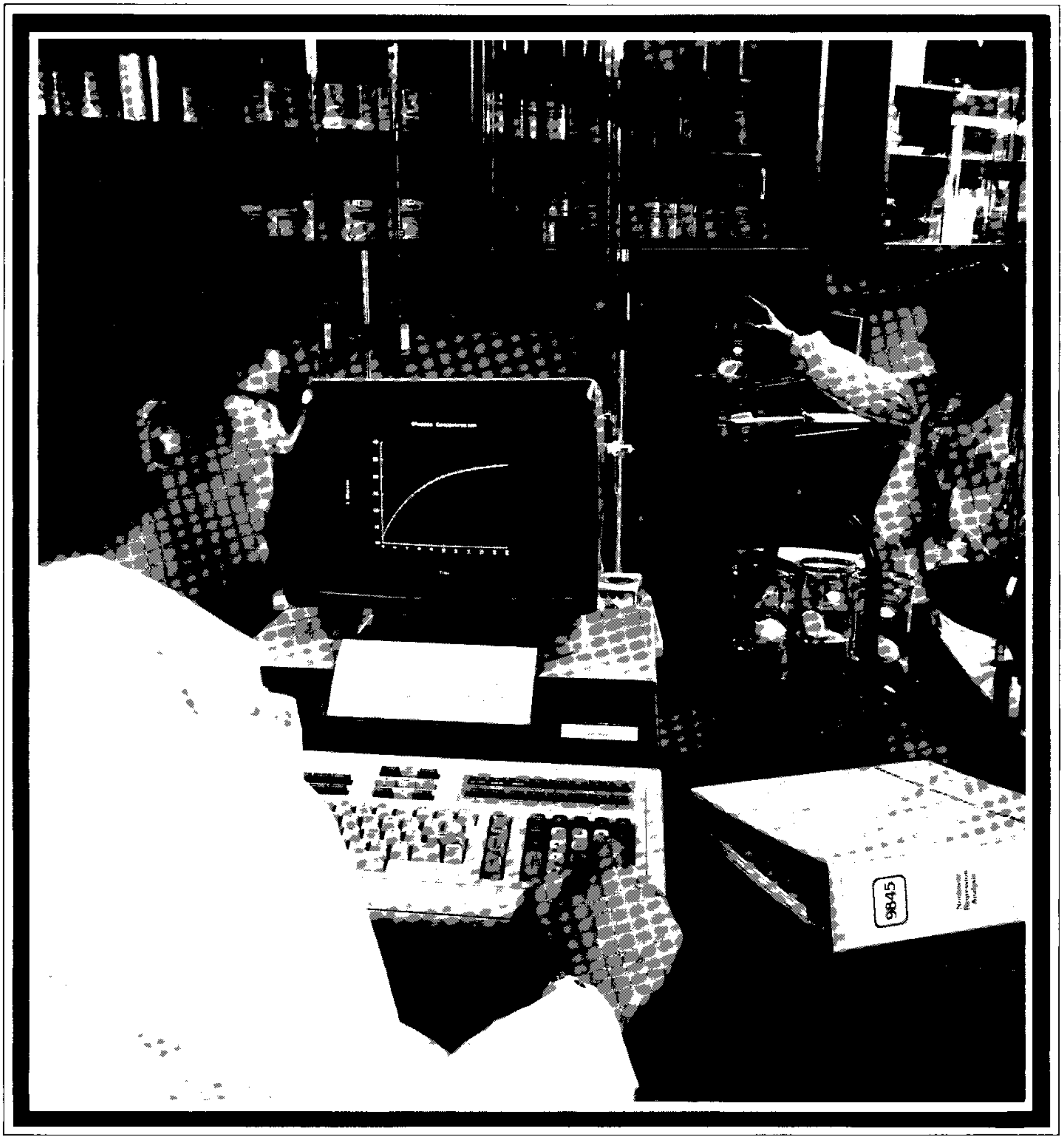
A Hewlett-Packard Software Summary
for the System 45B Desktop Computer

System 45B
Statistical/Numerical Analysis



HP's System 45B can help you make the right decisions

The Total Solution Package

Whether you have a simple statistical analysis problem or more complex jobs such as multiple linear regression or analysis of variance, HP's System 45B Desktop Computer puts all the pieces together for you—both hardware and software.

The hardware integrates keyboard, large memory, central processor, mass storage, CRT and optional printer, into one compact unit small enough to sit on your desk. You can eliminate the turnaround times so characteristic of batch or the charges for timeshare systems.

But hardware is only part of the total solution package. Hewlett-Packard also offers an extensive statistics software library that ranges from basic statistics to highly complex analyses such as non-linear regression.

To develop this software, HP has worked closely with a renowned university statistics department to assemble a comprehensive library of statistical and numerical analysis programs. These professionally prepared programs, when combined with HP's extensive experience in building desktop computing systems, provide you with a powerful, yet easy-to-use, total solution.

Graphics Means Faster, Simpler Data Evaluation

With this software and System 45B's graphics mode, getting plots of your data is fast and easy. Because a plot gives you added insight into your data, you can quickly determine what further analyses need to be performed. You can easily try various alternatives to get the optimum solution. Then when you want a hard copy record of your plot, simply type DUMP GRAPHICS and the displayed plot is transferred to System 45B's thermal line printer. Or, for more eye-catching plots of your data, you can easily interface System 45B to HP's 9872A Four-Color Plotter.

Ease-of-Use Features Built-in

Because we know you want to concentrate more on the science of statistics and less on the science of computers, HP has made its software extremely easy to use. Conversational-like user prompts on the CRT guide you through the program so even less-experienced computer users can perform complicated analyses quickly.

A Variety of Routines for Extensive Data Manipulation

To make things even easier for you, nearly all of Hewlett-Packard's statistics software features data preparation routines to speed pre-analysis manipulation.* The first part of each pack consists of an assortment of routines for entering, editing, transforming or otherwise manipulating your data to prepare it for later analysis. There are additional routines for sorting, recoding, joining two data sets, dividing a data set into subfiles and other manipulative operations.

*Excludes Numerical Analysis and Monte Carlo Simulation Utilities programs.

Uniform Data Structure

The data array in these programs is compatible with all other statistics programs available from HP.* This means you don't need to reenter your data when you want to perform an analysis with other HP statistics programs. Your data can be collected independently of any program, stored on tape or disk and then analyzed at a later date.

(For a more complete review of the data manipulation routines, refer to the Basic Statistics and Data Manipulation section of this software summary.)

Software Support To Meet Your Needs

On the following pages, you'll find more detailed information on System 45B's statistical and numerical analysis software which includes:

- Basic Statistics and Data Manipulation
- General Statistics
- Statistical Graphics
- Regression Analysis
- Non-Linear Regression
- Analysis of Variance
- Monte Carlo Simulation Utilities
- Numerical Analysis Library, Vol. 1.

Depending on your application, our software can provide either a total solution or convenient building blocks for developing your own specialized programs. So, if you're tired of chasing results on a big computer, look through this software summary and then ask an HP Field Engineer to show you the alternate path: The Series 9800/System 45B Total Solution Package. With a hands-on demonstration, you can experience how its finesse gets you from problem definition to solution faster and easier than just raw power.

Automatically prepare your statistical data for analysis.

Basic Statistics and Data Manipulation

When masses of numerical information are to be analyzed, some means of summarization must be performed. To simplify the task, the Basic Statistics and Data Manipulation program package offers a large collection of sophisticated routines.

A Collection of Routines to Summarize Your Statistical Data

The first part of the program package gives you several methods for entering your data into the System 45B's memory. Current data can be entered through the keyboard or with punched cards (9869 Card Reader required). And data previously stored on magnetic tape or disk can be loaded directly into the System 45B's memory.

For example, you can collect data using any program of your choice. Then, store the data on the System 45B's tape transports or on one of the mass storage devices compatible with the System 45B. Later, you can use the Data Manipulation routines to retrieve and arrange the collected data for analysis.

Formatting Your Data

Statistical data ordinarily consists of a number of observations on one or more random variables. This program structures that data in a rectangular array in which the rows are the variables and the columns are the observations.

The Basic Statistics and Data Manipulation routines have been designed to handle 50 variables and 20 subfiles. An array of 1500 elements may be input. For example, 500 observations on three variables or 750 observations on two variables may be entered. Instructions are included in the program manuals for expanding the data capacity of the programs if this is desirable.

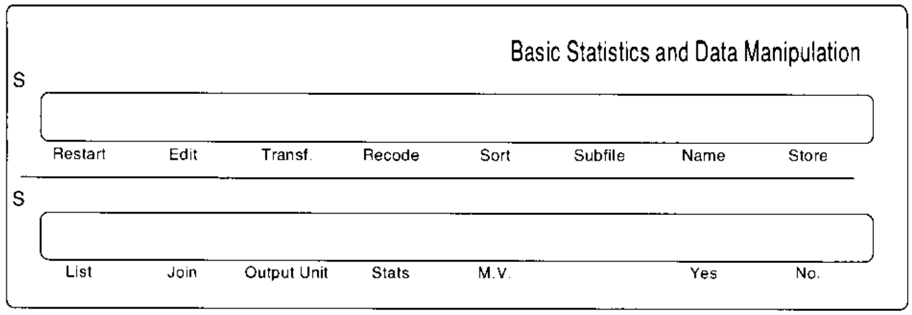


Figure 1-2. Overlay supplied with software to define Special Function keys on the computer keyboard.

Special Function Keys

Once the data array is in memory, you have a wide choice of operations available for modifying it. An operation is chosen simply by pressing one of the following program-dedicated Special Function keys (see Figure 1-2).

Edit

Allows correction of erroneous data and additions or deletions of variables or observations.

Transform

Permits any variable to be modified by any one of 17 transformations:

1. $aX^b + c$
2. a log(bX) + c
3. a ln(bX) + c
4. a exp(bX) + c
5. a (b^{cX})
6. a cos(bX) + c
7. a sin(bX) + c
8. $\sqrt{\text{arcsin(bX)}}$ + c
9. aX+bY+c
10. aX^bY^c
11. a log(bX + cY)
12. a ln (bX + cY)
13. a cos (bX + cY)
14. a sin (bX + cY)
15. PROUND (X,a)
16. DROUND (X,a)
17. User defined

The resulting values of the transformation replace the original variable or become a new variable.

