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Realtime Multi-Plot Graphics System

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REALTIME MULTI-PLOT GRAPHICS SYSTEM

by Michael S. Shipkowski

Summary

An investigation was conducted at the National Transonic Facility (NTF) to determine if the existing realtime graphics system could be enhanced to provide the high speed, high resolution, and flexibility necessary to meet current and future needs. The end result was a cost effective system, based upon hardware already in place, that is capable of providing the high quality and quantity of data required by increasing test program demands.

Introduction

The National Transonic Facility (NTF) is a fan-driven, closed circuit, continuous-flow, pressurized wind tunnel capable of operating at MACH numbers ranging from .2 to 1.2. The wind tunnel supports testing using air or gaseous nitrogen. The use of nitrogen as a test medium and operating the tunnel in the transonic speed range imposes high operational costs on a per-point basis. To reduce these costs the NTF data acquisition systems are designed for high speed acquisition, reduction, and display of realtime data collected during tunnel operations. This data is displayed on alphanumeric and graphic cathode ray tubes (CRTs), tabular printouts, and hardcopy data plots. The NTF also supports testing in a Model Preparation Area (MPA) for pre-test analysis.

In realtime test environments the acquisition and display of data are tightly bound together. If acquired data must to be displayed in realtime, the acquisition rate is then a function of the display rate. If acquisition goes on without adequate data display, critical aspects of the test may not be displayed or may be displayed improperly. The design and implementation of the display system has a large effect on overall system performance.

This type of environment requires several things from the plot system; that the resolution of the plotted data is of a high enough quality to allow realtime decisions to be made, that the system is flexible enough to handle changing test criteria, and that operation of the plot system does not degrade the data acquisition system.

Post test analysis of plotted data requires a hard copy system with the same high resolution as the plot system.

Investigation and Findings

The investigation of the NTF realtime plotting system concentrated on two broad areas: the interfaces to the acquisition system and graphics terminals, and the unused capabilities of available graphics terminals. Analysis of these areas directed the design and functional requirements of the Enhanced Graphics System (EGS) now operating at NTF.

Initial Plot System

The NTF realtime plotting system, prior to this investigation, consisted of three graphics terminals, two monochrome storage monitors and one color monitor (used in the monochrome mode), distributed across two computer systems. The two storage tube terminals shared a monochrome hardcopy unit and the color terminal had a dedicated monochrome hardcopy unit. Each terminal was driven by a unique plot task, using a general purpose FORTRAN interface, to plot data.

Hardware and software constraints forced data acquisition and plotting functions to operate on different computers systems during realtime operations. Figure 1 shows the NTF plotting system in its initial state.

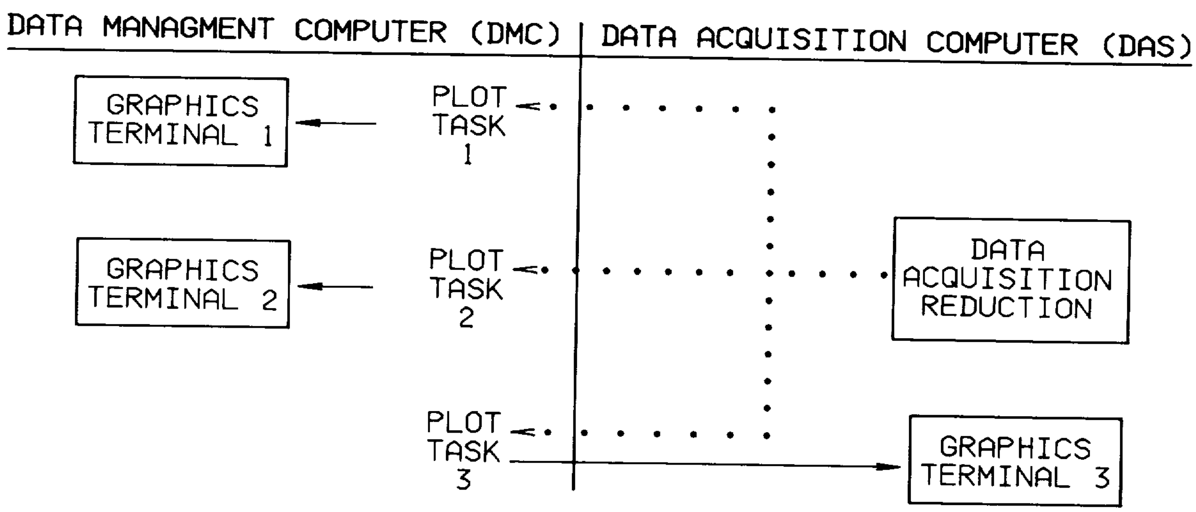


FIGURE 1, NTF REALTIME PLOT SYSTEM

The initial NTF plot system supported both realtime and offline operations. The two distinct plot formats generally used were categorized as force and pressure plots. Each plot format was handled by a separate task. Differences between the three graphics terminals required terminal specific versions of the plot tasks for both formats to be maintained. The system also contained two offline plot tasks, one for each format, for a total of eight plot tasks to support realtime and offline operations. Each of the realtime tasks was driven by a separate plot definition file and the offline tasks prompted for a plot definition file.

The maintenance of eight tasks and multiple definition files complicated operations, especially as plot requirements changed over the course of a test.

The plot software was tightly designed around the existing Data Acquisition System (DAS) data structures and graphic interface package. There were no provisions for alternate data formats or graphics terminals. This approach restricted access to the graphic terminals to DAS specific requirements. Alternate plot requirements required the generation of new plot software, complicating system maintenance even further. The graphics interface supported a single plot on a single terminal and required a separate task to drive each terminal. This limitation restricted realtime operations to a maximum of three plots. Wind tunnel testing normally requires more than three plot definitions to fully examine model data. The extra plots required were generated offline when the tunnel was not operating. There are two problems with this method; (1) the researcher involved with the test must decide which three plots out of the set of possible plots will provide the most realtime information, and (2) tunnel operations may not free up a graphics terminal for an extended period of time.

The requirement for a unique plot task per terminal and plot format, generated a group of stand alone plot tasks. The design of these tasks placed data point input, data processing, and graphics output all in the same realtime task. This approach linked graphics terminal processing speed to the data acquisition rate on a different computer system. Plot tasks were notified of new data points by a "resume" command sent from the acquisition system. The computer system queued a single "resume" for each plot task. If data points were acquired faster than they were plotted, the plot tasks and acquisition system would get out of syncronization. There were no software provisions for identifying and rectifying this condition. The plot tasks could be manually resynchronized but this approach was susceptible to error and inappropriate for realtime operations. This linkage therefore required the data acquisition rate to be reduced to a level the plot tasks could handle.

During realtime operations, three of a possible six plot tasks competed for CPU time, computer link use, terminal I/O, and hardcopy use, to plot their respective data. Two of these resources, link and hardcopy use, contributed to computer system overhead and reduced plot throughput due to the distributed nature of the plot system.

The NTF computer complex contains four computers which communicate over high priority serial links. With the realtime plot system executing on a different computer than the data acquisition software, acquired data had to be passed over the link for each plot task. Although the necessary data for all plot tasks was on the same data point, each task required its own copy. In a worst case scenario with three plots active, realtime plotting required three network transfers to notify the plot tasks of a new data point and three data point transfers to be processed. Each data point required multiple reads across the computer link to access all of the data. This approach placed a double burden on two computers for each data point plotted. Link transfers are handled by a high priority task on each computer which reduces available CPU time for other tasks, and, the link only allows one task at a time to communicate. Therefore, the three control commands and three data points occurred serially, not in parallel. Figure 2 shows the associated host computer overhead associated with link traffic.

