.0	0.	311.0	22.61	5.843	146.2	0.0
9200.00	0.010	442.6	464.6	415.1	0.0	1107.1	19.	0.0	0.	311.1	22.62	5.843	146.2	0.0
9210.00	0.010	442.5	464.5	414.8	0.0	1111.7	66.	236.1	1.	311.1	22.63	5.846	146.2	0.0
9220.00	0.013	442.4	464.2	416.1	0.0	1072.0	164.	228.6	1.	311.2	22.63	5.901	146.5	0.0
9230.00	0.012	440.6	462.3	415.3	0.0	1058.0	45.	0.0	0.	311.2	22.64	5.938	146.7	0.0
9240.00	0.010	439.7	461.5	414.3	0.0	1067.9	20.	0.0	0.	311.3	22.65	5.938	146.7	0.0
9250.00	0.010	439.5	461.4	413.9	0.0	1077.0	20.	0.0	0.	311.3	22.66	5.938	146.7	0.0
9260.00	0.010	439.4	461.4	413.5	0.0	1086.1	20.	0.0	0.	311.4	22.66	5.938	146.7	0.0
9270.00	0.010	439.3	461.4	413.2	0.0	1095.4	19.	0.0	0.	311.4	22.67	5.938	146.7	0.0
9280.00	0.010	439.2	461.3	412.8	0.0	1104.6	19.	0.0	0.	311.4	22.68	5.938	146.7	0.0

Table B.5 (continued)

TIME	PREL	LDCVZ	LYAR	LSHRC	WINJ	P	WTDST	WSTC	LCGREL	TGLW	PTCWG	LWSPAV	TWSPAV	WECC
9290.00	0.010	439.2	461.3	412.5	0.0	1113.9	20.	C.0	C.	311.5	22.68	5.938	146.7	0.0
9300.00	0.C13	439.0	460.9	413.4	0.0	1080.0	164.	230.1	1.	311.5	22.69	5.982	146.9	C.C
9310.00	0.013	438.0	459.8	413.7	C.C	1C53.1	113.	0.0	0.	311.6	22.70	6.034	147.2	C.C
9320.00	0.010	436.4	458.3	412.1	C.0	1065.5	21.	0.0	0.	311.7	22.71	6.033	147.2	0.C
9330.00	0.C1C	436.1	458.1	411.6	0.0	1074.5	20.	0.0	0.	311.7	22.72	6.C33	147.2	0.C
9340.00	0.010	436.0	458.1	411.2	C.C	1C83.6	20.	0.0	0.	311.7	22.72	6.C33	147.2	C.C
9350.00	0.010	435.9	458.1	410.9	0.0	1092.8	19.	C.0	0.	311.8	22.73	6.033	147.2	0.0
9360.00	0.C1C	435.9	458.1	410.5	0.0	1102.0	19.	C.0	C.	311.8	22.73	6.C33	147.2	0.0
9370.00	0.01C	435.8	458.1	410.2	0.0	1111.2	20.	0.0	0.	311.9	22.74	6.033	147.2	C.C
9380.00	0.013	435.5	457.7	410.6	C.C	1C90.0	165.	232.0	1.	311.9	22.75	6.061	147.4	C.C
9390.00	0.013	435.2	457.1	411.4	0.0	1058.0	155.	225.8	1.	312.C	22.75	6.115	147.6	0.0
9400.00	0.010	433.1	455.2	409.9	0.0	1060.6	26.	0.0	0.	312.C	22.76	6.131	147.7	C.C
9410.00	0.010	432.7	454.8	409.3	C.C	1C69.7	20.	0.0	0.	312.1	22.77	6.131	147.7	0.C
9420.00	0.010	432.6	454.7	408.9	0.0	1078.8	19.	0.0	C.	312.1	22.78	6.131	147.7	0.0
943 .00	0.C1C	432.5	454.8	408.6	0.0	1086.0	19.	0.0	0.	312.2	22.78	6.131	147.7	0.0
9440.00	0.010	432.4	454.8	408.3	C.C	1C97.1	20.	0.0	0.	312.2	22.79	6.131	147.7	C.C
9450.00	0.010	432.3	454.7	407.9	0.0	1106.3	20.	0.0	0.	312.2	22.8C	6.131	147.7	0.0
9460.00	0.C10	432.2	454.8	407.6	0.0	1115.5	20.	236.9	1.	312.3	22.8C	6.131	147.7	0.0
