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THE USE OF NEURAL NETWORKS TO PREDICT THE
PARTICLE-SIZE DISTRIBUTION OF COAL GROUND IN THE
PETC PRF HAMMERMILL

By
D. McKeegan

April 1996

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The Use of Neural Networks to Predict the
Particle-Size Distribution of Coal Ground
in the PETC PRF Hammermill

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April 1996

**THE USE OF NEURAL NETWORKS TO PREDICT
THE PARTICLE-SIZE DISTRIBUTION OF COAL
GROUND IN THE PETC PRF HAMMER MILL**

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March 15, 1995

ABSTRACT

Sieve-analysis data obtained pursuant to grinding several types of coal using various settings of adjustable parameters on a hammer mill in PETC's Process Research Facility were input to a neural-network simulation program in a variety of ways. The quality of the resulting particle-size predictions were tabulated and analyzed to determine which approach yielded the most accurate results. The simplicity of each approach was considered as a secondary factor. The most successful approaches yielded errors averaging 10 percent or less in the prediction of characteristic particle sizes such as the D-80 point. Generally speaking, the simpler approaches worked better, in that complicated manipulations of the input data produced either less accurate predictions or such small improvements in predictions that the extra effort seemed unjustified. Likely reasons for the success or failure of each approach are discussed. The methodology described could also prove useful for predicting coal particle sizes resulting from more complex grinding configurations.

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INTRODUCTION

This work investigated the feasibility of using neural-network computer software to analyze coal-grinding data generated by PETC's Coal Preparation Division in its Process Research Facility (PRF). The objective was to determine if neural-network simulations could accurately predict coal particle-size distributions as a function of the physical properties of the coal and the hammer-mill operating parameters. If so, they could be used as a guide for adjusting operating conditions to obtain a desired product grind. Though the hammer mill that ground all coal samples used in this work was a single unit that was not very complex to operate, successful demonstration of the suitability of this technique would be promising for its application to more complex grinding configurations.

Two aspects of using neural networks to analyze coal-grinding data were investigated: (1) methods of presenting data to the neural-network software and (2) parameters related to the mechanics of using the software. Most of the effort focused on the first topic, however, where the raw sieve-analysis data were manipulated in a variety of ways to see if any particular way of presenting data to the simulator produced superior results. Nine different approaches were tried, which were of two basic types: (1) those based on the specific sieve sizes used by the Coal Preparation Division and (2) those based on interpolated values of often-used D-points (D-95, D-90, D-80, etc.). The experimental data consisted initially of 101 sets of hammer-mill operating parameters and ensuing sieve analyses of the ground coal, though this was subsequently reduced to 99 sets, owing to duplications. The neural-network simulator used was a product named Brainmaker, sold by California Scientific Software.

Though this report contains sufficient material to stand on its own, it should prove most useful as a guide to using the software it describes. This is particularly true of the Programs section of the report.

NEURAL-NETWORK SOFTWARE

Neural-Network Basics

"Neural network" is a term used to describe a computer software product thought to mimic the functioning of neurons and their connections in the human brain. The term is probably best applied to an output file that is created when a simulation program such as Brainmaker is run but is sometimes used more generally. The basic principle that must be implemented in a neural network is that each "node" (neuron) is connected to several other nodes so as to form a complex network where the "activation" of a given node causes other nodes in the network to be activated according to the strengths of the connections between them. All inputs to the neural network may affect all outputs from the network to varying degrees. While the human brain contains billions of neurons, the scope of software that simulates its functioning is much more limited. A typical neural-network simulation may employ fewer than a hundred nodes. These nodes are typically divided into at least three

layers: an input layer, an output layer, and one or more "hidden" layers. In theory there may be connections between nodes in any of the layers, but in practice, connections are usually only between nodes in adjoining layers. Activation values for nodes in the input and output layers correspond to real-world values through a scaling function, but activation values for nodes in the hidden layers are strictly mathematical. Strengths of the connections between nodes are determined by weight matrices that connect adjoining layers of nodes and by a mathematical transfer function. Elements of the weight matrices are dynamically adjusted as the simulation program runs, and this constitutes the process of "training" the network, which will be described later.

All the nodes within a layer can be considered to form a vector (1 x n matrix). Then the weight matrix connecting the first (input) and second (hidden) layers, for example, would have $n_1 + k$ rows and n_2 columns, where n_1 and n_2 are the numbers of nodes in the first and second layers, respectively. The value k represents the number of "threshold" nodes that are added to the input vector of each layer junction just before matrix multiplication and is most often equal to 1. The activation value of threshold nodes is typically set to the maximum value. These nodes are added so that if all other nodes in the input vector of a given layer junction should happen to have a value of zero, there will be at least one node present that will allow the output vector to be non-zero if necessary.

The transfer function may be selected to suit a particular application but is fixed for any given simulation. Various transfer functions such as linear or step functions may be used, but a "sigmoid" function is often the best choice for a wide variety of applications. This function gets its name from the fact that its graphical representation somewhat resembles the letter S, and it has the form:

$$y = \frac{1}{1 + e^{-x}}$$

where y is an element of the output vector of a given layer junction and x is an element of the product vector obtained by matrix multiplication of the input vector of the layer junction by the corresponding weight matrix. This function has the properties of being near linear at its center and asymptotically approaching finite minimum (0) and maximum (1) values at its extremes. These properties make the function most sensitive near the center of its range, where most data is usually concentrated, and less sensitive at its extremes, where some data may represent "outliers." The idea of increasing sensitivity near the center of the data range and diminishing the effect of outliers is sometimes carried further by limiting the scaled range of the input and output layers so that only some fraction of the original data, typically 90 percent, produces variation in the activation values of nodes in that layer. The behavior of the transfer function may also be altered by employing a "gain" factor other than 1 to change the relative extent of the near-linear portion of the function.

Training of a neural network occurs when a simulation program such as Brainmaker is run. The elements of all weight matrices are initialized with a random set of values that are clustered near the center of the available range of values and then iteratively

adjusted. In each iteration, inputs are presented to the network and the outputs predicted by the network are compared to training values that are assumed to be correct. The magnitudes of the differences are used by the simulator to adjust the elements of the weight matrices so as to try to improve the accuracy of the network predictions. This often means pushing some values toward the positive extreme and others toward the negative extreme. Only when the relationship between the network inputs and outputs is strong and unambiguous will the network train quickly and elements of the weight matrices retain moderate values. The network is ultimately considered to be trained when some error measurement becomes acceptably small. This criterion may typically be defined as having all network predictions matching the training values within some desired tolerance. Alternatively, statistics such as the number of iterations, the distribution of values in the weight matrices, the arithmetic or root-mean-square average error, the standard deviation, the coefficient of determination, etc. may also be used. The selection of appropriate training criteria is subjective because a "best" choice is not obvious. It often happens that highly trained networks are better able to replicate outputs from the training data, but are less general in that they do not perform as well when predicting outputs arising from similar data not used for training.

Brainmaker Software

The Brainmaker software package used in this work comprises several different programs. Chief among these are programs named Brainmaker, Netmaker, Minmax, and Shuffle. Brainmaker is the actual neural-network simulation program that adjusts elements of weight matrices based on network inputs and outputs and produces an output file representing a trained network. The other three programs are utilities that aid in the preparation of Brainmaker input files. Netmaker will read data from text or spreadsheet files and produce "definition" and "test" files used by Brainmaker. Definition files describe the configuration of the network, and test files contain "facts," sets of network inputs and corresponding network outputs used for training. These may be produced with any text editor, but Netmaker automates the process to a great extent by providing default values for most parameters. The output from Netmaker may be edited if desired to change any of these values. Minmax is a program that reads test files and writes various statistics about the facts therein to the standard output device. These include the actual minimum, maximum, average, and standard deviation, as well as suggested minimum and maximum values to be used to limit the range used by the network so as to respond to only about the middle 90 percent of the original data. Shuffle is a program that rearranges facts in a test file in a pseudo-random order. This should be run if any patterns exist in the original data, since a random fact order works best for training neural networks. In the worst alternative, a network may tend to "learn" a particular relationship from the first half of the facts and then "unlearn" it from the second half.

A real-world network input is sometimes referred to in Brainmaker software as a "basis," and a real-world output as a "result." A result appearing in a training fact, which is assumed to be correct, is sometimes called a "pattern." Though the word

"run" might normally be used to refer to a single instance of running the Brainmaker program, the Brainmaker program itself uses the word to refer to a single iteration of processing all facts in the test file. At the end of each iteration, it displays the number of facts that were "good" and "bad," i.e., the number of network outputs predicted correctly and incorrectly, respectively, within the specified tolerance. The tolerance is expressed as a fraction between 0 and 1 and represents the greatest absolute value of the deviation between the predicted and correct values of the output nodes. For the usual case where node values range between 0 and 1, achieving a tolerance of 0.1, for example, means that all outputs predicted by the network match the correct values within 10 percent.

The values available for elements of the weight matrices used in Brainmaker range from -8 to +8. The reason for limiting the absolute value to 8 can be seen by substituting for x in the sigmoid transfer function equation. This shows that the node output values from each layer will then have a range of 0.0003 to 0.9997 - essentially 0 to 1 - without the elements of the weight matrices being subject to assuming excessively large absolute values. The Brainmaker program has a feature that allows for the display of weight-matrix histograms on the screen as it is running. These are closely spaced bar graphs that show the number of elements of the weight matrix for a given layer junction that are set at or near the value shown on the horizontal axis. They can be used to obtain an appraisal of the extent of training and the prospects for convergence of a neural network. The behavior of the shape of the weight-matrix histograms was fairly consistent throughout all of this work. Each histogram always started out as a bell shape extending from about -3 to +3 on the horizontal axis. As training progressed, the bell shape would spread out to cover the entire range from -8 to +8. Then it would transform to a W shape as the number of nodes assuming an extreme value increased. Finally, the center peak would flatten out so much that the histogram took on a U shape or even individual vertical lines at -8 and +8. There were typically three layers of nodes and, thus, two weight matrices in each run: the input-to-hidden layer matrix and the hidden-to-output layer matrix. Of the two, the input-to-hidden layer weight matrix was generally the first to be driven to the extremes (flatten in the middle), so it was the one that was routinely monitored more closely. Whenever it was driven to a U shape, further training efforts generally proved futile.

Various set-up screens available in Brainmaker software allow for the specification of many of the parameters associated with running the simulator, but only a few of the parameters were routinely specified in this work. In most cases the default values provided by the software were adequate. After some initial experimentation, all simulations performed in this work used the defaults of three layers of nodes, one threshold node, and a sigmoid transfer function with a range of 0 to 1 and a gain of 1. Some parameters, however, were changed because of the results of initial testing. The default number of nodes in the hidden layer is equal to the greater of the number of nodes in the input and output layers, but this number was routinely increased by a factor of about two (typically from 10 to 20). The default minimum and maximum values specified in the definition file are those suggested by the Netmaker program to

allow the Brainmaker simulator to respond to only the middle 90 percent of the input data. These were replaced by the actual minimum and maximum values in the training facts because of the limited amount of data available. An additional item worth mentioning is the use of a Brainmaker feature that allows the training tolerance to be automatically stepped down whenever the program is predicting a specified number of outputs correctly, within the current tolerance. This feature was typically used to step the tolerance down by 2 percent whenever all outputs were being predicted correctly. This seemed to help the stability of the simulation and allow a more precise approach to the lowest-achievable tolerance.

The following outline describes a recommended procedure for performing Brainmaker simulations similar to those done in this work. It is substantially equivalent, though not identical, to what was actually done. The main difference is that more trained network and matrix files were saved in this work. A salient feature of this procedure is that each simulation may be done in a separate (sub)directory, since the Brainmaker files required in the default directory are copied. Also, several simulations may be done simultaneously if windowing software is in use.

Procedure for Running Brainmaker Simulations in Separate Directories

1. Create a data file (or import a file in another format)
2. Copy NETMAKER.MNU, BRAINMAKER.MNU, NEURON.TBL, CHAR.MAP
3. Use Netmaker to create a definition file (.DEF) with facts
 - A. Read in the data file
 - B. Manipulate data - choose Files menu item
 - a. Set test file percentage to zero
 - b. Create Brainmaker file - specify Basis / Result
4. Delete the binary fact file (.BIN) created by Netmaker
5. Run Minmax on the definition file - redirect and print results
6. Edit the definition file
 - A. Change the number of hidden neurons if desired
 - B. Change the bold attribute to pattern rows
 - C. Change minimums and maximums to actual values
7. Run Shuffle on the definition file
8. Run Brainmaker
 - A. Select filenames
 - a. Change saved network file to R?????.NET (6 '?'s)
 - b. Write a new binary fact file (.BIN)
 - c. Eliminate the training statistics file (too big)
 - B. Change the display
 - a. Turn on auto histograms
 - b. Edit position of hidden histogram - row 7, col 40
 - C. Change the learning parameters
 - a. Set maximum number of runs to 100,000 - 200,000 range
 - b. Set initial tolerance to 0.400 - 0.200 range
 - c. Set final tolerance to 0.100 - 0.050 range

- d. Set multiplier to 0.95 - 0.98 range
- e. Set testing tolerance to 0.200 - 0.100 range
- f. Set test-network parameter to every 250 runs
- g. Set save-network parameter to every 1000 runs
- D. Run - train network
- 9. Use Brainmaker to examine the saved network files (R?????.NET)
 - A. Find about five (hidden) histogram shapes as follows:
 - a. Bell shape extending to about ± 6
 - b. Bell shape extending to about ± 8
 - c. W shape with ends about half as high as middle
 - d. W shape with ends about equal to middle height
 - e. W shape with ends about twice as high as middle
 - B. Reload the saved network files
 - C. Set tolerance near current value and continue training
 - D. Save the trained network files (.NET) after tolerance is met
 - E. Print weight matrices to files (.MTX) after tolerance is met
- 10. Use testing programs to select the best network (of the five)

Results of Changing the Number of Hidden Nodes and Layers

In one preliminary test the number of hidden nodes was varied to test the effect of this parameter on the predicted results. Using the default value of 14 nodes (for 14 outputs) in a single hidden layer, the network trained to a tolerance of 0.133 before the weight-matrix histogram began to flatten too much. This resulted in an overall average cumulative error of 2.86% - i.e., on average, the amount of coal predicted to pass through each sieve was off by 2.86% of the total amount of the coal sample. The average cumulative error will be discussed in more detail later. When the number of hidden nodes was increased to 40 the network trained to a tolerance of 0.120 before the weight-matrix histogram began to flatten too much. This resulted in an overall average cumulative error of 2.06%. Since adding nodes to the hidden layer allowed the network to train to a tighter tolerance and improved the quality of the predicted results, an attempt was made to push this trend further by adding a second hidden layer of 40 nodes. The training tolerance was set up to step down by 10 percent whenever all facts were predicted correctly, from an initial value of 0.200 (which was easily achieved in 15 minutes) to a final value of 0.100 (which was never achieved). After running for 16 hours, the network was still trying to meet a tolerance of 0.106 and getting only about 5 percent of the facts correct. Statistics were not saved for this long run, but it was probably difficult for the network to meet the previous tolerance of 0.118, even though it did so. The weight-matrix histograms for both hidden layers after 16 hours showed all elements of the weight matrices in the -7 to -8 or +7 to +8 ranges, none between -6 and +6. This is sometimes called a brain-dead network. In previous runs, it was seen that the predicted outputs tended to follow the training facts too closely, rather than just predicting the overall trend, as the weight-matrix histograms flattened too much. For this reason, the results observed after 16 hours of training with two layers of hidden nodes were a surprise. The predicted outputs became almost fixed at some average values

regardless of the values of the inputs to which they were supposed to respond. Overall, these preliminary tests suggested that doubling or tripling the default number of hidden nodes was somewhat beneficial for the data used in this work, but that more nodes or more hidden layers were not justified.

SIEVE-ANALYSIS APPROACHES

Sieve-Analysis Data

The data received from the Coal Preparation Division are shown in Table 1. This table contains 19 columns of data, arranged in chronological order. The first 15 columns show test data such as coal characteristics and hammer-mill operating parameters. Taken in order from left to right, these are: (1) Date - the date the coal was ground, (2) Test # - a unique designation assigned to each test, (3) Coal - the name of the coal seam from which the coal sample was obtained, (4) HG - the Hardgrove grindability index of the coal, (5) Ash - the ash content of the coal expressed as a percentage, (6) Set - a description of the number of hammers installed in the mill, with a full set being the maximum number possible, (7) Liner - the type of liner installed in the mill, either smooth or ribbed, (8) Hammers - the type of hammers installed in the mill, either bar or saddle-shaped, (9) Feed - the feed rate of coal to the mill in pounds per hour, (10) Damper - the setting of the control for the air damper on the mill, (11) Hammer-hours - the number of operating hours on the mill since the hammers were installed, (12) Liner-hours - the number of operating hours on the mill since the liner was installed, (13) Sweep - the setting of the control for the sweep air to the mill, (14) Speed - the rotational speed of the mill in revolutions per minute, and (15) Screen - the size of the perforations in the screen at the exit of the mill, in inches. The last four columns show the sieve analysis of the ground coal. Each entry in these columns represents the cumulative percentage of the feed coal that is retained on a sieve of the mesh size indicated by the column heading.

Table 1 contains several columns that are of little or no use in modeling the behavior of the PRF hammer mill with a neural network. Consequently, the following alterations were made to the data. First, four columns containing the date, test number, coal, and damper setting were dropped. The reason for dropping the first two is obvious; it is unlikely that the date and test number would have any effect on the coal-grinding results. The reason for dropping the damper setting is that it never varied; it was always 100. This makes it irrelevant since neural networks predict variations in outputs based on *variations* in inputs. Although the type of coal being ground could certainly have an effect on the grinding results, the name of the coal seam was dropped because it was redundant. Two other columns, the Hardgrove grindability index and the ash content, also characterized the coal, and there were no instances in the data where either of these parameters varied independently from the type of coal. Both a Hardgrove grindability index of 90 and an ash content of 26 percent, for example, always corresponded to Upper Freeport coal. In addition to dropping four columns of data, two others were consolidated. The values of hammer

hours and liner hours were always equal to each other, so they were replaced by a single operation-hours column.

Neural networks require that each unique set of inputs generates a unique set of outputs. This was not always the case with the data supplied by the Coal Preparation Division. In particular, rows 5 and 6 (tests 93-82-1 and 93-82-4) and rows 67 and 68 (tests 94-008H and 94-010) in Table 1 had identical inputs (coal and grinding conditions) but slightly different outputs (sieve analyses). Consequently, these two pairs of data were combined by replacing each pair with a single row in which the sieve-analysis columns contained values representing an average of the two tests that had identical inputs. This reduced the total number of ground-coal samples from 101 to 99. These are shown in Table 2. The columns retained in this table are: Hardgrove grindability index, ash content (%), hammer set, hammer type, liner type, operation hours, feed rate (lbs./hr.), sweep-air setting, mill speed (RPM), and screen aperture (in.) for the ten inputs, and +28, +100, +200, and +325 mesh (%) for the four outputs. The hammer set, hammer type, and liner type are represented in this table as numeric values (0 or 1), with the first letter of the description also shown in parentheses. The rows are sorted in order of increasing coarseness, according to the D-80 size of the coal sample. The method of computing this will be described later.

Table 3 contains calculated values for various sieve cuts and Rosin-Rammler parameters. The order of the rows in this table corresponds to the order of the rows in Table 2, and it could be viewed as an extension of that table.

Sieve-Analysis Methods

The four columns labeled +28, +100, +200, and +325 mesh in Table 2 contain sieve-analysis data expressed as percentages of a given coal sample retained on sieves of the indicated sizes. These values are cumulative in that they represent the *total* amount of a coal sample that is coarser than the indicated sieve size. Each coal sample was actually separated into five fractions using an ordered stack of four sieves with a 28 mesh sieve on top, followed by 100, 200, and 325 mesh sieves below. Only the +28 mesh sieve cut in Table 2 corresponds to a coal fraction that was actually measured. The other measured coal fractions can be calculated from the values in Table 2 by difference. These are shown in Table 3 in columns labeled 28x100, 100x200, 200x300, and -325 mesh.

From the beginning of this work it was thought that there might be a way of presenting data to a neural network that would result in the network being better able to predict outputs correctly. Consequently, a variety of presentations were tested. The first two approaches presented neural networks with cumulative and fractional data as described above. Each of these approaches could have its advantages under different circumstances. The cumulative approach would be expected to predict cumulative values more accurately, since neural networks are often better at predicting items of interest directly. Cumulative values are significant for reasons that will be explained later. The fractional approach, on the other hand, could be expected

to benefit from a narrowing of the range of data for each fraction. Errors in predicted outputs tend to be small when the differences between the maximum and minimum values of those outputs are small.

One of the shortcomings of neural networks is that there is no provision built in for imposing constraints on the solution of a problem. This would be a desirable feature when predicting sieve fractions. In the case where cumulative amounts are being predicted, a desired constraint would be that the amount of coal passing through a finer sieve must be less than or equal to the amount passing through a coarser sieve. In the case where fractional amounts are being predicted, a desired constraint would be that the sum of all fractions equals the total amount of the coal sample. Such discrepancies can be resolved externally to the neural network, of course, and the programs that were written to display neural-network results do just that. If the cumulative amount retained on a finer-mesh sieve is predicted by the neural network to be less than the cumulative amount retained on a coarser-mesh sieve, both values are set equal to the average of the two, making the fraction of the coal sample between the two sieves equal to zero. If the sum of all fractional amounts predicted by the neural network is not equal to 100 percent of the coal sample, each predicted fractional amount is multiplied by a normalization factor.

Averaging Technique for Cumulative/Fractional Combined Approach

Each of the methods described above for correcting obvious inconsistencies in results has its own bias, as do the methods for having a neural network predict the unconstrained sieve amounts to begin with. It was speculated that a way of eliminating these biases might be to have a neural network predict both cumulative and fractional amounts simultaneously, and then average all results to achieve consistency. This idea was actually carried even further by having a network predict all possible combinations of individual fractions - pairs, trios, and quartets. The quintet of all five fractions was naturally assumed to equal 100 percent of the coal sample. The method used for averaging all predictions in the subsequent display programs is somewhat complicated and is shown in the following pseudo-Fortran code. The basic idea is that a value for each fractional amount is calculated by all possible differences of cumulative amounts, in addition to the amount predicted directly, and a weighting technique is used to obtain an average value, where the weighting factor is inversely related to the number of subtractions required to calculate the desired value. The reason for weighting each term is that the potential error introduced is likely to be directly related to the number of operands required to perform the calculation, assuming that each operand has an approximately equal individual error. After calculating an average value for each of the five fractions, the five values are normalized to 100 percent. It should be noted that the denominator of each weighting factor employed in calculating an average for each fractional amount is equal to 48, but this number does not appear in the code because it is absorbed into the normalization factor. The 14 neural-network outputs, which are used as inputs to the averaging algorithm, are named in the first line of the code.

Pseudo-Fortran Code for Averaging Neural-Network Predictions

SIEVE-CUT VARIABLES: A, B, C, D, E, AB, BC, CD, DE, ABC, BCD, CDE, ABCD, BCDE

```
AAVG = 5 * A
+ 4 * (AB-B + ABC-BC + ABCD-BCD + 100-BCDE)
+ 3 * (ABC-B-C + ABCD-BC-D + ABCD-B-CD + 100-BCD-E + 100-BC-DE + 100-B-CDE)
+ 2 * (ABCD-B-C-D + 100-BC-D-E + 100-B-CD-E + 100-B-C-DE)
+ 1 * (100-B-C-D-E)
```

```
BAVG = 5 * B
+ 4 * (AB-A + BC-C + BCD-CD + BCDE-CDE)
+ 3 * (ABC-A-C + BCD-C-D + ABCD-A-CD + BCDE-CD-E + BCDE-C-DE + 100-A-CDE)
+ 2 * (ABCD-A-C-D + BCDE-C-D-E + 100-A-CD-E + 100-A-C-DE)
+ 1 * (100-A-C-D-E)
```

```
CAVG = 5 * C
+ 4 * (BC-B + CD-D + ABC-AB + CDE-DE)
+ 3 * (ABC-A-B + BCD-B-D + CDE-D-E + ABCD-AB-D + BCDE-B-DE + 100-AB-DE)
+ 2 * (ABCD-A-B-D + BCDE-B-D-E + 100-AB-D-E + 100-A-B-DE)
+ 1 * (100-A-B-D-E)
```

```
DAVG = 5 * D
+ 4 * (CD-C + DE-E + BCD-BC + ABCD-ABC)
+ 3 * (BCD-B-C + CDE-C-E + ABCD-AB-C + ABCD-A-BC + BCDE-BC-E + 100-ABC-E)
+ 2 * (ABCD-A-B-C + BCDE-B-C-E + 100-AB-C-E + 100-A-BC-E)
+ 1 * (100-A-B-C-E)
```

```
EAVG = 5 * E
+ 4 * (DE-D + CDE-CD + BCDE-BCD + 100-ABCD)
+ 3 * (CDE-C-D + BCDE-BC-D + BCDE-B-CD + 100-ABC-D + 100-AB-CD + 100-A-BCD)
+ 2 * (BCDE-B-C-D + 100-AB-C-D + 100-A-BC-D + 100-A-B-CD)
+ 1 * (100-A-B-C-D)
```

```
FACTOR = 100 / (AAVG + BAVG + CAVG + DAVG + EAVG)
```

```
A = AAVG * FACTOR
B = BAVG * FACTOR
C = CAVG * FACTOR
D = DAVG * FACTOR
E = EAVG * FACTOR
```

```
AB = A + B
BC = B + C
CD = C + D
DE = D + E
ABC = A + B + C
BCD = B + C + D
CDE = C + D + E
ABCD = A + B + C + D
BCDE = B + C + D + E
```

Even though the fractional values receive the greatest single weight by this method, the overall technique is more cumulative in nature since all possible pairs, trios, and quartets of adjacent fractions are included in the average. All of the above sieve cuts are shown in Tables 2 and 3 in columns labeled +28, 28x100, 100x200, 200x325, -325, +100, 28x200, 100x325, -200, +200, 28x325, -100, +325, and -28 mesh, respectively.

Least Squares Fit for Rosin-Rammler Distribution

The remaining approach tried for predicting sieve fractions was to force the experimental data to fit a theoretical particle-size distribution. A Rosin-Rammler distribution was used because previous work in the Coal Preparation Division had shown that it fits the particle-size distribution of coal ground in the PRF hammer mill quite well. Speculation was that having a neural network predict only a pair of constants that represent the overall trend in the data might eliminate any measurement error inherent in the data presented to the neural networks for the other approaches tested. Also, neural networks often perform better when the number of outputs is kept at a minimum.

The Rosin-Rammler equation used in this work can be written as:

$$\ln \ln \frac{100}{R} = S \ln A + C$$

where:

- R = percent of sample retained on sieve
- A = aperture size of sieve (microns)
- S = constant related to material
- C = constant related to size range

This equation can be linearized by letting:

$$Y = \ln \ln \frac{100}{R} ; \quad X = \ln A$$

so that:

$$Y = SX + C$$

A plot of Y versus X as defined above yields a straight line and is referred to as a Rosin-Rammler plot. The least-squares line for a set of N values of X and Y is defined by the following values of S and C :

$$S = \frac{N \sum XY - \sum X \sum Y}{N \sum X^2 - (\sum X)^2} ; \quad C = \frac{\sum X^2 \sum Y - \sum X \sum XY}{N \sum X^2 - (\sum X)^2}$$

where the summations are taken over all N values. These values of the slope and constant (intercept) are shown in Table 3.

Explanation of Average Cumulative Errors

For all of the above simulation runs, an overall average cumulative error value was calculated. This is the average of all individual average cumulative errors, where each individual average cumulative error is the error in the cumulative amount of coal retained on each sieve, averaged over the four sieves used for each coal sample.

The data received from the Coal Preparation Division reported sieve-analysis results cumulatively as percentages of a coal sample retained on each of four sieves of sizes 28, 100, 200, and 325 mesh, rather than reporting percentages of a coal sample in individual sieve fractions. If, for example, the results were reported as 3% + 28, 28% + 100, 48% + 200, and 60% + 325 mesh, this indicates that the coal sample was actually separated into five fractions: 3% + 28 mesh, 25% 28x100, 20% 100x200, 12% 200x325, and 40% -325 mesh. Cumulative values are also used in this report for comparing measured and predicted amounts of coal. The advantage of cumulative over fractional values is evident in the event that a given amount of coal is predicted to be in a fraction where it does not actually belong. In this case, it is considered preferable if the fraction where the coal is mis-predicted to be is near the one where it actually belongs, rather than as many as four fractions away. If the cumulative predictions in the example above were to be 7%, 28%, 48%, and 60% instead of the measured values of 3%, 28%, 48%, and 60%, the individual errors would be 4%, 0%, 0%, and 0%, respectively. Summing the errors and dividing by 4 yields an average cumulative error of 1%. By comparison, if the predictions were to be 7%, 32%, 52%, and 64%, the individual errors would be 4%, 4%, 4%, and 4%, yielding an average cumulative error of 4%. In each of these two examples, 4% of the coal sample is predicted to be in the wrong fraction. The difference is that, in the first example, the coal that is mis-predicted to be in the first fraction actually belongs in the second fraction; whereas in the second example, it actually belongs in the fifth fraction. The fact that the mis-predicted amount of coal in the second example actually belongs four fractions away, compared to only one fraction away in the first example, causes the average cumulative error to be four times as large. Of course the average cumulative error would also be four times as large if any of the individual errors were four times as large, e.g., predicted values of 19%, 28%, 48%, and 60% yielding errors of 16%, 0%, 0%, and 0%, respectively.

It should be noted that even though the numbers above are followed by a percent sign, the errors are differences in percentages, not percentage errors. For example, if a measured value is 20% and the predicted value is 21%, the error is reported as 1% of the total coal sample, not 5% of the measured amount. It should also be noted that the absolute value of the difference between the measured and predicted values is used when computing the average cumulative error. Again, if the measured value is 20%, predicted values of 19% and 21% are both off by 1%; a minus sign is not applied to the error in either case.

D-POINT APPROACHES

D-Point Data

Of particular interest in the Coal Preparation Division is the ability to accurately predict the D-95 or similar size of a coal sample (e.g., the particle diameter greater than that of 95 percent of the ground coal). Consequently, two additional approaches were investigated that predicted a series of six D-points for each sample, D-95, D-90, D-80, D-70, D-50, and D-30, rather than predicting the amount of coal in specific sieve fractions as was done previously. This is seen as preferable since not all workers use the same set of sieve sizes, but much of the coal literature characterizes particle-size distributions using at least one of the measures above. Before the D-point approaches could be used, it was necessary to transform the sieve analysis data supplied by the Coal Preparation Division into the desired format. This was done by the computational equivalent of drawing a straight line through pairs of sieve-analysis data points (i.e., sieve aperture and percentage of coal retained for 28 and 100 mesh, 100 and 200 mesh, etc.) on a Rosin-Rammler plot of the data and then interpolating or extrapolating the particle size for the desired D-point. This transformation introduces relatively little error since the data fit a Rosin-Rammler distribution quite well, as was stated earlier. The resulting particle sizes (in microns) for the six D-points mentioned are shown in Table 4, along with the same experimental operating parameters shown in Table 2. A feature of this table is that the data are broken down into nine groups. These data groups relate to the simulation of the hammer mill using a two-stage neural network, which will be discussed below.

D-Point Methods

The first of the D-point approaches employed a conventional single-stage neural network as was used previously for predicting sieve cuts. Coal characteristics and experimental operating parameters were again used as network inputs, and the network outputs were the six D-points mentioned above.

The second approach investigated the extent of the benefit that could be achieved by employing a two-stage neural network. A first stage was used to predict the D-80 size of all 99 coal samples to classify them into five categories, and a different second stage was then used for each category. The categories were defined so as to treat coal samples of similar coarseness as a set, and the number of samples in each set varied from 7 to 44. The five categories were named using Latin/Greek numbers as follows: Unus (fine), Duo (medium-fine), Tres (medium), Quattuor (medium-coarse), and Pente (coarse). The purpose of using Latin/Greek numbers was to have a unique first letter for the name of each category to facilitate a systematic file-naming convention. The nine groups in Table 4 were numbered using ordinary Arabic numerals, and each of the five base sets comprised one or two of the groups in the table. To allow for the possibility that the first stage might not be completely accurate in determining to which of the five categories a given coal sample should belong, the training set for each of the second stages included one or two of the

adjoining groups from the table, for a total of three or four. This typically caused the training set to be about twice the size of the base set for each category, with the number of coal samples varying from 17 to 78. The composition, number of samples, and D-80 particle-size ranges (in microns) are shown in the following table for the base and training sets of each category. These data were abstracted from Table 4, in which capitalization is used to denote the *base* set to which each group belongs.

DATA GROUPS FOR BASE AND TRAINING SETS

Set	Base				Training			
	Groups	Number	Min.	Max.	Groups	Number	Min.	Max.
Unus	1,2	20	18	90	1,2,3	35	18	119
Duo	3,4	44	90	190	2,3,4,5	78	37	273
Tres	5	18	190	273	4,5,6	53	119	319
Quattuor	6,7	10	273	402	5,6,7,8	32	190	576
Pente	8,9	7	402	1171	6,7,8,9	17	273	1171

The nine groups in Table 4 were generally chosen so that the boundaries fell on what appeared to be a natural break in the D-80 points. There were a couple of exceptions to this general rule, however. A more natural break point between the third and fourth group would have been a D-80 size of 123. It was set at 119 instead because that resulted in all data in the first three groups (the Unus training set) having binary parameters (hammer set, hammer type, and liner type) equal to 1. A similar occurrence is that the last four groups (the Pente training set) all had a feed rate equal to 500 lb./hr. This occurred naturally, however, rather than being selected in order to achieve a special purpose. A consequence of the fact that some parameters did not vary in the Unus and Pente training sets is that these parameters were not used for neural-network training for these sets. One other fact worth noting with regard to special training conditions is that the maximum D-80 value of 1171 microns in the Pente set was not actually used. Instead, a value of 700 was used because it narrowed the range of values while still being significantly greater than the next largest value of 632, thus increasing precision with no adverse effect.

Equation Methods

The work just described showed that a two-stage neural network could predict results better than a single-stage neural network. However, the difference was not so dramatic that the extra effort seemed justified, and using a separate second stage for each of the five different categories of coal coarseness probably compromised the generality of the results. Therefore, a different approach was tried to get some of the benefit of a two-stage neural network without the extra effort and loss of generality associated with an actual two-stage network. The crux of this approach was to use a semi-empirical equation based on the Bond equation to predict an approximate value for each of the six D-points being considered and to use a conventional single-stage

neural network to predict a correction factor to be applied to the approximate value in order to arrive at the final prediction of the measured value. This approach is somewhat analogous to a two-stage neural network in that the modified Bond equation can be viewed as a first stage, with the second stage being a single neural network rather than five separate ones as were used previously. The single neural network for predicting the correction factors has the same advantage that multiple second stages have in a two-stage network, i.e., the range of values is not as great as the range of values in the original data. Averaged over the six ranges considered, the ratio of the maximum to the minimum correction factor was only about 21 (varying from 11 to 64), whereas the ratio of the maximum to the minimum D-point was about 75 (varying from 54 to 109).

A constant in the modified Bond equation was chosen so that the average correction factor was near unity. Since the transfer function used in the neural network was a sigmoid function that was rotationally symmetrical and most sensitive about the origin, it seemed likely that a transformation that caused values of the correction factors near unity to fall near the center of the transfer function would increase the accuracy of the neural network predictions. Therefore, in addition to the neural network used to predict the correction factors directly, another neural network that predicted the natural logarithms of the correction factors was also tested. To increase the sensitivity of the neural network even further for values of the correction factors near unity, the prediction of the sign-transferred square roots of the logarithms of the correction factors was also tried. The sign-transferred square root of a number is the square root of the absolute value of the number preceded by its sign.

The modified Bond equation error factors, their natural logarithms, and the sign-transferred square roots of those logarithms are shown in Tables 5 through 7, respectively.

Modified Bond Equation

The modified Bond equation used to predict an approximate value of the product particle size can be written as follows:

$$x_P = \frac{A}{\left(\frac{GV^2}{cF} + \frac{1}{\sqrt{x_F}} \right)^2}$$

where:

- x_P = product particle size (microns)
- x_F = feed particle size (microns)
- G = Hardgrove grindability index
- V = hammer mill speed (RPM)
- F = coal feed rate (pounds/hour)

$c = 0.6$ (an empirical dimensional constant)

and A is an empirical equipment adjustment factor defined as:

$$A = \max (1.4 S , 2.1 H , 1.6 L , 1)$$

where:

S is a hammer-set value: 0 = half set, 1 = full set
 H is a hammer-type value: 0 = bar hammers, 1 = saddle hammers
 L is a liner-type value: 0 = smooth liner, 1 = ribbed liner

The "maximum" function is used in defining the equipment adjustment factor because the nature of any interaction among equipment parameters is not known. This is because there were no data where more than one of these parameters were changed at a time from the usual value of 1. All of the constants in the above equations are empirical and were determined by inspection of the data. They are not meant to be precise, but they do not need to be since they are only being used to estimate an approximate value of the particle size that is subject to correction by a factor obtained from running a neural-network simulation.

The particle sizes of the feed coal were not measured before grinding each sample; therefore, a constant set of values was used for all cases. These values were approximations of the particle sizes of the coarsest coal sample of the 99 samples used in this work. They were derived by fitting a least-squares line to a Rosin-Rammler plot of the sieve data for the coarsest coal sample, and using it to interpolate particle sizes for each of the D-points being predicted by the neural network. The values thus obtained are shown below.

VALUES USED FOR FEED COAL D-POINT SIZE IN MODIFIED BOND EQUATION

D-point	Microns
95	4325
90	2764
80	1502
70	917
50	358
30	116

For reference, these particle sizes may also be found in the last row of Table 32.

Explanation of Weighted Average Percentage Errors

For all instances where a neural network was used to predict D-points for this report, an overall weighted average percentage error was computed, where the overall error is an average of the individual weighted average percentage errors for each coal

sample. The individual weighted average percentage errors characterize how well the predicted D-points match the measured D-points. The absolute value of the percentage error in the particle size for each D-point was averaged over all six D-points considered for each coal sample, while weighting each error in a way that minimized the tendency of small absolute errors in small numbers at lower D-points to be unduly manifested as large percentage errors.

It is often of interest to measure or predict a coal-particle size that is nearer to the largest size in a given coal sample. A measure such as the D-80 point, the particle size larger than 80 percent of the sample, is often used in this case. Other measures such as the D-95 or D-50 points are also used sometimes. The six D-points used in this work, D-95, D-90, D-80, D-70, D-50, and D-30, were chosen so as to emphasize the significance of the coarser particles in the coal sample without ignoring the finer particles altogether. A simple arithmetic average of the percentiles of these six D-points equals 69.2, suggesting that the accuracy of predicting these points is about equal on average to the accuracy with which the D-69 point would be predicted. In choosing a measure for reporting the accuracy of predicted values, however, it was desired to emphasize the significance of the coarser particles a little more than this. Consequently, a weighted average was chosen in which each of the six D-point predictions was weighted in proportion to the amount of coal passing through an aperture of the corresponding size. That is, the average was computed as $95/415 \times D-95 + 90/415 \times D-90 + \dots + 30/415 \times D-30$, where 415 is the sum of the percentiles of the six D-points. The weighting factors for the values of the D-95 through D-30 points by this method then worked out to be 22.9%, 21.7%, 19.3%, 16.9%, 12.0% and 7.2%, respectively. Converting the percentiles to fractions and calculating the sum of the squares divided by the sum of the fractions equals 0.767. This suggests that the accuracy of predicting the weighted average of these six D-points is about equal to the accuracy with which the D-77 point would be predicted. This is reasonably close to the often-used D-80 point, and is, therefore, judged to be a reasonable characterization of the coal sample overall. The exact choice of a suitable characterization is not critical, however, because the errors between calculated and predicted values of the six D-points generally varied in the same direction and were not too far from being equal.

In contrast to the average cumulative errors described earlier, the weighted average percentage errors are quoted with respect to the measured values, i.e., as a percentage of the corresponding particle sizes. As before, however, absolute values of the individual errors are used when computing the overall average error.

Comparison of Sieve-Analysis and D-Point Simulations

Since a major objective of this work was to determine the best way to present experimental data on the performance of the PRF hammer mill to a neural network, a consistent measure of the accuracy of the network predictions was needed. The only real choice for this measure was the accuracy of predicting the six D-points as measured by the weighted average percentage errors described above. The primary

reason for this is that some information about the finer end of the particle-size distribution, e.g., the D-10 size, was discarded when the choice was made regarding which D-points would be predicted. The secondary reason is the same as that which motivated the aforementioned choice, i.e., the desire to place greater emphasis on the significance of the coarser end of the particle-size distribution.

The sieve-analysis predictions resulting from the first four approaches described for presenting data to a neural network were transformed to the D-point format using the same technique of Rosin-Rammler interpolation between pairs of adjacent data points as was used to transform the experimental data. Weighted average percentage errors corresponding to the resulting D-points were also calculated. These errors were, of course, different in magnitude from the average cumulative errors that were initially calculated for these simulation runs, owing to the inherent difference in the two error definitions. It happened, however, that the trends in results differed very little between the two methods. It is unclear whether this means that the choice of an error measure is not critical or that the two measures chosen just happened to be roughly equivalent with regard to indicating trends in results.

TABLES AND RESULTS

Summary Tables of Simulation Inputs

Tables 8 and 9 contain summaries of the minimums, maximums, averages, and standard deviations of all simulation input variables. Table 8 summarizes the coal characteristics and operating parameters for grinding coal samples, and Table 9 summarizes the sieve-analysis data and calculated D-point and equation-error-factor values. The following abbreviations are used in these tables to refer to the approaches used for presenting data to the various neural networks. These same abbreviations are used in naming some of the computer files associated with this work.