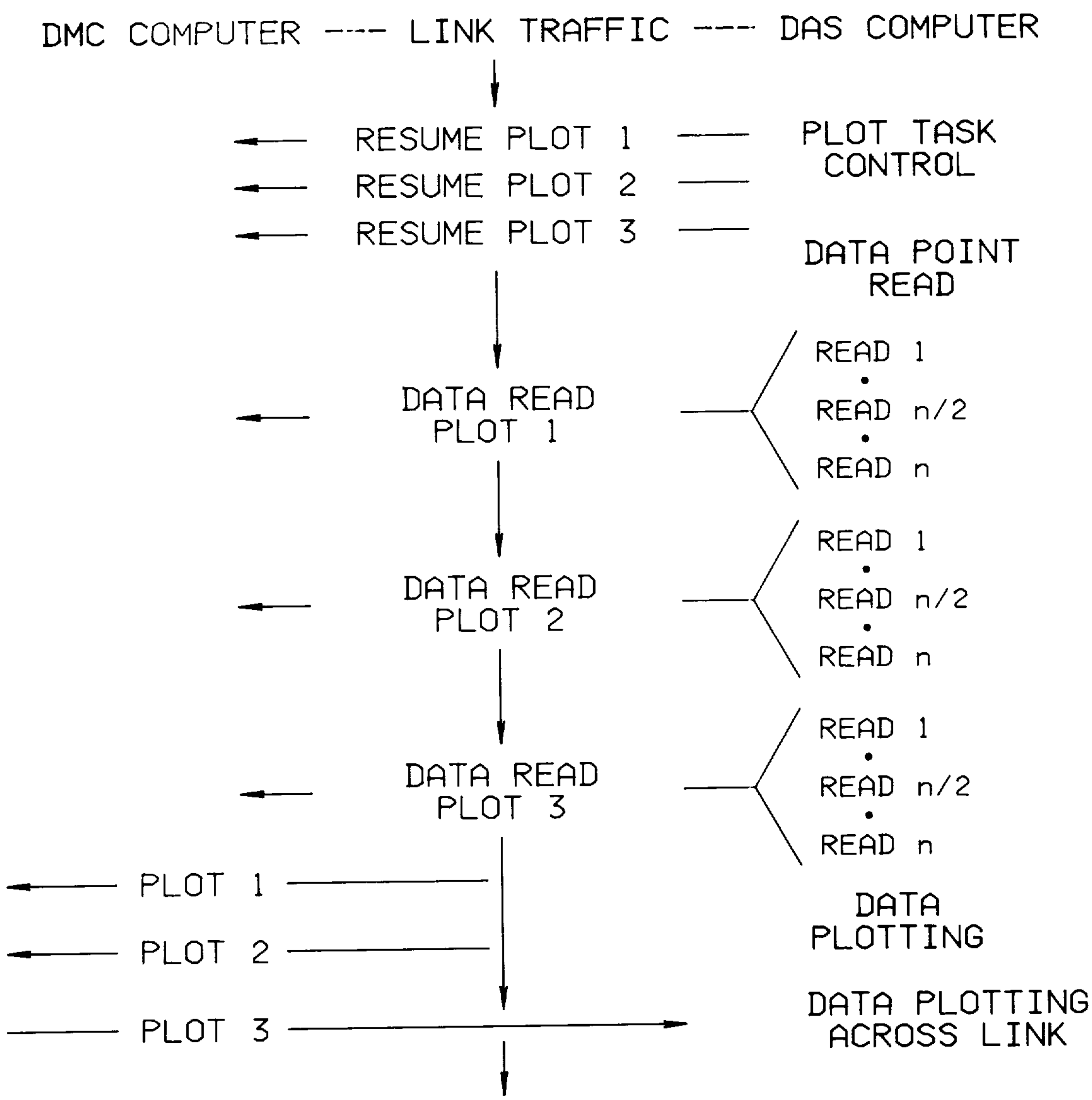
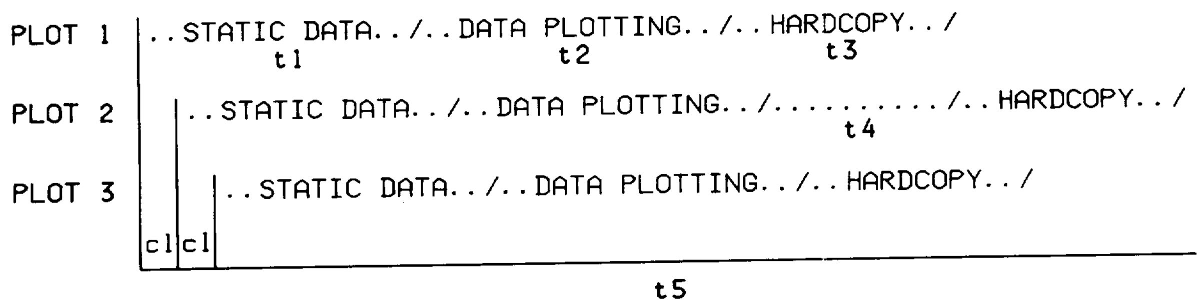


FIGURE 2, HOST SYSTEM LINK TRAFFIC OVERHEAD

The realtime plotting throughput was also affected by the distribution of hardcopy devices. Under normal operations a hardcopy of a completed plot would be generated after each data run or point, depending upon the type of plot required. Each hardcopy required a fixed amount of time to complete. With two plot tasks sharing a hardcopy unit, this time penalty was incurred serially, not simultaneously; the second task was forced to wait for the first to complete a hardcopy before generating its own. Not only did the hardcopy process use a substantial portion of the total plot cycle, but the graphics terminal was also disabled until the copy was completed. Figure 3 shows the reduced throughput due to the distribution of plot tasks and hardcopy units.



c1 = Overhead for multiple tasks/terminals/link traffic

t1 = Static data generation (Grids/Titles/Axis Labels)

t2 = Dynamic data plotting (Symbols/Lines)

t3 = Black/White hardcopy time

t4 = Waiting for hardcopy unit

t5 = Total Time for Plot Cycle

1 + c1 + 4 = Total overhead to distributed plot system

FIGURE 3, REDUCED THROUGHPUT DUE TO DISTRIBUTED PLOT SYSTEM

The distributed nature of the plot system was directly related to the use of a general purpose interface package to communicate with the graphics terminal. The package provided a FORTRAN callable interface between the host computer and the graphics terminals. This provided a simple method of generating graphics but applied general purpose methods to the specific needs of the realtime plot system. The interface package contributed significantly to the low plot throughput rate by placing all of the burden for graphics generation on the host computer. The destination graphics terminal was treated as a dumb device doing no processing on its own, even if such capability existed. All aspects of a plot, including grid generation, labels and plot symbols were recalculated and redrawn each time they were used.

To remove the design and throughput penalties associated with this interface, a new interface, based on a detailed examination of the graphics terminal command set, was developed. The investigation of the existing graphics terminals concentrated on the color unit since it was a raster scan device. This terminal also supported a superior command set, peripherals, and multiple plots simultaneously. The use of color for realtime plots was also considered in this decision. The design effort was based on four general goals listed below:

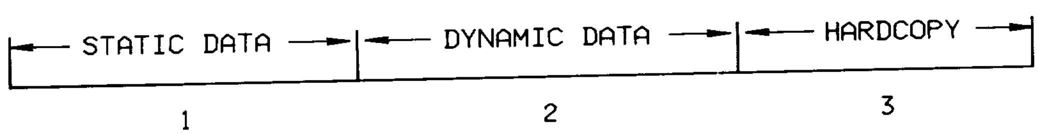
* Increased Plot System Efficiency
* Improved Host / Terminal Communications
* Increased Plot Resolution/Readability
* Multiple Plot Generation/Display Support

Plot System Efficiency

Optimizing plot data throughput is accomplished by making the graphics generation process as efficient as possible and by offloading graphics processing from the host system to the graphics terminal. To do this a thorough analysis of the data plotting cycle and the graphics terminal capabilities was necessary to show where the efficiency of the plot system could be improved.

The plot cycle is composed of several distinct blocks. Figure 4 shows the breakdown of a pressure plot cycle.

PRESSURE PLOT CYCLE



1) Generation of static data : Grid, axis labels, Title, etc.
2) Generation of dynamic plot : Symbols, lines, parameter fields.
3) Completion of a data plot : Hardcopy.

FIGURE 4, PRESSURE POINT PLOT CYCLE

Improvements to plot system efficiency cover the reduction of task overhead and simplification of the position-draw symbol process. Overhead within the plot task is identified as any activity not directly associated with displaying plot symbols.

The first block in figure 4 is static data generation. The original graphics interface package did not differentiate between static data and dynamic data. Each was redrawn multiple times over the course of a test even though the static data did not change.

The generation of static data could not be completly eliminated but it could be removed from the plot cycle and generated prior to realtime operations. This was possible using the terminal's ability to retain a series of graphics commands in a construct called a segment. A segment is a list of graphics primitives that can be identified and manipulated as a unique entity. These constructs can be opened for additional commands or closed from further update via software control. The terminal selected for the EGS supports numerous segment definitions that can be added together or displayed separately. This provided an excellent solution to the static data generation problem.

All static data could be generated and stored as separate segments prior to realtime testing. Since the data was retained by the terminal it only needed to be redisplayed, not redrawn for each data point or run.

Table 1 compares the throughput of the original system to the EGS, as a function of task overhead. This table shows that the generation of static data originally accounted for 25% of the plot cycle. Elimination of this part of the plot provides a substantial improvement in throughput and reduces the graphics burden on the host system.

TABLE 1, REDUCED THROUGHPUT DUE TO TASK OVERHEAD

PLOT SYSTEM	# DATA PT PLOTTED	PLOT SYMBOLS PER DATA PT	STATIC DATA TIME (SEC)	HARDCOPY TIME (SEC)	DISK SAVE TIME (SEC)	TOTAL PLOT TIME (SEC)	SECONDS PER PLOT SYMBOL	% OF PLOT CYCLE DUE TO STATIC DATA	% OF PLOT CYCLE DUE TO TASK OVERHEAD
ORIGINAL	1	87	10.1	9	–	40.6	.47	25	47
EGS	1	85	1.0	–	4	16.5	.19	6	30

This approach also provides a side benefit in improving plot resolution and readability. As shown above, grid generation required a large portion of the plot cycle. Because of this, plot grids tended to be relatively simple, using a few major lines and tick marks.

This forced the researcher to interpret plotted data by visually aligning data symbols and axis position or consulting tabular data to determine X and Y values. Figure 5 shows a standard plot format for the initial system.

Interpolation of plotted data is cumbersome and prone to error. In some cases plots show only general trends when specific values are of interest. With the grid generation process removed from the plot cycle, more dense grid segments can be generated prior to tunnel testing to provide a more precise background. The complexity of the grid has a negligible affect on the redisplay time of the segment. Figure 6 shows a 160 x 120 grid with plotted data produced by the EGS. This grid provides a resolution of .001 on the X axis, .005 on the Y axis and takes less time to display than the more simple grid on Figure 5. Plot readability can be improved even further by separating major and minor lines with color. In the case of figure 6 the minor lines are normally magenta and the major lines black. The effect is similar to graph paper which uses lighter and darker lines to improve readability.

