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HOUSTON-GALVESTON VESSEL TRAFFIC SERVICE WATCHSTANDER ANALYSIS

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16. Abstract

A team of human factors specialists analyzed the performance of watchstanders in the U.S. Coast Guard Vessel Traffic Center at Houston, TX. Data collected included copies of the center's forms and logs, records of watchstander activities for a total of fifteen hours of observation, timed measurements of typical watchstander activities and computer delays, records of twelve in-depth interviews with center personnel, stress questionnaires administered to nine watchstanders, and photographs of equipment and workspace layout. Analysis of the data yielded tentative models of time utilization and the relationship of activity to traffic load and sixteen suggestions for improving operations.

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PREFACE

This is an interim report on the analysis of watchstander activities at the Houston-Galveston Vessel Traffic Service. The study was performed by the Human Factors Branch of the Department of Transportation's Transportation Systems Center (TSC) under the sponsorship of the US Coast Guard's Office of Research and Development. Further analysis of the Houston-Galveston data is planned, particularly with the transcripts of radio communications. These initial results, however, were judged to be of enough interest to warrant an early report.

The authors wish to express their sincere thanks to LCDR C.T. Johnson and LT P.R. Corpuz of the Office of Research and Development and to CDR E. Schneider and all the personnel of the Houston-Galveston VTS for the encouragement and support provided by them in every phase of this study. We also gratefully acknowledge the guidance and contributions to the report provided by Dr. H.P. Bishop, Program Manager and Chief, Human Factors Branch (DTS-532) at TSC.

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EXECUTIVE SUMMARY

As the first study in a program for the evaluation of watchstander productivity in US Coast Guard Vessel Traffic Services (VTS's), a team of human factors specialists from the Department of Transportation's Transportation Systems Center (TSC) collected and analyzed data on watchstander activities at the Houston-Galveston VTS. During the period September 19-21, 1977, the following information was obtained:

Copies of VTS forms and logs;
Detailed records of watchstander activities for a total of fifteen hours of observation;
Repeated time measurements of typical watchstander actions and computer delays;
Records of twelve in-depth interviews with VTS personnel;
Stress questionnaires administered to nine watchstanders;
Photographs of equipment and workspace layout.

The Houston-Galveston area is divided into three sectors, each served by a Sector Watchstander (SW) at a sector position in the Vessel Traffic Center (VTC). Each sector position has a control console for a VHF-FM radio communications system, a computer terminal (a keyboard and two cathode-ray-tube displays) for the VTS-Data Acquisition and Control System (VTS-DACS), and controls for surveillance aids (television or radar). Position reports and identifying data are radioed from the vessels to the SW, who manually enters the data into the VTS-DACS via the keyboard. The computer then dead-reckons and displays current vessel positions and other relevant traffic information. Subsequent positions, reported or observed on television or radar, are used to verify and (if necessary) correct the computed data. At the time of the study, the Houston-Galveston VTS was maintaining a backup tracking system that involved advancing traffic status cards along a slotted board.

The SW monitors his displays and periodically radios a traffic advisory to each vessel in his sector. The advisory is generally limited to an enumeration of traffic that the vessel will encounter, discrepancies in aids to navigation, significant weather, and channel hazards or obstructions. If conditions require it, special cautions and directions may be included in an advisory.

The SW's are supervised by a Watch Supervisor (WS) and assisted by an External Communicator (XC).

The comments and opinions expressed by the VTS personnel in the interviews identified some operational problems that were also reflected in the data. The principal set of problems centers on inadequacies of the VTS-DACS, including:

Inadequate integration of displayed data
Excessive keying requirements
Display delays
Request rejections
Inaccurate data.

Basically, the SW needs to know the location and identification of every vessel in his sector. To get this information from the VTS-DACS, he must look at two displays (a plan position display and a vessel listing) and mentally integrate this information. To get supplementary information (such as vessel intentions, future encounters, vessel in port, etc.) from the VTS-DACS, or to enter information, the SW must call up other displays. Since he has only two display devices, he must always lose a basic display while using any supplementary display. To change a display requires at least four keystrokes and may require up to fourteen. Because of computer memory limitations, there is a delay of at least one second, generally two seconds, and possibly ten seconds after the keying is completed before the requested information is displayed. If keying is too fast, or if power fluctuates, the computer may reject a request, forcing the SW to repeat the entire keying operation. In our limited testing, two-to-seven percent of our display requests were rejected. Finally, since changes in vessel speeds are often unreported and undetected, the displayed positions and projected positions are frequently in error.

The first consequence of these problems is that the SW fails to make full use of the capabilities of the VTS-DACS. Both the usage ratings of displays made in the interviews and the observations of watchstanders at work showed that SW's tend to use only those displays they can't avoid using, rarely calling up supplementary information. In particular, the display that should be the basis for every traffic advisory (Traffic Status Summary), requiring excessive keying and subject to excessive delay, is almost never used.

A second consequence of this situation is that the Vessel Status Card tracking and reference system is still relied on heavily for information. About one-quarter of the SW's time is spent in maintaining and using it, and it seems unlikely that it can be dropped until the VTS-DACS can be made more responsive to the SW's needs.

p. Establish a set of criteria for selection of personnel for VTS duty.

1. INTRODUCTION

1.1 Purpose

In order to reduce the probability of vessel collisions and groundings in crowded waterways, and to keep individual vessels apprised of the total traffic situation, the US Coast Guard is operating several Vessel Traffic Services (VTS's). To profit from the experience gained in operating these VTS's, both to improve present services and plan future services, the Coast Guard's Office of Research and Development has undertaken a broad program of analysis of VTS operations.

Human performance is basic to the operation of a VTS. The principal product of a VTS is a traffic advisory communicated by a VTS watchstander to a vessel master or pilot via VHF radio. The value of the advisory is dependent on the skills of the various watchstanders in acquiring and monitoring traffic data, in integrating the data into a coherent picture of present and anticipated traffic, and in composing and delivering a clear, concise and accurate traffic advisory. Therefore the Coast Guard has recognized that any model of VTS operations and productivity must include the influence of watchstander performance on system performance. The Coast Guard's Office of Research and Development has commissioned the Human Factors Branch of the Department of Transportation's Transportation Systems Center (TSC) to obtain and analyze data on watchstander performance and to integrate the results into models of watchstander activity and productivity.

1.2 Scope

For its first year's work on this study of VTS watchstanders, TSC has undertaken the collection and analysis of data on watchstander activities in routine operations in four operating VTS's: Houston-Galveston, Puget Sound, New Orleans and San Francisco. This report presents the initial results of the analysis of the first VTS -- Houston-Galveston.

2. DESCRIPTION OF HOUSTON-GALVESTON VESSEL TRAFFIC SERVICE

2.1 Purpose of VTS's

The Ports and Waterways Safety Act of 1972 authorizes the Coast Guard to operate vessel traffic services (VTS's) in designated areas to "...prevent collisions and groundings and to protect the navigable waters of the VTS Area from environmental harm resulting from collisions and groundings."* VTS's meet this objective "... by providing pilots and masters of vessels information concerning vessel traffic conditions and navigational hazards that would otherwise not be available to them."**

2.2 General Characteristics of HOU-GAL VTS

The Houston-Galveston Vessel Traffic Service (HOU-GAL VTS) provides a 24-hour service to three major ports (Houston, Galveston and Texas City), several sub-ports, and more than 70 miles of navigable channels. The VTS handles about 250 transits per day*** some 20 percent of which are ships, 80 percent tows (barges pushed by tug boats). Because of the narrowness of the Houston Ship Channel (300 to 400 feet) and the shallowness of Galveston Bay, there is relatively little traffic other than commercial. The commercial traffic volume is increasing; over the first two years of VTS operation (March 1975-March 1977), traffic load increased by 38 percent. Over 60 percent of the cargo tonnage in the system is dangerous -- petroleum, liquefied natural gas (LNG), acetone, chemical fertilizers and sulfuric acid --making Houston the nation's leading port in terms of dangerous and volatile cargoes.**** All of this traffic moves in narrow, shallow, often winding channels lined with some 300 docks and industrial facilities. Figure 2-1 shows the principal characteristics of the HOU-GAL VTS area, including its division into three sectors to facilitate information processing.

The HOU-GAL VTS is based on a voluntary Vessel Movement Reporting System (VMRS), in which participating vessels report their position to the Vessel Traffic Center (VTC) via VHF-FM radio from designated reporting points, and the VTC radios back advisories on traffic and related conditions. Surveillance is

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*Code of Federal Regulations, 33CFR161.101
**Puget Sound VTS Traffic Center Manual, #1.1.2
***Statistics provided by HOU-GAL VTS
****O'Hara, E. "How to Guide Ships Through a Dangerous Port: VTS Does it in Houston." Transportation USA, 3, 2, p.6-10, 1977

aided by a precision radar site in Galveston (effective range 8 nautical miles) and four camera sites (2 cameras per site) for a closed-circuit low-light-level television (LLLTV) system along the northeastern portion of the Houston Ship Channel. To assist the Coast Guard watchstanders at the VTC, a Data Acquisition and Control System (VTS-DACS) accepts manually input information on each vessel (location, speed, destination, etc.), automatically computes a track for each vessel by dead reckoning, and presents track data and listings of summary information on cathode ray tube (CRT) displays.

2.3 Functions

A standing order of the HOU-GAL VTS lists their traffic control functions, in "marching order", as follows:

Monitor
Anticipate
Inform
Caution
Direct (only when necessary).

2.3.1 Monitoring

Monitoring the traffic situation involves creating and maintaining as accurate a picture of the current traffic situation as available data permit. This picture is based on the VMRS position reports, supplemented by whatever surveillance (radar, television) information is available.

The basic display of such information is the Dead Reckoning Plot Sheet (DR), a CRT display produced by the VTS-DACS. A DR display covers only one sector of the system; thus to survey the entire system one must either call up three successive displays on one CRT or view three separate CRT's. Since the DR display does not include identity tags, it is usually paired with a Vessels Underway Sheet (VU), displayed on a second CRT, which lists the names and basic data of vessels underway in the sector. Several other listings of traffic information are available, usually called up on the CRT used for the VU sheet. (See Section 2.6.2 for a more detailed description of available displays and Appendix A for examples).

Prior to inauguration of the VTS-DACS, the traffic picture was maintained on a large, wooden plotting board. Slits in the board represented locations in the system, and each vessel

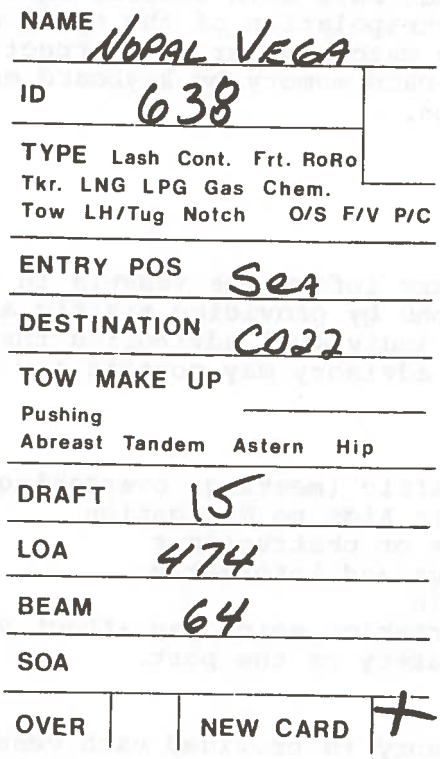


FIGURE 2-2. EXAMPLE OF A VESSEL STATUS CARD

2.3.4 Cautioning

When an unusual event occurs, every vessel that could be affected by it is given a special advisory in sufficient time for the Master or Pilot to initiate appropriate action. Unusual events include:

Channel closures ordered by higher authority

Controlled traffic situations ordered by higher authority

Dangerous conditions in the port

Major collisions, fires, groundings, etc.

Any other situation judged dangerous by the VTC Watch Officer.

A caution advisory includes a brief description of the situation followed by timely updates. Channel conditions (closed, blocked, hazardous, etc.) are included, and the vessel is requested to report its intentions.

2.3.5 Directing

Although the HOU-GAL VTS, being a voluntary service, does not have direct authority to control traffic, each Captain of the Port (COTP) in the VTS area not only has such authority for emergency situations but must coordinate such control with the VTS. Beyond relaying orders for vessel traffic control through the VTS, the COTP's have delegated their authority to the Watch Supervisor on duty in situations requiring immediate direction and control of vessel traffic. This authority is used sparingly and must never include (or imply) direct orders for control of vessel speed or direction (such as "stop engines", "slow ahead", turn" or "back down.") A direction will generally include a statement imposing the necessary restrictions, a description of the circumstances requiring them, and the requirement that the vessel report its intentions.

Typical directing advisories follow: "SEA SPEED this is HOUSTON TRAFFIC. Due to severe channel congestion between Greens Bayou and Sims Bayou proceed at reduced speed; do not overtake the tug STARLIGHT. Report when passing Sims Bayou." "PURPLE KAY this is HOUSTON TRAFFIC. A fire has been reported in the Texas City Canal. Captain of the Port Galveston has closed

TABLE 2-1.

HOU-GAL VTS OPERATIONAL COMPLEMENT

CDR Commanding Officer

LCDR Executive Officer

	Section 1	Section 2	Section 3	Section 4
LT	1	1	1	1
RDCS		1		
RDC	1			1
QMC			1	
RD1	2	1	1	
QM1	1		1	1
RD2	1	1	1	
QM2		1	1	1
RD3	1			2
QM3	1	1	1	1

TABLE 2-2.

HOU-GAL VTS WATCH SCHEDULES

Table Entries are Watch Sections (1-4)

New Schedule	M	T	W	T	F	S	S
Week 1							
06-18	1	1	1	1	4	4	4
18-06	2	2	2	2	3	3	3
Week 2							
06-18	4	2	2	2	2	3	3
18-06	3	1	1	1	1	4	4
Week 3							
06-18	3	3	1	1	1	1	4
18-06	4	4	2	2	2	2	3
Old Schedule							
Week 1							
00-08	1	1	1	1	2	2	2
08-16	3	3	3	3	1	1	1
16-24	4	4	4	4	3	3	3
Week 2							
00-08	2	4	4	4	4	3	3
08-16	1	2	2	2	2	4	4
16-24	3	1	1	1	1	2	2
Week 3							
00-08	3	3	1	1	1	1	2
08-16	4	4	3	3	3	3	1
16-24	2	2	4	4	4	4	3

traffic situation against all other available information (such as monitored radio communications, television, and radar displays), setting and adjusting associated equipment as required. He anticipates developing traffic problems and advises the masters and pilots in time for them to initiate corrective action. If the situation requires it, he issues such directions as not to enter certain areas, not to overtake certain traffic, not to exceed a certain speed, and the like. When the situation permits or requires it, he assists other agencies (Coast Guard units, industrial organizations, etc.) by relaying messages via his communications equipment.

2.5.3 External Communicator

The XC functions basically to assist the WS. He generally handles routine incoming enquiries about traffic in the system and other matters. At the direction of the WS, he may assist a busy SW by entering data into the VTS-DACS. In practice, when traffic is light, the XC duty functions as a relief assignment. With WS approval, the XC may eat lunch, study, or leave the room for personal matters. The XC's VTS-DACS terminal is often used for demonstrations for visitors, practice by trainees, and familiarization with the traffic situation by relieving watchstanders.

2.6 Equipment and Workspace

2.6.1 VHF-FM Radio and Communications

The HOU-GAL VTS is equipped with VHF-FM communications with a microwave relay and control system. Radio coverage is provided by three high level transmitting/receiving sites--one for each sector. Six radio frequencies (channels) have been assigned to the VTS.

Each of the five operating positions at the VTC has a communications console which includes controls for selection of sites and channels for monitoring and transmitting, along with volume and squelch controls as needed.

The channel assigned specifically for VTS communications concerning vessel traffic management is Channel 12. Using a monaural headset, each SW continuously monitors Channel 12 through the site assigned to his sector and can transmit over that channel by actuating either a press-to-talk switch on the console or a foot pedal.

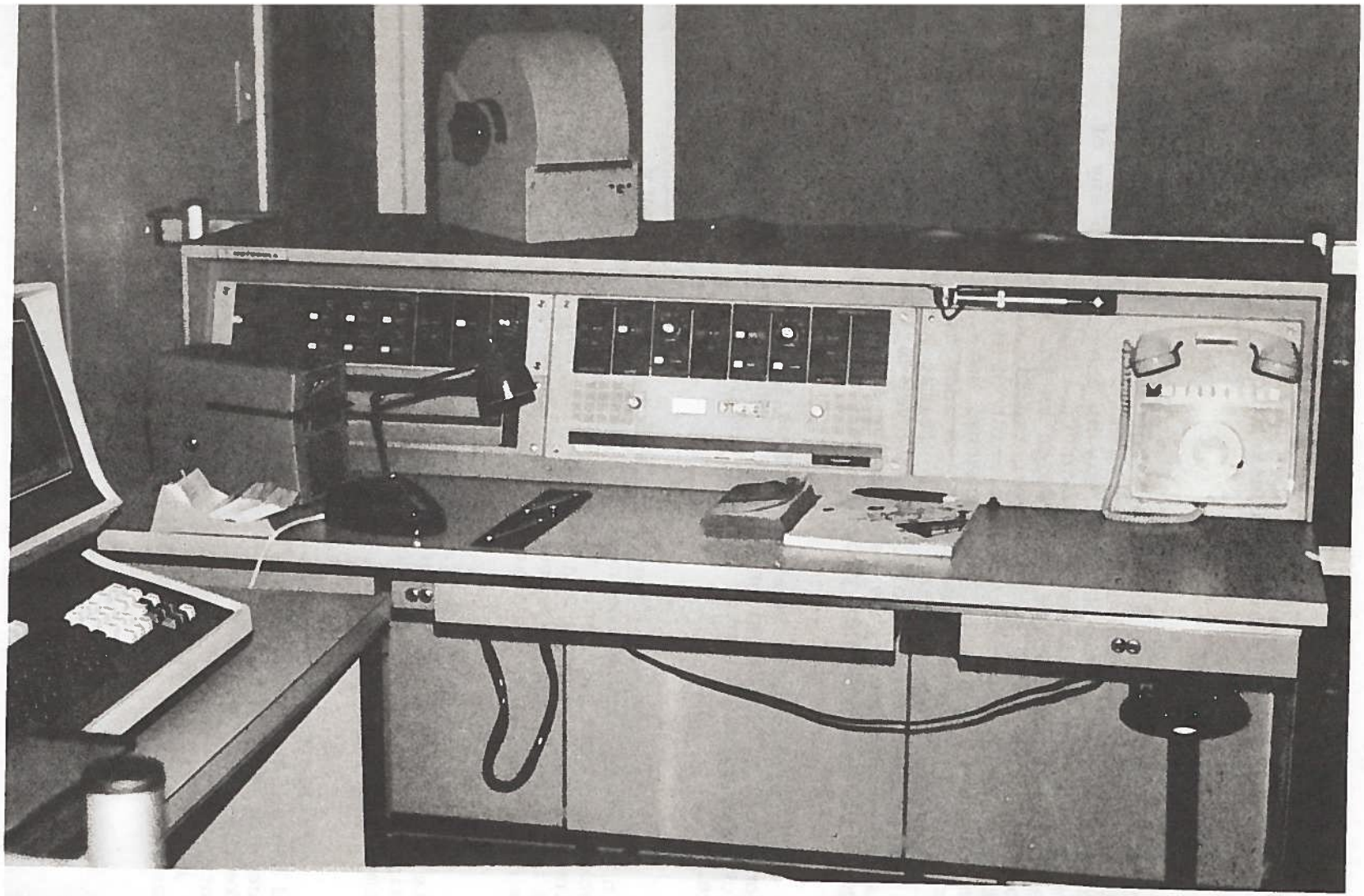


FIGURE 2-3. A COMMUNICATIONS CONSOLE

Vessel Departures Sheet. This display lists every vessel that has left the system during the current day (except ships docked in port). It is printed out off-line at the end of each day as a permanent record.

Command Dictionary. This display simply lists the commands that may be given the VTS-DACS via the Command keyboard.

Figure 2-4 shows a VTS-DACS terminal at one SW position and a closup of a typical display on the CRT.