RUN ABBREVIATIONS USED IN TABLES AND FILE NAMES

Abbrev.	Description
CUM	Cumulative sieve analysis
FRAC	Fractional sieve analysis
ALL	All combinations of sieve analyses
RR	Rosin-Rammler parameters
EF	modified Bond equation Error Factor
LOG	Log of equation error factor
SQR	Square root of log of equation error factor
IND	Individual (one) stage D-points
MULT	Multiple (two) stage D-points, first stage (1)
UNUS	multiple stage D-points, second stage Unus (2-1)
DUO	multiple stage D-points, second stage Duo (2-2)

TRES	multiple stage D-points, second stage Tres (2-3)
QUAT	multiple stage D-points, second stage Quattuor (2-4)
PENT	multiple stage D-points, second stage Pente (2-5)

The ellipses in the ALL entry of Table 9 indicate that the eight columns (one duplicated) of the preceding two entries (CUM and FRAC) are to be included as part of the ALL entry, for a total of 14 columns.

The values in parentheses in Table 9 (under RR and MULT) represent the values used in the neural-network definition files for the two cases where those values did not correspond to the actual data. The use of the value of 700 for the maximum particle size in the MULT runs was intentional and was explained earlier. The use of the value of 0.482 instead of 0.497 for the slope in the RR runs was not intentional. The value 0.482 corresponded to the fifth coal sample in Table 1. Since the data for the fifth and sixth samples were combined because of identical operating parameters, the value 0.497 corresponding to the average sieve analysis should have been used instead. The resulting error is sufficiently minor that it was not worth running the RR simulations again to correct it.

It is informative to take note of the variation in the average values of the operating parameters for the five second stages shown in Table 8. The averages that show the strongest and most consistent trends in variation from the first to the last stage are the hammer mill speed (1.78:1), coal feed rate (1:1.62), hammer type (1.55:1), and liner type (1.42:1). All of these variables also appear in the modified Bond equation used in this work. Hammer and liner operating hours and Hardgrove grindability index also show significant variations (1:1.18 and 1.10:1, respectively), but the ratios are not as large and the trends are not consistent. The average value of the operating hours takes a big step between the third and fourth stages, and the average value of the Hardgrove grindability index takes a big step between the first and second stages.

Summary Tables of Simulation Results

Tables 10 and 11 contain summaries of the results of all neural-network simulations. Table 10 is for simulations that predicted sieve analyses, and Table 11 is for simulations that predicted D-points. In each case, the first column shows file names for weight-matrix files, with the standard .MTX extension omitted. These names are systematically derived from the type of simulation approach, the number of "runs" (iterations), and the tolerance achieved. The first letter of each file name is unique and corresponds to the first letter of one of the abbreviations in the table above. It is also capitalized in the descriptions in that table. Characters 2 through 4 in the file name represent the approximate number of runs in thousands; the exact number is shown in the runs column. Character 5 is a T if the desired tolerance was achieved for all facts or a B if it was not, i.e., some facts were "bad." The remaining characters represent either the tolerance achieved in thousandths (for T) or the number of bad facts (for B).

Tables 10 and 11 show two blocks of results for each simulation approach (each unique first letter). In the first block the tolerance shown is the tolerance actually achieved in a series where the tolerance was progressively lowered. In the second block the tolerance column shows the tolerance that was being sought and the number of bad facts, where the desired tolerance was not achieved. This series has entries for every approximate multiple of 10,000 runs. The deviation from an exact multiple of 10,000 is generally less than 250 and was chosen so that the number of bad facts in the range of runs between $10,000n$ and $10,000n + 250$ was at or near a minimum.

The shape of each input-to-hidden layer weight-matrix histogram is described in Tables 10 and 11 in the three columns that contain a pair of values separated by a colon. In each case, the value to the left of the colon is the absolute value of an element of the weight matrix (0 to 8), and the value to the right of the colon is the number of occurrences of that value in the weight matrix. The range of values that weights may assume is actually from -8 to $+8$; the absolute value is shown because the histograms were generally symmetrical. In the few cases where a histogram was not exactly symmetrical, the weight with the larger number of occurrences is shown. In either case, the number of occurrences shown is for a single value of the weight, not for the sum of the negative and positive values of the same magnitude. The first of the three columns describing the input-to-hidden layer weight-matrix histograms shows the location and size of the peak near the middle of each histogram; the second shows the minimum values on either side of the middle peak; and the third shows the size of the end peaks, which always occurred at -8 and $+8$. The third column contains a dash if the weight-matrix histogram for the number of runs indicated was bell-shaped rather than W-shaped.

The last three columns in Tables 10 and 11 summarize the simulation results. They show the maximum, average, and standard deviation of the overall average values of either the average cumulative error when predicting sieve analyses (Table 10) or the weighted average percentage error when predicting D-points (Table 11).

A few additional entries are included in these tables. Table 10 includes an entry named Regress. This contains the results of fitting a least-squares straight line to the experimental sieve-analysis data represented on a Rosin-Rammler plot. Table 11 includes additional entries named Equation and MULT-2. The first contains the results of predicting the six D-points with the modified Bond equation alone, i.e., with an equation error factor of 1. The second contains the results of predicting the six D-points using a combination of the best results for each of the six stages that constitute a two-stage simulation (one first stage and five second stages). These three entries are included only for comparison.

For each simulation approach represented in Tables 10 and 11, certain entries are shown in boldface type to indicate that they are the "best" values in that group. Such entries appear in the maximum, average, and standard deviation columns, where they represent the best value in the group for their respective columns, and in the file name

column, where they represent the overall best file in the group. The overall best file in each group was selected based on the sum of the values of the average and standard deviation. The best results for each approach are summarized in Table 12. If a normal distribution of average error values is assumed - though that is not necessarily an accurate assumption - the value of the average error $\pm$ the standard deviation includes the error for about 68 percent of the coal samples. If it is further assumed that half of the remaining 32 percent lie on either side of this range - again not necessarily true - then the error value represented by the last column in Table 12 may be considered to be the weighted average percentage error that is greater than that of 84 percent of the coal samples. In other words, only about one-sixth of the coal samples would likely have a greater percentage error in the D-77 size than this.

Tables of Best Calculated Results

The values in Table 12 are also found in the last lines of Tables 13 through 34. These tables show calculated simulation results, along with the individual average errors, for all 99 coal samples. They are essentially the output generated by programs that display calculated predictions of sieve analyses and D-points based on the weight-matrix files generated by the neural networks. Such tables were created for all of the weight-matrix files shown in Tables 10 and 11, but only the "best" example of each type is included in this report. Tables 13 through 34 are in the same order as the entries in Tables 10 and 11, and each is sorted by the D-80 particle size, in accordance with Tables 2 through 7. In each of these tables, the last column contains either an average cumulative error or a weighted average percentage error for all differences between measured and predicted values in the corresponding row. The values appearing at the end of each table, as well as in Table 12, represent the maximum, average, and standard deviation of all the average error values in the last column.

Table 26, containing the best predictions of D-80 points for the first stage of a two-stage simulation, has been annotated with two additional columns. These are the ideal and actual second stages that would be used based on the predictions of the first stage. In most cases the two are equal, so the actual second stages are indicated only where they are *not* equal.

Discussion of Results

Inspection of Table 26 reveals that the first stage of the two-stage simulation (designated MULT) predicted a D-80 particle size lying in the range of the "ideal" base data set 90 percent of the time and in the range of the corresponding training set 100 percent of the time. This suggests that the range of the training set was sufficiently broad to perform well and perhaps even broader than necessary.

Table 12 shows that the four neural networks having the smallest errors were four of the second stages: PENT, QUAT, UNUS and TRES. This suggests two things: (1) that the QUAT and PENT data sets could have possibly been combined without much

additional error, even though the ranges of the data in each are significantly different, because both are small and accurately predicted, and (2) when the accuracy of the MULT first stage and these four second stages are considered together, the two-stage network should be expected to be one of the most accurate. This is in fact the case; the "best" two-stage network, which is represented by the entry in Table 12 labeled MULT-2, is the network simulation having the fifth smallest error. The entry labeled Regress is not counted as one of the most accurate neural networks, because the entries labeled Regress and Equation do not actually represent neural networks but rather mathematical fits to the data that are included in the table only for comparative purposes.

There are probably two considerations that kept the two-stage network from performing better: (1) the direct prediction of D-points by a neural network was not one of the more accurate approaches used, and (2) the DUO second stage contained a relatively large number of coal samples, even though the range of D-80 sizes within it was less than one-tenth the range of D-80 sizes in all 99 coal samples. Evidence of the first consideration can be seen in Table 12 by noting the error for the IND entry. This is the approach that used a single (individual) neural network to predict the six D-points for all 99 coal samples. As can be seen, it produced the second worst results of all the simulation approaches. The significance of the number of coal samples considered by a given network can be seen by considering the five second stages, along with the single IND network. Table 12 shows that the ranking of each network with regard to accuracy is directly related to the number of coal samples used for training. It is even possible to devise a crude correlation in which the average of the number of coal samples in the base and training sets is about equal to triple the sum of the average and standard deviation appearing in the last column of Table 12. Values for these two quantities are shown in the following table for all six neural networks that predicted D-points directly.

COMPARISON BETWEEN NUMBER OF COAL SAMPLES AND AVERAGE ERROR

Set	(Base# + Train#)/2	3(Average + SD)
IND	99	84.9
UNUS	27.5	25.8
DUO	61	58.2
TRES	35.5	38.4
QUAT	21	18.9
PENT	12	8.3

This correlation has no theoretical basis, and the fact that it works so well is probably a fluke. However, the fact that it works at all is an indication that neural networks can often find some correlation in small data sets, even if it does not actually correspond to a real-world phenomenon. This is especially true if the number of network inputs is relatively large compared to the number of network outputs, and the

underlying principle is probably similar to that of the aphorism about the possibility of plotting an elephant with a sufficient number of parameters in an equation.

The semi-empirical modified Bond equation that was used to predict D-points based on coal properties and hammer-mill operating parameters is represented by the entry labeled Equation in Table 12. It yielded results having the greatest error but was still accurate enough to be useful; only about 13 percent of the predictions were in error by more than a factor of two. Its real value, though, was in its use with a neural network that predicted error factors to be applied to the values predicted by the equation alone (the EF approach). The results of using this combination were fairly good, but it was possible to improve upon them by having a neural network predict the natural logarithm of the error factors instead (the LOG approach). This approach yielded results having the smallest error of all the single-stage neural networks. The apparent reason that the LOG approach worked better than the EF approach is that it reduced the range of predicted values and caused more of them to fall near the center of the range. When this technique was extended even further by having a neural network predict the sign-transferred square root of the natural logarithm of the error factor (the SQR approach), the results were significantly worse. The apparent reason is that squaring a predicted value to arrive at a final result magnified any error present in the predicted value.

Since having a neural network predict the logarithms of the modified Bond equation error factors improved the quality of the results, the possibility of performing a similar logarithmic transformation on other data was considered. Values for the screen size in particular seemed amenable to benefitting from such a transformation, because they happened to follow a geometric progression. For example, values of 1/16, 1/8, 1/4, and 1/2 inch could be represented as 1, 2, 4, and 8 sixteenths, respectively, and be predicted by a network as 0, 1, 2, and 3, where the last four numbers equal the power of 2 required to obtain the previous four. This linearizing transformation was not performed, however, for two reasons: (1) the screen size did not seem to be a critical input variable, and (2) it was not considered desirable to introduce extraneous changes if results of testing the various approaches were to be compared on a level basis.

It is instructive to compare the statistics on the weighted average percentage errors in Table 12 to those of the average cumulative errors, for those entries where the latter were calculated. What is obvious immediately is that the ranking of each entry with regard to accuracy is the same regardless of which statistics are used. The following table extends this comparison by showing values of the ratios of corresponding statistics for the two error measures.

WAPE/ACE RATIOS FOR THE BEST RESULTS OF SIEVE-ANALYSIS APPROACHES

Approach	Maximum	Average	Std. Dev.
Regress	9.7	5.8	7.2
CUM	12.5	6.3	9.9
ALL	12.9	6.7	10.0
FRAC	9.5	5.8	6.5
RR	5.1	5.7	6.0
<hr/>			
Average	9.9	6.1	7.9
Std. Dev.	3.1	0.4	1.9

While the ratios of the maximum values show the greatest variation, from 5.1 to 12.9, the ratios of the average values are remarkably consistent, from 5.7 to 6.7. This is further evidence that the choice between these two measures of error is not critical.

Whichever error measure is used, Table 12 shows that the simulation approach that predicted cumulative amounts of coal on each sieve (the CUM approach) produced results having the smallest error of the sieve-analysis approaches. Overall, the quality of this approach was surpassed only by the two-stage (MULT-2) and LOG approaches. This is evidence that neural networks tend to work best when predicting quantities of interest directly and the number of outputs is kept at a minimum. The sieve-analysis approach that predicted individual sieve fractions (the FRAC approach) produced noticeably worse results. This is probably because the anticipated benefit of breaking cumulative amounts into fractions in which the ranges of values of the predicted outputs were smaller than the ranges of the corresponding cumulative values was largely unrealized. Examining the first two entries in Table 9 reveals that the average range of fractional values was 40, compared to the average range of cumulative values of 65.2. This range reduction of about 39 percent was apparently not sufficient to cause the FRAC approach to perform better. The performance of the ALL approach, which predicted all possible combinations of sieve cuts (cumulative and fractional) was intermediate in quality between those of the CUM and FRAC approaches. This is not too surprising, even though it was hoped that biases in the CUM and FRAC approaches might tend to cancel out each other in this approach.

The neural network that predicted the slope and constant for a Rosin-Rammler distribution (the RR approach) yielded predicted results having the greatest error. However, about a fourth of this error can be attributed to the linear regression that forced experimental data to fit a Rosin-Rammler distribution, even though the fit is actually fairly good. If the error attributable to the regression is subtracted out, the results of the RR approach are on a par with those of the IND and SQR approaches. Both the RR and the SQR approaches have the same disadvantage that caused them to rank among the least successful approaches, i.e., that an output from a neural network must be mathematically manipulated in a way that magnifies any error in the

network output. In the RR case, the network output is a logarithm of a logarithm and an exponential function must be applied twice to obtain a final predicted value. This makes it extremely sensitive to errors, even though the network probably benefitted from the fact that only *two* outputs were being predicted. In contrast, the IND approach was probably among the worst because it predicted *six* D-points, even though it probably benefitted from predicting them directly.

PROGRAMS

Programs for Displaying Neural-Network Predictions

There are two different types of programs for displaying neural-network predictions: (1) programs named *CAL.EXE, which read inputs from one file and write results to another, and (2) programs named *BAR.EXE, which display results dynamically in bar-graph form on an 80 x 25 character screen. Tables 13 through 34 were generated by *CAL.EXE programs. The asterisk in the preceding names is a "wild card" that represents any string of characters. There are actually two types of programs that fit this naming convention. Those in which the asterisk represents one of the abbreviations for the type of simulation approach (CUM, FRAC, ALL, etc.) may be considered "low-level" programs, while those in which it represents one of the single letters S or D may be considered "high-level" programs. The letters S and D stand for sieve-analysis and D-point, respectively, and each program displays predicted results in the corresponding format. The high-level programs call the low-level programs, while providing a simpler user interface by automatically selecting the proper definition and test files based on the first letter of the weight-matrix file name. They require that all auxiliary files be located in the default directory. The high-level *CAL.EXE programs assume that the short (tabular) output format is desired unless the medium output format is specified.

For all of the programs just described, help with specifying program inputs may be obtained by typing the program name alone on a DOS command line. For the low-level programs, help screens indicate that there are up to four different types of auxiliary files needed (two for *BAR.EXE programs). These are: (1) *.IN or *.TST files containing input data for coal properties and hammer-mill operating parameters, (2) *.DEF files containing neural-network definitions, (3) *.MTX files containing weight matrices for trained neural networks, and (4) *.CAL files for storing *CAL.EXE program output. The file extensions just mentioned are the defaults; others may be used if desired. All of these types of files except *.CAL files are provided. For the high-level programs, only the weight-matrix file name shown in the first column of Tables 10 and 11 is required, and a .MTX file extension is assumed. SCAL.EXE creates output files with a .CSA (calculated sieve analysis) extension, and DCAL.EXE creates output files with a .CDP (calculated D-point) extension. Both low-level and high-level *CAL.EXE programs will recognize the last parameter on a DOS command line as an optional output-format switch (short, medium, or long) only if all other parameters are specified.

Considerations for Evaluating Neural Networks

Each weight-matrix file shown in Tables 10 and 11 represents a different level of training of a neural network, only some of which meet the desired tolerance. The reason for including so many *.MTX files is to permit the investigation of the effect of the training level on network performance. It may be presumed that only one of the networks is "best" and that all others are extraneous. However, it is unlikely that the network showing the lowest statistical error in the tables is necessarily the best in all respects. There are several reasons for this: (1) the tabulated errors were somewhat arbitrarily defined, (2) the extent of the data is limited for many of the parameters of interest, and (3) highly trained networks may fit the training data too closely, at the expense of correctly predicting overall trends.

The *BAR.EXE programs are especially useful for determining if the last condition holds true. These programs interactively change the bar-graph display of network inputs (coal properties and hammer-mill operating conditions) and predicted outputs (sieve analyses or D-point sizes) in response to keystrokes entered by the user. They therefore allow trial-and-error testing to determine if outputs behave as expected. Because the display responds quickly, both the direction and the rate of change may be observed. This characteristic can reveal an overly trained network by the presence of an unexpected "wiggle" in the motion of an output bar while an input is varied smoothly over a given range.

When running the *BAR.EXE programs, it is advantageous to set the keyboard typematic rate to the maximum 30 characters/second and hold down the desired key. The typematic rate can be changed from its default of 10 characters/second using the MODE command in DOS version 5 and higher as follows: MODE CON: RATE=32 DELAY=1. Several commercially available products such as the NCC (Norton Control Center) program in the Norton Utilities and the RP (Repeat Performance) program in WordPerfect Office can also be used. Another alternative on Gateway 2000 Anykey keyboards is to use the Repeat Rate key, followed by F1 through F8 (F8 is maximum).

When evaluating the ability of a neural network to properly predict trends in the results, the following considerations should be kept in mind. The predicted particle sizes should vary directly with: (1) the ash content of the coal, because ash is usually harder than coal and, therefore, less grindable, (2) the mill-operation hours, because the mill becomes less efficient with increasing wear, (3) the coal feed rate, because the energy input per unit of coal varies inversely with feed rate, (4) the sweep air setting, because high amounts of sweep air blow product out of the mill more quickly, and (5) the mill screen aperture, because small screen openings prevent coal from exiting the mill before the desired particle size is attained. The predicted particle sizes should vary inversely with: (1) the Hardgrove grindability index of the coal, because hard coal is more difficult to grind, and (2) the mill speed, because the energy input per unit of coal varies directly with mill speed. A full hammer set should produce finer particle sizes than a half hammer set because the energy input per unit of coal is

greater. Saddle hammers and a ribbed liner should produce finer particle sizes than bar hammers and a smooth liner, respectively, because of more efficient geometries.

Running Display Programs with New Data

The neural networks that are embodied in the weight-matrix files may be used with new data that was not included in the training set, but the advisability of doing so depends on the nature of such data. If the new data are similar to the training data in that all variables are in the same ranges as those used for training and no variables are introduced that were not accounted for in the training data, then predictions based on the new data would be expected to be reasonably accurate. If not, then it should be recognized that neural networks are quite similar to empirical correlations, and predictions arising from data significantly different from the training data should be considered suspect.

To run the *CAL.EXE programs with new data, an input file must be prepared containing the words "facts run" on the first line, with each succeeding line containing 10 values for the coal and hammer-mill operating parameters in a Fortran 10(F7.0,1X) format. The order of the 10 input values must be the same as that used in Tables 2 and 4. The procedure for using new data with the *BAR.EXE programs is obvious; one simply enters new input values on the screen in accordance with the on-screen instructions.

Matrix Comparison Program

An additional program, MC.EXE, is provided to display neural-network weight-matrix files graphically. This is useful for identifying trends that may appear in a set of related weight-matrix files. Such trends can indicate the relative importance of different inputs on the outputs predicted by a neural network. Help with running the program may be obtained by typing the program name alone on a DOS command line.

CONCLUSIONS

The main conclusion of this work is that for the grinding data on 99 (originally 101) coal samples prepared by the Coal Preparation Division, various neural networks were able to predict an average of the D-95, D-90, D-80, D-70, D-50, and D-30 points with an average error varying from about 8 percent to about 18 percent. Since the variation in results was only a factor of about two between the worst and best approaches for presenting data to a neural network, it may be concluded that the approach is not *extremely* critical. A few general principles, however, may be discerned by considering the best and worst approaches. The two-stage approach yielded the best results because it used a set of five small networks to predict outputs for five specialized categories of coal samples. It may suffer from a lack of generality, however, and multiple-stage networks are probably best reserved for situations where there is a fundamental reason for categorizing data rather than cases such as this where categories were somewhat arbitrarily defined. The approach of predicting

logarithms of equation error factors yielded the second best results and illustrates the benefit of two techniques: (1) using a theoretical consideration to approximate the results and then using a neural network to predict the errors in those approximations, and (2) using a mathematical transformation to shift most of the network input data toward the center of the range. The approach of predicting cumulative sieve amounts yielded the third best results and illustrates two additional principles: (1) the number of outputs should generally be held to the minimum required by the data - four in this case, since four sieves were used in the analysis, and (2) the network outputs should generally predict experimental results directly, unless there is a discernable advantage to be gained by using a transformation. The approach of predicting Rosin-Rammler parameters yielded the worst results because the subsequent exponentiations required magnified errors present in the neural-network outputs. Similar results with squaring predicted square roots also indicate that such error-magnifying mathematical operations should be avoided.

With regard to creating a neural network, the most important consideration is probably the number of hidden nodes to be included. The usual number of hidden nodes is the larger of the number of network inputs and outputs. The few tests done in this work suggested that for this coal-grinding data, using a number of hidden nodes that was double or triple the usual number increased the accuracy of predicted results by about 20 to 30 percent. With regard to training a neural network, it is worth noting that automatically stepping down the training tolerance in small increments seemed to improve the stability and ultimate accuracy of the neural networks used in this work.

The most significant conclusion of a more general nature would probably be that a simple (single stage) neural network can predict coal particle-size distributions with an average error as small as about 10 percent, assuming that the raw data is of a quality comparable to that of the data generated using the single hammer mill in the PRF. It seems reasonable to speculate that this might hold true for more complex grinding configurations also, as long as there are sufficient sieve-analysis data to correlate with all significant operating parameters. In the absence of a more accurate technique for predicting particle-size distributions versus operating parameters, a 10 percent error might easily be considered acceptable.

TABLE 1
EXPERIMENTAL OPERATING PARAMETERS AND SIEVE ANALYSES (received data)

Date	Test #	Coal	HG	Ash	Set	Liner	Hammer	Fed	Dmp	H-Hrs	L-Hrs	Swp	Sped	Scrn	+28	+100	+200	+325
1/9/93	93-78A	U.Freeport	90	26	Full	Ribbed	Saddle	250	100	0	0	0.6	6750	0.06	0	0.2	2.5	6.5
4/8/93	93-78C	U.Freeport	90	26	Full	Ribbed	Saddle	250	100	0	0	0.6	6750	0.25	0	1.1	4	9.5
4/8/93	93-78G	U.Freeport	90	26	Full	Ribbed	Saddle	250	100	1	1	1	6750	0.50	0	6.4	14.8	22.4
4/9/93	93-78K	U.Freeport	90	26	Full	Ribbed	Saddle	250	100	2	2	0.6	4912	0.25	0.2	7.3	19.3	31.3
4/15/93	93-82-1	U.Freeport	90	26	Full	Ribbed	Saddle	210	100	7	7	0.8	6840	0.50	0.7	9.2	17.8	27.2
4/18/93	93-82-4	U.Freeport	90	26	Full	Ribbed	Saddle	210	100	7	7	0.8	6840	0.50	0.7	8	17	23.9
4/22/93	93-84-1	U.Freeport	90	26	Full	Ribbed	Saddle	210	100	13	13	0.8	6840	0.25	0	1.5	5.6	12.6
4/25/93	93-85-1	U.Freeport	90	26	Full	Ribbed	Saddle	210	100	19	19	0.8	6840	0.25	0	0.9	4.4	10.2
4/28/93	93-86-A	U.Freeport	90	26	Full	Ribbed	Saddle	210	100	30	30	0.8	4919	0.25	0.9	9.3	21.2	32.4
4/29/93	93-86-B	U.Freeport	90	26	Full	Ribbed	Saddle	230	100	30	30	0.8	4919	0.25	0.2	6.9	18.6	30.9
5/5/93	93-91-E	Pgh-Ohio	55	23	Full	Ribbed	Saddle	225	100	54	54	0.8	6109	0.25	0.1	8	22	34.9
5/5/93	93-91-F	Pgh-Ohio	55	23	Full	Ribbed	Saddle	500	100	54	54	0.8	6109	0.25	0.3	10.2	26	39.9
5/5/93	93-91-M	Pgh-Ohio	55	23	Full	Ribbed	Saddle	225	100	54	54	0.8	4912	0.13	0.5	11.8	29.9	44.1
5/7/93	93-93	Pgh-Ohio	55	23	Full	Ribbed	Saddle	225	100	63.5	63.5	0.8	6109	0.25	0.2	6.5	19.2	32.6
5/10/93	93-94	Pgh-Ohio	55	23	Full	Ribbed	Saddle	150	100	67	67	0.8	6109	0.25	0.1	5.7	17.2	28.6
5/11/93	93-95	Pgh-Ohio	55	23	Full	Ribbed	Saddle	225	100	69	69	0.8	6109	0.25	0	5	15.7	28.1
5/12/93	93-97	Pgh-Ohio	55	23	Full	Ribbed	Saddle	300	100	75	75	0.8	6109	0.25	0	6.1	18	30
5/13/93	93-98	Pgh-Ohio	55	23	Full	Ribbed	Saddle	300	100	82	82	0.8	4916	0.25	0.4	11.7	30.1	44.4
5/17/93	93-100	Pgh-Ohio	55	23	Full	Ribbed	Saddle	250	100	86	86	0.8	4916	0.25	0.3	12.5	30.3	43.8
5/24/93	93-103	Pgh-Ohio	55	23	Full	Ribbed	Saddle	250	100	100	100	0.8	4916	0.25	0.8	12.6	31.6	45.7
5/31/93	93-108F	Pgh-Ohio	55	23	Full	Ribbed	Saddle	500	100	112.5	112.5	0.8	3500	0.25	4.1	31.2	52.4	64.9
6/1/93	93-108E	Pgh-Ohio	55	23	Full	Ribbed	Saddle	500	100	112.7	112.7	0.8	3500	0.13	2.1	28.9	51.6	63
5/27/93	93-109	Pgh-Ohio	55	23	Full	Ribbed	Saddle	250	100	113	113	0.8	4910	0.25	0.3	12	28.6	43.5
6/1/93	93-110	Pgh-Ohio	55	23	Full	Ribbed	Saddle	250	100	120	120	0.8	4912	0.25	1.1	12.3	27.4	44.5
6/7/93	93-113	Pgh-Ohio	55	23	Full	Ribbed	Saddle	280	100	134	134	0.8	4910	0.25	0.7	14	32	44.6
6/8/93	93-114	Pgh-Ohio	55	23	Full	Ribbed	Saddle	280	100	141	141	0.8	4910	0.25	0.6	12.6	30.1	43.4
6/9/93	93-115	Pgh-Ohio	55	23	Full	Ribbed	Saddle	280	100	151	151	0.8	4910	0.25	0.7	13	29.2	43.4
6/14/93	93-117	Pgh-Ohio	55	23	Full	Ribbed	Saddle	280	100	161	161	0.8	4910	0.25	0.7	14.1	34.1	48.3
6/16/93	93-120	Pgh-Ohio	55	23	Full	Ribbed	Saddle	280	100	172	172	0.8	4910	0.25	0.2	11.9	30.2	44.4
9/2/93	93-129A	Pgh-Greene	60	20	Full	Ribbed	Saddle	500	100	4	4	0.8	4912	0.50	1.1	25.2	51.1	64.2
9/3/93	93-129B	Pgh-Greene	60	20	Full	Ribbed	Saddle	500	100	4.25	4.25	1	4912	0.50	2.3	22.4	43.8	57.1
9/3/93	93-129C	Pgh-Greene	60	20	Full	Ribbed	Saddle	500	100	4.5	4.5	0.8	4912	0.25	0.9	17.2	39.4	54.3
9/2/93	93-129D	Pgh-Greene	60	20	Full	Ribbed	Saddle	500	100	4.75	4.75	0.8	6800	0.50	0.3	7.8	20.5	34.2

9/3/93	93-129E	Pgh-Greene	60	20	Full	Ribbed	Saddle	500	100	5	5	0.8	6800	0.25	0	3.8	13.2	20.1
9/3/93	93-129F	Pgh-Greene	60	20	Full	Ribbed	Saddle	500	100	5.25	5.25	1	6800	0.25	0.2	4.6	15.3	27.3
9/3/93	93-129G	Pgh-Greene	60	20	Full	Ribbed	Saddle	500	100	5.5	5.5	0.8	3500	0.25	3.4	34.9	56.2	66.7
9/2/93	93-129H	Pgh-Greene	60	20	Full	Ribbed	Saddle	500	100	5.75	5.75	0.8	3500	0.13	1.9	33.8	56.8	67.6
9/4/93	93-129I	Pgh-Greene	60	20	Full	Ribbed	Saddle	500	100	6	6	1	3500	0.13	1.8	30.6	53.9	65.2
9/3/93	93-129J	Pgh-Greene	60	20	Full	Ribbed	Saddle	500	100	6.25	6.25	0.8	3500	0.06	0.1	25.5	51.5	64.4
9/7/93	93-129K	Pgh-Greene	60	20	Full	Ribbed	Saddle	200	100	6.5	6.5	0.8	4912	0.50	0.4	14.4	31.6	42.3
9/7/93	93-129L	Pgh-Greene	60	20	Full	Ribbed	Saddle	300	100	6.75	6.75	0.8	4912	0.50	0.6	16	35.7	50.7
9/7/93	93-129M	Pgh-Greene	60	20	Full	Ribbed	Saddle	400	100	7	7	0.8	4912	0.50	1	17.8	35.6	47.6
9/4/93	93-129N	Pgh-Greene	60	20	Full	Ribbed	Saddle	500	100	7.25	7.25	0.8	4912	0.50	2	19.5	39.5	53.4
9/4/93	93-129O	Pgh-Greene	60	20	Full	Ribbed	Saddle	600	100	7.5	7.5	0.8	4912	0.50	1.7	19.8	40.7	54.5
9/7/93	93-129P	Pgh-Greene	60	20	Half	Ribbed	Saddle	200	100	7.75	7.75	0.8	4912	0.50	1.2	21	40.5	54.2
9/2/93	93-129Q	Pgh-Greene	60	20	Half	Ribbed	Saddle	400	100	8	8	0.8	4912	0.50	0.3	22.7	42.4	55.8
9/4/93	93-129R	Pgh-Greene	60	20	Half	Ribbed	Saddle	600	100	8.25	8.25	0.8	4912	0.50	3	29.2	49.1	60.6
9/3/93	93-129S	Pgh-Greene	60	20	Half	Ribbed	Saddle	500	100	8.5	8.5	0.8	6800	0.50	0.8	14.5	33.5	49.4
9/3/93	93-129T	Pgh-Greene	60	20	Half	Ribbed	Saddle	500	100	8.75	8.75	0.8	3500	0.13	4.2	41.3	60	66.7
9/14/93	93-132	Pgh-Greene	60	20	Full	Ribbed	Saddle	500	100	14	14	0.8	3202	0.13	1.4	30.6	53.7	65.2
9/16/93	93-135	Pgh-Greene	60	20	Full	Ribbed	Saddle	500	100	28	28	0.8	4912	0.50	1.4	18.5	38.4	52.8
9/21/93	93-137	Pgh-Greene	60	20	Full	Ribbed	Saddle	450	100	33	33	0.8	4912	0.50	2	19.4	38.3	52.2
9/22/93	93-138	Pgh-Greene	60	20	Full	Ribbed	Saddle	500	100	37	37	0.8	4912	0.50	1.3	18.7	38.8	52.8
9/23/93	93-139	Pgh-Greene	60	20	Full	Ribbed	Saddle	500	100	45	45	0.8	3200	0.13	2.9	38.8	60.5	70.6
9/27/93	93-141	Pgh-Greene	60	20	Full	Ribbed	Saddle	500	100	50	50	0.8	3200	0.13	1.4	33	55.4	65.6
9/30/93	93-144	Pgh-Greene	60	20	Full	Ribbed	Saddle	500	100	65.75	65.75	0.8	4912	0.50	1.5	22	41.9	55.5
10/4/93	94-001	Pgh-Greene	60	20	Full	Ribbed	Saddle	500	100	71.25	71.25	0.8	6750	0.50	0.5	9.2	23.4	36.1
10/5/93	94-002	Pgh-Greene	60	20	Full	Ribbed	Saddle	500	100	76.75	76.75	0.8	6750	0.50	1.2	12.3	26.4	40.1
10/6/93	94-3	Pgh-Greene	60	20	Full	Ribbed	Saddle	500	100	86.75	86.75	0.8	4912	0.50	2	21	40.3	53.5
10/7/93	94-5	Pgh-Greene	60	20	Full	Ribbed	Saddle	500	100	95.75	95.75	0.8	4912	0.50	2.5	21.7	40.5	54
10/13/93	94-008A	Pgh-Greene	60	20	Full	Ribbed	Saddle	500	100	109	109	0.8	2572	0.13	4.5	47.4	66.5	73.8
10/13/93	94-008B	Pgh-Greene	60	20	Full	Ribbed	Saddle	500	100	109	109	0.8	2572	0.25	7.7	49.1	66.4	74
10/13/93	94-008D	Pgh-Greene	60	20	Full	Smooth	Saddle	500	100	110	110	0.8	2572	0.25	17	60.5	73.4	79.1
10/13/93	94-008E	Pgh-Greene	60	20	Full	Smooth	Saddle	500	100	110	110	0.8	3190	0.13	3.4	45.9	65.1	72.8
10/13/93	94-008F	Pgh-Greene	60	20	Full	Smooth	Saddle	500	100	110	110	0.8	4912	0.50	6.4	37.2	54.9	64.7
10/13/93	94-008G	Pgh-Greene	60	20	Full	Ribbed	Saddle	500	100	110	110	0.8	3190	0.13	2.2	33.7	55.6	67.3
10/13/93	94-008H	Pgh-Greene	60	20	Full	Ribbed	Saddle	500	100	111	111	0.8	4912	0.50	1.5	16.5	35.4	50.3
10/15/93	94-010	Pgh-Greene	60	20	Full	Ribbed	Saddle	500	100	111	111	0.8	4912	0.50	1.4	17.8	36.3	53.7
10/18/93	94-11	Pgh-Greene	60	20	Full	Ribbed	Saddle	500	100	118	118	0.8	4912	0.50	1.3	17.1	36.3	51.1
10/19/93	94-12	Pgh-Greene	60	20	Full	Ribbed	Saddle	500	100	126	126	0.8	4912	0.50	3.7	23.6	41.1	56.3
10/20/93	94-14	Pgh-Greene	60	20	Full	Ribbed	Saddle	500	100	131	131	0.8	4912	0.50	1	17.3	36.4	50.1

10/21/93	94-15	Pgh-Greene	60	20	Full	Ribbed	Saddle	500	100	140	140	0.8	4912	0.50	1.6	18.5	38.2	51.6
10/25/93	94-18	Pgh-Greene	60	20	Full	Ribbed	Saddle	500	100	150	150	0.8	4912	0.50	2.4	21.1	39.7	52.9
10/26/93	94-19	Pgh-Greene	60	20	Full	Ribbed	Saddle	500	100	158	158	0.8	4912	0.50	2.4	22.6	40.3	56.5
10/28/93	94-021A	Illinois	55	32	Full	Ribbed	Saddle	500	100	168	168	0.8	4912	0.50	3.5	27.6	47.6	60.8
10/28/93	94-021B	Illinois	55	32	Full	Smooth	Saddle	500	100	168	168	0.8	4912	0.50	13.4	48.7	65.1	72.5
10/28/93	94-021C	Illinois	55	32	Full	Smooth	Saddle	500	100	168	168	0.8	3205	0.13	5.2	42.5	57.4	63.8
10/28/93	94-021D	Illinois	55	32	Full	Ribbed	Saddle	500	100	169	169	0.8	3205	0.13	2.7	34.4	50.3	59.2
10/28/93	94-021E	Illinois	55	32	Full	Ribbed	Saddle	500	100	169	169	0.8	2619	0.13	4.9	45.4	60.7	66.5
10/28/93	94-021H	Illinois	55	32	Full	Ribbed	Saddle	500	100	169	169	0.8	2619	0.25	9.8	44.9	58.3	64.3
10/28/93	94-021I	Illinois	55	32	Full	Ribbed	Saddle	500	100	170	170	0.8	6796	0.50	0.2	5.1	15.6	27.9
10/28/93	94-02J	Illinois	55	32	Full	Smooth	Saddle	500	100	170	170	0.8	6796	0.50	2.1	18	32.7	43.3
10/28/93	94-021K	Illinois	55	32	Full	Ribbed	Saddle	500	100	170	170	0.8	6796	0.13	0.6	7.1	16.4	27.8
10/28/93	94-021L	Illinois	55	32	Full	Ribbed	Saddle	500	100	170	170	0.8	4922	0.13	0.9	13.3	28.4	39.2
11/15/93	94-31	Illinois	55	32	Full	Ribbed	Saddle	350	100	196	196	0.8	4922	0.13	1.4	22.1	42.4	55.2
11/16/93	94-32	Illinois	55	32	Full	Ribbed	Saddle	350	100	202	202	0.8	4922	0.13	5	27.6	45	57.3
11/17/93	94-33	Illinois	55	32	Full	Ribbed	Saddle	350	100	211	211	0.8	4922	0.13	5.9	29.9	47.9	59.9
11/18/93	94-34	Illinois	55	32	Full	Ribbed	Saddle	350	100	0	0	0.8	4922	0.13	4.4	26.2	44.3	55.4
12/1/93	94-38	Illinois	55	32	Full	Ribbed	Saddle	500	100	3	3	0.8	4922	0.13	1.8	21.4	40.2	53
12/2/93	94-39	Illinois	55	32	Full	Ribbed	Saddle	500	100	15	15	0.8	4922	0.13	3	22.8	40.9	53.6
12/16/93	94-44	Illinois	55	32	Full	Ribbed	Saddle	600	100	40	40	0.8	4922	0.13	5.7	30.6	48.1	59.1
4/29/94	94-057A	Pgh-Greene	60	20	Full	Ribbed	Bar	500	100	26	26	0.8	4925	0.25	2.4	30	53	64
4/29/94	94-057B	Pgh-Greene	60	20	Full	Ribbed	Bar	500	100	26	26	0.8	4925	0.5	8.1	40	59	70
5/2/94	94-057C	Pgh-Greene	60	20	Full	Ribbed	Bar	500	100	26	26	0.8	6824	0.5	5	27	46	59
5/2/94	94-057D	Pgh-Greene	60	20	Full	Ribbed	Bar	500	100	27	27	0.8	6824	0.25	2.3	24	48	65
5/2/94	94-057E	Pgh-Greene	60	20	Full	Ribbed	Bar	500	100	27	27	0.8	2615	0.25	22	69	80	84
5/4/94	94-057F	Pgh-Greene	60	20	Full	Ribbed	Bar	500	100	27	27	0.8	2615	0.5	37	69	77	80
5/4/94	94-057G	Pgh-Greene	60	20	Full	Ribbed	Bar	500	100	27	27	0.8	3196	0.5	21	62	75	81
5/4/94	94-057H	Pgh-Greene	60	20	Full	Ribbed	Bar	500	100	28	28	0.8	3196	0.25	14	62	78	83
5/5/94	94-057I	Pgh-Greene	60	20	Full	Ribbed	Bar	500	100	28	28	1	3196	0.25	11	58	75	83
5/5/94	94-057K	Pgh-Greene	60	20	Full	Ribbed	Saddle	500	100	28	28	0.8	3196	0.5	7	43	63	72

TABLE 2
EXPERIMENTAL OPERATING PARAMETERS AND SIEVE ANALYSES (sorted by D-80 size)