Recode

Assigns codes to intervals of your data in order to simplify large data sets.

Sort

Rearranges the observations so that data values of a selected variable are in ascending order.

Subfiles

Divides the data into smaller sets of observations, each of which can be treated independently for analysis.

Name

Allows variables and subfiles to be named.

Store

Stores the data set on a Hewlett-Packard mass storage device.

List

Outputs the data set on the System 45B's CRT or selection of hardcopy printers.

set, thus forming an enlarged set.

Output Unit

Provides selection of an output device other than that currently in use.

Missing Values

Indicates missing data values.

Statistics

Calculates the following summary statistics (basic statistics and order statistics).

Standard
Skewness
Kurtosis
Standard Error
Confidence Interval for Mean
Coefficient of Variation
Correlation Coefficient for each pair of variables

- Order Statistics:
  Range
  Midrange
  Median
  Percentiles
  Tukey's Middlemeans

Software

This package provides common input and storage techniques for your statistical data. With this program package, you can enter your data once and it can be analyzed using any of the programs in the HP statistics library (e.g., Regression Analysis, Statistical Graphics, or General Statistics). And, you don't have to learn a new technique for data entry when switching from one program to another. The routines in this package

SAMPLE

```
Data file name: DATA
Number of observations: 20
Number of variables: 4

Variables names:
   1. AGE
   2. HEIGHT
   3. WEIGHT
   4. PRESSURE

Subfiles:  NONE
```

SAMPLE

OBS#	Variable # 1	Variable # 2	Variable # 3	Variable # 4
1	24.00000	172.50000	66.10000	76.60000
2	41.00000	196.00000	55.60000	74.20000
3	28.00000	189.80000	69.80000	72.40000
4	46.00000	149.50000	71.70000	83.30000
5	46.00000	145.60000	66.50000	77.80000
6	52.00000	155.30000	56.80000	72.70000
7	45.00000	158.80000	67.60000	82.90000
8	43.00000	172.10000	68.70000	82.20000
9	40.00000	182.30000	77.20000	82.40000
10	34.00000	187.40000	70.90000	81.70000
11	27.00000	181.80000	74.60000	73.50000
12	28.00000	183.30000	74.00000	75.50000
13	30.00000	165.40000	62.30000	87.20000
14	40.00000	177.60000	59.90000	79.30000
15	36.00000	202.90000	78.90000	78.20000
16	44.00000	147.50000	64.50000	75.10000
17	37.00000	176.30000	80.50000	81.00000
18	21.00000	156.80000	71.90000	77.60000
19	37.00000	150.10000	82.80000	79.10000
20	54.00000	171.20000	73.20000	74.20000

Figure 1-3. Listing of raw data printed on optional thermal line printer.

OBS#	Variable # 1	Variable # 2	Variable # 6
1	21.00000	156.80000	4.27528
2	24.00000	172.50000	4.19117
3	27.00000	181.80000	4.31214
4	28.00000	183.30000	4.30407
5	28.00000	189.80000	4.24563
6	30.00000	165.	4.13196
7	34.00000	187.40000	4.26127
8	36.00000	202.90000	4.36818
9	37.00000	176.30000	4.38826
10	37.00000	150.10000	4.41643
11	40.00000	177.60000	4.09101
12	40.00000	182.30000	4.34640
13	41.00000	196.00000	4.01818
14	43.00000	172.10000	4.22975
15	44.00000	147.50000	4.16667
16	45.00000	158.80000	4.21361
17	46.00000	145.60000	4.19720
18	46.00000	149.50000	4.27249
19	52.00000	155.30000	4.03954
20	54.00000	171..	4.29320

Figure 1-4. Data listing after sorting, recoding are performed.

combined with the System 45B give you unprecedented power and flexibility in manipulating your statistical data.

Easy Manipulation of Your Statistics Problem

No matter what your application,

you can perform daily repetitive operations with this program package quickly and easily. Consider a data set consisting of 20 observations on four variables.

The observations are human subjects, and the variables are age, weight in kg, height in cm., and diastolic blood pressure. Figure 1-3 shows the raw data. Figure 1-4 shows the same data after several operations are performed. First, the data is sorted on variable 1. Then variable 5 is added by using the recode operation on variable 1. The age ranges 21-25, 26-30, 31-35, 36-40, 41-45, 46-50, 51-55 are coded 1, 2, 3, 4, 5, 6, 7, respectively. Variable 6 is then created by taking the natural log of variable 3 using the transformation routine. Figure 1-5 shows the summary statistics for this data.

Variable # 3	Variable # 4	Variable # 5
71.90000	77.60000	1.00000
66.10000	76.60000	1.00000
74.60000	73.50000	2.00000
74.00000	75.50000	2.00000
69.80000	72.40000	2.00000
30000	87.20000	2.00000
70.90000	81.70000	3.00000
78.90000	78.20000	4.00000
80.50000	81.00000	4.00000
82.80000	79.10000	4.00000
59.80000	79.30000	4.00000
77.20000	82.40000	4.00000
55.60000	74.20000	5.00000
68.70000	82.20000	5.00000
64.50000	75.10000	5.00000
67.60000	82.90000	5.00000
66.50000	77.80000	6.00000
71.70000	83.30000	6.00000
56.80000	72.70000	7.00000
20000	74.20000	7.00000

and transforming operations

BASIC STATISTICS

VARIABLE	# OBSERVATIONS	# MISS. VALUES	SUM	MEAN
AGE	20	0	753.00000	37.65000
HEIGHT	20	0	3422.20000	171.11000
WEIGHT	20	0	1393.40000	69.67000
PRESSURE	20	0	1566.90000	78.34500
CODED AGE	20	0	79.00000	3.95000
LOG WEIGHT	20	0	84.76242	4.23812

VARIABLE	VARIANCE	STANDARD DEV.	COEF OF SKEWNESS	COEF OF KURTOSIS
AGE	84.02895	9.16673	-.09154	-.84599
HEIGHT	287.38621	16.95247	.05750	-1.03693
WEIGHT	56.20011	7.49667	-.19108	-.62928
PRESSURE	16.96787	4.11921	.29589	-.79817
CODED AGE	3.41842	1.84890	-.02761	-.99277
LOG WEIGHT	.01207	.10987	-.40370	-.51794

VARIABLE	COEF VARIATION	STANDARD ERROR OF THE MEAN	95 % CONFIDENCE INTERVAL ON MEAN LOWER LIMIT	UPPER LIMIT
AGE	24.34723	2.04974	33.35879	41.94121
HEIGHT	9.90735	3.79069	163.17407	179.04593
WEIGHT	10.76026	1.67631	66.16060	73.17940
PRESSURE	5.25778	.92108	76.41668	80.27332
CODED AGE	46.80753	.41343	3.08448	4.81552
LOG WEIGHT	2.59247	.02457	4.18669	4.28956

CORRELATION MATRIX

	HEIGHT	WEIGHT	PRESSURE	CODED AGE	LOG WEIGHT
AGE	-.3317544	-.2337557	.0140989	.9064340	-.2440782
HEIGHT		.1094591	-.1684442	-.3369973	.0988512
WEIGHT			.1646883	-.2044040	.9981084
PRESSURE				-.0404620	.1743010
CODED AGE					-.2187474

ORDER STATISTICS

VARIABLE	MAXIMUM	MINIMUM	RANGE	MIDRANGE
AGE	54.00000	21.00000	33.00000	37.50000
HEIGHT	202.90000	145.60000	57.30000	174.25000
WEIGHT	82.80000	55.60000	27.20000	69.20000
PRESSURE	87.20000	72.40000	14.80000	79.80000
CODED AGE	7.00000	1.00000	6.00000	4.00000
LOG WEIGHT	4.41643	4.01818	.39824	4.21731

TUKEY'S HINGES

VARIABLE	MEDIAN	25-th %-ile	75-th %-ile
AGE	38.50000	29.00000	44.50000
HEIGHT	172.30000	156.05000	182.80000
WEIGHT	70.35000	65.30000	74.30000
PRESSURE	78.00000	74.65000	81.95000
CODED AGE	4.00000	2.00000	5.00000
LOG WEIGHT	4.25345	4.17892	4.30810

TUKEY'S MIDDLEMEANS

VARIABLE	MIDMEAN	TRIMEAN	MIDSPREAD
AGE	38.20000	37.62500	15.50000
HEIGHT	171.48000	170.86250	26.75000
WEIGHT	70.04000	70.07500	9.00000
PRESSURE	78.19000	78.15000	7.30000
CODED AGE	4.00000	3.75000	3.00000
LOG WEIGHT	4.24837	4.24848	.12919

Figure 1-5. Printout of basic statistics and order statistics.

Of Statistical Tests For Thorough Data Evaluation

Whether your concern is life science, industry, behavioral science or pure research, Hewlett-Packard has a General Statistics Software Pack that offers you unprecendented flexibility in treating your data. This extensive collection of statistical tests was designed to make your data evaluation jobs easier to perform.

Choose from dozens of statistical inference tests. The General Statistics Pack is divided into five sections. The first four contain a variety of statistical tests: one sample tests, paired-sample tests, two-sample (independent) and multiple-sample tests. Each section usually contains several tests of the same hypothesis, both parametric and nonparametric, allowing you to choose the one most appropriate for your data. The fifth section consists of the most commonly used statistical distributions, eliminating the need to spend time referring to standard statistics tables.