2.6.3 Television

The HOU-GAL VTS has four closed-circuit television surveillance sites. At each site two cameras are mounted so that each can be rotated through a full horizontal circle. Zoom optics permit a continuous range of adjustment of focal length. Two sites are in Sector II, two in Sector III.

At the VTC, the WS, SWII and SWIII positions each have a TV console containing four side-by-side twelve-inch monitors, set on top of the communications console. Each monitor is limited to one site. Each console has controls available and within reach of the seated watchstander to select either camera at each site, to pan or zoom each camera, and to adjust the brightness and contrast of each monitor. A TV console can be seen in the background of Figure 2-4a.

Typically the SW will set the two cameras at each of his two sites so that one looks up-channel, one down-channel, and will then arbitrarily select which camera at each site to monitor. When an event of interest occurs, he will use camera selection, pan and zoom actions to focus on the area of interest. Camera selection, pan and zoom actions at any console affect the corresponding display at the other consoles; that is, only one picture can be displayed in the VTC at a given time for a given site.

Two twenty-one-inch repeater monitors are suspended from the ceiling above the SWIII position. These are used for briefings, demonstrations for visitors, or group actions. The two pictures to be shown on the repeaters are selected by the WS. Figure 2-5 was photographed from such a repeater display.

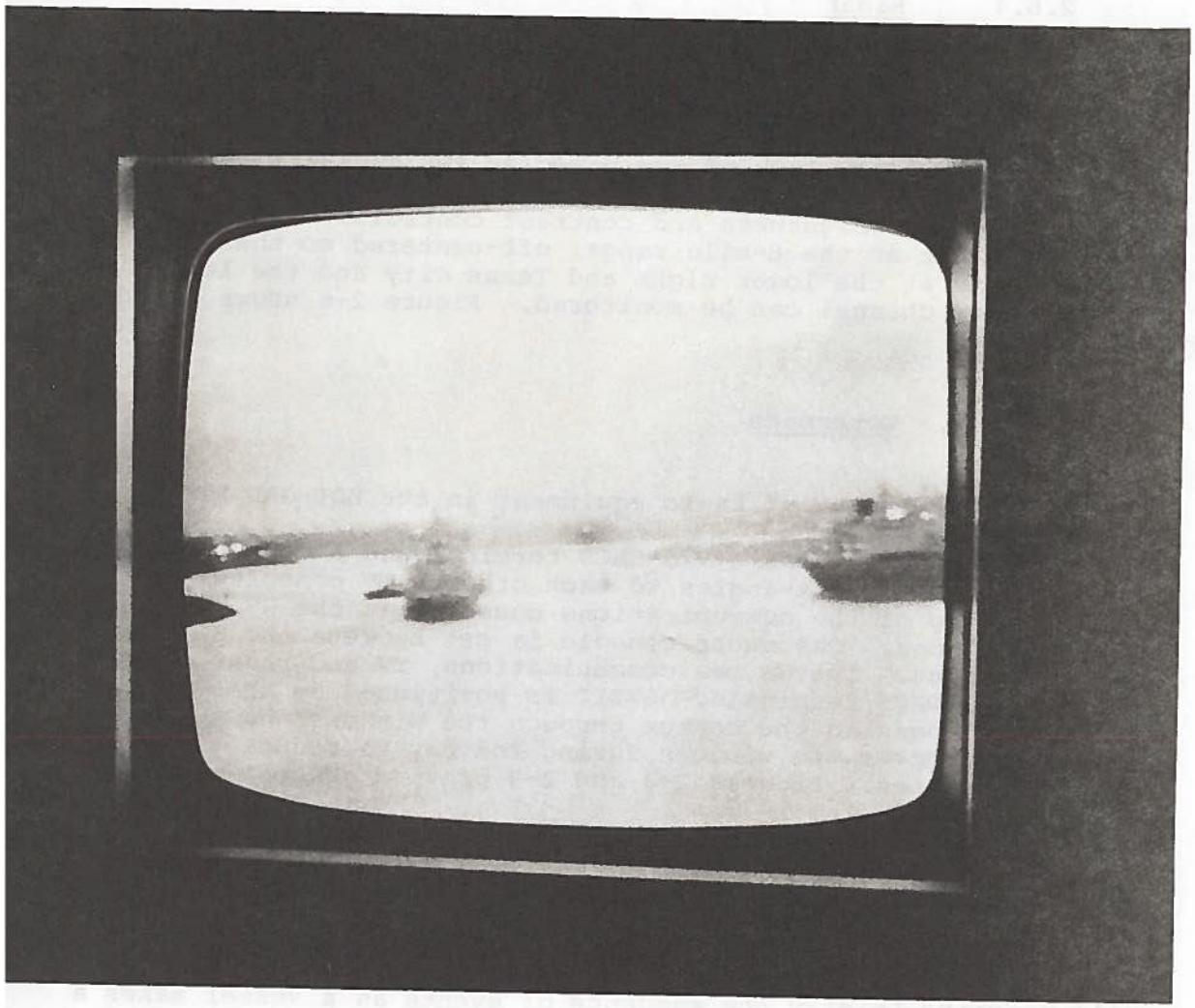


FIGURE 2-5. A TELEVISION DISPLAY

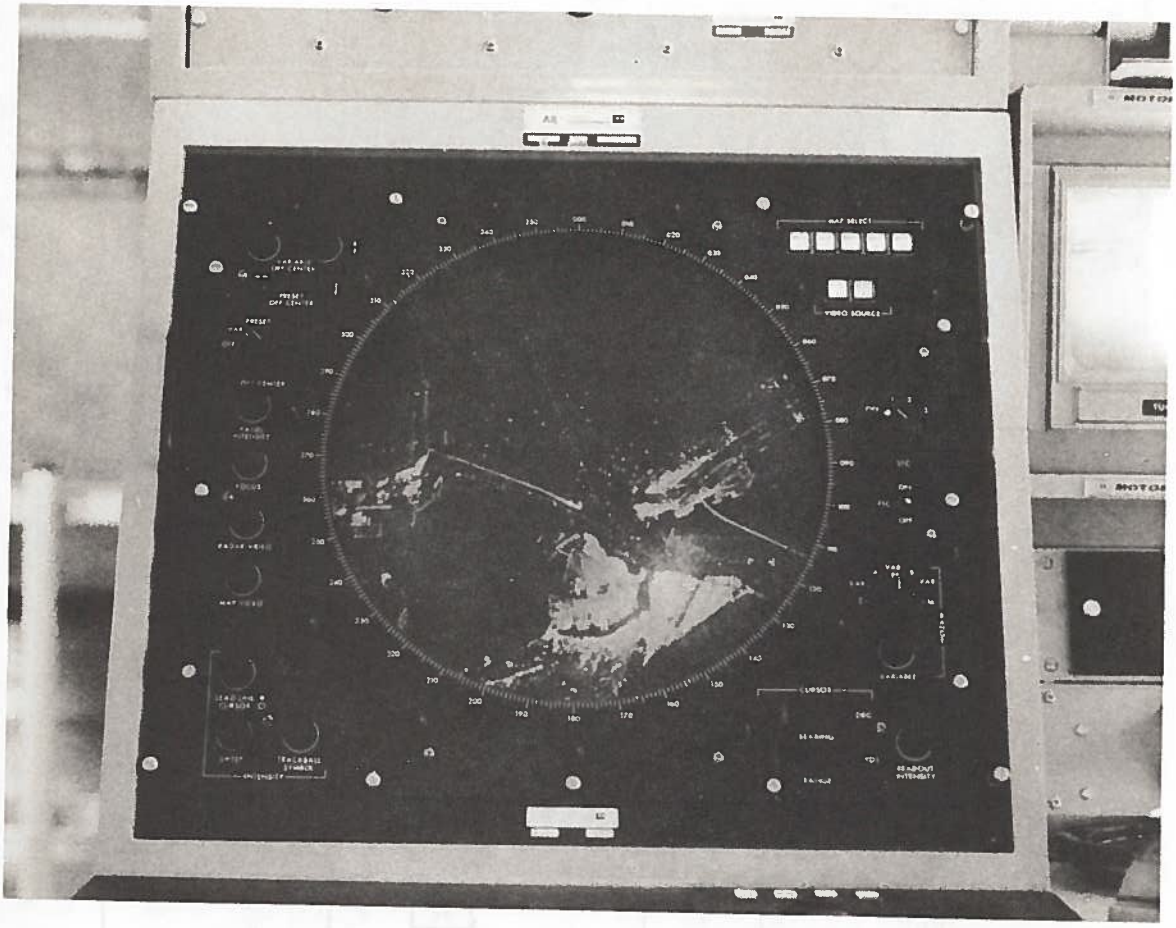
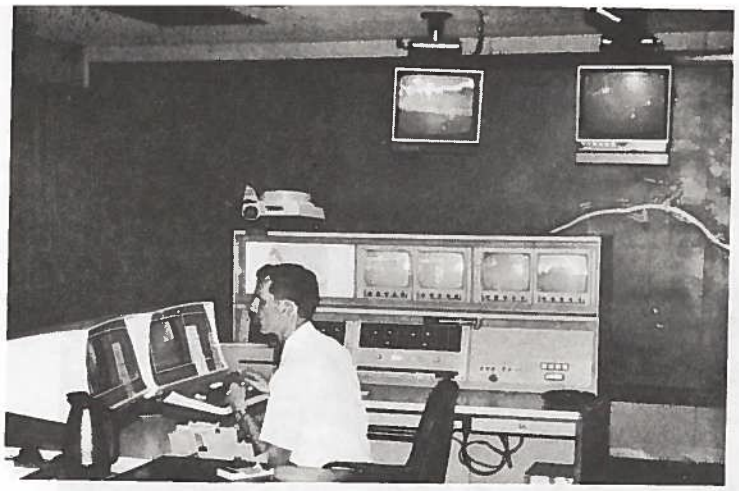


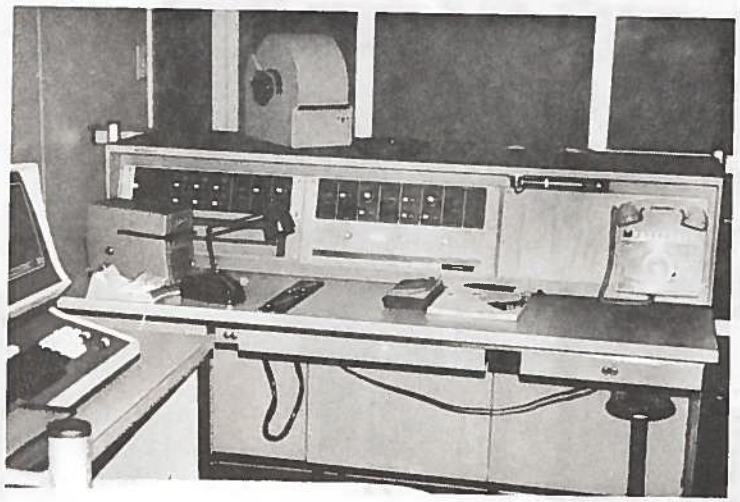
FIGURE 2-6. A RADAR PPI DISPLAY



a. SW III

b. SW II

c. SW I



d. External Communicator

FIGURE 2-8. VTC POSITIONS

or master notifies the VTC. The SW copies the SOA and any new data onto the card and scans his displays while listening, then acknowledges and gives a traffic advisory. Following this transmission, the SW time stamps the card and enters the new information into the VTS-DACS by keyboard. Completion of this entry starts the VTS-DACS tracking the vessel, dead-reckoning on the entered SOA and updating all data every 15 seconds.

Sometimes a vessel may fail to make the initial report, instead giving all information when entering. Sometimes, too, the SW may become aware of an unreported vessel in the system by overhearing bridge-to-bridge communications on Channel 13. In such cases, he will attempt to call the vessel and enter it into the VTS-DACS memory.

2.7.2 Transit

The HOU-GAL VTS has eleven vessel reporting points -- two on the main channel and three on side channels in Sector I, three on the main channel and one on a side channel in Sector II, and six in Sector III (see Figure 2-1). When the VTS-DACS has tracked a vessel to a reporting point, it ceases tracking, and the vessel's symbol on the DR display blinks. At about the same time, generally, the vessel will call in at the reporting point. The SW issues an advisory and, by key action, releases the VTS-DACS to continue tracking to the next reporting point. When a vessel fails to report as expected, its position is checked on TV or radar (if in range) or the SW calls the vessel to resolve the difficulty, updating the computer as necessary. The Vessel Status Card is manually advanced along the small plotting board to keep pace with the vessel's progress. In a routine transit from the sea to Houston, a vessel would make at least an entry report, eleven calls at reporting points, and an exit report.

Throughout the transit, all traffic is monitored by whatever means (radio, radar, TV) are available. When discrepancies are discovered between apparent position and computed position (on the DR display), action is taken to resolve the discrepancy, usually by manually entering corrections via the VTS-DACS keyboard. Developing situations (such as passing, overtaking or crossing encounters) are monitored, and the affected vessels are given advisories in time for them to initiate appropriate actions if required.

3. COLLECTION OF DATA

3.1 Scope

The data collected during VTS operations at the HOU-GAL VTC included: frequency and duration of watchstander activities; display delay times in computer operations; interviews and stress questionnaires individually administered to watchstanders during break periods; tape and photographic recordings and center records obtained to cover the data-collecting periods.

Watchstander activities were observed to determine how often watchstanders perform their various tasks. Activity frequency data were collected over a three-day, mid-week period during a moderately dense traffic load. Fifteen hours of data were obtained to include five hours of data from each of the three sector positions. The data sampling included three watch crews (eleven individual watchstanders plus two trainees) and covered morning, afternoon and evening time periods. (See Table 3-1). Duration data, interviews and questionnaires were accomplished on the same days.

3.2 Procedures

3.2.1 Traffic Data

Information on vessel traffic in the system during periods of data collection was obtained from VTC records and from photographs of relevant VTS-DACS displays. At the end of each day, a hard copy of the VTS-DACS Vessel Departures (DE) Sheet (see 2.6.2) was printed out. The WS maintained a Daily Vessel Tally log (see 2.7.3) which repeated much of the data in the DE sheet and added the time that each vessel entered the system. Copies of both of these records were obtained for each day on which observations were made.

Vessel traffic information for specific time periods in individual sectors was obtained from the Vessels Underway Sheet (VU). Every fifteen minutes an experimenter in the equipment room called up the VU display on the VTS-DACS terminal there, read selected information onto one channel of a voice tape, and photographed both the VU and DR displays.

3.2.2 Watchstander Activity Data

An observer, seated beside the watchstander, manually tallied the observed activities onto an Activity Log (See Fig. 3-1). The observer initiated the data-collecting session with a brief explanation of the procedure to the watchstander. When ready to start recording data, the observer signaled an experimenter in the equipment room to begin tape recording voice communications over Channel 12. For a one-hour period, the observer collected activity data at a single sector and periodically verified timing accuracy against the digital clock at the sector. At the end of the session, the observer organized the log sheets, conferred with the experimenter recording communications and moved to another sector position to repeat the data-collecting procedure.

The Activity Log was mounted on a clipboard and held by the observer while recording data. Across the top of the log were listed six major watchstander activity categories, thirty-four associated subactivities and a Remarks heading. The six major watchstander activity categories were: (1) Communications, (2) Computer, (3) Cards, (4) TV, (5) Radar and (6) Miscellaneous. (See Appendix C for explanation of categories.)

The log was divided into thirty lines, each representing a thirty-second interval; so each log sheet covered a fifteen-minute observation period. As observed, each activity was tallied in the appropriate column. A timing device signalled every thirty seconds, alerting the observer to begin recording in a new time interval by moving down to the next line. Each recorded tally represented an occurrence of an activity that had been predefined by the observer. (Definitions of beginning and ending of activities are included in Appendix C.) When an activity continued into the next thirty-second period, the tally mark was continued onto the next line. The Remarks column provided space to add information on tallied activities, such as those designated "Other".

3.2.3 Duration, Delay and Rejection Data

The observer was fully occupied tallying the various watchstander activities and could not time them beyond extending tally marks onto successive thirty-second lines. However, a second observer used a stopwatch to time separately some of the more critical activities of the watchstanders on duty. These duration measurements were done in batches--- that is, a series of measurements were taken on a single activity, followed by a series on another activity, and so on.

Because of comments on the delay between keying a request for a display into the VTS-DACS and the appearance of the display on the CRT, display delay data were recorded in the equipment room. An experimenter seated at the console started a stop-watch as he made the first keystroke of a display request and stopped it when the complete display had appeared on the CRT. This procedure was repeated for one hundred measurements. Similarly, one hundred delay measurements were taken for each of the seven displays. For two displays, the measurements were repeated starting the watch at the last (execute) keystroke of the request entry in order to get separate estimates of keying and computer response times.

It was observed that keying too fast could cause the computer to reject an entry. To check rejection frequencies, two display requests were keyed alternately one hundred times and a record kept of rejections.

3.2.4 Interviews

Twelve individual interviews were conducted by one interviewer. Each interview generally followed the same format and covered the same topics but was open-ended in nature. The interviewer and interviewee were seated comfortably either in the lounge area or the equipment room. The interviewee was assured that he was not being evaluated--rather, that he was helping evaluate the system, and anonymity was assured. The interview proceeded as a conversation, with the interviewer observing the planned format but freely following up leads and probing interesting topics at his discretion. Interview durations ranged from 30 to 70 minutes.

3.2.5 Stress Questionnaires

A questionnaire intended to elicit information on subjective stress was administered to nine watchstanders. The questionnaire contained 30 items (20 on body functions, 10 on mood) that could be simply checked off by the subject. (A copy of the questionnaire appears in Appendix G). During the course of the interviews, generally at the end, a second experimenter administered the questionnaire. He explained its purpose briefly, let the subject read the written instructions, answered questions, and then observed as the subject checked off the items. Each subject was given a packet of 16 additional copies of the questionnaires and was asked to fill them out four times daily for the next four days and to mail them back to the experimenter in an envelope that was provided. Nine subjects

4. RESULTS

4.1 Traffic

Data collection at the HOU-GAL VTS took place on September 19, 20, and 21, 1977. Total traffic counts for those three days (taken from the Daily Vessel Tally) were 212, 249, and 267, respectively. VTC records give a daily traffic average of about 250 vessels; thus the three days sampled had below average, average and slightly above average traffic. The total traffic consisted of 132 ships and 596 tows (18 and 82 percent respectively) compared to an annual average 20 and 80 percent. No significant incidents were reported on the observation days. We conclude that on those days traffic load constituted a reasonably representative sample of "routine" operations.

From the data on entry and exit points and times, the traffic loading was plotted for each day in each sector (Figures 4-1, 4-2 and 4-3). On these graphs the observation periods are indicated by dashed vertical lines. (The first period in Sector III covers 105 minutes, consisting of 30 minutes of observation, a 45-minute break due to equipment problems,and 30 minutes of observation; all others involved one hour of continuous observation.)

An estimate of traffic load was made for each period from the graphs by counting the number of vessel lines within the observation period. Because of variations in vessel speed, there is very likely some error in these estimates. An independent estimate of traffic load was made from the VU displays photographed every 15 minutes during observations. From these data, an average number of vessels was calculated for each period for each sector. These traffic load estimates are summarized in Table 4-1.

A vessel entering or leaving the system requires more watchstander attention than one in routine transit. Therefore, for each sector an estimate was made of the number of entries and exits occurring during the observation periods. Changes in the VU display between successive fifteen minute periods were counted from scope photographs where available. Missing data were partially compensated for by taped voice annotations. Where no data were available, the mean number of changes per period for the observed periods was assumed for the missing periods. These estimated traffic change loads are also given in Table 4-1.

