AERB SAFETY GUIDE NO.AERB/SG/D-18

LOSS OF COOLANT ACCIDENT ANALYSIS FOR PRESSURISED HEAVY WATER REACTOR

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FOREWORD

Safety of public, occupational workers and protection of the environment should be assured while activities for economic and social progress are pursued. These activities include the establishment and utilisation of nuclear facilities and use of radioactive sources. They have to be carried out in accordance with relevant provisions in the Atomic Energy Act 1962 (33 of 1962).

Assuring high safety standard has been of prime importance since the inception of nuclear power programme in the country. Recognising this aspect, the Government of India constituted the Atomic Energy Regulatory Board (AERB) in November 1983, vide Statutory Order No. 4772 notified in the Gazette of India dated 31.12.1983. The Board has been entrusted with the responsibility of laying down safety standards and framing rules and regulations in respect of regulatory and safety functions envisaged under the Atomic Energy Act of 1962. Under its programme of developing safety codes and guides, AERB has issued four codes of practice in the area of nuclear safety covering the following topics:

Safety in Nuclear Power Plant Siting

Safety in Nuclear Power Plant Design

Safety in Nuclear Power Plant Operation

Quality Assurance for Safety in Nuclear Power Plants

Safety guides are issued to describe and make available methods of implementing specific parts of relevant codes of practice as acceptable to AERB. Methods and solutions other than those set out in the guides may be acceptable if they provide at least comparable assurance that nuclear power plants can be operated without undue risk to the health and safety of plant personnel, general public and the environment.

Codes and safety guides may be revised as and when necessary in the light of experience as well as relevant developments in the field. The annexures, foot-notes, references and bibliography are not to be considered integral part of the document. They are included to provide information that might be helpful to the user.

The emphasis in the codes and guides is on protection of site personnel and public from undue radiological hazards. However, for other aspects not covered in the codes and guides, applicable and acceptable national and international codes and standards shall be followed. In particular, industrial safety shall be assured through good engineering practices and compliance with the Factories Act 1948 as amended in 1987 and the Atomic Energy (Factories) Rules, 1996.

This Safety Guide is one of a series of guides which have been prepared or are under preparation as a follow-up to the Code of Practice on Design for Safety in Pressurised Heavy Water Reactor Based Nuclear Power Plants (SC/D). One of the requirements in designing a nuclear power plant is to analyse various postulated initiating events and assess the effectiveness of the systems important to safety. Loss of Coolant Accident (LOCA) is one of such postulated initiating events. This safety guide on "LOCA Analysis for PHWR" provides necessary guidelines for developers and users of computer codes for LOCA analysis.

This Safety Guide has been prepared by the staff of AERB, BARC, IGCAR and NPC. It has been reviewed by experts and vetted by the AERB Advisory Committees before issue. AERB wishes to thank all individuals and organisations who have prepared and reviewed the draft and helped in finalisation of the Safety Guide. The list of persons who have participated in the committee meetings, along with their affiliation, is included for information.

(Prof. S. P. Sukhatme)
Chairman, AERB

DEFINITIONS

Accident Conditions

Substantial deviations[1] from Operational States, and which could lead to release of unacceptable quantities of radioactive materials if the relevant engineered safety features did not function as per design intent.

Anticipated Operational Occurrences[2]

All operational processes deviating from Normal Opera-tion which are expected to occur once or several times during the operating life of the Plant and which, in view of appropriate design provisions, do not cause any significant damage to items important to safety nor lead to accident conditions.

Convergence

A method is convergent if the solution of discretised equations approaches to exact solution as the size of grid spacing or time step tends to zero.

Critical Break

A break that causes prolonged low flow condition in the core with resultant heat up of the fuel.

Intermediate Break

Break size that causes gross phase separation with flow rates sufficient enough not to demand additional heat rejection in steam generator.

Initial Condition

The initial data, used in the safety analysis, of main primary and secondary coolant circuit parameters (e.g. Pres-sure, Temperature etc.) including the plant thermal power.

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1 A substantial deviation may be a major fuel failure, a Loss of Codant Accident (LOCA), etc Examples of engineered safety features are Emergency Core Cooling Systems (ECCS) and containment.

2 Examples of Anticipated Operational Occurrence are loss of normal power and faults such as tubine trip, malfunction of individual items of control equipment, loss of power to main coolant pump.

Initiating Events

An identified event (initiator) that leads to Anticipated Operational Occurrences or Accident Conditions and challenges one or more safety functions.

Large Break

A break in which discharge rates are such that no phase separation occurs and decay heat removal starts before low pressure injection comes into action.

Loss of Coolant Accident (LOCA)

An accident in which coolant is lost from primary heat transport system at a rate greater than the rate which make-up system can cater to.

Mechanical Equilibrium

The state of equilibrium when all the constituents of the fluid at a location are at equal velocity.

Nodalisation

Simulation of a system by dividing it into finite number of volumes or grids for solving applicable set of conservation equations.

Normal Operation

Operation of a Nuclear Power Plant within specified Operational Limits and Conditions including shutdown, power operation, shutting down, starting up, maintenance, testing and refuelling (see Operational States).

Numerical Diffusion

Errors that arise in numerical solution of partial differential equations due to truncation Error terms.

Operational States

The states defined under Normal Operation and Antici-pated Operational Occurrences together.

Small Break

Break of smaller size than intermediate break size, such that phase separation occurs and additional heat rejection in steam generator is needed before low pressure injection comes into action.

Small Leak

Any leak due to break size smaller than LOCA is defined as small leak.

Thermal Equilibrium

The state of equilibrium when all the constituent of a fluid at a location are at equal temperature.

Truncation Error

Errors arising due to representation of derivatives using finite difference.

CONTENTS

1 INTRODUCTION

1.1 General

1.1.1 For safety assessment of a nuclear reactor, postulated Loss of Coolant Accidents (LOCA) are analysed. In a LOCA the cooling water which transports the heat from the nuclear core is progressively lost through a break in the reactor coolant system, with a resulting risk of core heat up, release of radioactivity and containment pressurisation. Predictions by the computer programs used for LOCA analyses depends on various assumptions, models, initial conditions, boundary conditions, performance of mitigating systems and methodologies used. The results also depend on the type of the end objective/ scenario, suitability of the computer program used, and the experience of the user.

1.1.2 This guide describes considerations for LOCA analyses and provides guidelines on acceptable practices and the use of the computer programs to enhance regulatory confidence in the assessments.

1.1.3 The LOCA analysis is still a subject of research & development and this guide is based on the present state of the art in this area.

1.2 Objective

This guide sets the requirements for various considerations that need to be incorporated for developing LOCA analysis methodology including validation of computer programs using appropriate experimental/analytical methods available. These guidelines are given so that the appropriate computer program developed uses correct method of analyses for the relevant application.

1.3 Scope

1.3.1 This guide covers the thermal hydraulic process simulation of LOCA from the occurrence of the initiating event to the end where reactor is in the cold, subcritical, pseudo steady/stable state, till the fuel is wet and the coolant is continuously in single phase which means till adequate long term cooling is established.

1.3.2 It gives guidelines for selection of the thermal hydraulic process/component models, initial and boundary conditions, the numerical schemes for solving governing equations. The subject of simulation of operator action is beyond the scope of the guide except for the case where it is given as a boundary condition.

1.3.3 Though this guide is primarily written for LOCA (i.e. pipe breaks in PHT System) analysis, the guidelines given here can also be used for analysis of steam line break scenarios.

1.3.4 Radioactive release calculation and containment design methodologies are not covered in this guide. Please refer to AERB/SG/D-21 for containment design guidelines.

2. INITIAL CONDITIONS

2.1 General

Initial conditions within operating limits (including margins accounting for instrument and other errors) should be chosen such that the predictions of the limiting parameters are on the conservative side. If the accident were such that impact of initial conditions, though significant, is difficult to understand before hand, a parametric study may be done including extreme design limits of the operating range in the initial conditions. The Reactor State (e.g., fuel burnup) and characteristics (e.g., void coefficient of reactivity at minimum permitted isotopic purity) should be conservatively chosen.

2.2 Initial reactor thermal power, mass and energy holdup

The initial reactor thermal power chosen for analysis should be higher than the nominal value. The margin should include maximum power measurement errors possible at the operating value due to instrument errors and other uncertainties (e.g., due to heat losses). The total Primary Heat Transport (PHT) system and secondary system inventory (with respect to mass and thermal energy) and its distribution in the system should include uncertainties in its estimation conservatively. This should include the inventory up to the first isolation points of the PHT system. The thermal energy added to the system due to PHT pump should also be included. The stored thermal energy in the system internals should be accounted for. Examples of initial mass and temperature distribution for an illustrative nodalisation are given in Table-A-2 of Annexure-I.

2.3 Thermal hydraulic parameters of the coolant and structures

The initial temperature, pressure and flow distribution in the heat transport system should be such that if the transient analysis is started without any disturbance, the parameters do not change significantly. This should be demonstrated in all runs by running steady state calculations before initiating the transient. The initial steady state computation should be checked by running the transient code for a sufficiently long period to establish the steady state condition. Usually duration would be 2 to 3 times the thermal hydraulic time constant of the system being analysed. The thermal energy distribution should be conservative by taking appropriate stored thermal energy of the coolant. The core outlet temperature adjustment should be done to account for higher initial power being considered. Appropriate conservative thermal-hydraulic properties of coolant and structures corresponding to the initial coolant temperature distribution should be considered.

2.4 Thermal consideration of fuel

2.4.1 Axial and radial power distribution shapes and power peaking factors should be so selected as to result in most severe calculated consequences for the LOCA analysed.

2.4.2 The steady state temperature distribution and stored thermal energy in the fuel before postulated accident shall be calculated based on properties calculated for the design burn-up. To accomplish this, the thermal diffusivity of fuel shall be evaluated as a function of temperature at design burnup. The contact resistance between fuel and cladding shall be chosen appropriately. The volumetric heat generation in the fuel may be considered uniform, as it is conservative.

2.5 Other conditions

In case the heat losses to the surroundings are simulated then these should be based on the appropriate sink temperatures (e.g., moderator temperature, containment atmosphere temperature etc.). The heat transfer rate calculations should include the consideration of fouling factors wherever applicable (e.g., in Steam Generators).

3. BOUNDARY CONDITIONS

3.1 The decay heat generation rates after reactor shutdown shall be calculated based on the guidelines given in AERB Design Safety Guide on "Decay Heat Load Calculations (AERB/SM/D-1)".

3.2 The PHT pressure control system (feed, bleed and relief systems) and active ECCS can be modelled as pressure dependent fill and leaks as applicable. However, these values should be supported by calculations taking into account the pump, controller and valve characteristics, and various flow resistances.

3.3 Turbine and electrical system need not be simulated if soon after the reactor trip the turbine is isolated. The steam flow to turbine can be given as one of the boundary conditions.

3.4 The secondary feed water system flow and temperature and steam discharge through various valves can be represented by appropriate parameter dependent tables and the valve control logic.

4. MODELLING

In this chapter the modelling aspects are discussed for basic scenarios.

4.1 Assumptions

4.1.1 A set of assumptions can be made depending on the Postulated Initiating Event (PIE) and the computer program used. The effect of these assumptions should be shown to be bounded and justified.

4.1.2 Some of the general assumptions (Appendix-I) are as follows:

(a) Correlations for pressure drop, heat transfer coefficient and critical heat flux which are developed for steady state can be assumed to be valid for the transient case also till better inputs are available.

(b) The entrance effects and effects due to developing flow can be neglected.

(c) Where data are not available (e.g. second, third and fourth quadrant data for pump characteristics), the pump characteristics can be obtained from available data based on the specific speed.

4.2 Nodalisation

4.2.1 The nodalisation scheme (Annexure-I) chosen should be such that it represents various components appropriately and model phenomena under consideration. The number of nodes should be chosen depending on the initial and anticipated spatial gradients of different parameters of the system and the size of break (Appendix-II) to be analysed. If the coarse grid is chosen, it should be justified by physically realistic behaviour and overall balance for the chosen grid.

4.2.2 The ratio of the adjacent volumes should not be too large. Channels can be lumped together based on power, initiating event and objective of the analysis. The channels at different elevations should be considered if the break size is so limited that the thermosyphoning plays a significant role. Appropriate axial nodes should be chosen to represent axial power distribution. Nodalisation should be such that upstream condition for the break and the thermodynamic conditions at the point of Emergency Core Coolant injection may be appropriately determined. The number of nodes in the upstream and downstream of the pump should be chosen in such a manner that relevant flow and void fraction inputs for the pump performance evaluation are realistically modelled.

4.2.3 For modelling of components such as steam generator, pressurizer, accumulators etc., nodalisation should account for any likely phase separation by appropriate mixture level modelling. Steam Generator nodalisation should be appropriate to account for different heat transfer regimes along the length. Appropriate nodalisation should be done to represent fuel position with heat generation, gap conductance and cladding.

4.3 Thermal modelling of the fuel

4.3.1 Fuel modelling can be done by using one or two dimensional heat conduction equation. Solution shall include variable thermal properties, appropriate convective boundary conditions and interaction between thermal hydraulics and fuel due to reactivity feedback.

4.3.2 Geometry of the fuel may be assumed to be unchanged. However, it should be verified with separate fuel models. The parameters used for modelling of fuel should be in line with the contents of AERB Design Safety Guide on "Fuel Design (AERB/SG/D-6)".

4.4 Thermal-hydraulic process

4.4.1 At least one equation should be solved for each of conservation equations of mass, momentum and thermal energy with appropriate slip or drift-flux correlations. Use of equilibrium model should be justified by demonstrating that thermal/mechanical non-equilibrium effects are not significant. In case it is not justifiable, appropriate multi-fluid model should be used simulating non-equilibrium.

4.4.2 Four, five or six equation models may be used to represent thermal and mechanical non-equilibrium but appropriate constitutive relations supported by adequate experimental data applicable within the range for different inter-facial transfer processes should be used.

4.4.3 Some of the important effects that shall be taken into account are as follows:

(a) Temporal change of momentum

(b) Momentum convection

(c) Momentum flux due to change in area

(d) Momentum change due to compressibility

(e) Pressure loss resulting from void fraction

(f) Pressure loss resulting from area change, fittings like elbows, bends, tees etc.

(g) Elevation pressure drop

(h) Frictional pressure drop

However, these are dependent on the computational model. Omission of any of these terms shall be justified. Use of appropriate momentum mixing model (for junctions) should be made depending upon dominant flow direction and various connections at the inlet and the outlet of control volume.

4.4.4 The frictional losses in pipes and other components including the reactor core shall be calculated using models that include realistic variation of friction factor with Reynolds number and realistic two phase multipliers that have been adequately verified by comparison with experimental data.

4.4.5 The heat transfer correlations used in LOCA analysis should include whole range experienced by fuel during complete transient period. It should use appropriate correlations for determining correct temperature transition boundaries like critical heat flux (CHF) correlations, minimum temperature for stable film boiling, rewetting temperature and characteristics.

4.4.6 Appropriate care should be taken so that different parametric and asymptotic trends are maintained. Extrapolation beyond the range should be justified if at all done. Discontinuities such as in the heat transfer correlations due to change in various parameters (example: flow, pressure, quality etc.) should be avoided by use of proper interpolation.

4.4.7 Correlations developed from appropriate steady state experimental data are acceptable for use in predicting the CHF. The computer programs in which these correlations are used shall contain suitable checks to assure that the physical parameters are within the range of those specified for use of the correlations by their respective authors. Examples of the steady state CHF correlations are given in Annexure-II.

4.4.8 Appropriate transient CHF correlations can be used provided they are applicable in the range of interest. Where appropriate, the comparisons shall use statistical uncertainty analysis of the data to demonstrate the conservatism of the transient correlation. Acceptable transient CHF correlations along with their ranges are given in Annexure-II.

