SSC-329

ICE LOADS AND SHIP RESPONSE TO ICE

SUMMER 1982/WINTER 1983 TEST PROGRAM

SHIP STRUCTURE COMMITTEE

1990

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In previous Ship Structure Committee (SSC) reports (SSC-309 and SSC-310), assessment of various rules pertaining to the design of ice-strengthened vessels was undertaken. There, empirical recommendations were made for vessel scantlings, and the need for full-scale data was recognized.

This report presents the results of obtaining full-scale local ice pressure loads near the bow on the U.S. Coast Guard Icebreaker POLAR SEA. The data collected is useful in working towards a statistically valid design approach.

Although this data is quite useful by itself, one must remember that it is for one "year" of ice, one hull form, one location, one displacement and one horsepower. A second "year" of data has been taken and the year-to-year variability will be assessed on a subsequent report.

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16. Abstract This paper presents work toward development of local ice load criteria for icebreaking ships. A bow panel of approximately 100 ft^2 (9.2 m^2) was instrumented to measure ice pressures by measuring compressive strains in the webs of transverse frames. The panel was divided into 60 sub-panel areas, six rows of ten frames, over which uniform pressures were calculated during an impact with ice. Finite element models of the hull structure were used to develop a data reduction matrix relating the measured strains to uniform pressures. Only events over a preset threshold strain were recorded. Approximately 1400 such events were recorded on two deployments, one to the Beaufort Sea in September-October 1982 recording summer multiyear ice impacts and one to the Chukchi Sea in March-April 1983 recording both first year and multiyear winter ice impacts.

Extreme pressure-area curves were developed for each event. Extreme envelopes of pressure versus area were developed from the data for each of five geographical areas; south Bering Sea, north Bering Sea, south Chukchi Sea, north Chukchi Sea, and Beaufort Sea. Trends in peak force and peak pressure are examined in terms of ship impact speed and ice conditions. Frequency of occurrences tables for highest average pressure are developed as a function of impact area for each geographical area. A statistical analysis of the extremes of the north Chukchi Sea data indicated that the peak pressure data followed a Gumbel extreme value distribution. Finally, a non-dimensional analysis was performed on selected data and an empirically based approach is presented for developing extreme pressure-area curves as a function of ice conditions, ship impact speeds, and the return period. Suggestions are made for further data collection and analysis toward a rational design procedure based on ice conditions.

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PREFACE

This paper presents work toward development of local ice load criteria for icebreaking ships. A bow panel of approximately 100 ft^2 (9.1 m^2) was instrumented to measure ice pressures by measuring compressive strains in the webs of transverse frames. The panel was divided into 60 sub-panel areas, six rows of ten frames, over which uniform pressures were calculated during an impact with ice. A sophisticated digital data acquisition system recorded only events over a preset threshold strain. A microprocessor controlling data acquisition allowed real time data to be streamed through memory such that the recorded data were the 60 channel strain time-history from one second before to four seconds after the threshold was exceeded, sampling each channel at 32 Hz. Approximately 1400 such events were recorded on two deployments, one to the Beaufort Sea in September-October 1982 recording summer multiyear ice impacts and one to the Chukchi Sea in March-April 1983 recording both first year and multiyear winter ice impacts. All strain data were converted to pressure time-histories over each of the 60 sub-panels.

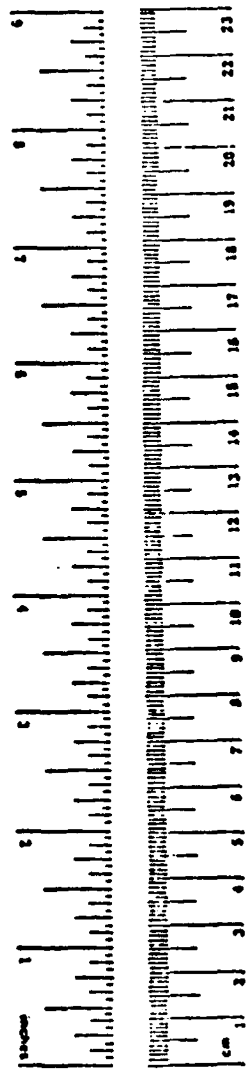
Finite element models of the hull structure were used to develop a data reduction matrix relating the measured strains to uniform pressures. The result is a spatial and time representation of each impact. Extreme pressure-area curves were developed for each event. Extreme envelopes of pressure versus area were developed from the data for each of five geographical areas; south Bering Sea, north Bering Sea, south Chukchi Sea, north Chukchi Sea, and Beaufort Sea. Trends in peak force and peak pressure are examined in terms of ship impact speed and ice conditions. Frequency of occurrence tables for highest average pressure are developed as a function of impact area for each geographical area. A statistical analysis of the extremes of the north Chukchi Sea data indicated that the peak pressure data followed a Gumbel extreme value distribution. Pressure-area curves are predicted for longer return periods indicating a pressure of 2920 psi (20.1 MPa) for a ten year return period in these ice conditions. Finally, a non-dimensional analysis was performed on selected data and an empirically based approach is presented for developing extreme pressure-area curves as a function of ice conditions, ship impact speeds, and the return period. Suggestions are made for further data collection and further analysis toward a rational design procedure based on ice conditions. It is recommended that this procedure be compared to the statistical analysis of extremes for each type of ice condition--first year ice, multiyear ice, and glacial ice--to ensure that the limiting conditions, ice mass far greater than ship mass or extreme ice thicknesses, are properly represented.

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F

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ICE LOADS

AND

SHIP RESPONSE TO ICE

1.0 INTRODUCTION

With the imminent oil exploration on the West Coast of Alaska and the ongoing oil exploration in the Canadian Arctic, commercial shipping in the Arctic will soon be a fact. For these ships to meet the rigors of maintaining a shipping schedule, a vast amount of information must be gathered about the environmental conditions and how they affect a ship. The USCG POLAR Class winter deployments sponsored by the Maritime Administration (MarAd) have provided a platform from which to gather this information. Environmental conditions, trafficability, and ship performance data have been collected in previous deployments. For the Phase V program, a deployment of the POLAR SEA in March and April 1983, the Ship Structure Committee in conjunction with the Canadian Ministry of Transport, sponsored a program to collect ice loads in addition to the MarAd sponsored research.

The ultimate objective of this jointly funded research is to develop ice load criteria for the design of ships. Specifically, the objective of this study was to measure the pressure that the ice exerts on the hull and the area or extent of that pressure for local impacts while transiting or ramming an ice field. The emphasis was to understand the loading in one particular area of the shell that is heavily loaded rather than attempting to determine the total load on the entire ship. Hull girder bending therefore was not investigated.

This test program documented the ice conditions, features, and the associated ice properties, with the force and pressure time histories collected for ice loads. It is important that in the development of an ice load criteria, the design pressure be linked to the anticipated ice conditions. A ship designed for the Bering Sea would experience lower ice loads than one in year-round Beaufort Sea service. The route and locations for the tests are shown in Figure 1 on the opposite page. A summer deployment, September-October 1982, was used to test the data acquisition system and valuable multi-year impact data were gathered. The major testing period, the winter deployment, began in the mildest ice conditions at the ice edge in the Bering Sea and eventually reached severe conditions of multiyear ice in the Chukchi Sea. Data were gathered which showed the variation in ice loads with changing ice conditions and the severity of ice impacts in most of the operating areas of the Alaskan Arctic.

This report describes the way the ice impact pressures were collected as well as a presentation and analysis of the collected data. A unique instrumentation procedure was used to measure local ice impact pressure as a function of area by strain gaging the webs of the cant frames (transverse framing perpendicular to the hull plating) for compression perpendicular to the hull plating. Finite element models of the hull structure were developed to relate the measured strains to uniform ice pressures over 60 equal areas on the bow of the ship. Full scale loading of the hull was performed to verify the finite element model. The elements of the test program are described in Sections 3.0 to 6.0. The data collected, approximately 1400 impacts, are analyzed with respect to measured and observed ice conditions, geographic area, and impact velocity in Sections 7.0 and 8.0. A non-dimensional analysis of the peak forces and pressure has been conducted and is presented in Section 9.0. Time variation of the pressure and a statistical analysis of extremes are presented in Sections 10.0 and 11.0. Finally, the data are compared to other measured data and classification society rules. These comparisons as well as the conclusions drawn from the study and recommendations for future research are given in the final sections.

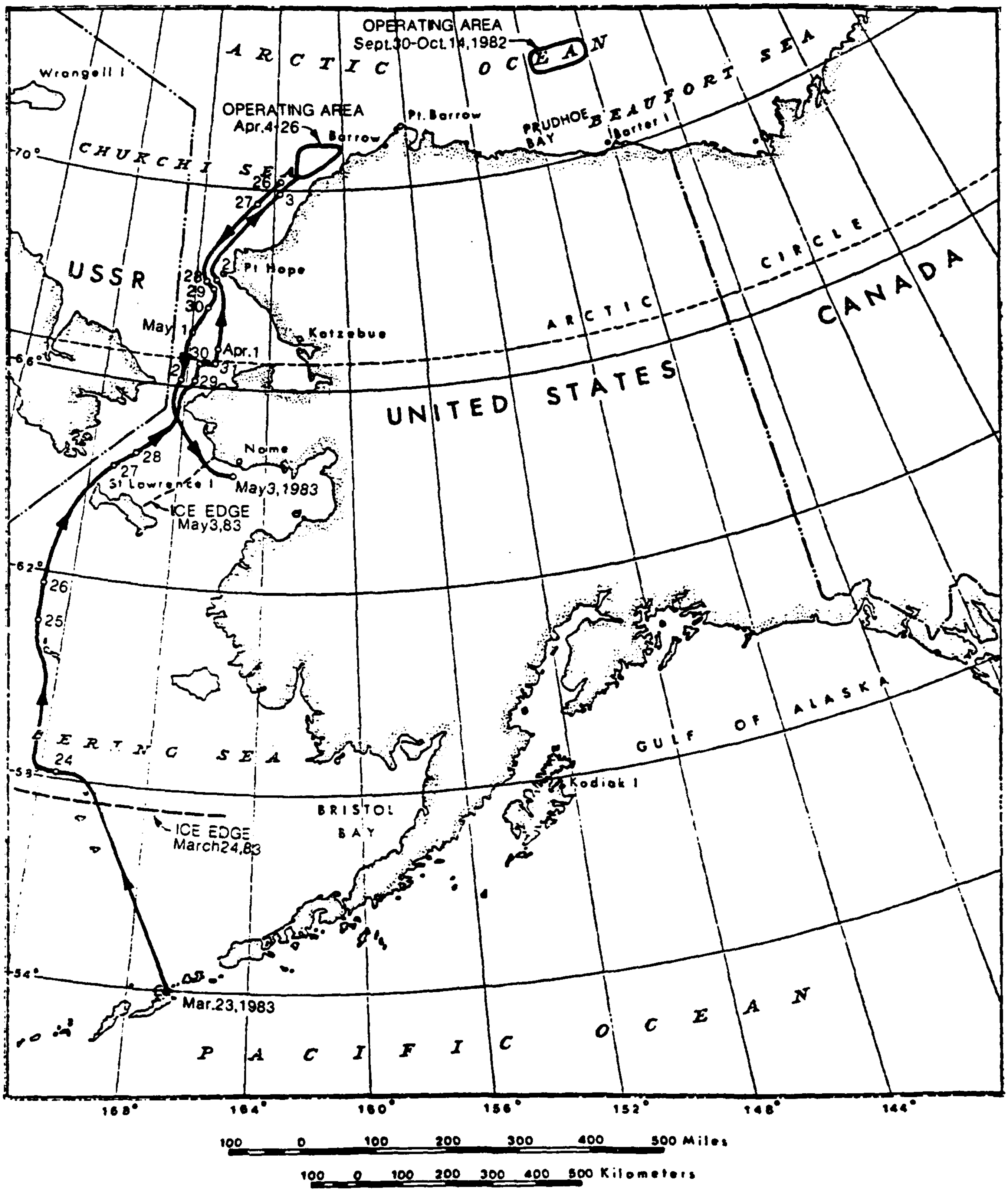

Figure 1

OPERATING AREAS FOR ICE IMPACT LOADS

2.0 EXPECTED ICE LOADS

2.1 Location of Maximum Loads

The departure point for any examination of the location of ice loads on a ship must be the operational draft and trim. The knowledge of draft and trim as well as the expected ice thickness will determine the vertical area of loading on the hull. Allowances, of course, must be made for pitching while ramming significant ice features.

Expected ship draft was predicted for various points along the proposed route based on hotel loads and fuel rates measured on the POLAR Class ships in these areas at the same time of the year from previous trafficability tests. A hotel load of 11 LT/day (0.11 MN) and a fuel rate of 1 LT/NM (0.1 MN/NM) in the Chukchi Sea were used. The weight loss due to fuel consumed was subtracted from the operational full load displacement and, using the ship's curves of form, the draft was predicted. Calculations assumed that the ship did not take on ballast. The range of operating drafts was calculated to be between 31.75 feet (9.7 m) and 29 feet (3.8 m).

Trim was not expected to be a problem. The large number of both fuel and ballast tanks made it relatively easy to keep the ship at level trim. Extreme pitches recorded on previous deployments were about 1 degree.

A number of different studies were examined to determine where the maximum loads might occur along the ice belt. It was initially felt that the peak loads would be experienced directly on the bow in a ramming condition where bending failure of the ice sheet did not occur to relieve the load (compression failure only). This was found not to be the case. A computer program developed by ARCTEC CANADA Limited which takes into account the response of the ship and the floe, was used to investigate the impact of the POLAR Class hull form with a 33 foot (10 meter) thick multiyear floe at different points aft of the bow. The results are shown in Figure 2. The peak load is shown to be at Station 2 on a 20 station ship. Also shown on the same plot are curves of the results of Johansson's methodology for the same conditions [1]* and the theoretical work of Dayton used in the design of the POLAR Class ships [2]. Dayton's work was based on a 1957 Russian paper by Tarshis [3] using the impact of 3,300 foot (1,000 meter) diameter floe of 24 foot (7.6 meter) thickness. The peak load, predicted by Dayton, is just aft of Station 2-1/2.

Figure 3 shows the occurrence of damage reported by Dayton on the WIND Class icebreakers of the U.S. Coast Guard [2]. The local stiffening of the hull in way of a bulkhead appears to be the reason for the double peak in the curve. This plot also shows that the most damage was sustained at about Station 2. Conclusions from this figure should be tempered by the fact that the step for the bow propeller, a structural weak point, was located at Station 1.25.

The conclusions drawn from these figures are that the peak loads will occur at about Station 2 and that the shoulder (about Station 5) will see loads of the same order as the bow, roughly 50 percent of that at Station 2.

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* Numbers in brackets refer to references listed in Section 10.

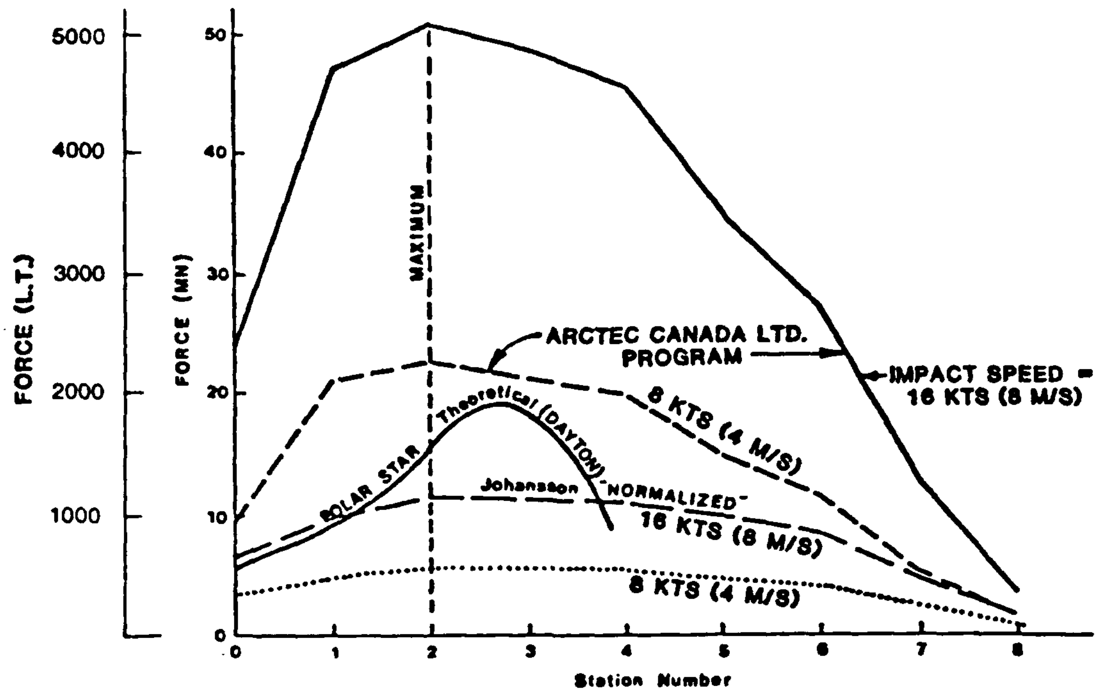


Figure 2

COMPARISON OF THEORETICAL PREDICTIONS OF ICE LOAD vs LENGTH FROM THE BOW

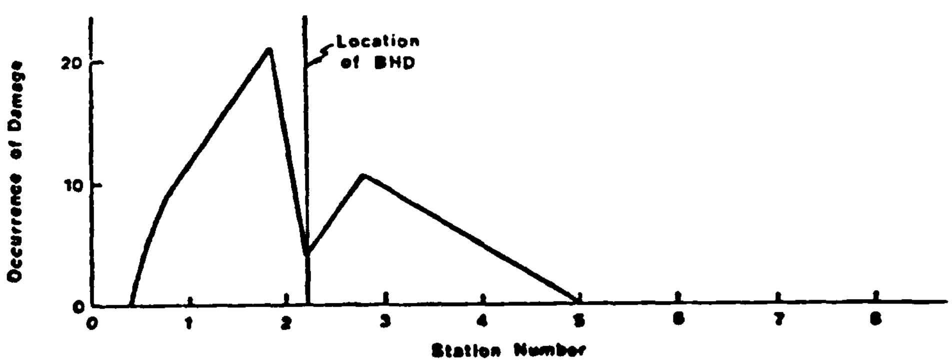


Figure 3

OCCURRENCE OF DAMAGE ON THE WIND CLASS vs LENGTH FROM THE BOW

2.2 The Magnitude and Extent of the Load

Much of the recent previous work on ice loads has been done by the Canadians in support and verification of their Canadian Arctic Pollution Prevention Regulations (CASPPR) [4]. A pressure area relationship has evolved from this effort to define maximum ice loads for ship design. Figure 4 shows the results of several different investigations done by the Canadians as well as the design requirements of the CASPPR Rules.

The CASPPR design pressures are presented for the highest and lowest Ice Class for Arctic Class ships. These rules specify one pressure for the design of the plating (the upper left horizontal line in Figure 4) and a second for the framing (the lower right horizontal line). Though areas of the hull are defined for ice strengthening by the rules, there is no limit on the extent of impact area or total load.

Johansson's proposed rules for CASPPR Ice Class 10 [1] are also presented as well as Tunik's comments to that paper [5]. These proposed rules calculate the design pressure as a function of the displacement and horsepower of the ship. The total load or extent of area over which the pressure acts is a function of the ship speed and displacement.

For design purposes, it is desirable to have a pressure versus area relationship for areas from the minimum unsupported panel size (the hull plating bounded by the frames and the longitudinals or decks) to as large as practical. A minimum unsupported panel area might be as low as 4 ft^2 (0.37 m^2) for an icebreaking ship. The peak areas associated with the impacts predicted by the ARCTEC CANADA LTD Program presented in Figure 2 were 182 ft^2 (16.9 m^2) for the 16 kt (8.2 MPS) impact and 75 ft^2 (7.0 m^2) for the 8 kt (4.1 MPS) impact. It was decided that the measurement system should be capable of resolving the minimum area, yet be large enough, 100-200 ft^2 (9.3-18.6 m^2) to also record the maximum area. Peak impact pressures during any given impact in the range of 400 psi (3 MPa) to 1,500 psi (10 MPa) could be expected depending on the impact speed and the extent of the load.

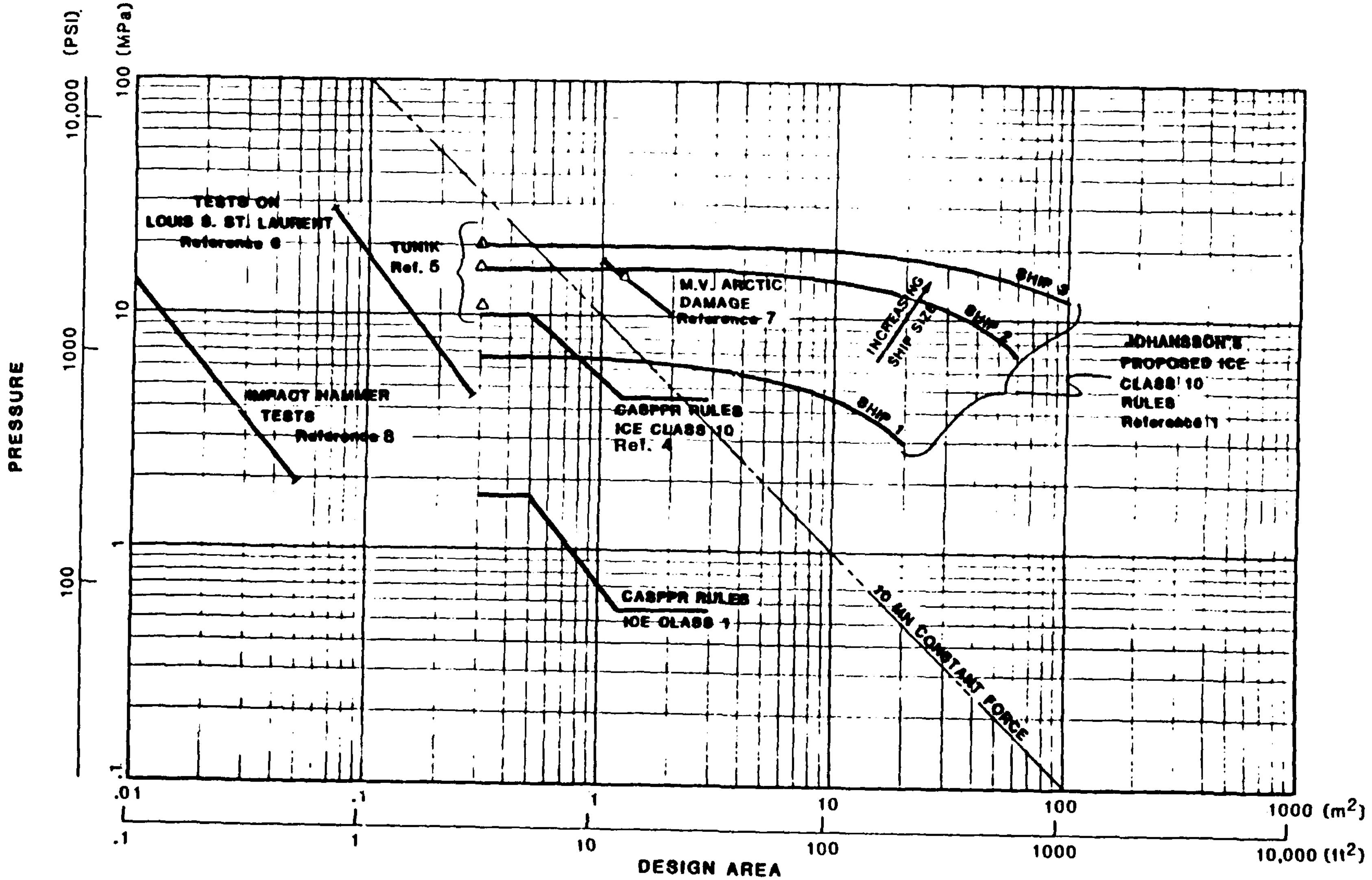


Figure 4

ICE IMPACT PRESSURE vs AREA-MEASURED DATA, PROPOSED AND CURRENT RULES

2.3 Time-History of the Loading

The time-history of loading is important for a number of reasons. The rise time of load application will determine how the data are collected and, if digital instrumentation is used, the sampling rate. The frequency of loading, when compared to the natural frequency of the structure, will determine whether dynamic analysis techniques must be used to analyze the structure or if the structure can be treated statically. This is also important in determining the use of a static or dynamic calibration technique.

Time-histories of previous tests on both the U.S. Coast Guard POLAR Class and the Canadian icebreakers were reviewed. For the original sea trials of the POLAR STAR, the flange of cant frames 40 to 44 were strain gaged and typical traces from a gage on each frame are shown in Figure 5 [9]. The duration of the load is up to 1.5 seconds and the rise time is typically 0.3 seconds. The fastest rise times are approximately 0.1 seconds. These measurements agree with the results obtained from the instrumentation of the CCGS LOUIS ST. LAURENT [6] and the CCGS PIERRE RADISSON [10].

The hull structure of the POLAR Class is very stiff. The unsupported panel natural frequency was calculated to be over 3,000 Hz. High natural frequencies can be expected for the plating acting with the frames as well. With loading typically at 1 Hz, or at the most 2.5 Hz, it seems unlikely that dynamic effects would influence the loading. The structure will respond much more rapidly than the load will be applied and, therefore, a quasi-static approach to the analysis appears valid.

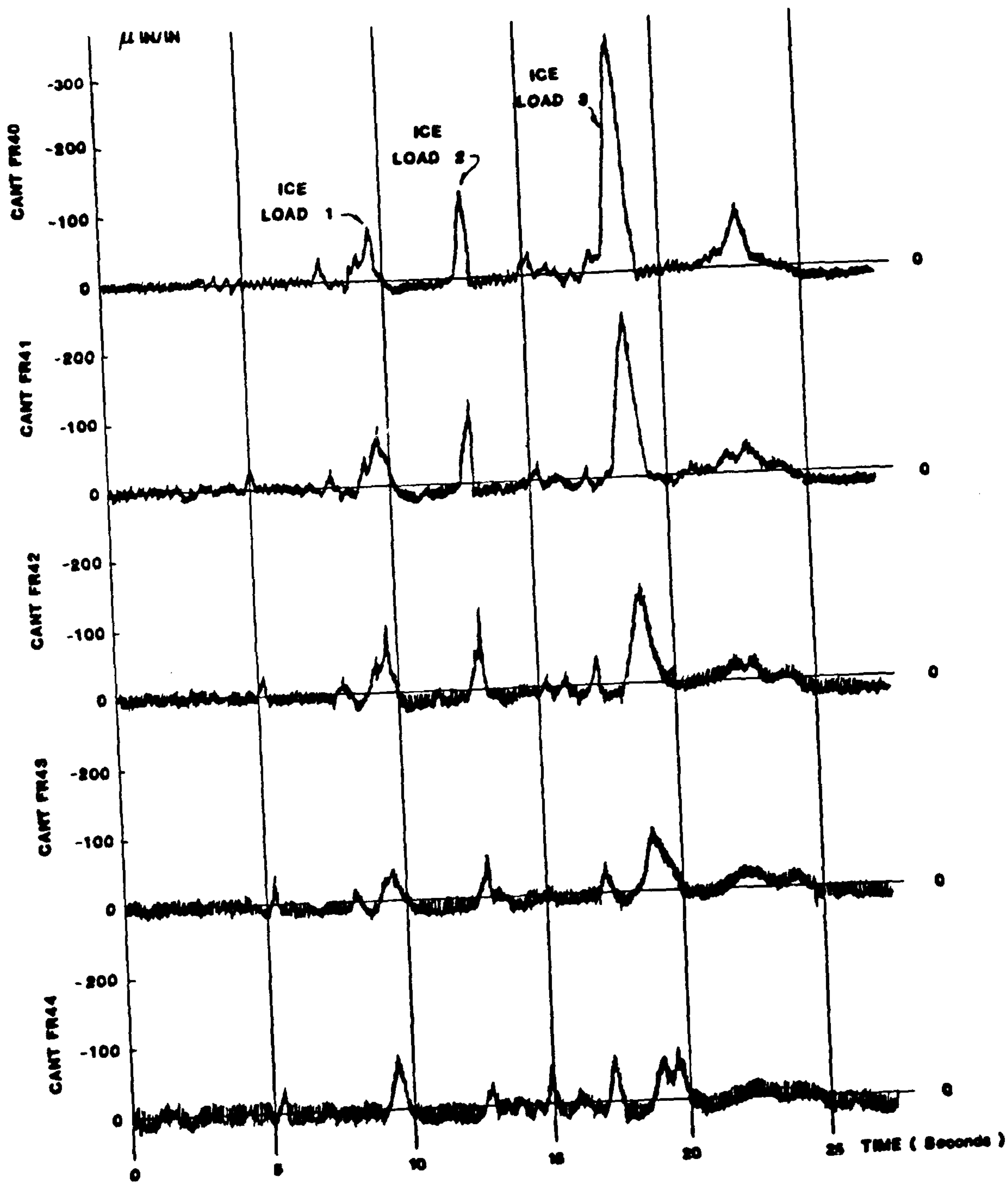


Figure 5

STRAIN GAGE DATA (CANT FRAMES 40 TO 44) SHOWING LONGITUDINAL DISTRIBUTION OF THE ICE LOADS

3.0 DESCRIPTION OF THE SELECTED TEST PANEL AND INSTRUMENTATION

3.1 Rationale for the Location and Area Selected

The work presented in Section 2.0 showed that the loads on the bow would be highest near Station 2. However, in choosing a suitable test location, other factors had to be considered. Access to the hull was of course a necessity and, due to the large number of tanks next to the shell plating on the POLAR Class, it was necessary to consider the ship's normal operating practice. Forward tanks were examined to determine whether they were normally full or empty and whether they were used for ballast or fuel. The aft end of the port side of a forward ballast tank designated 4-D-0-W was chosen for its easy access from the windlass room; its proximity to Station 2 and predicted high loading; its normally dry status; and its access to the cant frames and shell plating. The selected area is shown with an expanded view of the tank framing in Figure 6.

As one can see, the frames are actually full floors in this area of the hull. The ship is very heavily built. The frames are canted to be perpendicular to the 1-3/4 in (45 mm) shell plating on 16 in (410 mm) centers. The frames are 1/2 in (13 mm) plate with an 18 in (460 mm) deep web capped by a 1 by 4 in (26 x 102 mm) flat bar for the flange. Decks are fabricated from 1/2 in (13 mm) plate. All material in this portion of the ship is ASTM-537-M, a steel specially modified from ASTM-537 plate for the POLAR Class to achieve high notch toughness at low temperatures. The yield strength of this material is 45,600 psi.

The problem with this area of the hull, in fact any area of the hull, was how to measure the ice loads on an area of the plating. Measurement of ice loads was attempted on the ice trials of the POLAR STAR in 1976 [9]. The flanges of the cant frames were strain gaged at high strain areas to record the bending of several frames. A pendulum hammer arrangement, hung from the gunwhale, was used to calibrate the system. The calibration could only be done in the water and therefore no calibration loads could be exerted below the waterline where the significant ice loads were expected.

There is difficulty in analyzing the loads with this method even with a good hull calibration. A load at one location on the frame causes responses at many or all of the measurement locations. In measuring actual ice loads where many points along the frame may be loaded simultaneously, one must make some assumption about the load shape to assess the magnitude. The load to cause a given set of strain readings is non-unique.

Several other load measurement techniques were examined. The Varsta type gages were considered [11] but the large amount of fabrication involved in making many of these type gages and incorporating the gages in the closely framed structure seemed prohibitive. The MANHATTAN Ice Trials [12] used the technique of measuring shear in the webs of the frames. This technique works well for prismatic-shaped frames. However, it would be very difficult to implement on the POLAR Class which has deep brackets above and below the third deck which is located at the operating waterline.

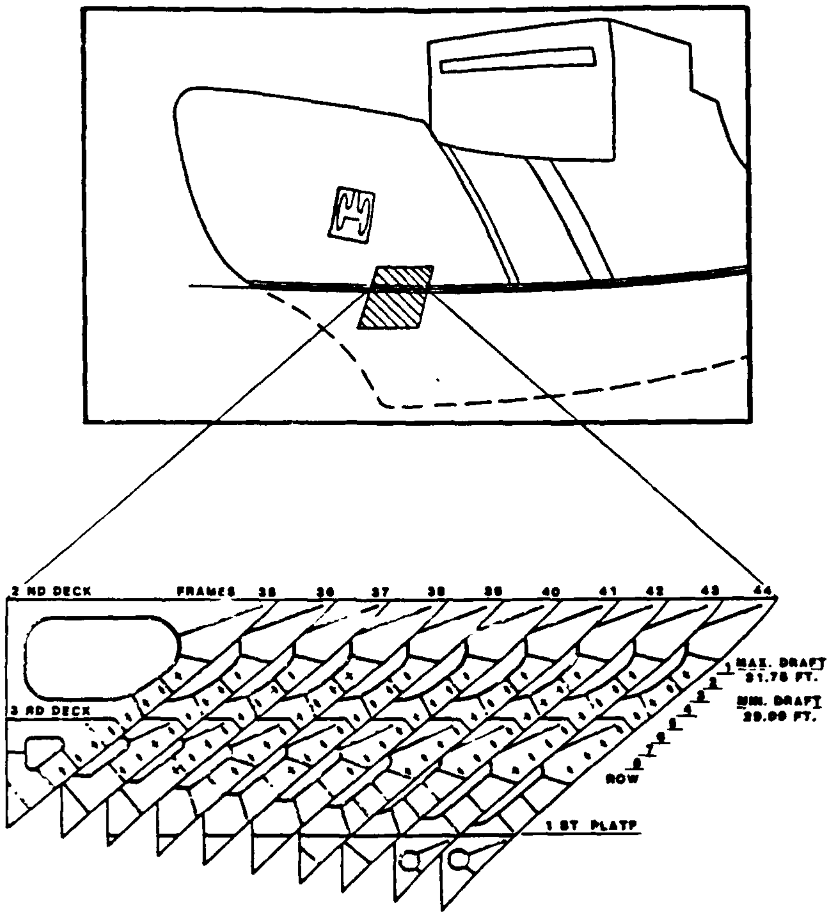


Figure 6

STRAIN GAGE LOCATIONS FOR INSTRUMENTED BOW PANEL ABOARD POLAR SEA

A new technique was selected; that of measuring compression in the webs of the frames. This technique leads to a very localized effect of the load on one area of the hull or, stated another way, a load on one portion of the hull affects only one sensor significantly and its adjacent neighbors to a lesser degree. The system provides a one-to-one correspondence between a sensor and the area where load occurs. A finite element model is used to create a matrix of strain readings for uniform pressure loadings over each gage area. Inverting the matrix gives a data reduction matrix that uniquely specifies the position and magnitude of the load for each set of strain gage readings.

The process assumes a uniform pressure over each area associated with and centered under each gage. At an instant of time during an impact, the actual pressure contours over the panel are approximated by the average pressure on sixty sub-panels computed from sixty strain readings. Figure 7 illustrates how the system would interpret an impact of varying pressure over the panel.

The size of the sub-panels was selected based on both finite element analysis and the fact that there is a minimum area of interest for design. This minimum area of interest is probably the minimum unsupported panel size. The finite element analysis showed that a gage spacing as large as 15 inches (380 mm) would work well if the strain gages were mounted 9 inches (230 mm) away from the shell plating on the webs of the frames. Two gages were mounted at each location, one on either side of the web. The gages were wired in a half-bridge arrangement such that the output of the strain gage pair gave an average reading, eliminating any web bending effects. Each of the strain gage pairs, therefore, was associated with a section of hull plating 15 inches high by 16 inches wide (380 by 410 mm). The gage pair was centered over the area; that is, each area extended from 7.5 inches (190 mm) below the gage pair to 7.5 inches above the gage pair and from the midpoint of the plating forward of the frame to the midpoint aft of the frame.

Each of these areas was termed a sub-panel. The entire panel contained 80 sub-panels, eight rows over ten frames, of which six rows can be active at one time (see Figure 6). The latter allows adjustment of the instrumented area with changes in the ship's draft. The panel extended from cant frame 35 to cant frame 44 and from approximately 5 feet (1.5 m) above to 5 feet below the margin plate at the third deck. The total panel area was 130 ft^2 ($12.1\ m^2$) of which 98 ft^2 ($9.1\ m^2$) is active at any single time.

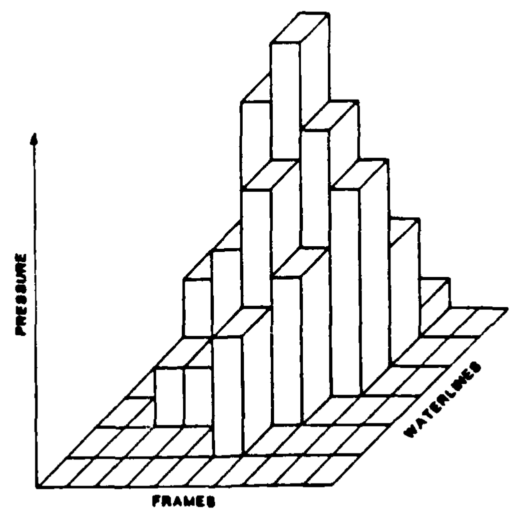


Figure 7
TYPICAL REPRESENTATION OF LOAD

3.2 Description of the Instrumentation System

Several conclusions were quickly reached about the design of the instrumentation system. A large number of channels were required to give the greatest total panel area if one channel of data would be required for each sub-panel area. If digital recording was employed, data records would have to be sampled at high frequency and, with many channels and potentially long duration events, real-time data storage would be required. Since the panel would likely encounter many impacts throughout the deployment, one could potentially be overwhelmed with data; making data reduction an exceedingly complicated task. It was apparent that the data recorded should ideally be limited to only the data of interest; that is, the data above some predetermined pressure, minimizing the data that must be reduced. It was also of interest to provide onboard data reduction of strains to pressures to give the engineers acquiring the data a feel for the level of loading and the validity of the data.

A microprocessor-driven digital system was selected; therefore the system constantly monitored and digitized all channels at 32 Hz. If the strain level on any one channel exceeded a threshold strain, all sixty channels were recorded to a high speed digital tape recorder in real-time. The recording duration was 5 seconds and, at the end of the recorded event, if the threshold strain was still exceeded on any channel, a second event was recorded. One second of data was constantly saved in memory in the data acquisition microprocessor. When the strain on one channel exceeded the threshold, the strains from one second before the current time were written to the digital recorder, thus capturing the initial rise to the threshold on all channels (see Figure 8).

The limiting factor in the size of the system was the speed with which data could be written to the digital tape recorder. Since the rate of data transfer to the tape recorder was limited, this forced a tradeoff between sampling frequency and the number of channels recorded. A sampling frequency of 32 Hz and a filter frequency of 10 Hz were selected as the practical minimum given the rise times shown in Section 2. These resulted in the capacity

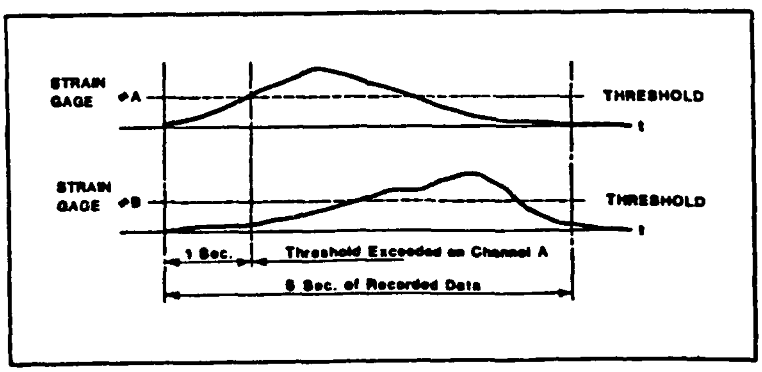


Figure 8

ILLUSTRATION OF TWO CHANNELS OF DATA AND HOW THE SYSTEM CAPTURES THE IMPACT EVENT WHEN THE THRESHOLD IS EXCEEDED ON ONE CHANNEL

for sixty channels of data which, with the size of each sub-panel, resulted in a maximum area of almost 100 ft^2 (9 m^2). At the time the decision was made this was the largest area over which published ice pressures had been measured on ships, however, it was still a small portion of the area that was loaded on such large structures as ships or offshore platforms where the data would be useful in developing design criteria.

An overview of the system is presented in Figure 9. Eight rows of weldable, single-axis strain gage pairs were installed on each of ten frames (160 gages in total). All the gages were waterproofed in the event that the ballast tank had to be used. Each gage was wired to one of five large multi-conductor cables through a waterproof junction box and these large cables exited the tank top through stuffing tubes. The cables connect the junction boxes in the tank to a set of terminal strips, one for each row of gage pairs, on the back of the instrument rack located in the windlass room two decks above the ballast tank. Instrumentation amplifiers were connected to six of the terminal strips and therefore six rows of gages, providing the sixty channels of data input. The rows of active gages could be changed as the ship's draft changes by shifting the instrumentation amplifiers to different terminal strips at this point.

Filters, Analog to Digital convertors, and the data acquisition computer were all housed in the instrument rack in the windlass room. The data acquisition computer performed all the collecting of data, the saving of one second of data in memory, and the tests for threshold exceedance. As one can see from the system layout in Figure 9, the digital tape recorder was located in the Scientists' Office which was approximately 300 feet (90 m) away in the after part of the ship. A high speed interface bus with bus extenders was used to transfer the data serially from the data acquisition computer to the tape deck.

A second computer, the data reduction microprocessor, listened on the bus as well. This computer was able to save five events in memory ranked by the highest peak strain. When an event was received from the data acquistion computer, the data reduction software immediately started converting each time step's set of strains to pressures. Each time a new event was sent to the tape recorder, the data reduction software would be interrupted long enough to receive the new event into the next space in memory. When five events filled memory, the new event was received in the space of the lowest peak strain event, thus causing the highest events to be reduced.

It took about 11 minutes to perform the 160 sixty-by-sixty matrix multiplications necessary to reduce a single 5 second event. Thus, only a portion of the data could be reduced while the system was receiving data. The reduced pressures would replace the raw data in memory until all five events had been reduced. The system would remain with the memory filled with reduced data and unable to accept new raw data until the operator allowed the reduced data to be stored and printed. Storing the reduced data prevented the system from receiving new raw data since both operations required the digital tape recorder. Having the program operator choose a convenient time to store data when all 5 events were reduced prevented the acquisition of raw data from being interrupted. The "convenient time" for storing reduced data was when the ship was backing or transiting a lead such that new impacts were not expected.

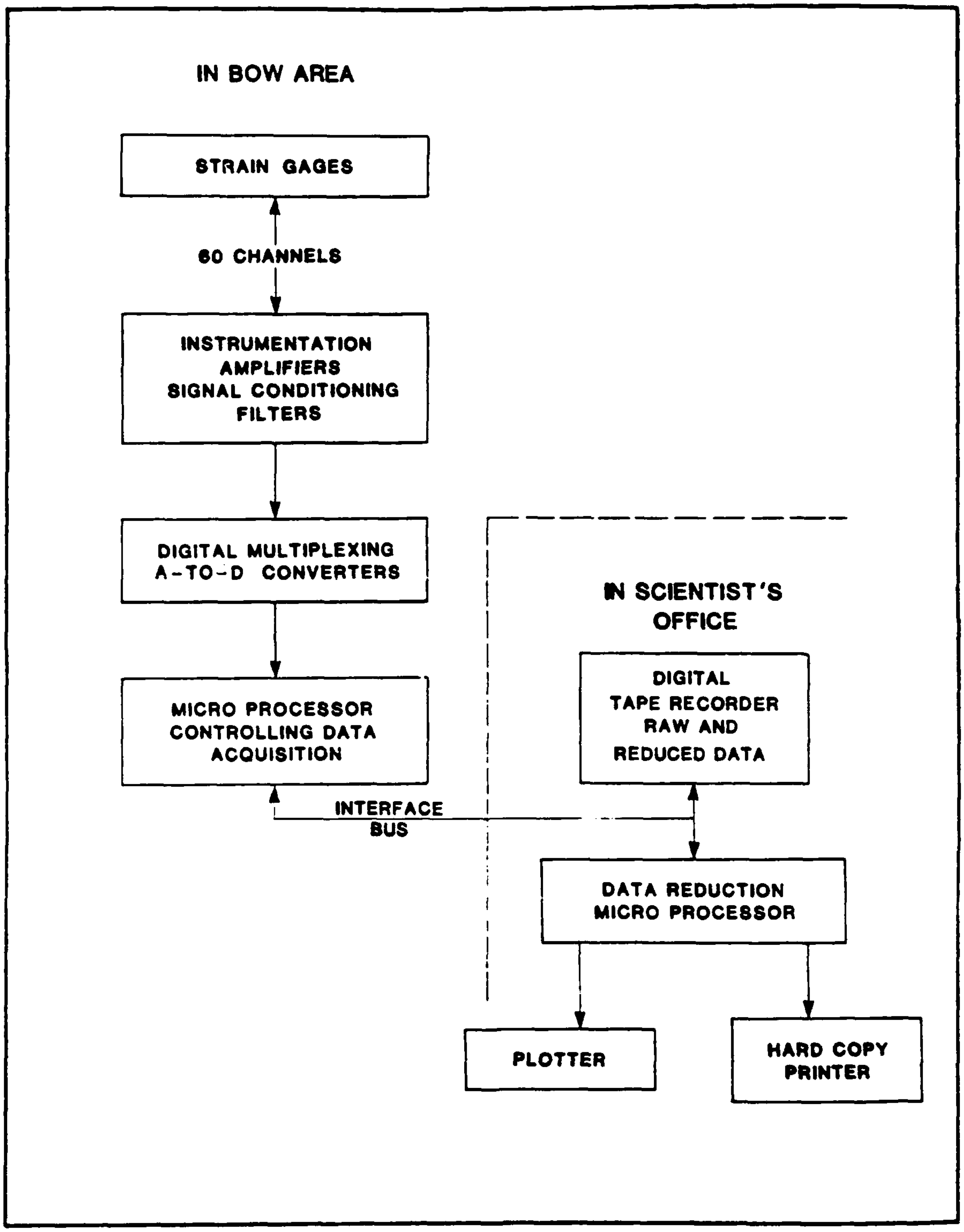


Figure 9

SCHEMATIC OF DATA COLLECTION SYSTEM

4.0 DESCRIPTION OF THE FINITE ELEMENT MODELS

4.1 Overview of the Modeling Approach and Presentation of the Single Frame Model

A portion of the ship structure at the location of the instrumented panel was modeled using the finite element technique. The objectives were twofold. It was necessary to determine the area of shell plating where impact pressures would influence the compression-type gages as a function of the distance of the gage away from the plate. This would determine the location of the gages and the spacing along the frames that would be possible. Secondly, a matrix of the average pressure over each sub-panel as a function of the strain reading at each gage had to be built for data reduction. This would be done by loading the sub-panels with a uniform pressure in a finite element model of the structure and determining the strain at each gage location. The resulting matrix was inverted to obtain the data reduction matrix.

The need to analyze the details of the strain distribution in the area of each gage combined with the large size of the structure posed conflicting requirements on the development of a structural model. The approach used was to model one frame at the center of the panel in detail, the single frame model referred to in the following sections. A second model, called the multi-frame model, was developed to assess the transfer of loads through the hull plating to the adjacent frames. The multi-frame model was considerably simpler and smaller than the single frame model. The assumption throughout the analysis was that the frames were similar and that the strains at the gage locations on one frame would be similar to the strains at the same gage on other frames. This decision was based on the high cost of modeling each frame to the detail of the single frame model and the fact that the actual structure would be loaded to verify the frame-to-frame effects.

The single frame model is shown in Figure 10. The model was built and analyzed using the "STARDYNE-3" program [13]. Almost the entire port side of cant frame 41 was modeled, including the hull plating, to the next frame fore and aft. The model consisted of 798 nodes, joined by 661 quad-plate elements, 73 triangular-plate elements, and 134 beam (or bar) elements. With 192 nodes with restraints, the model had a total of 3552 undeleted degrees-of-freedom and a bandwidth of 249 degrees-of-freedom after reordering.

The boundary conditions consisted of complete fixity along the centerline longitudinal bulkhead and at the extreme upper end of the model (the inboard nodes of the frame at the uppermost deck), out of plane restraint along the decks and a pinned connection along the edges of the shell plating at the points where the neighboring cant frames would join the shell. It was recognized that pinned connections at the neighboring cant frames do not exactly represent the true structure. In fact, a moment can be transferred across the neighboring cant frames by the shell plating. This difference is quantifiable for specific loading conditions and was accounted for with a correction factor. A larger model would have made the correction unnecessary but it was not felt to be worth the increased cost. For a uniform pressure centered over a web the correction for boundary conditions results in a 7% reduction in the reaction (and strain) at the loaded webs. For a point load applied at mid span, as in the case of the full scale hull loading, the change in boundary conditions results in a 10% decrease in the reaction (and strain) in the cant frame. These corrections have been taken into account in both the evaluation of the full scale hull loading and the determination of the matrix for converting measured strains to ice loads. (See Appendix A for the development of the corrections and how they were applied).

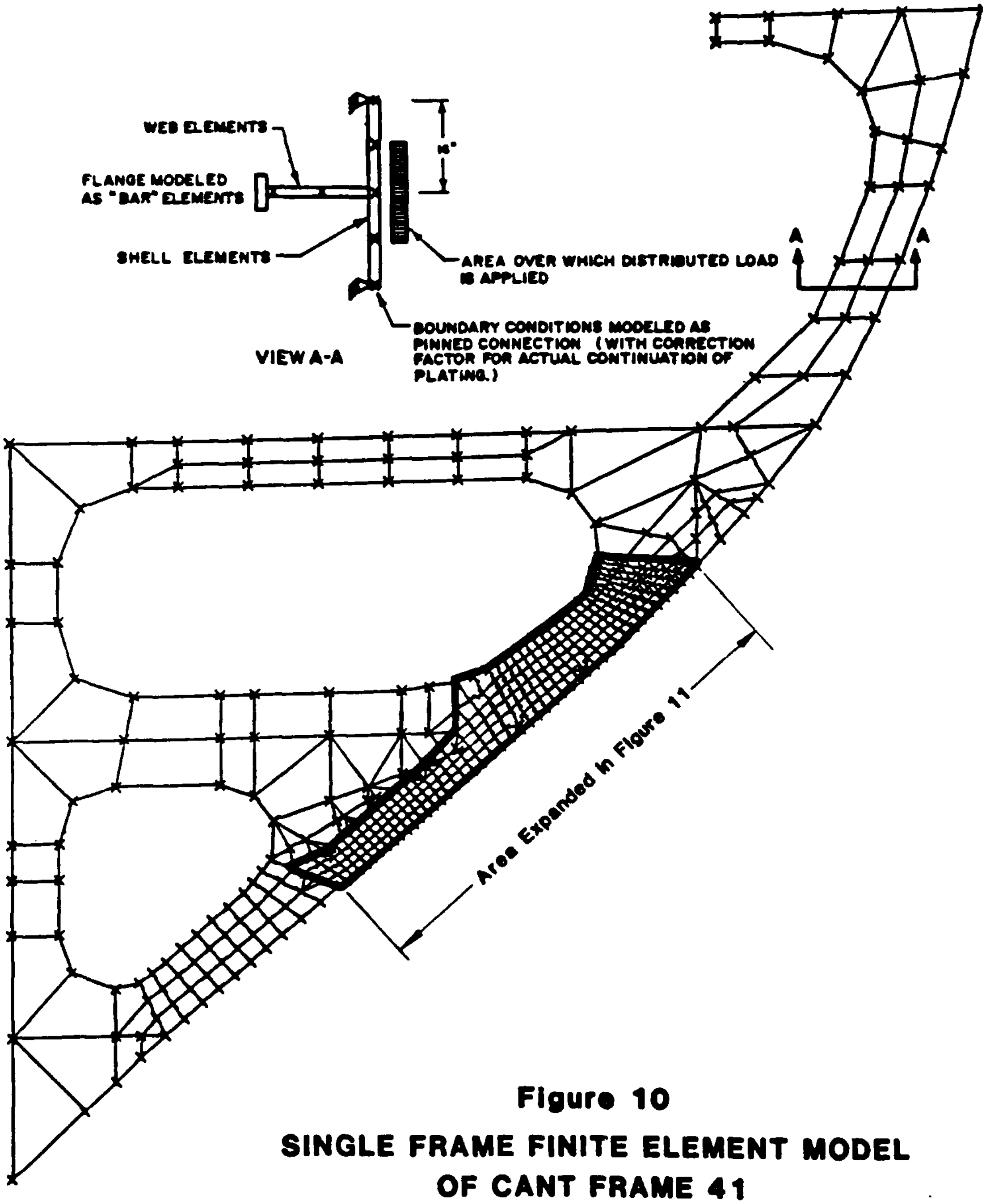


Figure 10

SINGLE FRAME FINITE ELEMENT MODEL OF CANT FRAME 41

4.2 The Influence of Strain Along the Web and the Selection of Gage Spacing

The detailed finite element model of frame 41 (single frame model) was run with point loads at each strain gage location to investigate the influence on gages adjacent to the load. With a spacing along the web of approximately the frame spacing and the gages placed 9 inches (230 mm) away from the shell plating, the crossover of influence lines was approximately midway between the gages at 50 percent of the peak strain (see Figure 11). Figure 11 is an expanded view of the elements surrounding the gages in the single frame model shown in Figure 10. This figure shows that the load was very localized; a point load at one gage caused a strain close to zero at the adjacent gages up and down the frame. Therefore, only adjacent gages up and down the frame need be considered in the reduction equation for the pressure on a given panel.

One idiosyncrasy of the structure was noted in the finite element runs. The influence of a load went to zero on the other side of a tripping bracket if the bracket was oriented roughly perpendicular to the hull. (The tripping brackets are shown in Figure 6.) This was to be expected since the bracket carries most of the compressive strain in the web. The effect of the tripping brackets was highly dependent on how close to the hull the bracket ended. These distances were measured on the ship to ensure proper representation in the model. Gages were placed to keep the brackets at the boundary between measurement areas, minimizing their influence on the strain measurement. The result was a spacing along the web averaging 14.7 inches (373 mm). The finite element model accounted for the influence of the tripping brackets in areas where the brackets adjoin a measurement area.

Table 1 presents the results in a slightly different form. The strains at all eight locations are given for eight separate point loads applied at each gage location. Again the results show no significant remote effects.

TABLE 1 RESULTS OF THE SINGLE FRAME FINITE ELEMENT MODEL STRAIN LEVELS AT ALL GAGE LOCATIONS DUE TO AN APPLIED POINT LOAD AT EACH GAGE LOCATION

		LOAD APPLIED AT LOCATION (LOAD = 50 L.T. = .51 MN)							
		1	2	3	4	5	6	7	8
STRAIN AT GAGE 10^{-6} in/in or 10^{-6} mm/mm	1	-214	31	8	4	0	- 1	- 1	1
	2	35	-234	23	14	8	6	5	5
	3	- 1	- 6	-220	20	24	14	9	6
	4	- 11	- 10	73	-262	31	29	19	12
	5	- 4	- 18	36	- 70	-365	2	19	17
	6	7	3	- 2	- 5	- 37	-375	- 15	17
	7	5	3	- 2	- 5	- 5	- 38	-385	- 23
	8	5	6	6	7	4	- 8	- 8	-365

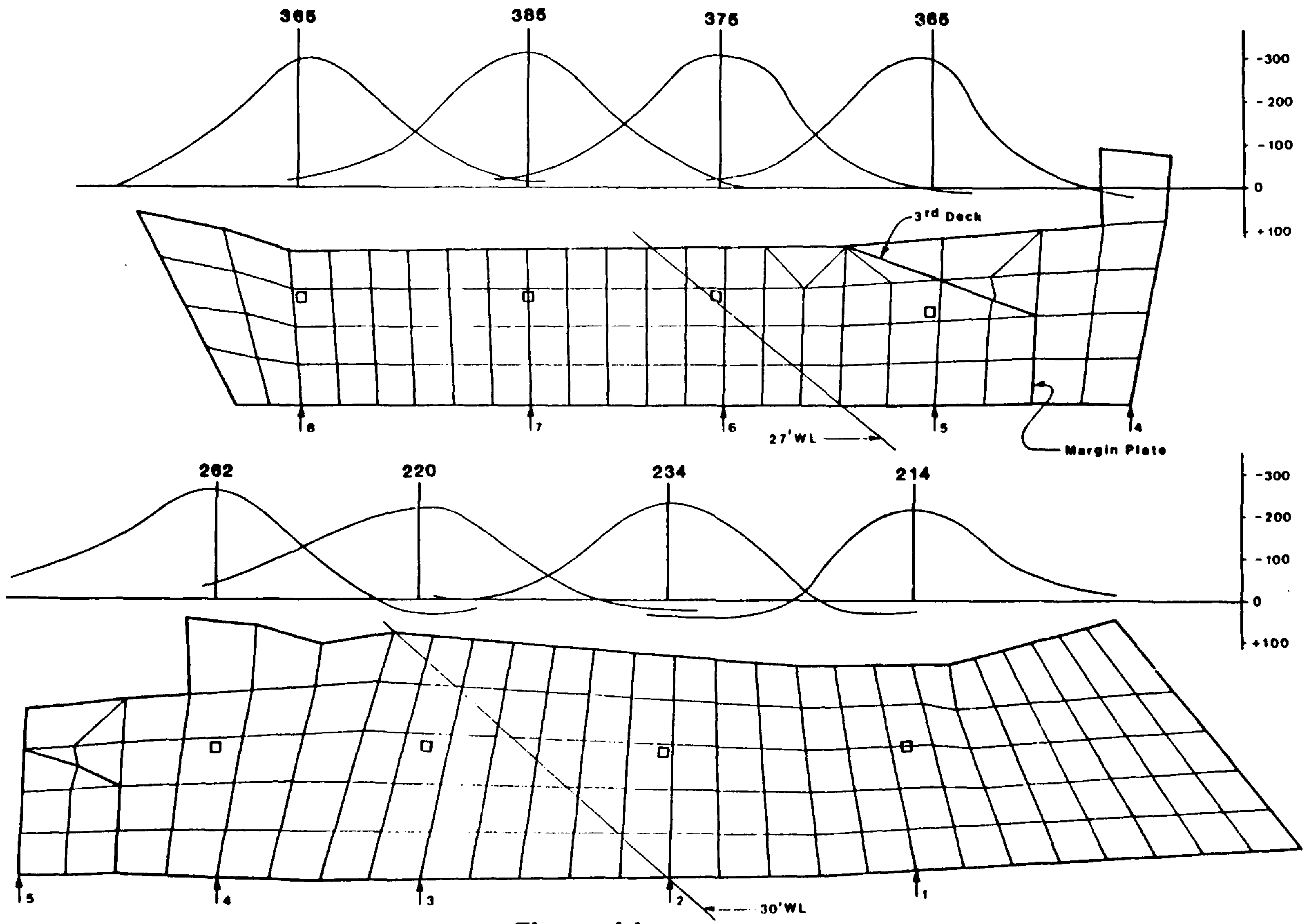


Figure 11

SECTIONS OF SINGLE FRAME MODEL SHOWING INFLUENCE OF STRAIN FOR LOADS AT GAGE LOCATIONS

4.3 Across the Frame Influence on Strain

A second simple finite element model was built to show the effects of strain effects across the frame. If one frame was individually loaded, this model was used to predict the strain at the gage locations in the frames that were not loaded. The model is shown in Figure 12. The shell plating was modeled as a series of plate elements. The stiffness of the frame structure was modeled as a series of spring elements attached at the gage locations. The stiffnesses were determined by loading the single frame model at each gage location and computing the resulting deflection. A single frame had a different stiffness at each gage location; however, each frame was assumed the same as described previously.