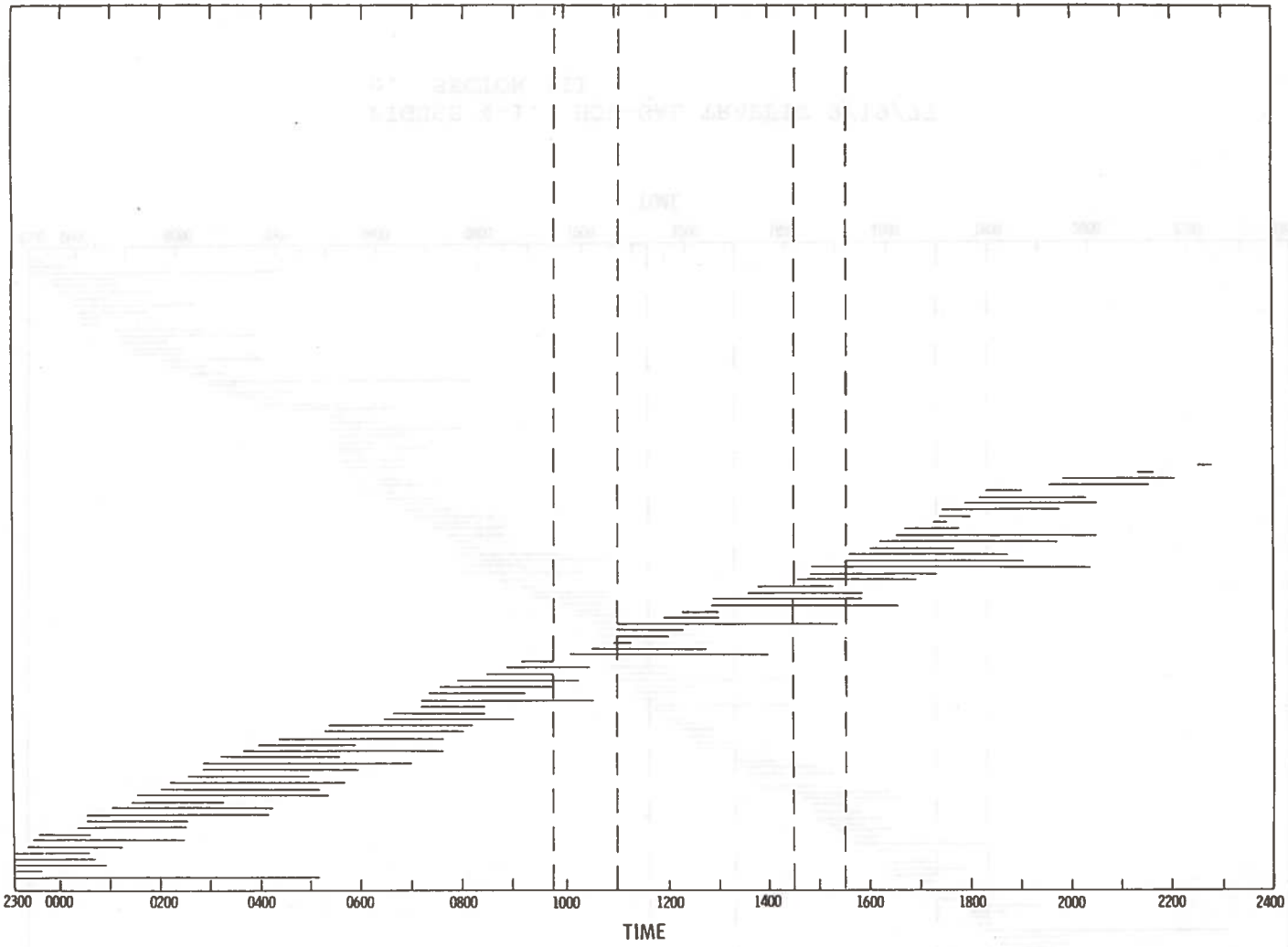


FIGURE 4-1. HOU-GAL TRAFFIC 9/19/77
b. SECTOR II

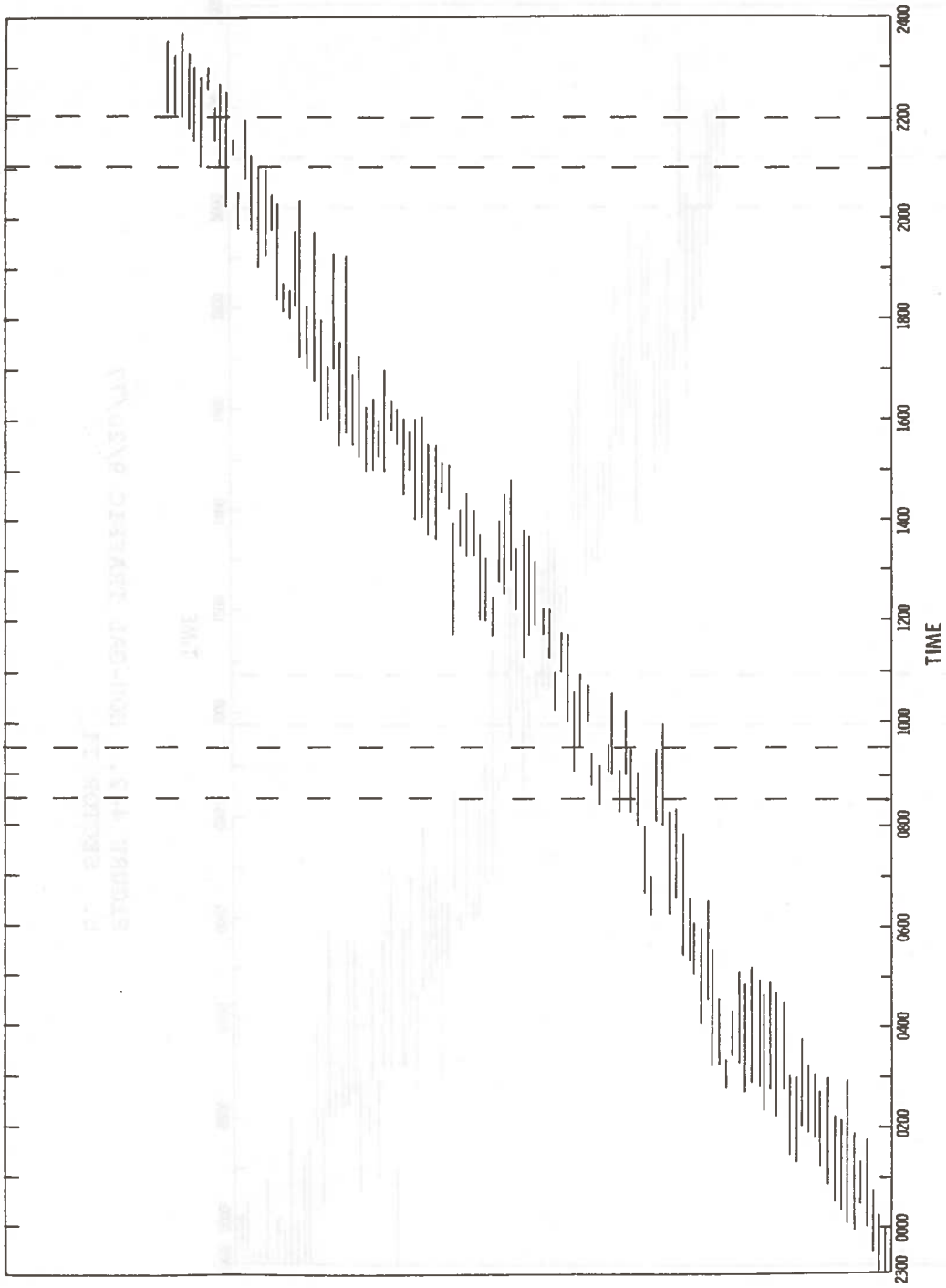


FIGURE 4-2. HOU-GAL TRAFFIC 9/20/77
a. SECTOR I

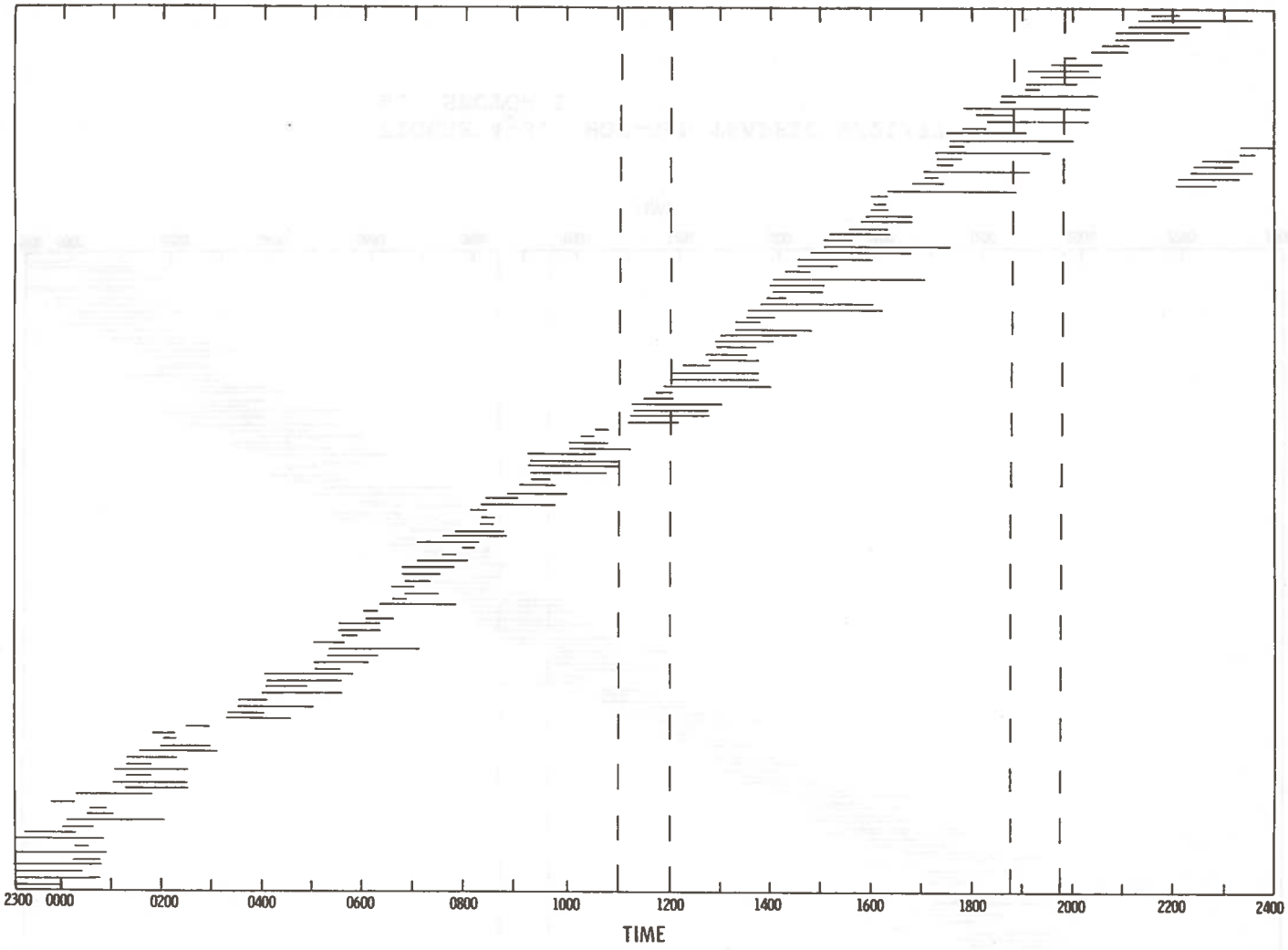


FIGURE 4-2. HOU-GAL TRAFFIC 9/20/77
c. SECTOR III

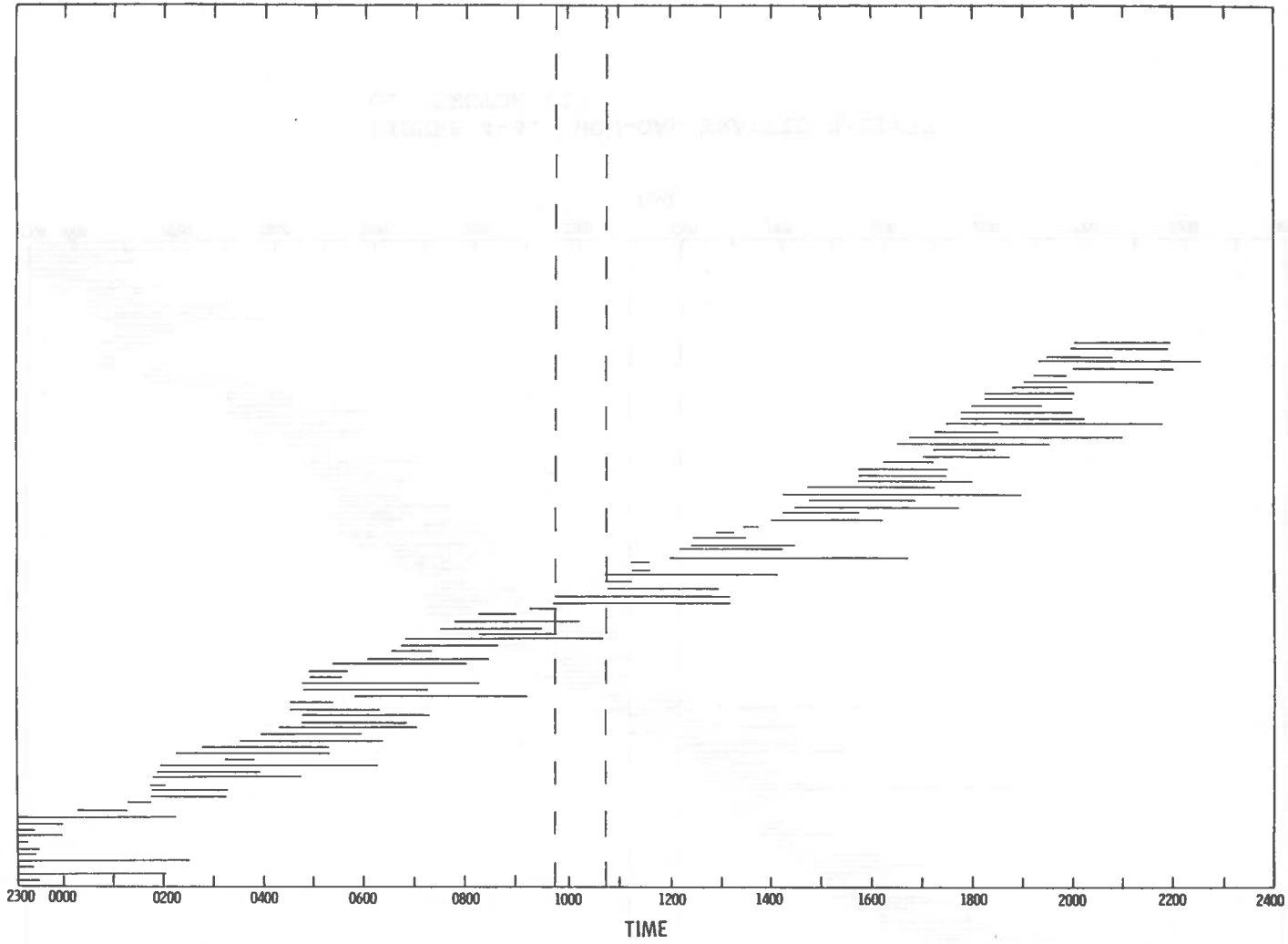


FIGURE 4-3. HOU-GAL TRAFFIC 9/21/77
b. SECTOR II

TABLE 4-1. TRAFFIC DATA FOR OBSERVATION PERIODS

	Period	Sector I	Sector II	Sector III
Total Traffic in Sectors (Estimated from Traffic Graphs)	1	14	5	17
	2	12	8	9
	3	11	8	8
	4	9	6	13
	5	13	4	8
	Total	59	31	55
	Mean	11.8	6.2	11.0
Average Traffic in Sectors from VU Displays	1	11.3	7.3	13.7
	2	9.8	7.8	9.7
	3	11.3	8.3	9.3
	4	9.8	10.3	18.5
	5	12.2	4.5	6.0
	Total	54.4	38.2	57.2
	Mean	10.9	7.6	11.4
Total Traffic Changes		57	41	66
Mean Hourly Traffic Changes		11.4	8.2	13.2

TABLE 4-2. SUMMARY OF OBSERVED ACTIVITIES

	FREQUENCIES				PERCENTS			
	I	II	III	Total	I	II	III	Total
COMMUNICATIONS				630				9
With Vessels	99	57	122	278	4	3	5	4
With Other SW's	27	32	19	78	1	2	1	1
With Other People	82	62	46	190	3	3	2	3
Adjusting Radio	22	31	31	84	1	2	1	1
VTS-DACS COMPUTER				3768				56
Keying	589	302	845	1736	25	16	34	26
Reference to Display	722	656	623	2001	31	34	26	30
Reference to Other SW's Display	7	18	6	31	-	1	-	-
CARDS				873				13
Marking	84	22	103	209	4	1	4	3
Time Punching	39	7	57	103	2	-	2	2
Reference to Cards	94	59	185	338	4	3	7	5
Moving Cards	93	56	74	223	4	3	3	3
RADAR				494				7
Monitoring	412	22		434	17	1		6
Adjusting	60			60	3			1
TELEVISION				942				14
Monitoring		310	167	477		16	7	7
Adjusting		280	185	465		15	7	7
OTHER				52				1
Using References	20	6	9	35		1	-	1
Moving from Position	5	5	7	17		-	-	-
TOTAL	2355	1925	2479	6759	35	28	37	
AVERAGE TRAFFIC LOAD	10.9	7.6	11.4	10.0	37	25	38	
TOTAL TRAFFIC CHANGES	57	41	66		35	25	40	

sectors. The detailed activity log records suggest that the Sector I SW often alternately looked at his radar and his DR display. Not even the television in the other sectors provided as ready a check on the DR accuracy as did the radar for Sector I. Allowing for this extra checking with the radar, we get a generally even distribution of references to displays showing that the computer displays were being monitored regularly regardless of traffic load.

Keying activities showed considerably more variation between sectors, in line with, but disproportionate to, the variation in traffic load. Within Sectors I and II, a detailed analysis of keying activity failed to reveal any systematic variation of keying with traffic load, probably because some keying associated with routine monitoring of traffic was kept up during periods when vessels required no servicing. The general level of keying activity, however, was lower in Sector II than in Sector I, probably because there are fewer check points in Sector II. When traffic was light, keying activity in Sector III was independent of traffic load and at about the same level as in Sector I. However, there were five 15-minute periods of observation when traffic load exceeded 15 vessels in Sector III. During these periods keying activity was considerably higher. The greatest increase in keying activity was in keyboard group B, the function keys. Apparently, when traffic load exceeds 15 vessels in this sector, vessel symbols become crowded together and much extra keying is required to establish their identities.

4.2.4 Cards

Thirteen percent of observed activities involved the Vessel Status Cards. The distribution of these activities roughly reflected the distribution of traffic load. Marking cards and time stamping them were almost exclusively associated with originating and ending transits in the system (as opposed to entering or exiting to or from adjacent sectors). The disproportionately higher frequencies of these actions in Sectors I and III very likely reflect the distribution of originating and destination points. Moving cards is associated with tracking - updating positions of vessels by advancing the cards on the small tracking boards - and with handoffs between sectors. These activities follow traffic loads in general; the relatively high frequency in Sector I can be traced to a greater number of handoffs during observations. References to the cards for informaion followed traffic load; the disproportionately high frequency in Sector III occurred because, during one observation period, the SW was explaining the cards to a trainee.

4.3 Activities of Other Personnel

4.3.1 Watch Supervisor

Using a modified activity log, an observer recorded the activities on one WS over six fifteen-minute periods. Over a third (37 percent) of the WS's activities involved communicating with people, mostly talking to the Sector Watchstanders (13 percent of all activities) or to other people in the Center (16 percent). There was some use of the telephone (5 percent) and radio (3 percent).

Using the computer accounted for 29 percent of the observed activities. The WS had four displays, three of which usually showed the DR sheets for the three sectors, the fourth showing VU for the busiest sector, or any other display the WS wished to call up. Monitoring these displays accounted for 21 percent of the observed activities; keying to call up different displays accounted for 8 percent.

Administrative actions constituted 16 percent of the observations. These included arranging and checking Vessel Status Cards (6 percent), referring to logs (5 percent), and making log entries (5 percent).

Monitoring surveillance aids accounted for 14 percent of activities, one percent on radar, the rest on television. Moving away from his position accounted for 4 percent.

In summary, during the periods of observation, the WS was primarily engaged in monitoring operations, using the computer displays somewhat more often than the surveillance aids. Along with watching operations, he conversed with the SW's and with others in the room and occasionally handled phone or radio communications. Administrative duties did not appear to interfere with his supervisory function.