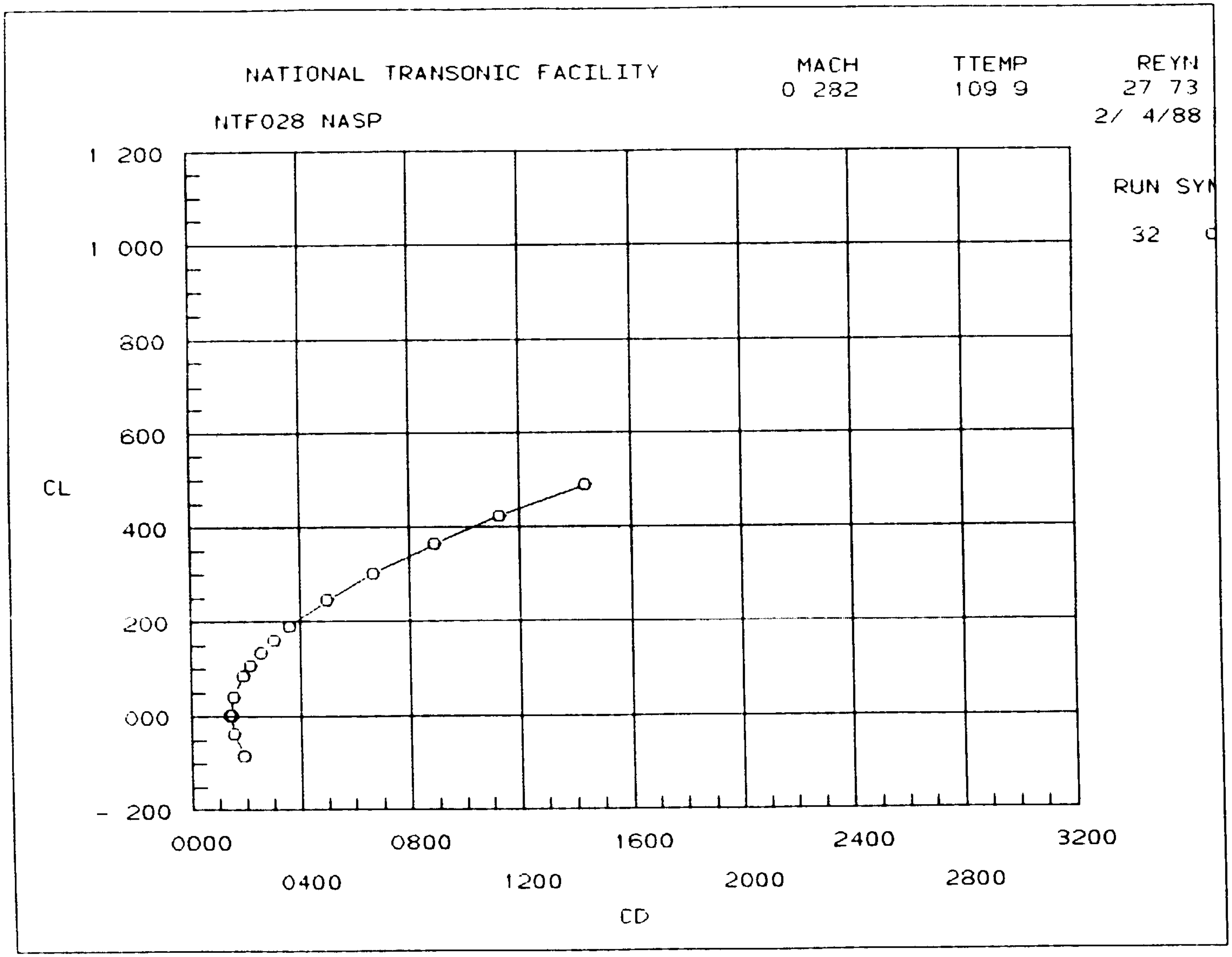


FIGURE 5, STANDARD PLOT

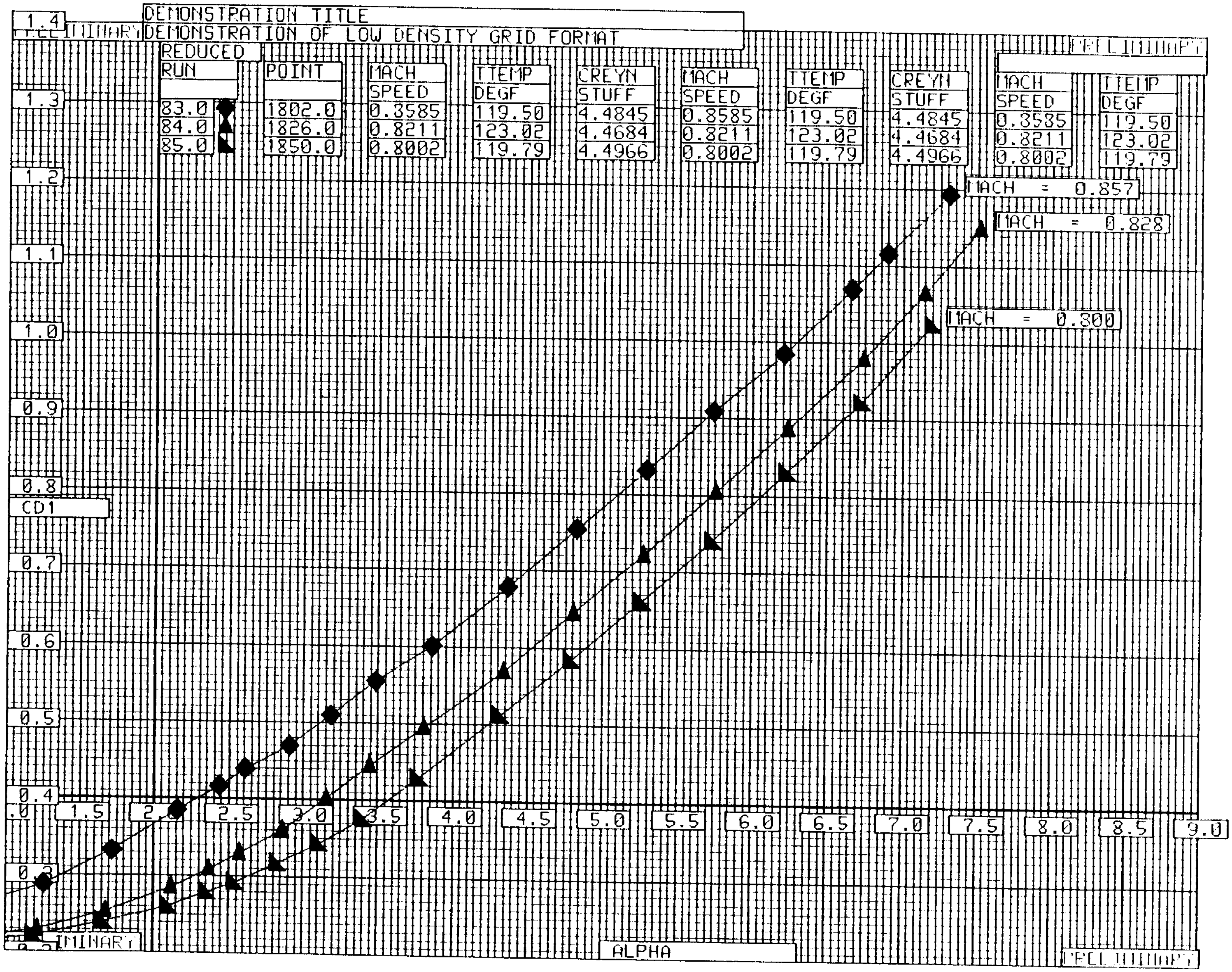


FIGURE 6, ENHANCED GRAPHICS SYSTEM PLOT

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OF POOR QUALITY

The second block in figure 4 is dynamic plot data. This data consists of tunnel parameter fields, plot symbols, and any associated connecting lines. To improve plot efficiency in this area the position-draw symbol process must be optimized. Optimization was accomplished by reducing the amount of data communicated and offloading symbol generation to the graphics terminal. The terminal command set provided several methods to simplify and speed symbol generation. This moved the plot system and terminal toward parallel processing; while the terminal processes and generates symbols, the plot task is free for other operations. Figure 7 shows comparison of circle generation using the EGS and the original system.

EGS TERMINAL COMMANDS	ORIGINAL SYSTEM INTERFACE PACKAGE
POSITION BEAM (15 BYTES) CALCULATE RADIUS DRAW CIRCLE (18 BYTES)	CALCULATE RADIUS CALL CIRCLE CALCULATE RADIANS CALL EMULATE ARC CALCULATE VECTOR ANGLE CALCULATE # VECTORS DO FOR ALL N VECTORS POSITION BEAM (25 BYTES) DRAW VECTOR (60 BYTES) ENDDO
33 BYTES	85N BYTES

FIGURE 7, COMPARISON OF CIRCLE GENERATION ALGORITHIMS

The final block in figure 4 is the hardcopy process. The penalty associated with generating a hardcopy is a function of test operations. In some cases where very high acquisition rates are required, the hardcopies cannot be examined in detail and do not need to be hardcopied immediately. These realtime plots need to be saved for future hardcopying. Under slower acquisition rates, hardcopies can be examined as they are produced to verify that test objectives are being met. To meet both requirements, the plot system must be able to generate realtime plots during realtime operations, and after the testing is completed. This is possible by using the previously described segment construct and by adding a hard disk drive added to the graphics terminal. During high speed acquisition, completed plots are stored on the disk to be recalled and hardcopied later. Table 1 shows that disk storage of a plot takes less than half the time required to generate a hardcopy.

Improved Host to Terminal Communications

The speed at which data is communicated from host to terminal is critical to realtime plot operations. In most cases the host system is capable of operating much faster than the associated graphics terminal(s). Improvements to the plot software will therefore have a limited effect if the plot system must wait on terminal processing.

Data communication efficiency is a function of the amount of data transmitted, the transmission rate, and the number of transmissions. The amount of data sent to the graphics terminal is reduced with the use of more efficient commands and the removal of static data from the plot cycle.