9470.00	0.013	432.1	454.3	408.8	0.0	1073.3	162.	228.8	1.	312.3	22.81	6.186	148.C	C.C
9480.00	0.012	430.3	452.6	408.2	C.C	1056.7	55.	C.0	0.	312.4	22.82	6.227	148.2	0.C
9490.00	0.010	429.4	451.7	407.1	0.0	1066.8	22.	0.0	C.	312.5	22.83	6.226	148.2	0.0
9500.00	0.010	429.2	451.5	406.6	0.0	1075.9	20.	0.0	0.	312.5	22.83	6.226	148.2	C.C
9510.00	0.010	429.1	451.5	406.3	C.C	1C85.C	20.	0.0	0.	312.5	22.84	6.226	148.2	0.C
9520.00	0.C10	429.1	451.5	406.0	0.0	1094.2	20.	0.0	C.	312.6	22.85	6.226	148.2	0.0
9530.00	0.C1C	428.9	451.5	405.6	0.0	1103.2	20.	0.0	0.	312.6	22.85	6.226	148.2	0.0
9540.00	0.010	428.9	451.5	405.3	C.C	1112.5	20.	0.0	0.	312.7	22.86	6.226	148.2	C.C
9550.00	0.013	428.7	451.1	406.0	0.0	1064.9	164.	231.1	1.	312.7	22.87	6.262	148.4	0.0
9560.00	0.C13	428.0	450.2	406.5	0.0	1053.6	151.	224.8	1.	312.8	2?.87	6.317	148.7	0.0
9570.00	0.010	426.2	448.5	404.9	0.0	1063.9	23.	0.0	0.	312.8	22.88	6.322	148.8	C.C
9580.00	0.010	425.7	448.1	404.2	0.0	1072.9	20.	C.0	0.	312.9	22.89	6.322	148.8	0.C
9590.00	0.010	425.5	448.C	403.8	0.0	1082.0	20.	0.0	C.	312.9	22.90	6.322	148.8	0.0
9600.00	0.010	425.3	447.9	403.4	0.0	1091.1	20.	0.0	0.	313.C	22.90	6.321	148.8	C.C
9610.00	0.010	425.1	447.8	403.1	C.C	11C0.2	20.	0.0	0.	313.0	22.91	6.321	148.8	0.C
9620.00	0.010	424.8	447.8	402.7	0.0	1109.3	21.	0.0	0.	313.C	22.92	6.321	148.7	0.0
9630.00	0.C12	424.3	447.0	402.5	0.0	1097.0	161.	233.3	1.	313.1	22.92	6.338	148.8	0.C
9640.00	0.013	423.7	446.7	403.5	C.C	1C63.5	164.	226.9	1.	313.1	22.93	6.393	149.1	0.C
9650.00	0.011	419.4	442.3	400.5	0.0	1058.9	3C.	0.0	0.	313.2	22.94	6.420	149.3	0.0
9660.00	0.C10	418.2	440.8	399.0	0.0	1068.2	20.	C.0	0.	313.3	22.95	6.42C	149.3	0.0
9670.00	0.010	417.9	440.6	398.5	0.0	1077.3	20.	0.0	0.	313.3	22.95	6.42C	149.3	C.C
9680.00	0.010	417.8	440.5	398.1	0.C	1086.4	2C.	C.0	0.	313.3	22.96	6.419	149.3	C.C
9690.00	0.010	417.6	440.5	397.8	0.0	1095.5	20.	C.0	C.	313.4	22.97	6.419	149.3	0.0
9700.00	0.010	417.3	440.4	397.3	0.0	1104.6	20.	0.0	0.	313.4	22.97	6.419	149.3	C.C
9710.00	0.010	417.2	440.3	397.C	C.C	1113.8	20.	0.0	0.	313.5	22.98	6.419	149.3	C.C
9720.0C	0.013	416.6	439.4	397.5	0.0	1C79.9	162.	230.1	1.	313.5	22.99	6.464	149.5	0.0
9730.00	0.C13	414.6	437.0	396.9	0.0	1049.1	149.	0.0	0.	313.6	23.CC	6.518	149.8	0.0
9740.00	0.010	411.1	433.9	394.C	C.C	1C63.5	22.	0.0	0.	313.6	23.00	6.517	149.8	0.C
9750.00	0.010	410.8	433.6	393.5	0.0	1072.7	20.	C.0	0.	313.7	23.C1	6.517	149.8	0.0
