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TECHNIQUES FOR DISPLAYING MULTIVARIATE DATA ON CATHODE RAY TUBES WITH APPLICATIONS TO NUCLEAR PROCESS CONTROL

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ABSTRACT

Current methods of graphical display design using Cathode Ray Tubes depend solely on the skill of the designer for choosing the appropriate display technique. This report formalizes the selection process by describing 65 graphical representations and categorizing them according to the type of data they best portray. The use of the display is also accounted for by attaching a "use category," such as a qualitative reading, to each technique. The representation selection process is then formalized by asking the designer to consider both data and use. Recommendations for techniques are given for the various data types and uses. The method was applied to data for representation of the multivariate state of a typical nuclear power plant under both normal and transient conditions. Nine alternative techniques were tested, three of which—Circular Profiles, Chernoff Faces, and Fourfold Circular Displays—were considered very adequate for the data and use given.

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SUMMARY

In the past, the choice of techniques for representing information on a Cathode Ray Tube were entirely subjective and vulnerable to the whims and biases of the display designer. Particularly in the process control field, this choice was based on unsubstantiated precedent that totally ignored better techniques or misused the chosen ones. It is surprising that only a few designers know the basics of charting, such as the difference between the Bar Chart and Column Chart. It is little wonder then that the designers become confused when faced with multivariate or other more sophisticated displays. This report attempts to correct that ignorance by establishing a discipline called "Information System Graphics." This specialty combines the knowledge of computer graphics and standard charting techniques to give the designers of displays for management and scientific information systems guidelines for choosing alternative representations.

A literature search uncovered over 60 methods of graphical representation. To better understand the intended purpose of these techniques, the evolution of graphing was traced from its inception. It is shown that each technique was established to solve a given problem and then modified over time to fit other problems. The historical perspective provided a means of initially categorizing the techniques. Eleven Spatial-Temporal Grid techniques were identified that locate a series of points in space or time. Representing data at a given point in time constituted the Discrete Quantitative Comparison category, in which 22 techniques were placed. Continuous Distributions, found in probability calculations, formed the next category. Graphical representation of multivariate data, which is of particular importance to the display of data in the nuclear power generating process, also had 22 entries. Finally, a Miscellaneous category was established to accommodate the techniques that did not fit elsewhere. All 65 techniques are described and illustrated in Appendix A.

To aid the designer in selecting the most appropriate graphical representation, a method was devised in which the designer inspects the data and assigns a label for the number of dimensions, the number of variables, and the number of samples. This assignment results in a data-type category that contains, in tabular form, display techniques most appropriate to that data. The alternatives may be further reduced by establishing a "use category," since not all representations portray the information in the same format. Hence, the designer must consider both the type of data and the intended use of the display before finding the recommended display technique or techniques in the tables given.

The method just described was tested for a single application—that of displaying information to a nuclear power plant operator on the overall state of the system. Fifteen distinct variables were chosen to represent this state. This application involves either Unidimensional-Multivariate data or Multidimensional-Multivariate data, depending on the designer's view of the system. The first view may be labeled individualistic whereas the second is a holistic approach. The tables included in the method yielded a total of 29 representations, which were quickly reduced to 12 based on an understanding of the alternatives. Further reduction was possible by considering the intended use of the displays.

Nine of the most promising representations were implemented for both normal and transient conditions related to the LOFT reactor at the Idaho National Engineering Laboratory. The FORTRAN code for generating all nine techniques is available from the author. "Normal" was defined as the expected values of the variables at 74% power. Two transient cases were considered: the L6-5 case, which involved a loss of steam load, and the L3-7 case in which a small pipe break occurred. Data at two-second intervals before and after transient initiation were used to illustrate the representations. Actual displays were created, and reproductions of these displays are included in this report. The efficacy of each technique was determined by applying an adequacy judgment.

The results indicate the method works, and the three most promising representations for this application are: Circular Profiles, Chernoff Faces, and Fourfold Circular Displays. More traditional displays of this data, such as Bar Charts and Mimics, fared less well in comparison. Without the method presented, one may not be aware of these techniques nor their applicability. Much work still needs to be done in fine-tuning these representations, and other applications must be considered.

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INTRODUCTION

The most frequently used justification for computer graphics is based on the adage "a picture is worth a thousand words." Computer-generated displays or "pictures" of data are the most efficient means of computer-human communication developed thus far. However, the efficiency of any communications channel depends on the skill of the user. The mere fact that a computer generates the picture by no means ensures efficient use of the channel. One has to know the subtleties of graphical representations, the intricacies of computer graphics, and the meaning of the data itself to properly exploit the graphical medium.

A thorough knowledge in all three areas is unreasonable for a single individual, but the criteria still can be met using a suggestion of Chernoff.[1,2] He advocates establishing graphical representation as a discipline unto itself that would provide guidance to users having knowledge of the data being displayed. Such an approach is taken in this report for the nuclear power field. The term "Information System Graphics" was coined to describe the application of computer graphics and charting techniques to both management and scientific information systems. This differentiates the techniques used in these areas from the techniques found in animation, image processing, and Computer-Aided-Design/Computer-Aided-Manufacturing (CAD/CAM).

This report catalogs the techniques that give the display designer adequate alternatives for information display and that somewhat formalize the process of choosing an appropriate representation for nuclear process control. The feasibility of such an approach is demonstrated using a sample problem currently facing the industry, i.e., the display of the overall state of a nuclear power plant.

History

To properly use the available alternatives of graphical representations one must be aware of how and why each technique came into being. The Bar Chart was invented to solve one problem, whereas the Column Chart addresses quite a different one. While only a cursory review is possible here, further details can be found in the excellent work done by Beniger.[3,4] The following summary is based on those works and traces the history of representing data in a two-dimensional form.

The earliest problem of graphical representation was that of location in time and space. Cartography is known to have existed in Mesopotamia as early as 3800 B.C., and extensive surveying was done from about 3200 B.C. by the Egyptians who used grid coordinates. Greek astronomers in the fourth century B.C. used terrestrial and celestial globes; the formal statement of geometrical principles was laid down by Euclid around 300 B.C. It was not until Descartes, in 1637, however, that the relationship between a graphed line and an equation was established. Cartesian coordinates have since been used for the spatial-temporal grid patterns and abstracted to "scatter plots."

The next problem that surfaced was that of discrete comparison in which many variables were compared at a single point in time. In the *Commercial and Political Atlas of 1768*, Playfair apologetically invented the Bar Chart because he had insufficient data to represent imports and exports as a time series. The Bar and Column Charts trace their inception to this time and have been modified since. Pie charts, pictograms, and similar representations fall into this category.

The development of probability theory in the nineteenth century posed the problem of representing continuous distributions and was solved by the invention of the cumulative frequency curve or ogive. Lorenz curves and density distributions were added as improvements.

The late nineteenth century posed a problem of multivariate representation of temperature-by-hour-by-month and population density within the city of Paris. The solution was a contour plot and later axonometric projections of three-dimensional data. Between 1933 and 1957 the interest in innovative techniques lapsed; after that time many radical representations were, and still are, proposed, such as glyphs and Chernoff Faces—all designed to represent multivariate correlation.

Within each phase mentioned above there is a transition from iconic representation—which deals mainly with the use of visual signs and representations that stand for an idea by virtue of a resemblance or analogy to what is being displayed—to symbolic representation where the meaning of the symbol is entirely nominal.[5] Beniger noted this pattern by concluding that,

> New solutions normally begin with variations on old solutions, and evolve from relatively literal to progressively more abstract representations. Each stage then dissolves into less-focused efforts to generalize solutions to a wider range of subsequent problems.[3]

He goes further by observing,

> The field of modern quantitative graphics is an ever expanding *bricolage*, with parts and modifications of previous solutions ready to serve in new problem areas. This process is often marked by the inability of workers to address a new problem directly, rather than via repetition of earlier forms.[3]

MULTIVARIATE DISPLAYS

Charts and their electronic equivalent, the cathode ray tube (CRT) display, have been used and misused for all imaginable purposes. It is undisputed that graphs are an extermely effective medium fo. illustration, analysis, and computation,[6,7] provided the chart has been properly planned. As outlined in Spear,[8] proper planning implies that:

1. The *data* have been carefully analyzed.

2. The *objective* of the message has been determined.

3. The most effective *type* of chart has been selected to depict that message.

4. The best *visual device* has been chosen to display it.

This section of the report discusses the types or techniques of charting and then relates them to the different data types. Uses or objectives of the display are discussed and a method for determining the most effective alternative is presented. The "visual device" in this report is assumed to be a CRT.

Types of Charts or Displays

An extensive literature search was performed to identify the various techniques available for charting in many different scientific disciplines. Appendix B is the Bibliography showing the results of this search. Beniger's historical sequence[3,4] was used to organize the techniques for analysis that consisted of a word description, graphic example, and list of specific uses. A data type and use category was assigned and comments and references added. Appendix A contains the Display Format Summary that resulted fro. he analysis of 65 separate techniques.

The Spatial-Temporal Grid category deals with identifying a series of points in space or time. Traditionally, the abscissa represents time, while the ordinate shows the value of the variable or variables. Table 1 lists 11 available Spatial-Temporal techniques. Both Line Charts and Surface Charts have variants that specialize the technique for very restricted applications.

The 22 techniques for displaying Discrete Quantitative Comparison data are listed in Table 2. This category deals with data at a given point in time rather than a time series. The basic intent is to compare variables at *that* time. Bar and Column Charts are subdivided to show specialized variations of these techniques.

Continuous Distribution display techniques, as found in probability calculations, are shown in Table 3. Two major subdivisions deal with Frequency Graphs and related techniques. Further

Table 1. Spatial-temporal grid techniques

	Technique Number	Technique
Line Charts	1	Arithmetic Line (two-dimensional)
	2	Staircase (step)
	3	Multiple Curve
	4	Multiple Amount
	5	Index
Surface Charts	6	Simple Surface
	7	Staircase Surface
	8	Multiple Surface/Band
	9	100% Surface
	10	Statistical Cartography
	11	Fan Charts

Table 2. Discrete quantitative comparison techniques

	Technique Number	Technique
Bar Charts	12	Simple Bar
	13	Bar and Symbol
	14	Subdivided Bar
	15	Subdivided—100% Bar
	16	Grouped Bar
	17	Paired Bar
	18	Deviation Bar
	19	Sliding Bar
	20	Range Bar
Column Charts	21	Simple Column
	22	Connected Column
	23	Grouped Column
	24	Subdivided Column
	25	Net Deviation Column
	26	Gross Deviation Column
	27	Floating Column
	28	Range Column
	29	Pictogram
	30	Pie Chart
	31	Graphic Rational Pattern
	32	Color Code Matrix
	33	Fourfold Circular Display

Table 3. Continuous distribution techniques

	Technique Number	Technique
Frequency Graphs	34	Frequency Polygon
	35	Histogram
	36	Smoothed Frequency Curve
Related Graphs	37	Ogive (cumulative)
	38	Lorenz Curve
	39	Probability Curve

charts, such as Hanging Rootograms, are included in the Multivariate category to reflect their applicability.

The Multivariate Distribution and Correlation category is a collection of techniques that reflect current interest in problems of this type. Multivariate may be defined as something having or involving a number of independent mathematical variables. The 22 techniques listed in Table 4 come primarily from the statistics field but are being applied in other areas as well. The detailed descriptions of these techniques can be found in Appendix A.

The final category, labeled Miscellaneous, was added as a catch-all and is relatively sparse. The small number of techniques shown in Table 5 will certainly grow in the future.

Table 4. Multivariate distribution and correlation techniques

Technique Number	Technique
40	Linear Profile
41	Circular Profile
42	Distance Along versus Distance Away From Plots (DAVA)
43	Scatter Plot
44	Linear Fourier Representation
45	Polar Fourier Representation
46	Factor Analysis
47	Multidimensional Scaling
48	Hanging Rootogram
49	Contour Map
50	Stereoscopic Plot
51	Perspective Plot
52	Spherical Projection
53	N-Axis Plot
54	Array Plot
55	Linkage Plot
56	Probability Plot of Ordered Distance
57	Dendogram
58	Vector Angle Plot
59	Mimic Diagram
60	Chernoff Face
61	Metroglyph

Table 5. Miscellaneous techniques

Technique Number	Technique
62	Digital Readout
63	Moving Pointer
64	Binary Indicator
65	Single-Value Line Chart

To classify the techniques according to data type, one needs a mechanism for describing the data that is to be displayed. Figure 1.0 illustrates the classification scheme chosen. Data were "typed" on three axes according to the number of independent dimensions involved, the number of variables, and the number of samples. Figure 1.0 shows how the three axes form a three-dimensional representation. Each axis of the figure was further subdivided into three parts to yield a 3 x 3 x 3 array for a total of 27 separate cells. Each cell deals with data whose type is closely defined.

The "number of independent dimensions" refers to the units of the variable. For example, a point in two-dimensional space would have both x and y units and be classified as Duodimensional whereas a single temperature or pressure would qualify as Unidimensional. The data are multidimensional when there are three or more units. The "number of variables" refers to the number of unique quantities that may assume a value. If only one temperature reading were displayed, the data would be Univariate. If five or less different temperatures were required, the display would be Limited Multivariate. More than

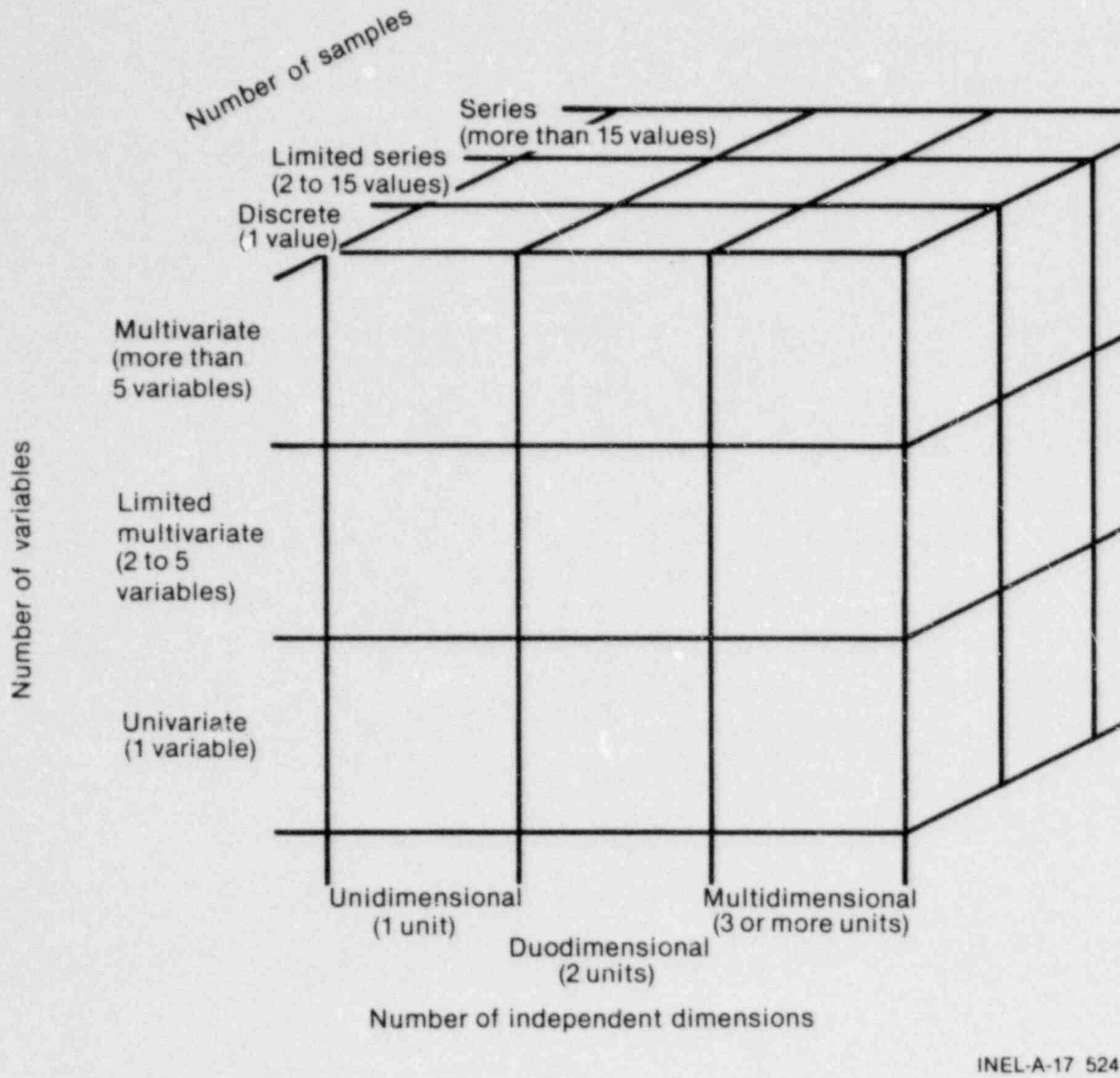

Figure 1.0 Data type classification scheme.

five variables were categorized as Multivariate. The "number of samples" axis implies the number of different values for the same variable. If one displayed the current temperature only, the data type would be Discrete. Two to 15 values for the same temperature, i.e., a history, is labeled Limited Series whereas more than 15 were labeled Series.

To illustrate this scheme further, imagine that one has a single temperature. The data type would be Unidimensional-Univariate-Discrete because there is one dimension (°F), one variable (the given temperature), and only one sample. A pressure-temperature plot of redundant measurement channels over time would be labeled Duodimensional (°F-psig), Limited Multivariate (Channel A, Channel B, etc.), and Series (points plotted for each minute over the last hour).

When dealing with a system that has many variables. one has to define terms carefully and be consistent in classification. The system's state could be viewed as being composed of all the individual input variables; in this case it should be classified as Multivariate. Alternately, one could take a holistic approach and say that the system's state is Univariate—treating the entire system as a single point. In the latter case, comparison of different systems would then constitute a Multivariate situation. Dimensionality must also be treated carefully. If one had a number of different units but the data were normalized, one should correctly call the type Unidimensional.

The method of determining the display techniques amenable to the various display types does not depend on which view, individualistic or holistic, is taken. As long as one is consistent in classifying the data, one can easily look up the recommended techniques in Tables 6 through 8. These tables give a number of techniques for each cell in the three-dimensional array. For instance, data typed as Unidimensional-Univariate-Discrete can be displayed in four different ways, as shown in Table 6.

Objectives of Displaying Data

Once the data have been typed and alternate display techniques identified, one must consider what the viewer will do with the information. Here again, there are many different ways of determining use. The more classic human engineering approach was taken by adopting the following definitions of McCormick[9] for use of visual displays:

- Quantitative information
- Qualitative information
- Check information
- Status and warning information.

Two more definitions were added to McCormick's to describe additional capabilities of CRTs and new problems facing operators:

- Prediction
- Pattern recognition.

A CRT display is rarely a single-use device; however, there often is a primary use. This primary purpose should determine the basic technique with modifications made to incorporate the secondary purposes.

In a *quantitative information* display, the user wishes "to obtain the actual quantitative value of some variable."[9] This means the data should be displayed so as to allow reading with great accuracy. For CRTs, a digital readout is one of the few viable techniques. A Line Chart done on paper allows such quantitative evaluations, but this is nearly impossible on a CRT screen, even if grid lines are included. The designer must be especially aware of this shortcoming of the CRT. It is not possible to place a ruler on the screen face and trace across to each axis to obtain the quantitative information.

The second major use is for *qualitative* purposes—using a display "to obtain the approximate value of some continuous changeable value or the direction of deviation from a given value."[9] The exact data are not important; only a rough estimate or approximate value is necessary. Here the CRT finds its true application because a wealth of techniques are available for display. *Check information* is closely related but has different purposes. This display is used to determine "if the value of a continuous changeable variable is normal, or within accepted normal range."[9]

Status and warning information is the least precise of the catagories and is used "to identify the specific status, or conditions, of some system, component, or situation."[9] The fact that a pump is running may be sufficient information as opposed to the amount of current applied to the motor windings. All alarm techniques that indicate something has happened, but not the severity, would fall into this category.

Prediction and *pattern recognition* uses were added to McCormick's list to accommodate the additional capabilities of CRTs and new problems facing operators. Given a suitable mathematical model of a system, one can show future as well as current and past data. Predictive displays are an active area of research in the aerospace industry but are just becoming known to the general scientific community. Pattern recognition is also a specialized area that should be better appreciated since it emphasizes the holistic approach. The human has an innate ability to recognize patterns and make judgments based on recognition, but that ability has not been exploited to any great extent.

Method

Tables 9 through 13 summarize the techniques along with the data type categorizations and uses. With this information, a display designer can narrow down the alternative techniques and then decide which of the alternatives is most appropriate for the application. Figure 2.0 is a flow chart representation of this simple method with references to various tables. Given the definition

Table 6. Display techniques for data typed as "discrete"

	Undimensional	Duodimensional	Multidimensional
Multivariate	• Simple Bar Chart (#12) • Subdivided Bar Chart (#14) • Subdivided—100% Bar Chart (#15) • Grouped Bar Chart (#16) • Deviation Bar Chart (#18) • Sliding Bar Chart (#19) • Graphic Rational Pattern (#13) • Frequency Polygon (#31) • Histogram (#35) • Smoothed Frequency Curve (#36) • Ogive (cumulative) (#37) • Probability Curve (#38) • Hanging Rootogram (#48)	• Paired Bar Chart (#17) • Color Coded Matrix (#32) • DAVA Plot (#42) • Scatter Plot (#43) • Contour Map (#49) • Vector Angle Plot (#58)	• Statistical Cartography (#10) • Fourfold Circular Display (#33) • Linear Profile (#40) • Circular Profile (#41) • Linear Fourier Representation (#44) • Polar Fourier Representation (#45) • Factor Analysis (#46) • Multidimensional Scaling (#47) • N-Axis Plot (#53) • Array Plot (#54) • Linkage Plot (#55) • Probability Plot at Ordered Distance (56) • Dendogram (#57) • Mimic Diagram (#59) • Chernoff Face (#60) • Metroglyph (#61)
Limited Multivariate	• Simple Bar Chart (#12) • Subdivided Bar Chart (#14) • Subdivided—100% Bar Chart (#15) • Grouped Bar Chart (#16) • Deviation Bar Chart (#18) • Pictogram (#29) • Graphic Rational Pattern (#13) • Color Coded Matrix (#32) • Digital Readout (#62) • Binary Indicator (#64)	• Paired Bar Chart (#17) • Color Coded Matrix (#32) • Vector Angle Plot (#58) • Digital Readout (#62) • Single-Value Line Chart (#65)	• Statistical Cartography (#10) • Fourfold Circular Display (#33) • Linear Profile (#40) • Circular Profile (#41) • Linear Fourier Representation (#44) • Polar Fourier Representation (#45) • Array Plot (#54) • Mimic Diagram (#59) • Metroglyph (#61)
Univariate	• Color Coded Matrix (#32) • Digital Readout (#62) • Moving Pointer (#63) • Binary Indicator (#64)	• Color Coded Matrix (#32) • Digital Readout (#62) • Binary Indicator (#64) • Single-Value Line Chart (#65)	• Digital Readout (#62) • Single-Value Line Chart (#65) • Binary Indicator (#64)

Table 7. Display techniques for data typed as "limited series"

	Unidimensional	Duodimensional	Multidimensional
Multivariate	• Bar and Symbol (#13) • Fourfold Circular Display (#33) • Lorenz Curve (#38) • Linear Profile (#40) • Circular Profile (#41) • Linear Fourier Representation (#44) • Polar Fourier Representation (#45) • Chernoff Face (#60) • Metroglyph (#61)		
Limited Multivariate	• Fan Chart (#11) • Grouped Column Chart (#23) • Subdivided Column Chart (#24) • Gross Deviation Chart (#26) • Floating Column Chart (#27) • Range Column Chart (#28)	• Multiple Surface/Band Chart (#8) • Index Chart (#5)	• Fourfold Circular Display (#33) • Linear Profile (#40) • Circular Profile (#41) • Linear Fourier Representation (#44) • Polar Fourier Representation (#45) • Chernoff Face (#60) • Metroglyph (#61)
Univariate	• Simple Column Chart (#21) • Connected Column Chart (#22) • Net Deviation Column Chart (#25) • Frequency Polygon (#34) • Histogram (#35) • Smoothed Frequency Curve (#36) • Ogive (cumulative) (#37) • Lorenz Curve (#38) • Probability Curve (#39)	• Staircase (step) Chart (#2) • Staircase Surface Chart (#7)	• Fourfold Circular Display (#33) • Linear Profile (#40) • Circular Profile (#41) • Linear Fourier Representation (#44) • Polar Fourier Representation (#45) • Chernoff Face (#60) • Metroglyph (#61)

Table 8. Display techniques for data typed as "series"

	Unidimensional	Duodimensional	Multidimensional
Multivariate	• Range Bar Chart (#20)		
Limited Multivariate	• Multiple Curve Chart (#3) • Multiple Surface Chart (#8) • 100% Surface Chart (#9)	• Multiple Amount (#4) • Index Chart (#5) • Perspective Plot (#51) • Spherical Projection (#52)	• Index Chart (#5) • Stereoscopic Plot (#50) • Perspective Plot (#51) • Spherical Projection (#52)
Univariate	• Arithmetic Line Chart (#1) • Staircase (step) Chart (#2) • Simple Surface Chart (#6) • Staircase Polygon (#7) • Frequency Polygon (#34) • Histogram (#35) • Smoothed Frequency Curve (#36) • Ogive (cumulative) (#37) • Lorenz Curve (#38) • Probability Curve (#35)	• Perspective Plot (#51) • Spherical Projection (#52)	

Table 9. Spatial-temporal grid display techniques with data types and uses[a]

Technique Number	Technique	Data Characteristics					
		Number of Dimensions			Number of Variable		
		Unidimensional	Duodimensional	Multidimensional	Univariate	Limited Multivariate	M
	Line Charts						
1	Arithmetic Line (two-dimensional)	1	—	—	1	—	
2	Staircase (step)	1	2	—	1	—	
3	Multiple Curve	1	—	—	—	1	
4	Multiple Amount	—	1	—	—	1	
5	Index	—	2	1	—	1	
	Surface Charts						
6	Simple Surface	1	—	—	1	—	
7	Staircase Surface	1	2	—	1	—	
8	Multiple Surface/Band	1	—	—	—	1	
9	100% Surface	1	—	—	—	1	
10	Statistical Cartography	—	—	1	—	2	
11	Fan Charts	1	—	—	—	1	

a. "1" indicates primary characteristics of the data.

"2" indicates secondary characteristics of the data.

"x" indicates what the technique can be used to show.

s	Number of Values			Uses							
ultivariate	Discrete	Limited Series	Series	Quantitative	Approximate Value	Deviation	Normal	Range	Status and Warning	Prediction	Pattern Recognition
—	—	—	1	—	x	—	—	—	—	x	x
—	—	2	1	—	x	—	—	—	—	—	—
—	—	—	1	—	x	x	x	x	—	x	x
—	—	2	1	—	x	—	—	—	—	x	x
—	—	2	1	—	—	—	x	x	—	x	x
—	—	—	1	—	x	—	—	—	—	x	x
—	—	2	1	—	x	—	—	—	—	—	—
—	—	—	1	—	x	—	—	—	—	x	x
—	—	—	1	—	x	—	—	—	—	x	—
1	1	—	—	—	x	x	x	x	x	—	x
—	—	1	—	—	—	—	—	—	—	x	—

Table 10. Discrete quantitative comparison display techniques with data types and uses[a]

Technique Number	Technique	Data Characteristics					
		Number of Dimensions			Number of Variables		
		Unidimensional	Duodimensional	Multidimensional	Univariate	Limited Multivariate	Multivar
	Bar Charts						
12	Simple Bar	1	—	—	—	2	1
13	Bar and Symbol	1	—	—	—	—	1
14	Subdivided Bar	1	—	—	—	2	1
15	Subdivided—100% Bar	1	—	—	—	2	1
16	Grouped Bar	1	—	—	—	2	1
17	Paired Bar	—	1	—	—	2	1
18	Deviation Bar	1	—	—	—	2	1
19	Sliding Bar	1	—	—	—	2	1
20	Range Bar	1	—	—	—	—	1
	Column Charts						
21	Simple Column	1	—	—	1	—	—
22	Connected Column	1	—	—	1	—	—
23	Grouped Column	1	—	—	—	1	—
24	Subdivided Column	1	—	—	—	1	—
25	Net Deviation Column	1	—	—	1	—	—
26	Gross Deviation Column	1	—	—	—	1	—
27	Floating Column	1	—	—	—	1	—
28	Range Column	1	—	—	—	1	—
	Other						
29	Pictogram	1	—	—	—	1	—
30	Pie Chart	1	—	—	—	1	—
31	Graphic Rational Pattern	1	—	—	—	2	1
32	Color Code Matrix	2	1	—	2	2	1
33	Fourfold Circular Display	—	—	1	2	2	1

a. "1" indicates primary characteristics of the data.

"2" indicates secondary characteristics of the data.

"x" indicates what the technique can be used to show.

Number of Values			Uses							
Discrete	Limited Series	Series	Quantitative	Approximate Value	Deviation	Normal	Range	Status and Warning	Prediction	Pattern Recognition
1	—	—	—	x	—	—	—	—	—	—
—	1	—	—	x	x	x	x	—	—	—
1	—	—	—	x	—	—	—	—	—	—
1	—	—	—	x	—	—	—	—	—	—
1	—	—	—	x	—	—	—	—	—	—
1	—	—	—	x	—	—	—	—	—	—
1	—	—	—	—	x	—	—	—	—	—
1	—	—	—	x	—	—	—	—	—	—
—	—	1	—	—	—	—	x	—	—	—
—	1	—	—	x	—	—	—	—	—	—
—	1	—	—	x	—	—	—	—	—	—
—	1	—	—	x	—	—	—	—	—	—
—	1	—	—	x	—	—	—	—	—	—
—	1	—	—	—	x	—	—	—	—	—
—	1	—	—	—	x	—	—	—	—	—
—	1	—	—	x	—	—	—	—	—	—
—	1	—	—	x	—	x	x	—	—	—
1	—	—	—	x	—	—	—	—	—	—
1	—	—	—	x	—	—	—	—	—	—
1	—	—	—	x	—	—	—	—	—	x
1	—	—	—	x	—	—	—	—	—	x
1	2	—	—	x	—	—	—	x	—	x

Table 11. Continuous distribution display techniques with data types and uses[a]

		Data Characteristics					
		Number of Dimensions			Number of Variabl		
Technique Number	Technique	Unidimensional	Duodimensional	Multidimensional	Univariate	Limited Multivariate	M
	Frequency Graphs						
34	Frequency Polygon	1	—	—	2	—	
35	Histogram	1	—	—	2	—	
36	Smoothed Frequency Curve	1	—	—	2	—	
	Related Graphs						
37	Ogive (cumulative)	1	—	—	2	—	
38	Lorenz Curve	1	—	—	2	—	
39	Probability Curve	1	—	—	2	—	

a. "1" indicates primary characteristics of the data.

"2" indicates secondary characteristics of the data.

"x" indicates what the technique can be used to show.

...s	Number of Values			Uses							
...ultivariate	Discrete	Limited Series	Series	Quantitative	Approximate Value	Deviation	Normal	Range	Status and Warning	Prediction	Pattern Recognition
1	1	2	2	—	x	—	—	—	—	—	x
1	1	2	2	—	x	—	—	—	—	—	x
1	1	2	2	—	x	—	—	—	—	—	x
1	1	2	2	—	—	—	—	—	x	—	x
1	—	1	2	—	—	—	—	—	x	—	—
1	1	2	2	—	—	x	—	—	—	—	—

Table 12. Multivariate distribution and correlation display techniques with data types and uses[a]

		Data Characteristics					
		Number of Dimensions			Number of Variables		
Technique Number	Technique	Unidimensional	Duodimensional	Multidimensional	Univariate	Limited Multivariate	Multivaria
40	Linear Profile	—	—	1	2	2	1
41	Circular Profile	—	—	1	2	2	1
42	DAVA Plot	—	1	—	—	—	1
43	Scatter Plot	—	1	—	—	—	1
44	Linear Fourier Representation	—	—	1	2	2	1
45	Polar Fourier Representation	—	—	1	2	2	1
46	Factor Analysis	—	—	1	—	—	1
47	Multidimensional Scaling	—	—	1	—	—	1
48	Hanging Rootogram	1	—	—	—	—	1
49	Contour Map	—	1	—	—	—	1
50	Stereoscopic Plot	—	—	1	—	1	—
51	Perspective Plot	—	1	2	2	1	—
52	Spherical Projection	—	1	2	2	2	1
53	N-Axis Plot	—	—	1	—	—	1
54	Array Plot	—	—	1	—	2	1
55	Linkage Plot	—	—	1	—	—	1
56	Probability Plot at Ordered Distance	—	—	1	—	—	1
57	Dendogram	—	—	1	—	—	1
58	Vector Angle Plot	—	1	—	—	2	1
59	Mimic Diagram	—	—	1	—	2	1
60	Chernoff Face	—	—	1	2	—	1
61	Metroglyph	—	—	1	2	2	1

a. "1" indicates primary characteristics of the data.

"2" indicates secondary characteristics of the data.

"x" indicates what the technique can be used to show.

Number of Values			Uses							
Discrete	Limited Series	Series	Quantitative	Approximate Value	Deviation	Normal	Range	Status and Warning	Prediction	Pattern Recognition
1	2	—	—	x	—	—	—	—	—	x
1	2	—	—	x	x	x	x	—	—	x
1	—	—	—	—	—	—	—	x	—	—
1	—	—	—	—	—	—	—	x	—	x
1	2	—	—	—	—	—	—	x	—	x
1	2	—	—	—	—	—	—	x	—	x
1	—	—	—	—	—	—	—	x	—	x
1	—	-	—	—	—	—	—	x	—	x
1	—	—	—	—	—	—	—	x	—	x
1	—	—	—	x	—	—	—	—	—	—
—	—	1	—	x	—	—	—	—	—	—
—	—	1	—	x	x	x	x	—	x	x
—	—	1	—	—	—	—	—	x	—	—
1	—	—	—	—	—	—	—	x	—	—
1	—	—	—	x	x	x	x	x	—	x
1	—	—	—	—	—	—	—	x	—	—
1	—	—	—	—	—	—	—	x	—	—
1	—	—	—	—	—	—	—	x	—	—
1	—	—	—	x	—	—	—	—	—	—
1	—	—	x	—	—	—	—	—	—	—
1	2	—	—	—	—	—	—	x	—	x
1	2	—	—	x	—	x	x	x	—	x

Table 13. Miscellaneous display techniques with data types and uses[a]

		Data Characteristics				
		Number of Dimensions			Number of Variabl	
Technique Number	Technique	Unidimensional	Duodimensional	Multidimensional	Univariate	Limited Multivariate
62	Digital Readout	1	—	—	1	—
63	Moving Pointer	1	—	—	1	—
64	Binary Indicator	1	—	—	1	—
65	Single-Value Line Chart	—	1	—	1	—

a. "1" indicates primary characteristics of the data.

"2" indicates secondary characteristics of the data.

"x" indicates what the technique can be used to show.

es	Number of Values			Uses							
ultivariate	Discrete	Limited Series	Series	Quantitative	Approximate Value	Deviation	Normal	Range	Status and Warning	Prediction	Pattern Recognition
—	1	—	—	x	—	—	—	—	—	—	—
—	1	—	—	—	x	—	—	—	—	—	—
—	1	—	—	—	—	—	—	—	x	—	x
—	1	—	—	—	x	x	x	—	—	x	—

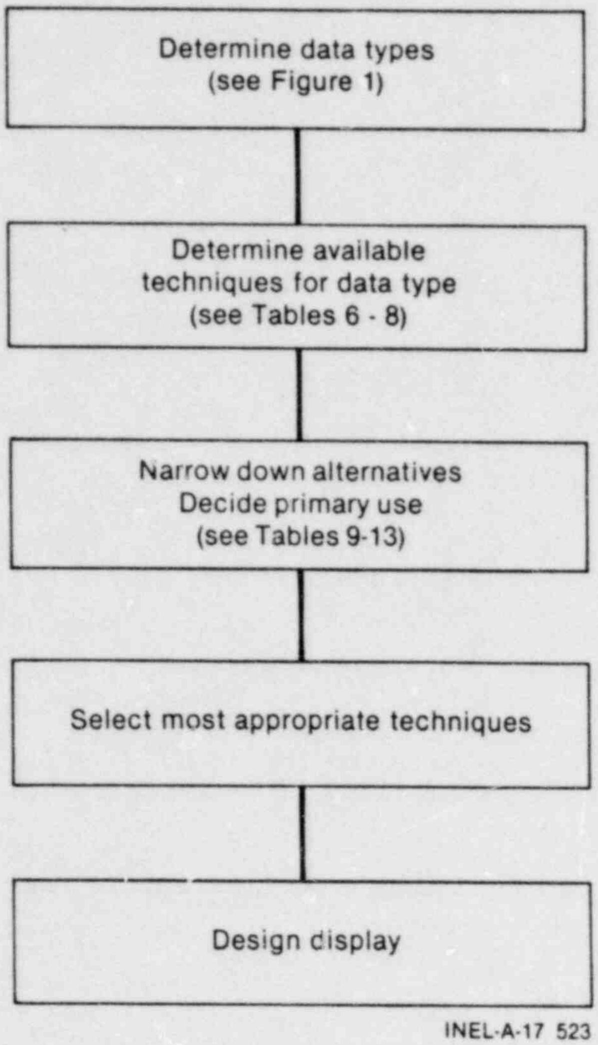

Figure 2.0 Display technique selection methodology.

of the axes of Figure 1.0, the designer would analyze the data for their types. This determination produces a variety of display techniques that are most amenable to that type, as shown in Tables 6 through 8. These alternatives are further reduced by determining the primary and secondary uses of the display via Tables 9 through 13. The designer must then use experience and intuition, or better yet—experimentation—to select the final technique.

PROCESS CONTROL DISPLAYS

To test the methodology of the previous section and also to provide short-term results for this project, a sample problem was postulated. The problem was to display crucial parameters of a nuclear reactor as exemplified by the pressurized water reactor (PWR) at the LOFT (Loss-of-Fluid Test) facility located at the Idaho National Engineering Laboratory. The parameters, listed in Table 14, cover both the primary and secondary sides of a typical PWR and are both continuous and binary in nature. Table 14 lists the units, normal value at 74% power, normal expected range at that power, and total expected range for 11 variables. The Rod Bottom Limits (variables 12 through 15) are binary because they indicate only whether or not the control rods are at the bottom. The bistable status variables listed are alphanumeric messages that represent alarm conditions produced by the control systems.

A good display design should be effective for both normal and off-normal situations. To test for the latter case, actual data from two transients were obtained. The first test case, labeled L6-5, was an operational transient test involving a loss of steam load. The second case, L3-7, was a small break test in which the pipe break was smaller than the capacity of the high-pressure injection system makeup capability. Data for each variable during the two tests are shown in Table 15. Ten time steps, taken at two-second intervals, were used to indicate the state of the system before and after initiation of the transients. Time step 5 is the condition at the time of initiation.