4.3.2 External Communicator

During the periods of routine operations covered by this report, the XC was in a standby rather than working status. Essentially the XC duty provided a break from the more demanding SW duties, permitting the watchstander to eat lunch and even to leave the operations room. A TSC experimenter conducted

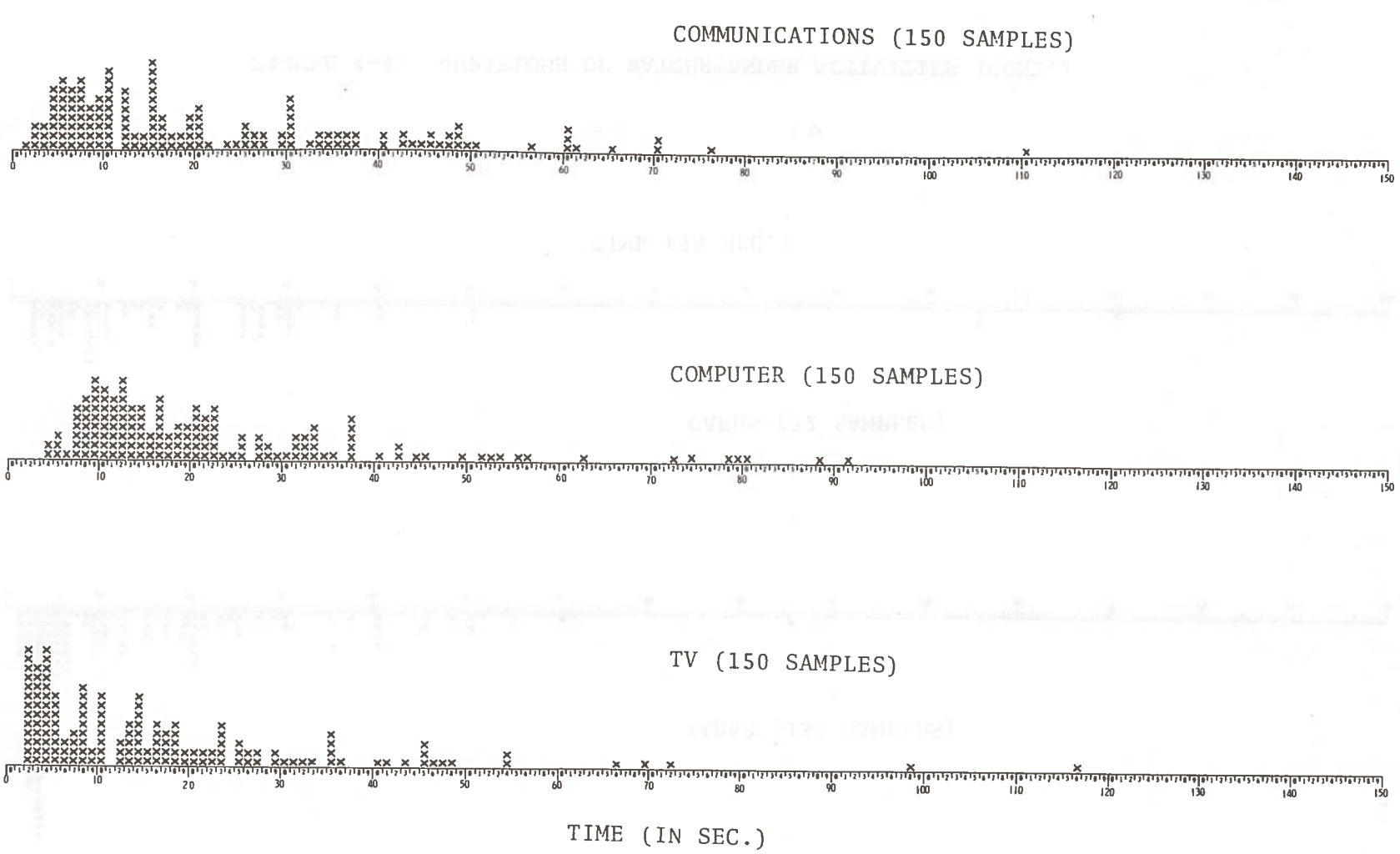


FIGURE 4-4. DURATIONS OF WATCHSTANDER ACTIVITIES

TABLE 4-3. DURATIONS OF WATCHSTANDER ACTIVITIES

Activity	Durations in Seconds			
	Shortest	Median	Mean	Longest
Radio Message to Vessel	1	15	21.5	110
Using Computer	4	16	22.9	91
Using Television	2	13	17.7	116
Using Radar	1	6	12.4	85
Using Vessel Status Cards	1	14	20.2	120

Television related activities (mean 17.7 seconds, median 13 seconds) took longer than radar related activities (mean 12.4 seconds, median 6 seconds), because many times the use of television involved panning and zooming of cameras as well as observation of the scopes.

The use of Vessel Status Cards occupied a mean time of 20.2 seconds, a median of 14 seconds.

4.4.2 Delays in Computer Response

Keyed requests for displayed data from the VTS-DACS computer were followed by a varying time delay before the complete display was on the scope. Delays varied with the type of display requested and even more with the additional amount of information processing that the computer happened to be engaged in at the time of the request. One hundred samples of these delays were timed for each of the seven basic sheets and for additional requests such as format change on the DR sheet and additional pages of multi-paged data. A stopwatch was started at the first keystroke of a request and stopped when the final character of the requested display appeared. Complete distributions of these measurements are given in Appendix E, and the highlights of the measures are summarized in Table 4-5, together with data on the number of keystrokes required for each entry and the frequency of usage of each display sheet.

Since the DR plot is usually kept up on one scope and not changed, its delays are not critical. However, the SS must be called up in place of the VU every time a new vessel enters the system, and the VU must then be recalled after the data entry. Apparently very little use is made of the other displays, perhaps because of the delays involved (see Section 5).

Since keying time is included in the measurements of Table 4-5, the measures were repeated for three displays, starting the watch when the last key was pressed and thus measuring only the computer-induced delay. These results are shown in Table 4-6. Using the modal times as most representative, we find modal differences averaging 1.8 seconds for pressing 4 keys, or a keying rate of 133 strokes per minute. This rate was achieved because the experimenter was repetitively pressing the same four keys. Watchstanders would be unlikely to key much faster; so we can conclude that the total callup delays of Table 4-5 are conservative estimates.

TABLE 4-6. SUPPLEMENTARY DELAY DATA

	No. of Keys	Time (in seconds) Min.	Mode	Max.	Diff. in Modes
Dead Reckoning Plot	4	1.2	2.0	5.7	1.9
Vessels Underway	4	2.0	2.3	7.1	1.9
Vessel Departures	4	1.6	1.9	8.8	1.7

Note: Time is the amount of time for a completed display to appear starting from the final key press. The difference (last column) between the modal times and the modes of Table 4-5 is an estimate of keying time.

sectors and to assist one another when the workload is unevenly distributed.

h. The primary aids to traffic surveillance (radio, radar, television, and the SS, DR and VU displays) were given high ratings for importance and frequency of usage. However, the TR sheet, supposedly an aid to giving traffic advisories, received low ratings.

i. Opinion was split on the computer, although those who disliked it were aware of its potential advantages. The principal disadvantage noted was its slowness, including the amount of keying required and the delays and rejections following keyed display requests. Several interviewees remarked on inaccuracies in tracking, but with awareness that it can only be as accurate as the data the operator gives it.

j. On the average, watchstanders felt they can comfortably handle up to 20 vessels at one time, although individual opinions varied widely.

k. There is an awareness that "bad traffic" (inaccurate advisories) could cause serious incidents or accidents and some concern that masters and pilots may become too reliant on the VTS and relax their own vigilance. Incidents are rare, but, as one watchstander put it, "The potential is always there."

4.6 Stress Questionnaires

As a part of the process of developing a questionnaire for the study of job-related stress, stress questionnaires were administered to some of the interviewees. Appendix G gives a detailed description of the questionnaire, its administration, and results.

Briefly, on all items (somatic and mood) there was a consistent increase in degree of stress during the progress of a watch. The most sensitive items were aching or burning eyes and tiredness. These results correlate well with those of an FAA study of air traffic controllers, from which the present questionnaire was adapted.

When examined on a day-to-day basis, the questionnaire results showed an increase in stress for three successive days with a leveling off on the fourth day, possibly reflecting adjustment to the new twelve-hour watch schedule. Day-to-day variation was much less than the increase in stress during the watch period within each day.

5. DISCUSSION AND RECOMMENDATIONS

5.1 Communications

Communicating with vessels, the primary mission of the VTS, accounted for 4 percent of observed activities. The number of transactions with vessels varied both with traffic load and with the number of transits originating or ending in the sector; they averaged about two per vessel per hour.

A more detailed analysis of ccommunications is planned for a later date, when typed transcripts of the taped Channel 12 communications become available.

5.2 The VTS-DACS Computer

5.2.1 Display Sheets

It is standard operating procedure to keep the DR display up constantly on one display unit, using the second unit for other displays as required but generally keeping the VU sheet up when nothing else is needed. Frequency data clearly reflected this usage, along with fairly frequent use of the SS display, which must be used whenever a new vessel's data base is entered. The other displays showed relatively little use.

5.2.2 Delay Factors

The data on display delay times clearly support the complaints about slow computer response in the interviews, with delays of up to 15 seconds recorded during our sampling. Several displays also gave rejection rates of 7 percent. Coupling delays and rejections with the number of keystrokes required to call up a display, we can understand why a display is generally called up only when SOP demands it. If we picture a watchstander preparing a traffic advisory for a waiting master or pilot, we can feel his reluctance to make an entry of 10 keystrokes (taking possibly 5 seconds) to request an assisting display that will displace his VU listing and almost certainly require a wait of 7 seconds (possibly 15 seconds) after the keying before the information is displayed. Furthermore, the predicted passings and overtakings on the TR sheet are progressively more inaccurate as time to the event increases. Watchstanders are aware of places where vessels are likely to change speed, and they can make more accurate judgments than the computer's linear extrapolation by dead-

A major weakness of the VTS-DACS is the inability to combine traffic position and identification data on the same display, thus requiring a DR sheet for position and a second display, VU, for identification and forcing the watchstander to perform continual integration of the two. Resolution limits of the VTS-DACS displays preclude adding ID tags to the DR display. However, if expanded DR displays could be programmed showing sub-sectors, ID tags could be used, and more precise position data could be displayed. Each cell in a display represents one-quarter nautical mile of channel. A vessel proceeding through a cell has its position updated every 15 seconds. At 6 knots SOA, a vessel's position is updated 10 times within one cell, yet its symbol is moved on the DR display only when it changes cells. If the DR could be expanded on command to cover a five-mile area, for example, four sub-cells per cell could be displayed, with a much more precise representation of the relative positions of vessels (a resolution of 380 feet). Any vessel with a speed under 15 knots would still be updated once per sub-cell. Such a capability would be invaluable in resolving problems where vessel density is high. This capability would be analogous to the zoom capability of television.

Another desirable capability within the limits of the VTS-DACS basic design is to off-center a DR display (at sector scale) to give the watchstander a look at approaching traffic in an adjacent sector (analogous to panning in television).

Although the TR sheet is seldom used, it has the potential for being the basic reference for traffic advisories. To realize this potential it would have to be made more accessible and more accurate. Accessibility could be improved by giving it a function key and an improved cursor control. To improve accuracy, a better tracking algorithm would be required--one that would anticipate speed changes at certain cells (such as at sharp channel bends, transition from channel to bay, and at destination).

Keying requirements can be reduced by using more function keys (with BREAK or COMMAND automatically included in the functions where they are required). A joystick or a trackball can simplify cursor operation.

In the meantime, the addition of one computer display scope at each position would increase the flexibility of cross-sector monitoring, permit the use of the SS or TR display without loss of DR and VU, and generally reduce keying requirements.

5.5 Operational Factors

5.5.1 Stress

The administration of the stress questionnaire revealed a progressive increase in stress indications during the course of a watch period. The principal complaint was aching or burning eyes. Two interviewees noted eye problems, blamed on the displays. One said his eyes get "fuzzy" after a long period of monitoring displays. The other said his eyes get "gritty", his eye muscles ache, and it hurts to be exposed to daylight. Primarily to accommodate the low light level of the radar PPI, the operations room is kept at a dim light level day and night. The light level in the visual field is not even; television and computer displays provide bright areas, and illuminated keys on the radio and computer consoles provide numerous bright "hot spots" (see Figure 5-1). Such glare is known to cause decreased visibility and visual discomfort.* Subtle effects of character changes on computer displays and the motion of the sweep on the radar PPI may aggravate these effects.

Although the stress evaluation took place during the first days of the 12-hour watch schedule, the comments of the interviewees reflected their experience during 8-hour watches. The visual stress data show the effect to be progressive through the watch period; so the additional watch time may be aggravating an already undesirable situation. The day-to-day changes in all indices of stress indicate that the watchstanders may have been adapting to stresses induced by the longer watch periods; follow-up administrations of the questionnaire are highly desirable to determine whether stress levels have dropped as adaptation has continued.

5.5.2 Individual vs. Group Operations

Several interviewees commented on the fact that the introduction of the computer has changed the nature of the VTS operation significantly. Previously, watchstanders were grouped around the status board, where each could see the status of the entire system, could interact easily with the other watchstanders, and could help one another when one's workload became heavy. Now the watchstanders are seated back-to one another, have ready access mainly to data for their sector only,

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*Human Engineering Guide to Equipment Design (Revised Edition), Washington, D.C., U.S. Government Printing Office, 1972.

are much less aware of the traffic situation system-wide, spend much time responding to computer requirements, and are less prepared or able to assist one another. Observations (admittedly limited to routine operations) were consistent with this picture. Only one percent of observed activity involved communications between SW's and less than one-percent in mobility between positions.

The data of this study can not indicate whether the segregation of watchstanders is desirable or undesirable from the standpoint of operational effectiveness. However, it was deplored by several interviewees, who suggested rearrangement of consoles to promote more group-like operation, and is thus considered worthy of mention.

5.5.3 Possible Improvements

Factors affecting stress and morale might be relieved through changes in the workspace. Reorientation and shielding of the radar PPI's could reduce the glare of reflections on their faces and permit raising the general level of ambient lighting in the room to the level of the television and computer scopes. Translucent paint on back-illuminated control buttons could dim them to less objectionable hot-spots without affecting the information they convey. Sector positions could be rearranged to give each SW a better view of the displays at adjacent positions and to permit more interaction among watchstanders.

It should be noted here that the interviews elicited many recommendations for personnel selection and training. They are worthy of review and consideration (see Section 4.5 and Appendix F).

5.6 Modeling Considerations

5.6.1 Time Distribution

It is tempting to combine the data on frequency of activities with representative measures of activity duration to obtain a first approximation of a model of the way a sector watchstander divides his working time. Since the duration data were not taken on the same people at the same time, such a combination carries the assumption that the timed operations were essentially the same as the tallied activities, and the results must be interpreted with caution.

TABLE 5-1. SECTOR WATCHSTANDER ACTIVITY AND TIME DISTRIBUTIONS, HOU-GAL VTS

Activity	Number	Duration (Secs.)	Percentage Frequency	Percentage Time
Radio Message to Vessel	446	22	9	18
Monitoring Computer	1080	6	22	12
Keying Computer	546	16	11	16
Using Cards	873	14	18	23
Using Radar	494	6	10	5
Using Television	942	13	20	23
Miscellaneous	435	4	9	3
TOTAL	4816			

Note: Assumptions and corrections leading to these figures are explained in the text.

TABLE 5-2. CORRELATIONS OF ACTIVITY WITH TRAFFIC

Correlations with Traffic Load

	Sectors I	II	III
Communication with Vessels	.19	.54**	.86***
Keyboard Activity	-.04	-.27	.74***
Marking and Stamping Cards	-.12	-.07	.25
Total Activity with Cards	.28	.18	.22
Reference to Radar/TV	-.27	.54**	-.08
General Use of Computer	.04	.26	.65**

Correlations with Traffic Changes

	Sectors I	II	III
Communications with Vessels	.08	.19	.36
Keyboard Activity	.70**	.01	.45*
Marking and Stamping Cards	.76***	.16	.42*

Statistical Significance

* = $p < .05$
** = $p < .01$
*** = $p < .001$

l. Mask down the brightness of self-illuminated panel buttons. (5.5.1)

m. Conduct follow-on stress evaluations as an aid to evaluation of the twelve-hour watch schedule. (5.5.1)

n. Study the relative merits of grouped versus segregated sector positions. (5.5.2)

o. Provide at least one position for a full-time training instructor. (2.4.3, 4.5e)

p. Establish a set of criteria for selection of personnel for VTS duty. (2.4.2, 4.5d)

APPENDIX A

HOU-GAL VTS-DACS DISPLAY SHEETS

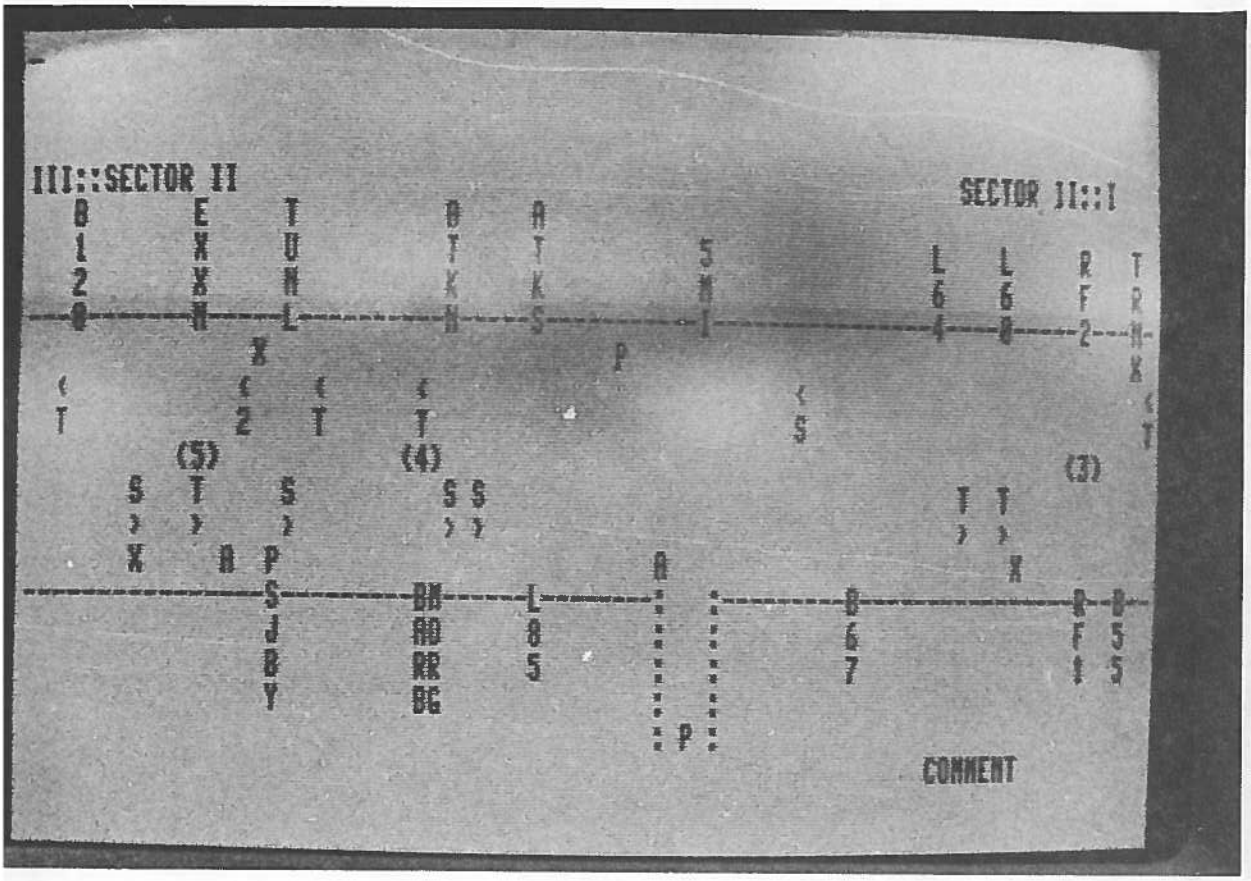


Figure A-2. DR - Dead Reckoning Plot, Format (A)

The Dead Reckoning Plot graphically displays the location of all vessels underway within the selected sector bounds. Format (A) also provides channel orientation points, check points, sector boundaries, channel navigation points, and mooring and docking facilities.