To increase the communication rate to the terminal, the host system was configured to communicate at the highest baud rate supported by both. This increased the communication rate by 100% (from 9600 to 19200), and throughput by 32%. Table 2 shows the increased throughput for the plot system due to the increased baud rate.

TABLE 2, EFFECTS OF BAUD RATE ON THROUGHPUT

PLOT SYSTEM	# DATA PT PLOTTED	PLOT SYMBOLS PER DATA PT	BAUD RATE	TOTAL PLOT TIME (SEC)	SECONDS PER PLOT SYMBOL
ORIGINAL	1	87	9600	40.6	.47
EGS	1	85	9600	16.5	.19
EGS	1	85	19200	11.5	.13

The number of writes to the terminal can affect throughput because of the overhead in handling I/O by the host system and waiting for I/O to complete. The number of individual writes was reduced by sending blocks of commands instead of individual commands. The choice of command block size is critical to plot system performance. A relatively small block size will not reduce the number of individual

I/O operations sufficiently. A overly large command block will reduce asynchronous processing. The graphics terminal selected for the EGS supports the queueing of received commands to be processed as soon as possible. The goal is to reduce the number of terminal writes but insure that the terminal always has queued commands to be processed. Figure 8 shows the asynchronous processing of graphics data when using queued commands.

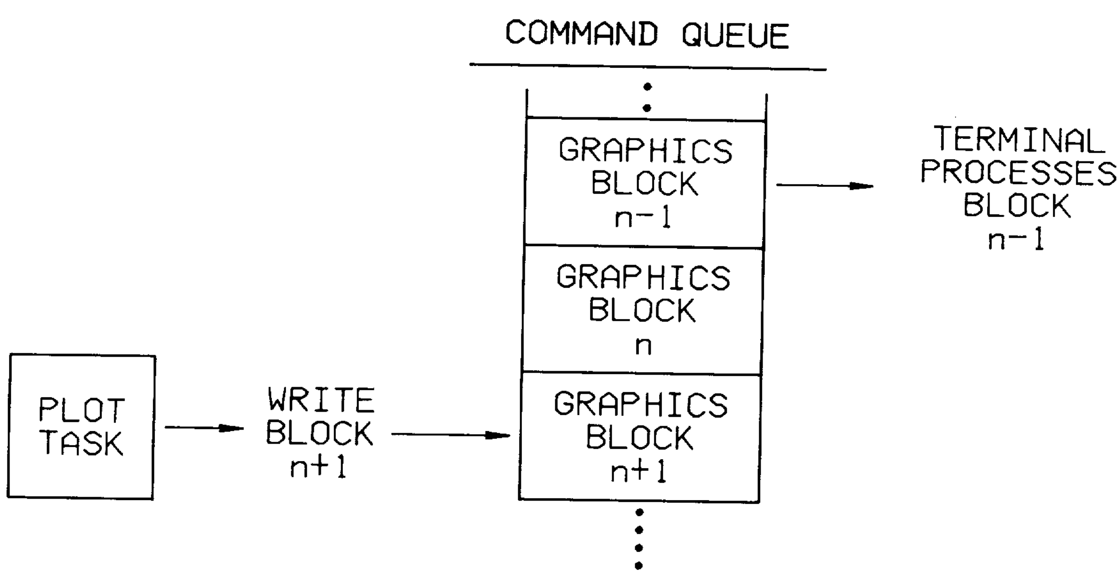

FIGURE 8, ASYNCRONOUS GRAPHICS PROCESSING

The communication improvements could not be implemented without protecting the graphics terminal from being overloaded. This is accomplished by taking advantage of two terminal features: command queue sizing and terminal reports.

The EGS graphics terminal allows manual or software control of the size of a queue for incoming commands. Increasing the size of the queue allows more data to be transferred to the terminal unprocessed but reduces the memory available for terminal graphics. Testing at various acquisition rates and plotting requirements was used to determine a median queue size.

The use of a command queue does not provide protection against overloading the graphics terminal, it merely allows a longer time before overloading occurs. The plot system must synchronize transmissons with terminal processing. Terminal reports provide this capability. The plot system sends multiple blocks of graphics data and requests periodic reports on terminal status. Reception of the terminal report tells the plot task the command queue is empty and available for new command blocks.

Since the report received indicates that the command queue is empty, report requests should only be made when the impact of an empty queue will not degrade throughput. The timing of this is dependent upon how testing is conducted. At NTF a set of points taken under certain tunnel conditions is called a data run. At the end of a run the tunnel conditions are modified for the next run. This is an opportune time to request a report. An alternate approach is to request reports whenever a certain percentage of the command queue could be filled based on a known total number of bytes sent.

Improved Plot Resolution and Readability

The redesign of the NTF graphics system provided an opportunity not only to improve plot throughput but also a chance to improve plot resolution and readability. Plot resolution is the accuracy in positioning and display of plotted symbols and the ability to accurately determine the data values of the plotted symbol. Plot readability is the ability of the plot to convey information to the researcher with as little need for interpretation as possible.

One improvement to plot resolution has already been described; the use of dense grids. Resolution was also increased by taking advantage of how the terminal displays graphics. The terminal screen is a grid of 1280 x 1024 pixels, where a pixel is the smallest piece of the screen that can be manipulated. This limits resolution when plotting in screen coordinates. To display graphics, the terminal maps a 4096 x 3276 memory area to the screen pixel area. By manipulating the size of the memory window the plot system can provide greater resolution. The EGS terminal firmware does all of the memory to screen scaling, adding no processing burden to the software when using this approach.

Table 3 compares the resolution of screen and memory coordinates for X and Y axis scales of 0 to 100.

TABLE 3, COMPARISON OF PLOT SYMBOL RESOLUTION

COORDINATE SYSTEM	Y SCALE	Y AXIS	Y RESOLUTION	X SCALE	X AXIS	X RESOLUTION
SCREEN	0-100	1024	.1	0-100	1280	.08
REG. MEMORY	0-100	3276	.03	0-100	4096	.02
EXTRA MEMORY	0-100	8000	.0125	0-100	8000	.0125

To take full advantage of this method, the generated plot should use as much of the terminal screen as is feasible. An examination of figure 5 shows that the original system used only 51% of the screen area for plotted data. Figure 6 shows one of the new plot formats supported by the EGS system that uses 90% of the screen for increased plot symbol resolution.

The goal of a data plot is to provide information through visual inspection. The EGS system manipulates symbol shape, color, size, and line type to convey information. With many plots, the data symbols, when viewed as a whole, show a trend for the information plotted. In some cases though, individual or sets of symbols need to be differentiated within the plot. An example of this occurred during NTF tunnel calibration. Part of the performance evaluation of the tunnel involves using a long pipe, called the Centerline Pipe, that extends in front of, and through the model test section. Although all of the data plotted is from the pipe, the data within the test section is of particular interest. To separate this information, all of the pipe data is plotted with circles for consistancy, and qualified with color; red for the test area and green for either end of the pipe.

Figure 9 shows a data plot for the Centerline Pipe. Without separating data with color, it would be necessary to reference the X axis and to have knowledge of centerline pipe port numbers relative to test section station numbers, to determine which symbols are within the test section. This requires previous knowledge of Centerline Pipe testing to understand the plot and restricts general use of the data.

The use of color along with symbol shape also allows different types of data in the same plot to be identified easily. Colored symbols are very helpful when data symbols are plotted near or on top of each other. A red triangle can be distinguished from a green circle as long as a part of the each symbol shows. With symbols composed of lines only, multiple symbols become a tangle of lines and cannot be easily read.