9760.00	0.010	410.6	433.5	393.1	0.0	1081.8	20.	0.0	0.	313.7	23.C2	6.517	149.8	0.0
9770.00	0.010	410.3	433.4	392.7	0.0	1090.8	20.	0.0	0.	313.9	23.02	6.517	149.8	C.C
9780.00	0.010	410.1	433.3	392.3	0.0	11C0.C	2C.	0.0	0.	313.8	23.03	6.517	149.8	0.C
9790.00	0.010	409.9	433.3	391.9	0.0	1109.2	20.	0.0	C.	313.8	23.04	6.517	149.8	0.0
9800.00	0.012	409.7	432.9	392.0	0.0	1097.0	158.	233.3	1.	313.9	23.04	6.534	149.9	C.C
9810.00	0.013	409.0	431.8	392.4	C.C	1C63.3	160.	226.9	1.	313.9	23.05	6.589	150.2	C.C
9820.00	0.011	406.8	429.6	390.9	0.0	1C63.7	22.	0.0	C.	314.C	23.06	6.613	150.3	0.0
9830.00	0.C1C	406.8	429.7	390.7	0.0	1071.2	20.	0.0	0.	314.1	23.C7	6.613	150.3	0.0
9840.00	0.009	406.8	429.9	390.4	C.C	1C80.5	2C.	0.0	0.	314.1	23.08	6.613	150.3	C.C
9850.00	0.009	406.8	430.0	390.2	0.0	1C89.8	20.	C.0	C.	314.1	23.08	6.612	150.3	0.0
9860.00	0.C09	406.5	429.9	389.8	0.0	1099.0	21.	0.0	0.	314.2	23.C9	6.612	150.3	0.0

Table B.5 (continued)

TIME	PREL	LDCVZ	LYAR	LSHRD	WINJ	P	WTOST	WSTC	LCGPEL	TGCW	PTCWG	LWSPAV	TWSPAV	WECC
9870.00	0.009	406.3	429.9	389.4	0.0	1108.2	21.	0.0	0.	314.2	23.09	6.612	150.3	0.0
9880.00	0.011	405.8	429.6	389.3	0.0	1101.2	144.	234.1	1.	314.2	23.10	6.62[illegible]	150.4	0.0
9890.00	0.013	404.5	427.4	389.1	0.0	1065.8	159.	227.4	1.	314.3	23.11	6.678	150.7	0.0
9900.00	0.011	403.6	426.4	388.7	0.0	1060.2	25.	0.0	0.	314.4	23.12	6.708	150.8	0.0
9910.00	0.010	403.5	426.6	388.4	0.0	1070.1	20.	0.0	0.	314.4	23.13	6.708	150.8	0.0
9920.00	0.009	403.5	426.7	388.1	0.0	1079.4	20.	0.0	0.	314.[illegible]	23.13	6.708	150.8	0.0
9930.00	0.009	403.5	426.8	387.9	0.0	1088.8	20.	0.0	0.	314.5	23.14	6.708	150.8	0.0
9940.00	0.009	403.2	426.7	387.5	0.0	1098.1	21.	0.0	0.	314.5	23.15	6.708	150.8	0.0
9950.00	0.009	403.0	426.7	387.1	0.0	1107.4	21.	0.0	0.	314.6	23.15	6.707	150.8	0.0
9960.00	0.010	402.8	426.5	386.8	0.0	1107.8	96.	235.3	1.	314.6	23.16	6.713	150.8	0.0
9970.00	0.013	401.0	424.4	386.8	0.0	1068.7	160.	227.9	1.	314.7	23.17	6.768	151.1	0.0
9980.00	0.011	400.2	423.2	386.4	0.0	1058.2	34.	0.0	0.	314.7	23.18	6.803	151.3	0.0
9990.00	0.010	400.2	423.3	386.1	0.0	1068.7	21.	0.0	0.	314.8	23.18	6.803	151.3	0.0
10000.00	0.009	400.2	423.5	385.8	0.0	1078.2	20.	0.0	0.	[illegible]4.8	23.19	6.803	151.3	0.0
10010.00	0.009	400.2	423.6	385.6	0.0	1087.6	21.	0.0	0.	[illegible]	23.20	6.803	151.3	0.0
10020.00	0.009	399.9	423.5	385.2	0.0	1097.0	21.	0.0	0.	[illegible]	23.20	6.803	151.3	0.0