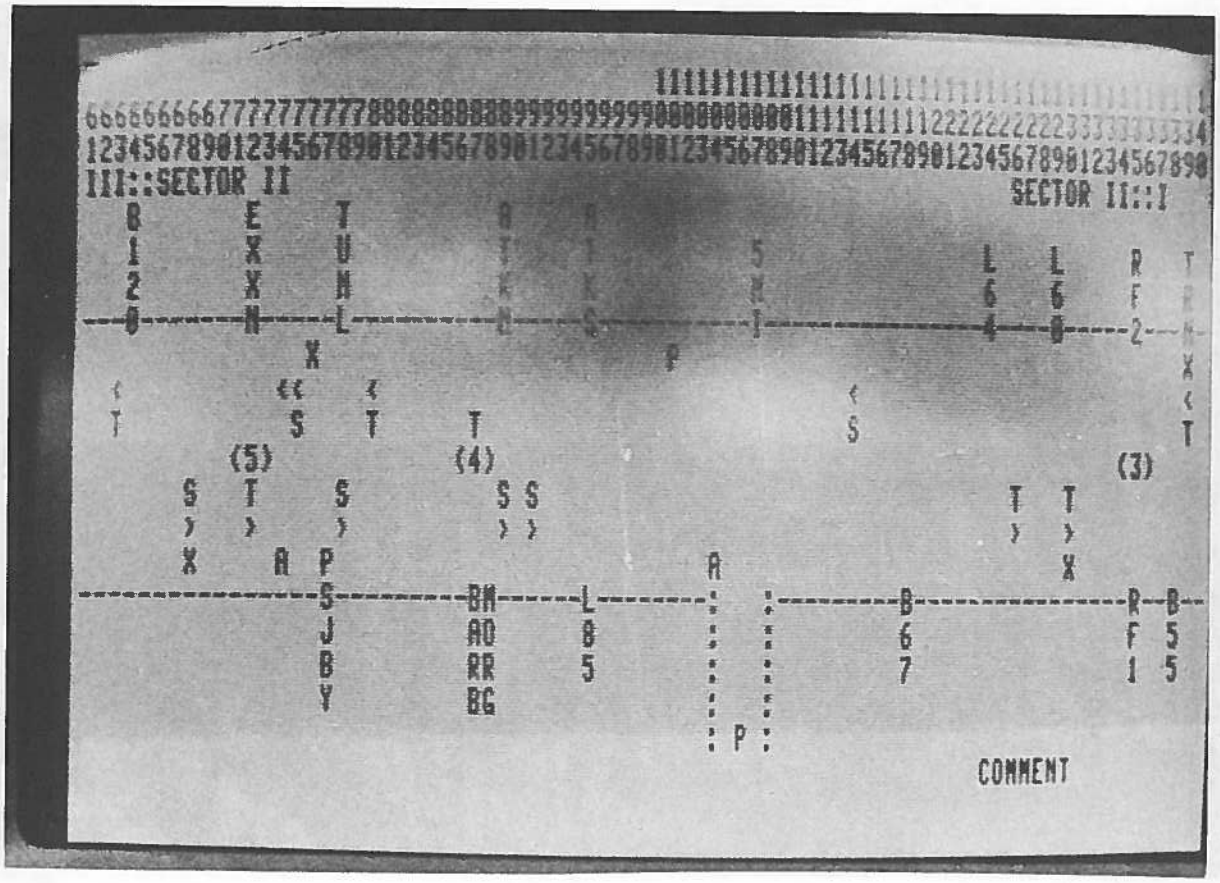


Figure A-4. DR - Dead Reckoning Plot, Format (A + C)

Format (A + C) includes Format (A) plus all cell numbers.

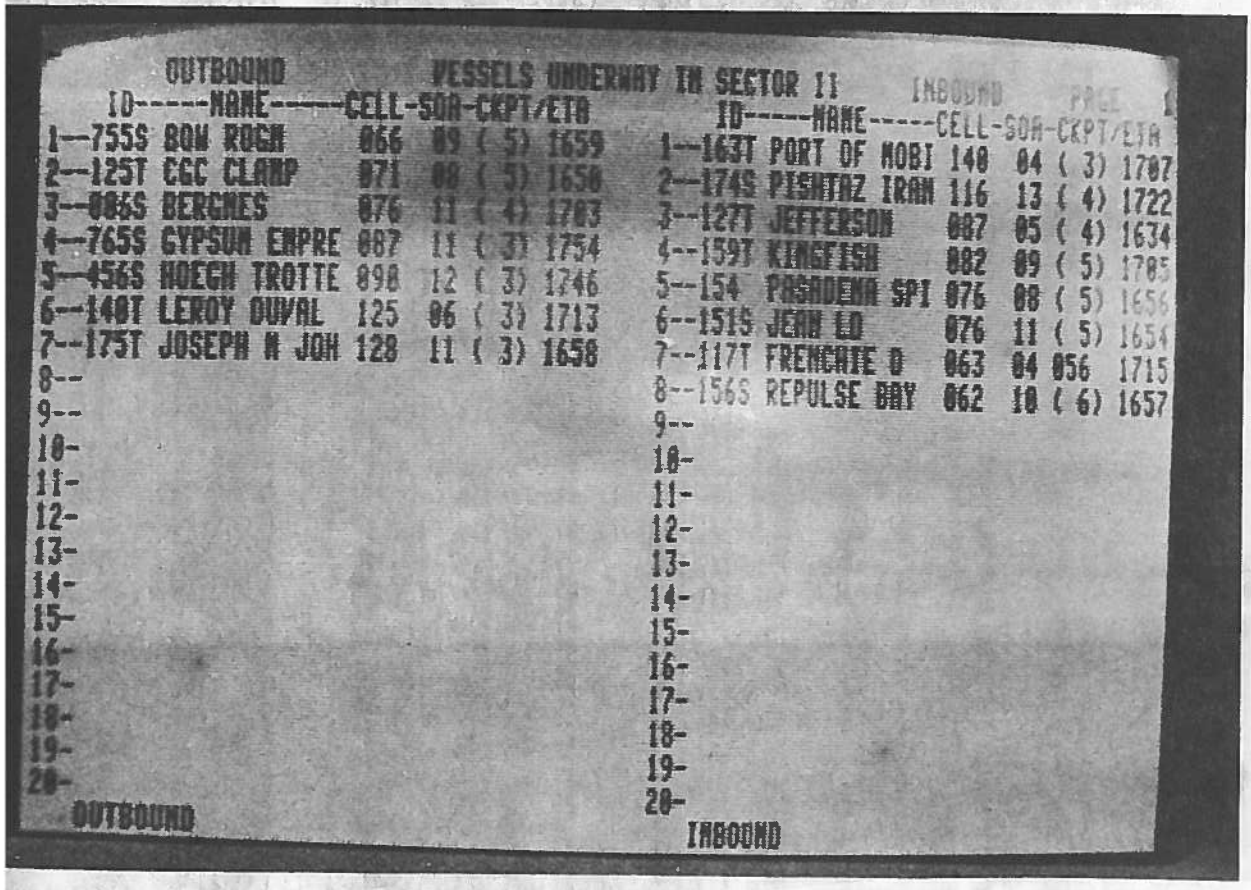


Figure A-6. VU - Vessels Underway Display

The Vessels Underway Display lists information concerning the inbound and outbound traffic operating within the bounds of the selected sector.

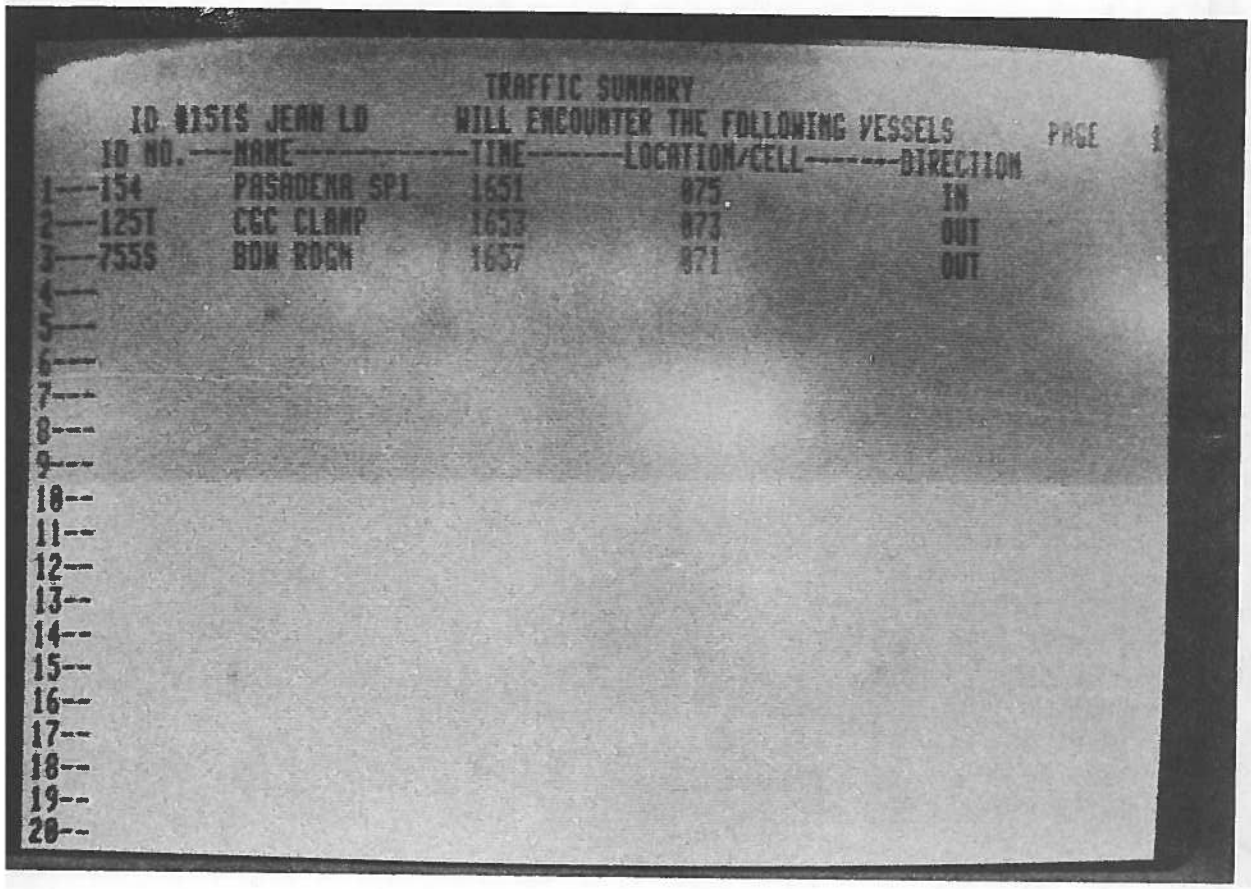


Figure A-8. TR - Traffic Summary Display

The Traffic Summary Display lists all vessels within a specified sector (or sectors) that a specified vessel will encounter, including time and cell location of each encounter. A total of 240 listings at 20 per page is possible.

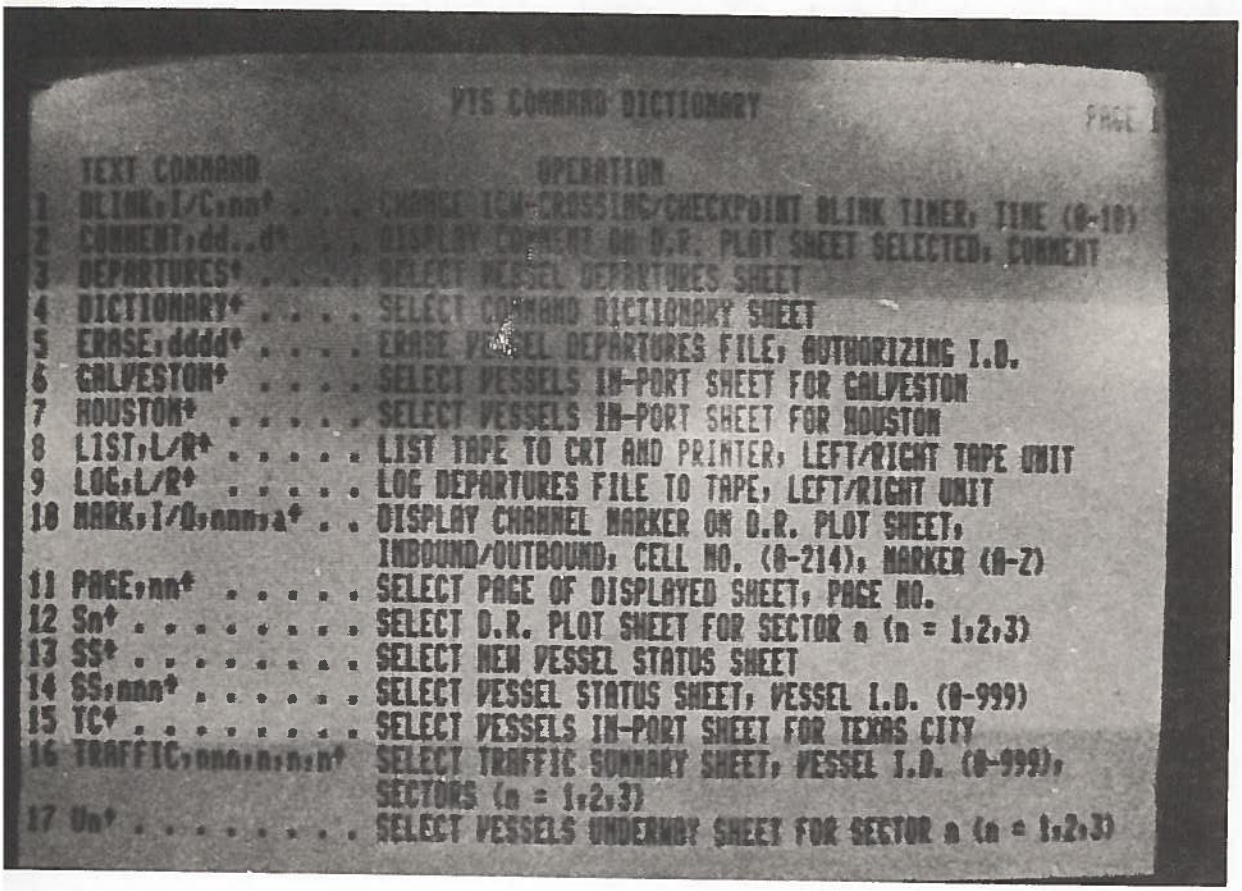
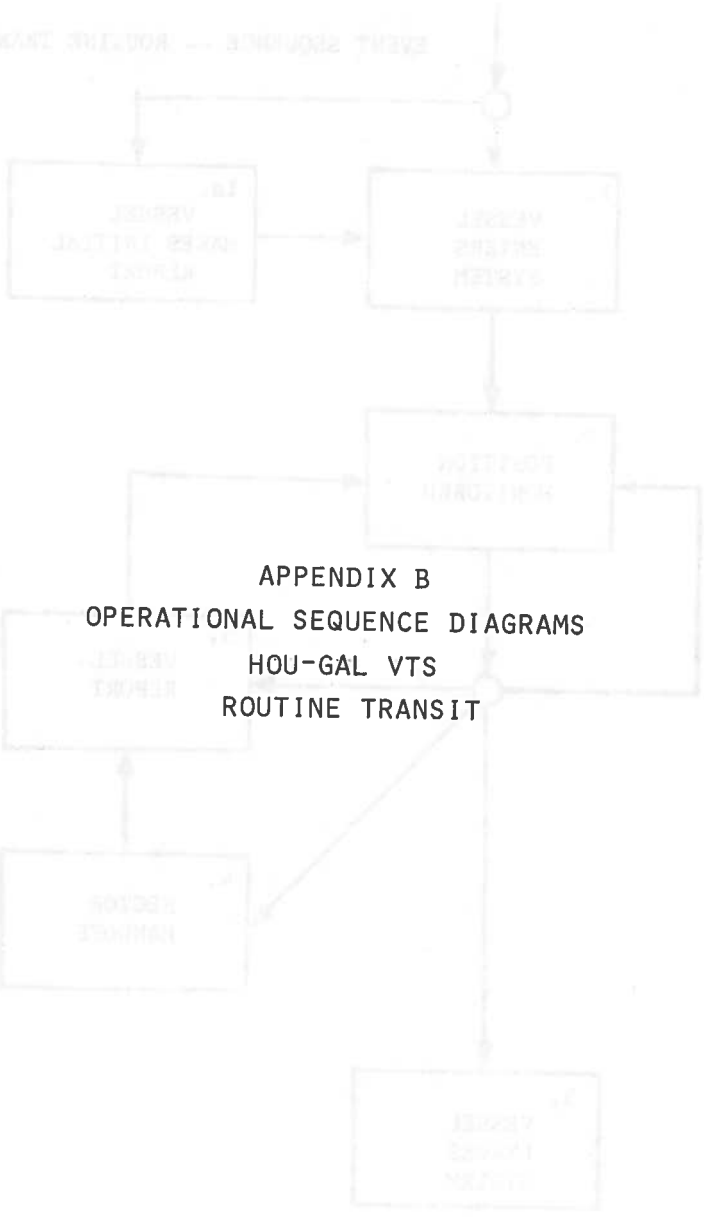


Figure A-10. DI - Command Dictionary Display

The Command Dictionary Display lists all available computer keyboard commands.