Program Organization of Statistical Tests

ONE SAMPLE ANALYSIS

- Serial correlation — the correlation between the elements of a time series and those elements lagging behind by a fixed time interval. (See Figure 2-1)
- Serial plot — a scatter plot of the data versus observation number.
- Ranks — a listing of each distinct observation together with its position number when the data set is ordered according to size.
- Histogram — a frequency distribution plot
- t test — a test of the hypothesis that the sample was taken from a population having a given mean.

```
*                              DATA MANIPULATION                              *
                                 Power Output

Data file name: DATA
Number of observations: 96
Number of variables: 1

Variables names:
   1. Power

Subfiles:  NONE

                                 Power Output

                                 VARIABLE # 1
```

I	OBS(I)	OBS(I+1)	OBS(I+2)	OBS(I+3)	OBS(I+4)
1	6.46000	7.10000	7.80000	8.75000	[illegible]
6	10.06000	9.22000	8.14000	[illegible]	[illegible]
11	6.69000	6.26000	6.45000	[illegible]	7.60000
16	8.56000	9.12000	9.71000	9.12000	8.24000
21	7.97000	7.15000	6.64000	6.29000	[illegible]
26	7.10000	7.73000	8.63000	[illegible]	[illegible]
31	9.18000	8.23000	8.00000	7.18000	6.71000
36	6.28000	6.56000	7.09000	7.63000	8.47000
41	9.05000	9.70000	9.12000	[illegible]	7.25000
46	7.23000	6.74000	6.35000	7.09000	[illegible]
51	8.20000	9.21000	9.81000	10.51000	[illegible]
56	8.79000	8.60000	7.77000	7.30000	6.80000
61	6.20000	6.65000	7.25000	7.91000	8.41000
66	8.94000	8.39000	7.63000	7.37000	6.70000
71	6.31000	5.36000	6.16000	5.69000	7.16000
76	7.88000	8.47000	3.90000	3.40000	7.59000
81	7.39000	6.70000	6.38000	5.98000	6.17000
86	6.65000	7.11000	7.83000	8.35000	[illegible]
91	8.40000	7.57000	7.35000	6.71000	6.32000
96	6.03000				

```
ONE SAMPLE TESTS

VARIABLE --Power

SERIAL CORRELATION

SERIAL CORRELATION WITH LAG =  3 IS   .07849
SERIAL CORRELATION WITH LAG =  6 IS  -.71957
SERIAL CORRELATION WITH LAG = 12 IS   .78234
SERIAL CORRELATION WITH LAG = 24 IS   .65994
```

Figure 2-1. Printout of raw data showing serial correlation of power output.

```
*                              DATA MANIPULATION                              *
                                 Gasoline Test

Data file name: MPG:T
Number of observations: 8
Number of variables: 2

Variables names:
   1. Brand A
   2. Brand B

Subfiles:  NONE

                                 Gasoline Test
```

OBS#	Variable # 1	Variable # 2
1	28.00000	31.00000
2	26.00000	26.00000
3	23.00000	25.00000
4	25.00000	27.00000
5	27.00000	29.00000
6	25.00000	28.00000
7	28.00000	26.00000
8	24.00000	26.00000

Figure 2-2. Data from a mileage test of two brands of gasoline.

- Chi-squared goodness-of-fit — a test comparing the distribution of the sample data with one of three hypothetical distributions: normal, exponential or uniform.
- Kolmogorov-Smirnov goodness-of-fit test — similar to the Chi-squared test.
- Shapiro-Wilk Test — a test of the normality of the data.
- Runs Test — a non-parametric test for investigating trends in the data.

PAIRED SAMPLE ANALYSIS

- Paired t test — a test of the hypothesis that the mean of the differences between paired samples equals a user-selected value. (See Figure 2-3)
- Cross correlation — correlation between members of one sample and members of the other sample lagging behind by a fixed time interval.
- Family Regression — provides four regression models, solved by the least squares method:

Linear	$y = ax + b$
Quadratic	$y = ax^2 + bx + c$
Exponential	$y = a \exp(bx)$
Power	$y = ax^b$

- Sign Test — a test of whether there is a significant mean difference between pair members.
- Wilcoxon Signed Rank Test — a more powerful test than the sign test. (See Figure 2-3)
- Higher Power Signed Ranks — a generalization of the sign test and Wilcoxon Signed Rank Test.
- Spearman's Rho and Kendall's Tau — measures of the rank correlation between two samples.

TWO INDEPENDENT SAMPLES

- Two sample t test — used to determine whether the means of two samples are equal. (See Figure 2-4)

```
PAIRED SAMPLE TESTS

VARIABLE FOR X --    Brand A
VARIABLE FOR Y --    Brand B



PAIRED-t TEST

 1
H0 : MU(X)-MU(Y) = 0
H1 : MU(X)-MU(Y) < 6

T VALUE =                    -2.510
DF =                          7

T(       .950,  7 ) =         1.895

        DO NOT REJECT H0 AT  .050 LEVEL OF SIGNFICANCE



WILCOXON SIGNED RANK

   N=      7
   SUM OF POSITIVE RANKS = 3

   (USING RANKS OF X(I)-Y(I) AND EXCLUDING THE       1
    POINTS WHERE X(I)=Y(I))

   YIELDS APPROXIMATE STANDARD NORMAL DEVIATES

        1) WITHOUT CORRECTION FOR CONTINUITY :

          A) NOT COMPENSATING FOR TIED DIFFERENCES :-1.8593

          B) CONDITIONAL ON THE EXISTING TIED DIFFERENCES :-1.9302

        2) WITH CORRECTION FOR CONTINUITY :

          A) NOT COMPENSATING FOR TIED DIFFERENCES :-1.9439
```

```
*****************************************************************************
*                            DATA MANIPULATION                              *
*****************************************************************************
                               Pig Weights

Data file name: DATA
Number of observations: 16
Number of variables: 1

Variables names:
  1. Wt.(lb)

Subfile name      beginning observation--number of observations
 1. Corn                          1                          9
 2. Oats                         10                          7


                               Pig Weights


                               VARIABLE # 1
   I        OBS(I)       OBS(I+1)      OBS(I+2)      OBS(I+3)      OBS(I+4)
   1     158.00000     144.00000     139.00000     154.00000     149.00000
   6     150.00000     154.00000     160.00000     147.00000     152.00000
  11     138.00000     154.00000     147.00000     158.00000     143.00000
  16     147.00000

TWO INDEPENDENT SAMPLE TESTS

VARIABLE --         Wt.(lb)
X SUBFILE --        Corn
Y SUBFILE --        Oats

t STAT FOR THE MEAN OF TWO SAMPLES

SAMPLE 1
N =    9
     158.00000      144.00000  ...          9.00000

MEAN =           150.5556
STD. DEV. =      6.7103

SAMPLE 2
N =    7
     152.00000      138.00000   ...         16.00000

MEAN =           149.1429
STD. DEV. =      6.3882

t=             .4414    DF=       14
PROB (t > .44137 ) = .33284


MANN-WHITNEY TEST

    SUM OF THE RANKS OF X = 81.5

    YIELDS AN APPROX. STD. NOR. DEV. OF :          .5283
         CONDITIONAL ON THE 5 EXISTING TIES
```

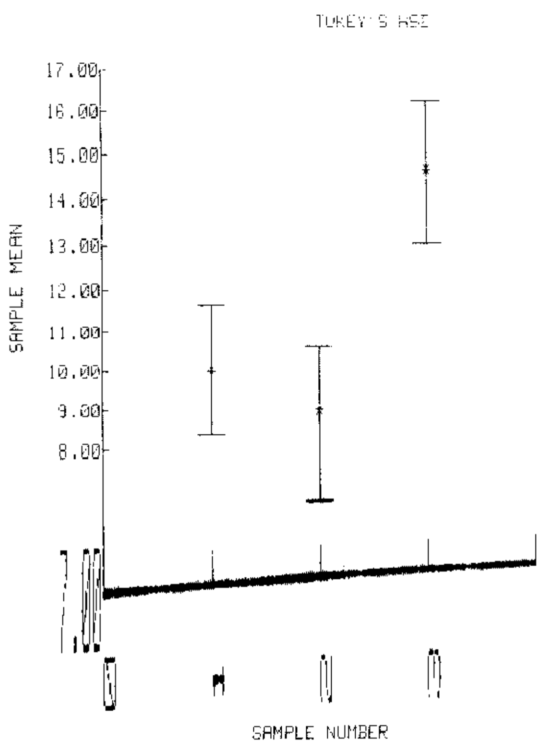
Figure 2-4. Independent-sample t test and the Mann-Whitney test for weights of two groups of pigs.

```
MULTIPLE SAMPLE TESTS

VARIABLE --          V
SUBFILE --           A
SUBFILE --           B
SUBFILE --           C


ONE WAY AOV

TRT # 1
        10.00000         8.00000          5.00000
        12.00000        14.00000         11.00000
TRT # 2
         6.00000         9.00000          9.00000
        13.00000
TRT # 3
        15.00000        14.00000         11.00000
        17.00000        16.00000

TRT.#    N          MEAN          VARIANCE    STD DEV    STD ERROR
  1      6        10.0000        10.0000      3.1623      1.2910
  2      4         9.0000         8.6667      2.9439      1.4720
  3      5        14.6000         5.3000      2.3022      1.0296


              AOV

SOURCE      DF        SS              MS              F
TOTAL       14      182.9333
TRTS         2       85.7333        42.9667         5.2922
ERROR       12       97.2000         8.1000

PROB (F > 5.2922 ) = .0225

BARTLETT'S TEST
DF = 2.0000 ,CHI-SQUARE = .3942
```

tribution. (See Figure 2-4)

MULTIPLE SAMPLE TESTS

- One-Way Analysis of Variance — tests the hypothesis that the means of several samples are equal. The sample sizes need not be equal. (See Figure 2-5)
- Kruskal-Wallis — a non-parametric version of one-way analysis of variance.
- Multiple Comparison Procedures — several tests for determining the smallest significant difference between the means of several samples. The tests in this section are: Least Significant Difference, Tukey's H.S.D, Scheffe's Test, Student-Newman-Keuls Test and Duncan's Test. (See Figure 2-6)




```
TUKEY'S HSD

ERROR MEAN SQUARE = 8.1
DEGREES OF FREEDOM = 12
LEVEL OF CONFIDENCE = .95
TABLE VALUE FROM STUDENTIZED RANGE =    2.5200 , HSD =    3.2517

SAMPLES RANKED
  2  1  3
A ----
B       -

MEANS
 1 -A
 2 -A
 3 -B
```