HG	Ash	Set	Hammer	Liner	Op-Hrs	Feed	Swp	Sped	Scrn	+28	+100	+200	+325
90	26	1 (F)	1 (S)	1 (R)	0	250	0.6	6750	0.06	0	0.2	2.5	6.5
90	26	1 (F)	1 (S)	1 (R)	0	250	0.6	6750	0.25	0	1.1	4	9.5
90	26	1 (F)	1 (S)	1 (R)	19	210	0.8	6840	0.25	0	0.9	4.4	10.2
90	26	1 (F)	1 (S)	1 (R)	13	210	0.8	6840	0.25	0	1.5	5.6	12.6
60	20	1 (F)	1 (S)	1 (R)	5	500	0.8	6800	0.25	0	3.8	13.2	20.1
90	26	1 (F)	1 (S)	1 (R)	1	250	1	6750	0.5	0	6.4	14.8	22.4
60	20	1 (F)	1 (S)	1 (R)	5.25	500	1	6800	0.25	0.2	4.6	15.3	27.3
55	32	1 (F)	1 (S)	1 (R)	170	500	0.8	6796	0.5	0.2	5.1	15.6	27.9
55	23	1 (F)	1 (S)	1 (R)	69	225	0.8	6109	0.25	0	5	15.7	28.1
90	26	1 (F)	1 (S)	1 (R)	7	210	0.8	6840	0.5	0.7	8.6	17.4	25.6
55	32	1 (F)	1 (S)	1 (R)	170	500	0.8	6796	0.13	0.6	7.1	16.4	27.8
55	23	1 (F)	1 (S)	1 (R)	67	150	0.8	6109	0.25	0.1	5.7	17.2	28.6
55	23	1 (F)	1 (S)	1 (R)	75	300	0.8	6109	0.25	0	6.1	18	30
90	26	1 (F)	1 (S)	1 (R)	30	230	0.8	4919	0.25	0.2	6.9	18.6	30.9
55	23	1 (F)	1 (S)	1 (R)	63.5	225	0.8	6109	0.25	0.2	6.5	19.2	32.6
90	26	1 (F)	1 (S)	1 (R)	2	250	0.6	4912	0.25	0.2	7.3	19.3	31.3
60	20	1 (F)	1 (S)	1 (R)	4.75	500	0.8	6800	0.5	0.3	7.8	20.5	34.2
90	26	1 (F)	1 (S)	1 (R)	30	210	0.8	4919	0.25	0.9	9.3	21.2	32.4
55	23	1 (F)	1 (S)	1 (R)	54	225	0.8	6109	0.25	0.1	8	22	34.9
60	20	1 (F)	1 (S)	1 (R)	71.25	500	0.8	6750	0.5	0.5	9.2	23.4	36.1
55	23	1 (F)	1 (S)	1 (R)	54	500	0.8	6109	0.25	0.3	10.2	26	39.9
60	20	1 (F)	1 (S)	1 (R)	76.75	500	0.8	6750	0.5	1.2	12.3	26.4	40.1
55	23	1 (F)	1 (S)	1 (R)	120	250	0.8	4912	0.25	1.1	12.3	27.4	44.5
55	23	1 (F)	1 (S)	1 (R)	113	250	0.8	4910	0.25	0.3	12	28.6	43.5
55	23	1 (F)	1 (S)	1 (R)	54	225	0.8	4912	0.13	0.5	11.8	29.9	44.1
55	23	1 (F)	1 (S)	1 (R)	82	300	0.8	4916	0.25	0.4	11.7	30.1	44.4
55	23	1 (F)	1 (S)	1 (R)	172	280	0.8	4910	0.25	0.2	11.9	30.2	44.4
55	32	1 (F)	1 (S)	1 (R)	170	500	0.8	4922	0.13	0.9	13.3	28.4	39.2
55	23	1 (F)	1 (S)	1 (R)	151	280	0.8	4910	0.25	0.7	13	29.2	43.4
55	23	1 (F)	1 (S)	1 (R)	86	250	0.8	4916	0.25	0.3	12.5	30.3	43.8
55	23	1 (F)	1 (S)	1 (R)	141	280	0.8	4910	0.25	0.6	12.6	30.1	43.4
55	23	1 (F)	1 (S)	1 (R)	100	250	0.8	4916	0.25	0.8	12.6	31.6	45.7
55	23	1 (F)	1 (S)	1 (R)	134	280	0.8	4910	0.25	0.7	14	32	44.6
60	20	1 (F)	1 (S)	1 (R)	6.5	200	0.8	4912	0.5	0.4	14.4	31.6	42.3
55	23	1 (F)	1 (S)	1 (R)	161	280	0.8	4910	0.25	0.7	14.1	34.1	48.3
60	20	0 (H)	1 (S)	1 (R)	8.5	500	0.8	6800	0.5	0.8	14.5	33.5	49.4
60	20	1 (F)	1 (S)	1 (R)	6.75	300	0.8	4912	0.5	0.6	16	35.7	50.7
60	20	1 (F)	1 (S)	1 (R)	118	500	0.8	4912	0.5	1.3	17.1	36.3	51.1
60	20	1 (F)	1 (S)	1 (R)	111	500	0.8	4912	0.5	1.5	17.1	35.8	52.0
60	20	1 (F)	1 (S)	1 (R)	131	500	0.8	4912	0.5	1	17.3	36.4	50.1
55	32	1 (F)	1 (S)	0 (S)	170	500	0.8	6796	0.5	2.1	18	32.7	43.3
60	20	1 (F)	1 (S)	1 (R)	4.5	500	0.8	4912	0.25	0.9	17.2	39.4	54.3
60	20	1 (F)	1 (S)	1 (R)	7	400	0.8	4912	0.5	1	17.8	35.6	47.6
60	20	1 (F)	1 (S)	1 (R)	28	500	0.8	4912	0.5	1.4	18.5	38.4	52.8
60	20	1 (F)	1 (S)	1 (R)	140	500	0.8	4912	0.5	1.6	18.5	38.2	51.6
60	20	1 (F)	1 (S)	1 (R)	37	500	0.8	4912	0.5	1.3	18.7	38.8	52.8
60	20	1 (F)	1 (S)	1 (R)	33	450	0.8	4912	0.5	2	19.4	38.3	52.2
60	20	1 (F)	1 (S)	1 (R)	7.25	500	0.8	4912	0.5	2	19.5	39.5	53.4
60	20	1 (F)	1 (S)	1 (R)	7.5	600	0.8	4912	0.5	1.7	19.8	40.7	54.5

60	20	0 (H)	1 (S)	1 (R)	7.75	200	0.8	4912	0.5	1.2	21	40.5	54.2
60	20	1 (F)	1 (S)	1 (R)	86.75	500	0.8	4912	0.5	2	21	40.3	53.5
60	20	1 (F)	1 (S)	1 (R)	150	500	0.8	4912	0.5	2.4	21.1	39.7	52.9
55	32	1 (F)	1 (S)	1 (R)	3	500	0.8	4922	0.13	1.8	21.4	40.2	53
60	20	1 (F)	1 (S)	1 (R)	95.75	500	0.8	4912	0.5	2.5	21.7	40.5	54
60	20	0 (H)	1 (S)	1 (R)	8	400	0.8	4912	0.5	0.3	22.7	42.4	55.8
60	20	1 (F)	1 (S)	1 (R)	65.75	500	0.8	4912	0.5	1.5	22	41.9	55.5
55	32	1 (F)	1 (S)	1 (R)	196	350	0.8	4922	0.13	1.4	22.1	42.4	55.2
60	20	1 (F)	1 (S)	1 (R)	4.25	500	1	4912	0.5	2.3	22.4	43.8	57.1
60	20	1 (F)	1 (S)	1 (R)	158	500	0.8	4912	0.5	2.4	22.6	40.3	56.5
55	32	1 (F)	1 (S)	1 (R)	15	500	0.8	4922	0.13	3	22.8	40.9	53.6
60	20	1 (F)	1 (S)	1 (R)	6.25	500	0.8	3500	0.06	0.1	25.5	51.5	64.4
60	20	1 (F)	0 (B)	1 (R)	27	500	0.8	6824	0.25	2.3	24	48	65
60	20	1 (F)	1 (S)	1 (R)	4	500	0.8	4912	0.5	1.1	25.2	51.1	64.2
60	20	1 (F)	1 (S)	1 (R)	126	500	0.8	4912	0.5	3.7	23.6	41.1	56.3
55	32	1 (F)	1 (S)	1 (R)	0	350	0.8	4922	0.13	4.4	26.2	44.3	55.4
55	23	1 (F)	1 (S)	1 (R)	112.75	500	0.8	3500	0.13	2.1	28.9	51.6	63
55	32	1 (F)	1 (S)	1 (R)	168	500	0.8	4912	0.5	3.5	27.6	47.6	60.8
60	20	1 (F)	1 (S)	1 (R)	14	500	0.8	3202	0.13	1.4	30.6	53.7	65.2
60	20	1 (F)	0 (B)	1 (R)	26	500	0.8	6824	0.5	5	27	46	59
60	20	1 (F)	1 (S)	1 (R)	6	500	1	3500	0.13	1.8	30.6	53.9	65.2
60	20	0 (H)	1 (S)	1 (R)	8.25	600	0.8	4912	0.5	3	29.2	49.1	60.6
60	20	1 (F)	0 (B)	1 (R)	26	500	0.8	4925	0.25	2.4	30	53	64
55	32	1 (F)	1 (S)	1 (R)	202	350	0.8	4922	0.13	5	27.6	45	57.3
60	20	1 (F)	1 (S)	1 (R)	50	500	0.8	3200	0.13	1.4	33	55.4	65.6
60	20	1 (F)	1 (S)	1 (R)	5.75	500	0.8	3500	0.13	1.9	33.8	56.8	67.6
60	20	1 (F)	1 (S)	1 (R)	110	500	0.8	3190	0.13	2.2	33.7	55.6	67.3
55	23	1 (F)	1 (S)	1 (R)	112.5	500	0.8	3500	0.25	4.1	31.2	52.4	64.9
55	32	1 (F)	1 (S)	1 (R)	169	500	0.8	3205	0.13	2.7	34.4	50.3	59.2
55	32	1 (F)	1 (S)	1 (R)	211	350	0.8	4922	0.13	5.9	29.9	47.9	59.9
55	32	1 (F)	1 (S)	1 (R)	40	600	0.8	4922	0.13	5.7	30.6	48.1	59.1
60	20	1 (F)	1 (S)	1 (R)	5.5	500	0.8	3500	0.25	3.4	34.9	56.2	66.7
60	20	1 (F)	1 (S)	1 (R)	45	500	0.8	3200	0.13	2.9	38.8	60.5	70.6
60	20	0 (H)	1 (S)	1 (R)	8.75	500	0.8	3500	0.13	4.2	41.3	60	66.7
60	20	1 (F)	1 (S)	0 (S)	110	500	0.8	4912	0.5	6.4	37.2	54.9	64.7
60	20	1 (F)	1 (S)	0 (S)	110	500	0.8	3190	0.13	3.4	45.9	65.1	72.8
55	32	1 (F)	1 (S)	0 (S)	168	500	0.8	3205	0.13	5.2	42.5	57.4	63.8
55	32	1 (F)	1 (S)	1 (R)	169	500	0.8	2619	0.13	4.9	45.4	60.7	66.5
60	20	1 (F)	1 (S)	1 (R)	109	500	0.8	2572	0.13	4.5	47.4	66.5	73.8
60	20	1 (F)	0 (B)	1 (R)	26	500	0.8	4925	0.5	8.1	40	59	70
60	20	1 (F)	1 (S)	1 (R)	28	500	0.8	3196	0.5	7	43	63	72
60	20	1 (F)	1 (S)	1 (R)	109	500	0.8	2572	0.25	7.7	49.1	66.4	74
55	32	1 (F)	1 (S)	1 (R)	169	500	0.8	2619	0.25	9.8	44.9	58.3	64.3
60	20	1 (F)	0 (B)	1 (R)	28	500	1	3196	0.25	11	58	75	83
55	32	1 (F)	1 (S)	0 (S)	168	500	0.8	4912	0.5	13.4	48.7	65.1	72.5
60	20	1 (F)	0 (B)	1 (R)	28	500	0.8	3196	0.25	14	62	78	83
60	20	1 (F)	1 (S)	0 (S)	110	500	0.8	2572	0.25	17	60.5	73.4	79.1
60	20	1 (F)	0 (B)	1 (R)	27	500	0.8	3196	0.5	21	62	75	81
60	20	1 (F)	0 (B)	1 (R)	27	500	0.8	2615	0.25	22	69	80	84
60	20	1 (F)	0 (B)	1 (R)	27	500	0.8	2615	0.5	37	69	77	80

TABLE 3
CALCULATED COAL FRACTIONS AND ROSIN-RAMMLER PARAMETERS (sorted by D-80 size)

28x100	100x200	200x325	-325	28x200	100x325	-200	28x325	-100	-28	Slope	Const
0.2	2.3	4	93.5	2.5	6.3	97.5	100	6.5	99.8	0.677	-1.577
1.1	2.9	5.5	90.5	4	8.4	96	100	9.5	98.9	0.53	-1.137
0.9	3.5	5.8	89.8	4.4	9.3	95.6	100	10.2	99.1	0.594	-1.419
1.5	4.1	7	87.4	5.6	11.1	94.4	100	12.6	98.5	0.577	-1.444
3.8	9.4	6.9	79.9	13.2	16.3	86.8	100	20.1	96.2	0.589	-1.785
6.4	8.4	7.6	77.6	14.8	16	85.2	100	22.4	93.6	0.5	-1.494
4.4	10.7	12	72.7	15.1	22.7	84.7	99.8	27.1	95.4	0.597	-1.949
4.9	10.5	12.3	72.1	15.4	22.8	84.4	99.8	27.7	94.9	0.603	-1.99
5	10.7	12.4	71.9	15.7	23.1	84.3	100	28.1	95	0.703	-2.417
7.9	8.8	8.2	74.4	16.7	17	82.6	99.3	24.9	91.4	0.497	-1.575
6.5	9.3	11.4	72.2	15.8	20.7	83.6	99.4	27.2	92.9	0.524	-1.693
5.6	11.5	11.4	71.4	17.1	22.9	82.8	99.9	28.5	94.3	0.657	-2.255
6.1	11.9	12	70	18	23.9	82	100	30	93.9	0.691	-2.433
6.7	11.7	12.3	69.1	18.4	24	81.4	99.8	30.7	93.1	0.637	-2.231
6.3	12.7	13.4	67.4	19	26.1	80.8	99.8	32.4	93.5	0.654	-2.324
7.1	12	12	68.7	19.1	24	80.7	99.8	31.1	92.7	0.643	-2.272
7.5	12.7	13.7	65.8	20.2	26.4	79.5	99.7	33.9	92.2	0.643	-2.326
8.4	11.9	11.2	67.6	20.3	23.1	78.8	99.1	31.5	90.7	0.547	-1.92
7.9	14	12.9	65.1	21.9	26.9	78	99.9	34.8	92	0.724	-2.694
8.7	14.2	12.7	63.9	22.9	26.9	76.6	99.5	35.6	90.8	0.632	-2.346
9.9	15.8	13.9	60.1	25.7	29.7	74	99.7	39.6	89.8	0.708	-2.746
11.1	14.1	13.7	59.9	25.2	27.8	73.6	98.8	38.9	87.7	0.6	-2.314
11.2	15.1	17.1	55.5	26.3	32.2	72.6	98.9	43.4	87.7	0.646	-2.572
11.7	16.6	14.9	56.5	28.3	31.5	71.4	99.7	43.2	88	0.744	-2.985
11.3	18.1	14.2	55.9	29.4	32.3	70.1	99.5	43.6	88.2	0.718	-2.891
11.3	18.4	14.3	55.6	29.7	32.7	69.9	99.6	44	88.3	0.737	-2.98
11.7	18.3	14.2	55.6	30	32.5	69.8	99.8	44.2	88.1	0.784	-3.182
12.4	15.1	10.8	60.8	27.5	25.9	71.6	99.1	38.3	86.7	0.625	-2.438
12.3	16.2	14.2	56.6	28.5	30.4	70.8	99.3	42.7	87	0.682	-2.734
12.2	17.8	13.5	56.2	30	31.3	69.7	99.7	43.5	87.5	0.753	-3.046
12	17.5	13.3	56.6	29.5	30.8	69.9	99.4	42.8	87.4	0.698	-2.809
11.8	19	14.1	54.3	30.8	33.1	68.4	99.2	44.9	87.4	0.699	-2.856
13.3	18	12.6	55.4	31.3	30.6	68	99.3	43.9	86	0.701	-2.866
14	17.2	10.7	57.7	31.2	27.9	68.4	99.6	41.9	85.6	0.723	-2.933
13.4	20	14.2	51.7	33.4	34.2	65.9	99.3	47.6	85.9	0.739	-3.092
13.7	19	15.9	50.6	32.7	34.9	66.5	99.2	48.6	85.5	0.734	-3.083
15.4	19.7	15	49.3	35.1	34.7	64.3	99.4	50.1	84	0.775	-3.304
15.8	19.2	14.8	48.9	35	34	63.7	98.7	49.8	82.9	0.714	-3.066
15.7	18.7	16.1	48	34.4	34.8	64.2	98.5	50.5	82.9	0.709	-3.055
16.3	19.1	13.7	49.9	35.4	32.8	63.6	99	49.1	82.7	0.73	-3.12
15.9	14.7	10.6	56.7	30.6	25.3	67.3	97.9	41.2	82	0.59	-2.416
16.3	22.2	14.9	45.7	38.5	37.1	60.6	99.1	53.4	82.8	0.786	-3.44
16.8	17.8	12	52.4	34.6	29.8	64.4	99	46.6	82.2	0.705	-2.984
17.1	19.9	14.4	47.2	37	34.3	61.6	98.6	51.4	81.5	0.729	-3.178
16.9	19.7	13.4	48.4	36.6	33.1	61.8	98.4	50	81.5	0.705	-3.061
17.4	20.1	14	47.2	37.5	34.1	61.2	98.7	51.5	81.3	0.737	-3.218
17.4	18.9	13.9	47.8	36.3	32.8	61.7	98	50.2	80.6	0.687	-3.001
17.5	20	13.9	46.6	37.5	33.9	60.5	98	51.4	80.5	0.702	-3.091
18.1	20.9	13.8	45.5	39	34.7	59.3	98.3	52.8	80.2	0.732	-3.246

19.8	19.5	13.7	45.8	39.3	33.2	59.5	98.8	53	79	0.76	-3.367
19	19.3	13.2	46.5	38.3	32.5	59.7	98	51.5	79	0.705	-3.121
18.7	18.6	13.2	47.1	37.3	31.8	60.3	97.6	50.5	78.9	0.678	-2.996
19.6	18.8	12.8	47	38.4	31.6	59.8	98.2	51.2	78.6	0.71	-3.14
19.2	18.8	13.5	46	38	32.3	59.5	97.5	51.5	78.3	0.686	-3.054
22.4	19.7	13.4	44.2	42.1	33.1	57.6	99.7	55.5	77.3	0.888	-3.961
20.5	19.9	13.6	44.5	40.4	33.5	58.1	98.5	54	78	0.756	-3.384
20.7	20.3	12.8	44.8	41	33.1	57.6	98.6	53.8	77.9	0.761	-3.41
20.1	21.4	13.3	42.9	41.5	34.7	56.2	97.7	54.8	77.6	0.734	-3.336
20.2	17.7	16.2	43.5	37.9	33.9	59.7	97.6	54.1	77.4	0.71	-3.194
19.8	18.1	12.7	46.4	37.9	30.8	59.1	97	50.6	77.2	0.663	-2.962
25.4	26	12.9	35.6	51.4	38.9	48.5	99.9	64.3	74.5	1.072	-4.969
21.7	24	17	35	45.7	41	52	97.7	62.7	76	0.825	-3.884
24.1	25.9	13.1	35.8	50	39	48.9	98.9	63.1	74.8	0.9	-4.227
19.9	17.5	15.2	43.7	37.4	32.7	58.9	96.3	52.6	76.4	0.661	-2.999
21.8	18.1	11.1	44.6	39.9	29.2	55.7	95.6	51	73.8	0.643	-2.955
26.8	22.7	11.4	37	49.5	34.1	48.4	97.9	60.9	71.1	0.825	-3.921
24.1	20	13.2	39.2	44.1	33.2	52.4	96.5	57.3	72.4	0.732	-3.447
29.2	23.1	11.5	34.8	52.3	34.6	46.3	98.6	63.8	69.4	0.894	-4.28
22	19	13	41	41	32	54	95	54	73	0.664	-3.116
28.8	23.3	11.3	34.8	52.1	34.6	46.1	98.2	63.4	69.4	0.871	-4.183
26.2	19.9	11.5	39.4	46.1	31.4	50.9	97	57.6	70.8	0.752	-3.557
27.6	23	11	36	50.6	34	47	97.6	61.6	70	0.826	-3.961
22.6	17.4	12.3	42.7	40	29.7	55	95	52.3	72.4	0.644	-3.002
31.6	22.4	10.2	34.4	54	32.6	44.6	98.6	64.2	67	0.903	-4.358
31.9	23	10.8	32.4	54.9	33.8	43.2	98.1	65.7	66.2	0.9	-4.398
31.5	21.9	11.7	32.7	53.4	33.6	44.4	97.8	65.1	66.3	0.877	-4.279
27.1	21.2	12.5	35.1	48.3	33.7	47.6	95.9	60.8	68.8	0.769	-3.737
31.7	15.9	8.9	40.8	47.6	24.8	49.7	97.3	56.5	65.6	0.751	-3.577
24	18	12	40.1	42	30	52.1	94.1	54	70.1	0.655	-3.127
24.9	17.5	11	40.9	42.4	28.5	51.9	94.3	53.4	69.4	0.653	-3.112
31.5	21.3	10.5	33.3	52.8	31.8	43.8	96.6	63.3	65.1	0.824	-4.06
35.9	21.7	10.1	29.4	57.6	31.8	39.5	97.1	67.7	61.2	0.902	-4.525
37.1	18.7	6.7	33.3	55.8	25.4	40	95.8	62.5	58.7	0.81	-4.082
30.8	17.7	9.8	35.3	48.5	27.5	45.1	93.6	58.3	62.8	0.713	-3.559
42.5	19.2	7.7	27.2	61.7	26.9	34.9	96.6	69.4	54.1	0.926	-4.767
37.3	14.9	6.4	36.2	52.2	21.3	42.6	94.8	58.6	57.5	0.739	-3.716
40.5	15.3	5.8	33.5	55.8	21.1	39.3	95.1	61.6	54.6	0.788	-4.017
42.9	19.1	7.3	26.2	62	26.4	33.5	95.5	69.3	52.6	0.91	-4.746
31.9	19	11	30	50.9	30	41	91.9	61.9	60	0.75	-3.864
36	20	9	28	56	29	37	93	65	57	0.813	-4.229
41.4	17.3	7.6	26	58.7	24.9	33.6	92.3	66.3	50.9	0.835	-4.441
35.1	13.4	6	35.7	48.5	19.4	41.7	90.2	54.5	55.1	0.65	-3.371
47	17	8	17	64	25	25	89	72	42	0.955	-5.336
35.3	16.4	7.4	27.5	51.7	23.8	34.9	86.6	59.1	51.3	0.713	-3.876
48	16	5	17	64	21	22	86	69	38	0.926	-5.294
43.5	12.9	5.7	20.9	56.4	18.6	26.6	83	62.1	39.5	0.789	-4.527
41	13	6	19	54	19	25	79	60	38	0.778	-4.562
47	11	4	16	58	15	20	78	62	31	0.848	-5.087
32	8	3	20	40	11	23	63	43	31	0.588	-3.822

TABLE 4
EXPERIMENTAL OPERATING PARAMETERS AND CALCULATED D-POINTS (sorted by D-80 size)

HG	Ash	S	H	L	Op-Hrs	Feed	Swp	Sped	Scrn	D-95	D-90	D-80	D-70	D-50	D-30
Group 1 - UNUS															
90	26	1	1	1	0	250	0.6	6750	0.06	51.6	32.7	17.6	10.6	4.1	1.3
90	26	1	1	1	0	250	0.6	6750	0.25	65.7	42.4	23.4	14.4	5.8	1.9
90	26	1	1	1	19	210	0.8	6840	0.25	69	44.6	24.6	15.2	6.1	2.0
90	26	1	1	1	13	210	0.8	6840	0.25	79.5	52	29.6	18.7	7.9	2.8
Group 2 - UNUS, Duo															
60	20	1	1	1	5	500	0.8	6800	0.25	131.1	89.3	44.3	23.2	6.8	1.5
90	26	1	1	1	1	250	1	6750	0.5	154.5	106	51.4	27.7	8.6	2.1
60	20	1	1	1	5.25	500	1	6800	0.25	143.3	98.8	59.6	39.6	18.2	7.1
55	32	1	1	1	170	500	0.8	6796	0.5	150.9	101.8	60.7	40.6	18.9	7.5
55	23	1	1	1	69	225	0.8	6109	0.25	149	101.6	61	40.9	19.1	7.7
90	26	1	1	1	7	210	0.8	6840	0.5	220.3	131.1	61.8	33.5	10.7	2.8
55	32	1	1	1	170	500	0.8	6796	0.13	193.5	115.5	62.1	40.1	17.5	6.4
55	23	1	1	1	67	150	0.8	6109	0.25	159.9	108.9	64.6	41.5	17.9	6.5
55	23	1	1	1	75	300	0.8	6109	0.25	153.4	112.8	67.4	44	19.5	7.4
90	26	1	1	1	30	230	0.8	4919	0.25	179.6	118.9	69.4	45.6	20.5	7.8
55	23	1	1	1	63.5	225	0.8	6109	0.25	173.9	117.5	71.6	48.4	23.1	9.4
90	26	1	1	1	2	250	0.6	4912	0.25	185	122.8	71.6	46.4	20.3	7.5
60	20	1	1	1	4.75	500	0.8	6800	0.5	195.3	128.2	75.7	51.3	24.6	10.1
90	26	1	1	1	30	210	0.8	4919	0.25	238.3	141.6	78.6	49	19.9	6.8
55	23	1	1	1	54	225	0.8	6109	0.25	188.4	131.3	80.4	53.3	24.2	9.4
60	20	1	1	1	71.25	500	0.8	6750	0.5	221.2	141.7	85.5	56.2	25	9.4
Group 3 - Unus, DUO															
55	23	1	1	1	54	500	0.8	6109	0.25	222.9	150.9	93.7	63.5	30	12.2
60	20	1	1	1	76.75	500	0.8	6750	0.5	289	177.4	99.1	64.4	30	12.0
55	23	1	1	1	120	250	0.8	4912	0.25	284.2	176.6	101.5	68.3	37	17.7
55	23	1	1	1	113	250	0.8	4910	0.25	239.6	166.9	103.3	70.4	34.8	14.9
55	23	1	1	1	54	225	0.8	4912	0.13	249.4	167	105.3	73.7	35.2	14.5
55	23	1	1	1	82	300	0.8	4916	0.25	243	165.2	105.4	74.2	35.7	14.7
55	23	1	1	1	172	280	0.8	4910	0.25	231.7	164.9	106	74.5	35.6	14.6
55	32	1	1	1	170	500	0.8	4922	0.13	284.2	184.9	106.6	68.4	25.9	8.1
55	23	1	1	1	151	280	0.8	4910	0.25	271.1	179.9	107.3	71.8	34.3	14.1
55	23	1	1	1	86	250	0.8	4916	0.25	243.7	170.9	107.8	74.8	34.4	13.5
55	23	1	1	1	141	280	0.8	4910	0.25	262.2	175.2	107.8	74.3	33.7	13.0
55	23	1	1	1	100	250	0.8	4916	0.25	272.5	177.2	110.3	78	37.3	15.3
55	23	1	1	1	134	280	0.8	4910	0.25	279.7	188.7	115.3	79.4	34.9	12.8
60	20	1	1	1	6.5	200	0.8	4912	0.5	265.1	187.2	116	78.5	29.9	9.2
55	23	1	1	1	161	280	0.8	4910	0.25	280.6	189.6	118.4	84.4	41.2	17.0
Group 4 - DUO, Tres															
60	20	0	1	1	8.5	500	0.8	6800	0.5	289.3	194.4	119.1	83.3	43.1	19.6
60	20	1	1	1	6.75	300	0.8	4912	0.5	289.1	202.7	127.3	89.4	45.1	19.7
60	20	1	1	1	118	500	0.8	4912	0.5	336	224.1	132.5	91.9	45.8	19.8

60	20	1	1	1	111	500	0.8	4912	0.5	344.3	227.1	132.5	91.1	47	21.9
60	20	1	1	1	131	500	0.8	4912	0.5	321.1	220.1	133.6	92.4	44.2	17.8
55	32	1	1	0	170	500	0.8	6796	0.5	385.7	246.3	134.3	83.6	31.4	9.5
60	20	1	1	1	4.5	500	0.8	4912	0.25	314.8	217.4	135	98.1	51.4	22.7
60	20	1	1	1	7	400	0.8	4912	0.5	324.4	223.8	135.5	91.2	39.5	13.9
60	20	1	1	1	28	500	0.8	4912	0.5	350.8	236.9	140.5	98.2	48.9	20.8
60	20	1	1	1	140	500	0.8	4912	0.5	361.6	240.8	140.5	97.8	46.9	18.7
60	20	1	1	1	37	500	0.8	4912	0.5	346.7	236.4	141.7	99.3	49	20.4
60	20	1	1	1	33	450	0.8	4912	0.5	389	255.8	145.4	99.5	47.9	19.7
60	20	1	1	1	7.25	500	0.8	4912	0.5	389.6	256.6	146.1	102	50.2	20.8
60	20	1	1	1	7.5	600	0.8	4912	0.5	375	252.7	147.9	104.7	52.5	21.8
60	20	0	1	1	7.75	200	0.8	4912	0.5	354.5	249.9	155.2	106.9	51.9	21.4
60	20	1	1	1	86.75	500	0.8	4912	0.5	398	267.7	156.1	106.5	50.8	20.1
60	20	1	1	1	150	500	0.8	4912	0.5	420.5	277.2	157.2	105.6	49.5	19.6
55	32	1	1	1	3	500	0.8	4922	0.13	389.3	266.1	158.5	107.2	49.9	19.2
60	20	1	1	1	95.75	500	0.8	4912	0.5	429.1	283.8	161.7	108.5	51.6	21.0
60	20	0	1	1	8	400	0.8	4912	0.5	304	232.8	161.9	114.1	55.5	22.7
60	20	1	1	1	65.75	500	0.8	4912	0.5	376.2	263.2	161.9	111.6	54.7	22.6
55	32	1	1	1	196	350	0.8	4922	0.13	371.2	261.5	162.3	112.6	54.7	21.4
60	20	1	1	1	4.25	500	1	4912	0.5	421.4	284.1	166.2	115.4	58.5	24.0
60	20	1	1	1	158	500	0.8	4912	0.5	427.8	287.8	167.8	110.4	54.7	26.0
55	32	1	1	1	15	500	0.8	4922	0.13	462.3	303.2	170.7	112	51.3	19.6
60	20	1	1	1	6.25	500	0.8	3500	0.06	291.4	232.7	171.4	131.8	77.2	33.7
60	20	1	0	1	27	500	0.8	6824	0.25	428.5	294.5	176.8	124.6	70	36.6
60	20	1	1	1	4	500	0.8	4912	0.5	369	271.3	178.6	130.6	76.3	33.5
60	20	1	1	1	126	500	0.8	4912	0.5	506.7	325.9	178.7	114.6	55	25.0

Group 5 - Duo, TRES, Quattuor

55	32	1	1	1	0	350	0.8	4922	0.13	555.7	361.4	201.2	128.3	57	19.4
55	23	1	1	1	112.75	500	0.8	3500	0.13	436.3	316.5	204.5	144	77.9	30.2
55	32	1	1	1	168	500	0.8	4912	0.5	505.6	345.5	205.8	136.8	67.7	28.5
60	20	1	1	1	14	500	0.8	3202	0.13	405.9	305.5	207.5	151.7	83.3	34.2
60	20	1	0	1	26	500	0.8	6824	0.5	595	383.1	210.4	133.2	63.5	26.0
60	20	1	1	1	6	500	1	3500	0.13	426.6	316.6	211	151.8	83.7	34.0
60	20	0	1	1	8.25	600	0.8	4912	0.5	483.1	341.1	212.4	144.8	71.2	26.6
60	20	1	0	1	26	500	0.8	4925	0.25	455	329.6	212.6	149	81.5	31.6
55	32	1	1	1	202	350	0.8	4922	0.13	595	386.5	214.9	135.1	60.3	23.1
60	20	1	1	1	50	500	0.8	3200	0.13	413.6	315.6	218.5	162.2	88.4	34.0
60	20	1	1	1	5.75	500	0.8	3500	0.13	441.2	333	227.1	166.6	92.1	38.6
60	20	1	1	1	110	500	0.8	3190	0.13	455.5	340.8	229.6	166.7	89.4	38.3
55	23	1	1	1	112.5	500	0.8	3500	0.25	544.9	379.7	232.2	155.9	80.4	34.3
55	32	1	1	1	169	500	0.8	3205	0.13	481.1	356.8	237.6	170.9	75	21.0
55	32	1	1	1	211	350	0.8	4922	0.13	652.6	425.5	237.7	148.4	67.9	26.1
55	32	1	1	1	40	600	0.8	4922	0.13	638.2	422.5	241	152.9	67.9	23.9
60	20	1	1	1	5.5	500	0.8	3500	0.25	515.4	377.1	246.6	174.7	91.7	36.5
60	20	1	1	1	45	500	0.8	3200	0.13	499.3	378.8	260.1	191.8	105.6	45.5

Group 6 - Tres, QUATTUOR, Pente

60	20	0	1	1	8.75	500	0.8	3500	0.13	559.6	420.7	285.3	208.2	109.2	33.1
60	20	1	1	0	110	500	0.8	4912	0.5	668.5	468.1	288.2	194.5	90.6	31.8
60	20	1	1	0	110	500	0.8	3190	0.13	530.8	414.2	295.5	224.7	130	53.8
55	32	1	1	0	168	500	0.8	3205	0.13	603.8	450.1	301.7	218.2	106	24.9

55	32	1	1	1	169	500	0.8	2619	0.13	590.9	450.2	311	230.4	122.1	31.1
60	20	1	1	1	109	500	0.8	2572	0.13	575.3	445.4	314.5	237.1	136.7	58.4

Group 7 - QUATTUOR, Pente

60	20	1	0	1	26	500	0.8	4925	0.5	757.1	527.6	322.8	216.7	104.6	44.0
60	20	1	1	1	28	500	0.8	3196	0.5	687	500.1	324.6	228.7	118.5	49.9
60	20	1	1	1	109	500	0.8	2572	0.25	703.9	529.8	359.9	263	144.2	58.6
55	32	1	1	1	169	500	0.8	2619	0.25	828.3	588.3	369.3	253.2	115.4	25.3

Group 8 - Quattuor, PENTE

60	20	1	0	1	28	500	1	3196	0.25	805	620.4	435.3	326.6	189.1	93.7
55	32	1	1	0	168	500	0.8	4912	0.5	1018.9	714.6	441	298.2	141.7	53.0
60	20	1	0	1	28	500	0.8	3196	0.25	898.7	694.5	489.1	368.1	214.4	108.9
60	20	1	1	0	110	500	0.8	2572	0.25	1059.5	793.4	535.3	389.1	212.1	90.9

Group 9 - PENTE

60	20	1	0	1	27	500	0.8	3196	0.5	1276.2	938	616.8	439.2	230.2	99.5
60	20	1	0	1	27	500	0.8	2615	0.25	1164.9	899	631.9	474.8	275.7	141.1
60	20	1	0	1	27	500	0.8	2615	0.5	2802	1936	1170.5	778.5	358.4	137.7

TABLE 5
MODIFIED BOND EQUATION ERROR FACTORS (sorted by D-80 size)

E-95	E-90	E-80	E-70	E-50	E-30						
0.233	0.358	0.635	1.005	2.292	5.735	0.214	0.287	0.421	0.555	0.896	1.435
0.183	0.276	0.477	0.74	1.62	3.924	0.624	0.825	1.168	1.421	1.926	2.499
0.119	0.18	0.314	0.488	1.094	2.742	0.59	0.797	1.16	1.433	1.976	2.563
0.103	0.154	0.261	0.397	0.845	1.959	0.723	0.934	1.28	1.556	2.118	2.764
0.658	0.901	1.613	2.737	6.963	19.410	0.579	0.779	1.128	1.395	1.896	2.392
0.078	0.11	0.217	0.385	1.093	3.550	0.807	0.955	1.166	1.408	1.97	2.629
0.602	0.814	1.199	1.603	2.601	4.101	0.66	0.839	1.126	1.356	1.788	2.222
0.664	0.914	1.35	1.778	2.798	4.231	0.435	0.562	0.773	0.954	1.352	1.913
0.24	0.336	0.518	0.714	1.247	2.166	0.589	0.778	1.097	1.312	1.672	2.093
0.037	0.061	0.125	0.221	0.624	1.959	0.58	0.768	1.087	1.371	1.788	1.932
0.518	0.805	1.319	1.8	3.021	4.958	0.609	0.82	1.188	1.489	2.06	2.708
0.106	0.15	0.24	0.353	0.708	1.494	2.177	2.269	2.306	2.293	2.165	2.155
0.39	0.501	0.759	1.051	1.841	3.157	0.418	0.567	0.84	1.059	1.408	1.659
0.186	0.269	0.427	0.602	1.099	2.041	0.673	0.814	1.021	1.159	1.282	1.499
0.206	0.291	0.442	0.603	1.031	1.774	0.49	0.678	1.02	1.321	1.779	2.009
0.211	0.304	0.48	0.682	1.261	2.362	0.291	0.407	0.624	0.837	1.297	2.110
0.442	0.627	0.944	1.238	1.925	2.883	1.616	1.836	2.099	2.256	2.263	2.491
0.119	0.192	0.322	0.482	0.987	2.083	0.56	0.723	0.991	1.225	1.567	1.867
0.19	0.26	0.393	0.548	0.984	1.774	1.932	2.095	2.247	2.301	2.231	2.276
0.4	0.582	0.855	1.154	1.93	3.143	0.301	0.436	0.706	0.991	1.552	2.335
0.642	0.867	1.202	1.53	2.267	3.152	1.487	1.668	1.873	1.991	1.997	2.136
0.306	0.465	0.738	1.007	1.608	2.462	0.944	1.17	1.512	1.803	2.27	2.973
0.327	0.49	0.754	0.992	1.353	1.719	1.137	1.397	1.789	2.12	2.508	3.326
0.389	0.519	0.742	0.964	1.44	2.043	0.272	0.38	0.584	0.795	1.226	1.772
0.311	0.435	0.617	0.787	1.243	1.888	1.899	2.031	2.137	2.154	2.104	2.290
0.519	0.702	0.956	1.18	1.745	2.448	1.438	1.585	1.74	1.814	1.815	1.881
0.487	0.632	0.86	1.071	1.618	2.321	1.736	1.893	2.045	2.106	2.087	2.038
0.99	1.344	1.903	2.438	4.081	6.553	1.294	1.531	1.849	2.084	2.193	2.193
0.416	0.579	0.85	1.111	1.679	2.404	1.794	1.956	2.113	2.176	2.595	3.818
0.381	0.505	0.709	0.904	1.453	2.250	0.248	0.346	0.528	0.724	1.089	1.568
0.43	0.595	0.846	1.074	1.709	2.607	0.575	0.754	1.052	1.333	1.824	2.481
0.34	0.487	0.693	0.867	1.34	1.985	1.231	1.4	1.603	1.73	1.823	1.990
0.403	0.552	0.791	1.005	1.65	2.648	1.573	1.692	1.795	1.821	1.761	1.711
0.204	0.274	0.402	0.54	1.111	2.385	1.587	1.757	1.939	2.032	2.143	3.072
0.402	0.55	0.77	0.945	1.398	1.994	0.594	0.755	1.012	1.245	1.728	2.527
0.417	0.579	0.84	1.067	1.538	2.080	2.384	2.492	2.542	2.499	2.297	2.321
0.378	0.499	0.696	0.869	1.248	1.691	2.287	2.481	2.662	2.727	2.937	5.152
0.739	0.986	1.376	1.647	2.136	2.537	2.193	2.225	2.183	2.087	1.913	2.893
0.721	0.973	1.376	1.662	2.081	2.293	2.15	2.159	2.087	1.971	1.675	1.522
0.773	1.004	1.365	1.638	2.213	2.822	0.683	0.873	1.178	1.458	1.954	2.388
0.416	0.604	0.976	1.382	2.694	5.344	1.146	1.285	1.441	1.53	1.571	1.562
0.789	1.016	1.351	1.543	1.903	2.213	1.757	1.815	1.824	1.777	1.588	1.517
0.54	0.71	0.995	1.258	1.977	3.067	1.564	1.703	1.838	1.9	2.024	3.556
0.708	0.933	1.298	1.541	2	2.415	2.054	2.175	2.257	2.25	2.068	1.747
0.687	0.918	1.298	1.548	2.086	2.686	0.444	0.56	0.74	0.899	1.198	1.607
0.716	0.935	1.287	1.524	1.996	2.462	1.84	1.943	2.009	1.997	1.824	1.503
0.543	0.741	1.09	1.339	1.842	2.366	1.868	1.939	1.962	1.922	1.727	1.564
0.637	0.861	1.248	1.484	1.949	2.415	1.296	1.439	1.593	1.674	1.699	1.645
0.868	1.128	1.551	1.781	2.199	2.591	2.161	2.185	2.132	2.028	1.721	1.312
						0.899	1.015	1.151	1.237	1.324	1.344

TABLE 6
NATURAL LOGARITHMS OF MODIFIED BOND EQUATION ERROR FACTORS (sorted by D-80 size)