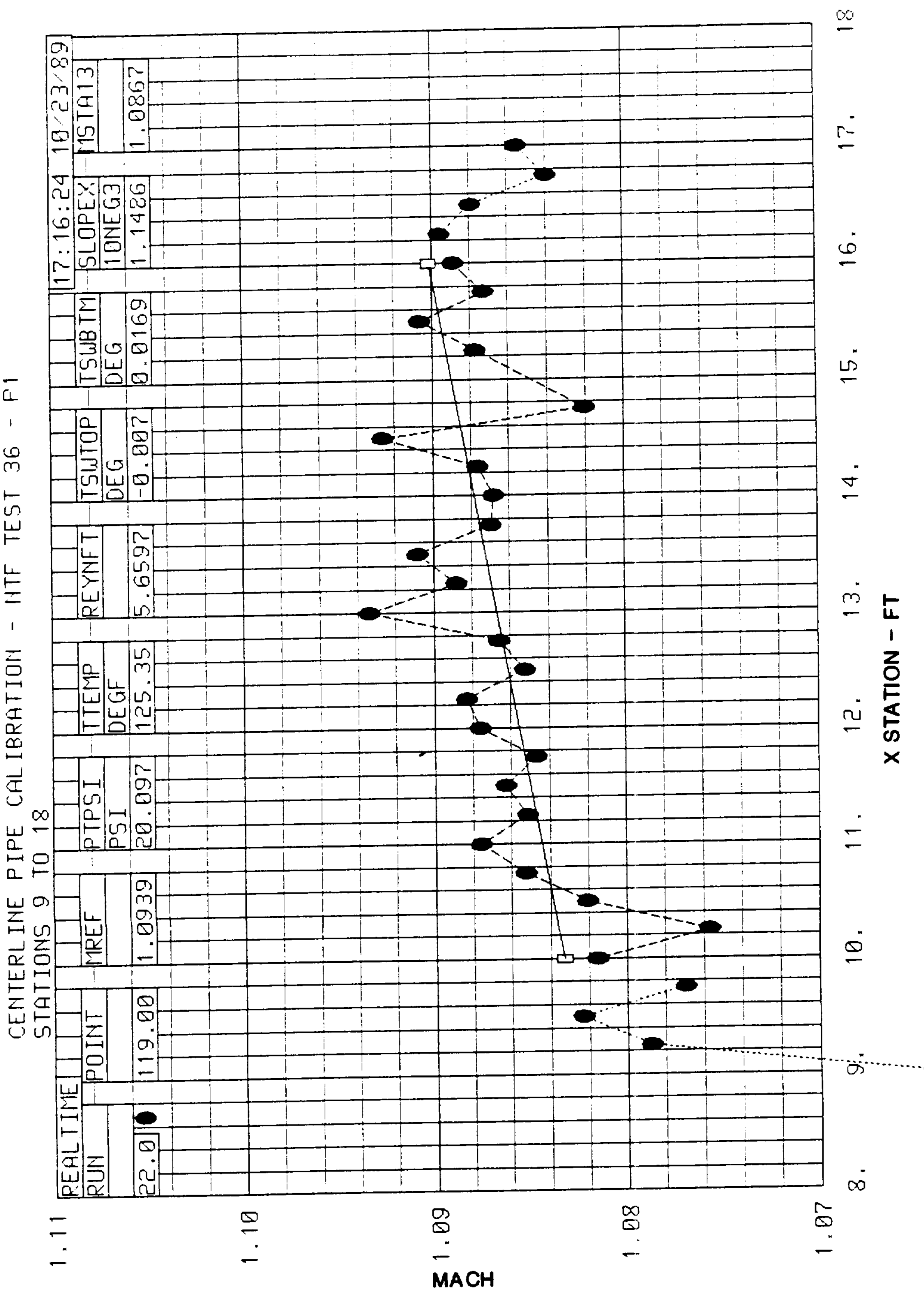

FIGURE 9, CENTERLINE PIPE PLOT

Support of Multiple Plot Generation/Display

Consolidation of the NTF plotting requirements to a single task and terminal required the capability to simultaneously maintain and display more than one plot on the terminal. Since different plots may be updated based on differing criteria, change in point or run number for example, the plots must be manipulated individually under software control.

The retained command list construct, the segment, meets these requirements. The ability to modify, display, or add these lists as unique items allows the plot system to handle each plot independently. As new plot data is acquired, the affected segment is opened, new data added, and then closed for redisplay. Since the segments are treated individually, their content and format are independent of other plots. This provides great flexibility in plot definition and content.

With multiple plots being manipulated simultaneously, the plot system needs the capability to display all plots or a subset of these plots on the CRT. Displaying multiple plots from the host computer would place a heavy burden on the plot system for scaling, positioning, and retaining data.

An alternate approach makes use of the window and viewport manipulation commands handled by the EGS terminal. Windows are rectangular areas of terminal memory. Viewports are rectangular areas of the display memory mapped to pixels on the CRT. The association of a single viewport with a single window is called a view. The terminal maintains multiple view definitions. Positioning each plot/segment in a unique memory window and associating a viewport to it provides a unique view to each plot. This allows any plot to be displayed by selecting the correct view definition. Since a viewport does not need to to be sized for the entire screen, multiple views can be displayed on a single CRT. Likewise, changing the viewport definition from a portion of the screen to full screen expands a specific plot image to full size. Modification of the memory window allows zooming-in on subsections of the plot image. This provides near-instantaneous expansion of complex graphics. The mapping and scaling of the graphics display is performed via the EGS terminal hardware and places no extra processing burden on the host system. The use of windows and viewports provides a simple and efficient method of handling the display of multiple plots maintained on the terminal. The flexibility of view definitions allows screen images to be configured to support different plot formats.

Figure 10 and 10A show two different view setups for multiple plot display, one for plots that have a longer X axis than Y axis and one for square plots.

The capability to display multiple plots on the same screen is a powerful feature in a graphics system. Not only does it allow the operator to view the results of many plots, it allows the organization of related plots into meaningful groups. For example, multiple dependent variable can be plotted against a common independent variable, on separate plots, and displayed simultaneously.