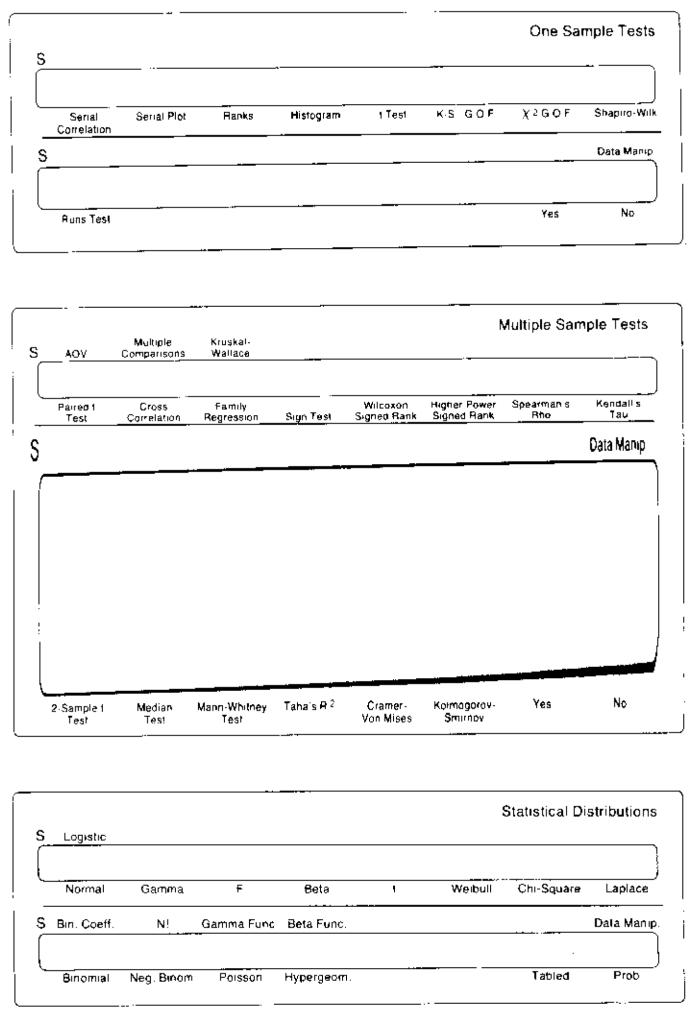
Figure 2-6. Tukey's HSD test — one of the five multiple comparison procedures available for showing differences among means either graphically or tabularly.

- Continuous distributions:
  Normal
  Gamma
  Beta
  Student's t

Binomial Coefficients
Gamma Function
Beta Function
N Factorial

```
F TABLED

N =  2 ,  D =  15 ,  P =  .005 ,  F =  7.70075862443
N =  6 ,  D =  24 ,  P =  .01 ,  F =  3.66671671811
N =  2 ,  D =  3 ,  P =  .05 ,  F =  9.55209449664


F PROB

N =  3 ,  D =  16 ,  P(F>  4.123465 ) = 2.40912275507E-02
N =  1 ,  D =  9 ,  P(F>  7.32 ) = 2.41730013752E-02
N =  3 ,  D =  18 ,  P(F>  58.78 ) = 1.69245259751E-09


T TABLED
DEGREES OF FREEDOM =  6 ,  P =  .005 ,  T =  3.70742802144
DEGREES OF FREEDOM =  46 ,  P =  .01 ,  T =  2.41018309622
DEGREES OF FREEDOM =  15 ,  P =  .05 ,  T =  1.75305035569


T PROB

DEGREES OF FREEDOM =  5 ,  P(T>  2.64565 ) = 2.28323440766E-02
DEGREES OF FREEDOM =  36 ,  P(T>  8.3146 ) = 3.36646265334E-10
DEGREES OF FREEDOM =  14 ,  P(T>  7.126 ) = 2.56192235012E-06
```

Figure 2-7. A printout from the statistical distributions showing the F and t distributions.



Overlays supplied with General Statistics Pack to define Special Function keys on the keyboard.

Plot your data automatically to recognize statistical relationships quickly and conveniently.

When masses of numerical data need to be analyzed, a graphic plot is usually your best means to visualize that data. A plot can quickly indicate information about your data that would be difficult and time-consuming to extract from data listings alone. With a clear picture of what the data represent, you can draw some basic conclusions and better select further statistical tests for your data .

System 45B's graphics CRT is an especially useful tool when performing statistical plots. The CRT allows you to continually evaluate the data and modify your plots. For a hard copy of the plot, System 45B has an internal thermal line printer that conveniently reproduces the results displayed on the CRT — all within minutes of entering your data into the machine. For a more eye-catching plot, simply modify the data on the CRT and when everything is exactly as you want it, output it to HP's 9872 four-color plotter.

Plotting Techniques

The Statistical Graphics program gives you a choice of nine plotting routines to help you gain greater insight into your data.

TIME SERIES PLOT — A plot of univariate data against observation number. Useful in detecting trends or autocorrelation in data. See Figure 3-1

HISTOGRAM — A plot representing the frequency distribution of the data. See Figure 3-2

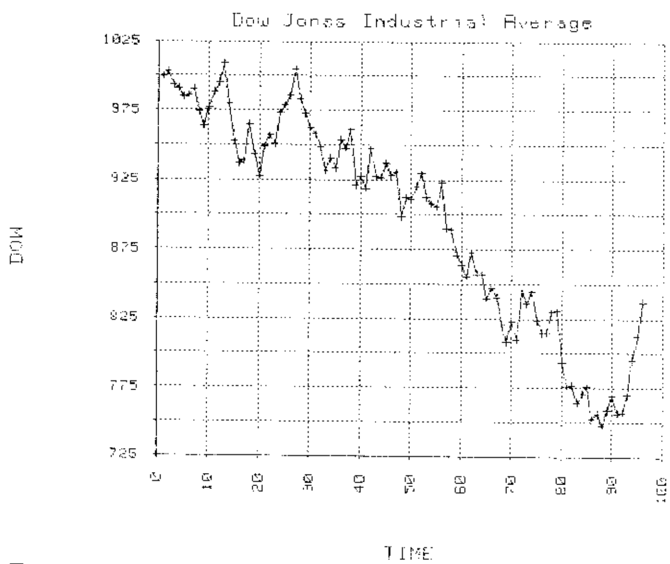


Figure 3-1. Time Series Plot

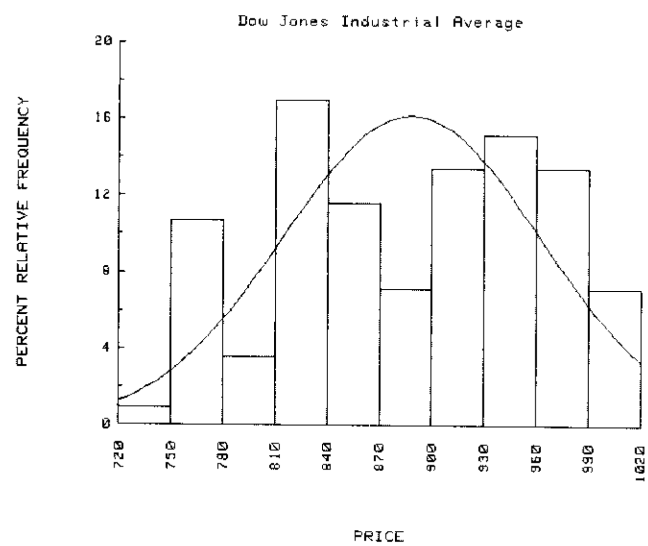
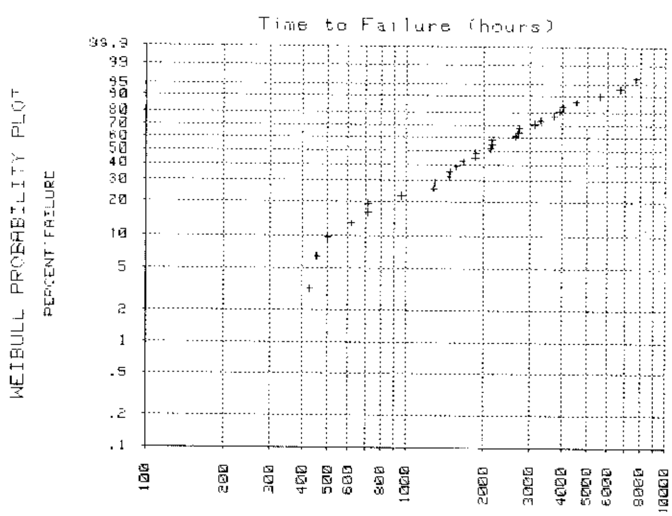
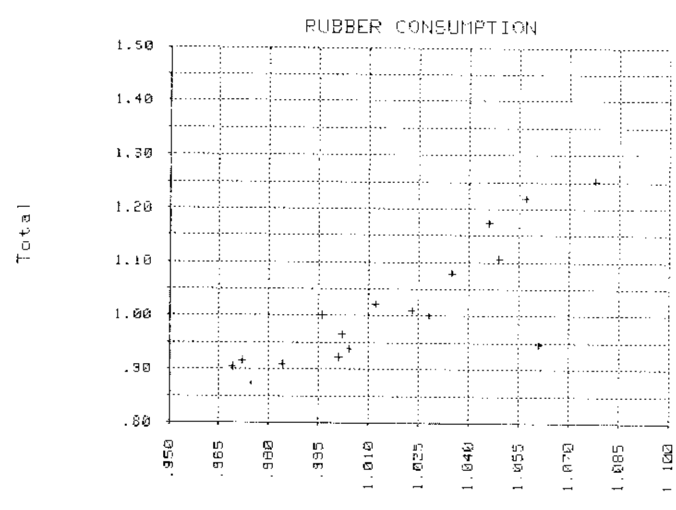


Figure 3-2. Histogram





SCATTERGRAM — A plot of bivariate data. The relationship between the two variables can often be determined by looking at a scatter plot. See Figure 3-4

SEMI-LOG PLOT — A scatter plot in which the X axis is logarithmic. It is useful in detecting a relation between one variable and the exponential of the other. See Figure 3-5

XYZ PLOT — Plots three-variable data in a scattergram. See Figure 3-7

ANDREWS PLOT — This method graphically represents multivariate data.