10030.00	0.009	399.7	423.5	384.8	0.0	1106.4	21.	0.0	0.	315.0	23.21	6.803	151.3	0.0
10040.00	0.009	399.4	423.4	384.4	0.0	1115.9	21.	236.9	1.	315.0	23.22	6.803	151.3	0.0
10050.00	0.013	398.0	421.3	384.4	0.0	1071.7	158.	228.5	1.	315.0	23.22	6.858	151.6	0.0
10060.00	0.011	397.1	420.2	384.2	0.0	1058.4	39.	0.0	0.	315.1	23.23	6.896	151.8	0.0
10070.00	0.010	397.1	420.4	383.9	0.0	1069.4	21.	0.0	0.	315.2	23.24	6.896	151.8	0.0
10080.00	0.009	397.1	420.5	383.6	0.0	1079.0	21.	0.0	0.	315.2	23.25	6.895	151.8	0.0
10090.00	0.009	396.9	420.5	383.3	0.0	1088.4	21.	0.0	0.	315.3	23.26	6.895	151.8	0.0
10100.00	0.009	396.6	420.4	382.8	0.0	1097.9	21.	0.0	0.	315.3	23.26	6.895	151.8	0.0
10110.00	0.009	396.3	420.4	382.5	0.0	1107.3	22.	0.0	0.	315.3	23.27	6.895	151.8	0.0
10120.00	0.010	396.2	420.2	382.2	0.0	1108.0	93.	235.3	1.	315.4	23.27	6.901	151.8	0.0
10130.00	0.013	394.6	418.1	382.1	0.0	1067.9	156.	227.8	1.	315.4	23.[illegible]	6.956	152.1	0.0
10140.00	0.011	393.9	417.1	381.8	0.0	1059.5	30.	0.0	0.	315.5	23.29	6.988	152.3	0.0
10150.00	0.010	393.8	417.2	381.6	0.0	1069.9	21.	0.0	0.	315.5	23.30	6.988	152.3	0.0
10160.00	0.009	393.8	417.4	381.3	0.0	1079.5	21.	0.0	0.	315.6	23.31	6.988	152.3	0.0
10170.00	0.009	393.6	417.4	380.9	0.0	1089.1	21.	0.0	0.	315.6	23.31	6.988	152.3	0.0
10180.00	0.009	393.4	417.3	380.5	0.0	1098.6	21.	0.0	0.	315.7	23.32	6.988	152.3	0.0
10190.00	0.009	393.1	417.3	380.2	0.0	1108.2	21.	0.0	0.	315.7	23.33	6.988	152.3	0.0
10200.00	0.011	392.6	417.0	380.1	0.0	1101.3	136.	234.1	1.	315.7	23.33	6.999	152.4	0.0
10210.00	0.013	391.2	414.6	379.8	0.0	1063.8	155.	227.0	1.	315.8	23.34	7.054	152.7	0.0
10220.00	0.011	390.5	413.8	379.4	0.0	1060.0	26.	0.0	0.	315.8	23.35	7.080	152.8	0.0
10230.00	0.010	390.5	414.0	379.1	0.0	1070.2	21.	0.0	0.	315.9	23.36	7.080	152.8	0.0
10240.00	0.009	390.4	414.1	378.9	0.0	1079.9	21.	0.0	0.	316.0	23.37	7.080	152.8	0.0
10250.00	0.009	390.4	414.3	378.7	0.0	1089.7	21.	0.0	0.	316.0	23.37	7.080	152.8	0.0
10260.00	0.009	390.1	414.3	378.3	0.0	1099.3	22.	0.0	0.	316.0	23.38	7.080	152.8	0.0
10270.00	0.009	389.9	414.1	377.8	0.0	1109.0	22.	0.0	0.	316.1	23.39	7.080	152.8	0.0
10280.00	0.012	389.1	413.5	377.7	0.0	1096.2	151.	233.1	1.	316.1	23.39	7.097	152.9	0.0
10290.00	0.013	387.9	411.3	377.5	0.0	1059.7	153.	226.2	1.	316.2	23.40	7.152	153.2	0.0
10300.00	0.010	387.4	410.9	377.2	0.0	1062.7	23.	0.0	0.	316.2	23.41	7.170	153.3	0.0