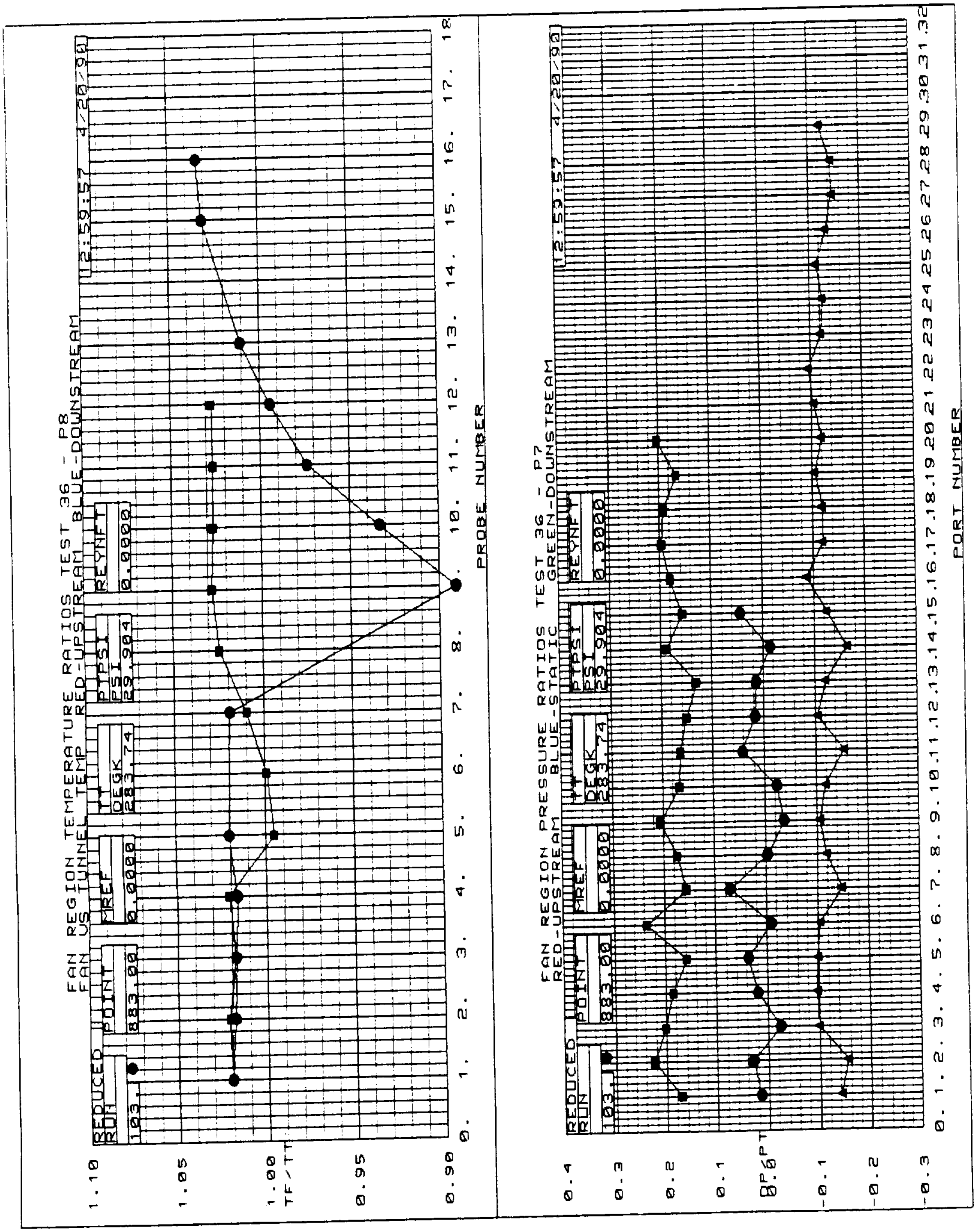

FIGURE 10, LONG VIEW DEFINITIONS

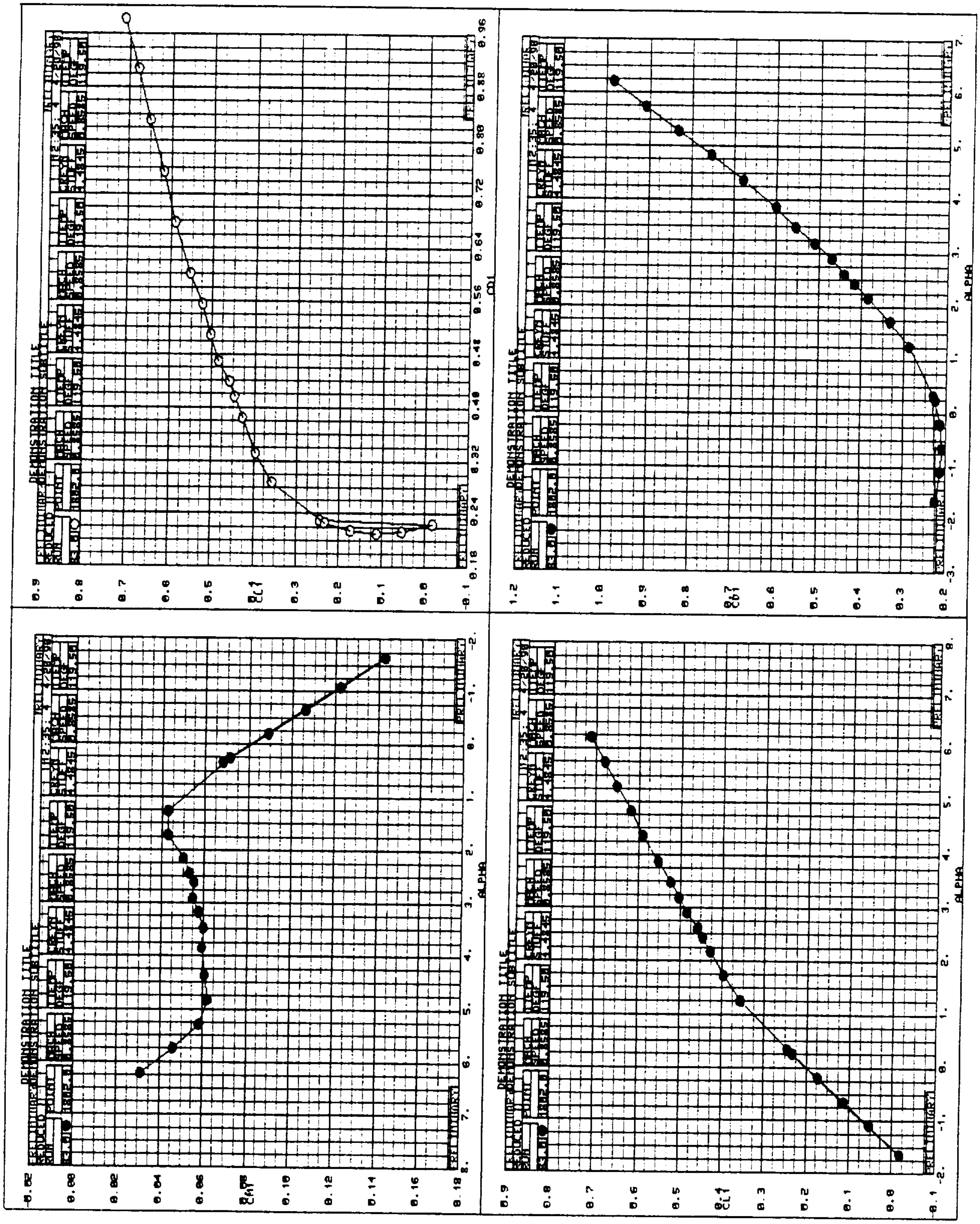

FIGURE 10A, SQUARE VIEW DEFINITIONS

Enhanced Graphics System

The investigations into the original plot system implementation and the utilization of the raster scan terminal produced a series of design goals and functional requirements for the enhanced system. These design goals can be generally categorized as:

* Consolidation of the realtime plot system
* Elimination of the acquisition system-to-graphics terminal timing linkage
* Asynchronous processing of acquired data
* Data format independence
* Graphics terminal independence
* Support for improved realtime plot capabilities

Consolidation of Realtime Plotting

The distributed nature of the initial system was identified as a source of host system overhead and reduced plot throughput. To remove these penalties the EGS system consolidated all of the plot requirements into a single plot task driving a single graphics terminal to support realtime and offline plotting. This approach removed redundant control and data transfers and shared hardcopier use to reduce host system overhead and improve throughput. Eliminating multiple terminals and plot tasks, plus the consolidation of multiple plot definition files into a single file, simplified operation and maintenance of the plot system. Figure 11 shows the consolidated plot task .

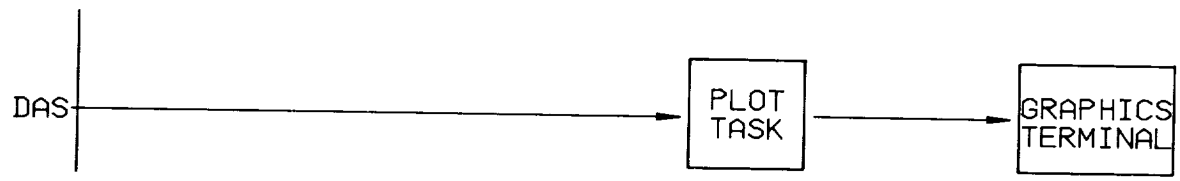

FIGURE 11, CONSOLIDATED PLOT TASK

Elimination of Acquisition to Graphics Terminal Timing Linkage

It was determined that the data acquisition rate was linked to the proccessing speed of the graphics terminal. This is unacceptable in realtime systems. The linkage was due to the combination of several distinct functions; data point retrieval, data point processing, and graphics generation into a single task. To minimize the timing linkage, the data point retrieval function was separated into a unique task. Figure 12 shows the separation of the data retrieval function.

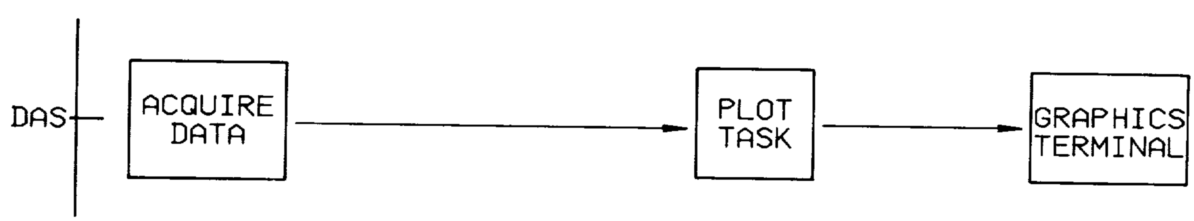

FIGURE 12, SEPARATION OF THE DATA RETRIEVAL FUNCTION

Asyncronous Processing of Acquired Data

Separating the data retrieval and graphics functions does not completely eliminate the timing linkage between acquisition and graphics systems as long as the system can only handle a single data point at a time. The retrieval of data and graphing of data should run asynchronously. To do this, the data retrieval task must operate independently of the graphics task. The retrieval task must be designed to handle the acquisition rate of the data acquisition system regardless of graphics processing. This can be done by queueing retrieved data points which are then passed to the graphics task as soon as possible. Table 4 show the affects of queueing on throughput.

TABLE 4, EFFECTS OF QUEUEING ON THROUGHPUT

PLOT SYSTEM	PLOT TYPE	# DATA PT PLOTTED	PLOT SYMBOLS PER DATA PT	DATA POINTS QUEUED	DATA READ TIME (SEC)	TOTAL PLOT TIME (SEC)	READ TIME PER PT (SEC)	PLOT TIME PER PT (SEC)	PERCENT DIFFERENCE
ORIGINAL	PRESSURE	10	87	0	209	209	20.9	20.9	0%
EGS	PRESSURE	10	85	3	87	122	8.7	12.5	30%
EGS	FORCE	23	1	5	17	21.5	.74	.93	20%

This approach does not completely eliminate the linkage but does provide a failsafe for short term high acquisition rates. The size of the data point queue can be configured based on system resources and anticipated needs. Figure 13 shows the addition of data point queuing.

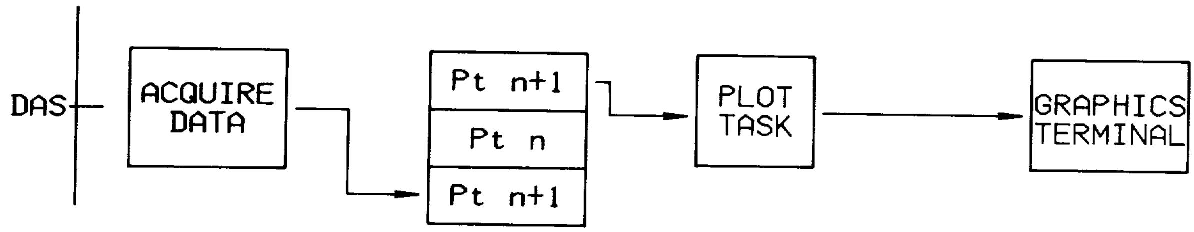

FIGURE 13, ADDITION OF DATA POINT QUEUEING

Data Format Independence

Designing a plot system around a specific data format restricts plotting capabilities and access to terminal equipment. To insure that the plot task is independent of external data formats, incoming data points are translated to a EGS plot task specific format. This format is designed around the needs of the plot task, not the needs of the associated acquisition system.

The translation process is separate from the data retrieval software to support alternate data formats. Generation of a translation task allows any external data source to access the graphics software by adding a new translation routine. This design supports the plotting of customer supplied data and experimental data to compare previous or anticipated model response with actual test data. An independent translation task also allows multiple data formats to use the graphics terminal simultaneously. Figure 14 show the addition of the data interface task.

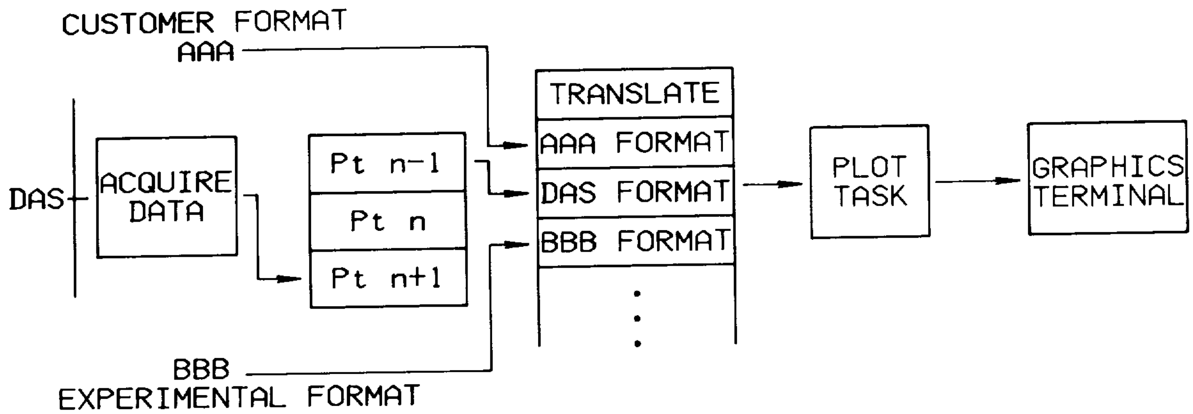

FIGURE 14, ADDITION OF DATA INTERFACE TASK

Graphics Terminal Independence

Designing the plot system around a specific graphics terminal reduces transportability and long term usability of the system. The linkage between plotting software and the graphic command set supported by the graphics terminal can be isolated to a degree with the correct task design. This approach separates plot data manipulation, intertask communications and other tasks from the command sequences used to drive the graphics terminal. To do this, all terminal commands used by the plotting system were implemented as single function subroutines. This modular approach has a threefold purpose. It allows the collection of these subroutines into a utility library which can be accessed not only by the realtime software but also by any task wishing to use the graphics terminal; any additional commands required by the system can be easily implemented by the creation of a new utility subroutine to support new requirements or terminal upgrades; and, this method allows the plot task to be transported between different graphics systems as long as there is a relatively high correlation between the command sets. The main body of the plot task will need only minor changes and the utility subroutines can be simply modified to fit with different command formats having similar functions. Figure 15 show the addition of the utility library to the plot system.