Figure 12 shows the deflected shape for a uniform pressure loading over one sub-panel centered on a gage in the middle of the panel. If the strain at the gage under the load was considered to have a strain of 100 percent, the gage on the same row one frame removed from the load had a strain of ten percent and the gage two frames removed had a strain of 0.1 percent.

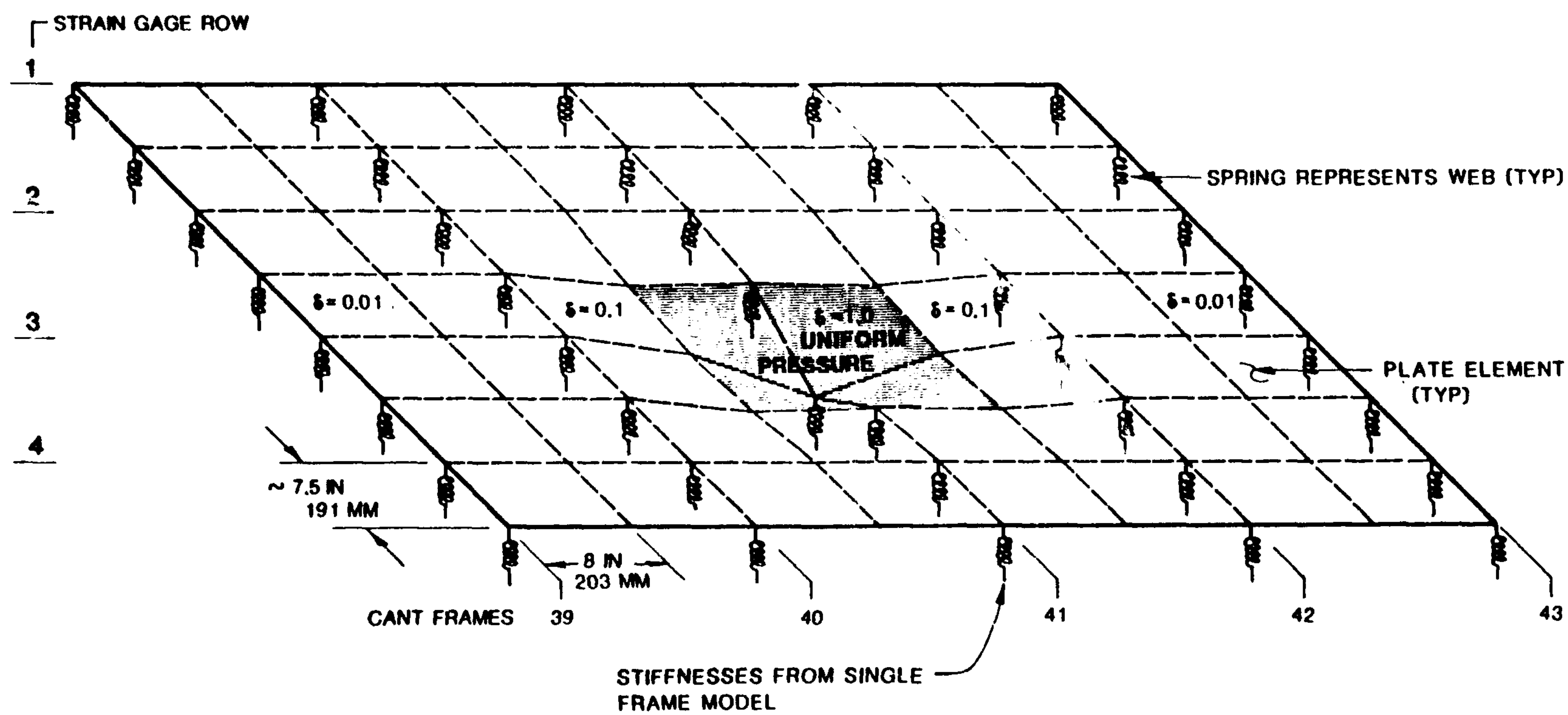


Figure 12

MULTI-FRAME MODEL SHOWING ACROSS THE FRAME EFFECTS

4.4 Construction of the Data Reduction Matrix

The data reduction matrix is the heart of the system, the algorithm that converts the measured strains to ice impact pressure. The algorithm was based on the premise that the ice load on the instrumented panel can be sufficiently well approximated as a group of distinct uniform pressures each acting over an area ot approximately 15 x 16 inches (380 x 400 mm). Further refinement of the ice pressure over a smaller area was not needed since the smallest area of interest was one sub-panel. An average ice pressure over this area was sufficient for the design of the plating. The averaging of more and more of these individual sub-panel pressures gave the average pressure for larger areas that are of interest in design of the internal scantlings.

The actual ice load algorithm transformed 60 measured strains into 60 distinct uniform pressures using the inverse of an influence matrix [K]. In the matrix formulation:

$$\underset{60 \times 1}{\{\text{Strains}\}} = \underset{60 \times 60}{[K]} \; \underset{60 \times 1}{\{\text{Pressures}\}} \qquad (1)$$

and inverting:

$$\underset{60 \times 1}{\{\text{Pressures}\}} = \underset{60 \times 60}{[K]^{-1}} \; \underset{60 \times 1}{\{\text{Strains}\}} \qquad (2)$$

where each column in the influence matrix [K] represents the 60 strains that resulted from the application of a unit pressure on one sub-panel in the model. The large matrix [K] can be constructed by the superposition of smaller matrices [k] for each frame which are 6 x 6 and relate the strain at 6 gage locations to a uniform pressure over the area for each gage on a frame (see Figure 13). The across web influences are handled by adding off-diagonal terms of appropriate magnitude, which are 10% of the diagonal terms. The 10% factor results from work with a small across web finite element model which showed that for a uniform load centered over one frame, the reaction at the neighboring frames is 10% of the reaction under the load.

$$[K] = \begin{bmatrix} [k] & [0.1k] & [0.01k] & & [10^{-9}k] \\ [0.1k] & [k] & [0.1k] & & \\ [0.01k] & [0.1k] & [k] & & \\ & & & & \\ [10^{-9}k] & & & & [k] \end{bmatrix} \qquad (3)$$

Separate matrices were made for Rows 1 to 6, Rows 2 to 7, and Rows 3 to 8. The form of the matrix is shown above. The actual matrices used are shown in Appendix B.

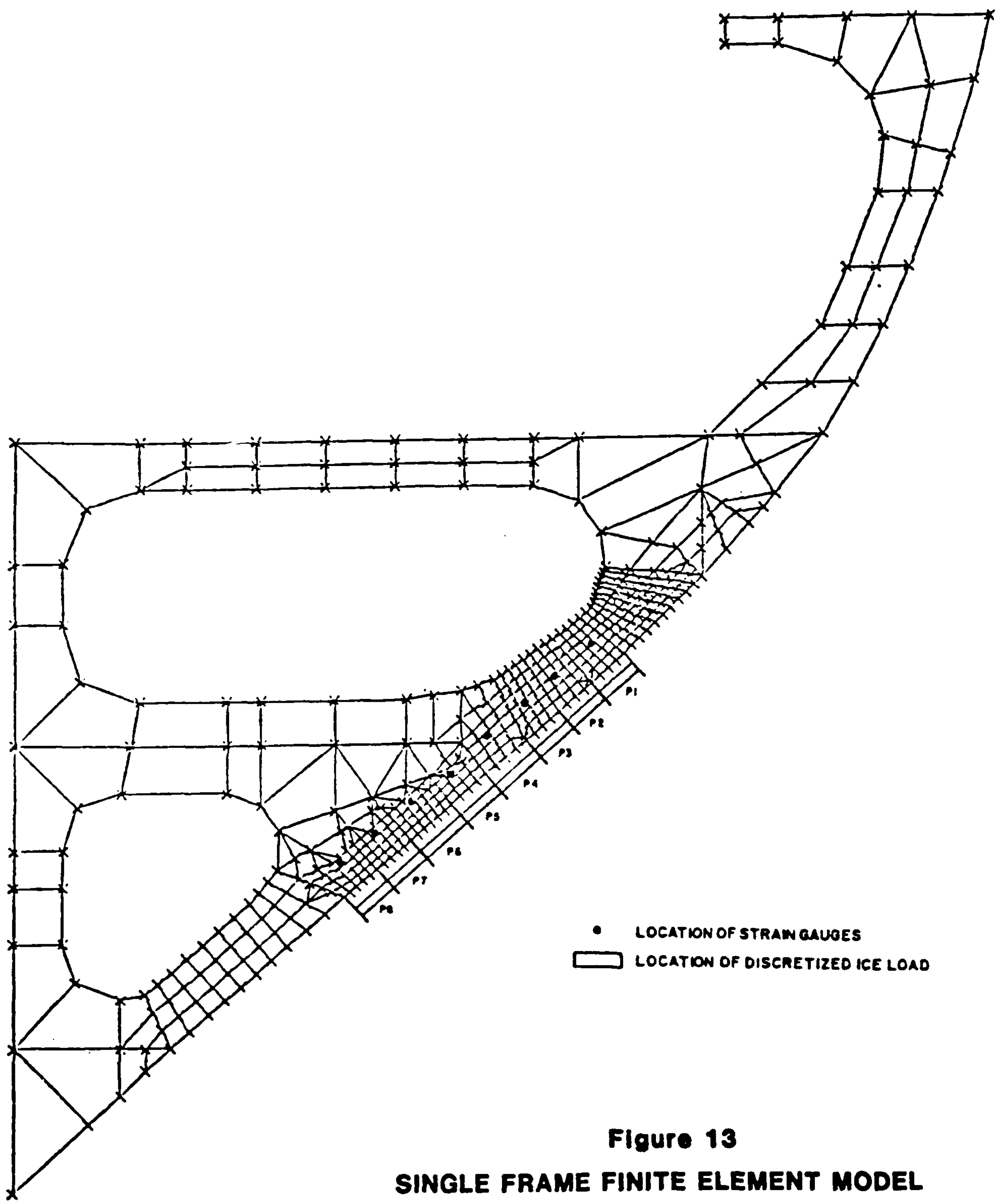


Figure 13

SINGLE FRAME FINITE ELEMENT MODEL

4.5 Sensitivity Analysis of the Matrix

Two questions were raised during the development of the project and were treated in further detail in a sensivity analysis presented in this section. The first question regarding sensitivity was to assess the effect of varying the 0.1 or ten percent factor for the off-diagonal terms. Two events from the Summer deployment were chosen and the raw strain data was reduced with matrices using a factor of 5, 10, and 20 percent for calculating the off-diagonal terms. The two events were chosen as representing a very localized impact and a very broad impact. The reduced data are presented in Appendix C and summarized in Table 2. The table shows that if the off-diagonal terms are doubled or halved, the worst case is to reduce the pressure and total load by 7 percent.

The second question was the error that resulted due to the assumed boundary conditions in the single frame finite element model. The model presented in Figure 13 and used for the development of the data reduction matrix assumed single degree-of-freedom in-plane restraints at the nodes associated with the decks. This assumption does not account for the stiffness of the decks and the fact that most of the load on the bow plating is eventually distributed into the rest of the hull through shear in the decks. To account for this effect, loads were applied to the model at the decks to simulate a deck shear load reaction (see Figure 14). It was assumed that for 45 LT (0.45 MN) ice load acting at the 2^{nd} deck, the decks would react in such a way as to apply a distributed load along the web as follows:

along 3^{rd} deck = 3.3 LT (0.33 MN)
along 2^{nd} deck = 15.6 LT (.156 MN)
along 1^{st} Platf. = 3.3 LT (0.33 MN)

which represents 50% of the total reaction to the ice load. Table 3 presents the eight strains that were determined for a 45 LT (0.45 MN) ice load at the second deck and the eight strains that resulted from the above applied reaction. It can be seen that the resulting error is less than 5%.

TABLE 2 PERCENT CHANGE IN PEAK FORCE AND HIGHEST AVERAGE PRESSURE FOR A CHANGE IN THE OFF-DIAGONAL TERMS IN THE DATA REDUCTION MATRIX

(Percent change in the answer by doubling or halving the factor used in computing the off-diagonal terms in the matrix)

EVENT DATE	OFF-DIAGONAL TERM FACTOR (%)	PEAK TOTAL FORCE	HIGHEST AVERAGE PRESSURE – NUMBER OF SUB-PANELS: 1	2	3	4	5	6	7	8	9	10
	5	5.04	0.65	1.05	4.15	4.44	4.15	4.19	4.14	4.14	4.18	4.21
10/13	10	0	0	0	0	0	0	0	0	0	0	0
	20	-5.75	-0.073	-0.76	-7.30	-5.18	-7.03	-7.12	-6.98	-6.98	-7.05	-7.10
	5	7.28	1.50	4.46								
10/8	10	0	0	0								
	20	-7.30	-1.73	-7.55								

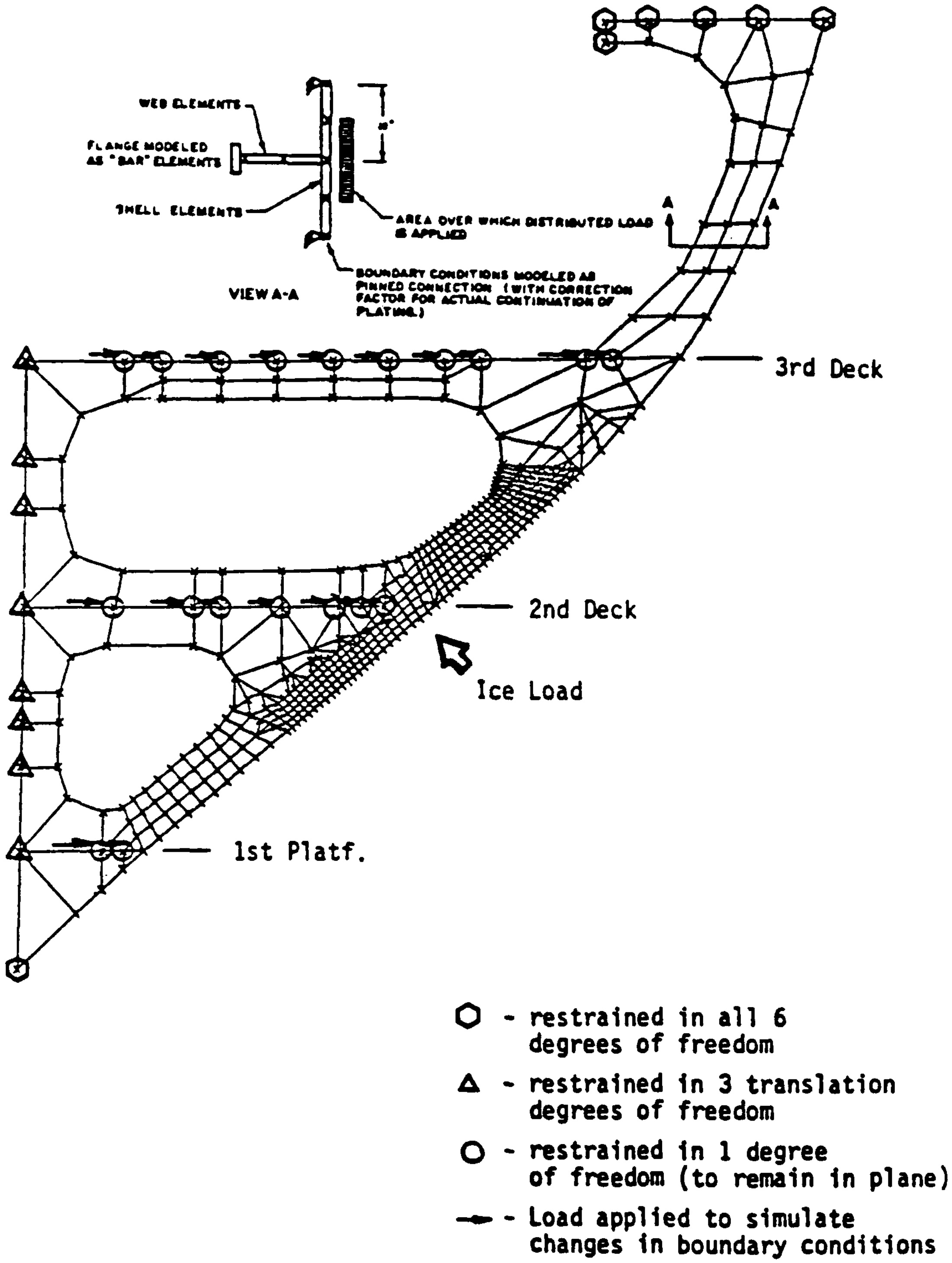


Figure 14

CANT FRAME FINITE ELEMENT MODEL SHOWING LOADS TO SIMULATE DECK SHEAR REACTION

TABLE 3 STRAINS DUE TO ICE LOAD AND SIMULATED REACTIONS

ROW NUMBER FOR GAGE	STRAINS DUE TO ICE LOAD	STRAINS DUE TO REACTION	% OF -156
1	9	- .3	.2
2	15	-2.9	1.8
3	5	-4.2	2.7
4	-156	-6.9	4.4
5	- 42	1.5	1.0
6	- 5	1.6	1.0
7	- 4	1.2	.8
8	- 1	1.7	1.1

5.0 FULL SCALE LOADING OF THE INSTRUMENTED PANEL

5.1 Selection of a Loading Method

Prior to acquiring data in an ice cover, the instrumented panel was loaded with a known load and strains were recorded on all the gages. This test correlated the actual structure to the finite element model, determined the influence effects of loads remote from gages, and ensured that all channels were operational.

Several alternatives for loading the hull were possible. An in-the-water calibration using a hydraulic jack was used on the tests of two Canadian Coast Guard Ships [6, 10]. The jack was fitted on the end of a long pipe and the pipe was placed between the ship and a breakwater or pier. This method gave a good calibration; however, the rigging for the pipe and jack assembly was difficult to handle and was further complicated by the ship springing on her mooring away from the load. This method also required a foundation that would carry the load; such as at the water's edge or below water where the ship could be tied. Such a place is difficult to find.

In the previous test on the POLAR Class [9], a dynamic calibration was performed in the water with a large hammer hung from the gunwhale. The hammer consisted of a weight on a long pendulum with springs between the pad that impacted the hull and the weight. The conclusions drawn from the hammer test were that it was extremely difficult to hit the hull square in a specific place because of the complex angles involved. Also, in this test, the ship could not be heeled or trimmed sufficiently to load the lower portion of the test area.

After considering these and all alternatives, internal loading seemed the most feasible. It was doubtful that an external in-the-water loading of the hull could reach the entire area to be calibrated. At the time of developing the test plan, it was not clear whether the ship would be drydocked, but if it was, there would be a very short time frame in which to install all equipment. A foundation would have to be built in the drydock if the loading was done externally. The internal method allowed the flexibility to load the hull at anytime. The mechanics of this method are greatly simplified and are much less labor intensive after the initial shipyard work is performed. Figure 15 shows schematically how each frame bay was loaded.

It should be noted that the full scale loading of the test panel differed from previous and similar tests in several ways. Typically, the hull was loaded to provide a "calibration" for the strain gages; that is to determine the strain at each gage for a known load on the shell plating. For the cases where hulls have been loaded, the frames or plating were generally instrumented in bending. Loading one portion of the hull caused significant strain levels on many gages. The full scale tests were used to develop complicated algorithms to relate the strain to pressure for an assumed load shape for ice impacts. In this study, the scheme of strain measurement causes the response to be localized around the load. The strains were related to uniform pressures on the sub-panel areas centered over the gages by using a finite element model. The objective, therefore, of this full scale test was to verify that the finite element model gave a good approximation to the response of the real structure.

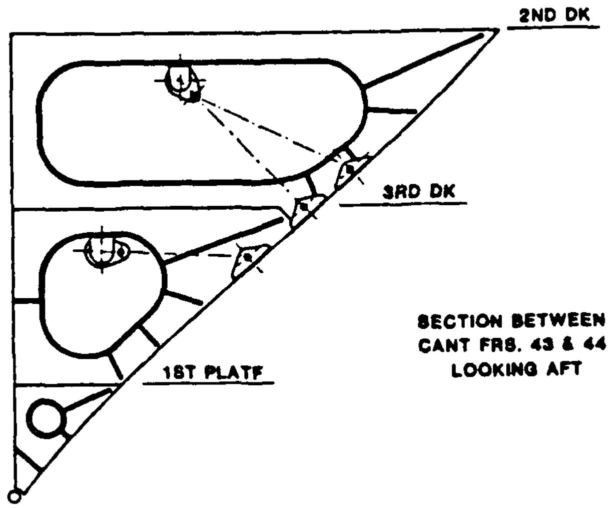


Figure 15
PADEYE LOCATION FOR STRUCTURAL CALIBRATION

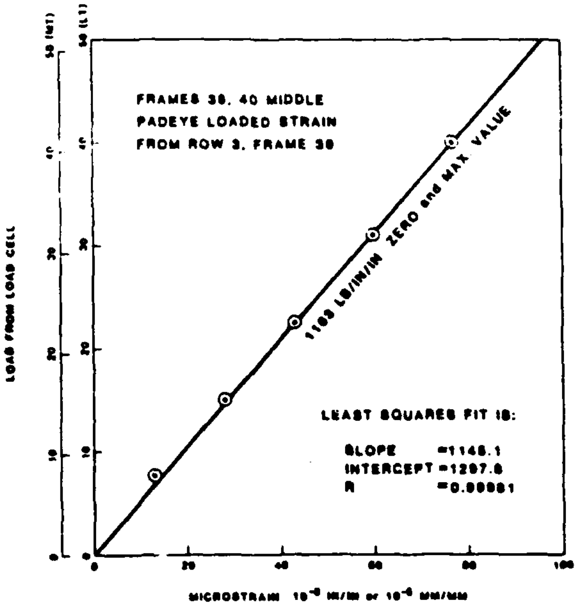


Figure 16
LINEARITY OF THE LOAD STRAIN RELATIONSHIP AT ONE TEST LOCATION

5.2 Description of the Test

Figure 15 on the previous page showed the arrangement used in the full scale tests. The shell plating mid span between the frames, at various heights vertically in the test area, was loaded by a hydraulic tensioning ram The process was repeated for every other frame bay to ensure the activation of all gages by the several separate test loads. Padeyes were welded to the shell plating at points vertically between every other frame as shown in Figure 15. Padeyes and sufficient backing structure to span the frames were added to the deck beams inboard to carry the load from the other end of the hydraulic tensioning ram. Four frame bays longitudinally and three positions vertically in each bay, or a total of twelve load points, were used. The padeyes were installed between frames 44 and 43; 42 and 41; 40 and 39; and 38 and 37. Padeyes could not be installed between frames 36 and 35 due to a shell plating seam at midspan between the frames.

Previous calibrations on this class of ship and others have used a load of approximately 22 LT (.22 MN). For this test, it was possible to develop loads of twice what was previously used, or 44 LT (.44 MN). This represents approximately two percent of the peak load or 2,000 LT (20 MN) predicted by the computer simulation described in Section 2.1 for an 8 kt (4 m/s) impact, or 8 percent of the highest load measured in the ice tests to date. The test load is equivalent to a uniform pressure of 419 psi (2.89 MPa) over one subpanel.

The tensioning device was remotely operated such that no personnel were required in the tank during tensioning for safety reasons. A video camera was installed in the tank so the operator could observe the tensioning process. Great care was taken to test and observe the padeye welds at lower loads prior to test loads. The typical test at each location involved applying a load of about 9 LT (0.09 MN) and recording strains on all sixty strain gage channels. The load was then removed and all welds and the structure were visually inspected by entering the tank. The process was repeated in approximately 9 LT (0.09 MN) increments until the maximum load was recorded. The procedure allowed a check on the linearity of the load-strain relationship in the actual structure. Figure 16 shows the relationship to be very linear for a typical set of measurements.

The load was measured simultaneously with the strain readings using a shear pin type load cell installed in the padeye at the deck beam end. The load cell had an 80 LT (.8 MN) capacity and a factory calibration factor was used to convert the strain reading of the load cell to force. Figure 17 shows the sketch of the tensioning system.

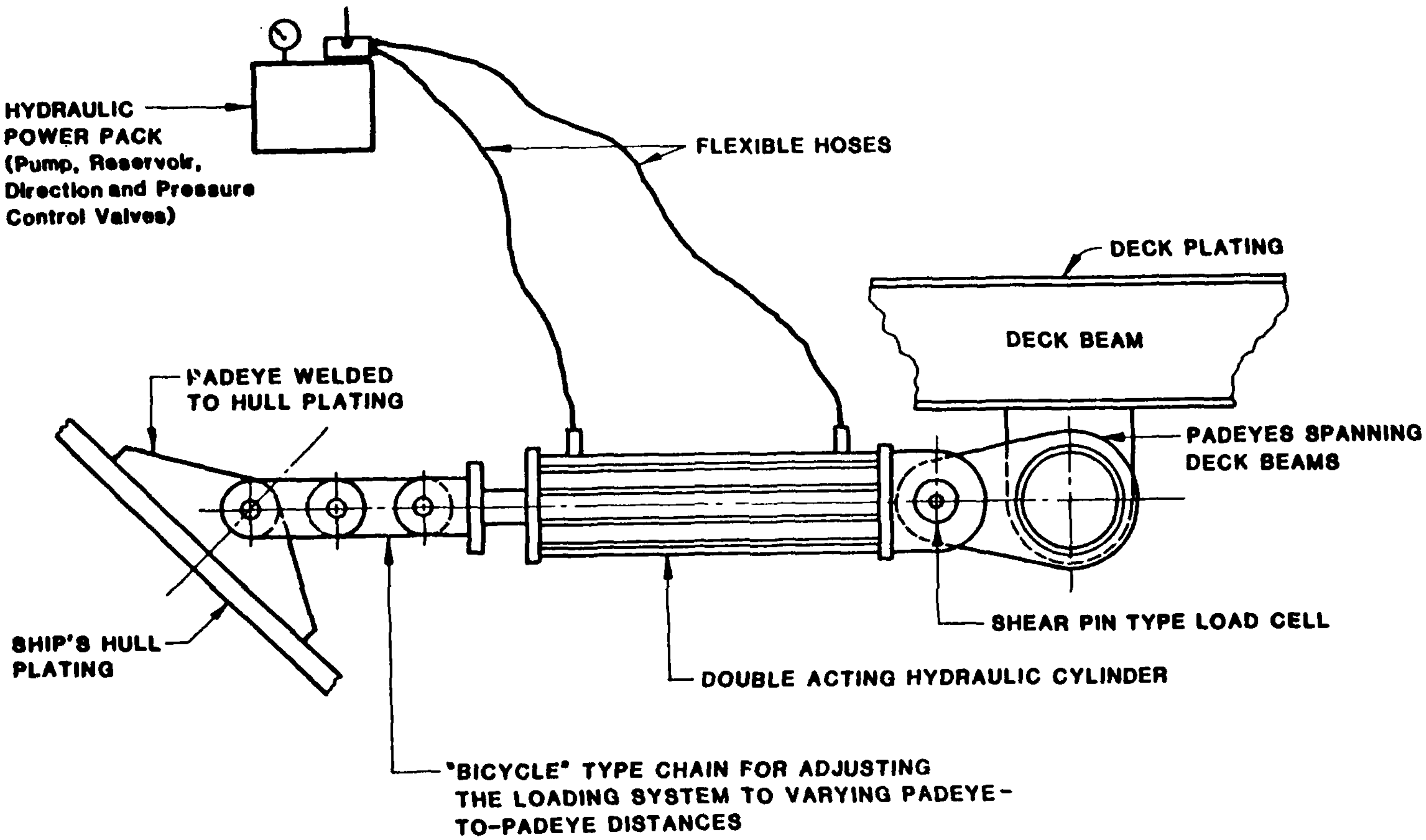


Figure 17

HYDRAULIC TENSIONING DEVICE FOR FULL-SCALE HULL LOADING

5.3 Modification of the Finite Element Model to Model the Internal Test Loads

The full scale load tests applied a line load to the plating midspan between the frames by introducing the load to the hull plating through the padeyes. To properly account for the distribution of these loads into the hull plating in the finite element model, the details of the padeyes were modeled as shown in Figure 18. The elements for the padeyes were added to the single frame model shown in Figure 10 and, applying a 44.64 LT (.4448 MN) load at the padeye centers, the strains at each gage location were calculated. The strains were corrected for the boundary conditions of the adjoining frame not included in the model (Appendix A describes this correction) and the resulting strains compared to the strains recorded during the full scale tests. The full scale recorded strains were linearly scaled to obtain the strains corresponding to the modeled condition by the ratio of the modeled load to the measured load. The results are presented in the following section.

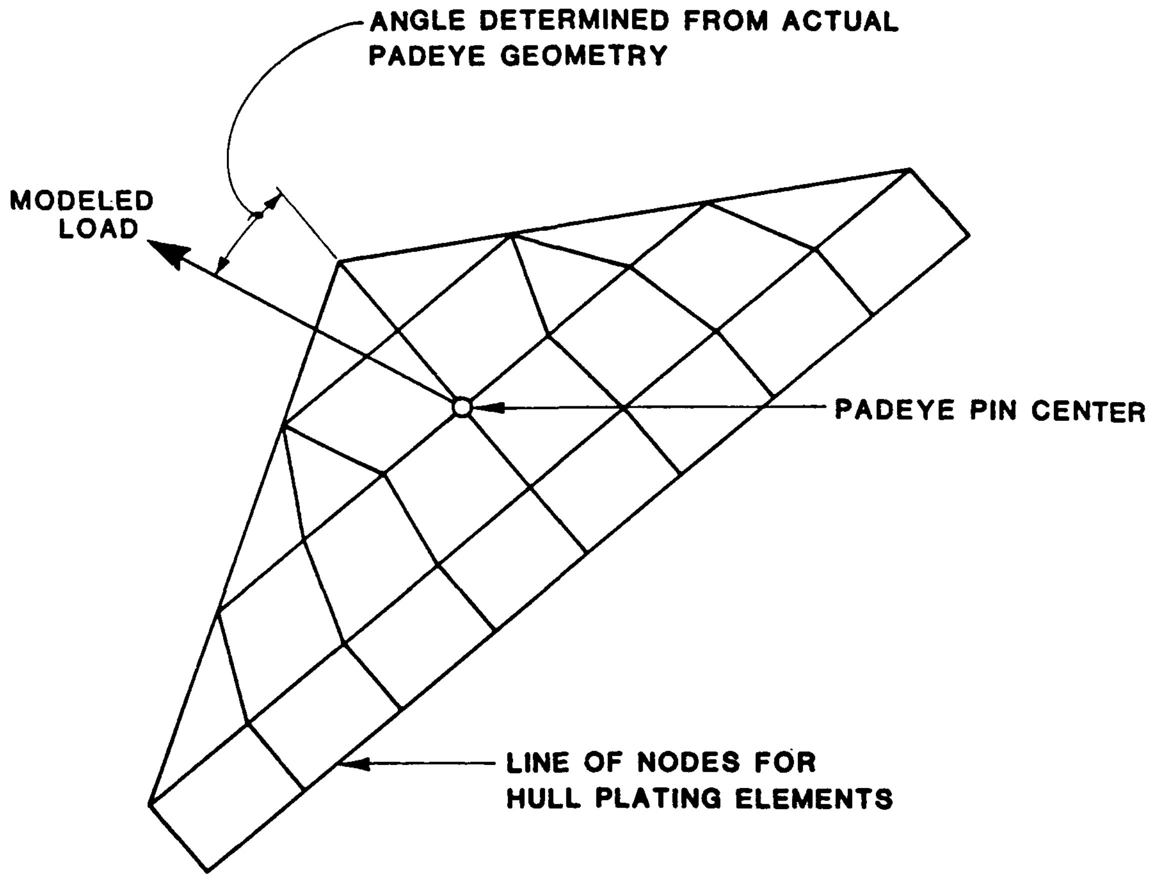


Figure 18

TYPICAL ARRANGEMENT OF PLATE ELEMENTS FOR THE FINITE ELEMENT MODEL OF THE PADEYES

5.4 Comparison of the Measured and Calculated Strains for the Full Scale Test Loads

Figure 19 shows a graphic comparison of the measured and calculated strains. The dotted lines in the figure follow the average measured strain readings between the gages on either side of the loaded section of plating at each row.

It is perhaps easier to examine the data in tabular form. Tables 4, 5, and 6 present the strains predicted by the finite element model and the measured strains for the upper, middle, and lower padeye locations shown in Figure 15. The average and root mean square (RMS) errors in microstrain ($\mu\varepsilon$) are also presented in the tables. The average error for all the data was 1.4 $\mu\varepsilon$ and the RMS error was 0.9 $\mu\varepsilon$.

More importantly, one must examine the error associated with the gages most heavily loaded, the row directly in line with the padeye center for each test load. The middle padeye, which was the only location where the load could be applied normal to the plating, showed excellent agreement with the model. The average error for all measured strains on Row 4 was -0.8 $\mu\varepsilon$ and the RMS error was 3.2 $\mu\varepsilon$. This represents an error of less than 4 percent. The gages directly in line with the padeyes at the upper and lower padeyes showed RMS errors of 4.5 $\mu\varepsilon$ at Row 2 and 9.2 $\mu\varepsilon$ at Row 7, respectively. The average errors for these locations, however, were -10.1 $\mu\varepsilon$ or 16 percent low and -25.8 $\mu\varepsilon$ or 25 percent low, respectively.

For the measured strains of Rows 6 and 8 of Frame 37 and 38 on the lower padeye loading, there is a large difference between the two strains at each of these rows. Frame 37 carried more of the load at Row 6 and frame 38 carried more load at Row 8. This is believed to be caused by a slight misalignment of the padeye at this location. This location had the poorest access and the shortest distance between padeyes making alignment more critical.

While the error for Row 7 is shown to be 25 percent low, several factors would indicate that the errors for strains measured in an ice impact situation would not be this high. The model used for these test loads apparently does not fully explain the twist introduced into the plate and structure by loading the padeyes at an angle relative to the normal. In the case where normal loads were applied, excellent agreement was achieved. The ice impact loads will, of course, be normal to the hull. Secondly, the strain distribution along the frame is less peaked than the model would predict, indicating that while the strain under the load is lower than predicted, the strains around the load are higher than predicted. This would tend to decrease the error slightly given the fact that the off-diagonal terms contribute to the predicted pressure. Lastly, since the pressure data will be averaged over many sub-panels, the accuracy will be better at large areas even though there was an error in a single sub-panel measurement. In summary, the error in ice loads is expected to be similar to the error on the middle padeye plus the errors introduced by noise, gage misalignment, temperature, drift, gage calibration error, etc. The far most significant of these is drift which was minimized by frequent zeroing. The range of these errors is approximately ±15 $\mu\varepsilon$ or 5 percent of an average peak strian of 300 $\mu\varepsilon$. Pressure data are expected to be accurate to ± 10 percent.

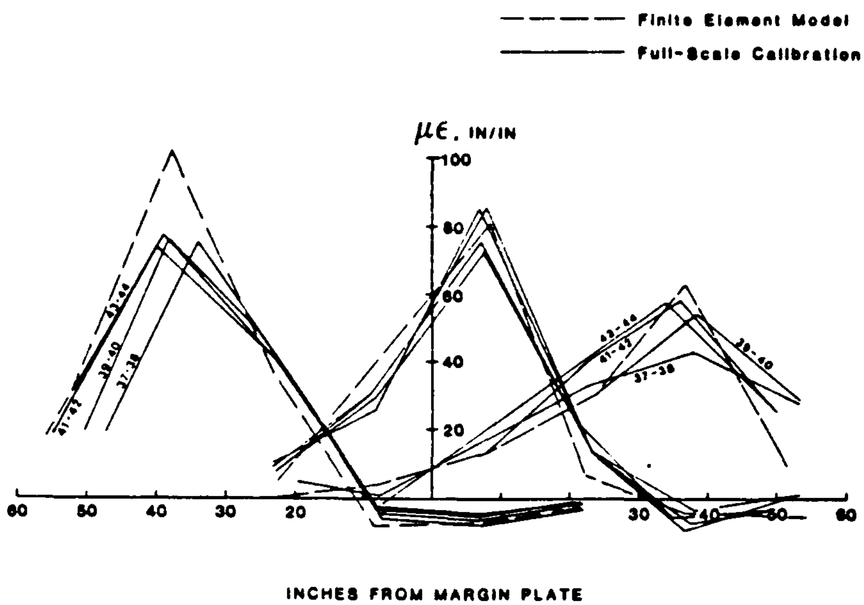


Figure 19
LOWER CALIBRATION POINT COMPARISON

TABLE 4 COMPARISON OF MEASURED AND COMPUTED
STRAINS AT THE UPPER PADEYE

		FRAMES								ERROR με			
ROW	FEM	37	38	39	40	41	42	43	44	MAX	MIN	AVG	RMS
1	10	28	28	31	26	25	25	31	23	21	13	17.1	6.1
2	63	34	51	58	50	59	56	58	57	- 4	-29	-10.1	4.5
3	31	32	33	29	28	39	43	38	40	12	- 3	4.3	2.6
4	15	12	14	17	13	17	12	20	17	5	- 3	0.3	1.0
5	4	2	- 1	6	0	- 2	- 2	- 2	- 4	2	- 8	- 4.4	1.9
6	0	4	6	3	3	6	4	4	4	6	3	4.3	1.6
	AVG	- 1.8	1.3	3.5	- 0.5	3.5	2.5	4.3	2.2			1.9	
	RMS	5.8	3.9	3.7	3.6	3.3	3.7	4.1	3.3				1.4

TABLE 5 COMPARISON OF MEASURED AND COMPUTED
STRAINS AT THE MIDDLE PADEYE

ROW	FEM	FRAMES 37	38	39	40	41	42	43	44	ERROR με MAX	MIN	AVG	RMS
1	- 5	1	1	1	2	- 3	- 3	- 2	- 4	7	1	4.1	1.7
2	- 4	- 1	- 7	- 9	- 8	- 9	- 7	- 4	- 7	3	- 5	-2.5	1.3
3	7	16	12	16	15	12	16	26	21	19	5	9.8	3.8
4	81	77	75	86	85	85	60	92	82	11	-21	-0.8	3.2
5	40	33	34	27	33	31	34	29	24	- 6	-16	-9.4	3.5
6	5	11	11	8	7	9	9	9	10	6	2	4.25	1.6
	AVG	2.2	0.3	0.8	1.7	0.2	- 2.5	4.3	0.3			0.9	
	RMS	2.5	2.2	3.1	2.4	2.2	4.0	4.2	3.7				1.1

TABLE 6 COMPARISON OF MEASURED AND COMPUTED
STRAINS AT THE LOWER PADEYE

ROW	REM	FRAMES 37	38	39	40	41	42	43	44	ERROR με MAX	MIN	AVG	RMS
3	- 3	- 1	- 1	- 2	- 3	0	- 1	- 1	0	3	0	1.9	0.7
4	- 6	- 7	- 7	- 8	- 8	- 5	- 4	- 6	- 7	2	- 2	- 0.5	0.5
5	- 8	- 5	- 4	- 4	- 8	- 4	- 2	- 2	- 3	6	0	4.0	1.6
6	36	50	25	48	39	42	40	48	43	14	-11	5.9	3.3
7	102	77	75	77	76	84	73	70	78	-18	-32	-25.8	9.2
8	27	- 8	50	10	6	27	17	12	15	23	-21	-10.9	6.8
	AVG	- 7.0	- 1.7	- 4.5	- 7.6	- 0.7	- 4.2	- 4.5	- 3.7			- 4.2	
	RMS	7.5	6.2	5.5	5.6	3.3	5.3	6.3	4.7				2.0

AVG OF ALL DATA -1.4 με
RMS OF ALL DATA 0.9 με

6.0 DESCRIPTION OF THE DATA COLLECTED

6.1 Description of the Locations and Ice Conditions Where Data Was Gathered

Data were initially collected on the September-October 1982 (Summer) deployment of the POLAR SEA in multiyear ice in the Beaufort Sea. The test program was conceived with testing being conducted only on the February-March 1983 (Winter) deployment, however the ship drydocking schedule dictated installing instrumentation prior to the summer deployment. The summer deployment became an opportunity to check out the system in real ice conditions as well as gather valuable impact data in multiyear ice.

This first deployment was quite successful. The system performed well and 167 good impact events were recorded over a two week period. A detailed map of the test area is shown in Figure 20 for the two legs of the deployment. Results of the data collected on this trip are summarized in Section 7.0. The data presented represents the impacts recorded for 13-1/2 hours and 34 hours of actual operation in ice for Legs 1 and 2, respectively. The ship was stopped to profile multiyear ice features and gather other environmental data much of the time in ice. Impact data was recorded either in dedicated rams of multiyear floes or in transiting from one test area to another. Three basic modes of operation were employed; impacting multiyear floes while transiting in open water or thin first year ice at slow to moderate speeds; backing and ramming in heavy multiyear ice; and slow, continuous progress in multiyear ice. Typical ice conditions were 70% coverage of multiyear ice, 10 to 20% coverage of grey ice, and 10 to 20% open water. Multiyear ice averaged 10 ft (3 m) thick with a maximum consolidated thickness of 48 ft (15 m) in the largest multiyear ridges. Grey ice was typically 4 inches (0.1 m) thick. By October 6, pancake ice had started to form as far south as 30 n.m. from the coast. The new ice was 8 inches (0.2 m) thick and extended to within a few miles of Barrow by October 17. Flexural strength, based on temperature and salinity using Vaudrey's method [14], averaged 81 psi (560 kPa) with a standard deviation of 19 psi (130 kPa) based on 18 ice cores in multiyear ice. A complete description of the ice and weather conditions is presented by Voelker, et al [15].

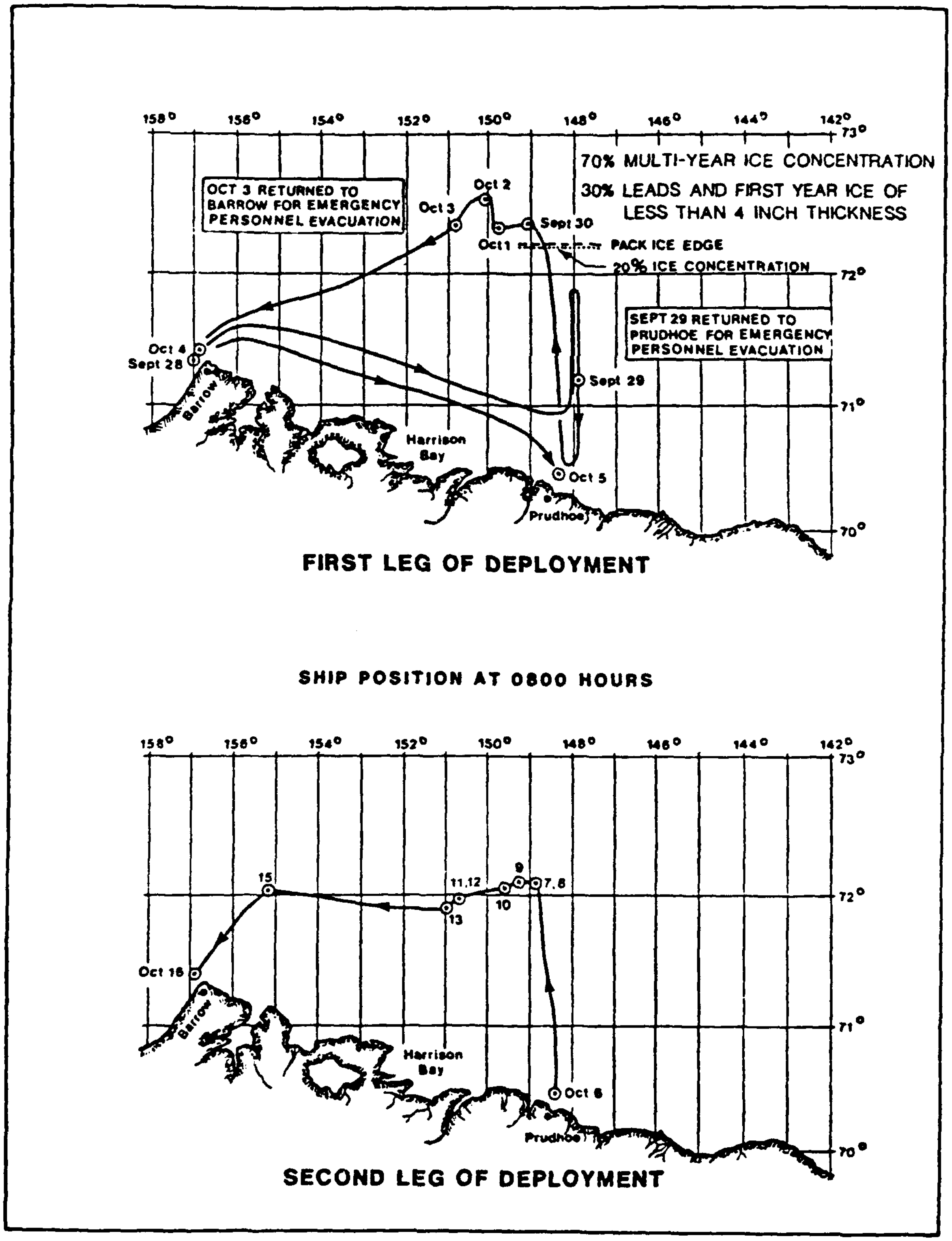


Figure 20
SEPTEMBER, OCTOBER 1982 (SUMMER) DEPLOYMENT
SHIP POSITION

The March-April-May 1983 (Winter) deployment departed Dutch Harbor, Alaska on March 23. The ice edge was encountered on the morning of the following day. Forty-one days were spent in ice gathering impact and environmental data until the deployment ended on May 3 at Nome. The principal operating area was in the northern Chukchi Sea off Wainwright. The ship stayed in this area from April 4 to April 26 profiling small multiyear floes and then ramming them. Impact data were collected in dedicated ramming tests in this area as well as transiting in predominately first year ice from one profiling area to another. Important impact data were also gathered on the transits to and from the operating area. These data have been separated into three sets of data for the southern Bering Sea, the northern Bering Sea (north of St. Lawrence Island), and the southern Chukchi Sea (north of the Bering Straits and south of Point Hope). The complete route of the ship during this deployment is shown in Figure 21.

Observed ice conditions were recorded at half-hour intervals during the transit. Average ship speeds were also computed each half-hour based on ship position. Average observed ice thicknesses varied from 0.5 to 6 feet (0.15 to 1.8 m) in the southern Bering Sea. Ice conditions were quite diverse in the area. There was a large shadow of light ice south of both St. Matthew and St. Lawrence Island due to northeasterly winds but heavily rubbled ice with considerable pressure in the ice was encountered when rounding the islands. Operating conditions varied from steaming at high speed in light ice conditions to backing and ramming at slow to moderate speeds in heavy rubble fields. Observed average ice conditions ranged from 0.5 to 4 ft (0.15 to 1.2 m) in the northern Bering Sea. All impact data that were recorded in the southern Bering Sea was in 100 percent coverage; coverage varied from 50 to 100 percent in northern Bering Sea.

Average ice thicknesses in the southern Chukchi Sea were from 0.25 to 6 ft (0.08 to 1.8 m). Coverages were predominately 100 percent, falling to as low as 80 percent near the Bering Strait. Extremely pressured ice and rubbled ice fields were encountered in the lower Hope Basin on the northbound trip and in the northern Hope Basin while returning south.

On the transit through the northern Chukchi Sea and in our primary operating area, heavy first year ice prevailed. Most impacts occurred when the average ice thickness was 3 to 6 ft (0.9 to 1.8 m), however some data were gathered in thicknesses as low a 0.5 ft (0.15 m) in refrozen leads.

Nine multiyear ridges were profiled in the operating area for which impact events were recorded while the ship transited the ridge. The ridges were located in relatively small multiyear floes of less than 500 feet (150 m) in diameter. These were completely constrained by a first year ice cover of approximately 5 feet (1.5 m) in thickness. A complete description of the environmental and weather conditions is presented in Voelker, et al [16].

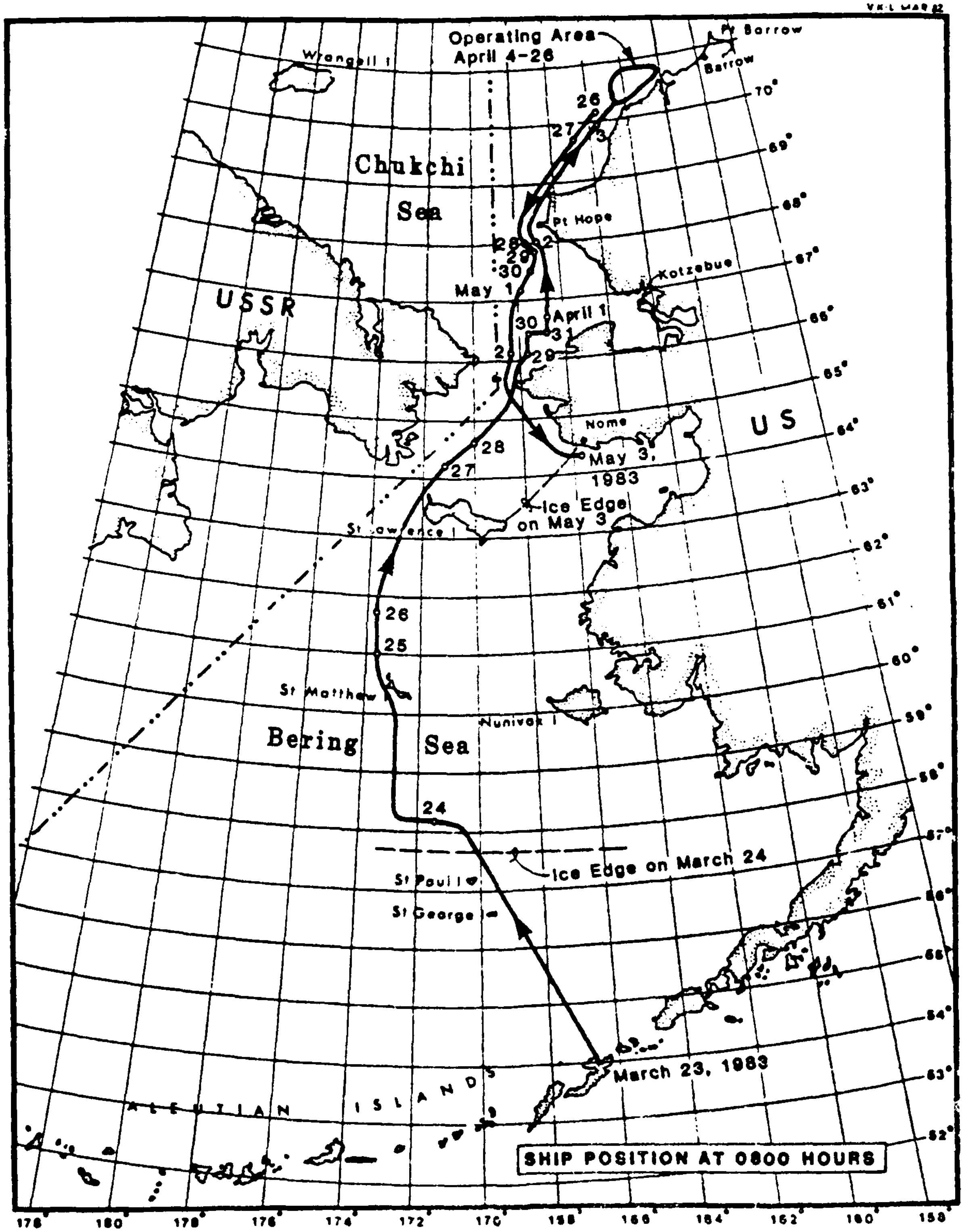


Figure 21

FEBRUARY, MARCH, APRIL 1983 (WINTER) DEPLOYMENT

SHIP POSITION

6.2 Overview of the Data Collected

The raw data that was collected during an impact of the panel with ice consisted of a 60 channel strain time history sampled 32 times a second for 5 seconds (winter deployment) or 6.25 seconds (summer deployment). The data were collected when the strain on any channel exceeded a preset threshold strain. Each exceedance of the threshold value triggering the recording of a fixed amount of data on 60 channels, 5 seconds for the winter deployment, was labeled an event. If the loads remained high during an impact and therefore the strains, several events could be recorded for a single impact.

The significant difference between the data for the summer and winter deployments is that there was insufficient time to install the planned data reduction and data storage system for the summer deployment. While the system used in the winter deployment could store data as fast as it was received, the system used in the summer required 30 seconds to store each event. Consequently, there was some loss of data when events occurred very close together in the summer deployment.

A total of 167 events were recorded in the summer deployment and of these, 29 involved multiple events where some loss of data above the threshold strain occurred. The winter deployment acquired 1,226 events of which 67 multiyear events, 61 occurring in dedicated and documented rams of multiyear ridges, were recorded.

Reduced data for each event consist of a 60 channel pressure time history; a summary file of the pressure area curve, the total panel force time history, and the pressure versus length and height along the hull at the time of peak pressure on a single sub-panel; and a directory of events including comments on observed ice conditions and ship speed. These data were stored on floppy disk for subsequent data analysis. Additionally, for the winter deployment, the reduced data were analyzed for the time of peak force as well and this data was also stored in the summary file. The summary files for the peak events in each geographic area are presented in Appendix D.

Observed ice conditions and the ship's average velocity were recorded during almost all of the time the ship was transiting to and from the operating area off Wainwright during the winter deployment. These data have been incorporated in the form of comments in the directory of events. Additionally, a channel of data for ship speed was added to the data acquisition system on the transit north on the winter deployment such that ship speed would automatically be recorded during an impact. For the summer deployment, ship speed was observed from the ship's doppler radar speed indicator during many of the impacts. A summary of all of the data showing the number of events where observed ice conditions and ship speeds were recorded is shown in Figure 22. It should be noted that most of the multiyear events occurred in dedicated tests where the floes or ridges were profiled and ice cores were taken to document ice strength prior to the impacts.