10310.00	0.009	387.4	411.1	376.9	0.0	1072.7	22.	0.0	0.	316.3	23.42	7.170	153.3	0.0
10320.00	0.009	3[illegible]7.4	411.3	376.7	0.0	1082.6	21.	0.0	0.	316.3	23.43	7.170	153.3	0.0
10330.00	0.009	38[illegible].2	411.3	376.3	0.0	1092.3	22.	0.0	0.	316.4	23.43	7.170	153.3	0.0
10340.00	0.009	386.[illegible]	411.2	375.9	0.0	1102.0	22.	0.0	0.	316.4	23.44	7.170	153.3	0.0
10350.00	0.009	386.7	411.1	375.5	0.0	1111.8	22.	0.0	0.	316.4	23.44	7.170	153.3	0.0
10360.00	0.013	385.5	409.8	375.4	0.0	1084.3	156.	230.9	1.	316.5	23.45	7.203	153.5	0.0
10370.00	0.013	384.5	407.9	375.3	0.0	1050.8	138.	224.2	1.	316.5	23.46	7.257	153.8	0.0
10380.00	0.010	384.2	407.9	374.9	0.0	1065.1	22.	0.0	0.	316.6	23.47	7.260	153.8	0.0
10390.00	0.009	384.2	408.1	374.6	0.0	1075.1	22.	0.0	0.	316.6	23.48	7.260	153.8	0.0
10400.00	0.009	384.2	408.3	374.4	0.0	1085.0	22.	0.0	0.	316.7	23.48	7.260	153.8	0.0
10410.00	0.009	384.0	408.3	374.1	0.0	1094.9	22.	0.0	0.	316.7	23.49	7.260	153.8	0.0
10420.00	0.009	383.7	408.1	373.6	0.0	1104.7	23.	0.0	0.	316.8	23.50	7.260	153.8	0.0
10430.00	0.009	383.4	408.1	373.2	0.0	1114.5	23.	0.0	0.	316.8	23.50	7.260	153.8	0.0
10440.00	0.013	382.1	406.1	373.1	0.0	1072.8	152.	228.7	1.	316.8	23.51	7.309	154.0	0.0

Table B.5 (continued)

TIME	PHEL	LDCVZ	LYAR	LSHRD	WINJ	P	WTDST	WSTC	LOGREL	TGDW	PTDWG	LWSPAV	TWSPAV	WECC
10450.00	0.011	381.3	404.9	372.9	0.0	1058.1	42.	0.0	0.	316.9	23.52	7.347	154.2	0.0
10460.00	0.010	381.2	405.1	372.6	0.0	1069.7	22.	0.0	0.	317.0	23.53	7.347	154.2	0.0
10470.00	0.009	381.2	405.3	372.4	0.0	1079.8	22.	0.0	0.	317.0	23.54	7.347	154.2	0.0
10480.00	0.009	381.1	405.4	372.1	0.0	1089.7	22.	0.0	0.	317.0	23.54	7.347	154.2	0.0
10490.00	0.009	380.8	405.3	371.7	0.0	1099.6	22.	0.0	0.	317.1	23.55	7.347	154.2	0.0
10500.00	0.009	380.5	405.2	371.3	0.0	1109.6	23.	0.0	0.	317.1	23.56	7.347	154.2	0.0
10510.00	0.012	379.6	406.3	371.2	0.0	1091.3	152.	232.7	1.	317.2	23.56	7.369	154.3	0.0
10520.00	0.013	378.5	402.2	37[illegible].0	0.0	1055.3	141.	225.2	1.	317.2	23.57	7.423	154.6	0.0
10530.00	0.010	378.3	402.2	370.7	0.0	1064.0	23.	0.0	0.	317.3	23.58	7.434	154.7	0.0
10540.00	0.009	378.3	402.4	370.5	0.0	1074.3	22.	0.0	0.	317.3	23.59	7.434	154.7	0.0
10550.00	0.009	378.1	402.6	370.2	0.0	1084.3	23.	0.0	0.	317.4	23.60	7.434	154.7	0.0
10560.00	0.009	378.0	402.5	369.8	0.0	1094.4	23.	0.0	0.	317.4	23.60	7.434	154.7	0.0
10570.00	0.009	377.7	402.4	369.4	0.0	1104.4	23.	0.0	0.	317.4	23.61	7.434	154.7	0.0