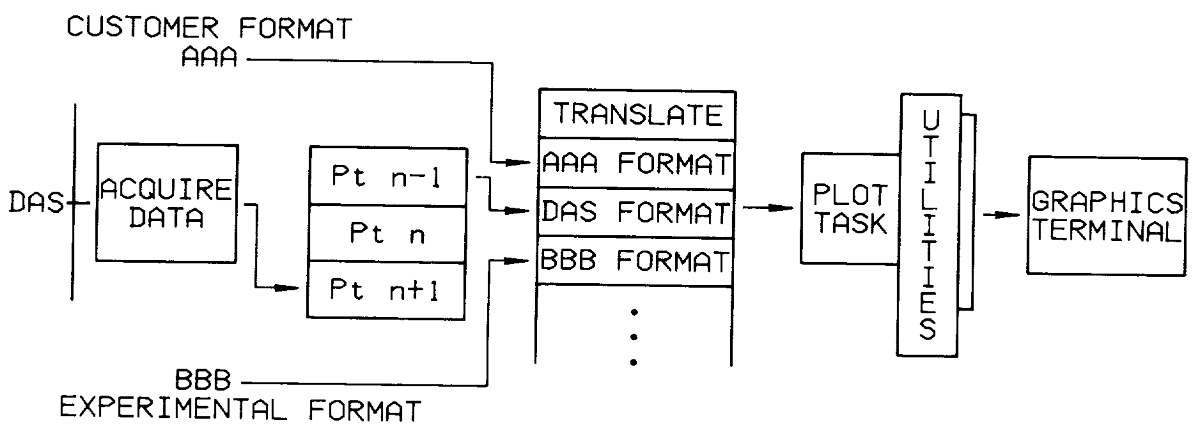

FIGURE 15, ADDITION OF UTILITIES LIBRARY

Enhanced Realtime Plotting

The EGS system is designed around the use of views, segments, and color. To support these features, the capabilities of the raster scan graphics terminal were augmented with the addition of several peripherals.

The EGS graphics terminal supports a maximum of 64 view definitions. Since there is a one to one correlation of view to plot, the EGS system supports a maximum of 64 plot definitions. All, or a subset of these plots, can be active at any time.

This number allows all of the plot requirements, pre-test, tunnel operations, and post-test analysis, to be consolidated into a single file. This approach simplifies operator maintenance without restricting research requirements. Selection from a set of plots allows the researcher to use only the subset that applies to the current test environment.

The NTF is used by numerous organizations to test a wide variety of models. Given the complexity of the multiple plot generation and display, the EGS system must support a simple, controlled operator interface that can be used by researchers unfamiliar with the system without inadvertantly damaging operations. This is accomplished by manipulating the 16 function keys supported by the terminal. The function keys are programmable, allowing their definition to change from test to test or during a test.

To demonstrate the interaction of multiple views and function keys, consider operations during Model Preparation Area (MPA) testing. Testing in the MPA sometimes involves the cryogenic cycling of a balance to measure response over a range of temperatures. There are six components measured from the balance and displaying the six simultaneously provides an overall picture of the balance behavior.

To handle this type of testing the EGS system maintains six plots and views. Figure 16 show six balance components displayed simultaneously. To examine any single component with higher resolution the operator simply presses the associated function key to zoom that component to full screen. Figure 17 shows this expansion. With all components of the balance monitored, any unexpected responses can be detected and examined rapidly. Prior to the EGS system, a single terminal was allocated to support MPA operations, displaying a single balance component. The monitoring of any of the other 5 components required manual plotting over the duration of the test which could take as long as 16 hours. Manual plotting for this period of time was tedious, but waiting for post test plots to determine if the balance behaved correctly could force repeated testing thus incurring unnecessary operation costs and lost time. The EGS solved this problem.