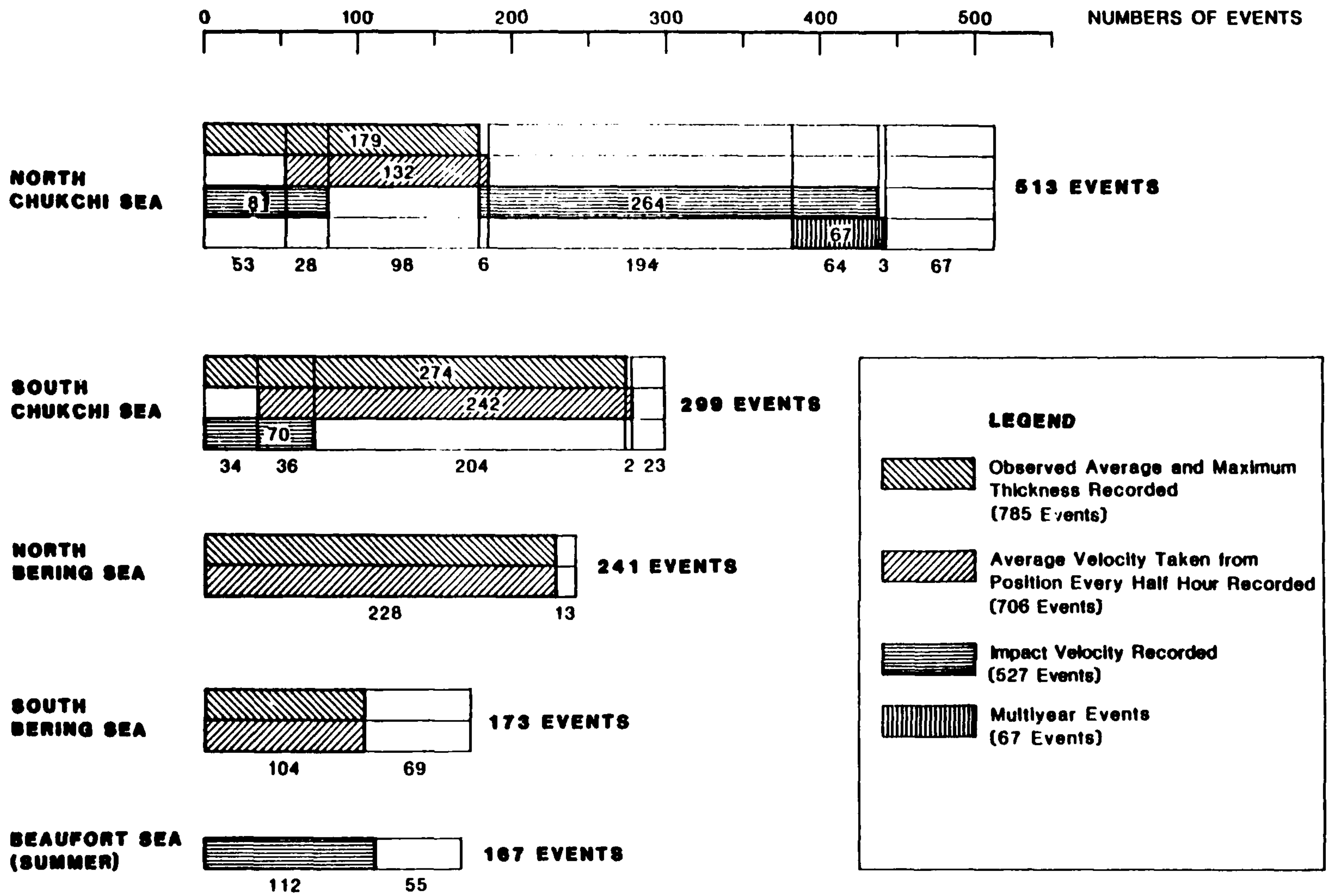


Figure 22

SUMMARY OF ALL DATA SHOWING THE NUMBER OF EVENTS AND THE TYPE OF DATA IN EACH GEOGRAPHICAL AREA

7.0 SEPTEMBER-OCTOBER 1982 (SUMMER) DATA

7.1 Presentation of Highest Average Pressures

The summer data were reduced prior to the winter deployment to appreciate the problems involved in reducing the data. Much was learned from the summer deployment both in the data acquisition and data reduction to improve the system for the winter deployment. Consequently, the summer data are not as complete. They are stored in a different format by a different computer, they have a longer time record, and they are only summarized for the time of the highest peak pressure on a single sub-panel. The emphasis throughout all of the data reduction and data analysis has been concentrated on the peak pressures that have been recorded, since these are the most interesting from a design point of view. Complete time histories of reduced pressures for all events have been generated and saved on disk, however the shear volume of data precludes presenting it all. Approximately ten thousand individual pressures are computed for each event.

It is interesting to examine the distribution of the frequency of occurrence of highest average pressures. Figures 23 and 24 present this data for several different areas for the summer Beaufort Sea impacts. The data presented in these figures include all the data recorded on both legs of the deployment. For the first leg, the threshold strain level was set at 100 micro-strain ($\mu\varepsilon$), roughly equivalent to a single sub-panel pressure of 200 psi (1.4 MPa). The first leg recorded 73 events. The second leg experienced heavier ice, and since the interest was in the extreme events, the threshold was increased to 250 $\mu\varepsilon$ or about 500 psi (3.4 MPa) on a single sub-panel.

The figures show that 126 of the 167 events of the data, or 75 percent, had an impact area of at least 9.79 ft^2 (0.91 m^2). Twenty-four percent, or 40 events, had an impact area of at least 24.5 ft^2 (2.28 m^2). Eight events, or 5 percent of the data, had an impact area of at least 50.6 ft^2 (4.70 m^2). The largest impact area covered an area of 88 ft^2 (8.2 m^2) with an average pressure of 22 psi (0.15 MPa).

Figure 23 shows that 4 events or 2 percent of the recorded data exceeded an average pressure of 1400 psi (9.7 MPa) on a single sub-panel of 1.63 ft^2 (0.15 m^2). The highest single sub-panel pressure was 1617 psi (11.15 MPa) which occurred while backing and ramming in multiyear floes at 3 to 4 kts (1.5 to 2.1 mps).

An envelope curve was developed from the pressure area curves for each event (Figure 25). This figure, therefore, shows the highest average pressure recorded for each area. This curve was developed from the pressure area curves for the time of peak pressure on a single sub-panel. A proper development of the envelope curve would examine each time step of each event. This process would require the analysis of an extremely large amount of data. The winter deployment data have shown that it is sufficient to analyze two time steps for each event; the time of peak pressure on a single sub-panel and the time of peak force on all sub-panels. Unfortunately, when the reduction and analysis of the summer data was performed, the pressure area curves were not developed for the time of peak force. The result was that the envelope curve shown in Figure 26 gives slightly lower pressure than the actual recorded maximum at the larger impact area. All data seems limited by a 500 LT (5 MN) line of constant force.

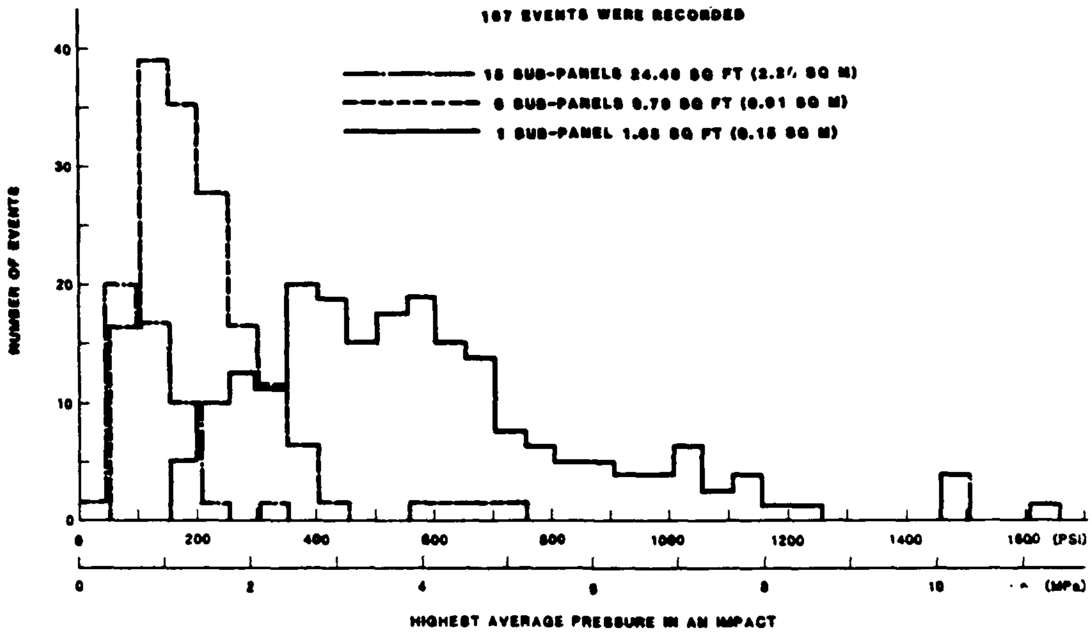


Figure 23
NUMBER OF EVENTS RECORDED vs HIGHEST AVERAGE PRESSURE FOR DIFFERENT IMPACT AREAS (Beaufort Sea, Summer)

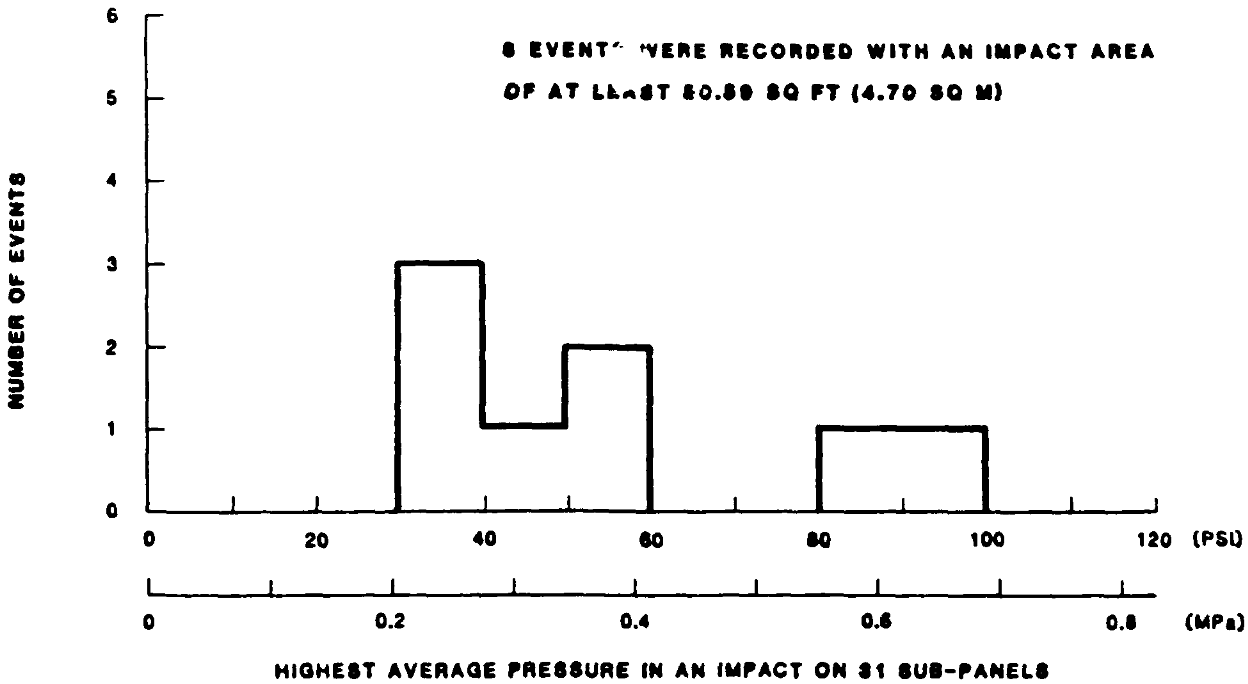


Figure 24
NUMBER OF IMPACTS vs HIGHEST AVERAGE PRESSURE ON 31 SUB-PANELS

The highest event shown in Figure 25 is typical of the pressure area relationships observed in all the data. Extreme events approach a constant pressure line at small impact areas and a constant force line at large areas. No attempt was made to limit the data to impacts that are totally contained within the panel. Such a curve represents the highest average pressures recorded at each area given a large number of impacts and the random nature of where the loads hit the hull. The pressure-area relationship of a single impact totally contained within the panel may be slightly different and could be examined individually.

A table of the locations where the highest single sub-panel pressures occurred is shown in Table 7. Impacts appear randomly distributed over the frames but there were a large number of impacts low on the panel in the thick ice. Forty-eight percent of the impacts peaked in pressure on the lowest two rows.

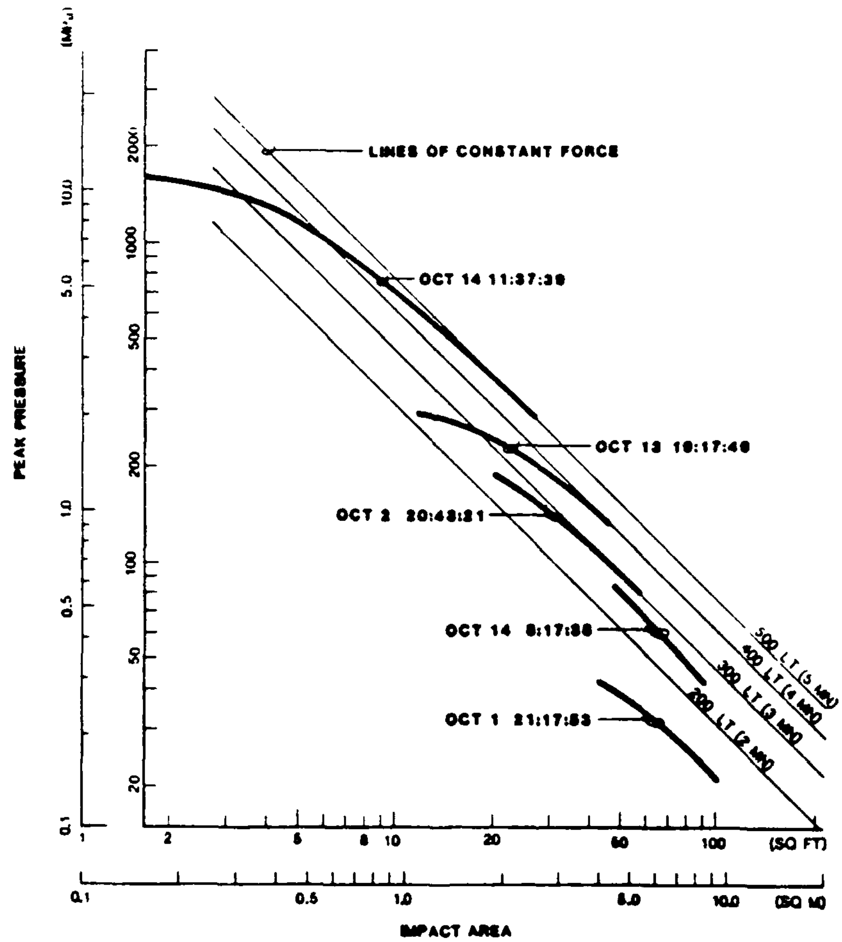


Figure 25

ENVELOPE CURVE FORMED BY THE PEAK EVENTS FROM THE BEAUFORT SEA DATA (Summer)

TABLE 7 NUMBER OF EVENTS RECORDED AT EACH SUB-PANEL FOR THE SEPTEMBER-OCTOBER 1982 (SUMMER) DATA

ROWS	FRAMES 44	43	42	41	40	39	38	37	36	35	1st 20 EVENTS*	OTHER EVENTS	TOTAL
1													
2	2					1	1				4		4
3	2/1	1/2	1/1		1/	/2	1/	2/2	1/1	/2	9	11	20
4	2/2		/1	/3	/1	/2	3/		1/1	1/	7	10	17
5	3	7	1	2	2		3	5	5	7		35	35
6		1			1	1	1	1	4	2		11	11
7	3		1	1	2	3		10	10	6		36	36
8	8	3	7	1	2	9	3	1	6	4		44	44
1st 20 EVENTS	6	1	1		1	1	5	2	2	1	20		
OTHER EVENTS	17	13	11	7	8	17	7	19	27	21		147	
TOTAL	23	14	12	7	9	18	12	21	29	22			167

* The first 20 events were recorded with Rows 1 to 6 active and subsequently, the gages on Rows 3 to 8 were active. For Rows 3 and 4, the number before the slash indicates the number of events with Rows 1 to 6 active and the number after the slash indicates the number of events with Rows 3 to 8 active.

7.2 Force and Pressure Variation with Ship Speed

The summer data include 112 events where the ship speed was recorded during the impact. An observer, who was positioned on the bridge, was in telephone communication with an operator at the data recording system. When an impact was registered by the instrumentation, the bridge observer would record the ship speed from the ship's doppler radar display. Since most of the tests were dedicated rams for this deployment, this procedure was adequate to document most of the ship impact speeds for the data. An automated system was developed and installed during the winter deployment to record ship impact speed directly with strain data.

Figure 26 shows the single sub-panel highest pressures versus ship impact speed. There appears to be an increase in impact pressure with velocity up to a ship speed of 3.5 kts (1.8 mps). This is the range of speeds where most of the dedicated rams in heavy multiyear ice occurred. Higher impact speeds correspond to cases where the ship was transiting in lighter ice conditions and impacted the edge of a multiyear floe, in general.

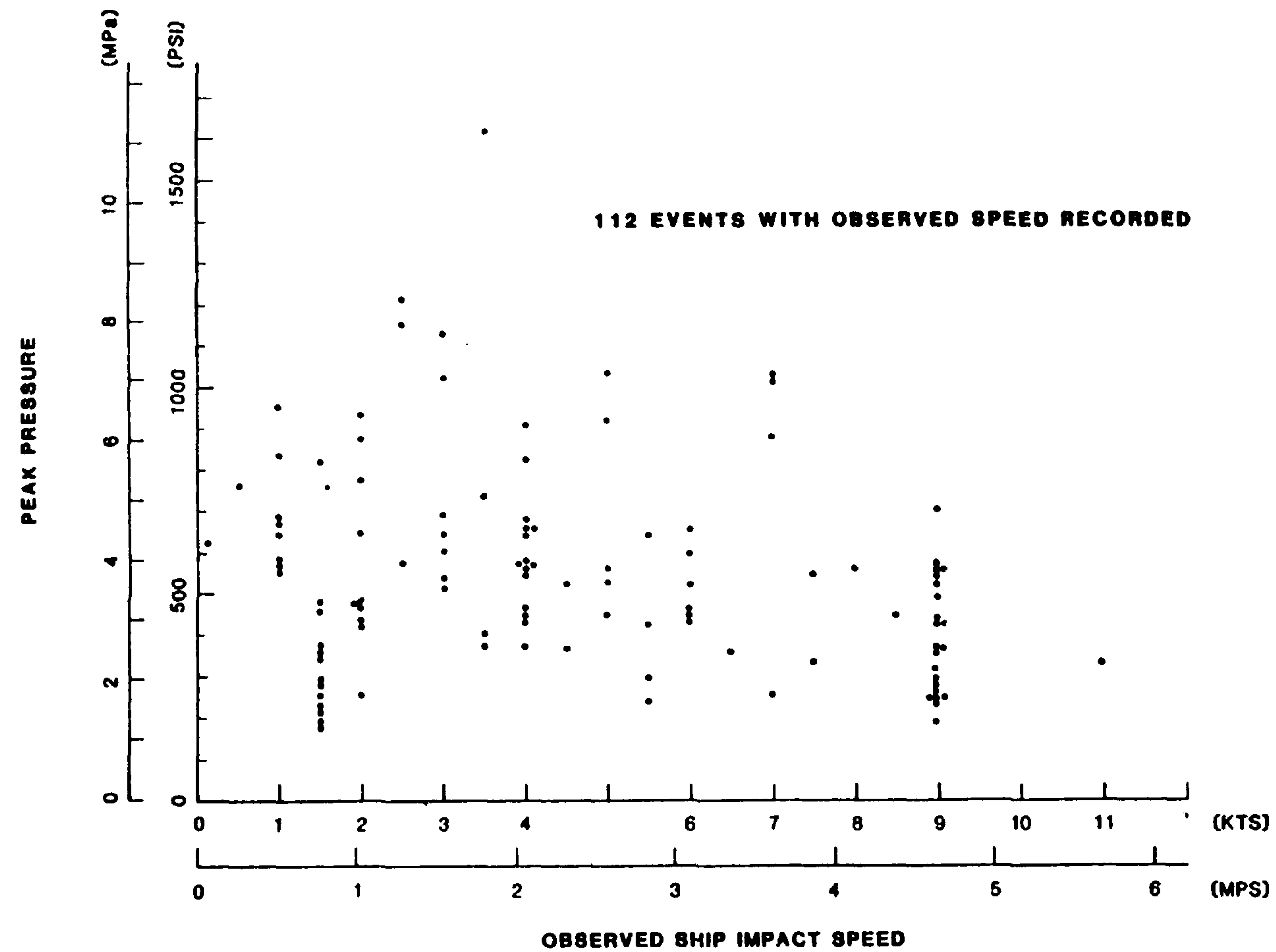


Figure 26

HIGHEST AVERAGE PRESSURE ON A SINGLE SUB-PANEL vs IMPACT SPEED FOR THE BEAUFORT SEA DATA (SUMMER)

8.0 MARCH-APRIL-MAY 1983 (WINTER) DATA

8.1 Frequency of Highest Average Pressures by Geographic Area

The first step in any statistical analysis of the data is an assembly of the distributions of the highest average pressure over different impact areas for each geographical area. The distributions are computed for six impact areas, the area associated with 1, 6, 15, 31, 46, and 60 sub-panels. The actual area for each number of sub-panels is shown in Table 8. These distributions are presented in Tables 9 through 12. All data collected during the winter deployment are represented in the tables. The total events shown in the single sub-panel column of each table indicates the number of events collected in that geographical area. For the north Chukchi Sea, Table 12, the data include both first year and multiyear events. It should be noted that the threshold value was varied in each area to some extent. The distributions for each threshold setting are presented in Appendix E. The thresholds for most of the data in each area were as follows; south Bering Sea 75 $\mu\varepsilon$, north Bering Sea 120 $\mu\varepsilon$, south Chukchi Sea 120 $\mu\varepsilon$, and north Chukchi Sea 150 $\mu\varepsilon$. While an exact correlation between the threshold strain and the minimum for the highest average pressure on a single sub-panel depends on the impact location on the panel, the strain roughly corresponds to half the average pressure in psi on one sub-panel. The data collected in the north Chukchi Sea are the events above approximately 300 psi (2.1 MPa), for instance.

In examining the data in the tables, one can see that there was one exceptional event in the south Bering Sea that was well above the rest of the data in that geographical area and even the data collected in the north Bering Sea. This was a very localized event that generated a single sub-panel pressure of 1137 psi (7.84 MPa). Similarly, there was one extreme event that occurred while transiting in the north Chukchi Sea, exceeding the single sub-panel pressure of all the data measured to date. This event was also very localized and had a single sub-panel pressure of 1640 psi (11.3 MPa). Summary data for the peak events in each geographical area are presented in Appendix D. There is no obvious explanation for these exceptional events. Both occurred while transiting first year ice. However, the Chukchi Sea event could have been caused by impacting a small undetected multiyear floe.

Underway times and actual miles traveled are shown for each geographical area in Table 13. Underway times exclude the time that the ship was stopped to gather environmental data or for other reasons. Often night operations in heavy rubble fields became impractical and the ship stopped until dawn. The intent of the data in Table 13 is to relate the frequency distributions of pressures presented in Tables 9 to 12 to actual hours of operation or miles traveled. Such information allows one to qualitatively assess the frequency of encounter of impacts to this or other ships in different operating scenarios or return periods.

TABLE 8 AREAS ASSOCIATED WITH EACH NUMBER OF SUB-PANELS

NUMBER OF SUB-PANELS	AREA FT^2	AREA M^2
1	1.63	0.15
6	9.79	0.91
15	24.5	2.28
31	50.6	4.70
46	75.1	6.98
60	97.9	9.10

TABLE 9 FREQUENCY OF IMPACTS VERSUS HIGHEST AVERAGE PRESSURE FOR SOUTH BERING SEA

PRESSURE (psi)	NUMBER OF SUB-PANELS 1	6	15	31	46	60
0-50	9	41	94	130	97	1
50-100	6	88	57	5	2	0
100-150	18	35	4	0	0	0
150-200	59	5	0	0	0	0
200-250	38	0	0	0	0	0
250-300	24	0	0	0	0	0
300-350	8	1	0	0	0	0
350-400	7	0	0	0	0	0
400-450	2	0	0	0	0	0
450-500	1	0	0	0	0	0
500-550	0	0	0	0	0	0
1100-1150	1	0	0	0	0	0
TOTALS	173	170	155	135	99	1

TABLE 10 FREQUENCY OF IMPACTS VERSUS HIGHEST AVERAGE PRESSURE FOR NORTH BERING SEA

PRESSURE (psi)	NUMBER OF SUB-PANELS 1	6	15	31	46	60
0-50	0	11	38	81	73	0
50-100	0	63	112	35	7	0
100-150	2	95	14	3	0	0
150-200	15	42	3	0	0	0
200-250	24	8	1	0	0	0
250-300	63	3	0	0	0	0
300-350	41	0	0	0	0	0
350-400	42	3	0	0	0	0
400-450	26	0	0	0	0	0
450-500	11	0	0	0	0	0
500-550	7	0	0	0	0	0
550-600	8	0	0	0	0	0
700-750	2	0	0	0	0	0
TOTALS	241	225	168	119	80	0

TABLE 11 FREQUENCY OF IMPACTS VERSUS HIGHEST AVERAGE PRESSURE FOR SOUTH CHUKCHI SEA

PRESSURE (psi)	NUMBER OF SUB-PANELS 1	6	15	31	46	60
0-50	0	2	39	52	18	0
50-100	0	73	96	15	2	0
100-150	0	121	20	0	0	0
150-200	1	41	2	0	0	0
200-250	36	9	0	0	0	0
250-300	85	6	0	0	0	0
300-350	72	2	0	0	0	0
350-400	46	0	0	0	0	0
400-450	27	0	0	0	0	0
450-500	11	0	0	0	0	0
500-550	4	0	0	0	0	0
550-600	8	0	0	0	0	0
600-650	3	0	0	0	0	0
650-700	2	0	0	0	0	0
700-750	0	0	0	0	0	0
750-800	2	0	0	0	0	0
800-850	0	0	0	0	0	0
850-900	1	0	0	0	0	0
900-950	0	0	0	0	0	0
950-1000	0	0	0	0	0	0
1000-1050	1	0	0	0	0	0
TOTALS	299	254	157	67	20	0

TABLE 12 FREQUENCY OF IMPACTS VERSUS HIGHEST AVERAGE PRESSURE FOR NORTH CHUKCHI SEA

PRESSURE (psi)	NUMBER OF SUB-PANELS 1	6	15	31	46	60
0-50	0	0	15	46	20	0
50-100	0	26	158	81	50	0
100-150	0	155	95	4	0	0
150-200	1	133	15	0	0	0
200-250	1	60	1	0	0	0
250-300	38	29	2	0	0	0
300-350	90	5	0	0	0	0
350-400	78	8	0	0	0	0
400-450	63	0	0	0	0	0
450-500	60	2	0	0	0	0
500-550	34	0	0	0	0	0
550-600	34	1	0	0	0	0
600-650	15	0	0	0	0	0
650-700	14	0	0	0	0	0
700-750	11	0	0	0	0	0
750-800	8	0	0	0	0	0
800-850	3	0	0	0	0	0
850-900	2	0	0	0	0	0
900-950	4	0	0	0	0	0
950-1000	0	0	0	0	0	0
1000-1050	4	0	0	0	0	0
1050-1100	0	0	0	0	0	0
1100-1150	1	0	0	0	0	0
1150-1200	0	0	0	0	0	0
1200-1250	2	0	0	0	0	0
1250-1300	0	0	0	0	0	0
1300-1350	2	0	0	0	0	0
1600-1650	1	0	0	0	0	0
TOTALS	466	419	286	131	70	0

TABLE 13 SUMMARY OF UNDERWAY TIME FOR EACH OPERATING AREA

AREA	UNDERWAY* TIME (hrs)	ELAPSED TIME (hrs)	APPROX. ACTUAL MILES TRAVELED
Southern Bering Sea	16-1/2	29	167
Northern Bering Sea	29-1/2	48-1/2	137
Southern Chukchi Sea	68	206-1/2	400
Northern Chukchi Sea	143	617	2470

* Underway time when the system was recording data.

8.2 Impact Frequency Versus Location on the Panel

Tables 14 through 17 show the number of impact occurrences at each sub-panel location for each of the geographic areas. The tables use the position where the highest pressure on a single sub-panel was recorded as the impact location. At the start of the deployment, Rows 1 to 6 on the panel were active, however, as heavier ice was encountered, the instrumentation was shifted to Rows 3 through 8. This change took place in the south Chukchi Sea on April 1. Forty events from the northbound trip and all of the 72 events from the southbound trip recorded in the south Chukchi Sea were taken with Rows 3 to 8 active. Only four of the impacts occurred on the top two rows so the data are all presented in a single table.

Impacts occurred more frequently in the after half of the panel centering around Frame 43, except in the north Chukchi Sea where a significant number of events were also centered in the lower front quarter of the panel. Vertically, most of the events appeared to occur within the panel except again for the north Chukchi Sea, where 24 percent of the data occurred on the bottom row and 48 percent of the data occurred on the bottom two rows.

Appendix F presents the frequency of impacts versus location data at the time of peak force. These tables present the number of occurrences where a given sub-panel recorded the highest average pressure at the time of peak force on the entire panel. As expected, the peak force data are more centrally located on the panel than the peak pressure data. The peak force is the pressure on each sub-panel integrated over the total panel area. If the impact is centrally located on the panel, the force will be higher than when the impact is partially on the panel and a portion is not recorded.

TABLE 14 FREQUENCY OF IMPACTS VERSUS LOCATION AT TIME OF PEAK PRESSURE ON A SINGLE SUB-PANEL, WINTER DEPLOYMENT, SOUTH BERING SEA

	FRAMES										
ROWS	44	43	42	41	40	39	38	37	36	35	TOTAL
1	2	2	1	0	2	3	0	0	3	3	16
2	0	1	4	0	0	0	3	0	0	0	8
3	5	11	6	1	1	2	5	2	3	1	37
4	1	7	0	6	1	7	1	1	2	1	27
5	1	31	5	6	2	1	8	4	10	1	69
6	3	1	4	1	0	2	0	2	2	1	16
TOTAL	12	53	20	14	6	15	17	9	20	7	173

TABLE 15 FREQUENCY OF IMPACTS VERSUS LOCATION AT TIME OF PEAK PRESSURE ON A SINGLE SUB-PANEL, WINTER DEPLOYMENT, NORTH BERING SEA

	FRAMES										
ROWS	44	43	42	41	40	39	38	37	36	35	TOTAL
1	0	1	1	2	0	0	0	0	0	0	4
2	2	0	0	2	1	2	0	0	0	2	9
3	8	7	2	4	3	2	3	5	2	4	40
4	3	12	0	9	2	3	2	2	5	4	41
5	15	21	15	5	8	0	12	10	10	4	100
6	2	5	16	3	4	8	0	4	5	0	47
TOTAL	30	46	34	24	18	15	17	21	22	14	241

TABLE 16 FREQUENCY OF IMPACTS VERSUS LOCATION AT TIME OF PEAK PRESSURE ON A SINGLE SUB-PANEL, WINTER DEPLOYMENT, SOUTH CHUKCHI SEA

	FRAMES										
ROWS	44	43	42	41	40	39	38	37	36	35	TOTAL
1	0	0	1	0	0	2	0	0	0	0	3
2	0	1	0	0	0	0	0	0	0	0	1
3	1/1	1	3/1	1	0	4/1	0	0	0	0	13
4	4/2	8/1	0	3/3	3/1	1	1	1	1	1/2	32
5	7/2	30/4	11/5	5/1	4/4	0	8/7	12/7	7/4	0/1	119
6	6/6	4	22/3	7	3	9/1	2/1	1	10	4	82
7	1	2	1	1	0	2	1	1	14	1	25
8	2	5	6	0	1	6	1	2	1	0	24
TOTAL 1-6	18	44	37	16	10	16	11	14	18	5	189
TOTAL 3-8	14	13	16	5	6	10	10	10	21	5	110
TOTAL	32	53	53	21	16	26	21	24	39	10	299

TABLE 17 FREQUENCY OF IMPACTS VERSUS LOCATION AT TIME OF PEAK PRESSURE ON A SINGLE SUB-PANEL, WINTER DEPLOYMENT, NORTH CHUKCHI SEA

	FRAMES										
ROWS	44	43	42	41	40	39	38	37	36	35	TOTAL
3	5	7	5	0	2	5	2	7	2	4	39
4	14	15	0	5	0	8	2	9	2	1	56
5	10	36	8	5	14	0	17	23	18	8	139
6	7	4	11	0	1	2	1	4	4	0	34
7	5	4	3	2	1	11	4	31	45	17	123
8	13	14	24	6	0	36	18	6	5	0	122
TOTAL	54	80	51	18	18	62	44	80	76	30	513

8.3 Pressure-Area Relationships as a Function of Observed Ice Conditions and Ship Speed

For much of the impact data collected during the transit to and from the primary operating area off Wainwright, average and maximum ice thicknesses were recorded on half-hour intervals by pilot house observers. This thickness data was correlated with the impact data to examine the effect of increasing impact pressure with increasing ice thickness. Figure 22 indicated the number of events for which ice conditions were observed for each operating area.

Figures 27 and 28 present the extreme pressure-area curves sorted by maximum ice thickness for each geographic area. The extreme pressure-area curve is determined by comparing each event that occurred at the specified range of maximum ice thicknesses. The highest average pressure, whether at the time of peak pressure or the time of peak force, is determined for all events over each area (number of sub-panels). This determines the extreme pressure-area envelope recorded for the range of maximum ice thicknesses being studied. Three to five ranges of maximum ice thicknesses are presented in the figures for each geographical area.

One can see an increase in the average pressure with increasing ice thickness up to a certain value. In general, the trend reverses above this thickness. The thickness where the pressure-area curves reach the extreme values is in the range of 4 to 6 feet (1.2 to 1.8 m) for maximum observed thickness.

A similar trend can be seen when the data are analyzed according to average observed ice thickness as shown in Figure 29. For average thickness, the trends of increasing pressure with increasing thickness appears to reverse at about 2 feet (0.6 m) for the Bering Sea data. The Chukchi Sea data, shown in Figure 30, are less conclusive. It does appear that the loads, and therefore the pressure-area curves, decrease at the highest observed ice conditions in almost all areas.

This fact is presumably due to the way the ship was operated rather than a physical phenomenon involved in the icebreaking process. In predominantly 100 percent ice coverage, the ship was forced to slower and slower speeds as the ice thickness increased. Even when ramming, it was difficult to gain high speed prior to a ram in the pressured ice conditions encountered much of the time in heavy ice. Several investigators [17, 18, 19] have shown that impact force increases with impact speed. Forty-five degree lines decreasing with increasing area on the pressure-area curves represent lines of constant force. One can see that at high areas, the pressure-area curves approach constant force. It is postulated that at light ice conditions and high speeds, the loads were low and at heavy ice conditions and low speeds the loads were also lower. The impact force peaked at intermediate ice conditions before the ship was slowed greatly.

Figures 31 and 32 show the data for which the speed at the time of impact was recorded. Ship speed for this data were digitized simultaneously with the strain data from a doppler radar. There are no apparent trends in this data when speed is examined independent of ice conditions. Speed will be discussed in more detail in the following sections.

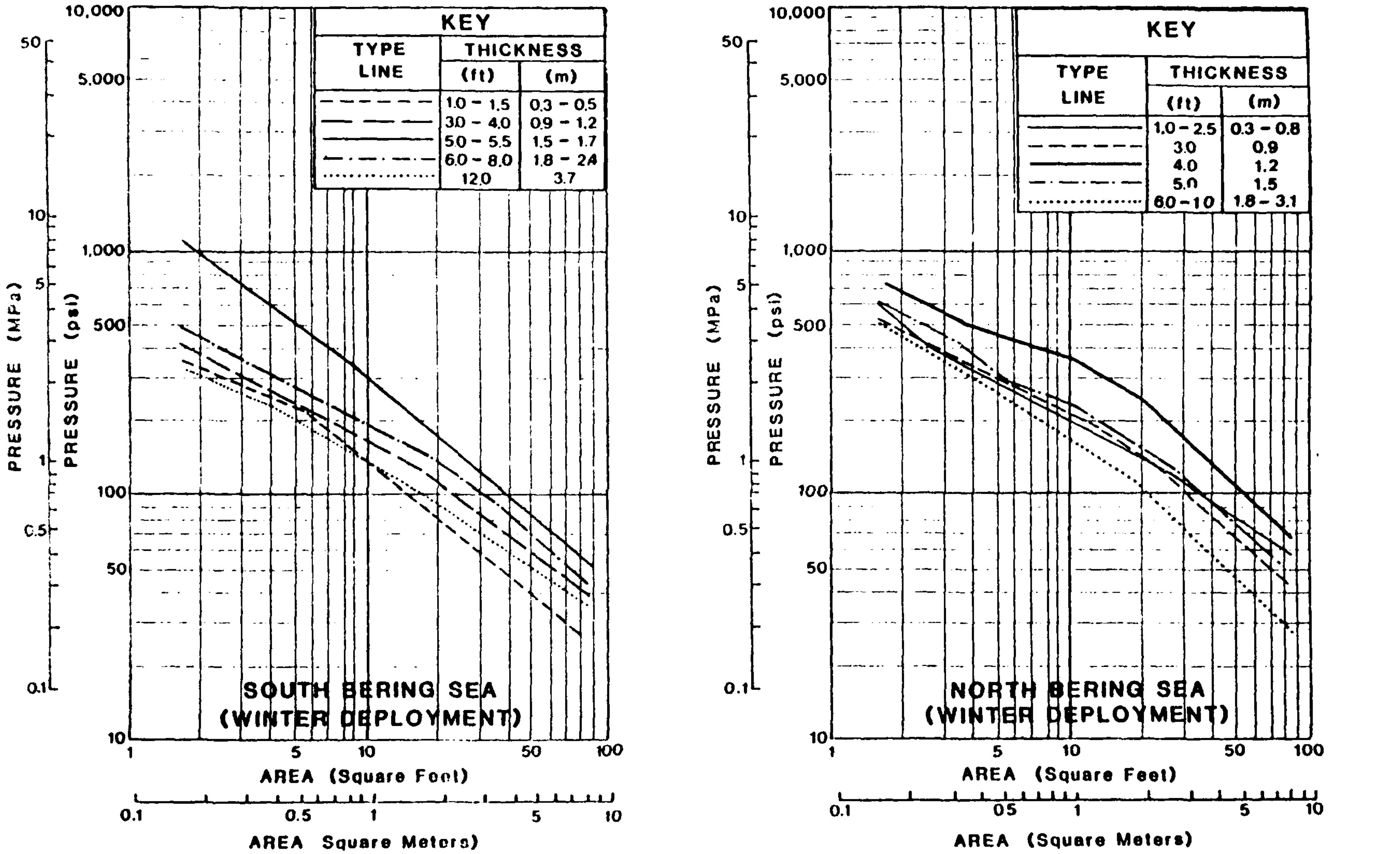


Figure 27

PRESSURE - AREA EXTREME ENVELOPES AS A FUNCTION OF MAXIMUM OBSERVED ICE THICKNESS

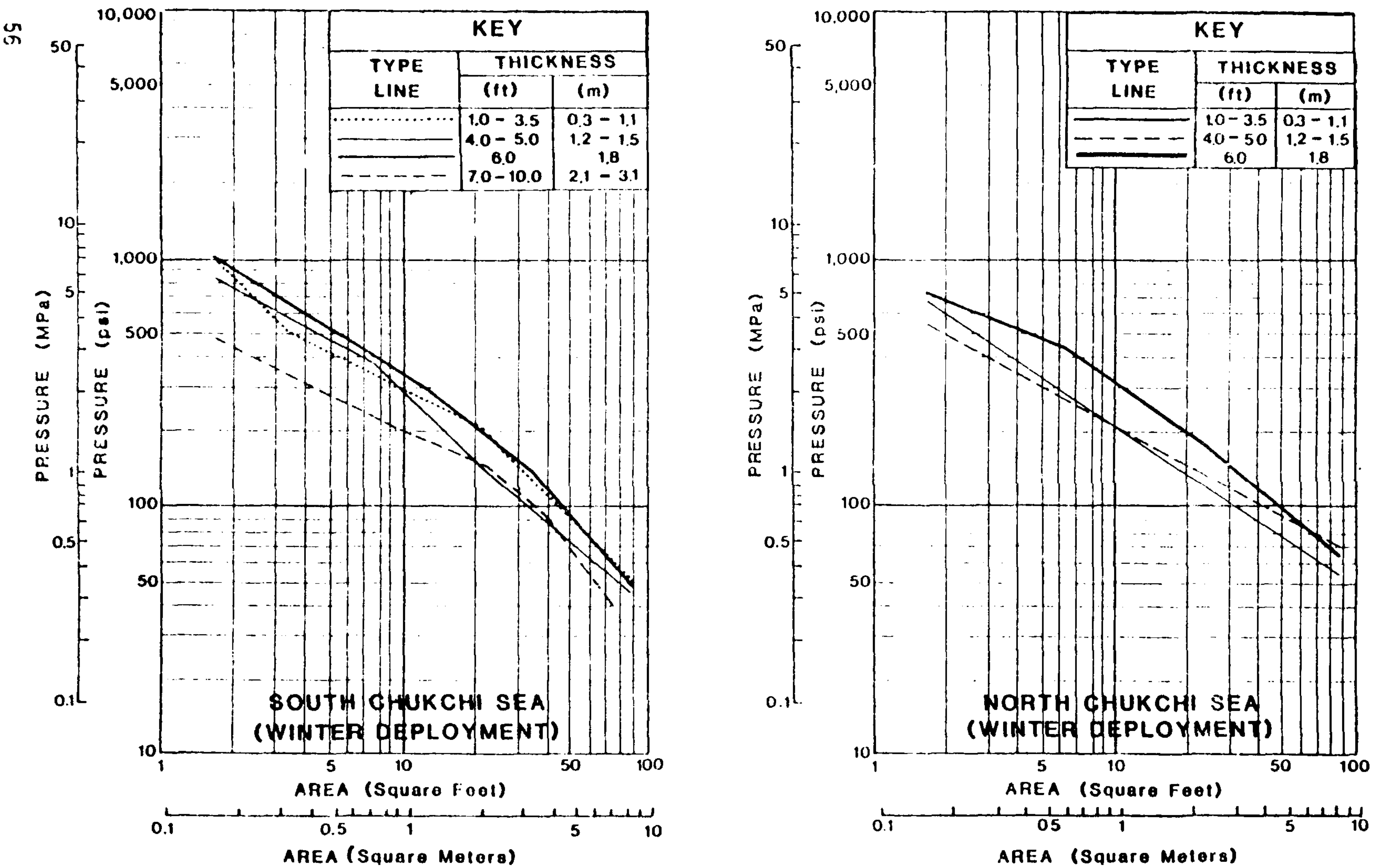


Figure 28

PRESSURE - AREA EXTREME ENVELOPES AS A FUNCTION OF MAXIMUM OBSERVED ICE THICKNESS

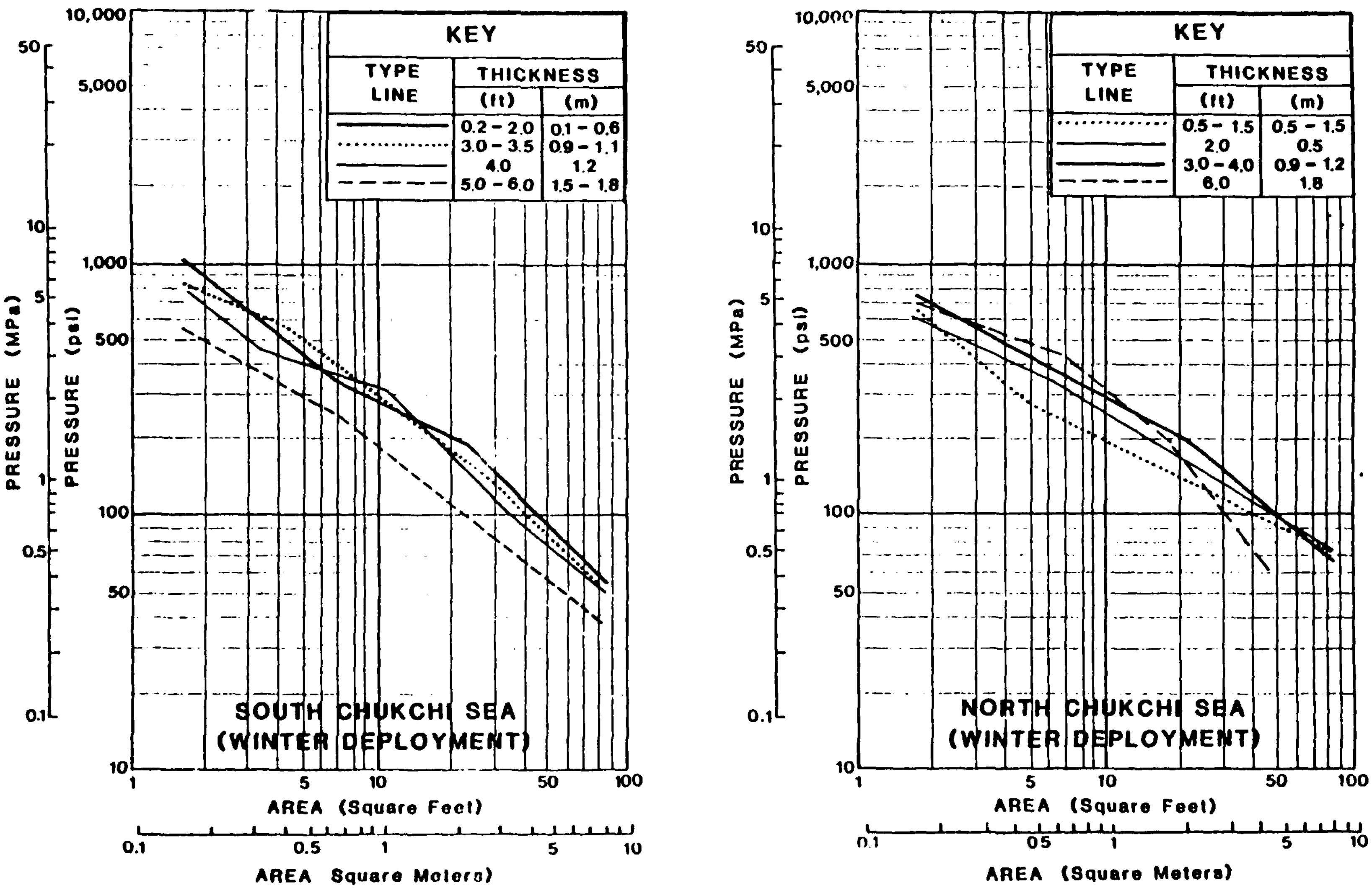


Figure 29

PRESSURE - AREA EXTREME ENVELOPES AS A FUNCTION OF AVERAGE OBSERVED ICE THICKNESS

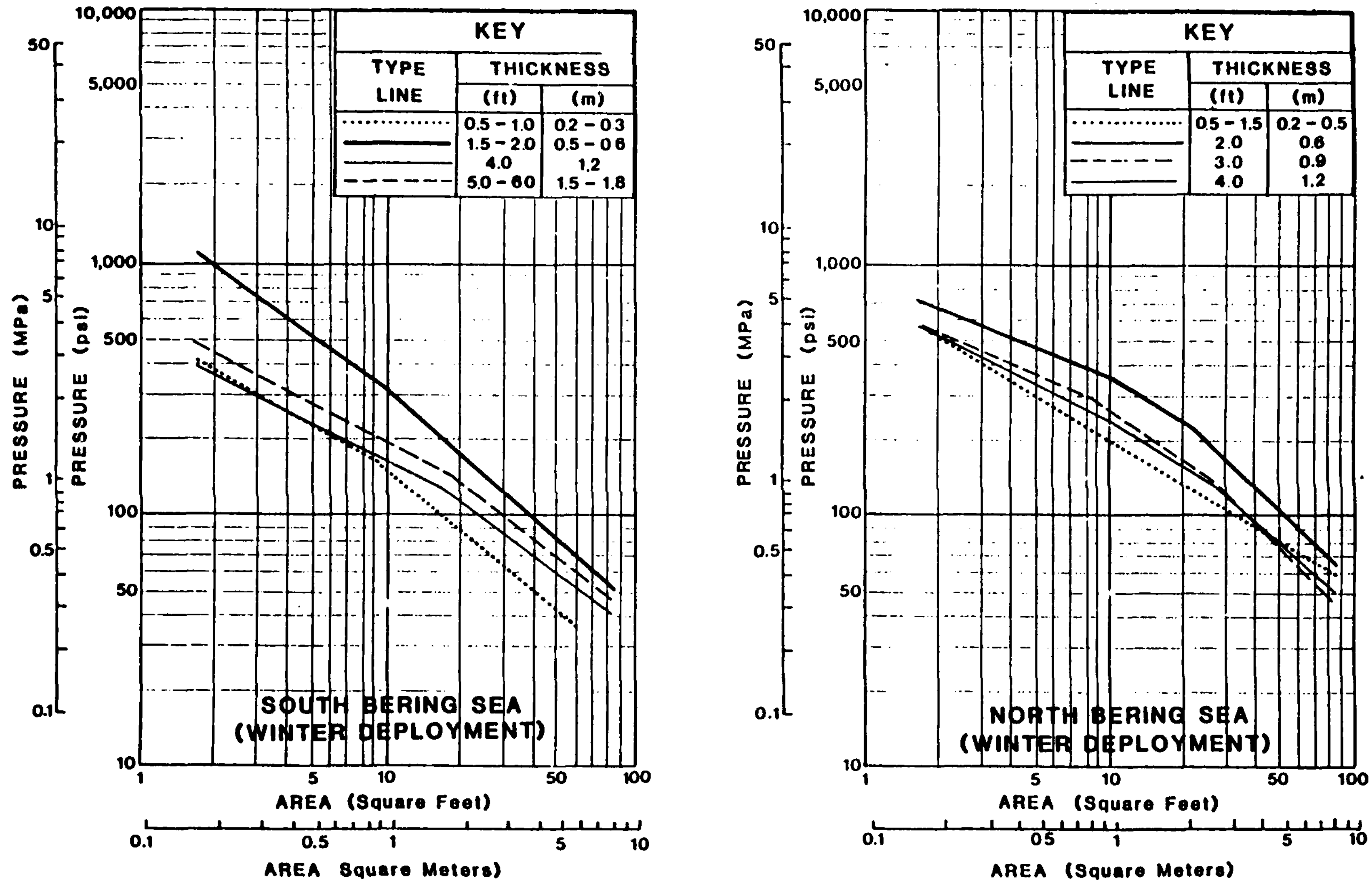


Figure 30

PRESSURE - AREA EXTREME ENVELOPES AS A FUNCTION OF AVERAGE OBSERVED ICE THICKNESS

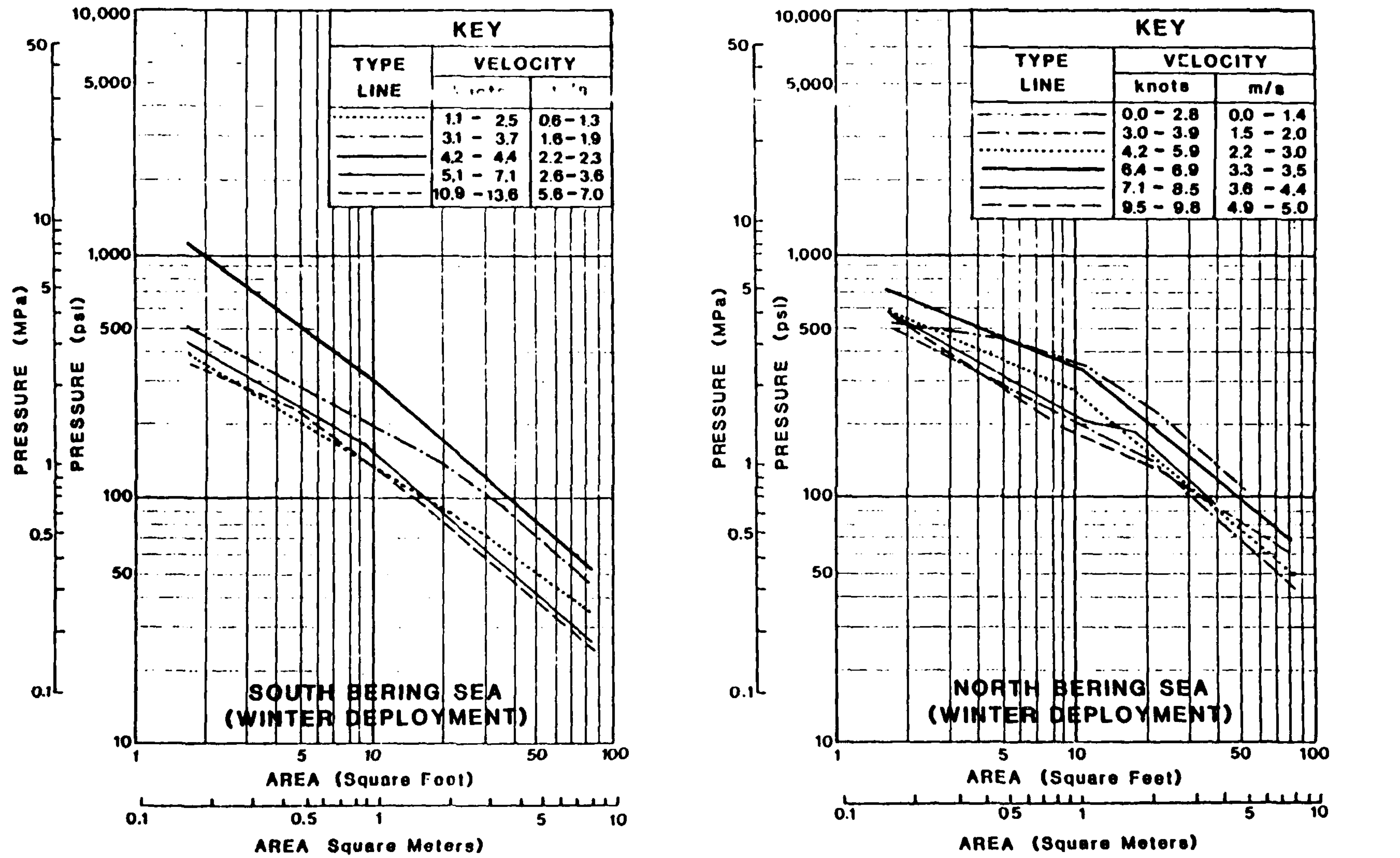


Figure 31

PRESSURE - AREA EXTREME ENVELOPES AS A FUNCTION OF MEASURED SHIP SPEED

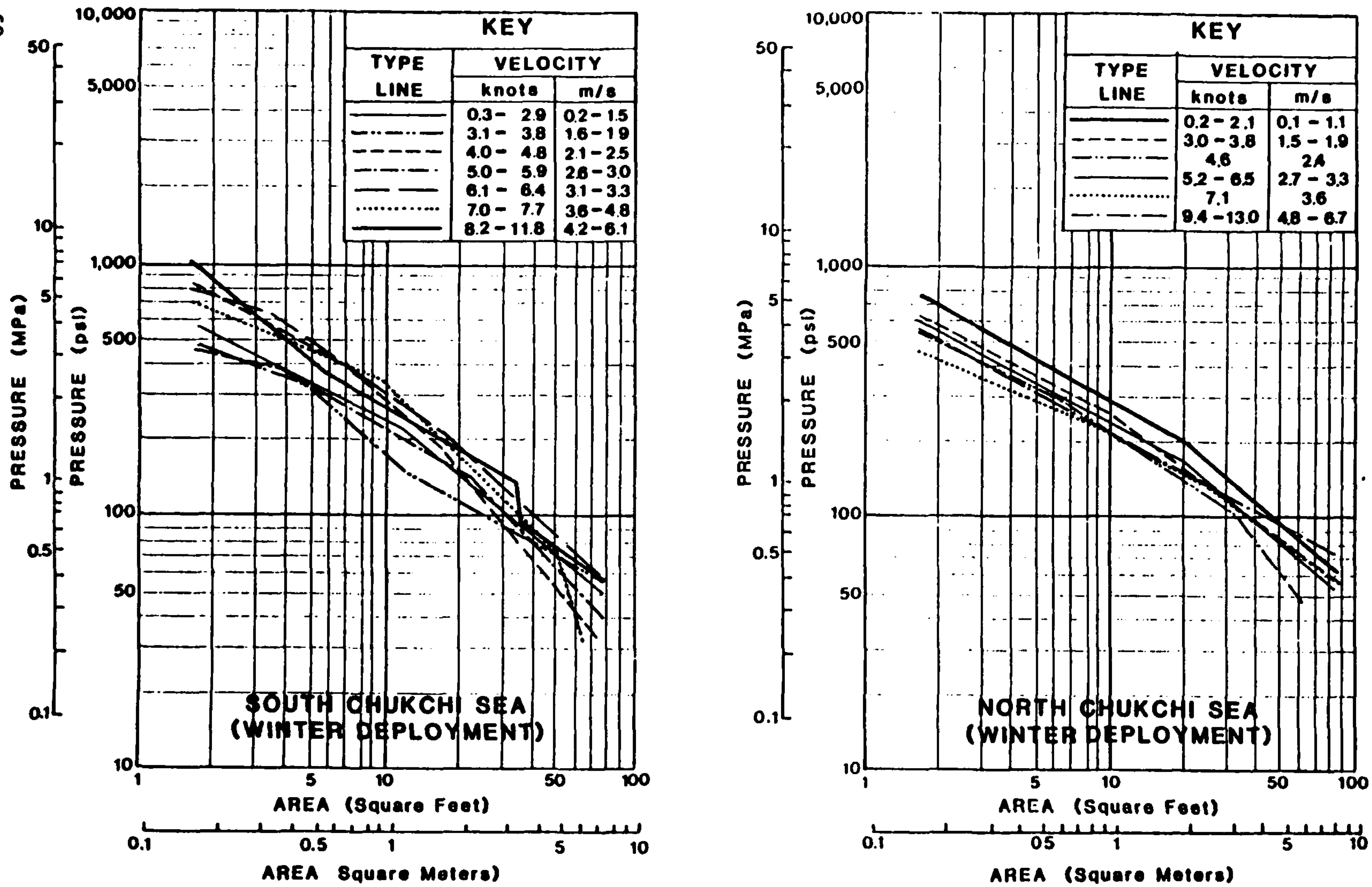


Figure 32

PRESSURE - AREA EXTREME ENVELOPES AS A FUNCTION OF MEASURED SHIP SPEED

The extreme envelopes for each geographical area are compared in Figure 33. One can see that pressures increased with the severity of ice conditions going north, in general. The exception was the north Bering Sea which recorded slightly higher pressures than the south Chukchi Sea. The multiyear impacts determine the extreme envelope for the north Chukchi Sea over most of the range of areas. The north Chukchi Sea envelope is substantially higher than the other operating areas.