A quick scan of Table 15 indicates the expected variation during normal (time steps 1-5) and off-normal operations. Parameters will fluctuate during normal operation, as indicated by the table. However, the rapid changes are the most important. During the operational transient test (L6-5), the secondary feed flow immediately drops to zero, followed by a decrease in steam generator level. The small break test (L3-7) results in a drop in primary pressure and pressurizer level.

Table 14. Normal values and ranges for key parameters of a Nuclear Reactor

Parameter	Unit	Normal Value at 74% power	Normal Range		Total Range	
			Minimum	Maximum	Minimum	Maximum
Primary Power	%	74	0	100	0	100
Primary Flow	M lb_m/hr	3.80	3.70	3.90	3.70	3.90
Primary Temperature (T_c)	°F	535	525	547	525	547
Primary ΔT	°F	26.615	26.54	26.678	7	36
Primary Pressure	psig	2156	2141	2171	2141	2171
Pressurizer Level	inches	44	37	51	37	51
Secondary Pressure	psig	816	744	888	700	950
Secondary Feed Flow	lb/hr	151.2	147.6	154.8	36	216
Steam Control Valve Position	% open	64	62	66	0	100
Steam Generator Level	inches	7.6	5.65	9.65	-2.0	12.0
Condenser Pressure	psig	288	263	213	263	313
Rod Bottom Limits (4)						
Bistable Status (First 5)						

Table 15. Test data for two real transients: L6-5—operational transient test and L3-7—small break test

Parameter	Unit	1	2	3	4	5	6	7	8	9	10
		Display Numbers									
L6-5											
Time	seconds	-8	-6	-4	-2	0	2	4	6	8	10
Power	%	73.80	73.65	73.63	73.65	73.77	73.70	73.70	73.72	73.80	73.80
Flow	M lb_m/hr	3.800	3.774	3.780	3.780	3.782	3.780	3.800	3.797	3.782	3.770
T_c	°F	535	535	535	535	535	535	535	535	535	535
ΔT	°F	27	27	27	27	27	27	27	27	27	27
Primary Pressure	psig	2146	2147	2147	2147	2147	2147	2146	2146	2147	2149
Pressurizer Level	inches	39.85	39.88	39.88	39.87	39.85	39.85	39.82	39.79	39.80	39.81
Secondary Pressure	psig	816	816	816	816	816	816	816	816	816	816
Secondary Feed Flow	lb/hr	152	152	152	152	152	0	0	0	0	0
Steam Control Valve Position	%	66.50	66.61	66.59	66.70	66.61	66.24	66.00	65.94	66.20	66.36
Steam Generator Level	inches	10.65	10.70	10.70	10.70	10.70	10.55	9.77	8.20	7.05	5.95
Condenser Pressure	psig	286.90	286.90	286.90	286.90	286.85	287.70	288.05	288.90	289.62	290.74
L3-7											
Time	seconds	-8	-6	-4	-2	0	2	4	6	8	10
Power	%	97.70	97.50	97.70	97.50	97.40	96.98	96.60	97.25	97.40	97.30
Flow	M lb_m/hr	3.838	3.820	3.806	3.832	3.850	3.840	3.790	3.806	3.822	3.822
T_c	°F	545	545	545	545	545	545	545	545	545	545
ΔT	°F	35	35	35	35	35	35	35	35	35	35
Primary Pressure	psig	2174	2172	2170	2168	2166	2151	2136	2138	2146	2144
Pressurizer Level	inches	43.16	43.14	43.10	43.10	43.08	42.90	42.60	42.18	41.70	41.37
Secondary Pressure	psig	789.15	789.30	789.50	789.80	789.40	789.15	788.55	788.85	788.78	789.30
Secondary Feed Flow	lb/hr	194.55	194.98	194.82	195.08	195.08	194.92	194.85	194.72	195.31	194.85
Steam Control Valve Position	%	94.44	94.44	94.44	94.44	94.44	94.38	94.30	94.30	94.19	94.33
Steam Generator Level	inches	10.57	10.50	10.57	10.50	10.30	10.30	10.20	10.13	10.10	10.10
Condenser Pressure	psig	301.80	301.71	301.95	301.69	302.00	302.05	302.10	301.20	302.42	302.68

A display of this information would be used to advise the operator of the current state of the system and to help in detecting the problems and their appropriate corrective action. The display should help the operator answer the following questions:

1. How well is my system working?

2. What is my problem?

3. How severe is my problem?

When describing reactor s ems, the primary purpose of the display is to answer Question 1; answers to Questions 2 and 3 are secondary.

Analysis of the L6-5 and L3-7 data for type categorization resulted in two possible cells: Unidimensional-Multivariate-Discrete and Multidimensional-Multivariate-Discrete. Both categories take a somewhat individualistic approach because the system was considered to be composed of its components rather than as a single state point. In other words, the operator, rather than the computer, is the integrator of the system data. This approach was chosen in order to try to satisfy the secondary purposes as well as the primary criterion.

There was little question that the data were Multivariate (15 variables) and Discrete (one point in time). Dimensionality, however, could be looked at in a variety of ways. If the data were normalized to a percentage of their range, the units would constitute a Unidimensional system. If each of the units were considered separately, one would have a Multidimensional system (as reflected by Table 14).

Table 6 lists 13 different techniques for displaying Unidimensional-Multivariate-Discrete data and 16 possible techniques for Multidimensional-Multivariate-Discrete data. These techniques are repeated in Table 16. One can immediately disregard alternatives 8 through 13 since they deal with Continuous Distribution data. Statistical Cartography is used for Spatial-Temporal data while Factor Analysis, Multidimensional Scaling, and N-Axis Plots wash out too many details (Appendix A). Furthermore, Linkage Plots, Probability of Ordered Distance, and Dendograms deal with statistical data. A second pass through the list eliminates Subdivided Bar Charts, Grouped Bar Charts, and Sliding Bar Charts because they deal with unique circumstances that do not apply to the data at hand (Appendix A). This procedure quickly reduces the number of alternatives from 29 to 12.

To reduce the number further, one must establish the use categories. Pattern recognition is the best method of comprehending the overall workings of the system to answer Question 1. Question 2 is satisfied with check information and Question 3 is answered best with qualitative information. Hence, the use dictates that the display be especially appropriate for pattern recognition, with check and quality information as secondary uses.

The reasonable alternative techniques for display are shown in Table 17. Note that only three techniques have use categories that satisfy both the primary and secondary purposes. At this point one must decide whether the purposes are to be treated equally or if more emphasis should be given to the primary purpose, as is often the case. When the primary purpose of the display is to allow the operator to determine how well the system is working (Question 1), the Simple Bar Chart and the Mimic Diagram can be eliminated because they both have a single use.

Table 16. Alternative display techniques for unidimensional-multivariate-discrete and multidimensional-multivariate-discrete data

Alternative	Technique	Technique Number
	Unidimensional-Multivariate-Discrete Data Techniques	
1	Simple Bar Chart	12
2	Subdivided Bar Chart	14
3	Subdivided—100% Bar Chart	15
4	Grouped Bar Chart	16
5	Deviation Bar Chart	18
6	Sliding Bar Chart	19
7	Graphic Rational Pattern	13
8	Frequency Polygon	31
9	Histogram	35
10	Smoothed Frequency Curve	36
11	Ogive (cumulative)	37
12	Probability Curve	38
13	Hanging Rootogram	48
	Multidimensional-Multivariate-Discrete Data Techniques	
14	Statistical Cartography	10
15	Fourfold Circular Display	33
16	Linear Profile	40
17	Circular Profile	41
18	Linear Fourier Representation	44
19	Polar Fourier Representation	45
20	Factor Analysis	46
21	Multidimensional Scaling	47
22	N-Axis Plot	53
23	Array Plot	54
24	Linkage Plot	55
25	Probability Plot at Ordered Distance	56
26	Dendogram	57
27	Mimic Diagram	59
28	Chernoff Face	60
29	Metroglyph	61

Table 17. Uses of alternative techniques for the system state problem

		Qualitative Information		Check Information				
	Quantitative Information	Approximate Value	Deviation	Normal	Range	Status and Warning	Prediction	Pattern Recognition
Simple Bar Chart	—	x	—	—	—	—	—	—
Deviation Bar Chart	—	—	x	—	—	—	—	x
Graphic Rational Pattern	—	x	—	—	—	—	—	x
Fourfold Circular Display	—	x	—	—	—	x	—	x
Linear Profile	—	x	—	—	—	—	—	x
Circular Profile	—	x	x	x	x	—	—	x
Linear Fourier Representation	—	—	—	—	—	x	—	x
Polar Fourier Representation	—	—	—	—	—	x	—	x
Array Plot	—	x	x	x	x	x	—	x
Mimic Diagram	x	—	—	—	—	—	—	—
Chernoff Face	—	—	—	—	—	x	—	x
Metroglyph	—	x	—	x	x	x	—	x

MULTIVARIATE DISPLAY DESIGNS

The various display techniques applied to the sample data are listed in Table 18. The Mimic Diagram is the most common form of display in process control but it is applicable mainly to quantitative information tasks. An example of this technique, Figure 3.0, was included for comparison purposes and shows the variables at normally expected values for 74% power. If the Mimic Diagram were used for the transient data, the values would change as required. The blocks containing the numbers 1, 2, 3, and 4 represent the Rod Bottom Limits, i.e., the binary values, and are color coded red when not on the bottom. When they are on the bottom the color green is used. The large space beneath the Mimic is reserved for the bistable status messages, which are not included here nor on any other display. Both the binary and bistable status messages were dealt with in the same manner for all displays, regardless of the display technique used.

The following examples contain 21 displays for each display technique. The first display in each series shows the normal conditions at 74% power. The next set of 10 represents the time steps for L6-5 followed by 10 steps for L3-7. Instances where the normal value and range of a variable change with power were accounted for by recomputing these values based on the given power reading. Color-coding of limits, where appropriate, was done with green, yellow, and red. When a variable was within its normal range, green was used. When the value fell below or above the *normal* range for the given power, yellow was chosen. Final lower and upper limits (low-low, high-high) were established at 5% and 95% of the variable's *total* range, respectively, and coded red.

Simple Bar Chart

A Simple Bar Chart contains horizontally oriented rectangles or bars emanating from a single vertical line. The horizontal axis indicates the range of values of the variables and the length of each bar is determined by the value or amount of each item. This technique compares the magnitude of items at a specified time on a single scale. Figure 4.0 illustrates the application of this technique for normal conditions at 74% power. The Simple Bar Chart emphasizes individual values but makes overall system evaluation difficult. Pattern recognition is next to impossible because one must look at each bar in relation to the others. Check information is somewhat difficult, but qualitative data for the individual variables are relatively easy to read. Figures 4.1 through 4.10 represent the time steps for L6-5. Although there are variations between displays, nothing is obvious until Figure 4.6, which indicates the problem with secondary feed flow. The steam generator level does show a decrease but the change is not immediately apparent. The small pipe break of L3-7 is shown in Figures 4.11 through 4.20. Close observation of displays in Figure 4.15 and the subsequent figures shows a drop in primary pressure but little indication for

Table 18. Display techniques tried on sample data

Alternative	Technique	Technique Number
1	Mimic Diagram	59
2	Simple Bar Chart	12
3	Deviation Bar Chart	18
4	Fourfold Circular Display	33
5	Linear Profile	40
6	Circular Profile	41
7	Linear Fourier Representation	44
8	Polar Fourier Representation	45
9	Array Plot	54
10	Chernoff Face	60

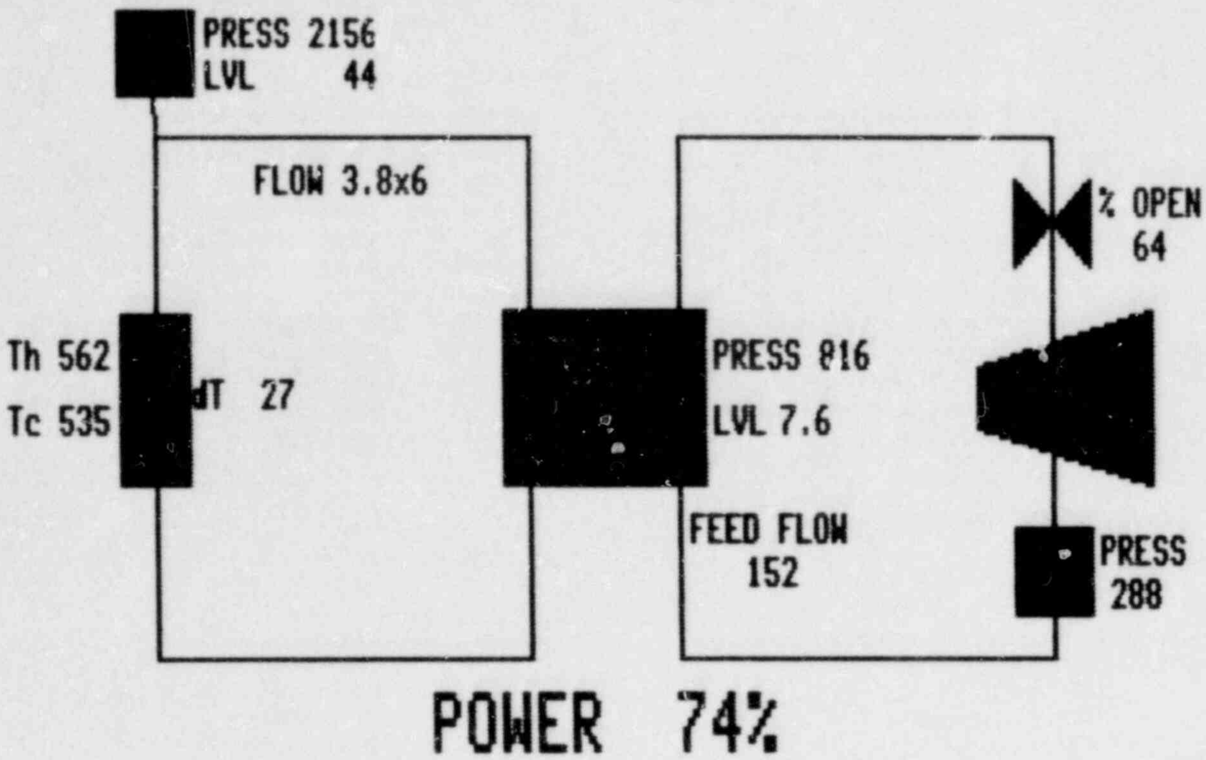

Figure 3.0 Mimic diagram of a nuclear system.

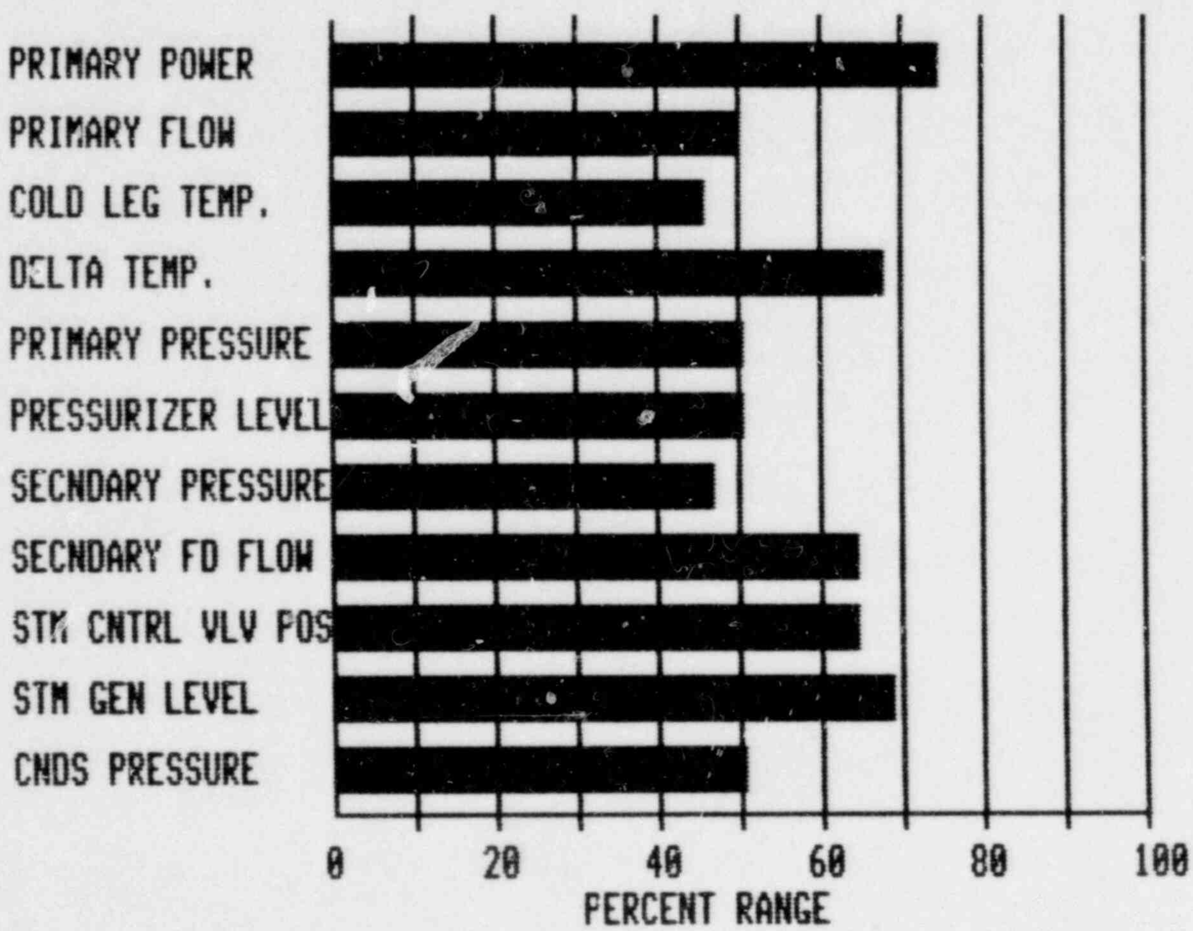

Figure 4.0 Simple Bar Chart representation at normal conditions, 74% power.

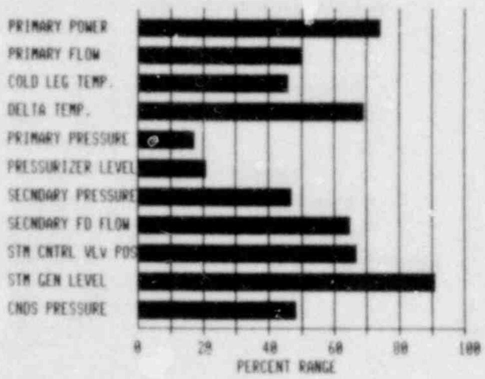

Figure 4.1 Simple Bar Chart for L6-5.

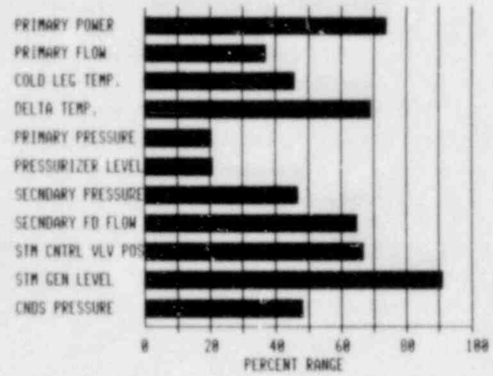

Figure 4.2 Simple Bar Chart for L6-5.

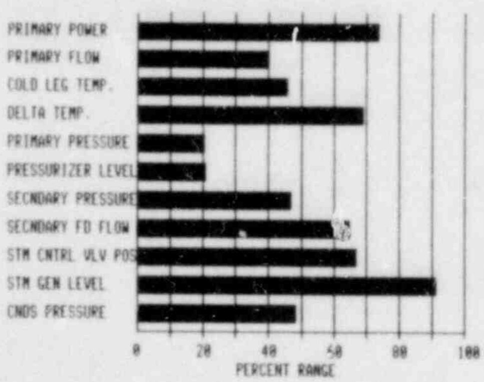

Figure 4.3 Simple Bar Chart for L6-5.

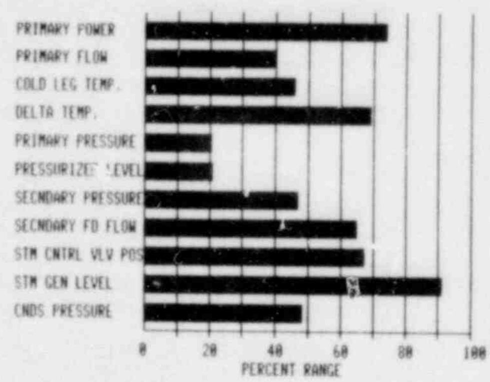

Figure 4.4 Simple Bar Chart for L6-5.

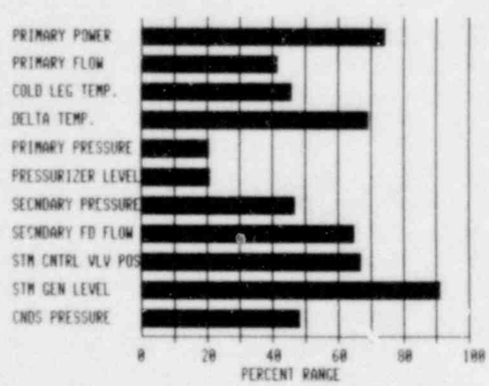

Figure 4.5 Simple Bar Chart for L6-5.

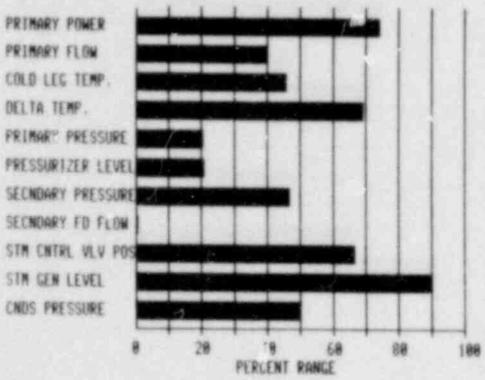

Figure 4.6 Simple Bar Chart for L6-5.

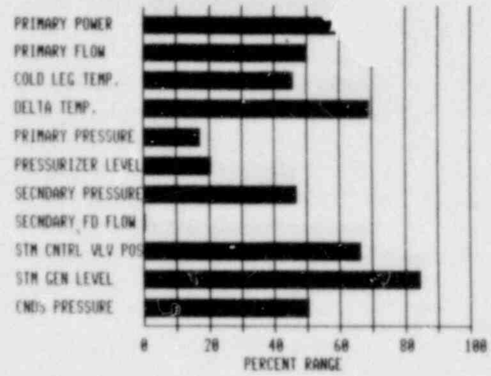

Figure 4.7 Simple Bar Chart for L6-5.

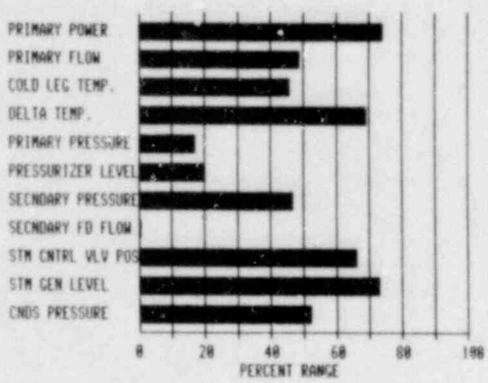

Figure 4.8 Simple Bar Chart for L6-5.

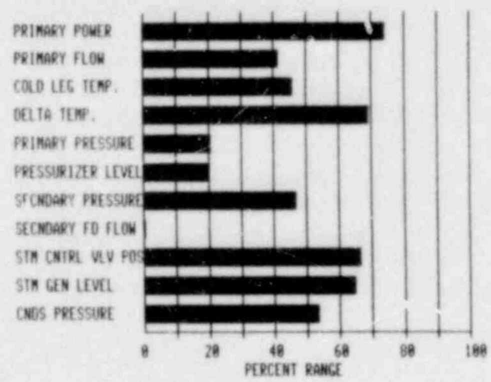

Figure 4.9 Simple Bar Chart for L6-5.

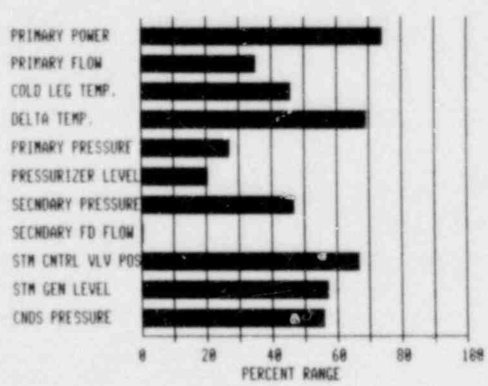

Figure 4.10 Simple Bar Chart for L6-5.

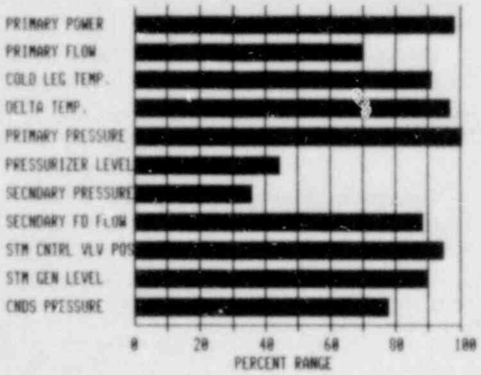

Figure 4.11 Simple Bar Chart for L3-7.

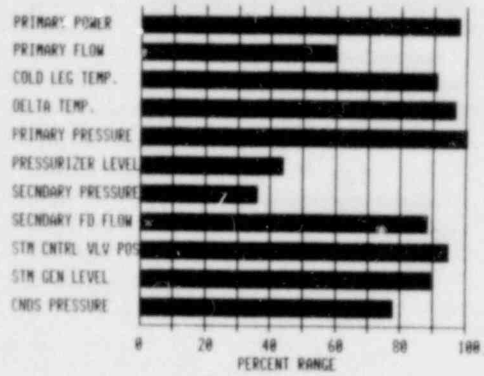

Figure 4.12 Simple Bar Chart for L3-7.

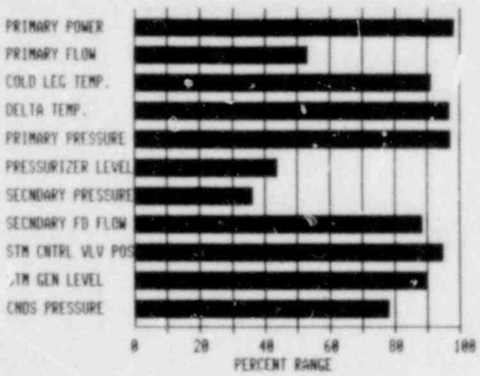

Figure 4.13 Simple Bar Chart for L3-7.

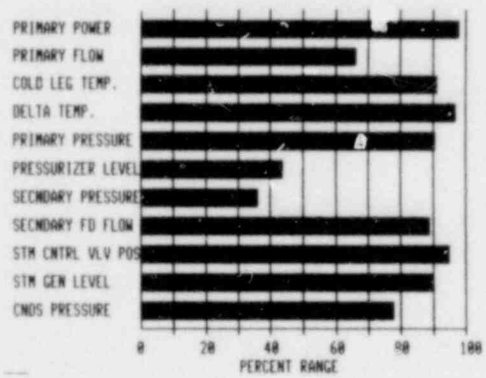

Figure 4.14 Simple Bar Chart for L3-7.

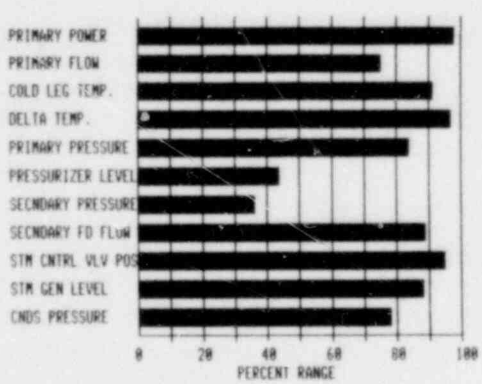

Figure 4.15 Simple Bar Chart for L3-7.

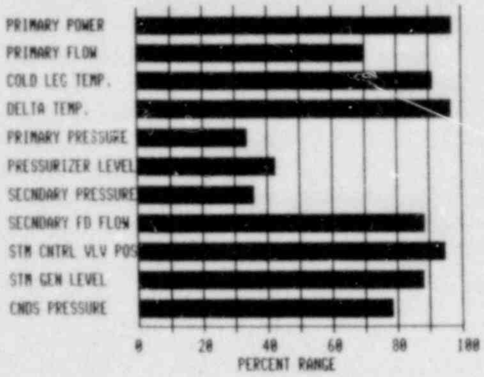

Figure 4.16 Simple Bar Chart for L3-7

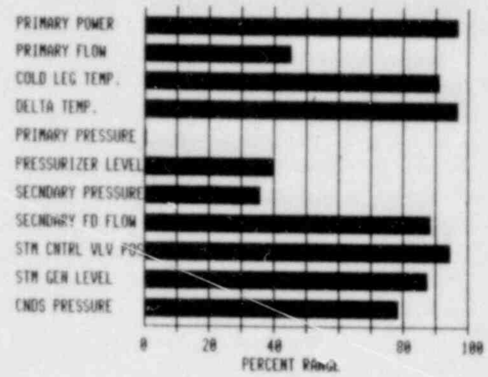

Figure 4.17 Simple Bar Chart for L3-7.

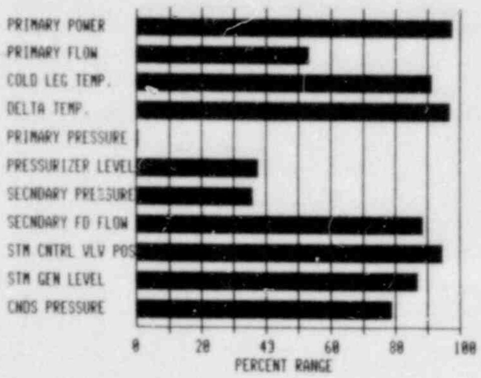

Figure 4.18 Simple Bar Chart for L3-7.

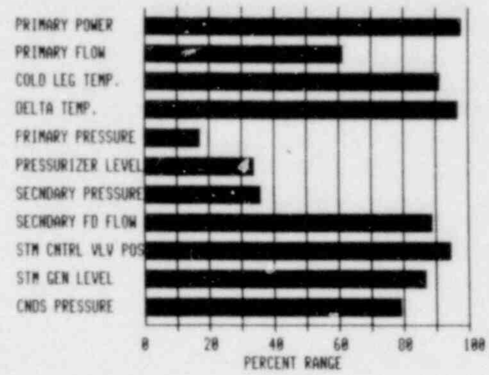

Figure 4.19 Simple Bar Chart for L3-7.

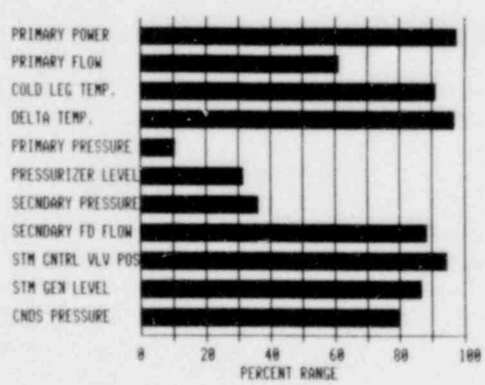

Figure 4.20 Simple Bar Chart for L3-7.

the change in pressurizer level. Unfortunately the individual bars get lost in the total display. One can conclude that the Simple Bar Chart is grossly inadequate for Question 1, marginal for Question 2, and adequate for Question 3.

Deviation Bar Chart

In the Deviation Bar Chart, each item has a bar extending either to the right or left of a common vertical base line to indicate deviations from some "normal" value. It is ideally suited for presentation of positive/negative data for a number of items. Figure 5.0 shows the Deviation Bar Chart under normal conditions at 74% power. This is a "report by exception" technique that is particularly effective for pattern recognition and check information. The ideal case of everything being normal would result in bars of zero length.

Unfortunately, the Deviation Bar Chart technique loses some of its beauty when variables have a normal range, as shown in Figures 5.1 through 5.5. The data are all perfectly acceptable, but the display may somewhat mislead the operator due to expected fluctuations. The loss of secondary feed flow is emphasized in Figure 5.6, as is the steam generator level change in subsequent displays (5.7-5.10). Working at high power levels also causes some confusion as shown in the series of Figures 5.11 through 5.20. Even though normalization was changed for the power level, there still are unnecessary stimuli under normal conditions. The turnaround in primary pressure, however, is immediately noticeable as is the change in pressurizer level. This technique is considered adequate for all three questions but would fare much better if the variables did not fluctuate about a normal value.

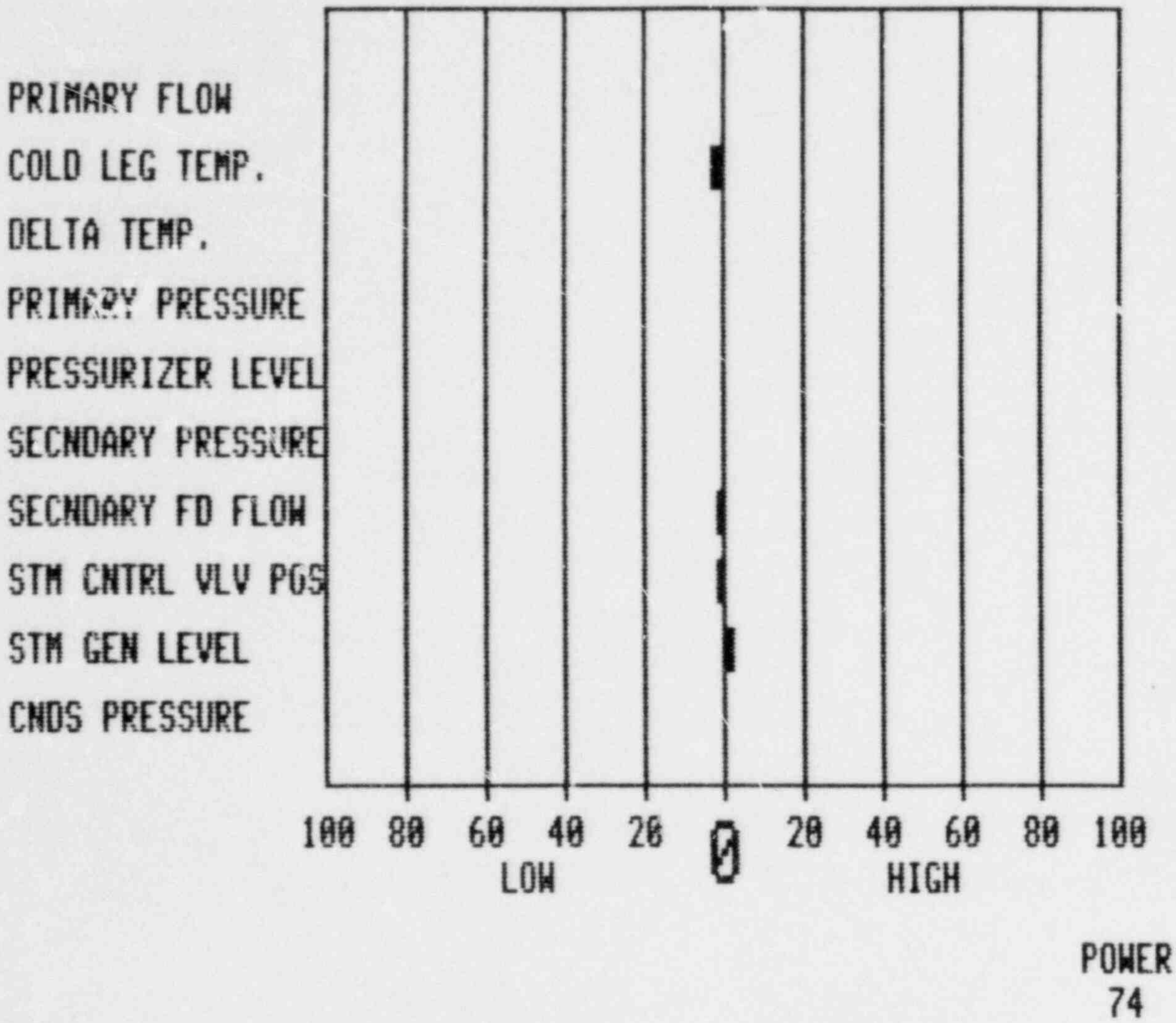

Figure 5.0 Deviation Bar Chart representation at normal conditions, 74% power.

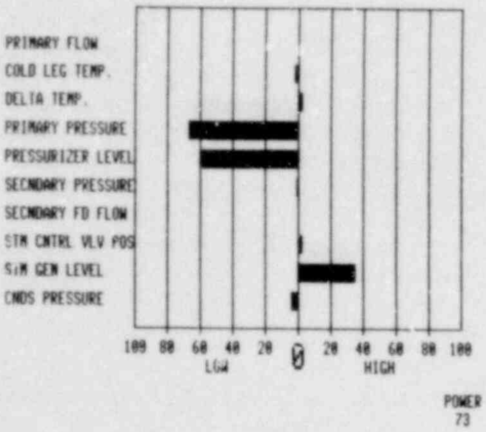

Figure 5.1 Deviation Bar Chart for L6-5.

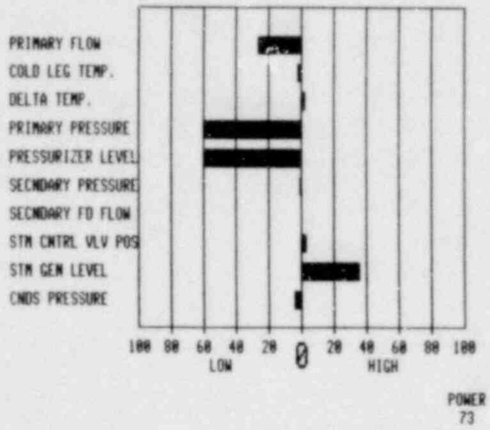

Figure 5.2 Deviation Bar Chart for L6-5.

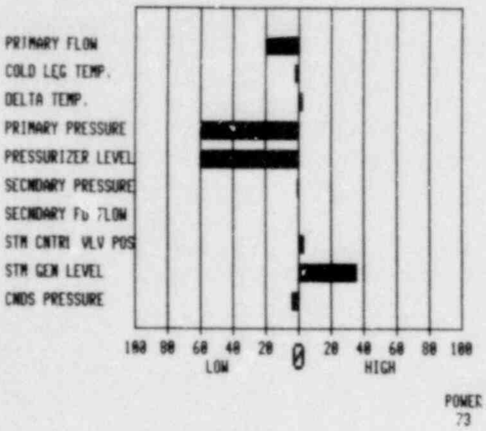

Figure 5.3 Deviation Bar Chart for L6-5.