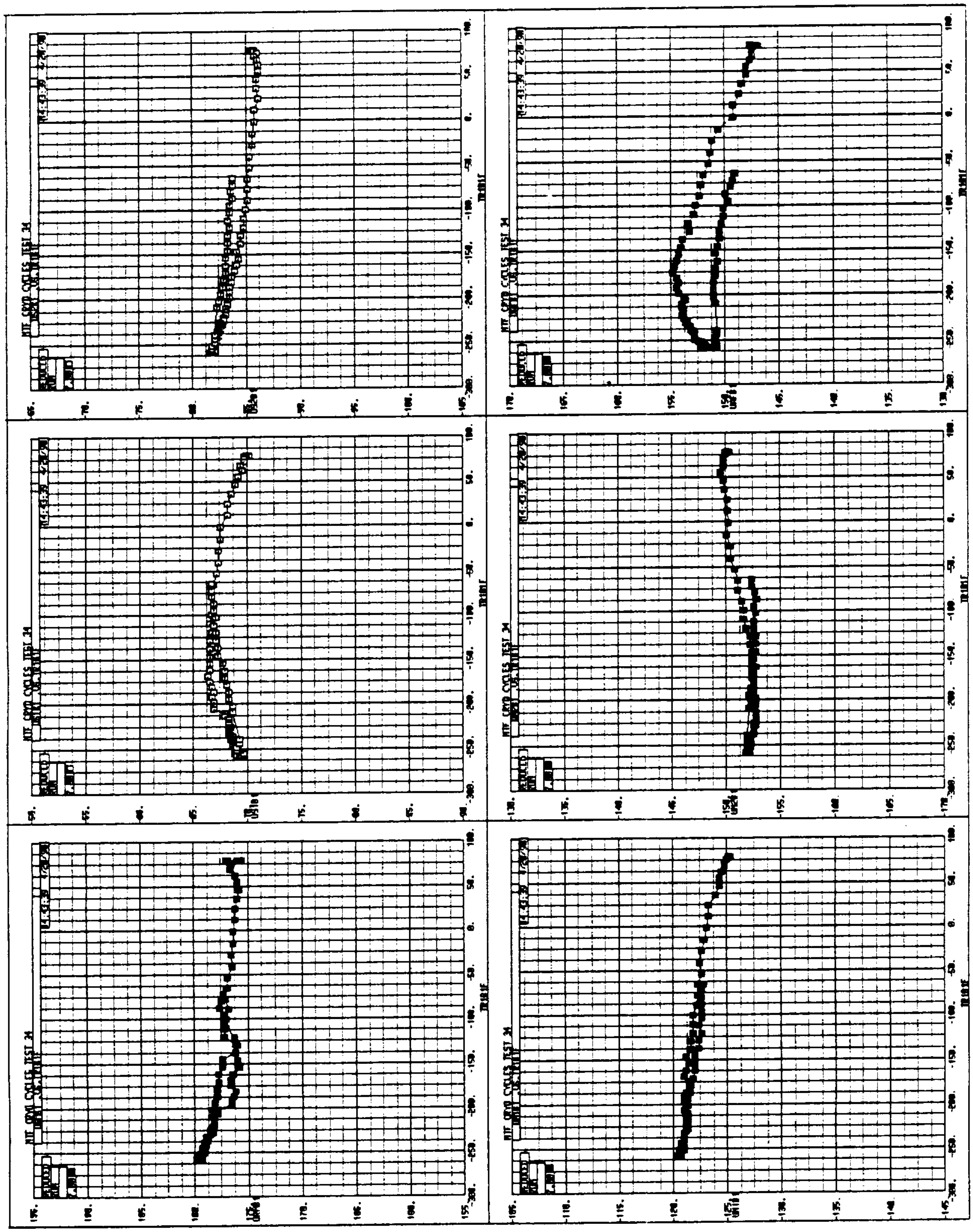

FIGURE 16, MULTIPLE PLOT CRYO CYCLE

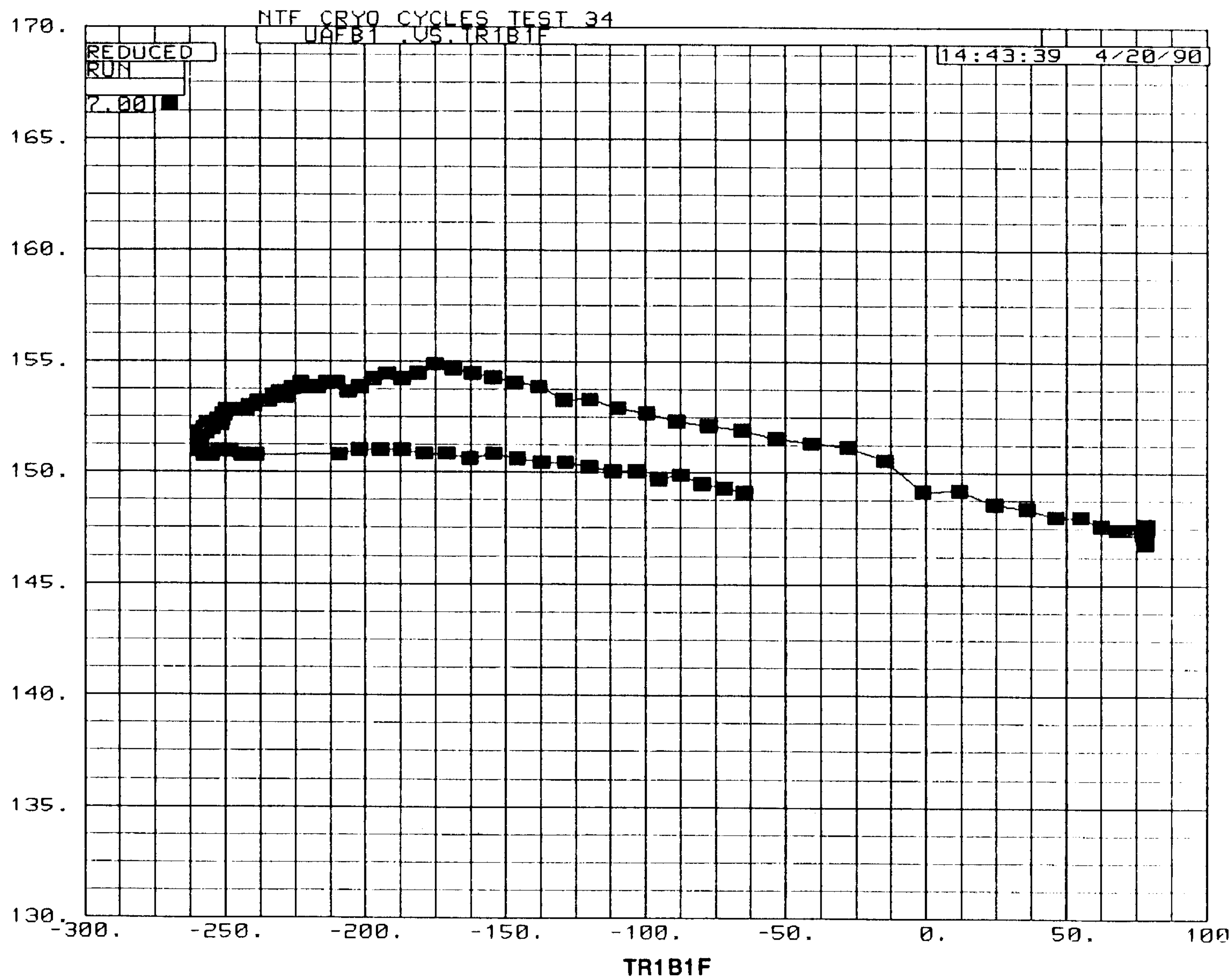

FIGURE 17, EXPANDED PLOT

To support the EGS system's use of segments, a hard disk and a floppy disk drive were added to the graphics terminal. The improved plot performance using stored grids and deferred hardcopying has been documented. The disk drives also provide the opportunity to add additional capabilities to the system. During realtime operations, completed plots are stored on the hard disk for future reference. These stored plots can be retrieved and viewed using the EGS system, or from the graphics terminal in a stand alone mode. This allows plotted data to be examined without use of the host computer system. Stored plots are also archieved to floppy disk for long term storage. This allows the examination of historical data without the need for replotting.

Under normal operations, the EGS system retrieves stored grids from disk. An alternate approach uses a stored data plot as a background for new plot data for direct comparison. Using a stored plot of data taken under similar conditions allows instantaneous comparison during tunnel operations. Combining this capability with the system ability to plot non-NTF data allows the comparison of realtime NTF data and data taken from other wind tunnels.

Figure 18 shows the use of comparison plotting within the EGS system.

The handling of data multiple formats also provides new capabilities during offline data analysis. The results of MPA testing are curve fitted to generate a third order fit of the hysteresis loop. A task generating data points using the resultant coefficients can retrieve a stored plot and plot the curve fitted data over it, showing how well the coefficients fit the actual data.

The final peripheral addition was a high resolution color copier. The EGS system allows operation of the color copier, a monochrome copier, or both during realtime and offline plotting. The color copier supports several expansion factors and paper size up to 11 X 17 inches. This ties in nicely with the use of very dense grids which are even more readable in an expanded form.

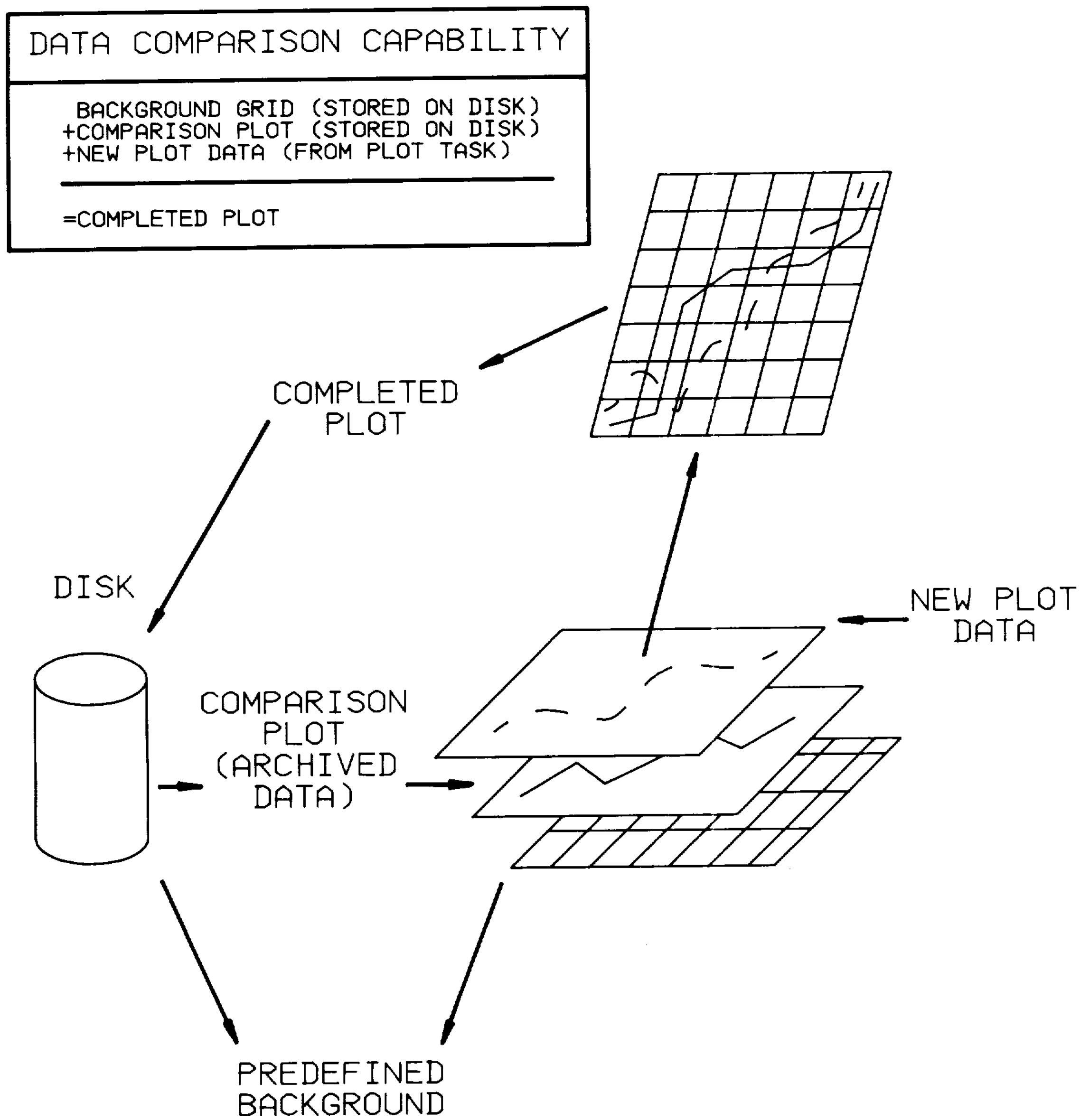

FIGURE 18, DATA COMPARISON PLOTTING

The design of the EGS system and the addition of several peripheral devices provide a highly flexible, high speed, high resolution plot system. The multiple task modular approach insures long term usability with reduced operational and maintenance costs.

Conclusions

The Enhanced Graphics System is a high speed, high resolution, multiple plot grphics system supporting realtime and offline plotting at the National Transonic Facility. The consolidation of plotting requirements and graphics generation has simplified operations and improved system usability. The system is the result of an in depth analysis of the internal and external interactions of the initial plot system, and graphics hardware already in place. The results of this study and the addition of inexpensive support peripherals for the graphics terminal has provided a cost effective, high performance graphics system that meets the current and future needs of the NTF.

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16. Abstract

The increased complexity of test operations and customer requirements at Langley Research Center's National Transonic Facility (NTF) surpassed the capabilities of the initial realtime graphics system. This report describes the analysis of existing hardware and software and the enhancements made to develop a new realtime graphics system. The result of this effort is a cost effective system, based on hardware already in place, that supports high speed, high resolution, generation and display of multiple realtime plots. The Enhanced Graphics System (EGS) meets the current and foreseeable future realtime graphics requirements of the NTF. While this system was developed to support wind tunnel operations, the overall design and capability of the system is applicable to other realtime data acquisition systems that have realtime plot requirements.

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