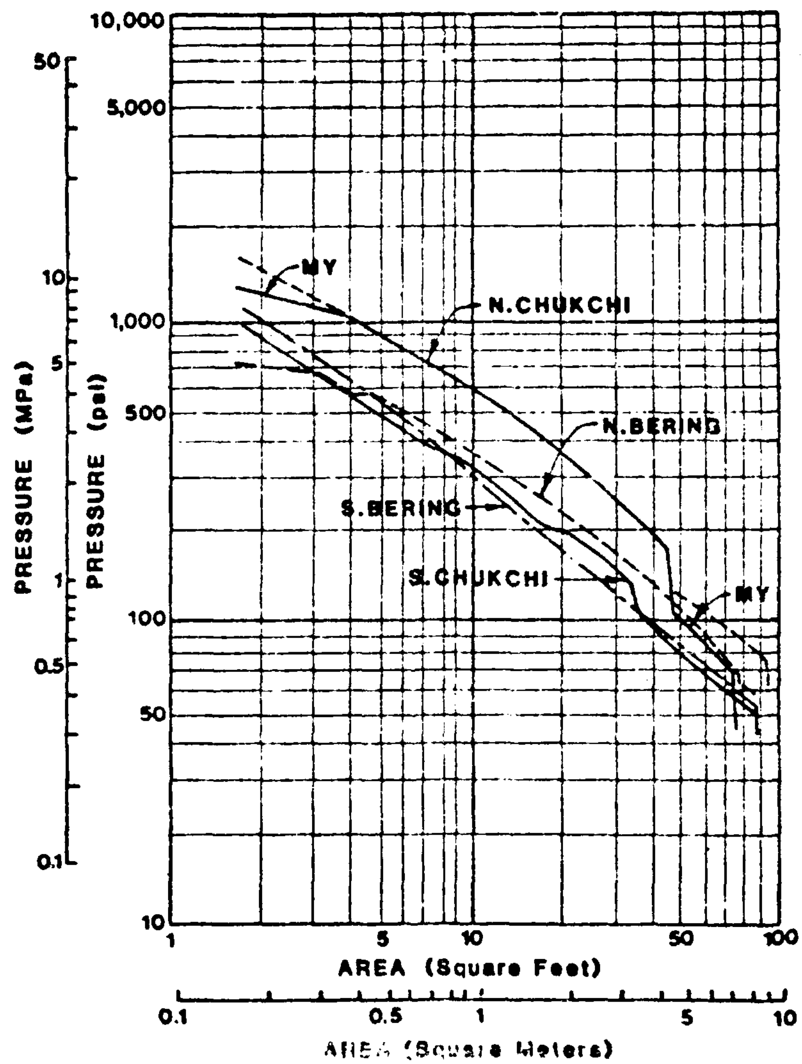


Figure 33

EXTREME ENVELOPE PRESSURE-AREA CURVES FOR EACH GEOGRAPHICAL AREA

8.4 Force and Peak Pressure as a Function of Observed Ice Conditions and Ship Speed

The winter deployment recorded 785 first year impacts for which observed ice conditions were recorded. These were recorded predominantly in the transit north to the operating area off Wainwright, however, some were recorded while moving from test area to test area in the Wainwright area and others on the transit south to Nome.

Figures 34 and 35 present the peak force recorded for each event as a function of observed maximum and average thickness, respectively. Level ice thicknesses up to 6 feet (1.8 m) and maximum thicknesses to 12 feet (36 m) were recorded. One can see that the peak force increases with ice thickness to a maximum at intermediate values of thickness as described in Section 8.3. At extreme ice thicknesses, the peak force decreases again. The highest forces in first year ice occurred at an average thickness of 1.5 to 2 feet (0.46 to 0.61 m) and a maximum thickness of 4 to 6 feet (1.2 to 1.8 m). The cause of the decrease in peak force is presumably due to speed effects. At extreme ice thicknesses, the ship was slowed to the point where an increasing trend in peak force does not occur. This could be due to the increased resistance or, more likely, the operator's perception of the increasing severity.

Figures 36 and 37 show the highest average pressure on a single subpanel as a function of the same ice thickness data. There is a slight trend for the pressures to peak at intermediate values of observed ice conditions. However, the trend is less distinct than that for the peak force. The "peak" in peak pressures at intermediate ice thicknesses is caused by a few events that are far higher than the bulk of the data.

During the northern transit to Wainwright, it was decided to add a channel of data to record ship speed directly with the strain data when an impact occurred. This modification was effective on April 8 when the ship reached the north Chukchi Sea. As a result, 351 events in first year ice conditions were recorded with the impact velocity of the ship. These data were all recorded in the Chukchi Sea. The peak force and the highest average pressure on a single sub-panel are presented versus speed in Figures 38 and 39. Peak pressure appears independent of ship speed (Figure 39). Peak force increases with increasing ship speed but again, as in the trend with ice thickness, the highest values of peak force are achieved at intermediate speeds of 7 knots (3.6 mps). A non-dimensional analysis of these data and the data collected during the dedicated multiyear ridge ramming are presented in Section 9.0. This analysis treats the combined effects of speed and ice thickness variation of peak force and peak pressure.

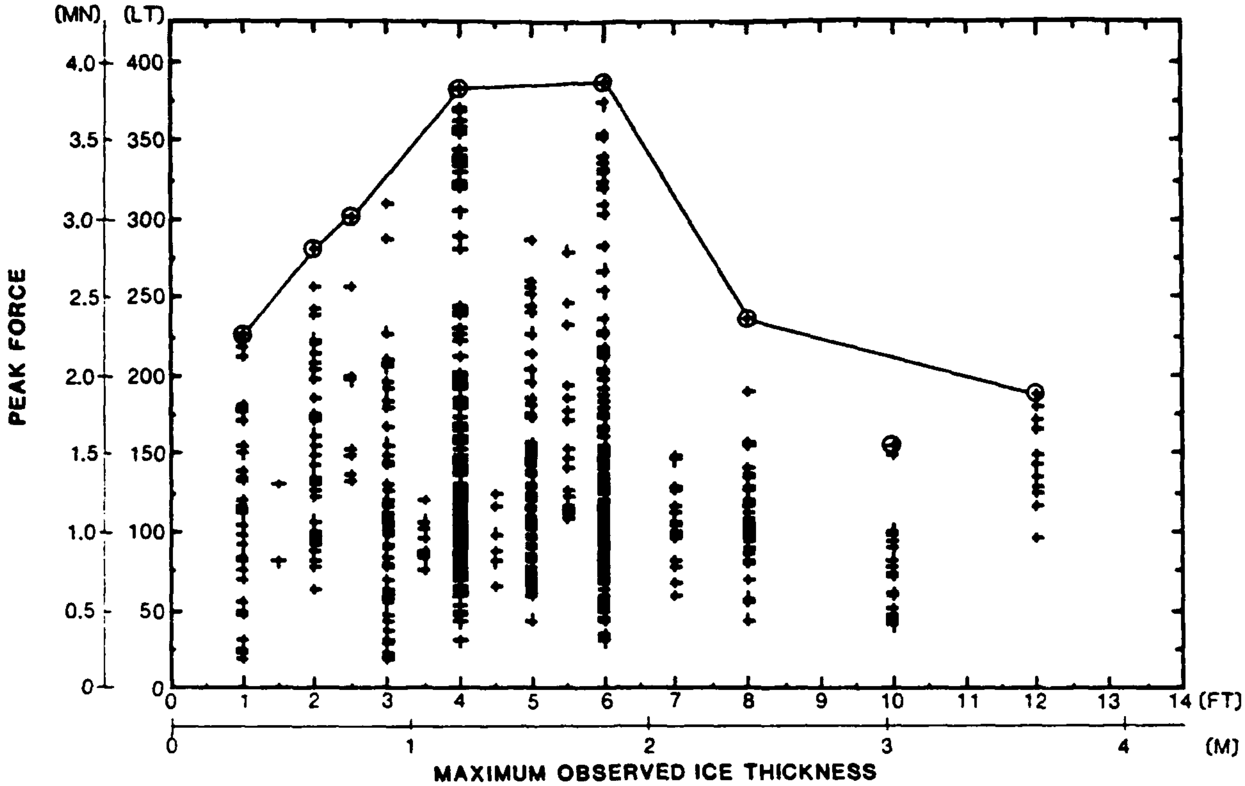


Figure 34

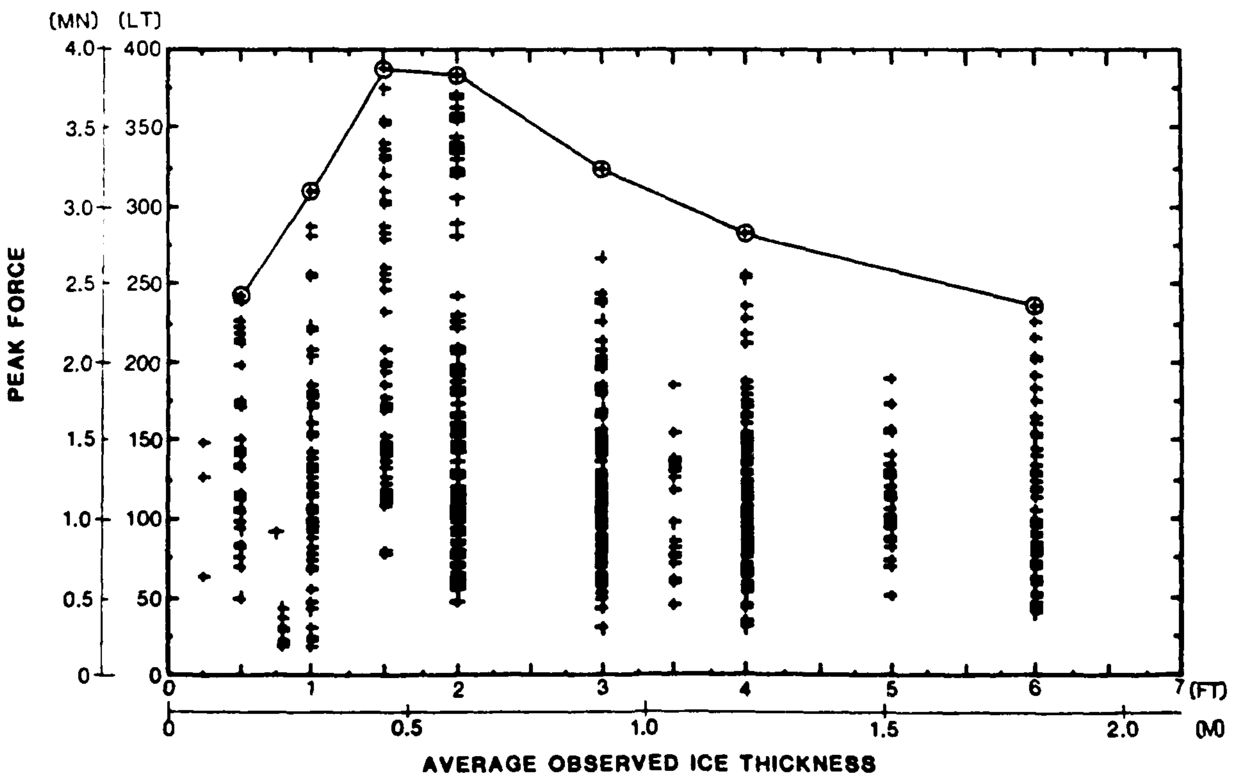


Figure 35

PEAK FORCE vs OBSERVED ICE THICKNESS FOR FIRST-YEAR IMPACTS

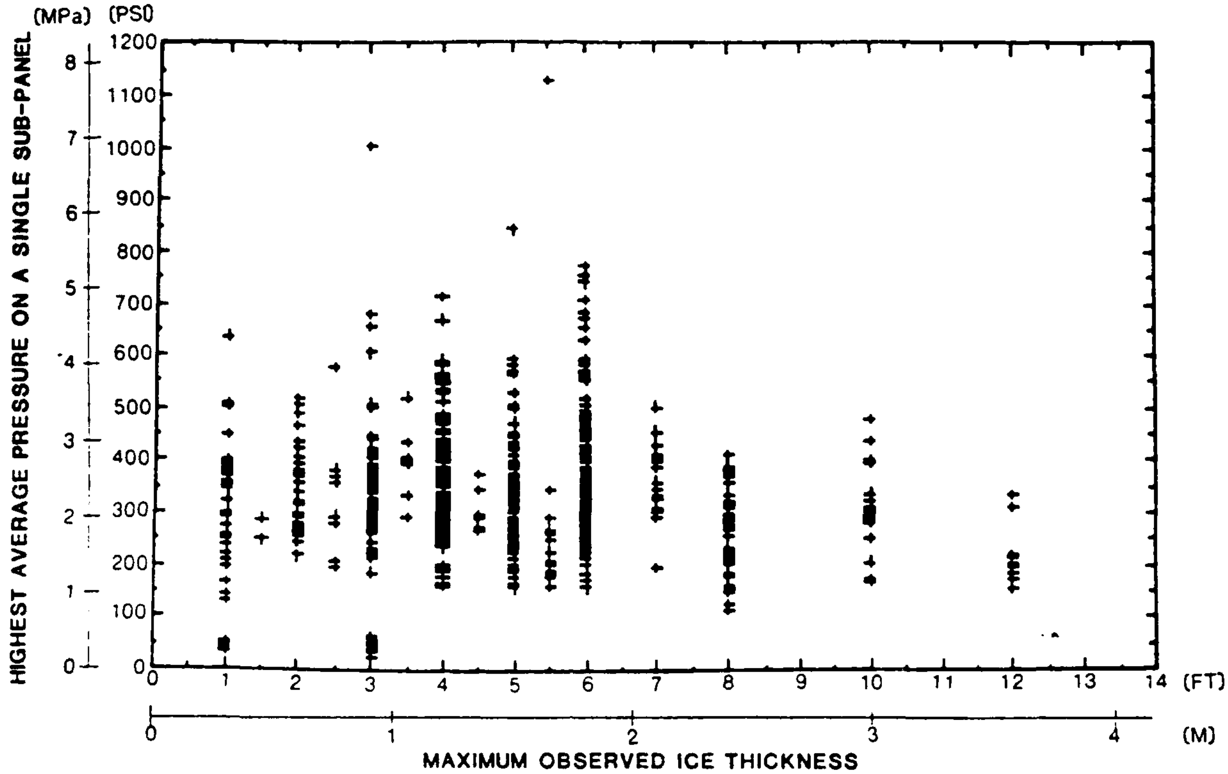


Figure 36

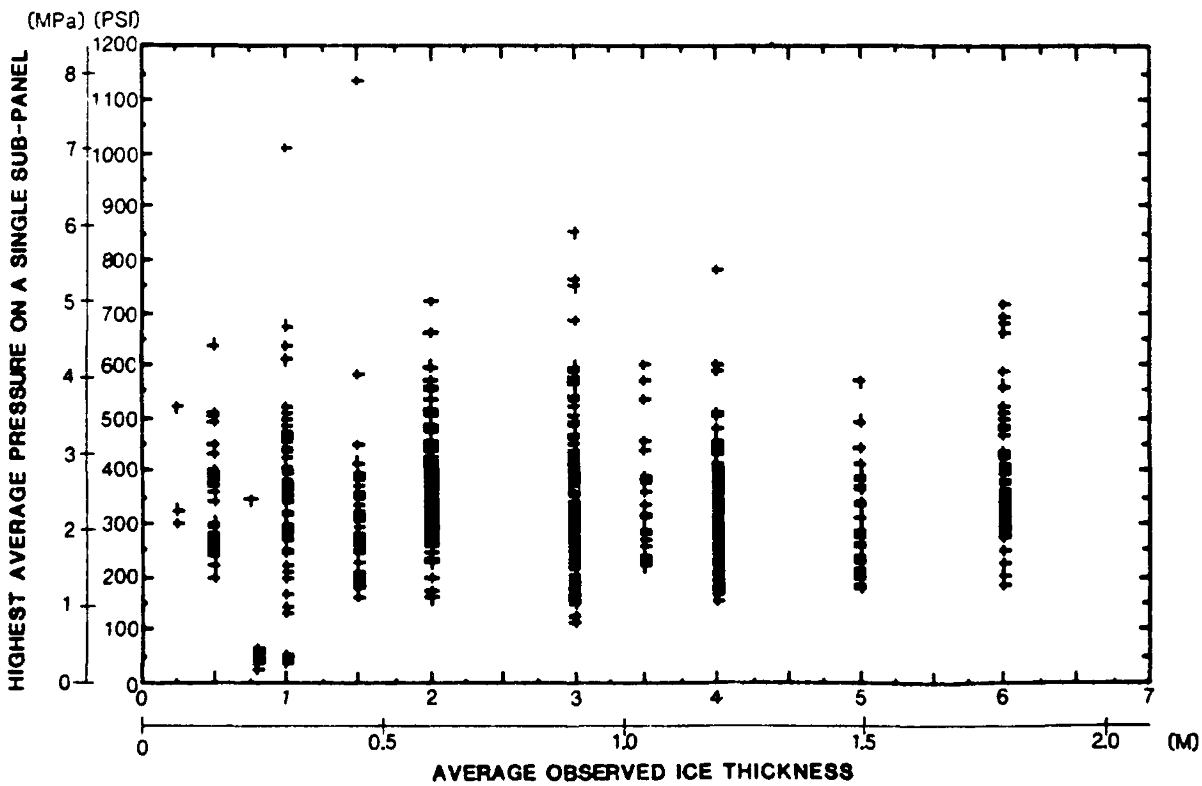


Figure 37

PEAK PRESSURE vs OBSERVED ICE THICKNESS FOR FIRST-YEAR IMPACTS

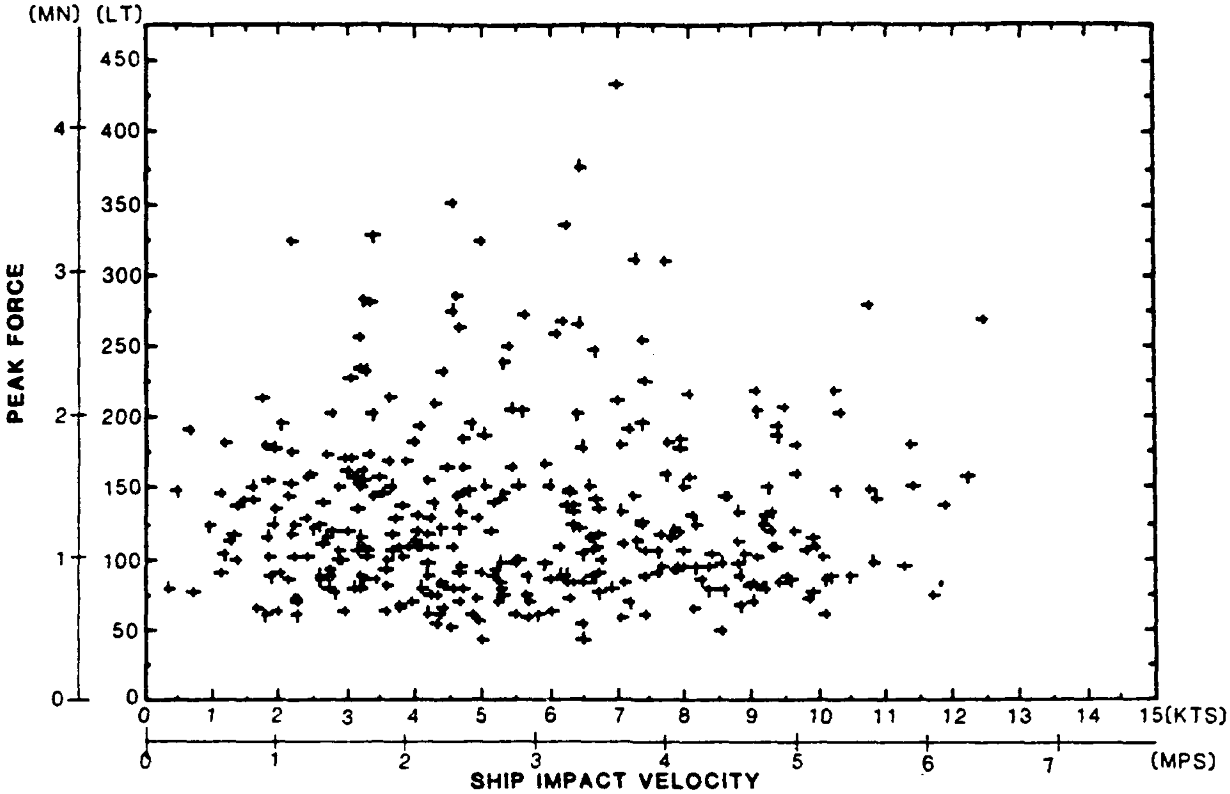


Figure 38

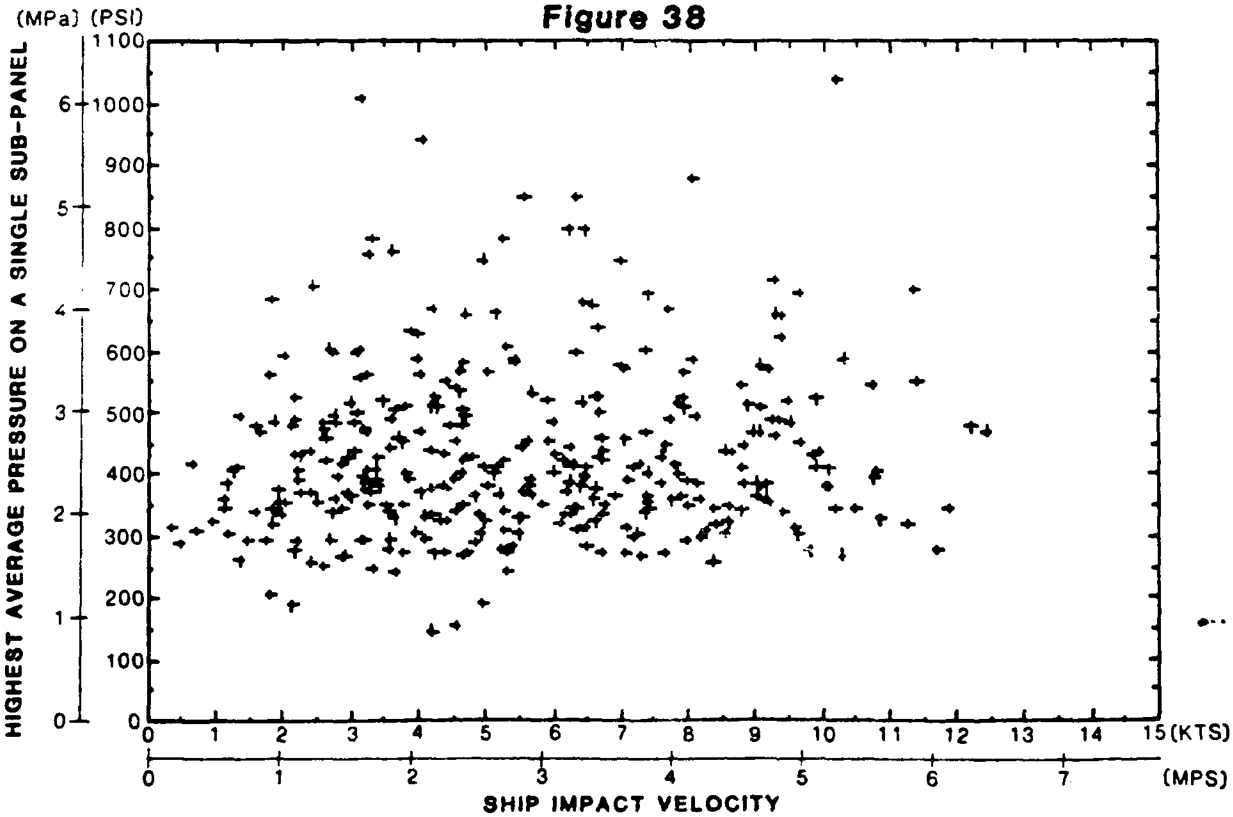


Figure 39

COMPARISON OF THE PEAK FORCE AND PRESSURE vs SHIP SPEED FOR FIRST-YEAR EVENTS

8.5 Dedicated Multiyear Ridge Ramming Tests

The POLAR SEA operated in the north Chukchi Sea off Wainwright from April 4 to April 26. During this time period, multiyear floes and ridges were located by helicopter reconnaissance. The ship would transit to an area with several ridges and dock in a floe. Environmental data collection would begin by surveying profiles along and across the crests of the ridges. Subsequently, holes would be drilled at regular intervals along these profiles to determine the consolidated depth. An upward-looking sonar and an electronic thickness measuring device aided the bottom profiling operation. A complete description of the data collection procedures and the collected data are presented in the 1983 Trafficability Report [16]. Ice cores were taken in each ridge and temperature-salinity data compiled for computing structural properties. Ice cores were also taken for a crystallographic analysis of the ice grain structure.

After the ridges were profiled, the ship transited through the ridges impacting the ice feature in a manner to cause high loads at the panel. Data were collected for 9 multiyear ridges with consolidated thicknesses up to 32.8 feet (10.0 m). All ridges failed in bending after multiple rams. The ridges were located in relatively small multiyear floes of less than 500 feet (150 m) in diameter completely constrained by a first year ice cover of approximately 5 feet (1.5 m) in thickness. A total of 61 events were recorded in the ramming of these 9 ridges. The data collected are summarized in Appendix F.

The multiyear events occurred at speeds up to 9 knots (4.6 mps). The peak force and highest average pressure on a single sub-panel are plotted as a function of ship speed in Figures 40 and 41, respectively. There is an upward trend of peak force with velocity throughout the whole speed range. It is interesting to note that the three peak events in Figure 40 at the low speeds occurred during the same ram on Ridge 11. The times of occurrence are shown in the figure for the peak events. Summaries of the data collected for individual events can be found in Appendix G.

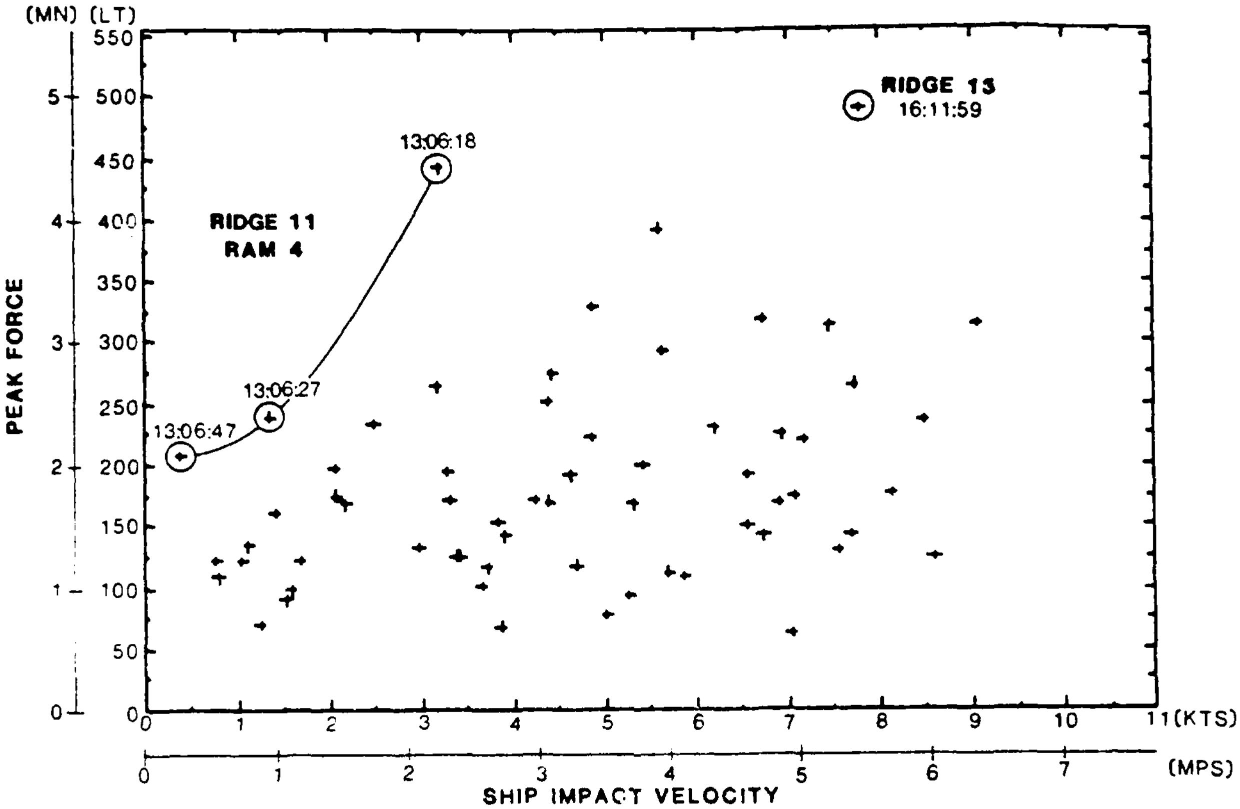


Figure 40

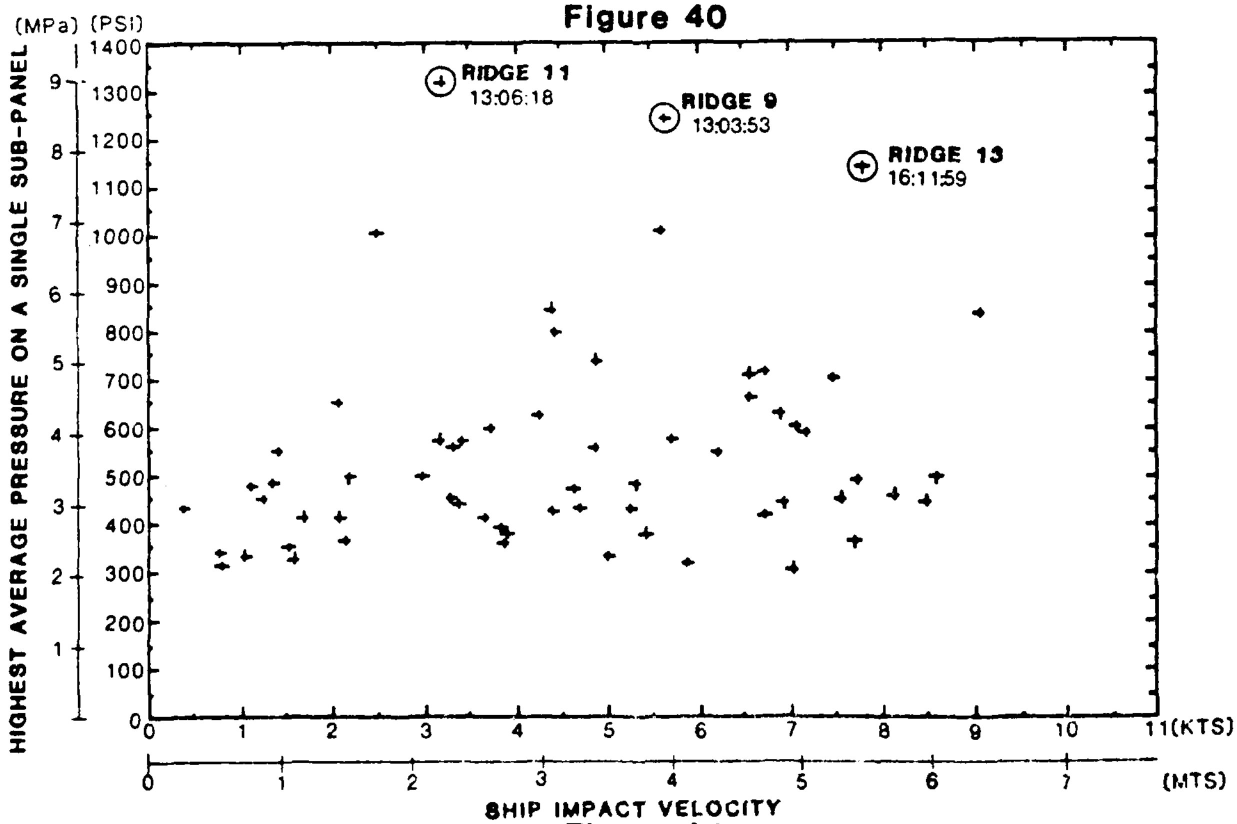


Figure 41

COMPARISON OF THE PEAK FORCE AND PRESSURE vs SPEED SHIP SPEED FOR MULTIYEAR EVENTS

9.0 NON-DIMENSIONAL ANALYSIS OF PEAK FORCE AND PRESSURE

Measured ship speed and observed ice conditions were both recorded for 151 first year events. These events occurred in the north Chukchi Sea between April 9 and April 30. During this time period, 15 first year ice cores were taken for which flexural and unconstrained crushing strengths have been calculated ([16] and Appendix H). The average of the nine cores taken in level ice was 95.9 psi (0.661 MPa) and 528 psi (3.64 MPa) for flexural and crushing strengths, respectively. These data are considered to be representative of the ice conditions for the impacts recorded. Six cores were taken in a large first year ridge on April 28 and showed much lower strengths. These data were not included in the average ice strengths.

Additionally, for the dedicated multiyear ridge rams, speed was recorded for all impacts. All but one of the ridges were completely profiled. The one ridge that was not profiled was directly between two other ridges that were profiled such that a good estimate of thickness can be made. Ice cores were taken in the area of each ridge such that flexural and crushing strengths could be determined for each ridge. Appendix I presents the thickness and strength data for each ridge. Flexural and crushing strengths averaged 121.5 psi (0.838 MPa) and 703 psi (4.85 MPa), respectively.

The 212 events described above represent an excellent data base for a non-dimensional analysis. The analysis presented here was limited to the non-dimensional relationships commonly presented in the literature. Comparison with other measured data is shown in Section 13.0.

The non-dimensional relationship between peak force (F^*) and the product of flexural strength (σ_f^*) and normal velocity (V_n^*) at the panel is shown in Figure 42. (All data are presented in Appendix L). Non-dimensional peak force is obtained by dividing the peak force (F) by the product of the weight density of seawater (ρg) and the cube of the ice thickness (h). Non-dimensional flexural strength is computed by dividing the strength (σ_f) by the product of the weight density of seawater and the ice thickness. Speed is non-dimensionalized by using a thickness based Froude Number multiplied by the direction cosine (ℓ) of an outward normal vector at the panel on an axis along the ship's centerline at the waterline. Investigators [17, 18] have found that the peak force follows the relationship:

$$F^* = C \left(\frac{1}{n}\right)^a \left(\sigma^* V_n^*\right)^b$$

where n is the direction cosine of an outward normal at the panel on a vertical axis in the ship's centerline plane, and

a, b, and C are constants.

The direction cosines, ℓ and n, can be related to the waterline half-angle at the panel (α) and the panel flare angle from the vertical (β) by the equations:

$$\ell = \tan \alpha \,/\, \sqrt{\tan^2 \alpha + \tan^2 \beta + 1} \qquad (5)$$

$$n = \tan \beta \,/\, \sqrt{\tan^2 \alpha + \tan^2 \beta + 1} \qquad (6)$$

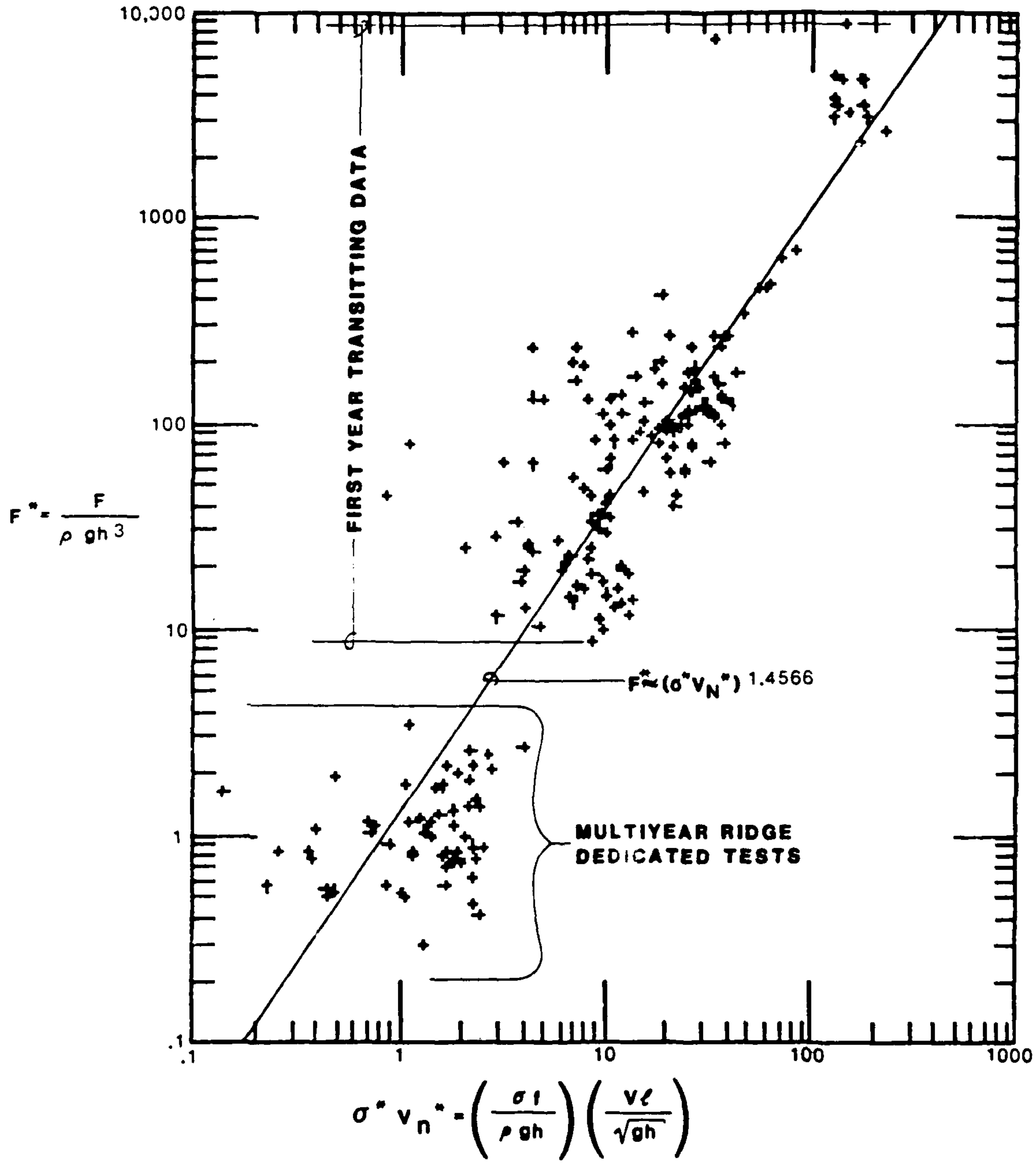


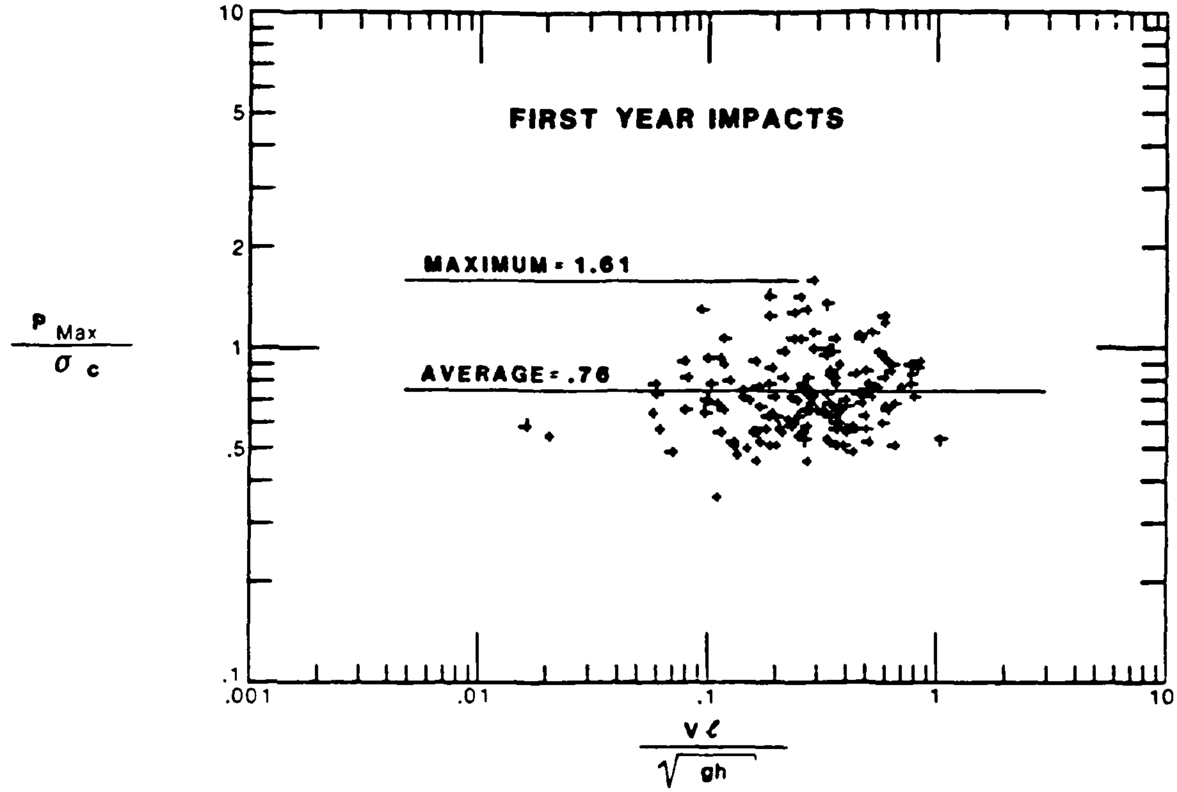
Figure 42

NON-DIMENSIONAL RELATIONSHIP BETWEEN FORCE AND NORMAL VELOCITY TIMES FLEXURAL STRENGTH FOR THE MEASURED DATA

For the panel location on the POLAR SEA, $\alpha = 30°$ and $\beta = 54°$. This gives values of 0.3 and 0.77 for ℓ and n, respectively.

Figure 42 shows that the coefficient b = 1.4655 fits the data well. The coefficient a cannot be determined since n is constant unless the data are compared with other ship data. It should be noted that the average value of flexural strength was used for all the first year data in Figure 42.

The peak pressure or the highest average pressure on a single sub-panel should be related to the crushing strength of the ice. In Figures 43 and 44 the peak pressures were non-dimensionalized by the crushing strength and plotted against the Froude Number normal to the panel. No speed effects are evident in this data. It should be noted that, as in the force relationship, the first year data uses the average crushing strength for all data. The peak values of non-dimensional pressure are 1.61 for first year ice and 1.99 for multiyear ice. The highest recorded event of 1640 psi (11.3 MPa) is not included in this data since speed was not measured for this event. This event would have a non-dimensional pressure of 3.11 using the average first year crushing strength. There is a good chance that this extreme event could have been caused by an impact with a small multiyear floe imbedded in heavy first year ice. If this were the case, the non-dimensional pressure would be 2.33 using the average value of compressive strength recorded for multiyear ice or 2.20 using the highest value recorded.



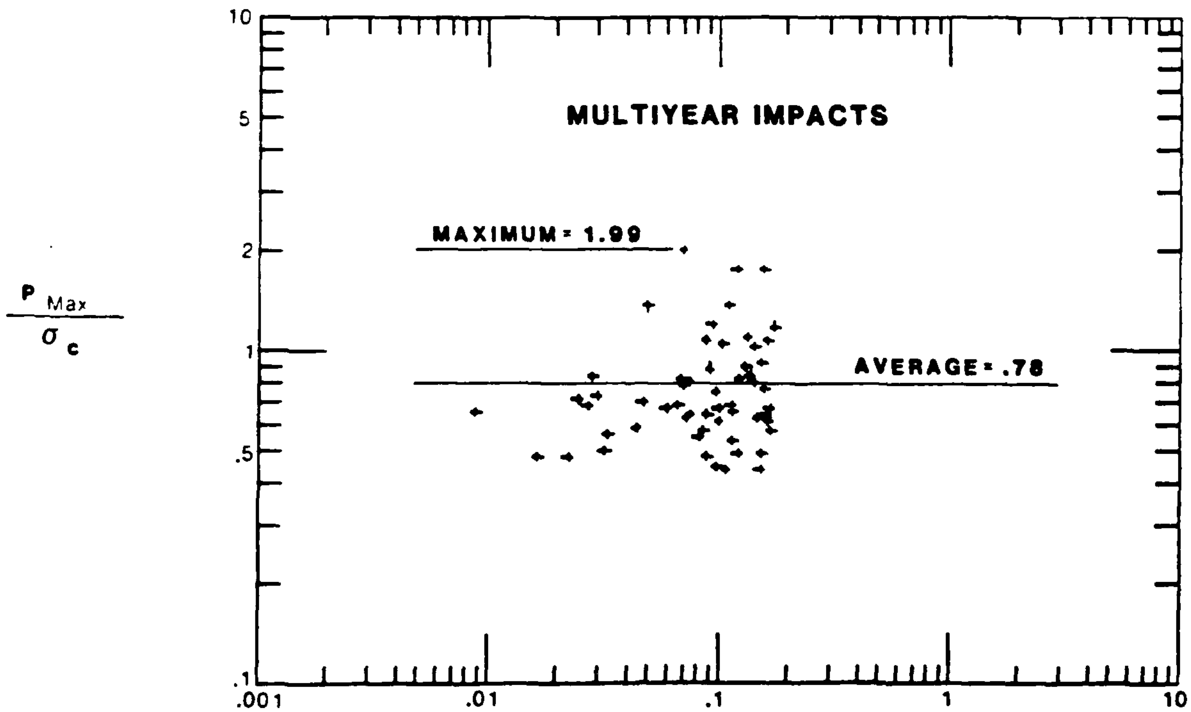


Figure 43 and Figure 44

NON-DIMENSIONAL RELATIONSHIP BETWEEN HIGHEST AVERAGE PRESSURE ON A SINGLE SUB-PANEL AND NORMAL VELOCITY

10.0 VARIATION OF THE PRESSURE-AREA RELATIONSHIP WITH TIME

Five events have been investigated in greater detail to better understand the variation of peak and average pressure and impact area with time. The events were selected from the highest 13 events on the basis of peak strain recorded in the north Chukchi Sea. All data are presented in Appendix J. One event, the event that recorded the highest single sub-panel pressure for a dedicated multiyear event, is presented in Figures 45 through 47.

Figure 45 presents an isometric plot showing the pressure-area curves changing in time for this event. The pressure and area axes are log scales. It is interesting to note the curves do not change too drastically from one time step to the next. The smoothness of the plot indicates that the sampling rate was sufficiently high. An oscillation of the peak pressure can also be seen, with a period of approximately 0.5 sec. Figures 46 anbd 47 show the peak pressure, the average pressure, and the total contact area versus time.

The events recorded were, of course, not controlled experiments and many unknowns exist. However, a particular question that arises is the relationship between average pressure and total area. Do confinement effects lead to increasing average pressures as the contact area grows? In Figures 46 and 47, there is a definite trend toward increasing average pressure as areas increase, suggesting a confinement effect. Three of the other four events exhibit the same trends. The event that recorded the highest single sub-panel pressure of all data, however, shows the reverse trend.

If confinement effects are taking place, this would suggest that large ships could experience much higher pressures, since larger contact areas could be experienced. A knowledge of the ice interaction process is necessary before the pressure-area relationships for large vessels can be fully understood.

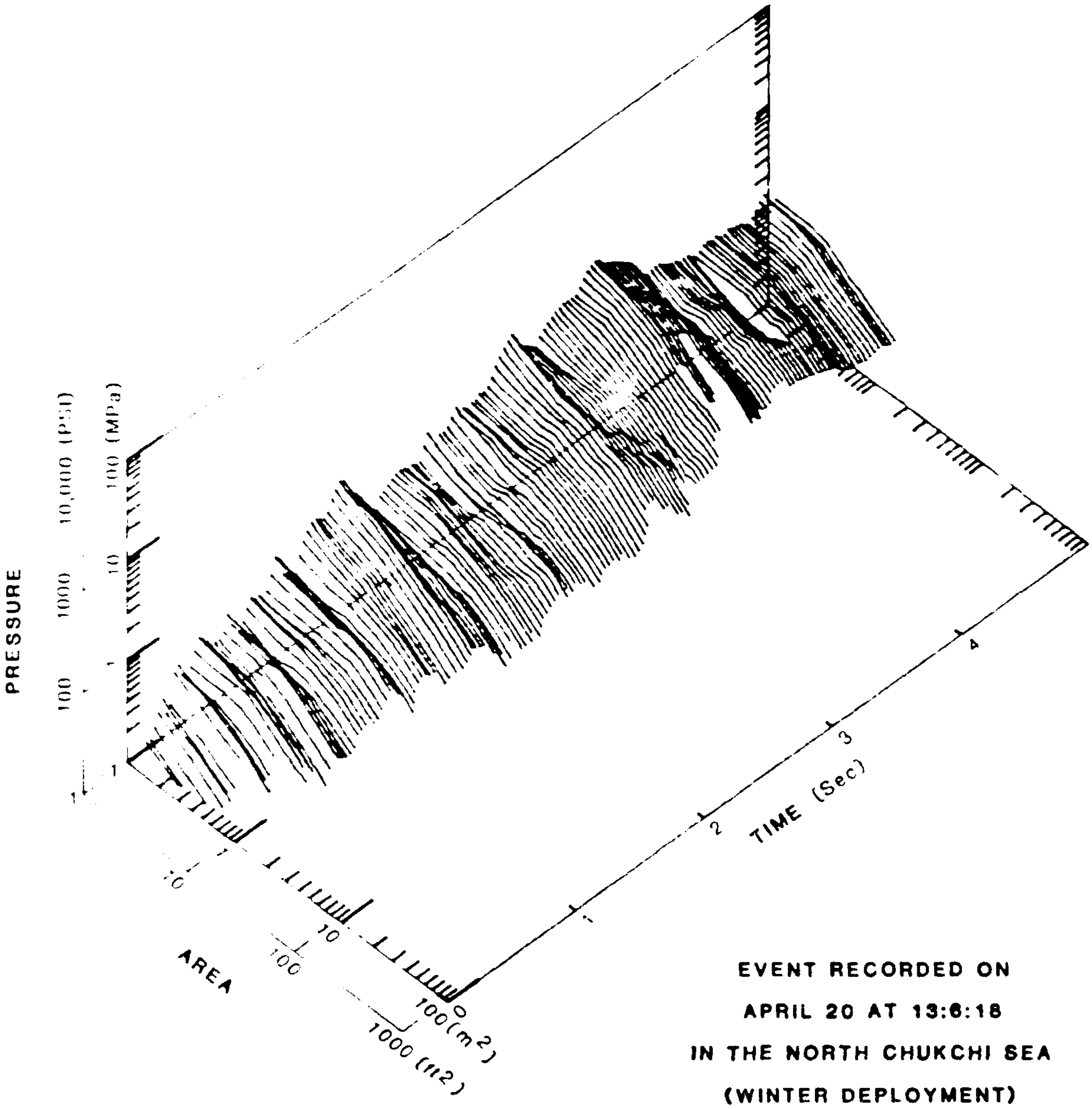
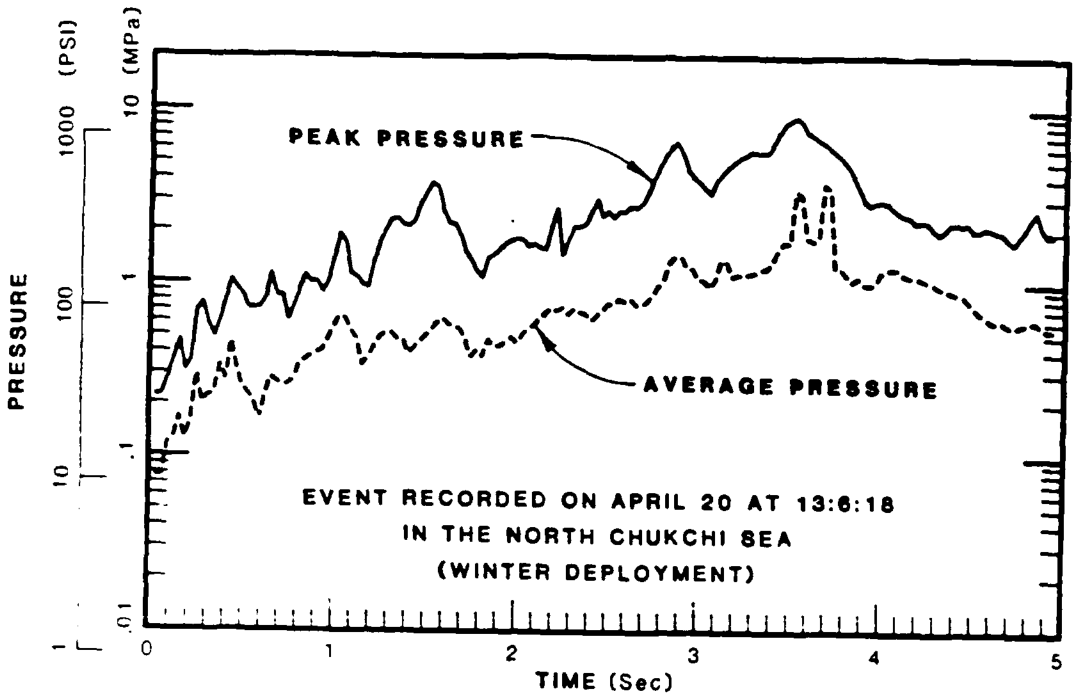


Figure 45
VARIATION OF THE PRESSURE/AREA CURVE WITH TIME FOR A SEVERE MULTIYEAR IMPACT



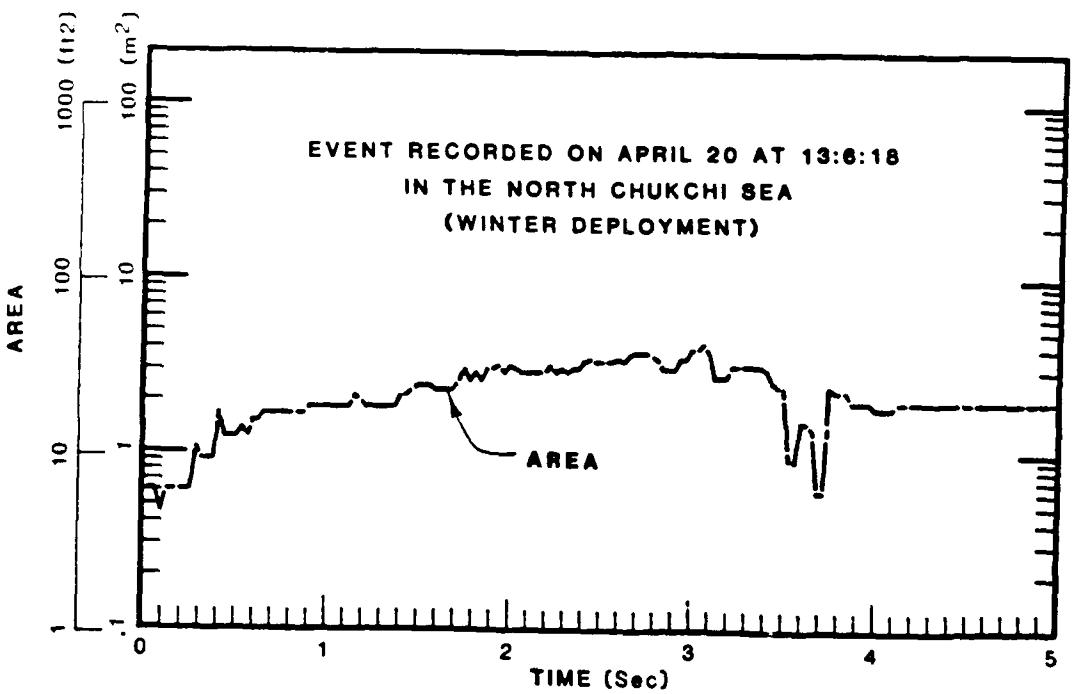


Figure 46 and Figure 47

VARIATION OF THE PEAK AND AVERAGE PRESSURE AND THE CONTACT AREA WITH TIME FOR A SEVERE MULTIYEAR IMPACT

11.0 STATISTICAL ANALYSIS OF ICE PRESSURES

11.1 Analysis of the Type of Extreme Value Distribution That Fits the Data

Ice pressure must be viewed as a random variable. For the purposes of structural design, the single extreme ice load occurring during a given time period is the critical load. Extreme value analysis provides a means of estimating expected maximums from measured data.

