Dominion Resources Services, Inc.
5000 Dominion Boulevard, Glen Allen, VA 23060
Web Address: www.dom.com

Dominion®

April 4, 2008

U.S. Nuclear Regulatory Commission	Serial No. 08-0174
Attention: Document Control Desk	NL&OS/ETS R
One White Flint North	Docket Nos. 50-305
11555 Rockville Pike	50-336/423
Rockville, MD 20852-2738	50-338/339
	50-280/281
	License Nos. DPR-43
	DPR-65/NPF-49
	NPF-4/7
	DPR-32/37

DOMINION ENERGY KEWAUNEE, INC.
DOMINION NUCLEAR CONNECTICUT, INC.
VIRGINIA ELECTRIC AND POWER COMPANY
KEWAUNEE POWER STATION
MILLSTONE POWER STATION UNITS 2 AND 3
NORTH ANNA AND SURRY POWER STATIONS UNITS 1 AND 2
REQUEST FOR APPROVAL OF APPENDIX C OF FLEET REPORT DOM-NAF-2
QUALIFICATION OF THE WESTINGHOUSE WRB-2M CHF CORRELATION IN THE DOMINION VIPRE-D COMPUTER CODE

VIPRE is a core thermal-hydraulics computer code developed by EPRI and approved by the NRC, which is currently in wide use throughout the nuclear industry. VIPRE-D is the Dominion version of VIPRE, which has been enhanced by the addition of several vendor specific CHF correlations. Dominion has validated VIPRE-D through extensive code benchmark calculations. In addition, the accuracy of VIPRE-D has been demonstrated through comparisons with other NRC-approved methodologies.

In letters dated September 30, 2004 and January 13, 2005 (Serial Nos. 04-606 and 05-020, respectively) Dominion submitted Topical Report DOM-NAF-2, "Reactor Core Thermal-Hydraulics Using the VIPRE-D Computer Code," and associated Appendices A and B, as supplemented by letters dated June 30 and September 8, 2005 (Serial Nos. 05-328 and 05-020A, respectively) for NRC review and approval. NRC approval of Fleet Report DOM-NAF-2 including Appendixes A and B was obtained in a letter dated April 4, 2006 as revised by the NRC in a letter dated June 23, 2006. Dominion provided the approved version of Fleet Report DOM-NAF-2-A to the NRC in a letter dated September 13, 2006 (Serial No. 06-773A).

Continuing with the modular approach to Fleet Report DOM-NAF-2, and as discussed during the public meeting held between the NRC and Dominion on August 4, 2004, Dominion is now submitting Appendix C to this Fleet Report, "Qualification of the

Westinghouse WRB-2M CHF Correlation in the Dominion VIPRE-D Computer Code," for NRC review and approval. Appendix C, which is provided in the Attachment to this letter, documents the qualification of the Westinghouse WRB-2M CHF Correlation with the VIPRE-D code and the associated code/correlation DNBR design limit.

Dominion requests the approval of the generic application of this appendix to DOM-NAF-2. Plant specific applications of this fleet report, including applicable appendixes, will be submitted to the NRC for review and approval, in accordance with Section 2.1 of DOM-NAF-2.

If you have further questions or require additional information, please contact Mr. Thomas Shaub at (804) 273-2763.

Very truly yours,

Gerald T. Bischof
Vice President – Nuclear Engineering
Dominion Energy Kewaunee, Inc.
Dominion Nuclear Connecticut, Inc.
Virginia Electric and Power Company

Attachment

Commitments made in this letter: None

cc: U.S. Nuclear Regulatory Commission
Region I
475 Allendale Road
King of Prussia, Pennsylvania 19406-1415

U.S. Nuclear Regulatory Commission
Region II
Sam Nunn Atlanta Federal Center
61 Forsyth Street, SW
Suite 23T85
Atlanta, Georgia 30303

U.S. Nuclear Regulatory Commission
Region III
2443 Warrenville Road
Suite 210
Lisle, Illinois 60532-4352

Ms. M. H. Chernoff
NRC Project Manager
U. S. Nuclear Regulatory Commission
One White Flint North
Mail Stop O-8 H4A
11555 Rockville Pike
Rockville, Maryland 20852-2738

Ms. J. D. Hughey
NRC Project Manager Millstone Units 2 and 3
U. S. Nuclear Regulatory Commission,
One White Flint North
Mail Stop O-8 G9A
11555 Rockville Pike
Rockville, MD 20852-2738

Mr. R. A. Jervey
NRC Project Manager
U. S. Nuclear Regulatory Commission
One White Flint North
Mail Stop O-8 G9A
11555 Rockville Pike
Rockville, Maryland 20852

Mr. S. P. Lingam
NRC Project Manager
U. S. Nuclear Regulatory Commission
One White Flint North
Mail Stop O-8 H4A
11555 Rockville Pike
Rockville, Maryland 20852

NRC Senior Resident Inspector
Kewaunee Power Station

NRC Senior Resident Inspector
Millstone Power Station

NRC Senior Resident Inspector
North Anna Power Station

NRC Senior Resident Inspector
Surry Power Station

Attachment

Appendix C to Fleet Report DOM-NAF-2

QUALIFICATION OF THE WESTINGHOUSE WRB-2M CHF CORRELATION IN THE DOMINION VIPRE-D COMPUTER CODE

Dominion Energy Kewaunee, Inc.
(DEK)
Dominion Nuclear Connecticut, Inc.
(DNC)
Virginia Electric and Power Company
(Dominion)

Dominion

DOM-NAF-2, Rev. 0.0
APPENDIX C

Qualification of the Westinghouse WRB-2M CHF Correlation in the Dominion VIPRE-D Computer Code

NUCLEAR ANALYSIS AND FUEL DEPARTMENT
DOMINION
RICHMOND, VIRGINIA
February, 2008

Prepared by:

Kurt F. Flaig

Reviewed by:

Rosa M. Bilbao y León

Recommended for Approval:

C. B. LaRoe
Supervisor, Nuclear Safety Analysis

Approved:

K. L. Basehore
Director, Nuclear Analysis and Fuel

CLASSIFICATION/DISCLAIMER

ABSTRACT

This appendix documents Dominion's qualification of the Westinghouse WRB-2M correlation with the VIPRE-D code. This qualification was performed against the same CHF experimental database used by Westinghouse to develop and license the correlation. This appendix summarizes the data evaluations that were performed to qualify the VIPRE-D/WRB-2M code/correlation pair, and to develop the corresponding DNBR design limit.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS AND ABBREVIATIONS

CHF	Critical Heat Flux
DNB	Departure from Nucleate Boiling
DNBR	Departure from Nucleate Boiling Ratio
FLC	Form Loss Coefficient
HTRF	Heat Transfer Research Facility at Columbia University
IFM	Intermediate Flow Mixer
LPD	Low Pressure Drop
M/P	Ratio of Measured-to-Predicted CHF
MIFM	Modified Intermediate Flow Mixer
MPS	Millstone Power Station
MVG	Mixing Vane Grid
NMVG	Non-Mixing Vane Grid
P/M	Ratio of Predicted-to-Measured CHF (equivalent to DNBR)
PWR	Pressurized Water Reactor
RFA	Robust Fuel Assembly
USNRC	US Nuclear Regulatory Commission

C.1 PURPOSE

Dominion currently uses the Westinghouse 17x17 Robust Fuel Assembly (RFA) fuel product at Millstone Power Station (MPS), Unit 3. The thermal-hydraulic analysis of this Westinghouse fuel product requires the use of the Westinghouse WRB-2M CHF correlation (Reference C1). In fact, the Westinghouse WRB-2M CHF correlation has been approved by the USNRC for use with the 17x17 RFA fuel design with or without the Intermediate Flow Mixer (IFM) grids (Reference C1).