L-95	L-90	L-80	L-70	L-50	L-30						
-1.458	-1.028	-0.454	0.005	0.829	1.747	-1.542	-1.247	-0.866	-0.589	-0.109	0.361
-1.699	-1.288	-0.739	-0.301	0.482	1.367	-0.472	-0.192	0.155	0.352	0.655	0.916
-2.131	-1.716	-1.159	-0.718	0.09	1.009	-0.527	-0.227	0.148	0.36	0.681	0.941
-2.273	-1.87	-1.344	-0.925	-0.168	0.672	-0.325	-0.068	0.247	0.442	0.751	1.017
-0.419	-0.105	0.478	1.007	1.941	2.966	-0.547	-0.25	0.12	0.333	0.640	0.872
-2.555	-2.204	-1.526	-0.956	0.089	1.267	-0.214	-0.046	0.153	0.342	0.678	0.967
-0.508	-0.206	0.182	0.472	0.956	1.411	-0.415	-0.175	0.119	0.305	0.581	0.799
-0.409	-0.09	0.3	0.576	1.029	1.442	-0.831	-0.576	-0.257	-0.047	0.301	0.649
-1.427	-1.09	-0.657	-0.337	0.221	0.773	-0.529	-0.251	0.093	0.271	0.514	0.738
-3.292	-2.795	-2.08	-1.508	-0.472	0.672	-0.544	-0.264	0.083	0.316	0.581	0.658
-0.658	-0.217	0.277	0.588	1.106	1.601	-0.497	-0.199	0.172	0.398	0.723	0.996
-2.247	-1.894	-1.426	-1.04	-0.345	0.401	0.778	0.819	0.835	0.83	0.772	0.768
-0.941	-0.692	-0.276	0.05	0.61	1.150	-0.873	-0.567	-0.175	0.057	0.342	0.506
-1.682	-1.313	-0.85	-0.507	0.095	0.713	-0.396	-0.205	0.021	0.148	0.248	0.405
-1.582	-1.235	-0.817	-0.505	0.031	0.573	-0.713	-0.389	0.02	0.278	0.576	0.698
-1.555	-1.192	-0.734	-0.383	0.232	0.859	-1.235	-0.899	-0.472	-0.177	0.26	0.747
-0.817	-0.466	-0.057	0.213	0.655	1.059	0.48	0.608	0.742	0.814	0.817	0.912
-2.131	-1.651	-1.132	-0.731	-0.013	0.734	-0.58	-0.324	-0.009	0.203	0.449	0.624
-1.662	-1.346	-0.933	-0.602	-0.016	0.573	0.658	0.74	0.81	0.833	0.802	0.822
-0.917	-0.542	-0.156	0.144	0.657	1.145	-1.202	-0.831	-0.349	-0.009	0.439	0.848
-0.444	-0.143	0.184	0.425	0.818	1.148	0.397	0.511	0.628	0.689	0.692	0.759
-1.184	-0.766	-0.304	0.007	0.475	0.901	-0.058	0.157	0.414	0.589	0.820	1.089
-1.117	-0.713	-0.282	-0.008	0.303	0.541	0.128	0.334	0.581	0.751	0.919	1.202
-0.945	-0.655	-0.298	-0.037	0.365	0.714	-1.303	-0.966	-0.538	-0.229	0.204	0.572
-1.167	-0.832	-0.483	-0.24	0.218	0.635	0.641	0.708	0.759	0.767	0.744	0.829
-0.656	-0.354	-0.045	0.166	0.557	0.895	0.363	0.461	0.554	0.596	0.596	0.632
-0.719	-0.459	-0.151	0.069	0.481	0.842	0.552	0.638	0.715	0.745	0.736	0.712
-0.01	0.296	0.643	0.891	1.406	1.880	0.257	0.426	0.615	0.734	0.785	0.785
-0.876	-0.546	-0.163	0.106	0.518	0.877	0.584	0.671	0.748	0.778	0.953	1.340
-0.966	-0.683	-0.344	-0.101	0.373	0.811	-1.395	-1.063	-0.638	-0.323	0.085	0.450
-0.843	-0.519	-0.168	0.071	0.536	0.958	-0.554	-0.282	0.05	0.288	0.601	0.909
-1.077	-0.719	-0.367	-0.143	0.292	0.686	0.208	0.337	0.472	0.548	0.6	0.688
-0.908	-0.593	-0.235	0.005	0.501	0.974	0.453	0.526	0.585	0.6	0.566	0.537
-1.588	-1.295	-0.911	-0.617	0.105	0.869	0.462	0.564	0.662	0.709	0.762	1.122
-0.911	-0.598	-0.261	-0.056	0.335	0.690	-0.52	-0.281	0.012	0.219	0.547	0.927
-0.874	-0.546	-0.174	0.065	0.43	0.732	0.869	0.913	0.933	0.916	0.831	0.842
-0.972	-0.695	-0.362	-0.14	0.222	0.525	0.827	0.909	0.979	1.003	1.078	1.639
-0.302	-0.014	0.319	0.499	0.759	0.931	0.785	0.8	0.781	0.736	0.649	1.062
-0.327	-0.027	0.319	0.508	0.733	0.830	0.765	0.769	0.736	0.679	0.516	0.42
-0.257	0.004	0.311	0.494	0.794	1.037	-0.381	-0.136	0.164	0.377	0.67	0.871
-0.877	-0.504	-0.024	0.323	0.991	1.676	0.137	0.251	0.366	0.426	0.452	0.446
-0.237	0.016	0.301	0.434	0.644	0.794	0.564	0.596	0.601	0.575	0.463	0.416
-0.615	-0.343	-0.005	0.23	0.681	1.121	0.447	0.532	0.609	0.642	0.705	1.269
-0.345	-0.07	0.261	0.433	0.693	0.882	0.72	0.777	0.814	0.811	0.727	0.558
-0.376	-0.086	0.261	0.437	0.735	0.988	-0.811	-0.581	-0.301	-0.106	0.181	0.474
-0.334	-0.068	0.252	0.422	0.691	0.901	0.61	0.664	0.698	0.692	0.601	0.407
-0.611	-0.3	0.087	0.292	0.611	0.861	0.625	0.662	0.674	0.653	0.547	0.447
-0.45	-0.15	0.222	0.395	0.667	0.882	0.259	0.364	0.466	0.515	0.53	0.498
-0.141	0.12	0.439	0.577	0.788	0.952	0.771	0.782	0.757	0.707	0.543	0.271
						-0.107	0.015	0.141	0.213	0.281	0.296

TABLE 7
SIGN-TRANSFERRED SQUARE ROOTS OF LOGARITHMS OF EQUATION ERROR FACTORS (by D-80)

S-95	S-90	S-80	S-70	S-50	S-30						
-1.207	-1.014	-0.674	0.07	0.911	1.322	-1.242	-1.117	-0.93	-0.768	-0.331	0.601
-1.304	-1.135	-0.86	-0.549	0.695	1.169	-0.687	-0.438	0.394	0.593	0.809	0.957
-1.46	-1.31	-1.077	-0.847	0.3	1.004	-0.726	-0.476	0.385	0.6	0.825	0.970
-1.508	-1.367	-1.159	-0.962	-0.41	0.820	-0.57	-0.262	0.497	0.665	0.866	1.008
-0.647	-0.323	0.692	1.003	1.393	1.722	-0.74	-0.5	0.347	0.577	0.8	0.934
-1.598	-1.485	-1.235	-0.978	0.298	1.126	-0.463	-0.214	0.392	0.585	0.823	0.983
-0.713	-0.453	0.426	0.687	0.978	1.188	-0.645	-0.418	0.345	0.552	0.762	0.894
-0.64	-0.301	0.548	0.759	1.014	1.201	-0.912	-0.759	-0.507	-0.216	0.549	0.805
-1.195	-1.044	-0.811	-0.581	0.47	0.879	-0.727	-0.501	0.304	0.521	0.717	0.859
-1.814	-1.672	-1.442	-1.228	-0.687	0.820	-0.738	-0.514	0.288	0.562	0.762	0.811
-0.811	-0.465	0.526	0.767	1.052	1.265	-0.705	-0.446	0.415	0.631	0.85	0.998
-1.499	-1.376	-1.194	-1.02	-0.588	0.634	0.882	0.905	0.914	0.911	0.879	0.876
-0.97	-0.832	-0.525	0.223	0.781	1.072	-0.934	-0.753	-0.418	0.239	0.585	0.711
-1.297	-1.146	-0.922	-0.712	0.308	0.845	-0.629	-0.453	0.144	0.384	0.498	0.636
-1.258	-1.111	-0.904	-0.711	0.175	0.757	-0.845	-0.623	0.142	0.528	0.759	0.835
-1.247	-1.092	-0.857	-0.619	0.482	0.927	-1.111	-0.948	-0.687	-0.421	0.51	0.864
-0.904	-0.683	-0.24	0.462	0.809	1.029	0.693	0.78	0.861	0.902	0.904	0.955
-1.46	-1.285	-1.064	-0.855	-0.116	0.857	-0.762	-0.569	-0.097	0.45	0.67	0.790
-1.289	-1.16	-0.966	-0.776	-0.126	0.757	0.811	0.86	0.9	0.913	0.896	0.907
-0.957	-0.736	-0.395	0.379	0.811	1.070	-1.096	-0.911	-0.59	-0.097	0.663	0.921
-0.666	-0.378	0.429	0.652	0.905	1.071	0.63	0.715	0.792	0.83	0.832	0.871
-1.088	-0.876	-0.551	0.086	0.689	0.949	-0.241	0.396	0.643	0.768	0.905	1.044
-1.057	-0.844	-0.531	-0.09	0.55	0.736	0.358	0.578	0.763	0.867	0.959	1.096
-0.972	-0.809	-0.546	-0.193	0.604	0.845	-1.141	-0.983	-0.733	-0.479	0.451	0.756
-1.08	-0.912	-0.695	-0.49	0.467	0.797	0.801	0.842	0.871	0.876	0.862	0.910
-0.81	-0.595	-0.213	0.407	0.746	0.946	0.603	0.679	0.744	0.772	0.772	0.795
-0.848	-0.677	-0.388	0.262	0.693	0.918	0.743	0.799	0.846	0.863	0.858	0.844
-0.101	0.544	0.802	0.944	1.186	1.371	0.507	0.652	0.784	0.857	0.886	0.886
-0.936	-0.739	-0.403	0.325	0.72	0.936	0.765	0.819	0.865	0.882	0.976	1.157
-0.983	-0.826	-0.587	-0.318	0.611	0.900	-1.181	-1.031	-0.799	-0.568	0.292	0.671
-0.918	-0.72	-0.409	0.267	0.732	0.979	-0.744	-0.531	0.224	0.536	0.775	0.953
-1.038	-0.848	-0.606	-0.378	0.541	0.828	0.456	0.58	0.687	0.74	0.775	0.829
-0.953	-0.77	-0.484	0.07	0.708	0.987	0.673	0.725	0.765	0.774	0.752	0.733
-1.26	-1.138	-0.955	-0.785	0.325	0.932	0.68	0.751	0.814	0.842	0.873	1.059
-0.954	-0.773	-0.511	-0.237	0.579	0.831	-0.721	-0.53	0.11	0.468	0.739	0.963
-0.935	-0.739	-0.417	0.255	0.656	0.856	0.932	0.956	0.966	0.957	0.912	0.918
-0.986	-0.834	-0.602	-0.375	0.471	0.725	0.91	0.953	0.989	1.002	1.038	1.280
-0.55	-0.119	0.565	0.706	0.871	0.965	0.886	0.894	0.884	0.858	0.805	1.031
-0.572	-0.166	0.565	0.713	0.856	0.911	0.875	0.877	0.858	0.824	0.718	0.648
-0.507	0.062	0.558	0.703	0.891	1.018	-0.617	-0.369	0.405	0.614	0.818	0.933
-0.937	-0.71	-0.155	0.569	0.996	1.295	0.37	0.501	0.605	0.652	0.672	0.668
-0.487	0.127	0.548	0.659	0.802	0.891	0.751	0.772	0.775	0.758	0.680	0.645
-0.784	-0.585	-0.071	0.479	0.825	1.059	0.669	0.73	0.78	0.801	0.84	1.126
-0.588	-0.264	0.51	0.658	0.833	0.939	0.849	0.881	0.902	0.901	0.852	0.747
-0.613	-0.293	0.51	0.661	0.857	0.994	-0.9	-0.762	-0.549	-0.326	0.425	0.689
-0.578	-0.26	0.502	0.649	0.831	0.949	0.781	0.815	0.835	0.832	0.775	0.638
-0.782	-0.548	0.294	0.54	0.781	0.928	0.79	0.814	0.821	0.808	0.739	0.669
-0.671	-0.387	0.471	0.628	0.817	0.939	0.509	0.603	0.682	0.718	0.728	0.705
-0.376	0.347	0.663	0.76	0.888	0.976	0.878	0.884	0.87	0.841	0.737	0.521
						-0.327	0.121	0.375	0.461	0.53	0.544

TABLE 8
MINIMUM, MAXIMUM, AVERAGE, AND STD. DEV. OF OPERATING PARAMETERS

STAGE 1 (including CUM, FRAC, ALL, RR, EF, LOG, SQR, IND, and MULT):

	HGI	Ash	Set	Hammer	Liner	Op-Hrs	Feed	Swp-A	Speed	Screen
Min	55	20	0	0	0	0	150	.6	2570	.06
Max	90	32	1	1	1	211	600	1	6840	.5
Avg	60.9	23.2	.949	.909	.939	70.4	422	.804	4860	.317
SD	9.54	4.45	.22	.289	.24	63.1	120	.057	1250	.156

STAGE 2:

UNUS	HGI	Ash	Set	Hammer	Liner	Op-Hrs	Feed	Swp-A	Speed	Screen
Min	55	20	1	1	1	0	150	.6	4910	.062
Max	90	32	1	1	1	172	500	1	6840	.5
Avg	64.9	24	1	1	1	70.8	309	.794	5820	.284
SD	15.1	3.17	0	0	0	59.4	118	.0765	872	.118

DUO	HGI	Ash	Set	Hammer	Liner	Op-Hrs	Feed	Swp-A	Speed	Screen
Min	55	20	0	0	0	0	150	.6	3190	.062
Max	90	32	1	1	1	211	600	1	6840	.5
Avg	59.9	23.1	.949	.962	.987	70.8	415	.808	5100	.326
SD	8.3	4.36	.222	.194	.113	63.5	123	.0504	1010	.158

TRES	HGI	Ash	Set	Hammer	Liner	Op-Hrs	Feed	Swp-A	Speed	Screen
Min	55	20	0	0	0	0	200	.8	2570	.062
Max	60	32	1	1	1	211	600	1	6820	.5
Avg	58.7	22.8	.906	.943	.925	70.7	480	.808	4560	.328
SD	2.23	5.04	.295	.233	.267	67.2	69.6	.0385	1010	.18

QUAT	HGI	Ash	Set	Hammer	Liner	Op-Hrs	Feed	Swp-A	Speed	Screen
Min	55	20	0	0	0	0	350	.8	2570	.125
Max	60	32	1	1	1	211	600	1	6820	.5
Avg	58.1	23.9	.938	.844	.844	82.9	492	.813	3810	.241
SD	2.46	5.57	.246	.369	.369	68.2	52.5	.0492	1030	.148

PENT	HGI	Ash	Set	Hammer	Liner	Op-Hrs	Feed	Swp-A	Speed	Screen
Min	55	20	0	0	0	8.75	500	.8	2570	.125
Max	60	32	1	1	1	169	500	1	4930	.5
Avg	58.8	22.8	.941	.647	.706	83.6	500	.812	3270	.303
SD	2.19	5.25	.243	.493	.47	61.2	0	.0485	844	.158

TABLE 9
MINIMUM, MAXIMUM, AVERAGE, AND STD. DEV. OF PARTICLE-SIZE DATA

CUM	+ 28	+ 100	+ 200	+ 325			
Min	0	.2	2.5	6.5			
Max	37	69	80	84			
Avg	3.19	23.4	40.2	51.6			
SD	5.33	15.8	17.7	17			
FRAC	+ 28	28x100	100x200	200x325	-325		
Min	0	.2	2.3	3	16		
Max	37	48	26	17.1	93.5		
Avg	3.19	20.2	16.8	11.5	48.4		
SD	5.33	11.8	4.79	3.15	17		
ALL	...	28x200	100x325	-200	28x325	-100	-28
Min	...	2.5	6.3	20	6.5	31	63
Max	...	64	41	97.5	72	99.8	100
Avg	...	37	28.3	59.8	48.4	76.6	96.8
SD	...	14.6	6.95	17.7	14.4	15.8	5.33
RR	Slope			Const			
Min	.497	(.482)		-5.336			
Max	1.072			-1.137			
Avg	.727			-3.21			
SD	.105			.901			
EF	E-95	E-90	E-80	E-70	E-50	E-30	
Min	.0372	.0611	.125	.221	.624	1.31	
Max	2.38	2.49	2.66	2.74	6.96	19.4	
Avg	.794	.947	1.18	1.38	1.83	2.65	
SD	.613	.615	.592	.569	.74	1.93	
LOG	L-95	L-90	L-80	L-70	L-50	L-30	
Min	-3.29	-2.79	-2.08	-1.51	-.472	.271	
Max	.869	.913	.979	1.01	1.94	2.97	
Avg	-.543	-.29	.0155	.22	.544	.873	
SD	.838	.737	.598	.49	.34	.382	
SQR	S-95	S-90	S-80	S-70	S-50	S-30	
Min	-1.81	-1.67	-1.44	-1.23	-.687	.521	
Max	.932	.956	.989	1	1.39	1.72	
Avg	-.489	-.292	.069	.308	.674	.915	
SD	.757	.726	.683	.595	.334	.188	

IND	D-95	D-90	D-80	D-70	D-50	D-30
Min	51.6	32.7	17.6	10.6	4.1	1.3
Max	2802	1936	1170.5	778.5	358.4	141.1
Avg	428	301	189	131	66	26.7
SD	332	239	155	110	57.7	25.5
MULT			D-80			
Min			17.6			
Max			1170.5 (700)			
Avg			189			
SD			155			
UNUS	D-95	D-90	D-80	D-70	D-50	D-30
Min	51.6	32.7	17.6	10.6	4.1	1.3
Max	289	189.6	118.4	84.4	41.2	17.7
Avg	201	133	79	52.5	23.7	9.17
SD	67	44.2	28.6	21	10.6	4.71
DUO	D-95	D-90	D-80	D-70	D-50	D-30
Min	131.1	89.3	44.3	23.2	6.8	1.5
Max	652.6	425.5	260.1	191.8	105.6	45.5
Avg	341	234	142	97.2	47.6	19.2
SD	126	88.1	56	40.1	22.5	9.68
TRES	D-95	D-90	D-80	D-70	D-50	D-30
Min	289.1	194.4	119.1	83.3	31.4	9.5
Max	668.5	468.1	314.5	237.1	136.7	58.4
Avg	441	309	193	134	68	26.8
SD	100	73.6	52.6	40.1	23.7	9.13
QUAT	D-95	D-90	D-80	D-70	D-50	D-30
Min	405.9	305.5	201.2	128.3	57	19.4
Max	1060	793.4	535.3	389.1	214.4	108.9
Avg	606	439	284	201	104	40.9
SD	166	124	87.2	67.1	40.2	21.2
PENT	D-95	D-90	D-80	D-70	D-50	D-30
Min	530.8	414.2	285.3	194.5	90.6	24.9
Max	2802	1936	1170.5	778.5	358.4	141.1
Avg	914	670	441	315	165	66.8
SD	519	355	213	142	70.5	36.9

TABLE 10
SIEVE-ANALYSIS RUN SUMMARY AND AVERAGE CUMULATIVE ERRORS

Filename	Runs	Tol/Bad	Mid-Hi	Low	End-Hi	Max-ACE	Avg-ACE	ACE-SD
C002T100	1653	.100	0:27	5:0	-	5.646	2.527	1.237
C002T095	2214	.095	0:29	5:0	-	4.685	2.546	1.027
C003T090	2725	.090	0:30	5:0	8:4	4.638	2.586	1.024
C004T085	3542	.085	1:27	5:0	8:12	4.568	2.453	1.091
C004T080	4246	.080	0:24	5:0	8:11	4.378	2.257	.929
C006T075	5845	.075	1:19	7:6	8:16	4.069	2.102	.900
C014T072	14036	.072	1:14	7:0	8:20	3.973	1.982	.859
C019T070	19199	.070	0:13	6:6	8:19	3.893	1.914	.815
C108T069	107505	.069	0:13	7:6	8:27	3.753	1.813	.717
C183T068	182543	.068	2:14	6:8	8:29	3.454	1.645	.704
C010B4	10024	.069-4	0:15	6:0	8:24	4.246	2.057	.785
C020B1	20013	.069-1	0:18	7:0	8:27	4.282	1.926	.776
C030B1	30002	.069-1	0:14	7:6	8:20	3.640	1.939	.723
C040B1	40011	.069-1	0:12	7:7	8:19	3.580	1.904	.773
C050B1	50010	.069-1	1:12	7:2	8:23	3.744	1.839	.770
C060B1	60016	.069-1	1:13	7:6	8:27	3.773	1.861	.718
C070B1	70041	.069-1	0:12	6:3	8:24	3.762	1.960	.752
C080B1	80001	.069-1	1:14	7:5	8:26	3.559	1.804	.733
C090B1	90002	.069-1	3:14	7:9	8:29	3.729	1.919	.751
C100B1	100001	.069-1	0:13	7:6	8:27	3.707	1.818	.754
C110B1	110001	.069-1	0:13	7:6	8:27	3.639	1.829	.698
C120B1	120006	.069-1	0:10	7:6	8:27	3.697	1.801	.753
C130B1	130009	.069-1	0:14	7:8	8:29	3.848	1.880	.785
C140B1	140007	.069-1	0:10	7:4	8:24	3.876	1.746	.756
C150B1	150006	.069-1	1:9	6:5	8:23	3.812	1.685	.803
C160B1	160008	.069-1	0:12	7:6	8:27	3.984	1.796	.684
C170B1	170001	.069-1	0:11	7:5	8:26	3.899	1.844	.745
C180B1	180003	.069-1	3:9	7:3	8:23	3.745	1.774	.716
C190B1	190004	.067-1	1:13	6:6	8:27	3.779	1.683	.739
C200B1	200006	.067-1	0:14	7:0	8:29	3.703	1.730	.751
F003T160	3143	.160	0:27	4:0	-	9.787	2.738	1.946
F008T155	7508	.155	0:33	5:0	-	9.203	2.783	1.941
F013T150	12643	.150	0:26	6:0	-	7.300	2.843	1.503
F014T145	14315	.145	1:22	7:0	-	7.564	2.770	1.578
F017T140	17414	.140	0:23	7:0	8:10	6.423	2.566	1.353
F030T135	30023	.135	0:15	7:0	8:22	8.040	2.859	1.708
F042T132	42063	.132	0:15	6:0	8:27	6.651	2.713	1.627
F044T130	44006	.130	0:13	6:0	8:31	8.327	2.792	1.715
F107T129	107809	.129	1:16	5:0	8:54	7.547	2.895	1.541

F010B21	10023	.129-21	0:30	5:0	-	7.197	2.784	1.490
F020B12	20002	.129-12	0:20	7:0	8:15	7.827	2.624	1.617
F030B6	30016	.129-6	0:13	6:0	8:22	8.281	3.023	1.910
F040B3	40005	.129-3	0:17	7:0	8:29	7.299	2.727	1.585
F050B2	50002	.129-2	1:14	6:0	8:32	7.276	2.826	1.703
F060B1	60002	.129-1	0:13	7:0	8:40	7.362	2.777	1.856
F070B2	70006	.129-2	0:14	6:0	8:41	6.644	2.694	1.469
F080B2	80011	.129-2	0:13	6:0	8:46	7.006	2.926	1.620
F090B2	90002	.129-2	0:11	6:0	8:47	7.483	2.900	1.615
F100B1	100005	.129-1	1:11	6:0	8:47	6.347	2.889	1.527
A001T160	1255	.160	0:59	4:0	-	5.784	2.760	1.323
A004T155	3815	.155	1:52	4:0	-	5.751	2.708	1.276
A008T150	8213	.150	1:60	4:0	8:8	5.746	2.536	1.341
A010T145	9880	.145	1:56	5:0	8:4	6.148	2.502	1.422
A013T140	12735	.140	1:61	6:0	8:9	6.577	2.607	1.460
A019T135	19225	.135	1:40	7:8	8:30	6.450	2.672	1.385
A025T130	24799	.130	1:32	7:0	8:47	5.447	2.119	1.122
A028T125	27730	.125	2:30	7:0	8:48	4.989	2.320	1.125
A033T122	32635	.122	0:28	7:0	8:43	4.518	2.321	1.145
A035T125	35100	.125	0:28	7:8	8:43	4.796	1.771	1.005
A040T121	40200	.121	0:31	7:0	8:56	5.956	2.008	.983
A041T120	41435	.120	0:28	7:0	8:56	6.143	1.891	1.128
A010B23	10039	.119-23	1:61	5:0	8:9	5.432	2.240	1.124
A020B13	20029	.119-13	1:39	7:0	8:34	6.007	2.243	1.170
A030B5	30049	.119-5	2:30	6:0	8:48	5.017	2.126	1.153
A040B1	40048	.119-1	0:27	6:0	8:55	5.594	1.909	1.084
A050B1	50010	.119-1	0:24	6:10	8:59	4.683	1.884	.935
A060B1	60042	.119-1	1:26	6:0	8:62	4.671	2.028	1.051
A070B1	70014	.119-1	1:26	7:0	8:76	5.522	2.393	1.230
A080B1	80014	.119-1	1:26	6:0	8:81	6.333	2.785	1.490
A090B4	90036	.119-4	0:24	6:0	8:79	4.072	1.766	.896
A100B1	100002	.119-1	1:19	5:0	8:85	6.737	2.556	1.401
A110B1	110004	.119-1	1:19	4:0	8:85	4.536	1.975	.846
A120B1	120065	.119-1	0:23	5:12	8:83	4.967	2.075	1.142
A130B1	130016	.119-1	1:23	6:0	8:83	5.080	2.133	1.146
A140B1	140004	.119-1	0:16	6:0	8:88	6.001	2.188	1.270
A150B1	150001	.119-1	1:17	6:0	8:89	4.054	1.896	.905
A160B1	160038	.119-1	1:18	6:0	8:90	5.989	1.915	1.023
A170B1	170024	.119-1	1:13	6:0	8:91	4.351	1.819	.987
A180B1	180005	.119-1	2:19	6:0	8:97	5.746	1.924	.996
A190B1	190005	.119-1	0:8	6:0	8:105	6.242	2.343	1.159
A200B1	200007	.119-1	0:16	5:0	8:106	6.191	2.424	1.241

R000T170	271	.170	0:33	4:0	-	19.67	5.638	3.705
R001T165	710	.165	0:30	4:0	-	13.01	4.637	2.832
R006T160	5964	.160	1:23	6:0	-	16.16	4.421	2.926
R018T155	18001	.155	0:17	6:0	8:5	18.31	4.481	2.955
R033T150	33123	.150	0:16	5:3	8:10	18.52	5.525	4.187
R048T145	48089	.145	2:19	7:7	8:26	11.47	3.980	2.488
R049T144	49353	.144	1:15	7:3	8:22	13.03	4.204	2.814
R059T143	59025	.143	1:18	5:0	8:25	16.87	4.842	3.207
R010B1	10068	.142-1	1:21	6:0	8:3	18.54	5.721	4.123
R020B1	20069	.142-1	0:19	7:0	8:9	17.72	4.545	3.052
R030B1	30017	.142-1	0:15	7:0	8:9	20.71	5.205	3.494
R040B1	40001	.142-1	0:16	6:6	8:19	15.07	5.060	3.619
R050B1	50001	.142-1	1:19	7:0	8:25	13.69	4.572	3.244
R060B1	60002	.142-1	2:18	5:6	8:27	14.77	4.257	3.188
R070B1	70005	.142-1	1:16	5:0	8:34	20.11	4.977	3.838
R080B1	80001	.142-1	1:20	5:0	8:34	15.19	5.447	3.427
R090B1	90001	.142-1	0:18	5:0	8:34	16.74	4.575	3.439
R100B1	100001	.142-1	0:14	6:0	8:34	16.87	5.239	3.487
R110B1	110002	.142-1	0:12	6:0	8:40	14.18	4.231	2.891
R120B1	120002	.142-1	0:18	6:0	8:34	16.55	4.519	3.059
R130B1	130002	.142-1	0:10	6:0	8:35	18.55	4.862	2.984
R140B1	140002	.142-1	0:16	7:0	8:32	18.84	5.058	3.457
R150B1	150004	.142-1	0:14	7:0	8:34	20.42	5.242	3.822
Regress	R-R Least Squares Linear Regression:					3.248	.868	.667

C = Cumulative, F = Fractional, A = All combinations, R = Rosin-Rammler fit

TABLE 11
D-POINT RUN SUMMARY AND WEIGHTED AVERAGE PERCENTAGE ERRORS

Filename	Runs	Tol/Bad	Mid-Hi	Low	End-Hi	Max-WAPE	Avg-WAPE	WAPE-SD
C002T100	1653	.100	0:27	5:0	-	75.71	16.78	11.59
C002T095	2214	.095	0:29	5:0	-	68.04	18.68	12.67
C003T090	2725	.090	0:30	5:0	8:4	59.23	18.45	12.11
C004T085	3542	.085	1:27	5:0	8:12	55.90	16.33	10.43
C004T080	4246	.080	0:24	5:0	8:11	56.55	14.62	9.636
C006T075	5845	.075	1:19	7:6	8:16	49.02	13.29	8.858
C014T072	14036	.072	1:14	7:0	8:20	47.88	12.66	9.043
C019T070	19199	.070	0:13	6:6	8:19	47.88	12.81	8.510
C108T069	107505	.069	0:13	7:6	8:27	53.21	11.21	7.603
C183T068	182543	.068	2:14	6:8	8:29	43.13	10.35	6.954
C010B4	10024	.069-4	0:15	6:0	8:24	43.36	13.21	7.490
C020B1	20013	.069-1	0:18	7:0	8:27	46.65	12.04	7.916
C030B1	30002	.069-1	0:14	7:6	8:20	50.58	12.33	8.181
C040B1	40011	.069-1	0:12	7:7	8:19	37.91	12.04	7.053
C050B1	50010	.069-1	1:12	7:2	8:23	41.75	12.15	7.575
C060B1	60016	.069-1	1:13	7:6	8:27	37.32	11.58	6.018
C070B1	70041	.069-1	0:12	6:3	8:24	36.31	12.30	6.660
C080B1	80001	.069-1	1:14	7:5	8:26	40.13	11.64	7.350
C090B1	90002	.069-1	3:14	7:9	8:29	41.21	11.90	7.283
C100B1	100001	.069-1	0:13	7:6	8:27	55.58	12.06	7.942
C110B1	110001	.069-1	0:13	7:6	8:27	51.20	11.77	8.417
C120B1	120006	.069-1	0:10	7:6	8:27	44.10	11.55	7.488
C130B1	130009	.069-1	0:14	7:8	8:29	42.87	11.54	8.193
C140B1	140007	.069-1	0:10	7:4	8:24	43.84	11.35	7.415
C150B1	150006	.069-1	1:9	6:5	8:23	39.05	10.87	7.287
C160B1	160008	.069-1	0:12	7:6	8:27	49.59	11.76	7.228
C170B1	170001	.069-1	0:11	7:5	8:26	49.59	12.43	8.174
C180B1	180003	.069-1	3:9	7:3	8:23	45.07	11.91	7.280
C190B1	190004	.067-1	1:13	6:6	8:27	57.12	11.09	8.268
C200B1	200006	.067-1	0:14	7:0	8:29	63.52	11.81	9.514
F003T160	3143	.160	0:27	4:0	-	56.23	16.31	10.55
F008T155	7508	.155	0:33	5:0	-	62.15	17.26	12.39
F013T150	12643	.150	0:26	6:0	-	42.78	16.90	8.831
F014T145	14315	.145	1:22	7:0	-	43.12	15.88	9.276
F017T140	17414	.140	0:23	7:0	8:10	61.01	14.76	8.789
F030T135	30023	.135	0:15	7:0	8:22	59.81	16.90	10.41
F042T132	42063	.132	0:15	6:0	8:27	64.64	16.44	10.99
F044T130	44006	.130	0:13	6:0	8:31	61.88	15.43	9.836
F107T129	107809	.129	1:16	5:0	8:54	78.11	18.45	13.92

F010B21	10023	.129-21	0:30	5:0	-	63.23	19.61	12.66
F020B12	20002	.129-12	0:20	7:0	8:15	39.83	15.29	8.886
F030B6	30016	.129-6	0:13	6:0	8:22	54.04	17.08	9.701
F040B3	40005	.129-3	0:17	7:0	8:29	52.02	15.50	8.888
F050B2	50002	.129-2	1:14	6:0	8:32	76.97	16.83	12.59
F060B1	60002	.129-1	0:13	7:0	8:40	65.57	16.56	11.97
F070B2	70006	.129-2	0:14	6:0	8:41	56.13	14.99	8.753
F080B2	80011	.129-2	0:13	6:0	8:46	63.73	16.75	11.47
F090B2	90002	.129-2	0:11	6:0	8:47	67.19	17.24	11.55
F100B1	100005	.129-1	1:11	6:0	8:47	59.34	17.99	12.06
A001T160	1255	.160	0:59	4:0	-	103.2	20.97	20.04
A004T155	3815	.155	1:52	4:0	-	88.31	19.00	16.11
A008T150	8213	.150	1:60	4:0	8:8	87.25	17.48	15.01
A010T145	9880	.145	1:56	5:0	8:4	98.42	19.36	18.14
A013T140	12735	.140	1:61	6:0	8:9	105.9	20.35	20.58
A019T135	19225	.135	1:40	7:8	8:30	103.3	23.16	19.95
A025T130	24799	.130	1:32	7:0	8:47	52.68	12.89	8.950
A028T125	27730	.125	2:30	7:0	8:48	81.85	17.71	13.99
A033T122	32635	.122	0:28	7:0	8:43	63.19	14.58	11.82
A035T125	35100	.125	0:28	7:8	8:43	54.11	12.07	9.061
A040T121	40200	.121	0:31	7:0	8:56	97.30	14.07	13.29
A041T120	41435	.120	0:28	7:0	8:56	102.7	12.66	12.16
A010B23	10039	.119-23	1:61	5:0	8:9	53.61	15.30	10.35
A020B13	20029	.119-13	1:39	7:0	8:34	82.16	17.34	15.43
A030B5	30049	.119-5	2:30	6:0	8:48	74.03	13.33	10.70
A040B1	40048	.119-1	0:27	6:0	8:55	90.50	12.89	11.61
A050B1	50010	.119-1	0:24	6:10	8:59	65.00	12.65	9.916
A060B1	60042	.119-1	1:26	6:0	8:62	67.17	13.78	12.00
A070B1	70014	.119-1	1:26	7:0	8:76	76.29	16.93	14.53
A080B1	80014	.119-1	1:26	6:0	8:81	97.00	24.98	18.46
A090B4	90036	.119-4	0:24	6:0	8:79	52.42	11.86	8.994
A100B1	100002	.119-1	1:19	5:0	8:85	88.35	19.79	17.21
A110B1	110004	.119-1	1:19	4:0	8:85	69.66	13.87	10.69
A120B1	120065	.119-1	0:23	5:12	8:83	57.79	15.06	10.50
A130B1	130016	.119-1	1:23	6:0	8:83	56.25	13.94	9.998
A140B1	140004	.119-1	0:16	6:0	8:88	97.67	18.31	17.39
A150B1	150001	.119-1	1:17	6:0	8:89	58.07	13.01	9.065
A160B1	160038	.119-1	1:18	6:0	8:90	95.68	12.81	12.96
A170B1	170024	.119-1	1:13	6:0	8:91	64.40	12.58	10.70
A180B1	180005	.119-1	2:19	6:0	8:97	80.31	13.78	12.85
A190B1	190005	.119-1	0:8	6:0	8:105	113.4	18.77	16.37
A200B1	200007	.119-1	0:16	5:0	8:106	95.52	19.29	18.26
R000T170	271	.170	0:33	4:0	-	332.8	36.43	40.22
R001T165	710	.165	0:30	4:0	-	126.8	27.90	22.27

R006T160	5964	.160	1:23	6:0	-	94.28	26.51	18.29
R018T155	18001	.155	0:17	6:0	8:5	189.2	29.25	26.96
R033T150	33123	.150	0:16	5:3	8:10	195.0	29.10	25.64
R048T145	48089	.145	2:19	7:7	8:26	78.95	22.57	15.91
R049T144	49353	.144	1:15	7:3	8:22	85.60	22.55	16.12
R059T143	59025	.143	1:18	5:0	8:25	178.8	32.06	28.07
R010B1	10068	.142-1	1:21	6:0	8:3	173.7	38.08	34.91
R020B1	20069	.142-1	0:19	7:0	8:9	183.9	28.33	27.42
R030B1	30017	.142-1	0:15	7:0	8:9	218.7	34.72	34.36
R040B1	40001	.142-1	0:16	6:6	8:19	91.13	24.81	16.68
R050B1	50001	.142-1	1:19	7:0	8:25	58.92	22.68	14.89
R060B1	60002	.142-1	2:18	5:6	8:27	81.45	24.23	18.51
R070B1	70005	.142-1	1:16	5:0	8:34	171.6	29.91	27.51
R080B1	80001	.142-1	1:20	5:0	8:34	150.1	39.13	32.39
R090B1	90001	.142-1	0:18	5:0	8:34	170.4	29.85	29.43
R100B1	100001	.142-1	0:14	6:0	8:34	122.3	32.54	24.85
R110B1	110002	.142-1	0:12	6:0	8:40	142.2	28.47	24.43
R120B1	120002	.142-1	0:18	6:0	8:34	100.3	26.47	18.97
R130B1	130002	.142-1	0:10	6:0	8:35	124.4	28.17	21.90
R140B1	140002	.142-1	0:16	7:0	8:32	188.4	32.05	34.02
R150B1	150004	.142-1	0:14	7:0	8:34	172.0	29.07	28.98
E002T100	2319	.100	0:26	5:0	-	50.49	15.30	7.021
E003T095	3218	.095	0:26	6:0	-	57.40	15.81	8.014
E007T090	7081	.090	1:18	6:5	8:7	87.79	16.13	14.16
E009T085	8969	.085	0:16	7:3	8:14	78.05	14.46	11.82
E012T080	11804	.080	1:20	7:2	8:28	83.67	15.19	14.33
E016T075	16199	.075	2:13	7:0	8:19	88.86	15.07	15.57
E019T072	19428	.072	3:14	7:6	8:20	57.83	12.75	10.48
E021T072	21017	.072	1:15	6:3	8:23	50.35	11.43	7.387
E055T071	54675	.071	4:13	7:7	8:33	54.52	12.72	10.32
E112T070	112149	.070	0:11	6:0	8:47	81.91	13.50	13.51
E010B26	10164	.069-26	1:14	6:2	8:21	71.68	15.35	12.87
E020B8	20001	.069-8	1:14	6:2	8:22	48.10	12.07	9.298
E030B17	30002	.069-17	2:11	6:0	8:49	59.69	11.71	9.135
E040B7	40001	.069-5	2:13	6:0	8:49	75.30	12.39	9.920
E050B11	50100	.069-11	0:13	6:0	8:46	55.71	11.47	9.219
E060B13	60107	.069-13	4:12	6:0	8:50	50.73	12.71	8.826
E070B15	70052	.069-15	4:11	6:4	8:36	72.30	13.35	11.51
E080B6	80012	.069-6	4:14	7:0	8:36	77.39	14.06	12.30
E090B14	90048	.069-14	3:13	7:8	8:40	66.07	12.61	9.955
E100B4	100011	.069-4	2:16	7:0	8:38	86.61	11.87	10.69
E110B4	110001	.069-4	0:14	6:0	8:41	69.67	12.36	11.23
E120B5	120066	.069-5	0:9	6:0	8:42	89.72	13.60	13.64
E130B13	130016	.069-13	1:12	4:7	8:39	73.86	11.91	10.47

E140B4	140014	.069-4	3:11	6:0	8:47	87.40	12.45	11.77
E150B4	150083	.069-4	2:13	6:0	8:46	71.36	12.19	10.60
E160B21	160154	.069-21	4:8	6:0	8:50	71.72	12.13	9.529
E170B7	170091	.069-7	2:14	6:0	8:41	72.34	11.86	10.50
E180B5	180181	.069-5	2:8	5:0	8:50	100.8	13.76	15.91
E190B10	190159	.069-10	2:15	7:0	8:48	83.01	14.22	14.43
E200B18	200105	.069-18	4:9	5:0	8:51	95.67	13.38	12.80
E210B19	210034	.069-19	6:9	7:6	8:51	73.30	13.23	12.26
E220B13	220111	.069-13	1:10	7:7	8:52	64.23	12.60	10.94
E230B13	230180	.069-13	6:8	7:5	8:50	97.23	13.60	13.41
E240B8	240167	.069-8	0:10	7:0	8:58	77.15	12.28	11.29
E250B20	250158	.069-20	1:5	5:0	8:57	86.28	12.85	11.92
L001T150	1160	.150	0:27	6:0	-	53.90	20.00	9.429
L001T140	1437	.140	0:24	6:0	-	49.56	18.36	9.389
L002T130	1649	.130	0:23	6:0	8:4	42.89	15.89	7.295
L003T120	2697	.120	0:23	6:0	8:4	36.81	16.33	6.658
L009T110	9076	.110	1:16	7:0	8:14	31.51	14.10	6.320
L014T100	14021	.100	0:17	7:0	8:12	28.30	12.32	5.944
L016T095	16201	.095	1:20	7:7	8:19	23.07	11.76	4.658
L018T090	17989	.090	1:15	6:0	8:23	23.70	11.78	4.662
L019T088	18874	.088	1:17	6:0	8:25	26.38	11.28	4.844
L029T086	29109	.086	0:17	7:0	8:25	25.71	11.97	5.762
L030T086	30084	.086	0:18	6:6	8:26	24.67	11.67	5.201
L095T084	95465	.084	0:9	7:4	8:36	23.25	11.94	5.215
L097T085	97638	.085	2:11	6:0	8:36	24.65	11.31	4.669
L010B31	10180	.083-31	2:15	6:2	8:13	32.97	13.57	6.161
L020B5	20248	.083-5	1:20	6:8	8:28	25.64	11.45	5.604
L030B1	30043	.083-1	0:18	6:6	8:26	26.29	11.64	5.406
L040B2	40224	.083-2	1:17	6:8	8:28	24.83	12.09	5.332
L050B1	50007	.083-1	1:17	7:8	8:28	23.24	10.67	4.989
L060B1	60017	.083-1	1:12	6:0	8:30	24.15	11.64	5.082
L070B1	70014	.083-1	0:18	7:8	8:29	26.88	11.46	5.199
L080B1	80046	.083-1	1:11	7:0	8:39	25.13	12.22	5.237
L090B1	90014	.083-1	2:15	7:7	8:33	22.19	11.42	4.489
L100B1	100035	.083-1	2:12	7:4	8:32	26.00	11.95	4.747
L110B1	110085	.083-1	0:15	7:0	8:35	25.28	11.02	5.305
L120B1	120031	.083-1	2:12	6:3	8:24	26.13	10.67	5.394
L130B1	130001	.083-1	0:13	7:0	8:33	24.83	10.44	4.512
L140B1	140012	.083-1	0:11	6:0	8:31	25.67	11.68	4.842
L150B1	150047	.083-1	1:13	7:0	8:40	25.65	11.56	4.764
L160B1	160003	.083-1	1:12	6:5	8:37	26.96	11.36	4.621
L170B1	170002	.083-1	0:9	7:0	8:36	24.80	11.36	4.477
L180B1	180009	.083-1	1:10	7:3	8:35	26.45	11.14	5.125
L190B1	190024	.083-1	1:9	7:0	8:36	21.86	10.80	4.560
L200B1	200001	.083-1	1:11	7:0	8:38	24.94	10.43	4.443