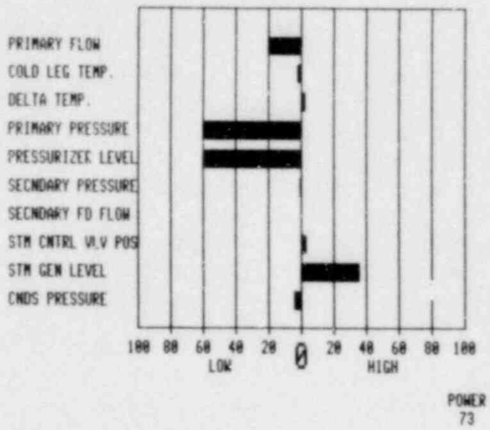

Figure 5.4 Deviation Bar Chart for L6-5.

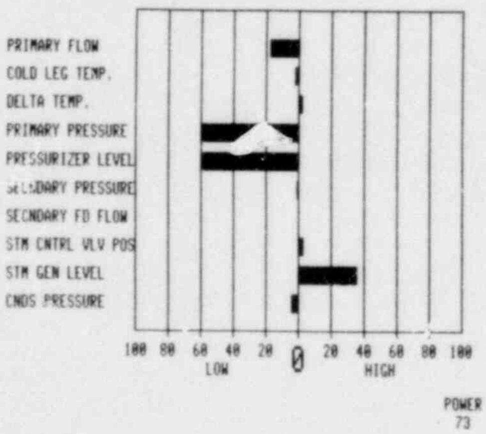

Figure 5.5 Deviation Bar Chart for L6-5.

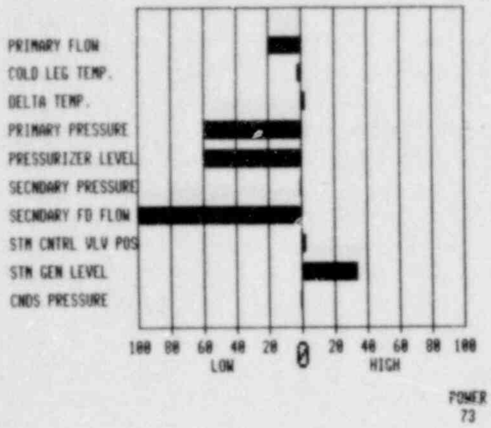

Figure 5.6 Deviation Bar Chart for L6-5.

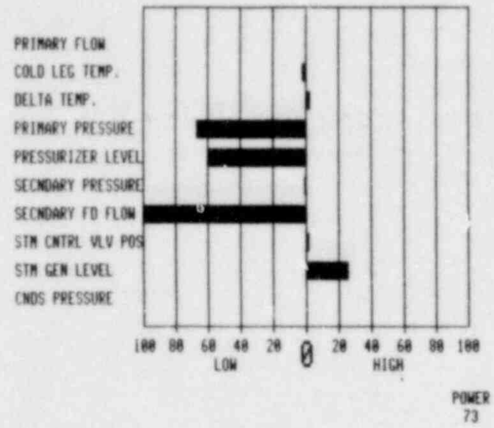

Figure 5.7 Deviation Bar Chart for L6-5.

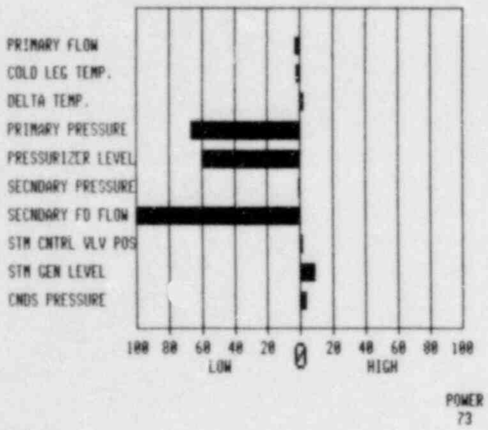

Figure 5.8 Deviation Bar Chart for L6-5.

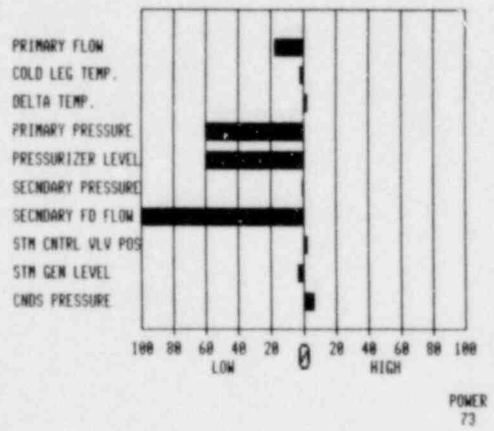

Figure 5.9 Deviation Bar Chart for L6-5.

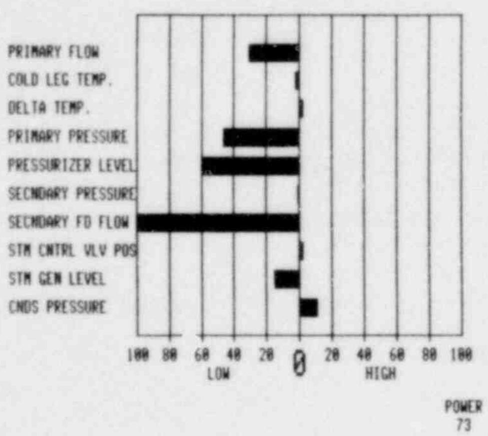

Figure 5.10 Deviation Bar Chart for L6-5.

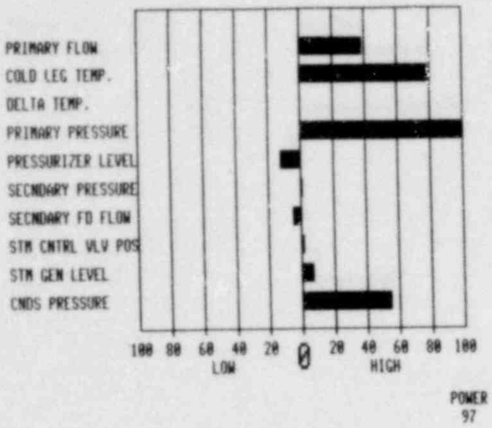

Figure 5.11 Deviation Bar Chart for L3-7.

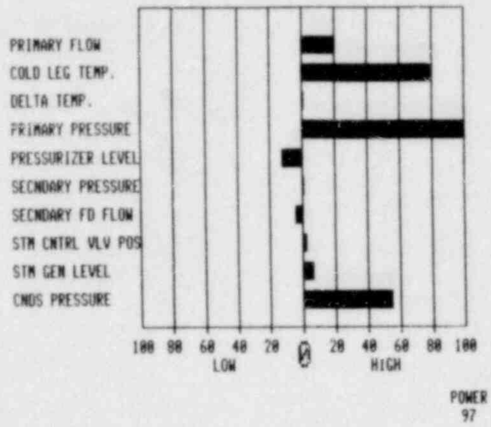

Figure 5.12 Deviation Bar Chart for L3-7.

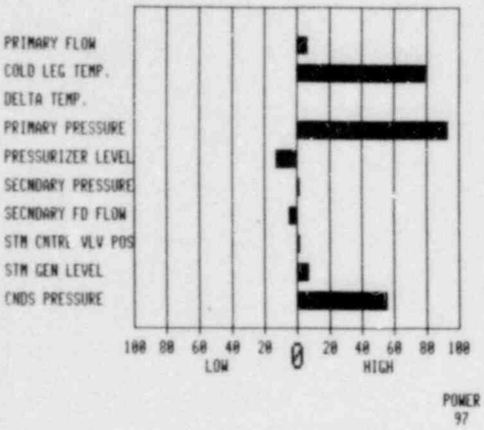

Figure 5.13 Deviation Bar Chart for L3-7.

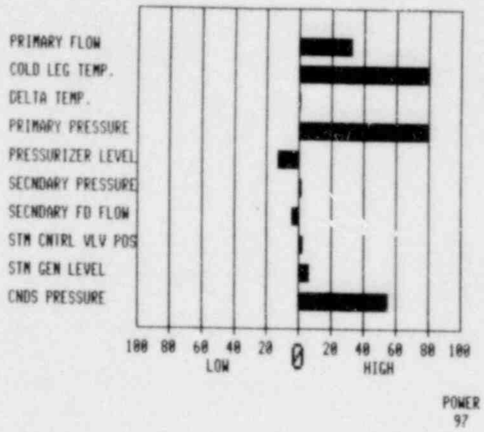

Figure 5.14 Deviation Bar Chart for L3-7.

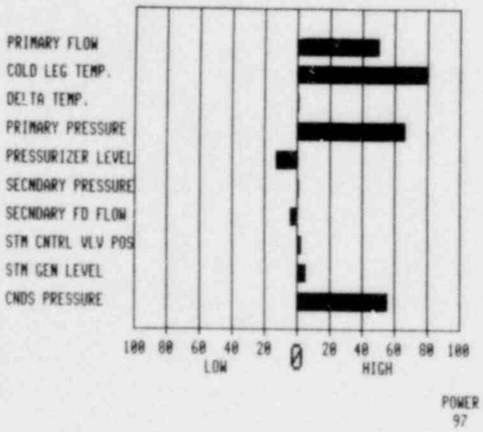

Figure 5.15 Deviation Bar Chart for L3-7.

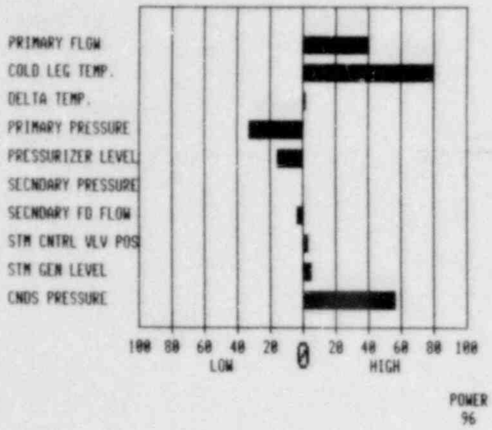

Figure 5.16 Deviation Bar Chart for L3-7.

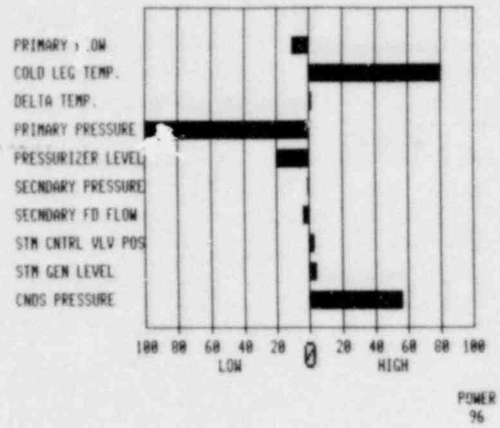

Figure 5.17 Deviation Bar Chart for L3-7

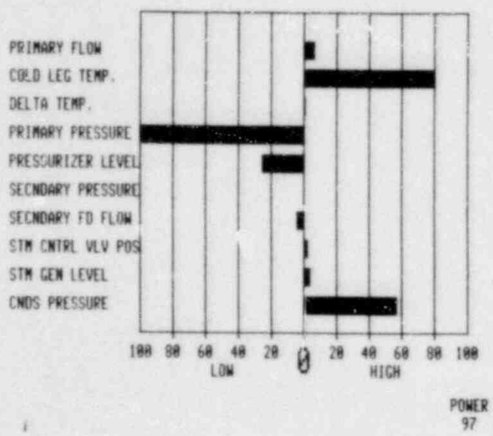

Figure 5.18 Deviation Bar Chart for L3-7.

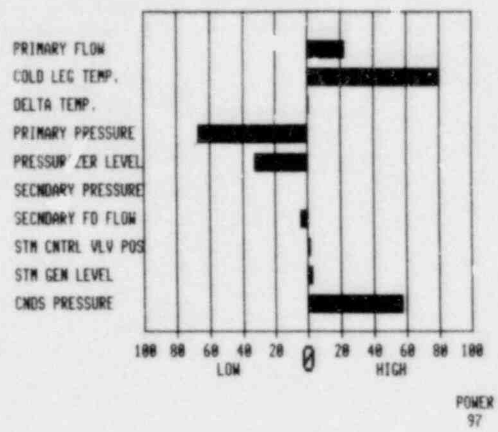

Figure 5.19 Deviation Bar Chart for L3-7.

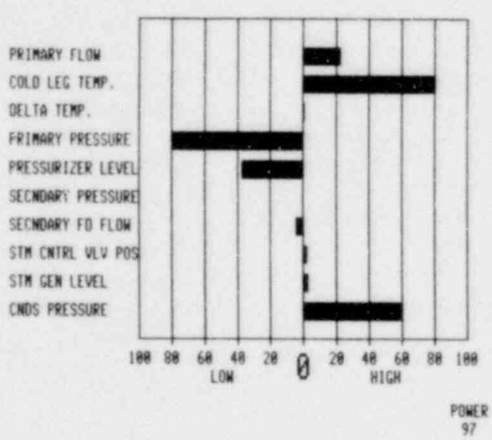

Figure 5.20 Deviation Bar Chart for L3-7.

Fourfold Circular Display

A Fourfold Circular Display (FCD) uses four quadrants to represent different variables. The values of the variables are indicated by the radius of the 90° arc associated with each variable. The ideal use of this technique is to compare two different sets of data at the same time. To apply FCD to the given data, one must make it a Fivefold Circular Display as shown in Figure 6.0. The primary system components are grouped on the left and the secondary components are on the right. Range rings indicate 25%, 50%, 75%, and 100% of the expected values.

Figures 6.1 through 6.10 show the technique for L6-5. The operator would soon learn the normal patterns without relating the individual parameters to specific values. An upset condition, as seen in Figure 6.6, shows the immediate loss of feed flow and subsequent decrease in steam generator level. Figure 6.16 also shows the decrease in primary pressure and level. The true value of this technique is the coarseness of the display during minor fluctuations and the obvious onset of a transient. Hence it was labeled very adequate for determining the overall system state (Question 1) and detecting the problem (Question 2) but marginal for indicating the severity (Question 3).

Linear Profile

The next technique, the Linear Profile, uses a polygonal line that connects the various heights corresponding to the values of the variables arranged along a base line. It is intended to show the nature of a relationship between variables. The technique was implemented as a variation of a Surface Chart, using the filled portion below the curve to emphasize magnitude (see Figure 7.0). The horizontal lines indicate the values in relation to the total range. A problem similar to the Deviation Chart arises with data that have a normal range, as seen in Figures 7.0 and 7.1.

Minor fluctuations for transient L6-5 are discernible but not overly obvious (Figures 7.1 through 7.5). The loss of feed flow is well-illustrated, as is the decrease in steam generator level. L3-7 is also nicely shown in Figures 7.11 through 7.20 with the primary pressure drop very evident. However, changes in pressurizer level are somewhat hidden.

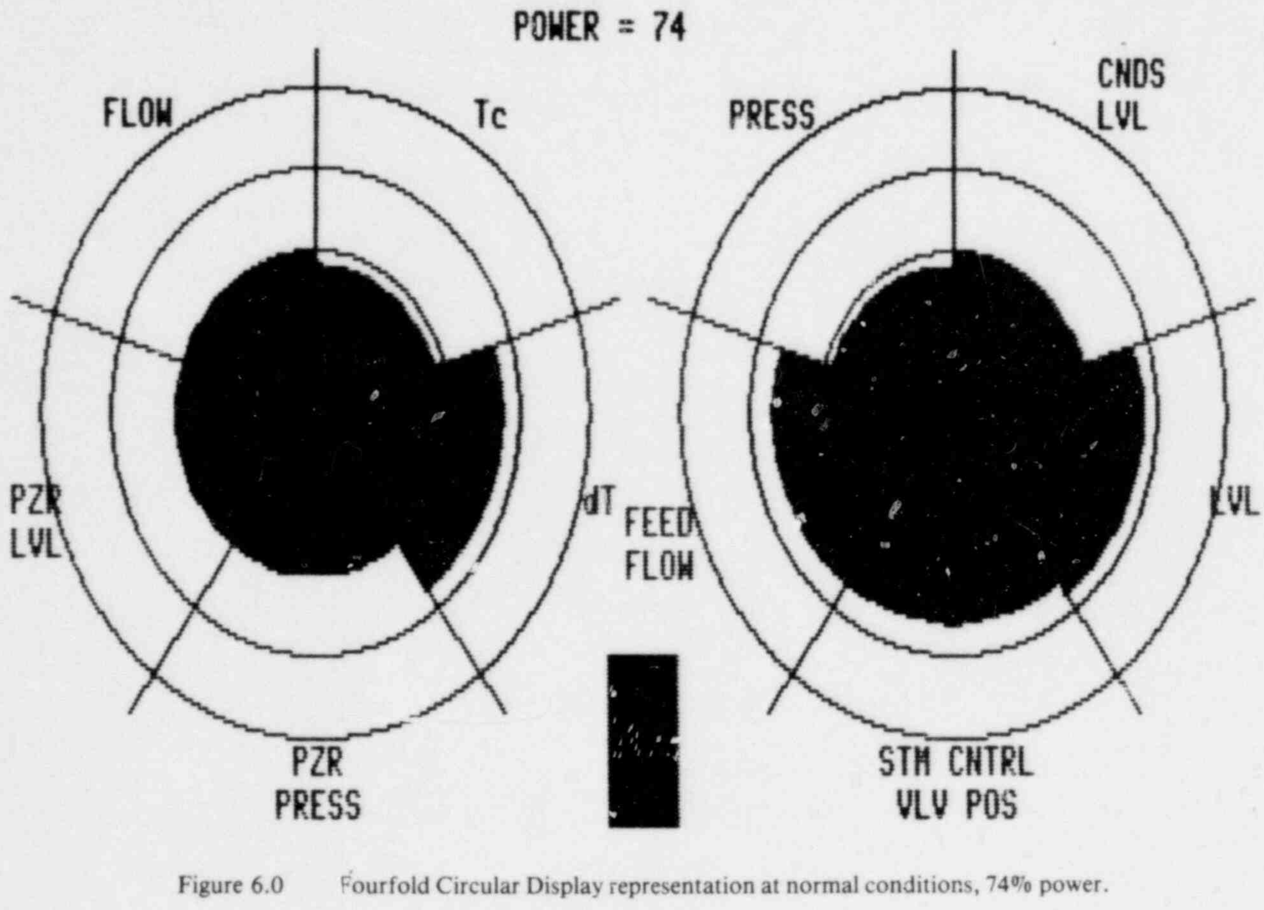

Figure 6.0 Fourfold Circular Display representation at normal conditions, 74% power.

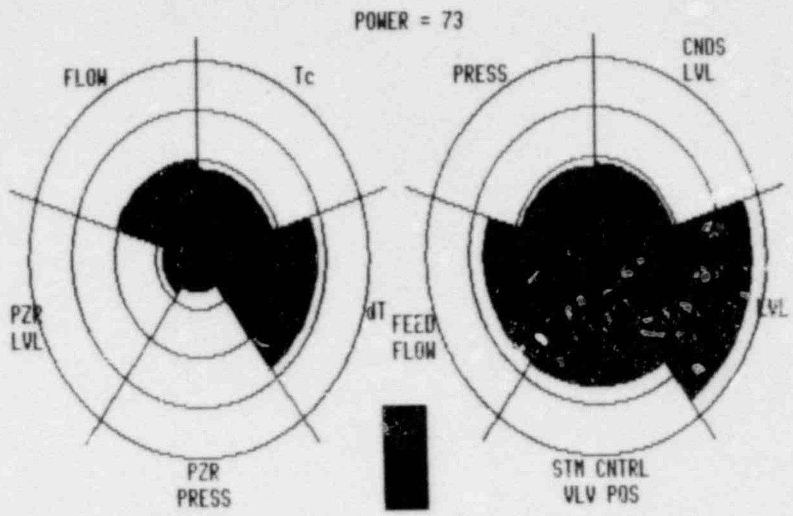

Figure 6.1 Fourfold Circular Display for L6-5.

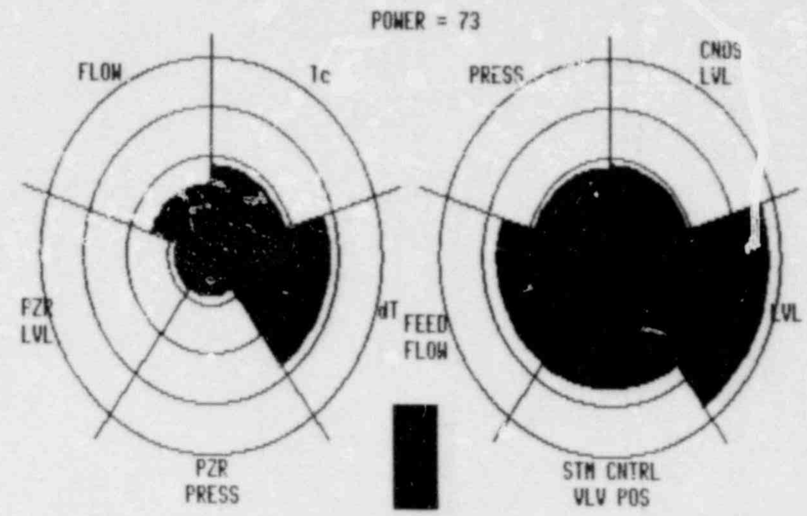

Figure 6.2 Fourfold Circular Display for L6-5.

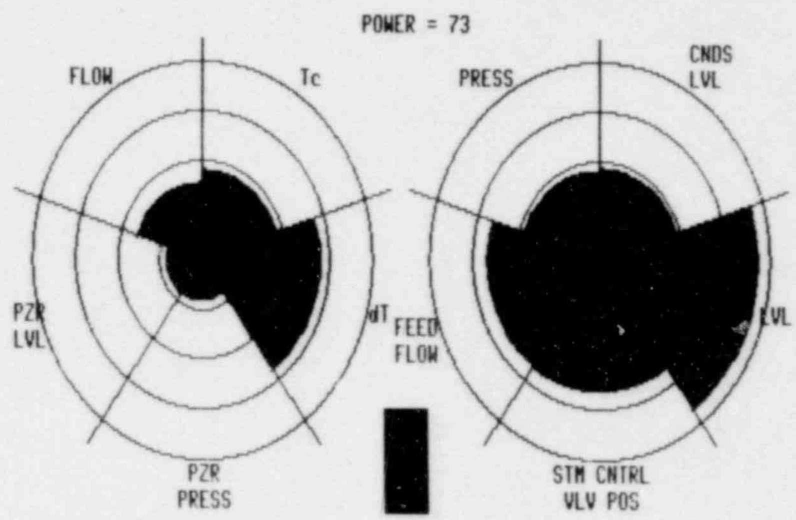

Figure 6.3 Fourfold Circular Display for L6-5.

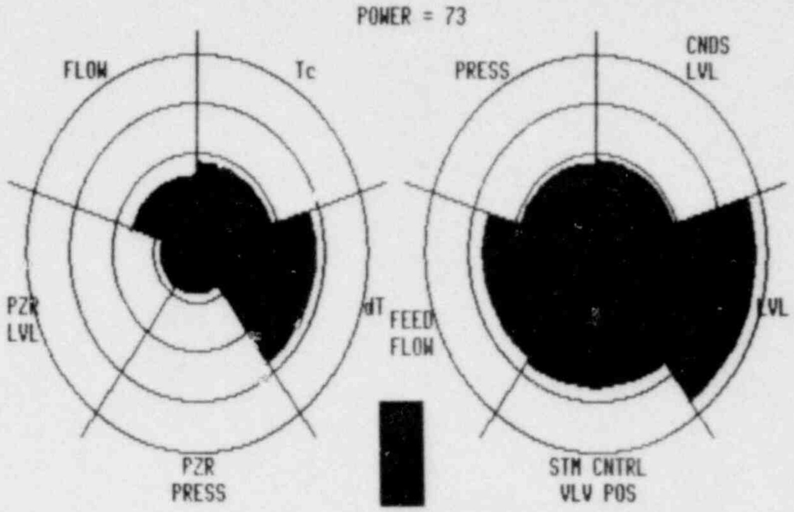

Figure 6.4 Fourfold Circular Display for L6-5.

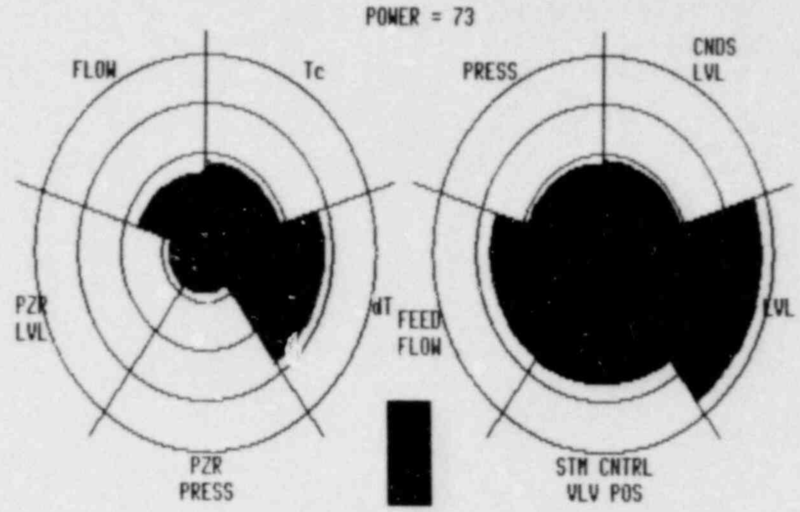

Figure 6.5 Fourfold Circular Display for L6-5.

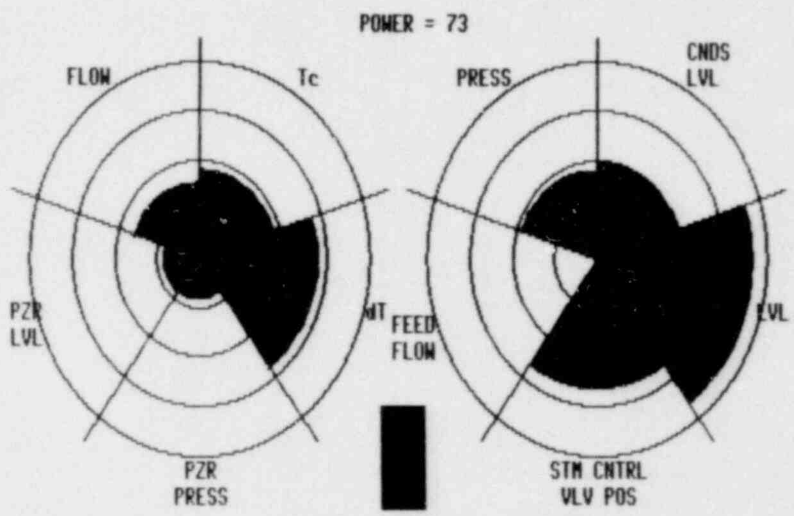

Figure 6.6 Fourfold Circular Display for L6-5.

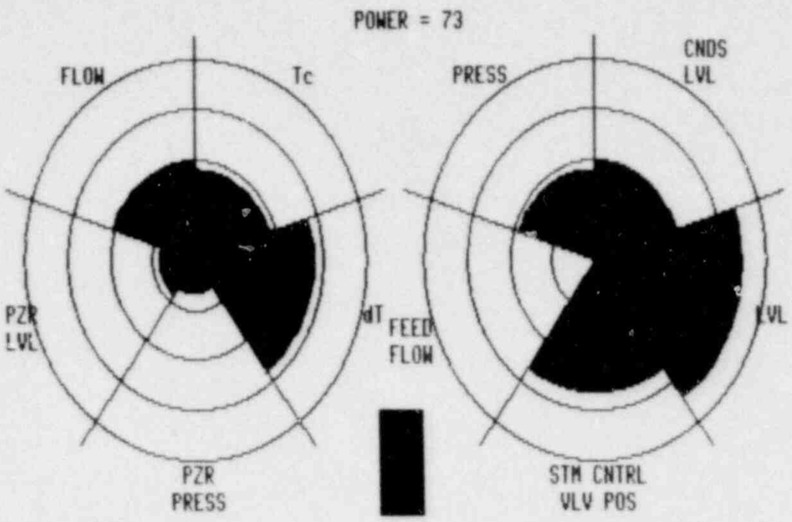

Figure 6.7 Fourfold Circular Display for L6-5.

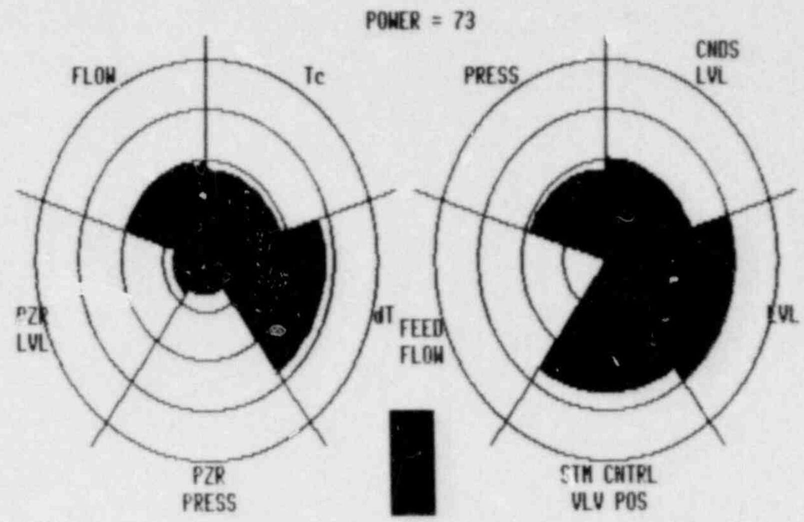

Figure 6.8 Fourfold Circular Display for L6-5.

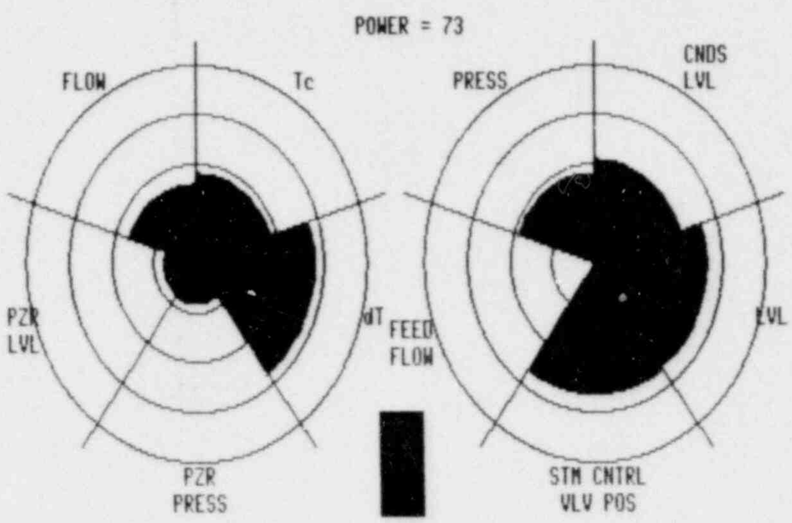

Figure 6.9 Fourfold Circular Display for L6-5.

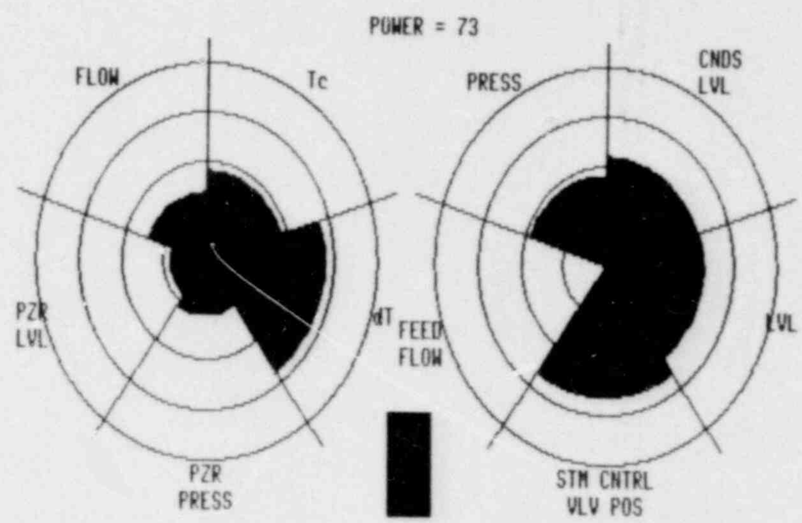

Figure 6.10 Fourfold Circular Display for L6-5.

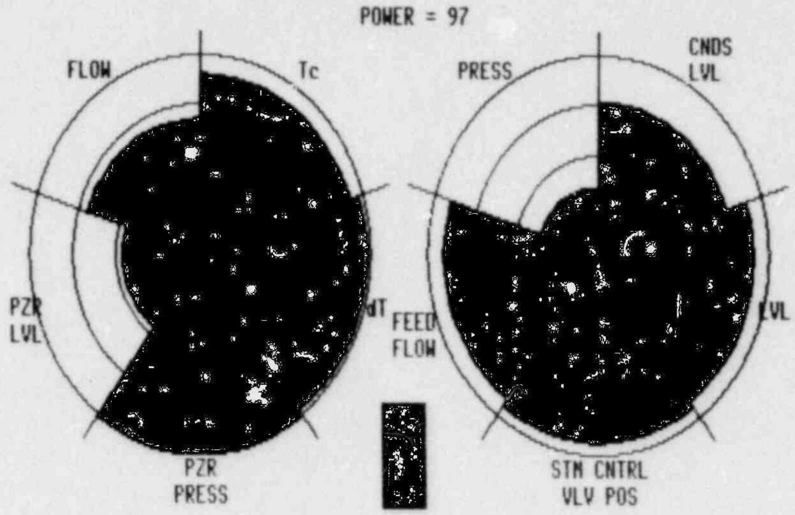

Figure 6.11 Fourfold Circular Display for L3-7.

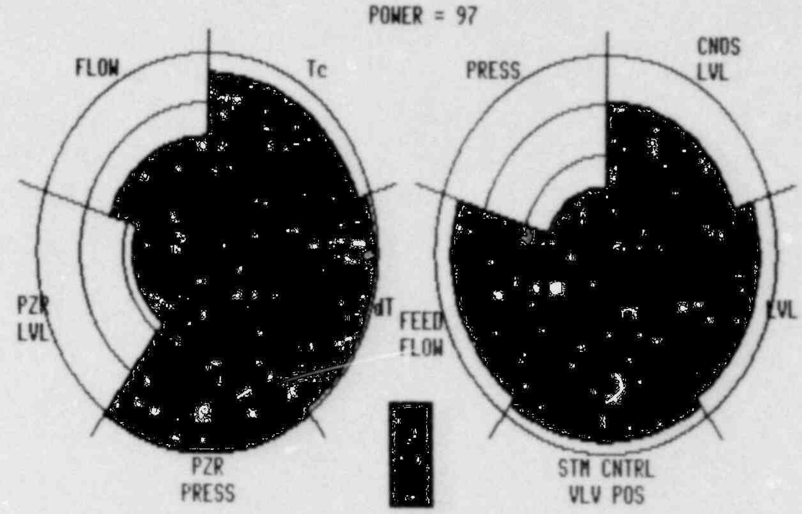

Figure 6.12 Fourfold Circular Display for L3-7.

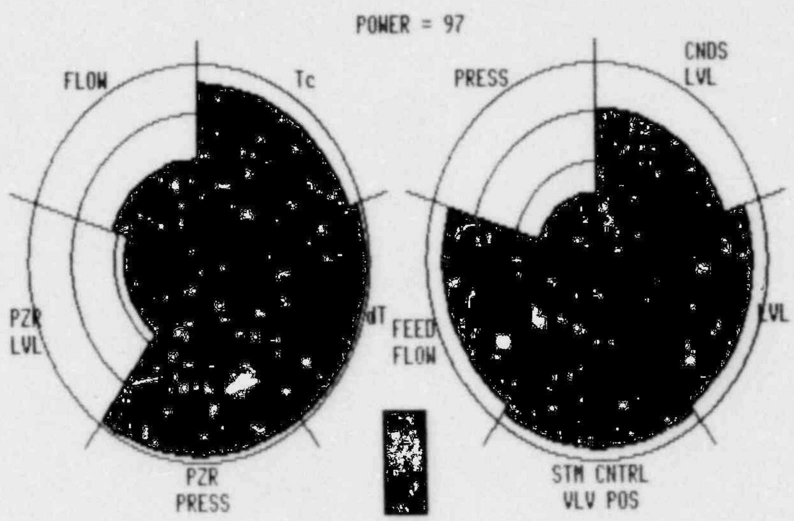

Figure 6.13 Fourfold Circular Display for L3-7.

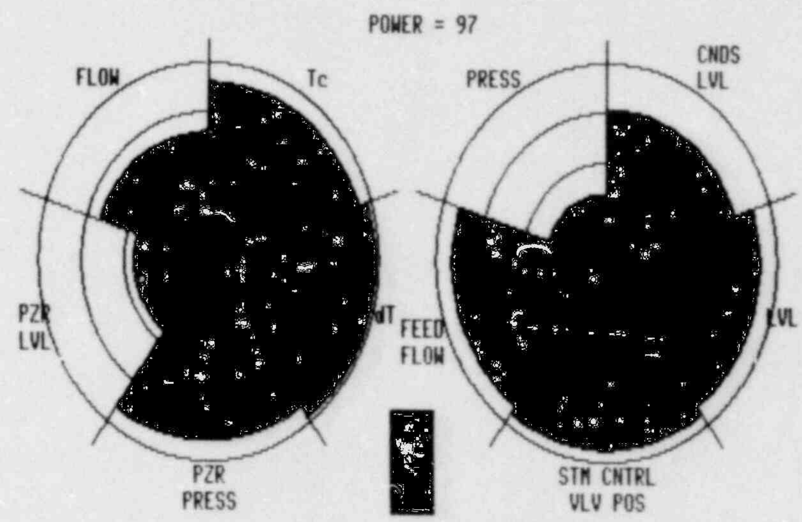

Figure 6.14 Fourfold Circular Display for L3-7.

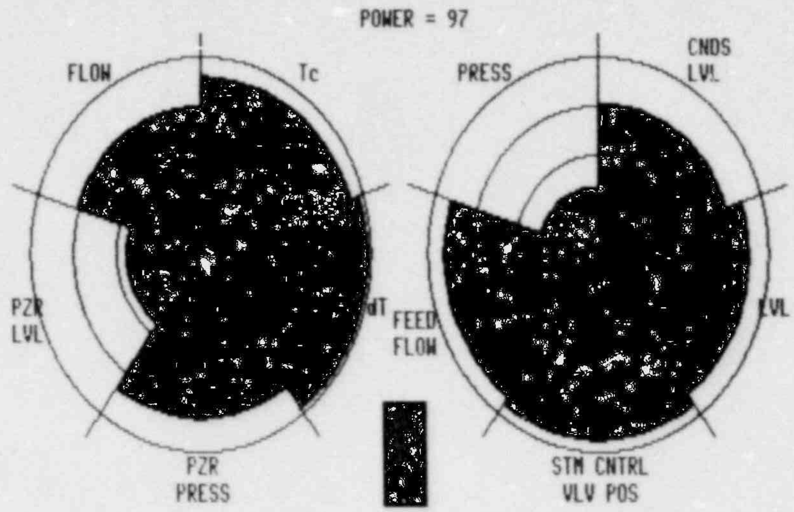

Figure 6.15 Fourfold Circular Display for L3-7.