APPENDIX B
OPERATIONAL SEQUENCE DIAGRAMS
HOU-GAL VTS
ROUTINE TRANSIT

OPERATIONAL SEQUENCE DIAGRAM LEGEND


Information received by an operator or a system component


Operator action


Transmission of information or action


Operator decision


Automatic action


Automatic receipt of information


Automatic transmission of information/data


Manual storage, filing of information


Automatic data storage


A communications loop between two operators, talk without aids

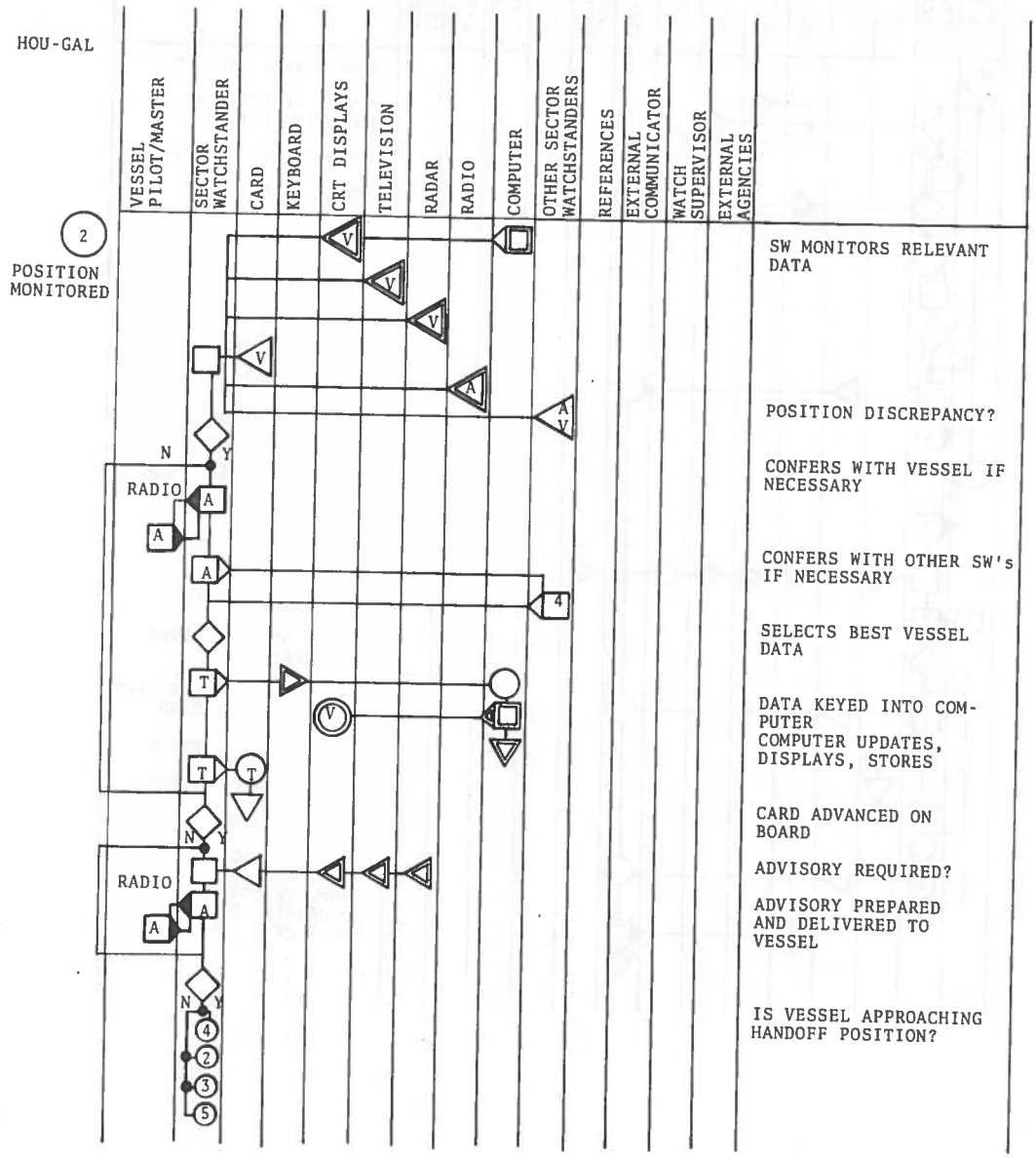

A communications loop between two operators, radio or interphone

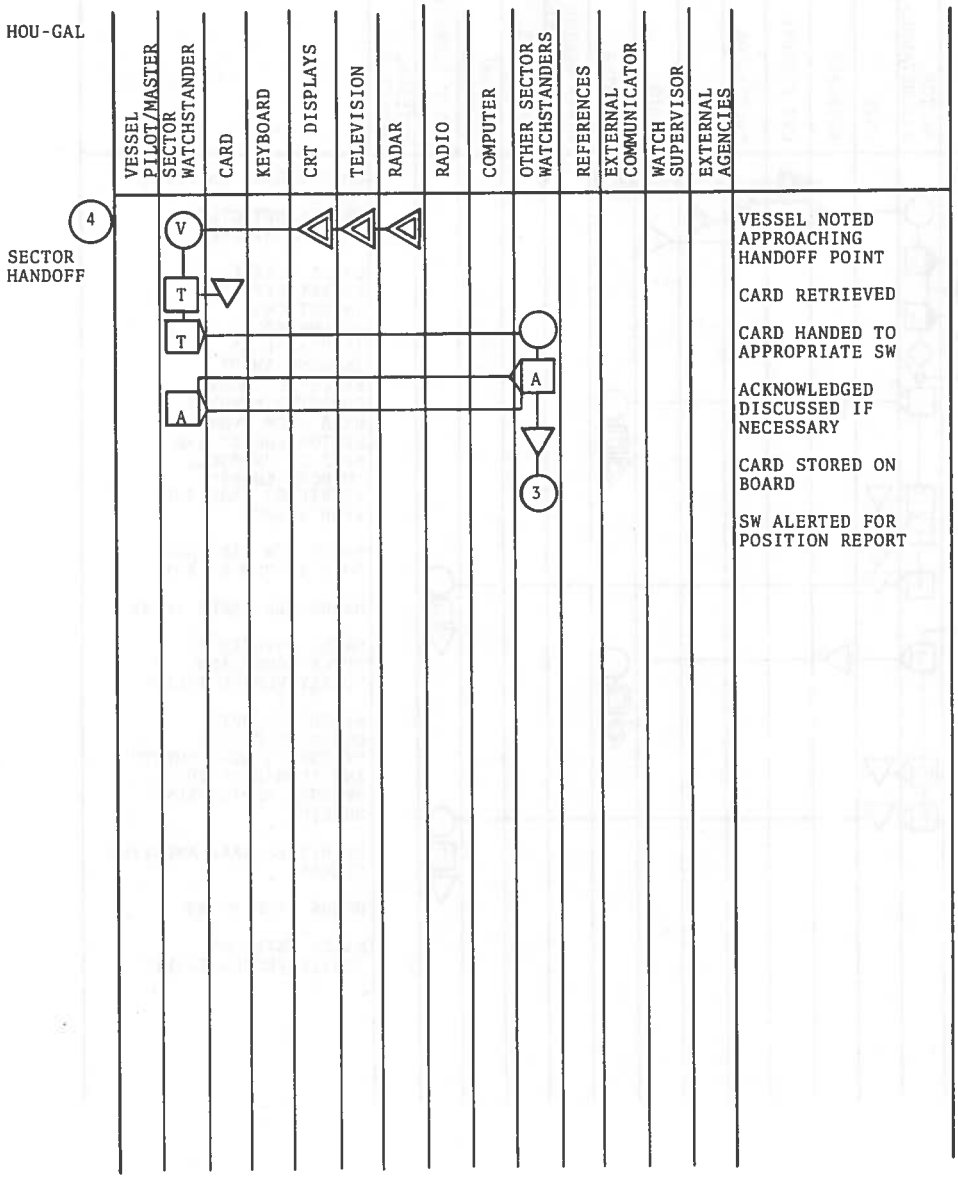
A Aurally or Vocally

T Tactually

V Visually

"Or gate"; follow one path only


HOU-GAL
VESSEL PILOT/MASTER
SECTOR WATCHSTANDER
CARD
KEYBOARD
CRT DISPLAYS
TELEVISION
RADAR
RADIO
COMPUTER
OTHER SECTOR WATCHSTANDERS
REFERENCES
EXTERNAL COMMUNICATOR
WATCH SUPERVISOR
EXTERNAL AGENCIES
2
POSITION MONITORED
SW MONITORS RELEVANT DATA
POSITION DISCREPANCY?
CONFERS WITH VESSEL IF NECESSARY
RADIO
CONFERS WITH OTHER SW's IF NECESSARY
SELECTS BEST VESSEL DATA
DATA KEYED INTO COMPUTER
COMPUTER UPDATES, DISPLAYS, STORES
CARD ADVANCED ON BOARD
ADVISORY REQUIRED?
RADIO
ADVISORY PREPARED AND DELIVERED TO VESSEL
IS VESSEL APPROACHING HANDOFF POSITION?


HOU-GAL
VESSEL PILOT/MASTER
SECTOR WATCHSTANDER
CARD
KEYBOARD
CRT DISPLAYS
TELEVISION
RADAR
RADIO
COMPUTER
OTHER SECTOR WATCHSTANDERS
REFERENCES
EXTERNAL COMMUNICATOR
WATCH SUPERVISOR
EXTERNAL AGENCIES
4
SECTOR HANDOFF
V
T
T
A
A
3
VESSEL NOTED APPROACHING HANDOFF POINT
CARD RETRIEVED
CARD HANDED TO APPROPRIATE SW
ACKNOWLEDGED DISCUSSED IF NECESSARY
CARD STORED ON BOARD
SW ALERTED FOR POSITION REPORT

APPENDIX C
ITEMS ON THE WATCHSTANDER ACTIVITY LOG

COMMUNICATIONS

VT - Any communication between the Watchstander and a vessel via radio. A tally was recorded on the log each time the Watchstander talked to the vessel. Should the Watchstander stop talking and perform another activity, such as marking a vessel status card, and then begin talking to the same or a different vessel, a new tally was recorded.

SW# - Communication between the Watchstander and one of the other two Sector Watchstanders, designated by sector numbers 1, 2 or 3.

XC - Communication between the Watchstander and the External Communicator. Tallies were not recorded consistently in this column because the observer was often unable to identify the External Communicator due to his high mobility. Tallies in this category were combined with the results of the "other" category listed below.

Oth - Communication between the Watchstander and any other individual (including the External Communicator).

WO - Communication between the Watchstander and the Watch Officer.

UK - Communication between the Watchstander and an unidentifiable individual. This category was deleted from the data analysis because no such activity was observed to occur.

Rad Adj - Any operation of radio controls performed by the Watchstander (such as channel selection or volume adjustment).

COMPUTER

Monitor S# - The Watchstander looked at the CRT display(s) of another Watchstander, designated by Sector numbers 1, 2 or 3. The third column entitled "S#" was not used in data collection.

CARDS

MK - The Watchstander marked a written entry on the Vessel Status Card. A tally was recorded each time the Watchstander was involved in writing on a card.

TP - The Watchstander time-punched a Vessel Status Card either upon vessel entry into or exit from the VTS. A tally was recorded for each time-punch activity.

CK - Watchstander referred to (or checked) one or more vessel status cards. In referring to a card, the Watchstander may have physically handled the card or simply viewed it.

F/U - The Watchstander filed one or more Vessel Status Cards or updated card positions on the plotting board at his position.

Hd - The Watchstander handed one or more Vessel Status Cards to another person or received one or more cards from another person.

TV

Mn - The Watchstander looked at the array of four TV displays at his position.

Cm - The Watchstander made a camera selection at his TV adjustment panel.

Pn - The Watchstander made one or more consecutive panning adjustments.

Zm - The Watchstander made one or more consecutive zooming adjustments.

Adj - The Watchstander made other TV adjustments (such as brightness or contrast).

APPENDIX D

FREQUENCIES OF OBSERVED ACTIVITIES

HOURLY FREQUENCIES BY SECTOR

Sector II

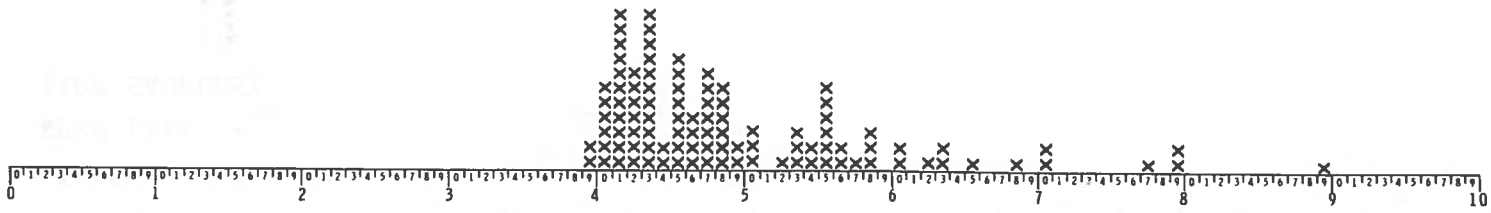
	COMMUNICATIONS							COMPUTER								CARDS					TV					RADAR	MISC.	
								Monitor		Disp		Keybd																	
HR.	Vt	SW[1]	SW[3]	Wo	Oth	UK	Rad Adj	S1	S3	1	2	A	B	C	D	Mk	TP	CK	F/U	Hd	M_N	Cm	P_N	Zm	Adj	Mn	Rf	mb
1°	8	1	5	1	2	0	3	0	7	65	47	8	19	7	4	1	1	8	8	5	47	2	7	6	2	3	3	2
2°	18	0	0	5	3	0	17	0	0	57	24	15	42	19	2	7	1	16	8	3	67	4	31	24	0	0	0	1
3°	8	3	1	0	20	0	1	0	1	119	77	13	29	13	2	6	2	19	11	3	85	12	50	30	1	0	0	0
4°	15	3	8	3	3	0	6	3	6	93	79	16	19	2	2	2	1	7	5	7	91	5	38	31	0	7	1	2
5°	8	5	6	3	22	0	4	0	1	57	38	39	46	0	5	6	2	9	4	2	20	4	18	15	0	12	2	0
Σ	57	12	20	12	50	0	31	3	15	391	265	91	155	41	15	22	7	59	36	20	310	27	144	106	3	22	6	5
$\bar{X}$	11	2	4	2	10	0	6	6	3	78	53	18	31	8	3	4	1	12	7	4	62	5	29	21	6	4	1	1
tot Σ	182				9%			976				51%				144			7%		590			31%		33	2%	
tot $\bar{X}$	36							195								29					118					7		

APPENDIX E
OBSERVED COMPUTER DELAY TIMES

DISPLAY: VESSEL STATUS SHEET

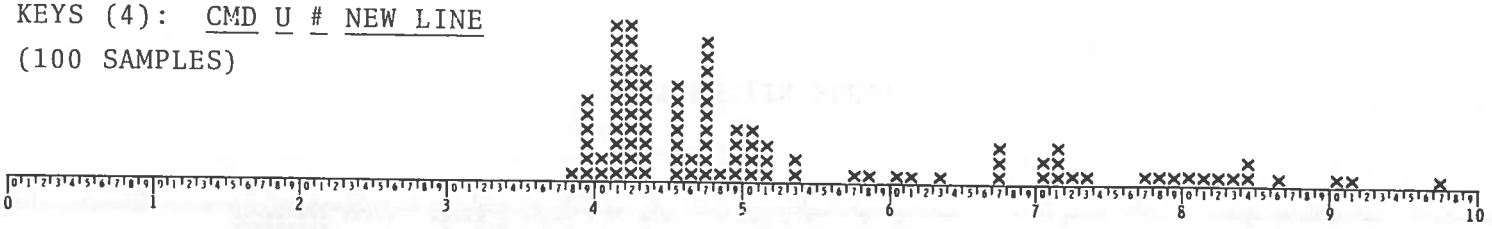
KEYS (8): CMD S S 1 # # # NEW LINE

(100 SAMPLES)

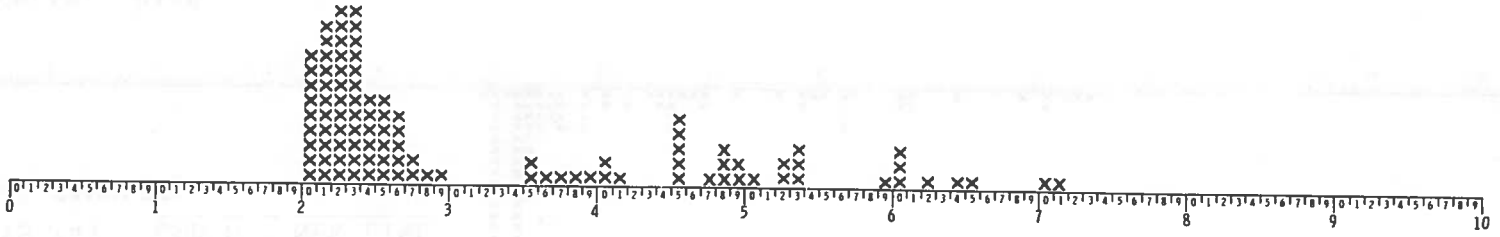


TIME (IN SEC.)

DISPLAY: VESSEL UNDERWAY
KEYS (4): CMD U # NEW LINE
(100 SAMPLES)



DISPLAY: VESSEL UNDERWAY
KEYS (0): LESS KEYING TIME
(100 SAMPLES)

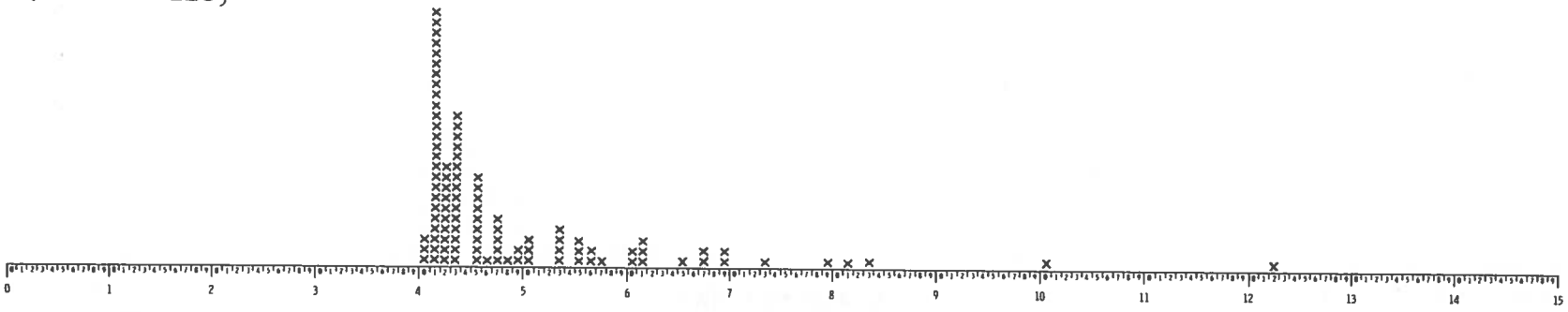


TIME (IN SEC.)

DISPLAY: VESSELS IN PORT

KEYS (4): CMD __ __ NEW LINE

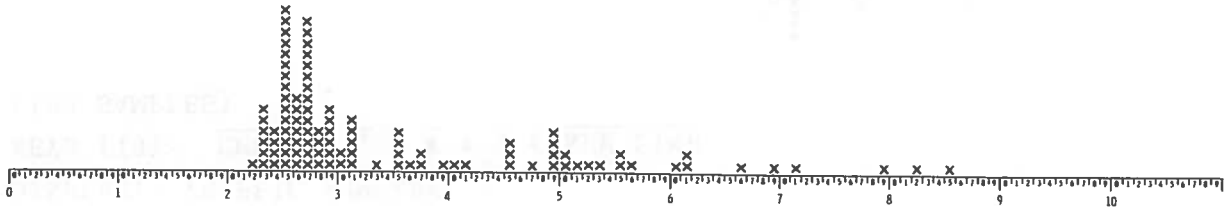
(100 SAMPLES)



DISPLAY: PAGE

KEYS (1): PAGE MOVE

(100 SAMPLES)



TIME (IN SEC.)

APPENDIX F
INTERVIEWS AT HOU-GAL VTS

TABLE F-1.

Interviewees	Years in Coast Guard	Years HOU-GAL VTS
Officers		
0-1	4.0	1.1
0-2	14.0	0.3
Enlisted		
1	5.5	2.4
2	24.0	0.3
3	6.0	4.0
4	4.3	1.5
5	3.2	1.1
6	6.0	3.0
7	3.2	0.8
8	3.3	1.2
9	6.0	3.2
10	4.0	1.5
Low	3.2	0.3
Median	4.9	1.4
High	24.0	4.0

learning to talk to civilians on the radio. One cited coordination of multiple activities.

F.10 What was toughest to learn in transition to the computer? Eight interviewees simply stated that transition to the computer was easy. Four had difficulty in learning to visualize the channel and traffic from the display formats. Two people noted that slowness of computer response made it hard to operate. Two cited the effort required to enter vessels into the system.

F.11 How would you improve watchstander training? Four interviewees called for a more organized training program, with more testing and evaluation of trainee progress. Three cited a need for more training personnel, particularly an instructor with time for teaching and evaluation. Five would like to see more vessel rides on the channel; one suggested following up rides with a reinforcing experience, such as slides and questions. Two interviewees called for continued training on the use of the board as a backup in case of computer failure. One person proposed more instruction on making clear, concise advisories.

F.11a How would you select people for VTS duty? The following criteria were suggested for selection of Coast Guard personnel for VTS duty. The number in parentheses indicates the number of interviewees proposing that criterion.

Good hearing (5)
Good general health (5)
Personal qualities (motivation, intelligence, willingness to learn) (4)
Language skills (3)
Relevant experience (communications, port traffic, ship handling, radar, knowledge of Houston area, service record) (3)
Motor coordination (2)
Visit to VTS before accepting assignment (1)

F.12 How do you feel about the work schedule? Interviewees were generally on their first day of the new 12-hour watch schedule when interviewed. Their responses, therefore, were estimates as to how they would like the new schedule. Of eleven responses, ten were favorable. The negative response reflected concern over fatigue effects. Two others anticipated some fatigue but felt that the extra free time made it acceptable. Five responses favored the better distribution of free time. One also indicated that there would be more continuity on the

F.18 Rate all aids for importance and usage. Interviewees were asked to rate each of twelve work aids on a five-point scale both for importance and frequency of usage. Table F-2 summarizes these ratings. They show clear agreement on the importance and frequency of usage of the computer keyboard and the display sheets (SS, DR, VU) necessary for data entry and system monitoring. Similarly, the radar, the individual television displays, and the radio were highly rated. Comments by interviewees emphasized their importance. On radar: "More improvement than the computer." "I use it continuously." "I'm blind without it." "Best thing that ever happened." On television: "You know he is there." On Channel 13: "It gives you the truth." Opinion differed more on the repeater television, averaging of medium importance and seldom used.