To be licensed for use, a critical heat flux (CHF) correlation must be tested against experimental data that span the anticipated range of conditions over which the correlation will be applied. Furthermore, the population statistics of the database must be used to establish a departure from nucleate boiling ratio (DNBR) design limit such that the probability of avoiding departure from nucleate boiling (DNB) will be at least 95% at a 95% confidence level.

This addendum documents Dominion's qualification of the WRB-2M correlation with the VIPRE-D code. This qualification was performed against the data from the Columbia University Heat Transfer Research facility (HTRF) for the Modified Vantage 5H and Modified Vantage 5H/IFM fuel types (Reference C1). This is the same set of the Columbia-EPRI CHF database used by Westinghouse in the qualification of the WRB-2M correlation with the VIPRE-01 code (Reference C1). This addendum summarizes the data evaluations that were performed to qualify the VIPRE-D/WRB-2M code/correlation pair, and to develop the corresponding DNBR design limits for the correlation.

C.2 APPLICABILITY

Dominion intends to use the VIPRE-D/WRB-2M code/correlation for Westinghouse 17x17 RFA fuel products, with or without modified intermediate flow mixers (MIFM) in a PWR reactor. When evaluating this type of fuel outside of the range of validity of the WRB-2M CHF correlation, Dominion intends to use the VIPRE-D/W-3 code/correlation pair. W-3 is one of the CHF correlations contained in the USNRC approved generic version of VIPRE-01 (References C3 and C4), and it has already been approved for use with the VIPRE-D code (Reference C5).

The intended VIPRE-D/WRB-2M applications discussed in this addendum are consistent with the generic intended applications listed in the main body of this report (Section 2.0 in Reference C5). Also, more specifically, Dominion intends to use VIPRE-D/WRB-2M to analyze the transients delineated in Table 2.1-1 in Section 2.0 of the main body of this report (Reference C5). The qualification of the WRB-2M correlation with the VIPRE D code has been performed following the modeling guidelines described in Section 4 of this report (Reference C5).

This Addendum is submitted to the USNRC for review and approval in order to meet the USNRC's requirement #2 listed in the VIPRE-01 SER, as outlined in Section 2.2 in the main body of this report (Reference C5).

C.3 DESCRIPTION OF THE WESTINGHOUSE WRB-2M CHF CORRELATION

In pressurized water reactor (PWR) cores, the energy generated inside the fuel pellets leaves the fuel rods at their surface in the form of heat flux, which is removed by the reactor coolant system flow. The normal heat transfer regime in this configuration is nucleate boiling, which is very efficient. However, as the capacity of the coolant to accept heat from the fuel rod surface degrades, a continuous layer of steam (a film) starts to blanket the tube. This heat transfer regime, termed film boiling, is less efficient than nucleate boiling and can result in significant increases of the fuel rod temperature for the same heat flux. Since the increase in temperature may lead to the failure of the fuel rod cladding, PWRs are designed to operate in the nucleate boiling regime and protection against operation in film boiling must be provided.

The heat flux at which the steam film starts to form is called CHF or the point of DNB. For design purposes, the DNBR is used as an indicator of the margin to DNB. The DNBR is the ratio of the predicted CHF to the actual local heat flux under a given set of conditions. Thus, DNBR is a measure of the thermal margin to film boiling and its associated high temperatures. The greater the DNBR value (above 1.0), the greater the thermal margin.

The CHF cannot be predicted from first principles, so it is empirically correlated as a function of the local thermal-hydraulic conditions, the geometry, and the power distribution measured in the experiments. Since a CHF correlation is an analytical fit to experimental data, it has an associated uncertainty, which is quantified in a DNBR design limit. A calculated DNBR value greater than this design limit provides assurance that there is at least a 95% probability at the 95% confidence level that a departure from nucleate boiling will not occur.

Correlations to predict the occurrence of CHF have undergone evolutions as nuclear fuel designs have changed. Westinghouse developed the WRB-1 CHF correlation for the prediction of DNB for Westinghouse fuel assemblies with mixing vane grids (MVGs). Subsequently, Westinghouse developed the WRB-2 CHF correlation for the prediction of DNB in Westinghouse fuel assemblies with MVGs and intermediate flow mixing grids (IFMs). More recently, Westinghouse has modified their nuclear fuel design to reduce fuel rod mechanical wear and to further improve thermal/hydraulic performance.

The new fuel design includes modified low pressure drop (LPD) mixing vane grids and modified intermediate flow mixing grids (MIFMs). This new fuel design is called the modified Vantage 5H and Modified Vantage 5H/IFM depending on whether the MIFMs have been included. (When the design includes the MIFM grids, it has also been referred to as the Robust Fuel Assembly (RFA)). CHF tests with the modified grids were conducted at the Columbia HTRF with and without control rod guide thimbles and with and without MIFM grids. Although the new data was successfully correlated by Westinghouse using the WRB-2 CHF correlation, a better correlation, the WRB-2M CHF correlation (a modification of the WRB-2 CHF correlation), was obtained by incorporation of a multiplier 'M' (Reference C1). The sensitivity of WRB-2M to other parameters, such as various power shapes is very similar to WRB-2. Thus, WRB-2M is applicable for 17x17 fuel with 0.374 inch OD rods, and Modified LPD grids with or without MIFM's. The range of applicable parameters is given in Table C.5-3. The WRB-2M correlation has been approved by the NRC (Reference C1).

The WRB-2M DNB correlation was developed from test bundles simulating the RFA fuel design with only a cosine axial power shape. As part of a scoping study for new grid designs, DNB tests were performed with the uniform axial power shape at the Columbia University test loop. Although the grid designs were not the same, the mixing vanes of the test bundles were similar to the RFA fuel design. When compared to the data from those tests, the WRB-2M measured-to-predicted (M/P) CHF average ratio was lower than 1.0. No significant trend in M/P was observed with respect to key parameters such as local flow rate, local equilibrium quality, and pressure. Based on this comparison with the test results, Westinghouse decided to adjust the DNB predictions for the WRB-2M DNB correlation. The adjustment factor does not constitute a change in the methodology as described in the licensing basis. The NRC staff has reviewed the adjustment factor and its consequences and found it acceptable (Reference C6).

The W-3 correlation is used when conditions are outside the range of the WRB-2M DNB correlation. Specifically, the W-3 correlation is applied to the lower portion of the fuel assemblies in the rod withdrawal from subcritical event because of the bottom peaked axial power distribution assumed, and in the steam line break event because of the low pressures involved. The W-3 correlation with a correlation limit of 1.30 is used below the fuel assembly first mixing vane grid for the rod withdrawal from subcritical event. For the steam line break event, the W-3 correlation is used with a correlation limit of 1.45 in the pressure range of 500 to 1000 psia and 1.30 for pressures above 1000 psia (Reference C8). The Westinghouse W-3 CHF correlation is described on page 10 in Reference C7.

C.4 DESCRIPTION OF THE VIPRE-D/WRB-2M DATABASE AND TEST ASSEMBLIES

The WRB-2M CHF correlation was developed from CHF data obtained at the Columbia University HTRF using full-scale, electrically heated rod bundle test sections (Reference C1). The Dominion qualification of WRB-2M in VIPRE-D was performed against the same test data from the Columbia-EPRI CHF database for Westinghouse 17x17 fuel. Dominion used the CHF experimental data used by Westinghouse to develop the WRB-2M correlation. No data point was deleted or excluded.