10580.00	0.009	377.3	402.3	369.0	0.0	1114.4	23.	0.0	0.	317.5	23.61	7.434	154.7	0.0
10590.00	0.013	376.2	400.4	368.9	0.0	1074.2	150.	228.9	1.	317.5	23.62	7.481	154.9	0.0
10600.00	0.012	375.2	399.0	368.6	0.0	1056.2	51.	0.0	0.	317.6	23.63	7.521	155.1	0.0
10610.00	0.009	375.2	399.2	368.4	0.0	1068.4	23.	0.0	0.	317.6	23.64	7.521	155.1	0.0
10620.00	0.009	375.1	399.4	368.1	0.0	1078.7	22.	0.0	0.	317.7	23.65	7.521	155.1	0.0
10[illegible]0.00	0.009	375.1	399.6	367.9	0.0	1088.8	23.	0.0	0.	317.7	23.65	7.521	155.1	0.0
10640.00	0.009	374.7	399.5	367.4	0.0	1098.9	23.	0.0	0.	317.8	23.66	7.521	155.1	0.0
10650.00	0.009	374.4	399.5	367.1	0.0	1109.0	24.	0.0	0.	317.8	23.67	7.521	155.1	0.0
10660.00	0.012	373.8	398.5	366.8	0.0	1093.3	145.	232.6	1.	317.8	23.67	7.540	155.2	0.0
10670.00	0.013	372.7	396.6	366.8	0.0	1055.8	140.	225.3	1.	317.9	23.68	7.595	155.5	0.0
10680.00	0.010	372.3	396.4	366.4	0.0	1064.7	24.	0.0	0.	317.9	23.69	7.605	155.6	0.0
10690.00	0.009	372.3	396.6	366.2	0.0	1075.1	23.	0.0	0.	318.0	23.70	7.605	155.6	0.0
10700.00	0.009	372.2	396.8	366.0	0.0	1085.4	23.	0.0	0.	318.0	23.71	7.605	155.6	0.0
10710.00	0.009	371.9	396.7	365.5	0.0	1095.6	23.	0.0	0.	318.1	23.71	7.605	155.6	0.0
10720.00	0.009	371.6	396.7	365.1	0.0	1105.8	23.	0.0	0.	318.1	23.72	7.605	155.6	0.0
10730.00	0.009	371.4	396.7	364.7	0.0	1111.8	54.	236.1	1.	318.1	23.73	7.608	155.6	0.0
10740.00	0.013	370.0	394.2	364.7	0.0	1065.4	146.	227.3	1.	318.2	23.73	7.663	155.9	0.0
10750.00	0.010	369.3	393.4	364.4	0.0	1060.4	29.	0.0	0.	318.3	23.74	7.690	156.0	0.0
10760.00	0.009	369.3	393.6	364.2	0.0	1071.4	23.	0.0	0.	318.3	23.75	7.690	156.0	0.0
10770.00	0.009	369.3	393.9	363.9	0.0	1081.8	23.	0.0	0.	318.4	23.76	7.690	156.0	0.0
10780.00	0.009	369.1	394.0	363.6	0.0	1092.2	23.	0.0	0.	318.4	23.77	7.690	156.0	0.0
10790.00	0.009	368.8	393.9	363.2	0.0	1102.4	24.	0.0	0.	318.4	23.77	7.689	156.0	0.0

APPENDIX C. GLOSSARY OF ACRONYMS

AC	Alternating current
ADS	Automatic depressurization system
ANS	American Society of Mechanical Engineers
ATWS	Anticipated transient without scram
BWR	Boiling water reactor
CBP	Condensate booster pump
CP	Condensate pump
CRD	Control rod drive
CRDHS	Control rod drive hydraulic system
CS	Core spray
CST	Condensate storage tank
DHR	Decay heat removal (from the pressure suppression pool)
ECCS	Emergency core cooling systems (typically refers to the HPCI, LPCI, and CS systems)