There was general agreement that the DE and DI sheets are unimportant and seldom used. Opinion spread more evenly on the importance of the TR sheet, ranging from high to very low, but with two-thirds of the ratings in the low and very low categories. There was more agreement, however, that usage of this display is low (eleven ratings of low or very low). The IP was rated of high importance but medium usage.

Comments on the display sheets are illuminating: On SS: "ETA's are inaccurate." On DR: "Used more than any other." On VU: "Cards take the place of VU." On IP: "Redundant to the box of cards." "Used mainly by supervisors." On TR: "Virtually useless." "Used mainly by supervisors." (One of the two supervisors interviewed rated it as used hardly ever, the other as used some). "Doesn't allow for changes in speed." "Predictions unreliable." On DE: "Redundant to the talley sheet." On DI: "Used only for training."

The Vessel Status Cards were generally rated important and very often used. Comments on cards included: "Easy to get the information." "Easy for handoff." "Good for getting statistics." "Fix the computer, and you can do away with the cards."

F.19 How do you like the computer? What are its advantages and disadvantages? Opinion split on the computer. Four interviewees liked it, five disliked it, and three were neutral. Comments of those who liked it included: "Love it." "Like it a lot." "Great." "Good." Comments of those who disliked it included: "Worthless." "Money was not spent wisely." A typical neutral comment was: "It's OK but needs changes." Table F-3 summarizes the advantages and disadvantages noted and shows the attitudes of those who noted them. It is interesting to observe that more advantages of the computer were noted by those who disliked it than by those who liked it. The principal complaint

TABLE F-3. ADVANTAGES AND DISADVANTAGES OF COMPUTER AND BOARD

Computer

Advantages	L	D	N	Disadvantages	L	D	N
Automatic Updating	2	3	1	Slow (keying, delays, rejects)	1	5	3
Accuracy	1	2	1	No better than board		2	
Computes speed	2	1		Isolates watchstander from others		1	1
Keeps marching order straight	1			Makes mistakes when speed changes		1	
Good for summary statistics	1			Hard to get destination and draft		1	
Would be good if improved		2					

Board

Advantages	L	D	N	Disadvantages	L	D	N
Accurate	1			Need to advance cards	2		3
Fast	1	2	1	Doesn't adjust speed		1	
No breakdowns		1		Not accurate		2	
Permits team operation	2		4	Operation too relaxed	1		
Don't have to do things twice			1				
Can tell ships from tows			1				
Fine with computer as backup	1						

L = Like
D = Dislike
N = Neutral

TABLE F-4. RATINGS OF COMPUTER QUALITY

Quality	Very High	High	Medium	Low	Very Low
*Accuracy	6	3	1		1
Speed			2	6	4
Ease	3	2	2	4	1
Legibility	5	6		1	

*11 responses

TABLE F-5. ESTIMATES OF NUMBER OF VESSELS THAT CAN BE HANDLED COMFORTABLY AT ONE TIME

Number of Vessels	Number of Estimates
10-14	2
15-19	6
20-24	6
25-29	0
30-34	2
Over 35	2

APPENDIX G
STRESS QUESTIONNAIRE

TABLE G-1. STRESS QUESTIONNAIRE

Complete only these first two lines.

I.D.: _____ DATE: _____ SHIFT: _____

TIME OF DAY	PRE	DURING	POST	HOME
TRAFFIC LOAD:	_____	_____	_____	_____
WEATHER:	_____	_____	_____	_____

Each line below represents a scale of symptoms you might experience ranging from none to severe. For each item below please mark an (X) anywhere along the line corresponding to the degree of symptom you are now experiencing. (You may go beyond the ends of the line if you wish.)

1. Headache: None — Moderate — Severe
2. Constipation: None — Moderate — Severe
3. Sweating: None — Moderate — Severe
4. Twitching muscles: None — Moderate — Severe
5. Dizziness: None — Moderate — Severe
6. Poor appetite: None — Moderate — Severe
7. Chest pains: None — Moderate — Severe
8. Loose bowels: None — Moderate — Severe
9. Loss of temper: None — Moderate — Severe
10. Difficulty in breathing: None — Moderate — Severe
11. Aching or burning eyes: None — Moderate — Severe

8. Upset:

None Moderate Severe

9. Anxious:

None Moderate Severe

10. Tired:

None Moderate Severe

11. Drowsy

None Moderate Severe

Results

The results are presented graphically in Figures G-1 through G-7 for the somatic items and Figures G-8 through G-15 for the mood items. Each figure presents the maximum, median, and minimum values for each instance during a day which the questionnaire was completed. The numbers on the vertical axis indicate the distance (in centimeters) along the scale from None (0 to 0.85 cm.) through Moderate (3.50 to 5.25 cm.) to severe (8.0 to 9.5 cm) at which subjects could mark each item. The most important result is that every item exhibits a worsening trend throughout the day. (Only those items for which the Post shift median exceeded the limit for None, 0.85, are shown.)

Table G-3 presents these results ordered by the magnitude of the Post shift median for those items exceeding None. Seven of the 19 somatic items and 8 out of the 11 mood items indicate appreciable stress. The most sensitive items are aching or burning eyes and tiredness.

The FAA results are also presented in rank order. Although not perfect, the two rankings agree fairly well (Spearman rank order correlation = 0.79, t (df - 17) = 8.76, $P<.0005$) lending support to the validity of the survey.

Finally, Figures G-16 and G-17 show trends of the most sensitive somatic and mood items over the four days. Both exhibit increases across the work week; however, the magnitude of these increasing trends is much less than that across periods within a day.

Summary

- This questionnaire is sensitive to both a somatic and a mood stress pattern at an active vessel traffic service center.
- This stress pattern worsens during the shift for all items.
- Aching or burning eyes and tiredness are the most sensitive of the somatic and mood items.
- The pattern of somatic stress indicators is quite similar to that found by the FAA.