The HTRF test assemblies had a 5x5 geometry, thus the test assemblies used by Dominion to qualify the VIPRE-D/WRB-2M code/correlation pair have a 5x5 geometry. These 5x5 test bundles have essentially a 17x17 subchannel geometry (Reference C1). Table C.4-1 provides a summary of the key information about each test.

Table C.4-1: Summary of CHF Tests

TEST	MATRIX	AXIAL HEAT FLUX SHAPE	PIN OD / GUIDE TUBE OD [inches]	HEATED LENGTH [inches]	MIFM grids?	NUMBER OF TESTS
A-1	5 x 5	Non-Uniform	0.374 / -	168	Yes	66
A-2	5 x 5	Non-Uniform	0.374 / 0.474	168	Yes	77
A-3	5 x 5	Non-Uniform	0.374 / 0.474	168	No	70
A-4	5 x 5	Non-Uniform	0.374 / -	168	No	28

C.5 VIPRE-D/WRB-2M RESULTS AND COMPARISON TO VIPRE-01

Reference C1 describes the mathematical model for each separate test section by providing the bundle and cell geometry, the rod radial peaking values, the rod axial flux shapes, the types, axial locations and form losses associated to the spacer grids, as well as the thermocouple locations. Reference C1 also provides the data for each CHF observation within a test, including power, flow, inlet temperature, pressure and CHF axial location.

Each test section was modeled for analysis with the VIPRE-D thermal-hydraulic computer code as a full assembly model following the modeling methodology discussed in Section 4 in the main body of this report. For each set of bundle data, VIPRE-D produces the local thermal-hydraulic conditions (mass velocity, thermodynamic quality, heat flux, etc.) at every axial node along the heated length of the test section. The ratio of measured-to-predicted CHF (M/P) is the variable that is normally used to evaluate the thermal-hydraulic performance of a code/correlation pair. The measured CHF is the local heat flux at a given location, while the predicted CHF is calculated by the code using the WRB-2M CHF correlation. The ratio of these two values provides the M/P ratio, which is the inverse of the DNB ratio. M/P ratios are frequently used to validate CHF correlations instead of DNB ratios, because their distribution is usually a normal distribution, which simplifies their manipulation and statistical analysis.

This section summarizes the VIPRE-D results and the associated significant statistics. This section also shows the variation of the M/P ratio with each independent variable to demonstrate that there are no biases in the data. Finally, it provides the VIPRE-D overall statistics for the WRB-2M tests and generates the DNBR design limit for the WRB-2M CHF correlation with VIPRE-D.

The WRB-2M correlation was developed by Westinghouse by correlating the CHF experimental results obtained in the tests as described in Reference C1. Westinghouse also used these test data to calculate a DNBR design limit of 1.14 for the WRB-2M correlation (Reference C1). Dominion used these experimental data, as described in section C.4, to develop the VIPRE-D/WRB-2M DNBR limit. Table C.5-1 summarizes the relevant statistics for each test, and calculates the aggregate statistics for the entire set of data.

Table C.5-1: Summary of VIPRE-D Results

Test	Number of Tests	M/P Ratio Average	M/P Ratio STDEV	M/P Ratio Max	M/P Ratio Min
A-1	66	1.0178	0.0789	1.2114	0.8287
A-2	77	0.9834	0.0538	1.1017	0.8614
A-3	70	1.0144	0.0559	1.1444	0.8954
A-4	28	0.9731	0.0490	1.1002	0.8688
Thimble	147	0.9982	0.0568	1.1444	0.8614
Typical	94	1.0045	0.0740	1.2114	0.8287
With MIFM	143	0.9993	0.0685	1.2114	0.8287
Without MIFM	98	1.0026	0.0570	1.1444	0.8688
All Results	241	1.0006	0.0640	1.2114	0.8287

One-sided tolerance theory (Reference C2) is used for the calculation of the VIPRE-D/WRB-2M DNBR design limit. This theory allows the calculation of a DNBR limit so that, for a DNBR equal to the design limit, DNB will be avoided with 95% probability at a 95% confidence level.

First, it is necessary to verify that the overall distribution for the M/P ratios is a normal distribution, because all the statistical techniques used below assume that the original data distribution is normal. To evaluate if the distribution is normal, the D' normality test was applied. A value of D' equal to 1047.04 was obtained for the VIPRE-D/WRB-2M database. This D' value is within the range of acceptability for 241 data points with a 95% confidence level (1038.60 to 1066.75)[1]. Thus, it is concluded that the M/P distribution for the VIPRE-D/WRB-2M database is indeed normal. Based on the results listed in Table C.5-1, the deterministic DNBR design limit can be calculated as:

$$DNBR_L = \frac{1.0}{M/P - K_{N,C,P} \cdot \sigma_{M/P}} \qquad [C.5.1]$$

where

- M/P = average measured to predicted CHF ratio
- $\sigma_{M/P}$ = standard deviation of the measured to predicted CHF ratios of the database
- $K_{N,C,P}$ = one-sided tolerance factor based on N degrees of freedom, C confidence level, and P portion of the population protected. This number can be obtained from Table 1.4.4 of Reference C2.

[1] From Table 5 in Reference C9
D' Lower Limit (241) [P = 0.025] = 1038.60
D' Upper Limit (241) [P = 0.975] = 1066.75

Normally, the number of degrees of freedom would be the total number of data minus one. However, because Westinghouse used these experimental data to correlate the 6 constants that appear in the WRB-2M correlation, the total number of degrees of freedom must be corrected to account for this. In addition, the standard deviation of the database needs to be corrected accordingly to account for this reduced number of degrees of freedom:

$$N = n - 1 - 6 \qquad [C.5.2]$$
$$\sigma_N = \sigma_{M/P} \cdot [\,(n-1)/N\,]^{1/2}$$

Then, the DNBR design limit for the VIPRE-D and the WRB-2M correlation can be calculated as shown in Table C.5-2.

Table C.5-2: Statistical Analysis of WRB-2M Design Limit

Number of data	n		241
Degrees of freedom	N	= n - 1 - 6	234
Average M/P	M/P		1.0006
Standard Deviation	$\sigma_{M/P}$		0.0640
Corrected Standard Deviation	σ_N	$= \sigma_{M/P} \cdot [\,(n-1)/N\,]^{1/2}$	0.0648
Owens Factor	K(N,0.95,0.95)		1.8170
WRB-2M Design limit	$DNBR_L$	$= 1 / (M/P - K(N,0.95,0.95) \cdot \sigma_N)$	1.1327

Even though this is not a large database, correcting for the number of constants in the WRB-2M correlation has no significant effect, and it is more conservative to make the correction. The calculated DNBR limit results in a value of **1.14**. This is the same number reported by Westinghouse in Reference C1 and has been approved by the NRC.

Table C.5-3 summarizes the ranges of validity for the VIPRE-D/WRB-2M correlation. These ranges, are identical to those submitted by Westinghouse and already approved by the NRC (Reference C1).

Table C.5-3: Range of Validity for WRB-2M

	VIPRE-D
Pressure [psia]	1495 to 2425
Mass Velocity [Mlbm/hr-ft^2]	0.97 to 3.1
Thermodynamic Quality at CHF	-0.1 to 0.29

Figures C.5-1 through C.5-4 display the performance of the M/P ratio, and its distributions as a function of the pressure, mass velocity and quality. The objective of these plots is to show that there are no biases in the M/P ratio distribution, and that the performance of the WRB-2M correlation is independent of the three independent variables of interest. The plots show a mostly uniform scatter of the data and no obvious trends or slopes. These plots also show that all the tests in the WRB-2M database are within 3.5 standard deviations from the average. Figures C.5-5 through C.5-7 display the performance of the P/M ratio (i.e., the DNBR) against the major independent variables for the WRB-2M database. These plots also include the DNBR design limit line. It can be seen that only six data points (2.49% of the database) are above the DNBR design limit, and that these data in excess of the limit are distributed over the variable ranges tested.