EOI	Emergency operating instruction
EPGs	Emergency Procedure Guidelines (published by the GE BWR Owners Group)
FSAR	Final Safety Analysis Report
GE	General Electric Company
HPCI	High pressure coolant injection
LOCA	Loss of coolant accident
LPCI	Low pressure coolant injection (emergency coolant injection operating mode of the RHR system)
LPECCS	Low pressure emergency core cooling systems (includes LPCI and CS systems)
MFP	Main feedwater pump
MSIV	Main steam isolation valve
NPSH	Net positive suction head
ORNL	Oak Ridge National Laboratory
OI	Operating instruction
PCS	Primary coolant system
PSP	Pressure suppression pool
RBCCW	Reactor building closed cooling water (provides cooling water to the drywell atmosphere coolers)
RCIC	Reactor core isolation cooling (steam-driven high pressure injection system)
RHR	Residual Heat Removal (multi-purpose heat removal and/or injection system with various operating modes — for example the LPCI mode or the PSP cooling mode)
SASA	Severe accident sequence analysis
SB	Small break (typically used to describe loss of coolant accidents)
SLC	Standby liquid control (system provided to pump sodium pentaborate solution into the reactor vessel, if necessary)
SRV	Safety relief valve
TAF	Top of active fuel (i.e. the elevation thereof)
TVA	Tennessee Valley Authority

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The BWR-LTAS code was developed by the SASA program at Oak Ridge National Laboratory for the detailed study of specific accident sequences at Browns Ferry Unit One: station blackout, small break LOCA outside primary containment, loss of decay heat removal, loss of vessel water injection, and anticipated transient without scram. The primary use of the code has been to estimate the effects of operator actions on the timing and course of events during the part of the sequence leading up to but not including severe fuel damage. This report documents the basis of the methods used to simulate the response of reactor vessel, primary coolant system, primary containment, and other reactor systems; the output from a sample use of the code is presented.

14 DOCUMENT ANALYSIS - a. KEYWORDS/DESCRIPTORS
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Station Blackout Accidents
SRV
BWR
Severe Accident Analyses
ATWS
Pressure Suppression Pool

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