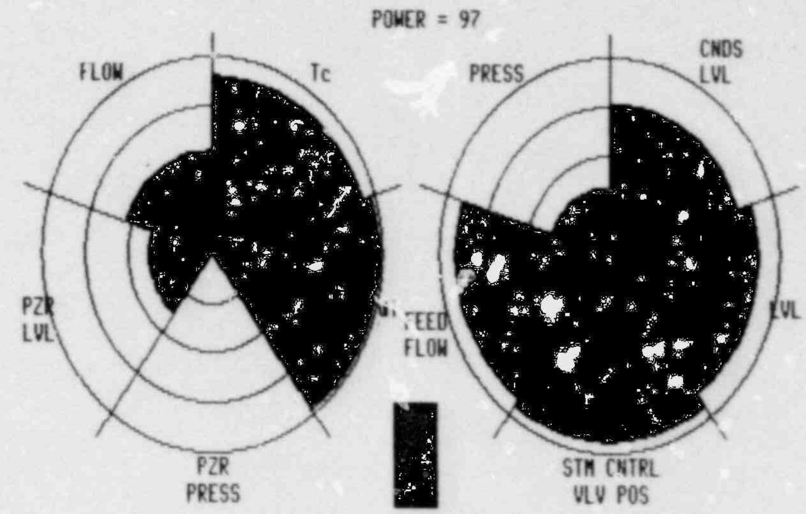

Figure 6.16 Fourfold Circular Display for L3-7.

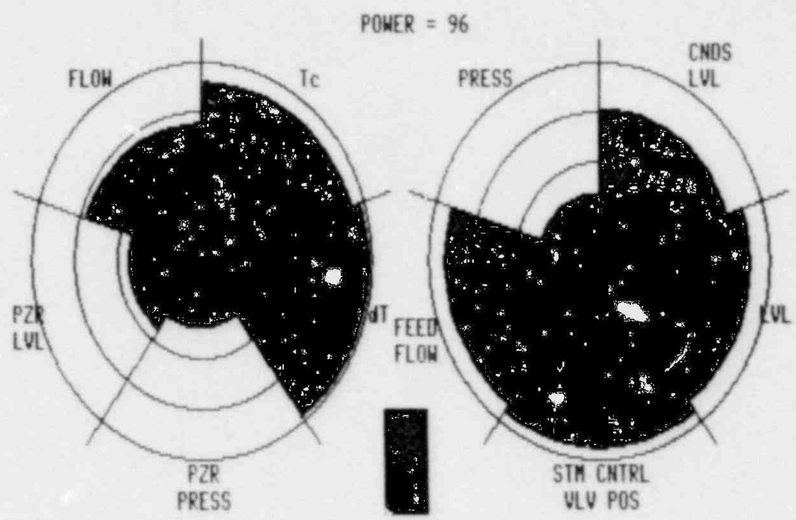

Figure 6.17 Fourfold Circular Display for L3-7.

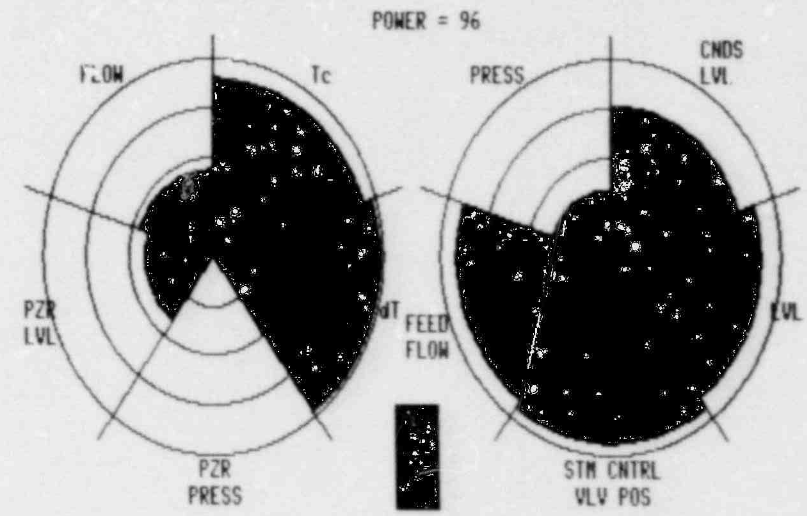

Figure 6.18 Fourfold Circular Display for L3-7.

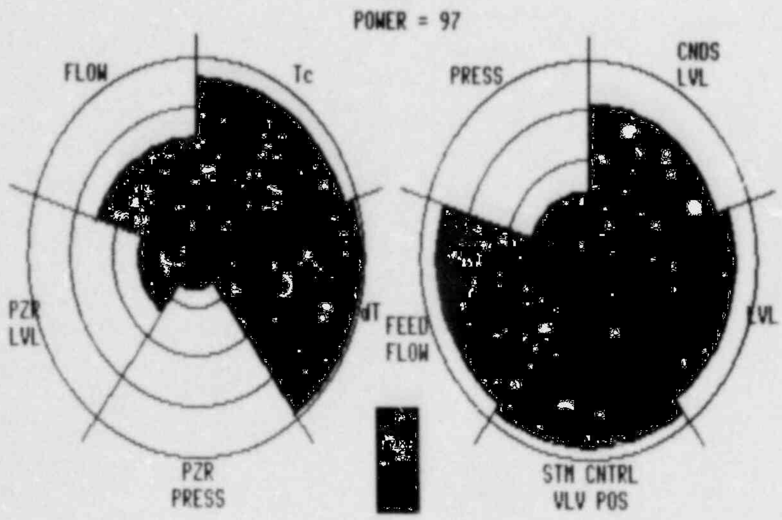

Figure 6.19 Fourfold Circular Display for L3-7.

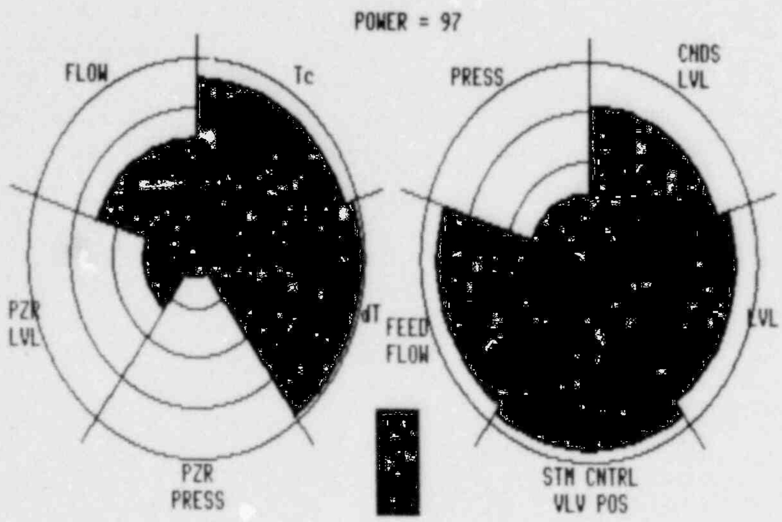

Figure 6.20 Fourfold Circular Display for L3-7.

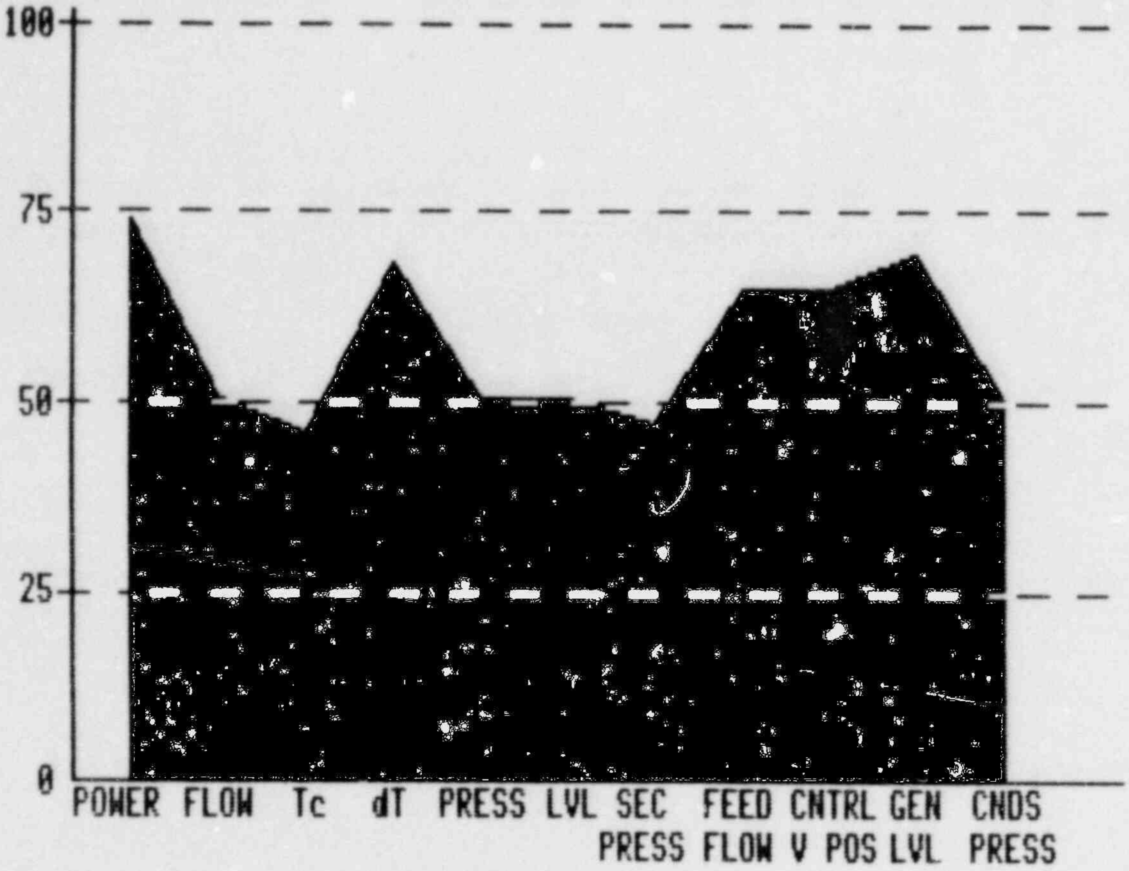

Figure 7.0 Linear Profile representation at normal conditions, 74% power.

The linear aspect of this display is confusing and makes pattern recognition marginal, but it is considered adequate for determining the problem as well as the severity.

Circular Profile

This technique is a variation of the Linear Profile in which the polygonal line connects points located on equally spaced rays, where the distance from the center represents the value for each of the variables. Each ray may have different units and the display shows the nature of a relationship between variables. The normal conditions shown in Figure 8.0 illustrate a good pattern recognition feature of the technique because deviations from a perfect circle represent off-normal conditions. Fluctuations within the normal range are evident but not overly disturbing.

The change in pattern between Figures 8.5 and 8.6 allows the operator to immediately determine the problem and get a rough idea of its severity. The loss of feed flow is reinforced with the drop in steam generator level in subsequent displays. The abrupt changes in pattern from Figures 8.11 through 8.15 and 8.16 through 8.20 show the transient for L3-7. A technical graphics problem arises here in filling concave polygons, as illustrated in Figure 8.17 for the steam generator level (LVL), but it can be corrected by using a more sophisticated fill algorithm. The Circular Profile technique is judged very adequate for both Questions 1 and 2 and adequate for Question 3.

Linear Fourier Representation

In this technique a Fourier Series is used to generate a function of an angle θ for each multidimensional point that is to be represented, i.e.,

$$F(\theta) = \frac{a}{1.414} + b\cos\theta + c\sin\theta + d\cos 2\theta$$

$$+ \ldots \quad 0 \le \theta \le 360°$$

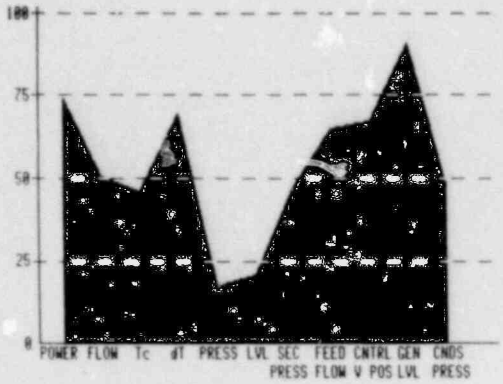

Figure 7.1 Linear Profile for L6-5.

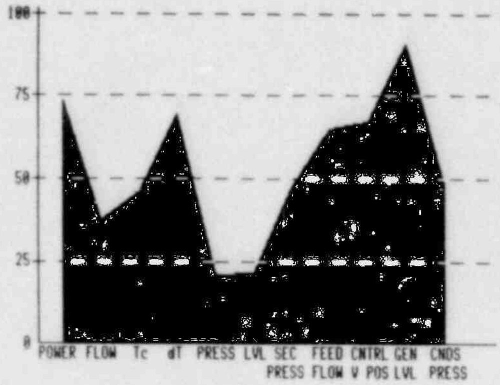

Figure 7.2 Linear Profile for L6-5.

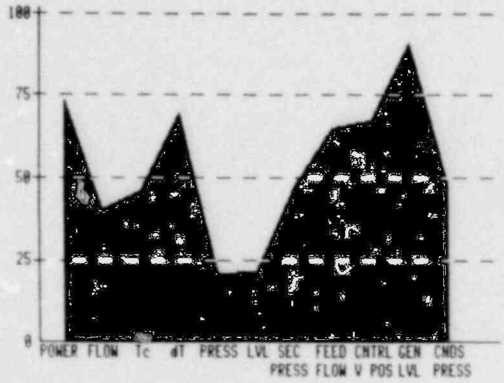

Figure 7.3 Linear Profile for L6-5.

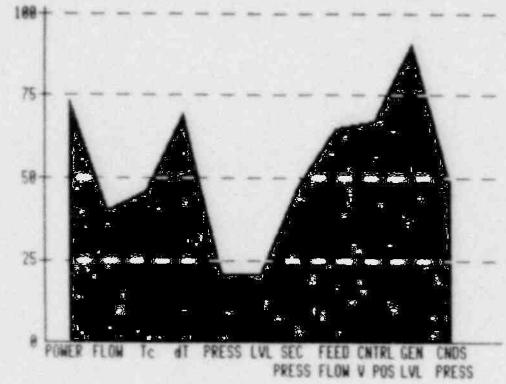

Figure 7.4 Linear Profile for L6-5.

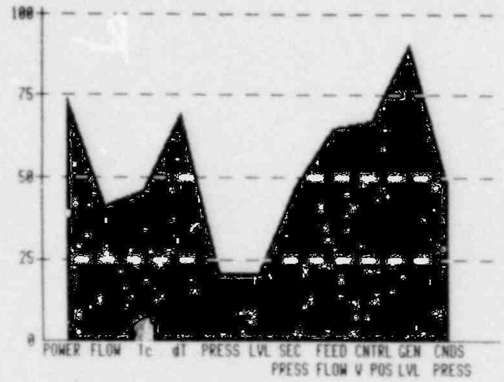

Figure 7.5 Linear Profile for L6-5.

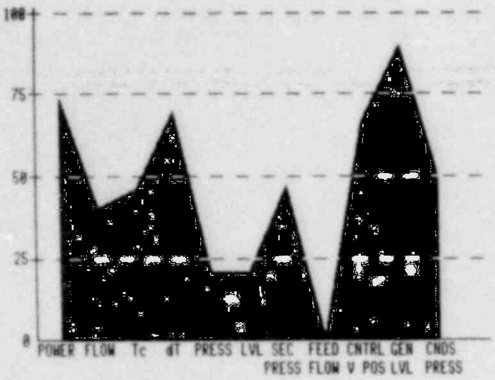

Figure 7.6 Linear Profile for L6-5.

Figure 7.7 Linear Profile for L6-5.

Figure 7.8 Linear Profile for L6-5.

Figure 7.9 Linear Profile for L6-5.

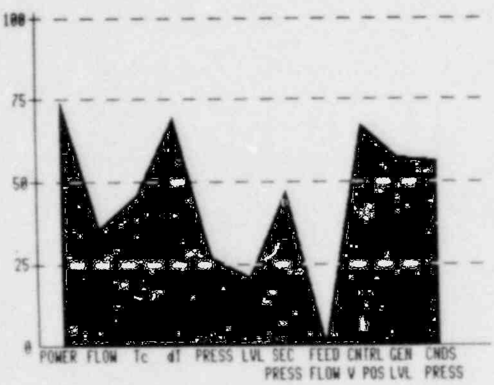

Figure 7.10 Linear Profile for L6-5.

Figure 7.11 Linear Profile for L3-7.

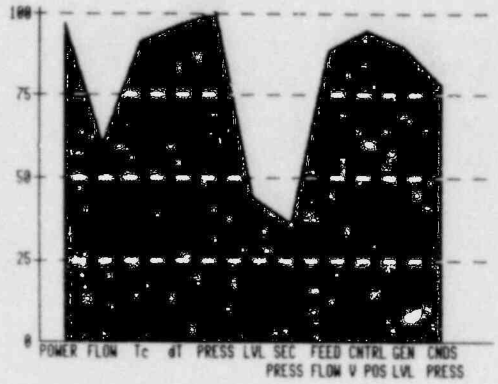

Figure 7.12 Linear Profile for L3-7.

Figure 7.13 Linear Profile for L3-7.

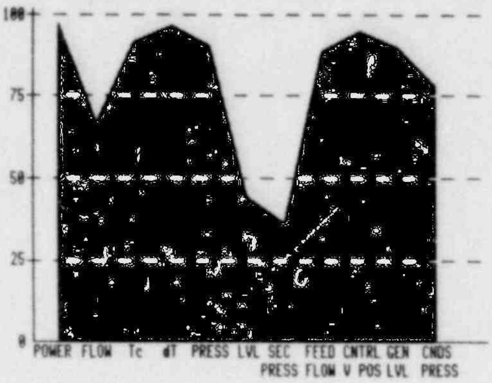

Figure 7.14 Linear Profile for L3-7.

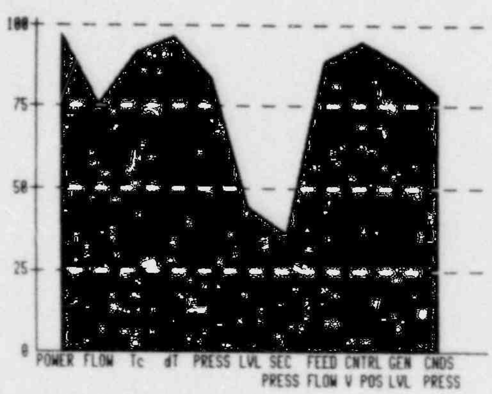

Figure 7.15 Linear Profile for L3-7.

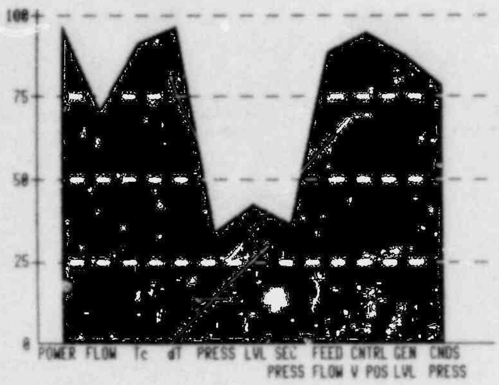

Figure 7.16 Linear Profile for L3-7.

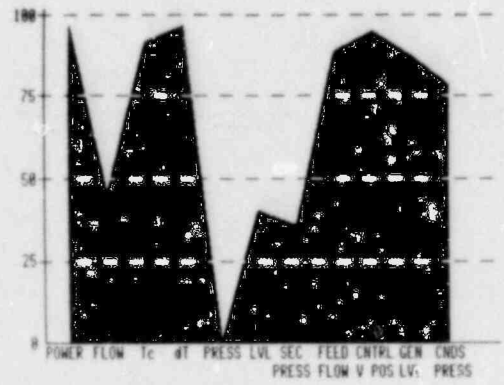

Figure 7.17 Linear Profile for L3-7.

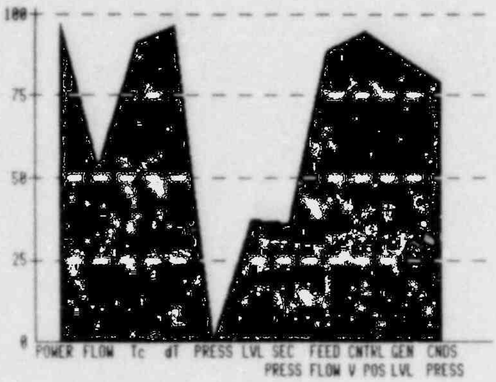

Figure 7.18 Linear Profile for L3-7.

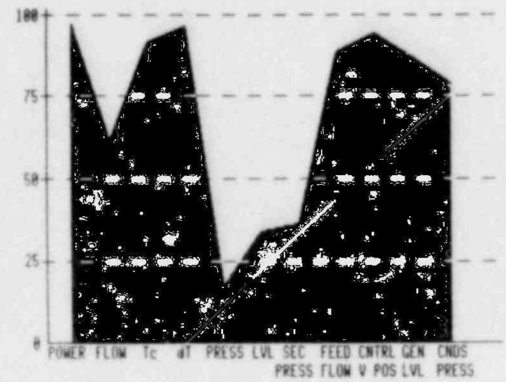

Figure 7.19 Linear Profile for L3-7.

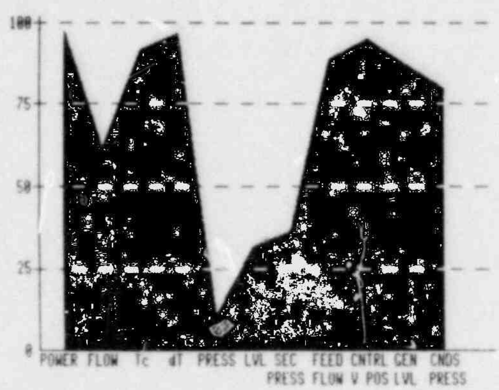

Figure 7.20 Linear Profile for L3-7.

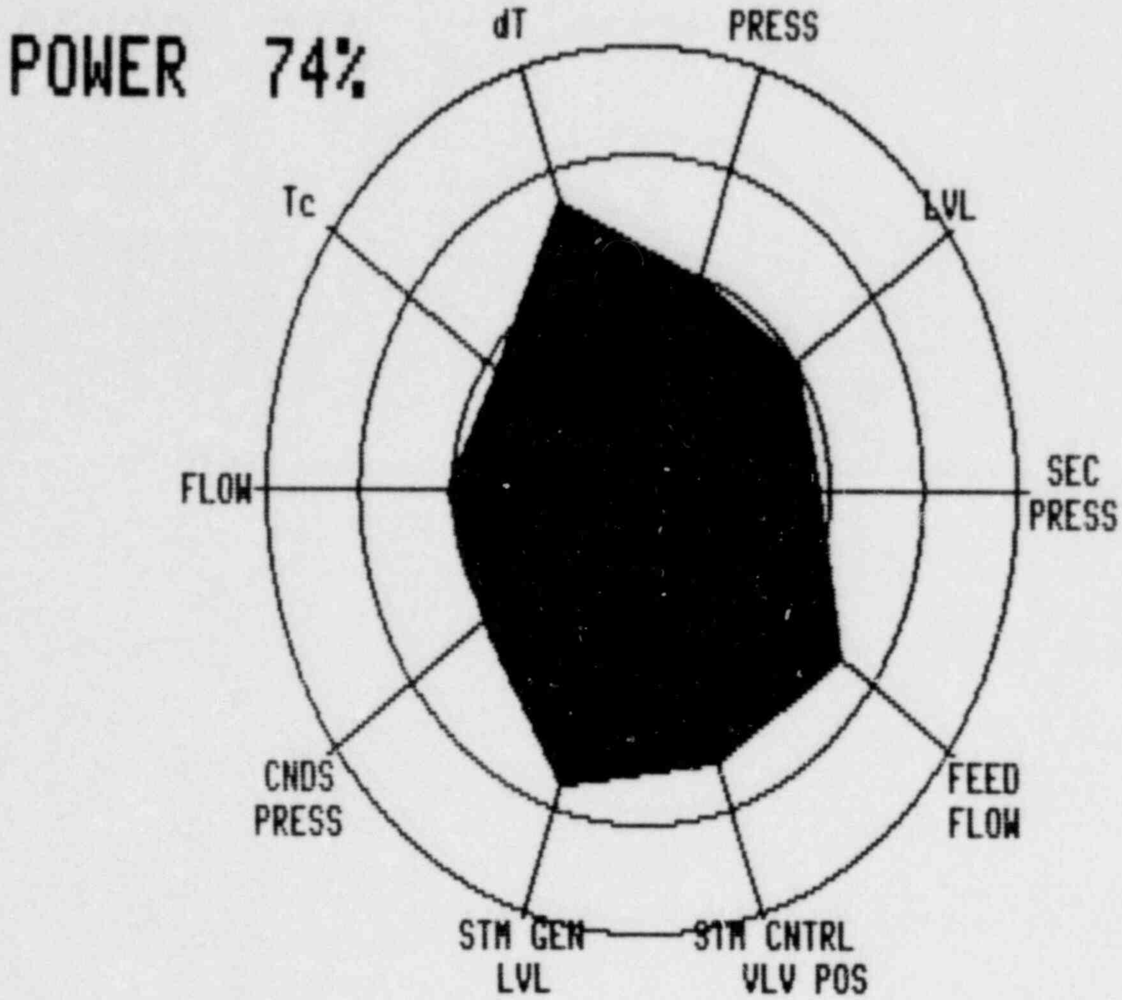

Figure 8.0 Circular Profile representation at normal conditions, 74% power.

where the coefficients of the trigonometric functions are the values of the variables. The intent here is to compare the interaction of several variables. Figure 9.0 shows the normal data at 74% in linear fashion. Both current values and expected values are shown in this display via a blue reference line and a green data line, respectively.

Observation of Figures 9.1 to 9.10 for L6-5 and Figures 9.11 to 9.20 for L3-7 reveal a total washout of minor fluctuations. The initiation of transients in Figures 9.6 and 9.16 are somewhat evident, provided that the changes are severe. This technique indicates that something has occurred but does not reveal what or how much. Applicability to pattern recognition is adequate but both check and qualitative information is grossly inadequate.

Polar Fourier Representation

The Polar Fourier Representation is similar to the Linear technique except that the function is plotted in polar rather than rectilinear coordinates. Figure 10.0 shows the normal condition at 74% power. Here again pattern recognition is well served in that the "blobs" will become familiar to the operator without undue stimuli during minor fluctuations. A data line in green is easily compared to a reference line in blue. The L6-5 transient series shown in Figures 10.1 through 10.10 does indicate the occurrence of the transient but gives no information as to what the problem is or its severity. Likewise one has similar observations of Figures 10.11 through 10.20. The Polar representation improves the pattern recognition capabilities but does little for Questions 2

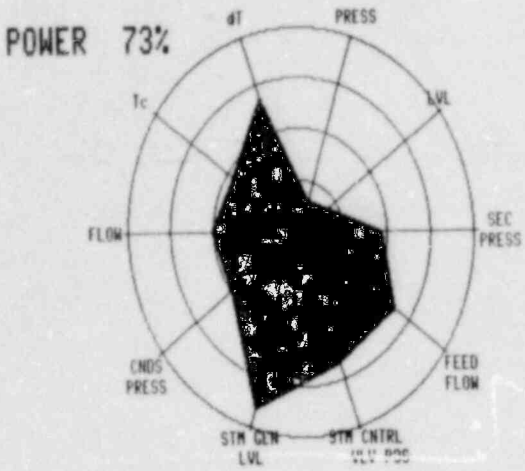

Figure 8.1 Circular Profile for L6-5.

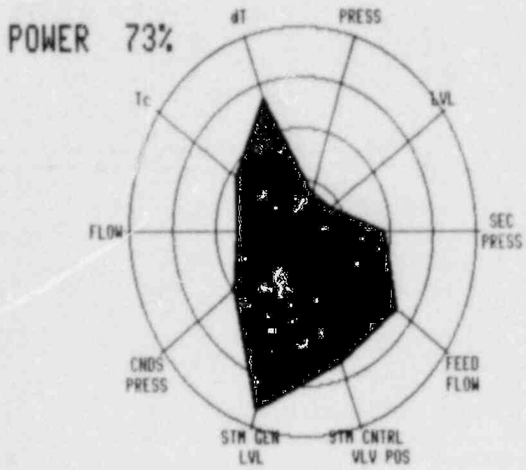

Figure 8.2 Circular Profile for L6-5.

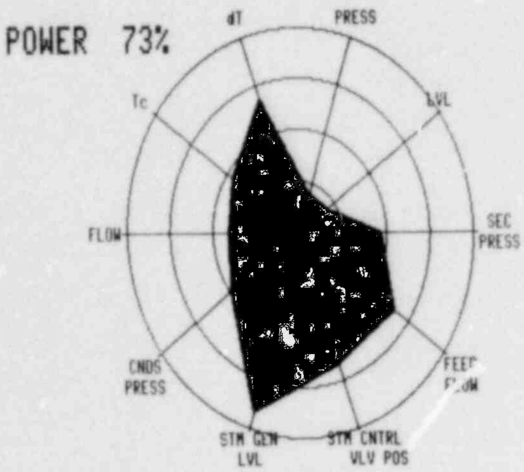

Figure 8.3 Circular Profile for L6-5.

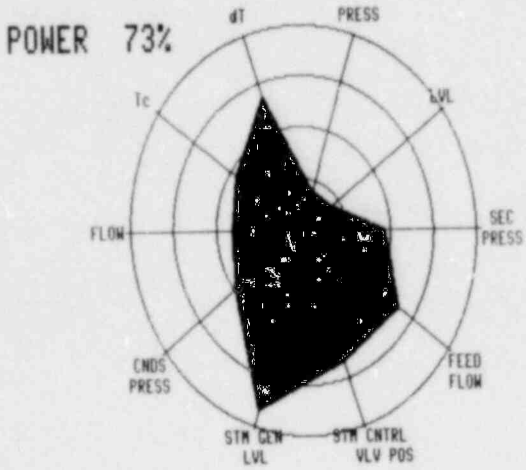

Figure 8.4 Circular Profile for L6-5.

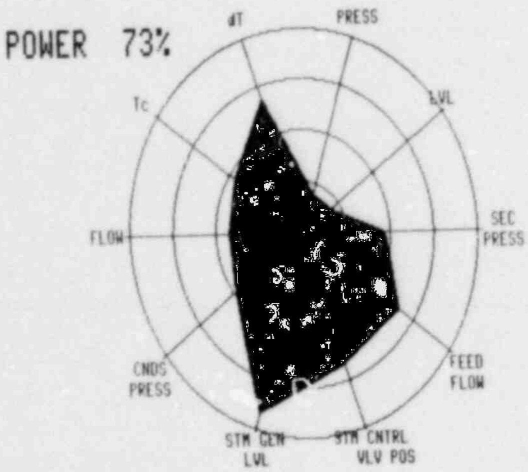

Figure 8.5 Circular Profile for L6-5.

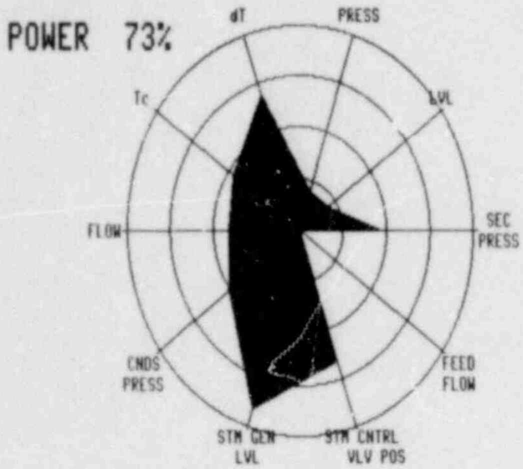

Figure 8.6 Circular Profile for L6-5.

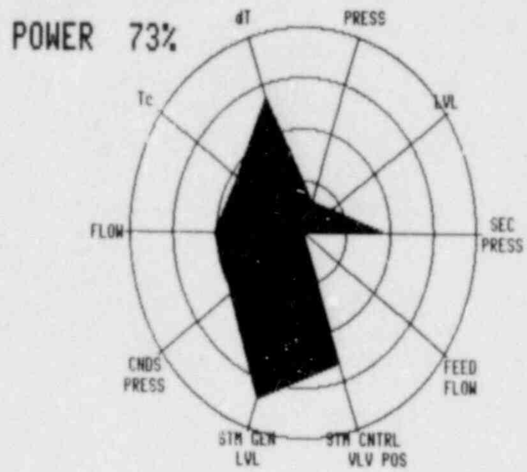

Figure 8.7 Circular Profile for L6-5.

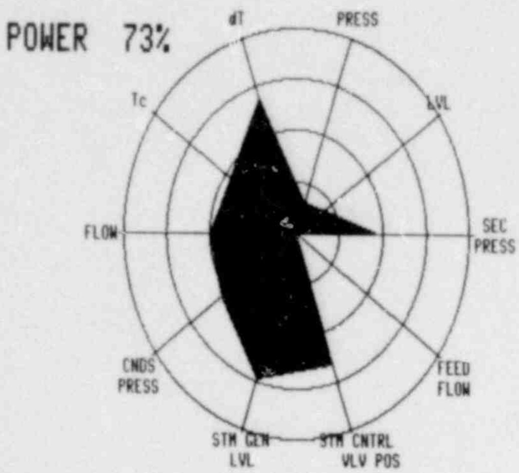

Figure 8.8 Circular Profile for L6-5.

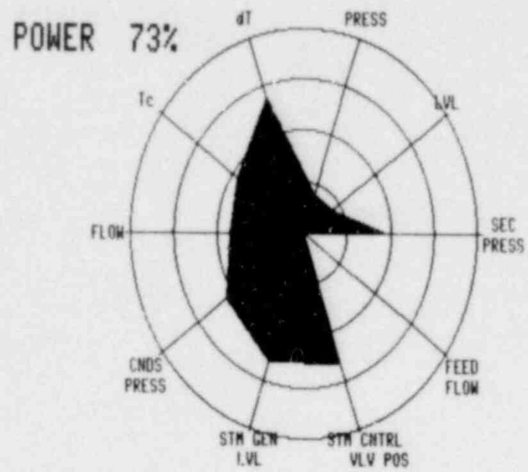

Figure 8.9 Circular Profile for L6-5.

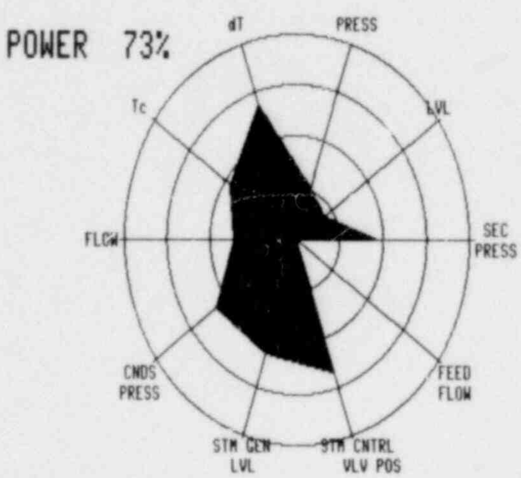

Figure 8.10 Circular Profile for L6-5.

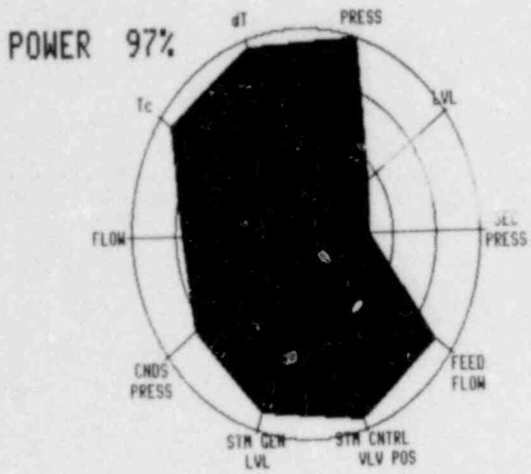

Figure 8.11 Circular Profile for L3-7.

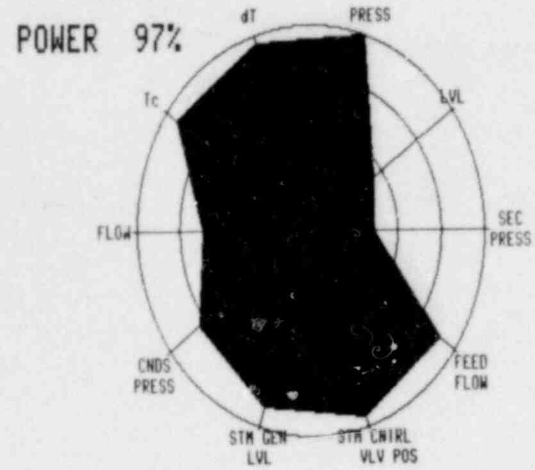

Figure 8.12 Circular Profile for L3-7.

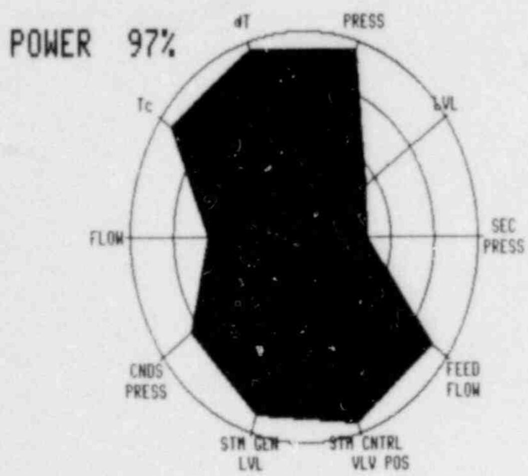

Figure 8.13 Circular Profile for L3-7.

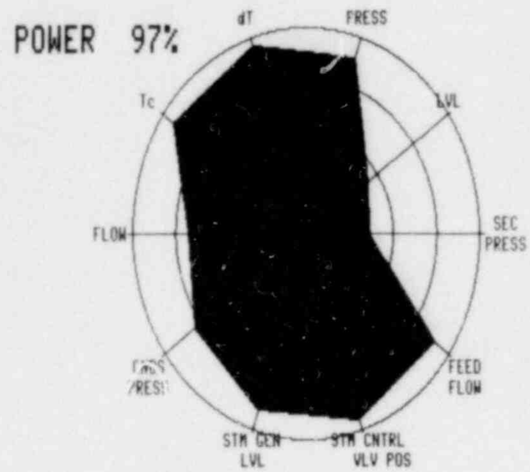

Figure 8.14 Circular Profile for L3-7.