4.4.9 The examples of the equations for the post CHF boiling regimes are given in Annexure-II.

4.4.10 The flow rate through the core during blowdown shall be calculated as a function of time.

4.4.11 Based on the results of the blowdown calculations, if required, detailed channel analysis shall be carried out. Such analyses should use combinations of boundary conditions like pressure, enthalpy, quality etc. consistent with blowdown analyses.

4.4.12 Use of look-up tables of experimental data for CHF evaluation can be done using appropriate factors relevant to PHWR geometry [18,19,20]. These correlations must include effect of horizontal geometry in PHWR in conservative fashion.

4.5 Discharge

Critical discharge models used for computation of break flow should consider the state of fluid (sub-cooled or two-phase), break geometry, flow friction and other phenomena as applicable. The models should be supported by adequate experimental data, corrected by appropriate discharge coefficient if required and be on conservative side. Examples of discharge models are given in Annexure-II.

4.6 Components

4.6.1 Single and two-phase pump characteristics used for the PHT pump should be corresponding or nearer to the specific speed in all four quadrants of its operation under both single phase and two phase conditions. The characteristics of rotating primary system pumps (axial flow, turbine, or centrifugal) shall be derived from a dynamic model that includes momentum transfer between the fluid and the rotating part, with change in pump speed taking into account pump motor inertia. The pump resistance used for analysis should be justified.

4.6.2 Accumulator modelling should consist of mixture level computation in accumulator and appropriate solution of equation of state for gas using exponent (n in PVn=constant) value based on the conservative approach.

4.6.3 Steam Generator tube should be appropriately represented by heat conduction model with proper boundary conditions at the primary and secondary sides of the steam generator. Steam Generator modelling should include phenomena such as recirculation, components such as preheater, downcomer etc. and associated control logic.

4.6.4 All the valves should be modelled by appropriate valve characteristics with correct opening and/or closing time in both forward and reverse flow.

4.6.5 Pressuriser should be appropriately modelled so that subcooled and saturated liquid, and steam regions are appropriately considered by mixture level simulation. Heat transfer from heaters and sprays should be included.

4.7 Metal-Water reaction

The rate of cladding oxidation, thermal energy release and hydrogen generation from the metal/water reaction (refer to AERB Design Safety Guide on "Hydrogen Release and Mitigation Systems under Accident Conditions", AERB/SG/D-19) shall be calculated using appropriate correlations. The reaction shall be assumed not to be steam limited. For fuel pin whose cladding is calculated to rupture during LOCA, the inside of the cladding shall also be assumed to react after the rupture. The calculation of the reaction rate on the inside of the cladding shall also follow the same correlation starting at the time when the cladding is calculated to rupture, and extending around the cladding inner circumference and axially not less than 3.81 cm (1.5 inches) each way from the location of the rupture.

4.8 Neutronics

Fission heat shall be calculated using reactivity and reactor kinetics. The reactivities resulting from temperatures and voids shall be given their conservative plausible values, including allowance for uncertainties for the range of power distribution, shapes and peaking factors relevant to the case. In the analysis no credit should be taken for action of Reactor Regulating System including Reactor Set Back and Reactor Step Back. However, in cases where actuation of these features worsen the scenario, the analysis should be repeated with these actions. Negative reactivity insertion due to postulated shutdown device actuation resulting in reactor trip should be accounted for in the analysis using single failure criteria. For large cores, spatial neutronics simulation should be considered.

4.9 Other considerations

The LOCA analysis computer program should simulate appropriate trip, control logic as anticipated during transients. It should also be able to simulate various switching actions required during transients.

4.10 Numerical modelling

Appropriate numerical technique should be used for solving the hydrodynamic equations and heat conduction equations used in safety analyses programs. Appropriate choice may be made among 1-D, 2-D and 3-D schemes depending upon physical situation. Check should be made for numerical diffusion if multidimensional codes are used. Stability and Convergence of the numerical method used in the safety analyses program must be ensured. Appropriate error control method should be used to limit the error encountered in the numerical solution procedures. When finite volume method is used, appropriate care should be taken in handling various non-realistic situations arising such as water packing and smoothening of discontinuities (e.g., by spline fitting technique for smoothening of discontinuity in interpolated parameter). If simplistic time integration method like Euler's method is used, sufficiently small time-step should be chosen. If linear enthalpy transport model is used for control volumes with heat source or sink, adequate care should be taken either to switch it off or devise alternate means to avoid erroneous estimation (e.g. as may occur during flow reversal in the core). Distinction should be made between numerical and physical oscillation based on the oscillating response time period.

5. COMPUTER PROGRAM

5.1 General

The computer program should be reviewed, revised and validated to the relevant current practice and experience. Analysis inputs for validation of the computer program should be independently cross-checked.

5.2 Structure of the computer program

The structure of the computer program should preferably be modular so that each model can be tested separately and latest analysis methodologies can be incorporated into it.

5.3 Computer program validation

The computer program should be validated for its different models and phenomena by using data from separate effect test or appropriate analytical models as applicable. It should also be validated against integral experimental data or results from other established and validated computer program. Validation results should be analysed so as to bring out computer program limitations. It is preferable that the calculations be supported with experimental data.

5.4 Code user qualification for the use of computer program

The use of computer program is strongly interactive and dependent on users understanding of the phenomena analysed. Hence it should be ensured that the computer program is used by the user qualified for the relevant application. The code user should have appropriate understanding of various phenomena involved in application of the computer program. The user should be familiar with various aspects of modelling which include various assumptions, discontinuities in modelling, range of application, and various numerical methods used.

5.5 Uncertainty Analysis

An uncertainty analysis should be carried out when best estimate codes are used and margins to acceptance limits are small and /or significant modelling uncertainty exists.

6. DOCUMENTATION

6.1 A description of each evaluation model shall be documented. The description shall be sufficiently complete to permit technical review of the analytical approach including the equations used, their approximations in different form, the assumptions made, and the values of all parameters and the procedure for their selection. The scope for Analysis and its limitations should be well defined in the documentation. Assumptions should be clearly justified.

6.2 A complete listing of each computer program, in the same form as used in the evaluation model, shall be furnished to the regulatory body on request and shall be treated as confidential.

6.3 The user manual should contain complete information on listing of computer program, sensitivity analysis, procedure for using it, methodology of error handling etc. The validation report should retain computer print-out in original including all calculations and results for future review. It should also mention various options used in different models. All the relevant data should be preserved. Details of parametric study should be documented.

6.4 For each computer program, solution convergence shall be demonstrated by studies of systems modelling or nodalisation and computational time steps.

APPENDIX-I

General Assumptions

It is required that the assumptions along with the effect of the same on the analysis are clearly mentioned in the reports.

In case correlations are used beyond the applicable conditions, the reason for such use and the effect of the same on predictions should be clearly mentioned.

Generally the correlations for pressure drop, heat transfer coefficient and critical heat flux developed for steady state condition are assumed to be valid for the transient case also. However, in cases where correlations for transient cases are available the use of the same is preferred.

The entrance effects and effects due to developing flow are generally assumed to be negligible. However, for the sake of accuracy to the level where these effects have important contribution on the results these assumptions should be avoided.

In case four quadrant pump characteristics (supplied by manufacturers) are not available then modified pump characteristics based on specific speed can be used for modelling the pump.

APPENDIX-II

BREAK DESCRIPTION

I.1 LOCA is an accident in which coolant is lost from pressure boundary of PHT system at a rate beyond the capability of the PHT make-up system. The break size may range up to double-ended rupture of largest piping in the system.

I.2 Break sizes below LOCA size are defined as leaks. Breaks on secondary side are non-LOCA events. However, these are also considered from safety of the SG, containment and also core in some cases.

Table-II-1: Break Characteristics and locations

Type	Break Size	Location
Transverse + Longitudinal	Small and Large	Header
	Small	Feeder
	Leak and Small	Pressure Tube
	Leak and small	Steam Generator tube
	Small and Large	Pump Discharge
	Large	Main Steam Line
	Large	Feed Water Line
	Leak + Small (10%)	Instrumented Relief Valve

ANNEXURE-I

Example of PHT system inventory distribution

Table-A-1:

Description of nodal representation [used in postulated pressure tube rupture analysis for RAPS-2 (Ref. 25)] [Figure A-1]

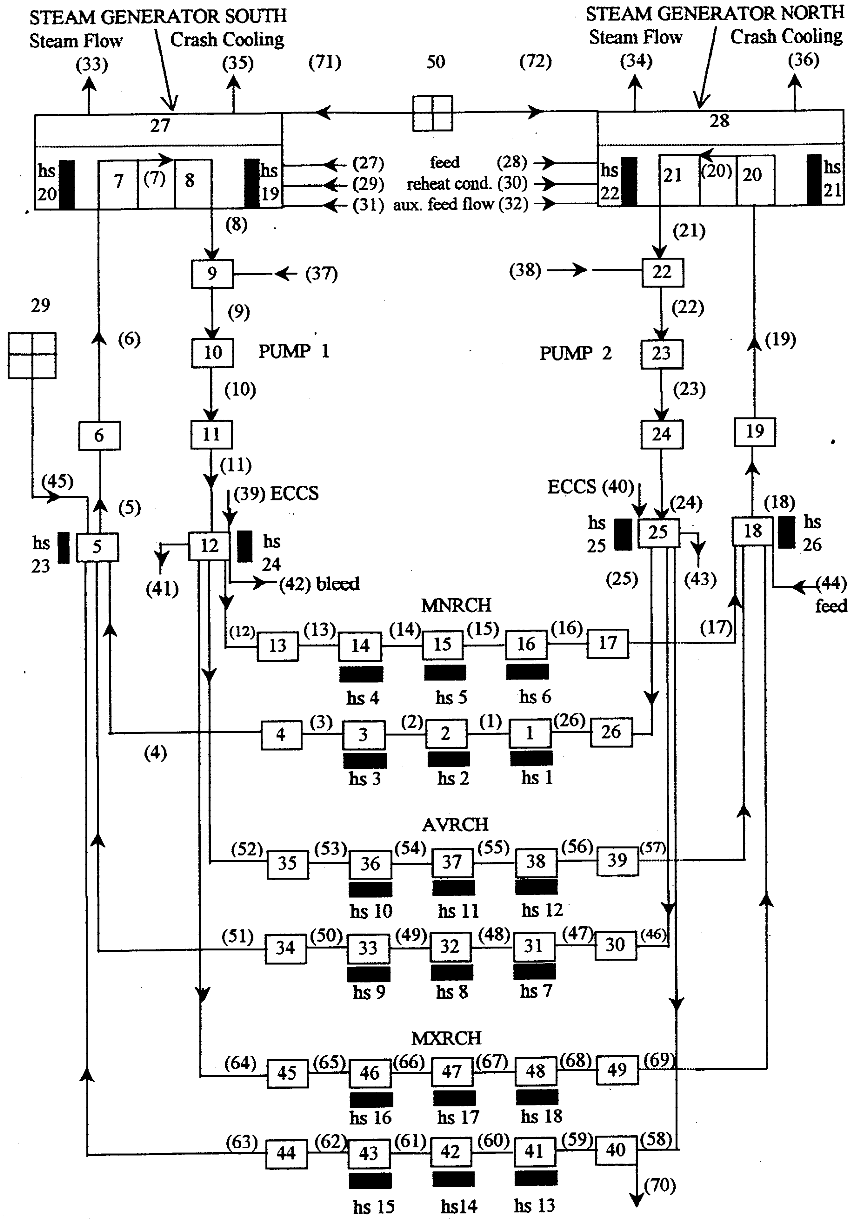
Volumes/Junctions	Description
V1, V2, V3, V14, V15, V16	Minimum Rated Channel (MNRCH)
V31, V32, V33, V36, V37, V38	Average Rated Channel (AVRCH)
V41, V42, V43, V46, V47, V48	Maximum Rated Channel (MXRCH)
V5	Reactor Outlet Header, South
V12	Reactor Inlet Header, South
V18	Reactor Outlet Header, North
V13, V26, V30, V35, V40 and V45	Reactor Inlet Feeders
V4, V17, V34, V39, V44 and V49	Reactor Outlet Feeders
V25 RIH(N)	Reactor Inlet Header, North
V10 AND V23	Primary Circulating Pumps
V7,V8,V20 & V21	SG tubing
V29 and V50	Time Dependent Volumes (TDV)
V6, V11, V19 and V24	Pipes
V9 and V22	Pump Glands
V27 and V28	Steam Domesx
J27 and J28	Boiler feed flow (main)
J29 and J30	Reheat condensate return flow
J31 and J32	Boiler feed flow (aux.)
J37 and J38	Gland Injection
J39 and J40	ECCS flow
J41 and J43	Primary leakage
J42	Primary bleed
J44	Primary feed
J70	Break flow
J45, J71 and J72	Time dependent junctions for obtaining steady state

Table-A-2: Volume data (initial steady state conditions) [Figure A-1]

VOL No.	Pressure (MPa)	Mass (kg)	Temperature (deg. C)	Mass flow rate (kg/s)
1	8.90	2.50	261.84	5.25
2	8.80	2.40	279.24	5.25
3	8.77	2.32	292.61	5.25
4	8.67	3.72	296.01	5.25
5	8.62	578.51	299.06	1409.50
6	8.42	237.69	298.61	1409.50
7	8.39	3122.48	275.18	1409.44
8	8.37	3250.91	256.42	1409.44
9	8.18	101.89	253.57	1412.00
10	8.85	113.16	254.27	1412.00
11	9.51	113.27	254.27	1412.00
12	9.53	646.76	254.30	1412.00
13	9.49	4.12	254.29	5.25
14	8.90	2.50	261.84	5.25
15	8.80	2.40	279.25	5.25
16	8.77	2.32	292.61	5.25
17	8.67	3.72	296.01	5.25
18	8.62	578.51	299.06	1409.50
19	8.42	237.69	298.61	1409.50
20	8.39	3122.48	275.18	1409.44
21	8.37	3250.91	256.42	1409.44
22	8.18	101.89	253.57	1412.00
23	8.85	113.16	254.27	1412.00
24	9.51	113.27	254.27	1412.00
25	9.53	646.76	254.30	1412.00

Table-A-2: Volume data (initial steady state conditions) (Continued)
[See Fig. A-1 on page No. 18]

VOL No.	Pressure (MPa)	Mass (kg)	Temperature (deg. C)	Mass flow rate (kg/s)
26	9.49	4.12	254.29	5.25
27	4.03	33404.82	250.84	174.66
28	4.03	33404.82	250.84	174.66
29	time dependent volume			
30	9.34	3533.05	254.29	1391.76
31	9.31	377.33	262.10	1391.77
32	9.10	361.45	280.97	1391.78
33	8.88	347.00	295.49	1391.78
34	8.67	3160.92	299.12	1391.78
35	9.34	3533.05	254.29	1391.76
36	9.31	377.33	262.10	1391.77
37	9.10	361.45	280.97	1391.78
38	8.88	347.00	295.49	1391.78
39	8.67	3160.92	299.12	1391.78
40	9.47	36.79	254.29	12.44
41	9.09	2.50	261.54	12.44
42	8.95	2.40	279.31	12.44
43	8.77	2.31	293.16	12.44
44	8.68	33.15	296.77	12.44
45	9.47	36.79	254.29	12.44
46	9.09	2.50	261.54	12.44
47	8.95	2.40	279.31	12.44
48	8.77	2.31	293.16	12.44
49	8.68	33.15	296.77	12.44
50	time dependent volume			



hs = heat slab

Figure A-1: Example of RAPS-2 nodalisation for tube rupture analysis

ANNEXURE-II

EXAMPLES OF THERMAL HYDRAULIC MODELS

Nomenclature

c	= specific heat
D	= diameter
D_h	= hydraulic diameter
D_{he}	= heated equivalent diameter
dz	= differential length in flow direction
f	= friction factor
f_{Fl}	= local Fanning friction factor for single phase liquid
G	= mass flux
g	= gravitational acceleration
g_c	= 32.174 lb_m-ft/lb_f -s^2, Newton's constant
h	= specific enthalpy
h	= heat transfer coefficient
h_{lg}	= latent heat of vapourisation
Dh_l	= liquid subcooling
J	= mechanical equivalent of heat, 778.17 ft-lb_f/BTU
J'	= J/144, 5.403, ft^3-lb_f/in^2-BTU
K	= slip ratio
k	= thermal conductivity
k_s	= Boltzman constant
L	= length along the flow path
n	= polytropic exponent for vapour compression
L_c	= Heat conductor length
p	= pressure
P_w	= wetted perimeter
q	= heat flux
s	= specific entropy
T_c	= thermodynamic critical temperature
T_i	= initial temperature in a depressurisation process
Tr	= reduced temperature= initial temperature/critical temperature
DT	= temperature difference
u	= velocity
v	= specific volume
x	= quality (can be negative for subcooled) or vapour mass void fraction
a	= void fraction
m	= viscosity coefficient
s	= surface tension
r	= density
v_{mol}	= molar specific volume
g	= isentropic exponent

Subscripts

c	= critical flow condition
d	= decompression
dfm	= drift flux model
e	= equilibrium
g	= vapour phase
in	= entrance condition
l	= liquid phase
m	= vapour-liquid mixture
max	= maximum
o	= stagnation point
p	= constant pressure condition
s	= saturation condition
S	= isentropic condition
t	= throat condition
TP	= two phase
upstream	= upstream condition
v	= saturated vapour
w	= wall

$2J\ h_0\text{-}h_1\text{-}$

II.1 Critical Discharge Model

Comparison of various critical discharge models may be found in reference [11].