A more formal determination of the lack of bias of the average M/P ratio can be done using the analysis of variance test (ANOVA) shown in Table C.5-4. ANOVA tests are normally applied to highly controlled situations, but they can be somewhat useful in CHF testing and correlation. However, the ANOVA test cannot be used as the sole measure of the performance of a CHF correlation, but it would indicate an extremely bad mismatch (with a very large F statistic). The variables analyzed were pressure, quality, mass velocity and test cell type. The ANOVA results for VIPRE-D/WRB-2M slightly exceed the critical values of F for pressure and quality, but other comparisons prove the hypothesis that all the groups belong to the same distribution; i.e., that there is no bias of the results regarding the analyzed variables. Furthermore, when looking at the figures in this section, there does not appear to be any trend or bias in the data. Therefore, it can be concluded that the WRB-2M M/P ratio database is independent of the pressure, quality, and mass velocity.

Table C.5-4: M/P CHF Performance by Independent Variable Grouping of the WRB-2M Database at 95% Confidence Level

Grouping	Number of Data	Average M/P	Standard Deviation	Maximum M/P	Minimum M/P
Analysis by Pressures					
Below 1575 psia	29	0.9831	0.0610	1.1153	0.8746
1575 - 1850 psia	67	0.9967	0.0666	1.1327	0.8614
1850 – 2250 psia	74	1.0210	0.0680	1.2114	0.9058
Above 2250 psia	71	0.9903	0.0534	1.1002	0.8287
	$F_{distribution}$ = 4.0812		$F_{critical}(3,237)$ = 2.6427		
Analysis by Qualities					
Below 5%	42	1.0107	0.0521	1.1193	0.8688
5% to 10%	71	1.0126	0.0581	1.1302	0.8862
10% to 15%	66	1.0051	0.0633	1.1744	0.8794
15% to 20%	46	0.9718	0.0628	1.1444	0.8287
Above 20%	16	0.9858	0.0961	1.2114	0.8336
	$F_{distribution}$ = 3.6650		$F_{critical}(4,236)$ = 2.4099		
Analysis by Mass Velocities					
Below 1.25 Mlbm/hr-ft^2	32	0.9915	0.0645	1.1444	0.8688
1.25 – 1.75 Mlbm/hr-ft^2	75	1.0055	0.0642	1.1302	0.8614
1.75 – 2.25 Mlbm/hr-ft^2	74	1.0023	0.0602	1.1744	0.8287
2.25 – 2.75 Mlbm/hr-ft^2	51	0.9911	0.0637	1.1264	0.8336
2.75 – 3.25 Mlbm/hr-ft^2	9	1.0323	0.0879	1.2114	0.9063
	$F_{distribution}$ = 1.1176		$F_{critical}(4,236)$ = 2.4099		
Analysis by Geometry Type					
With MIFM Grids	143	0.9993	0.0685	1.2114	0.8287
Without MIFM Grids	98	1.0026	0.0571	1.1444	0.8688
	$F_{distribution}$ = 0.1580		$F_{critical}(1,239)$ = 3.8807		
Analysis by Thimble vs. Typical					
Thimble	147	0.9982	0.0568	1.1444	0.8614
Typical	94	1.0045	0.0740	1.2114	0.8287
	$F_{distribution}$ = 0.5546		$F_{critical}(1,239)$ = 3.8807		
All Data WRB-2M					
All Data	241	1.0006	0.0640	1.2114	0.8287