L210B1	210025	.083-1	0:13	6:0	8:38	24.70	10.95	4.912
L220B1	220010	.083-1	2:14	6:0	8:34	27.10	11.56	5.249
L230B2	230007	.083-2	1:16	7:0	8:41	26.80	11.67	4.928
L240B1	240065	.083-1	1:12	7:7	8:39	25.13	11.20	4.615
L250B1	250010	.083-1	0:10	7:3	8:35	23.96	11.38	5.128
S001T180	1151	.180	1:25	5:0	-	74.70	25.75	15.96
S002T170	1717	.170	1:24	5:0	-	71.93	25.35	15.44
S006T160	5868	.160	0:24	7:0	-	88.76	25.57	18.12
S009T150	9449	.150	0:25	7:0	8:10	61.75	23.18	12.12
S010T145	10480	.145	1:18	7:0	8:11	99.77	24.12	15.10
S012T140	11718	.140	0:18	6:0	8:14	88.04	23.07	15.82
S014T135	13613	.135	0:16	6:0	8:18	67.77	21.08	12.40
S017T130	16691	.130	1:17	7:0	8:24	58.43	18.93	10.61
S022T128	21695	.128	1:15	7:0	8:23	68.19	18.72	11.34
S024T127	23996	.127	1:13	6:0	8:19	53.87	16.35	9.305
S010B16	10087	.126-16	1:17	7:4	8:10	87.76	22.53	12.94
S020B3	20080	.126-3	2:18	7:0	8:27	71.14	18.36	12.86
S030B2	30191	.126-2	3:14	6:0	8:23	72.35	16.53	10.34
S040B1	40079	.126-1	0:13	7:0	8:19	71.04	19.02	10.49
S050B1	50074	.126-1	1:14	7:6	8:20	96.69	17.28	14.01
S060B1	60007	.126-1	0:10	6:3	8:17	67.90	18.65	11.17
S070B1	70005	.126-1	0:11	7:3	8:17	55.11	16.19	8.201
S080B1	80007	.126-1	0:18	7:6	8:27	60.44	17.22	9.870
S090B1	90007	.126-1	2:14	7:6	8:20	67.44	17.48	11.17
S100B1	100011	.126-1	0:15	7:3	8:24	76.26	18.35	12.62
S110B1	110029	.126-1	1:18	7:6	8:27	74.28	19.61	13.12
S120B1	120006	.126-1	3:14	7:2	8:23	91.81	18.85	14.72
S130B1	130001	.126-1	1:13	6:5	8:19	90.45	19.74	15.24
S140B1	140001	.126-1	1:12	6:2	8:23	100.0	18.79	14.40
S150B1	150010	.126-1	1:13	6:6	8:27	89.29	17.36	13.28
S160B1	160010	.126-1	4:15	6:0	8:26	64.13	18.26	11.42
S170B1	170014	.126-1	4:15	6:0	8:33	82.19	19.56	12.20
S180B1	180017	.126-1	2:17	6:0	8:35	82.85	20.69	15.35
S190B1	190012	.126-1	4:12	7:0	8:40	103.4	21.15	17.21
S200B1	200009	.126-1	4:15	7:0	8:35	68.63	18.99	11.98
S210B1	210007	.126-1	1:16	7:0	8:36	67.32	19.36	13.06
S220B1	220043	.126-1	2:14	7:0	8:36	63.90	18.08	10.57
S230B1	230005	.126-1	3:11	7:5	8:33	93.39	19.44	15.05
S240B1	240002	.126-1	3:13	6:0	8:35	60.67	16.54	9.700
S250B1	250012	.126-1	2:12	6:2	8:30	61.86	16.15	9.797
I002T120	1594	.120	0:27	5:0	-	251.9	41.96	42.70
I002T110	2382	.110	0:29	6:0	-	274.3	43.45	45.49
I004T100	3510	.100	0:25	5:0	8:6	228.0	35.16	38.75
I004T095	3813	.095	0:28	6:0	8:4	233.6	34.78	36.86

I004T090	4091	.090	0:23	6:0	8:7	229.0	32.48	35.38
I004T085	4440	.085	0:26	7:0	8:10	232.8	32.51	35.16
I005T080	5200	.080	0:27	7:0	8:9	195.1	28.97	26.88
I005T075	5455	.075	0:20	7:0	8:8	158.1	25.90	23.53
I006T070	6065	.070	0:22	5:0	8:5	114.4	23.18	19.29
I006T065	6486	.065	0:19	6:0	8:8	98.69	22.01	18.01
I007T060	7257	.060	0:18	6:0	8:9	98.45	19.80	16.01
I017T055	17470	.055	2:15	6:6	8:27	100.9	19.88	15.89
I051T050	51219	.050	0:15	7:6	8:26	81.31	17.40	14.71
I082T048	82012	.048	3:13	7:0	8:43	74.66	14.99	13.63
I087T047	86772	.047	4:12	7:0	8:42	90.01	17.23	14.49
I122T046	122325	.046	2:12	6:0	8:42	92.90	16.86	16.41
I125T045	125325	.045	2:9	6:0	8:45	156.3	19.54	23.24
I010B28	10004	.044-28	0:14	7:2	8:21	104.1	17.66	15.19
I020B41	20019	.044-41	0:10	7:2	8:30	163.8	22.07	23.92
I030B34	30078	.044-34	0:15	4:8	8:40	114.4	21.37	19.45
I040B34	40093	.044-34	1:12	4:7	8:39	161.3	24.37	28.19
I050B13	50156	.044-13	0:9	5:3	8:24	148.5	17.54	21.39
I060B12	60081	.044-12	0:14	6:0	8:39	84.50	14.31	13.98
I070B14	70145	.044-14	0:14	5:0	8:42	86.44	15.85	13.99
I080B7	80058	.044-7	0:9	6:0	8:39	82.96	15.80	13.84
I090B9	90084	.044-9	0:12	5:0	8:40	96.09	18.55	19.33
I100B13	100017	.044-13	1:18	4:8	8:36	114.3	17.89	18.20
I110B8	110071	.044-8	3:9	6:0	8:45	190.8	18.69	25.60
I120B7	120099	.044-7	0:6	5:3	8:45	117.4	16.07	15.98
I130B6	130192	.044-6	2:10	7:0	8:40	83.09	15.27	14.94
I140B9	140191	.044-9	1:10	5:0	8:49	75.85	15.89	14.13
I150B7	150034	.044-7	6:9	7:0	8:61	110.9	17.71	17.22
I160B4	160072	.044-4	0:9	7:0	8:65	176.7	21.11	27.84
I170B8	170011	.044-8	1:6	4:0	8:64	129.0	20.33	23.22
I180B10	180092	.044-10	0:13	4:0	8:55	158.1	20.63	27.35
I190B4	190023	.044-4	0:13	6:0	8:55	240.3	17.36	30.67
I200B4	200002	.044-4	0:7	4:0	8:49	116.5	17.99	18.75
M001T080	1019	.080	0:15	4:0	-	295.0	25.63	42.50
M001T075	1116	.075	0:14	5:0	-	268.2	23.39	39.02
M001T070	1213	.070	0:13	6:0	-	237.9	21.70	35.04
M001T065	1352	.065	0:15	4:0	-	185.4	19.10	28.10
M002T060	1529	.060	0:15	4:0	-	91.33	15.44	15.17
M002T055	2485	.055	0:15	8:0	-	202.1	19.58	28.84
M004T050	4334	.050	0:13	6:0	8:6	111.3	16.83	17.25
M029T048	29461	.048	1:6	5:0	8:22	167.4	17.54	22.04
M029T046	29499	.046	1:4	4:0	8:22	166.4	17.42	21.89
M031T045	30544	.045	0:9	6:6	8:19	173.8	15.28	22.86
M181T044	180793	.044	3:7	6:0	8:16	79.22	13.81	13.19
M183T042	183176	.042	5:10	7:6	8:13	95.23	12.65	13.73

M184T040	183645	.040	2:10	7:7	8:14	70.75	13.14	12.26
M184T039	184060	.039	2:6	7:2	8:14	68.28	12.29	11.95
M192T038	192321	.038	0:9	6:0	8:17	144.6	13.85	20.06
M010B24	10152	.037-24	3:6	7:0	8:16	188.8	16.88	25.60
M020B24	20106	.037-24	1:6	5:0	8:26	99.30	17.25	16.95
M030B13	30172	.037-13	1:6	5:0	8:22	178.5	15.89	23.50
M040B9	40073	.037-9	1:6	5:0	8:22	202.9	14.62	25.04
M050B8	50191	.037-8	0:6	4:0	8:24	206.3	14.64	25.34
M060B9	60057	.037-9	0:7	5:0	8:22	220.0	15.41	27.06
M070B8	70024	.037-8	0:7	7:0	8:23	240.4	14.92	29.41
M080B13	80100	.037-13	6:9	7:5	8:19	49.38	12.74	10.15
M090B16	90169	.037-16	0:11	6:0	8:19	64.31	13.49	13.21
M100B19	100130	.037-19	0:6	6:0	8:24	78.67	13.90	13.03
M110B15	110162	.037-15	3:7	6:0	8:23	141.3	15.07	19.77
M120B27	120175	.037-27	0:7	3:0	8:20	120.7	17.59	19.01
M130B16	130131	.037-16	0:6	7:0	8:30	141.8	14.67	18.18
M140B18	140220	.037-18	3:11	5:0	8:29	96.40	14.43	15.28
M150B22	150134	.037-22	3:6	7:0	8:30	106.3	14.90	17.12
M160B11	160089	.037-11	0:7	7:0	8:23	109.2	14.31	17.11
M170B12	170106	.037-12	0:9	6:0	8:18	94.15	15.00	16.00
M180B9	180086	.037-9	2:9	7:6	8:13	94.66	12.53	13.85
M190B10	190101	.037-10	0:10	6:0	8:13	139.4	13.48	20.36
M200B4	200104	.037-4	0:9	6:0	8:17	141.1	13.13	18.49
U002T150	1788	.150	0:17	4:0	-	35.56	11.68	8.383
U004T140	4391	.140	1:19	6:0	-	25.23	9.568	5.541
U016T130	16499	.130	2:13	7:7	8:8	24.32	10.19	5.711
U022T120	22094	.120	1:11	7:6	8:12	33.02	9.770	6.881
U039T110	39168	.110	2:11	7:0	8:17	23.43	7.730	3.926
U054T100	54152	.100	0:10	6:6	8:13	32.37	7.913	5.636
U074T095	73857	.095	1:9	6:3	8:17	21.32	6.734	4.277
U108T090	108288	.090	0:9	5:0	8:17	25.38	6.281	4.767
U114T088	114039	.088	1:10	5:0	8:19	23.88	6.728	4.629
U119T087	119327	.087	5:7	7:0	8:17	16.70	5.697	2.902
U010B12	10080	.086-12	2:14	6:0	-	28.81	8.625	5.831
U020B11	20175	.086-11	2:11	7:5	8:10	24.51	8.259	5.016
U030B10	30139	.086-10	1:11	7:7	8:14	32.15	8.238	6.812
U040B8	40168	.086-8	2:10	7:6	8:13	18.86	7.083	3.952
U050B8	50072	.086-8	1:10	7:6	8:13	21.28	6.210	3.710
U060B5	60105	.086-5	4:10	7:0	8:16	19.06	6.324	3.829
U070B8	70127	.086-8	5:11	6:0	8:19	21.47	6.738	4.363
U080B6	80111	.086-6	2:10	6:6	8:20	17.92	6.139	4.048
U090B5	90116	.086-5	3:6	7:2	8:23	18.02	6.519	3.696
U100B3	100151	.086-3	0:6	5:0	8:24	18.07	6.618	3.722
U110B3	110008	.086-3	3:7	6:0	8:16	18.63	5.950	3.719

U120B1	120098	.086-1	0:8	5:0	8:17	24.02	6.053	4.668
U130B3	130004	.086-3	4:10	6:0	8:20	20.48	6.163	4.498
U140B2	140011	.086-2	0:9	7:0	8:20	25.07	6.313	4.390
U150B2	150061	.086-2	0:6	7:0	8:23	32.80	6.919	5.608
U160B2	160043	.086-2	0:8	6:0	8:26	25.84	6.719	4.969
U170B2	170017	.086-2	0:8	6:0	8:26	15.74	6.198	3.555
U180B3	180030	.086-3	2:9	6:0	8:33	18.01	6.329	3.268
U190B3	190056	.086-3	0:4	6:0	8:30	28.13	6.531	5.655
U200B4	200034	.086-4	0:9	6:8	8:29	19.32	6.537	3.761
D002T200	1547	.200	0:23	5:0	-	64.97	14.58	9.663
D002T195	1776	.195	0:21	6:0	-	74.07	15.30	10.03
D002T190	2043	.190	0:23	5:0	-	70.81	14.81	10.07
D002T185	2263	.185	0:23	8:0	-	71.02	14.30	9.592
D003T180	2509	.180	0:22	8:0	-	66.85	13.88	9.045
D003T175	2964	.175	0:22	8:0	-	58.21	13.23	7.823
D004T173	4204	.173	1:21	8:0	-	43.22	13.23	6.457
D007T172	6589	.172	0:21	6:0	8:3	45.98	14.14	6.868
D010B1	10006	.171-1	0:24	7:0	8:5	36.21	14.01	6.551
D020B1	20003	.171-1	0:20	6:0	8:13	32.88	13.34	6.062
D030B1	30006	.171-1	2:17	6:0	8:18	41.04	13.48	7.491
D040B1	40005	.171-1	1:16	7:0	8:22	37.42	13.51	7.472
D050B1	50003	.171-1	2:17	7:0	8:23	44.40	14.88	8.849
D060B1	60008	.171-1	0:18	7:0	8:27	33.97	13.23	6.719
D070B1	70004	.171-1	2:17	7:0	8:26	45.81	13.92	8.278
D080B1	80005	.171-1	2:18	5:0	8:27	42.20	13.33	7.727
D090B1	90004	.171-1	1:15	6:0	8:24	44.78	13.89	8.847
D100B1	100006	.171-1	1:14	6:0	8:23	38.16	14.09	7.629
D110B1	110002	.171-1	1:18	5:2	8:30	35.90	14.55	7.461
D120B1	120003	.171-1	1:18	6:0	8:30	52.06	14.29	8.448
D130B1	130002	.171-1	1:15	5:3	8:24	49.51	14.01	8.081
D140B1	140006	.171-1	1:12	5:3	8:24	71.76	14.23	10.69
D150B1	150004	.171-1	1:12	5:2	8:30	55.71	14.31	9.216
T002T300	1980	.300	1:28	5:0	-	27.78	13.20	5.575
T002T290	2184	.290	1:29	5:0	-	27.74	13.70	5.173
T003T280	2509	.280	1:27	5:0	-	26.78	13.10	5.018
T003T270	2809	.270	1:26	5:0	-	25.02	12.13	4.654
T003T260	3422	.260	1:28	6:0	-	22.52	11.47	4.470
T004T250	4067	.250	1:23	7:0	-	28.46	12.37	5.175
T017T245	17201	.245	1:20	5:0	8:10	23.97	11.03	4.664
T077T240	77292	.240	0:16	7:0	8:22	19.54	10.51	4.074
T079T238	78715	.238	0:17	7:0	8:21	21.12	10.50	4.691
T110T236	110101	.236	0:15	6:0	8:19	18.85	9.792	4.155
T171T235	170586	.235	0:14	7:8	8:29	19.32	11.01	4.185

T010B1	10014	.234-1	1:24	6:0	8:9	23.49	10.66	4.835
T020B1	20048	.234-1	1:20	6:0	8:9	24.46	10.12	4.060
T030B1	30010	.234-1	0:18	6:0	8:7	24.76	11.14	5.066
T040B1	40050	.234-1	0:20	7:7	8:12	21.72	10.79	4.450
T050B1	50024	.234-1	1:15	7:3	8:14	22.64	11.31	4.979
T060B1	60021	.234-1	0:14	6:4	8:17	19.65	10.49	4.283
T070B1	70002	.234-1	0:14	7:0	8:23	23.64	11.02	4.245
T080B1	80010	.234-1	0:19	7:0	8:23	18.99	10.30	3.763
T090B1	90004	.234-1	0:13	7:3	8:22	23.77	10.06	4.044
T100B1	100005	.234-1	0:16	7:8	8:20	20.06	9.984	3.535
T110B1	110005	.234-1	0:15	7:7	8:20	18.04	9.323	3.482
T120B1	120018	.234-1	1:13	6:3	8:22	19.80	10.09	3.878
T130B1	130009	.234-1	3:12	6:2	8:28	22.47	10.18	4.191
T140B1	140001	.234-1	0:13	6:6	8:25	21.67	10.38	4.012
T150B1	150002	.234-1	0:10	5:2	8:28	25.12	10.86	3.922
T160B1	160001	.234-1	2:13	5:5	8:31	19.59	10.32	3.831
T170B1	170003	.234-1	1:14	7:8	8:29	19.95	10.54	4.470
T180B1	180001	.234-1	1:14	7:9	8:29	18.69	10.11	3.827
T190B1	190003	.234-1	1:10	6:2	8:30	20.72	9.701	4.211
T200B1	200008	.234-1	2:10	7:2	8:30	22.85	9.651	4.592
T210B1	210001	.234-1	1:13	7:7	8:35	19.47	10.02	3.718
T220B1	220002	.234-1	0:9	6:0	8:39	16.38	9.719	3.210
T230B1	230005	.234-1	0:9	5:0	8:39	21.93	10.29	4.516
T240B1	240004	.234-1	3:12	6:0	8:40	23.67	10.62	4.408
T250B1	250006	.234-1	2:12	6:0	8:42	20.98	9.817	3.783
T260B1	260004	.234-1	2:9	5:0	8:39	19.03	9.906	3.772
T270B1	270001	.234-1	2:11	6:0	8:39	19.91	10.08	3.906
T280B1	280003	.234-1	1:10	6:0	8:40	18.97	9.750	4.046
T290B1	290002	.234-1	2:11	7:0	8:39	23.61	10.03	4.245
T300B1	300003	.234-1	0:9	5:4	8:39	19.51	9.711	3.663
Q001T100	1265	.100	0:27	5:0	-	14.78	7.004	3.062
Q001T095	1371	.095	0:26	5:0	-	14.20	6.857	3.038
Q002T090	1533	.090	1:24	5:0	-	14.38	6.760	2.914
Q002T085	1659	.085	1:24	5:0	-	13.69	6.732	2.894
Q002T080	1872	.080	1:26	6:0	-	13.40	6.508	2.710
Q003T075	2516	.075	0:28	7:0	-	12.69	5.949	2.698
Q004T070	3754	.070	1:21	7:0	8:3	11.97	5.497	2.666
Q004T068	4427	.068	1:23	5:0	8:5	11.77	5.411	2.536
Q035T066	34737	.066	0:16	7:0	8:34	11.52	4.131	2.432
Q051T064	50587	.064	1:15	6:8	8:27	11.45	4.133	2.277
Q061T063	60573	.063	1:14	7:7	8:39	11.09	4.587	2.418
Q010B2	10203	.062-2	0:16	6:4	8:17	10.53	4.885	2.519
Q020B2	20037	.062-2	0:18	6:0	8:30	10.73	4.885	2.538
Q030B2	30039	.062-2	0:14	7:6	8:32	11.27	4.721	2.533
Q040B1	40017	.062-1	2:12	7:0	8:30	11.68	4.333	2.123

Q050B2	50006	.062-2	0:15	7:3	8:29	11.43	4.154	2.240
Q060B1	60110	.062-1	0:16	7:9	8:41	10.86	4.516	2.170
Q070B2	70005	.062-2	0:14	7:9	8:41	10.63	4.673	2.076
Q080B2	80006	.062-2	0:8	4:0	8:50	11.26	4.721	2.243
Q090B1	90153	.062-1	6:10	7:0	8:43	11.39	4.501	2.585
Q100B1	100031	.062-1	0:12	7:0	8:48	10.53	3.919	2.390
Q110B1	110019	.062-1	5:9	6:3	8:42	10.50	4.086	2.301
Q120B1	120017	.062-1	0:14	7:8	8:34	10.62	4.052	2.297
Q130B1	130009	.062-1	1:12	7:6	8:32	10.86	4.261	2.339
Q140B1	140037	.062-1	0:8	7:0	8:35	10.37	4.485	2.056
Q150B1	150018	.062-1	1:10	7:4	8:32	11.02	4.242	1.971
P001T080	1029	.080	0:22	6:0	-	14.93	9.595	3.149
P001T070	1179	.070	0:22	7:0	-	13.00	8.580	2.935
P001T060	1340	.060	0:20	7:0	-	13.16	7.750	2.454
P002T050	1535	.050	1:20	7:0	8:9	10.58	6.071	2.500
P002T045	1711	.045	0:20	7:0	8:11	10.78	6.339	2.322
P002T040	1872	.040	0:20	7:7	8:13	8.886	5.471	2.427
P002T035	2387	.035	0:23	6:0	8:16	8.769	4.965	2.355
P003T030	3441	.030	0:15	6:3	8:24	7.774	3.718	1.929
P004T025	4285	.025	0:19	7:0	8:28	6.264	3.391	1.835
P007T020	7485	.020	1:15	6:0	8:24	4.740	2.569	.8961
P010T018	10008	.018	2:18	5:0	8:18	3.441	2.014	.7381
P025T017	24658	.017	0:16	5:0	8:26	3.494	2.117	.8548
P010B4	10195	.016-4	2:16	7:6	8:19	4.026	1.933	.9175
P020B5	20057	.016-5	0:10	6:0	8:28	3.854	2.243	1.023
P030B7	30040	.016-7	0:12	6:0	8:27	4.773	2.284	1.095
P040B9	40008	.016-9	0:10	5:0	8:40	6.063	2.569	1.285
P050B13	50054	.016-13	0:11	4:0	8:38	5.519	3.172	1.560
Regress	R-R Least Squares Linear Regression:					31.35	5.048	4.794
Equation	Modified Bond Equation Alone:					256.0	65.20	33.89
MULT-2	Best Mult, Unus, Duo, Tres, Quat, Pent:					19.73	8.404	4.769

C = Cumulative, F = Fractional, A = All combinations, R = Rosin-Rammler fit, E = Equation error factor, L = Log of equation error factor, S = Square root of log of equation error factor, I = Individul-stage D-point, M = Multi-stage D-point first stage, U = multi-stage D-point second stage Unus, D = multi-stage D-point second stage Duo, T = multi-stage D-point second stage Tres, Q = multi-stage D-point second stage Quattour, P = multi-stage D-point second stage Pente

TABLE 12
BEST RESULTS OF EACH SIMULATION APPROACH (sorted by Avg + SD)

Approach	Average Cumulative Error			Weighted Average Percentage Error			
	Max	Avg	SD	Max	Avg	SD	Avg + SD
PENT ¹				3.441	2.014	0.738	2.75
QUAT ¹				10.53	3.919	2.390	6.31
UNUS ¹				16.70	5.697	2.902	8.60
Regress ²	3.248	0.868	0.667	31.35	5.048	4.794	9.84
TRES ¹				18.04	9.323	3.482	12.80
MULT-2				19.73	8.404	4.769	13.17
LOG				24.94	10.43	4.443	14.87
CUM	3.454	1.645	0.704	43.13	10.35	6.954	17.30
EF				50.35	11.43	7.387	18.82
DUO ¹				32.88	13.34	6.062	19.40
ALL	4.072	1.766	0.896	52.42	11.86	8.994	20.85
MULT ³				49.38	12.74	10.15	22.89
FRAC	6.423	2.566	1.353	61.01	14.76	8.789	23.55
SQR				55.11	16.19	8.201	24.39
IND				84.50	14.31	13.98	28.29
RR	11.47	3.980	2.488	58.92	22.68	14.89	37.57
Equation ²				256.0	65.20	33.89	99.11

1 - narrow size distribution

2 - mathematical fit

3 - D-80 point only

(superscripts indicate components of other methods)

TABLE 13
NEURAL-NETWORK PREDICTIONS USING CUMULATIVE SIEVE ANALYSES
(measured amount on left, predicted amount on right)

+ 28		+ 100		+ 200		+ 325		ACE
.0	.0	.2	.8	2.5	4.4	6.5	10.2	1.56
.0	.0	1.1	1.7	4.0	6.9	9.5	14.6	2.13
.0	.0	.9	2.8	4.4	8.7	10.2	14.9	2.74
.0	.0	1.5	2.7	5.6	8.5	12.6	14.7	1.54
.0	.1	3.8	5.8	13.2	14.2	20.1	22.2	1.28
.0	.0	6.4	3.8	14.8	11.1	22.4	19.3	2.33
.2	.0	4.6	3.8	15.3	13.1	27.3	24.8	1.39
.2	.1	5.1	3.7	15.6	14.9	27.9	29.4	.94
.0	.4	5.0	6.6	15.7	20.2	28.1	32.6	2.72
.7	.0	8.6	4.4	17.4	13.6	25.6	21.8	3.10
.6	.8	7.1	6.2	16.4	16.8	27.8	29.8	.88
.1	.3	5.7	6.6	17.2	18.8	28.6	30.4	1.14
.0	.4	6.1	6.3	18.0	19.8	30.0	32.5	1.22
.2	.2	6.9	7.8	18.6	21.0	30.9	31.2	.89
.2	.3	6.5	6.7	19.2	20.8	32.6	33.4	.70
.2	.0	7.3	5.5	19.3	20.3	31.3	34.9	1.65
.3	1.5	7.8	10.1	20.5	21.1	34.2	33.5	1.21
.9	.3	9.3	8.8	21.2	23.4	32.4	33.8	1.16
.1	.3	8.0	6.9	22.0	22.0	34.9	34.8	.35
.5	1.2	9.2	9.0	23.4	22.5	36.1	38.5	1.04
.3	1.2	10.2	10.1	26.0	23.5	39.9	36.2	1.80
1.2	1.2	12.3	8.9	26.4	22.5	40.1	38.7	2.17
1.1	1.1	12.3	13.6	27.4	31.5	44.5	45.9	1.73
.3	1.0	12.0	13.5	28.6	31.4	43.5	45.7	1.81
.5	.4	11.8	10.6	29.9	28.2	44.1	42.4	1.17
.4	.5	11.7	10.7	30.1	29.1	44.4	44.3	.57
.2	.6	11.9	11.1	30.2	29.0	44.4	45.3	.84
.9	.9	13.3	11.9	28.4	26.0	39.2	37.3	1.44
.7	.9	13.0	12.2	29.2	30.6	43.4	46.4	1.32
.3	.7	12.5	12.1	30.3	30.0	43.8	44.4	.42
.6	.9	12.6	12.6	30.1	31.0	43.4	46.5	1.09
.8	.9	12.6	12.8	31.6	30.8	45.7	45.1	.42
.7	1.0	14.0	12.6	32.0	31.1	44.6	46.4	1.09
.4	.1	14.4	13.5	31.6	34.3	42.3	46.8	2.09
.7	.8	14.1	11.8	34.1	30.0	48.3	46.0	2.21
.8	.3	14.5	15.0	33.5	31.8	49.4	46.2	1.46
.6	.2	16.0	12.3	35.7	33.8	50.7	47.4	2.33
1.3	1.7	17.1	20.5	36.3	39.1	51.1	54.0	2.35
1.5	1.8	17.1	20.5	35.8	39.0	52.0	53.8	2.16
1.0	1.5	17.3	20.3	36.4	39.0	50.1	54.1	2.52
2.1	2.1	18.0	15.4	32.7	36.0	43.3	46.3	2.24
.9	.4	17.2	17.7	39.4	41.6	54.3	55.2	1.05
1.0	.6	17.8	15.5	35.6	37.8	47.6	51.9	2.30
1.4	2.4	18.5	19.7	38.4	39.6	52.8	54.1	1.16
1.6	1.3	18.5	20.0	38.2	38.8	51.6	54.1	1.22
1.3	2.4	18.7	19.0	38.8	38.2	52.8	52.9	.50
2.0	1.4	19.4	17.1	38.3	37.2	52.2	51.5	1.18
2.0	2.5	19.5	22.5	39.5	44.7	53.4	58.4	3.45

1.7	3.4	19.8	23.0	40.7	43.0	54.5	57.9	2.63
1.2	.5	21.0	18.4	40.5	38.6	54.2	52.3	1.76
2.0	2.0	21.0	19.8	40.3	38.1	53.5	52.8	1.03
2.4	1.2	21.1	19.5	39.7	38.5	52.9	54.0	1.28
1.8	2.1	21.4	22.7	40.2	42.1	53.0	54.4	1.21
2.5	1.9	21.7	20.2	40.5	38.6	54.0	53.2	1.21
.3	.8	22.7	21.2	42.4	42.7	55.8	56.3	.69
1.5	2.2	22.0	18.9	41.9	37.1	55.5	51.9	3.05
1.4	3.2	22.1	21.8	42.4	39.7	55.2	52.9	1.79
2.3	3.6	22.4	18.5	43.8	41.0	57.1	55.9	2.29
2.4	1.1	22.6	19.1	40.3	38.1	56.5	53.9	2.42
3.0	1.4	22.8	19.4	40.9	38.9	53.6	50.9	2.44
.1	1.0	25.5	26.8	51.5	51.3	64.4	64.0	.70
2.3	2.7	24.0	23.6	48.0	50.7	65.0	65.9	1.12
1.1	2.5	25.2	23.2	51.1	45.7	64.2	59.2	3.45
3.7	1.5	23.6	20.4	41.1	39.1	56.3	54.1	2.40
4.4	4.5	26.2	26.3	44.3	44.1	55.4	58.2	.79
2.1	2.7	28.9	32.1	51.6	55.9	63.0	66.1	2.80
3.5	2.7	27.6	25.2	47.6	46.8	60.8	59.5	1.31
1.4	1.6	30.6	33.7	53.7	58.2	65.2	69.2	2.96
5.0	5.5	27.0	23.7	46.0	44.1	59.0	59.6	1.59
1.8	2.3	30.6	30.0	53.9	53.6	65.2	62.4	1.07
3.0	1.2	29.2	27.7	49.1	50.1	60.6	62.0	1.42
2.4	2.9	30.0	28.6	53.0	53.4	64.0	67.0	1.31
5.0	3.6	27.6	24.3	45.0	42.9	57.3	55.9	2.05
1.4	1.6	33.0	35.0	55.4	59.6	65.6	70.0	2.71
1.9	1.3	33.8	29.6	56.8	54.5	67.6	66.6	2.03
2.2	3.0	33.7	36.8	55.6	57.9	67.3	67.9	1.71
4.1	4.1	31.2	33.1	52.4	54.4	64.9	65.4	1.11
2.7	3.4	34.4	33.2	50.3	51.4	59.2	60.2	1.00
5.9	4.2	29.9	28.6	47.9	47.8	59.9	60.2	.83
5.7	5.5	30.6	31.4	48.1	50.8	59.1	58.4	1.07
3.4	1.2	34.9	30.7	56.2	56.0	66.7	67.7	1.93
2.9	1.6	38.8	34.7	60.5	59.4	70.6	70.0	1.78
4.2	3.2	41.3	40.4	60.0	61.8	66.7	69.7	1.68
6.4	5.2	37.2	37.4	54.9	59.2	64.7	64.5	1.48
3.4	2.9	45.9	43.6	65.1	65.8	72.8	71.5	1.21
5.2	6.6	42.5	44.1	57.4	59.0	63.8	65.4	1.55
4.9	7.1	45.4	43.6	60.7	58.7	66.5	66.0	1.64
4.5	6.3	47.4	50.3	66.5	69.0	73.8	75.4	2.20
8.1	5.9	40.0	39.1	59.0	58.6	70.0	69.9	.88
7.0	5.6	43.0	40.8	63.0	59.3	72.0	69.2	2.54
7.7	7.2	49.1	46.0	66.4	64.1	74.0	72.2	1.93
9.8	10.6	44.9	48.2	58.3	60.6	64.3	68.4	2.63
11.0	10.0	58.0	60.2	75.0	78.9	83.0	83.2	1.83
13.4	15.5	48.7	50.8	65.1	67.1	72.5	72.3	1.58
14.0	12.7	62.0	59.5	78.0	76.0	83.0	80.9	1.98
17.0	18.3	60.5	58.8	73.4	74.1	79.1	78.3	1.13
21.0	21.5	62.0	59.4	75.0	72.5	81.0	78.9	1.93
22.0	22.0	69.0	64.9	80.0	78.4	84.0	82.7	1.77
37.0	34.8	69.0	65.4	77.0	76.0	80.0	81.1	1.97

Maximum, Average, and Standard Deviation of Average Cumulative Errors:
3.454 1.645 .7042

TABLE 14
NEURAL-NETWORK PREDICTIONS USING FRACTIONAL SIEVE ANALYSES
(measured amount on left, predicted amount on right)

+ 28		28x100		100x200		200x325		-325		ACE
.0	.0	.2	1.3	2.3	4.5	4.0	3.9	93.5	90.3	1.90
.0	.0	1.1	2.1	2.9	5.7	5.5	5.2	90.5	87.0	2.04
.0	.0	.9	1.3	3.5	5.7	5.8	6.2	89.8	86.7	1.52
.0	.0	1.5	1.2	4.1	5.4	7.0	5.8	87.4	87.6	.37
.0	.0	3.8	2.6	9.4	12.1	6.9	8.4	79.9	76.9	1.44
.0	.0	6.4	5.7	8.4	5.9	7.6	8.6	77.6	79.8	1.50
.2	.0	4.4	1.6	10.7	13.0	12.0	10.2	72.7	75.2	1.59
.2	2.1	4.9	9.5	10.5	12.4	12.3	11.3	72.1	64.7	6.09
.0	.1	5.0	6.8	10.7	12.6	12.4	13.0	71.9	67.4	2.61
.7	.0	7.9	3.7	8.8	9.3	8.2	9.5	74.4	77.5	3.26
.6	.3	6.5	5.5	9.3	11.9	11.4	9.7	72.2	72.6	.80
.1	.1	5.6	7.0	11.5	12.0	11.4	13.6	71.4	67.4	1.79
.0	.2	6.1	6.9	11.9	13.5	12.0	12.6	70.0	66.8	1.76
.2	.0	6.7	9.3	11.7	12.9	12.3	11.0	69.1	66.8	2.13
.2	.1	6.3	6.6	12.7	12.4	13.4	12.8	67.4	68.0	.25
.2	.0	7.1	10.0	12.0	12.4	12.0	9.5	68.7	68.0	1.67
.3	.3	7.5	6.4	12.7	15.9	13.7	12.7	65.8	64.6	1.09
.9	.0	8.4	9.4	11.9	12.9	11.2	10.9	67.6	66.8	.74
.1	.1	7.9	6.2	14.0	12.0	12.9	12.4	65.1	69.2	2.39
.5	1.0	8.7	6.5	14.2	14.6	12.7	13.8	63.9	64.2	.97
.3	.1	9.9	8.9	15.8	18.1	13.9	12.1	60.1	60.8	.79
1.2	1.1	11.1	6.4	14.1	14.4	13.7	13.8	59.9	64.4	3.53
1.1	.3	11.2	15.3	15.1	17.6	17.1	14.5	55.5	52.3	3.24
.3	.3	11.7	15.3	16.6	17.7	14.9	14.5	56.5	52.2	3.12
.5	.0	11.3	13.8	18.1	17.4	14.2	14.3	55.9	54.5	1.30
.4	.3	11.3	15.0	18.4	18.3	14.3	14.2	55.6	52.3	2.63
.2	.4	11.7	14.6	18.3	16.9	14.2	14.0	55.6	54.1	1.64
.9	1.3	12.4	15.7	15.1	17.0	10.8	10.8	60.8	55.1	3.89
.7	.4	12.3	14.6	16.2	17.2	14.2	14.2	56.6	53.6	2.08
.3	.2	12.2	15.3	17.8	17.9	13.5	14.5	56.2	52.2	2.53
.6	.4	12.0	14.6	17.5	17.4	13.3	14.2	56.6	53.4	2.05
.8	.3	11.8	15.3	19.0	17.8	14.1	14.5	54.3	52.2	1.81
.7	.4	13.3	14.7	18.0	17.5	12.6	14.2	55.4	53.2	1.04
.4	.4	14.0	9.1	17.2	15.6	10.7	13.1	57.7	61.8	3.86
.7	.4	13.4	14.6	20.0	17.0	14.2	14.1	51.7	53.8	1.34
.8	.2	13.7	9.5	19.0	19.8	15.9	14.1	50.6	56.4	3.82
.6	.9	15.4	12.5	19.7	18.4	15.0	13.5	49.3	54.8	3.11
1.3	3.6	15.8	17.1	19.2	19.7	14.8	14.3	48.9	45.2	3.45
1.5	3.4	15.7	17.4	18.7	20.0	16.1	14.4	48.0	44.8	3.42
1.0	3.9	16.3	16.7	19.1	19.1	13.7	14.3	49.9	46.0	3.36
2.1	5.4	15.9	13.6	14.7	13.6	10.6	10.0	56.7	57.4	1.28
.9	.0	16.3	15.5	22.2	21.8	14.9	12.8	45.7	49.8	2.18
1.0	1.1	16.8	16.8	17.8	21.1	12.0	14.0	52.4	47.0	2.23
1.4	1.2	17.1	20.3	19.9	22.6	14.4	14.4	47.2	41.5	3.67
1.6	4.1	16.9	16.3	19.7	18.8	13.4	14.3	48.4	46.5	1.83
1.3	1.4	17.4	20.1	20.1	22.4	14.0	14.4	47.2	41.6	3.41
2.0	1.6	17.4	18.4	18.9	21.5	13.9	14.3	47.8	44.2	1.95
2.0	.9	17.5	20.7	20.0	22.9	13.9	14.3	46.6	41.3	3.36

1.7	.6	18.1	22.8	20.9	23.7	13.8	14.3	45.5	38.6	4.48
1.2	1.0	19.8	24.1	19.5	20.9	13.7	12.8	45.8	41.3	3.57
2.0	2.7	19.0	18.4	19.3	20.9	13.2	14.4	46.5	43.5	1.39
2.4	4.3	18.7	16.0	18.6	18.3	13.2	14.2	47.1	47.2	.95
1.8	2.5	19.6	23.5	18.8	18.4	12.8	10.9	47.0	44.7	2.90
2.5	3.0	19.2	18.0	18.8	20.6	13.5	14.4	46.0	44.0	1.08
.3	.9	22.4	26.4	19.7	22.6	13.4	13.9	44.2	36.2	5.17
1.5	2.1	20.5	19.2	19.9	21.6	13.6	14.5	44.5	42.6	1.07
1.4	1.8	20.7	22.7	20.3	17.8	12.8	11.3	44.8	46.4	1.12
2.3	.2	20.1	21.3	21.4	22.9	13.3	13.7	42.9	41.8	1.18
2.4	4.4	20.2	15.8	17.7	18.0	16.2	14.2	43.5	47.6	2.67
3.0	2.7	19.8	23.1	18.1	18.3	12.7	11.1	46.4	44.7	2.06
.1	.1	25.4	28.8	26.0	21.8	12.9	10.7	35.6	38.6	1.79
2.3	.5	21.7	18.5	24.0	23.1	17.0	15.5	35.0	42.5	5.08
1.1	.8	24.1	20.7	25.9	22.9	13.1	14.3	35.8	41.3	4.00
3.7	3.8	19.9	16.8	17.5	19.4	15.2	14.3	43.7	45.7	1.54
4.4	2.1	21.8	23.7	18.1	15.6	11.1	10.1	44.6	48.6	2.42
2.1	.6	26.8	30.9	22.7	21.8	11.4	11.5	37.0	35.2	1.93
3.5	7.0	24.1	25.1	20.0	16.6	13.2	10.9	39.2	40.4	2.58
1.4	.3	29.2	32.7	23.1	22.5	11.5	10.2	34.8	34.4	1.43
5.0	4.8	22.0	19.6	19.0	23.4	13.0	15.7	41.0	36.5	2.27
1.8	2.0	28.8	34.4	23.3	21.4	11.3	12.8	34.8	29.4	3.80
3.0	.6	26.2	21.8	19.9	21.2	11.5	12.8	39.4	43.6	4.76
2.4	1.4	27.6	33.9	23.0	23.2	11.0	12.4	36.0	29.1	4.71
5.0	1.8	22.6	22.7	17.4	17.8	12.3	11.2	42.7	46.5	3.23
1.4	.4	31.6	32.9	22.4	21.8	10.2	10.1	34.4	34.7	.46
1.9	.2	31.9	30.1	23.0	22.4	10.8	10.7	32.4	36.6	3.43
2.2	.8	31.5	33.3	21.9	20.5	11.7	9.8	32.7	35.6	1.41
4.1	1.5	27.1	31.6	21.2	22.3	12.5	11.5	35.1	33.1	2.36
2.7	4.8	31.7	32.6	15.9	18.4	8.9	9.3	40.8	34.9	4.09
5.9	1.6	24.0	22.7	18.0	17.8	12.0	11.1	40.1	46.7	5.55
5.7	2.4	24.9	21.1	17.5	19.9	11.0	11.5	40.9	45.2	4.88
3.4	.5	31.5	31.8	21.3	23.0	10.5	11.0	33.3	33.6	1.67
2.9	.4	35.9	32.9	21.7	21.9	10.1	10.1	29.4	34.7	4.64
4.2	3.6	37.1	34.0	18.7	18.4	6.7	7.3	33.3	36.7	2.98
6.4	2.8	30.8	31.8	17.7	20.6	9.8	11.5	35.3	33.3	2.14
3.4	1.7	42.5	45.7	19.2	21.2	7.7	6.7	27.2	24.7	2.30
5.2	6.0	37.3	40.0	14.9	19.6	6.4	5.5	36.2	28.9	4.99
4.9	8.5	40.5	36.7	15.3	16.8	5.8	7.5	33.5	30.4	2.07
4.5	1.2	42.9	37.2	19.1	20.8	7.3	8.6	26.2	32.3	6.42
8.1	7.3	31.9	32.3	19.0	22.8	11.0	11.6	30.0	26.0	2.15
7.0	7.7	36.0	34.1	20.0	21.5	9.0	9.9	28.0	26.7	.87
7.7	6.9	41.4	38.3	17.3	19.9	7.6	7.0	26.0	27.9	2.03
9.8	10.9	35.1	37.6	13.4	16.2	6.0	6.7	35.7	28.6	4.54
11.0	13.0	47.0	42.3	17.0	17.7	8.0	6.5	17.0	20.4	2.49
13.4	14.3	35.3	32.9	16.4	13.8	7.4	7.9	27.5	31.0	2.49
14.0	15.4	48.0	41.1	16.0	17.2	5.0	5.1	17.0	21.2	3.86
17.0	17.1	43.5	43.7	12.9	15.1	5.7	4.0	20.9	20.1	.96
21.0	24.2	41.0	35.5	13.0	14.3	6.0	4.5	19.0	21.6	2.28
22.0	23.3	47.0	40.0	11.0	12.6	4.0	3.6	16.0	20.5	3.92
37.0	31.4	32.0	34.9	8.0	6.8	3.0	3.0	20.0	23.9	4.05

Maximum, Average, and Standard Deviation of Average Cumulative Errors:

6.423 2.566 1.353

TABLE 15
NEURAL-NETWORK PREDICTIONS USING ALL SIEVE ANALYSIS DATA
(measured amount on left, predicted amount on right)

+ 28		+ 100		+ 200		+ 325		ACE
.0	.5	.2	2.8	2.5	7.6	6.5	12.3	3.50
.0	.5	1.1	2.9	4.0	7.3	9.5	12.1	2.06
.0	.3	.9	3.1	4.4	9.2	10.2	15.7	3.17
.0	.3	1.5	3.4	5.6	9.6	12.6	16.4	2.49
.0	.8	3.8	6.8	13.2	15.6	20.1	25.0	2.76
.0	1.2	6.4	6.7	14.8	14.5	22.4	24.2	.87
.2	.2	4.6	4.2	15.3	13.8	27.3	24.9	1.08
.2	1.5	5.1	7.8	15.6	18.3	27.9	29.5	2.09
.0	.3	5.0	5.6	15.7	16.6	28.1	28.8	.60
.7	1.0	8.6	6.3	17.4	13.7	25.6	23.2	2.17
.6	.5	7.1	6.6	16.4	15.9	27.8	26.7	.59
.1	.5	5.7	8.1	17.2	18.5	28.6	30.7	1.57
.0	.6	6.1	8.6	18.0	19.8	30.0	31.9	1.73
.2	1.7	6.9	9.9	18.6	19.9	30.9	32.0	1.72
.2	.3	6.5	5.3	19.2	16.4	32.6	28.8	1.95
.2	.4	7.3	5.1	19.3	15.0	31.3	25.6	3.10
.3	.5	7.8	7.9	20.5	21.5	34.2	35.6	.67
.9	1.3	9.3	7.9	21.2	17.9	32.4	30.0	1.88
.1	.2	8.0	4.9	22.0	16.3	34.9	28.8	3.77
.5	.7	9.2	9.1	23.4	22.3	36.1	37.0	.58
.3	.4	10.2	5.6	26.0	21.4	39.9	35.4	3.43
1.2	.8	12.3	9.3	26.4	22.4	40.1	36.9	2.63
1.1	1.9	12.3	12.9	27.4	29.3	44.5	44.5	.86
.3	1.9	12.0	12.9	28.6	29.2	43.5	44.4	.99
.5	.7	11.8	11.0	29.9	27.3	44.1	41.1	1.64
.4	1.1	11.7	11.4	30.1	27.4	44.4	41.7	1.61
.2	1.6	11.9	13.7	30.2	32.5	44.4	46.4	1.88
.9	1.9	13.3	17.2	28.4	33.7	39.2	44.5	3.88
.7	1.8	13.0	13.5	29.2	30.7	43.4	44.9	1.14
.3	1.3	12.5	12.1	30.3	28.6	43.8	43.5	.83
.6	1.9	12.6	13.4	30.1	30.0	43.4	44.3	.77
.8	1.6	12.6	12.7	31.6	28.9	45.7	44.0	1.31
.7	1.9	14.0	13.3	32.0	29.6	44.6	44.0	1.23
.4	.3	14.4	10.0	31.6	27.3	42.3	40.2	2.75
.7	1.7	14.1	13.6	34.1	31.5	48.3	45.6	1.71
.8	1.7	14.5	18.2	33.5	36.3	49.4	51.8	2.48
.6	.3	16.0	13.8	35.7	31.6	50.7	45.6	2.94
1.3	1.6	17.1	20.3	36.3	38.2	51.1	53.0	1.85
1.5	1.6	17.1	20.1	35.8	38.0	52.0	52.8	1.55
1.0	1.7	17.3	20.8	36.4	38.8	50.1	53.6	2.52
2.1	2.8	18.0	18.1	32.7	32.7	43.3	44.5	.52
.9	.6	17.2	16.4	39.4	35.9	54.3	51.0	1.96
1.0	.7	17.8	18.8	35.6	38.3	47.6	51.5	2.00
1.4	1.2	18.5	19.9	38.4	41.3	52.8	55.5	1.81
1.6	1.8	18.5	21.1	38.2	39.4	51.6	54.1	1.62
1.3	1.2	18.7	19.6	38.8	40.5	52.8	54.7	1.14
2.0	1.0	19.4	19.7	38.3	39.6	52.2	53.2	.92
2.0	1.2	19.5	21.5	39.5	44.3	53.4	58.3	3.12

1.7	1.5	19.8	22.1	40.7	45.1	54.5	59.6	2.99
1.2	.9	21.0	19.9	40.5	39.0	54.2	53.7	.84
2.0	1.5	21.0	19.8	40.3	38.0	53.5	52.8	1.18
2.4	1.8	21.1	21.5	39.7	40.2	52.9	54.8	.85
1.8	2.6	21.4	23.4	40.2	42.8	53.0	56.0	2.09
2.5	1.6	21.7	19.9	40.5	37.9	54.0	52.7	1.66
.3	1.3	22.7	23.6	42.4	43.3	55.8	55.7	.73
1.5	1.4	22.0	19.6	41.9	38.7	55.5	53.2	2.01
1.4	2.4	22.1	22.3	42.4	40.9	55.2	53.9	1.00
2.3	2.0	22.4	21.1	43.8	43.1	57.1	58.2	.88
2.4	1.9	22.6	21.8	40.3	40.8	56.5	55.5	.72
3.0	2.8	22.8	23.2	40.9	41.5	53.6	54.1	.43
.1	1.6	25.5	26.6	51.5	49.4	64.4	61.9	1.82
2.3	2.2	24.0	22.5	48.0	45.8	65.0	61.7	1.76
1.1	1.2	25.2	21.9	51.1	44.9	64.2	58.9	3.75
3.7	1.7	23.6	20.6	41.1	38.5	56.3	53.3	2.64
4.4	3.2	26.2	25.0	44.3	44.3	55.4	56.3	.81
2.1	4.0	28.9	30.9	51.6	53.2	63.0	65.2	1.93
3.5	3.7	27.6	27.8	47.6	46.4	60.8	59.3	.77
1.4	2.9	30.6	32.0	53.7	55.5	65.2	66.4	1.48
5.0	4.4	27.0	27.3	46.0	47.3	59.0	62.1	1.32
1.8	3.5	30.6	31.5	53.9	53.7	65.2	66.4	1.01
3.0	2.6	29.2	30.3	49.1	50.8	60.6	62.4	1.26
2.4	6.0	30.0	31.2	53.0	53.3	64.0	66.6	1.92
5.0	3.0	27.6	25.1	45.0	42.9	57.3	55.8	2.04
1.4	3.0	33.0	34.2	55.4	56.7	65.6	67.6	1.52
1.9	2.0	33.8	29.4	56.8	52.3	67.6	64.2	3.11
2.2	3.1	33.7	34.9	55.6	56.4	67.3	68.3	.95
4.1	4.2	31.2	32.5	52.4	55.5	64.9	68.7	2.09
2.7	5.0	34.4	37.1	50.3	53.5	59.2	62.4	2.86
5.9	3.8	29.9	29.5	47.9	45.9	59.9	58.3	1.55
5.7	3.9	30.6	28.6	48.1	45.1	59.1	56.7	2.29
3.4	2.8	34.9	33.7	56.2	56.5	66.7	67.2	.66
2.9	3.0	38.8	33.9	60.5	56.5	70.6	67.4	3.05
4.2	4.2	41.3	41.5	60.0	60.5	66.7	67.4	.35
6.4	5.2	37.2	36.7	54.9	52.6	64.7	63.2	1.35
3.4	7.2	45.9	47.5	65.1	66.7	72.8	74.2	2.12
5.2	5.6	42.5	43.3	57.4	58.8	63.8	67.3	1.52
4.9	7.1	45.4	45.2	60.7	59.9	66.5	67.6	1.10
4.5	6.7	47.4	47.5	66.5	68.6	73.8	76.5	1.78
8.1	8.6	40.0	37.9	59.0	59.2	70.0	71.5	1.09
7.0	5.8	43.0	44.0	63.0	65.6	72.0	72.6	1.36
7.7	8.7	49.1	51.7	66.4	70.7	74.0	77.5	2.84
9.8	8.5	44.9	45.4	58.3	59.8	64.3	68.2	1.80
11.0	10.9	58.0	58.9	75.0	74.7	83.0	82.2	.52
13.4	12.1	48.7	44.9	65.1	61.3	72.5	70.4	2.76
14.0	14.2	62.0	58.3	78.0	73.7	83.0	80.1	2.78
17.0	13.8	60.5	59.2	73.4	73.2	79.1	79.1	1.17
21.0	22.8	62.0	62.2	75.0	74.9	81.0	81.6	.71
22.0	18.8	69.0	63.7	80.0	75.6	84.0	80.6	4.07
37.0	33.7	69.0	66.7	77.0	76.8	80.0	82.4	2.07

Maximum, Average, and Standard Deviation of Average Cumulative Errors:

4.072 1.766 .8956

TABLE 16
NEURAL-NETWORK PREDICTIONS USING ROSIN-RAMMLER FIT OF DATA
(measured amount on left, predicted amount on right)

+ 28		+ 100		+ 200		+ 325		Slope	Const	ACE
.0	.0	.2	.6	2.5	3.6	6.5	8.9	.607	-1.416	.999
.0	.0	1.1	1.6	4.0	6.5	9.5	13.4	.597	-1.564	1.725
.0	.0	.9	1.6	4.4	6.3	10.2	12.8	.572	-1.444	1.321
.0	.0	1.5	1.6	5.6	6.1	12.6	12.5	.567	-1.412	.180
.0	.1	3.8	5.9	13.2	16.4	20.1	27.3	.637	-2.151	3.159
.0	.1	6.4	2.9	14.8	8.4	22.4	14.8	.502	-1.252	4.399
.2	.0	4.6	1.6	15.3	7.3	27.3	15.5	.655	-1.859	5.741
.2	.1	5.1	7.1	15.6	18.7	27.9	30.3	.653	-2.294	1.912
.0	.7	5.0	14.1	15.7	29.3	28.1	42.0	.668	-2.668	9.302
.7	.1	8.6	3.1	17.4	9.3	25.6	16.6	.539	-1.455	5.784
.6	.0	7.1	2.7	16.4	9.3	27.8	17.3	.589	-1.667	5.636
.1	.9	5.7	13.7	17.2	27.6	28.6	39.4	.621	-2.421	7.509
.0	.5	6.1	13.9	18.0	30.0	30.0	43.5	.708	-2.864	8.453
.2	.1	6.9	4.0	18.6	11.7	30.9	20.4	.580	-1.733	5.096
.2	.7	6.5	13.8	19.2	28.7	32.6	41.2	.659	-2.615	6.466
.2	.1	7.3	6.3	19.3	17.0	31.3	28.0	.637	-2.168	1.690
.3	.8	7.8	14.0	20.5	28.6	34.2	40.8	.644	-2.549	5.369
.9	.1	9.3	4.3	21.2	12.1	32.4	20.8	.573	-1.717	6.648
.1	.7	8.0	13.2	22.0	27.5	34.9	39.7	.643	-2.514	4.031
.5	2.1	9.2	18.8	23.4	33.4	36.1	44.9	.605	-2.511	7.503
.3	.4	10.2	10.1	26.0	23.0	39.9	34.8	.634	-2.345	2.070
1.2	2.0	12.3	18.9	26.4	33.8	40.1	45.5	.616	-2.568	5.046
1.1	1.0	12.3	17.3	27.4	34.1	44.5	47.3	.698	-2.929	3.632
.3	1.0	12.0	17.1	28.6	33.8	43.5	46.9	.694	-2.905	3.610
.5	.7	11.8	14.7	29.9	30.4	44.1	43.4	.681	-2.759	1.088
.4	.8	11.7	16.3	30.1	33.0	44.4	46.4	.703	-2.925	2.479
.2	1.2	11.9	19.6	30.2	37.4	44.4	50.9	.724	-3.133	5.600
.9	.3	13.3	8.5	28.4	20.3	39.2	31.6	.624	-2.221	5.269
.7	1.0	13.0	18.3	29.2	35.9	43.4	49.4	.720	-3.076	4.600
.3	1.0	12.5	16.6	30.3	32.7	43.8	45.5	.676	-2.797	2.214
.6	1.0	12.6	17.9	30.1	35.4	43.4	48.9	.719	-3.054	4.103
.8	1.0	12.6	16.9	31.6	33.2	45.7	46.3	.686	-2.858	1.667
.7	.9	14.0	17.7	32.0	35.0	44.6	48.5	.717	-3.039	2.709
.4	.6	14.4	14.3	31.6	30.5	42.3	43.9	.706	-2.867	.760
.7	1.1	14.1	18.9	34.1	36.6	48.3	50.1	.722	-3.101	2.348
.8	1.2	14.5	17.5	33.5	33.7	49.4	46.5	.673	-2.815	1.645
.6	.9	16.0	17.8	35.7	35.3	50.7	48.8	.719	-3.054	1.126
1.3	.9	17.1	16.3	36.3	32.8	51.1	46.0	.695	-2.882	2.463
1.5	.9	17.1	16.5	35.8	33.1	52.0	46.3	.697	-2.901	2.409
1.0	.9	17.3	16.1	36.4	32.3	50.1	45.3	.687	-2.834	2.556
2.1	1.3	18.0	16.8	32.7	32.0	43.3	44.1	.637	-2.612	.862
.9	.3	17.2	15.6	39.4	34.8	54.3	50.0	.810	-3.430	2.782
1.0	1.1	17.8	20.9	35.6	39.9	47.6	53.9	.761	-3.361	3.459
1.4	2.3	18.5	22.9	38.4	40.0	52.8	52.5	.679	-3.009	1.790
1.6	.9	18.5	16.0	38.2	32.0	51.6	44.9	.679	-2.791	4.050
1.3	2.2	18.7	21.9	38.8	38.5	52.8	50.9	.663	-2.901	1.591
2.0	1.9	19.4	21.1	38.3	37.9	52.2	50.5	.674	-2.931	.981
2.0	1.4	19.5	23.6	39.5	43.5	53.4	57.5	.787	-3.570	3.198

1.7	1.8	19.8	25.9	40.7	46.0	54.5	59.7	.791	-3.657	4.158
1.2	.6	21.0	18.8	40.5	38.7	54.2	53.6	.806	-3.521	1.298
2.0	1.1	21.0	17.6	40.3	34.3	53.5	47.4	.692	-2.911	4.121
2.4	1.0	21.1	15.9	39.7	31.6	52.9	44.3	.670	-2.740	5.830
1.8	6.3	21.4	32.4	40.2	48.8	53.0	59.9	.647	-3.119	7.768
2.5	1.0	21.7	17.1	40.5	33.8	54.0	47.0	.697	-2.917	4.966
.3	1.9	22.7	29.2	42.4	50.6	55.8	64.5	.847	-4.029	6.224
1.5	1.5	22.0	19.2	41.9	35.6	55.5	48.3	.673	-2.864	4.072
1.4	2.4	22.1	23.3	42.4	40.4	55.2	53.0	.681	-3.029	1.585
2.3	1.6	22.4	21.2	43.8	38.8	57.1	51.9	.706	-3.094	3.005
2.4	1.0	22.6	15.8	40.3	31.3	56.5	43.9	.661	-2.698	7.426
3.0	3.7	22.8	26.5	40.9	43.3	53.6	55.2	.659	-3.015	2.076
.1	1.1	25.5	32.4	51.5	57.1	64.4	71.6	.996	-4.866	5.185
2.3	1.3	24.0	22.6	48.0	42.0	65.0	55.9	.769	-3.453	4.362
1.1	1.1	25.2	23.3	51.1	43.9	64.2	58.3	.814	-3.698	3.768
3.7	.9	23.6	16.1	41.1	32.5	56.3	45.6	.690	-2.854	7.403
4.4	2.2	26.2	18.4	44.3	32.5	55.4	43.7	.587	-2.411	8.368
2.1	1.8	28.9	30.2	51.6	52.3	63.0	66.4	.879	-4.216	1.429
3.5	2.8	27.6	23.8	47.6	40.5	60.8	52.7	.662	-2.948	4.964
1.4	2.3	30.6	36.4	53.7	59.4	65.2	72.8	.949	-4.738	4.998
5.0	3.3	27.0	28.9	46.0	47.6	59.0	60.2	.733	-3.452	1.618
1.8	.4	30.6	20.9	53.9	43.5	65.2	59.5	.904	-4.077	6.788
3.0	2.6	29.2	30.6	49.1	51.1	60.6	64.4	.813	-3.897	1.909
2.4	2.9	30.0	35.5	53.0	57.4	64.0	70.4	.888	-4.409	4.208
5.0	2.9	27.6	25.8	45.0	43.4	57.3	55.8	.692	-3.158	1.759
1.4	1.4	33.0	31.6	55.4	55.2	65.6	69.5	.943	-4.576	1.374
1.9	1.5	33.8	32.5	56.8	56.1	67.6	70.3	.953	-4.652	1.291
2.2	2.4	33.7	33.1	55.6	55.0	67.3	68.5	.880	-4.304	.640
4.1	1.5	31.2	23.3	52.4	42.6	64.9	56.3	.764	-3.447	7.248
2.7	2.9	34.4	26.3	50.3	44.4	59.2	57.0	.708	-3.255	4.096
5.9	3.8	29.9	29.3	47.9	47.4	59.9	59.6	.708	-3.341	.858
5.7	1.9	30.6	21.1	48.1	37.9	59.1	50.5	.675	-2.936	7.988
3.4	2.3	34.9	33.3	56.2	55.4	66.7	68.9	.888	-4.346	1.435
2.9	1.5	38.8	32.0	60.5	55.6	70.6	69.8	.946	-4.602	3.480
4.2	6.0	41.3	39.6	60.0	59.0	66.7	70.6	.803	-4.095	2.105
6.4	4.6	37.2	32.3	54.9	50.6	64.7	62.7	.723	-3.498	3.245
3.4	3.3	45.9	35.4	65.1	56.7	72.8	69.5	.860	-4.269	5.565
5.2	11.0	42.5	42.6	57.4	58.9	63.8	69.1	.685	-3.587	3.171
4.9	5.3	45.4	34.7	60.7	53.2	66.5	65.1	.738	-3.638	4.995
4.5	3.7	47.4	36.8	66.5	57.8	73.8	70.4	.860	-4.301	5.866
8.1	6.3	40.0	38.5	59.0	57.3	70.0	68.9	.770	-3.899	1.527
7.0	1.9	43.0	29.5	63.0	51.0	72.0	64.9	.850	-4.055	9.449
7.7	2.8	49.1	31.9	66.4	52.7	74.0	65.9	.826	-3.999	11.008
9.8	8.6	44.9	38.2	58.3	54.8	64.3	65.5	.674	-3.411	3.136
11.0	2.2	58.0	39.4	75.0	63.2	83.0	76.3	1.015	-5.149	11.468
13.4	12.0	48.7	43.8	65.1	59.9	72.5	69.8	.681	-3.599	3.570
14.0	10.3	62.0	51.3	78.0	69.8	83.0	79.7	.884	-4.827	6.482
17.0	8.8	60.5	47.2	73.4	66.1	79.1	76.6	.849	-4.536	7.820
21.0	22.0	62.0	57.1	75.0	71.2	81.0	79.2	.717	-4.166	2.895
22.0	25.9	69.0	64.0	80.0	77.5	84.0	84.5	.800	-4.813	2.975
37.0	38.7	69.0	67.9	77.0	78.2	80.0	83.9	.647	-4.187	1.973

Maximum, Average, and Standard Deviation of Average Cumulative Errors:

11.47 3.980 2.488

TABLE 17
LEAST-SQUARES LINEAR REGRESSION FOR ROSIN-RAMMLER DISTRIBUTION
(measured amount on left, predicted amount on right)

+ 28		+ 100		+ 200		+ 325		Slope	Const	ACE
.0	.0	.2	.2	2.5	2.2	6.5	6.8	.677	-1.577	.219
.0	.0	1.1	1.1	4.0	4.3	9.5	9.2	.530	-1.137	.224
.0	.0	.9	.9	4.4	4.4	10.2	10.2	.594	-1.419	.032
.0	.0	1.5	1.4	5.6	5.9	12.6	12.3	.577	-1.444	.221
.0	.1	3.8	4.1	13.2	12.0	20.1	21.0	.589	-1.785	.806
.0	.4	6.4	6.5	14.8	14.5	22.4	22.6	.500	-1.494	.319
.2	.2	4.6	5.9	15.3	15.5	27.3	25.5	.597	-1.949	.835
.2	.2	5.1	6.1	15.6	16.0	27.9	26.2	.603	-1.990	.795
.0	.0	5.0	5.0	15.7	15.9	28.1	27.9	.703	-2.417	.154
.6	.5	7.1	7.9	16.4	17.2	27.8	26.2	.524	-1.693	.823
.7	.7	8.6	8.4	17.4	17.3	25.6	25.8	.497	-1.578	.137
.1	.1	5.7	6.0	17.2	17.0	28.6	28.4	.657	-2.255	.190
.0	.1	6.1	6.1	18.0	17.9	30.0	30.1	.691	-2.433	.095
.2	.2	6.9	7.4	18.6	18.9	30.9	30.2	.637	-2.231	.367
.2	.2	6.5	7.5	19.2	19.5	32.6	31.2	.654	-2.324	.685
.2	.2	7.3	7.6	19.3	19.4	31.3	30.9	.643	-2.272	.207
.3	.3	7.8	8.7	20.5	21.1	34.2	32.8	.643	-2.326	.726
.9	.8	9.3	10.4	21.2	21.4	32.4	31.3	.547	-1.920	.617
.1	.1	8.0	8.0	22.0	21.8	34.9	35.1	.724	-2.694	.121
.5	.4	9.2	10.4	23.4	23.4	36.1	35.1	.632	-2.346	.575
.3	.3	10.2	10.9	26.0	26.0	39.9	39.3	.708	-2.746	.345
1.2	1.1	12.3	13.7	26.4	27.1	40.1	38.5	.600	-2.314	.984
1.1	.9	12.3	14.5	27.4	29.2	44.5	41.5	.646	-2.572	1.798
.3	.3	12.0	12.4	28.6	28.9	43.5	43.0	.744	-2.985	.285
.5	.4	11.8	13.4	29.9	29.6	44.1	43.2	.718	-2.891	.708
.4	.4	11.7	13.1	30.1	29.7	44.4	43.7	.737	-2.980	.631
.2	.2	11.9	12.2	30.2	29.7	44.4	44.6	.784	-3.182	.252
.9	.9	13.3	13.7	28.4	27.7	39.2	39.5	.625	-2.438	.359
.7	.6	13.0	14.0	29.2	29.5	43.4	42.5	.682	-2.734	.571
.3	.3	12.5	12.8	30.3	29.7	43.8	44.0	.753	-3.046	.281
.6	.5	12.6	13.8	30.1	29.6	43.4	42.9	.698	-2.809	.544
.8	.7	12.6	14.9	31.6	31.1	45.7	44.4	.699	-2.856	1.040
.7	.7	14.0	14.9	32.0	31.2	44.6	44.6	.701	-2.866	.446
.4	.4	14.4	13.7	31.6	30.2	42.3	43.9	.723	-2.933	.951
.7	.6	14.1	16.0	34.1	33.5	48.3	47.5	.739	-3.092	.838
.8	.7	14.5	16.4	33.5	33.9	49.4	47.8	.734	-3.083	1.015
.6	.6	16.0	16.9	35.7	35.6	50.7	50.2	.775	-3.304	.398
1.5	1.3	17.1	19.4	35.8	36.7	52.0	50.0	.706	-3.039	1.362
1.3	1.1	17.1	19.0	36.3	36.5	51.1	49.9	.714	-3.066	.854
1.0	.9	17.3	18.3	36.4	36.1	50.1	49.8	.730	-3.120	.428
2.1	2.1	18.0	18.1	32.7	32.3	43.3	43.5	.590	-2.416	.191
.9	.8	17.2	19.5	39.4	38.9	54.3	53.4	.786	-3.440	.952
1.0	1.0	17.8	17.8	35.6	34.9	47.6	48.2	.705	-2.984	.337
1.4	1.3	18.5	20.3	38.4	38.3	52.8	51.9	.729	-3.178	.728
1.6	1.4	18.5	20.3	38.2	37.8	51.6	50.9	.705	-3.061	.767
1.3	1.2	18.7	20.2	38.8	38.5	52.8	52.2	.737	-3.218	.642
2.0	1.8	19.4	21.2	38.3	38.3	52.2	51.1	.687	-3.001	.778
2.0	1.8	19.5	21.7	39.5	39.3	53.4	52.3	.702	-3.091	.937

1.7	1.5	19.8	21.9	40.7	40.3	54.5	53.7	.732	-3.246	.880
1.2	1.2	21.0	21.3	40.5	40.3	54.2	54.2	.760	-3.367	.127
2.0	1.9	21.0	22.3	40.3	40.0	53.5	53.0	.705	-3.121	.558
2.4	2.2	21.1	22.6	39.7	39.6	52.9	52.2	.678	-2.996	.618
1.8	1.8	21.4	22.0	40.2	39.8	53.0	52.9	.710	-3.140	.277
2.5	2.3	21.7	23.2	40.5	40.5	54.0	53.1	.686	-3.054	.660
.3	.4	22.7	19.7	42.4	41.8	55.8	57.7	.888	-3.961	1.391
1.5	1.5	22.0	22.6	41.9	41.6	55.5	55.4	.756	-3.384	.265
1.4	1.4	22.1	22.5	42.4	41.7	55.2	55.5	.761	-3.410	.359
2.3	2.1	22.4	24.6	43.8	43.2	57.1	56.4	.734	-3.336	.926
2.4	2.2	22.6	23.9	40.3	41.8	56.5	54.7	.710	-3.194	1.198
3.0	2.8	22.8	24.1	40.9	40.8	53.6	53.0	.663	-2.962	.528
.1	.1	25.5	22.6	51.5	49.6	64.4	66.9	1.072	-4.969	1.845
2.3	1.8	24.0	27.9	48.0	48.9	65.0	62.7	.825	-3.884	1.883
1.1	1.0	25.2	26.8	51.1	49.6	64.2	64.5	.900	-4.227	.863
3.7	3.3	23.6	25.6	41.1	42.4	56.3	54.4	.661	-2.999	1.381
4.4	4.2	26.2	27.3	44.3	43.7	55.4	55.3	.643	-2.955	.495
2.1	2.1	28.9	29.3	51.6	50.2	63.0	63.8	.825	-3.921	.660
3.5	3.3	27.6	29.0	47.6	47.6	60.8	60.2	.732	-3.447	.547
1.4	1.5	30.6	29.7	53.7	52.2	65.2	66.5	.894	-4.280	.942
5.0	4.6	27.0	29.2	46.0	46.2	59.0	57.9	.664	-3.116	.990
1.8	1.9	30.6	30.4	53.9	52.4	65.2	66.3	.871	-4.183	.715
3.0	3.0	29.2	29.2	49.1	48.3	60.6	61.1	.752	-3.557	.348
2.4	2.4	30.0	30.5	53.0	51.4	64.0	64.8	.826	-3.961	.751
5.0	4.8	27.6	28.7	45.0	45.2	57.3	56.6	.644	-3.002	.549
1.4	1.6	33.0	30.9	55.4	53.5	65.6	67.7	.903	-4.358	1.578
1.9	2.1	33.8	32.8	56.8	55.2	67.6	69.0	.900	-4.398	1.019
2.2	2.3	33.7	32.8	55.6	54.7	67.3	68.2	.877	-4.279	.714
4.1	3.9	31.2	32.7	52.4	52.0	64.9	64.5	.769	-3.737	.597
2.7	3.3	34.4	30.1	50.3	49.2	59.2	61.9	.751	-3.577	2.180
5.9	5.6	29.9	31.3	47.9	47.9	59.9	59.3	.655	-3.127	.577
5.7	5.6	30.6	31.1	48.1	47.8	59.1	59.1	.653	-3.112	.244
3.4	3.6	34.9	34.4	56.2	54.9	66.7	67.7	.824	-4.060	.716
2.9	3.2	38.8	37.3	60.5	59.1	70.6	72.0	.902	-4.525	1.148
4.2	5.0	41.3	37.8	60.0	57.6	66.7	69.6	.810	-4.082	2.416
6.4	6.7	37.2	36.4	54.9	54.2	64.7	65.5	.713	-3.559	.637
3.4	4.2	45.9	41.6	65.1	63.2	72.8	75.3	.926	-4.767	2.377
5.2	6.5	42.5	37.4	57.4	55.6	63.8	67.1	.739	-3.716	2.858
4.9	6.3	45.4	39.6	60.7	58.6	66.5	70.1	.788	-4.017	3.248
4.5	5.4	47.4	43.8	66.5	64.6	73.8	76.2	.910	-4.746	2.210
8.1	7.9	40.0	40.8	59.0	58.8	70.0	69.8	.750	-3.864	.325
7.0	7.2	43.0	42.7	63.0	61.7	72.0	72.9	.813	-4.229	.684
7.7	8.7	49.1	46.3	66.4	65.1	74.0	75.7	.835	-4.441	1.694
9.8	11.2	44.9	41.1	58.3	56.9	64.3	66.9	.650	-3.371	2.305
11.0	11.7	58.0	56.4	75.0	74.6	83.0	83.6	.955	-5.336	.834
13.4	13.9	48.7	47.9	65.1	64.0	72.5	73.5	.713	-3.876	.836
14.0	15.5	62.0	59.6	78.0	76.3	83.0	84.6	.926	-5.294	1.796
17.0	18.8	60.5	57.1	73.4	72.4	79.1	80.7	.789	-4.527	1.954
21.0	22.3	62.0	59.9	75.0	74.3	81.0	82.0	.778	-4.562	1.258
22.0	24.8	69.0	65.0	80.0	78.8	84.0	85.8	.848	-5.087	2.445
37.0	39.3	69.0	66.1	77.0	76.0	80.0	81.7	.588	-3.822	1.970

Maximum, Average, and Standard Deviation of Average Cumulative Errors:

3.248 .8681 .6665

TABLE 18
NEURAL-NETWORK PREDICTIONS USING CUMULATIVE SIEVE ANALYSES
(measured point on left, predicted point on right)

D-95		D-90		D-80		D-70		D-50		D-30		WAPE
52	69	33	45	18	25	11	15	4	6	1	2	40.96
66	89	42	58	23	33	14	21	6	9	2	3	43.13
69	108	45	66	25	31	15	17	6	5	2	1	33.81
80	106	52	64	30	31	19	17	8	5	3	1	22.76
131	160	89	100	44	50	23	28	7	9	2	3	23.81
155	128	106	80	51	42	28	25	9	9	2	3	17.53
143	131	99	89	60	54	40	36	18	17	7	7	8.81
151	132	102	94	61	61	41	43	19	23	8	10	10.77
149	179	102	119	61	74	41	49	19	22	8	8	18.23
220	140	131	93	62	49	34	28	11	10	3	3	22.99
194	181	116	111	62	65	40	44	18	21	6	9	9.33
160	179	109	118	65	70	42	45	18	19	7	7	8.81
153	176	113	117	67	73	44	48	20	22	7	9	10.41
180	193	119	129	69	77	46	47	21	17	8	5	10.06
174	180	118	121	72	77	48	50	23	23	9	9	4.37
185	154	123	114	72	75	46	52	20	26	8	11	15.65
195	275	128	150	76	79	51	51	25	22	10	8	16.30
238	207	142	139	79	85	49	53	20	20	7	6	7.14
188	182	131	124	80	80	53	53	24	24	9	9	2.50
221	247	142	140	86	83	56	58	25	30	9	14	10.03
223	261	151	150	94	87	64	56	30	25	12	9	10.92
289	242	177	139	99	83	64	58	30	31	12	14	14.86
284	297	177	190	102	113	68	78	37	38	18	16	8.43
240	292	167	188	103	113	70	78	35	37	15	16	12.46
249	231	167	155	105	99	74	69	35	33	15	14	6.46
243	241	165	156	105	101	74	72	36	36	15	16	3.33
232	249	165	161	106	102	75	72	36	38	15	17	5.79
284	270	185	171	107	97	68	61	26	25	8	8	6.96
271	272	180	174	107	108	72	76	34	39	14	17	5.00
244	260	171	171	108	106	75	74	34	36	14	15	3.19
262	278	175	178	108	109	74	77	34	39	13	17	6.73
273	277	177	180	110	110	78	76	37	37	15	15	1.55
280	281	189	179	115	110	79	77	35	39	13	17	6.46
265	238	187	175	116	117	79	84	30	38	9	14	12.17
281	262	190	168	118	105	84	74	41	38	17	17	9.19
289	265	194	190	119	119	83	79	43	38	20	16	6.00
289	233	203	168	127	112	89	83	45	40	20	16	14.58
336	377	224	257	133	152	92	103	46	51	20	22	13.06
344	382	227	259	133	152	91	103	47	51	22	22	11.50
321	365	220	251	134	151	92	103	44	51	18	23	14.38
386	364	246	221	134	125	84	90	31	36	10	11	8.70
315	287	217	210	135	138	98	103	51	54	23	22	4.83
324	286	224	199	136	127	91	93	40	47	14	20	12.06
351	414	237	266	141	147	98	102	49	51	21	22	9.45
362	357	241	246	141	149	98	102	47	51	19	23	5.25
347	406	236	260	142	143	99	99	49	49	20	21	6.66
389	341	256	226	145	133	100	94	48	47	20	20	8.28
390	434	257	290	146	168	102	117	50	61	21	26	15.15

375	485	253	314	148	173	105	116	53	58	22	26	19.90
355	298	250	216	155	140	107	99	52	48	21	20	11.22
398	392	268	259	156	148	107	100	51	49	20	21	3.93
421	346	277	240	157	146	106	100	50	51	20	23	10.70
389	409	266	280	159	167	107	114	50	53	19	20	5.48
429	389	284	260	162	150	109	101	52	50	21	21	7.04
304	335	233	242	162	156	114	111	56	56	23	23	4.71
376	395	263	255	162	142	112	96	55	47	23	20	8.91
371	471	262	301	162	163	113	107	55	50	21	20	12.06
421	481	284	281	166	142	115	103	59	54	24	24	9.06
428	338	288	235	168	144	110	99	55	50	26	23	15.16
462	354	303	243	171	146	112	101	51	46	20	16	16.66
291	371	233	277	171	186	132	136	77	77	34	33	12.72
429	447	295	301	177	175	125	126	70	75	37	37	2.89
369	437	271	294	179	172	131	120	76	63	34	27	11.71
507	370	326	253	179	151	115	103	55	51	25	23	17.25
556	563	361	365	201	202	128	128	57	60	19	26	3.73
436	474	317	346	205	226	144	160	78	89	30	35	10.72
506	457	346	312	206	186	137	127	68	65	29	26	8.28
406	427	306	325	208	224	152	166	83	95	34	42	9.02
595	632	383	376	210	185	133	119	64	61	26	29	7.12
427	452	317	328	211	212	152	149	84	83	34	26	4.35
483	385	341	287	212	192	145	139	71	74	27	29	11.85
455	474	330	334	213	208	149	143	82	82	32	38	3.96
595	502	387	328	215	184	135	120	60	56	23	22	12.62
414	431	316	330	219	230	162	171	88	99	34	44	7.39
441	395	333	297	227	202	167	148	92	85	39	37	10.09
456	502	341	375	230	253	167	183	89	98	38	39	9.32
545	548	380	389	232	243	156	167	80	86	34	34	3.64
481	514	357	371	238	238	171	166	75	78	21	23	3.95
653	550	426	371	238	217	148	142	68	68	26	27	9.07
638	627	423	421	241	245	153	158	68	76	24	18	4.70
515	393	377	299	247	206	175	152	92	88	37	39	16.32
499	428	379	328	260	228	192	170	106	98	46	44	11.63
560	514	421	391	285	270	208	200	109	111	33	43	7.44
669	607	468	435	288	277	195	192	91	101	32	24	7.72
531	508	414	395	296	280	225	212	130	124	54	51	4.90
604	666	450	491	302	325	218	233	106	114	25	29	9.08
591	692	450	505	311	329	230	233	122	112	31	32	9.06
575	643	445	495	315	347	237	260	137	150	58	69	11.23
757	641	528	460	323	294	217	204	105	102	44	44	9.32
687	623	500	456	325	298	229	211	119	107	50	42	9.25
704	691	530	512	360	341	263	245	144	129	59	51	5.49
828	849	588	614	369	395	253	276	115	135	25	39	10.39
805	756	620	594	435	428	327	328	189	198	94	108	4.35
1019	1135	715	792	441	486	298	327	142	153	53	56	9.88
899	864	695	664	489	463	368	346	214	199	109	99	5.39
1060	1168	793	854	535	558	389	395	212	205	91	92	5.58
1276	1400	938	999	617	631	439	435	230	215	100	86	6.03
1165	1265	899	946	632	637	475	462	276	251	141	118	5.97
2802	2911	1936	1951	1171	1132	779	728	358	314	138	113	5.60

Maximum, Average, and Standard Deviation of Weighted Average Percentage Errors:

43.13 10.35 6.954

TABLE 19
NEURAL-NETWORK PREDICTIONS USING FRACTIONAL SIEVE ANALYSES
(measured point on left, predicted point on right)

D-95		D-90		D-80		D-70		D-50		D-30		WAPE
52	80	33	43	18	17	11	8	4	2	1	0	36.09
66	96	42	58	23	25	14	13	6	4	2	1	30.80
69	88	45	56	25	29	15	16	6	6	2	2	18.47
80	85	52	54	30	26	19	15	8	5	3	1	15.89
131	121	89	90	44	53	23	30	7	10	2	3	23.82
155	159	106	88	51	45	28	27	9	10	2	3	13.51
143	111	99	87	60	56	40	35	18	14	7	5	15.90
151	329	102	176	61	91	41	56	19	22	8	7	61.01
149	177	102	121	61	73	41	49	19	23	8	9	18.69
220	130	131	88	62	50	34	31	11	12	3	4	26.60
194	166	116	111	62	65	40	39	18	14	6	4	9.98
160	175	109	120	65	71	42	48	18	23	7	10	16.38
153	182	113	124	67	76	44	50	20	22	7	9	14.01
180	192	119	142	69	82	46	51	21	20	8	7	12.43
174	173	118	119	72	71	48	47	23	22	9	9	1.87
185	190	123	149	72	83	46	49	20	17	8	5	13.98
195	182	128	124	76	81	51	54	25	24	10	9	5.56
238	192	142	143	79	83	49	51	20	20	7	7	6.77
188	167	131	115	80	69	53	45	24	21	9	8	13.51
221	211	142	128	86	80	56	54	25	26	9	11	6.30
223	198	151	142	94	94	64	65	30	28	12	10	6.80
289	212	177	127	99	80	64	54	30	26	12	11	21.36
284	267	177	194	102	123	68	83	37	40	18	17	12.53
240	267	167	193	103	123	70	83	35	40	15	17	15.78
249	220	167	172	105	113	74	77	35	37	15	15	6.72
243	262	165	191	105	122	74	84	36	40	15	17	12.87
232	271	165	192	106	119	75	80	36	38	15	15	11.95
284	336	185	224	107	130	68	87	26	34	8	11	23.72
271	271	180	192	107	119	72	80	34	38	14	16	7.98
244	260	171	191	108	123	75	84	34	41	14	17	12.74
262	271	175	192	108	120	74	81	34	39	13	16	9.99
273	264	177	192	110	123	78	83	37	41	15	17	7.80
280	271	189	192	115	120	79	81	35	39	13	16	5.62
265	223	187	145	116	91	79	61	30	27	9	11	18.59
281	271	190	192	118	119	84	80	41	38	17	16	3.58
289	210	194	147	119	100	83	73	43	35	20	14	21.34
289	283	203	185	127	113	89	78	45	36	20	14	10.96
336	491	224	302	133	156	92	106	46	53	20	23	26.90
344	480	227	298	133	156	91	107	47	53	22	23	24.20
321	512	220	308	134	154	92	105	44	51	18	22	30.96
386	632	246	331	134	141	84	84	31	30	10	8	24.73
315	235	217	183	135	127	98	92	51	44	23	17	14.98
324	329	224	226	136	138	91	98	40	49	14	21	8.62
351	360	237	255	141	159	98	114	49	60	21	27	12.30
362	524	241	311	141	153	98	103	47	50	19	21	21.16
347	370	236	259	142	159	99	113	49	60	20	27	13.19
389	370	256	252	145	149	100	106	48	55	20	24	6.28
390	340	257	246	146	158	102	114	50	61	21	27	12.13

375	327	253	246	148	166	105	122	53	67	22	30	14.78
355	364	250	268	155	178	107	126	52	63	21	25	11.97
398	439	268	285	156	158	107	110	51	56	20	24	7.24
421	536	277	314	157	152	106	102	50	49	20	21	10.94
389	445	266	310	159	190	107	127	50	57	19	19	15.58
429	454	284	290	162	157	109	109	52	55	21	24	4.19
304	364	233	275	162	187	114	137	56	74	23	33	22.26
376	407	263	273	162	159	112	112	55	58	23	26	4.75
371	406	262	287	162	179	113	120	55	52	21	18	9.00
421	291	284	224	166	156	115	114	59	61	24	26	13.95
428	543	288	315	168	151	110	101	55	48	26	20	14.78
462	455	303	314	171	190	112	127	51	57	20	19	6.87
291	299	233	243	171	183	132	144	77	76	34	27	6.10
429	300	295	219	177	144	125	105	70	57	37	27	22.80
369	337	271	244	179	158	131	114	76	61	34	27	12.37
507	504	326	306	179	155	115	105	55	52	25	22	6.97
556	424	361	299	201	187	128	123	57	47	19	14	15.30
436	364	317	284	205	203	144	155	78	83	30	33	8.98
506	722	346	471	206	263	137	164	68	70	29	25	27.75
406	340	306	273	208	203	152	160	83	89	34	34	8.10
595	584	383	362	210	189	133	126	64	69	26	34	7.80
427	451	317	345	211	239	152	178	84	97	34	45	13.05
483	324	341	241	212	161	145	115	71	57	27	23	25.44
455	422	330	326	213	229	149	172	82	97	32	46	11.66
595	402	387	284	215	178	135	119	60	52	23	18	21.88
414	355	316	282	219	207	162	161	88	88	34	33	6.83
441	316	333	255	227	190	167	150	92	81	39	30	19.48
456	382	341	300	230	216	167	165	89	87	38	31	9.13
545	420	380	319	232	220	156	163	80	88	34	37	12.32
481	583	357	422	238	272	171	191	75	93	21	32	20.29
653	395	426	281	238	176	148	119	68	51	26	17	30.13
638	431	423	293	241	174	153	118	68	55	24	19	27.03
515	356	377	281	247	204	175	158	92	88	37	36	18.15
499	353	379	281	260	207	192	161	106	88	46	33	22.90
560	527	421	391	285	261	208	188	109	94	33	26	9.49
669	486	468	360	288	240	195	172	91	89	32	37	17.83
531	463	414	374	296	279	225	220	130	138	54	67	9.00
604	637	450	480	302	327	218	239	106	131	25	49	15.90
591	756	450	548	311	354	230	248	122	124	31	43	18.01
575	419	445	330	315	238	237	183	137	102	58	38	25.93
757	712	528	501	323	311	217	211	105	110	44	54	5.78
687	726	500	518	325	327	229	225	119	116	50	53	3.10
704	676	530	501	360	333	263	239	144	127	59	52	7.35
828	865	588	625	369	401	253	280	115	140	25	49	15.25
805	916	620	682	435	457	327	330	189	178	94	85	7.80
1019	1116	715	762	441	453	298	297	142	131	53	41	6.78
899	1029	695	757	489	499	368	356	214	187	109	88	9.18
1060	1059	793	795	535	538	389	392	212	214	91	101	1.14
1276	1652	938	1153	617	706	439	475	230	223	100	92	16.78
1165	1408	899	1028	632	670	475	474	276	245	141	105	12.25
2802	2116	1936	1489	1171	923	779	626	358	299	138	103	21.79