It is necessary to understand the rationale behind each distribution before one is chosen to represent the data. There are three common forms of extreme value distributions, TYPE I (also called GUMBEL), TYPE II, and TYPE III [20]. They represent the extreme values of three different types of random variables:

TYPE I - Values are unbounded both positively and negatively; represents the extremes of an additive process such as variables that are 'normally' distributed

$$F_Y(y) = e^{-e^{-\alpha(y-u)}} \tag{8}$$

TYPE II - Values are bounded by zero, but unbounded positively, represents the extremes of a multiplicative process, such as variables that are 'log normally' distributed

$$F_Y(y) = e^{-(u/y)^k} \tag{9}$$

TYPE III - Values are bounded in the tail of interest, such as minimum strength, or any phenomenon whose largest values have a physical limitation

$$F_Y(y) = e^{-\left[\frac{w-y}{w-u}\right]^k} \tag{10}$$

where $F_Y(y)$ = cumulative distribution function of the random variable Y (CDF)
u = mode of the distribution
α, k = constants
w = upper limit of y.

A portion of the data collected in the north Chukchi Sea was chosen for statistical analysis. Data from all 368 events collected between April 7, 1983 and April 24, 1983 have been included in the analysis. For each five second event, the extreme pressure for each area (1 to 60 sub-panels) was obtained. This was done by constructing a pressure-area curve from the highest of the two pressure-area curves developed for each event, the curve for the time of peak pressure on one sub-panel and the time of peak force on the entire area. Eleven areas (representing impact areas of 1, 2, 3, 4, 6, 8, 10, 15, 20, 30, and 60 sub-panels) were considered in the subsequent analysis of the extremes.

All pressures of the same area were ranked and assigned a probability according to the following formula:

$$F_p(p) = 1 - \frac{N}{369} \tag{11}$$

where $Fp(p)$ = CDF of ice pressure (p)
N = rank of p

The probability of the peak pressure is therefore:

$$F(\text{peak}) = 1 - \frac{N}{369} = .997 \tag{12}$$

The data were plotted on extreme value type probability paper (Figure 48) such that TYPE I extreme value equations are represented by a straight line. A more detailed view of the distributions for the larger areas is shown in Appendix K. The dashed lines in the figure are TYPE I equations as a function of area that have been fitted to the data.

These equations take the following form:

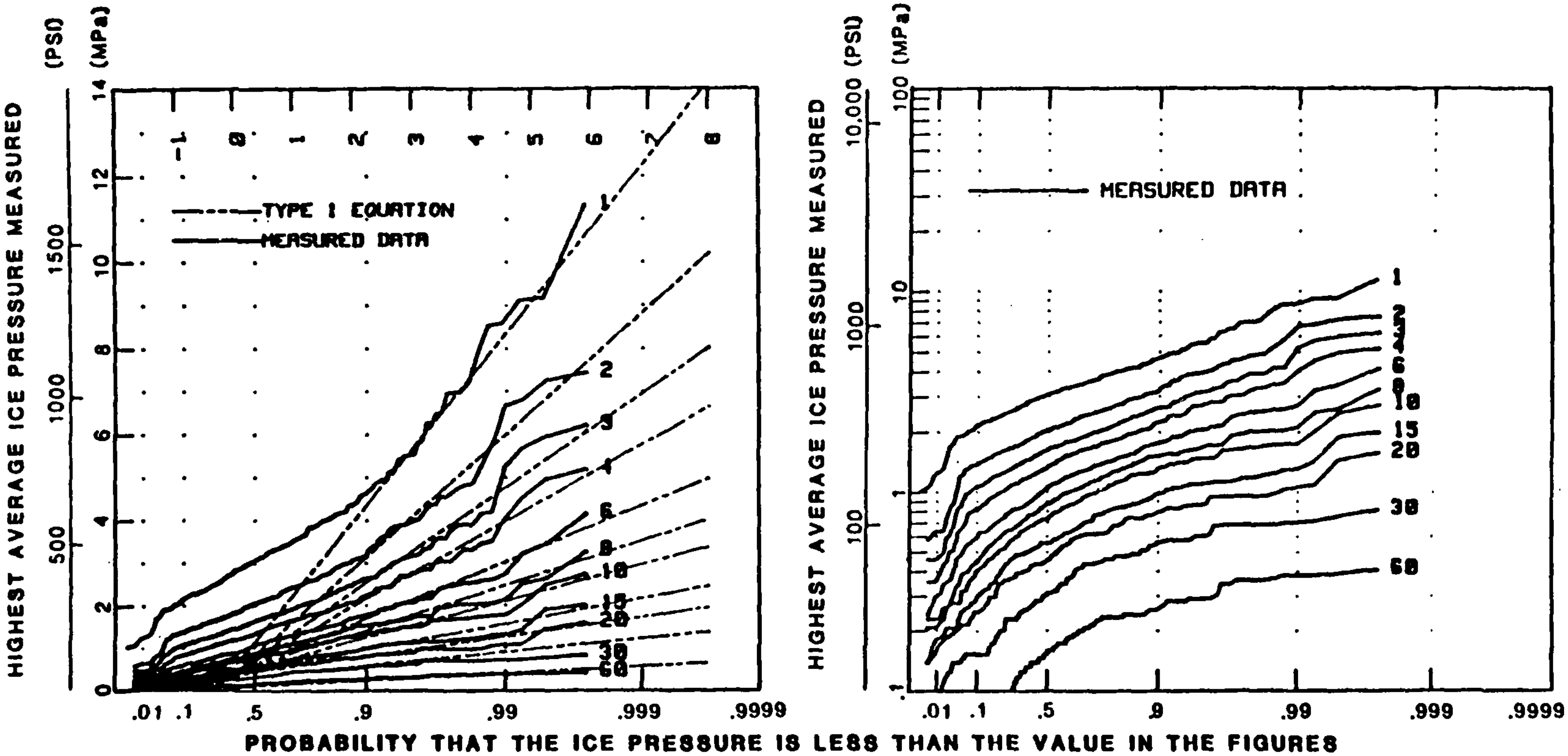
$$Fp(p) = e^{-e^{-\alpha(p-u)}} \tag{13}$$

where p = ice pressure (MPa)
$u = C_1 A + .5$
$\alpha = C_2 A + .35$
A = impact area
$C_1 = -.046$, $C_2 = 1.563$ for area in square meters
$C_1 = -.00428$, $C_2 = 0.145$ for area in square feet

It can be seen that while Equation 13 above fits the data in the upper region, it does not fit well in the lower region, especially for the smaller areas. This can be explained by the fact that the equation is meant to fit the extremes, not necessarily all the data.

Figure 49 represents the same body of data plotted as if it were TYPE II extreme value distribution (a straight line on this type of paper is a TYPE II distribution). Clearly the TYPE II cumulative distribution function (CDF) of the single sub-panel pressures fit very well. Refer again to Figure 48 and note that the TYPE I equation appears to fit the large areas very well. It appears that the nature of the distribution may change as the area grows, with small areas following a TYPE II (multiplicative process) distribution while large areas follow a TYPE I (additive process) distribution. This could be explained by the fact that the large area pressures represent the sum of many small area pressures. Conversely, pressure on a very small area results when the weakest (not average) layer in the adjacent ice fails.

An understanding of the physics of the ice failure phenomena would help to clarify which type of distribution is correct. It is quite important to know which is correct because, while the TYPE I distribution results in a one year extreme pressure of 2320 psi (16 MPa) and a ten year extreme pressure of 2900 psi (20 MPa), the TYPE II distribution predicts a one year extreme of 4060 psi (28 MPa) and a ten year extreme of 7100 psi (49 MPa). For the purposes of further analysis of TYPE I distribution, Equation 13 is assumed to be valid.



NUMBER OF SUB-PANELS	AREA FT^2	AREA M^2	NUMBER OF SUB-PANELS	AREA FT^2	AREA M^2
1	1.63	.152	10	16.5	1.52
2	3.26	.303	15	24.5	2.27
3	4.90	.455	20	32.6	3.03
4	6.53	.606	30	49.0	4.55
6	9.79	.910	60	97.9	9.10
8	13.1	1.21			

Figure 48
TYPE I (GUMBEL)

Figure 49
TYPE II (LOG EXTREME VALUE)

COMPARISON OF THE HIGHEST AVERAGE PRESSURES RECORDED FOR 363 EVENTS IN THE NORTH CHUKCHI SEA TO AN EXTREME VALUE DISTRIBUTION FOR DIFFERENT IMPACT AREAS

11.2 A Pressure-Area Relationship Based on Probability

The data shown in Figure 48 can be plotted in another format, of more use to the ship designer. A vertical line in Figure 48 gives a number of pressures and areas of equal probability. Figure 50 compares the measured data to Equation 13 for four levels of probability from .5 to .997. The equation fits the data quite well and allows for extrapolation to higher, less likely, pressure-area curves. Figure 51 shows the same equation extrapolated to a probability of .99999 (approximately equivalent to ten years of continuous operations in conditions similar to those seen in the north Chukchi Sea).

The curves shown in Figure 51 can be described by reworking Equation 13 into the form:

$$P(A) = C_1 + .5 - \frac{\ln(-\ln(Fp(p))}{C_2 A + .35} \quad (14)$$

where $P(A)$ = pressure as a function of area
$Fp(p)$ = probability of not exceeding P.

As described above, the data presented here were collected over a two week period and consisted of 368 events. An event was triggered when one of the cells exceeded a strain of 150 $\mu\varepsilon$ (approximately 300 psi (2 MPa)). To use this data for prediction purposes it is necessary to relate the severity of this data to another vessel. One way would be to convert on the basis of the number of impacts. However, since it is very difficult to estimate the total number of all discrete impacts for any vessel, total time will be used. Since this data represents two weeks of data, the level of the CDF can be expressed in terms of the total number of weeks operating (in similar conditions):

$$Fp(p) = 1 - \frac{1}{184.5N} \quad (15)$$

where N = number of weeks
i.e., 10 years = 520 weeks; $Fp(p)$ = .99999

It would be ideal to generalize this data by knowing how many impacts any given ship is likely to encounter. There are so many variables involved that this would prove nearly impossible. The eventual solution will be reached when considerably more ice impact data exists for a full range of ships.

Equation 14 and Figure 51 should be used with discretion. They are only valid for the range of areas, probabilities, and conditions covered in this study. Extrapolation beyond the bounds of the data is not advised, due to the limited amount of impacts used in the analysis compared to the number of impacts that a ship would experience in its lifetime.

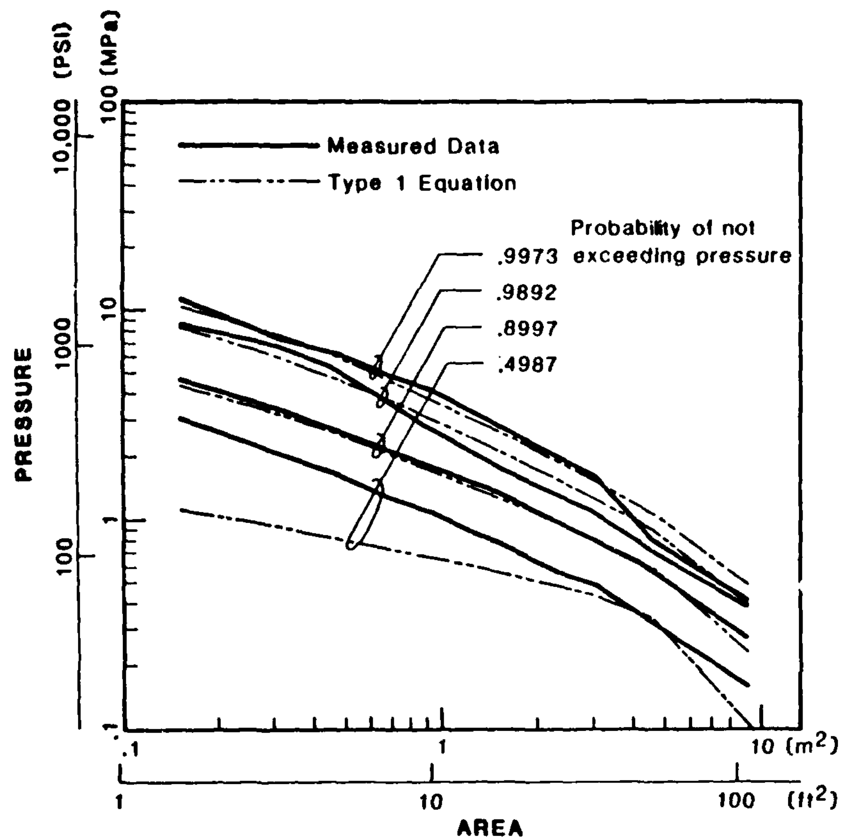


Figure 50

COMPARISON OF MEASURED AND CALCULATED PRESSURE-AREA CURVES FOR EQUAL PROBABILITY

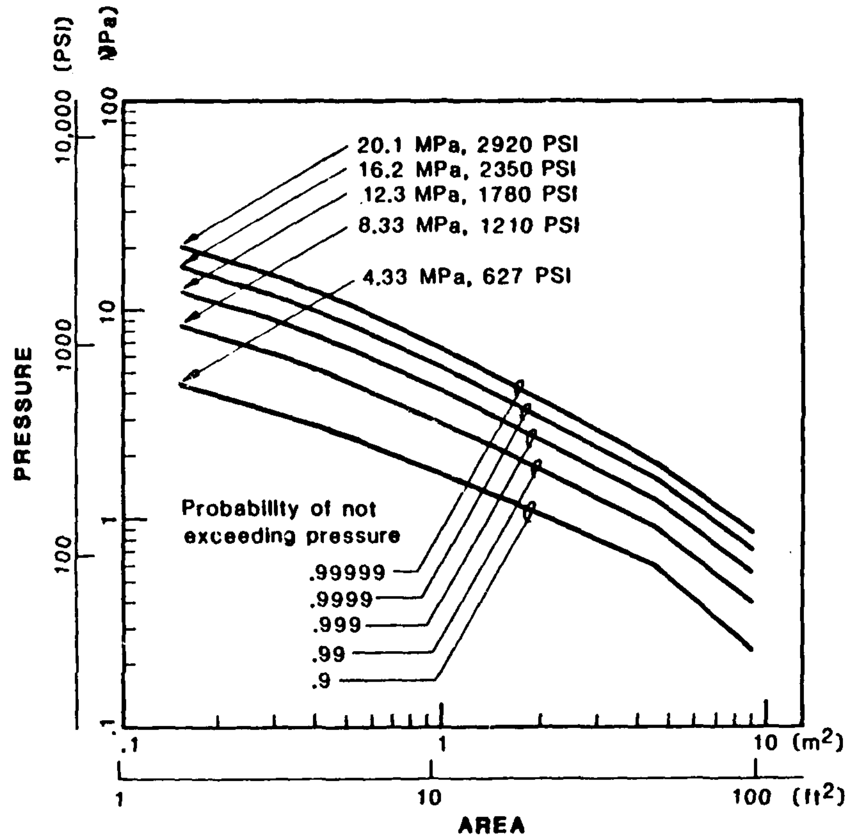


Figure 51

CALCULATED PRESSURE -AREA CURVES FOR EQUAL PROBABILITY COMPUTED FOR LONG RETURN PERIODS

12.0 COMPARISON WITH OTHER MEASURED DATA AND CLASSIFICATION SOCIETY DESIGN PRESSURES

The results of the non-dimensional analysis of force versus flexural strength and ship speed presented in Section 9.0 have been combined in Figure 52 with data from tests on three other ships; the LEON FRAZER [17], the CCGC NORMAN MCLEOD ROGERS [18], and the USCGC MACKINAW [19]. Just the envelopes of the other measured data have been presented, however, these represent individual force measurements for a variety of different ice conditions. One can see there is good agreement with the previously collected data. As shown in Figure 52, the mean regression line of the POLAR SEA measured data with an exponent of 1.4566 seems to fit the other measured data well.

Comparisons of the extreme envelopes of both the summer and winter data with other measured pressure data are shown in Figure 53 [6, 7, 10, 11, 12, 21, 22]. The ice conditions, test conditions, and the geographical area of the tests varied considerably among the data; however, the comparison is an interesting one. It indicates the range of areas over which this research project was able to gather pressure data, compared with previous efforts. With the exception of the damage incident on the MV ARCTIC [7], the data would indicate a decreasing trend in pressure and force with ship size. This trend is contrary to the expected trend and, in this case, presumably results from the ice and test conditions. The KIGORIAK was tested to a point beyond the yield of the hull structure by repeated rams into the same bow-print in thick multiyear ice [21]. The MANHATTAN data were collected while transiting in weak summer ice [12]. It is not surprising that the current data falls between these two when the conditions during the tests are considered. Even considering the test conditions, however, the data would most likely indicate that the peak pressure is not a strong function of ship size.

Figure 54 shows the envelope curves for the summer and winter deployments plotted against the design pressures recommended by various Classification Society Rules [4, 23, 24], the proposed CASPPR Ice Class 10 Rule of Johansson [1], and Tunik's proposed A5 Rule [25], which presumably describe the recent ABS efforts towards high Arctic rules development. Johansson's proposed rule is a function of ship displacement and power and has been calculated using the appropriate values for the POLAR Class. The new Soviet Rules [23] and Tunik's proposed rules are a function of the position on the hull and the ship size and displacement. These have been calculated at the location of the panel for the POLAR SEA.

The CASPPR Ice Class 10 [4], Tunik's proposed rules, and the Soviet Rules agree well with each other and with the measured pressures at small areas. It should be noted that average pressures on a single sub-panel exceeded those design pressures by 100 to 150 psi (0.7-1.0 MPa) on two occasions in the eight weeks of data collection. Tunik's proposed rules and the Soviet Rules do not treat the decrease in pressure with increasing area. They do calculate a length over which the pressure acts which is approximately 2.7 feet (0.8 m). The CASPPR frame design pressures appear more conservative when compared with the measured data than those for the plating. Johansson's proposed rules are much higher than the measured data at large areas and do not converge to a constant force as the measured data would indicate. In summary, there is good agreement between the CASPPR and the Soviet Rules and the measured data. This is surprising since one would expect the measured data to be below the design pressures. The rules do not address the higher area pressures so conclusions cannot be drawn.

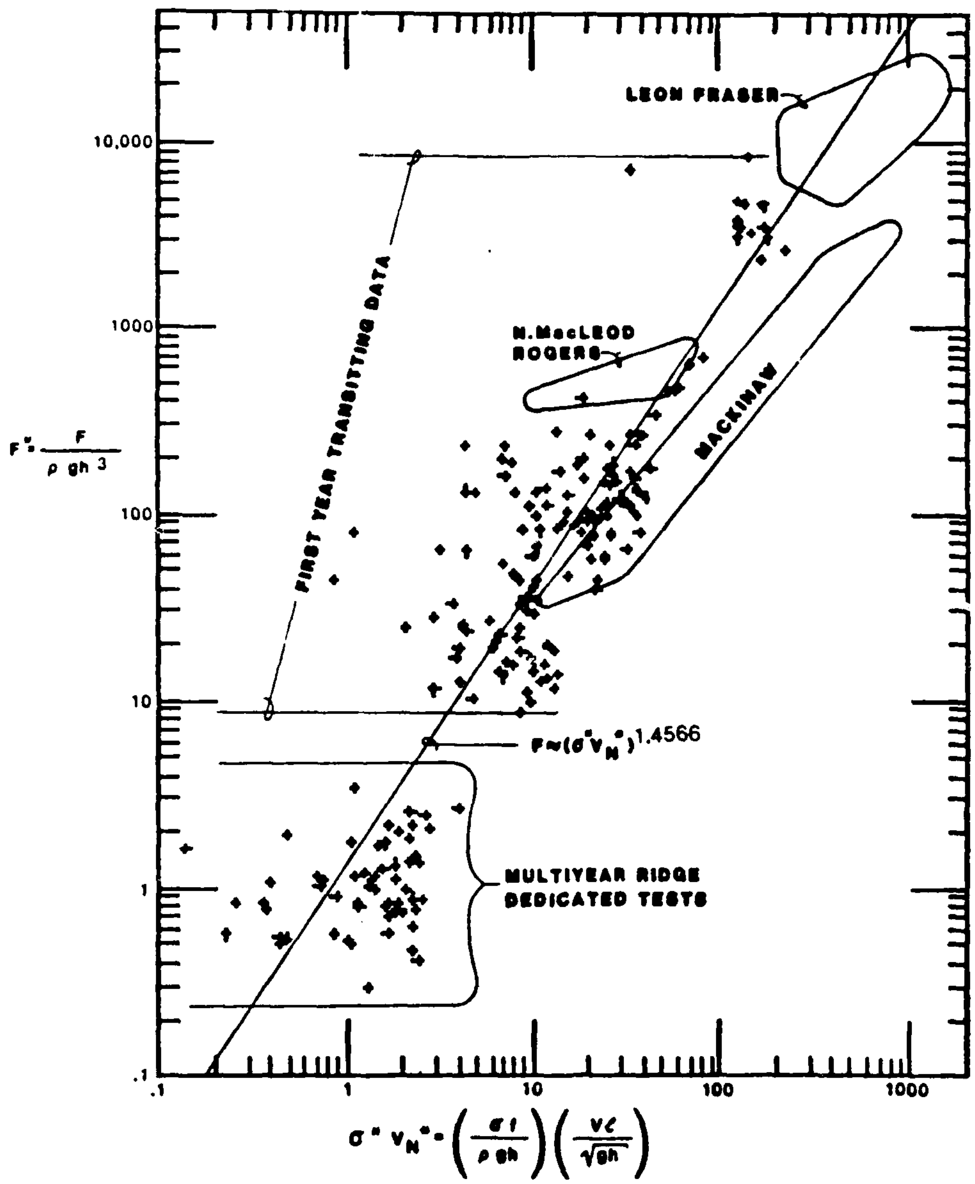


Figure 52

COMPARISON OF NON-DIMENSIONAL FORCE RELATIONSHIP WITH OTHER MEASURED DATA

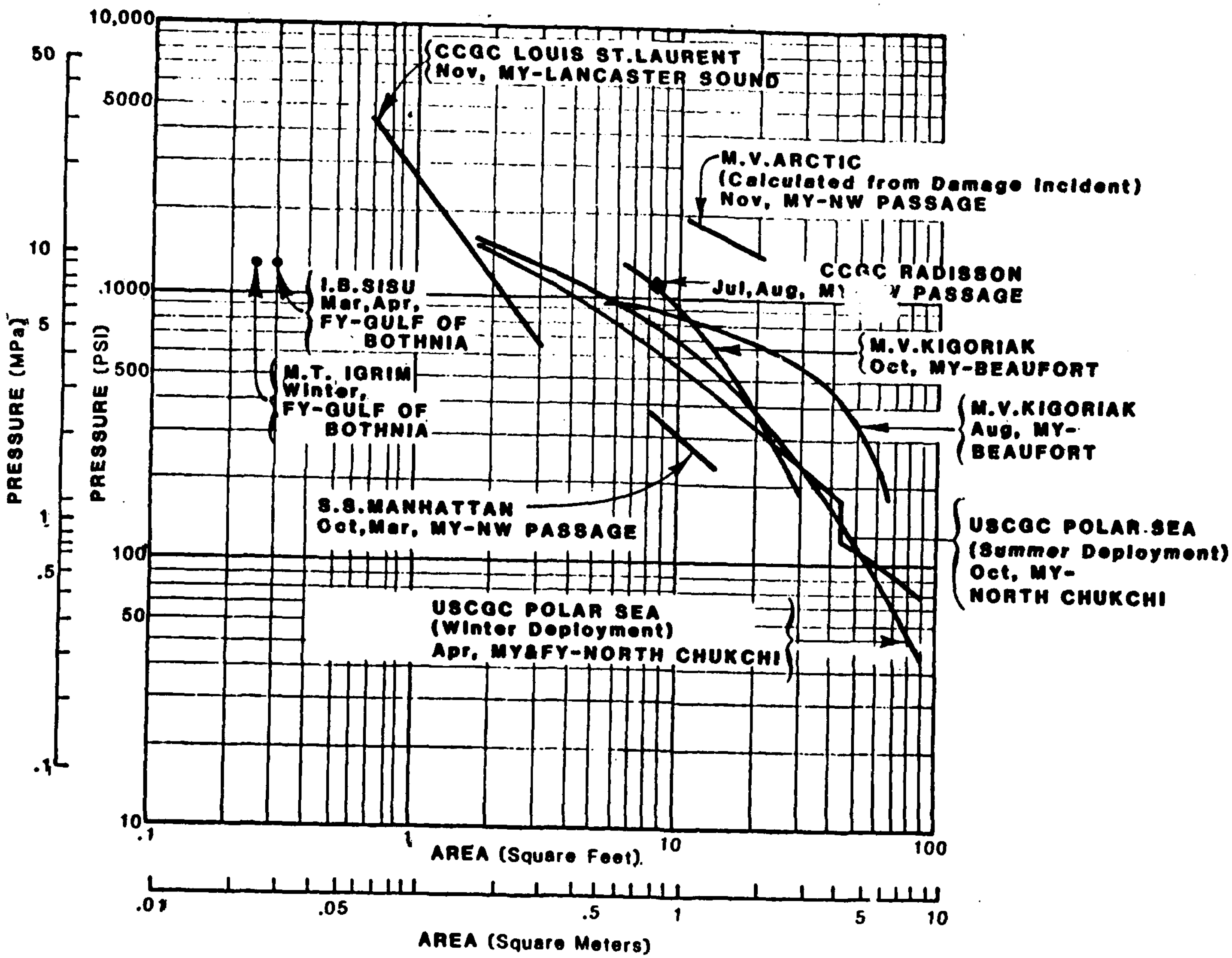


Figure 53

COMPARISON OF THE EXTREME ENVELOPES OF VARIOUS MEASURED DATA

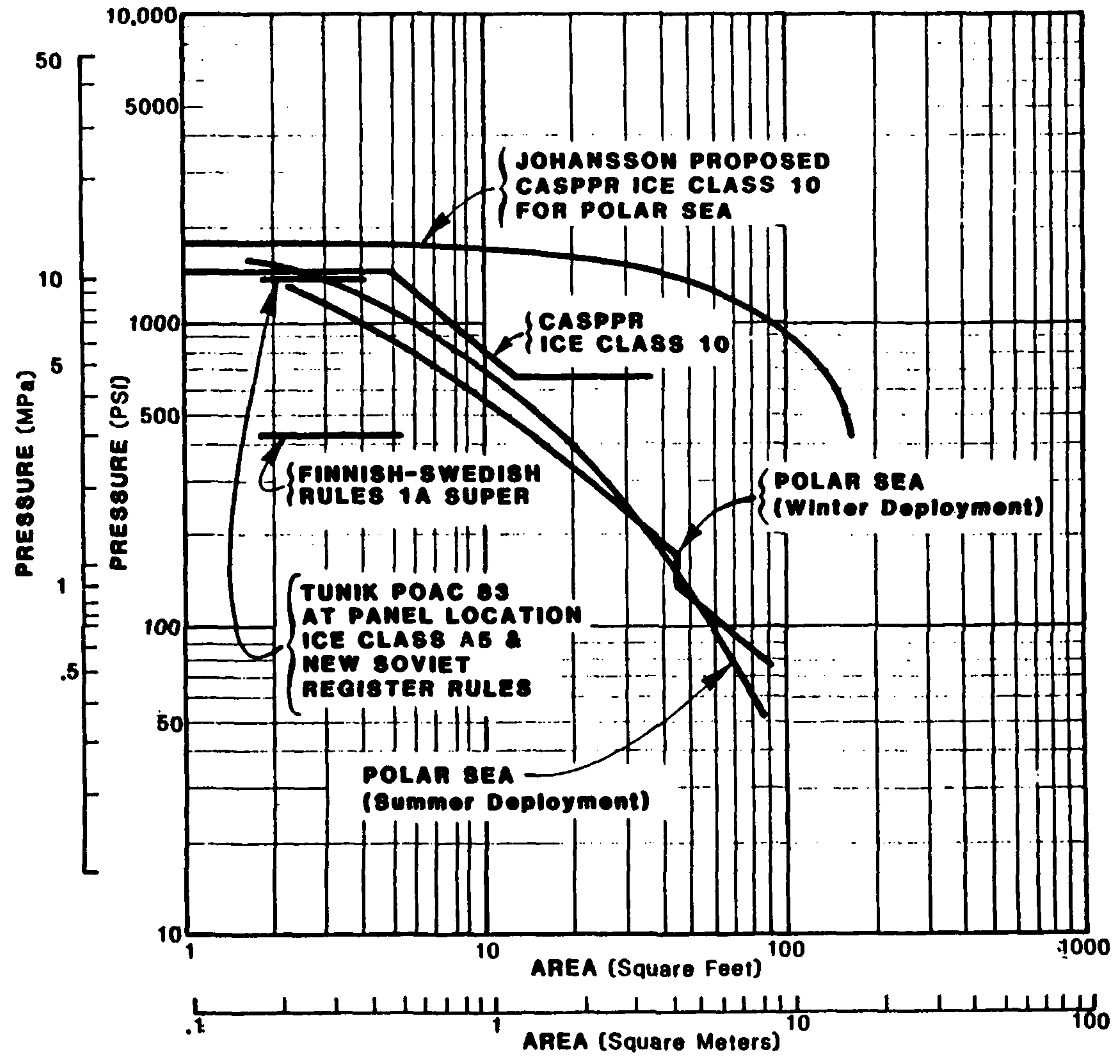


Figure 54

REGULATION DESIGN PRESSURES
WITH EXTREME ENVELOPE FOR THE COMPARISON OF MEASURED DATA

13.0 A RATIONAL PROCEDURE FOR DETERMINING ICEBREAKING SHIP DESIGN PRESSURES

The non-dimensional analysis of Section 9.0 has confirmed previous analyses that the peak force in an impact is related to the flexural strength, ice thickness, and the normal velocity at the impact location. The relationship that fits measured data appears to be:

$$\frac{F}{\rho\, g\, h^3} = C_1 \left[\left(\frac{\sigma_f}{\rho\, g\, h}\right)\left(\frac{V_\ell}{\sqrt{g\, h}}\right)\right]^{1.4566} \qquad (16)$$

Similarly, the highest average pressure over one sub-panel can be relat 1 to the unconstrained crushing strength by a factor that is a function of the level of confinement during the impact. The non-dimensional analysis of Section 9.0 also shows that this factor is independent of the thickness-based Froude Number.

The pressure-area curves presented throughout this study, either for a single impact or for the extreme envelope of many impacts in a geographical area, exhibit a decreasing trend in highest average pressure with increasing area. Further, the envelope curves can be described in most instances by a limiting pressure and force when plotted on a log-log scale (see Figure 55).

It is postulated that the rational design pressure-area curve should be developed from these two values, the expected peak force, and the expected peak pressure during the ship's lifetime (see Figure 55). From the work of Sections 9.0 and 11.0, it appears that these two values can be generated for any ship as a function of expected ice conditions, ship speed, and location along the hull. That is not to say that the current body of data is adequate to generate design pressures for all ships. What is proposed is a framework to generate design pressure-area curves based on ice and ship parameters that directs further research and data collection toward a useful result.

The extremes of the data presented in Figures 42, 43, and 44 can be analyzed for an extreme value distribution similar to the work of Section 11.0. For Equation 16, the coefficient C_1 can be expressed as a function of probability from lines parallel to the mean regression line through the extremes in the data (see Figure 56). The probability for each line is obtained by the rank of the data point divided by the number of points measured. A similar analysis can be done for the data in Figures 43 and 44 following the equation:

$$\frac{P}{\sigma_c} = C_2\ (P) \qquad (17)$$

If the data are normally distributed about the mean regression line,one would expect the coefficients C_1 (P) and C_2 (P) to follow a TYPE I (Gumbel) distribution. Figure 57 presents the two coefficients plotted on TYPE I probability paper.

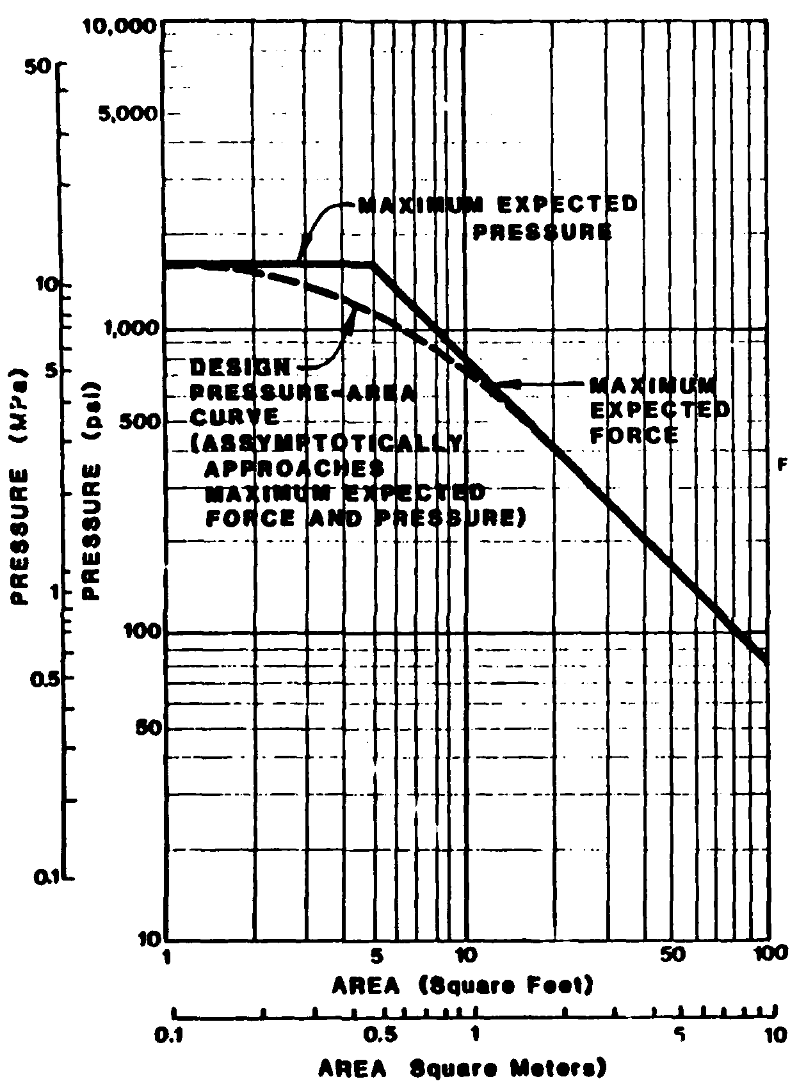


Figure 55

EXAMPLE DESIGN CURVE GENERATED FROM A MAXIMUM EXPECTED FORCE AND PRESSURE

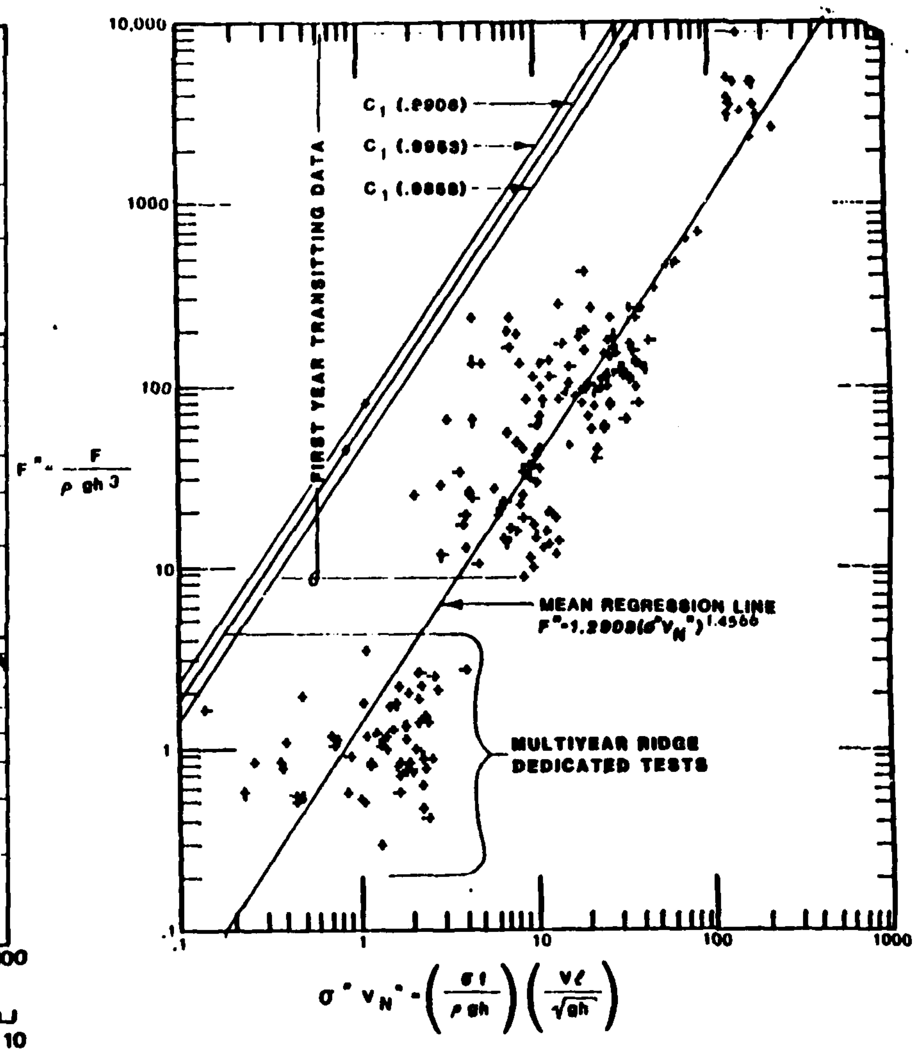


Figure 56

ILLUSTRATION OF THE COEFFICIENT C_1 AS A FUNCTION OF PROBABILITY

Summarizing the procedure for developing the design pressure-area curve, the maximum expected force (F_0) and pressure (P_0) are related to the expected (design) ice conditions (ice thickness, flexural strength, and unconstrained crushing strength), the ship shape factors (local waterline half-angle and the local flare angle), the ship speed, and the return period by the following equations.

$$\frac{F}{\rho\ g\ h^3} = C_1\ \left[\left(\frac{\sigma f}{\rho\ g\ h}\right)\left(\frac{V\ell}{\sqrt{g\ h}}\right)\right]^{1.4566} \quad (16)$$

$$\frac{P}{\sigma_C} = C_2\ (P) \quad (17)$$

$$C_1\ (P) = 0.6278\ (2.5542)^{-\ell n\ (\ell n\ \frac{1}{P})} \quad (18)$$

$$C_2\ (P) = 0.7115\ (1.2193)^{-\ell n\ (\ell n\ \frac{1}{P})} \quad (19)$$

$$1 - P = \frac{1}{110.6\ N}\ ,\ N = \text{Number of days operating in design ice conditions in the life of the ship} \quad (20)$$

$$\ell = \tan\alpha / \sqrt{\tan^2\alpha + \tan^2\beta + 1} \quad (5)$$

Speed can be related to ship displacement and power by several empirical relationships summarized by Tunik [26]. He suggests the following:

$$SHP = C\ \Delta^{.67}\ (V)^{2.5} \quad (21)$$

as the appropriate relationship for icebreaking ship design where C is a function of ice conditions. Such a formulation is useful in determining the limiting speed possible in a given set of ice conditions which would then be used with Equation 16 to predict the limiting force.

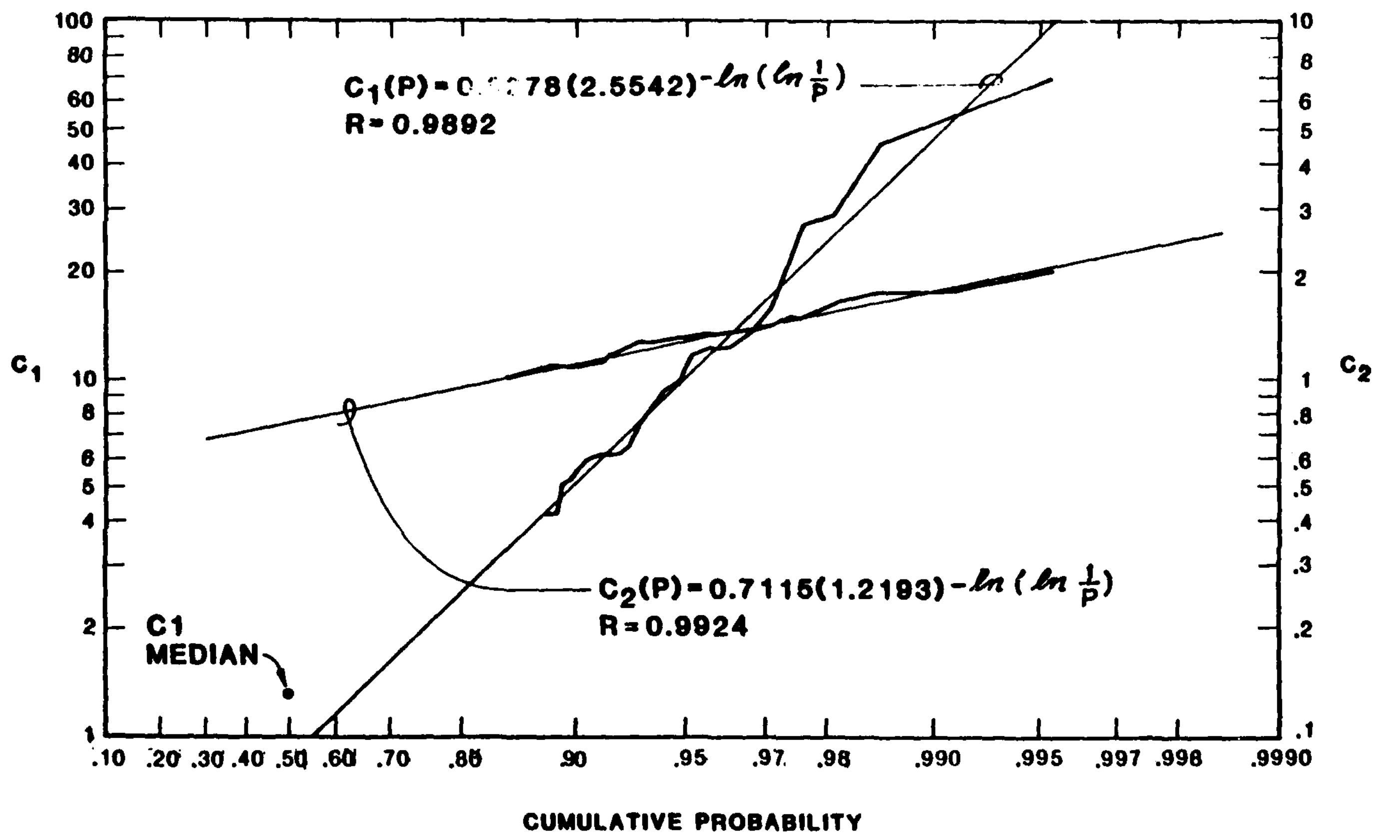


Figure 57

REGRESSION OF THE EXTREMES OF THE FORCE AND PRESSURE DISTRIBUTIONS

14.0 CONCLUSIONS

Conclusions from the study are summarized below.

1. The measurement system, measuring compression in the webs of the cant frames, worked well and should be considered in the instrumentation of closely spaced, transversely framed ships. The inclusion of spacial variation of pressure proved useful in understanding the load shape changes with time.

2. The accuracy of the pressure measurements is approximately plus or minus 10 percent and falls within the range of other measured data at the same impact areas.

3. The pretest internal loading of the panel was easy to conduct and compared well with the analytical model for normally loaded locations, however, the eccentrically loaded locations were difficult to interpret. An external uniform load would be much more difficult to conduct but affords a direct comparison with the ice load finite element model for this type of measurement system.

4. Impacts were randomly distributed over the frames but were grouped on the lower two rows of the panel in multiyear ice.

5. The highest pressures were recorded in dedicated rams in multiyear ice and, specifically, while ramming summer multiyear floes. This is presumably because the ship's progress was not impeded by the presence of thick first year ice surrounding the multiyear floes in the summer conditions.

6. Ice forces for transiting data increased with increasing ice thickness to a maximum observed ice thickness of about 4 to 6 feet (1.2 to 1.8 m) and then decreased at thicker ice conditions. The decrease at greater ice thicknesses is thought to be due to the operator's perception of more severe ice conditions manifested in reduced speed and therefore lower loads. The authors are not aware of other data that support or refute this conclusion. Loads due to dedicated ramming at large ice thicknesses will be limiting for design in any case.

7. Peak pressures appear relatively independent of speed and ice thickness.

8. Peak pressures on a single sub-panel were approximately 2 times the unconstrained crushing strength calculated from temperature and salinity measurements.

9. Non-dimensional force is related to the non-dimensional flexural strength and normal velocity by the equation:

$$\frac{F}{\rho\ g\ h^3} = 1.2908\ \left[\left(\frac{\sigma_f}{\rho\ g\ h}\right)\left(\frac{v\ \ell}{\sqrt{g}\ h}\right)\right]^{1.4566}$$

   This is the mean regression line of the data presented in Figures 42 and 56.

10. Comparison of pressure-area curves for available measured data in Figure 53 does not show a strong trend of peak pressure with ship size. Variations in ice conditions among the measure preclude any specific conclusions.

11. Analysis of the impacts with time showed that the average pressure can increase simultaneously with increasing impact area indicating confinement effects.

12. Statistical analysis of the extremes of average pressure over different areas indicated that small area pressures are best represented by a TYPE II (log-normal) probability distribution and large areas are best represented by a TYPE I (Gumbel) probability distribution. The TYPE I distribution can be used to approximate the extremes of average pressure over all areas and extrapolate the pressure-area curve to longer return periods with good agreement.

13. An approach to the development of the design pressure-area curve based on ice conditions and ship parameters is presented in Section 13. The method presented has promise. The non-dimensional relationship for peak force needs a complete regression analysis and additional data to fully describe the relationships for different failure modes. (Equation 16 presumably describes the peak force for conditions where the impact is limited by a bending failure. The ultimate load in extreme events could be limited by crushing or shear failure or the total energy of the ship in the impact. These limits need to be investigated in future studies.) An approach that incorporates the appropriate characteristics of the ice failure process is necessary to relate the ship design to the area in which it is intended to operate. The ice class, therefore, is directly related to the expected extremes of ice conditions in the operating area. Currently, ice class rules are not related to ice conditions except for the CASSPR Regulations in the Canadian Arctic, so the designer must choose an appropriate ice class, a difficult decision.

14. Current rule design pressures are at the same level as the measured data for small areas. Larger area pressures are not treated in general in the rules. Increasing area impacts appear to be limited by a peak force.

15.0 RECOMMENDATIONS

Recommendations are grouped into three categories: additional data collection with the current instrumentation, future instrumentation programs, and future analysis. The recommendations are outlined below and described in more detail in the paragraphs below.

1. Recommendations for Additional Data Collection with the Current Instrumentation

    1.1 Collect additional summer multiyear data in September 1984 in the Beaufort Sea.
    1.2 Collect glacial ice impact data near Valdez or Glacier Bay on the transit to the Beaufort Sea.
    1.3 Add two rows of strain gages below the existing rows.
    1.4 Attempt an external calibration in ice using an ice floe as a foundation for the hydraulic jack.

2. Recommendations for Future Instrumentation Programs

    2.1 Measure ice pressures in other locations to evaluate the effect of local hull angles.
    2.2 Measure ice pressures on larger ships to evaluate the effect of ship displacement.
    2.3 Measure total bow load and midship bending response to evaluate hull girder strength requirements.

3. Recommendations for Future Analysis

    3.1 Regress the data from all deployments to develop empirical equations to relate the pressure-area curve to ice conditions, ship speed, and expected return period.
    3.2 Statistically analyze the extremes of the data from all deployments for first year and multiyear ice.
    3.3 Compare the two approaches to ensure there is agreement for limiting ice conditions.
    3.4 Develop an ice-structure interaction model

15.1 Recommendations for Additional Data Collection with the Current Instrumentation

The 1982 summer deployment showed that pressures were higher in summer multiyear ice than in winter 1983 ice conditions for most impact areas. The open ice conditions around summer multiyear floes allow a more controlled experiment; the ship can impact the floe at higher speeds and control the impact location much easier in summer. Unfortunately, in 1982, there was only a short time frame for data collection and the data collection system was not fully complete. It is recommended that another summer deployment be conducted in September 1984. On this deployment, more accurate velocities can be recorded during the impacts since direct measurement of ship speed has been added to the instrumentation. Hopefully, many more events will be collected and substantially extend the data base of multiyear events. It is recommended that as many temperature/salinity profiles be taken as possible to provide good ice strength data on this deployment.

One type of ice that has not been recorded is glacial ice. This type of ice is a danger to shipping in the form of bergy bits and growlers on the east coast of Canada and parts of Alaska such as Valdez. The upcoming summer deployment offers an excellent opportunity to gather data on glacial ice at minimal cost. Impacts could be measured in one of the areas along the southern coast of Alaska near one of the glaciers that calve bergs at that time of year. This would be a minor diversion of the ship on its northern transit to the operating area off Barrow. It is recommended that glacial ice impact data be gathered.

Two enhancements should be considered in future data collection efforts with the current instrumentation system. Loads in multiyear ice were heavily grouped toward the lower portion of the panel. Future collection efforts should consider adding two additional rows of strain gages below those already installed.

Also, the full scale loading of the hull compared measured strains from a line type loading to the finite element model modified for the same loading. Strains compared very well for loads perpendicular to the hull but not as well for eccentric loads. Additionally, the line load does not allow a direct comparison with the model used to reduce the ice loads. It appears that for this type of pressure measurement, an external calibration distributed load would have been more appropriate. It may be possible to calibrate portions of the panel by ramming and riding up on a floe sufficiently to load the hull from the ice floe. The ice floe would become a foundation for a hydraulic jack to apply the load. It is recommended that this be included in a future program.

15.2 Recommendations for Future Instrumentation Programs

It is expected that the summer 1984 data collection, with the data from the summer 1982, winter 1983, and the recent January 1984 Antarctic deployment, will provide adequate data for a proper regression and statistical analysis. Three important future measurement programs could be undertaken when this program is complete. The first measurement is of the pressures at other locations along the hull or on different ships to examine the change in ice pressures with local hull angles. Secondly, it would be of interest to measure ice pressures on other size ships, particularly larger ones, to understand the effects of displacement on ice pressures. However, few ships exist currently that are suitably strengthened. Thirdly, total bow load and midship section response, and therefore the measurement of these, is an important aspect of icebreaking ship design where little work has been done.

15.3 Recommendations for Future Analysis

When all data collection for this program are complete, it is recommended that a regression analysis be conducted to examine the relationships of peak force and pressure for varying ice conditions. This should be a study that examines all the non-dimensional relationships appropriate for the various limiting conditions or failure processes. A statistical analysis of the variation of the data about a mean regression line should also be done. The result should be a predicted extreme pressure-area curve based on ship speed, ice conditions, and return period similar to Section 13.0 and based on collection of data on four deployments.

Simultaneously, a statistical analysis should be conducted similar to Section 11.0 on both the multiyear and the first year data. The two analyses represent different approaches to the same problem. The regression analysis attempts to understand the loads and pressures at any given set of ice conditions and the statistical analysis of Section 11.0 addresses the limiting conditions in a type of ice, first year or multiyear, directly. The two approaches should give the same results as ice thickness and ice strength in the former approach, tend toward limiting values. This fact should be verified by comparing the two approaches.

It would appear that the next step would then be the development of an ice-structure interaction model for ships. The model should probably start with a level ice impact allowing correlation with the Antarctic deployment data. The model could then be extended to examine more significant ice features and correlated with the dedicated tests in the Arctic.

16.0 REFERENCES

1. "Technical Development of an Environmentally Safe Arctic Tanker", paper presented at the 1981 SNAME Spring Meeting/Star Symposium, June 17-19, 1981.

2. "Polar Icebreaker Preliminary Structural Design and Special Studies", CONSULTEC, Inc. for U.S. Coast Guard, Office of Engineering Icebreaker Design Project, August 1968.

3. Tarshis, M.K., "Ice Loads Acting on Ships", Translation of Russian Text published in Rechnoi Transport, Vol. 16, No. 12, pp. 19, 1957.

4. "Arctic Waters Pollution Prevention Act; Arctic Shipping Pollution Prevention Regulations", Issued by the Canadian Government, Canada Gazette, Part II, Vol. 106, November 1972.

5. Tunik, A., Comments on Reference 1, the 1981 SNAME Spring Meeting/Star Symposium, June 17-19, 1981.

6. "Results of Trials in Ice and Open Water of CCGS PIERRE RADISSON", ARCTEC CANADA Limited Report No. 245C-7 for Canadian Coast Guard, Ottawa, Ontario, August 1979.

7. Glen, I., et al., "Studies Supporting the Update of the CASPP Regulations", ARCTEC CANADA Limited Report No. 586A for Canadian Coast Guard, March 1982.

8. "Unsoliciated Proposal to Experimentally Investigate the Development of Ice Pressure During Ice Impact with Icebreaking Ship Hulls", ARCTEC CANADA Limited Report No. 450 to Supply and Services Canada.

9. Lecourt, E.J. and J.A. McIntosh, "POLAR STAR 1976 Ice Trials", ARCTEC, Incorporated Final Report No. 165C-6, Contract No. DOT-CG-433339-A to U.S. Coast Guard, October 1977.

10. "Results of Trials in Ice and Open Water of CCGS PIERRE RADISSON", ARCTEC CANADA Limited Report No. 245C-7 for Canadian Coast Guard, Ottawa, Ontario, August 1979.

11. Varsta, P., J. Vuorio, and K. Riska, "Long Term Measurements of Ice Pressure and Ice-Inducted Stresses on the Icebreaker SISU in Winter 1978", Research Report No. 28 for Winter Navigation Research Board, 1979.

12. Newport News Shipbuilding and Dry Dock Company, "SS MANHATTAN Shell Loading Analysis", prepared for Humble Oil and Refining Company, January 1971.

13. "STARDYNE-3 SYSTEM", User's Manual, Mechanics Research Inc., System Development Corporation, 1974.

14. Vaudrey, K.D., "Ice Engineering--Study of Related Properties of Floating Sea-Ice Sheets and Summary of Elastic and Viscoelastic Analyses", Civil Engineering Laboratory, Naval Construction Battalion Center Report No. TR-860, December 1977.

15. Voelker, R.P., et al, "Summer Multi-Year Ice Properties in the Beaufort Sea (October 1982)", ARCTEC, Incorporated Report No. 797C prepared for the Alaskan Oil and Gas Association, December 1982.

16. Voelker, R.P., et al, "Arctic Deployment of USCGC POLAR SEA - Winter 1983", ARCTEC, Incorporated Report No. 868C prepared for the Alaskan Oil and Gas Association, July 1983.

17. Levine, G.H., et al, "A Full-Scale Test Program on a Great Lakes Ore Carrier During Winter Operations", Technical Report Contract No. 3-3626, U.S. Maritime Administration by ARCTEC, Incorporated, July 1973.

18. Dunne, et al, "Results of Full-Scale Impact Load Studies Aboard CCGS NORMAL MCLEOD ROGERS", paper presented at the Fourth International Conference on Port and Ocean Engineering Under Arctic Conditions, POAC 77, Memorial University, St. John's, Newfoundland, September 1977.

19. Edwards, et al., "Full-Scale and Model Tests of a Great Lakes Icebreaker", Trans. SNAME, Vol. 80, 1972.

20. Gumbel, E.J., "Statistical Theory of Extremes and Some Practical Applications", National Bureau of Standards Applied Mathematics Series 33, 1954.

21. Ghoneim, G.A.M. and A. Keinonen, "Full Scale Collision Tests of Canmar KIGORIAK in Very Thick Ice", Proceedings of the Seventh International Conference on Port and Ocean Engineering Under Arctic Conditions, Volume 1, Helsinki, Finland, April 1983.

22. "On the Ice Trail of a 14500 DWT Tanker on the Gulf of Bothnia", Technical Research Centre of Finland.

23. Rules for Classing and Building of Steel Ships, The USSR Register of Shipping, Leningrad, 1981.

24. Finnish-Swedish Ice Class Rules, Finnish Board of Navigation, Helsinki, 1971.

25. Tunik, A.L., "Strength Standard for Arctic Ships", Proceedings of the Seventh International Conference on Port and Ocean Engineering Under Arctic Conditions, Volume 1, Helsinki, Finland, April 1983.

APPENDIX A

CORRECTIONS TO THE FINITE ELEMENT MODEL FOR ACTUAL BOUNDARY CONDITIONS

The web frame model was used to determine the gage strains due to both the simulated ice load and the applied calibration load. In the model the plate was assumed pinned at the fore and aft adjacent frames. In actual fact, the plate extended over the adjacent frames, providing a reaction moment to any plate bending. This reaction moment caused a reduction in the load carried by the central web, resulting in a corresponding decrease in actual strain, as compared to model predictions.

To determine the true reaction it is necessary to match the angular deformation (slope) in the modeled plate to that of the adjacent plate by means of an internal moment. At the frame adjacent to the gage the angular deflection due to ice load as modeled was:

$$\theta_i = \frac{.011 \; w \; L^3}{EI}$$

Also

$$\theta_1 + \theta_2 = \theta_i \quad \text{(for continuity)}$$

where:

θ_1 = angular deflection in modeled plate due to internal moment
θ_2 = angular deflection in adjacent plate due to internal moment

$\theta_1 = \frac{ML}{4\;EI}$ (for end fixed)

$\theta_2 = \frac{ML}{3\;EI}$ (for end pinned)

$$\therefore \quad \frac{7}{12}\frac{ML}{EI} = \frac{.011 \; w \; L^3}{EI}$$

$M = .0189 \; w \; L^2$

where:

M = internal moment (boundary condition adjustment)
L = plate span
w = ice load
EI = plate properties.