Figure C.5-1: Measured vs. Predicted CHF for VIPRE-D/WRB-2M Database

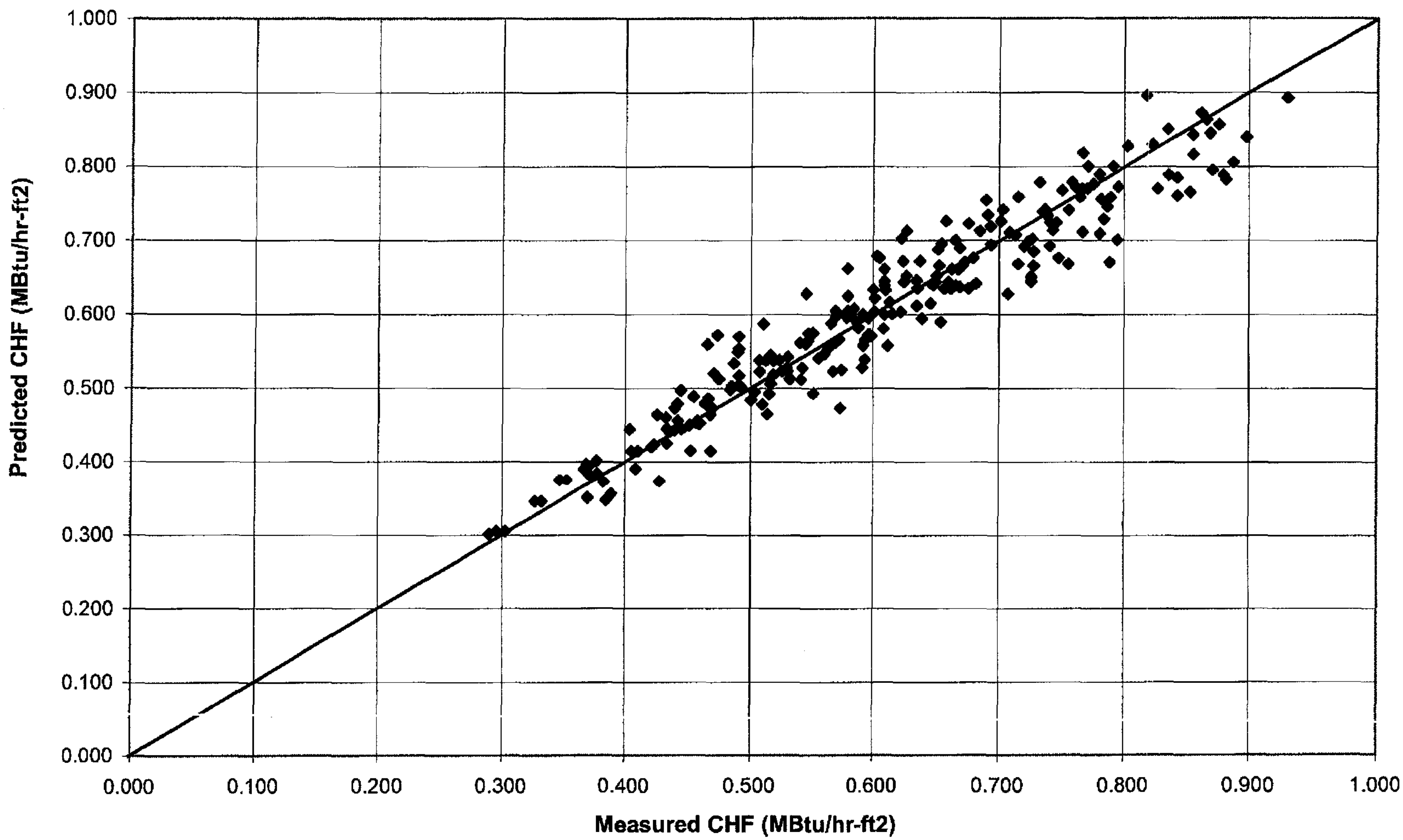


Figure C.5-2: M/P vs. Pressure for VIPRE-D/WRB-2M Database

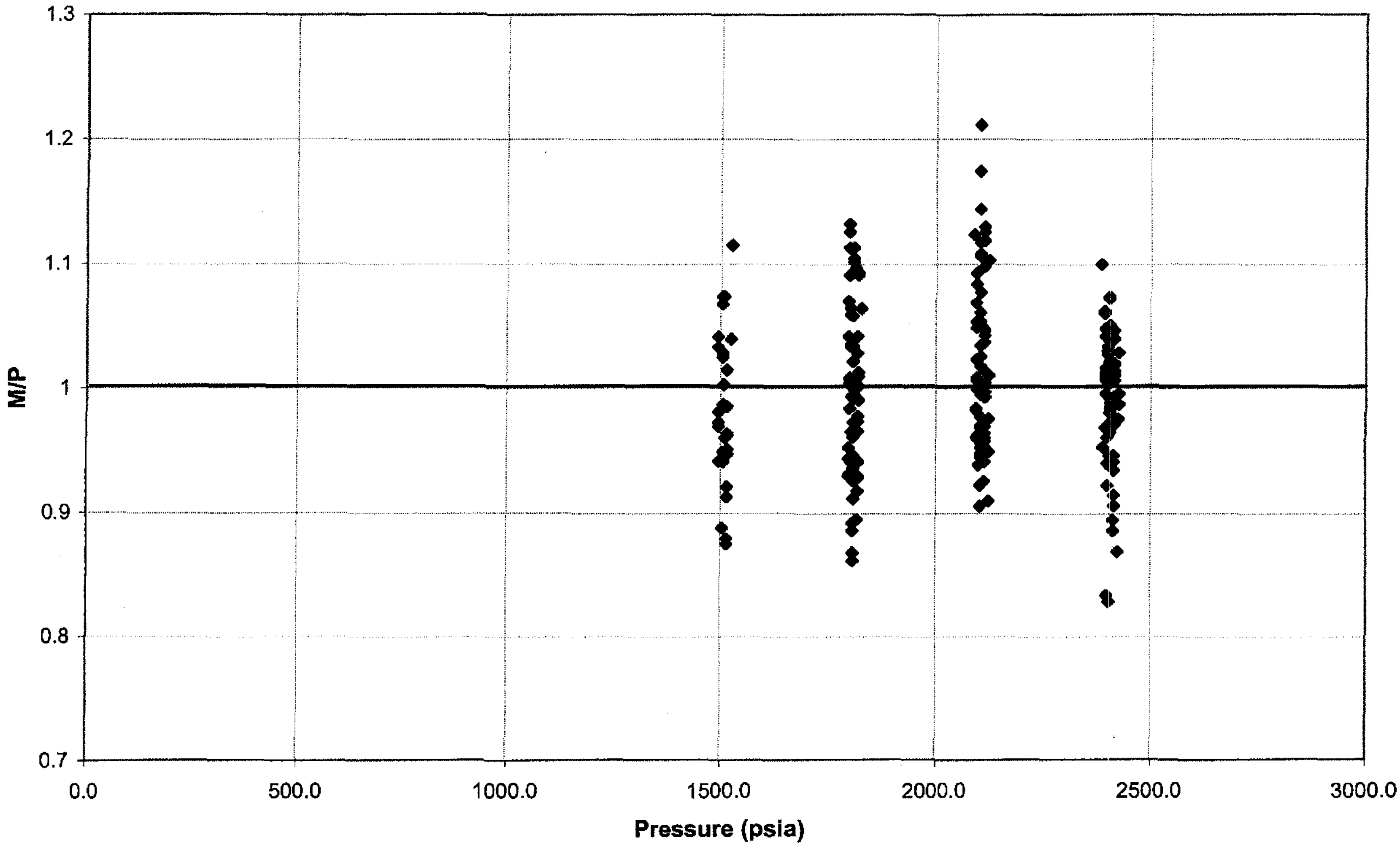