II.1.1 Moody's Model [33, 34]:

This is one of the Thermodynamic Equilibrium separated flow models.

Mass flux (Gc, lbm/ft2-s) in terms of stagnation properties is given by Moody-65 Model as follows:

Mass Flux, (II.1)

Slip, (II.2)

Moody-66 model includes the energy equation, the mass flux equation (II.1) and the momentum equation considering fluid friction.

Energy Equation:

(II.3)

Momentum equation:
(II.4)

Where,
(II.5)
(II.6)

The terms are in consistent FPS units. fFl = local Fanning friction factor for single phase liquid; dimensionless, G = mass flux; lbm/ft2-s, gc = 32.2 lbm-ft/lbf -s2; Newton's constant, h = specific enthalpy; BTU/lbm, J = mechanical equivalent of heat; 778.17 ft-lbf/BTU, J' = J/144=5.403 ft3-lbf/in2-BTU, K =

slip ratio, L = pipe length; ft, Pw= wetted perimeter; ft, s = specific entropy; BTU/lbm-°F, v = specific volume; ft3/lbm and x = quality.

II.1.2 Alamgir and Lienhard correlation [1, 38]

In order to take into consideration the delay caused in nucleation, the following may be used for subcooled critical flow model.

Mass Flux, (II.7)

Abuf's Recommendation: Use discharge coefficient 0.9 to get good prediction.

The decompression pressure difference:

(II.8)

S is rate of depressurisation, Matm/s. In case break geometry is also nodalised, for simplicity åav over pipe length can be used for å in equation (II.8).
(II.9)

II.1.3 Burnell's Model [48]

This is a subcooled flow model which takes into account the delay caused in nucleation that causes high flow rate through nozzles and orifices.

Critical Mass Flux, (II.10)

C is given by Weisman & Tentner as follows:
(II.11)
sps is the surface tension at saturation pressure.

II.1.4 Homogeneous Equilibrium Model [38, 11]

The critical mass flux is given by:
(II.12)

The derivatives are evaluated at the critical pressure pc. vm is mixture specific volume given by vm = 1/rm =[x/rg+(1-x)/rl]

II.1.5 Two more thermodynamic equilibrium separated flow models are given below:

Fauske's Model [11, 13]

(II.13)
(II.14)
(II.15)
(II.16)
(II.17)
(II.18)

Levy's Model [11, 26]

The model is based on the following equations:
Mass Flux, (II.19)
(II.20)
(II.21)

(II.22)
(II.23)

II.1.6 Henry-Fauske's Model [22]

This is one of the thermodynamic non-equilibrium critical discharge models and is based on empirical equations. The equations constituting this model are given below:
(II.24)
(II.25)
where N=N(Xe), for example, and (II.26)

and (II.27)

Momentum equation integrated between p0 and pt becomes as follows:

(II.28)

II.1.7 Physical Model for One Dimensional Critical Discharge

Critical Discharge can also be simulated by use of physical one-dimensional model based on conservation equations for mass, momentum and energy (4 or 5 or 6 equations model). The system of partial differential equations describing transient one-dimensional two-phase flow is written at the break geometry in mathematical form as follows:

A Xt + B X z = C (II.29)

Where,

X is the column vector for flow variables, and the subscripts t and z represent functions of time and space respectively. A and B are the matrices and C is the column vector for the transfer terms.

The necessary condition for steady critical flow within a section is determined by relationship

det |B| = 0 (II.30)

The propagation velocities of disturbances are obtained by resolving the equation (II.29). The set of eigenvalues of this characteristic equation so determined will have one eigenvalue which will satisfy above system of equations and correspondingly determine the critical flow for which disturbance is hindered to travel upstream.

II.2 Frictional Pressure Drop

The frictional losses in the pipes and other components including reactor core shall be calculated considering the models that include realistic variation of friction factor with Reynolds number and realistic two-phase friction multipliers that have been adequately verified with experimental data or models that prove at least equally conservative with respect to the maximum clad temperature calculated during the hypothetical accident. Examples of some of the correlations used are given below.

II.2.1 Single Phase Pressure Drop

Moody's Chart [35] and Standard Equations [37]:
(II.31)

For laminar flow, Hagen-Poiseuille equation is applicable.
(II.32)
For turbulent fully developed flow in smooth pipe, the Fanning friction factor is given by Karman-Nikuradse relation:
(II.33)
In the range 5000 < Re < 30000 Blasius equation, given below, may be used.
(II.34)
In the range 30000 < Re < 1000000 the Karman-Nikuradse relation is closely approximated by:
(II.35)
Friction factor is uncertain in the transition range 2000 < Re < 5000 and a conservative choice should be made for design purposes.

II.2.2 Two-Phase Frictional Pressure Drop

Separated Flow Model (Friedel's Correlation) [15]:

This correlation is applied for both vertical upward flow and horizontal flow and various flow regimes. The ratio of frictional two phase pressure drop to the frictional pressure drop of the liquid flowing alone in the tube with a flow rate equal to the total flow rate of the two phase flow is flo.
(II.36)
(II.37)
where
(II.38)
(II.39)
(II.40)
(II.41)
(II.42)
fgo ,flo = friction factors for total mass flux for vapour and liquid only respectively.
(II.43)
(II.44)

Martinelli-Nelson Method [30]:

This is Valid for pressures lower than 17 kg/cm2 (250 psia).

The Martinelli-Nelson method consists of representing and the void fraction as a function of quality for various constant pressure.

(II.45)

The relationship between and flo2 is

(II.46)

The integrated momentum balance using the multiplier is given by:

(II.47)

where

Acceleration Multiplier, (II.48)

and

(II.49)

flo is the friction factor of the liquid flow when the liquid mass velocity is G.

Combination of Thom's Correlation and Martinelli-Nelson Correlation [45]:

Thom who correlated a large number of points, especially at high pressure, recommended use of the Martinelli-Nelson method with values of the multipliers r2, r3 and r4. Thom's correlation [46] is valid for pressures equal to or greater than 17 kg/cm2 (250 psia). The multipliers are defined as follows:

Acceleration multiplier:

(II.50)

Friction multiplier:

(II.51)

Gravitational multiplier:

(II.52)

(II.53)

(II.54)

II.3 Heat Transfer

The following examples of heat transfer correlations used in loss of coolant accident analysis.

II.3.1 Convective Heat Transfer to Single Phase Fluid

i) Sieder-Tate correlation [40] for fully developed, turbulent forced convective heat transfer to single phase fluid (sub-cooled liquid or superheated vapour): (II.55)

where, the properties are evaluated at bulk temperature of the fluid.

ii) McAdams Correlation [47] for modelling natural convection of vapour: (II.56)

Subscript gf indicates vapour at film temperature. This correlation is reported to be valid for turbulent convection.

II.3.2 Net Vapour Generationation Point

If the wall temperature exceeds the minimum temperature required for nucleation, subcooled nucleate boiling occurs. Correlations exist for calculating the incipience of boiling. However, use of such a calculation is felt to add undue complication in an area that is relatively unimportant because the subcooled condition is very short lived. Simpler models considers that the subcooled nucleate boiling occurs whenever the subcooled nucleate boiling heat transfer coefficient equals or exceeds that for single phase convective heat transfer. The following is one of the correlations used for calculating the incipience of nucleate boiling.

Saha and Zuber Correlation [39]:

This is used for vertical flow.

(II.57)

(II.58)

DT is the temerature difference between wall and the fluid at the point of net vapour generation.

Other example is Bergles Correlation [4].

II.3.3 Pre-CHF Boiling Heat Transfer

(i) Sub-cooled nucleate boiling

Modified Chen Correlation [9, 7]

q = hmac(TW-Tl) + hmic(TW-TS) (II.59)

where,
hmac = 0.023 (kl/D) Rel0.8 Prl0.4 F (II.60)
hmic=0.00122 (A/B) (TW-TS)0.24 DP0.75 S (II.61)
(II.62)
(II.63)
(II.64)

Using the Clausius-Clapeyron-equation we get:
(II.65)

for ReTP < 4.1´105

(II.66)

with
ReTP = Rel(1-x) F1.25 (II.67)

(II.68)
(II.69)
S and F are approximations of curves given in Ref. 9.

(ii) Saturated Nucleate Boiling

Chen's correlation [16] can be used for possible heat transfer during saturated nucleate boiling in low quality region and forced convective evaporation (normally associated with annular flow) in the high quality high flow region

(II.70)

Where PW is the saturation pressure at TW, F and S are the Reynolds number factor and nucleate boiling suppression factor respectively.

(II.71)

(II.72)

(II.73)

as defined in equation (II.69).

Thom's Correlation [14]

(II.74)

p is in Mega Pascals, T in Kelvin and q in MW/m2.

II.3.4 Critical Heat Flux

The applicable equations for the post CHF boiling regimes are given below. In case correlations not listed here are used for heat transfer from fuel cladding to the surrounding fluid in the post-CHF regimes of transition and film boiling, these are required to be compared to the applicable steady state and transient-state data (as per the sections 4.4.7 and 4.4.8 of this guide). Such comparison has to demonstrate that the correlations predict values of heat transfer coefficient equal to or less than the mean value of the applicable experimental heat transfer data throughout the range of parameters for which the correlations are to be used. The comparison has to quantify the relation of the correlations to the statistical uncertainty of the applicable data.

Some of the Critical Heat Flux correlations used for steady state and transient cases are given below.

II.3.4.1 The Steady State CHF correlations for use in LOCA transients include the following:

W3 Correlation [47]

(II.75)

This is valid for circular or round tubes and uniform heat flux.

Range of validity:

(II.76)

(II.77)

(II.78)

(II.79)

(II.80)

(II.81)

(II.82)

B&W2 Correlation [16]

(II.83)

(II.84)

(II.85)

Range of validity:

(II.86)

(II.87)

GE correlation [24]

(II.88)

(II.89)

(II.90)

(II.91)

(II.92)

The above mentioned correlation is valid only for the pressure:

(II.93)

An extrapolation to other pressure is possible with the equation:

(II.94)

Range of validity:

(II.95)

(II.96)

(II.97)

(II.98)

(II.99)

Macbeth Correlation [27]

(II.100)

and (II.101)

Range of validity:

p = 70´105 Pa (II.102)

244 < G < 543 kg/(m2 s) (II.103)

Barnett Correlation [2]

(II.104)

(II.105)

(II.106)

(II.107)

(II.108)

(II.109)

(II.110)

F=cross sectional area, m2

S=S(q/qmax)rod (II.111)

D2 = rod diameter, m

Range of Validity:

(II.112)

(II.113)

(II.114)

(II.115)

(II.116)

Hughes Correlation [23]

(II.117)

(II.118)

(II.119)
(II.120)

Range of Validity:
106 < p < 5´106 Pa (II.121)
40 < G < 2300 kg/(m2 s) (II.122)
9.8´10-3 < D2 < 13.5´10-3 m (II.123)
0.83 < Lc < 4.30 m (II.124)

For definitions of DH, DY, D1 and D2 see Barnett Correlation.

Szmolin Correlation [7, 37]

(II.125)

Range of Validity:
2.94´106 < p < 1.37´107 Pa (II.126)
380 < G < 4930 kg/(m2 s) (II.127)
-0.18 < x < 0.6 (II.128)

GE transient CHF or Transient Hench-Levy Correlation [41]:
(II.129)
(II.130)

Biasi's correlation [5]:

In high flow region G >200 kg/m2s Biasi's correlation is used for vertical flow. This is valid for entire pressure range for both up and down flow. Higher of the values predicted by the following equations should be used.

for the low quality region, (II.131)

for the high quality region (II.132)

where
(II.133)

(II.134)

Range of validity:

(II.135)

30 ata < p < 100 ata

0.35 cm < D < 3 cm

20 g/cm2/s < G < 550 g/cm2/s

20 cm < L < 500 cm

xin < 0

x--0 > 0

Zuber's Correlation [42]:

For low flow region (G < 100 kg/m2/s) Zuber's correlation is applicable for vertical flow.

(II.136)

Merilo's Correlation [31]:

This correlation is used for horizontal flow.

(II.137)

where

(II.138)

(II.139)

This correlation is "global", and is not "local". Therefore, care should be taken while using this correlation.

Groeneveld's Look-up tables (Table A-3) [19, 20]

Although the standard CHF table was derived for very specific cases of upward flow in uniformly heated 8-mm tube, it may also be used for many other geometries and flow conditions, e.g., CHF prediction for non-uniformly heated geometries, downward flow, flow in bundle geometries, horizontal flow etc. For these cases the CHF values must be multiplied by correction factors K1 to K6---- as discussed below:

Subchannel or Tube cross section factor (K1)

This factor includes the observed effect of diameter on critical heat flux. The effect is quality-dependent, which can be included by Replacing the exponent 1/3 by (2-x)/4 in the formulation of K1. The equations are as follows:

For 0.002 m < Dhe <0.016 m
(II.140)

For Dhe > 0.016 m
(II.141)

Bundle factor (K2)

It is quality dependent and is given by

(II.142)

Grid space factor (K3)

This factor depends upon spacer dimensions and mass flux and is given by
(II.143)
where
(II.144)
B = 0.1 and K is loss coefficient.

Heated length factor (K4)

It depends upon heated length, L/Dh and void fraction, a. Void fraction is computed by homogeneous model. Inclusion of a predicts the diminishing length effect at subcooled condition. The length effect is particularly noticeable if L/Dh. The expression is as follows:

For L/Dh > 5: (II.145)
where a is calculated from homogeneous model as follows:
(II.146)

Axial flux distribution factor (K5)

Effect of axial flux under saturated condition is accounted as follows:

(II.147)

for x < 0 this factor is 1.

Tong's F factor may also be used but within narrow ranges of conditions.

Flow factor (K6) for vertical geometry

This effect is dependent on void fraction, density and mass flux range and is computed as follows:

For mass flux < -400 kg m-2 s-1 or quality < 0 this factor (K6) is unity.

For value of mass flux between -50 kg m-2 s-1 and 10 kg m-2 s-1, CHF is computed as follow:

(II.148)

where C1 is given by

For a < 0.8 C1=1.0

(II.149)

Linear interpolation may be used for the following mass flux ranges:

10 < G < 100 kg m-2 s-1

-400 < G < -50 kg m-2 s-1

Flow factor (K-6) for horizontal geometry

Based on transition mass fluxes for stratified and intermittent flow regime, the multiplication factor K6 is calculated as follows:

(II.150)

Gstr (kg m-2 s-1) is the mass flux boundary between fully stratified and intermittent flow. Gint is the mass flux boundary between intermittent and annular flow. To find Gstr and Gint use Taitel and Dukler's [44] flow regime map.