The reaction at the gaged frame due to moment is:

$$R = -\frac{3}{2}\frac{M}{L}$$

substituting for M

$$R = -.029 \; w \; L$$

This is compared to an original reaction of .43 w L, to result in a 7% decrease in reaction in the gaged frame due to modified boundary conditions for the ice load.

In the case of the calibration load applied to the center of the web, the load is asymmetrical with respect to the web and therefore the web must be considered as a pinned support rather than fixed.

$$\theta_C = .047 \frac{P L^2}{EI} \quad \text{(angle due to calibration)}$$

$$\theta_1 = \theta_2 = \frac{ML}{3 EI} \quad \text{(for end pinned)}$$

Again

$$\theta_C = \theta_1 + \theta_2$$

It can be shown that

$$M = .07 P L$$

where:

P = applied ice load.

The reaction due to the moment M is

$$R = .07 P$$

which when compared to the original reaction of .69 P results in a 10% decrease in the reaction in the gaged frame due to the modified boundary conditions for the calibration load.

APPENDIX B

DATA REDUCTION MATRICES

The matrix for rows 1 through 6 is labelled "Row 1 Version" and the matrix for rows 3 through 8 is labelled "Row 3 Version". K is the row number of the matrix. Matrix row 1 corresponds to gage row 1, frame 44; matrix row 2 corresponds to gage row 2, frame 44: etc. Frames are in reverse order, 44 to 35.

CALMATINV DUMP: ROW 1 VERSION

K= 1

-3.640	.364	-0.000	0.000	0.000	-0.000	-0.000	0.000	0.000	-0.000
-.006	.001	0.000	0.000	0.000	-0.000	0.000	-0.000	-0.000	0.000
-.412	.041	-0.000	0.000	0.000	-0.000	0.000	0.000	-0.000	-0.000
-.190	.019	0.000	-0.000	0.000	-0.000	0.000	-0.000	0.000	-0.000
-.117	.012	0.000	-0.000	-0.000	-0.000	0.000	0.000	0.000	0.000
-.083	.008	-0.000	-0.000	-0.000	0.000	0.000	-0.000	0.000	0.000

K= 2

.400	-.040	0.000	0.000	-0.000	0.000	0.000	-0.000	0.000	-0.000
-3.926	.393	0.000	0.000	-0.000	-0.000	0.000	-0.000	-0.000	0.000
.485	-.048	-0.000	0.000	-0.000	-0.000	-0.000	-0.000	0.000	-0.000
-.316	.032	0.000	-0.000	0.000	0.000	0.000	-0.000	-0.000	0.000
-.072	.007	-0.000	0.000	0.000	-0.000	0.000	0.000	-0.000	0.000
-.095	.010	0.000	-0.000	-0.000	0.000	-0.000	0.000	-0.000	-0.000

K= 3

-.125	.013	-0.000	0.000	0.000	-0.000	-0.000	-0.000	-0.000	0.000
.733	-.073	0.000	-0.000	0.000	-0.000	-0.000	0.000	-0.000	0.000
-3.260	.326	0.000	0.000	-0.000	-0.000	0.000	-0.000	-0.000	0.000
.055	-.005	-0.000	-0.000	0.000	-0.000	-0.000	0.000	0.000	-0.000
-.349	.035	-0.000	-0.000	-0.000	0.000	0.000	0.000	-0.000	0.000
-.070	.007	0.000	-0.000	-0.000	0.000	0.000	-0.000	0.000	0.000

K= 4

.260	-.026	0.000	-0.000	-0.000	0.000	0.000	-0.000	0.000	-0.000
.199	-.020	-0.000	0.000	-0.000	-0.000	0.000	-0.000	-0.000	0.000
.860	-.086	0.000	0.000	-0.000	-0.000	-0.000	-0.000	0.000	-0.000
-2.740	.274	0.000	-0.000	0.000	0.000	-0.000	0.000	-0.000	0.000
.091	-.009	-0.000	0.000	0.000	-0.000	0.000	0.000	-0.000	0.000
-.245	.024	0.000	-0.000	-0.000	0.000	-0.000	-0.000	0.000	-0.000

K= 5

-.013	.001	-0.000	0.000	0.000	-0.000	-0.000	0.000	-0.000	0.000
.047	-.005	0.000	0.000	0.000	0.000	-0.000	0.000	-0.000	0.000
-.014	.001	-0.000	0.000	0.000	-0.000	0.000	0.000	-0.000	0.000
.643	-.064	-0.000	-0.000	-0.000	-0.000	0.000	-0.000	0.000	-0.000
-2.421	.242	-0.000	-0.000	-0.000	0.000	-0.000	-0.000	0.000	-0.000
.384	-.038	-0.000	0.000	0.000	-0.000	0.000	0.000	-0.000	0.000

K= 6

-.076	.008	0.000	-0.000	0.000	0.000	0.000	-0.000	0.000	-0.000
-.051	.005	-0.000	0.000	-0.000	0.000	0.000	-0.000	0.000	0.000
.007	-.001	0.000	-0.000	0.000	-0.000	-0.000	-0.000	0.000	-0.000
-.050	.005	0.000	0.000	-0.000	0.000	-0.000	0.000	-0.000	0.000
.378	-.038	-0.000	0.000	0.000	-0.000	-0.000	-0.000	-0.000	-0.000
-1.898	.190	0.000	-0.000	-0.000	-0.000	0.000	-0.000	0.000	-0.000

K= 7

.364	-3.676	.364	0.000	-0.000	0.000	-0.000	0.000	-0.000	0.000
.001	-.006	.001	-0.000	0.000	0.000	-0.000	0.000	0.000	-0.000
.041	-.416	.041	-0.000	0.000	-0.000	-0.000	0.000	-0.000	0.000
.019	-.191	.019	0.000	-0.000	0.000	-0.000	-0.000	0.000	0.000
.012	-.118	.012	-0.000	0.000	0.000	0.000	-0.000	0.000	-0.000
.008	-.084	.008	0.000	-0.000	-0.000	-0.000	0.000	0.000	0.000

K= 8

-.040	.404	-.040	0.000	0.000	0.000	0.000	-0.000	-0.000	-0.000
.393	-3.965	.393	0.000	0.000	-0.000	-0.000	-0.000	-0.000	-0.000
-.048	.490	-.048	0.000	-0.000	0.000	0.000	-0.000	0.000	0.000
.032	-.320	.032	0.000	0.000	-0.000	-0.000	0.000	-0.000	-0.000
.007	-.073	.007	0.000	-0.000	-0.000	-0.000	0.000	0.000	0.000
.010	-.096	.010	-0.000	-0.000	-0.000	0.000	0.000	-0.000	-0.000

K= 9

.013	-.126	.013	-0.000	-0.000	0.000	0.000	0.000	0.000	0.000
-.073	.740	-.073	-0.000	-0.000	0.000	-0.000	0.000	0.000	0.000
.326	-3.292	.326	0.000	-0.000	-0.000	-0.000	0.000	-0.000	-0.000
-.005	.056	-.005	-0.000	-0.000	0.000	-0.000	-0.000	0.000	0.000
.035	-.352	.035	-0.000	-0.000	0.000	0.000	0.000	-0.000	0.000
.007	-.071	.007	0.000	0.000	0.000	0.000	-0.000	0.000	-0.000

K= 10

-.026	.263	-.026	0.000	0.000	-0.000	0.000	-0.000	0.000	-0.000
-.020	.201	-.020	0.000	0.000	-0.000	-0.000	-0.000	0.000	0.000
-.086	.869	-.086	0.000	-0.000	0.000	0.000	-0.000	-0.000	0.000
.274	-2.767	.274	-0.000	0.000	-0.000	0.000	0.000	0.000	-0.000
-.009	.092	-.009	0.000	0.000	-0.000	-0.000	-0.000	-0.000	0.000
.024	-.247	.024	0.000	-0.000	-0.000	-0.000	0.000	-0.000	-0.000

K= 11

.001	-.013	.001	0.000	-0.000	-0.000	-0.000	-0.000	0.000	-0.000
-.005	.048	-.005	0.000	-0.000	0.000	0.000	-0.000	0.000	-0.000
.001	-.014	.001	-0.000	0.000	0.000	-0.000	0.000	0.000	-0.000
-.064	.649	-.064	-0.000	-0.000	-0.000	0.000	-0.000	-0.000	0.000
.242	-2.445	.242	0.000	-0.000	0.000	-0.000	0.000	0.000	-0.000
-.038	.388	-.038	-0.000	-0.000	-0.000	0.000	-0.000	0.000	0.000

K= 12

.008	-.077	.008	-0.000	-0.000	-0.000	0.000	-0.000	-0.000	0.000
.005	-.052	.005	-0.000	0.000	0.000	-0.000	0.000	0.000	-0.000
-.001	.007	-.001	-0.000	-0.000	0.000	0.000	-0.000	0.000	-0.000
.005	-.050	.005	0.000	-0.000	0.000	-0.000	0.000	-0.000	0.000
-.038	.381	-.038	-0.000	0.000	-0.000	0.000	-0.000	0.000	-0.000
.190	-1.917	.190	0.000	-0.000	-0.000	-0.000	0.000	-0.000	0.000

K= 13

0.000	.364	-3.676	.364	0.000	-0.000	0.000	-0.000	0.000	-0.000
0.000	.001	-.006	.001	-0.000	-0.000	0.000	-0.000	-0.000	0.000
0.000	.041	-.416	.041	-0.000	0.000	0.000	-0.000	0.000	-0.000
0.000	.019	-.191	.019	0.000	-0.000	0.000	0.000	-0.000	-0.000
-0.000	.012	-.118	.012	-0.000	-0.000	-0.000	0.000	-0.000	0.000
0.000	.008	-.084	.008	0.000	0.000	0.000	-0.000	-0.000	-0.000

K= 14

0.000	-.040	.404	-.040	-0.000	-0.000	-0.000	0.000	0.000	0.000
0.000	.393	-3.965	.393	-0.000	0.000	0.000	0.000	0.000	0.000
0.000	-.048	.490	-.048	0.000	-0.000	-0.000	0.000	-0.000	-0.000
-0.000	.032	-.320	.032	-0.000	0.000	0.000	-0.000	0.000	0.000
0.000	.007	-.073	.007	0.000	0.000	0.000	-0.000	-0.000	-0.000
-0.000	.010	-.096	.010	0.000	0.000	-0.000	-0.000	0.000	0.000

K= 15

-0.000	.013	-.126	.013	0.000	-0.000	-0.000	-0.000	-0.000	-0.000
0.000	-.073	.740	-.073	0.000	-0.000	0.000	-0.000	-0.000	-0.000
0.000	.326	-3.292	.326	0.000	-0.000	0.000	-0.000	-0.000	-0.000
0.000	-.005	.056	-.005	0.000	-0.000	0.000	-0.000	-0.000	-0.000
-0.000	.035	-.352	.035	0.000	-0.000	-0.000	-0.000	0.000	-0.000

0.000	.007	-.071	.007	-0.000	-0.000	-0.000	0.000	-0.000	0.000

K= 16

-0.000	-.026	.263	-.026	-0.000	0.000	-0.000	0.000	-0.000	0.000
-0.000	-.020	.201	-.020	-0.000	0.000	0.000	0.000	-0.000	-0.000
-0.000	-.086	.869	-.086	0.000	-0.000	-0.000	0.000	0.000	-0.000
0.000	.274	-2.767	.274	-0.000	0.000	-0.000	-0.000	-0.000	0.000
-0.000	-.009	.092	-.009	-0.000	0.000	0.000	0.000	0.000	-0.000
0.000	.024	-.247	.024	0.000	0.000	0.000	-0.000	0.000	0.000

K= 17

0.000	.001	-.013	.001	0.000	0.000	0.000	0.000	-0.000	0.000
-0.000	-.005	.048	-.005	0.000	-0.000	-0.000	0.000	-0.000	0.000
0.000	.001	-.014	.001	-0.000	-0.000	0.000	-0.000	-0.000	0.000
-0.000	-.064	.649	-.064	0.000	0.000	-0.000	0.000	0.000	-0.000
0.000	.242	-2.445	.242	0.000	-0.000	0.000	-0.000	-0.000	0.000
-0.000	-.038	.388	-.038	0.000	0.000	-0.000	0.000	-0.000	-0.000

K= 18

-0.000	.008	-.077	.008	0.000	0.000	-0.000	0.000	0.000	-0.000
0.000	.005	-.052	.005	-0.000	-0.000	0.000	-0.000	-0.000	0.000
0.000	-.001	.007	-.001	0.000	-0.000	-0.000	0.000	-0.000	0.000
-0.000	.005	-.050	.005	0.000	-0.000	0.000	-0.000	0.000	-0.000
-0.000	-.038	.381	-.038	-0.000	0.000	-0.000	0.000	-0.000	0.000
-0.000	.190	-1.917	.190	0.000	0.000	0.000	-0.000	0.000	-0.000

K= 19

-0.000	0.000	.364	-3.676	.364	-0.000	-0.000	0.000	-0.000	-0.000
-0.000	0.000	.001	-.006	.001	-0.000	-0.000	0.000	0.000	-0.000
-0.000	0.000	.041	-.416	.041	0.000	-0.000	0.000	-0.000	-0.000
-0.000	0.000	.019	-.191	.019	0.000	0.000	0.000	0.000	-0.000
0.000	-0.000	.012	-.118	.012	-0.000	0.000	-0.000	-0.000	0.000
-0.000	0.000	.008	-.084	.008	0.000	-0.000	-0.000	-0.000	0.000

K= 20

-0.000	-0.000	-.040	.404	-.040	0.000	0.000	-0.000	0.000	0.000
-0.000	0.000	.393	-3.965	.393	0.000	0.000	-0.000	0.000	-0.000
-0.000	-0.000	-.048	.490	-.048	-0.000	0.000	0.000	-0.000	0.000
-0.000	0.000	.032	-.320	.032	-0.000	-0.000	-0.000	0.000	-0.000
0.000	-0.000	.007	-.073	.007	0.000	-0.000	0.000	-0.000	0.000
-0.000	0.000	.010	-.096	.010	0.000	-0.000	0.000	0.000	-0.000

K= 21

0.000	-0.000	.013	-.126	.013	-0.000	0.000	0.000	-0.000	0.000
-0.000	0.000	-.073	.740	-.073	-0.000	-0.000	0.000	-0.000	0.000
-0.000	-0.000	.326	-3.292	.326	0.000	-0.000	0.000	0.000	-0.000
-0.000	0.000	-.005	.056	-.005	-0.000	0.000	-0.000	-0.000	0.000
-0.000	-0.000	.035	-.352	.035	-0.000	-0.000	-0.000	0.000	-0.000
-0.000	0.000	.007	-.071	.007	-0.000	0.000	-0.000	0.000	0.000

K= 22

0.000	-0.000	-.026	.263	-.026	-0.000	0.000	-0.000	0.000	-0.000
0.000	-0.000	-.020	.201	-.020	-0.000	0.000	-0.000	-0.000	-0.000
0.000	-0.000	-.086	.869	-.086	-0.000	0.000	-0.000	0.000	0.000
-0.000	0.000	.274	-2.767	.274	0.000	0.000	-0.000	-0.000	0.000
0.000	0.000	-.009	.092	-.009	0.000	-0.000	0.000	0.000	0.000
0.000	-0.000	.024	-.247	.024	-0.000	0.000	-0.000	-0.000	-0.000

K= 23

0.000	0.000	.001	-.013	.001	0.000	-0.000	0.000	-0.000	0.000
0.000	0.000	-.005	.048	-.005	-0.000	-0.000	0.000	-0.000	0.000

-0.000	0.000	.001	-.014	.001	0.000	-0.000	0.000	-0.000	-0.000
0.000	-0.000	-.064	.649	-.064	-0.000	-0.000	0.000	-0.000	0.000
-0.000	0.000	.242	-2.445	.242	0.000	0.000	-0.000	0.000	-0.000
0.000	-0.000	-.038	.388	-.038	0.000	0.000	0.000	-0.000	0.000

K= 24

-0.000	0.000	.008	-.077	.008	-0.000	0.000	-0.000	-0.000	-0.000
-0.000	0.000	.005	-.052	.005	0.000	-0.000	0.000	0.000	-0.000
-0.000	0.000	-.001	.007	-.001	-0.000	0.000	-0.000	-0.000	0.000
0.000	-0.000	.005	-.050	.005	0.000	-0.000	0.000	0.000	-0.000
0.000	-0.000	-.038	.381	-.038	-0.000	0.000	-0.000	-0.000	0.000
-0.000	0.000	.190	-1.917	.190	0.000	-0.000	0.000	0.000	-0.000

K= 25

0.000	-0.000	0.000	.364	-3.676	.364	0.000	-0.000	0.000	0.000
0.000	-0.000	0.000	.001	-.006	.001	0.000	-0.000	-0.000	0.000
0.000	-0.000	0.000	.041	-.416	.041	0.000	-0.000	0.000	0.000
-0.000	0.000	0.000	.019	-.191	.019	-0.000	-0.000	-0.000	0.000
-0.000	0.000	-0.000	.012	-.118	.012	-0.000	0.000	0.000	-0.000
0.000	-0.000	0.000	.008	-.084	.008	0.000	0.000	-0.000	-0.000

K= 26

-0.000	0.000	0.000	-.040	.404	-.040	-0.000	0.000	-0.000	-0.000
-0.000	0.000	0.000	.393	-3.965	.393	-0.000	0.000	-0.000	0.000
-0.000	0.000	0.000	-.048	.490	-.048	-0.000	-0.000	0.000	-0.000
0.000	-0.000	-0.000	.032	-.320	.032	0.000	0.000	-0.000	0.000
0.000	0.000	0.000	.007	-.073	.007	0.000	-0.000	0.000	-0.000
-0.000	0.000	-0.000	.010	-.096	.010	0.000	-0.000	-0.000	0.000

K= 27

-0.000	-0.000	0.000	.013	-.126	.013	-0.000	-0.000	0.000	-0.000
0.000	-0.000	-0.000	-.073	.740	-.073	0.000	-0.000	0.000	-0.000
0.000	0.000	0.000	.326	-3.292	.326	0.000	-0.000	-0.000	0.000
0.000	-0.000	-0.000	-.005	.056	-.005	-0.000	0.000	0.000	-0.000
-0.000	-0.000	-0.000	.035	-.352	.035	0.000	0.000	-0.000	0.000
0.000	-0.000	0.000	.007	-.071	.007	-0.000	0.000	-0.000	-0.000

K= 28

-0.000	0.000	-0.000	-.026	.263	-.026	-0.000	0.000	-0.000	0.000
-0.000	0.000	-0.000	-.020	.201	-.020	-0.000	0.000	0.000	0.000
-0.000	0.000	-0.000	-.086	.869	-.086	-0.000	0.000	-0.000	-0.000
0.000	-0.000	0.000	.274	-2.767	.274	-0.000	0.000	0.000	-0.000
0.000	0.000	0.000	-.009	.092	-.009	0.000	-0.000	-0.000	-0.000
-0.000	0.000	-0.000	.024	-.247	.024	0.000	0.000	0.000	0.000

K= 29

0.000	-0.000	0.000	.001	-.013	.001	0.000	-0.000	0.000	-0.000
-0.000	-0.000	0.000	-.005	.048	-.005	0.000	-0.000	0.000	-0.000
0.000	-0.000	0.000	.001	-.014	.001	0.000	-0.000	0.000	0.000
-0.000	0.000	-0.000	-.064	.649	-.064	0.000	-0.000	0.000	-0.000
0.000	-0.000	0.000	.242	-2.445	.242	-0.000	0.000	-0.000	0.000
-0.000	0.000	0.000	-.038	.388	-.038	-0.000	-0.000	0.000	-0.000

K= 30

0.000	-0.000	-0.000	.008	-.077	.008	-0.000	0.000	0.000	0.000
0.000	-0.000	0.000	.005	-.052	.005	0.000	-0.000	-0.000	0.000
0.000	-0.000	0.000	-.001	.007	-.001	-0.000	0.000	0.000	-0.000
-0.000	0.000	0.000	.005	-.050	.005	0.000	-0.000	-0.000	0.000
-0.000	0.000	-0.000	-.038	.381	-.038	-0.000	0.000	0.000	-0.000
0.000	-0.000	0.000	.190	-1.917	.190	0.000	-0.000	-0.000	0.000

K= 31

-0.000	0.000	-0.000	-0.000	.364	-3.676	.364	0.000	-0.000	-0.000
0.000	-0.000	-0.000	0.000	.001	-.006	.001	0.000	0.000	0.000
-0.000	0.000	-0.000	-0.000	.041	-.416	.041	0.000	-0.000	0.000
0.000	-0.000	-0.000	0.000	.019	-.191	.019	-0.000	0.000	-0.000
0.000	0.000	0.000	-0.000	.012	-.118	.012	0.000	-0.000	0.000
-0.000	0.000	-0.000	0.000	.008	-.084	.008	-0.000	0.000	-0.000

K= 32

0.000	-0.000	0.000	-0.000	-.040	.404	-.040	-0.000	0.000	-0.000
0.000	0.000	-0.000	0.000	.393	-3.965	.393	-0.000	-0.000	0.000
0.000	0.000	0.000	-0.000	-.048	.490	-.048	0.000	0.000	0.000
-0.000	0.000	-0.000	-0.000	.032	-.320	.032	0.000	-0.000	-0.000
-0.000	-0.000	0.000	0.000	.007	-.073	.007	-0.000	-0.000	0.000
-0.000	-0.000	0.000	-0.000	.010	-.096	.010	-0.000	0.000	-0.000

K= 33

-0.000	0.000	-0.000	0.000	.013	-.126	.013	0.000	-0.000	0.000
-0.000	0.000	-0.000	-0.000	-.073	.740	-.073	0.000	-0.000	0.000
-0.000	0.000	-0.000	0.000	.326	-3.292	.326	0.000	-0.000	0.000
0.000	-0.000	0.000	-0.000	-.005	.056	-.005	-0.000	0.000	-0.000
0.000	0.000	-0.000	-0.000	.035	-.352	.035	0.000	-0.000	-0.000
-0.000	0.000	0.000	0.000	.007	-.071	.007	0.000	-0.000	0.000

K= 34

0.000	-0.000	0.000	-0.000	-.026	.263	-.026	-0.000	0.000	0.000
0.000	-0.000	0.000	-0.000	-.020	.201	-.020	-0.000	-0.000	-0.000
0.000	-0.000	0.000	-0.000	-.086	.869	-.086	-0.000	0.000	-0.000
-0.000	0.000	-0.000	-0.000	.274	-2.767	.274	0.000	-0.000	0.000
0.000	-0.000	0.000	0.000	-.009	.092	-.009	0.000	0.000	-0.000
0.000	-0.000	0.000	-0.000	.024	-.247	.024	0.000	-0.000	0.000

K= 35

-0.000	0.000	-0.000	0.000	.001	-.013	.001	0.000	-0.000	0.000
-0.000	0.000	0.000	-0.000	-.005	.048	-.005	0.000	0.000	-0.000
-0.000	0.000	-0.000	0.000	.001	-.014	.001	0.000	-0.000	0.000
0.000	-0.000	0.000	-0.000	-.064	.649	-.064	0.000	0.000	-0.000
-0.000	0.000	-0.000	-0.000	.242	-2.445	.242	-0.000	0.000	0.000
0.000	-0.000	0.000	0.000	-.038	.388	-.038	0.000	-0.000	-0.000

K= 36

0.000	-0.000	0.000	0.000	.008	-.077	.008	-0.000	0.000	-0.000
0.000	0.000	-0.000	0.000	.005	-.052	.005	0.000	0.000	0.000
-0.000	0.000	0.000	-0.000	-.001	.007	-.001	0.000	-0.000	-0.000
-0.000	-0.000	-0.000	0.000	.005	-.050	.005	-0.000	0.000	-0.000
-0.000	-0.000	0.000	-0.000	-.038	.381	-.038	0.000	-0.000	0.000
-0.000	0.000	-0.000	0.000	.190	-1.917	.190	-0.000	0.000	-0.000

K= 37

-0.000	0.000	0.000	-0.000	0.000	.364	-3.676	.364	-0.000	0.000
-0.000	0.000	-0.000	0.000	-0.000	.001	-.006	.001	0.000	-0.000
-0.000	0.000	0.000	-0.000	0.000	.041	-.416	.041	-0.000	0.000
0.000	-0.000	0.000	-0.000	0.000	.019	-.191	.019	-0.000	0.000
-0.000	0.000	-0.000	0.000	-0.000	.012	-.118	.012	-0.000	-0.000
0.000	-0.000	0.000	-0.000	-0.000	.008	-.084	.008	-0.000	0.000

K= 38

-0.000	0.000	-0.000	0.000	0.000	-.040	.404	-.040	-0.000	0.000
0.000	-0.000	0.000	-0.000	0.000	.393	-3.965	.393	0.000	-0.000
-0.000	0.000	-0.000	0.000	0.000	-.048	.490	-.048	-0.000	-0.000

0.000	-0.000	0.000	0.000	-0.000	.032	-.320	.032	0.000	-0.000
-0.000	-0.000	0.000	-0.000	0.000	.007	-.073	.007	0.000	-0.000
0.000	-0.000	-0.000	0.000	-0.000	.010	-.096	.010	-0.000	-0.000

K= 39

0.000	-0.000	0.000	0.000	-0.000	.013	-.126	.013	0.000	0.000
0.000	-0.000	-0.000	0.000	-0.000	-.073	.740	-.073	-0.000	0.000
0.000	-0.000	0.000	-0.000	-0.000	.326	-3.292	.326	0.000	-0.000
-0.000	-0.000	-0.000	-0.000	0.000	-.005	.056	-.005	-0.000	0.000
0.000	0.000	-0.000	0.000	0.000	.035	-.352	.035	0.000	-0.000
0.000	-0.000	-0.000	0.000	-0.000	.007	-.071	.007	-0.000	0.000

K= 40

0.000	0.000	-0.000	0.000	-0.000	-.026	.263	-.026	-0.000	-0.000
-0.000	0.000	-0.000	-0.000	-0.000	-.020	.201	-.020	-0.000	0.000
-0.000	0.000	-0.000	0.000	-0.000	-.086	.869	-.086	-0.000	0.000
-0.000	0.000	0.000	0.000	0.000	.274	-2.767	.274	0.000	-0.000
0.000	-0.000	0.000	-0.000	0.000	-.009	.092	-.009	-0.000	0.000
-0.000	0.000	-0.000	0.000	0.000	.024	-.247	.024	0.000	-0.000

K= 41

0.000	-0.000	0.000	-0.000	0.000	.001	-.013	.001	0.000	0.000
0.000	-0.000	-0.000	0.000	0.000	-.005	.048	-.005	-0.000	-0.000
0.000	-0.000	0.000	-0.000	0.000	.001	-.014	.001	0.000	-0.000
-0.000	0.000	-0.000	0.000	-0.000	-.064	.649	-.064	-0.000	0.000
0.000	-0.000	0.000	0.000	0.000	.242	-2.445	.242	0.000	-0.000
-0.000	0.000	-0.000	0.000	-0.000	-.038	.388	-.038	0.000	0.000

K= 42

-0.000	0.000	0.000	-0.000	0.000	.008	-.077	.008	-0.000	0.000
-0.000	0.000	0.000	-0.000	0.000	.005	-.052	.005	-0.000	0.000
-0.000	0.000	-0.000	0.000	0.000	-.001	.007	-.001	-0.000	0.000
0.000	-0.000	0.000	-0.000	0.000	.005	-.050	.005	-0.000	-0.000
0.000	0.000	-0.000	0.000	-0.000	-.038	.381	-.038	0.000	-0.000
0.000	-0.000	0.000	-0.000	0.000	.190	-1.917	.190	-0.000	0.000

K= 43

0.000	-0.000	-0.000	0.000	-0.000	0.000	.364	-3.676	.364	-0.000
0.000	-0.000	0.000	-0.000	0.000	0.000	.001	-.006	.001	-0.000
0.000	-0.000	-0.000	0.000	-0.000	0.000	.041	-.416	.041	0.000
-0.000	0.000	-0.000	-0.000	-0.000	0.000	.019	-.191	.019	-0.000
-0.000	-0.000	0.000	-0.000	0.000	-0.000	.012	-.118	.012	0.000
0.000	-0.000	-0.000	0.000	-0.000	0.000	.008	-.084	.008	0.000

K= 44

0.000	-0.000	0.000	-0.000	-0.000	0.000	-.040	.404	-.040	0.000
-0.000	0.000	-0.000	0.000	-0.000	-0.000	.393	-3.965	.393	0.000
0.000	-0.000	0.000	-0.000	-0.000	0.000	-.048	.490	-.048	-0.000
-0.000	0.000	-0.000	-0.000	0.000	-0.000	.032	-.320	.032	0.000
0.000	0.000	-0.000	0.000	-0.000	-0.000	.007	-.073	.007	-0.000
-0.000	0.000	0.000	-0.000	0.000	-0.000	.010	-.096	.010	0.000

K= 45

-0.000	0.000	-0.000	-0.000	0.000	-0.000	.013	-.126	.013	-0.000
0.000	-0.000	0.000	-0.000	0.000	0.000	-.073	.740	-.073	0.000
-0.000	0.000	-0.000	0.000	0.000	-0.000	.326	-3.292	.326	-0.000
0.000	-0.000	0.000	-0.000	-0.000	0.000	-.005	.056	-.005	-0.000
0.000	-0.000	0.000	0.000	-0.000	0.000	.035	-.352	.035	-0.000
0.000	-0.000	0.000	-0.000	0.000	0.000	.007	-.071	.007	-0.000

K= 46

-0.000	0.000	0.000	-0.000	0.000	0.000	-.026	.263	-.026	0.000
-0.000	0.000	-0.000	0.000	-0.000	-0.000	-.020	.201	-.020	-0.000
0.000	-0.000	0.000	-0.000	0.000	0.000	-.086	.869	-.086	0.000
0.000	-0.000	0.000	0.000	-0.000	0.000	.274	-2.767	.274	-0.000
-0.000	0.000	-0.000	0.000	0.000	-0.000	-.009	.092	-.009	0.000
-0.000	-0.000	0.000	0.000	-0.000	0.000	.024	-.247	.024	-0.000

K= 47

-0.000	0.000	-0.000	0.000	-0.000	-0.000	.001	-.013	.001	-0.000
-0.000	-0.000	0.000	0.000	0.000	-0.000	-.005	.048	-.005	0.000
-0.000	0.000	-0.000	0.000	-0.000	-0.000	.001	-.014	.001	-0.000
0.000	-0.000	-0.000	-0.000	0.000	-0.000	-.064	.649	-.064	0.000
0.000	0.000	0.000	-0.000	-0.000	0.000	.242	-2.445	.242	0.000
-0.000	-0.000	0.000	-0.000	0.000	-0.000	-.038	.388	-.038	0.000

K= 48

0.000	-0.000	-0.000	0.000	-0.000	0.000	.008	-.077	.008	0.000
0.000	-0.000	-0.000	-0.000	0.000	0.000	.005	-.052	.005	0.000
0.000	-0.000	0.000	-0.000	0.000	0.000	-.001	.007	-.001	0.000
-0.000	0.000	-0.000	0.000	-0.000	-0.000	.005	-.050	.005	-0.000
-0.000	0.000	0.000	-0.000	0.000	-0.000	-.038	.381	-.038	-0.000
0.000	0.000	-0.000	0.000	-0.000	0.000	.190	-1.917	.190	-0.000

K= 49

-0.000	0.000	-0.000	-0.000	0.000	0.000	-0.000	.364	-3.676	.364
-0.000	0.000	-0.000	0.000	-0.000	0.000	0.000	.001	-.006	.001
-0.000	0.000	0.000	-0.000	-0.000	0.000	-0.000	.041	-.416	.041
0.000	-0.000	0.000	0.000	0.000	-0.000	0.000	.019	-.191	.019
0.000	-0.000	-0.000	0.000	-0.000	0.000	-0.000	.012	-.118	.012
0.000	-0.000	0.000	-0.000	0.000	-0.000	0.000	.008	-.084	.008

K= 50

0.000	-0.000	-0.000	0.000	0.000	0.000	-0.000	-.040	.404	-.040
0.000	-0.000	0.000	0.000	0.000	-0.000	0.000	.393	-3.965	.393
0.000	-0.000	-0.000	0.000	-0.000	0.000	-0.000	-.048	.490	-.048
-0.000	0.000	-0.000	0.000	-0.000	0.000	-0.000	.032	-.320	.032
-0.000	-0.000	0.000	-0.000	-0.000	-0.000	0.000	.007	-.073	.007
-0.000	0.000	-0.000	0.000	0.000	-0.000	-0.000	.010	-.096	.010

K= 51

-0.000	-0.000	0.000	0.000	-0.000	0.000	0.000	.013	-.126	.013
0.000	0.000	-0.000	0.000	-0.000	-0.000	-0.000	-.073	.740	-.073
-0.000	-0.000	0.000	-0.000	-0.000	0.000	0.000	.326	-3.292	.326
0.000	0.000	-0.000	0.000	0.000	-0.000	0.000	-.005	.056	-.005
0.000	0.000	0.000	-0.000	-0.000	0.000	-0.000	.035	-.352	.035
-0.000	0.000	-0.000	0.000	0.000	-0.000	0.000	.007	-.071	.007

K= 52

-0.000	0.000	-0.000	0.000	-0.000	-0.000	0.000	-.026	.263	-.026
0.000	-0.000	0.000	-0.000	0.000	-0.000	-0.000	-.020	.201	-.020
0.000	0.000	-0.000	0.000	0.000	-0.000	0.000	-.086	.869	-.086
0.000	-0.000	0.000	-0.000	0.000	-0.000	0.000	.274	-2.767	.274
-0.000	-0.000	-0.000	0.000	-0.000	0.000	0.000	-.009	.092	-.009
-0.000	0.000	-0.000	-0.000	0.000	-0.000	0.000	.024	-.247	.024

K= 53

0.000	-0.000	0.000	-0.000	-0.000	-0.000	0.000	.001	-.013	.001
-0.000	0.000	-0.000	-0.000	-0.000	0.000	-0.000	-.005	.048	-.005
0.000	-0.000	0.000	-0.000	0.000	-0.000	0.000	.001	-.014	.001
0.000	-0.000	-0.000	0.000	-0.000	0.000	-0.000	-.064	.649	-.064

-0.000	0.000	-0.000	-0.000	0.000	-0.000	0.000	.242	-2.445	.242
0.000	-0.000	0.000	0.000	-0.000	0.000	-0.000	-.038	.388	-.038

K= 54

-0.000	0.000	-0.000	-0.000	0.000	0.000	-0.000	.008	-.077	.008
-0.000	0.000	-0.000	0.000	-0.000	0.000	0.000	.005	-.052	.005
-0.000	0.000	-0.000	0.000	-0.000	0.000	-0.000	-.001	.007	-.001
-0.000	0.000	0.000	-0.000	0.000	-0.000	-0.000	.005	-.050	.005
0.000	-0.000	0.000	-0.000	-0.000	0.000	0.000	-.038	.381	-.038
0.000	0.000	-0.000	-0.000	0.000	-0.000	-0.000	.190	-1.917	.190

K= 55

-0.000	-0.000	0.000	-0.000	-0.000	0.000	-0.000	0.000	.364	-3.640
0.000	-0.000	0.000	-0.000	0.000	0.000	-0.000	-0.000	.001	-.006
0.000	-0.000	0.000	0.000	0.000	-0.000	0.000	0.000	.041	-.412
0.000	-0.000	-0.000	0.000	-0.000	0.000	0.000	-0.000	.019	-.190
-0.000	0.000	-0.000	0.000	-0.000	0.000	-0.000	-0.000	.012	-.117
-0.000	0.000	0.000	-0.000	-0.000	-0.000	0.000	0.000	.008	-.083

K= 56

-0.000	0.000	0.000	-0.000	0.000	-0.000	0.000	-0.000	-.040	.400
0.000	0.000	-0.000	0.000	-0.000	0.000	-0.000	0.000	.393	-3.926
-0.000	0.000	0.000	-0.000	0.000	-0.000	0.000	-0.000	-.048	.485
0.000	-0.000	0.000	-0.000	-0.000	0.000	-0.000	0.000	.032	-.316
0.000	0.000	0.000	-0.000	0.000	-0.000	-0.000	-0.000	.007	-.072
-0.000	0.000	-0.000	-0.000	-0.000	0.000	0.000	0.000	.010	-.095

K= 57

0.000	-0.000	-0.000	0.000	-0.000	0.000	-0.000	0.000	.013	-.125
-0.000	0.000	0.000	-0.000	0.000	-0.000	0.000	-0.000	-.073	.733
0.000	-0.000	-0.000	0.000	-0.000	0.000	-0.000	0.000	.326	-3.260
-0.000	0.000	0.000	0.000	-0.000	-0.000	0.000	-0.000	-.005	.055
-0.000	-0.000	-0.000	0.000	-0.000	-0.000	0.000	0.000	.035	-.349
0.000	0.000	0.000	-0.000	-0.000	0.000	-0.000	0.000	.007	-.070

K= 58

0.000	-0.000	-0.000	0.000	-0.000	0.000	0.000	0.000	-.025	.260
-0.000	0.000	-0.000	0.000	-0.000	0.000	0.000	-0.000	-.020	.199
-0.000	0.000	0.000	-0.000	-0.000	-0.000	0.000	0.000	-.086	.860
0.000	-0.000	-0.000	0.000	0.000	-0.000	-0.000	-0.000	.274	-2.740
0.000	0.000	0.000	-0.000	-0.000	0.000	0.000	0.000	-.009	.091
0.000	-0.000	0.000	0.000	0.000	-0.000	0.000	-0.000	.024	-.245

K= 59

0.000	0.000	-0.000	0.000	0.000	-0.000	-0.000	-0.000	.001	-.013
0.000	-0.000	0.000	0.000	-0.000	-0.000	0.000	0.000	-.005	.047
0.000	0.000	-0.000	0.000	0.000	0.000	-0.000	-0.000	.001	-.014
-0.000	0.000	0.000	-0.000	-0.000	0.000	0.000	-0.000	-.064	.643
-0.000	-0.000	0.000	-0.000	0.000	-0.000	-0.000	0.000	.242	-2.421
-0.000	0.000	-0.000	0.000	0.000	0.000	0.000	-0.000	-.038	.384

K= 60

-0.000	0.000	0.000	-0.000	-0.000	0.000	-0.000	0.000	.008	-.076
0.000	-0.000	0.000	-0.000	0.000	0.000	-0.000	0.000	.005	-.051
0.000	-0.000	0.000	-0.000	0.000	-0.000	0.000	0.000	-.001	.007
0.000	-0.000	0.000	-0.000	-0.000	0.000	0.000	-0.000	.005	-.050
-0.000	0.000	-0.000	0.000	-0.000	0.000	-0.000	-0.000	-.038	.378
-0.000	-0.000	0.000	-0.000	-0.000	0.000	-0.000	0.000	.190	-1.898

CALMATINV DUMP: ROW 3 VERSION

K= 1

-3.165	.317	0.000	-0.000	0.000	-0.000	0.000	0.000	0.000	-0.000
.001	-0.000	-0.000	0.000	-0.000	0.000	-0.000	0.000	0.000	-0.000
-.362	.036	0.000	0.000	-0.000	-0.000	-0.000	0.000	0.000	-0.000
-.065	.007	0.000	-0.000	0.000	-0.000	0.000	0.000	-0.000	0.000
-.093	.009	0.000	0.000	-0.000	-0.000	0.000	0.000	-0.000	-0.000
-.060	.006	0.000	0.000	0.000	0.000	-0.000	0.000	-0.000	-0.000

K= 2

.851	-.085	-0.000	0.000	-0.000	0.000	-0.000	0.000	0.000	0.000
-2.768	.277	0.000	-0.000	0.000	-0.000	0.000	-0.000	0.000	0.000
.078	-.008	-0.000	-0.000	0.000	0.000	0.000	-0.000	-0.000	-0.000
-.236	.024	0.000	-0.000	0.000	-0.000	0.000	0.000	-0.000	-0.000
-.082	.008	-0.000	0.000	0.000	0.000	-0.000	0.000	0.000	-0.000
-.092	.009	-0.000	0.000	-0.000	0.000	0.000	-0.000	0.000	0.000

K= 3

-.008	.001	0.000	-0.000	0.000	-0.000	0.000	-0.000	0.000	0.000
.645	-.064	0.000	0.000	-0.000	0.000	-0.000	0.000	-0.000	0.000
-2.426	.243	0.000	-0.000	0.000	-0.000	0.000	-0.000	0.000	0.000
.429	-.043	0.000	0.000	-0.000	0.000	-0.000	-0.000	0.000	0.000
-.205	.021	0.000	-0.000	-0.000	-0.000	0.000	-0.000	-0.000	-0.000
-.025	.002	0.000	0.000	0.000	0.000	-0.000	0.000	-0.000	0.000

K= 4

.005	-.001	-0.000	-0.000	0.000	0.000	0.000	0.000	-0.000	-0.000
-.051	.005	0.000	-0.000	0.000	-0.000	0.000	-0.000	-0.000	0.000
.393	-.039	-0.000	0.000	-0.000	0.000	-0.000	0.000	0.000	-0.000
-1.976	.198	0.000	-0.000	0.000	0.000	0.000	-0.000	-0.000	0.000
.386	-.039	0.000	0.000	-0.000	0.000	-0.000	0.000	-0.000	0.000
-.224	.022	0.000	-0.000	0.000	0.000	-0.000	0.000	-0.000	-0.000

K= 5

.012	-.001	0.000	0.000	0.000	-0.000	-0.000	-0.000	0.000	0.000
.056	-.006	-0.000	0.000	-0.000	0.000	-0.000	0.000	-0.000	0.000
-.062	.006	0.000	-0.000	0.000	-0.000	-0.000	0.000	-0.000	0.000
.503	-.050	-0.000	0.000	-0.000	-0.000	-0.000	-0.000	0.000	-0.000
-2.324	.232	0.000	-0.000	-0.000	0.000	0.000	-0.000	-0.000	-0.000
.659	-.066	-0.000	0.000	0.000	-0.000	0.000	0.000	0.000	0.000

K= 6

-.052	.005	0.000	-0.000	-0.000	0.000	0.000	0.000	-0.000	0.000
-.012	.001	-0.000	0.000	0.000	-0.000	-0.000	-0.000	0.000	-0.000
.046	-.005	0.000	-0.000	0.000	0.000	-0.000	-0.000	0.000	-0.000
-.087	.009	-0.000	0.000	-0.000	-0.000	-0.000	0.000	-0.000	-0.000
.575	-.057	0.000	-0.000	-0.000	0.000	-0.000	0.000	0.000	0.000
-2.209	.221	0.000	-0.000	-0.000	0.000	0.000	0.000	-0.000	-0.000

K= 7

.317	-3.197	.317	0.000	0.000	0.000	0.000	0.000	-0.000	0.000
-0.000	.001	-0.000	0.000	-0.000	0.000	-0.000	-0.000	0.000	0.000
.036	-.366	.036	-0.000	0.000	0.000	-0.000	-0.000	0.000	-0.000
.007	-.066	.007	0.000	-0.000	-0.000	0.000	0.000	0.000	0.000
.009	-.094	.009	0.000	0.000	-0.000	-0.000	-0.000	-0.000	-0.000
.006	-.060	.006	0.000	-0.000	-0.000	0.000	0.000	0.000	0.000

K= 8

-.085	.859	-.085	-0.000	0.000	-0.000	-0.000	0.000	-0.000	-0.000

.277	-2.796	.277	-0.000	-0.000	-0.000	0.000	-0.000	-0.000	-0.000
-.008	.078	-.008	0.000	-0.000	0.000	0.000	0.000	-0.000	-0.000
.024	-.238	.024	-0.000	0.000	-0.000	-0.000	0.000	-0.000	-0.000
.008	-.083	.008	-0.000	0.000	0.000	0.000	0.000	0.000	0.000
.009	-.093	.009	-0.000	0.000	-0.000	0.000	-0.000	-0.000	-0.000

K= 9

.001	-.008	.001	0.000	-0.000	0.000	0.000	-0.000	0.000	0.000
-.064	.651	-.064	0.000	0.000	0.000	0.000	0.000	0.000	0.000
.243	-2.450	.243	0.000	0.000	-0.000	-0.000	0.000	0.000	-0.000
-.043	.433	-.043	0.000	-0.000	0.000	0.000	-0.000	-0.000	0.000
.021	-.207	.021	-0.000	-0.000	0.000	0.000	-0.000	-0.000	-0.000
.002	-.025	.002	-0.000	0.000	0.000	-0.000	-0.000	0.000	0.000

K= 10

-.001	.005	-.001	0.000	0.000	-0.000	-0.000	-0.000	0.000	-0.000
.005	-.051	.005	0.000	-0.000	0.000	-0.000	0.000	0.000	-0.000
-.039	.397	-.039	-0.000	0.000	-0.000	0.000	-0.000	0.000	0.000
.198	-1.996	.198	0.000	-0.000	0.000	-0.000	0.000	-0.000	-0.000
-.039	.390	-.039	-0.000	-0.000	0.000	0.000	-0.000	0.000	-0.000
.022	-.226	.022	0.000	0.000	0.000	0.000	-0.000	-0.000	0.000

K= 11

-.001	.012	-.001	-0.000	-0.000	0.000	0.000	-0.000	-0.000	0.000
-.006	.057	-.006	-0.000	0.000	-0.000	-0.000	-0.000	-0.000	0.000
.006	-.063	.006	0.000	-0.000	0.000	-0.000	-0.000	0.000	-0.000
-.050	.508	-.050	-0.000	0.000	-0.000	-0.000	-0.000	0.000	0.000
.232	-2.347	.232	-0.000	0.000	-0.000	-0.000	-0.000	-0.000	0.000
-.066	.666	-.066	-0.000	-0.000	0.000	-0.000	0.000	0.000	-0.000

K= 12

.005	-.052	.005	0.000	-0.000	0.000	-0.000	0.000	-0.000	0.000
.001	-.012	.001	-0.000	0.000	-0.000	0.000	-0.000	0.000	0.000
-.005	.047	-.005	0.000	-0.000	0.000	0.000	0.000	-0.000	-0.000
.009	-.088	.009	-0.000	0.000	0.000	-0.000	-0.000	-0.000	0.000
-.057	.581	-.057	0.000	-0.000	0.000	0.000	-0.000	0.000	-0.000
.221	-2.231	.221	0.000	-0.000	-0.000	-0.000	0.000	0.000	0.000

K= 13

-0.000	.317	-3.197	.317	0.000	-0.000	-0.000	-0.000	0.000	-0.000
-0.000	-0.000	.001	-0.000	0.000	-0.000	0.000	0.000	-0.000	-0.000
0.000	.036	-.366	.036	-0.000	-0.000	0.000	0.000	-0.000	0.000
-0.000	.007	-.066	.007	0.000	0.000	-0.000	-0.000	-0.000	-0.000
0.000	.009	-.094	.009	-0.000	0.000	0.000	0.000	0.000	0.000
-0.000	.006	-.060	.006	0.000	0.000	-0.000	-0.000	-0.000	-0.000

K= 14

-0.000	-.085	.859	-.085	-0.000	0.000	0.000	-0.000	0.000	0.000
0.000	.277	-2.796	.277	0.000	0.000	-0.000	0.000	0.000	0.000
-0.000	-.008	.078	-.008	0.000	-0.000	-0.000	-0.000	0.000	0.000
0.000	.024	-.238	.024	-0.000	0.000	0.000	-0.000	0.000	0.000
-0.000	.008	-.083	.008	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
-0.000	.009	-.093	.009	-0.000	0.000	-0.000	-0.000	0.000	0.000

K= 15

0.000	.001	-.008	.001	0.000	-0.000	-0.000	0.000	-0.000	-0.000
-0.000	-.064	.651	-.064	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
0.000	.243	-2.450	.243	-0.000	0.000	0.000	-0.000	-0.000	0.000
-0.000	-.043	.433	-.043	0.000	-0.000	-0.000	0.000	0.000	-0.000
0.000	.021	-.207	.021	0.000	-0.000	-0.000	0.000	0.000	0.000
0.000	.002	-.025	.002	-0.000	-0.000	0.000	0.000	-0.000	-0.000

K= 16

-0.000	-.001	.005	-.001	-0.000	0.000	0.000	0.000	-0.000	0.000
-0.000	.005	-.051	.005	0.000	-0.000	0.000	-0.000	-0.000	0.000
-0.000	-.039	.397	-.039	-0.000	0.000	-0.000	0.000	-0.000	-0.000
0.000	.198	-1.996	.198	0.000	-0.000	0.000	-0.000	0.000	0.000
0.000	-.039	.390	-.039	0.000	-0.000	-0.000	0.000	-0.000	0.000
0.000	.022	-.226	.022	-0.000	-0.000	-0.000	0.000	0.000	-0.000

K= 17

0.000	-.001	.012	-.001	0.000	-0.000	-0.000	0.000	0.000	-0.000
0.000	-.006	.057	-.006	-0.000	0.000	0.000	0.000	0.000	0.000
0.000	.006	-.063	.006	0.000	-0.000	0.000	0.000	-0.000	0.000
-0.000	-.050	.508	-.050	-0.000	0.000	0.000	0.000	-0.000	-0.000
0.000	.232	-2.347	.232	-0.000	0.000	0.000	0.000	0.000	-0.000
0.000	-.066	.666	-.066	0.000	-0.000	0.000	-0.000	-0.000	0.000

K= 18

-0.000	.005	-.052	.005	0.000	-0.000	0.000	-0.000	0.000	-0.000
-0.000	.001	-.012	.001	-0.000	0.000	-0.000	0.000	-0.000	-0.000
0.000	-.005	.047	-.005	0.000	-0.000	-0.000	-0.000	0.000	0.000
-0.000	.009	-.088	.009	-0.000	0.000	0.000	0.000	0.000	-0.000
0.000	-.057	.581	-.057	0.000	-0.000	-0.000	0.000	-0.000	0.000
-0.000	.221	-2.231	.221	0.000	0.000	0.000	-0.000	-0.000	-0.000

K= 19

-0.000	0.000	.317	-3.197	.317	0.000	-0.000	-0.000	-0.000	0.000
-0.000	-0.000	-0.000	.001	-0.000	0.000	0.000	0.000	0.000	0.000
-0.000	0.000	.036	-.366	.036	-0.000	0.000	-0.000	-0.000	-0.000
-0.000	-0.000	.007	-.066	.007	0.000	-0.000	-0.000	-0.000	-0.000
0.000	0.000	.009	-.094	.009	-0.000	-0.000	-0.000	0.000	0.000
-0.000	0.000	.006	-.060	.006	0.000	0.000	0.000	-0.000	0.000

K= 20

0.000	-0.000	-.085	.859	-.085	-0.000	0.000	-0.000	-0.000	0.000
0.000	0.000	.277	-2.796	.277	-0.000	0.000	-0.000	0.000	0.000
-0.000	-0.000	-.008	.078	-.008	-0.000	-0.000	0.000	-0.000	0.000
0.000	0.000	.024	-.238	.024	-0.000	0.000	-0.000	-0.000	0.000
-0.000	-0.000	.008	-.083	.008	0.000	0.000	0.000	-0.000	-0.000
0.000	-0.000	.009	-.093	.009	-0.000	0.000	-0.000	-0.000	0.000

K= 21

-0.000	0.000	.001	-.008	.001	0.000	-0.000	0.000	-0.000	-0.000
0.000	-0.000	-.064	.651	-.064	-0.000	-0.000	0.000	-0.000	-0.000
-0.000	0.000	.243	-2.450	.243	0.000	0.000	0.000	0.000	0.000
-0.000	-0.000	-.043	.433	-.043	0.000	-0.000	0.000	-0.000	-0.000
-0.000	0.000	.021	-.207	.021	-0.000	0.000	-0.000	-0.000	0.000
-0.000	0.000	.002	-.025	.002	0.000	-0.000	0.000	0.000	-0.000

K= 22

0.000	-0.000	-.001	.005	-.001	-0.000	-0.000	-0.000	-0.000	0.000
-0.000	0.000	.005	-.051	.005	-0.000	-0.000	-0.000	0.000	0.000
0.000	-0.000	-.039	.397	-.039	0.000	0.000	0.000	0.000	-0.000
-0.000	0.000	.198	-1.996	.198	0.000	-0.000	-0.000	0.000	0.000
0.000	0.000	-.039	.390	-.039	0.000	0.000	0.000	-0.000	-0.000
-0.000	-0.000	.022	-.226	.022	-0.000	-0.000	-0.000	0.000	0.000

K= 23

-0.000	0.000	-.001	.012	-.001	0.000	-0.000	0.000	-0.000	-0.000
0.000	0.000	-.006	.057	-.006	0.000	0.000	0.000	0.000	-0.000
-0.000	-0.000	.006	-.063	.006	-0.000	0.000	-0.000	-0.000	0.000

0.000	-0.000	-.050	.508	-.050	0.000	-0.000	0.000	0.000	-0.000
-0.000	-0.000	.232	-2.347	.232	-0.000	0.000	-0.000	0.000	0.000
-0.000	0.000	-.066	.666	-.066	0.000	-0.000	0.000	0.000	-0.000

K= 24

0.000	0.000	.005	-.052	.005	-0.000	0.000	-0.000	0.000	0.000
0.000	-0.000	.001	-.012	.001	0.000	-0.000	0.000	-0.000	0.000
-0.000	0.000	-.005	.047	-.005	0.000	-0.000	0.000	0.000	-0.000
0.000	-0.000	.009	-.088	.009	-0.000	0.000	-0.000	-0.000	0.000
0.000	0.000	-.057	.581	-.057	0.000	-0.000	0.000	0.000	-0.000
-0.000	-0.000	.221	-2.231	.221	-0.000	0.000	0.000	-0.000	0.000

K= 25

0.000	-0.000	0.000	.317	-3.197	.317	0.000	0.000	0.000	-0.000
0.000	0.000	-0.000	-0.000	.001	-0.000	-0.000	-0.000	-0.000	-0.000
-0.000	0.000	0.000	.036	-.366	.036	-0.000	0.000	0.000	0.000
0.000	-0.000	-0.000	.007	-.066	.007	0.000	0.000	0.000	0.000
-0.000	-0.000	0.000	.009	-.094	.009	0.000	0.000	-0.000	-0.000
0.000	-0.000	-0.000	.006	-.060	.006	-0.000	-0.000	0.000	0.000

K= 26

-0.000	0.000	-0.000	-.085	.859	-.085	-0.000	0.000	0.000	-0.000
-0.000	-0.000	0.000	.277	-2.796	.277	-0.000	0.000	-0.000	-0.000
0.000	-0.000	-0.000	-.008	.078	-.008	0.000	-0.000	0.000	-0.000
-0.000	0.000	0.000	.024	-.238	.024	-0.000	0.000	0.000	-0.000
0.000	0.000	-0.000	.008	-.083	.008	0.000	-0.000	0.000	0.000
-0.000	0.000	0.000	.009	-.093	.009	-0.000	0.000	0.000	-0.000

K= 27

0.000	-0.000	0.000	.001	-.008	.001	0.000	-0.000	0.000	0.000
-0.000	-0.000	-0.000	-.064	.651	-.064	0.000	-0.000	0.000	0.000
0.000	0.000	0.000	.243	-2.450	.243	-0.000	-0.000	-0.000	-0.000
0.000	-0.000	-0.000	-.043	.433	-.043	0.000	-0.000	0.000	0.000
-0.000	0.000	0.000	.021	-.207	.021	-0.000	0.000	0.000	-0.000
0.000	-0.000	-0.000	.002	-.025	.002	0.000	-0.000	-0.000	0.000

K= 28

-0.000	0.000	-0.000	-.001	.005	-.001	0.000	0.000	0.000	-0.000
0.000	-0.000	0.000	.005	-.051	.005	0.000	0.000	-0.000	-0.000
-0.000	0.000	-0.000	-.039	.397	-.039	-0.000	-0.000	-0.000	0.000
0.000	-0.000	0.000	.198	-1.996	.198	0.000	0.000	-0.000	-0.000
0.000	-0.000	0.000	-.039	.390	-.039	0.000	-0.000	0.000	0.000
0.000	0.000	-0.000	.022	-.226	.022	0.000	0.000	0.000	-0.000

K= 29

0.000	-0.000	0.000	-.001	.012	-.001	0.000	-0.000	0.000	0.000
-0.000	0.000	-0.000	-.006	.057	-.006	-0.000	-0.000	-0.000	0.000
0.000	0.000	-0.000	.006	-.063	.006	-0.000	0.000	0.000	-0.000
0.000	0.000	0.000	-.050	.508	-.050	0.000	-0.000	-0.000	0.000
-0.000	0.000	-0.000	.232	-2.347	.232	-0.000	0.000	-0.000	-0.000
-0.000	-0.000	0.000	-.066	.666	-.066	0.000	-0.000	-0.000	0.000

K= 30

0.000	-0.000	-0.000	.005	-.052	.005	-0.000	0.000	-0.000	0.000
0.000	0.000	-0.000	.001	-.012	.001	0.000	-0.000	0.000	-0.000
-0.000	-0.000	0.000	-.005	.047	-.005	0.000	-0.000	-0.000	0.000
0.000	0.000	-0.000	.009	-.088	.009	-0.000	0.000	0.000	-0.000
-0.000	-0.000	0.000	-.057	.581	-.057	0.000	-0.000	-0.000	0.000
0.000	-0.000	-0.000	.221	-2.231	.221	-0.000	-0.000	0.000	-0.000