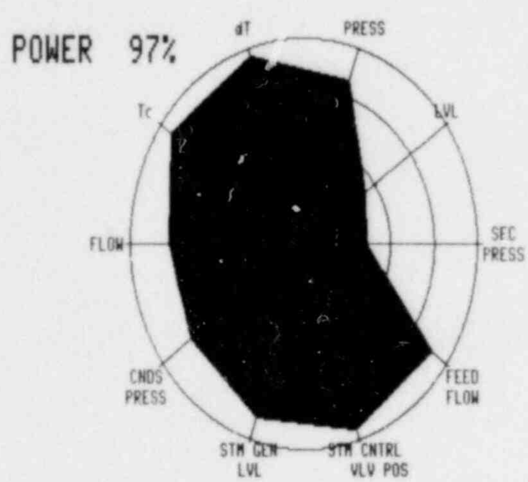

Figure 8.15 Circular Profile for L3-7.

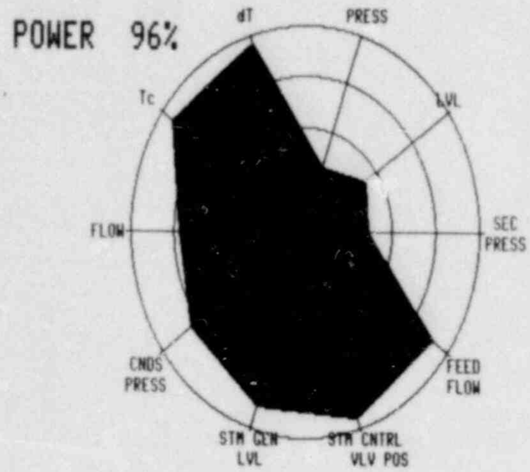

Figure 8.16 Circular Profile for L3-7.

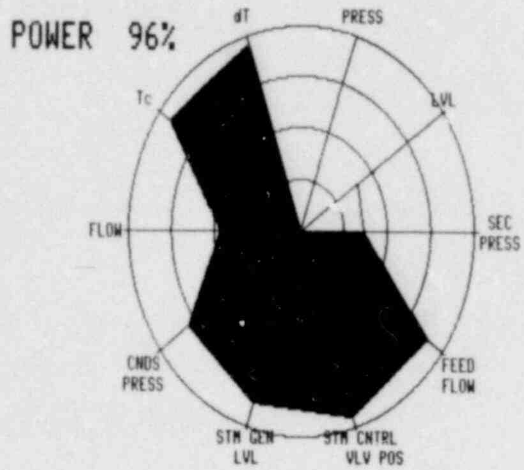

Figure 8.17 Circular Profile for L3-7.

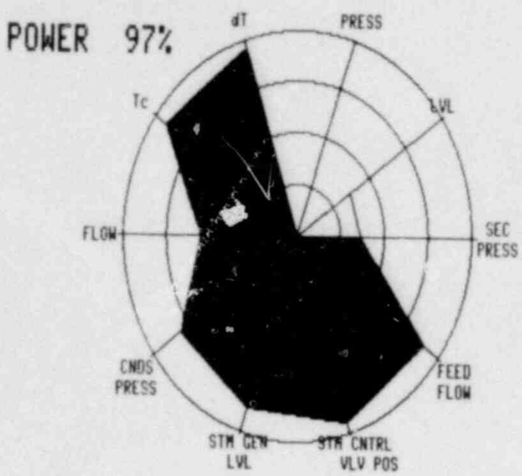

Figure 8.18 Circular Profile for L3-7.

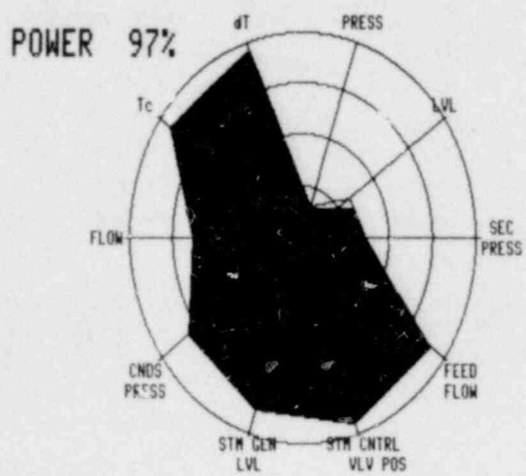

Figure 8.19 Circular Profile for L3-7.

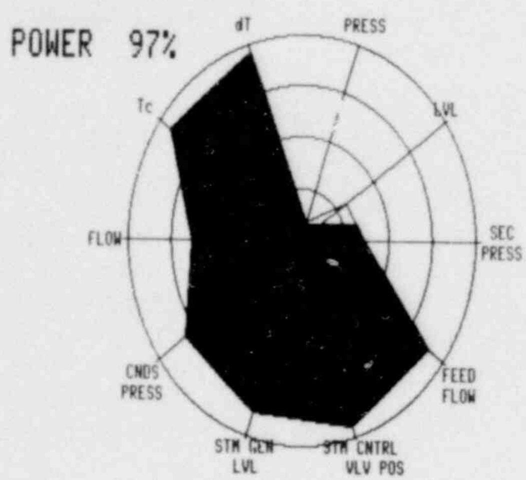

Figure 8.20 Circular Profile for L3-7.

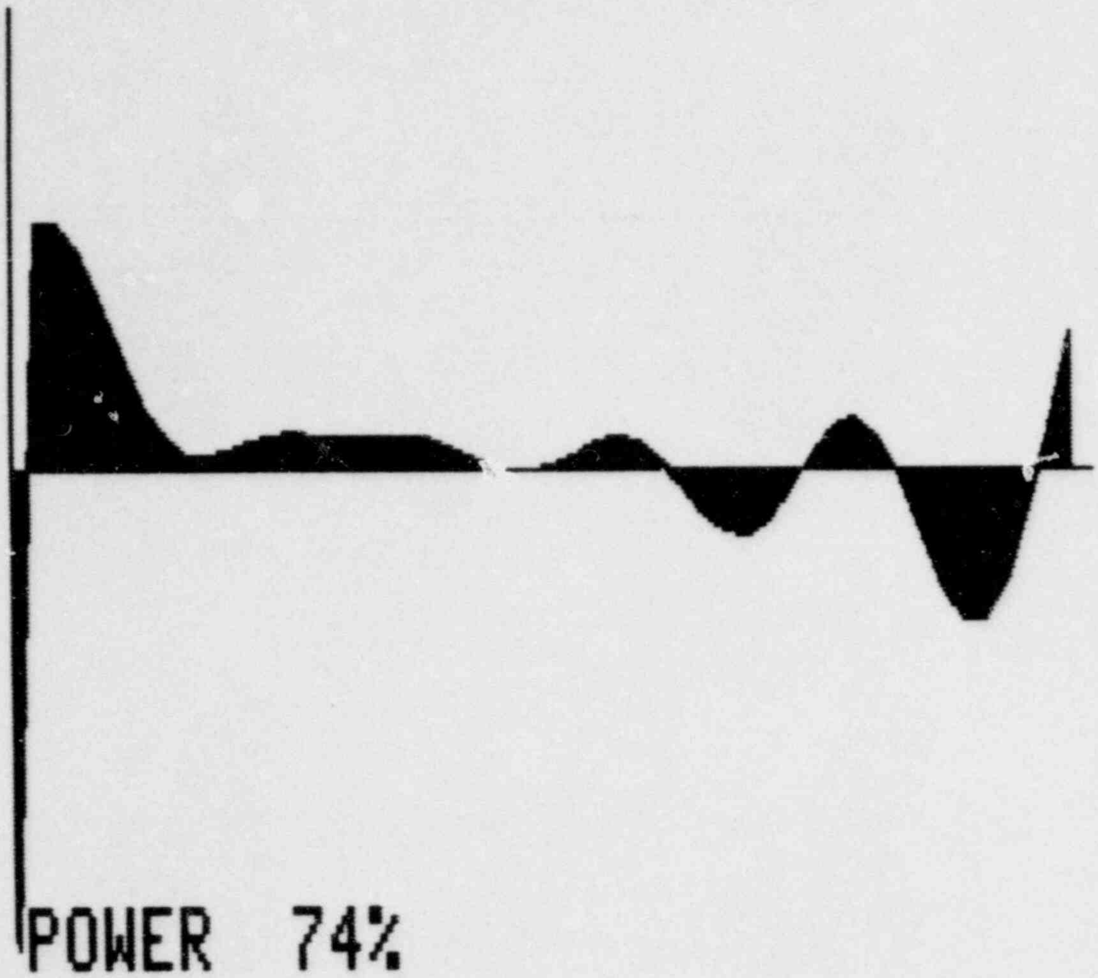

Figure 9.0 Linear Fourier representation at normal conditions, 74% power.

and 3. Hence the display was judged very adequate for Question 1, but grossly inadequate for Questions 2 and 3.

Array Plot

An Array Plot, as used in Figure 11.0, is defined as an m x n array where each cell represents a unique parameter. The values could be binary, such as in existing annunciator panels, or could take on a number of values. Figure 11.0 displays the primary system parameters on the top row and the secondary system parameters on the bottom. The display allowed five different value ranges to be displayed by using color coding. If a parameter value was within the bottom 5% of its total range, its rectangle was coded in dark blue. If the value was greater than 5%, but still below the normal range, it was coded cyan (greenish blue). Green was used when the value was within the normal range. At the high end, yellow represented a value above normal range, and red depicted values greater than 95% of the total range. Hence the coding scheme follows the natural color spectrum to indicate value. This technique could be made more precise by using additional colors. Close attention must be paid to the choice of color for the text foreground and the rectangular background to ensure legibility.

The sequence of displays for both L6-5 and L3-7 are available from the author. The technique is adequately suited for pattern recognition and problem detection but only marginal for severity. Additional colors could be used to improve the latter case but one quickly encounters the problem of subtle color detection by operators under stress conditions. By their nature, Array Plots are imprecise. However, the technique is a vast improvement over existing alarm and annunciator systems.

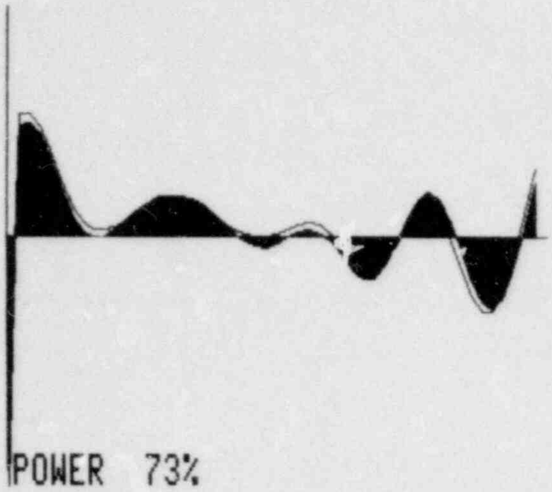

Figure 9.1 Linear Fourier representation for L6-5.

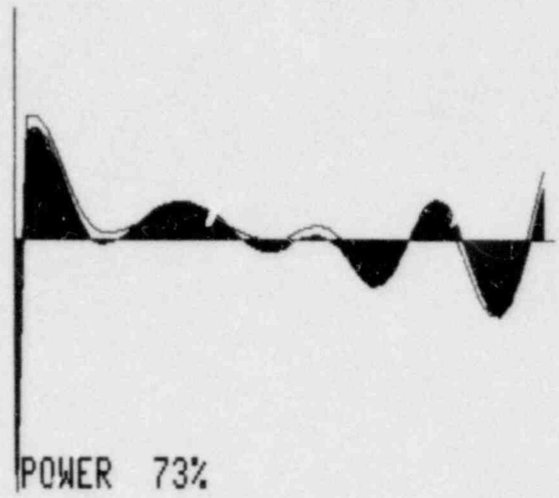

Figure 9.2 Linear Fourier representation for L6-5.

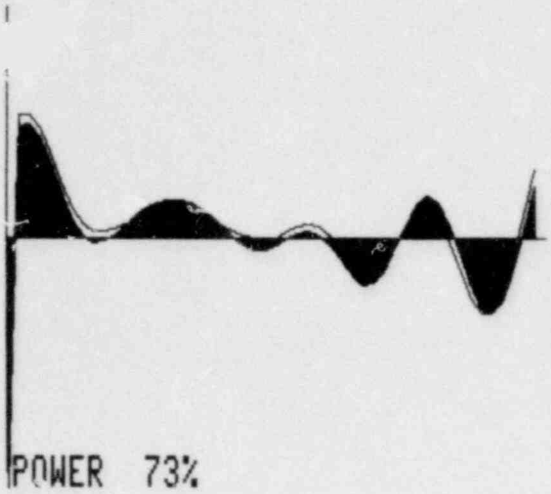

Figure 9.3 Linear Fourier representation for L6-5.

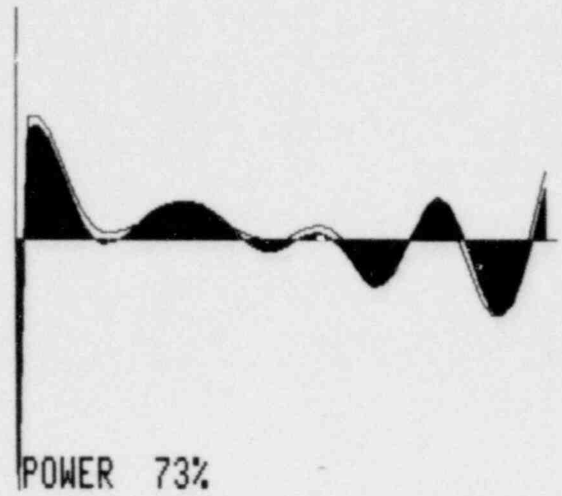

Figure 9.4 Linear Fourier representation for L6-5.

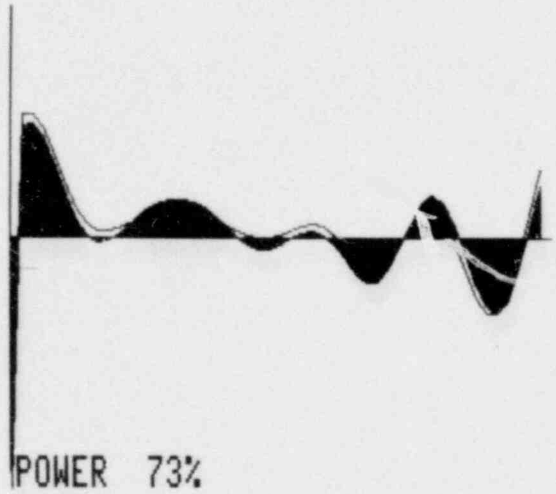

Figure 9.5 Linear Fourier representation for L6-5.

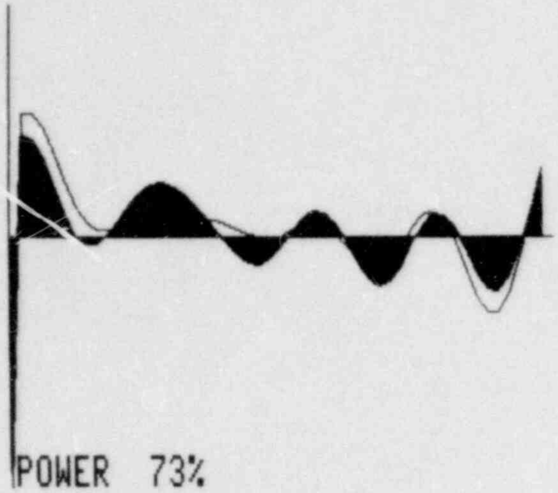

Figure 9.6 Linear Fourier representation for L6-5.

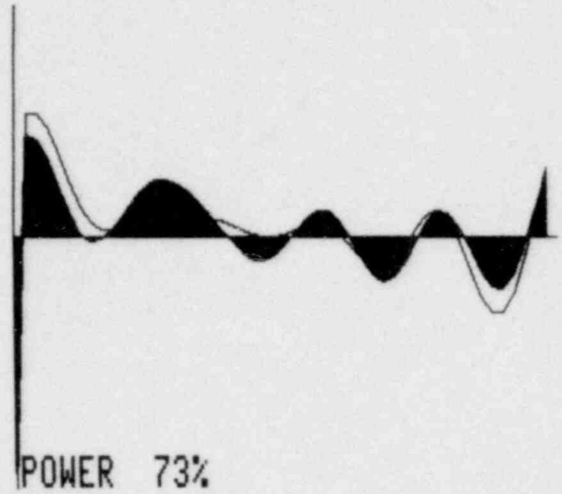

Figure 9.7 Linear Fourier representation for L6-5.

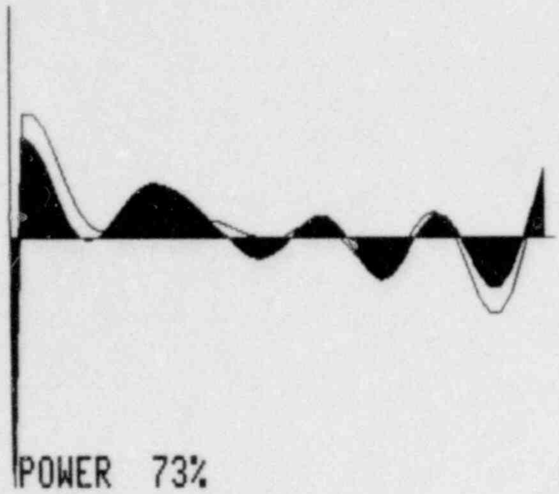

Figure 9.8 Linear Fourier representation for L6-5.

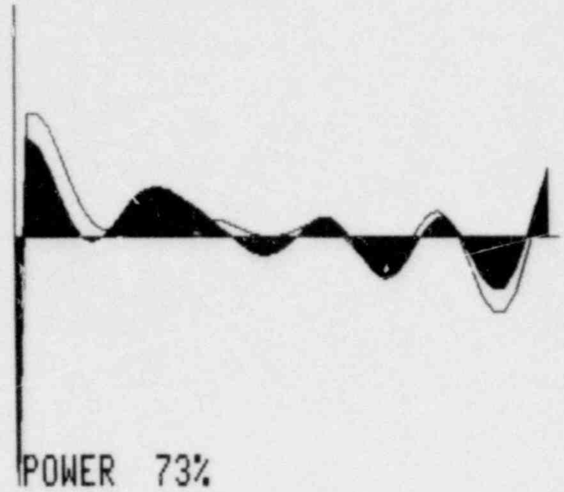

Figure 9.9 Linear Fourier representation for L6-5.

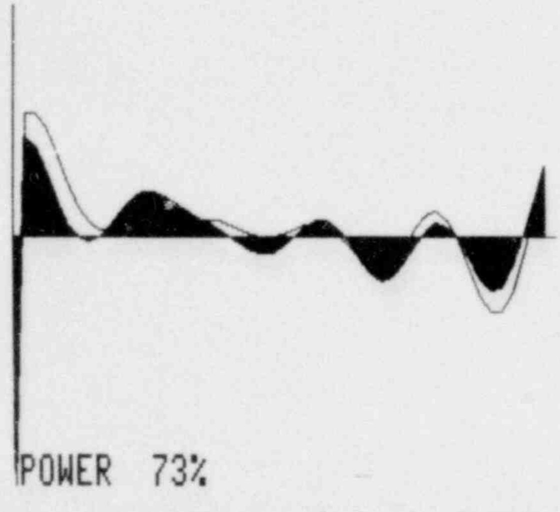

Figure 9.10 Linear Fourier representation for L6-5.

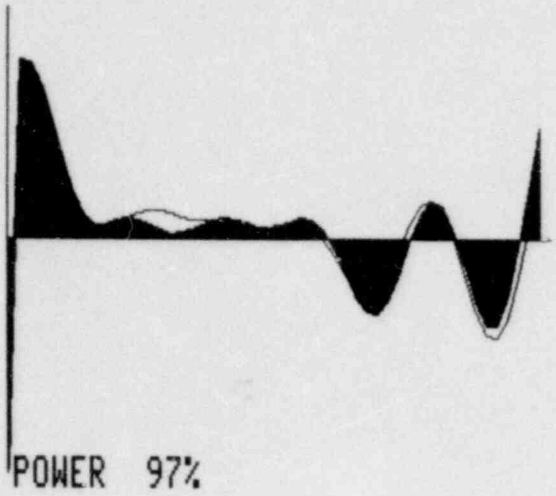

Figure 9.11 Linear Fourier representation for L3-7.

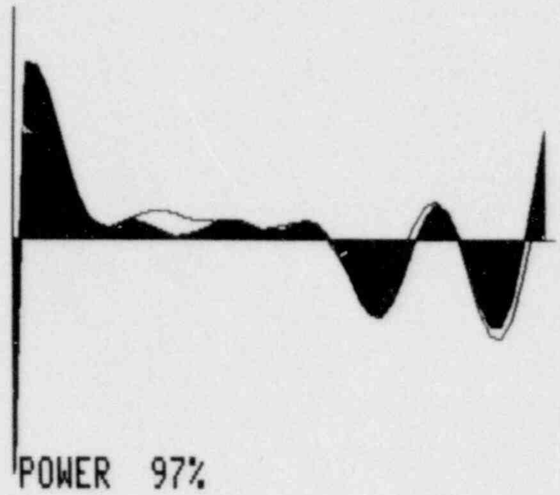

Figure 9.12 Linear Fourier representation for L3-7.

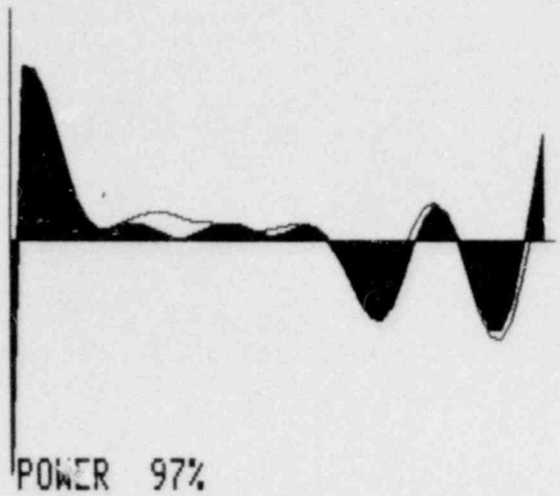

Figure 9.13 Linear Fourier representation for L3-7.

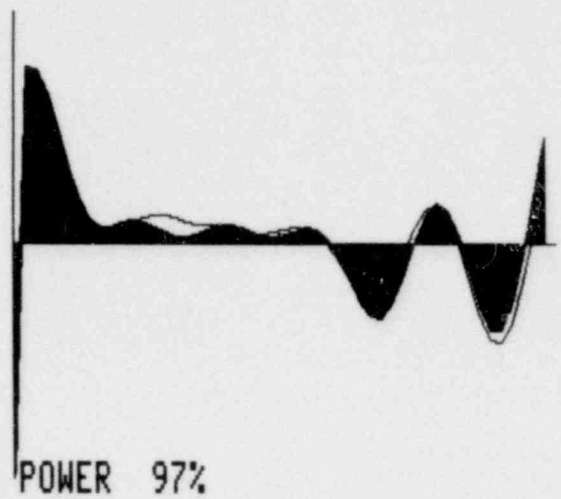

Figure 9.14 Linear Fourier representation for L3-7.

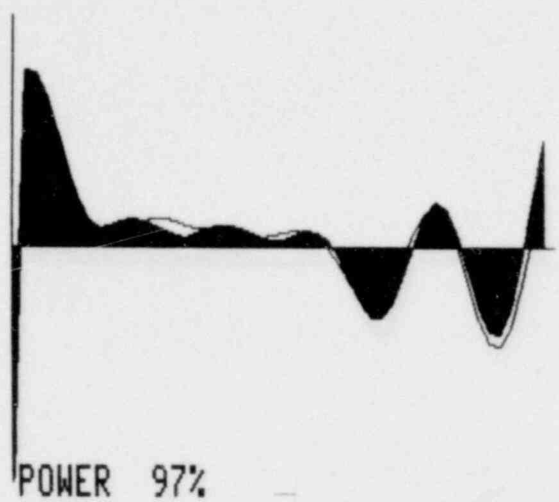

Figure 9.15 Linear Fourier representation for L3-7.

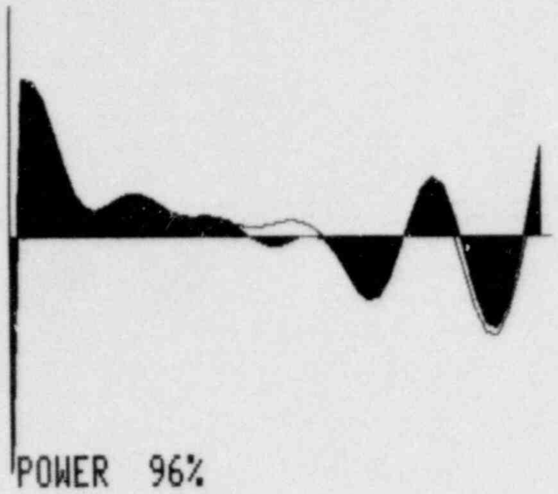

Figure 9.16 Linear Fourier representation for L3-7.

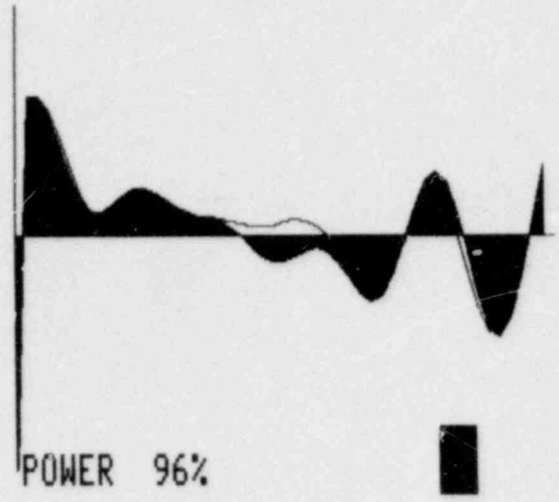

Figure 9.17 Linear Fourier representation for L3-7.

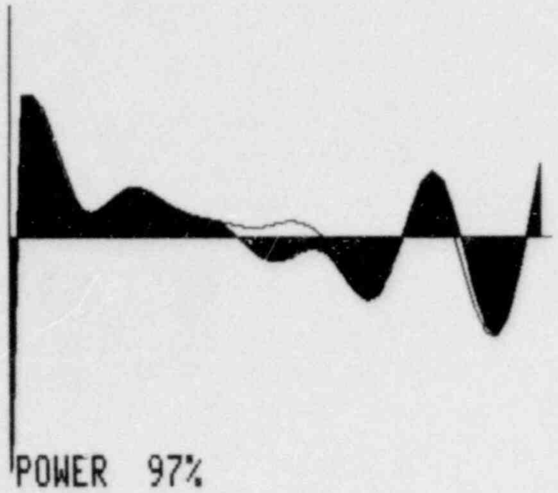

Figure 9.18 Linear Fourier representation for L3-7.

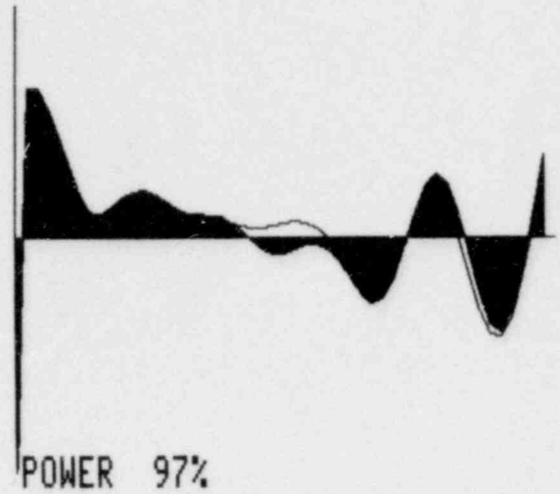

Figure 9.19 Linear Fourier representation for L3-7.

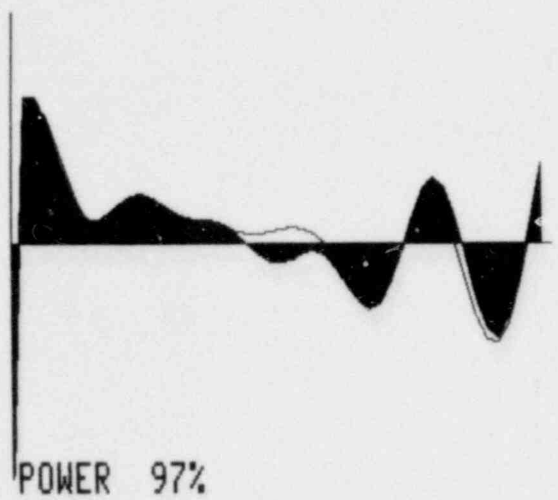

Figure 9.20 Linear Fourier representation for L3-7.

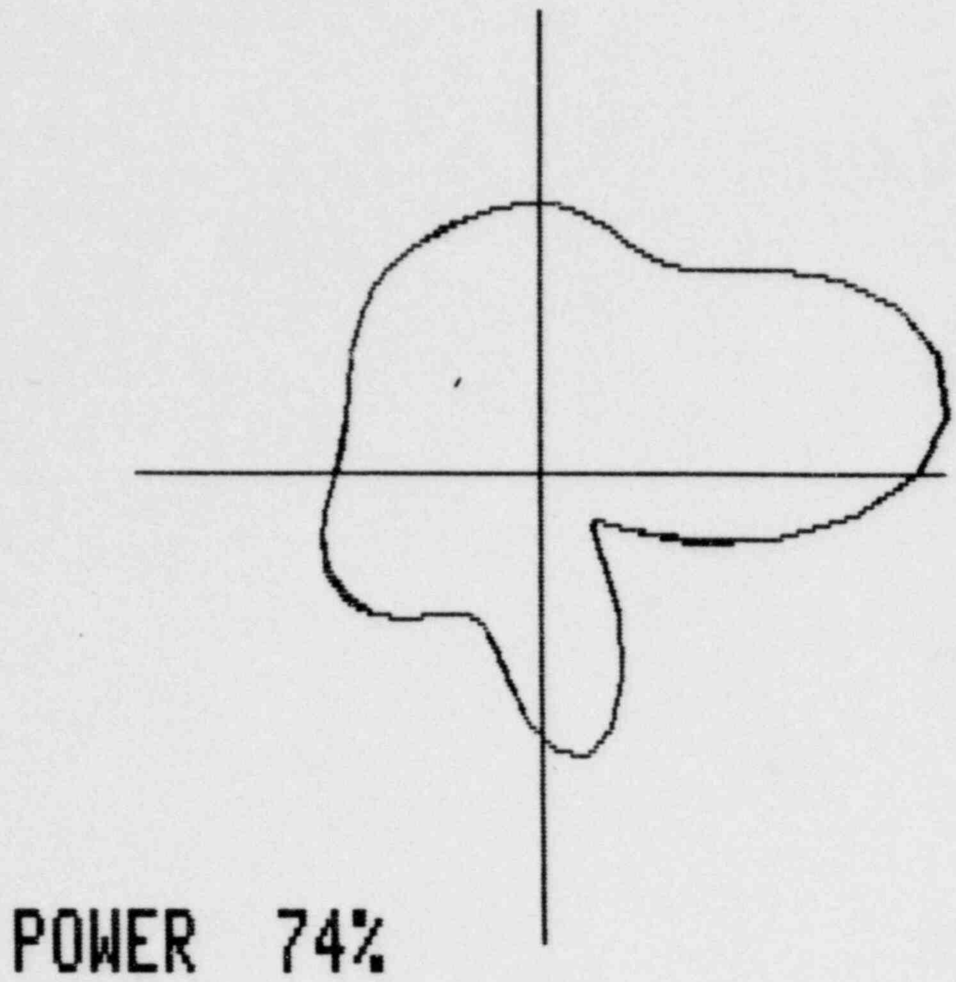

Figure 10.0 Polar Fourier representation at normal conditions, 74% power.

Copies of Figures 11.1—11.20 were not included since they use color to indicate value. The figures reproduced in black and white would look identical to Figure 11.0.

Chernoff Face

The final technique, the Chernoff Face, is a radical departure from all others and therein may lay its usefulness. The Face is a graphical method in which every multivariate or multidimensional system is visualized as a computer-drawn, human-like face. Each feature of the Face can reflect the value of a variable. This technique is definitely holistic and capitalizes on man's ability to detect subtle changes in human-like expressions that have been learned from childhood. Faces have been used successfully in both comparison tasks (for cluster analysis) and in making limited absolute decisions.[10] The Face, as drawn in Figure 12.0, can represent up to 20 different variables. The sample data contained only 11 non-binary variables, so a decision had to be made as to which facial features to vary and which to keep constant. Chernoff and Rizvi[11] claim that the assignment is immaterial, at least for cluster analysis. Mezzich and Worthington[12] give some evidence to the contrary and present an interesting problem. Would the technique succeed or fail due to its concept or due to the assignment of facial features? For this application, it was decided to concentrate on the eyes, nose, and mouth with the assignments as listed in Table 19.

Figures 12.1 through 12.5 show surprising sensitivity to minor fluctuations in system parameters, particularly the change in brow angle between steps 1 and 2 (Figures 12.1 and 12.2). While the brow angle can be controlled independently, in this case it follows the slant of the eyes which represent primary flow. The sudden change

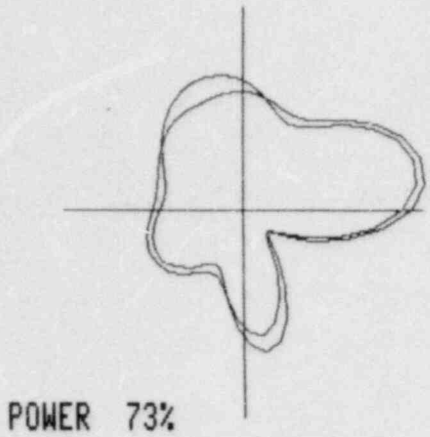

Figure 10.1 Polar Fourier representation for L6-5.

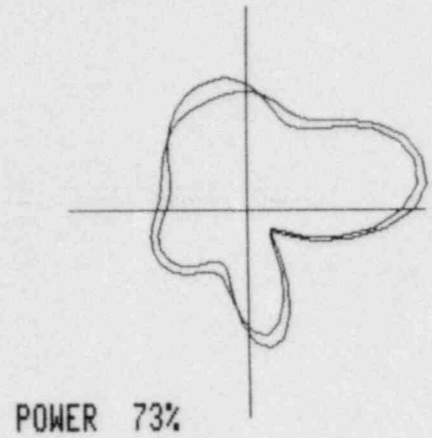

Figure 10.2 Polar Fourier representation for L6-5.

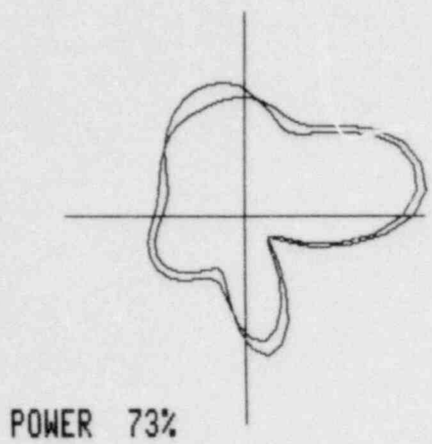

Figure 10.3 Polar Fourier representation for L6-5.

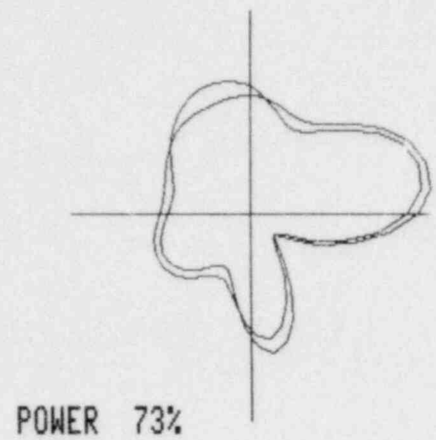

Figure 10.4 Polar Fourier representation for L6-5.

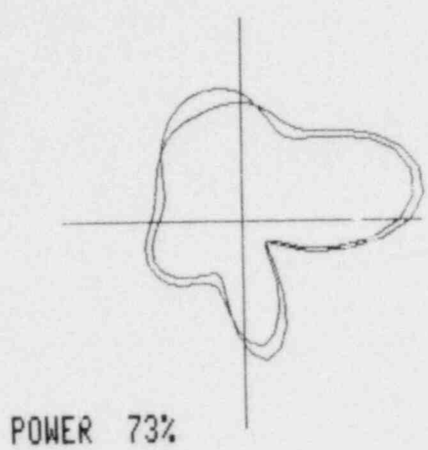

Figure 10.5 Polar Fourier representation for L6-5.

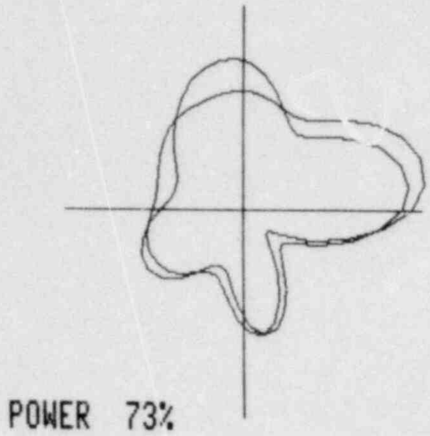

Figure 10.6 Polar Fourier representation for L6-5.

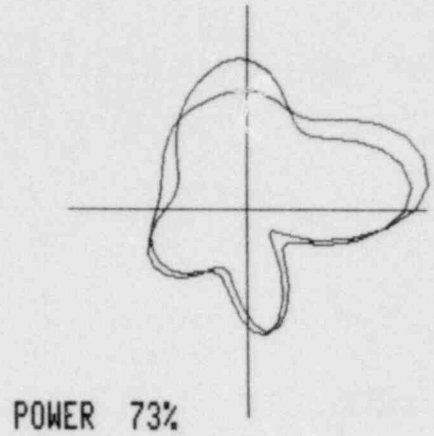

Figure 10.7 Polar Fourier representation for L6-5.

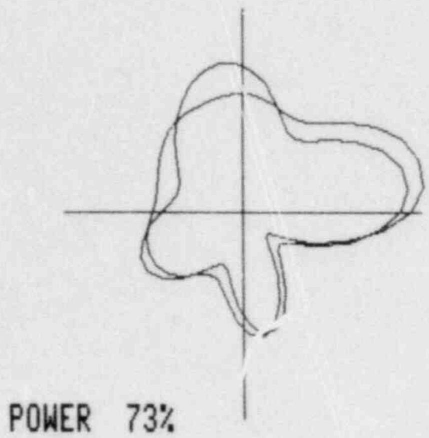

Figure 10.8 Polar Fourier representation for L6-5.