II.3.5 Transition Boiling Heat Transfer [29]

McDonough, Milich and King Correlation, one of the useful correlations for transition boiling, is given below:

(II.151)

C(p)=5560 W/m2-K at p=138 bar
C(p)=6710 W/m2-K at p=83 bar
C(p)=8530 W/m2-K at p=55 bar

II.3.6 Film Boiling Heat Transfer

Modified form of original Dittus Boelter equation for pressure less than or equal to 13.8 kg/cm2 [24].

(II.152)

adfm is the void fraction from drift flux model.

Groeneveld flow film boiling correlation [18]:

The Groeneveld Correlation shall not be used in the region near its low pressure singularity.

(II.153)

(II.154)

(II.155)

(II.156)

Dougall-Rohsenow flow film boiling correlation [12]:

(II.157)

(II.158)

(II.159)

II.3.7 Pool Boiling heat transfer coefficients

Berenson correlation [3]:
(II.160)

In the event of inverted annular post-CHF regime, the Berenson correlation with modification to account for subcooled liquid is used.

(II.161)

Where

Interfacial diameter, D1 = Dh (1-) (II.162)

and

(II.163)

Here rg and kg are vapour properties based at vapour temperature, while kgW, mgW and PrgW are vapour properties based on average temperature obtained from wall and vapour temperatures.

Bromley correlation [6]:

(II.164)

(II.165)

II.3.8 Stable Film Boiling Temperature

The temperature required to support stable film boiling can be determined by using following correlation:

Groeneveld and Stewart Correlation [17]: (II.166)

Where

Dhl and hlg are liquid subcooling and latent heat of vapourisation in kJ/kg. TMSFB and p are minimum stable film boiling temperature in Centigrade and pressure in kPa.

II.4 Heat Removal by the ECCS

Single Failure Criterion: An analysis of possible failure modes of ECCS equipment and of their effects on ECCS performance must be made. In carrying out the accident evaluation, the combination of ECCS subsystem assumed to be operative shall be those available after the most damaging single failure of ECCS equipment has taken place.

II.5 Flow Regime Transitions in vapour liquid Flow

II.5.1 Horizontal Channel [44]

Example of the models used for prediction of flow regime transitions in horizontal channel may be found in the following reference:

Taitel Y., & Dukler A.T., "A model for predicting flow regime transition in horizontal & near horizontal gas-liq. flow", AIChE J., Vol.22, No.1, pp. 47-55, January 1976.

II.5.2 Vertical Channel [32]

Example of the models used for prediction of flow regimes in a vertical tube may be found in the following model reference:

Mishima K, and Ishii M., "Flow regime Transition Criteria consistent with Two-fluid Model for Vertical Two-phase Flow", ANL-83-42, NUREG/CR-3338, April 1983.

Table-A-3: Groeneveld Look-up Table (1995) [19]

P= Pressure (kPa) G= Mass Velocity (kg m-2 s-1)

P	G	Quality									
		-0.5	-0.4	-0.3	-0.2	-0.15	-0.1	-0.05	0	0.05	0.1
	0.15	0.2	0.25	0.3	0.35	0.4	0.45	0.5	0.6	0.7	0.8
	0.9	1									
100	0	4593	4593	4593	4593	4593	3419	2247	1066	421	298
	207	158	142	130	120	111	103	99	84	74	68
	67	0									
100	50	4940	4940	4940	4940	4940	3881	2618	1526	787	754
	683	635	620	609	600	591	582	570	513	401	288
	253	0									
100	100	5206	5206	5206	5206	5206	4124	2942	1947	1159	1137
	1123	1107	1093	1084	1078	1070	1060	1037	961	747	550
	416	0									
100	300	5232	5232	5232	5232	5232	4206	3475	2792	1693	1665
	1651	1598	1536	1502	1475	1378	1243	1151	979	751	626

	550	0									
100	500	5261	5261	5261	5261	5261	4305	3768	3204	2040	1887
	1883	1875	1798	1725	1714	1615	1486	1463	1188	752	558
	415	0									
100	1000	5387	5387	5387	5387	5387	4626	4129	3527	2528	2286
	2280	2211	2129	2028	1870	1655	1632	1631	1438	850	428
	206	0									
100	1500	5432	5432	5432	5432	5432	4734	4216	3606	2652	2427
	2405	2292	2195	2084	1905	1857	1856	1856	1597	839	348
	109	0									
100	2000	5434	5434	5434	5434	5434	4739	4218	3616	2693	2487
	2446	2333	2212	2054	1950	1918	1889	1815	1466	674	183
	62	0									
100	2500	5443	5443	5443	5443	5443	4745	4220	3631	2743	2548
	2505	2367	2217	1985	1846	1779	1693	1582	1162	494	80
	12	0									
100	3000	5452	5452	5452	5452	5452	4751	4239	3651	2795	2606
	2572	2418	2245	1941	1738	1596	1472	1315	842	341	61
	15	0									
100	3500	5504	5504	5504	5504	5504	4827	4277	3662	2843	2652
	2624	2470	2282	1937	1684	1449	1264	1059	610	220	70
	33	0									
100	4000	5660	5660	5660	5660	5660	4908	4310	3688	2947	2727
	2685	2530	2327	1960	1638	1316	1098	891	503	239	108
	51	0									
100	4500	5902	5902	5902	5902	5902	5006	4338	3707	3060	2820
	2738	2560	2353	2026	1696	1378	1145	939	591	324	151
	71	0									
100	5000	6242	6242	6242	6242	6242	5266	4412	3738	3157	2893
	2777	2599	2401	2097	1798	1496	1262	1054	693	398	194
	92	0									
100	5500	6513	6513	6513	6513	6513	5487	4529	3813	3242	2952
	2824	2663	2454	2156	1863	1587	1355	1149	776	466	238
	113	0									
100	6000	6772	6772	6772	6772	6772	5668	4684	3933	3349	3040
	2892	2699	2492	2167	1912	1662	1437	1230	853	530	282
	135	0									
100	6500	7060	7060	7060	7060	7060	5876	4856	4103	3439	3089

	2934	2718	2502	2208	1968	1731	1511	1305	925	592	362
	157	0									
100	7000	7349	7349	7349	7349	7349	6087	5029	4223	3505	3132
	2965	2741	2507	2251	2019	1792	1577	1374	993	651	369
	179	0									
100	7500	7643	7643	7643	7643	7643	6288	5181	4300	3559	3176
	2996	2765	2530	2291	2066	1848	1638	1436	1056	708	413
	201	0									
100	8000	7939	7939	7939	7939	7939	6507	5370	4375	3517	3220
	3027	2793	2550	2326	2108	1898	1693	1495	1116	763	458
	223	0									

300	0	5024	5024	5024	5024	4349	3432	2433	1596	1575	1029
	665	467	317	234	194	178	171	170	149	143	143
	90	0									
300	50	5644	5644	5644	5644	4951	3882	2842	2003	1987	1443
	1123	938	813	745	708	686	660	642	601	472	391
	300	0									
300	100	6174	6174	6174	6174	5211	4235	3225	2431	2076	1574
	1291	1258	1230	1211	1190	1168	1118	1081	1026	857	669
	473	0									
300	300	6403	6403	6403	6403	5447	4544	3889	3371	2433	2095
	2071	1995	1895	1828	1771	1636	1494	1418	1203	866	695
	564	0									
300	500	6414	6414	6414	6414	5498	4667	4234	3832	2863	2479
	2435	2333	2185	2072	1869	1700	1539	1447	1155	764	574
	521	0									
300	1000	6430	6430	6430	6430	5590	4931	4585	4189	3285	2845
	2750	2550	2388	2283	1968	1766	1586	1545	1174	677	439
	288	0									
300	1500	6438	6438	6438	6438	5610	4985	4609	4209	3339	2922
	2834	2570	2424	2301	2021	1834	1615	1525	1103	568	220
	130	0									
300	2000	3454	3454	3454	3454	5629	4995	4615	4210	3370	2948
	2863	2590	2462	2320	2066	1771	1571	1410	1029	490	143
	60	0									
300	2500	6547	6547	6547	6547	5663	5004	4622	4225	3415	2979

	2869	2610	2444	2282	1916	1700	1524	1327	957	407	74
	23	0									
300	3000	6735	6735	6735	6735	5786	5087	4656	4239	3462	3021
	2879	2630	2426	2245	1806	1577	1380	1180	777	333	61
	19	0									
300	3500	7036	7036	7036	7036	6024	5320	4744	4249	3515	3073
	2895	2650	2407	2154	1692	1390	1258	1043	581	264	77
	34	0									
300	4000	7495	7495	7495	7495	6343	5601	4851	4254	3520	3102
	2908	2670	2389	2044	1718	1372	1166	935	545	275	111
	51	0									
300	4500	8034	8034	8034	8034	6702	5832	4927	4266	3525	3110
	2926	2691	2405	2064	1846	1490	1203	978	610	340	152
	69	0									
300	5000	8435	8435	8435	8435	7062	6098	5000	4275	3530	3141
	2959	2713	2489	2200	1867	1536	1303	1088	710	411	191
	90	0									
300	5500	8809	8809	8809	8809	7372	6360	5090	4277	3536	3178
	2988	2730	2572	2259	1914	1667	1402	1187	799	477	237
	112	0									
300	6000	9216	9216	9216	9216	7692	6645	5211	4287	3543	3194
	3003	2762	2610	2269	1970	1742	1488	1273	879	543	283
	136	0									
300	6500	9605	9605	9605	9605	8015	6908	5346	4308	3577	3229
	3029	2992	2625	2291	2073	1809	1565	1351	954	608	329
	159	0									
300	7000	9975	9975	9975	9975	8325	7175	5592	4450	3642	3268
	3058	2823	2649	2337	2115	1868	1634	1422	1024	669	374
	182	0									
300	7500	10356	10356	10356	10356	8630	7427	5870	4662	3727	3302
	3090	2849	2670	2376	2152	1920	1697	1486	1089	728	420
	204	0									
300	8000	10707	10707	10707	10707	8936	7656	6117	4840	3802	3338
	3118	2872	2697	2407	2185	1966	1753	1545	1150	784	465
	227	0									

Table-A-3: Groeneveld Look-up Table 1995 [19] (Continued)

P= Pressure (kPa) G= Mass Velocity (kg m-2 s-1)

P	G	Quality

		-0.5	-0.4	-0.3	-0.2	-0.15	-0.1	-0.05	0	0.05	0.1	0.15	0.2	0.25	0.3	0.35	0.4	0.45	0.5	0.6	0.7	0.8	0.9	1
500	0	4879	4879	4879	4879	4200	3469	2595	1783	1697	1174	786	535	374	278	226	207	191	183	151	150	149	140	0
500	50	5568	5568	5568	5568	4962	3983	3168	2424	2249	1728	1380	1145	1005	921	865	826	793	754	611	493	476	359	0
500	100	6195	6195	6195	6195	5267	4489	3688	2975	2478	1780	1683	1623	1566	1525	1492	1440	1391	1292	1158	1045	875	539	0
500	300	6589	6589	6589	6589	5783	5098	4547	4089	3396	2921	2801	2679	2527	2409	2050	1799	1552	1489	1188	1049	919	607	0
500	500	6629	6629	6629	6629	5876	5250	4853	4452	3784	3247	3074	2888	2695	2498	2187	1887	1593	1414	959	774	622	554	0
500	1000	6650	6650	6650	6650	5991	5531	5273	4873	4075	3452	3256	2975	2923	2629	2277	1911	1547	1385	962	635	445	301	0
500	1500	6664	6664	6664	6664	5994	5576	5323	4909	4093	3456	3313	3293	3154	2782	2260	1811	1453	1268	911	543	271	232	0
500	2000	6677	6677	6677	6677	6037	5601	5327	4911	4104	3460	3407	3406	3261	2790	2184	1696	1383	1164	852	335	130	65	0
500	2500	6839	6839	6839	6839	6141	5645	5331	4913	4138	3605	3545	3527	3335	2696	1991	1535	1290	1067	605	298	72	29	0
500	3000	7189	7189	7189	7189	6430	5789	5366	4915	4182	3750	3725	3662	3428	2621	1871	1427	1224	972	570	283	61	21	0
500	3500	7654	7654	7654	7654	6789	6006	5430	4939	4271	3726	3712	3652	3350	2426	1700	1330	1214	963	541	271	82	35	0
500	4000	8155	8155	8155	8155	7143	6293	5553	4951	4152	3593	3578	3485	3154	2345	1798	1428	1234	973	555	301	115	51	0

500	4500	8688	8688	8688	8688	7556	6584	5670	4963	4006	3513
	3501	3404	3064	2352	1871	1483	1261	1016	624	358	153
	68	0									
500	5000	9138	9138	9138	9138	7969	6877	5748	4922	3913	3408
	3159	2840	2783	2354	1903	1577	1337	1111	719	420	190
	88	0									
500	5500	9580	9580	9580	9580	8334	7180	5765	4815	3863	3407
	3157	2816	2690	2362	1964	1676	1434	1210	810	482	235
	111	0									
500	6000	10022	10022	10022	10022	8690	7517	5734	4632	3880	3494
	3361	3079	2727	2371	2025	1760	1519	1300	893	548	282
	135	0									
500	6500	10439	10439	10439	10439	9036	7799	5735	4402	3899	3494
	3368	3093	2749	2389	2084	1837	1599	1379	971	615	330
	159	0									
500	7000	10822	10822	10822	10822	9366	8112	6026	4577	3945	3496
	3388	3096	2791	2408	2147	1901	1670	1451	1042	678	376
	182	0									
500	7500	11192	11192	11192	11192	9675	8411	6441	4962	3964	3498
	3409	3116	2811	3426	2190	1958	1734	1517	1109	738	423
	206	0									
500	8000	11571	11571	11571	11571	9969	8642	6746	5268	3985	3518
	3428	3135	2832	2463	2236	2110	1791	1577	1171	795	469
	229	0									

1000	0	5619	5619	5619	4685	4058	3564	2859	2175	1910	1438
	1030	717	519	389	312	286	270	556	198	188	181
	175	0									
1000	50	6371	6371	6371	5523	4991	4436	3928	3323	2944	2469
	2071	1752	1559	1414	1307	1230	1157	1076	876	806	804
	700	0									
1000	100	6981	6981	6981	6252	5685	5281	4851	4268	3386	2799
	2651	2531	2415	2292	2184	2041	1891	1703	1312	1291	1250
	732	0									
1000	300	7492	7492	7492	7295	7089	6901	6766	6620	6215	5289
	4760	4456	4120	3432	2600	2151	1924	1708	1343	1289	1215
	660	0									