Figure C.5-3: M/P vs. Mass Velocity for VIPRE-D/WRB-2M Database

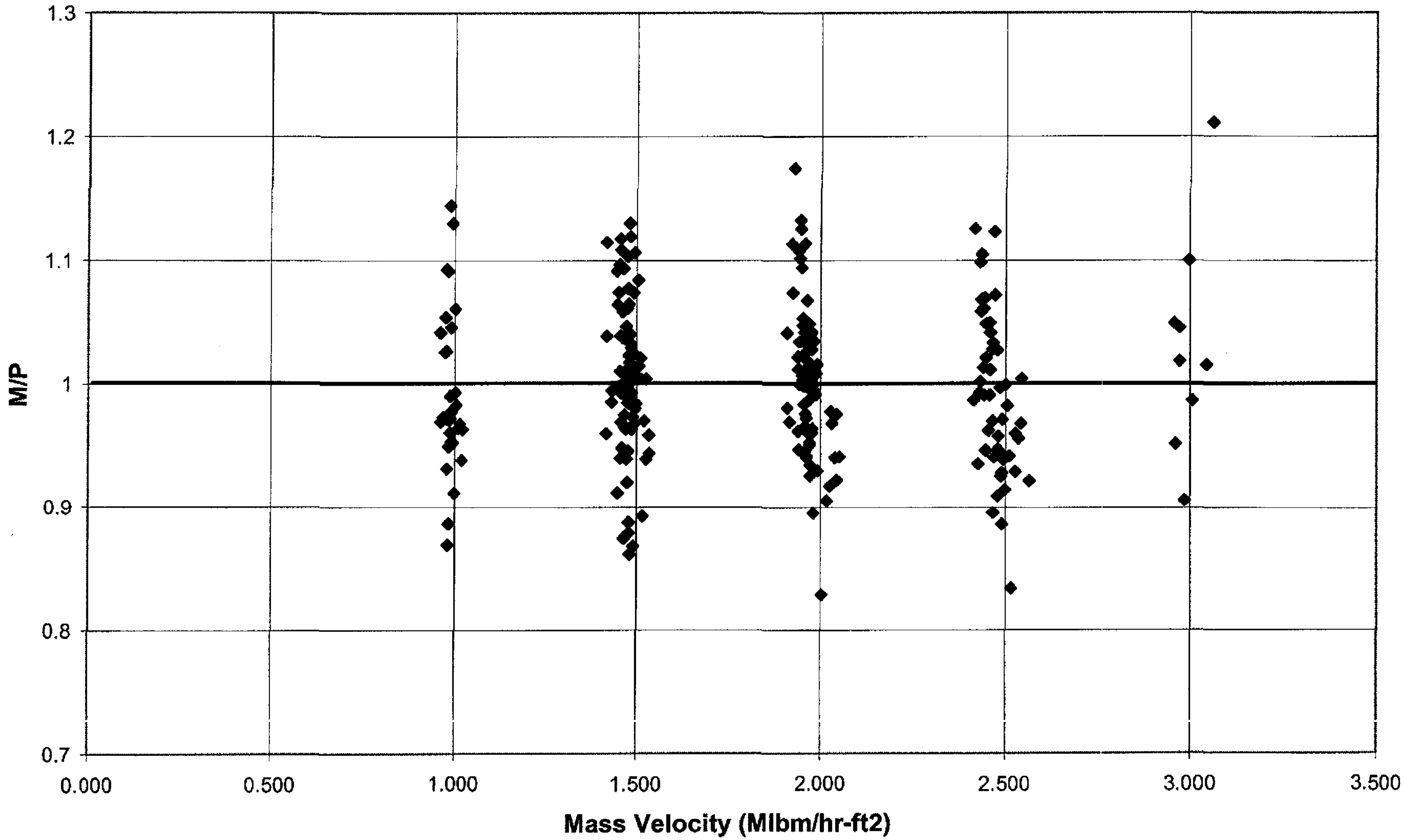


Figure C.5-4: M/P vs. Quality for VIPRE-D/WRB-2M Database

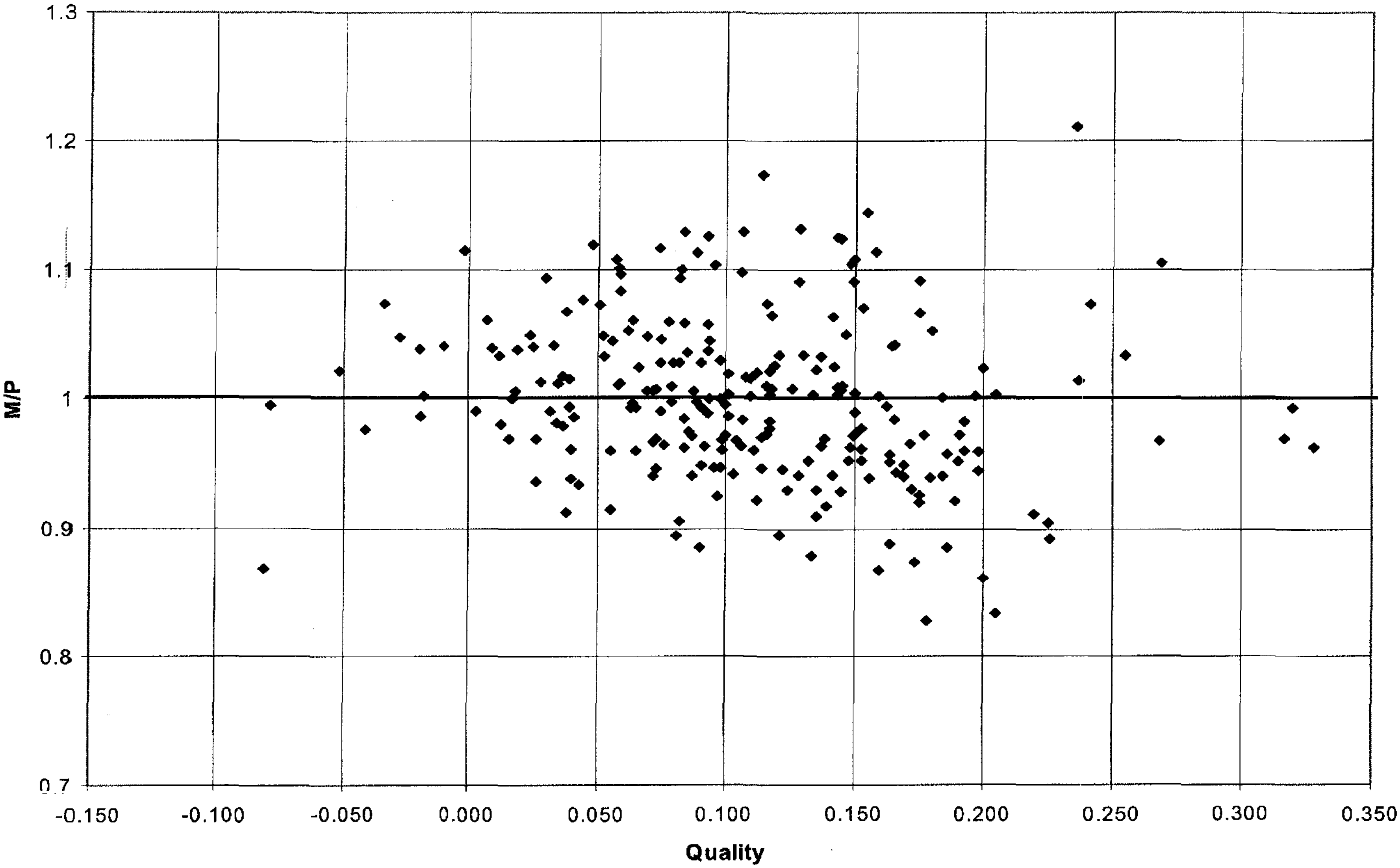


Figure C.5-5: DNBR vs. Pressure for VIPRE-D/WRB-2M Database