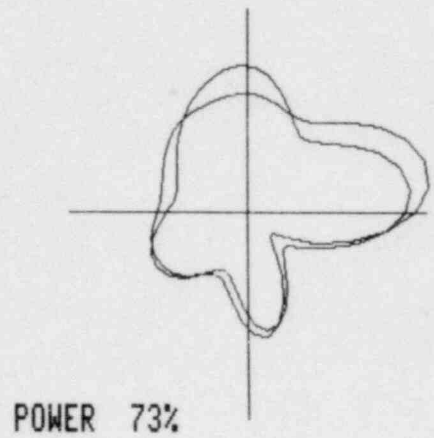

Figure 10.9 Polar Fourier representation for L6-5.

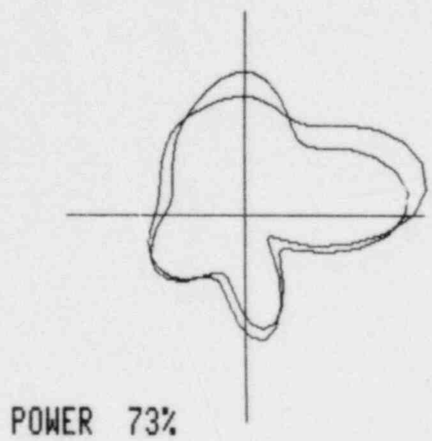

Figure 10.10 Polar Fourier representation for L6-5.

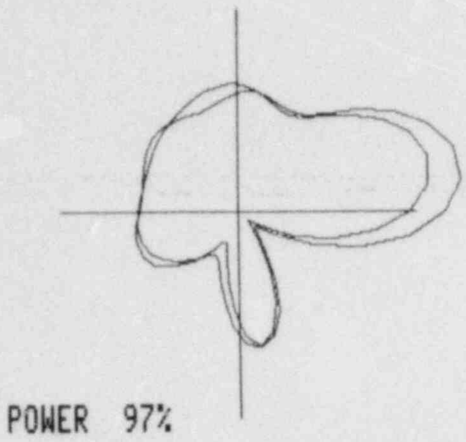

Figure 10.11 Polar Fourier representation for L3-7.

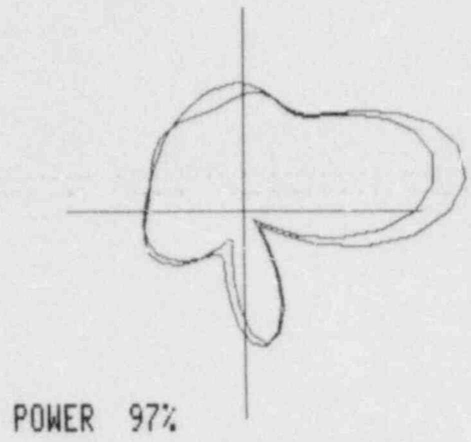

Figure 10.12 Polar Fourier representation for L3-7.

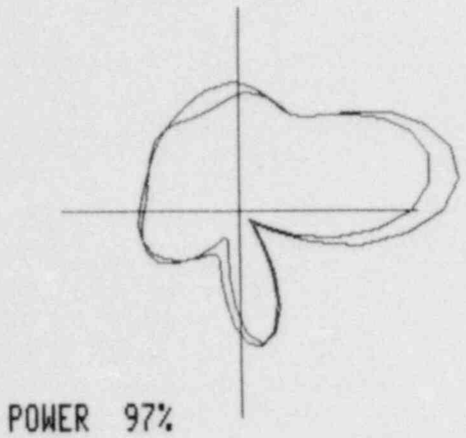

Figure 10.13 Polar Fourier representation for L3-7.

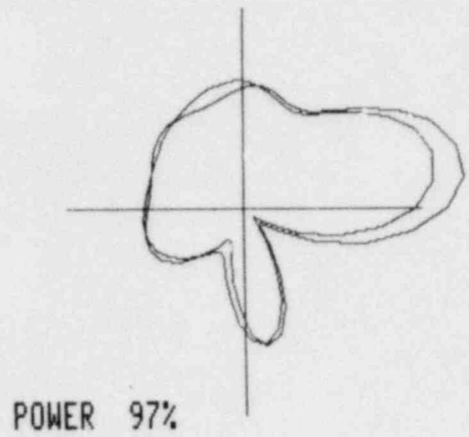

Figure 10.14 Polar Fourier representation for L3-7.

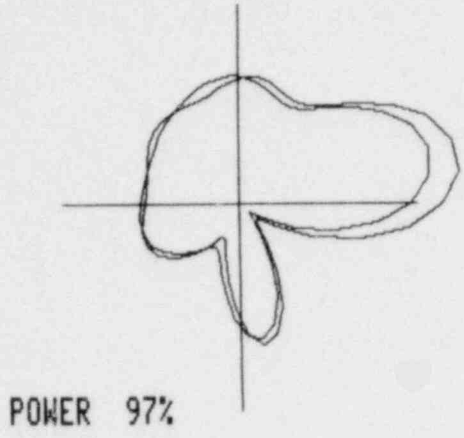

Figure 10.15 Polar Fourier representation for L3-7.

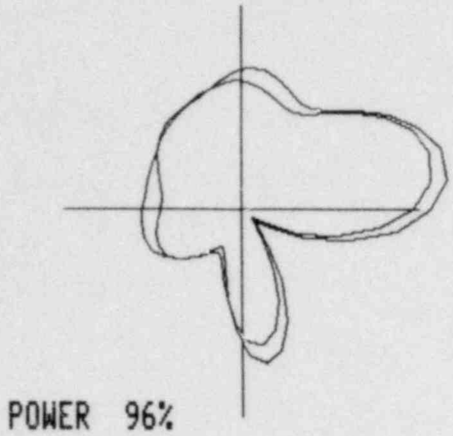

Figure 10.16 Polar Fourier representation for L3-7.

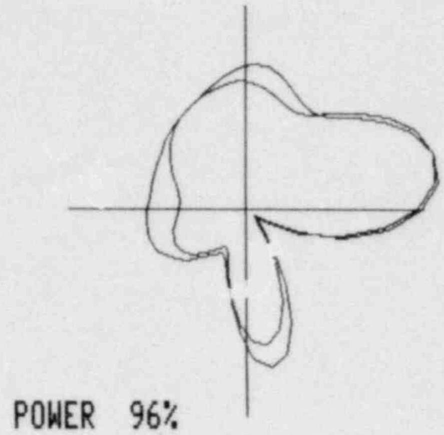

Figure 10.17 Polar Fourier representation for L3-7.

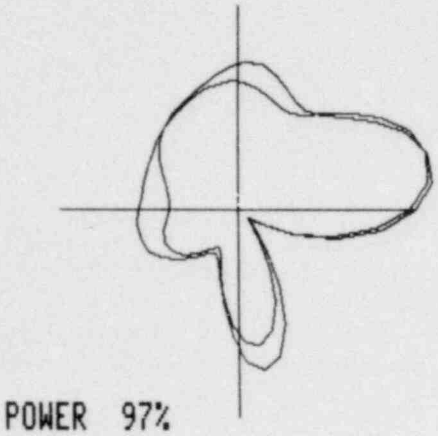

Figure 10.18 Polar Fourier representation for L3-7.

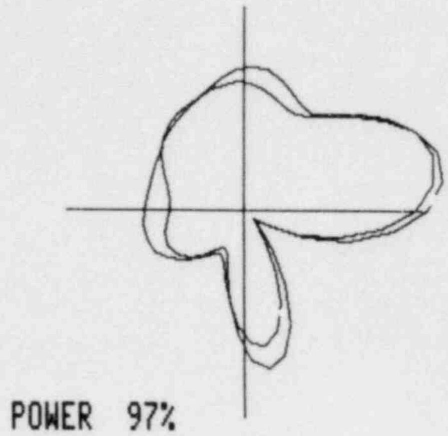

Figure 10.19 Polar Fourier representation for L3-7.

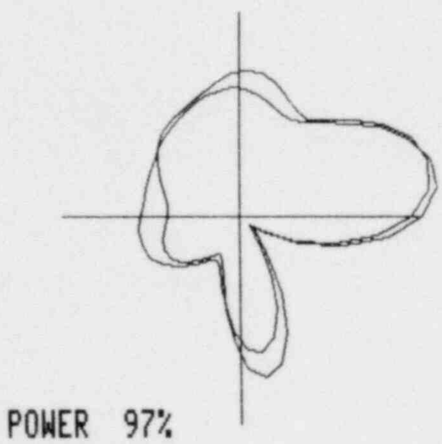

Figure 10.20 Polar Fourier representation for L3-7.

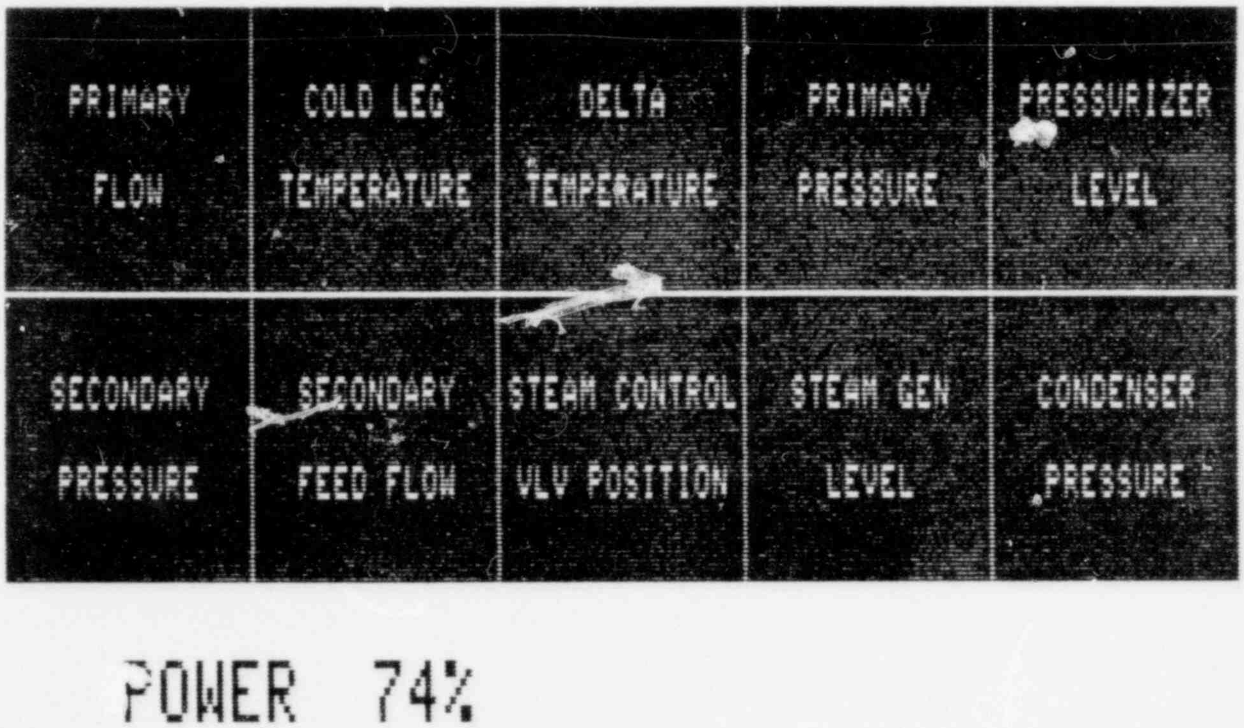

Figure 11.0 Array Plot representation at normal conditions, 74% power.

in nose width in Figure 12.6 indicates the loss of secondary feed flow, and the decrease in steam generator level is shown through the change in the length of the mouth. Similar sensitivity is found during the L3-7 transient. The separation of the eyes is controlled by the primary pressure; the height of the center of the eyes, reflected in the brow change, represents pressurizer level. While this technique needs much further work for Process Control, it was still judged very adequate for both Questions 1 and 2 and adequate for Question 3.

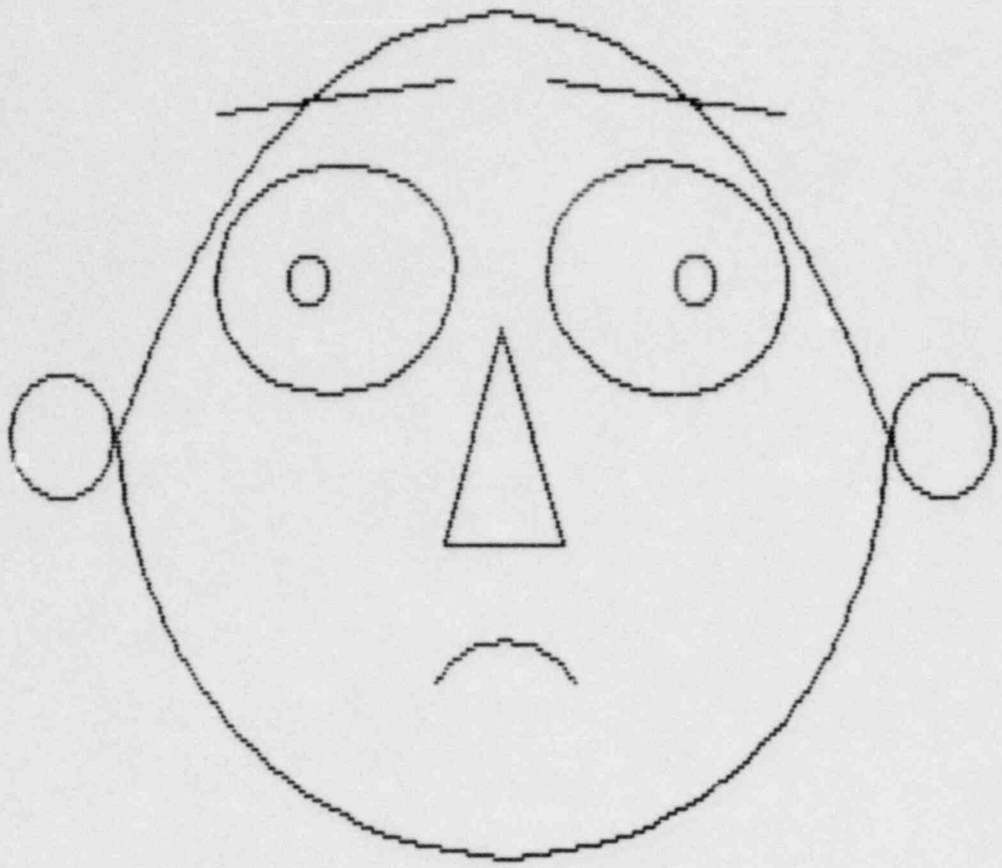

Figure 12.0 Chernoff Face representation at normal conditions, 74% power.

Table 19. Assignment of variables to facial features for Chernoff faces

Variable	Facial Feature
Power	Size (half length) of eyes
Primary Flow	Slant of eyes
Cold Leg Temperature	Eccentricity of eyes
Delta Temperature	Position of pupils
Primary Pressure	Separation of eyes
Pressurizer Level	Height of center of eyes
Secondary Pressure	Length of nose
Secondary Feed Flow	Nose width
Steam Control Valve Position	Curvature of mouth
Steam Generator Level	Length of mouth
Condenser Pressure	Position of center of mouth

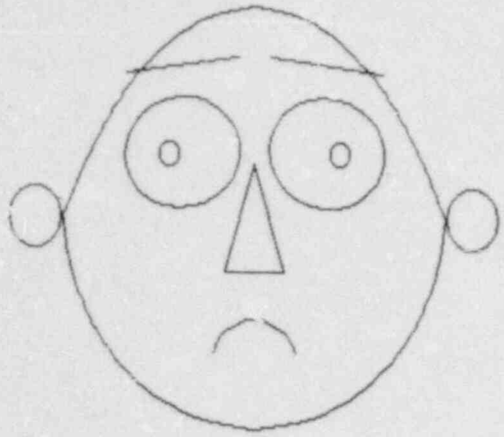

Figure 12.1 Chernoff Face representation for L6-5.

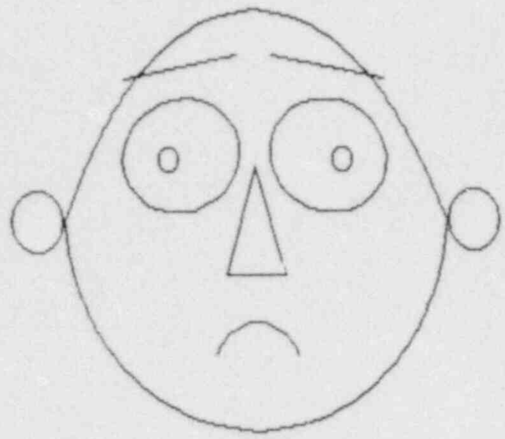

Figure 12.2 Chernoff Face representation for L6-5.

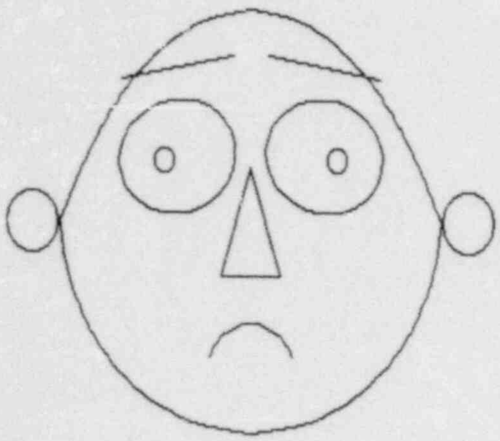

Figure 12.3 Chernoff Face representation for L6-5.

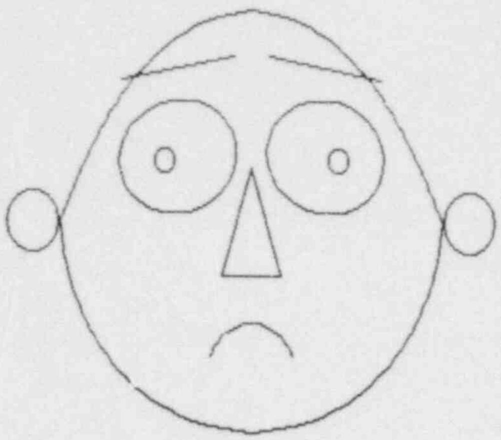

Figure 12.4 Chernoff Face representation for L6-5.

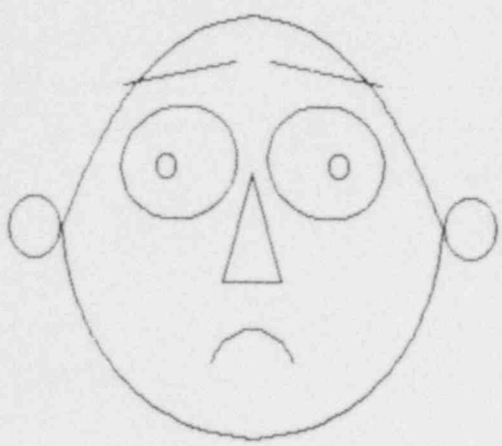

Figure 12.5 Chernoff Face representation for L6-5.

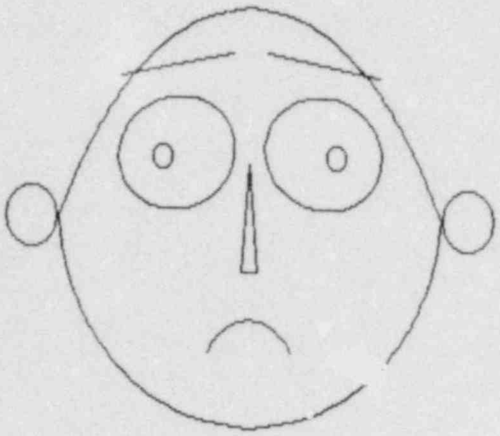

Figure 12.6 Chernoff Face representation for L6-5.

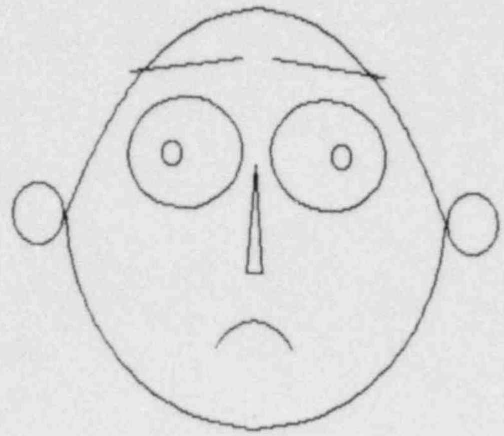

Figure 12.7 Chernoff Face representation for L6-5.

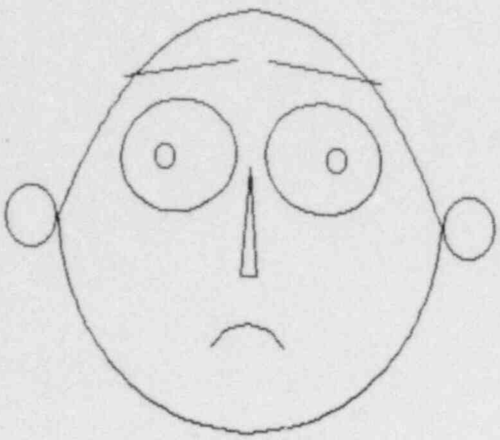

Figure 12.8 Chernoff Face representation for L6-5.

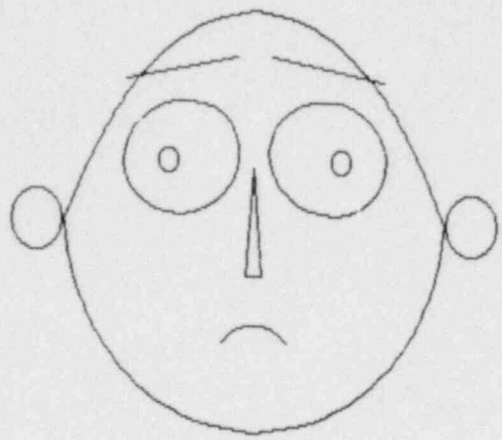

Figure 12.9 Chernoff Face representation for L6-5.

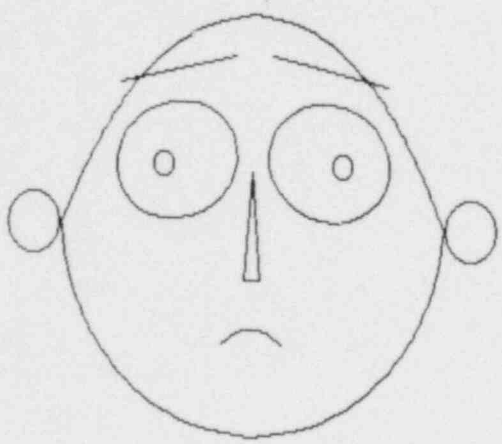

Figure 12.10 Chernoff Face representation for L6-5.

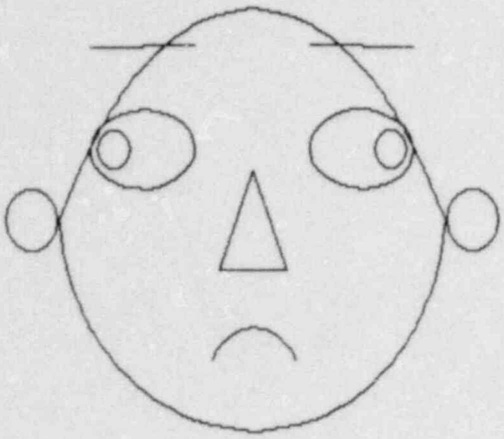

Figure 12.11 Chernoff Face representation for L3-7.

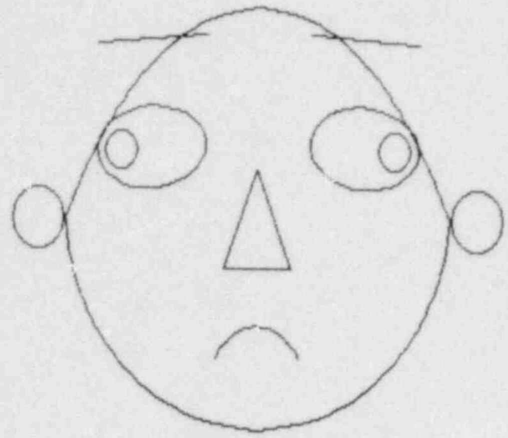

Figure 12.12 Chernoff Face representation for L3-7.

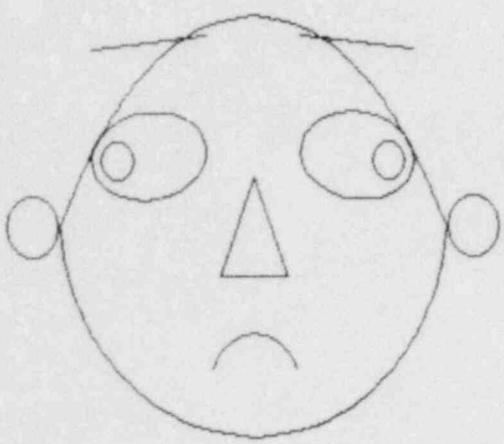

Figure 12.13 Chernoff Face representation for L3-7.

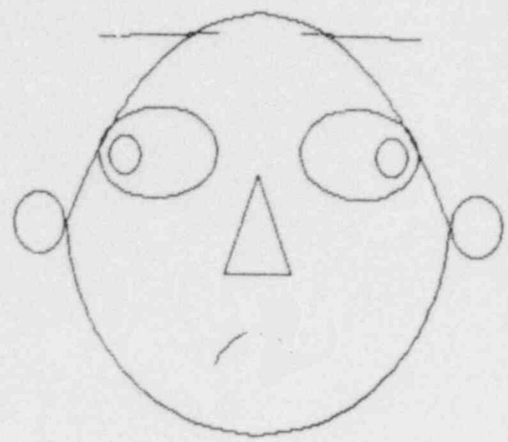

Figure 12.14 Chernoff Face representation for L3-7.

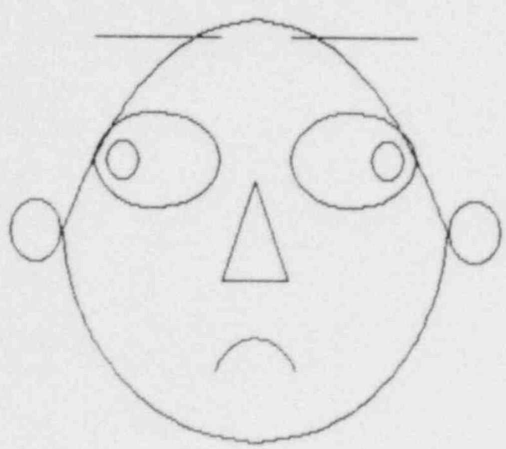

Figure 12.15 Chernoff Face representation for L3-7.

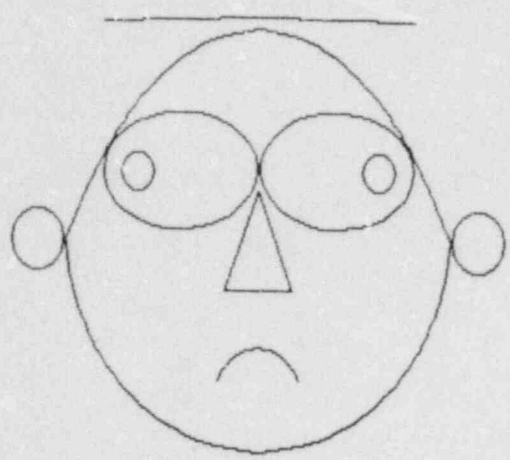

Figure 12.16 Chernoff Face representation for L3-7.

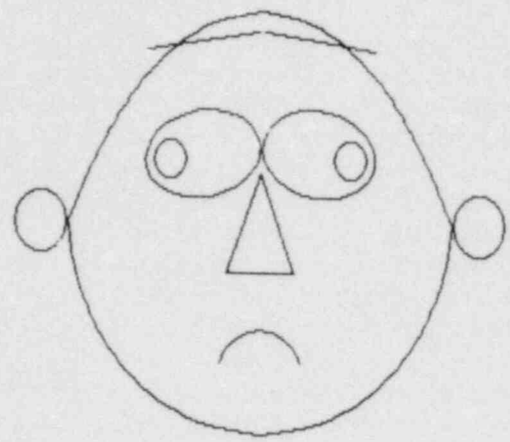

Figure 12.17 Chernoff Face representation for L3-7.

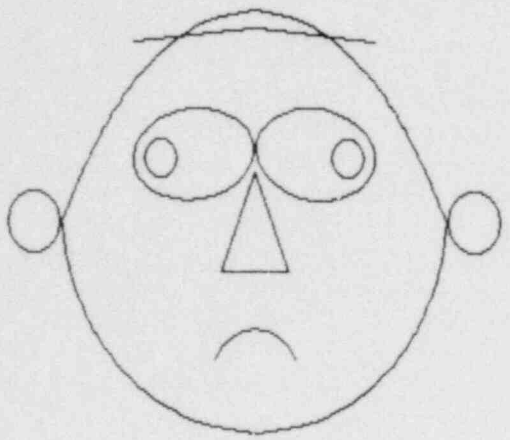

Figure 12.18 Chernoff Face representation for L3-7.

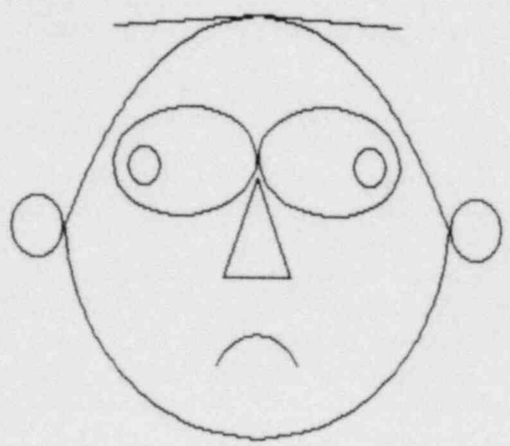

Figure 12.19 Chernoff Face representation for L3-7.

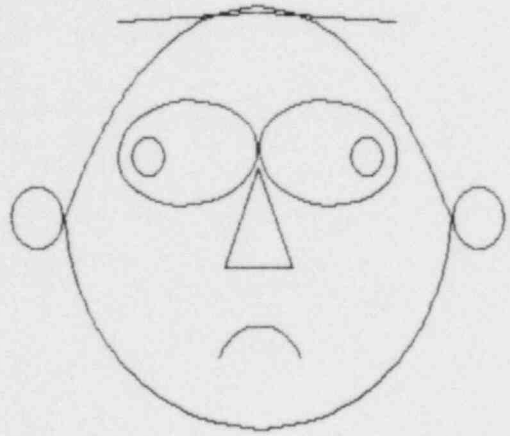

Figure 12.20 Chernoff Face representation for L3-7.

CONCLUSIONS AND RECOMMENDATIONS

The primary purpose of this study was to collect available display techniques for evaluation. The categorizations in the section, entitled "Multivariate Displays" effectively bring together and explain the different alternatives and give the display designer a method of determining the appropriate techniques. In the sections "Process Control Displays" and "Multivariate Display Designs," a sample problem was posed and the method was illustrated to show its simplicity and effectiveness. An ancillary result was the initial selection of techniques for the systems state problem of a pressurized water reactor. These results should not be interpreted as definitive, but do indicate the relative applicability of the few techniques implemented. Although each display implemented was designed with the principles of human factors in mind, many improvements can be made on each.

Table 20 summarizes the display evaluations described previously. The adequacy of each technique to answer the three questions asked of the data is shown and the list is ordered from best to worst. The results are interesting because the questions themselves seem to be at odds with each other. Can a single display be designed to meet all three uses equally well? The results seem to indicate that it cannot. However some techniques, on the whole, are much better than others.

The Circular Profile has good pattern recognition features but has shortcomings in portraying qualitative information. It also has problems in the fill function, but that is not insurmountable. The Chernoff Face concept is novel and potentially powerful. A great deal of training is required but the end result may surpass anything available today. The Fourfold Circular Display washes out normal fluctuations without hiding the initiation of transients. However, qualitative information is again marginal. Both the Deviation Bar Chart and Linear Profile are certainly viable techniques; the Array Plot also has potential. The Simple Bar Chart, along with Polar and Linear Fourier Representations, can be excluded from the list for this type of problem. This is not to say that they should be discarded entirely. There may be many problems for which these techniques would be ideally suited.

For the short term, the top six techniques should be looked at more closely for the systems state problem. Many improvements can be made and suitable experiments need to be conducted before choosing the optimum technique. In the long term, the method presented in this report should be refined by posing other problems and then following a similar cycle of testing alternatives. There never is, and never will be, a single display technique that satisfies all requirements. The display designer must know the available alternatives and their applications and attempt to formalize the design for the benefit of those that follow. This report is a first step in that direction.

Table 20. Summary of evaluations for the nine display techniques (ranked from best to worst)

Technique Used	How Well Is the System Working?	What Is the Problem?	How Severe Is the Problem?
Circular Profile	Very adequate	Very adequate	Adequate
Chernoff Face	Very adequate	Very adequate	Adequate
Fourfold Circular Display	Very adequate	Very adequate	Marginal
Deviation Bar Chart	Adequate	Adequate	Adequate
Linear Profile	Marginal	Adequate	Adequate
Array Plot	Adequate	Adequate	Marginal
Simple Bar Chart	Grossly inadequate	Marginal	Adequate
Polar Fourier Representation	Very adequate	Grossly inadequate	Grossly inadequate
Linear Fourier Representation	Adequate	Grossly inadequate	Grossly inadequate

REFERENCES

1. H. Chernoff, *Graphical Representation as a Discipline*, AD-A056-633, April 1978.

2. H. Chernoff, "Graphical Representation as a Discipline," in P. C. C. Wang, *Graphical Representation of Multivariate Data*, New York: Academic Press, 1978, pp. 1-12.

3. J. R. Beniger, "Science's 'Unwritten' History: The Development of Quantitative and Statistical Graphics," *71st Annual Meeting of the American Sociological Association, New York, New York, August 30 - September 3, 1976*, p. 1.

4. J. R. Beniger and D. L. Robyn, "Quantitative Graphics in Statistics: A Brief History," *American Statistician, 32*, 2, 1979, pp. 1-11.

5. W. H. Huggins and D. R. Entwisle, *Iconic Communications: An Annotated Bibliography*, Baltimore: Johns Hopkins Press, 1974, p. 1.

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8. M. E. Spear, *Practical Charting Techniques*, New York: McGraw Hill, 1969.

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10. P. C. C. Wang, *Graphical Representation of Multivariate Data*, New York: Academic Press, 1978.

11. H. Chernoff and M. H. Rizvi, "Effect on Classification Error of Random Permutations of Features in Representing Multivariate Data by Faces," *Journal of the American Statistical Association, 70*, 1975, p. 548.

12. J. E. Mezzich and D. R. L. Worthington, "A Comparison of Graphical Representations of Multidimensional Psychiatric Diagonostic Data," in P. C. C. Wang, *Graphical Representation of Multivariate Data*, New York: Academic Press, 1978, p. 123.

APPENDIX A

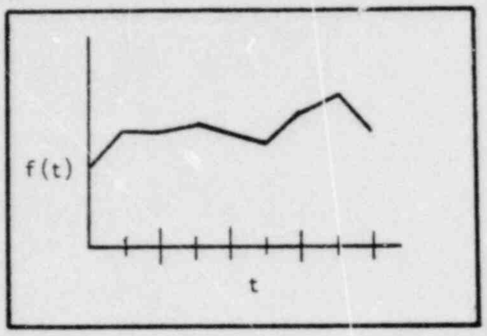
DISPLAY FORMAT SUMMARIES FOR THE 65 REPRESENTATION TECHNIQUES

APPENDIX A

DISPLAY FORMAT SUMMARIES FOR THE 65 REPRESENTATION TECHNIQUES

NAME: Arithmetic Line Chart (2D) I.D.#: 1

DESCRIPTION: Chart with two orthogonal axes. The horizontal axis (abscissa) usually indicates time while the vertical axis (ordinate) indicates values that are a function of the abscissa. succe-sssive data points are connected by a straight line.



INPUT DATA TYPE:
- Unidimensional
- Univariate
- Series

USE CATEGORY:
- Approximate value
- Prediction
- Pattern recognition

SPECIFIC USES:
* For a series where there are many successive values to be portrayed.
* For close reading and interpolation.
* When emphasis should be on movement rather than on actual amounts.

Not to be used for:
* When there are relatively few plotted values in the series.
* When emphasis should be on changes in amounts rather than on movement.
* To emphasize differences between values or amounts on different data.
* When movement of data is extremely violent or irregular.
* When presentation is for popular appeal.

COMMENTS:

For 3D see Perspective Plot (#51).
See Schmid or Spear for detailed recommendations.

REFERENCES:

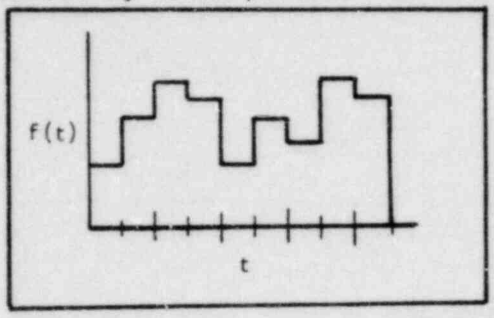
C.F. Schmid, S.E. Schmid, Handbook of Graphic Presentation, Second Edition, New York: John Wiley and Son, 1979, pp. 32

M.E. Spear, Practical Charting Techniques, New York: McGraw-Hill, 1969, pp. 72

DISPLAY FORMAT SUMMARY

NAME: Staircase (Step) Chart (2D) I.D.#: 2

DESCRIPTION: Similar to an Arithmetic Line Chart, however successive points are connected by lines parallel to the axes.



INPUT DATA TYPE:
Unidimensional
Univariate
Series

USE CATEGO /:
Ap roximate value

SPECIFIC USES:

* For showing abrupt fluctuations in data.
* When presenting irregular periods of time.
* When depicting frequency distributions.

COMMENTS:

For 3D see Perspective Plot (#51)

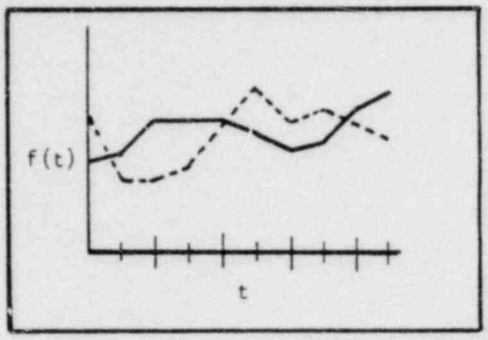
REFERENCES:

M. E. Spear, Practical Charting Techniques, New York: McGraw-Hill, 1969, pp. 110

DISPLAY FORMAT SUMMARY

NAME: Multiple Curve Chart I.D.#: 3

DESCRIPTION: Similar to an Arithmetic Line Chart. More than one curve is plotted per chart. All data has the same range for the ordinate and the abscissa.



INPUT DATA TYPE:

Unidimensional
Limited Multivariate
Series

USE CATEGORY:

Approximate value
Deviation
Normal
Range
Prediction
Pattern Recognition

SPECIFIC USES:

* When several series of the same range are shown for comparison.