1000	500	7577	7577	7577	7464	7327	7177	7110	7048	6818	5771
	5094	4660	4233	3856	2784	2284	1979	1659	1035	825	767
	589	0									
1000	1000	7594	7594	7594	7466	7329	7192	7124	7022	6705	5694
	5042	4634	3953	3264	2670	2035	1741	1516	958	592	452
	338	0									
1000	1500	7700	7700	7700	7468	7349	7230	7153	7013	6604	5532
	4989	4422	3952	3236	2429	1557	1145	930	637	411	370
	266	0									
1000	2000	8187	8187	8187	7552	7424	7281	7192	7012	6401	5196
	4720	4404	3952	3143	2259	1373	980	713	541	343	137
	86	0									
1000	2500	8962	8962	8962	7788	7544	7314	7202	6979	6100	5028
	4668	4397	3924	2999	2081	1281	925	690	512	306	84
	25	0									
1000	3000	9731	9731	9731	8149	7728	7370	7206	6966	5900	4920
	4647	4391	3898	2880	1955	1234	908	701	510	349	95
	30	0									
1000	3500	10456	10456	10456	8659	8005	7450	7179	6910	5800	4849
	4628	4385	3865	2765	1797	1252	1059	1000	595	356	108
	36	0									
1000	4000	11146	11146	11146	9203	8342	7591	7143	6778	5752	4752
	4584	4380	3794	2723	1891	1484	1292	1021	605	375	134
	51	0									
1000	4500	11816	11816	11816	9746	8754	7750	7141	6500	5537	4627
	4477	4304	3715	2689	1953	1498	1327	1034	643	401	159
	65	0									
1000	5000	12447	12447	12447	10239	9182	7859	6988	5900	5107	4361
	4211	3924	3338	2581	1978	1579	1363	1126	726	438	188
	83	0									
1000	5500	13033	13033	13033	10745	9599	8124	6794	5800	4822	4239
	4085	3729	3112	2523	2017	1703	1469	1235	816	484	227
	104	0									
1000	6000	13573	13573	13573	11285	10064	8595	6647	5530	4654	4096
	3966	3625	3050	2519	2063	1767	1555	1325	902	546	275
	129	0									
1000	6500	14101	14101	14101	11770	10479	8933	6351	5228	4460	3913
	3804	3484	2973	2497	2115	1852	1633	1406	983	616	326
	155	0									

1000	7000	14608	14608	14608	12172	10857	9325	6654	4850	4232	3734
	3547	3336	2867	2461	2178	1945	1707	1480	1057	681	375
	180	0									
1000	7500	15109	15109	15109	12524	11194	9725	7272	5409	4227	3683
	3525	3287	2851	2478	2246	2006	1774	1548	1126	744	423
	204	0									
1000	8000	15629	15629	15629	12866	11463	9958	7772	6039	4447	3684
	3536	3341	3061	2571	2306	2062	1834	1612	1190	802	470
	227	0									

Table-A-3: Groeneveld Look-up Table 1995 [19] (Continued)

P= Pressure (kPa) G= Mass Velocity (kg m-2 s-1)

P	G	Quality									
		-0.5	-0.4	-0.3	-0.2	-0.15	-0.1	-0.05	0	0.05	0.1
	0.15	0.2	0.25	0.3	0.35	0.4	0.45	0.5	0.6	0.7	0.8
	0.9	1									
3000	0	6583	5927	5252	4544	4205	3891	3536	3022	2429	2009
	1564	1145	892	699	568	502	452	413	321	275	266
	256	0									
3000	50	7307	6575	5972	5386	5107	4857	4570	4135	3478	3061
	2653	2266	2041	1865	1722	1614	1521	1418	1409	1400	1392
	1000	0									
3000	100	7888	7106	6580	6114	5897	5708	5479	5057	4121	3502
	3326	3186	3051	2936	2696	2625	2467	2367	2191	1936	1587
	1015	0									
3000	300	8463	7476	7307	7303	7302	7300	7298	7255	6954	5922
	5380	5211	4936	4635	3997	3322	3177	3173	2865	2078	1536
	953	0									
3000	500	8655	7674	7578	7560	7554	7641	7627	7621	7496	7000
	6400	5660	5269	4807	4297	3392	3376	3324	2745	1841	1320
	835	0									
3000	1000	9003	7776	7660	7598	7560	7548	7818	7512	7444	6846
	6208	5620	4728	4200	3745	3079	2910	2618	1925	1242	8300
	471	0									
3000	1500	9523	8313	7824	7647	7578	7560	7471	7436	7250	6661
	5980	5043	4364	3792	3422	2691	2130	1728	1080	626	499
	312	0									
3000	2000	10680	9563	8247	7706	7640	7567	7453	7298	6723	6026
	5315	4507	3991	3485	2958	2279	1686	1211	608	373	330

	216	0									
3000	2500	11975	10928	9397	8034	7681	7634	7441	7158	6226	5999
	4880	4175	3702	3152	2369	1726	1252	867	431	308	89
	25	0									
3000	3000	12932	11900	10414	8640	7947	7643	7439	7069	5966	5339
	4712	4094	3619	2963	2085	1423	1037	772	520	374	129
	45	0									
3000	3500	13887	12661	11230	9396	8434	7824	4737	6995	5829	5131
	4586	4067	3540	2705	1715	1329	1127	1020	578	431	137
	44	0									
3000	4000	14813	13379	11939	10174	9013	8023	7418	6832	5753	4966
	4471	4021	3424	2463	1474	1234	1228	1118	699	440	147
	54	0									
3000	4500	15714	14077	12608	10862	9586	8292	7365	6566	5570	4792
	4348	3945	3273	2302	1514	1311	1306	1145	713	445	163
	63	0									
3000	5000	16584	14778	13200	11500	10262	8818	7348	6039	5258	4610
	4242	3867	3121	2196	1610	1505	1405	1173	766	466	179
	72	0									
3000	5500	17426	15454	13765	12044	10824	9249	7402	6188	5134	4431
	4136	3794	3006	2155	1712	1650	1500	1252	846	493	197
	83	0									
3000	6000	18238	16101	14321	12489	11385	10063	7735	6382	5070	4332
	4061	3753	3042	2265	1853	1738	1542	1311	876	532	234
	103	0									
3000	6500	19035	16814	14849	12926	11946	10878	8193	6446	5002	4181
	3931	3693	3067	2360	2043	1876	1622	1388	982	589	282
	129	0									
3000	7000	19813	17464	15350	13332	12053	11351	8542	6507	4694	3888
	3705	3557	3084	2530	2209	2008	1755	1514	1062	656	333
	155	0									
3000	7500	20584	18107	15834	13724	12429	11527	8891	6526	4644	3817
	3643	3459	3103	2699	2390	2073	1825	1588	1138	724	385
	181	0									
3000	8000	21353	17830	16299	14090	12789	11585	9157	7075	4971	3980
	3715	3448	3291	2904	2413	2112	1885	1654	1205	787	437
	207	0									

5000	0	5951	5460	4941	4459	4230	4011	3762	3360	2628	2234
	1791	1346	1083	877	731	638	571	515	405	345	341
	323	0									
5000	50	6644	6095	5629	5224	5030	4840	4626	4294	3606	3225
	2837	2450	2224	2047	1896	1774	1666	1553	1532	1512	945
	830	0									
5000	100	7234	6636	6223	5891	5734	5573	5387	5065	4165	3609
	3458	3315	3174	3061	2936	2803	2655	2476	2300	2148	1757
	1080	0									
5000	300	7680	6990	6769	6737	6722	6686	6677	6619	6280	5401
	5007	4907	4741	4509	4202	3881	3659	3315	2973	2543	1823
	1215	0									
5000	500	7918	7164	6943	6900	6882	6819	6812	6739	6395	5734
	5296	5178	5027	4588	4244	3975	3803	3503	3040	2459	1769
	1118	0									
5000	1000	8364	7454	7171	7014	6944	6829	6743	6595	6107	5662
	5289	4957	4676	4166	3759	3447	3322	3086	2066	1433	1034
	763	0									
5000	1500	9068	8009	7470	7142	7025	6859	6707	6441	5779	5317
	4899	4530	4074	3623	3337	2983	2569	2134	1194	913	899
	744	0									
5000	2000	10326	9287	8159	7346	7139	6944	6593	6110	5262	4779
	4405	3984	3610	3206	2865	2557	1973	1332	668	650	650
	526	0									
5000	2500	11531	10599	9179	7837	7458	7195	6565	5849	4915	4515
	3981	3594	3401	3067	2474	1861	1301	921	401	313	117
	53	0									
5000	3000	12458	11530	10191	8483	7761	7353	6543	5664	4750	4321
	3782	3428	3268	2855	2024	1406	948	793	584	420	132
	53	0									
5000	3500	13348	12271	10990	9196	8178	7551	6527	5421	4581	4144
	3693	3380	3109	2510	1688	1195	958	874	645	441	149
	55	0									
5000	4000	14214	12958	11651	9917	8669	7764	6476	5139	4421	3916
	3540	3317	2945	2221	1437	1140	1108	1049	688	441	151
	58	0									
5000	4500	15045	13625	12254	10566	9102	7980	6502	5044	4317	3784
	3457	3260	2799	2059	1425	1247	1242	1187	734	453	167

																							61	0
5000	5000	15844	14283	12804	11186	9669	8443	6655	4986	4255	3723	3454	3251	2745	1990	1470	1385	1295	1205	786	472	164	66	0
5000	5500	16626	14896	13352	11741	10379	8952	6807	5334	4253	3656	3421	3240	2717	1992	1583	1504	1459	1234	804	481	182	76	0
5000	6000	17388	15495	13856	12319	11076	9876	7558	5744	4314	3627	3415	3239	2688	2091	1812	1679	1529	1296	850	500	211	94	0
5000	6500	18126	16100	14340	12662	11773	10800	8118	5954	4356	3603	3397	3235	2711	2303	2034	1869	1611	1370	913	531	289	110	0
5000	7000	18845	16707	14796	12961	11971	11295	8492	6049	4363	3613	3445	3291	2801	2510	2189	1951	1689	1444	989	592	282	130	0
5000	7500	19549	17295	15245	13320	12236	11413	8865	6189	4478	3749	3547	3350	3051	2667	2329	2021	1764	1519	1064	656	328	154	0
5000	8000	20238	17880	15671	13711	12701	11561	9151	6556	4717	3975	3695	3482	3290	2882	2405	2074	1829	1588	1130	717	379	178	0

Table-A-3: Groeneveld Look-up Table 1995 [19] (Continued)

P= Pressure (kPa) G= Mass Velocity (kg m-2 s-1)

P	G	Quality																						
		-0.5	-0.4	-0.3	-0.2	-0.15	-0.1	-0.05	0	0.05	0.1	0.15	0.2	0.25	0.3	0.35	0.4	0.45	0.5	0.6	0.7	0.8	0.9	1
6000	0	5626	5219	4798	4387	4185	3995	3777	3415	3669	2291	1859	1416	1150	941	787	686	608	547	439	348	344	327	0
6000	50	6300	5838	5443	5092	4920	4720	4760	4575	4272	3564	3191	2812	2431	2204	1871	1749	1645	1537	1229	989	942	823	0
6000	100	6873	6366	5999	5708	5567	5434	5273	4973	4079	3530	3377	3237	3089	2966	2866	2724	2598	2431	1833	1647	1511	1070	0
6000	300	7318	6710	6451	6395	6379	6330	6310	6255	5942	5126													

	4783	4679	4496	4269	4066	3800	3584	3283	2663	2330	1766
	1193	0									
6000	300	7573	6883	6586	6512	6480	6364	6316	6261	5978	5371
	5005	4822	4683	4333	4077	3812	3707	3468	2874	2374	1636
	1061	0									
6000	1000	8080	7186	6742	6576	6502	6256	6114	6008	5633	5334
	4857	4429	4177	3788	3528	3418	3263	2964	1965	1257	803
	735	0									
6000	1500	8817	7758	7023	6667	6585	6331	6146	5787	5138	4703
	4326	3964	3637	3309	3056	2839	2550	2068	1029	785	714
	707	0									
6000	2000	10109	9053	7842	6970	6796	6559	6147	5531	4716	4227
	3875	3532	3229	2919	2460	2383	1789	1096	532	518	439
	435	0									
6000	2500	11237	10324	8947	7698	7356	7038	6235	5383	4543	4030
	3545	3254	3054	2797	2311	1632	930	519	370	305	107
	52	0									
6000	3000	12123	11219	9913	8360	7693	7264	6241	5237	4449	3882
	3340	3043	2876	2560	1887	1093	571	477	472	353	122
	52	0									
6000	3500	12969	11949	10669	8979	7986	7458	6243	4962	4218	3651
	3219	2961	2696	2235	1522	871	582	576	505	382	145
	57	0									
6000	4000	13791	12626	11288	9594	8324	7679	6245	4590	3787	3318
	3038	2893	2570	1996	1376	988	952	952	580	384	146
	59	0									
6000	4500	14582	13274	11857	10119	8549	7682	6247	4578	3624	3133
	2922	2814	2470	1863	1358	1154	1133	1124	622	386	147
	60	0									
6000	5000	15341	13920	12372	10555	8820	7811	6336	4701	3674	3115
	2918	2795	2432	1792	1319	1237	1183	1130	350	390	148
	64	0									
6000	5500	16091	14489	12910	11165	9671	8416	6533	4793	3751	3148
	2936	2816	2475	1877	1459	1363	1345	1149	698	411	167
	74	0									
6000	6000	16823	15039	13396	12151	10623	9568	7356	5118	3824	3169
	2946	2843	2506	2049	1755	1621	1405	1192	756	438	196
	90	0									
6000	6500	17524	15635	13826	12525	11575	10720	8043	5370	3900	3211

	2979	2886	2586	2247	2026	1760	1468	1250	818	472	223
	105	0									
6000	7000	18210	16212	14268	12743	11838	11239	8441	5556	4010	3305
	3095	2988	2795	2492	2169	1822	1545	1314	887	528	260
	123	0									
6000	7500	18884	16771	14706	13013	12063	11299	8839	5779	4287	3660
	3411	3187	2980	2635	2268	1901	1632	1394	960	587	299
	142	0									
6000	8000	19548	17309	15140	13347	12447	11537	9144	6019	4481	3966
	3675	3423	3262	2860	2359	1981	1717	1479	1034	646	341
	162	0									

7000	0	5361	5010	4651	4293	4118	3954	3762	3426	2692	2336
	1918	1485	1212	996	834	723	641	575	466	369	357
	339	0									
7000	50	6002	5599	5236	4926	4778	4644	4483	4198	3498	3137
	2769	2397	2165	1981	1826	1706	1604	1501	1200	984	940
	774	0									
7000	100	6539	6094	5738	5474	5335	5245	5105	4818	3957	3401
	3239	3093	2941	2820	2707	2595	2489	2302	1710	1515	1479
	1060	0									
7000	300	6998	6441	6104	6015	6002	5947	5886	5865	5582	4834
	4494	4247	4046	3862	3632	3430	3318	3065	2402	2144	1735
	1179	0									
7000	500	7264	6617	6233	6123	6088	5953	5940	5887	5690	5134
	4683	4316	4157	3900	3634	3469	3366	3157	2596	2213	1587
	1029	0									
7000	1000	7798	6930	6386	6216	6135	5799	5604	5505	5318	5070
	4472	3892	3626	3347	3136	3031	3028	2838	1774	1121	735
	613	0									
7000	1500	8557	7520	6715	6339	6253	5886	5603	5145	4673	4301
	3874	3486	3189	2964	2735	2523	2250	1728	805	488	273
	250	0									
7000	2000	9793	8774	7597	6676	6480	6142	5684	4952	4275	3785
	3407	3122	2890	2731	2451	2023	1445	844	432	322	196
	190	0									
7000	2500	10882	9986	8709	7496	7142	6690	5806	4876	4104	3537

												3147	2922	2723	2445	1983	1367	789	424	261	204	99	51	0
7000	3000	11730	10850	9620	8170	7523	6953	5816	4724	3981	3369	2940	2714	2491	2133	1570	967	553	425	346	263	112	52	0
7000	3500	12535	11558	10344	8740	7757	7135	5848	4567	3834	3199	2786	2565	2294	1896	1323	782	519	490	409	317	135	57	0
7000	4000	13317	12216	10929	9320	8041	7398	5938	4372	3469	2928	2645	2490	2201	1730	1228	840	734	732	470	317	136	58	0
7000	4500	14070	12839	11469	9769	8188	7399	6061	4410	3347	2743	2515	2418	2139	1640	1200	930	872	854	492	317	137	59	0
7000	5000	14792	13465	11954	10124	8354	7427	6225	4552	3378	2696	2458	2380	2105	1591	1193	1010	949	888	521	326	138	63	0
7000	5500	15509	14000	12474	10713	9223	8025	6409	4682	3454	2710	2471	2382	2146	1673	1308	1154	1102	952	582	348	153	70	0
7000	6000	16208	14521	12931	11464	10460	9338	7226	4752	3483	2714	2470	2415	2213	1840	1539	1385	1228	1032	655	379	179	84	0
7000	6500	16875	15091	13336	12214	11432	10650	7804	4867	3535	2784	2519	2466	2330	2140	1879	1599	1311	1108	725	422	210	99	0
7000	7000	17529	15640	13763	12432	11718	11183	8065	5055	3745	3006	2708	2595	2464	2260	2014	1687	1401	1186	795	476	243	116	0
7000	7500	18170	16174	14182	12682	11740	11185	8202	5208	5208	3974	3032	2913	2779	2541	2199	1773	1489	1269	866	530	277	132	0
7000	8000	18806	16673	14610	12995	12067	11187	8424	5405	4172	3727	3483	3384	3259	2846	2288	1851	1576	1353	936	581	312	149	0