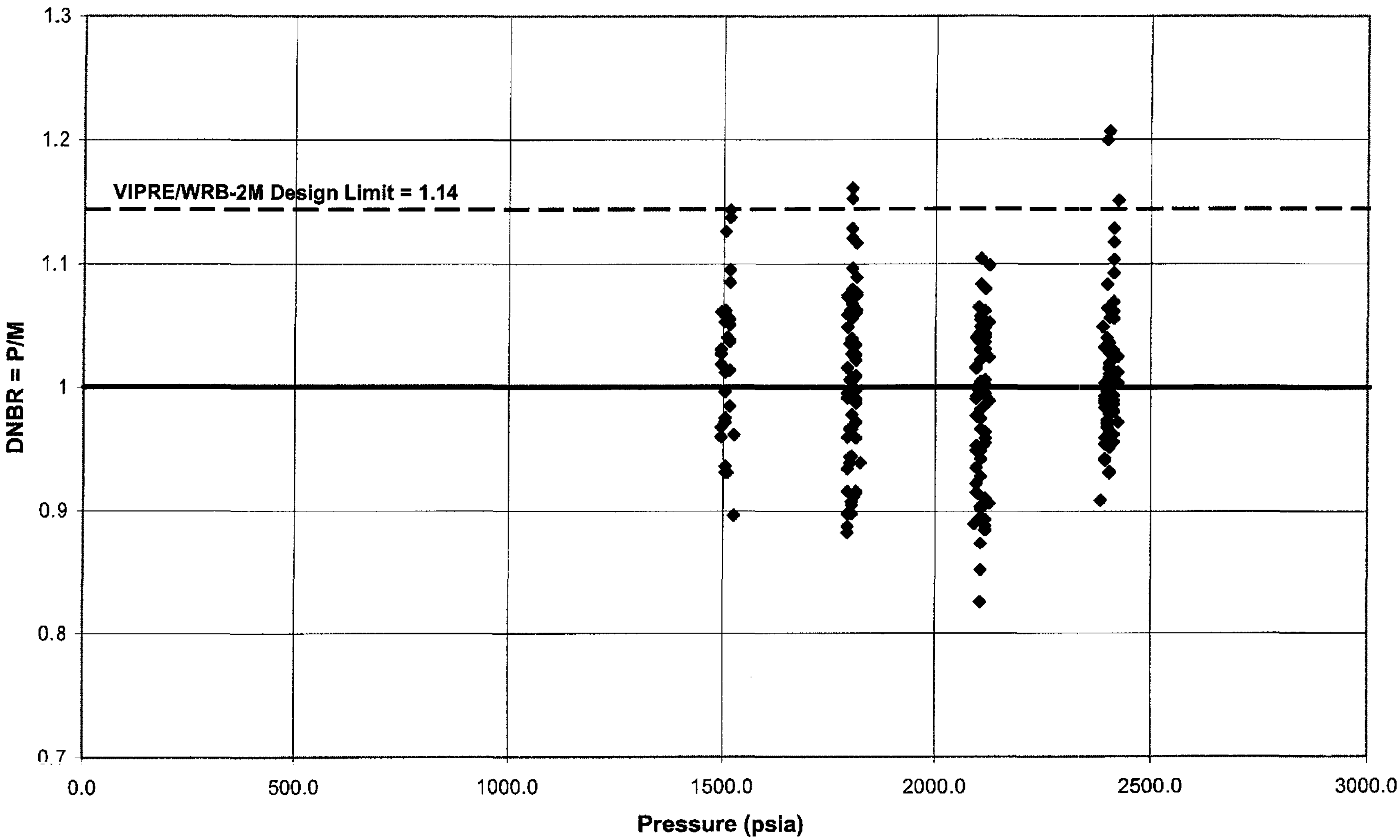


Figure C.5-6: DNBR vs. Mass Velocity for VIPRE-D/WRB-2M Database

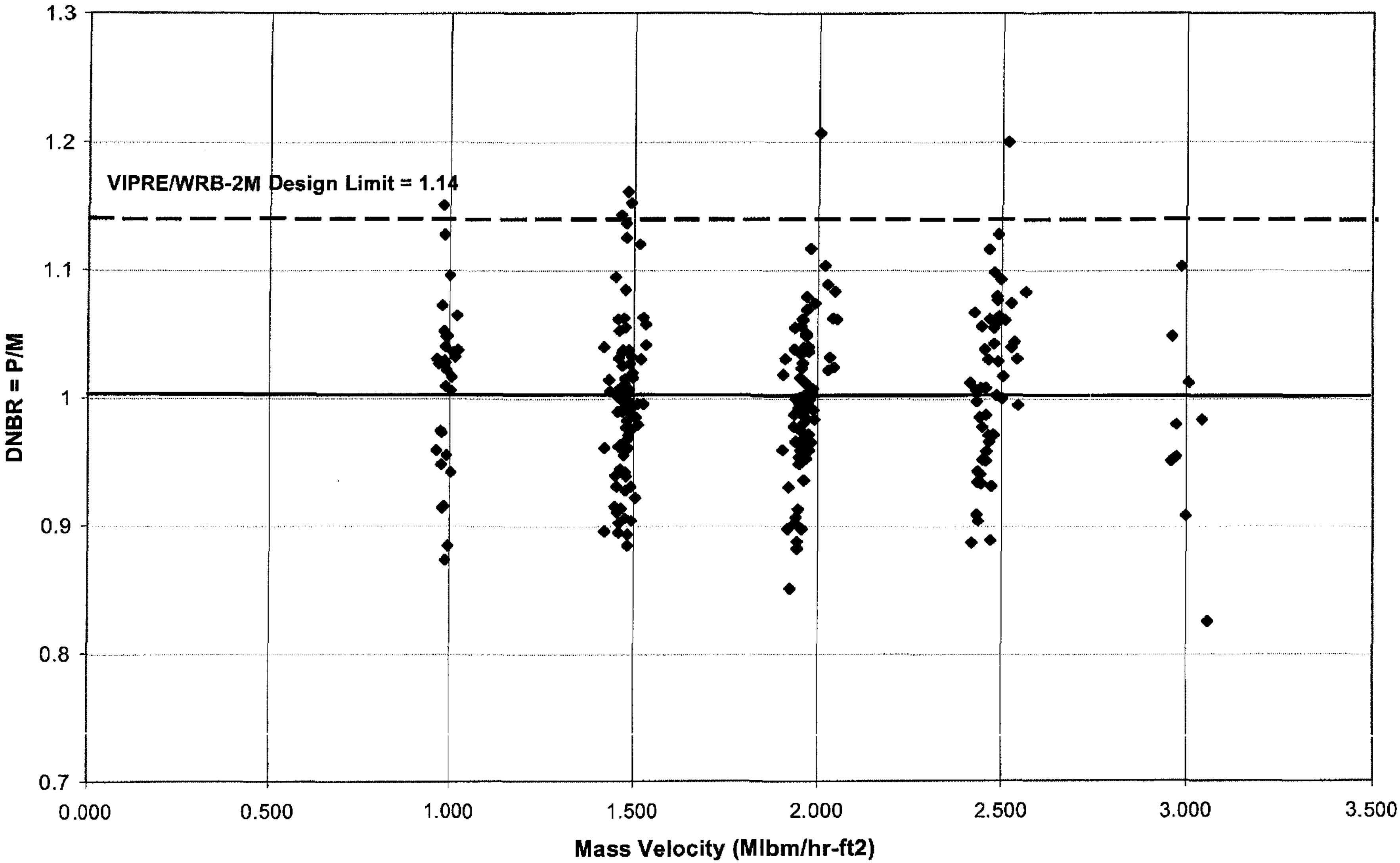
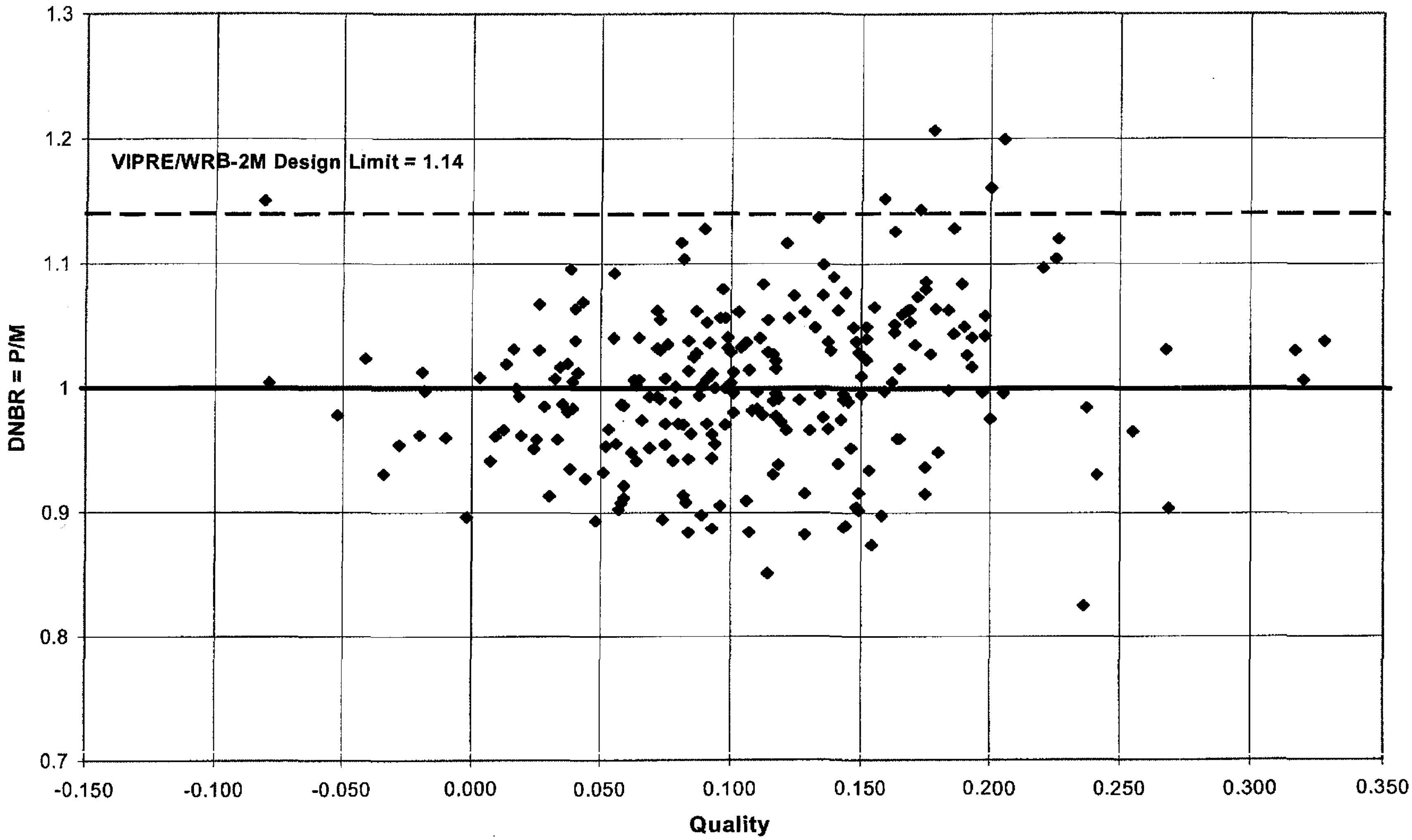
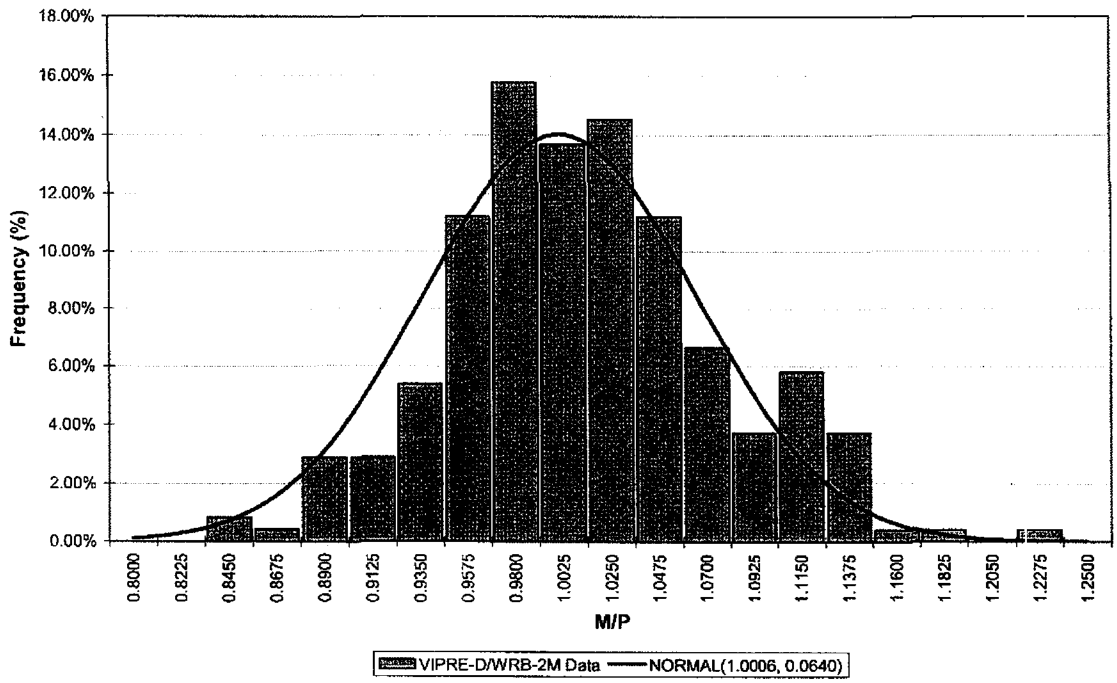