COMMENTS:

Keep the number of curves to < 5.

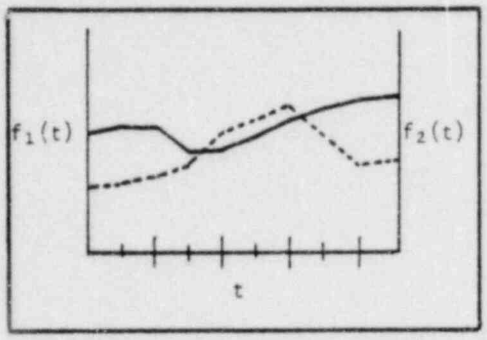
REFERENCES:

M.E. Spear, Practical Charting Techniques, New York: McGraw-Hill, 1969, pp. 84

DISPLAY FORMAT SUMMARY

NAME: Multiple Amount Chart　　　　　I.D.#: 4

DESCRIPTION: This chart has two different ordinates, one at each extreme of a common abscissa. One curve is plotted using the abscissa and the left ordinate, the second curve uses the same abscissa but the right ordinate.



INPUT DATA TYPE:

Duodimensional
Limited Multivariate
Series

USE CATEGORY:

Approximate value
Prediction
Pattern recognition

SPECIFIC USES:

* For comparison of two series with unlike units that extend over a common abscissa.

COMMENTS:

No more than two curves/display.
Must use a common baseline.

REFERENCES:

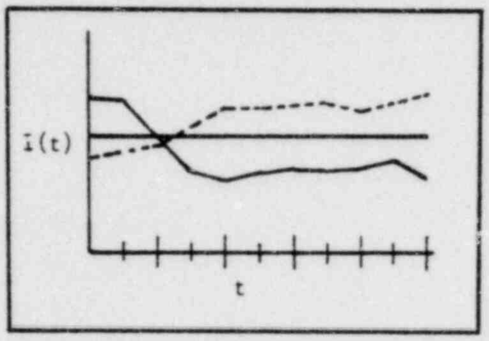
C.F. Schmid, S.E. Schmid, Handbook of Graphics Representation, Second Edition, New York: John Wiley and Sons, 1979, pp. 42

M.E. Spear, Practical Charting Techniques, New York: McGraw-Hill, 1969, pp. 88

DISPLAY FORMAT SUMMARY

NAME: Index Chart   I.D.#: 5

DESCRIPTION: Similar to a Multiple Curve Chart except the ordinate values are normalized to a selected base or index.



INPUT DATA TYPE:

- Multidimensional
- Limited Multivalue
- Series

USE CATEGORY:

- Normal
- Range
- Prediction
- Pattern recognition

SPECIFIC USES:

* For comparing the relationship of two series which differ greatly in amount.
* When the relationship of two or more series of unlike basic units is to be shown.

COMMENTS:

Since all data is normalized to a common baseline, one cannot read values directly.

REFERENCES:

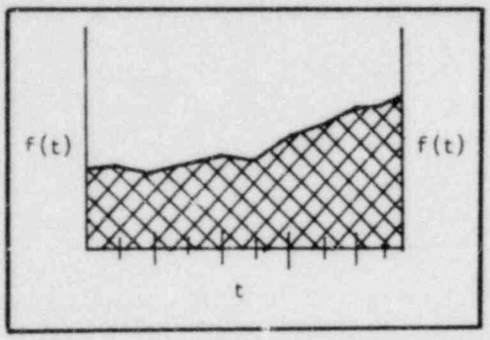
C.F. Schmid, S.E. Schmid, Handbook of Graphical Representation, Second Edition, New York: John Wiley and Sons, 1979, pp. 44

M.E. Spear, Practical Charting Techniques, New York: McGraw-Hill, 1969, pp. 92

DISPLAY FORMAT SUMMARY

NAME: Simple Surface/Silhoutte Chart (2D) I.D.#: 6

DESCRIPTION: Similar to an Arithmetic Line Chart. It depicts a single series with shading, crosshatching, phototgraphs or illustrations falling in the area between the data and the baseline.



INPUT DATA TYPE:

Unidimensional
Univariate
Series

USE CATEGORY:

Approximate value
Prediction
Pattern recognition

SPECIFIC USES:

* When the magnitude of a series is to be emphasized.
* When some portion of a chart is to be accented for a specific purpose.

COMMENTS:

For 3D see Perspective Plot (#51).

REFERENCES:

C.F. Schmid, S.F. Schmid, Handbook of Graphical Representation, Second Edition, New York: John Wiley and Sons, 1979, pp. 50.

M.E. Spear, Practical Charting Techniques, New York: McGraw-Hill, 1969, pp. 141.

DISPLAY FORMAT SUMMARY

NAME: Staircase (Step) Surface Chart (2D) I.D.#: 7

DESCRIPTION: Similar to a Staircase Chart except that the area between the data and the baseline is shaded, etc.

INPUT DATA TYPE:
Unidimensional
Univariate
Series

USE CATEGORY:
Approximate value

SPECIFIC USES:

* When the magnitude of a series is to be emphasized.
* When some portion of a chart is to be accented.
* When showing abrupt fluctuations in data.
* When presenting irregular periods of time.
* When depicting frequency distributions.

COMMENTS:

For 3D see Perspective Plot (#51).

REFERENCES:

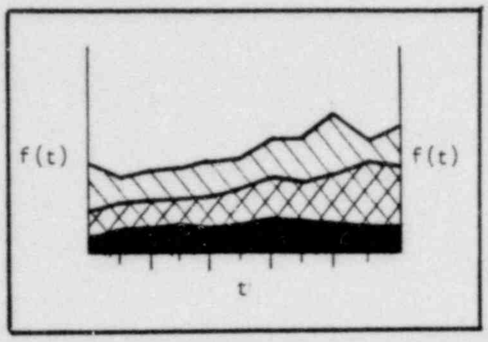
C.F. Schmid, S.E. Schmid, Handbook of Graphical Representation, Second Edition, New York: John Wiley and Sons, 1979, pp. 50.

M.E. Spear, Practical Charting Techniques, New York: McGraw-Hill, 1969, pp. 118.

DISPLAY FORMAT SUMMARY

NAME: Multiple Surface/Band Chart I.D.#: 8

DESCRIPTION: Similar to a Simple Surface Chart but contains a series of bands or strata depicting the components of a total series. Each band value is added to the previous value, i.e., it is cumulative. The right side of the chart must be closed at the maximum abscissa value.



INPUT DATA TYPE:

Unidimensional
Limited Multivariate
Series

USE CATEGORY:

Approximate value
Prediction
Pattern recognition

SPECIFIC USES:

* All of Simple Surface Chart

+

* When a general cumulative picture of components of a total series is to be shown.

Not to be used:
* When changes in the movement of a series are abrupt.
* Where accurate reading of a component is of paramount importance.

COMMENTS:

Also called a subdivided surface chart.
All the components must be related to the total.
The sequence of bands should begin with the component of least movement.

REFERENCES:

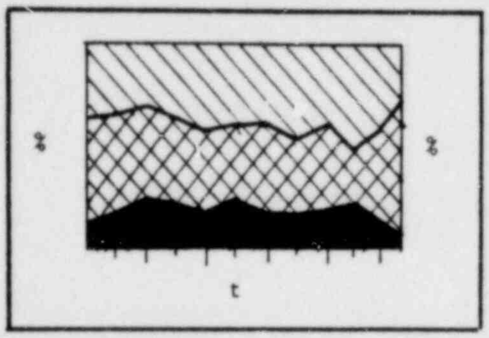
C.F. Schmid, S.E. Schmid, Handbook of Graphical Representation, Second Edition, New York: John Wiley and Sons, 1979, pp. 54.

M.E. Spear, Practical Charting Techniques, New York: McGraw-Hill, 1969, pp. 148.

DISPLAY FORMAT SUMMARY

NAME: 100% Surface Chart I.D.#: 9

DESCRIPTION: Similar to a Multiple Surface Chart except that the area above the component total also has meaning. The top of the chart must be closed at the upper limit of the ordinate as well as the right at the abscissa maximum.



INPUT DATA TYPE:
Unidimensional
Limited Multivariate
Series

USE CATEGORY:
Approximate value
Prediction

SPECIFIC USES:

* All of Multiple Surface Charts
+
* When the comlement (remainder) is important.

COMMENTS:

All components must be related.

REFERENCES:

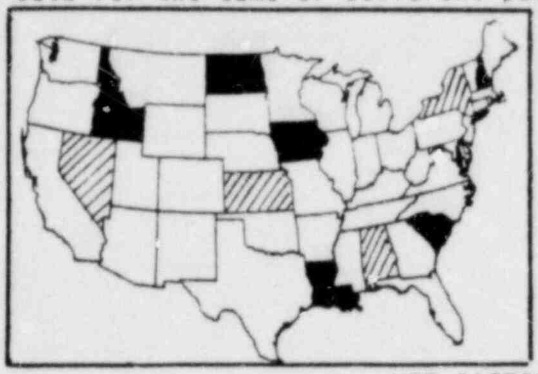
C.F. Schmid, S.E. Schmid, Handbook of Graphical Representation, Second Edition, New York: John Wiley and Sons, 1979, pp. 56.

M.E. Spear, Practical Charting Techniques, New York: McGraw-Hill, 1969, pp. 154.

DISPLAY FORMAT SUMMARY

NAME: Statistical Cartography (2D) I.D.#: 10

DESCRIPTION: Geographic or spatial map combined with the display of statistical data for the same or different parameters.



INPUT DATA TYPE:

Multidimensional
Multivariate
Discrete

USE CATEGORY:

Approximate value
Deviation
Normal
Range
Status & Warning
Pattern recognition

SPECIFIC USES:

* When portraying spatial relationships of variables.

COMMENTS:

For 3D see Perspective Plot (#51).
The same variable(s) can be shown at different locations.
Different variables can be shown at different locations.

REFERENCES:

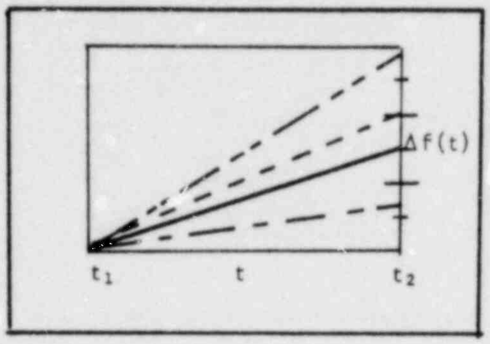
C.F. Schmid, S.E. Schmid, Handbook of Graphical Representation, Second Edition, New York: John Wiley and Sons, 1979, pp. 170

M.E. Spear, Practical Charting Techniques, New York: McGraw-Hill, 1969, pp. 275.

DISPLAY FORMAT SUMMARY

NAME: Fan Chart I.D.#: 11

DESCRIPTION: This chart shows percent changes or the index increase or decrease of items from one selected base date to another period of time.



INPUT DATA TYPE:
Unidimensional
Limited Multivariate
Limited Series

USE CATEGORY:
Deviation
Prediction

SPECIFIC USES:

* To portray rates of change for two different periods either by % or by index number.

COMMENTS:

NONE

REFERENCES:

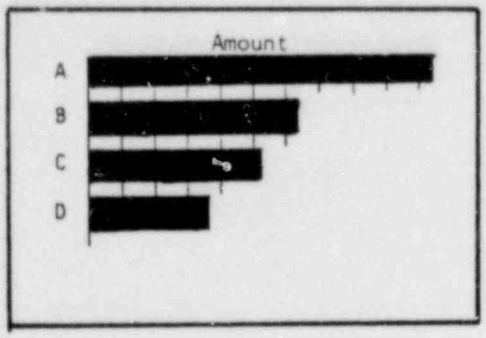
C.F. Schmid, S.E. Schmid, Handbook of Graphical Representation, Second Edition, New York: John Wiley and Sons, 1979, pp. 162.

M.E. Spear, Practical Charting Techniques, New York: McGraw-Hill, 1969, pp. 137.

DISPLAY FORMAT SUMMARY

NAME: Simple Bar Chart I.D.#: 12

DESCRIPTION: Horizontally oriented rectangles or bars emanating from a vertical line. The horizontal axis indicates values of the independent variable, the length of the bar is determined by the value or amount of each item.



INPUT DATA TYPE:
Unidimensional
Multivariate
Discrete

USE CATEGORY:
Approximate value

SPECIFIC USES:

* Compares the magnitude of items as of a specified time on a single scale.

COMMENTS:

Item sequence coule be in the following orders:
* numerical
* alphabetic
* progressive
* qualitative
* chronological

REFERENCES:

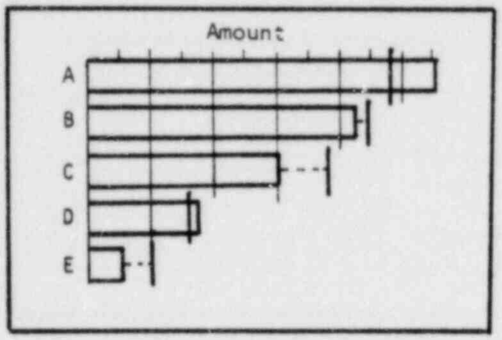
C.F. Schmid, S.E. Schmid, Handbook of Graphical Representation, Second Edition, New York: John Wiley and Sons, 1979, pp. 64.

M.E. Spear, Practical Charting Techniques, New York: McGraw-Hill, 1969, pp. 191.

DISPLAY FORMAT SUMMARY

NAME: Bar & Symbol Chart I.D.#: 13

DESCRIPTION: A Simple Bar Chart with supplementary information indicated by a crossline, circle, diamond or some other symbol.



INPUT DATA TYPE:
Unidimensional
Multivariate
Discrete

USE CATEGORY:
Approximate value
Deviation
Normal
Range

SPECIFIC USES:

* Comparing different items on the same scale.
* Differences between the current value and one or more other values for the same item.

COMMENTS:

NONE

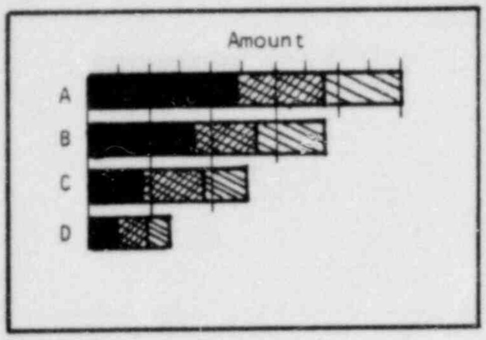
REFERENCES:

M.E. Spear, Practical Charting Techniques, New York: McGraw-Hill, 1969, pp. 218.

DISPLAY FORMAT SUMMARY

NAME: Subdivided Bar Chart I.D.#: 14

DESCRIPTION: This is a Simple Bar Chart with the item bars subdivided to show components.



INPUT DATA TYPE:
Unidimensional
Multivariate
Discrete

USE CATEGORY:
Approximate value

SPECIFIC USES:

* Present the component parts of several items in a series.
* Compare the component parts with others.

COMMENTS:

Also referred to as a Segmented Bar or Component Bar Chart.
Segments of the bars should be arranged in accordance with a logical or analytical sequence (most common is magnitude).
The total and components are important; components must be related to the total.

REFERENCES:

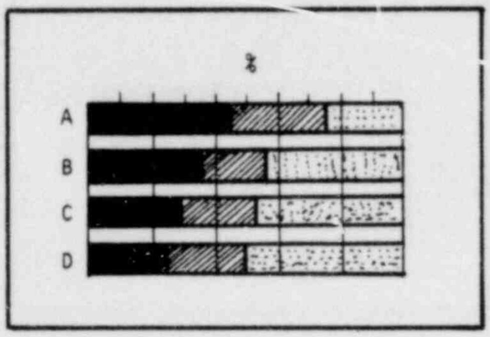
C.F. Schmid, S.E. Schmid, Handbook of Graphical Representation, Second Edition, New York: John Wiley and Sons, 1979, pp. 68.

M.E. Spear, Practical Charting Techniques, New York: McGraw-Hill, 1969, pp. 207.

DISPLAY FORMAT SUMMARY

NAME: Subdivided-100% Chart I.D.#: 15

DESCRIPTION: Similar to a Subdivided Bar Chart. It consists of one or more segmented bars where each bar totals 100% of the item value. The various divisions of the bars represents a percent of the whole.



INPUT DATA TYPE:
Unidimensional
Multivariate
Discrete

USE CATEGORY:
Approximate value

SPECIFIC USES:

* Comparison of components whose sum for each item adds to 100%. The total is not important.

COMMENTS:

Segments are arranged as in the Subdivided Bar Chart.

REFERENCES:

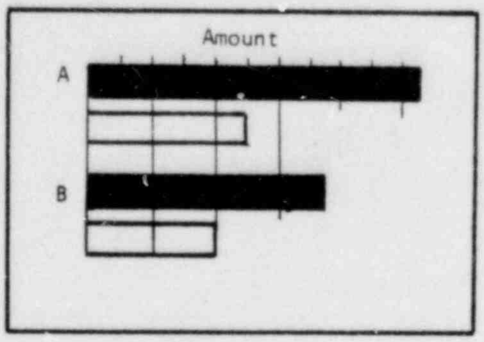
C.F. Schmid, S.E. Schmid, Handbook of Graphical Representation, Second Edition, New York: John Wiley and Sons, 1979, pp 78.

M.E. Spear, Practical Charting Techniques, New York: McGraw-Hill, 1969, pp. 210.

DISPLAY FORMAT SUMMARY

NAME: Grouped Bar Chart I.D.#: 16

DESCRIPTION: Each item consists of two or more entries with their related bars joined at their vertical boundaries. Otherwise it appears similar to a Simple Bar Chart.



INPUT DATA TYPE:
Unidimensional
Multivariate
Discrete

USE CATEGORY:
Approximate value

SPECIFIC USES:

* Comparison of a number of items in two, or sometimes three, respects at the same time.

COMMENTS:

NONE

REFERENCES:

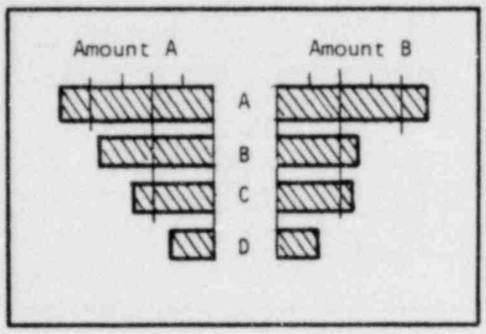
C.F. Schmid, S.E. Schmid, Handbook of Graphical Representation, Second Edition, New York: John Wiley and Sons, 1979, pp. 68.

M.E. Spear, Practical Charting Techniques, New York: McGraw-Hill, 1969, pp. 202.

D.SPLAY FORMAT SUMMARY

NAME: Paired Bar Chart I.D.#: 17

DESCRIPTION: Each item on this chart has a bar emanating from both the left and the right of the same baseline. Different units and scales can be used for each set of bars.



INPUT DATA TYPE:
Duodimensional
Multivariate
Discrete

USE CATEGORY:
Approximate value

SPECIFIC USES:

* Two different horizontal scales may be used to compare a number of items in two respects.

COMMENTS:

NONE

REFERENCES:

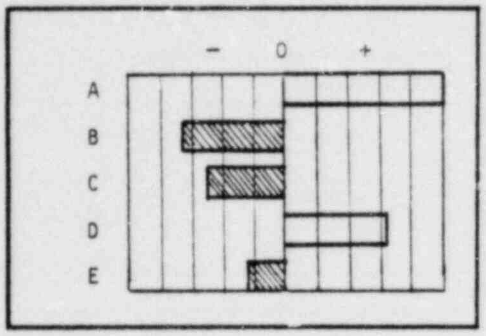
C.F. Schmid, S.E. Schmid, Handbook of Graphical Representation, Second Edition, New York: John Wiley and Sons, 1979, pp. 71.

M.E. Spear, Practical Charting Techniques, New York: McGraw-Hill, 1969, pp. 213.

DISPLAY FORMAT SUMMARY

NAME: Deviation Bar Chart I.D.#: 18

DESCRIPTION: Each item has a bar extending either to the right or left of a common vertical baseline to indicate the deviation from some "normal" value.



INPUT DATA TYPE:

Unidimensional
Multivariate
Discrete

USE CATEGORY:

Deviation

SPECIFIC USES:

* Presentation of positive/negative data for a number of items.

COMMENTS:

NONE

REFERENCES:

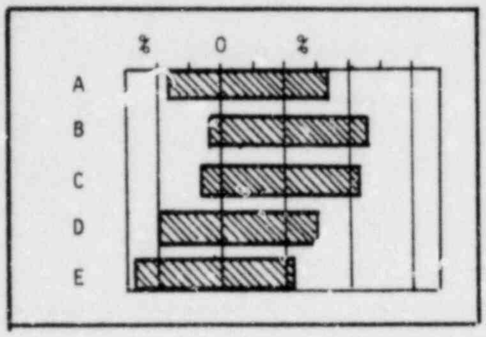
C.F. Schmid, S.E. Schmid, Handbook of Graphical Representation, Second Edition, New York: John Wiley and Sons, 1979, pp. 71.

M.E. Spear, Practical Charting Techniques, New York: McGraw-Hill, 1969, pp. 219.

DISPLAY FORMAT SUMMARY

NAME: Sliding Bar Chart I.D.#: 19

DESCRIPTION: This is a bilateral chart in which each bar represents the total of two main components. One part of the bar is left and the other part is right of a center common baseline.



INPUT DATA TYPE:
Unidimensional
Multivariate
Discrete

USE CATEGORY:
Approximate value

SPECIFIC USES:
* Comparison where the total of the two parts adds to the whole.

COMMENTS:
NONE

REFERENCES:

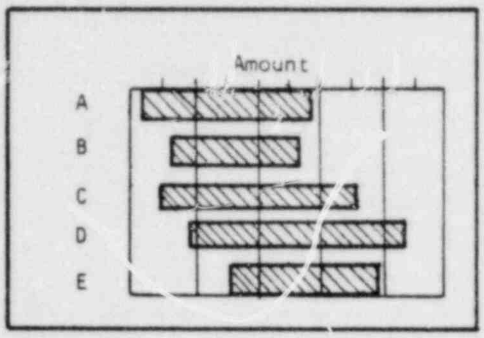
C.F. Schmid, S.E. Schmid, Handbook of Graphical Representation, Second Edition, New York: John Wiley and Sons, 1979, pp. 75.

M.E. Spear, Practical Charting Techniques, New York: McGraw-Hill, 1969, pp. 225.

DISPLAY FORMAT SUMMARY

NAME: Range Chart I. D. #: 20

DESCRIPTION: On this chart the bars are not aligned at the base, but start at its low point and end at its high point. The result is a comparison of their ranges.



INPUT DATA TYPE:
Unidimensional
Multivariate
Discrete

USE CATEGORY:
Range

SPECIFIC USES:

* When high and low points of several items are to be compared.

COMMENTS:

The endpoints rather than some midpoint are important.

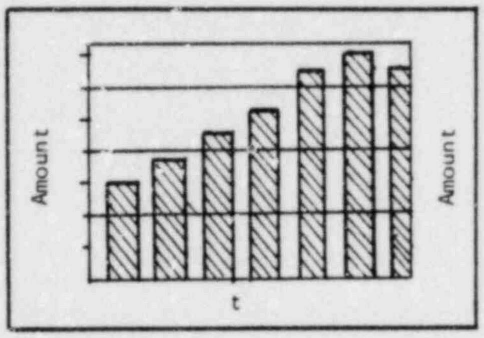
REFERENCES:

M. E. Spear, Practical Charting Techniques, New York: McGraw-Hill, 1969, pp. 222.

DISPLAY FORMAT SUMMARY

NAME: Simple Column Chart I.D. #: 21

DESCRIPTION: This abscissa of this chart has a small number of values while the ordinate has a greater number. Vertically oriented rectangles indicate the value of the independent variable by the length of the rectangle from a common horizontal baseline.



INPUT DATA TYPE:

Unidimensional
Univariate
Limited series

USE CATEGORY:

Approximate value

SPECIFIC USES:

* Depicting a small number of numerical values within a series, usually time. It can provide greater emphasis in portraying amounts in a single series.

COMMENTS:

NONE

REFERENCES:

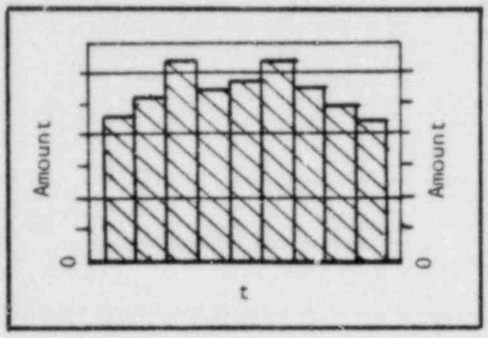
C.F. Schmid, S.E. Schmid, Handbook of Graphical Representation, Second Edition, New York: John Wiley and Sons, 1979, pp. 82.

M.E. Spear, Practical Charting Techniques, New York: McGraw-Hill, 1969, pp. 163.

DISPLAY FORMAT SUMMARY

NAME: Connected Column Chart I.D.#: 22

DESCRIPTION: This chart possesses characteristics of both the Simple Column Chart and the Staircase Surface Chart. Although all the columns are distinct, there is no spacing between them.



INPUT DATA TYPE:
Unidimensional
Univariate
Limited series

USE CATEGORY:
Approximate value

SPECIFIC USES:

* Shows the overall picture for a long period of time.
* Accents time incidents more sharply than a Simple Line Chart.
* When spaced columns would appear too crowded in a series.

COMMENTS:

NONE

REFERENCES:

C.F. Schmid, S.E. Schmid, Handbook of Graphical Representation, Second Edition, New York: John Wiley and Sons, 1979, pp. 84.

M.E. Spear, Practical Charting Techniques, New York: McGraw-Hill, 1969, pp. 170.

DISPLAY FORMAT SUMMARY

NAME: Grouped Column Chart I.D.#: 23

DESCRIPTION: Similar to a Simple Column Chart but two or three columns represent different series or different classes in the same series. The related columns do not have spacing between them.

INPUT DATA TYPE:
Unidimensional
Limited Multivariate
Limited Series

USE CATEGORY:
Approximate value

SPECIFIC USES:

* When comparing two or three independent series over a common period.

COMMENTS:

NONE

REFERENCES:

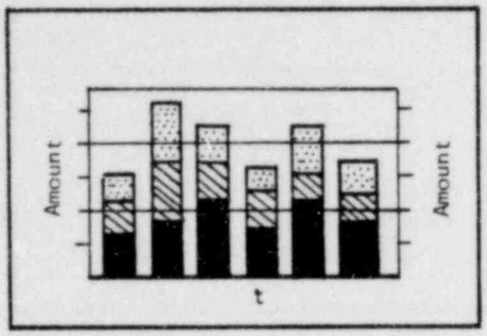
C.F. Schmid, S.E. Schmid, Handbook of Graphical Representation, Second Edition, New York: John Wiley and Sons, 1979, pp. 85.

M.E. Spear, Practical Charting Techniques, New York: McGraw-Hill, 1969, pp. 169.

DISPLAY FORMAT SUMMARY

NAME: Subdivided Column Chart I.D.#: 24

DESCRIPTION: Similar to a Simple Column Chart except that each column is subdivided to represent components of the total.



INPUT DATA TYPE:

Unidimensional
Limited Multivariate
Limited Series

USE CATEGORY:

Approximate value

SPECIFIC USES:

* Used to show a series of values with respect to their components.
* Defines fluctuations of the segments sharply.

COMMENTS:

NONE

REFERENCES:

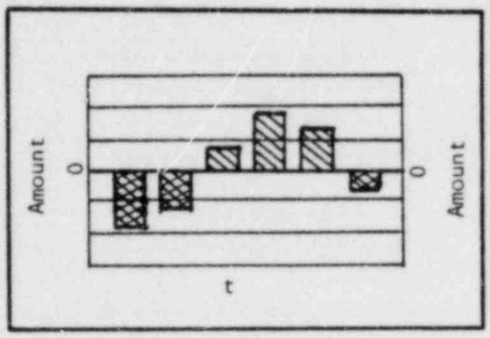
C.F. Schmid, S.E. Schmid, Handbook of Graphical Representation, Second Edition, New York: John Wiley and Sons, 1979, pp. 86.

M.E. Spear, Practical Charting Techniques, New York: McGraw-Hill, 1969, pp. 171.

DISPLAY FORMAT SUMMARY

NAME: Net Deviation Column Chart I.D.#: 25

DESCRIPTION: Similar to a Simple Column Chart except the baseline is located above the bottom of the chart. The columns extend either above or below the baseline, but not in both directions.



INPUT DATA TYPE:
Unidimensional
Univariate
Limited Series

USE CATEGORY:
Deviation

SPECIFIC USES:

* When the emphasis is on increases/decreases, losses/gains, or deviation from a requirement or norm over a period of time.

COMMENTS:

NONE

REFERENCES:

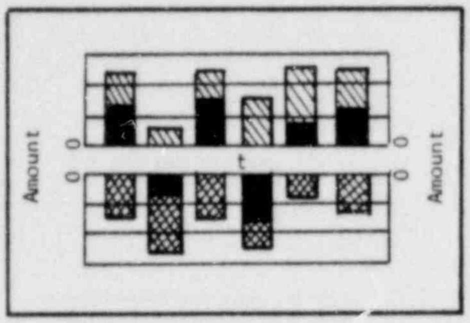
C.F. Schmid, S.E. Schmid, Handbook of Graphical Representation, Second Edition, New York: John Wiley and Sons, 1979, pp. 88.

M.E. Spear, Practical Charting Techniques, New York: McGraw-Hill, 1969, pp. 180.

DISPLAY FORMAT SUMMARY

NAME: Gross Deviation Column Chart   I.D. #: 26

DESCRIPTION: Similar to the Net Deviation Column Chart but the columns may extend in both directions from the horizontal baseline to indicate effects in either direction. The net change may then be shown in the appropriate direction using crosshatching.



INPUT DATA TYPE:
Unidimensional
Limited Multivariate
Limited Series

USE CATEGORY:
Deviation

SPECIFIC USES:

* When both the net and gross changes must be shown over a period of time.

COMMENTS:

Applicable only when the items have values that oppose each other.

REFERENCES:

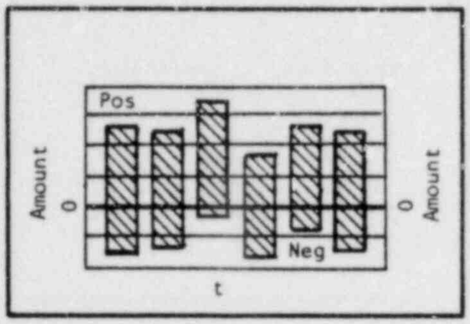
C.F. Schmid, S.E. Schmid, Handbook of Graphical Representation, Second Edition, New York: John Wiley and Sons, 1979, pp. 90.

M.E. Spear, Practical Charting Techniques, New York: McGraw-Hill, 1969, pp. 180.

DISPLAY FORMAT SUMMARY

NAME: Floating Column Chart I.D. #: 27

DESCRIPTION: Similar to the Net Deviation Column Chart with 100% component columns. The deviations from the baseline represent positive and negative values or differential attributes.



INPUT DATA TYPE:

Unidimensional
Limited Multivariate
Limited Series

USE CATEGORY:

Approximate value

SPECIFIC USES:

* When two components make up the total height of the column and represent a total amount or 100%.

COMMENTS:

Similar to a Subdivided Column Chart

REFERENCES:

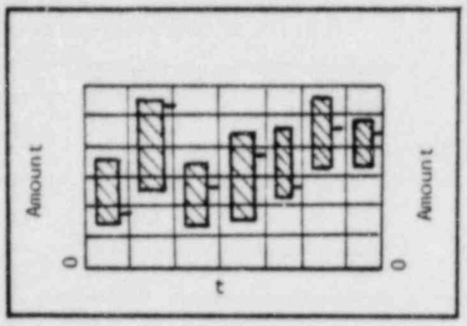
C.F. Schmid, S.E. Schmid, Handbook of Graphical Representation, Second Edition, New York: John Wiley and Sons, 1979, pp. 79.

M.E. Spear, Practical Charting Techniques, New York: McGraw-Hill, 1969, pp. 184.

DISPLAY FORMAT SUMMARY

NAME: Range Column Chart I.D.#: 28

DESCRIPTION: Shows the minimal, average and maximal values of a variable in a time series.



INPUT DATA TYPE:
Unidimensional
Limited Multivariate
Limited Series

USE CATEGORY:
Approximate value
Normal
Range

SPECIFIC USES:

* When the values of the time series may vary over a range within the given time value.

COMMENTS:

Has also been referred to as the "stock-price" chart.

REFERENCES:

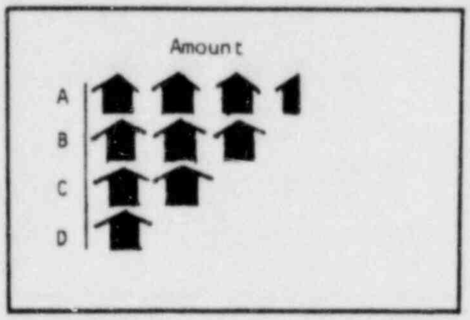
C.F. Schmid, S.E. Schmid, Handbook of Graphical Representation, Second Edition, New York: John Wiley and Sons, 1979, pp. 90.

M.E. Spear, Practical Charting Techniques, New York: McGraw-Hill, 1969, pp. 182.

DISPLAY FORMAT SUMMARY

NAME: Pictogram I.D. #: 29

DESCRIPTION: This format uses pictures or caricatures to represent the quantity of items. The pictures usually relate physically to the item being displayed. The size of the symbol may be varied to indicate quantity or a number of same size symbols can be used to replace the bars or columns in those formats.



INPUT DATA TYPE:

Unidimensional
Limited Multivariate
Discrete

USE CATEGORY:

Approximate value

SPECIFIC USES:

* To communicate information to nontechnical viewers.

COMMENTS:

Not useful for analysis.

REFERENCES:

C. F. Schmid, S. E. Schmid, <u>Handbook of Graphical Representation</u>, Second Edition, New York: John Wiley and Sons, 1979, pp. 220.

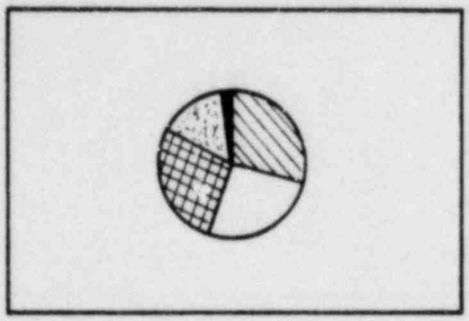
M. E. Spear, <u>Practical Charting Techniques</u>, New York: McGraw-Hill, 1969, pp. 321.

DISPLAY FORMAT SUMMARY

NAME: Pie Chart

I.D.#: 30

DESCRIPTION: A circle whose interior is subdivided into wedges and shaded to represent portions of a total.



INPUT DATA TYPE:

Unidimensional
Limited Multivariate
Discrete

USE CATEGORY:

Approximate value

SPECIFIC USES:

* Makes a comparison of the segments and shows their relation to the whole.
* Good for communication, but not analysis.

COMMENTS:

A Simple Bar Chart may be better, especially if analysis is involved.
Usually has quantitative annotations.
Also called a Sector Chart.

REFERENCES:

C.F. Schmid, S.E. Schmid, Handbook of Graphical Representation, Second Edition, New York: John Wiley and Sons, 1979, pp. 146.

M.E. Spear, Practical Charting Techniques, New York: McGraw-Hill, 1969, pp. 233.

DISPLAY FORMAT SUMMARY

NAME: Graphics Rational Patterns I.D. #: 31

DESCRIPTION:

DESCRIPTION: This represents, in a distinct and readable form, any integer number included between given limits by means of a small symbol covering an area proportional to the number represented.

INPUT DATA TYPE:
- Unidimensional
- Multivariate
- Discrete

USE CATEGORY:
- Approximate value
- Pattern recognition

SPECIFIC USES:

* When one needs to grasp the general characteristics of the distribution of the values of each of the variables (k).
* When one must grasp the general relationships between the s variables or between groups of variables.
* To identify clusters of i having similar characteristics.
* To identify individuals i being strongly at variance from other cases.

COMMENTS:

Often used with cartography.

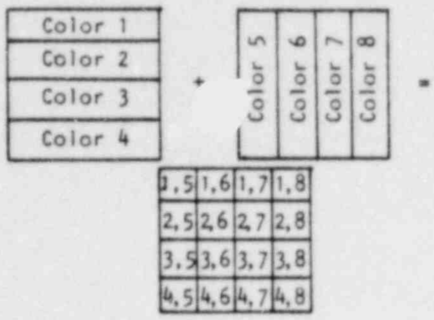
REFERENCES:

R. Bachi, "Proposals for the Development of Selected Graphical Methods", Graphical Presentation of Statistical Information, Bureau of the Cencus, Technical Paper 43, 1978, pp. 23.

DISPLAY FORMAT SUMMARY

NAME: Color Coded Matrix I.D.#: 32

DESCRIPTION: This format uses color to indicate values for two independent but interacting variables. A matrix is established whose columns represent values of variable A by a series of colors. The matrix rows represent values of variable B, but use a different color series. The intersections of these colored rows and columns yield unique colors for those intersections.



INPUT DATA TYPE:
Duodimensional
Multivariate
Discrete

USE CATEGORY:
Approximate value
Pattern recognition

SPECIFIC USES:
* Cartographic statistical data

COMMENTS:
NONE

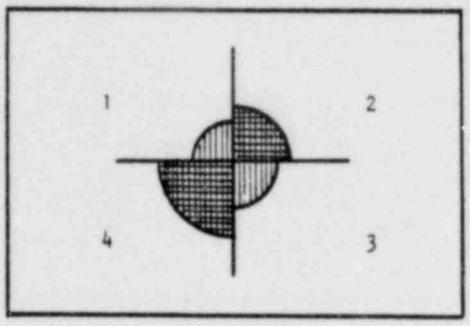
REFERENCES:

V.P. Barabba, A.L. Finker, "The Utilization of Primary Printing Colors in Displaying More Than One Variable", Graphic Representation of Statistical Information, Bureau of the Cencus, Technical Paper 43, 1978, pp. 14.

DISPLAY FORMAT SUMMARY

NAME: Fourfold Circular Display   I.D.#: 33

DESCRIPTION: Display that used four quadrants to represent different variables. The value of the variables are indicated by the radius of the 90 degree arc associated with each variable.



INPUT DATA TYPE:

Multidimensional
Multivariate
Discrete

USE CATEGORY:

Approximate value
Status & Warning
Pattern recognition

SPECIFIC USES:

* Comparison tasks between different sets of four variable data.