Each observation $(x_1,\ldots,x_k)$ defines a function

$X_1 \sqrt{2} + X_2 \sin t + X_3 \cos t + X_4 \sin 2t + \ldots,$

which is plotted over the interval $-\pi<t<\pi$. The method is excellent for detecting clusters and outliers, especially when the number of variables is large and the number of observations is relatively small. See Figure 3-8

In each of the programs all plotting parameters, such as scale factors, labeling information and plotting symbols, can be selected automatically. After viewing the plot on the CRT screen, you can modify any or all of these parameters to your liking before making a hard-copy plot on the thermal line printer or the 9872A four-color plotter.

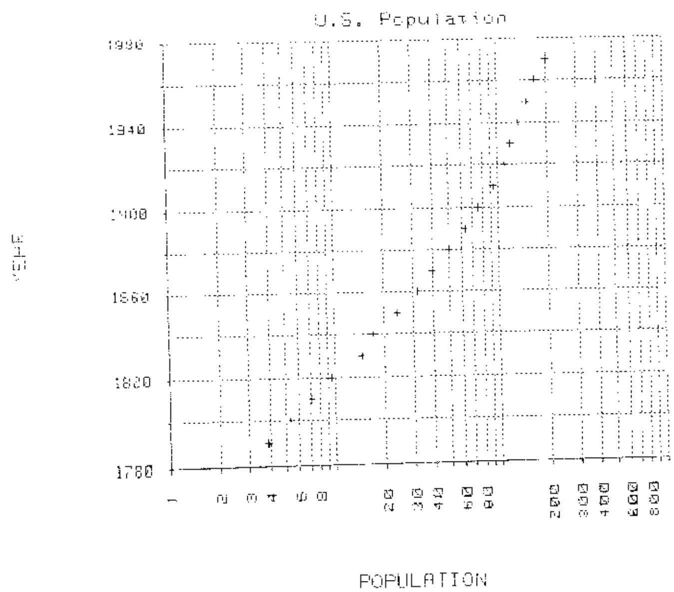


Figure 3-5. Semi-Log Plot

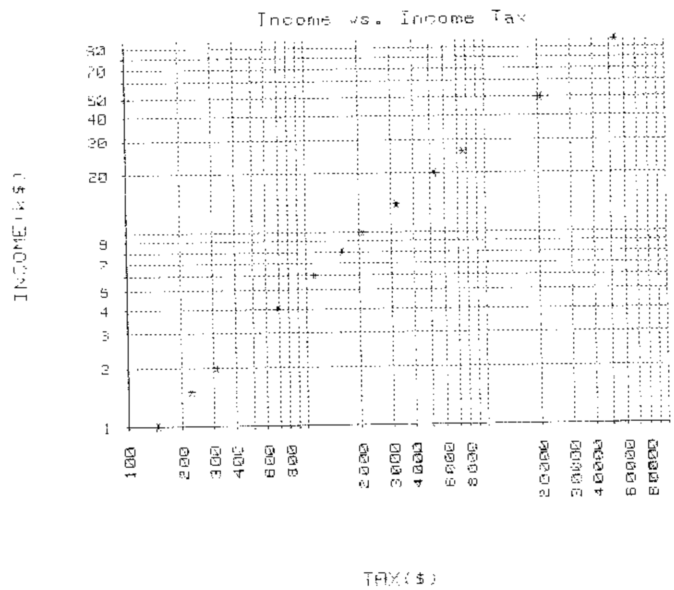


Figure 3-6. Log-Log Plot

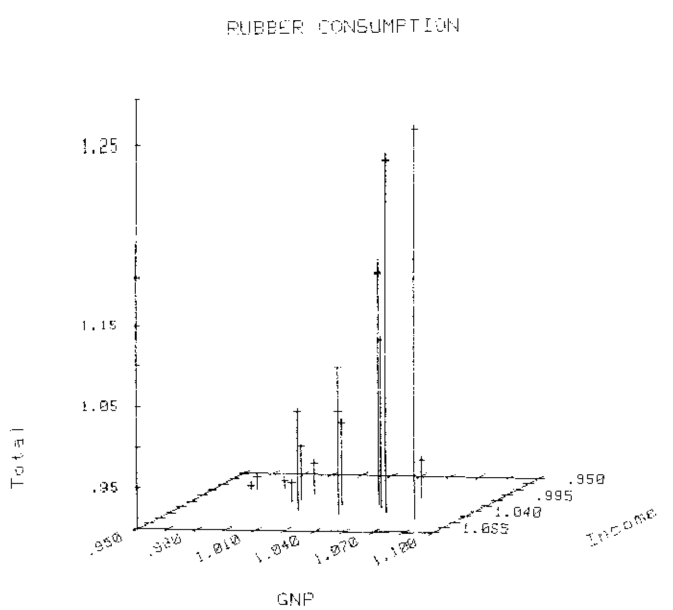


Figure 3-7. XYZ Plot

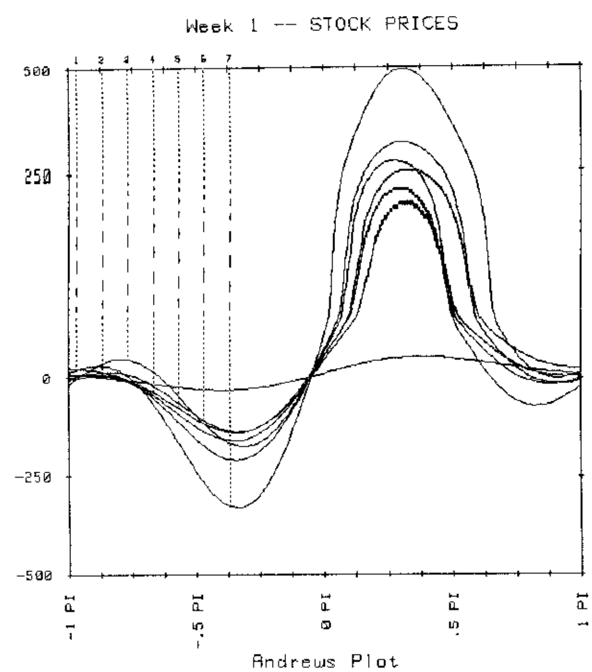


Figure 3-8. Andrews Plot

Sophisticated, flexible routines for statistical model building

The Regression Analysis programs give you a choice of three regression techniques and a collection of routines for entering, editing and transforming your data for later analysis. They provide, as well, an extensive set of summary statistic routines. Besides all these, there is a program for analyzing residuals from any of the regression programs.

A Choice Of Regression Methods

The program package gives you a choice of three regression techniques to analyze your data: polynomial regression (up to degree nine); multiple linear regression (up to 50 variables); and multiple regression with four variable-selection procedures.

Polynomial regression. This program fits a polynomial of the form

$$y = a_0 + a_1x + a_2x^2 + \ldots + a_n x^n$$

to your data, using the least squares method to determine the coefficients. Program output includes:

- mean, variance, standard deviation and coefficient of variation of the dependent and independent variables.
- the correlation coefficient and standard error of estimate,
- a preliminary analysis of variance table to assist in selecting the degree of polynomial desired,
- a final analysis of variance table which includes the F-ratio associated with each degree,
- the computed regression coefficients together with their associated standard errors and t-values
- a confidence interval for each coefficient.

You can also obtain a scatter plot of your data, together with plots of any of the polynomials you have chosen to examine. Figure 4-1 shows a sample data set with the results from polynomial regression.

```
*****************************************************************************
*                           DATA MANIPULATION                               *
*****************************************************************************
                        Bus Passenger Service Time

Data file name: DATA
Number of observations: 31
Number of variables: 2

Variables names:
  1. NUMBER
  2. TIME

Subfiles:  NONE



                        Bus Passenger Service Time

      Variable # 1   Variable # 2
OBS#
  1
        1.00000        1.40000
  2
        1.00000        2.30000
  3
        1.00000        3.00000
  4
        1.00000        1.80000
  5
        1.00000        2.00000
  6
        2.00000        4.70000
  7
        2.00000        8.00000

       11.00000       22.90000
 27
       11.00000       22.60000
 28
       13.00000       25.20000
 29
       17.00000       33.50000
 30
       19.00000       33.70000
 31
       25.00000       54.20000

*****************************************************************************
POLYNOMIAL REGRESSION ON DATA SET:
                        Bus Passenger Service Time
*****************************************************************************

--where:  Dependent variable = TIME
          Independent variable = NUMBER


                                                   STANDARD    COEFFICIENT
VARIABLE       N          MEAN       VARIANCE     DEVIATION   OF VARIATION
NUMBER        31       6.67742       33.22581       5.76410       86.32351
TIME          31      13.91290      139.39983      11.80677       84.86202

CORRELATION =  .974353347879

Selected degree of regression =  1
R-SQUARED = .949364446536
STANDARD ERROR OF ESTIMATE = 2.70221890456

                                  AOV

SOURCE          DF     SUM OF SQUARES      MEAN SQUARE      F-VALUE

TOTAL           30       4181.99484
REGRESSION       1       3970.23722         3970.23722       543.72
 X^1             1       3970.23722         3970.23722       543.72
RESIDUAL        29        211.75762            7.30199

                  REGRESSION COEFFICIENTS          STANDARD ERROR
VARIABLE         STD. FORMAT          E-FORMAT    REG. COEFFICIENT    T-VALUE
'CONSTANT'            .58633  .586330096900E+00             .74979        .78
X^1                  1.99577  .199576699031E+01             .08559      23.32



                                   95 % CONFIDENCE INTERVAL
               COEFFICIENT        LOWER LIMIT       UPPER LIMIT
'CONSTANT'          .58633            -.94752          2.12018
X^1                1.99577            1.82068          2.17086
```

Bus Passenger Service Time

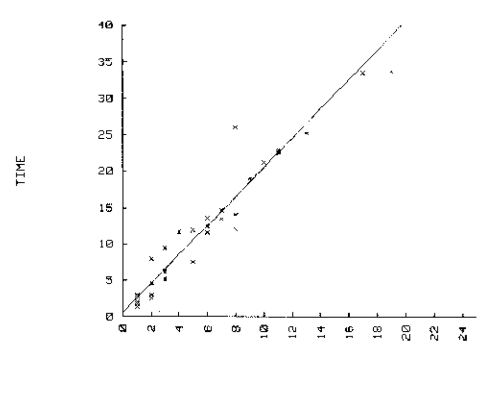


Figure 4-1. Sample polynomial regression showing the relationship between the number of passengers and service time.

of estimate; an analysis of variance table including the F-ratio associated with each variable; and the regression coefficients with their associated standard errors, t-values and confidence intervals.

lowing you to examine an analysis of variance table at each step of the routine and delete insignificant variables from those previously added. This is called a manual selection procedure. The program also includes

until all variables in the model are significant and the variables omitted are insignificant. Program output includes the correlation matrix, an analysis of variance table, and the regression coefficients with their associated standard errors. Figure 4-2 shows a sample data set using stepwise selection.