Maximum, Average, and Standard Deviation of Weighted Average Percentage Errors:

61.01 14.76 8.789

TABLE 20
NEURAL-NETWORK PREDICTIONS USING ALL SIEVE ANALYSIS DATA
(measured point on left, predicted point on right)

D-95		D-90		D-80		D-70		D-50		D-30		WAPE
52	102	33	56	18	23	11	11	4	3	1	1	52.42
66	101	42	54	23	23	14	11	6	3	2	1	33.73
69	113	45	69	25	33	15	18	6	6	2	2	38.16
80	118	52	72	30	35	19	19	8	6	3	2	28.44
131	192	89	111	44	57	23	34	7	13	2	4	52.27
155	198	106	107	51	54	28	33	9	13	2	4	24.51
143	137	99	93	60	55	40	36	18	16	7	6	8.57
151	233	102	125	61	68	41	43	19	18	8	6	22.51
149	160	102	107	61	63	41	42	19	19	8	8	4.17
220	184	131	101	62	52	34	32	11	13	3	4	18.31
194	181	116	110	62	60	40	38	18	16	6	6	5.95
160	207	109	128	65	69	42	45	18	20	7	8	16.46
153	219	113	134	67	73	44	48	20	21	7	8	18.12
180	280	119	148	69	74	46	48	21	21	8	8	20.42
174	155	118	105	72	63	48	42	23	19	9	8	12.55
185	151	123	100	72	57	46	36	20	15	8	5	20.83
195	204	128	130	76	79	51	54	25	26	10	11	4.31
238	229	142	125	79	67	49	44	20	20	7	7	8.76
188	148	131	103	80	63	53	42	24	20	9	8	21.04
221	228	142	140	86	82	56	56	25	28	9	12	5.16
223	163	151	116	94	78	64	54	30	26	12	11	19.56
289	234	177	143	99	83	64	56	30	28	12	12	15.03
284	333	177	191	102	107	68	72	37	36	18	16	8.96
240	329	167	190	103	107	70	72	35	36	15	16	13.48
249	253	167	161	105	98	74	67	35	31	15	13	6.31
243	275	165	167	105	99	74	67	36	32	15	13	7.62
232	322	165	196	106	115	75	81	36	38	15	15	17.40
284	371	185	236	107	131	68	86	26	33	8	10	27.09
271	332	180	197	107	112	72	76	34	36	14	15	9.98
244	291	171	176	108	104	75	70	34	35	14	15	7.82
262	335	175	196	108	110	74	74	34	36	13	15	11.00
273	313	177	185	110	106	78	71	37	36	15	15	7.20
280	334	189	195	115	109	79	73	35	35	13	15	8.79
265	218	187	149	116	96	79	66	30	29	9	11	16.13
281	327	190	197	118	113	84	78	41	37	17	15	8.71
289	367	194	241	119	138	83	93	43	47	20	21	18.16
289	250	203	180	127	114	89	78	45	37	20	15	13.50
336	375	224	255	133	151	92	101	46	49	20	21	11.56
344	372	227	253	133	150	91	100	47	49	22	21	9.28
321	381	220	260	134	154	92	103	44	50	18	22	16.44
386	427	246	261	134	135	84	84	31	34	10	12	6.76
315	291	217	205	135	129	98	90	51	46	23	20	7.32
324	310	224	223	136	142	91	99	40	47	14	18	7.90
351	346	237	242	141	148	98	106	49	54	21	23	5.26
362	386	241	263	141	157	98	105	47	51	19	22	9.54
347	347	236	241	142	147	99	104	49	53	20	22	3.48
389	336	256	237	145	147	100	103	48	50	20	20	6.34
390	356	257	252	146	158	102	114	50	60	21	26	10.12

375	379	253	265	148	162	105	116	53	63	22	28	9.43
355	334	250	237	155	149	107	102	52	50	21	22	4.66
398	365	268	249	156	148	107	100	51	49	20	21	6.45
421	390	277	267	157	159	106	107	50	53	20	23	4.98
389	442	266	298	159	174	107	117	50	56	19	23	11.76
429	368	284	250	162	148	109	100	52	49	21	21	9.58
304	373	233	268	162	171	114	118	56	56	23	21	10.63
376	357	263	244	162	146	112	101	55	50	23	21	7.75
371	428	262	286	162	166	113	110	55	52	21	20	7.23
421	396	284	267	166	157	115	111	59	59	24	27	5.36
428	395	288	270	168	161	110	109	55	54	26	24	4.87
462	451	303	301	171	173	112	114	51	52	20	20	1.70
291	402	233	292	171	189	132	134	77	72	34	29	18.24
429	416	295	282	177	167	125	118	70	65	37	32	5.31
369	360	271	256	179	161	131	116	76	62	34	27	9.49
507	379	326	258	179	153	115	102	55	50	25	22	17.01
556	480	361	322	201	187	128	124	57	58	19	22	8.42
436	538	317	375	205	230	144	154	78	82	30	34	14.67
506	515	346	351	206	208	137	137	68	64	29	26	2.20
406	486	306	352	208	227	152	159	83	88	34	36	11.63
595	559	383	369	210	209	133	135	64	68	26	32	4.91
427	515	317	366	211	230	152	158	84	84	34	37	11.10
483	464	341	335	212	215	145	151	71	76	27	29	3.85
455	657	330	434	213	247	149	157	82	83	32	38	22.64
595	468	387	317	215	187	135	122	60	56	23	22	14.10
414	495	316	364	219	240	162	171	88	92	34	38	12.06
441	434	333	317	227	207	167	146	92	80	39	33	7.91
456	501	341	369	230	243	167	174	89	92	38	40	6.69
545	553	380	389	232	241	156	164	80	88	34	41	5.13
481	594	357	428	238	273	171	190	75	87	21	26	18.17
653	526	426	363	238	220	148	146	68	63	26	24	10.76
638	531	423	362	241	215	153	140	68	60	24	21	12.57
515	485	377	357	247	235	175	168	92	91	37	38	4.34
499	495	379	363	260	238	192	169	106	92	46	38	7.57
560	559	421	421	285	286	208	209	109	111	33	36	.84
669	607	468	433	288	274	195	189	91	83	32	30	6.58
531	688	414	515	296	348	225	253	130	137	54	60	19.02
604	622	450	463	302	310	218	224	106	111	25	36	6.26
591	689	450	508	311	336	230	241	122	120	31	37	10.47
575	666	445	502	315	341	237	250	137	139	58	68	10.23
757	804	528	542	323	317	217	206	105	102	44	47	4.07
687	629	500	469	325	315	229	228	119	125	50	54	5.14
704	739	530	559	360	383	263	281	144	157	59	76	7.96
828	755	588	548	369	354	253	249	115	120	25	39	9.02
805	797	620	618	435	437	327	330	189	194	94	94	.88
1019	982	715	674	441	404	298	267	142	121	53	45	8.30
899	944	695	711	489	484	368	354	214	195	109	90	4.92
1060	916	793	696	535	480	389	355	212	200	91	89	10.15
1276	1410	938	1023	617	661	439	464	230	237	100	99	7.03
1165	1101	899	834	632	571	475	421	276	235	141	106	10.22
2802	2465	1936	1704	1171	1031	779	686	358	316	138	121	11.98

Maximum, Average, and Standard Deviation of Weighted Average Percentage Errors:

52.42 11.86 8.994

TABLE 21
NEURAL-NETWORK PREDICTIONS USING ROSIN-RAMMLER FIT OF DATA
(measured point on left, predicted point on right)

D-95		D-90		D-80		D-70		D-50		D-30		WAPE
52	57	33	37	18	20	11	13	4	5	1	2	16.98
66	92	42	58	23	31	14	19	6	7	2	2	31.62
69	67	45	43	25	23	15	14	6	6	2	2	5.07
80	65	52	41	30	23	19	14	8	5	3	2	24.10
131	153	89	101	44	58	23	37	7	16	2	6	58.92
155	97	106	58	51	29	28	16	9	5	2	1	40.69
143	105	99	70	60	40	40	26	18	11	7	4	32.40
151	158	102	107	61	63	41	41	19	18	8	7	4.19
149	238	102	162	61	96	41	63	19	28	8	11	54.66
220	130	131	81	62	42	34	25	11	9	3	3	29.58
194	97	116	62	62	34	40	21	18	8	6	3	48.94
160	245	109	162	65	92	42	58	18	24	7	9	44.56
153	230	113	160	67	97	44	65	20	30	7	12	48.50
180	110	119	71	69	39	46	24	21	10	8	3	44.82
174	237	118	161	72	95	48	62	23	27	9	10	29.80
185	163	123	106	72	58	46	36	20	15	8	5	19.00
195	275	128	182	76	104	51	66	25	28	10	10	32.46
238	110	142	70	79	38	49	24	20	9	7	3	52.26
188	237	131	159	80	92	53	59	24	26	9	9	15.86
221	348	142	225	86	125	56	77	25	31	9	10	44.79
223	223	151	148	94	85	64	54	30	23	12	8	10.04
289	341	177	223	99	125	64	78	30	32	12	11	19.56
284	270	177	186	102	112	68	75	37	34	18	13	8.60
240	270	167	186	103	112	70	74	35	34	15	13	8.96
249	269	167	185	105	110	74	73	35	33	15	13	6.93
243	267	165	186	105	113	74	75	36	35	15	14	7.22
232	284	165	199	106	122	75	82	36	39	15	16	15.77
284	205	185	136	107	77	68	49	26	20	8	7	25.79
271	274	180	191	107	117	72	79	34	37	14	15	6.17
244	273	171	187	108	112	75	73	34	33	14	13	6.74
262	270	175	188	108	115	74	77	34	36	13	15	6.25
273	271	177	186	110	112	78	74	37	34	15	13	4.64
280	269	189	187	115	114	79	77	35	36	13	14	3.10
265	219	187	151	116	92	79	61	30	28	9	11	18.09
281	278	190	194	118	119	84	80	41	38	17	15	3.50
289	297	194	200	119	117	83	76	43	33	20	12	8.61
289	267	203	186	127	113	89	76	45	35	20	14	12.86
336	256	224	177	133	107	92	71	46	33	20	13	23.40
344	257	227	178	133	108	91	72	47	33	22	13	23.97
321	256	220	176	134	106	92	70	44	32	18	13	22.46
386	274	246	182	134	104	84	66	31	28	10	10	21.72
315	239	217	173	135	112	98	78	51	40	23	18	20.87
324	312	224	220	136	137	91	93	40	45	14	19	5.92
351	382	237	258	141	152	98	99	49	44	21	16	8.53
362	257	241	176	141	106	98	70	47	32	19	12	28.52
347	368	236	248	142	145	99	93	49	41	20	15	7.82
389	343	256	233	145	137	100	90	48	40	20	15	11.19
390	356	257	253	146	159	102	109	50	53	21	23	6.57

375	401	253	286	148	180	105	123	53	60	22	26	14.59
355	341	250	244	155	155	107	107	52	53	21	23	2.19
398	274	268	189	156	114	107	76	51	35	20	14	29.85
421	260	277	177	157	105	106	69	50	31	20	12	36.18
389	535	266	363	159	214	107	140	50	62	19	23	32.73
429	265	284	183	162	111	109	74	52	34	21	13	34.49
304	452	233	329	162	213	114	150	56	77	23	34	39.85
376	306	263	209	162	124	112	81	55	36	23	14	24.87
371	408	262	280	162	167	113	110	55	50	21	19	6.63
421	362	284	250	166	151	115	101	59	46	24	18	14.01
428	263	288	178	168	105	110	69	55	30	26	11	40.07
462	384	303	262	171	156	112	103	51	46	20	18	11.83
291	383	233	294	171	206	132	154	77	88	34	45	23.91
429	360	295	255	177	160	125	109	70	53	37	22	16.12
369	344	271	247	179	158	131	110	76	55	34	24	13.96
507	255	326	176	179	106	115	71	55	32	25	13	44.09
556	304	361	198	201	111	128	69	57	28	19	10	46.45
436	410	317	305	205	204	144	148	78	80	30	38	4.64
506	376	346	255	206	151	137	98	68	44	29	16	28.77
406	458	306	347	208	238	152	175	83	98	34	49	16.46
595	498	383	346	210	211	133	141	64	66	26	26	7.45
427	323	317	241	211	162	152	118	84	64	34	31	22.55
483	474	341	341	212	218	145	152	71	76	27	33	4.45
455	457	330	339	213	225	149	162	82	86	32	40	6.03
595	437	387	301	215	181	135	120	60	55	23	21	17.36
414	375	316	284	219	195	162	144	88	80	34	40	10.64
441	401	333	304	227	209	167	154	92	86	39	43	8.38
456	376	341	281	230	188	167	136	89	74	38	35	17.02
545	410	380	293	232	185	156	128	80	63	34	27	21.82
481	450	357	312	238	190	171	127	75	59	21	23	15.85
653	477	426	331	238	201	148	134	68	62	26	25	16.92
638	313	423	214	241	128	153	84	68	38	24	15	47.09
515	445	377	331	247	221	175	159	92	86	37	40	10.88
499	382	379	290	260	199	192	146	106	82	46	41	22.52
560	456	421	331	285	215	208	151	109	78	33	35	22.07
669	367	468	253	288	153	195	102	91	47	32	18	46.26
531	450	414	332	296	219	225	157	130	83	54	38	24.41
604	1110	450	754	302	445	218	290	106	129	25	49	57.99
591	565	450	397	311	246	230	167	122	80	31	33	16.83
575	459	445	340	315	226	237	162	137	87	58	41	27.14
757	637	528	448	323	278	217	188	105	90	44	37	14.60
687	397	500	292	325	192	229	137	119	72	50	33	40.57
704	406	530	298	360	196	263	139	144	73	59	33	45.05
828	690	588	473	369	282	253	186	115	84	25	32	22.39
805	424	620	328	435	231	327	174	189	102	94	53	46.69
1019	652	715	444	441	263	298	172	142	77	53	29	40.10
899	710	695	528	489	352	368	254	214	136	109	64	28.02
1060	718	793	525	535	344	389	244	212	127	91	58	35.38
1276	1342	938	923	617	554	439	366	230	167	100	65	12.14
1165	1419	899	1020	632	651	475	452	276	226	141	98	13.63
2802	2919	1936	1927	1171	1095	779	693	358	290	138	102	8.34

Maximum, Average, and Standard Deviation of Weighted Average Percentage Errors:

58.92 22.68 14.89

TABLE 22
NEURAL-NETWORK PREDICTIONS USING EQUATION ERROR FACTOR
(measured point on left, predicted point on right)

D-95		D-90		D-80		D-70		D-50		D-30		WAPE
52	50	33	30	18	18	11	10	4	5	1	1	6.19
66	86	42	49	23	27	14	17	6	7	2	2	21.41
69	95	45	55	25	32	15	23	6	8	2	3	35.07
80	98	52	56	30	32	19	23	8	8	3	3	13.86
131	148	89	89	44	42	23	25	7	7	2	2	6.52
155	195	106	107	51	62	28	39	9	9	2	3	19.01
143	149	99	110	60	65	40	42	18	19	7	8	7.89
151	156	102	109	61	61	41	43	19	21	8	10	7.08
149	182	102	111	61	71	41	50	19	21	8	10	16.91
220	87	131	50	62	28	34	19	11	7	3	2	50.35
194	185	116	114	62	63	40	42	18	18	6	8	4.04
160	127	109	74	65	47	42	35	18	13	7	6	23.11
153	180	113	118	67	78	44	50	20	24	7	10	15.90
180	272	119	156	69	88	46	62	21	23	8	7	31.61
174	189	118	115	72	73	48	50	23	20	9	9	4.93
185	228	123	136	72	90	46	62	20	25	8	7	21.31
195	290	128	173	76	89	51	56	25	24	10	8	25.55
238	251	142	143	79	80	49	59	20	21	7	7	6.54
188	201	131	120	80	75	53	50	24	19	9	9	8.61
221	337	142	195	86	100	56	60	25	26	9	8	25.59
223	274	151	178	94	101	64	59	30	27	12	9	14.41
289	337	177	194	99	99	64	59	30	25	12	8	11.57
284	231	177	158	102	109	68	81	37	42	18	18	13.11
240	234	167	160	103	110	70	82	35	42	15	18	9.52
249	323	167	201	105	133	74	96	35	41	15	17	24.56
243	258	165	180	105	125	74	83	36	43	15	17	12.99
232	217	165	155	106	107	75	81	36	45	15	20	10.14
284	261	185	181	107	109	68	73	26	28	8	9	5.90
271	217	180	155	107	107	72	80	34	44	14	19	15.65
244	251	171	169	108	117	75	83	34	41	14	17	9.03
262	218	175	155	108	108	74	79	34	44	13	19	14.53
273	240	177	163	110	113	78	82	37	42	15	18	8.31
280	219	189	156	115	108	79	79	35	44	13	19	16.37
265	194	187	127	116	91	79	61	30	27	9	9	22.38
281	216	190	155	118	107	84	80	41	45	17	19	13.93
289	340	194	212	119	113	83	79	43	39	20	13	11.02
289	268	203	179	127	118	89	81	45	39	20	13	11.30
336	380	224	257	133	152	92	102	46	53	20	21	13.08
344	373	227	253	133	150	91	102	47	53	22	21	10.97
321	393	220	264	134	154	92	102	44	52	18	20	17.38
386	344	246	223	134	131	84	88	31	35	10	11	8.34
315	380	217	252	135	145	98	93	51	46	23	16	13.97
324	355	224	234	136	139	91	98	40	49	14	18	9.72
351	376	237	255	141	151	98	108	49	58	21	22	8.97
362	403	241	268	141	156	98	102	47	51	19	20	9.58
347	366	236	250	142	149	99	106	49	57	20	22	7.24
389	348	256	234	145	140	100	98	48	52	20	19	6.37
390	407	257	271	146	158	102	113	50	59	21	22	8.19

375	406	253	276	148	161	105	114	53	60	22	23	9.33
355	352	250	239	155	185	107	152	52	57	21	21	13.41
398	356	268	245	156	147	107	102	51	55	20	22	7.64
421	413	277	273	157	157	106	102	50	50	20	20	1.52
389	422	266	283	159	175	107	117	50	57	19	19	8.45
429	361	284	247	162	148	109	102	52	54	21	21	9.89
304	341	233	244	162	153	114	116	56	69	23	28	9.76
376	352	263	243	162	146	112	103	55	56	23	22	6.85
371	521	262	306	162	191	113	133	55	56	21	22	19.89
421	364	284	260	166	162	115	122	59	72	24	25	9.66
428	418	288	276	168	158	110	102	55	50	26	19	6.89
462	460	303	302	171	181	112	119	51	56	20	19	3.83
291	313	233	248	171	179	132	133	77	84	34	32	5.63
429	314	295	231	177	154	125	115	70	63	37	23	18.50
369	413	271	274	179	159	131	114	76	59	34	22	12.34
507	388	326	261	179	153	115	102	55	52	25	21	16.11
556	501	361	301	201	182	128	122	57	52	19	20	9.92
436	399	317	304	205	206	144	148	78	75	30	28	4.35
506	565	346	377	206	215	137	148	68	65	29	22	9.08
406	431	306	329	208	225	152	164	83	97	34	36	8.52
595	417	383	290	210	193	133	139	64	66	26	22	15.82
427	436	317	314	211	206	152	145	84	85	34	27	3.66
483	474	341	337	212	198	145	149	71	84	27	35	6.98
455	427	330	333	213	227	149	160	82	89	32	32	5.44
595	522	387	305	215	192	135	133	60	55	23	22	11.11
414	453	316	345	219	238	162	176	88	106	34	37	10.37
441	403	333	307	227	209	167	153	92	91	39	33	7.69
456	450	341	343	230	240	167	179	89	103	38	36	4.87
545	524	380	378	232	240	156	166	80	84	34	30	4.14
481	469	357	354	238	243	171	174	75	87	21	24	4.38
653	521	426	302	238	192	148	132	68	54	26	21	20.23
638	548	423	363	241	222	153	145	68	68	24	21	9.61
515	564	377	400	247	246	175	173	92	93	37	34	4.42
499	451	379	344	260	237	192	175	106	105	46	37	8.82
560	588	421	429	285	275	208	194	109	99	33	33	4.66
669	812	468	526	288	294	195	210	91	103	32	35	11.59
531	569	414	444	296	309	225	230	130	143	54	52	5.95
604	615	450	464	302	308	218	222	106	118	25	31	4.96
591	619	450	458	311	305	230	217	122	119	31	31	3.16
575	620	445	459	315	305	237	219	137	123	58	40	7.76
757	639	528	459	323	296	217	210	105	110	44	38	10.02
687	787	500	539	325	317	229	219	119	112	50	38	8.62
704	747	530	536	360	347	263	246	144	129	59	41	6.97
828	828	588	590	369	388	253	271	115	136	25	32	6.41
805	847	620	650	435	437	327	329	189	217	94	86	4.80
1019	851	715	625	441	452	298	360	142	150	53	40	12.88
899	866	695	679	489	472	368	343	214	202	109	74	6.18
1060	1007	793	750	535	520	389	404	212	276	91	75	8.43
1276	1456	938	1049	617	676	439	471	230	253	100	77	11.74
1165	1259	899	950	632	642	475	460	276	273	141	86	6.88
2802	2420	1936	1673	1171	1064	779	734	358	365	138	93	11.37

Maximum, Average, and Standard Deviation of Weighted Average Percentage Errors:

50.35 11.43 7.387

TABLE 23
NEURAL-NETWORK PREDICTIONS USING LOG OF EQUATION ERROR
(measured point on left, predicted point on right)

D-95		D-90		D-80		D-70		D-50		D-30		WAPE
52	44	33	30	18	16	11	10	4	4	1	1	8.40
66	76	42	52	23	26	14	16	6	6	2	2	15.78
69	80	45	51	25	28	15	17	6	6	2	2	13.54
80	79	52	51	30	28	19	17	8	6	3	2	6.26
131	117	89	82	44	41	23	27	7	8	2	2	12.52
155	124	106	108	51	53	28	26	9	10	2	2	9.19
143	137	99	116	60	58	40	36	18	16	7	7	8.42
151	183	102	127	61	73	41	44	19	18	8	8	16.17
149	153	102	116	61	67	41	46	19	21	8	9	9.43
220	161	131	102	62	52	34	30	11	10	3	3	18.79
194	156	116	114	62	68	40	43	18	19	6	8	10.22
160	128	109	99	65	56	42	37	18	15	7	6	14.06
153	136	113	102	67	59	44	40	20	19	7	9	10.45
180	194	119	131	69	77	46	49	21	19	8	6	9.46
174	155	118	118	72	68	48	47	23	21	9	9	6.08
185	140	123	110	72	63	46	41	20	18	8	6	14.95
195	189	128	136	76	77	51	53	25	27	10	12	5.66
238	209	142	142	79	84	49	54	20	20	7	7	6.90
188	161	131	124	80	70	53	48	24	21	9	9	10.45
221	234	142	161	86	91	56	59	25	28	9	11	9.12
223	270	151	181	94	97	64	60	30	28	12	11	11.85
289	241	177	165	99	94	64	60	30	28	12	11	9.03
284	239	177	187	102	110	68	79	37	39	18	15	10.96
240	240	167	187	103	110	70	79	35	39	15	15	7.68
249	206	167	158	105	95	74	70	35	35	15	15	8.48
243	250	165	190	105	111	74	77	36	39	15	16	7.39
232	242	165	189	106	112	75	80	36	40	15	16	8.77
284	311	185	224	107	129	68	80	26	28	8	8	15.25
271	240	180	187	107	110	72	78	34	39	14	16	7.93
244	242	171	188	108	110	75	78	34	39	14	15	6.09
262	240	175	187	108	110	74	77	34	39	13	15	7.59
273	240	177	187	110	110	78	78	37	39	15	15	4.60
280	240	189	186	115	109	79	77	35	39	13	15	7.81
265	253	187	212	116	114	79	79	30	33	9	11	7.18
281	241	190	188	118	111	84	79	41	40	17	16	6.78
289	309	194	234	119	138	83	93	43	47	20	17	12.93
289	314	203	252	127	138	89	98	45	46	20	16	12.00
336	356	224	266	133	156	92	102	46	49	20	21	11.89
344	350	227	263	133	154	91	102	47	48	22	20	9.60
321	369	220	275	134	161	92	104	44	50	18	21	17.87
386	444	246	303	134	154	84	82	31	29	10	10	12.73
315	356	217	263	135	155	98	111	51	57	23	26	14.84
324	263	224	207	136	119	91	85	40	41	14	17	11.39
351	320	237	246	141	150	98	108	49	53	21	23	7.81
362	380	241	282	141	165	98	106	47	51	19	22	11.86
347	319	236	245	142	149	99	106	49	51	20	22	5.61
389	297	256	232	145	137	100	98	48	47	20	20	9.29
390	324	257	251	146	156	102	118	50	61	21	26	12.88

375	320	253	235	148	155	105	114	53	55	22	23	7.97
355	290	250	253	155	148	107	104	52	53	21	18	6.99
398	334	268	252	156	150	107	101	51	47	20	20	7.70
421	394	277	291	157	170	106	108	50	53	20	22	6.34
389	442	266	326	159	175	107	106	50	57	19	23	13.14
429	339	284	256	162	151	109	101	52	47	21	20	10.82
304	301	233	230	162	142	114	101	56	50	23	20	6.71
376	325	263	247	162	148	112	101	55	47	23	20	10.26
371	427	262	327	162	188	113	119	55	56	21	21	13.23
421	449	284	345	166	187	115	122	59	57	24	22	10.52
428	408	288	300	168	174	110	110	55	55	26	23	3.61
462	406	303	299	171	163	112	100	51	52	20	21	6.42
291	336	233	261	171	187	132	145	77	82	34	32	10.52
429	429	295	325	177	190	125	124	70	68	37	33	5.04
369	324	271	252	179	157	131	120	76	63	34	27	11.55
507	364	326	271	179	159	115	103	55	49	25	21	16.25
556	439	361	398	201	206	128	120	57	61	19	21	9.85
436	531	317	387	205	243	144	166	78	83	30	28	17.21
506	464	346	332	206	200	137	128	68	75	29	30	5.96
406	391	306	304	208	211	152	163	83	97	34	40	5.68
595	429	383	343	210	208	133	140	64	67	26	26	10.46
427	402	317	317	211	201	152	143	84	76	34	31	4.92
483	482	341	338	212	228	145	161	71	65	27	24	5.41
455	403	330	329	213	217	149	158	82	76	32	37	6.06
595	449	387	343	215	198	135	125	60	58	23	22	11.59
414	394	316	306	219	214	162	166	88	103	34	41	6.02
441	326	333	256	227	182	167	141	92	77	39	33	20.47
456	399	341	309	230	214	167	160	89	89	38	35	7.61
545	713	380	510	232	289	156	186	80	92	34	31	24.94
481	578	357	433	238	271	171	177	75	81	21	21	13.62
653	486	426	368	238	214	148	135	68	62	26	23	14.28
638	596	423	414	241	227	153	136	68	77	24	28	8.02
515	372	377	296	247	204	175	162	92	97	37	41	17.15
499	394	379	306	260	213	192	165	106	102	46	41	15.84
560	416	421	329	285	233	208	178	109	98	33	40	19.32
669	815	468	581	288	343	195	180	91	79	32	38	18.17
531	633	414	499	296	356	225	253	130	152	54	54	17.01
604	587	450	455	302	310	218	226	106	106	25	25	2.20
591	673	450	504	311	326	230	225	122	141	31	35	9.88
575	595	445	446	315	296	237	220	137	141	58	51	4.39
757	574	528	462	323	291	217	208	105	91	44	43	12.45
687	754	500	587	325	369	229	261	119	127	50	48	12.05
704	643	530	487	360	319	263	230	144	123	59	49	10.99
828	759	588	557	369	334	253	218	115	103	25	31	10.32
805	1028	620	815	435	510	327	372	189	174	94	108	20.83
1019	933	715	651	441	441	298	287	142	141	53	48	5.18
899	881	695	704	489	482	368	363	214	202	109	92	3.13
1060	1082	793	828	535	568	389	386	212	231	91	79	4.78
1276	1373	938	1115	617	717	439	510	230	269	100	109	14.43
1165	1235	899	949	632	637	475	481	276	308	141	120	5.45
2802	2033	1936	1591	1171	999	779	693	358	368	138	129	15.62

Maximum, Average, and Standard Deviation of Weighted Average Percentage Errors:

24.94 10.43 4.443

TABLE 24
NEURAL-NETWORK PREDICTIONS USING SQUARE ROOT OF LOG OF EQUATION ERROR
(measured point on left, predicted point on right)

D-95		D-90		D-80		D-70		D-50		D-30		WAPE
52	43	33	20	18	14	11	11	4	3	1	1	20.03
66	78	42	38	23	27	14	13	6	5	2	2	14.18
69	54	45	39	25	48	15	23	6	6	2	2	35.70
80	82	52	60	30	53	19	28	8	7	3	2	30.18
131	133	89	81	44	49	23	25	7	8	2	2	11.96
155	259	106	177	51	86	28	47	9	9	2	2	55.11
143	119	99	91	60	53	40	27	18	16	7	8	15.87
151	180	102	97	61	67	41	34	19	14	8	7	13.68
149	115	102	88	61	68	41	38	19	23	8	10	15.82
220	132	131	67	62	49	34	31	11	8	3	3	28.59
194	199	116	117	62	69	40	31	18	12	6	5	12.71
160	113	109	83	65	71	42	48	18	15	7	7	18.91
153	162	113	122	67	74	44	45	20	21	7	9	7.87
180	167	119	129	69	63	46	35	21	21	8	8	9.97
174	138	118	104	72	76	48	42	23	23	9	10	11.04
185	260	123	178	72	69	46	41	20	22	8	8	23.29
195	325	128	166	76	87	51	51	25	18	10	8	29.54
238	130	142	110	79	63	49	36	20	19	7	7	24.54
188	198	131	147	80	94	53	53	24	24	9	10	8.19
221	177	142	131	86	91	56	59	25	25	9	12	10.36
223	281	151	178	94	101	64	43	30	23	12	9	21.50
289	173	177	131	99	92	64	60	30	26	12	12	18.82
284	187	177	131	102	102	68	68	37	32	18	15	16.39
240	197	167	135	103	103	70	69	35	31	15	14	10.20
249	306	167	236	105	160	74	88	35	41	15	16	29.93
243	375	165	231	105	124	74	85	36	27	15	13	30.70
232	186	165	143	106	113	75	80	36	40	15	18	12.94
284	275	185	168	107	109	68	70	26	28	8	11	6.92
271	206	180	151	107	113	72	79	34	35	14	16	13.27
244	232	171	152	108	108	75	70	34	31	14	14	6.09
262	220	175	156	108	112	74	79	34	33	13	15	9.44
273	214	177	142	110	104	78	69	37	30	15	14	15.07
280	231	189	160	115	112	79	79	35	32	13	15	10.28
265	226	187	155	116	148	79	117	30	31	9	10	21.80
281	195	190	147	118	113	84	80	41	38	17	17	14.76
289	330	194	159	119	125	83	72	43	51	20	20	12.61
289	466	203	305	127	168	89	109	45	51	20	17	37.58
336	382	224	245	133	167	92	108	46	36	20	19	16.08
344	389	227	247	133	166	91	105	47	35	22	18	16.74
321	365	220	241	134	169	92	115	44	39	18	20	16.97
386	564	246	198	134	137	84	84	31	31	10	11	16.58
315	266	217	219	135	95	98	64	51	35	23	19	20.34
324	520	224	320	136	139	91	105	40	46	14	18	30.25
351	411	237	277	141	165	98	100	49	53	21	23	13.19
362	352	241	239	141	171	98	121	47	42	19	22	11.53
347	412	236	272	142	165	99	100	49	48	20	22	11.64
389	414	256	258	145	154	100	96	48	40	20	18	5.84
390	413	257	295	146	166	102	102	50	65	21	27	12.97

375	344	253	283	148	128	105	84	53	58	22	28	13.60
355	273	250	205	155	232	107	166	52	48	21	20	29.11
398	407	268	254	156	165	107	100	51	35	20	17	8.46
421	338	277	236	157	173	106	128	50	46	20	24	15.80
389	408	266	309	159	162	107	103	50	48	19	22	7.38
429	402	284	252	162	165	109	102	52	35	21	17	10.63
304	366	233	229	162	177	114	89	56	43	23	20	13.92
376	413	263	260	162	165	112	99	55	38	23	18	9.79
371	450	262	352	162	175	113	119	55	64	21	25	18.36
421	376	284	271	166	156	115	96	59	55	24	28	9.30
428	327	288	234	168	175	110	134	55	50	26	26	15.09
462	399	303	311	171	160	112	99	51	48	20	23	8.96
291	302	233	228	171	156	132	121	77	79	34	36	5.34
429	360	295	343	177	210	125	130	70	65	37	30	13.78
369	415	271	298	179	166	131	103	76	67	34	27	12.71
507	372	326	243	179	168	115	112	55	38	25	20	18.43
556	574	361	416	201	224	128	128	57	54	19	19	7.11
436	393	317	283	205	183	144	137	78	73	30	37	9.65
506	469	346	340	206	206	137	155	68	81	29	34	8.10
406	384	306	281	208	185	152	142	83	86	34	40	7.76
595	708	383	513	210	217	133	132	64	77	26	30	16.20
427	371	317	243	211	165	152	121	84	62	34	28	20.00
483	472	341	344	212	157	145	104	71	48	27	26	14.51
455	378	330	337	213	263	149	140	82	50	32	29	15.14
595	468	387	363	215	182	135	121	60	64	23	25	12.18
414	378	316	279	219	185	162	140	88	77	34	39	12.42
441	318	333	235	227	157	167	121	92	70	39	35	26.85
456	370	341	277	230	192	167	155	89	87	38	45	14.25
545	643	380	479	232	247	156	173	80	101	34	42	17.54
481	631	357	366	238	243	171	161	75	66	21	21	10.73
653	496	426	380	238	193	148	124	68	62	26	25	15.70
638	682	423	490	241	214	153	116	68	68	24	28	12.74
515	358	377	260	247	165	175	129	92	86	37	39	25.65
499	379	379	279	260	185	192	140	106	77	46	39	25.74
560	379	421	297	285	209	208	157	109	72	33	27	28.62
669	726	468	465	288	287	195	200	91	91	32	40	4.47
531	595	414	454	296	307	225	234	130	142	54	66	9.06
604	812	450	573	302	399	218	259	106	66	25	20	29.13
591	833	450	499	311	326	230	212	122	91	31	28	17.89
575	560	445	408	315	269	237	220	137	161	58	58	8.66
757	618	528	475	323	356	217	207	105	123	44	51	12.47
687	768	500	591	325	294	229	230	119	148	50	49	11.66
704	583	530	423	360	284	263	234	144	139	59	54	15.27
828	637	588	433	369	292	253	202	115	92	25	30	22.27
805	732	620	557	435	397	327	293	189	239	94	82	11.78
1019	1620	715	952	441	434	298	297	142	146	53	48	22.11
899	1240	695	742	489	444	368	335	214	177	109	93	16.65
1060	926	793	675	535	430	389	312	212	170	91	75	16.93
1276	1521	938	1119	617	617	439	433	230	181	100	96	11.68
1165	1661	899	946	632	570	475	464	276	336	141	121	16.84
2802	2521	1936	1940	1171	1015	779	799	358	353	138	126	6.17

Maximum, Average, and Standard Deviation of Weighted Average Percentage Errors:

55.11 16.19 8.201

TABLE 25
NEURAL-NETWORK PREDICTIONS USING INDIVIDUAL-STAGE D-POINTS
(measured point on left, predicted point on right)

D-95		D-90		D-80		D-70		D-50		D-30		WAPE
52	52	33	33	18	18	11	11	4	4	1	1	.60
66	60	42	37	23	20	14	13	6	5	2	2	13.47
69	55	45	34	25	19	15	12	6	4	2	1	23.97
80	56	52	34	30	19	19	12	8	4	3	1	36.72
131	170	89	114	44	69	23	45	7	19	2	6	84.50
155	55	106	35	51	19	28	12	9	4	2	1	59.94
143	89	99	57	60	36	40	24	18	12	7	3	41.03
151	147	102	90	61	50	41	36	19	15	8	7	11.80
149	219	102	146	61	88	41	60	19	27	8	11	44.31
220	254	131	128	62	65	34	47	11	18	3	6	27.79
194	190	116	120	62	63	40	43	18	13	6	4	8.20
160	223	109	147	65	89	42	61	18	28	7	11	44.18
153	214	113	145	67	87	44	60	20	26	7	10	33.39
180	208	119	113	69	68	46	49	21	20	8	5	9.64
174	219	118	147	72	88	48	61	23	27	9	11	23.03
185	57	123	36	72	20	46	13	20	5	8	1	72.52
195	174	128	122	76	71	51	48	25	19	10	8	10.07
238	194	142	108	79	65	49	47	20	19	7	4	16.92
188	220	131	149	80	89	53	61	24	27	9	11	13.65
221	171	142	115	86	67	56	47	25	19	9	8	19.96
223	201	151	153	94	93	64	65	30	26	12	10	6.18
289	174	177	116	99	67	64	48	30	19	12	8	33.65
284	239	177	160	102	98	68	69	37	32	18	13	9.88
240	237	167	160	103	98	70	69	35	32	15	13	4.35
249	243	167	185	105	119	74	87	35	37	15	14	9.49
243	242	165	171	105	105	74	74	36	33	15	13	2.60
232	314	165	203	106	124	75	88	36	43	15	18	23.34
284	336	185	223	107	128	68	84	26	32	8	11	21.86
271	271	180	178	107	109	72	77	34	36	14	15	2.89
244	236	171	164	108	101	75	71	34	32	14	13	5.11
262	258	175	171	108	105	74	74	34	35	13	14	2.54
273	236	177	161	110	99	78	69	37	32	15	13	11.91
280	251	189	168	115	103	79	72	35	34	13	14	9.38
265	197	187	137	116	85	79	60	30	27	9	11	23.16
281	288	190	188	118	115	84	81	41	39	17	16	3.01
289	249	194	177	119	103	83	66	43	35	20	16	14.82
289	240	203	165	127	101	89	69	45	31	20	13	22.01
336	400	224	265	133	153	92	109	46	48	20	19	15.34
344	396	227	264	133	153	91	108	47	47	22	18	14.31
321	397	220	260	134	151	92	109	44	49	18	20	17.10
386	353	246	216	134	124	84	92	31	36	10	12	11.25
315	284	217	191	135	127	98	83	51	44	23	15	12.55
324	313	224	211	136	127	91	83	40	39	14	17	6.20
351	380	237	254	141	151	98	96	49	46	21	20	6.07
362	387	241	250	141	147	98	107	47	50	19	21	6.57
347	370	236	248	142	147	99	95	49	45	20	20	5.52
389	320	256	215	145	129	100	84	48	40	20	17	15.37
390	401	257	266	146	160	102	99	50	50	21	22	4.19