K= 31

-0.000	0.000	-0.000	0.000	.317	-3.197	.317	0.000	0.000	-0.000
0.000	-0.000	0.000	-0.000	-0.000	.001	-0.000	0.000	0.000	-0.000
0.000	-0.000	0.000	0.000	.036	-.366	.036	-0.000	-0.000	0.000
-0.000	0.000	0.000	-0.000	.007	-.066	.007	0.000	0.000	-0.000
-0.000	-0.000	-0.000	0.000	.009	-.094	.009	0.000	-0.000	0.000
0.000	0.000	-0.000	0.000	.006	-.060	.006	-0.000	0.000	-0.000

K= 32

0.000	-0.000	0.000	-0.000	-.085	.859	-.085	-0.000	0.000	0.000
-0.000	0.000	-0.000	0.000	.277	-2.796	.277	-0.000	-0.000	0.000
-0.000	0.000	-0.000	-0.000	-.008	.078	-.008	-0.000	0.000	0.000
-0.000	0.000	0.000	0.000	.024	-.238	.024	0.000	-0.000	0.000
0.000	-0.000	-0.000	-0.000	.008	-.083	.008	-0.000	0.000	-0.000
-0.000	-0.000	0.000	-0.000	.009	-.093	.009	-0.000	-0.000	0.000

K= 33

-0.000	0.000	-0.000	0.000	.001	-.008	.001	0.000	-0.000	-0.000
0.000	-0.000	0.000	-0.000	-.064	.651	-.064	0.000	-0.000	-0.000
-0.000	0.000	-0.000	0.000	.243	-2.450	.243	0.000	-0.000	0.000
-0.000	0.000	-0.000	-0.000	-.043	.433	-.043	-0.000	0.000	-0.000
0.000	-0.000	0.000	0.000	.021	-.207	.021	-0.000	0.000	0.000
-0.000	0.000	-0.000	0.000	.002	-.025	.002	0.000	-0.000	-0.000

K= 34

0.000	-0.000	0.000	-0.000	-.001	.005	-.001	-0.000	-0.000	0.000
-0.000	0.000	-0.000	0.000	.005	-.051	.005	0.000	-0.000	0.000
0.000	-0.000	0.000	-0.000	-.039	.397	-.039	-0.000	0.000	-0.000
-0.000	0.000	-0.000	0.000	.198	-1.996	.198	-0.000	-0.000	-0.000
0.000	-0.000	0.000	-0.000	-.039	.390	-.039	0.000	0.000	-0.000
-0.000	-0.000	-0.000	0.000	.022	-.226	.022	-0.000	-0.000	0.000

K= 35

-0.000	0.000	-0.000	-0.000	-.001	.012	-.001	0.000	-0.000	-0.000
0.000	-0.000	0.000	-0.000	-.006	.057	-.006	-0.000	-0.000	0.000
0.000	-0.000	-0.000	0.000	.006	-.063	.006	0.000	-0.000	0.000
-0.000	-0.000	0.000	-0.000	-.050	.508	-.050	-0.000	0.000	0.000
0.000	0.000	-0.000	0.000	.232	-2.347	.232	-0.000	0.000	0.000
0.000	0.000	0.000	-0.000	-.066	.666	-.066	0.000	-0.000	-0.000

K= 36

-0.000	-0.000	-0.000	0.000	.005	-.052	.005	-0.000	0.000	-0.000
0.000	0.000	-0.000	-0.000	.001	-.012	.001	0.000	-0.000	-0.000
0.000	-0.000	0.000	0.000	-.005	.047	-.005	-0.000	0.000	0.000
-0.000	0.000	0.000	-0.000	.009	-.088	.009	0.000	-0.000	-0.000
-0.000	-0.000	0.000	0.000	-.057	.581	-.057	0.000	-0.000	0.000
-0.000	0.000	-0.000	0.000	.221	-2.231	.221	-0.000	0.000	-0.000

K= 37

0.000	-0.000	0.000	-0.000	0.000	.317	-3.197	.317	-0.000	0.000
-0.000	0.000	-0.000	0.000	-0.000	-0.000	.001	-0.000	-0.000	0.000
0.000	-0.000	0.000	0.000	-0.000	.036	-.366	.036	-0.000	-0.000
0.000	0.000	-0.000	0.000	0.000	.007	-.066	.007	-0.000	0.000
-0.000	0.000	0.000	-0.000	0.000	.009	-.094	.009	-0.000	-0.000
0.000	-0.000	-0.000	0.000	-0.000	.006	-.060	.006	-0.000	0.000

K= 38

0.000	0.000	-0.000	0.000	-0.000	-.085	.859	-.085	-0.000	0.000
0.000	-0.000	0.000	-0.000	0.000	.277	-2.796	.277	0.000	-0.000
0.000	0.000	-0.000	0.000	-0.000	-.008	.078	-.008	0.000	-0.000

0.000	-0.000	0.000	-0.000	0.000	.024	-.238	.024	0.000	-0.000
-0.000	0.000	-0.000	0.000	-0.000	.008	-.083	.008	-0.000	0.000
0.000	-0.000	0.000	-0.000	-0.000	.009	-.093	.009	0.000	-0.000

K= 39

0.000	-0.000	0.000	-0.000	0.000	.001	-.008	.001	0.000	-0.000
-0.000	0.000	-0.000	0.000	-0.000	-.064	.651	-.064	-0.000	-0.000
0.000	-0.000	0.000	-0.000	0.000	.243	-2.450	.243	0.000	0.000
0.000	0.000	-0.000	0.000	0.000	-.043	.433	-.043	-0.000	0.000
0.000	-0.000	-0.000	-0.000	-0.000	.021	-.207	.021	-0.000	0.000
-0.000	-0.000	0.000	0.000	0.000	.002	-.025	.002	0.000	-0.000

K= 40

-0.000	0.000	-0.000	0.000	-0.000	-.001	.005	-.001	-0.000	-0.000
0.000	-0.000	0.000	-0.000	-0.000	.005	-.051	.005	0.000	-0.000
0.000	0.000	-0.000	0.000	0.000	-.039	.397	-.039	-0.000	0.000
-0.000	-0.000	0.000	-0.000	-0.000	.198	-1.996	.198	0.000	0.000
-0.000	0.000	0.000	-0.000	0.000	-.039	.390	-.039	-0.000	0.000
-0.000	0.000	-0.000	0.000	-0.000	.022	-.226	.022	-0.000	-0.000

K= 41

-0.000	-0.000	0.000	-0.000	0.000	-.001	.012	-.001	0.000	0.000
-0.000	0.000	-0.000	0.000	0.000	-.006	.057	-.006	0.000	-0.000
-0.000	0.000	0.000	-0.000	-0.000	.006	-.063	.006	0.000	0.000
0.000	0.000	-0.000	0.000	0.000	-.050	.508	-.050	-0.000	-0.000
0.000	-0.000	0.000	-0.000	0.000	.232	-2.347	.232	-0.000	0.000
-0.000	-0.000	-0.000	0.000	0.000	-.066	.666	-.066	0.000	-0.000

K= 42

0.000	0.000	0.000	-0.000	0.000	.005	-.052	.005	-0.000	-0.000
0.000	-0.000	0.000	-0.000	-0.000	.001	-.012	.001	-0.000	0.000
-0.000	-0.000	-0.000	-0.000	0.000	-.005	.047	-.005	-0.000	-0.000
-0.000	0.000	-0.000	0.000	-0.000	.009	-.088	.009	-0.000	0.000
0.000	0.000	-0.000	-0.000	0.000	-.057	.581	-.057	0.000	-0.000
0.000	-0.000	0.000	-0.000	-0.000	.221	-2.231	.221	-0.000	0.000

K= 43

0.000	0.000	0.000	0.000	-0.000	0.000	.317	-3.197	.317	-0.000
-0.000	0.000	0.000	-0.000	0.000	0.000	-0.000	.001	-0.000	-0.000
-0.000	0.000	-0.000	0.000	0.000	-0.000	.036	-.366	.036	-0.000
0.000	-0.000	0.000	-0.000	-0.000	0.000	.007	-.066	.007	-0.000
-0.000	-0.000	-0.000	0.000	0.000	-0.000	.009	-.094	.009	0.000
-0.000	0.000	0.000	-0.000	-0.000	-0.000	.006	-.060	.006	0.000

K= 44

0.000	-0.000	-0.000	0.000	0.000	-0.000	-.085	.859	-.085	0.000
-0.000	0.000	-0.000	0.000	-0.000	0.000	.277	-2.796	.277	0.000
-0.000	-0.000	0.000	-0.000	-0.000	0.000	-.008	.078	-.008	0.000
0.000	0.000	-0.000	0.000	0.000	-0.000	.024	-.238	.024	0.000
-0.000	-0.000	0.000	-0.000	0.000	-0.000	.008	-.083	.008	-0.000
-0.000	0.000	-0.000	0.000	0.000	0.000	.009	-.093	.009	0.000

K= 45

-0.000	0.000	-0.000	0.000	0.000	-0.000	.001	-.008	.001	-0.000
0.000	-0.000	0.000	-0.000	-0.000	-0.000	-.064	.651	-.064	0.000
-0.000	0.000	-0.000	0.000	-0.000	0.000	.243	-2.450	.243	0.000
-0.000	0.000	0.000	-0.000	-0.000	-0.000	-.043	.433	-.043	-0.000
0.000	0.000	-0.000	0.000	0.000	0.000	.021	-.207	.021	-0.000
0.000	-0.000	0.000	-0.000	-0.000	-0.000	.002	-.025	.002	-0.000

K= 46

0.000	-0.000	0.000	-0.000	0.000	0.000	-.001	.005	-.001	0.000
0.000	0.000	-0.000	0.000	0.000	0.000	.005	-.051	.005	0.000
-0.000	0.000	0.000	0.000	-0.000	-0.000	-.039	.397	-.039	0.000
0.000	-0.000	-0.000	-0.000	0.000	0.000	.198	-1.996	.198	-0.000
-0.000	-0.000	0.000	0.000	-0.000	0.000	-.039	.390	-.039	0.000
0.000	-0.000	0.000	-0.000	0.000	0.000	.022	-.226	.022	0.000

K= 47

-0.000	0.000	-0.000	0.000	-0.000	0.000	-.001	.012	-.001	-0.000
-0.000	-0.000	0.000	0.000	-0.000	-0.000	-.006	.057	-.006	0.000
0.000	-0.000	-0.000	-0.000	0.000	0.000	.006	-.063	.006	-0.000
-0.000	0.000	0.000	0.000	-0.000	-0.000	-.050	.508	-.050	0.000
0.000	0.000	-0.000	0.000	-0.000	0.000	.232	-2.347	.232	0.000
-0.000	0.000	0.000	0.000	-0.000	-0.000	-.066	.666	-.066	-0.000

K= 48

0.000	-0.000	0.000	-0.000	0.000	-0.000	.005	-.052	.005	0.000
-0.000	0.000	0.000	-0.000	0.000	0.000	.001	-.012	.001	-0.000
-0.000	0.000	-0.000	0.000	0.000	-0.000	-.005	.047	-.005	-0.000
0.000	-0.000	0.000	-0.000	-0.000	0.000	.009	-.088	.009	0.000
-0.000	-0.000	0.000	0.000	0.000	-0.000	-.057	.581	-.057	-0.000
-0.000	0.000	-0.000	-0.000	0.000	-0.000	.221	-2.231	.221	0.000

K= 49

-0.000	0.000	-0.000	-0.000	-0.000	0.000	-0.000	.317	-3.197	.317
0.000	-0.000	0.000	0.000	-0.000	-0.000	-0.000	-0.000	.001	-0.000
0.000	-0.000	-0.000	0.000	-0.000	0.000	0.000	.036	-.366	.036
0.000	-0.000	0.000	-0.000	-0.000	-0.000	0.000	.007	-.066	.007
-0.000	0.000	-0.000	-0.000	0.000	-0.000	0.000	.009	-.094	.009
0.000	-0.000	0.000	-0.000	-0.000	0.000	-0.000	.006	-.060	.006

K= 50

0.000	-0.000	-0.000	-0.000	0.000	-0.000	0.000	-.085	.859	-.085
-0.000	-0.000	0.000	-0.000	0.000	-0.000	0.000	.277	-2.796	.277
-0.000	0.000	0.000	0.000	0.000	-0.000	-0.000	-.008	.078	-.008
-0.000	-0.000	-0.000	0.000	-0.000	-0.000	0.000	.024	-.238	.024
0.000	0.000	-0.000	0.000	-0.000	0.000	-0.000	.008	-.083	.008
0.000	-0.000	0.000	-0.000	0.000	-0.000	0.000	.009	-.093	.009

K= 51

-0.000	0.000	-0.000	0.000	-0.000	-0.000	0.000	.001	-.008	.001
0.000	0.000	-0.000	-0.000	0.000	0.000	-0.000	-.064	.651	-.064
-0.000	-0.000	0.000	0.000	0.000	-0.000	0.000	.243	-2.450	.243
0.000	0.000	0.000	-0.000	0.000	0.000	-0.000	-.043	.433	-.043
-0.000	-0.000	0.000	-0.000	0.000	-0.000	0.000	.021	-.207	.021
0.000	0.000	-0.000	0.000	-0.000	0.000	-0.000	.002	-.025	.002

K= 52

0.000	0.000	-0.000	0.000	-0.000	0.000	-0.000	-.001	.005	-.001
-0.000	0.000	0.000	-0.000	0.000	-0.000	0.000	.005	-.051	.005
0.000	-0.000	0.000	0.000	-0.000	0.000	-0.000	-.039	.397	-.039
-0.000	0.000	0.000	0.000	0.000	0.000	0.000	.198	-1.996	.198
0.000	0.000	-0.000	-0.000	0.000	-0.000	-0.000	-.039	.390	-.039
-0.000	0.000	-0.000	-0.000	0.000	-0.000	-0.000	.022	-.226	.022

K= 53

-0.000	-0.000	0.000	-0.000	0.000	-0.000	0.000	-.001	.012	-.001
0.000	0.000	-0.000	0.000	-0.000	0.000	-0.000	-.006	.057	-.006
-0.000	0.000	-0.000	-0.000	0.000	-0.000	0.000	.006	-.063	.006
0.000	-0.000	-0.000	-0.000	-0.000	0.000	-0.000	-.050	.508	-.050

-0.000	-0.000	0.000	-0.000	0.000	-0.000	0.000	.232	-2.347	.232
0.000	-0.000	0.000	-0.000	0.000	0.000	0.000	-.066	.666	-.066

K= 54

0.000	0.000	-0.000	0.000	-0.000	0.000	-0.000	.005	-.052	.005
0.000	-0.000	-0.000	0.000	-0.000	0.000	-0.000	.001	-.012	.001
0.000	-0.000	-0.000	-0.000	-0.000	0.000	0.000	-.005	.047	-.005
-0.000	0.000	0.000	-0.000	-0.000	-0.000	-0.000	.009	-.088	.009
0.000	0.000	-0.000	0.000	0.000	-0.000	0.000	-.057	.581	-.057
0.000	0.000	-0.000	0.000	-0.000	0.000	-0.000	.221	-2.231	.221

K= 55

0.000	-0.000	-0.000	0.000	0.000	-0.000	0.000	0.000	.317	-3.165
-0.000	0.000	-0.000	-0.000	0.000	-0.000	0.000	-0.000	-0.000	.001
0.000	-0.000	0.000	-0.000	0.000	0.000	-0.000	0.000	.036	-.362
-0.000	0.000	-0.000	0.000	-0.000	-0.000	0.000	-0.000	.007	-.065
0.000	-0.000	0.000	-0.000	0.000	0.000	-0.000	0.000	.009	-.093
-0.000	0.000	-0.000	0.000	0.000	-0.000	0.000	-0.000	.006	-.060

K= 56

-0.000	0.[illegible]0	[illegible].000	-0.000	-0.000	0.000	-0.000	0.000	-.095	.95[illegible]
0.000	-0.000	0.000	0.000	-0.000	0.000	-0.000	-0.000	.277	-2.768
-0.000	0.000	-0.000	0.000	-0.000	-0.000	0.000	-0.000	-.008	.078
0.000	-0.000	0.000	-0.000	0.000	0.000	-0.000	0.000	.024	-.236
-0.000	0.000	-0.000	0.000	-0.000	-0.000	0.000	-0.000	.008	-.082
0.000	-0.000	0.000	-0.000	-0.000	0.000	-0.000	0.000	.009	-.092

K= 57

0.000	-0.000	-0.000	0.000	-0.000	0.000	0.000	-0.000	.001	-.008
-0.000	0.000	0.000	-0.000	-0.000	0.000	-0.000	0.000	-.064	.645
-0.000	-0.000	-0.000	0.000	-0.000	0.000	0.000	0.000	.243	-2.426
0.000	-0.000	-0.000	-0.000	-0.000	-0.000	0.000	-0.000	-.043	.429
0.000	0.000	0.000	-0.000	0.000	-0.000	-0.000	0.000	.021	-.205
-0.000	-0.000	0.000	-0.000	-0.000	0.000	0.000	-0.000	.002	-.025

K= 58

-0.000	0.000	0.0[illegible]	-0.000	0.000	0.000	-0.000	0.000	-.001	.005
0.000	-0.000	-0.00[illegible]	0.000	-0.000	0.000	0.000	-0.000	.005	-.051
0.000	0.000	-0.000	-0.000	0.000	-0.000	-0.000	0.000	-.039	.393
-0.000	0.000	-0.000	0.000	-0.000	0.000	0.000	-0.000	.198	-1.976
-0.000	-0.000	-0.000	0.000	-0.000	-0.000	0.000	-0.000	-.039	.386
-0.000	0.000	0.000	-0.000	-0.000	0.000	-0.000	-0.000	.022	-.224

K= 59

0.000	0.000	-0.000	0.000	-0.000	0.000	-0.000	-0.000	-.001	.012
-0.000	-0.000	-0.000	-0.000	0.000	-0.000	-0.000	0.000	-.006	.056
0.000	-0.000	0.000	-0.000	-0.000	0.000	0.000	-0.000	.006	-.062
-0.000	0.000	-0.000	0.000	-0.000	0.000	-0.000	0.000	-.050	.503
0.000	0.000	-0.000	0.000	0.000	0.000	-0.000	0.000	.232	-2.324
0.000	-0.000	-0.000	0.000	0.000	0.000	-0.000	0.000	-.066	.659

K= 60

-0.000	-0.000	-0.000	-0.000	0.000	-0.000	0.000	0.000	.005	-.052
-0.000	0.000	0.000	-0.000	0.000	-0.000	0.000	-0.000	.001	-.012
-0.000	0.000	-0.000	-0.000	0.000	-0.000	-0.000	0.000	-.005	.046
0.000	-0.000	0.000	-0.000	0.000	-0.000	0.000	-0.000	.009	-.087
0.000	-0.000	0.000	-0.000	-0.000	0.000	-0.000	0.000	-.057	.575
-0.000	0.000	0.000	0.000	-0.000	-0.000	0.000	-0.000	.221	-2.209

APPENDIX C

CALCULATION OF PRESSURES VARYING THE EFFECT OF THE MATRIX OFF-DIAGONAL TERMS

FIVE PERCENT FACTOR USED FOR OFF-DIAGONAL TERMS

EVENT AT 10:13:20:14:41   BACKING & RAMMING @ 3 KT

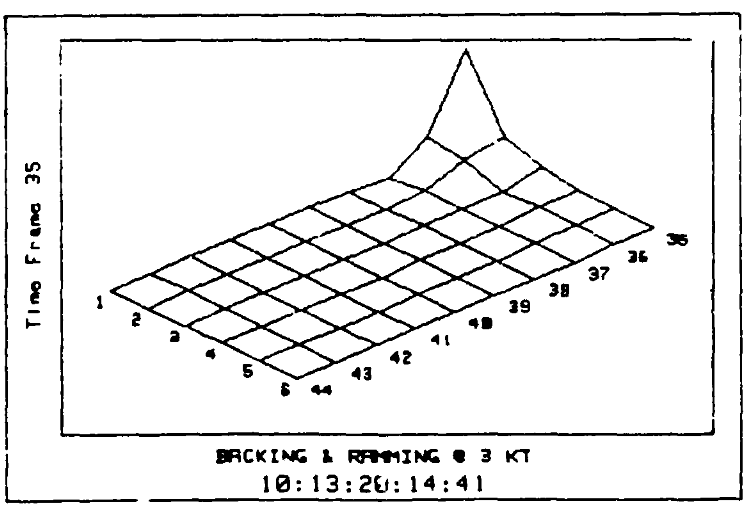
FIRST SENSOR ROW: 3

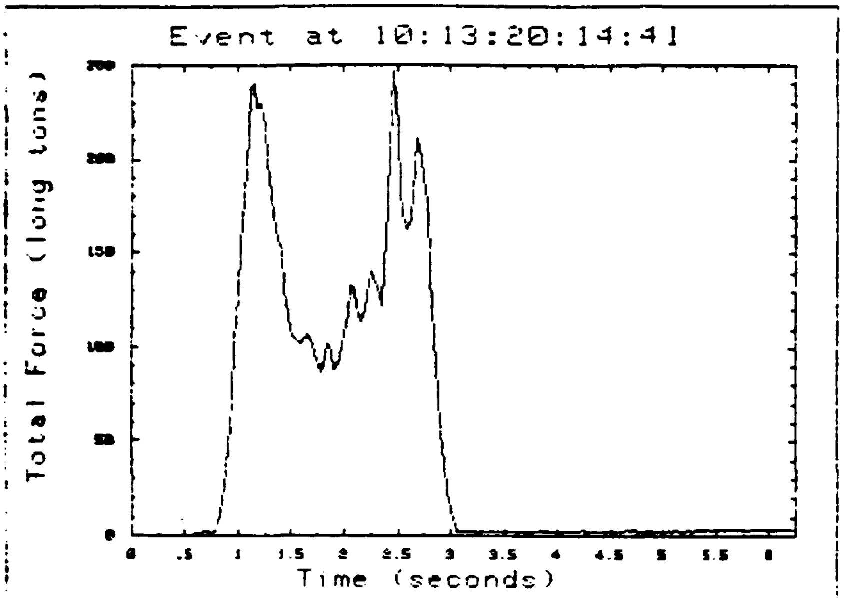
MAX PRESSURE: 1122.57 PSI. TIME FRAME 35. REAL TIME 1.09: FRAME 10. ROW 1

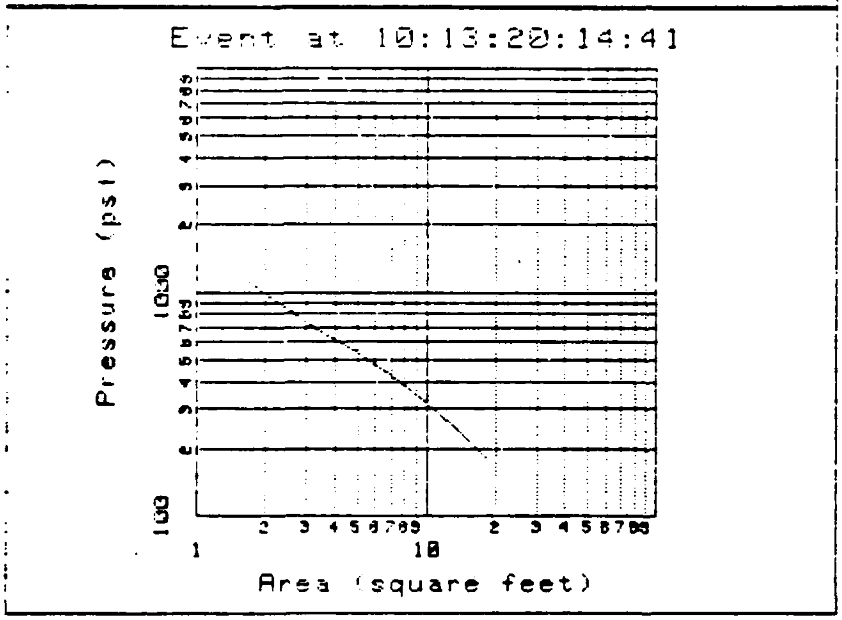
AVERAGE PRESSURE (psi) vs AREA (square feet)

Area	1.63	3.26	4.90	6.53	8.16	9.79	11.4
Pressure	1122.57	691.02	546.27	450.96	381.93	322.33	281.3
Area	13.06	14.69	16.32	17.95			
Pressure	250.08	225.25	203.55	185.09			

MAX TOTAL FORCE: 246.25 LONG TONS AT TIME FRAME 79. REAL TIME: 2.47




Event at 10:13:20:14:41
Total Force (long tons)
Time (seconds)


Event at 10:13:20:14:41
Pressure (psi)
Area (square feet)

TEN PERCENT FACTOR USED FOR OFF-DIAGONAL TERMS

EVENT AT 10:13:20:14:41   BACKING & RAMMING @ 3 KT

FIRST SENSOR ROW: 3

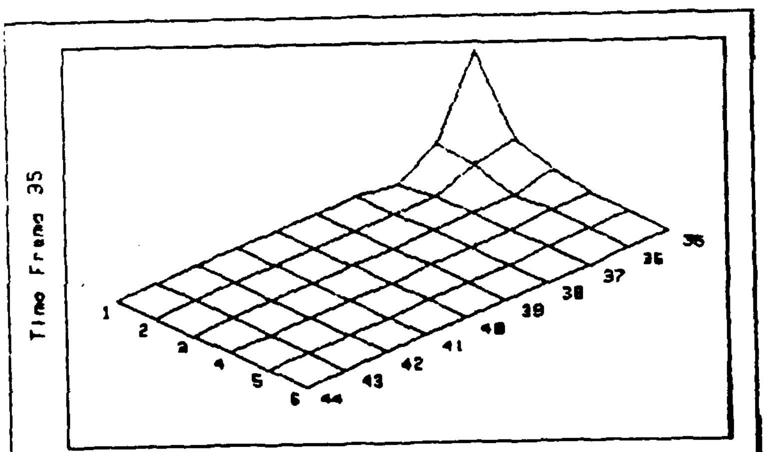
MAX PRESSURE: 1115.27 PSI. TIME FRAME 35, REAL TIME 1.09: FRAME 10, ROW 1

AVERAGE PRESSURE (psi) vs AREA (square feet)

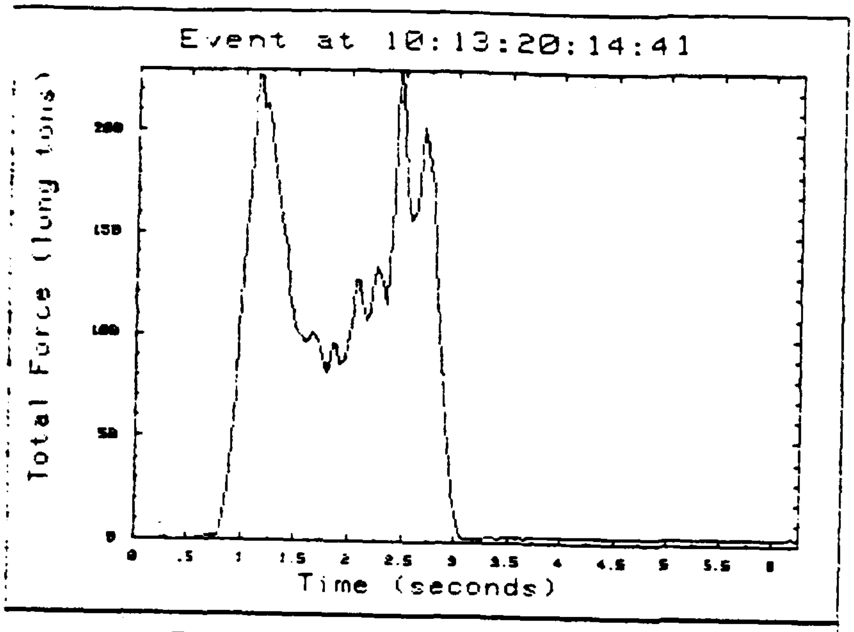
Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	1115.27	683.86	524.49	431.80	366.71	309.36	270.16

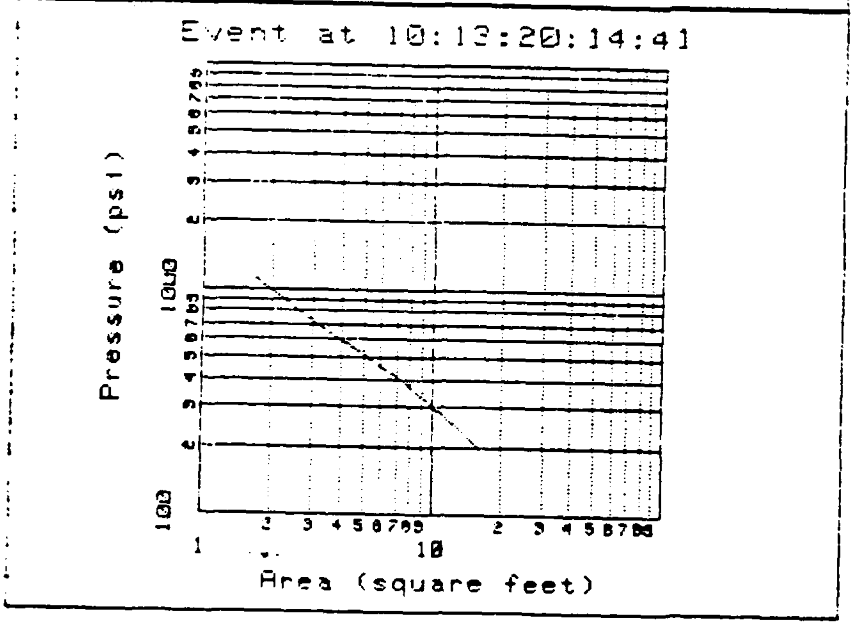
Area	13.06	14.69	16.32
Pressure	240.14	216.22	195.32

MAX TOTAL FORCE: 234.43 LONG TONS AT TIME FRAME 79, REAL TIME: 2.47



BACKING & RAMMING @ 3 KT
10:13:20:14:41


Event at 10:13:20:14:41
Total Force (long tons)
Time (seconds)
0
.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6


Event at 10:13:20:14:41
Pressure (psi)
100
1000
Area (square feet)
1
10

TWENTY PERCENT FACTOR USED FOR OFF-DIAGONAL TERMS

EVENT AT 10:13:20:14:41   BACKING & RAMMING @ 3 KT

FIRST SENSOR ROW: 3

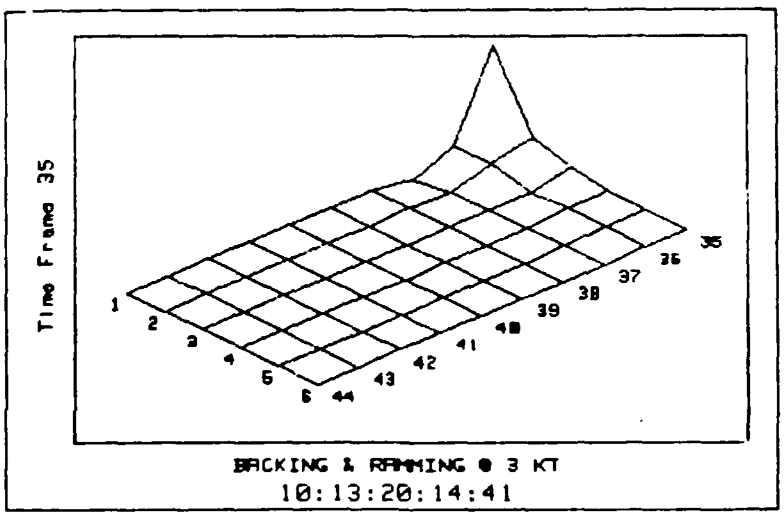
MAX PRESSURE: 1116.08 PSI, TIME FRAME 35, REAL TIME 1.09; FRAME 10, ROW 1

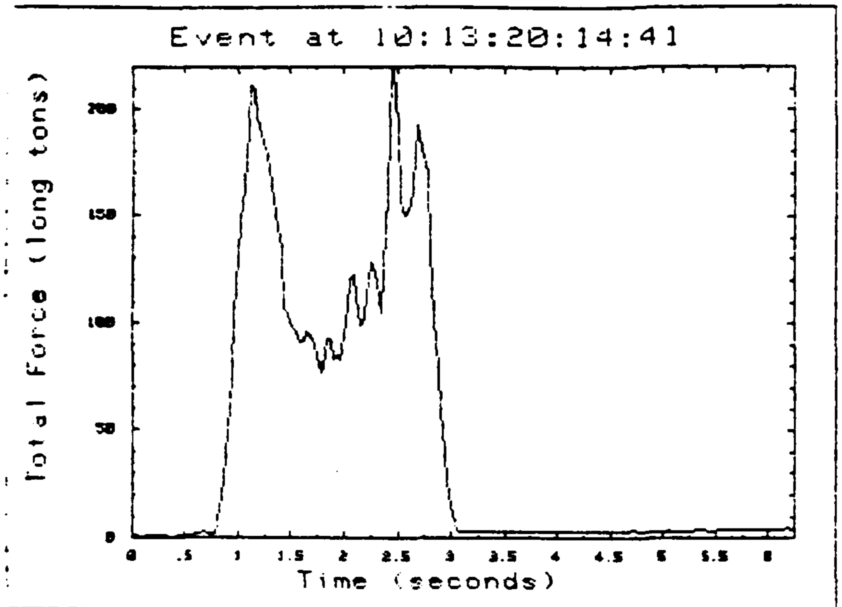
AVERAGE PRESSURE (psi) vs AREA (square feet)

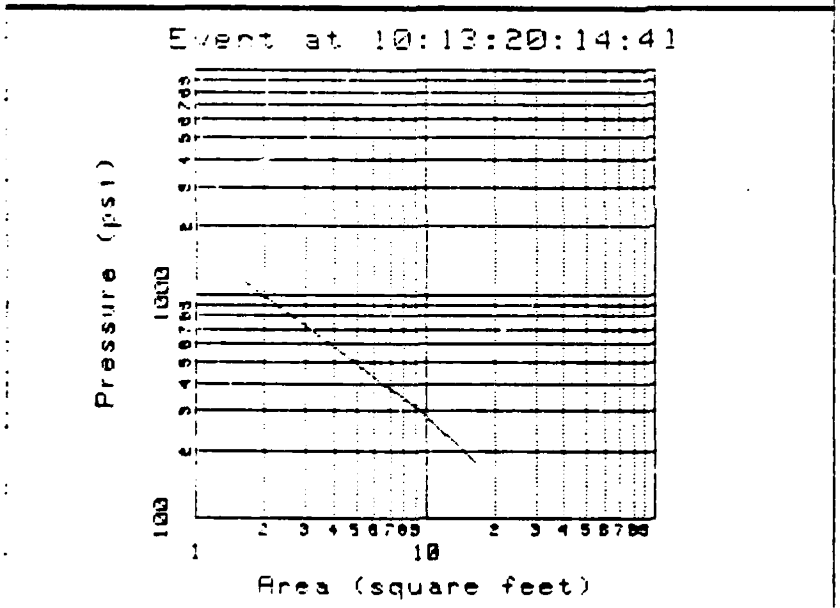
Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	1116.08	678.69	497.33	400.26	340.93	287.33	251.27

Area	13.06	14.69	16.32
Pressure	223.17	200.98	181.45

MAX TOTAL FORCE: 220.95 LONG TONS AT TIME FRAME 79, REAL TIME: 2.47




Event at 10:13:20:14:41
Total Force (long tons)
Time (seconds)


Event at 10:13:20:14:41
Pressure (psi)
Area (square feet)

FIVE PERCENT FACTOR USED FOR OFF-DIAGONAL TERMS

EVENT AT 10:08:09:00:44   Ram in MY. ice at 3 kts.

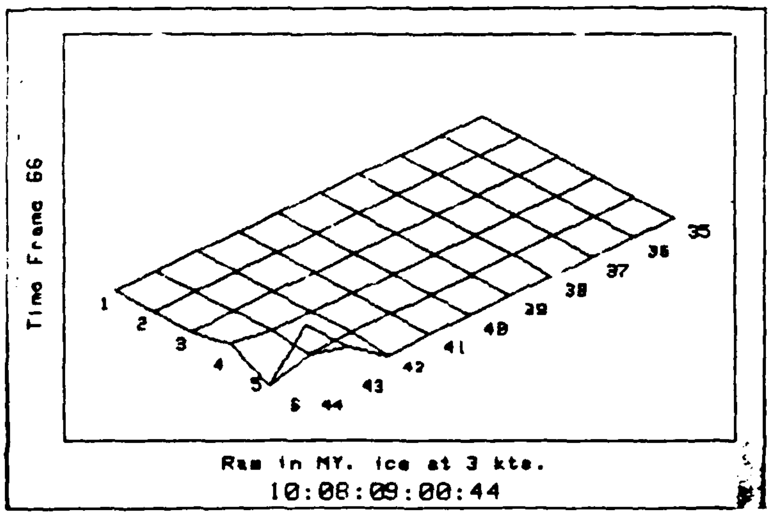
FIRST SENSOR ROW: 3

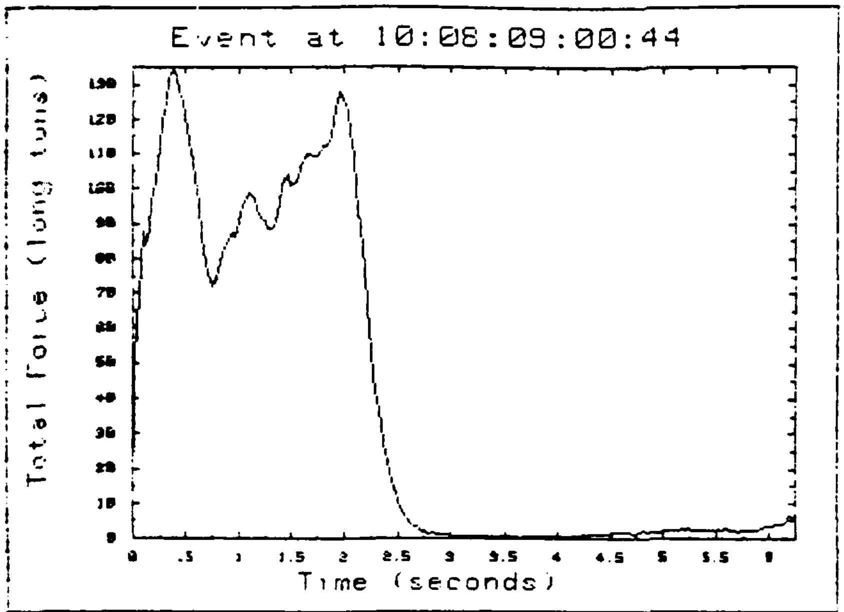
MAX PRESSURE: 706.63 PSI. TIME FRAME 66. REAL TIME   2.06: FRAME 1, ROW 6

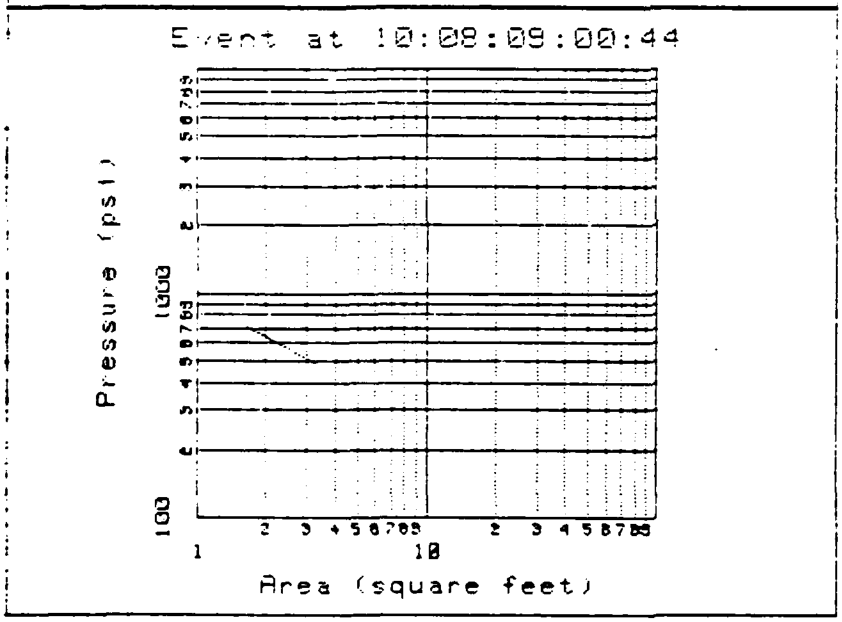
AVERAGE PRESSURE (psi) vs AREA (square feet)

Area	1.63	3.26
Pressure	706.63	492.47

MAX TOTAL FORCE: 134.34 LONG TONS AT TIME FRAME 12, REAL TIME: .38




Event at 10:08:09:00:44
Total Force (long tons)
Time (seconds)


Event at 10:08:09:00:44
Pressure (psi)
Area (square feet)

TEN PERCENT FACTOR USED FOR OFF-DIAGONAL TERMS

EVENT AT 10:08:09:00:44   Ram in MY. ice at 3 kts.

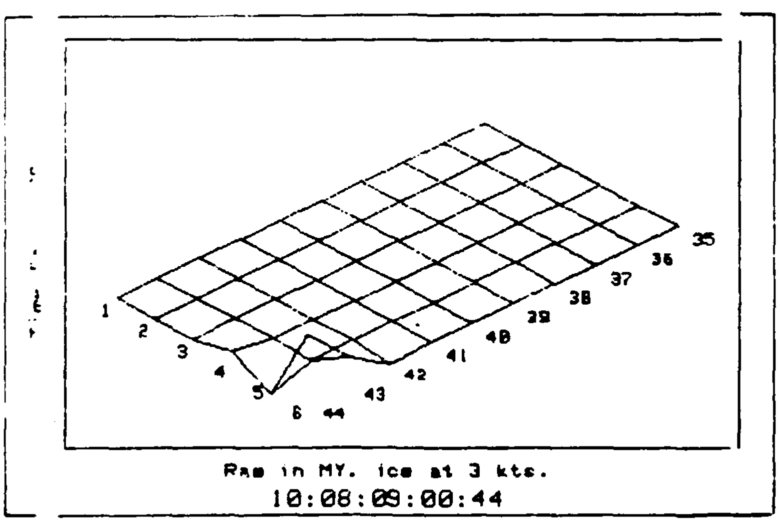
FIRST SENSOR ROW: 3

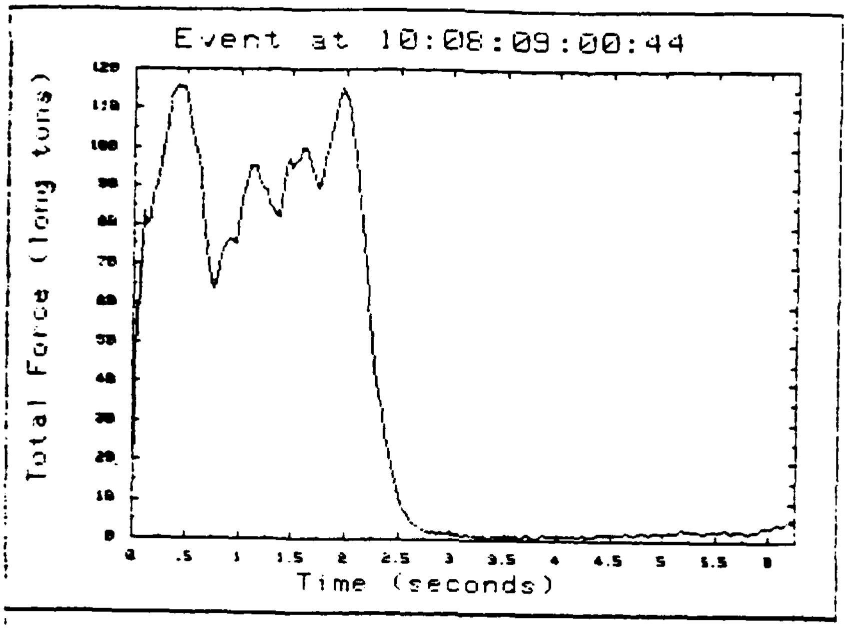
MAX PRESSURE: 696.14 PSI. TIME FRAME 66. REAL TIME   2.06: FRAME 1. ROW 6

AVERAGE PRESSURE (psi) vs AREA (square feet)

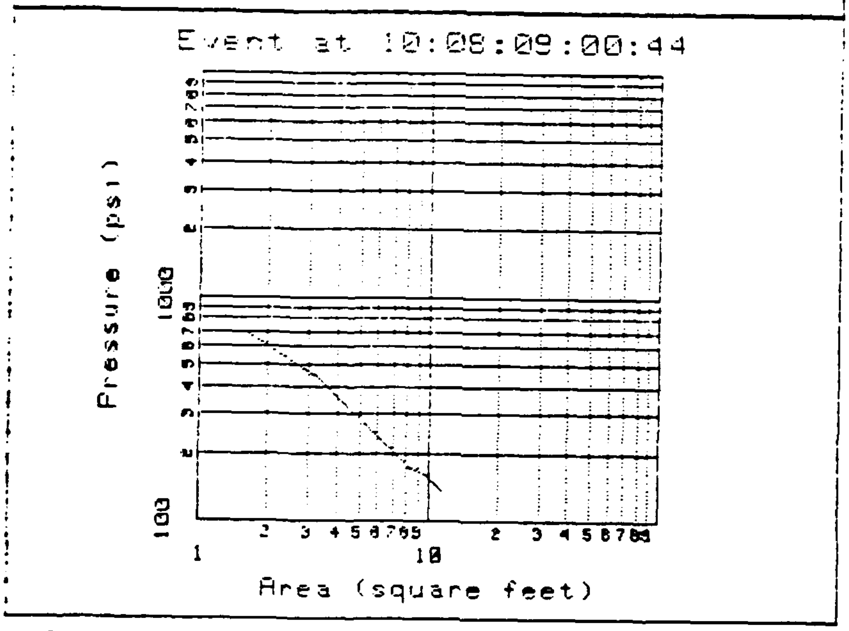
Area	1.63	3.26
Pressure	696.14	471.45

MAX TOTAL FORCE: 125.22 LONG TONS AT TIME FRAME 12. REAL TIME: .38





Event at 10:08:09:00:44
Total Force (long tons)
Time (seconds)



Event at 10:08:09:00:44
Pressure (psi)
Area (square feet)

TWENTY PERCENT FACTOR USED FOR OFF-DIAGONAL TERMS

EVENT AT 10:08:09:00:44   Ram in MY. ice at 3 kts.

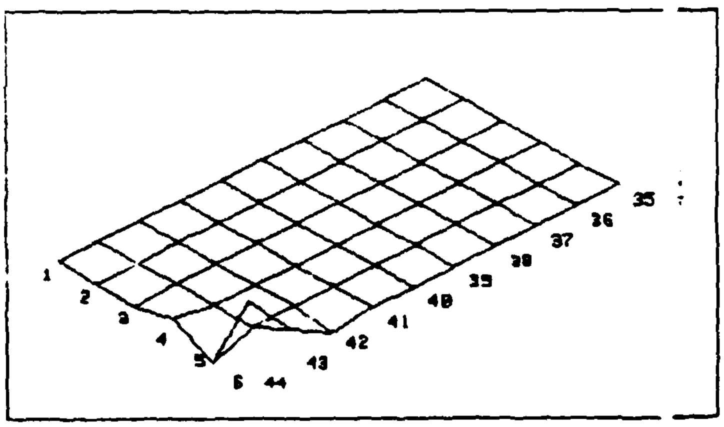
FIRST SENSOR ROW: 3

MAX PRESSURE: 684.10 PSI. TIME FRAME 66. REAL TIME 2.06: FRAME 1. ROW 6

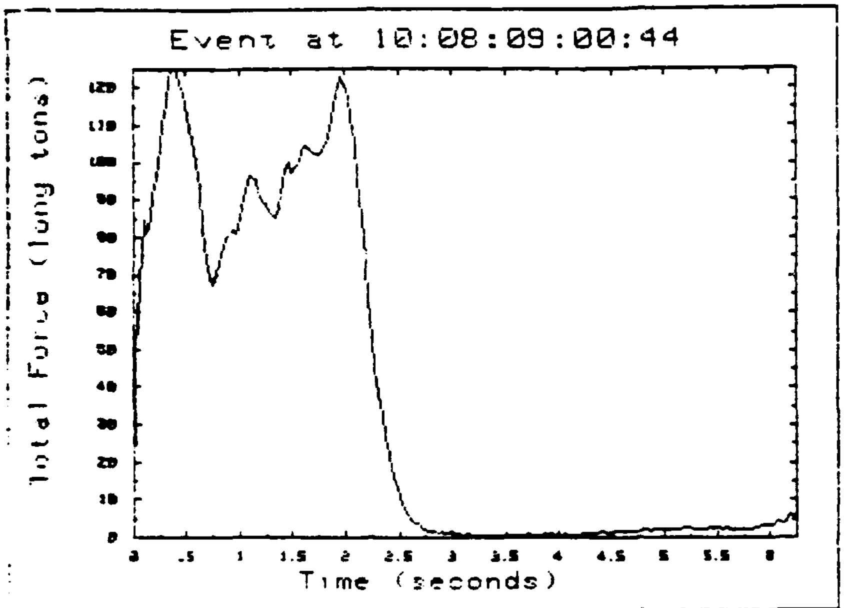
AVERAGE PRESSURE (psi) vs AREA (square feet)

Area	1.63	3.26	4.90	6.53	8.16	9.79	11.4
Pressure	684.	435.85	291.09	219.65	176.71	159.08	137.5

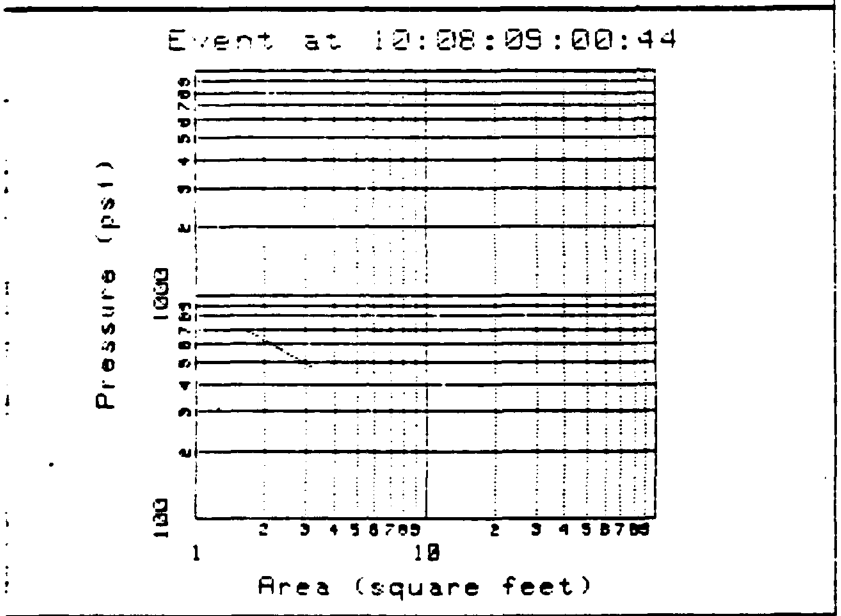
MAX TOTAL FORCE: [illegible] LONG TONS AT TIME FRAME 13. REAL TIME: .41



Ram in MY. ice at 3 kts.
10:08:09:00:44



Event at 10:08:09:00:44
Total Force (long tons)
Time (seconds)



Event at 10:08:09:00:44
Pressure (psi)
1000
100
1
10
Area (square feet)

APPENDIX D

SUMMARY OF PEAK EVENTS BY GEOGRPAHICAL AREA

SUMMER DEPLOYMENT - BEAUFORT SEA

EVENT AT 10:14:11:37:39   BACKING & RAMMING INTO M.Y. @ 3-4 KT

FIRST SENSOR ROW: 3

MAX PRESSURE: 1617.00 PSI. TIME FRAME 33, REAL TIME 1.03; FRAME 8, ROW 3

AVERAGE PRESSURE (psi) vs AREA (square feet)

Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	1617.00	1460.00	1167.00	973.00	816.00	708.00	619.00
Area	13.06	11.69	16.32	17.95	19.58	21.22	22.85
Pressure	546.00	483.00	455.00	421.00	391.00	362.00	337.00
Area	24.48	26.11					
Pressure	315.00	295.00					

MAX TOTAL FORCE: 501.00 LONG TONS AT TIME FRAME 33, REAL TIME: 1.03

PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

LENGTH	1.33	2.67	4.00	5.33
PRESSURE	1617.00	1460.00	1029.00	299.00

PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

GIRTH	1.25	2.50	3.75	5.00	6.25
PRESSURE	1617.00	1099.00	733.00	591.00	376.00

EVENT AT 10:07:23:30:29   M.Y. FRAGMENTS IN 1st YR ICE @<3 Kts

FIRST SENSOR ROW: 3

MAX PRESSURE: 1499.00 PSI. TIME FRAME 32, REAL TIME 1.00; FRAME 10, ROW 3

AVERAGE PRESSURE (psi) vs AREA (square feet)

Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	1499.00	1100.00	918.00	777.00	692.00	609.00	538.00
Area	13.06	14.69	16.32				
Pressure	479.00	438.00	394.00				

MAX TOTAL FORCE: 415.00 LONG TONS AT TIME FRAME 32, REAL TIME: 1.00

PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

LENGTH	1.33	2.67	4.00
PRESSURE	1499.00	1100.00	59.00

PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

GIRTH	1.25	2.50	3.75	5.00	6.25
PRESSURE	1499.00	926.00	735.00	390.00	326.00

EVENT AT 10:10:16:38:15

FIRST SENSOR ROW: 3

MAX PRESSURE: 1464.00 PSI. TIME FRAME 34, REAL TIME 1.06; FRAME 10, ROW 5

AVERAGE PRESSURE (psi) vs AREA (square feet)

Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	1464.00	908.00	729.00	686.00	628.00	581.00	544.00
Area	13.06	14.69	16.32	17.95	19.58		
Pressure	485.00	437.00	397.00	365.00	335.00		

MAX TOTAL FORCE: 441.00 LONG TONS AT TIME FRAME 35, REAL TIME: 1.09

PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

LENGTH	1.33	2.67	4.00	5.33	6.67	8.00
PRESSURE	1464.00	908.00	729.00	686.00	557.00	472.00

PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

GIRTH	1.25	2.50	3.75	5.00
PRESSURE	1464.00	477.00	341.00	269.00

EVENT AT 10:01:12:21:26   3-4 KTS PUSHING MYR WITH SLOW CONTINUOUS PROGRESS

FIRST SENSOR ROW: 1

MAX PRESSURE: 1453.00 PSI. TIME FRAME 22, REAL TIME .69; FRAME 3, ROW 3

AVERAGE PRESSURE (psi) vs AREA (square feet)

Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	1453.00	950.00	710.00	550.00	464.00	394.00	350.00
Area	13.06	14.69	16.32	17.95	19.58	21.22	22.85
Pressure	311.00	280.00	254.00	232.00	213.00	197.00	183.00

MAX TOTAL FORCE: 281.00 LONG TONS AT TIME FRAME 20, REAL TIME: .63

PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

LENGTH	1.33	2.67	4.00	5.33	6.67	8.00	9.33
PRESSURE	1453.00	950.00	660.00	523.00	75.00	63.00	0.00
LENGTH	10.67						
PRESSURE	0.00						

PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

GIRTH	1.25	2.50
PRESSURE	1453.00	339.00

EVENT AT 10:14:11:30:12   BACKING & RAMMING INTO M.Y. @ 2-3 KT

FIRST SENSOR ROW: 3

MAX PRESSURE: 1206.00 PSI. TIME FRAME 33, REAL TIME 1.03; FRAME 2, ROW 6

AVERAGE PRESSURE (psi) vs AREA (square feet)

Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	1206.00	896.00	614.00	464.00	379.00	325.00	282.00
Area	13.06	14.69	16.32	17.95	19.58	21.22	22.85
Pressure	248.00	221.00	199.00	184.00	169.00	156.00	145.00
Area	24.48						
Pressure	136.00						

MAX TOTAL FORCE: 220.00 LONG TONS AT TIME FRAME 33, REAL TIME: 1.03

PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

LENGTH	1.33	2.67	4.00	5.33
PRESSURE	1206.00	896.00	614.00	0.00

PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

GIRTH	1.25	2.50	3.75	5.00	6.25
PRESSURE	1206.00	301.00	213.00	162.00	22.00

EVENT AT 10:14:11:40:20   BACKING & RAMMING INTO M.Y. @ 2-3 KT

FIRST SENSOR ROW: 3

MAX PRESSURE: 1156.00 PSI. TIME FRAME 37, REAL TIME 1.16; FRAME 1, ROW 3

AVERAGE PRESSURE (psi) vs AREA (square feet)

Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	1156.00	992.00	720.00	553.00	451.00	380.00	329.00
Area	13.06	14.69	16.32	17.95			
Pressure	209.00	258.00	233.00	212.00			

MAX TOTAL FORCE: 442.00 LONG TONS AT TIME FRAME 194, REAL TIME: 6.06

PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

LENGTH	1.33	2.67	4.00	5.33	6.67
PRESSURE	1156.00	992.00	677.00	514.00	411.00

PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

GIRTH	1.25	2.50	3.75
PRESSURE	1156.00	503.00	39.00

EVENT AT 10:13:20:14:41 BACKING & RAMMING @ 3 KT

FIRST SENSOR ROW: 3

MAX PRESSURE: 1115.00 PSI. TIME FRAME 35, REAL TIME 1.09; FRAME 10, ROW 1

AVERAGE PRESSURE (psi) vs AREA (square feet)

Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	1115.00	685.00	525.00	432.00	367.00	310.00	270.00