Table-A-3: Groeneveld Look-up Table 1995 [19] (Continued)

P= Pressure (kPa)   G= Mass Velocity (kg m-2 s-1)

P   G   Quality

		-0.5	-0.4	-0.3	-0.2	-0.15	-0.1	-0.05	0	0.05	0.1	0.15	0.2	0.25	0.3	0.35	0.4	0.45	0.5	0.6	0.7	0.8	0.9	1
8000	0	5101	4795	4484	4175	4022	3883	3716	3403	2547	2044	1674	1295	1195	994	838	731	653	591	542	456	423	364	0
8000	50	5714	5359	5025	4744	4615	4503	4362	4081	3170	2622	2374	2169	2006	1871	1761	1667	1579	1490	1183	980	938	720	0
8000	100	6229	5834	5487	5235	5132	5039	4916	4650	3796	3239	3086	2969	2837	2708	2601	2507	2417	2281	1678	1457	1449	1050	0
8000	300	6685	6179	5792	5654	5637	5577	5512	5484	5250	4549	4207	3911	3759	3642	3458	3328	3212	2893	2144	1877	1538	1083	0
8000	500	6958	6354	5920	5763	5718	5605	5597	5544	5324	4784	4306	3829	3583	3411	3248	3096	2964	2629	2068	1858	1427	917	0
8000	1000	7518	6668	6144	5919	5765	5314	5072	5040	4997	4755	4106	3452	3103	2847	2749	2560	2331	2069	1413	944	554	511	0
8000	1500	8280	7266	6556	6124	5911	5334	5042	4774	4459	4066	3562	3137	2863	2639	2355	2001	1661	1209	643	364	205	195	0
8000	2000	9465	8470	7416	6490	6179	5626	5178	4623	4015	3483	3039	2749	2551	2345	2014	1559	1068	656	388	250	154	134	0
8000	2500	10508	9633	8457	7323	6937	6335	5386	4575	3816	3144	2769	2551	2319	1899	1514	1099	655	396	237	178	96	49	0
8000	3000	11320	10465	9316	7976	7376	6702	5426	4348	3609	2906	2535	2340	2093	1694	1253	811	524	397	307	225	111	50	0
8000	3500	12091	11136	10017	8489	7576	6794	5461	4205	3479	2798	2381	2179	1947	1616	1128	696	501	470	385	258	122	55	0
8000	4000	12839	11763	10584	9021	7836	7014	5626	4145	3241	2592	2238	2084	1893	1528	1063	702	603	577	401	258	122	56	0

8000	4500	13559	12361	11093	9494	8078	7215	5921	4248	3137	2403
	2116	2037	1867	1475	1066	783	738	676	425	259	122
	57	0									
8000	5000	14251	12945	11568	9938	8351	7424	6106	4394	3169	2420
	2120	2031	1821	1450	1147	923	859	756	470	275	125
	59	0									
8000	5500	14934	13466	12056	10488	9083	7990	6213	4479	3283	2478
	2177	2070	1878	1570	1300	1076	988	850	535	304	139
	65	0									
8000	6000	15597	13983	12477	11140	10142	9265	6851	4526	3352	2510
	2237	2159	1998	1721	1519	1256	1136	938	607	346	165
	77	0									
8000	6500	16235	14521	12879	11791	10678	9903	7172	4629	3419	2556
	2432	2391	2207	2027	1794	1514	1225	1025	678	396	197
	93	0									
8000	7000	16859	15043	13288	12019	11214	10542	7253	4766	3593	2843
	2558	2466	2287	2179	1832	1585	1316	1111	747	447	228
	108	0									
8000	7500	17470	15550	13689	12260	11235	10544	7292	4874	3748	3136
	2935	2820	2611	2287	1980	1654	1402	1193	814	498	260
	124	0									
8000	8000	18075	16026	14098	12584	11555	10546	7482	4967	3931	3490
	3380	3376	3257	2798	2157	1719	1479	1272	881	548	295
	140	0									
9000	0	4836	4571	4301	4034	3902	3783	3639	3352	2503	1977
	1637	1290	1179	992	843	739	660	608	560	471	431
	349	0									
9000	50	5422	5114	4813	4547	4432	4335	4213	3960	3071	2528
	2304	2110	1945	1810	1699	1610	1536	1457	1152	971	938
	650	0									
9000	100	5916	5571	5251	4988	4892	4811	4704	4462	3658	3134
	2976	2841	2697	2575	2458	2373	2317	2165	1554	1306	1300
	1040	0									
9000	300	6366	5916	5527	5300	5260	5239	5236	5194	4944	4270
	3692	3478	3344	3257	3065	2894	2713	2334	1672	1380	1197
	899	0									

9000	500	6641	6100	5668	5412	5332	5205	5147	5114	4925	4243
	3625	3364	3160	2999	2887	2741	2351	1983	1583	1282	904
	626	0									
9000	1000	7221	6432	5947	5625	5398	4936	4705	4703	4697	4204
	3520	3118	2854	2661	2545	2118	1553	1143	984	729	346
	311	0									
9000	2000	9111	8171	7160	6258	5863	5299	4835	4196	3569	3097
	2746	2448	2312	1931	1428	1027	745	603	345	186	97
	48	0									
9000	2500	10108	9252	8185	7162	6749	6025	5004	4119	3339	2797
	2521	2241	1942	1373	1028	809	570	348	211	136	96
	48	0									
9000	3000	10887	10041	8998	7755	7210	6399	5097	4045	3240	2604
	2289	2038	1724	1354	967	708	508	393	282	169	103
	49	0									
9000	3500	11622	10683	9660	8227	7395	6453	5140	3995	3155	2487
	2124	1896	1643	1276	952	650	457	419	305	184	107
	54	0									
9000	4000	12336	11283	10200	8756	7669	6674	5266	3983	3066	2349
	1931	1750	1604	1375	982	664	558	499	331	190	108
	55	0									
9000	4500	13022	11857	10680	9235	7924	6936	5469	4047	3026	2245
	1827	1719	1631	1385	1037	771	670	615	381	205	109
	56	0									
9000	5000	13683	12418	11127	9685	8259	7305	5645	4183	3080	2249
	1836	1755	1663	1416	1152	908	816	717	445	239	116
	57	0									
9000	5500	14332	12927	11580	10180	8872	7818	5764	4272	3210	2355
	1963	1856	1760	1542	1290	1071	935	801	512	281	130
	62	0									
9000	6000	14961	13402	11998	10758	9759	8777	6149	4331	3303	2421
	2126	2045	1937	1699	1500	1219	1072	892	578	329	157
	73	0									
9000	6500	15570	13909	12387	11336	10230	9157	6353	4416	3344	2492
	2346	2317	2197	1985	1710	1431	1170	977	646	378	186
	88	0									
9000	7000	16165	14403	12779	11578	10702	9737	6355	4542	3482	2788
	2527	2402	2245	2070	1785	1497	1258	1058	712	426	216
	103	0									

9000	7500	16748	14881	13166	11824	10747	9739	6394	4637	3660	3076	2877	2745	2567	2142	1800	1557	1339	1140	778	475	248	118	0
9000	8000	17323	15340	13551	12107	10954	9741	6556	4714	3838	3419	3342	3299	3162	2736	2042	1620	1420	1218	842	525	281	134	0

Table-A-3: Groeneveld Look-up Table 1995 [19] (Continued)

P= Pressure (kPa) G= Mass Velocity (kg m-2 s-1)

P	G	Quality																						
		-0.5	-0.4	-0.3	-0.2	-0.15	-0.1	-0.05	0	0.05	0.1	0.15	0.2	0.25	0.3	0.35	0.4	0.45	0.5	0.6	0.7	0.8	0.9	1
10000	0	4568	4337	4103	3874	3760	3658	3534	3274	2464	1922	1596	1276	1163	991	849	748	680	625	562	474	410	282	0
10000	50	5126	4857	4591	4336	4230	4146	4040	3814	3002	2482	2256	2057	1890	1750	1641	1555	1482	1415	1139	965	886	645	0
10000	100	5597	5296	5007	4734	4637	4565	4472	4253	3512	3015	2865	2728	2682	2457	2347	2266	2213	2105	1551	1296	1211	897	0
10000	300	6039	5642	5266	4961	4891	4870	4868	4832	4636	4016	3506	3393	3315	3233	2987	2781	2593	2240	1383	1076	1021	674	0
10000	500	6318	5831	5417	5074	4965	4855	4800	4765	4599	4013	3353	3165	3038	2871	2644	2239	2002	1651	1127	848	796	522	0
10000	1000	6912	6184	5732	5328	5073	4676	4463	4376	4328	3822	3225	2936	2680	2484	2171	1342	1033	802	636	460	298	250	0
10000	1500	7650	6747	6118	5570	5212	4712	4476	4178	3843	3402	2958	2559	2393	2102	1655	938	647	541	451	253	127	86	0
10000	2000	8720	7826	6896	6030	5591	5000	4575	3974	3349	2872	2468	2106	1912	1402	972	677	480	355	303	155	95	46	0
10000	2500	9664	8829	7895	7010	6589	5726	4678	3901	3191	2623													

	2258	1901	1601	1035	666	533	399	280	195	126	95
	47	0									
10000	3000	10400	9580	8648	7587	7077	6149	4779	3891	3089	2444
	2030	1701	1419	1001	647	478	388	300	256	147	97
	48	0									
10000	3500	11099	10200	9259	8008	7253	6254	4797	3830	3005	2327
	1877	1591	1361	1062	723	525	414	364	274	151	99
	51	0									
10000	4000	11783	10775	9774	8533	7582	6503	4841	3728	2909	2178
	1686	1470	1345	1147	870	641	492	429	291	160	101
	53	0									
10000	4500	12444	11327	10230	8989	7824	6797	4940	3754	2892	2087
	1605	1476	1410	1262	1016	768	590	545	359	188	105
	54	0									
10000	5000	13081	11867	10655	9402	8114	7092	5116	3898	2977	2088
	1612	1562	1539	1383	1130	876	686	639	430	229	111
	56	0									
10000	5500	13694	12355	11078	9834	8616	7476	5265	4034	3114	2208
	1742	1692	1663	1496	1261	993	796	703	490	274	126
	59	0									
10000	6000	14268	12772	11467	10320	9342	8224	5687	4147	3227	2286
	1927	1902	1821	1641	1440	1183	993	842	553	317	150
	70	0									
10000	6500	14835	13236	11837	10808	9713	8600	5912	4241	3275	2378
	2206	2200	2098	1895	1687	1382	1133	942	620	363	179
	85	0									
10000	7000	15399	13708	12204	11028	10083	8975	5926	4267	3390	2707
	2422	2309	2182	2003	1720	1432	1211	1021	686	410	208
	99	0									
10000	7500	15952	14166	12567	11253	10103	8977	5940	4279	3559	2995
	2729	2594	2483	2092	1733	1484	1287	1097	750	459	240
	114	0									
10000	8000	16496	14588	12938	11536	10351	8979	5955	4484	3783	3325
	3120	2988	2864	2621	2015	1596	1393	1182	812	507	272
	129	0									
11000	0	14294	14095	13891	3694	3599	3513	3407	3175	2437	1880

	1560	1270	1146	989	854	757	693	643	565	493	389
	267	0									
11000	50	4821	4588	3456	4124	4017	3938	3844	3646	2917	2416
	2184	1985	1820	1673	1579	1510	1451	1375	1101	938	837
	565	0									
11000	100	5267	5006	4752	4492	4379	4303	4217	4027	3358	2892
	2727	2589	2441	2299	2230	2182	2146	2048	1471	1039	960
	741	0									
11000	300	5694	5346	5002	4672	4560	4526	4505	4452	4236	3709
	3392	3301	3207	2996	2871	2516	2259	1687	1316	963	652
	548	0									
11000	500	5966	5534	5145	4765	4640	4516	4468	4393	4218	3706
	3250	3083	2957	2761	2395	1926	1663	1311	959	728	550
	344	0									
11000	1000	6553	5906	5430	4911	4665	4365	4197	4035	3837	3389
	2981	2693	2389	2153	1682	919	791	696	477	363	245
	189	0									
11000	1500	7281	6484	5794	5105	4739	4389	4171	3806	3390	2982
	2564	2201	1934	1567	1212	675	458	361	295	209	124
	65	0									
11000	2000	8285	7469	6600	5732	5270	4675	4221	3695	3122	2619
	2195	1772	1484	972	738	554	341	305	228	135	94
	46	0									
11000	2500	9166	8371	7589	6807	6361	5371	4332	3676	3005	2461
	1970	1537	1265	818	529	399	283	241	192	115	90
	47	0									
11000	3000	9861	9055	8268	7343	6854	5785	4446	3668	2920	2257
	1695	1311	1109	802	457	322	277	176	237	126	90
	48	0									
11000	3500	10518	9636	8798	7680	7019	5939	4491	3619	2843	2127
	1570	1251	1101	820	524	407	349	331	247	129	92
	49	0									
11000	4000	11153	10169	9265	8151	7358	6242	4605	3503	2761	1952
	1471	1266	1160	962	733	572	434	359	274	151	97
	50	0									
11000	4500	11765	10675	9696	8592	7672	6551	4757	3566	2765	1999
	1476	1336	1256	1133	922	699	489	408	338	186	104
	51	0									
11000	5000	12351	11158	10092	8934	7863	6763	4892	3707	2890	2004

	1540	1491	1440	1299	1057	804	550	462	397	226	112
	53	0									
11000	5500	12922	11622	10478	9284	8203	7035	5020	3849	2985	2108
	1677	1645	1578	1416	1181	936	664	534	450	272	126
	57	0									
11000	6000	13495	12064	10871	9741	8840	7663	5414	4024	3128	2210
	1846	1823	1716	1518	1326	1115	920	780	529	307	146
	68	0									
11000	6500	14034	12509	11220	10197	9174	7996	5637	4157	3262	2360
	2118	2112	2032	1743	1521	1302	1104	992	602	351	173
	82	0									
11000	7000	14562	12953	11560	10403	9509	8328	5655	4188	3347	2669
	2349	2256	2110	1824	1591	1396	1178	994	666	399	203
	97	0									
11000	7500	15082	13381	11899	10634	9563	8334	5673	4209	3497	2915
	2635	2511	2375	2020	1689	1451	1248	1061	729	447	233
	111	0									
11000	8000	15594	13784	12241	10923	9825	8435	5691	4231	3680	3152
	2836	2703	2634	2467	1976	1595	1381	1159	790	493	265
	126	0									

Table-A-3: Groeneveld Look-up Table 1995 [19] (Continued)

P= Pressure (kPa) G= Mass Velocity (kg m-2 s-1)