375	392	253	273	148	166	105	99	53	50	22	21	6.86
355	295	250	194	155	114	107	87	52	46	21	20	18.76
398	371	268	251	156	146	107	100	51	43	20	17	8.09
421	369	277	235	157	140	106	103	50	51	20	22	9.66
389	460	266	300	159	174	107	110	50	49	19	18	10.16
429	381	284	257	162	149	109	103	52	44	21	18	9.98
304	372	233	253	162	146	114	102	56	55	23	22	10.87
376	357	263	242	162	142	112	95	55	42	23	18	12.29
371	500	262	326	162	196	113	125	55	56	21	19	20.43
421	335	284	216	166	135	115	99	59	61	24	26	16.82
428	350	288	220	168	133	110	99	55	51	26	23	16.81
462	515	303	333	171	190	112	120	51	53	20	20	8.42
291	405	233	324	171	228	132	163	77	86	34	33	29.11
429	485	295	326	177	199	125	141	70	67	37	32	11.49
369	403	271	267	179	161	131	99	76	50	34	22	15.01
507	400	326	263	179	153	115	109	55	49	25	19	15.62
556	447	361	292	201	167	128	108	57	42	19	13	19.98
436	430	317	330	205	219	144	161	78	82	30	34	6.23
506	525	346	355	206	210	137	140	68	63	29	25	3.92
406	393	306	328	208	231	152	170	83	86	34	32	7.27
595	474	383	302	210	165	133	113	64	46	26	22	20.39
427	416	317	274	211	178	152	130	84	82	34	37	9.96
483	424	341	403	212	234	145	159	71	69	27	25	11.22
455	412	330	317	213	226	149	161	82	76	32	31	6.54
595	527	387	341	215	208	135	131	60	61	23	21	7.26
414	452	316	356	219	248	162	181	88	94	34	38	11.09
441	401	333	330	227	231	167	167	92	86	39	33	4.41
456	435	341	315	230	221	167	164	89	90	38	35	4.38
545	462	380	355	232	229	156	168	80	82	34	34	6.78
481	557	357	398	238	253	171	175	75	80	21	23	9.09
653	580	426	373	238	230	148	145	68	71	26	25	7.24
638	511	423	346	241	197	153	123	68	54	24	22	18.49
515	424	377	360	247	249	175	180	92	89	37	36	6.24
499	452	379	359	260	250	192	182	106	94	46	38	7.44
560	520	421	477	285	304	208	226	109	101	33	28	9.29
669	675	468	479	288	285	195	202	91	92	32	34	2.33
531	543	414	409	296	281	225	217	130	127	54	57	2.97
604	600	450	446	302	299	218	218	106	96	25	24	1.83
591	717	450	520	311	346	230	245	122	120	31	31	11.76
575	537	445	414	315	295	237	227	137	123	58	50	7.25
757	707	528	488	323	310	217	213	105	103	44	45	4.52
687	699	500	540	325	338	229	236	119	114	50	48	4.20
704	711	530	525	360	355	263	267	144	141	59	56	1.54
828	844	588	617	369	400	253	274	115	127	25	30	6.95
805	818	620	624	435	418	327	308	189	166	94	85	4.31
1019	998	715	677	441	411	298	269	142	132	53	48	6.09
899	983	695	757	489	538	368	405	214	238	109	121	9.87
1060	1101	793	836	535	558	389	397	212	220	91	91	3.72
1276	1647	938	1175	617	752	439	523	230	259	100	112	21.98
1165	1326	899	1020	632	698	475	515	276	288	141	134	10.47
2802	2723	1936	1877	1171	1131	779	753	358	350	138	140	2.89

Maximum, Average, and Standard Deviation of Weighted Average Percentage Errors:

84.50 14.31 13.98

TABLE 26
NEURAL-NETWORK PREDICTIONS USING INDIVIDUAL-STAGE D-POINTS FOR MULTIPLE (1)
(measured point on left, predicted point on right)

Ideal	Actual	D-80		WAPE
1		18	22	22.69
1		23	35	49.38
1		25	22	10.41
1		30	22	24.80
1		44	51	14.52
1		51	55	7.39
1		60	35	41.13
1		61	75	23.45
1		61	63	2.52
1		62	46	25.43
1		62	86	38.50
1		65	71	9.98
1		67	69	3.09
1		69	53	24.16
1		72	64	11.25
1		72	56	22.10
1	2	76	108	42.75
1		79	54	31.04
1		80	66	17.84
1		86	72	16.13
2	1	94	87	7.26
2	1	99	69	30.61
2	1	102	85	16.70
2	1	103	85	17.51
2		105	120	14.41
2		105	94	10.73
2		106	112	5.43
2		107	141	32.68
2		107	100	6.65
2		108	96	11.31
2		108	96	11.33
2	1	110	88	19.78
2		115	93	19.41
2		116	140	20.69
2		118	105	10.94
2		119	118	.73
2		127	135	5.89
2		133	157	18.11
2		133	155	17.16
2		134	160	19.59
2		134	153	13.80
2		135	114	15.47
2		136	166	22.83
2		141	160	13.65
2		141	163	15.87
2		142	158	11.22
2		145	160	9.85
2		146	167	14.25

2		148	158	6.90
2		155	160	3.14
2		156	153	1.87
2		157	167	6.22
2		159	177	11.56
2		162	154	5.04
2		162	159	1.81
2		162	154	5.03
2	3	162	201	23.71
2		166	188	13.13
2		168	171	1.91
2		171	174	1.78
2	3	171	197	15.21
2		177	150	14.88
2		179	168	5.69
2		179	158	11.38
3	2	201	182	9.61
3		205	228	11.28
3	2	206	171	16.70
3		208	240	15.72
3		210	239	13.51
3		211	222	5.33
3		212	217	2.25
3		213	232	9.02
3		215	207	3.75
3		219	238	9.04
3		227	210	7.49
3		230	261	13.75
3		232	233	.37
3		238	260	9.28
3		238	213	10.30
3		241	218	9.34
3		247	247	.06
3		260	239	8.29
4		285	278	2.58
4		288	311	7.90
4		296	274	7.32
4		302	322	6.79
4		311	346	11.21
4		315	338	7.42
4		323	333	3.05
4		325	329	1.23
4		360	351	2.57
4		369	355	4.00
5		435	467	7.17
5		441	448	1.53
5		489	518	5.82
5		535	518	3.17
5		617	645	4.61
5		632	594	5.98
5		1171	676	42.27

Maximum, Average, and Standard Deviation of Weighted Average Percentage Errors:
49.38 12.74 10.15

TABLE 27
NEURAL-NETWORK PREDICTIONS USING INDIVIDUAL-STAGE D-POINTS FOR UNUS (2-1)
(measured point on left, predicted point on right)

D-95		D-90		D-80		D-70		D-50		D-30		WAPE
52	63	33	35	18	19	11	11	4	4	1	1	9.28
66	68	42	36	23	19	14	11	6	4	2	1	16.70
69	64	45	43	25	24	15	16	6	6	2	2	5.26
80	72	52	50	30	27	19	17	8	7	3	2	11.46
131	129	89	89	44	43	23	23	7	5	2	1	4.49
155	170	106	113	51	53	28	31	9	11	2	3	12.24
143	160	99	104	60	60	40	39	18	20	7	6	6.02
151	169	102	114	61	61	41	43	19	19	8	7	7.28
149	160	102	111	61	60	41	42	19	19	8	9	5.45
220	205	131	125	62	58	34	30	11	10	3	2	7.29
194	180	116	122	62	64	40	41	18	18	6	8	5.32
160	178	109	118	65	62	42	46	18	18	7	6	7.68
153	169	113	123	67	68	44	47	20	19	7	7	6.29
180	194	119	123	69	70	46	45	21	18	8	7	5.56
174	171	118	120	72	66	48	46	23	22	9	9	3.98
185	184	123	118	72	68	46	48	20	19	8	7	3.76
195	184	128	121	76	78	51	49	25	24	10	9	4.34
238	227	142	143	79	79	49	48	20	19	7	8	3.33
188	186	131	135	80	77	53	54	24	26	9	10	3.81
221	241	142	148	86	88	56	59	25	26	9	10	5.59
223	223	151	158	94	96	64	65	30	33	12	13	3.39
289	268	177	167	99	99	64	65	30	29	12	11	3.92
284	264	177	178	102	105	68	73	37	37	18	16	4.23
240	260	167	177	103	104	70	72	35	36	15	16	4.72
249	235	167	169	105	100	74	76	35	35	15	14	3.55
243	235	165	172	105	102	74	76	36	35	15	14	3.25
232	249	165	174	106	110	75	80	36	39	15	16	6.43
284	269	185	181	107	103	68	70	26	28	8	8	3.83
271	273	180	182	107	110	72	78	34	37	14	15	3.68
244	241	171	173	108	103	75	76	34	35	14	15	2.55
262	275	175	183	108	109	74	76	34	36	13	14	4.10
273	253	177	175	110	102	78	73	37	35	15	15	5.08
280	275	189	183	115	108	79	75	35	35	13	14	3.75
265	248	187	176	116	108	79	81	30	31	9	10	5.51
281	266	190	180	118	111	84	79	41	38	17	16	6.27

Maximum, Average, and Standard Deviation of Weighted Average Percentage Errors:
16.70 5.697 2.902

TABLE 28
NEURAL-NETWORK PREDICTIONS USING INDIVIDUAL-STAGE D-POINTS FOR DUO (2-2)
(measured point on left, predicted point on right)

D-95		D-90		D-80		D-70		D-50		D-30		WAPE
131	143	89	96	44	47	23	28	7	13	2	3	26.63
155	131	106	89	51	44	28	23	9	7	2	2	16.76
143	143	99	101	60	56	40	28	18	22	7	8	10.11
151	211	102	125	61	66	41	54	19	30	8	12	32.88
149	222	102	118	61	62	41	39	19	20	8	6	18.32
220	136	131	91	62	45	34	24	11	7	3	2	32.29
194	138	116	96	62	52	40	31	18	18	6	7	17.63
160	218	109	117	65	61	42	37	18	19	7	6	14.43
153	220	113	118	67	62	44	41	20	21	7	6	15.99
180	178	119	110	69	45	46	29	21	14	8	4	22.35
174	238	118	123	72	64	48	41	23	20	9	6	18.56
185	133	123	92	72	48	46	34	20	20	8	6	24.62
195	186	128	119	76	63	51	43	25	24	10	7	11.16
238	182	142	111	79	45	49	29	20	14	7	4	31.38
188	270	131	134	80	70	53	44	24	22	9	6	20.14
221	208	142	127	86	71	56	47	25	29	9	11	13.02
223	290	151	153	94	79	64	61	30	35	12	11	13.21
289	209	177	129	99	72	64	47	30	30	12	12	22.39
284	212	177	134	102	84	68	61	37	34	18	12	19.48
240	221	167	136	103	85	70	63	35	35	15	12	12.72
249	274	167	158	105	97	74	64	35	42	15	11	11.19
243	299	165	163	105	104	74	78	36	42	15	13	9.42
232	242	165	183	106	108	75	72	36	40	15	18	7.47
284	211	185	169	107	109	68	79	26	38	8	11	19.56
271	207	180	147	107	90	72	63	34	35	14	14	14.83
244	263	171	146	108	93	75	69	34	37	14	11	11.08
262	207	175	142	108	87	74	62	34	34	13	13	15.42
273	240	177	140	110	88	78	65	37	36	15	12	16.30
280	211	189	141	115	87	79	63	35	34	13	13	19.73
265	314	187	163	116	108	79	78	30	39	9	12	14.06
281	216	190	159	118	95	84	66	41	36	17	15	18.47
289	245	194	173	119	123	83	81	43	43	20	16	8.58
289	302	203	168	127	114	89	83	45	43	20	15	10.43
336	422	224	276	133	147	92	99	46	53	20	23	17.13
344	424	227	276	133	147	91	99	47	53	22	23	15.43
321	412	220	274	134	146	92	97	44	52	18	22	18.67
386	432	246	241	134	140	84	80	31	41	10	11	9.61
315	257	217	174	135	105	98	88	51	57	23	23	15.80
324	305	224	185	136	126	91	92	40	53	14	21	14.52
351	354	237	229	141	140	98	103	49	61	21	26	6.48
362	400	241	271	141	146	98	96	47	52	19	22	8.86
347	365	236	235	142	141	99	102	49	60	20	26	6.44
389	331	256	206	145	129	100	94	48	55	20	23	13.66
390	334	257	220	146	142	102	105	50	63	21	27	12.83
375	376	253	260	148	155	105	114	53	66	22	29	8.37
355	383	250	215	155	147	107	91	52	43	21	17	11.78
398	418	268	269	156	145	107	100	51	55	20	24	5.79
421	381	277	264	157	145	106	94	50	51	20	22	7.94

389	459	266	304	159	180	107	105	50	60	19	18	13.04
429	422	284	272	162	146	109	100	52	54	21	23	5.88
304	370	233	245	162	177	114	119	56	65	23	28	12.25
376	400	263	256	162	143	112	101	55	57	23	24	6.87
371	426	262	294	162	171	113	113	55	59	21	20	8.54
421	444	284	272	166	168	115	97	59	70	24	26	7.96
428	361	288	257	168	143	110	93	55	51	26	22	13.27
462	494	303	325	171	194	112	114	51	64	20	20	9.24
291	336	233	276	171	189	132	141	77	86	34	33	12.37
429	467	295	318	177	192	125	109	70	75	37	33	9.12
369	331	271	219	179	143	131	106	76	64	34	28	16.76
507	416	326	275	179	147	115	98	55	53	25	23	14.59
556	493	361	318	201	195	128	108	57	64	19	21	10.71
436	490	317	347	205	225	144	165	78	91	30	36	12.59
506	536	346	322	206	176	137	143	68	63	29	23	8.52
406	466	306	335	208	223	152	161	83	90	34	36	9.49
595	561	383	360	210	198	133	116	64	61	26	22	7.64
427	388	317	347	211	226	152	131	84	95	34	30	10.27
483	449	341	312	212	212	145	149	71	65	27	23	6.10
455	531	330	364	213	242	149	163	82	94	32	37	13.45
595	504	387	335	215	191	135	127	60	64	23	23	10.57
414	489	316	359	219	238	162	172	88	98	34	40	12.52
441	414	333	304	227	203	167	148	92	84	39	34	9.20
456	429	341	367	230	244	167	179	89	103	38	42	7.98
545	541	380	354	232	221	156	163	80	84	34	34	4.08
481	551	357	363	238	211	171	154	75	67	21	19	9.57
653	590	426	382	238	218	148	147	68	73	26	26	7.10
638	567	423	373	241	216	153	138	68	67	24	21	9.89
515	502	377	334	247	212	175	156	92	82	37	33	9.53
499	488	379	356	260	237	192	171	106	97	46	40	7.21

Maximum, Average, and Standard Deviation of Weighted Average Percentage Errors:

32.88 13.34 6.062

TABLE 29
NEURAL-NETWORK PREDICTIONS USING INDIVIDUAL-STAGE D-POINTS FOR TRES (2-3)
(measured point on left, predicted point on right)

D-95		D-90		D-80		D-70		D-50		D-30		WAPE
289	325	194	222	119	133	83	101	43	43	20	17	12.90
289	303	203	210	127	131	89	98	45	46	20	19	4.37
336	416	224	264	133	145	92	103	46	42	20	23	15.39
344	417	227	263	133	146	91	104	47	43	22	24	14.28
321	406	220	263	134	145	92	100	44	40	18	21	15.76
386	314	246	278	134	143	84	89	31	32	10	10	9.41
315	346	217	244	135	149	98	118	51	57	23	22	12.08
324	334	224	227	136	137	91	105	40	48	14	20	9.34
351	377	237	251	141	147	98	114	49	52	21	22	7.59
362	393	241	262	141	145	98	98	47	38	19	19	6.82
347	375	236	249	142	145	99	112	49	50	20	22	6.40
389	358	256	239	145	142	100	110	48	49	20	22	6.54
390	389	257	260	146	154	102	120	50	56	21	22	6.15
375	442	253	288	148	161	105	121	53	56	22	23	12.77
355	326	250	240	155	152	107	129	52	60	21	24	9.42
398	404	268	257	156	145	107	107	51	46	20	24	5.35
421	375	277	259	157	146	106	97	50	37	20	16	10.91
389	437	266	288	159	164	107	108	50	52	19	17	6.32
429	412	284	260	162	145	109	106	52	45	21	25	7.76
304	353	233	238	162	142	114	110	56	50	23	21	8.81
376	385	263	250	162	143	112	108	55	48	23	23	6.03
371	458	262	301	162	166	113	121	55	43	21	17	14.50
421	437	284	282	166	168	115	128	59	61	24	27	4.40
428	360	288	257	168	148	110	95	55	36	26	15	17.82
462	400	303	274	171	154	112	104	51	49	20	16	10.02
291	319	233	246	171	156	132	130	77	68	34	25	8.79
429	454	295	279	177	173	125	129	70	59	37	26	7.53
369	391	271	262	179	155	131	121	76	56	34	23	11.44
507	411	326	264	179	145	115	101	55	41	25	22	18.04
556	480	361	334	201	192	128	121	57	49	19	14	10.14
436	434	317	347	205	202	144	159	78	77	30	27	5.17
506	552	346	330	206	183	137	121	68	49	29	18	13.14
406	443	306	331	208	216	152	175	83	89	34	35	8.39
595	566	383	329	210	182	133	116	64	50	26	22	12.77
427	477	317	325	211	225	152	168	84	88	34	38	7.91
483	420	341	288	212	184	145	130	71	61	27	22	13.68
455	490	330	298	213	206	149	164	82	78	32	36	7.59
595	553	387	335	215	200	135	133	60	49	23	22	8.81
414	460	316	346	219	222	162	183	88	90	34	37	7.88
441	384	333	288	227	185	167	151	92	77	39	30	14.61
456	427	341	310	230	206	167	183	89	82	38	37	8.24
545	484	380	363	232	217	156	173	80	82	34	29	7.75
481	513	357	384	238	255	171	184	75	63	21	16	9.28
653	636	426	383	238	256	148	155	68	63	26	32	7.57
638	609	423	387	241	229	153	154	68	72	24	23	5.13
515	487	377	336	247	214	175	167	92	83	37	34	8.61
499	463	379	348	260	223	192	183	106	90	46	37	10.04
560	527	421	377	285	252	208	193	109	99	33	38	9.31

669	631	468	429	288	303	195	217	91	71	32	32	8.61
531	538	414	436	296	314	225	237	130	135	54	56	4.28
604	664	450	467	302	314	218	237	106	95	25	22	7.37
591	641	450	448	311	305	230	231	122	104	31	30	4.43
575	599	445	414	315	293	237	231	137	120	58	52	6.48

Maximum, Average, and Standard Deviation of Weighted Average Percentage Errors:

18.04 9.323 3.482

TABLE 30
NEURAL-NETWORK PREDICTIONS USING INDIVIDUAL-STAGE D-POINTS FOR QUATTUOR (2-4)
(measured point on left, predicted point on right)

D-95		D-90		D-80		D-70		D-50		D-30		WAPE
556	542	361	354	201	214	128	138	57	65	19	23	6.43
436	448	317	323	205	211	144	142	78	75	30	34	3.23
506	482	346	345	206	220	137	146	68	65	29	23	5.34
406	446	306	336	208	230	152	165	83	87	34	36	8.90
595	600	383	383	210	222	133	136	64	60	26	27	2.55
427	420	317	319	211	215	152	149	84	75	34	30	3.22
483	478	341	343	212	220	145	149	71	68	27	26	2.35
455	446	330	332	213	216	149	145	82	73	32	29	3.29
595	600	387	386	215	218	135	134	60	59	23	22	1.07
414	455	316	348	219	241	162	178	88	97	34	40	10.53
441	449	333	338	227	229	167	164	92	86	39	35	2.72
456	450	341	344	230	235	167	172	89	94	38	37	2.37
545	560	380	386	232	238	156	169	80	81	34	30	3.96
481	518	357	370	238	246	171	173	75	80	21	24	5.22
653	660	426	417	238	224	148	135	68	60	26	23	5.73
638	623	423	399	241	223	153	144	68	58	24	19	7.20
515	481	377	354	247	234	175	164	92	88	37	41	6.28
499	457	379	349	260	242	192	179	106	98	46	40	7.77
560	581	421	456	285	291	208	222	109	119	33	38	6.43
669	678	468	461	288	283	195	195	91	90	32	36	2.19
531	574	414	442	296	289	225	224	130	129	54	50	4.41
604	630	450	442	302	296	218	210	106	101	25	27	3.54
591	609	450	444	311	308	230	231	122	113	31	29	2.64
575	585	445	451	315	310	237	243	137	141	58	55	2.18
757	763	528	521	323	322	217	224	105	110	44	47	2.23
687	700	500	498	325	320	229	237	119	123	50	49	2.02
704	670	530	519	360	356	263	271	144	150	59	57	2.95
828	824	588	584	369	358	253	255	115	111	25	28	2.24
805	796	620	624	435	425	327	323	189	187	94	94	1.24
1019	1008	715	737	441	432	298	296	142	145	53	51	1.99
899	880	695	695	489	490	368	371	214	209	109	104	1.34
1060	1053	793	788	535	523	389	377	212	203	91	92	1.83

Maximum, Average, and Standard Deviation of Weighted Average Percentage Errors:
10.53 3.919 2.390

TABLE 31
NEURAL-NETWORK PREDICTIONS USING INDIVIDUAL-STAGE D-POINTS FOR PENTE (2-5)
(measured point on left, predicted point on right)

D-95		D-90		D-80		D-70		D-50		D-30		WAPE
560	537	421	419	285	292	208	207	109	105	33	34	2.16
669	679	468	474	288	294	195	198	91	94	32	30	2.05
531	561	414	436	296	300	225	219	130	132	54	53	3.44
604	579	450	447	302	311	218	224	106	109	25	26	2.98
591	588	450	461	311	325	230	238	122	121	31	30	2.35
575	551	445	434	315	310	237	232	137	138	58	58	2.38
757	747	528	518	323	307	217	211	105	102	44	45	2.59
687	649	500	509	325	335	229	223	119	116	50	51	3.04
704	669	530	523	360	368	263	265	144	145	59	57	2.16
828	830	588	600	369	367	253	251	115	111	25	27	1.73
805	811	620	606	435	439	327	329	189	190	94	96	1.19
1019	1003	715	702	441	454	298	289	142	141	53	52	2.12
899	894	695	676	489	476	368	369	214	212	109	108	1.43
1060	1051	793	780	535	544	389	381	212	212	91	91	1.26
1276	1247	938	925	617	614	439	440	230	231	100	99	1.02
1165	1169	899	878	632	622	475	479	276	279	141	140	1.22
2802	2774	1936	1910	1171	1160	779	769	358	354	138	140	1.14

Maximum, Average, and Standard Deviation of Weighted Average Percentage Errors:
3.441 2.014 .7381

TABLE 32
LEAST-SQUARES LINEAR REGRESSION FOR ROSIN-RAMMLER DISTRIBUTION
(measured point on left, predicted point on right)

D-95		D-90		D-80		D-70		D-50		D-30		WAPE
52	52	33	35	18	21	11	13	4	6	1	2	19.61
66	68	42	41	23	21	14	12	6	4	2	1	11.57
69	69	45	45	25	25	15	15	6	6	2	2	.00
80	82	52	52	30	28	19	17	8	7	3	2	7.33
131	134	89	85	44	46	23	28	7	11	2	4	23.78
155	179	106	106	51	52	28	29	9	10	2	3	7.55
143	165	99	105	60	58	40	36	18	14	7	5	12.38
151	168	102	108	61	60	41	37	19	15	8	5	10.86
149	149	102	102	61	61	41	41	19	18	8	7	1.27
194	204	116	124	62	62	40	36	18	13	6	4	11.23
221	218	131	129	62	62	34	35	11	11	3	3	2.49
160	164	109	110	65	64	42	41	18	18	7	7	1.26
153	166	113	113	67	67	44	44	20	20	7	8	2.42
180	186	119	123	69	70	46	44	21	19	8	7	4.54
174	188	118	125	72	72	48	46	23	20	9	7	7.35
185	189	123	125	72	72	46	46	20	19	8	7	2.34
195	207	128	136	76	78	51	50	25	21	10	7	7.48
238	249	142	154	79	80	49	47	20	17	7	5	7.51
188	188	131	131	80	80	53	53	24	25	9	10	.87
221	230	142	153	86	87	56	55	25	23	9	8	5.49
223	230	151	157	94	95	64	63	30	29	12	11	3.08
289	298	177	191	99	105	64	65	30	26	12	9	7.26
284	295	177	196	102	112	68	72	37	31	18	11	10.94
240	243	167	170	103	105	70	71	35	34	15	14	2.11
249	257	167	180	105	109	74	73	35	34	15	13	4.38
243	255	165	177	105	109	74	73	36	35	15	14	4.20
232	234	165	167	106	106	75	73	36	36	15	16	1.48
284	288	185	189	107	106	68	67	26	28	8	10	3.17
271	274	180	187	107	111	72	73	34	32	14	12	3.66
244	246	171	173	108	108	75	73	34	35	14	15	1.71
262	267	175	184	108	111	74	73	34	33	13	13	2.67
273	287	177	196	110	117	78	77	37	35	15	14	6.38
280	287	189	196	115	117	79	78	35	35	13	14	2.89
265	260	187	182	116	111	79	75	30	35	9	14	8.24
281	289	190	203	118	125	84	84	41	40	17	16	3.92
289	298	194	208	119	127	83	86	43	40	20	16	5.86
289	295	203	209	127	131	89	90	45	44	20	19	2.39
347	351	228	241	132	145	91	96	47	44	22	17	6.74
336	338	224	234	133	143	92	95	46	44	20	17	4.56
321	322	220	225	134	138	92	93	44	44	18	18	1.58
386	386	246	247	134	135	84	82	31	32	10	10	1.38
315	323	217	231	135	146	98	101	51	50	23	22	4.76
324	324	224	224	136	135	91	90	40	41	14	16	1.85
351	356	237	248	141	151	98	101	49	48	21	19	4.18
362	362	241	250	141	151	98	100	47	46	19	18	3.34
347	350	236	245	142	150	99	101	49	48	20	20	3.08
389	388	256	265	145	157	100	103	48	46	20	18	4.22
390	391	257	268	146	161	102	106	50	48	21	19	4.76

375	376	253	263	148	161	105	109	53	51	22	21	3.97
355	356	250	252	155	157	107	107	52	52	21	22	.63
398	399	268	274	156	165	107	109	51	50	20	19	2.54
421	417	277	283	157	167	106	109	50	48	20	18	3.26
389	392	266	270	159	163	107	108	50	50	19	20	1.29
429	425	284	289	162	172	109	112	52	50	21	19	3.45
304	298	233	221	162	147	114	106	56	57	23	27	6.14
376	379	263	267	162	166	112	113	55	54	23	23	1.20
371	373	262	264	162	165	113	113	55	55	21	23	1.14
421	420	284	293	166	180	115	121	59	57	24	23	3.75
428	423	288	292	168	176	110	117	55	54	26	21	4.09
462	456	303	307	171	179	112	116	51	50	20	19	2.78
291	280	233	221	171	160	132	122	77	73	34	39	6.29
429	418	295	304	177	197	125	139	70	71	37	32	6.58
369	370	271	276	179	186	131	135	76	73	34	35	2.64
507	489	326	329	179	192	115	124	55	54	25	20	5.57
556	545	361	362	201	208	128	133	57	56	19	20	2.09
436	438	317	319	205	207	144	146	78	75	30	33	1.83
506	498	346	348	206	213	137	143	68	67	29	27	2.37
406	408	306	304	208	204	152	148	83	80	34	38	2.32
595	571	383	384	210	223	133	144	64	63	26	23	4.42
427	431	317	318	211	211	152	151	84	80	34	37	1.71
483	483	341	341	212	212	145	145	71	69	27	29	.86
455	456	330	332	213	215	149	152	82	78	32	35	2.03
595	583	387	387	215	221	135	141	60	60	23	21	2.47
414	417	316	313	219	211	162	153	88	83	34	40	4.06
441	448	333	334	227	224	167	162	92	88	39	42	2.34
456	458	341	340	230	226	167	163	89	87	38	41	1.71
545	537	380	381	232	239	156	164	80	80	34	34	2.15
481	501	357	353	238	220	171	150	75	72	21	30	8.22
653	631	426	423	238	245	148	157	68	68	26	25	2.98
638	631	423	422	241	244	153	156	68	67	24	24	1.10
515	524	377	380	247	246	175	173	92	88	37	40	1.90
499	510	379	381	260	256	192	186	106	101	46	48	2.44
560	595	421	430	285	277	208	194	109	98	33	43	7.09
669	688	468	475	288	287	195	191	91	88	32	35	2.38
531	560	414	422	296	287	225	210	130	116	54	56	5.05
604	674	450	472	302	290	218	196	106	93	25	38	11.39
591	659	450	472	311	300	230	208	122	103	31	44	10.96
575	612	445	459	315	310	237	225	137	123	58	59	4.56
757	742	528	523	323	325	217	221	105	106	44	44	1.29
687	698	500	505	325	326	229	228	119	116	50	51	1.14
704	760	530	555	360	361	263	255	144	131	59	59	4.57
828	963	588	643	369	371	253	237	115	102	25	37	11.55
805	844	620	641	435	440	327	325	189	182	94	91	2.81
1019	1069	715	739	441	447	298	297	142	137	53	54	2.73
899	993	695	747	489	508	368	371	214	204	109	100	6.10
1060	1246	793	893	535	567	389	393	212	195	91	84	9.59
1276	1450	938	1033	617	651	439	448	230	220	100	94	7.71
1165	1466	899	1075	632	705	475	501	276	261	141	119	15.05
2802	4325	1936	2764	1171	1502	779	917	358	358	138	116	31.35

Maximum, Average, and Standard Deviation of Weighted Average Percentage Errors:

31.35 5.048 4.794

TABLE 33
PREDICTIONS OF D-POINTS USING A MODIFIED BOND EQUATION
(measured point on left, predicted point on right)

D-95		D-90		D-80		D-70		D-50		D-30		WAPE
52	12	33	12	18	11	11	11	4	9	1	7	88.41
66	12	42	12	23	11	14	11	6	9	2	7	77.48
69	8	45	8	25	8	15	7	6	7	2	5	73.56
80	8	52	8	30	8	19	7	8	7	3	5	72.10
131	86	89	80	44	71	23	63	7	47	2	29	256.02
155	12	106	12	51	11	28	11	9	9	2	7	85.43
143	86	99	80	60	71	40	63	18	47	7	29	68.87
151	100	102	93	61	82	41	72	19	53	8	32	74.44
149	36	102	34	61	32	41	29	19	24	8	17	57.31
220	8	131	8	62	8	34	7	11	7	3	5	83.86
194	100	116	93	62	82	40	72	18	53	6	32	87.88
160	17	109	16	65	16	42	15	18	13	7	10	71.54
153	60	113	56	67	51	44	46	20	36	7	23	56.03
180	33	119	32	69	30	46	27	21	23	8	16	60.95
174	36	118	34	72	32	48	29	23	24	9	17	56.99
185	39	123	37	72	34	46	32	20	26	8	18	61.54
195	86	128	80	76	71	51	63	25	47	10	29	50.70
238	28	142	27	79	25	49	24	20	20	7	14	67.50
188	36	131	34	80	32	53	29	24	24	9	17	59.70
221	88	142	82	86	73	56	65	25	48	9	30	54.89
223	143	151	131	94	113	64	97	30	68	12	38	54.75
289	88	177	82	99	73	64	65	30	48	12	30	50.57
284	93	177	87	102	77	68	68	37	50	18	30	40.77
240	93	167	87	103	77	70	68	35	50	15	30	42.84
249	78	167	73	105	65	74	58	35	44	15	27	48.35
243	126	165	116	105	101	74	88	36	62	15	36	40.82
232	113	165	104	106	91	75	80	36	58	15	34	40.61
284	281	185	249	107	203	68	167	26	106	8	53	126.61
271	113	180	104	107	91	72	80	34	58	14	34	45.58
244	93	171	86	108	76	75	68	34	50	14	30	46.64
262	113	175	104	108	91	74	80	34	58	13	34	46.20
273	93	177	86	110	76	78	68	37	50	15	30	45.61
280	113	189	104	115	91	79	80	35	58	13	34	47.22
265	54	187	51	116	47	79	42	30	33	9	22	64.61
281	113	190	104	118	91	84	80	41	58	17	34	40.78
289	121	194	113	119	100	83	89	43	66	20	41	40.96
289	109	203	101	127	89	89	78	45	56	20	33	41.15
336	248	224	221	133	182	92	151	46	98	20	50	49.24
344	248	227	221	133	182	91	151	47	98	22	50	47.76
321	248	220	221	134	182	92	151	44	98	18	50	50.85
386	160	246	149	134	131	84	116	31	85	10	51	80.67
315	248	217	221	135	182	98	151	51	98	23	50	40.75
324	175	224	159	136	135	91	115	40	78	14	43	47.97
351	248	237	221	141	182	98	151	49	98	21	50	45.30
362	248	241	221	141	182	98	151	47	98	19	50	49.21
347	248	236	221	142	182	99	151	49	98	20	50	44.86
389	211	256	190	145	159	100	133	48	88	20	47	43.56
390	248	257	221	146	182	102	151	50	98	21	50	45.92

375	326	253	285	148	229	105	186	53	115	22	56	55.54
355	76	250	72	155	65	107	59	52	47	21	31	56.53
398	248	268	221	156	182	107	151	51	98	20	50	44.73
421	248	277	221	157	182	106	151	50	98	20	50	47.22
389	281	266	249	159	203	107	167	50	106	19	53	48.77
429	248	284	221	162	182	109	151	52	98	21	50	44.43
304	245	233	222	162	189	114	161	56	109	23	60	38.92
376	248	263	221	162	182	112	151	55	98	23	50	38.04
371	162	262	147	162	126	113	107	55	74	21	41	38.39
421	248	284	221	166	182	115	151	59	98	24	50	37.35
428	248	288	221	168	182	110	151	55	98	26	50	38.81
462	281	303	249	171	203	112	167	51	106	20	53	49.87
291	634	233	528	171	395	132	302	77	167	34	73	123.82
429	179	295	167	177	148	125	132	70	99	37	61	36.49
369	248	271	221	179	182	131	151	76	98	34	50	21.61
507	248	326	221	179	182	115	151	55	98	25	50	41.14
556	162	361	147	201	126	128	107	57	74	19	41	50.69
436	705	317	581	205	429	144	325	78	176	30	75	100.61
506	283	346	250	206	204	137	168	68	106	29	53	33.15
406	784	306	640	208	466	152	349	83	186	34	78	115.11
595	179	383	167	210	148	133	132	64	99	26	61	50.38
427	634	317	528	211	395	152	302	84	167	34	73	79.39
483	456	341	399	212	321	145	261	71	162	27	79	57.96
455	517	330	460	213	380	149	316	82	204	32	105	80.82
595	162	387	147	215	126	135	107	60	74	23	41	49.88
414	785	316	641	219	467	162	349	88	186	34	78	106.92
441	634	333	528	227	395	167	302	92	167	39	73	66.90
456	791	341	645	230	469	167	351	89	187	38	78	95.60
545	705	380	581	232	429	156	325	80	176	34	75	75.88
481	863	357	698	238	502	171	372	75	195	21	80	119.78
653	162	426	147	238	126	148	107	68	74	26	41	50.34
638	367	423	319	241	253	153	204	68	124	24	59	42.32
515	634	377	528	247	395	175	302	92	167	37	73	54.95
499	785	379	641	260	467	192	349	106	186	46	78	71.60
560	888	421	739	285	553	208	423	109	234	33	102	94.11
669	397	468	354	288	292	195	242	91	157	32	80	38.77
531	1265	414	1032	296	751	225	562	130	299	54	125	144.22
604	1381	450	1117	302	803	218	595	106	311	25	128	176.11
591	1296	450	1002	311	679	230	481	122	234	31	90	119.71
575	1237	445	961	315	656	237	467	137	229	58	89	100.69
757	517	528	460	323	380	217	316	105	204	44	105	42.69
687	788	500	643	325	468	229	350	119	186	50	78	37.93
704	1237	530	961	360	656	263	467	144	229	59	89	74.80
828	1296	588	1002	369	679	253	481	115	234	25	90	90.31
805	1654	620	1349	435	983	327	735	189	391	94	164	113.21
1019	453	715	400	441	326	298	268	142	170	53	85	35.76
899	1654	695	1349	489	983	368	735	214	391	109	164	89.51
1060	1979	793	1538	535	1050	389	748	212	366	91	142	87.16
1276	1654	938	1349	617	983	439	735	230	391	100	164	52.15
1165	2517	899	1964	632	1347	475	963	276	474	141	185	102.38
2802	2517	1936	1964	1171	1347	779	963	358	474	138	185	15.94

Maximum, Average, and Standard Deviation of Weighted Average Percentage Errors:

256.0 65.20 33.89

TABLE 34
NEURAL-NETWORK PREDICTIONS USING MULTIPLE-STAGE D-POINTS (TWO STAGES)
(measured point on left, predicted point on right)

D-95		D-90		D-80		D-70		D-50		D-30		WAPE
52	63	33	35	18	19	11	11	4	4	1	1	9.28
66	68	42	36	23	19	14	11	6	4	2	1	16.70
69	64	45	43	25	24	15	16	6	6	2	2	5.26
80	72	52	50	30	27	19	17	8	7	3	2	11.46
131	129	89	89	44	43	23	23	7	5	2	1	4.49
155	170	106	113	51	53	28	31	9	11	2	3	12.24
143	160	99	104	60	60	40	39	18	20	7	6	6.02
151	169	102	114	61	61	41	43	19	19	8	7	7.28
149	160	102	111	61	60	41	42	19	19	8	9	5.45
220	205	131	125	62	58	34	30	11	10	3	2	7.29
194	180	116	122	62	64	40	41	18	18	6	8	5.32
160	178	109	118	65	62	42	46	18	18	7	6	7.68
153	169	113	123	67	68	44	47	20	19	7	7	6.29
180	194	119	123	69	70	46	45	21	18	8	7	5.56
174	171	118	120	72	66	48	46	23	22	9	9	3.98
185	184	123	118	72	68	46	48	20	19	8	7	3.76
195	186	128	119	76	63	51	43	25	24	10	7	11.16
238	227	142	143	79	79	49	48	20	19	7	8	3.33
188	186	131	135	80	77	53	54	24	26	9	10	3.81
221	241	142	148	86	88	56	59	25	26	9	10	5.59
223	223	151	158	94	96	64	65	30	33	12	13	3.39
289	268	177	167	99	99	64	65	30	29	12	11	3.92
284	264	177	178	102	105	68	73	37	37	18	16	4.23
240	260	167	177	103	104	70	72	35	36	15	16	4.72
249	274	167	158	105	97	74	64	35	42	15	11	11.19
243	299	165	163	105	104	74	78	36	42	15	13	9.42
232	242	165	183	106	108	75	72	36	40	15	18	7.47
284	211	185	169	107	109	68	79	26	38	8	11	19.56
271	207	180	147	107	90	72	63	34	35	14	14	14.83
244	263	171	146	108	93	75	69	34	37	14	11	11.08
262	207	175	142	108	87	74	62	34	34	13	13	15.42
273	253	177	175	110	102	78	73	37	35	15	15	5.08
280	211	189	141	115	87	79	63	35	34	13	13	19.73
265	314	187	163	116	108	79	78	30	39	9	12	14.06
281	216	190	159	118	95	84	66	41	36	17	15	18.47
289	245	194	173	119	123	83	81	43	43	20	16	8.58
289	302	203	168	127	114	89	83	45	43	20	15	10.43
336	422	224	276	133	147	92	99	46	53	20	23	17.13
344	424	227	276	133	147	91	99	47	53	22	23	15.43
321	412	220	274	134	146	92	97	44	52	18	22	18.67
386	432	246	241	134	140	84	80	31	41	10	11	9.61
315	257	217	174	135	105	98	88	51	57	23	23	15.80
324	305	224	185	136	126	91	92	40	53	14	21	14.52
351	354	237	229	141	140	98	103	49	61	21	26	6.48
362	400	241	271	141	146	98	96	47	52	19	22	8.86
347	365	236	235	142	141	99	102	49	60	20	26	6.44
389	331	256	206	145	129	100	94	48	55	20	23	13.66
390	334	257	220	146	142	102	105	50	63	21	27	12.83

375	376	253	260	148	155	105	114	53	66	22	29	8.37
355	383	250	215	155	147	107	91	52	43	21	17	11.78
398	418	268	269	156	145	107	100	51	55	20	24	5.79
421	381	277	264	157	145	106	94	50	51	20	22	7.94
389	459	266	304	159	180	107	105	50	60	19	18	13.04
429	422	284	272	162	146	109	100	52	54	21	23	5.88
304	370	233	245	162	177	114	119	56	65	23	28	12.25
376	400	263	256	162	143	112	101	55	57	23	24	6.87
371	458	262	301	162	166	113	121	55	43	21	17	14.50
421	444	284	272	166	168	115	97	59	70	24	26	7.96
428	361	288	257	168	143	110	93	55	51	26	22	13.27
462	494	303	325	171	194	112	114	51	64	20	20	9.24
291	319	233	246	171	156	132	130	77	68	34	25	8.79
429	467	295	318	177	192	125	109	70	75	37	33	9.12
369	331	271	219	179	143	131	106	76	64	34	28	16.76
507	416	326	275	179	147	115	98	55	53	25	23	14.59
556	493	361	318	201	195	128	108	57	64	19	21	10.71
436	434	317	347	205	202	144	159	78	77	30	27	5.17
506	536	346	322	206	176	137	143	68	63	29	23	8.52
406	443	306	331	208	216	152	175	83	89	34	35	8.39
595	566	383	329	210	182	133	116	64	50	26	22	12.77
427	477	317	325	211	225	152	168	84	88	34	38	7.91
483	420	341	288	212	184	145	130	71	61	27	22	13.68
455	490	330	298	213	206	149	164	82	78	32	36	7.59
595	553	387	335	215	200	135	133	60	49	23	22	8.81
414	460	316	346	219	222	162	183	88	90	34	37	7.88
441	384	333	288	227	185	167	151	92	77	39	30	14.61
456	427	341	310	230	206	167	183	89	82	38	37	8.24
545	484	380	363	232	217	156	173	80	82	34	29	7.75
481	513	357	384	238	255	171	184	75	63	21	16	9.28
653	636	426	383	238	256	148	155	68	63	26	32	7.57
638	609	423	387	241	229	153	154	68	72	24	23	5.13
515	487	377	336	247	214	175	167	92	83	37	34	8.61
499	463	379	348	260	223	192	183	106	90	46	37	10.04
560	581	421	456	285	291	208	222	109	119	33	38	6.43
669	678	468	461	288	283	195	195	91	90	32	36	2.19
531	574	414	442	296	289	225	224	130	129	54	50	4.41
604	630	450	442	302	296	218	210	106	101	25	27	3.54
591	609	450	444	311	308	230	231	122	113	31	29	2.64
575	585	445	451	315	310	237	243	137	141	58	55	2.18
757	763	528	521	323	322	217	224	105	110	44	47	2.23
687	700	500	498	325	320	229	237	119	123	50	49	2.02
704	670	530	519	360	356	263	271	144	150	59	57	2.95
828	824	588	584	369	358	253	255	115	111	25	28	2.24
805	811	620	606	435	439	327	329	189	190	94	96	1.19
1019	1003	715	702	441	454	298	289	142	141	53	52	2.12
899	894	695	676	489	476	368	369	214	212	109	108	1.43
1060	1051	793	780	535	544	389	381	212	212	91	91	1.26
1276	1247	938	925	617	614	439	440	230	231	100	99	1.02
1165	1169	899	878	632	622	475	479	276	279	141	140	1.22
2802	2774	1936	1910	1171	1160	779	769	358	354	138	140	1.14

Maximum, Average, and Standard Deviation of Weighted Average Percentage Errors:

19.73 8.404 4.769