COMMENTS:

NONE

REFERENCES:

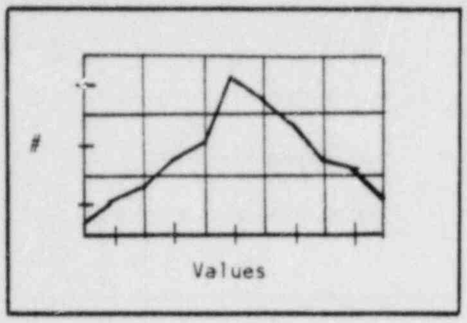
H. Wainer, M. Reiser, "Assessing the Efficacy of Visual Displays", Graphical Representation of Statistical Information, Bureau of the Cencus, Technical Paper 43, 1978, pp. 83.

DISPLAY FORMAT SUMMARY

NAME: Frequency Polygon

I.D.#: 34

DESCRIPTION: Similar to a Staircase or Step Chart but the dependent variable may be other that time. The appropiate frequency of each class is located at the midpoint of the interval, and the plotting points are connected by straight lines.



INPUT DATA TYPE:

Unidimensional
Multivariate
Discrete

USE CATEGORY:

Approximate value
Pattern recognition

SPECIFIC USES:

* Show continuous distribution.
* Recognize a "normal" distribution.

COMMENTS:

NONE

REFERENCES:

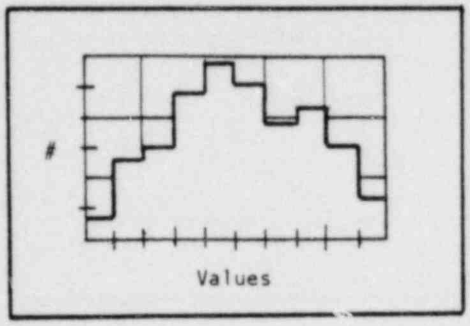
C.F. Schmid, S.E. Schmid, Handbook of Graphical Representation, Second Edition, New York: John Wiley and Sons, 1979, pp. 119.

M.E. Spear, Practical Charting Techniques, New York: McGraw-Hill, 1969, pp. 112.

DISPLAY FORMAT SUMMARY

NAME: Histogram I.D.#: 35

DESCRIPTION: This chart is constructed by erecting vertical lines at the limits of the class intervals and forming a series of contiguous rectangles or columns (interior lines may be deleted).



INPUT DATA TYPE:
Unidimensional
Multivariate
Discrete

USE CATEGORY:
Approximate value
Pattern recognition

SPECIFIC USES:

* Show the area of each rectangle that represents the respective class frequencies.
* Shows discrete series.
* Recognize a "normal" distribution.

COMMENTS:

NONE

REFERENCES:

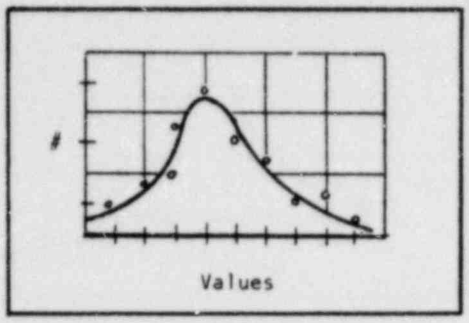
C.F. Schmid, S.E. Schmid, Handbook of Graphical Representation, Second Edition, New York: John Wiley and Sons, 1979, pp. 119.

M.E. Spear, Practical Charting Techniques, New York: McGraw-Hill, 1969, pp. 115.

DISPLAY FORMAT SUMMARY

NAME: Smoothed Frequency Curve   I.D.#: 36

DESCRIPTION: Similar to the Frequency Polygon but it fits a smooth curve to the sampled data rather than plotting as is.



INPUT DATA TYPE:
Unidimensional
Multivariate
Discrete

USE CATEGORY:
Approximate value
Pattern recognition

SPECIFIC USES:

* Irons out or eliminates the accidental irregularities resulting from sampling errors.

COMMENTS:

Displayed data is not real but theoretical.

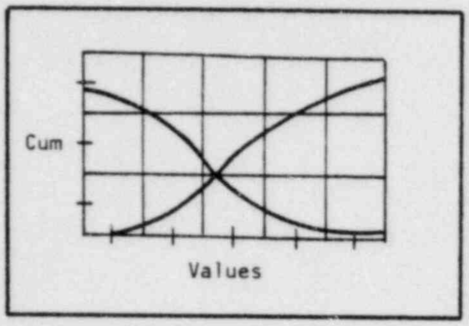
REFERENCES:

C.F. Schmid, S.E. Schmid, Handbook of Graphical Representation, Second Edition, New York: John Wiley and Sons, 1979, pp. 121.

DISPLAY FORMAT SUMMARY

NAME: Ogive (Cumulative) Chart I.D.#: 37

DESCRIPTION: A cumulative frequency is represented by the ordinate and class intervals by the abscissa.



INPUT DATA TYPE:
Unidimensional
Multivariate
Discrete

USE CATEGORY:
Status & Warning
Pattern recognition

SPECIFIC USES:
* When the primary interest is in the cumulative pattern over a period of time or class intervals.
* Recognize a "normal" distribution.

COMMENTS:
NONE

REFERENCES:

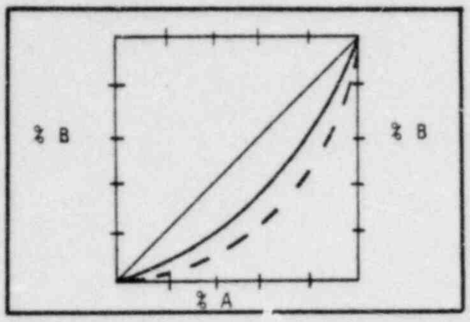
C.F. Schmid, S.E. Schmid, Handbook of Graphical Representation, Second Edition, New York: John Wiley and Sons, 1979, pp. 134.

M.E. Spear, Practical Charting Techniques, New York: McGraw-Hill, 1969, pp. 121.

DISPLAY FORMAT SUMMARY

NAME: Lorenz Curve I.D.#: 38

DESCRIPTION: A special type of cumulative-frequency graph. Data is transposed into percentages and arranged into "less than" types of cumulative-frquency distribution. The abscissa represents the percent cumulated from lowest to highest and the ordinate shows the percent of the variable cumulated from lowest to highest.



INPUT DATA TYPE:
Unidimensional
Multivariate
Limited Series

USE CATEGORY:
Status & Warning

SPECIFIC USES:

* To portray such data as the distribution of wealth & income in relation to certain segments of the population, the productivity of farms in terms of cumulative proportions of farms, distribution or retail sales as related to various groupings of stores, etc.

COMMENTS:

Construct a square grid with both axes representing 0 to 100 %.

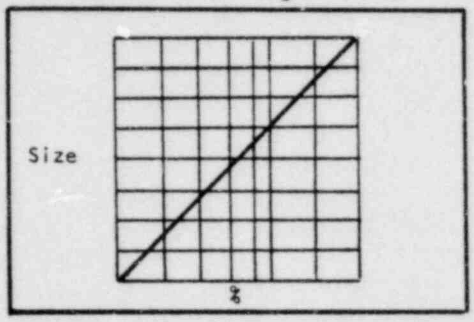
REFERENCES:

C.F. Schmid, S.E. Schmid, Handbook of Graphical Representation, Second Edition, New York: John Wiley and Sons, 1979, pp. 136.

DISPLAY FORMAT SUMMARY

NAME: Probability Graphs   I.D.#: 39

DESCRIPTION: A special arrangement of vertical and horizontal spacing of a grid that has the property of representing the cumulative normal function as a straight line.



INPUT DATA TYPE:
Unidimensional
Multivariate
Discrete

USE CATEGORY:
Deviation

SPECIFIC USES:

* To detect deviations from the norm, as defined statistically.

COMMENTS:

NONE

REFERENCES:

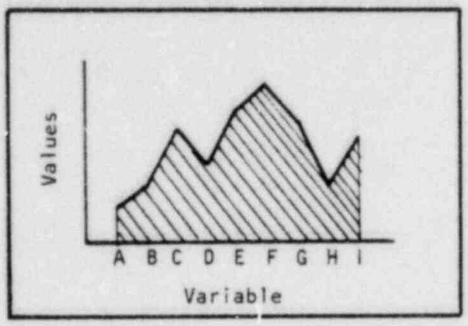
C.F. Schmid, S.E. Schmid, Handbook of Graphical Representation, Second Edition, New York: John Wiley and Sons, 1979, pp. 138.

DISPLAY FORMAT SUMMARY

NAME: Linear Profile

I.D. #: 40

DESCRIPTION: Polygonal line that connects the various heights corresponding to the values of the variables arranged along a baseline.



INPUT DATA TYPE:
Multidimensional
Multivariate
Discrete

USE CATEGORY:
Approximate value
Pattern recognition

SPECIFIC USES:

* To show the nature of a relationship between variables.

COMMENTS:

Better done with a Simple Bar Chart (#12).

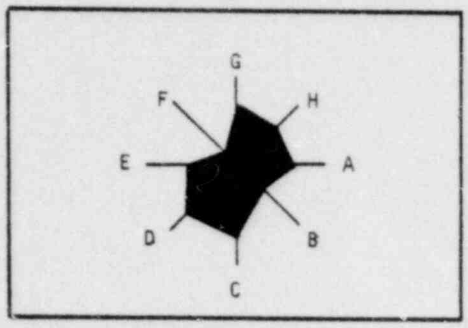
REFERENCES:

J.E. Mezzich, D.L. Worthington, " A Comparison of Graphical Representations of Multidimensional Psychiatric Diagnostic Data", in P.C. Wang, Graphical Representation of Multivariate Data, New York: Academic Press, 1978, pp. 123.

DISPLAY FORMAT SUMMARY

NAME: Circular Profile I. D. #: 41

DESCRIPTION: Variation of the linear profile in which the polygonal line connects points located on equally spaced rays, where the distance from the center represents the value for each of the variables. Each ray may have different units.



INPUT DATA TYPE:

Multidimensional
Multivariate
Discrete

USE CATEGORY:

Approximate value
Deviation
Normal
Range
Pattern recognition

SPECIFIC USES:

* To show the nature of a relationship between variables not having the same units.

COMMENTS:

Also called Polar Plots, Star Diagrams and Multivariate Polygons.
Good mnemonic character.
High dimensionality.

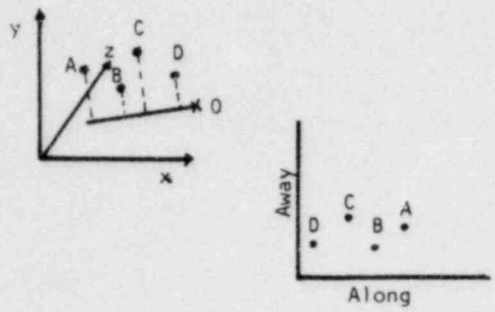
REFERENCES:

J. H. Siegel, R. M. Goldwyn, H. P. Friedman, "Pattern and Process in the Evolution of Human Septic Shock", Surgery, Vol. 70, No. 2, August, 1971, pp. 232.

DISPLAY FORMAT SUMMARY

NAME: "Distance-Along Vs. Distance-Away-From" Plots I. D. #: 42
DAVA

DESCRIPTION: A referent line with a local origin is established for three dimensional data. All data points are projected onto that line with the resulting plot having an abscissa indicating the distance from the local origin (Distance Along) and the ordinate showing distance from the line (Distance Away) as determined by the projection.
projection.



INPUT DATA TYPE:
Duodimensional
Multivariate
Discrete

USE CATEGORY:
Status & Warning
Pattern recognition

SPECIFIC USES:

* Shows how well a line segment or a curve fits a set of data.

COMMENTS:

Most applicable for analysis.

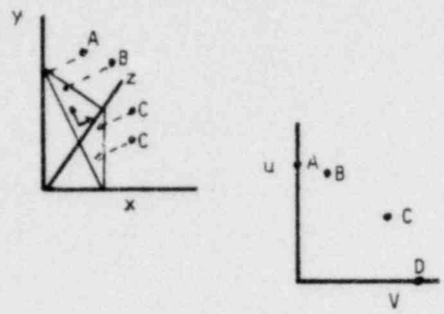
REFERENCES:

G. H. Ball, A Collection of Graphical Plots for Examining Multivariate Data", AD 734 360, August, 1967, pp. 9.

DISPLAY FORMAT SUMMARY

NAME: Scatter Plots (2D & 3D) I.D. #: 43

DESCRIPTION: This is a plot that projects data points perpendincularly onto a plane in the data hyperspace. 3D plots use line length to give the value of the third variable.



INPUT DATA TYPE:

Duodimensional
Multivariate
Discrete

USE CATEGORY:

Status & Warning
Pattern recognition

SPECIFIC USES:

* To indicate relationships between pairs of variables (2D) or triples of variables (3D).

COMMENTS:

Good for analysis.

REFERENCES:

G.H. Ball, A Collection of Graphical Plots for Examining Multivariate Data, AD 734 360, August, 1967, pp. 13.

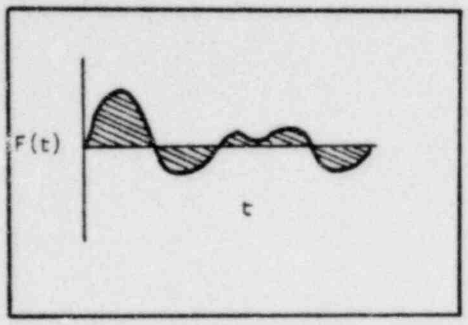
DISPLAY FORMAT SUMMARY

NAME: Linear Fourier Representation I.D. #: 44

DESCRIPTION: A Fourier Series is used to generate a function of an angle t for each multidimensional point that is to be represented, i.e.,

$$F(t) = a/1.414 + b \text{ Cos}t + c \text{ Sin } t + d \text{ Cos}2t + \ldots$$

where the coefficients of the trigonometric functions are the values of the variables.



INPUT DATA TYPE:

Multidimensional
Multivariate
Discrete

USE CATEGORY:

Status & Warning
Pattern recognition

SPECIFIC USES:

* To compare the intera tion of several variables at the same time.

COMMENTS:

The first term determines the height of the function, F(t), and the remaining terms determine its shape.
Little emotional value.
Low dimensionality.

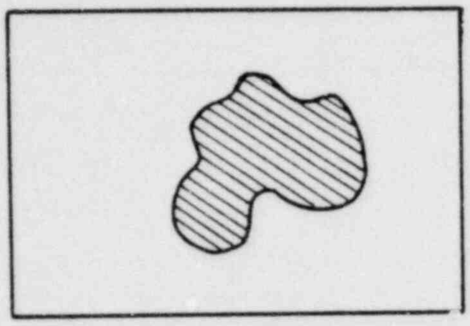
REFERENCES:

J.E. Mezzich, D.R.L. Worthington, " A Comparison of Graphical Representations of Multidimensional Psychiatric Diagnostic Data", in P.C. Wang, Graphical Representation of Multivariate Data, New York: Academic Press, 1978, pp. 123.

DISPLAY FORMAT SUMMARY

NAME: Polar Fourier Representation I.D.#: 45

DESCRIPTION: Similar to the Linear Fourier Representation except the function is plotted in polar rather than rectilinear coordinates.



INPUT DATA TYPE:
Multidimensional
Multivariate
Discrete

USE CATEGORY:
Status & Warning
Pattern recognition

SPECIFIC USES:

* To compare the relationship between variables having different units

COMMENTS:

Much better than Linear Fourier Representation.
Little emotional response.
May have mnemonic character.
Low dimensionality

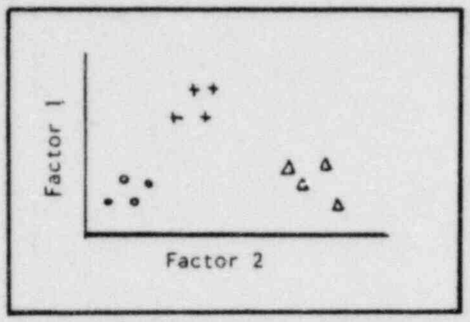
REFERENCES:

J.E. Mezzich, D.R.L. Worthington, "A Comparison of Graphical Representations of Multidimensional Psychiatric Diagnostic Data", in P.C. Wang, Graphical Representation of Multivariate Data, New York: Academic Press, 1978, pp. 123.

DISPLAY FORMAT SUMMARY

NAME: Factor Analysis I.D. #: 46

DESCRIPTION: Reduces the dimensionality of data to 2 or 3D. The eigenvalues and eigenvectors of the correlation matrix of the original variables are found. Dimensionality is determined from the eigenvalues, and the first few eigenvectors are used as a basis for lower dimensional representation.



INPUT DATA TYPE:
Multidimensional
Multivariate
Discrete

USE CATEGORY:
Status & Warning
Pattern recognition

SPECIFIC USES:
* For analysis of multidimensional data.

COMMENTS:
Washes out the detail.
Good for cluster analysis.

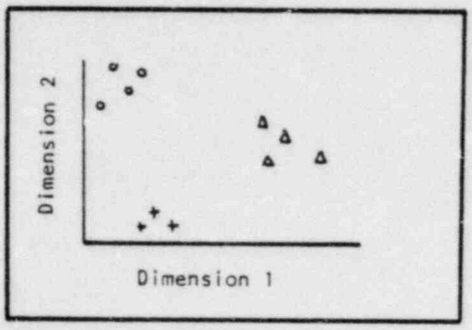
REFERENCES:

J. E. Mezzich, D. R. L. Worthington, "A Comparison of Graphical Representations of Multidimensional Psychiatric Diagnostic Data", in P. C. Wang, Graphical Representation of Multivariate

DISPLAY FORMAT SUMMARY

NAME: Multidimensional Scaling (MDSCAL) I.D. #: 47

DESCRIPTION: Infers a multidimensional metric structure from non-metric ordinal data, and represents it in a visualizable, geometrical form, usually on a two dimensional space. The points are arranged in the low dimensional vector space in such a way as to maximize the correspondence of the ranking of inter-point distances in that space to the ranking in the original high dimension vector space.



INPUT DATA TYPE:

Multidimensional
Multivariate
Discrete

USE CATEGORY:

Status & Warning
Pattern recognition

SPECIFIC USES:

* For analysis of limited data types.

COMMENTS:

Washes out detail.

REFERENCES:

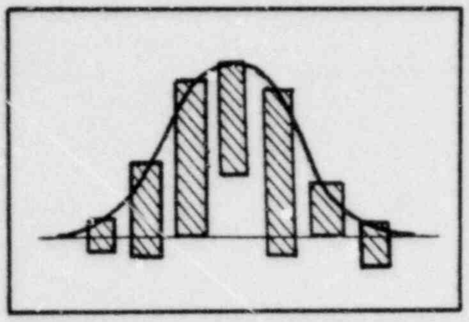
J.E. Mezzich, D.R.L. Worthington, "A Comparison of Graphical Representations of Multidimensional Psychiatric Diagnostic Data", in P.C. Wang, Graphical Representation of Multivariate Data, New York: Academic Press, 1978, pp. 123.

J.B. Kruskal, "Multidimensional Scaling By Optimizing Goodness of Fit to a Nonmetric Hypothesis", Psychometrika, Vol. 29, No. 1, March, 1964, pp. 1.

DISPLAY FORMAT SUMMARY

NAME: Hanging Rootogram I. D. #: 48

DESCRIPTION: The probability density function is overlayed with a histogram. Crosshatched bars have width and height proportional to the number of samples in each class. The density function may be: normal, Poisson, Binomial, etc.



INPUT DATA TYPE:

Unidimensional
Multivariate
Discrete

USE CATEGORY:

Status & Warning
Pattern recognition

SPECIFIC USES:

* Analysis of multivariate continuous distributions.

COMMENTS:

Good when looking for systematic kinds of variation from a particular function.

REFERENCES:

G. H. Ball, A Collection of Graphical Plots for Examining Multivariate Data, AD 734 360, August, 1967, pp. 3

H. Wainer, "The Suspended Rootogram and Other Visual Displays: An Empirical Validation", The American Statistician, Vol. 28, No. 4, November, 1974, pp. 143.

DISPLAY FORMAT SUMMARY

NAME: Contour Map I.D. #: 49

DESCRIPTION: An orthographic projection in which locations in the z-axis are projected on tne xy plane and equal z values are connected to form isocurves.

INPUT DATA TYPE:
Duodimensional
Multivariate
Discrete

USE CATEGORY:
Approximate value

SPECIFIC USES:

* To show the interrelationships of 3 variables.

COMMENTS:

NONE

REFERENCES:

J.R. Beniger, D.L. Robyn, "Quantitative Graphics in Statistics: A Brief Histr-y", The American Sta;istician, Vol. 32, No. 1, February, 1978, pp. 2.

DISPLAY FORMAT SUMMARY

NAME: Stereoscopic Plots I.D. #: 50

DESCRIPTION: An axonometric projection of data onto two separate graphs, each with a slightly different viewpoint. When viewed with special equipment, a 3D impression is gained. Size and tilt could be used to add a fourth and fifth dimension.

See Reference

INPUT DATA TYPE:
Multidimensional
Limited Multivariate
Discrete

USE CATEGORY:
Approximate value

SPECIFIC USES:
* Display of 3D data.

COMMENTS:
Needs special viewing equipment

REFERENCES:

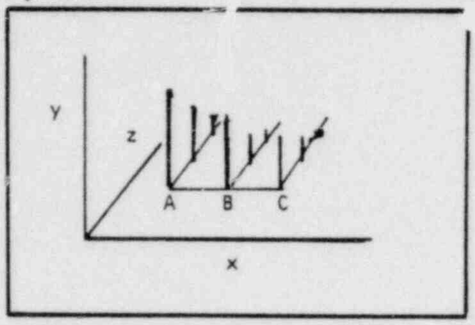
G.H. Ball, A Collection of Graphical Plots for Examining Multivariate Data, AD 734 360, August, 1967, pp. 31

J.R. Beniger, D.L. Robyn, "Quantitative Graphics in Statistics: A Brief History", The American Statistician, Vol. 32, No. 1, February, 1973, pp. 2.

DISPLAY FORMAT SUMMARY

NAME: Perspective Plots I.D.#: 51

DESCRIPTION: This format induces the illusion of a third dimension by maki size associated with a data point proportional to the slant range from the viewer's pseudo-position in data space to th position of the data point. A fourth variable can be added using tilt.



INPUT DATA TYPE:
Duodimensional
Limited Multivariate
Series

USE CATEGORY:
Approximate value
Deviation
Normal
Range
Prediction
Pattern recongition

SPECIFIC USES:
* Realistic appearing display of 3D data.

COMMENTS:
Popular technique when used with Line Chart, Bar and Column Charts and Statistical Cartography.

REFERENCES:

G.H. Ball, A Collection of Graphical Plots for Examining Data, AD 734 360, August, 1967, pp.31.

DISPLAY FORMAT SUMMARY

NAME: Spherical Projections I.D.#: 52

DESCRIPTION: Three dimensional data points are projected onto a flattened sphere. Points with large residuals are indicated by an "x"

See Reference

INPUT DATA TYPE:
Duodimensional
Multivariate
Series

USE CATEGORY:
Status & Warning

SPECIFIC USES:

* Analysis in which data tends to fall on the surface of a hypersphere.

COMMENTS:
NONE

REFERENCES:

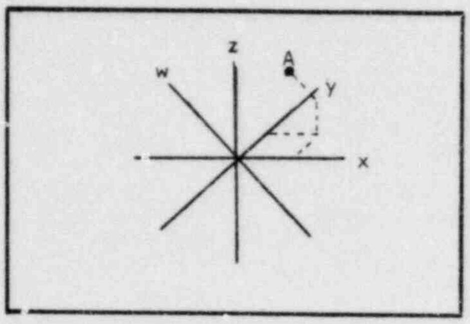
G.H. Ball, A Collection of Graphical Plots for Examining Data, AD 734 360, August, 1967, pp. 34

DISPLAY FORMAT SUMMARY

NAME: N-Axis Plot

I.D.#: 53

DESCRIPTION: An extension of a 3D drawing where additional axes are added for each additional dimension.



INPUT DATA TYPE:
Multidimensional
Multivariate
Series

USE CATEGORY:
Status & Warning

SPECIFIC USES:

* Plotting points that are determined by a large number of coordinates.

COMMENTS:

This display is confusing due to the number of axes required.

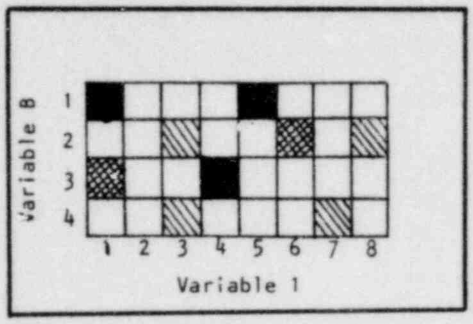
REFERENCES:

G.H. Ball, A Collection of Graphical Plots for Examining Data, AD 734 360, August, 1967, pp. 36.

DISPLAY FORMAT SUMMARY

NAME: Array Plots I. D. #: 54

DESCRIPTION: An n x n array of numbers is shown by n x n cells. If an element a(i, j) < y, put a mark (color), if not leave blank. Rather than using a binary value system, one can also display the data using columns at the array intersections to give a 3D effect.



INPUT DATA TYPE:
Multidimensional
Multivariate
Discrete

USE CATEGORY
Deviation
Normal
Range
Status & Warning
Pattern recognition

SPECIFIC USES:

* Rapid assimilation of an array.

COMMENTS

Similar to a 3D Column Chart that has been projected.

REFERENCES:

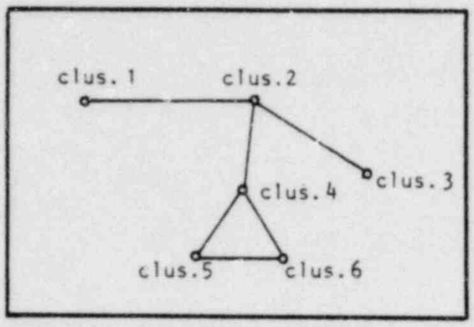
G. H. Ball, A Collection of Graphical Plots for Examining Multivariate Data, AD 734 360, August, 1967, pp. 51.

DISPLAY FORMAT SUMMARY

NAME: Linkage Plots

I.D.#: 55

DESCRIPTION: Links are established between nodes when a specified relationship exists. Each node and the center point of each link has a mnemonic label associated with it.



INPUT DATA TYPE:

Multidimensional
Multivariate
Discrete

USE CATEGORY:

Status & Warning

SPECIFIC USES:

COMMENTS:

NONE

REFERENCES:

G.H. Ball, A Collection of Graphical Plots for Examining Mu tivariate Data, AD 734 360, August, 1967, pp. 53.

DISPLAY FORMAT SUMMARY

NAME: Probability Plots of Ordered Distance I.D.#: 56

DESCRIPTION: Please see Reference listed below.

INPUT DATA TYPE:
Multidimensional
Multivariate
Discrete

USE CATEGORY:
Status & Warning

SPECIFIC USES:

* Graphical plots of the statistical structure of multi-response data.

COMMENTS:

Limited to special cases.

REFERENCES:

G.H. Ball, A Collection of Graphical Plots for Examining Multivariate Data, AD 734 360, August, 1967, pp. 57.

M.B. Wilk, R. Gnanadesikan, "Graphical Methods for Internal Comparison in Multiresponse Experiments", Annals of Mathematical Statistics, Vol. 35, No. 2, June, 1964, pp. 613.

DISPLAY FORMAT SUMMARY

NAME: Dendogram I.D.#: 57

DESCRIPTION: A node-link graph constrained NOT to be reentrant, i.e. a tree structure.

See Reference

INPUT DATA TYPE:
Multidimensional
Multivariate
Discrete

USE CATEGORY:
Status & Warning

SPECIFIC USES:

* To show the data relationships when a hierarchical clustering approach is used.

COMMENTS:

Limited to hierarchical structures.

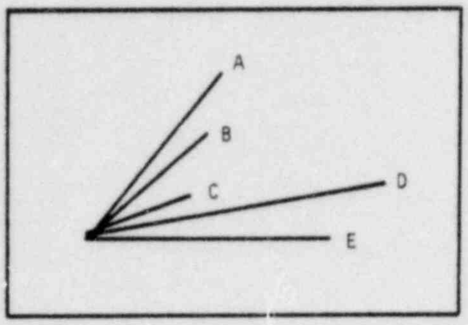
REFERENCES:

G.H. Ball, A Collection of Graphical Plots for Examining Multivariate Data, AD 734 360, August, 1967, pp. 59.

DISPLAY FORMAT SUMMARY

NAME: Vector-Angle Plot   I.D.#: 58

DESCRIPTION: Shows the angles of a set of vectors to a common reference vector, given a particular data origin. The length of each vector can be indicated in the plot.



INPUT DATA TYPE:

Duodimensional
Multivariate
Discrete

USE CATEGORY:

Approximate value

SPECIFIC USES:

* To display correlation measures of similarity.
* For exploring the results of a principal component analysis or a factor analysis.

COMMENTS:

Applicable mainly to analysis of data.

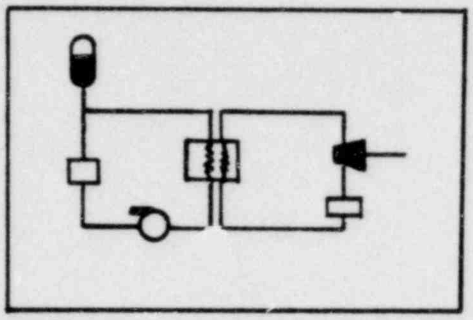
REFERENCES:

G.H. Ball, A Collection of Graphical Plots for Examining Multivariate Data, AD 734 360, August, 1967, pp. 61.

DISPLAY FORMAT SUMMARY

NAME: Mimic Diagrams   I. D. #: 59

DESCRIPTION: Alphanumeric and graphic representations of data related to a system in caricature form.



INPUT DATA TYPE:

Multidimensional
Multivariate
Discrete

USE CATEGORY:

Quantitative

SPECIFIC USES:

* When describing physical processes having variables with dissimilar units.

COMMENTS:

Used extensively in process control.
A map is a mimic of a geographic entity.

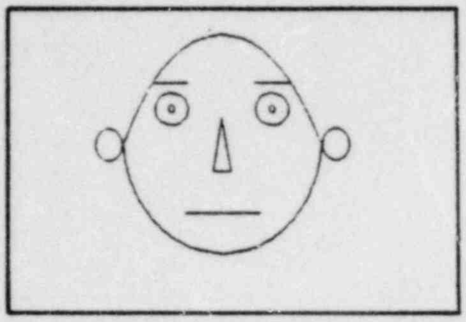
REFERENCES:

None

DISPLAY FORMAT SUMMARY

NAME: Faces I. D. #: 60

DESCRIPTION: A graphical method in which every multivariate point is visualized as a computer drawn humanlike face. Each feature of the face can reflect the value of a variable.



INPUT DATA TYPE:
- Multidimensional
- Multivariate
- Discrete

USE CATEGORY:
- Status & Warning
- Pattern recognition

SPECIFIC USES:

* Cluster analysis and pattern recognition
* Can be used for communication after training.

COMMENTS:

Has mnemonic character.
Comprehensive.
High dimensionality.
Needs a computer

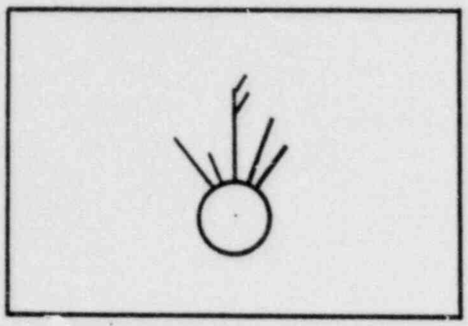
REFERENCES:

H. Chernoff, "The Use of Faces to Represent Points in k-Dimensional Space Graphically". Journal of the American Statistics Association, Vol. 68, No. 342, June, 1977, pp. 361.

DISPLAY FORMAT SUMMARY

NAME: Metroglyphs I.D. #: 61

DESCRIPTION: Uses "symbols" to indicate the value of variables. The symbols could be circles, rays, location within an area, color, line length, line tilt, etc.



INPUT DATA TYPE:

Multidimensional
Multivariate
Discrete

USE CATEGORY:

Approximate value
Normal
Range
Status & Warning
Pattern recognition

SPECIFIC USES:

COMMENTS:

Rays are easily visualized and remembered.
One sees glyphs as a whole and take in all data.
Long rays = 3*short rays
Use 3-7 rays/glyph.
Slant the rays in the same direction.

REFERENCES:

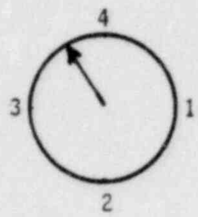
J.E. Mezzich, R.D.L. Worthington, "A Comparison of Graphical Representations of Multidimensional Psychiatric Diagnostic Data", in P.C. Wang, Graphical Representation of Multivariate Data, New York: Academic Press, 1978, pp. 123.

E. Anderson, "A Semigraphical Method for the Analysis of Complex Problems", Technometrics, Vol.2, No.3, August, 1960, pp. 387.

DISPLAY FORMAT SUMMARY

NAME: Moving Pointer I.D. #: 63

DESCRIPTION: A display with a single moving line fixed at one end. The angle of inclination determines the current value.



INPUT DATA TYPE:
Unidimensional
Univariate
Discrete

USE CATEGORY:
Approximate value
Pattern recognition

SPECIFIC USES:
* Historically used to indicate values, such as a time clock

COMMENTS:
Good pattern recognition.

REFERENCES:
None.

DISPLAY FORMAT SUMMARY

NAME: Digital Readout I.D. #: 62

DESCRIPTION: A numeric display indicating the current value of the variable

123.4

INPUT DATA TYPE:
Undimensional
Univariate
Discrete

USE CATEGORY:
Quantitative

SPECIFIC USES:
* When very precise reading if a value is required.

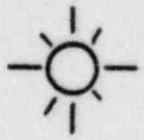
COMMENTS:
None

REFERENCES:
None

DISPLAY FORMAT SUMMARY

NAME: Binary Indicator I.D. #: 64

DESCRIPTION: A simple indicator, such as a lamp, that lights when a certain limit of the variable has been exceeded, or vice versa.



INPUT DATA TYPE:
Unidimensional
Univariate
Discrete

USE CATEGORY:
Status & Warning
Pattern recognition

SPECIFIC USES:
* For annunciation of a limit violation.

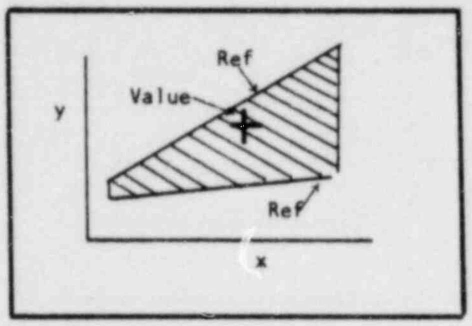
COMMENTS:
None

REFERENCES:
None

DISPLAY FORMAT SUMMARY

NAME: Single Value Line Chart I.D.#: 65

DESCRIPTION: A Line Chart whose time series is fixed as background data. A moving point indicator displays the current value of the parameter in relation to the fixed reference line.



INPUT DATA TYPE:
Duodimensional
Univariate
Discrete

USE CATEGORY:
Approximate value
Deviation
Normal
Prediction

SPECIFIC USES:
* To indicate a value in reference to a time series.

COMMENTS:
None.

REFERENCES:
None.

APPENDIX B

BIBLIOGRAPHY FOR GRAPHICAL REPRESENTATION OF MULTIVARIATE DATA

APPENDIX B

BIBLIOGRAPHY FOR GRAPHICAL REPRESENTATION OF MULTIVARIATE DATA

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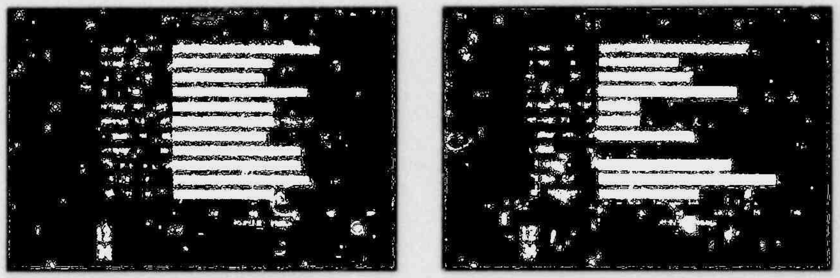
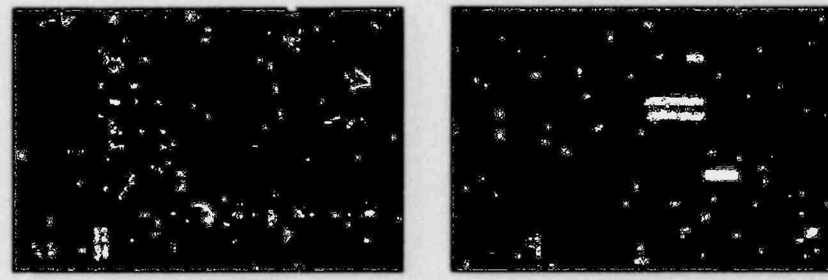
APPENDIX C

SELECTIONS OF CERTAIN TECHNIQUES SHOWING THE USE OF COLOR



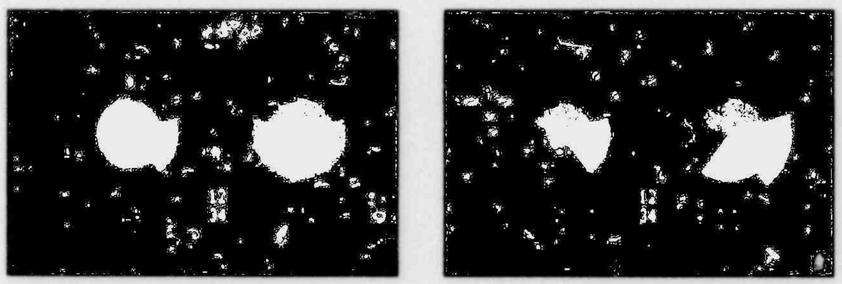
Normal Conditions L6-5 6

Simple Bar Chart



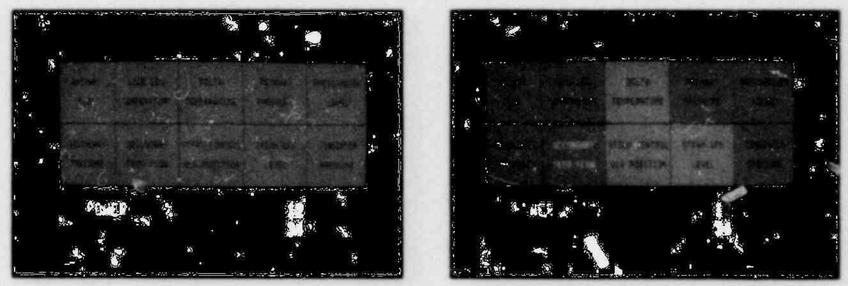
Normal Conditions L6-5 6

Deviation Bar Chart



Normal Conditions L6-5 6

Fourfold Circular Display



Normal Conditions L6-5 6

Array Plot

Selections of Certain Techniques Showing the Use of Color

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