Residual analysis. The residual analysis program may be used after any regression program. It will automatically determine the differences between actual Y values and predicted Y values. This program prints a table of residuals and standardized residuals and may plot the standardized residuals either against the observation number, or against any variable. Figure 4-3 shows the residual analysis of the data in Figure 4-2.

STEPWISE REGRESSION ON
SAMPLE

Dependent variable:Water Use
Independent variable(s) = Temp(C)
Production
Days
Payroll

Tolerance = .01
F-value for inclusion = 4
F-value for deletion = 4

CORRELATION MATRIX

	Temp(C)	Production	Days	Payroll	Water Use
Temp(C)	1.0000000	-.0923502	.2685939	-.1073726	.2503744
Production		1.0000000	.1057436	.9184717	.6308869
Days			1.0000000	.0318812	-.0887635
Payroll				1.0000000	.4134486
Water Use					1.0000000

#--VARIABLE	F TO ENTER	PART CORR	TOL	F TO DELETE	REGRESSION COEFFICIENTS STD.FORMAT	E-FORMAT	STD ERROR
1.Temp(C)	1.00	.250	1.000				
2.Production	9.92	.631	1.000				
3.Days	.12	.089	1.000				
4.Payroll	3.09	.413	1.000				

STEP NUMBER 1
VARIABLE'Production' ADDED
R-SQUARED = .39801325079

AOV

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-VALUE
TOTAL	16	3861967.52900		
REGRESSION	1	1537133.56050	1537133.56050	9.92
RESIDUAL	15	2324833.96850	154988.93123	

STANDARD ERROR = 393.686336102

#--VARIABLE	F TO ENTER	PART CORR	TOL	F TO DELETE	REGRESSION COEFFICIENTS STD.FORMAT	E-FORMAT	STD ERROR
1.Temp(C)	2.66	.399	.991				
2.Production				9.92	.09765	.976476057819E-01	.0310
3.Days	.59	.202	.989				
4.Payroll	5.79	.541	.156				

Constant = 2499.97697139

STEP NUMBER 2
VARIABLE'Payroll' ADDED
R-SQUARED = .57420302157

AOV

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-VALUE
TOTAL	16	3861967.52900		
REGRESSION	2	2217553.42435	1108776.71218	9.44
RESIDUAL	14	1644414.10465	117458.15033	

STANDARD ERROR = 342.721680568

#--VARIABLE	F TO ENTER	PART CORR	TOL	F TO DELETE	REGRESSION COEFFICIENTS STD.FORMAT	E-FORMAT	STD ERROR
1.Temp(C)	3.10	.439	.988				
2.Production				13.26	.24853	248526359013E+00	.0683
3.Days	1.83	.351	.962				
4.Payroll				5.79	-23.70679	-.237067948772E+02	9.8498

Constant = 5177.19960983

Tolerance value too small and/or F-values insufficient to proceed.

Figure 4-2. Sample stepwise regression showing the effect of average external temperature, production yield, number of working days in the month, and number of employees on water use.

OBS#	OBSERVED Y	PREDICTED Y	RESIDUAL	STAND.RES.	SIGNIF.
1	3373.00000	3590.06369	-217.06369	-.63335	
2	3110.00000	3141.55475	-31.55475	-.09207	
3	3180.00000	2951.51323	228.48677	.66668	
4	3293.00000	3182.87562	110.12438	.32132	
5	3390.00000	3791.88564	-401.88564	-1.17263	
6	4287.00000	3835.76492	451.23508	1.31662	
7	3852.00000	3586.10837	265.89163	.77582	
8	3366.00000	3674.51316	-308.51316	-.90019	
9	3532.00000	3385.08984	146.91016	.42866	
10	3614.00000	3783.51944	-169.51944	-.49463	
11	3896.00000	4169.20360	-273.20360	-.79716	
12	3437.00000	3434.24056	2.75944	.00805	
13	3324.00000	3410.90783	-86.90783	-.25358	
14	3214.00000	3767.12980	-553.12980	-1.61393	
15	4345.00000	3786.36312	558.63688	1.63000	
16	4936.00000	4471.67328	464.32672	1.35482	
17	3624.00000	3810.59316	-186.59316	-.54445	

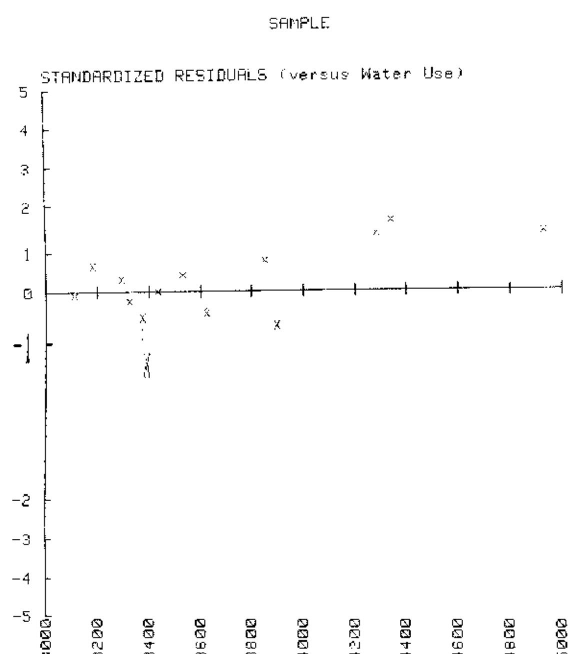


Figure 4-3. Residual table and plot using the data from Figure 4-2.

Statistical Model Building Offering User Control Of Curve Quality And Fit

Non-Linear Regression Analysis

Hewlett-Packard's Non-Linear Regression package offers excellent user control in rapid determination of functional relationships among tabulated observations.

The Non-Linear Regression software pack offers sophisticated routines to determine the best-fitting curve for a set of data. The model may be any combination of algebraic or Boolean expressions involving one or more independent variables and up to 10 parameters. The program also includes a set of routines to analyze residuals to check the quality of curve fit.

Iterative Method Increases Number Of Solvable Problems.

The Non-Linear Regression program uses Marquardt's method of estimating non-linear parameters. This iterative method represents a compromise between the linearization (or Taylor series) method and the Steepest Descent method. Marquardt's Compromise has been found to solve a wider variety of problems than either of the other methods. Convergence is determined by monitoring small changes in the parameters. The required input consists of an equation representing the desired model, together with the first derivative of the model with respect to each parameter, and an initial guess for each parameter value.

```
**************************************************
*                              DATA MANIPULATION
**************************************************
                              Per Cent Chlorine

Data file name: DATA
Number of observations: 19
Number of variables: 2

Variables names:
   1. Time
   2. % Cl

Subfiles:  NONE


                              Per Cent Chlorine
```

OBS#	Variable # 1	Variable # 2
1	0.00000	12.00000
2	1.00000	15.50000
3	2.00000	18.40000
4	3.00000	21.00000
5	4.00000	23.20000
6	5.00000	25.00000
7	6.00000	26.50000
8	7.00000	27.80000
9	8.00000	29.00000
10	9.00000	30.00000
11	10.00000	30.80000
12	11.00000	31.50000
13	12.00000	32.00000
14	13.00000	32.50000
15	14.00000	32.90000
16	15.00000	33.30000
17	16.00000	33.60000
18	17.00000	33.90000
19	18.00000	34.20000

Figure 5-1. Variable 1 is time measured in seconds and Variable 2 is per cent of chlorine present.

$$y = a - bc^x.$$

For example, Figure 5-1 shows the data measured from a reaction in which Variable 1 is time (in seconds) and Variable 2 is the amount of chlorine present (in per cent). Figure 5-2 shows the initial and final values of the three parameters (a, b, and c) together with a plot of the data and the regression curve. The 95% confidence intervals for the parameters are shown in Figure 5-3.

Features/Benefits of Using Non-Linear Regression Software

Data Input

Data can be entered from tape cartridge, keyboard, mass storage or other external device (e.g. card reader).

Confidence Intervals

Confidence intervals can be established for each parameter. You can specify your own confidence level.

Scatter Plots

Presenting the data in a scatter plot is invaluable for selecting the best model and for selecting the initial estimate of parameters. The dependent variable can be plotted against any independent variable.

Interactive Computation

Results from each iteration are displayed on the CRT so you can monitor the convergence. You can change the functional form to "speed up" the convergence.

Curve Plot

If the chosen model has one independent variable, the curve can be plotted. By plotting, you can see the quality of fit and judge the appropriateness of the model. Successive choices are overlayed on the same plot so the best fit can be chosen.