P	G	Quality									
		-0.5	-0.4	-0.3	-0.2	-0.15	-0.1	-0.05	0	0.05	0.1
	0.15	0.2	0.25	0.3	0.35	0.4	0.45	0.5	0.6	0.7	0.8
	0.9	1									
12000	0	4022	3849	3671	3501	3419	3349	3259	3053	2397	1859
	1535	1258	1130	988	859	766	706	660	565	494	376
	224	0									
12000	50	4511	4309	4111	3909	3809	3729	3634	3462	2826	2360
	2111	1910	1745	1598	1505	1436	1383	1309	1069	933	818
	507	0									
12000	100	4924	4699	4488	4261	4147	4058	3957	3791	3213	2789
	2599	2447	2293	2152	2088	2036	2008	1916	1415	985	946
	708	0									
12000	300	5311	5011	4728	4435	4333	4239	4176	4057	3775	3401
	3187	3099	2966	2695	2591	2227	2034	1389	1132	820	636
	545	0									

12000	500	5533	5172	4848	4467	4300	4185	4097	3919	3659	3254
	3004	2866	2685	2402	2057	1673	1341	940	716	537	263
	228	0									
12000	1000	6063	5518	5083	4489	4119	3776	3577	3372	3118	2733
	2496	2232	1947	1675	1318	815	619	514	338	262	128
	96	0									
12000	1500	6852	6169	5458	4626	4129	3854	3569	3177	2823	2464
	2101	1764	1474	1094	793	536	408	320	235	175	114
	54	0									
12000	2000	7804	7104	6246	5206	4596	4089	3659	3172	2712	2281
	1898	1497	1168	747	568	474	345	257	221	119	91
	44	0									
12000	2500	8606	7926	7227	6161	5502	4523	3768	3225	2688	2203
	1707	1262	949	640	457	363	275	221	176	107	87
	44	0									
12000	3000	9263	8483	7798	6682	6060	4884	3885	3274	2659	2064
	1477	1064	850	620	402	310	263	253	209	113	87
	48	0									
12000	3500	9873	8929	8209	7076	6416	5166	4024	3319	2654	1983
	1395	1053	900	682	485	376	335	309	220	116	88
	49	0									
12000	4000	10395	9339	8589	7553	6877	5668	4293	3390	2687	1935
	1384	1160	1038	867	687	559	419	342	260	145	94
	50	0									
12000	4500	10866	9753	8951	7997	7296	6103	4504	3487	2735	1952
	1450	1285	1176	1020	863	684	462	363	318	181	101
	51	0									
12000	5000	11303	10049	9228	8306	7473	6374	4628	3605	2874	2068
	1598	1465	1359	1211	995	777	540	433	376	226	109
	52	0									
12000	5500	11820	10479	9563	8588	7674	6576	4720	3697	2952	2165
	1738	1625	1501	1343	1135	914	650	518	424	265	123
	55	0									
12000	6000	12614	11227	10153	9051	8222	7070	5076	3873	3098	2268
	1877	1799	1673	1456	1281	1109	894	749	513	299	142
	66	0									
12000	6500	13206	11751	10530	9514	8530	7357	5290	3991	3239	2429
	2116	2091	2020	1664	1445	1280	1076	903	588	343	169
	80	0									

12000	7000	13689	12152	10841	9715	8838	7643	5346	4035	3319	2652
	2326	2225	2106	1800	1576	1390	1150	973	652	390	198
	94	0									
12000	7500	14161	12534	11149	9952	8942	7712	5403	4054	3404	2855
	2556	2423	2286	1948	1653	1433	1223	1037	714	437	228
	109	0									
12000	8000	14662	12943	11474	10247	9213	7919	5460	4075	3533	3020
	2664	2570	2496	2307	1914	1594	1374	1140	774	484	260
	123	0									

13000	0	3766	3617	3465	3317	3247	3184	3111	2935	2352	1850
	1530	1255	1115	987	865	775	720	677	588	518	373
	187	0									
13000	50	4208	4039	3883	3712	3624	3555	3463	3302	2728	2293
	2039	1827	1658	1496	1404	1326	1237	1143	1005	926	752
	444	0									
13000	100	4575	4391	4236	4030	3947	3870	3762	3597	3067	2675
	2463	2279	2106	1909	1830	1749	1618	1446	1234	940	933
	636	0									
13000	300	4843	4613	4448	4050	4030	4018	3934	3831	3536	3175
	2868	2663	2492	2124	1896	1746	1454	1179	931	746	622
	506	0									
13000	1000	4923	4655	4500	4070	4000	3803	3654	3560	3358	3019
	2708	2485	2193	1864	1584	1320	1069	716	473	397	245
	208	0									
13000	1500	5355	4921	4614	4095	3769	3369	3032	2832	2644	2307
	1992	1724	1540	1361	1136	721	471	351	254	202	122
	72	0									
13000	1500	6344	5777	5070	4197	3817	3594	3201	2766	2390	2013
	1697	1396	1182	937	699	476	361	293	229	162	112
	50	0									
13000	2000	7337	6773	5836	4656	4124	3820	3363	2852	2361	1983
	1637	1277	962	638	455	387	307	243	206	113	86
	44	0									
13000	2500	8056	7515	6896	5685	4865	4126	3471	2940	2403	1965
	1567	1149	797	504	362	290	231	192	161	105	84
	44	0									

13000	3000	9210	8021	7365	6395	5766	4775	3802	3091	2491	1978
	1413	1065	874	681	462	364	331	287	201	112	86
	46	0									
13000	4000	9436	8108	7419	6533	5984	5113	4060	3223	2622	2024
	1493	1222	1050	882	695	586	452	342	244	139	90
	47	0									
13000	4500	9495	8197	7536	6741	6215	5464	4230	3342	2784	2106
	1604	1362	1188	1023	866	712	526	387	298	178	97
	48	0									
13000	5000	9545	8199	7622	7067	6480	5834	4420	3429	2879	2232
	1789	1532	1324	1139	950	769	530	403	355	218	105
	49	0									
13000	5500	10034	8609	7982	7400	6731	6064	4489	3515	2935	2324
	1949	1726	1520	1303	1094	904	640	473	403	255	119
	54	0									
13000	6000	11456	10012	9157	8347	7605	6635	4586	3609	3029	2384
	2027	1894	1714	1449	1265	1098	890	735	499	292	139
	65	0									
13000	6500	12458	11078	9915	8897	8120	6995	4727	3679	3121	2471
	2174	2110	2016	1658	1431	1278	1051	982	578	336	165
	78	0									
13000	7000	12882	11431	10179	9113	8280	7180	4812	3703	3206	2607
	2298	2192	2090	1791	1573	1369	1137	955	641	383	194
	93	0									
13000	7500	13246	11713	10405	9314	8405	7305	4870	3742	3310	2761
	2431	2305	2191	1898	1640	1434	1217	1022	703	431	225
	107	0									
13000	8000	13772	12145	10756	9606	8630	7448	4957	3776	3396	2923
	2537	2427	2360	2161	1859	1592	1365	1126	763	477	257
	122	0									

Table-A-3: Groeneveld Look-up Table 1995 [19] (Continued)

P= Pressure (kPa) G= Mass Velocity (kg m-2 s-1)

P	G	Quality									
		-0.5	-0.4	-0.3	-0.2	-0.15	-0.1	-0.05	0	0.05	0.1
	0.15	0.2	0.25	0.3	0.35	0.4	0.45	0.5	0.6	0.7	0.8
	0.9	1									
14000	0	3493	3365	3232	3106	3046	2994	2930	2779	2271	1812

	1510	1248	1089	963	851	767	714	695	598	509	351
	175	0									
14000	50	3895	3750	3620	3476	3402	3343	3266	3123	2618	2211
	1958	1756	1588	1423	1327	1253	1169	1070	974	807	632
	355	0									
14000	100	4229	4272	3948	3794	3708	3641	3551	3403	2933	2560
	2336	2169	2005	1804	1708	1636	1509	1300	992	764	615
	350	0									
14000	300	4448	4260	4142	3958	3862	3800	3706	3630	3411	3099
	2800	2552	2404	1967	1669	1554	1263	986	757	563	378
	246	0									
14000	500	4497	4278	4181	3970	3832	3618	3453	3399	3267	2963
	2612	2295	1941	1605	1318	1124	950	626	381	321	224
	164	0									
14000	1000	4928	4533	4349	4004	3659	3197	2864	2705	2530	2189
	1791	1508	1359	1209	980	627	434	334	223	190	116
	70	0									
14000	1500	5911	5399	4821	4046	3724	3394	3020	2650	2255	1886
	1534	1287	1089	877	629	396	307	273	205	150	93
	47	0									
14000	2000	6752	6229	5421	4413	3994	3672	3200	2739	2230	1847
	1520	1188	902	629	425	316	248	220	195	109	80
	41	0									
14000	2500	7369	6879	6351	5379	4639	4017	3363	2826	2300	1938
	1477	1078	782	529	351	266	200	170	148	104	82
	43	0									
14000	3000	8033	7236	6834	6001	5227	4390	3551	2931	2372	1959
	1498	1089	826	589	388	285	218	202	166	108	83
	43	0									
14000	3500	8543	7311	6865	6069	5420	4584	3679	3013	2439	2039
	1546	1190	943	696	496	383	312	257	185	111	84
	44	0									
14000	4000	8724	7332	6886	6137	5545	4794	1790	3086	2620	2184
	1688	1356	1106	871	702	596	471	330	227	135	87
	44	0									
14000	4500	8731	7377	6942	6292	5734	5054	3846	3189	2929	2368
	1828	1489	1240	1067	874	746	586	394	282	172	94
	45	0									
14000	5000	8733	7394	6999	6618	6103	5568	4075	3321	3081	2520

	1993	1648	1390	1164	988	840	685	480	338	210	101
	47	0									
14000	5500	9100	7685	7266	6926	6363	5822	4241	3364	3088	2583
	2156	1850	1596	1343	1148	985	803	568	382	240	116
	53	0									
14000	6000	10544	9148	8464	7715	7010	6223	4288	3456	3126	2611
	2254	1996	1776	1472	1280	1152	942	721	484	286	136
	64	0									
14000	6500	11595	10306	9186	8230	7474	6512	4416	3503	3132	2665
	2333	2149	2002	1646	1413	1270	1053	866	568	332	163
	77	0									
14000	7000	11986	10624	9429	8450	7655	6686	4467	3523	3169	2673
	2344	2172	2079	1741	1567	1364	1136	942	633	379	192
	91	0									
14000	7500	12314	10864	9636	8641	7821	6853	4610	3613	3242	2682
	2356	2240	2133	1870	1623	1444	1217	1012	695	427	212
	106	0									
14000	8000	12821	11286	9967	8893	8043	7029	4837	3735	3362	2870
	2481	2313	2243	2034	1810	1588	1357	1116	757	474	255
	121	0									

15000	0	3196	3087	2976	2868	2815	2772	2720	2595	2165	1750
	1456	1221	1047	923	831	745	694	693	645	501	297
	172	0									
15000	50	3566	3437	3319	3207	3149	3098	3033	2910	2485	2114
	1873	1695	1514	1341	1223	1152	1073	968	900	712	520
	332	0									
15000	100	3874	3730	3611	3497	3434	3373	3295	3163	2768	2430
	2229	2087	1906	1686	1537	1472	1355	1123	871	648	494
	327	0									
15000	300	4082	3878	3747	3630	3543	3442	3358	3274	3111	2884
	2667	2393	2193	1807	1514	1251	1128	866	644	482	351
	227	0									
15000	500	4184	3933	3790	3638	3517	3315	3195	3115	3003	2739
	2384	1923	1657	1425	1191	1038	895	597	368	299	213
	134	0									
15000	1000	4678	4287	4068	3724	3482	3068	2708	2468	2251	1897

	1523	1286	1204	1147	927	606	420	312	200	174	108
	60	0									
15000	1500	5402	4961	4532	3891	3586	3155	2674	2312	1955	1649
	1367	1179	1025	850	595	368	259	233	176	135	92
	43	0									
15000	2000	5890	5387	4879	4196	3805	3351	2833	2464	2071	1843
	1501	1178	918	664	424	281	202	190	163	107	76
	39	0									
15000	2500	6438	5806	5478	4946	4365	3686	3083	1705	2224	1911
	1559	1171	891	618	395	272	193	149	139	103	80
	41	0									
15000	3000	7244	6348	6122	5596	4858	4010	3336	2854	2322	1974
	1595	1225	954	675	461	344	257	180	154	107	81
	42	0									
15000	3500	7886	6597	6342	5765	5039	4226	3459	2904	2340	2055
	1670	1339	1062	769	557	454	360	266	185	116	82
	42	0									
15000	4000	8278	6675	6445	5899	4239	4502	3517	2916	2615	2270
	1815	1483	1217	939	750	673	549	377	231	132	83
	42	0									
15000	4500	8512	6767	6565	6179	5561	4808	3552	3057	2953	2472
	1951	1607	1355	1103	934	841	676	455	291	164	88
	43	0									
15000	5000	8629	6956	6681	6504	5999	5383	3789	3255	3188	2657
	2131	1774	1495	1250	1083	944	762	524	352	204	95
	45	0									
15000	5500	8926	7284	6913	6707	6217	5673	3984	3297	3216	2744
	2295	1947	1676	1419	1232	1065	855	605	406	244	113
	52	0									
15000	6000	9942	8684	7860	7163	6512	5863	4029	3339	3221	2785
	2397	2063	1838	1539	1321	1180	967	739	484	283	135
	63	0									
15000	6500	10615	9447	8361	7475	6767	5984	4103	3419	3228	2823
	2440	2165	2010	1656	1421	1300	1079	855	558	328	162
	77	0									
15000	7000	10992	9718	8592	7676	6946	6098	4135	3443	3286	2826
	2450	2179	2030	1754	1570	1400	1160	938	623	375	191
	91	0									
15000	7500	11337	9941	8797	7866	7112	6222	4282	3522	3297	2831

												2461	2194	2120	1845	1610	1458	1230	1013	689	424	221	105	0
15000	8000	11774	10337	9087	8074	7319	6455	4633	3670	3309	2836	2470	2218	2166	1988	1784	1576	1349	1111	753	471	253	121	0

Table-A-3: Groeneveld Look-up Table 1995 [19] (Continued)

P= Pressure (kPa) G= Mass Velocity (kg m-2 s-1)

P	G	Quality																						
		-0.5	-0.4	-0.3	-0.2	-0.15	-0.1	-0.05	0	0.05	0.1	0.15	0.2	0.25	0.3	0.35	0.4	0.45	0.5	0.6	0.7	0.8	0.9	1
16000	0	2883	2793	2700	2612	2571	2530	2489	2380	2020	1647	1379	1162	997	873	769	674	614	612	537	383	260	167	0
16000	50	3213	3103	3009	2911	2857	2816	2759	2664	2329	1998	1756	1586	1404	1228	1076	975	888	791	693	482	383	319	0
16000	100	3486	3359	3268	3163	3101	3054	2983	2888	2593	2295	2072	1940	1741	1521	1333	1226	1114	907	695	550	360	311	0
16000	300	3649	3441	3336	3210	3159	3080	3009	2934	2818	2597	2432	1194	2016	1688	1438	1124	978	747	508	428	325	210	0
16000	500	3683	3473	3359	3236	3112	2886	2775	2673	2545	1268	1963	1580	1362	1198	1051	934	803	574	333	272	203	127	0
16000	1000	4042	3623	3491	3323	3149	2725	2366	2089	1853	1528	1251	1076	992	948	804	587	407	288	190	154	102	59	0
16000	1500	4726	4312	4002	3586	3329	2901	2360	1945	1655	1419	1235	1071	907	743	541	357	228	172	125	115	80	39	0
16000	2000	5241	4790	4395	3873	3538	3050	2500	2166	1841	1688	1477	1188	943	704	462	312	201	147	110	105	72	36	0
16000	2500	5901	5360	5038	4546	4031	3307	2724	2446	2112	1888	1628	1298	1031	754	495	339	244	197	165	120	76	37	0