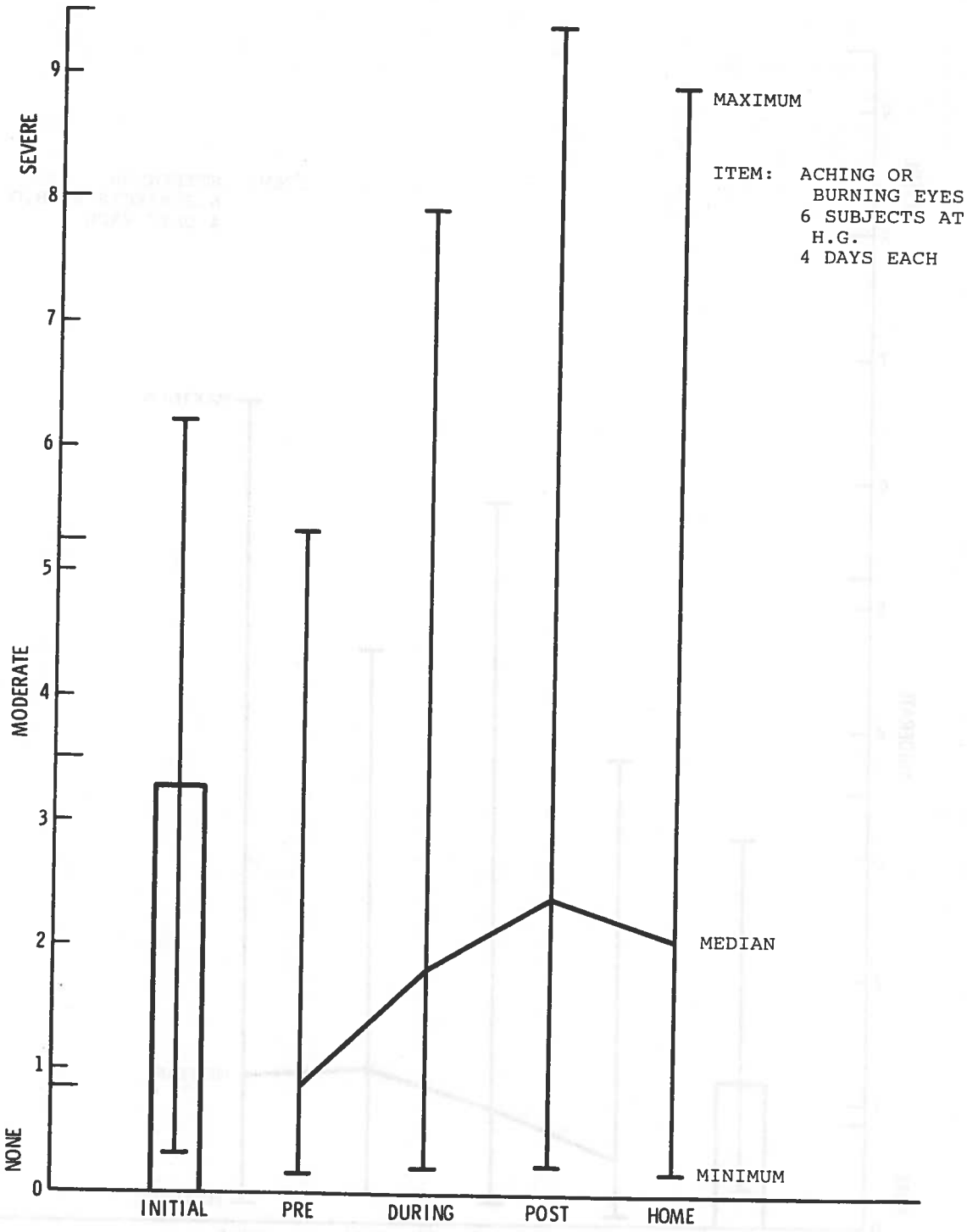


FIGURE G-1. SOMATIC ITEM: ACHING OR BURNING EYES

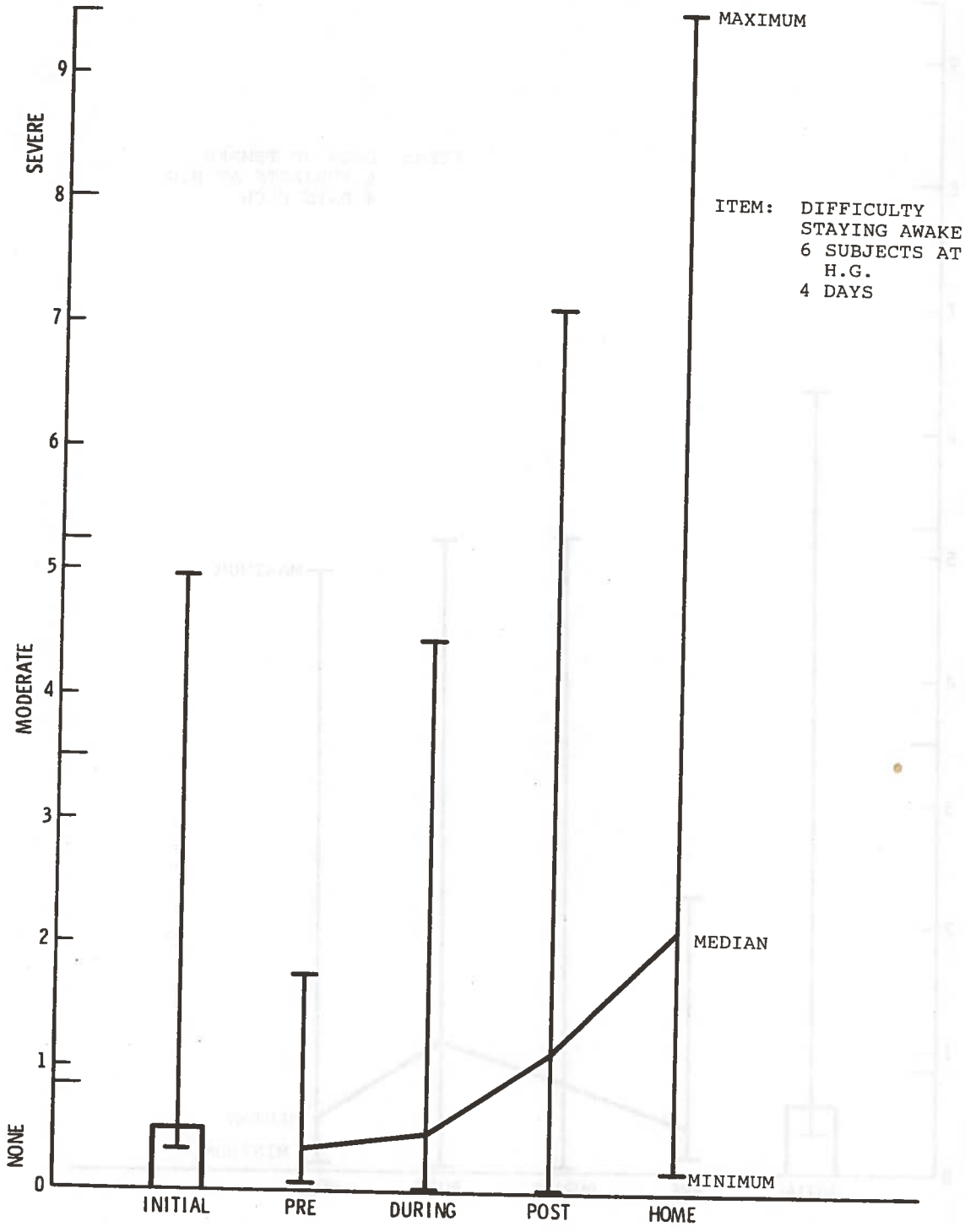


FIGURE G-3. SOMATIC ITEM: DIFFICULTY IN STAYING AWAKE

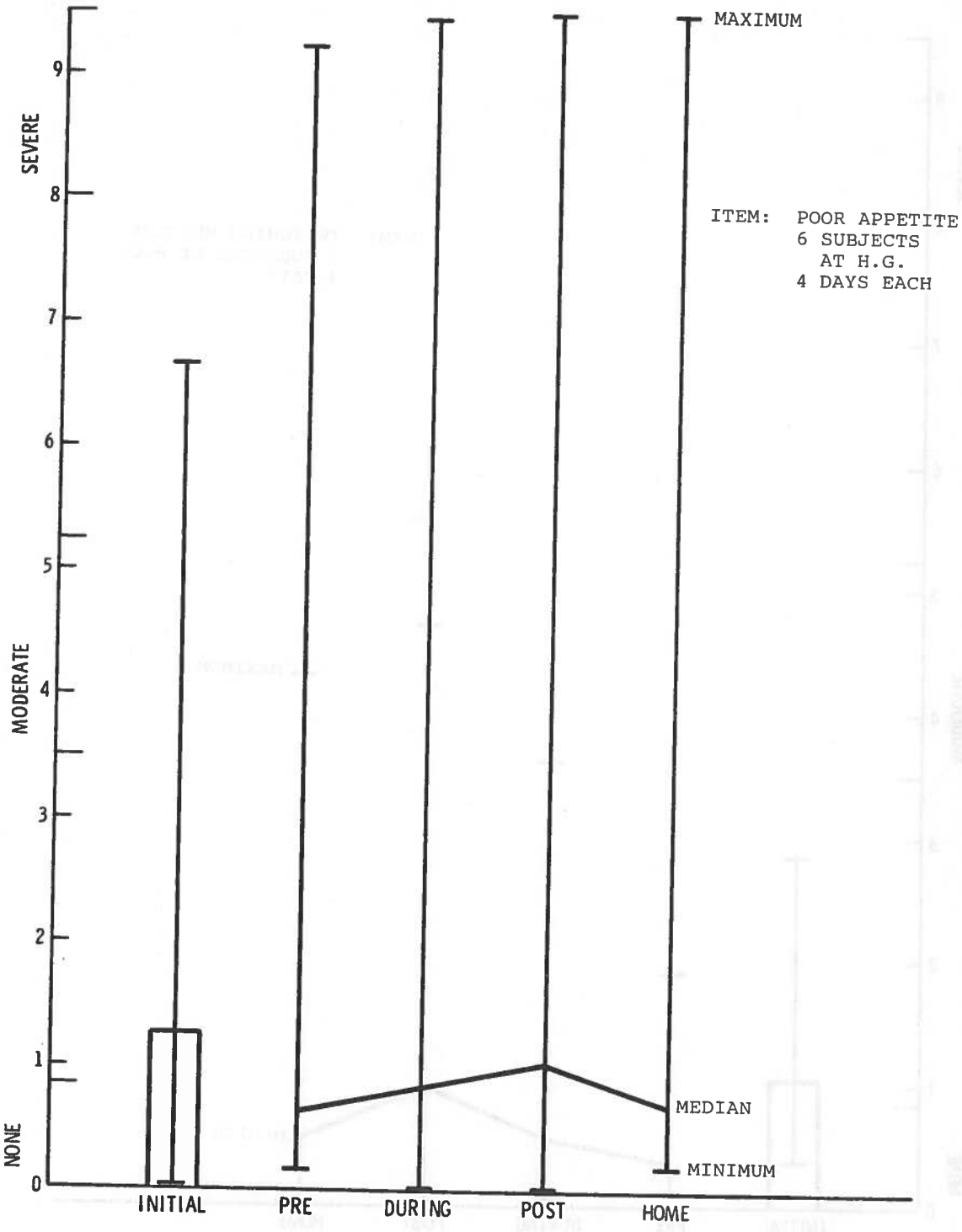


FIGURE G-5. SOMATIC ITEM: POOR APPETITE

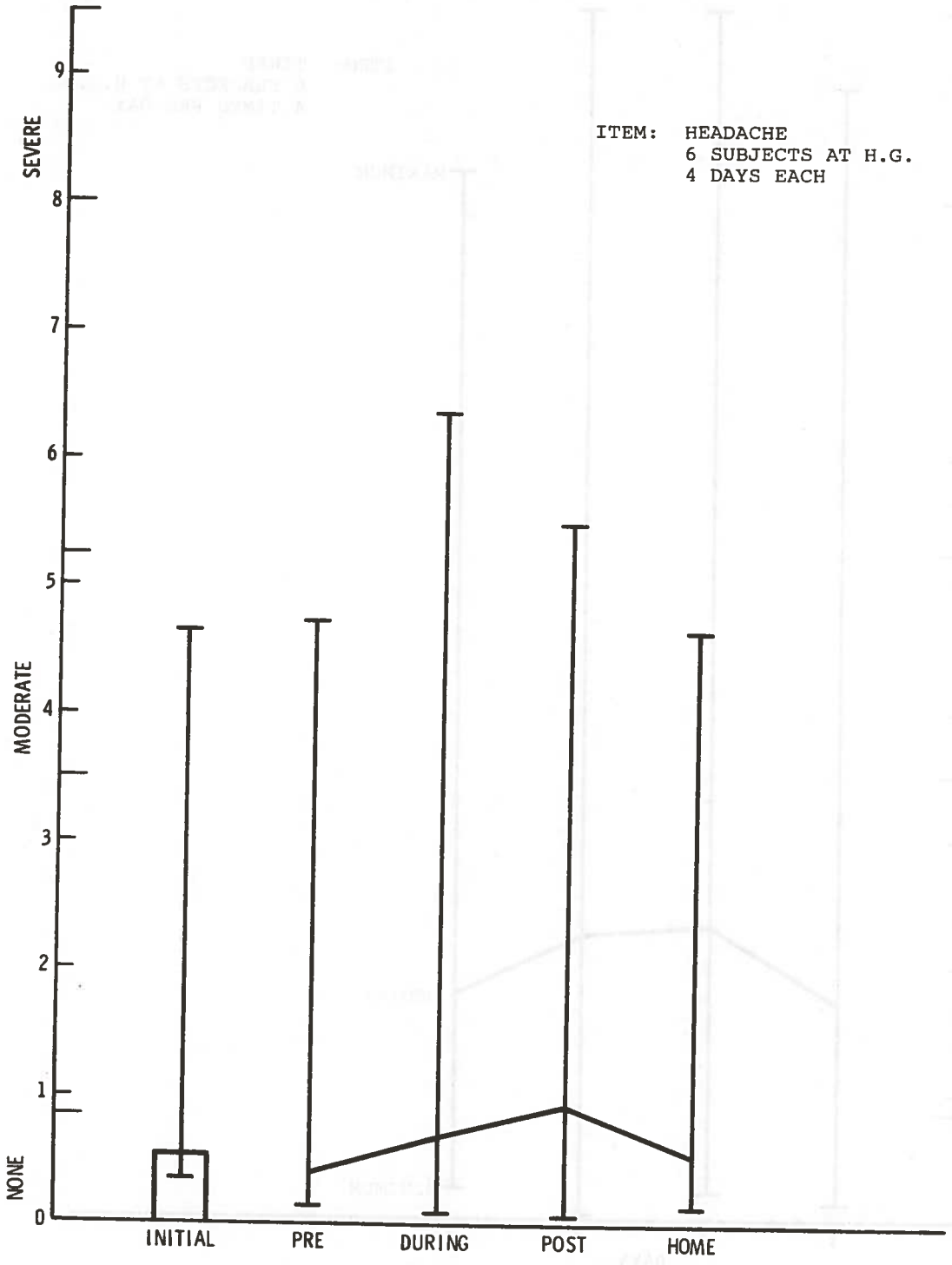


FIGURE G-7. SOMATIC ITEM: HEADACHE

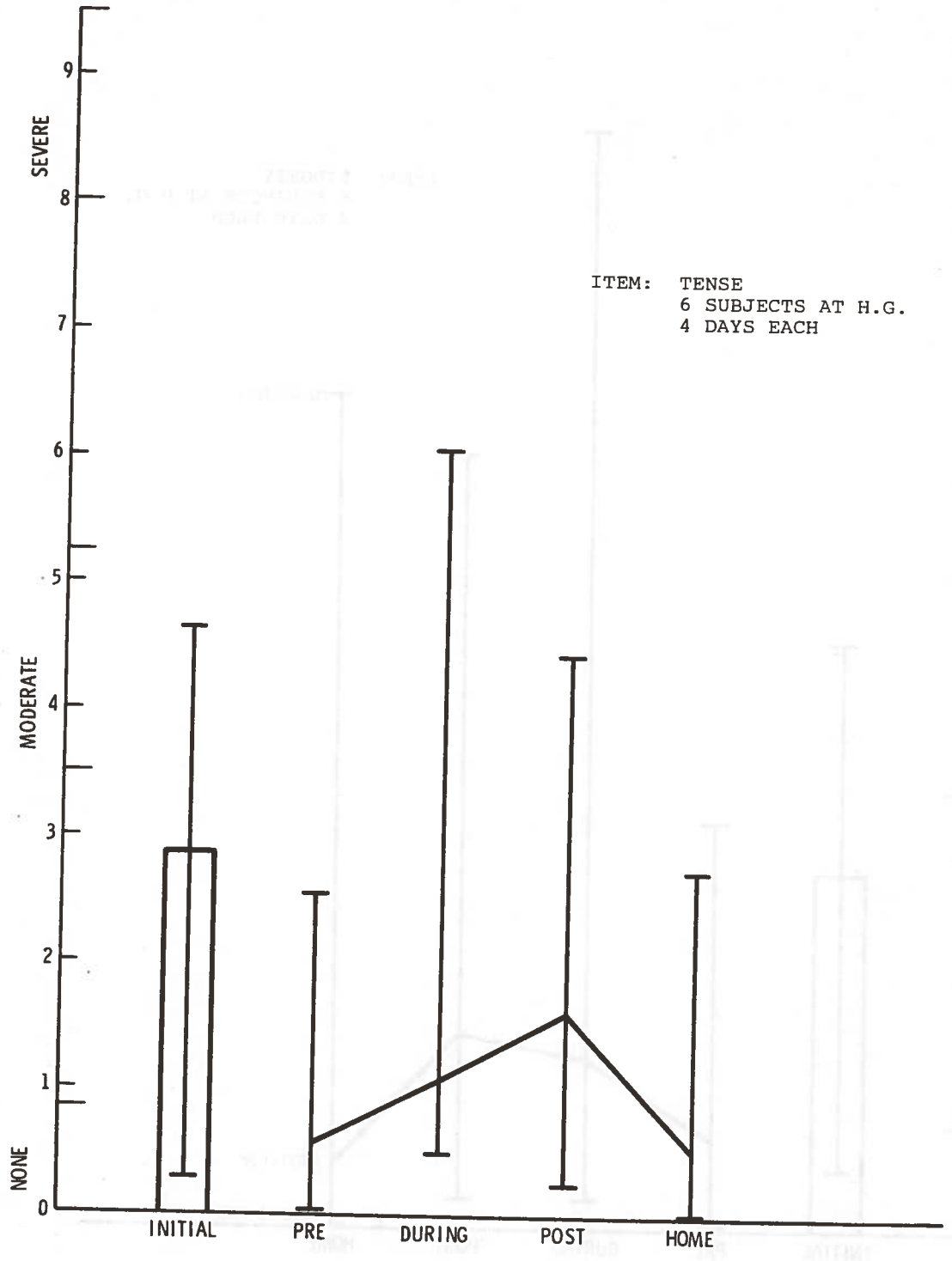


FIGURE G-9. MOOD ITEM: TENSE

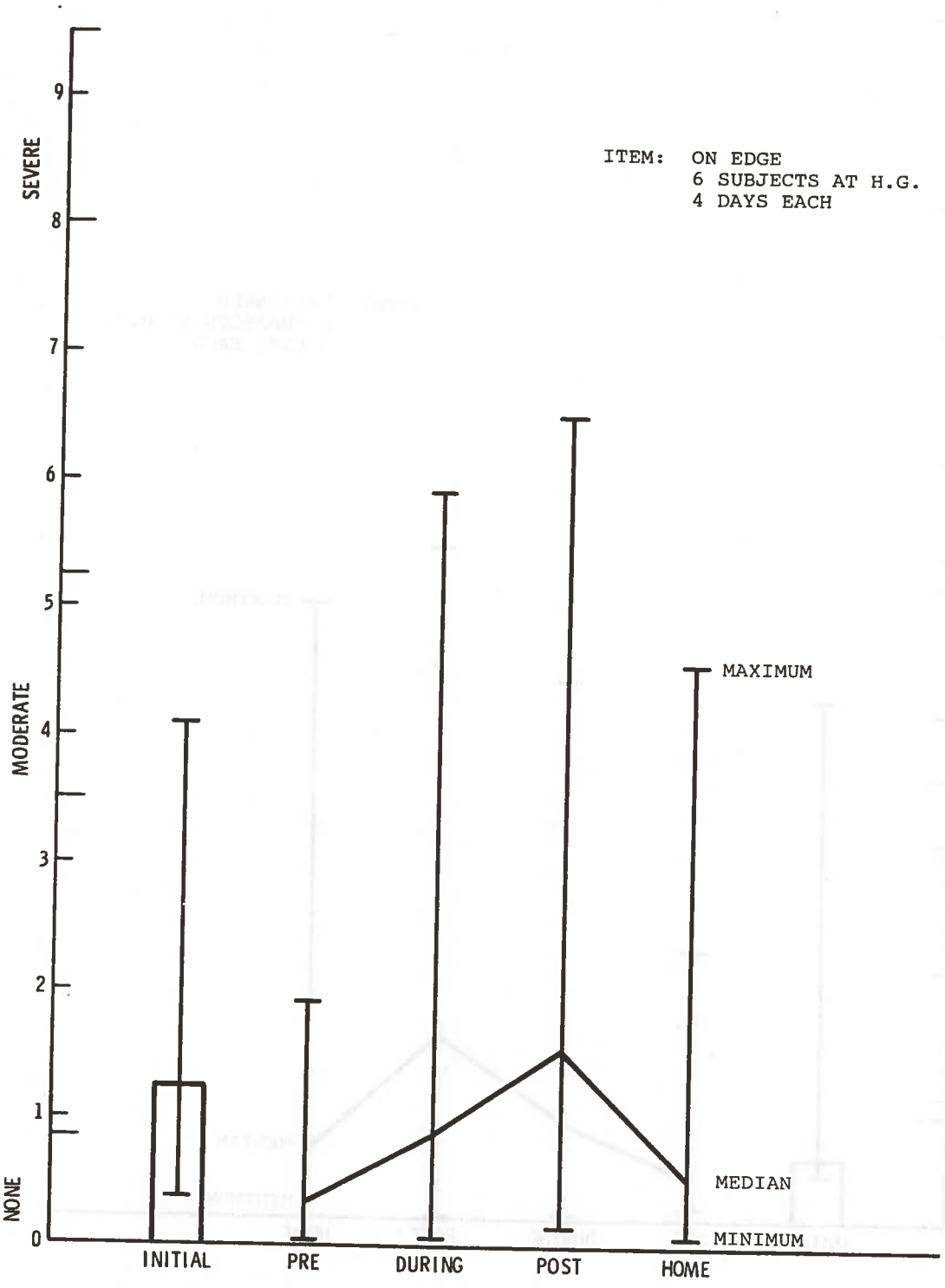


FIGURE G-11. MOOD ITEM: ON EDGE

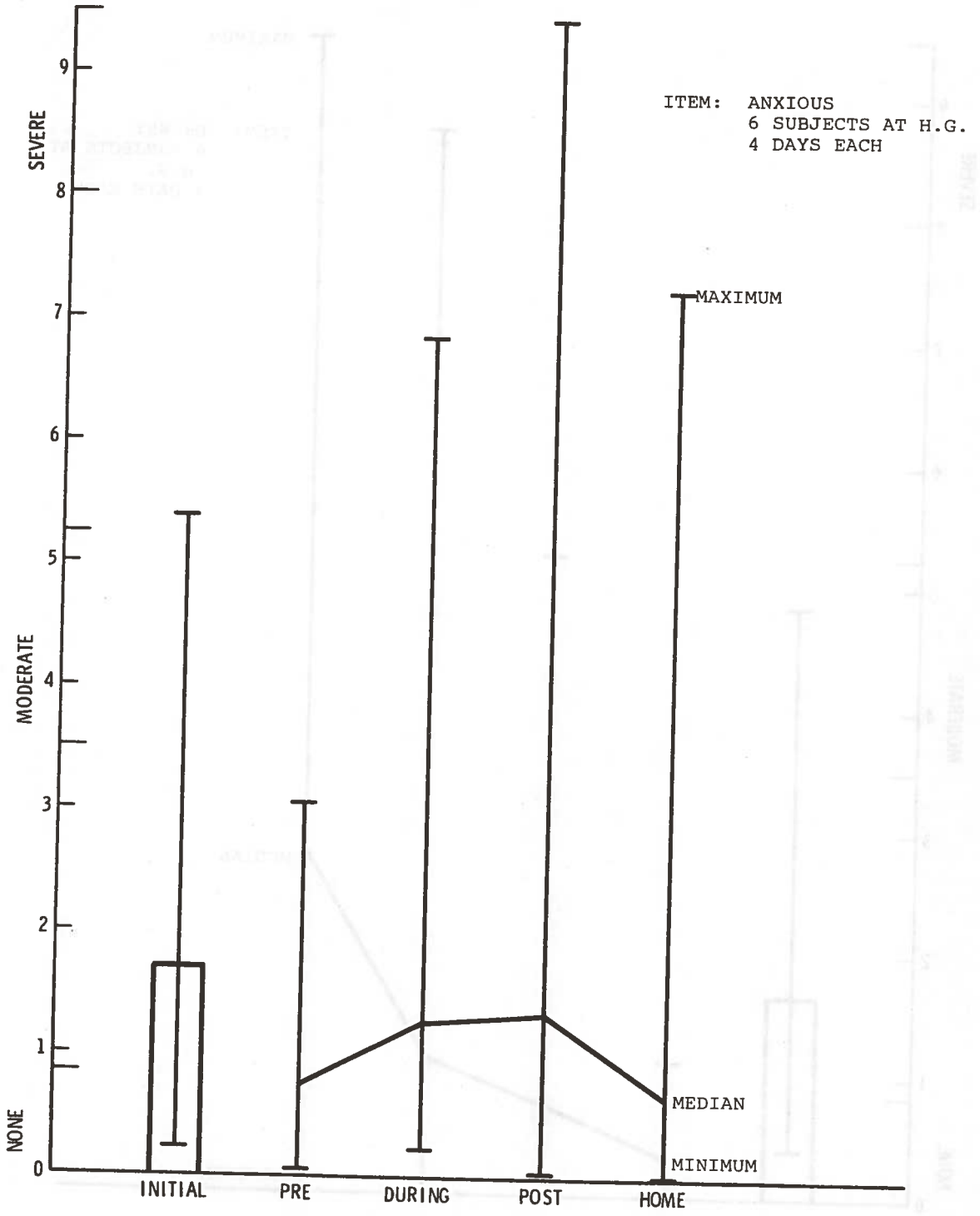


FIGURE G-13. MOOD ITEM: ANXIOUS

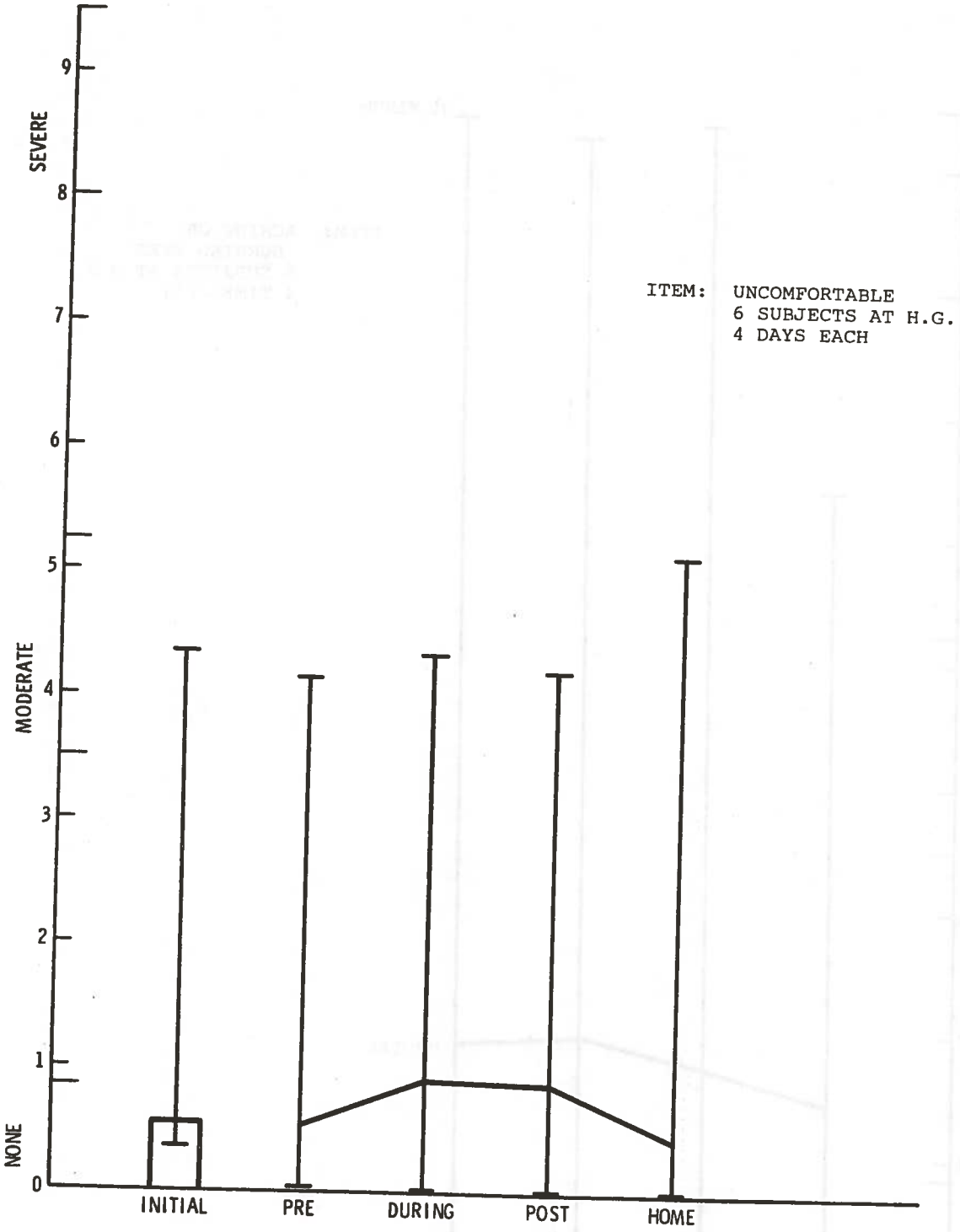


FIGURE G-15. MOOD ITEM: UNCOMFORTABLE

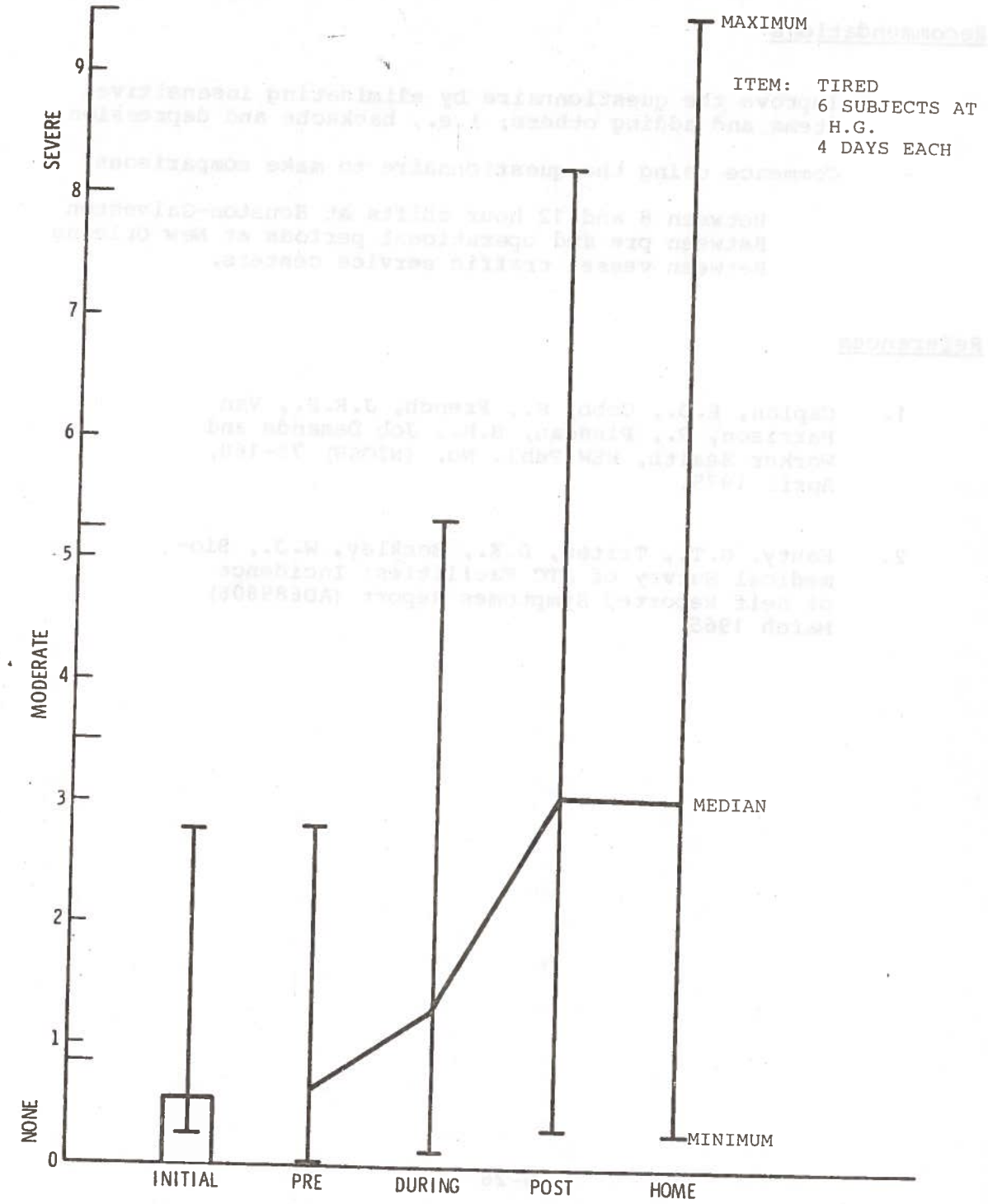


FIGURE G-17. MOOD ITEM: TIRED