Residual Analysis

This routine calculates the difference between actual and predicted values of the dependent variable. The standardized residuals are printed and may be plotted by customers with graphic capabilities. The residuals help establish the appropriateness of the model.

```
        PARAMETER 1 = 35
        PARAMETER 2 = 20
        PARAMETER 3 = .7
*****************************************************************************
        THE ESTIMATED PARAMETER VALUES AFTER 5 ITERATIONS ARE :
       PARAMETER  1=        35.3834768 ( 3.5383476846E+01)
       PARAMETER  2=        23.3951156 ( 2.3395115590E+01)
       PARAMETER  3=          .8503918 ( 8.5039181495E-01)
*****************************************************************************
        THE INITIAL VALUE OF SUM OF SQUARED RESIDUALS = 384.705765365
        AFTER 5 ITERATIONS THE SUM OF SQUARED RESIDUALS= 3.58884133275E-02
*****************************************************************************
```

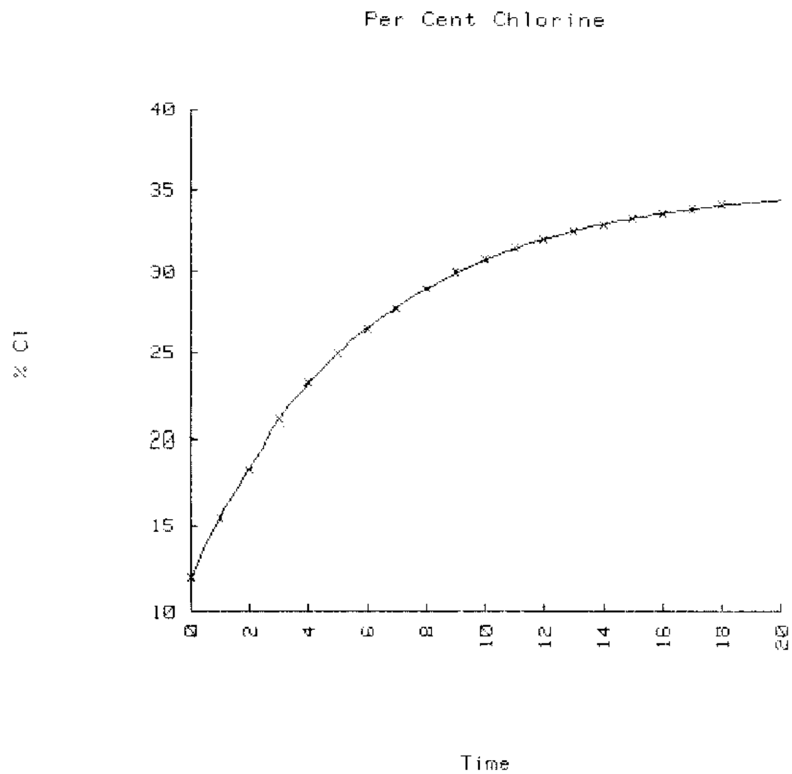


Figure 5-2. The initial and final values of the three parameters and a plot of the data.

```
*****************************************************************************
                  95 % CONFIDENCE INTERVALS ON PARAMETERS

 PARAMETER        ONE-AT-A TIME C.I.                  SIMULTANEOUS C.I.

             LOWER LIMIT     UPPER LIMIT         LOWER LIMIT     UPPER LIMIT
     1         35.300          35.467              35.261          35.506
     2         23.308          23.482              23.267          23.523
     3           .849            .852                .848            .853
*****************************************************************************
```

Figure 5-3. 95% confidence intervals for the three parameters.

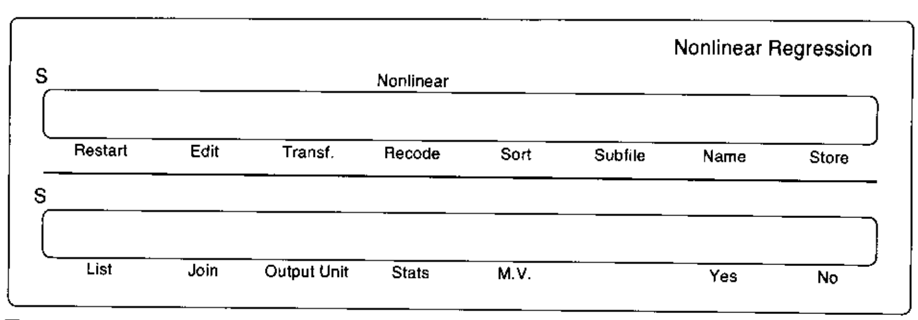


Figure 5-4. Special Function Key overlay.

Gain Additional Insight Into Your Statistical Data

Analysis of Variance

The Analysis of Variance (AOV) package contains routines for the analysis of data obtained from statistically planned experiments. Each of the designs will accept data which has been entered via the Basic Statistics and Data Manipulation routines in one of several modes.

AOV will handle these designs:

FACTORIAL — up to four factors may be combined in a balanced experiment. There may be multiple observations per treatment combination and the entire experiment may be replicated in blocks. (See Figure 6-1.)

NESTED — up to four factors (five if samples are included) can be combined in a nested or partially nested completely balanced design.

SPLIT PLOT — up to three factors may be combined in either a split plot or split-split plot design. At least two blocks are required and multiple observations may be included.

ONE FACTOR — a one-way AOV is performed for an experiment with equal or unequal numbers of observations per treatment.

TWO-FACTOR UNBALANCED — an analysis may be performed on a two-factor design with unequal numbers of observations per treatment combination.

ONE FACTOR WITH COVARIATE — a one-way analysis of covariance is performed for equal or unequal numbers of observations per treatment.

```
******************************************************************************
*                        FACTORIAL ANALYSIS OF VARIANCE                      *
******************************************************************************
                            HOLE-CUTTING PERFORMANCE


DESIGN
------
   Number of factors =  2
    No. of levels of factor A =  2
    No. of levels of factor B =  3
    No. of major replications (blocks) =  1
    No. of minor replications (samples) =  3

Subfiles will be ignored
Response variable(s) are :
Variable no.  1      REP 1
Variable no.  2      REP 2
Variable no.  3      REP 3

MEANS
-----
* Overall mean =          .968333


* Main Effect Means :



Factor A - PRESSURE    Levels ( 1 - 2 ) :
        .923333          1.013333
Factor B - BIT SPEED    Levels ( 1 - 3 ) :
        .940000           .985000          .980000


* Two Way Interaction Means :

Factor A - PRESSURE  down and  Factor B - BIT SPEED  across
                         1               2               3
    1                 .900000         .950000         .920000
    2                 .980000        1.020000        1.040000



ANOVA TABLE
-----------
                   Factorial Analysis of Variance

Source (Name)     df     Sums of Squares          Mean Square   F Ratio  F-Prob
-------------------------------------------------------------------------------
Total             17            .097050             .005709
A    PRESSURE      1            .036450             .036450      8.543   .0128
B    BIT SPEED     2            .007300             .003650       .855   .4495
AB                 2            .002100             .001050       .246   .7857
Sampling Error    12            .051200             .004267
    NOTE: F tests assume that all factors are fixed
```

Figure 6-1. Factorial Analysis of Variance.

In addition to the actual analysis of variance tables, several Special Function Keys enable you to gain further insight into your experiment and provide greater flexibility in your analysis.

NEW RESPONSE — this key allows you to change the response (and covariate if applicable) and perform an identical analysis on the new response.

FPROB — a key is provided which gives the significance level of computed F statistics.

ORTHOGONAL POLYNOMIALS — a routine is provided which generates orthogonal polynomials. These help you evaluate the effects of quantitative factors whose treatment levels are either equally or unequally spaced.

TREATMENT CONTRASTS — given the contrast coefficients, this routine computes the contrast, the sum of squares and F-value associated with the contrast, as well as the significance of the F statistic.

INTERACTION PLOTS — a graphical display of two-way or three-way interactions may be obtained on the CRT or on a hardcopy plotter. (See Figure 6-2.)

MULTIPLE COMPARISONS — five multiple comparison procedures are available, namely, Least Significant Differences, Honestly Significant Differences, Scheffe's, Student-Newman-Keuls, and Duncan's test. (See Figure 6-3.)

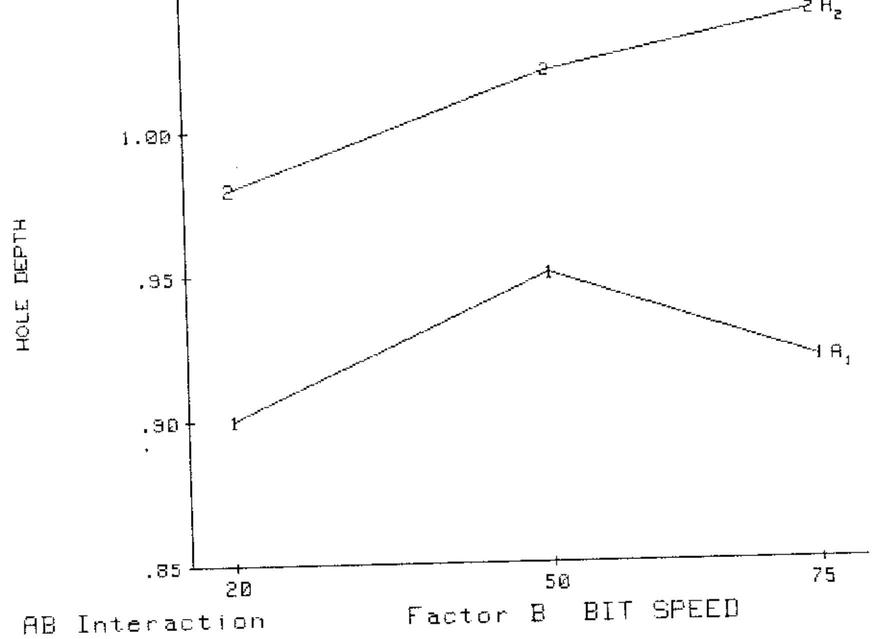


Figure 6-2. Interaction Plot.