16000	3000	6667	5912	5709	5190	4449	3540	2937	2617	2282	2058
	1745	1408	1139	849	597	465	370	271	190	123	78
	39	0									
16000	3500	7252	6155	5907	5393	4622	3772	3075	2660	2440	2199
	1859	1554	1254	947	698	588	485	369	247	129	79
	39	0									
16000	4000	7734	6288	6048	5561	4834	4052	3170	2824	2668	2401
	2011	1691	1412	1104	867	763	634	476	297	136	80
	39	0									
16000	4500	8088	6346	6193	5888	5220	4407	3270	2980	2932	2554
	2118	1807	1543	1240	1026	901	736	543	343	163	81
	40	0									
16000	5000	8350	6494	6277	6217	5695	4991	3561	3223	3209	2774
	2307	1979	1684	1391	1174	990	803	597	395	201	89
	42	0									
16000	5500	8669	6857	6463	6376	5903	5268	3783	3344	3321	2940
	1470	2116	1814	1519	1189	1084	885	667	449	244	109
	50	0									
16000	6000	9148	7890	7094	6537	5988	5386	3873	3367	3321	2993
	2586	2242	1942	1627	1389	1211	1009	765	499	283	134
	63	0									
16000	6500	9555	8478	7462	6654	6074	5402	3928	3388	3321	3003
	2611	2301	2033	1704	1481	1339	1121	857	557	328	161
	76	0									
16000	7000	9926	8738	7682	6811	6188	5423	3952	3406	3395	3020
	2629	2340	2040	1774	1572	1405	1199	940	618	373	190
	90	0									
16000	7500	10287	8963	7885	6963	6314	5492	4090	3520	3414	3039
	2650	2359	2110	1830	1598	1473	1249	1018	686	422	220
	105	0									
16000	8000	10652	9312	8130	7145	6495	5785	4413	3660	3434	3050
	2669	2380	2141	1969	1749	1554	1342	1107	751	470	253
	120	0									
17000	0	2551	2479	2406	2335	2300	2276	2235	2146	1849	1547
	1327	1114	993	866	761	672	608	598	494	354	251
	156	0									

17000	50	2800	2707	2619	2530	2485	2439	2398	2319	2046	1734
	1473	1299	1154	1022	922	858	798	726	581	407	347
	292	0									
17000	100	2998	2886	2789	2685	2631	2566	2521	2439	2196	1878
	1584	1423	1286	1150	1054	1007	946	806	587	490	350
	258	0									
17000	300	2970	2769	2607	2439	2347	2260	2175	2102	1972	1755
	1532	1399	1286	1107	1000	941	821	659	429	390	295
	192	0									
17000	500	2817	2549	2374	2227	2138	2044	1917	1774	1661	1487
	1308	1151	1048	958	868	802	685	534	291	243	194
	118	0									
17000	1000	3054	2719	2452	2318	2233	2074	1850	1597	1407	1205
	1045	912	839	744	635	483	354	173	180	136	95
	52	0									
17000	1500	3874	3538	3124	2722	2518	2320	2043	1753	1526	1305
	1187	1020	859	685	527	361	223	155	104	83	74
	39	0									
17000	2000	4639	4218	3790	3214	2860	2568	2288	2018	1757	1533
	1448	1223	993	780	567	405	273	180	125	108	69
	33	0									
17000	2500	5565	5074	4638	3963	3416	2911	2529	2283	1991	1790
	1637	1408	1148	885	618	462	358	288	218	136	72
	35	0									
17000	3000	6358	5769	5238	4406	3758	3197	2726	2415	2218	2081
	1832	1562	1289	1006	719	568	483	407	302	148	73
	36	0									
17000	3500	6917	6047	5368	4467	3874	3398	2844	2588	2526	2337
	1993	1685	1399	1114	831	694	609	533	462	193	76
	36	0									
17000	4000	7403	6224	5569	4621	4012	3528	2931	2765	2746	2519
	2134	1807	1533	1246	978	832	702	615	489	112	77
	37	0									
17000	4500	7593	6226	5723	4953	4355	3694	3017	2902	2863	2619
	2245	1935	1681	1380	1120	947	775	646	499	216	80
	37	0									
17000	5000	7689	6218	5814	5285	4769	3933	3247	3128	3110	2821
	2406	2092	1833	1539	1273	1048	849	685	508	242	89
	40	0									

17000	5500	7871	6397	5943	5432	4936	4086	3463	3458	3330	3024	2545	2203	1931	1643	1365	1135	938	743	530	275	109	49	0
17000	6000	8132	6991	6277	5506	4986	4123	3557	3471	3370	3080	2673	2311	1984	1694	1457	1277	1069	821	577	307	135	62	0
17000	6500	8472	7405	6535	5600	5049	4154	3656	3485	3374	3097	2709	2349	2037	1733	1526	1395	1174	872	597	140	161	76	0
17000	7000	8820	7664	6746	5718	5133	4169	3754	3498	3415	3116	2719	2357	2050	1785	1580	1435	1237	947	629	376	189	90	0
17000	7500	9163	7907	6947	5876	5271	4622	3853	3517	3434	3135	2738	2367	2100	1825	1593	1490	1269	1023	683	420	219	104	0
17000	8000	9480	8235	7110	6148	5620	5075	4230	3649	3455	3155	2757	2388	2120	1952	1722	1537	1334	1104	748	468	251	120	0

Table-A-3: Groeneveld Look-up Table 1995 [19] (Continued)

P= Pressure (kPa) G= Mass Velocity (kg m-2 s-1)

P	G	Quality																						
		-0.5	-0.4	-0.3	-0.2	-0.15	-0.1	-0.05	0	0.05	0.1	0.15	0.2	0.25	0.3	0.35	0.4	0.45	0.5	0.6	0.7	0.8	0.9	1
18000	0	2189	2133	2078	2022	1997	1976	1950	1885	1647	1398	1213	1060	930	812	726	657	595	577	444	315	228	139	0
18000	50	2382	2308	2239	2172	2137	2103	2070	2004	1782	1532	1325	1183	1062	937	849	796	752	691	525	400	314	248	0
18000	100	2524	2435	2357	2282	2239	2192	2152	2077	1880	1632	1410	1278	1168	1040	940	892	865	757	542	478	340	233	0
18000	300	2378	2223	2101	2002	1936	1854	1777	1693	1600	1481	1325	1192	1112	991	871	759	688	580	392	375	271	174	0
18000	500	2137	1930	1790	1698	1657	1582	1487	1377	1275	1210	1096	964	895	854	749	653	545	457	274	231	184		

	115	0									
18000	1000	2484	2220	1960	1832	1759	1689	1587	1399	1195	1049
	979	854	747	652	543	420	350	269	170	126	88
	47	0									
18000	1500	3354	3048	2648	2304	2097	2004	1862	1606	1377	1204
	1165	1011	849	695	554	383	229	198	112	73	71
	35	0									
18000	2000	4160	3773	3358	2874	2589	2408	2176	1855	1637	1484
	1435	1259	1077	897	675	447	288	234	138	115	66
	31	0									
18000	2500	5115	4671	4271	3613	3118	2736	2410	2108	1885	1730
	1680	1431	1241	1010	532	757	413	352	268	147	68
	32	0									
18000	3000	5776	5147	4697	3919	3353	2939	2529	2224	2092	2088
	1863	1569	1328	1104	860	653	513	465	368	158	69
	33	0									
18000	3500	6200	5263	4751	3952	3428	3073	2613	2476	2473	2291
	1953	1645	1395	1186	966	764	640	606	526	209	72
	34	0									
18000	4000	6698	5557	5016	4100	3537	3146	2683	2602	2600	2432
	2107	1808	1584	1341	1080	881	705	643	583	238	74
	34	0									
18000	4000	6863	5589	5164	4349	3817	3236	2917	2828	2795	2504
	2176	2020	1761	1486	1188	1000	777	664	585	239	76
	35	0									
18000	5000	6894	5600	5215	4608	4132	3365	3148	3069	2992	2578
	2354	2132	1877	1636	1342	1113	887	720	628	260	88
	39	0									
18000	5500	6982	5726	5328	4726	4258	3473	3458	3348	3313	2865
	2532	2295	2023	1768	1410	1167	983	817	635	291	109
	49	0									
18000	6000	7157	6118	5497	4754	4297	3667	3478	3399	3334	2885
	2620	2357	2031	1778	1494	1312	1126	869	651	324	135
	62	0									
18000	6500	7437	6468	5657	4756	4302	3860	3524	3399	3355	2904
	2640	2363	2038	1789	1535	1417	1227	898	654	356	162
	75	0									
18000	7000	7750	6724	5829	4805	4340	4053	3580	3437	3374	2924
	2659	2383	2060	1799	1580	1451	1261	965	667	387	190

	89	0									
18000	7500	8065	6948	6031	5039	4556	4247	3770	3511	3393	2945
	2680	2404	2090	1809	1590	1464	1275	1034	697	423	218
	104	0									
18000	8000	8347	7225	6148	5286	4856	4441	3952	3525	3414	2965
	2701	2423	2114	1934	1710	1515	1331	1103	746	468	249
	120	0									

19000	0	1786	1744	1699	1656	1639	1628	1618	1567	1367	1393
	1069	964	856	741	664	630	570	528	402	281	194
	116	0									
19000	50	1935	1889	1843	1802	1777	1752	1711	1660	1503	1316
	1154	1055	974	843	724	660	624	590	460	369	278
	214	0									
19000	100	2032	1932	1940	1903	1872	1830	1760	1706	1570	1388
	1208	1113	1056	918	760	666	655	624	483	423	332
	220	0									
19000	300	1682	1612	1549	1545	1528	1462	1358	1290	1218	1115
	974	854	807	763	646	534	485	452	342	333	248
	156	0									
19000	500	1364	1264	1167	1123	1099	1067	980	911	833	810
	799	724	695	671	575	508	447	381	250	207	174
	112	0									
19000	1000	1882	1752	1537	1372	1286	1241	1189	1085	909	890
	889	800	705	646	529	409	340	263	160	119	83
	33	0									
19000	1500	2838	2604	2302	2033	1827	1702	1623	1428	1225	1170
	1114	986	838	737	605	406	303	244	137	83	63
	31	0									
19000	2000	3670	3283	2917	2593	2380	2218	2014	1679	1498	1465
	1402	1226	1101	945	746	470	335	249	150	116	60
	29	0									
19000	2500	4468	3900	3580	3169	2932	2523	2261	1905	1694	1672
	1531	1393	1246	1064	840	618	481	373	279	156	66
	30	0									
19000	3000	4747	4016	3725	3315	2968	2642	2332	1977	1769	1768
	1610	1472	1328	1169	929	735	587	490	388	173	67

	31	0									
19000	3500	4918	4106	3813	3355	3013	2717	2393	2047	1917	1890
	1742	1595	1391	1216	993	821	671	646	550	225	71
	31	0									
19000	4000	5285	4443	4086	3441	3077	2773	2470	2158	2021	2014
	1875	1753	1455	1280	1098	883	710	646	587	258	72
	32	0									
19000	4500	5496	4642	4166	3493	3159	2859	2813	2534	2280	2130
	2127	1902	1593	1455	1212	1021	823	673	588	262	75
	33	0									
19000	5000	5668	4833	4311	3646	3301	2910	2760	2757	2546	2342
	2151	1963	1762	1648	1414	1127	897	740	638	288	88
	39	0									
19000	5500	5862	5120	4534	3738	3375	3017	2879	2877	2796	2587
	2350	2135	1945	1771	1509	1211	996	836	692	301	109
	48	0									
19000	6000	6118	5409	4659	3748	3396	3107	3059	3058	3028	2756
	2485	2290	1948	1775	1531	1328	1170	893	693	333	135
	61	0									
19000	6500	6389	5636	4757	3765	3426	3162	3134	3123	3069	2775
	2505	2348	1950	1779	1546	1439	1257	929	695	365	162
	75	0									
19000	7000	6653	5832	4906	3883	3540	3240	3160	3143	3087	2797
	2526	2367	2070	1800	1580	1458	1265	985	696	396	190
	89	0									
19000	7500	6916	5989	5136	4275	3911	3493	3268	3164	3119	2815
	2545	2388	2080	1800	1585	1461	1294	1048	716	430	219
	103	0									
19000	8000	7164	6190	5284	4511	4158	3526	3509	3204	3139	2836
	2566	2409	2090	1919	1703	1502	1311	1102	745	468	248
	119	0									

Table-A-3: Groeneveld Look-up Table 1995 [19] (Continued)

P= Pressure (kPa) G= Mass Velocity (kg m-2 s-1)

P	G	Quality									
		-0.5	-0.4	-0.3	-0.2	-0.15	-0.1	-0.05	0	0.05	0.1
	0.15	0.2	0.25	0.3	0.35	0.4	0.45	0.5	0.6	0.7	0.8
	0.9	1									
20000	0	1367	1333	1304	1277	1261	1255	1235	1193	1092	988

	921	846	761	665	573	522	472	418	321	228	154
	90	0									
20000	50	1628	1593	1576	1552	1522	1477	1396	1314	1222	1094
	1001	951	881	747	623	547	476	421	345	270	215
	152	0									
20000	100	1806	1774	1772	1752	1715	1633	1508	1394	1310	1165
	1044	1014	957	797	651	553	480	424	371	369	224
	187	0									
20000	300	1524	1476	1461	1461	1449	1379	1253	1173	1072	904
	721	667	652	609	547	432	400	318	292	291	223
	140	0									
20000	500	1167	1090	1024	997	978	962	905	858	750	685
	592	572	572	539	487	430	375	269	210	185	165
	72	0									
20000	1000	1538	1403	1259	1142	1086	996	936	873	781	713
	712	711	667	610	485	393	330	259	150	103	77
	31	0									
20000	1500	1411	2193	1966	1766	1640	1468	1328	1194	1161	1161
	1096	949	769	681	611	533	385	250	139	102	63
	29	0									
20000	2000	3269	2881	2536	2229	2049	1812	1633	1469	1396	1360
	1198	1153	1029	939	825	593	411	283	167	129	62
	27	0									
20000	2500	3945	3350	2983	2597	2338	2012	1864	1692	1534	1369
	1252	1250	1153	1124	939	808	611	428	291	159	64
	28	0									
20000	3000	4169	3514	3182	2767	2442	2077	1949	1770	1566	1380
	1294	1293	1292	1227	1033	905	672	558	390	184	65
	29	0									
20000	3500	4171	3606	3286	2850	2522	2154	2014	1854	1763	1669
	1581	1522	1331	1253	1128	962	813	671	582	232	70
	29	0									
20000	4000	4173	3765	3426	2954	2639	2294	2174	2013	1960	1959
	1870	1720	1371	1264	1188	1035	856	690	601	272	72
	29	0									
20000	4500	4233	4009	3596	3034	2742	2472	2308	2123	2096	2096
	2008	1892	1473	1425	1280	1044	871	695	611	278	75
	31	0									
20000	5000	4436	4270	3812	3193	2893	2659	2489	2485	2256	2120

	2038	1927	1576	1571	1374	1150	900	750	692	300	88
	37	0									
20000	5500	4687	4581	4048	3320	3002	2825	2661	2657	2428	2146
	2068	1962	1678	1669	1519	1230	1021	857	693	302	109
	48	0									
20000	6000	4915	4686	4148	3416	3109	2950	2733	2728	2611	2172
	2100	1999	1832	1671	1521	1335	1178	935	694	333	135
	60	0									
20000	6500	5129	4688	4157	3492	3206	3018	2820	2815	2697	2220
	2116	2040	1891	1674	1534	1438	1273	958	696	366	163
	74	0									
20000	7000	5338	4706	4158	3532	3242	3051	2840	2835	2717	2260
	2147	2083	1937	1725	1548	1463	1287	998	700	399	190
	88	0									
20000	7500	5548	4808	4185	3586	3298	3110	2861	2854	2736	2329
	2179	2114	1983	1776	1561	1478	1296	1053	726	433	220
	103	0									
20000	8000	5757	4976	4232	3614	3338	3135	2882	2876	2755	2443
	2255	2164	2075	1912	1697	1493	1304	1102	744	467	247
	119	0									

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