Figure C.5-7: DNBR vs. Quality for VIPRE-D/WRB-2M Database



The 241 data points of the VIPRE-D/WRB-2M M/P distribution calculated by Dominion were used to create the empirical probability density function. These data points were distributed among 21 equal bins that covered the entire range of M/P in the VIPRE D/WRB-2M distribution, and the frequency of data in each bin was determined. The resulting empirical probability density functions for the VIPRE-D/WRB-2M distribution were then compared with the probability density function of a normal distribution of mean 1.0006 and standard deviation 0.0640, which is the mean and standard deviation for the VIPRE-D/WRB-2M distribution calculated in Section C.5 above. Figure C.5-8 displays the resulting empirical probability density function for the VIPRE-D/WRB-2M M/P distribution, and compares it with the probability density function of the normal distribution of mean 1.0006 and standard deviation 0.0640.

Figure C.5-8: VIPRE-D/WRB-2M Probability Density Function



C.6 CONCLUSIONS

The WRB-2M correlation has been qualified with Dominion's VIPRE-D computer code. Table C.6-1 summarizes the DNBR design limits for VIPRE-D/WRB-2M that yields a 95% non-DNB probability at a 95% confidence level. The limit of 1.14 from VIPRE-D is the same limit as found with Westinghouse's version of VIPRE (Reference C1). The Westinghouse WRB-2M CHF correlation has been approved by the USNRC for use with Westinghouse 17x17 with 0.374 inch OD rods, and Modified LPD grids with or without MIFM's in a PWR reactor.

Table C.6-1: DNBR Limits for WRB-2M

	Dominion VIPRE-D	Westinghouse VIPRE-01
DNBR limit	**1.14**	1.14

Table C.6-2 summarizes the applicability and the ranges of validity for VIPRE-D/WRB-2M, which are the same as those on page 4-2 of Reference C1.

Table C.6-2: Range of Validity for VIPRE-D/WRB-2M

Pressure [psia]	1440 to 2425
Mass Velocity [Mlbm/hr-ft^2]	0.97 to 3.1
Thermodynamic Quality at CHF	-0.1 to 0.29

C.7 REFERENCES

C1. Technical Report, WCAP-15025-P-A, "Modified WRB-2 Correlation, WRB-2M, for predicting Critical Heat Flux in 17x17 Rod Bundles with Modified LPD Mixing Vane Grids," L.D. Smith, et al, April 1999.

C2. Technical Report, "Tables for Normal Tolerance Limits, Sampling Plans and Screening," R. E. Odeh and D. B. Owen, 1980.

C3. Letter from C. E. Rossi (NRC) to J. A. Blaisdell (UGRA Executive Committee), "Acceptance for Referencing of Licensing Topical Report, EPRI NP-2511-CCM, 'VIPRE-01: A Thermal-Hydraulic Analysis Code for Reactor Cores,' Volumes 1, 2, 3 and 4," May 1, 1986.

C4. Letter from A. C. Thadani (NRC) to Y. Y. Yung (VIPRE-01 Maintenance Group), "Acceptance for Referencing of the Modified Licensing Topical Report, EPRI NP-2511-CCM, Revision 3, 'VIPRE-01: A Thermal Hydraulic Analysis Code for Reactor Cores,' (TAC No. M79498)," October 30, 1993.

C5. Fleet Report, DOM-NAF-2-A, including Appendixes A and B, "Reactor Core Thermal-Hydraulics Using the VIPRE-D Computer Code," Rosa M. Bilbao y León, August 2006. (ML062650184)

C6. Letter from D. S. Collins (NRC) to J. A. Gresham (Westinghouse), "Modified WRB-2 Correlation WRB-2M for Predicting Critical Heat Flux in 17X17 Rod Bundles with Modified LPD Mixing Vane Grids," February 3, 2006.

C7. Technical Report, "Boiling Crisis and Critical Heat Flux," TID-25887, 1972.

C8. Letter from A.C. Thadani (NRC) to W.J. Johnson (Westinghouse), "Acceptance for Referencing of Licensing Topical Report, WCAP-9226-P, Reactor Core Response to Excessive Secondary Steam Releases." 1989.

C9. Technical Report, "Assessment of the Assumption of Normality (employing individual observed values)," American National Standards Institute, ANSI N15.15.1974.