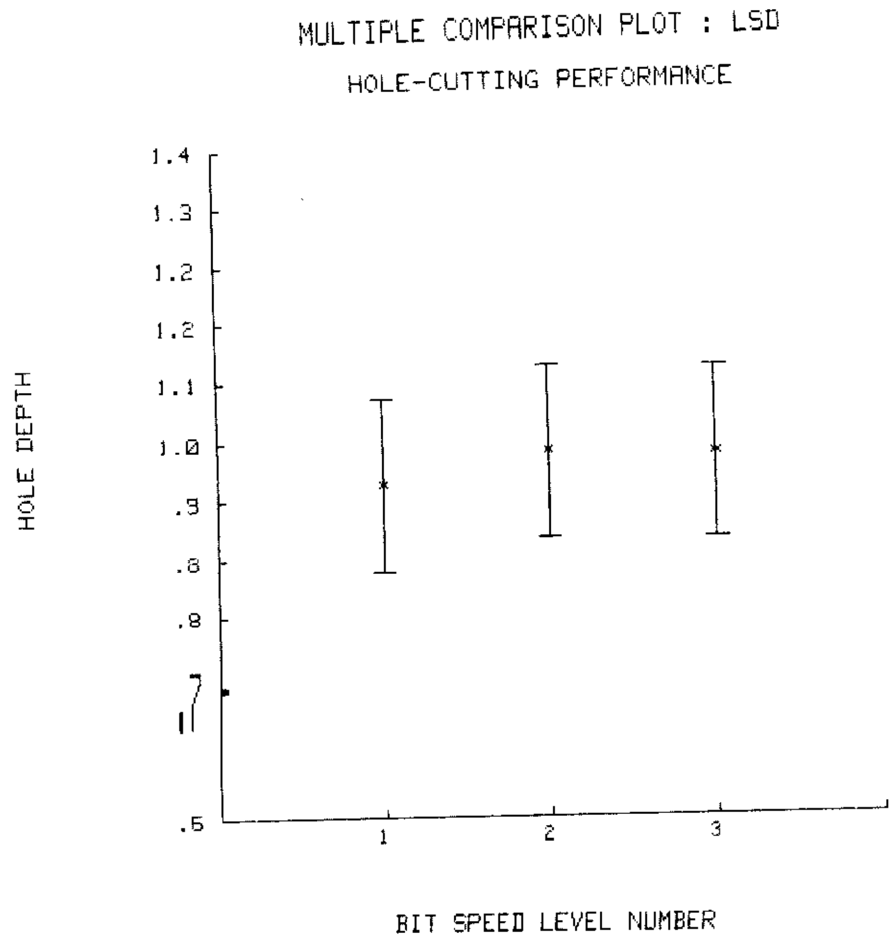


Figure 6-3. Multiple Comparisons.

Sophisticated Simulation Utilities For Complex Model Building

Monte Carlo Simulation Utilities

This set of utilities is intended for the customer who is performing serious statistical simulations. A uniform random number generator is provided which will produce 10^{12} pseudo-random numbers before repeating. Since the random number generator is built into the machine and intended only for unsophisticated applications, these utilities are a must for simulations.

Binary programs give you four new commands for generating uniform random numbers. The first two are designed for the general user:

IRND – produces a uniformly distributed (pseudo) random number.

SEED – allows you to specify the seed for the generator. Thus, you can duplicate a series of random numbers by specifying the same seed.

The second set of commands are intended for more sophisticated users. The random numbers, R(I), are generated using the linear congruential model $R(I+1) = (A \cdot R(I) + C) \text{ MOD } M$. In the binary routines A and C have been chosen based on certain theoretical considerations. However, you may change these values if you desire.

ACOEF – allows you to assign your own value to A.

CCOEF – allows you to assign your own value to C.

The improved uniform random number generator, IRND, is also used to generate random deviates from the following statistical distributions:

Beta
Binomial
Chi-square
Exponential
F
Gamma (Alpha)
Gamma
Geometric
Lognormal
Negative Binomial
Standard Normal
Normal
Dependent Normal
Pareto of the First Kind
Pareto of the Second Kind
Poisson
Random Points on an M-dimensional Unit Sphere
Super Uniform
t
Type 1 Extreme Value
Type 2 Extreme Value
Weibull

A set of statistical tests for randomness are also included in the package. The tests enable you to easily evaluate the "randomness" of your results. These routines are written as utility subprograms but also have optional drivers. The drivers are set up so you can evaluate the performance of the improved random number generator, IRND.

The following tests are provided:

- Chi-square Test
- Kolmogorov-Smirnov Test
- Maximum of T Test
- Modified Poker Test
- Runs Test
- Serial Test
- Spectral Test

In addition, the package includes two elementary sampling utilities. The first routine allows you to select a simple random sample without replacement. So, if you have 1000 parts and want to randomly select 10 of them, the program will tell you which ones to choose. A second routine allows you to arrange an array of numbers in a random order. For example, the numbers from 1 to 52 could correspond to playing cards. This routine would effectively shuffle the cards for you.

right at your desk.

Perform Numerical Analysis Routines Quickly and Simply

The Numerical Analysis Library, Vol. 1, provides you quick access to 49 commonly used numerical analysis routines. The following is a description of the programs in each section which are designed to handle a variety of your numerical analysis problems.

These routines can be called up from the library as you need them — minimizing reprogramming time and memory. Think of each routine as a black box having one or more input parameters and one or more output parameters. You don't need to be concerned about what's happening inside the routine — only how to call it from your application program.

Root Finders. One of the most difficult tasks in numerical analysis is to find the roots or zeros of a function.

This section contains four methods:

- Bisection method - This method is relatively slow but theoretically always works.
- Secant method - This method works well with poorly-behaved functions.
- Muller's method - This method converges rapidly for most functions, provided good initial guesses for the roots are known.
- Siljak's method - This method finds the zeros of a polynomial with complex coefficients.

Integration. There are several reasons for using numerical integration methods. First, some integrals cannot be expressed in closed form; that is, no finite combination of elementary functions has a derivative equal to the integrand. Secondly, the integral of a relatively simple function can be so complicated that evaluating it requires more calculations than evaluation by numerical methods. And finally, the function to be integrated may not be expressed as a formula, but as a table of x-y values.

There are three methods contained in this section:

- Simpson's rule - The easiest method to use for well-behaved functions.
- Filon's method - This method is for functions of the form f(x) sin x or f(x) cos x.
- Adaptive Romberg method - This method is used for a great many functions when other methods fail.

There are also methods for integrating functions which are expressed in tabular form with:

- Equally spaced x-values
- Unequally spaced x-values

Ordinary Differential Equations. A differential equation is a relation among an independent variable and a dependent variable and its derivatives. For example, $y' + xy^2 = 0$. The solution is a function y of x satisfying this equation and passing through a given point, (x_0, y_0).

This section contains two methods for solving systems of first order differential equations (higher order equations may be solved by reducing to a system of first order equations):

- Runge-Kutta method - This method is very stable and is a good choice when accuracy requirements are not high or when the equation does not involve a large number of calculations.
- Adams-Bashford-Moulton method - This method is more accurate and requires fewer computations but may not be as stable in some cases.

Linear Algebraic Systems. This section contains a wide variety of routines dealing with matrices and systems of simultaneous linear equations. Although the System 45B has a matrix inversion routine in firmware, significant savings in storage are obtained in these routines by taking advantage of special types of matrices, such as positive definite. And an additional digit or two of accuracy can be obtained in many cases. There are also routines for storing symmetric matrices using a minimal memory and for transposing a matrix in place; that is, replacing a matrix by its transpose.

Eigen Analysis. This section contains several routines for computing the eigenvalues and eigenvectors of real variables. Suppose A is a square matrix, and consider the equation

$$Ax = \lambda x,$$

where x is a vector and λ is a constant. A number λ for which this equation has a non-zero solution vector x is called an eigenvalue of the matrix A. The solution x is called an eigenvector of the matrix A.

Interpolation. This section begins with a routine for computing a table of divided differences, which is then used in the two Newton interpolation routines:

- Forward differences
- Backward differences

The two remaining interpolation programs are:

- Spline function
- Chebyschev polynomials ($T_n(x) = \cos(n \arccos x)$, n=0, 1, 2,...).

Additional Functions. Built into the System 45B are many commonly used mathematical functions. This program section complements them by adding:

- hyperbolic cosine
- hyperbolic sine
- hyperbolic tangent
- gamma
- log gamma

In addition, there are seven functions for complex numbers:

- addition
- multiplication
- division
- square root
- exponential
- absolute value
- polynomial evaluation

Fourier Analysis. This section contains routines for computing Fourier series coefficients using equally or unequally spaced data, and a fast Fourier transform routine.

Designed to Solve Your Numerical Analysis Problems.

By utilizing these programs, you can focus your efforts on your problem without worrying about the routine calculations that may be necessary. And you can write your programs without regard to the variables and labels that are used within the subprogram. Simply call the subprogram using the appropriate parameters and the computations will be carried out independent of your program. The results are then returned to your program and can be displayed on the System 45B's CRT or printed on the optional hard-copy thermal printer.

Drivers are provided with each subprogram to illustrate some of the techniques for calling the subprograms. Each section contains several techniques, giving you the flexibility to choose the most appropriate one for your specific problem.

Benefit From The BASIC User's Club

Another way many owners get even more value from their equipment is through our free-membership BASIC User's Club. The BASIC User's Club is a service provided by Hewlett-Packard for people who own HP desktop computers and want to share programming ideas. You'll discover creative solutions to many problems while using your desktop computer. At the same time, many other users are working on their problems using similar machines. So why not exchange programs?

The club maintains a library of user-contributed BASIC language programs covering a wide range of applications. You can submit as many programs as you like, and for each program you contribute, you can choose three others from the library. The club catalog, which you receive free when you join, lists all available software. You can also get additional programs through the information exchange service and exchange ideas at area meetings.

Peripheral Enhancements

Hewlett-Packard also offers a wide range of printers, plotters and mass storage devices to further enhance your System 45B Desktop Computer. For more information, contact your HP sales representative.

Ordering Information

To order any or all of these software packages, specify the appropriate Part No.(s). Each program package includes the following materials: User instruction manual, Special Function key overlays, program cartridge.

Program	Part No.
Basic Statistics and Data Manipulation	09845-15100
General Statistics	09845-15130
Statistical Graphics	09845-15120
Regression Analysis	09845-15110
Non-Linear Regression	09845-15140
Analysis of Variance	09845-15170
Monte Carlo Simulation Utilities	09845-15160
Numerical Analysis Library Vol. 1	09845-10350

Hardware Configuration

Program	Req'd Hardware	Product No.
Basic Statistics and Data Manipulation	Mainframe	9845B Desktop Computer
General Statistics*	Mainframe	9845B Desktop Computer
Statistical Graphics	Mainframe with Graphics	9845B Desktop Computer, Graphics ROM Opt. 311, Graphics Display Subsystem Opt. 700 and/or 9872A Four-Color Plotter
Regression Analysis*	Mainframe	9845B Desktop Computer
Non-linear Regression*	Mainframe	9845B Desktop Computer
Analysis of Variance*	Mainframe	9845B Desktop Computer
Monte Carlo Simulation Utilities	Mainframe	9845B Desktop Computer
Numerical Analysis Library, Vol. 1	Mainframe	9845B Desktop Computer

*To take full advantage of all the routines available in these packages, graphics capabilities are necessary.

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Ask for an HP Desktop Computer representative.

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