Area	13.06	14.69	16.32
Pressure	241.00	217.00	196.00

MAX TOTAL FORCE: 235.00 LONG TONS AT TIME FRAME 79, REAL TIME: 2.47

PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

LENGTH	1.33	2.67	4.00
PRESSURE	1115.00	660.00	21.00

PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

GIRTH	1.25	2.50	3.75	5.00	6.25
PRESSURE	1115.00	685.00	492.00	375.00	306.00

EVENT AT 10:10:18:41:16

FIRST SENSOR ROW: 3

MAX PRESSURE: 1109.00 PSI. TIME FRAME 32, REAL TIME 1.00; FRAME 3, ROW 2

AVERAGE PRESSURE (psi) vs AREA (square feet)

Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	1109.00	650.00	487.00	384.00	323.00	278.00	244.00
Area	13.06	14.69	16.32	17.95	19.58	21.22	22.85
Pressure	214.00	197.00	179.00	163.00	150.00	140.00	131.00
Area	24.48	26.11					
Pressure	122.00	115.00					

MAX TOTAL FORCE: 201.00 LONG TONS AT TIME FRAME 33, REAL TIME: 1.03

PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

LENGTH	1.33	2.67	4.00	5.33
PRESSURE	1109.00	650.00	450.00	20.00

PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

GIRTH	1.25	2.50	3.75	5.00	6.25	7.50
PRESSURE	1109.00	635.00	66.00	50.00	41.00	36.00

EVENT AT 10:10:18:20:07

FIRST SENSOR ROW: 3

MAX PRESSURE: 1093.00 PSI. TIME FRAME 35, REAL TIME 1.09; FRAME 4, ROW 2

AVERAGE PRESSURE (psi) vs AREA (square feet)

Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	1093.00	730.00	609.00	487.00	412.00	356.00	308.00

MAX TOTAL FORCE: 243.00 LONG TONS AT TIME FRAME 35, REAL TIME: 1.09

PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

LENGTH	1.33	2.67	4.00	5.33
PRESSURE	1093.00	730.00	609.00	487.00

PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

GIRTH	1.25	2.50
PRESSURE	1093.00	239.00

EVENT AT 10:12:17:07:44   STEADY RUNNING THRU M.Y. & FIRST YEAR

FIRST SENSOR ROW: 3

MAX PRESSURE: 1053.00 PSI. TIME FRAME 34, REAL TIME 1.06; FRAME 5, ROW 5

AVERAGE PRESSURE (psi) vs AREA (square feet)

Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	1053.00	861.00	804.00	787.00	722.00	670.00	607.00

Area	13.06	14.69
Pressure	563.00	518.00

MAX TOTAL FORCE: 496.00 LONG TONS AT TIME FRAME 34, REAL TIME: 1.06

PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

LENGTH	1.33	2.67	4.00
PRESSURE	1053.00	733.00	564.00

PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

GIRTH	1.25	2.50	3.75	5.00
PRESSURE	1053.00	861.00	804.00	420.00

EVENT AT 10:07:18:48:11   M.Y. FRAGMENTS IN 1st YR ICE

FIRST SENSOR ROW: 3

MAX PRESSURE: 1030.00 PSI. TIME FRAME 121, REAL TIME 3.78; FRAME 1, ROW 6

AVERAGE PRESSURE (psi) vs AREA (square feet)

Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	1030.00	640.00	430.00	340.00	274.00	230.00	198.00
Area	13.06						
Pressure	174.00						

MAX TOTAL FORCE: 191.00 LONG TONS AT TIME FRAME 112, REAL TIME: 3.50

PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

LENGTH	1.33	2.67	4.00
PRESSURE	1030.00	640.00	428.00

PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

GIRTH	1.25	2.50	3.75
PRESSURE	1030.00	520.00	369.00

EVENT AT 10:12:18:58:17   7 KT IMPACT

FIRST SENSOR ROW: 3

MAX PRESSURE: 1015.00 PSI. TIME FRAME 33, REAL TIME 1.03; FRAME 2, ROW 1

AVERAGE PRESSURE (psi) vs AREA (square feet)

Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	1015.00	762.00	607.00	511.00	430.00	367.00	362.00
Area	13.06	14.69	16.32	17.95			
Pressure	341.00	310.00	280.00	254.00			

MAX TOTAL FORCE: 368.00 LONG TONS AT TIME FRAME 35, REAL TIME: 1.09

PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

LENGTH	1.33	2.67	4.00	5.33	6.67	8.00
PRESSURE	1015.00	762.00	583.00	450.00	0.00	39.00

PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (1 1)

GIRTH	1.25	2.50
PRESSURE	1015.00	656.00

EVENT AT 10:10:16:36:14

FIRST SENSOR ROW: 3

MAX PRESSURE: 1010.00 PSI. TIME FRAME 34, REAL TIME 1.06; FRAME 8, ROW 3

AVERAGE PRESSURE (psi) vs AREA (square feet)

Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	1010.00	705.00	558.00	465.00	387.00	332.00	292.00
Area	13.06	14.69	16.32	17.95	19.58	21.22	
Pressure	262.00	238.00	217.00	202.00	186.00	172.00	

MAX TOTAL FORCE: 255.00 LONG TONS AT TIME FRAME 33, REAL TIME: 1.03

PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

LENGTH	1.33	2.67	4.00
PRESSURE	1010.00	638.00	177.00

PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

GIRTH	1.25	2.50	3.75	5.00	6.25
PRESSURE	1010.00	705.00	531.00	410.00	328.00

APPENDIX D (CONTINUED)

WINTER DEPLOYMENT - SOUTH BERING SEA

EVENT ON 26 MAR AT 2:52:14
TAPE NUMBER 2 : TRACK NUMBER 1 ; FILE NUMBER 66
PEAK STRAIN 505; THRESHOLD 75
RELATIONSHIPS FOR TIME OF PEAK PRESSURE

MAX PRESSURE 1137 PSI; TIME FRAME 146; REAL TIME 4.56
FRAME 38; ROW 5

AVERAGE PRESSURE (psi) vs AREA (square feet)

Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	1137.00	688.00	487.00	382.00	315.00	268.00	234.00
Area	13.06	14.69	16.32	17.95	19.58	21.22	22.85
Pressure	207.00	186.00	169.00	154.00	143.00	134.00	127.00
Area	24.48	26.11	27.74	29.38	31.01	32.64	34.27
Pressure	123.00	120.00	114.00	109.00	106.00	102.00	98.00
Area	35.90	37.53	39.17	40.80	42.43	44.06	45.69
Pressure	95.00	91.00	88.00	85.00	82.00	80.00	78.00
Area	47.33	48.96	50.59	52.22	53.85	55.49	57.12
Pressure	76.00	74.00	72.00	71.00	69.00	67.00	66.00
Area	58.75	60.38	62.01	63.65	65.28	66.91	68.54
Pressure	64.00	63.00	61.00	60.00	59.00	57.00	56.00
Area	70.17	71.81	73.44	75.07	76.70	78.33	79.97
Pressure	55.00	54.00	53.00	52.00	51.00	50.00	49.00
Area	81.60	83.23					
Pressure	48.00	47.00					

PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

GIRTH	1.25	2.50	3.75	5.00	6.25	7.50
PRESSURE	1137.00	592.00	57.00	20.00	17.00	15.00

PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

LENGTH	1.33	2.67	4.00	5.33	6.67	8.00	9.33
PRESSURE	1137.00	688.00	487.00	375.00	37.00	35.00	33.00
LENGTH	10.67	12.00	13.33				
PRESSURE	30.00	29.00	28.00				

RELATIONSHIPS FOR TIME OF PEAK FORCE

MAX TOTAL FORCE 280 LONG TONS: TIME FRAME 106: REAL TIME 3.31
FRAME 37: ROW 5

AVERAGE PRESSURE (psi) vs AREA (square feet)

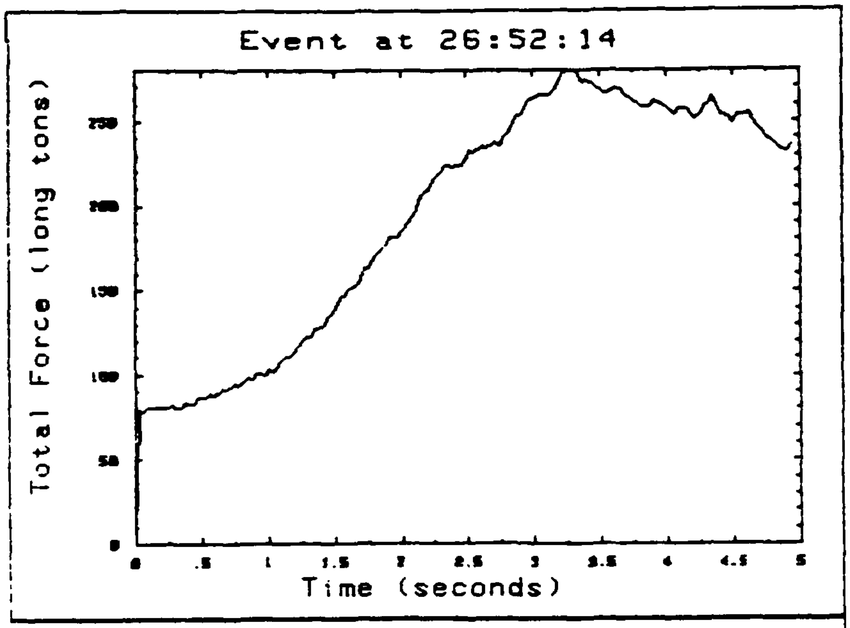
Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	717.00	689.00	537.00	435.00	361.00	311.00	268.00
Area	13.06	14.69	16.32	17.95	19.58	21.22	22.85
Pressure	236.00	215.00	200.00	184.00	171.00	162.00	153.00
Area	24.48	26.11	27.74	29.38	31.01	32.64	34.27
Pressure	145.00	137.00	130.00	124.00	120.00	115.00	110.00
Area	35.90	37.53	39.17	40.80	42.43	44.06	45.69
Pressure	106.00	102.00	98.00	95.00	92.00	90.00	87.00
Area	47.33	48.96	50.59	52.22	53.85	55.49	57.12
Pressure	85.00	82.00	80.00	78.00	75.00	74.00	72.00
Area	58.75	60.38	62.01	63.65	65.28	66.91	68.54
Pressure	71.00	69.00	67.00	66.00	65.00	63.00	62.00
Area	70.17	71.81	73.44	75.07	76.70	78.33	79.97
Pressure	61.00	60.00	58.00	57.00	56.00	55.00	54.00
Area	81.60	83.23	84.86	86.49	88.12		
Pressure	53.00	52.00	51.00	50.00	49.00		

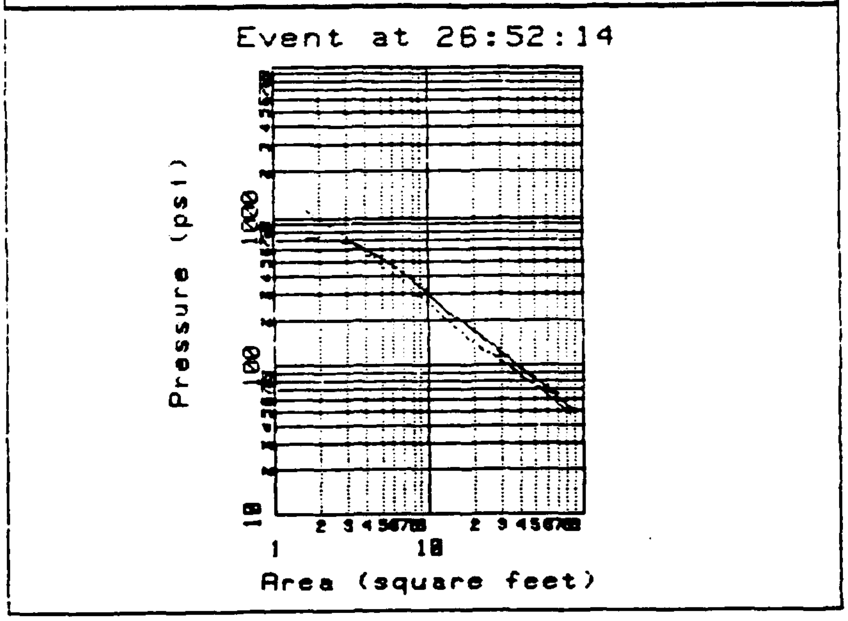
PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

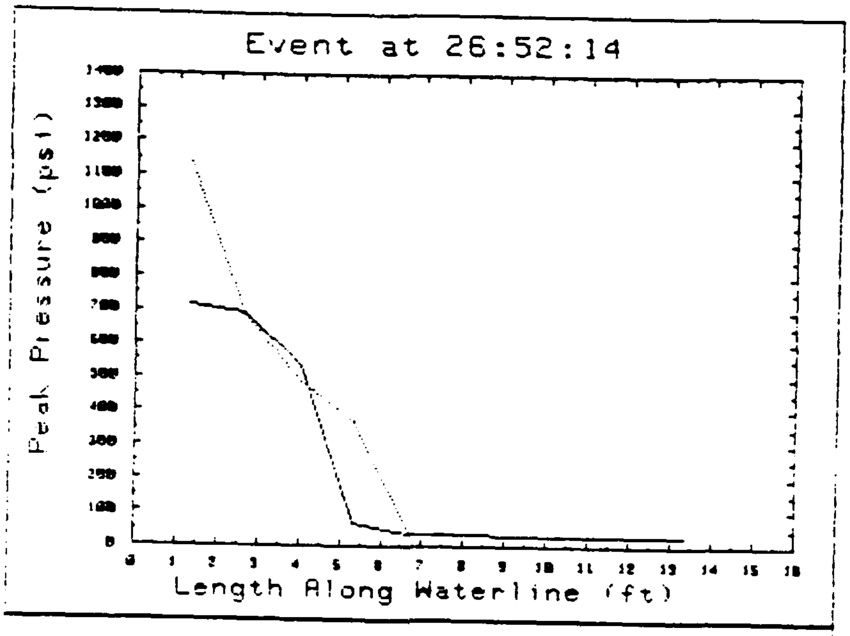
GIRTH	1.25	2.50	3.75	5.00	6.25	7.50
PRESSURE	717.00	423.00	103.00	81.00	69.00	63.00

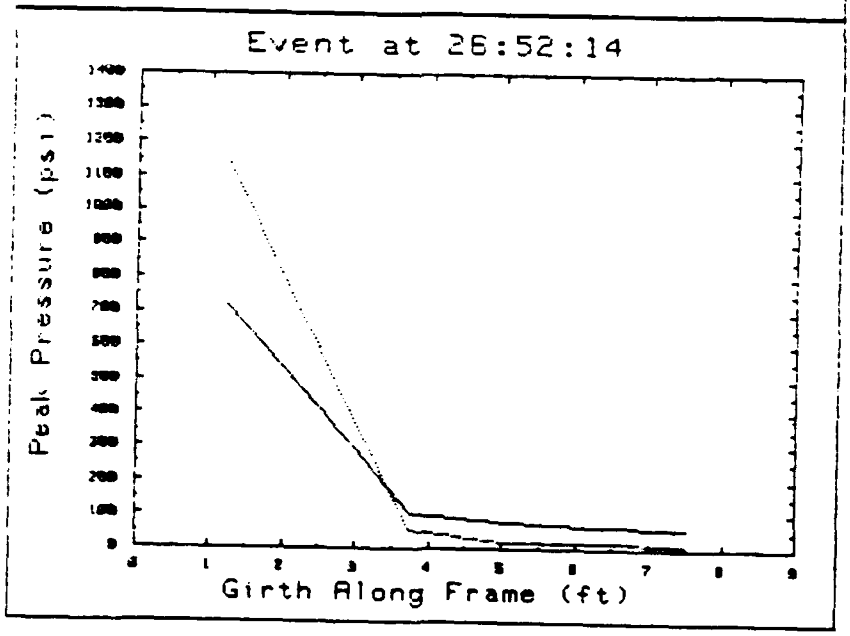
PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

LENGTH	1.33	2.67	4.00	5.33	6.67	8.00	9.33
PRESSURE	717.00	689.00	537.00	64.00	37.00	36.00	33.00
LENGTH	10.67	12.00	13.33				
PRESSURE	31.00	30.00	29.00				


Event at 26:52:14
Total Force (long tons)
Time (seconds)


Event at 26:52:14
Pressure (psi)
Area (square feet)


Event at 26:52:14
Peak Pressure (psi)
Length Along Waterline (ft)


Event at 26:52:14
Peak Pressure (psi)
Girth Along Frame (ft)

EVENT ON 25 MAR AT 22:2:30
TAPE NUMBER 2 ; TRACK NUMBER 1 ; FILE NUMBER 12
PEAK STRAIN 212; THRESHOLD 75
RELATIONSHIPS FOR TIME OF PEAK PRESSURE

MAX PRESSURE 369 PSI; TIME FRAME 128; REAL TIME 4.00
FRAME 41; ROW 6

AVERAGE PRESSURE (psi) vs AREA (square feet)

Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	369.00	276.00	193.00	151.00	122.00	102.00	89.00
Area	13.06	14.69	16.32	17.95	19.58	21.22	22.85
Pressure	78.00	70.00	64.00	59.00	55.00	53.00	50.00
Area	24.48	26.11	27.74	29.38	31.01	32.64	34.27
Pressure	48.00	45.00	43.00	41.00	40.00	39.00	37.00
Area	35.90	37.53	39.17	40.80	42.43	44.06	45.69
Pressure	36.00	35.00	33.00	32.00	31.00	31.00	30.00
Area	47.33	48.96	50.59	52.22	53.85	55.49	57.12
Pressure	29.00	28.00	27.00	27.00	26.00	25.00	25.00
Area	58.75	60.38	62.01	63.65	65.28	66.91	68.54
Pressure	24.00	24.00	23.00	22.00	22.00	22.00	21.00
Area	70.17	71.81	73.44	75.07	76.70	78.33	
Pressure	21.00	20.00	20.00	20.00	19.00	19.00	

PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

GIRTH	1.25	2.50	3.75	5.00	6.25	7.50
PRESSURE	369.00	27.00	19.00	8.00	6.00	6.00

PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

LENGTH	1.33	2.67	4.00	5.33	6.67	8.00	9.33
PRESSURE	369.00	276.00	193.00	145.00	16.00	16.00	16.00
LENGTH	10.67	12.00	13.33				
PRESSURE	7.00	7.00	7.00				

RELATIONSHIPS FOR TIME OF PEAK FORCE

MAX TOTAL FORCE 103 LONG TONS: TIME FRAME 35: REAL TIME 1.0S
FRAME 38: ROW 5

AVERAGE PRESSURE (psi) vs AREA (square feet)

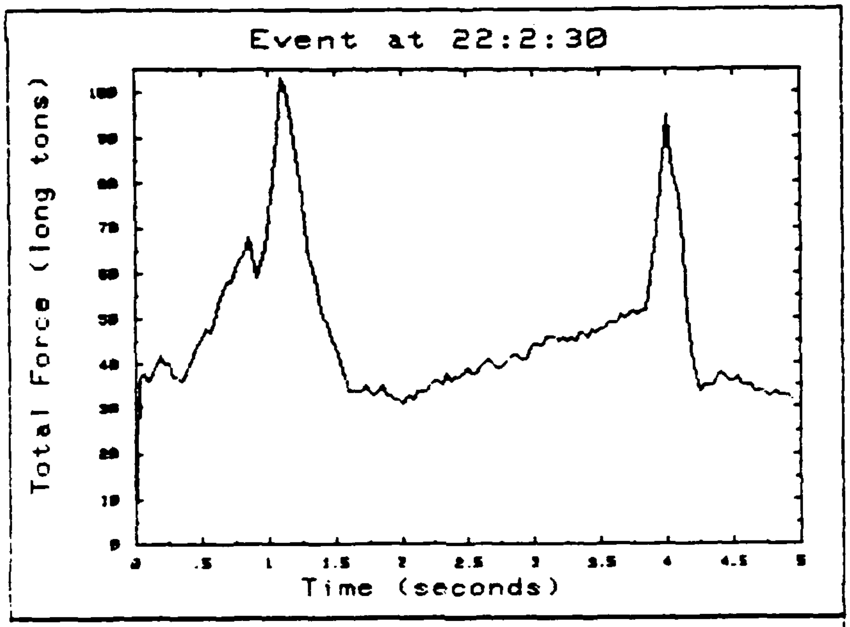
Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	182.00	151.00	121.00	94.00	77.00	66.00	57.00
Area	13.06	14.69	16.32	17.95	19.58	21.22	22.85
Pressure	51.00	47.00	44.00	41.00	40.00	39.00	37.00
Area	24.48	26.11	27.74	29.38	31.01	32.64	34.27
Pressure	36.00	34.00	33.00	32.00	31.00	29.00	28.00
Area	35.90	37.53	39.17	40.80	42.43	44.06	45.69
Pressure	28.00	27.00	27.00	26.00	26.00	26.00	29.00
Area	47.33	48.96	50.59	52.22	53.85	55.49	57.12
Pressure	29.00	28.00	28.00	27.00	27.00	26.00	26.00
Area	58.75	60.38	62.01	63.65	65.28	66.91	68.54
Pressure	25.00	25.00	24.00	24.00	23.00	23.00	23.00
Area	70.17	71.81	73.44	75.07	76.70	78.33	79.97
Pressure	22.00	22.00	21.00	21.00	21.00	20.00	20.00
Area	81.60	83.23	84.86	86.49	88.12	89.76	
Pressure	20.00	19.00	19.00	19.00	18.00	18.00	

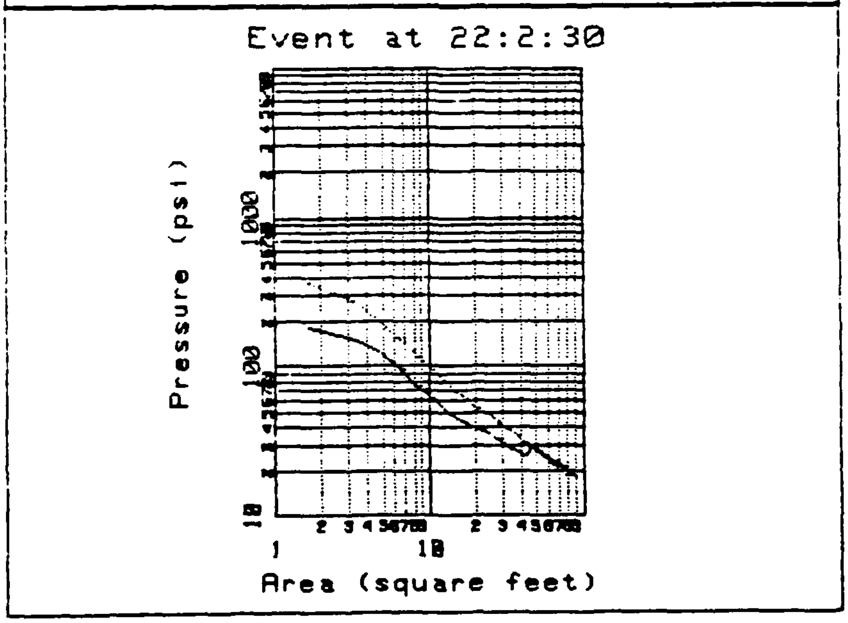
PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

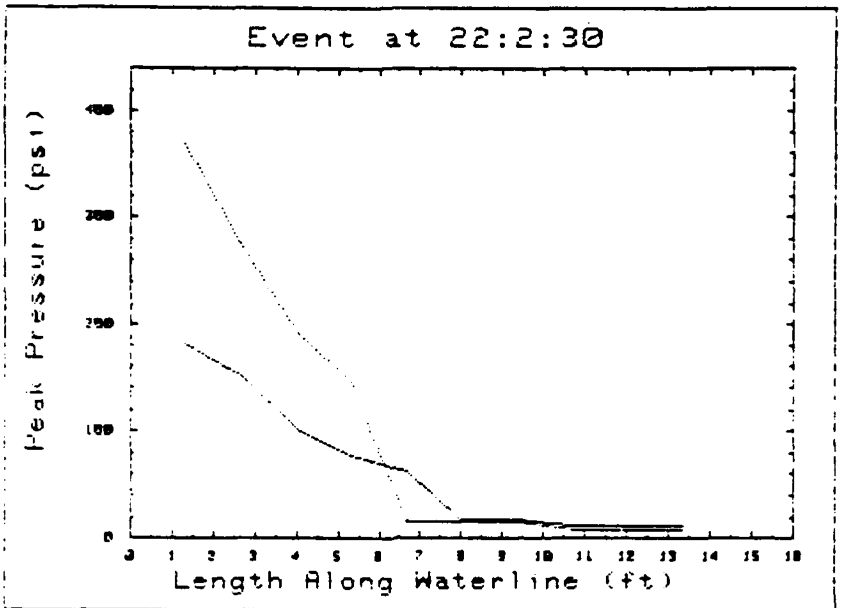
GIRTH	1.25	2.50	3.75	5.00	6.25	7.50
PRESSURE	182.00	122.00	45.00	37.00	33.00	28.00

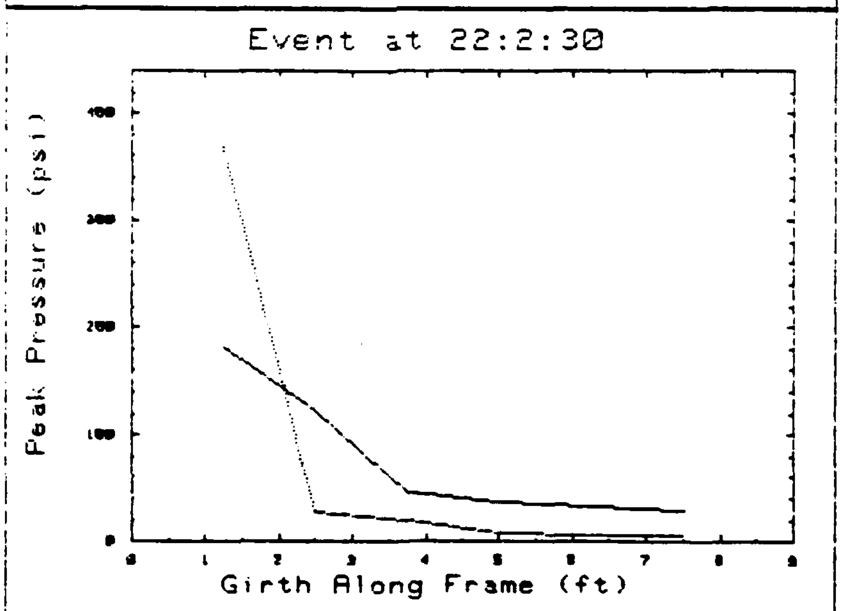
PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

LENGTH	1.33	2.67	4.00	5.33	6.67	8.00	9.33
PRESSURE	182.00	151.00	103.00	78.00	63.00	17.00	17.00
LENGTH	10.67	12.00	13.33				
PRESSURE	11.00	11.00	11.00				


Event at 22:2:30
Total Force (long tons)
Time (seconds)


Event at 22:2:30
Pressure (psi)
Area (square feet)


Event at 22:2:30
Peak Pressure (psi)
Length Along Waterline (ft)


Event at 22:2:30
Peak Pressure (psi)
Girth Along Frame (ft)

EVENT ON 26 MAR AT 10:1:38
TAPE NUMBER 2 ; TRACK NUMBER 2 : FILE NUMBER 9
PEAK STRAIN 174: THRESHOLD 75
RELATIONSHIPS FOR TIME OF PEAK PRESSURE

MAX PRESSURE 367 PSI: TIME FRAME 59: REAL TIME 1.84
FRAME 40: ROW 5

AVERAGE PRESSURE (psi) vs AREA (square feet)

Area	1.63	3.26	4.90	6.53	8.16
Pressure	367.00	196.00	137.00	107.00	87.00

PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

GIRTH	1.25	2.50	3.75
PRESSURE	367.00	187.00	20.00

PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

LENGTH	1.33	2.67
PRESSURE	367.00	196.00

RELATIONSHIPS FOR TIME OF PEAK FORCE

MAX TOTAL FORCE 59 LONG TONS: TIME FRAME 68: REAL TIME 2.13
FRAME 40: ROW 5

AVERAGE PRESSURE (psi) vs AREA (square feet)

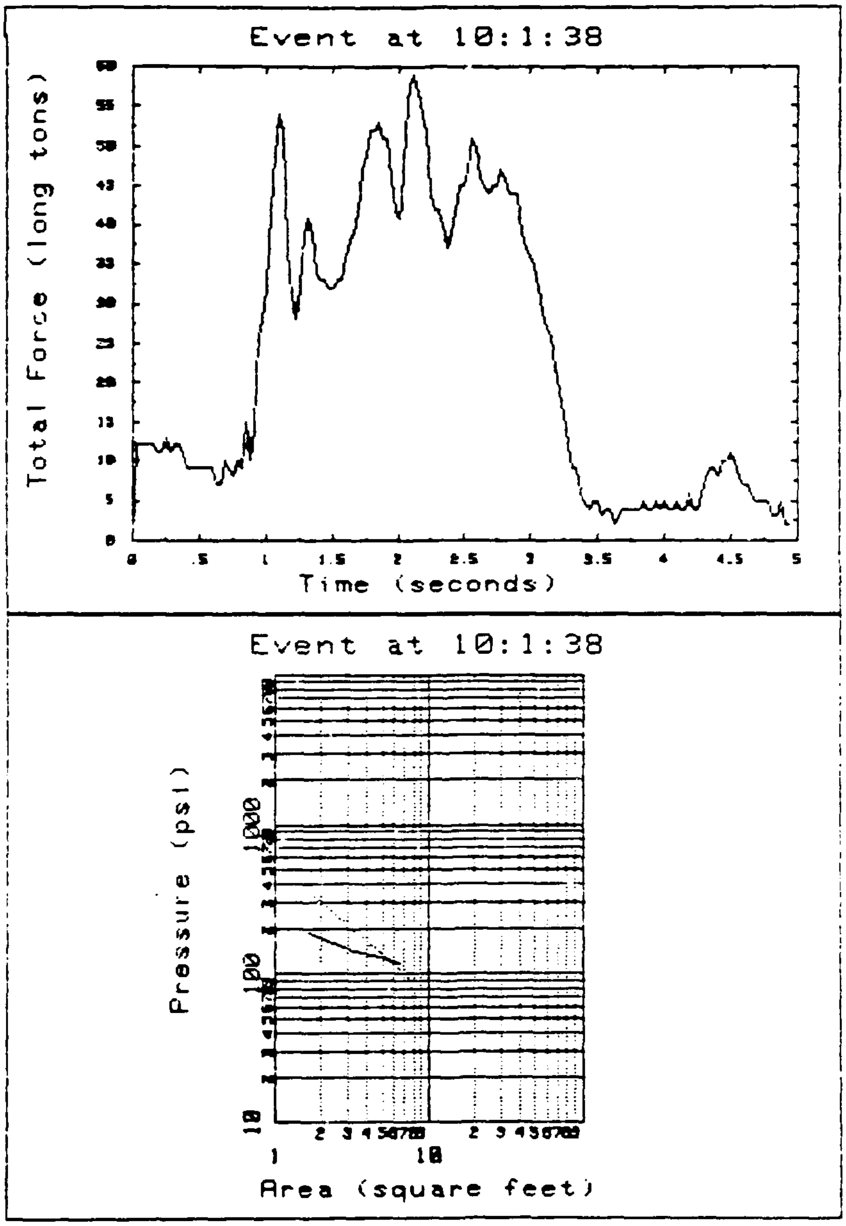
Area	1.63	3.26	4.90	6.53
Pressure	189.00	141.00	131.00	120.00

PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

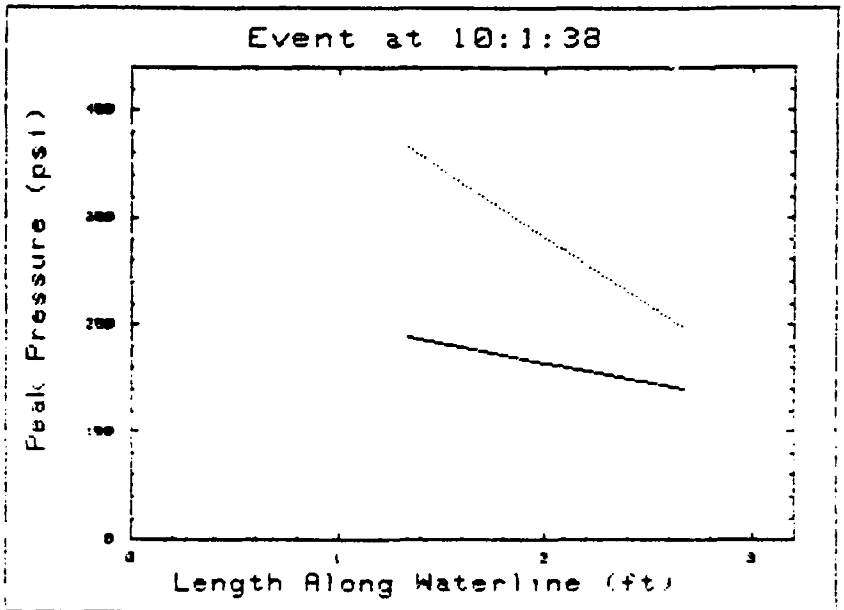
GIRTH	1.25	2.50
PRESSURE	189.00	141.00

PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

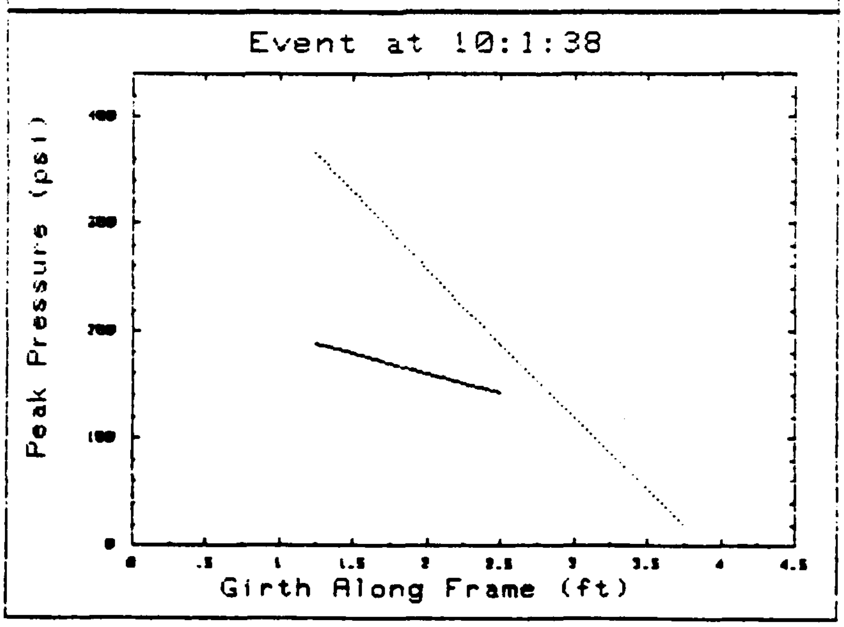
LENGTH	1.33	2.67
PRESSURE	189.00	139.00



Event at 10:1:38
Total Force (long tons)
Time (seconds)
Event at 10:1:38
Pressure (psi)
Area (square feet)



Event at 10:1:38
Peak Pressure (psi)
Length Along Waterline (ft)



Event at 10:1:38
Peak Pressure (psi)
Girth Along Frame (ft)

EVENT ON 25 MAR AT 21:49:3
TAPE NUMBER 2 : TRACK NUMBER 1 ; FILE NUMBER 9
PEAK STRAIN 168: THRESHOLD 75
RELATIONSHIPS FOR TIME OF PEAK PRESSURE

MAX PRESSURE 483 PSI: TIME FRAME 74; REAL TIME 2.31
FRAME 42: ROW 3

AVERAGE PRESSURE (psi) vs AREA (square feet)

Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	483.00	367.00	275.00	228.00	199.00	176.00	159.00
Area	13.06	14.69	16.32	17.95	19.58	21.22	22.85
Pressure	149.00	151.00	143.00	134.00	126.00	121.00	115.00
Area	24.48	26.11	27.74	29.38	31.01	32.64	34.27
Pressure	110.00	105.00	100.00	96.00	93.00	89.00	86.00
Area	35.90	37.53	39.17	40.80	42.43	44.06	45.69
Pressure	82.00	79.00	76.00	74.00	72.00	70.00	69.00
Area	47.33	48.96	50.59	52.22	53.85	55.49	57.12
Pressure	67.00	65.00	63.00	61.00	59.00	57.00	56.00
Area	58.75	60.38	62.01	63.65	65.28	66.91	68.54
Pressure	54.00	53.00	52.00	51.00	50.00	49.00	48.00
Area	70.17	71.81	73.44	75.07	76.70	78.33	79.97
Pressure	47.00	46.00	45.00	45.00	44.00	43.00	42.00

PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

GIRTH	1.25	2.50	3.75	5.00	6.25	7.50
PRESSURE	483.00	258.00	192.00	98.00	20.00	18.00

PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

LENGTH	1.33	2.67	4.00	5.33	6.67	8.00	9.33
PRESSURE	483.00	367.00	275.00	228.00	195.00	171.00	169.00
LENGTH	10.67	12.00	13.33				
PRESSURE	160.00	150.00	139.00				

RELATIONSHIPS FOR TIME OF PEAK FORCE

MAX TOTAL FORCE 236 LONG TONS: TIME FRAME 51: REAL TIME 1.59
FRAME 42: ROW 2

AVERAGE PRESSURE (psi) vs AREA (square feet)

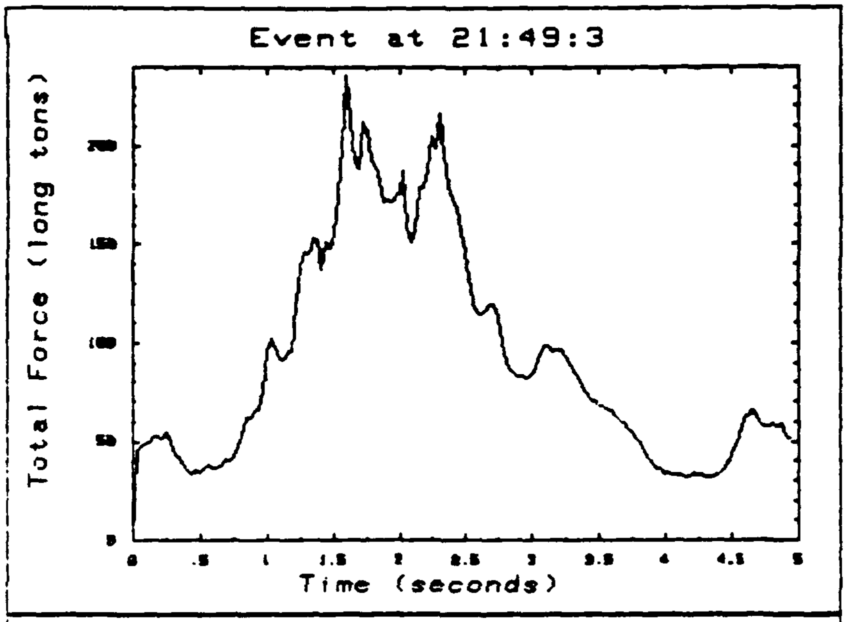
Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	281.00	247.00	221.00	200.00	200.00	185.00	172.00
Area	13.06	14.69	16.32	17.95	19.58	21.22	22.85
Pressure	158.00	153.00	151.00	143.00	136.00	129.00	125.00
Area	24.48	26.11	27.74	29.38	31.01	32.64	34.27
Pressure	119.00	114.00	110.00	105.00	101.00	97.00	94.00
Area	35.90	37.53	39.17	40.80	42.43	44.06	45.69
Pressure	90.00	87.00	84.00	82.00	79.00	77.00	74.00
Area	47.33	48.96	50.59	52.22	53.85	55.49	57.12
Pressure	72.00	70.00	68.00	66.00	64.00	63.00	61.00
Area	58.75	60.38	62.01	63.65	65.28	66.91	68.54
Pressure	59.00	58.00	57.00	56.00	55.00	54.00	53.00
Area	70.17	71.81	73.44	75.07	76.70	78.33	79.97
Pressure	52.00	51.00	50.00	49.00	48.00	47.00	46.00
Area	81.60						
Pressure	45.00						

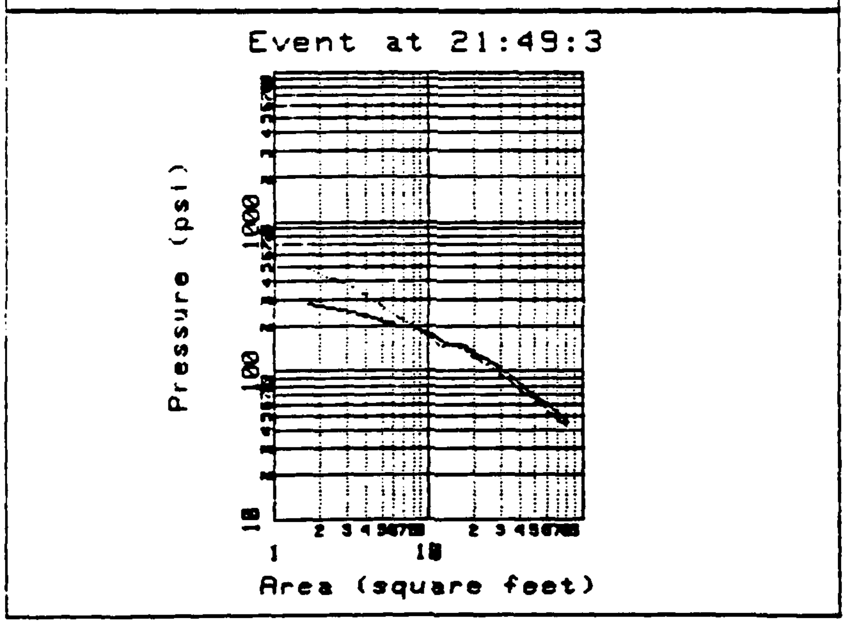
PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

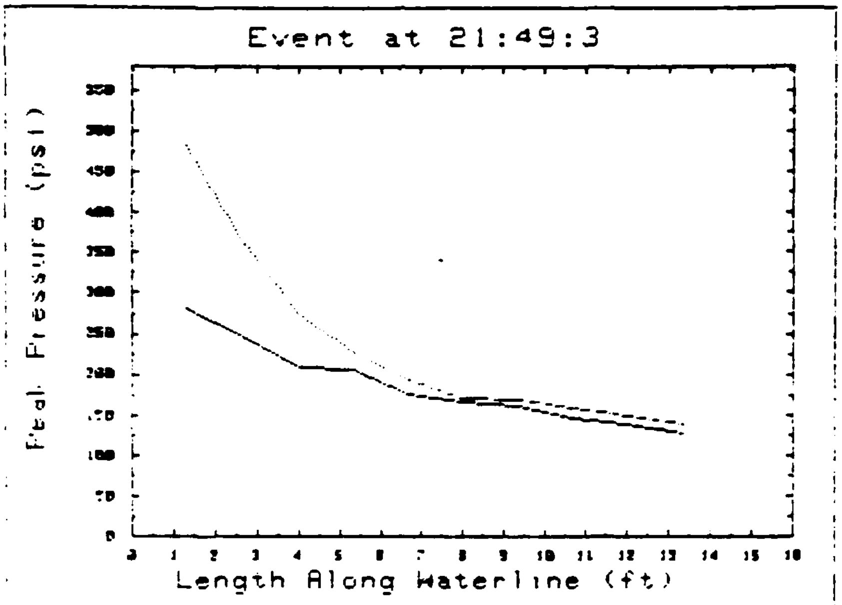
GIRTH	1.25	2.50	3.75	5.00	6.25	7.50
PRESSURE	281.00	226.00	158.00	91.00	28.00	24.00

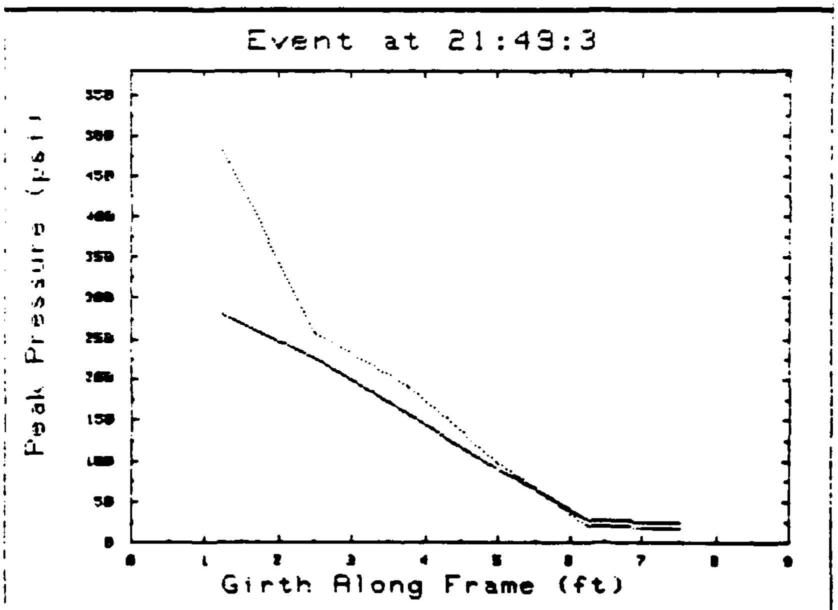
PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

LENGTH	1.33	2.67	4.00	5.33	6.67	8.00	9.33
PRESSURE	281.00	247.00	210.00	207.00	178.00	167.00	162.00
LENGTH	10.67	12.00	13.33				
PRESSURE	148.00	139.00	127.00				


Event at 21:49:3
Total Force (long tons)
Time (seconds)


Event at 21:49:3
Pressure (psi)
Area (square feet)


Event at 21:49:3
Peak Pressure (psi)
Length Along Waterline (ft)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16


Event at 21:49:3
Peak Pressure (psi)
Girth Along Frame (ft)
0 1 2 3 4 5 6 7 8 9

EVENT ON 26 MAR AT 19:39:42
TAPE NUMBER 2 : TRACK NUMBER 3 ; FILE NUMBER 22
PEAK STRAIN 168; THRESHOLD 50
RELATIONSHIPS FOR TIME OF PEAK PRESSURE

MAX PRESSURE 327 PSI; TIME FRAME 108; REAL TIME 3.38
FRAME 43; ROW 5

AVERAGE PRESSURE (psi) vs AREA (square feet)

Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	327.00	165.00	128.00	101.00	84.00	74.00	66.00
Area	13.06	14.69	16.32	17.95	19.58	21.22	22.85
Pressure	60.00	55.00	54.00	50.00	46.00	43.00	40.00
Area	24.48	26.11	27.74	29.38	31.01	32.64	34.27
Pressure	38.00	37.00	36.00	34.00	32.00	31.00	30.00
Area	35.90	37.53	39.17	40.80	42.43	44.06	45.69
Pressure	29.00	28.00	28.00	27.00	27.00	26.00	25.00
Area	47.33	48.96	50.59	52.22	53.85	55.49	57.12
Pressure	24.00	24.00	23.00	23.00	23.00	22.00	22.00
Area	58.75	60.38	62.01	63.65	65.28	66.91	
Pressure	22.00	21.00	21.00	21.00	20.00	20.00	

PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

GIRTH	1.25	2.50	3.75	5.00	6.25	7.50
PRESSURE	327.00	165.00	116.00	92.00	78.00	6.00

PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

LENGTH	1.33	2.67	4.00	5.33	6.67	8.00	9.33
PRESSURE	327.00	32.00	25.00	19.00	15.00	14.00	12.00
LENGTH	10.67						
PRESSURE	11.00						

RELATIONSHIPS FOR TIME OF PEAK FORCE

MAX TOTAL FORCE 117 LONG TONS: TIME FRAME 100: REAL TIME 3.13
FRAME 42: ROW 5

AVERAGE PRESSURE (psi) vs AREA (square feet)

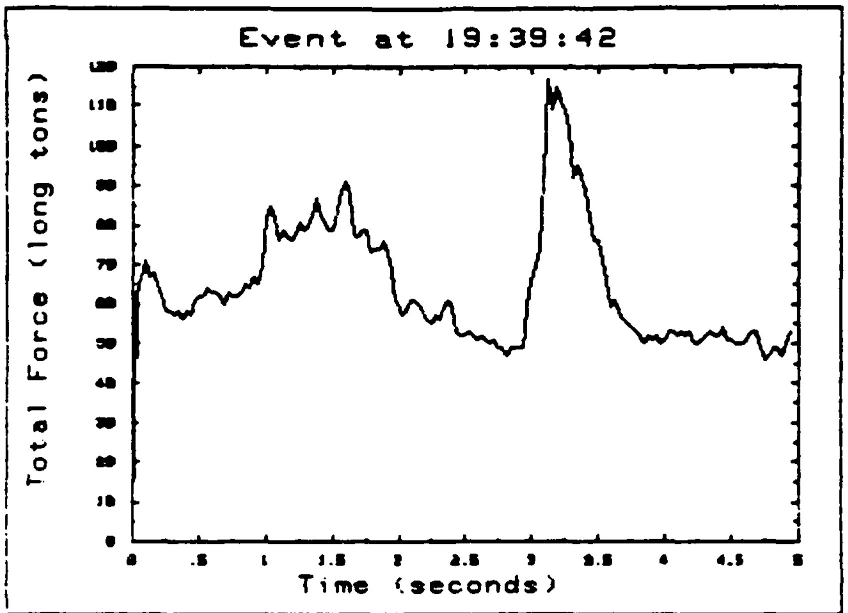
Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	319.00	225.00	189.00	163.00	144.00	125.00	110.00
Area	13.06	14.69	16.32	17.95	19.58	21.22	22.85
Pressure	99.00	90.00	83.00	77.00	72.00	68.00	64.00
Area	24.48	26.11	27.74	29.38	31.01	32.64	34.27
Pressure	60.00	57.00	54.00	51.00	50.00	48.00	46.00
Area	35.90						
Pressure	44.00						

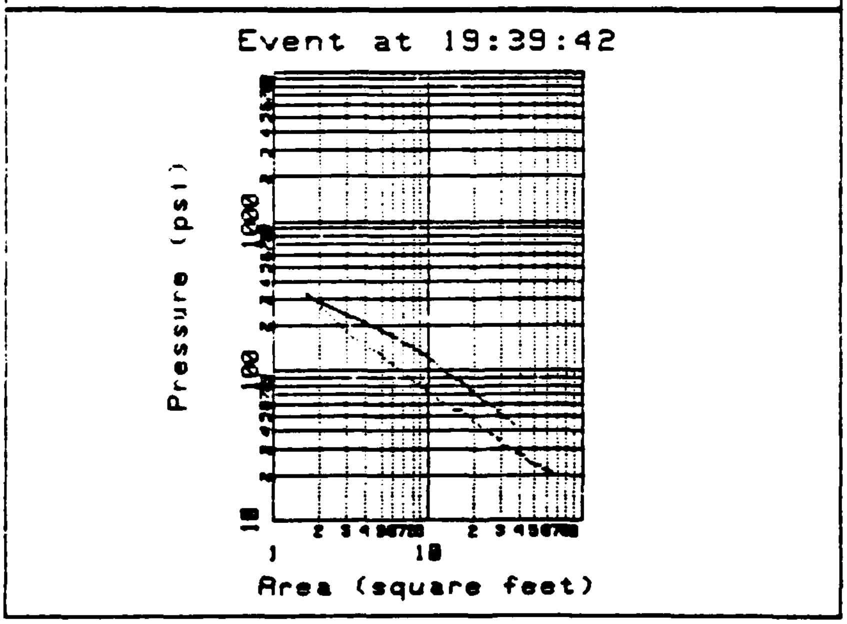
PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

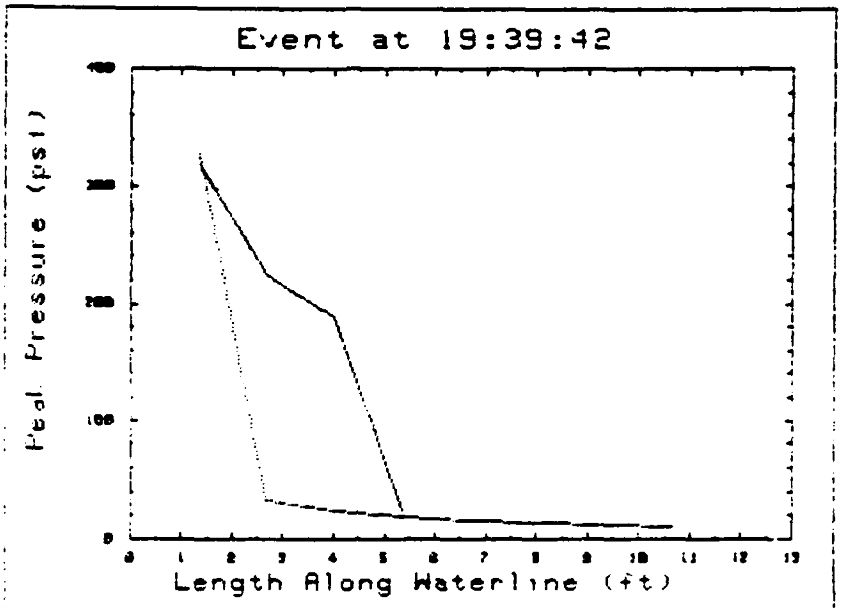
GIRTH	1.25	2.50	3.75	5.00	6.25
PRESSURE	319.00	171.00	115.00	90.00	77.00

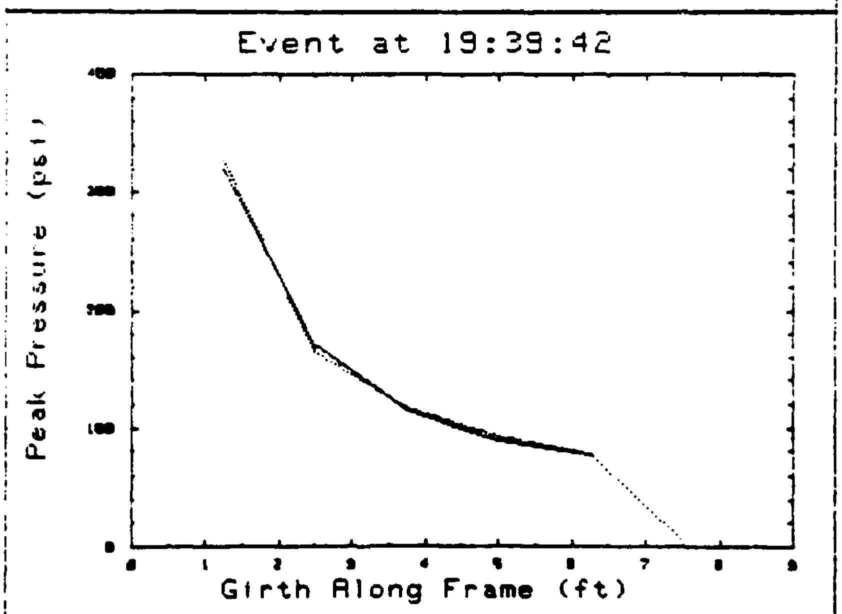
PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

LENGTH	1.33	2.67	4.00	5.33
PRESSURE	319.00	225.00	189.00	24.00


Event at 19:39:42
Total Force (long tons)
Time (seconds)


Event at 19:39:42
Pressure (psi)
Area (square feet)


Event at 19:39:42
Peak Pressure (psi)
Length Along Waterline (ft)


Event at 19:39:42
Peak Pressure (psi)
Girth Along Frame (ft)

APPENDIX D (CONTINUED)

WINTER DEPLOYMENT - NORTH BERING SEA

EVENT ON 28 MAR AT 7:54:47
TAPE NUMBER 3 ; TRACK NUMBER 1 : FILE NUMBER 70
PEAK STRAIN 308: THRESHOLD 120
RELATIONSHIPS FOR TIME OF PEAK PRESSURE

MAX PRESSURE 745 PSI: TIME FRAME 62: REAL TIME 1.94
FRAME 43: ROW 4

AVERAGE PRESSURE (psi) vs AREA (square feet)

Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	745.00	637.00	570.00	469.00	376.00	321.00	279.00
Area	13.06	14.69	16.32	17.95	19.58	21.22	22.85
Pressure	246.00	220.00	200.00	187.00	172.00	160.00	149.00
Area	24.48	26.11	27.74	29.38	31.01	32.64	34.27
Pressure	140.00	132.00	125.00	119.00	114.00	109.00	104.00
Area	35.90	37.53	39.17	40.80	42.43	44.06	45.69
Pressure	103.00	99.00	96.00	93.00	90.00	87.00	84.00
Area	47.33	48.96	50.59	52.22	53.85	55.49	57.12
Pressure	81.00	79.00	78.00	76.00	75.00	75.00	73.00
Area	58.75	60.38	62.01	63.65	65.28	66.91	68.54
Pressure	71.00	70.00	68.00	66.00	65.00	63.00	62.00
Area	70.17						
Pressure	61.00						

PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

GIRTH	1.25	2.50	3.75	5.00	6.25	7.50
PRESSURE	745.00	482.00	34.00	33.00	12.00	10.00

PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

LENGTH	1.33	2.67	4.00	5.33	6.67	8.00	9.33
PRESSURE	745.00	637.00	426.00	326.00	264.00	222.00	192.00
LENGTH	10.67	12.00					
PRESSURE	168.00	157.00					

RELATIONSHIPS FOR TIME OF PEAK FORCE

MAX TOTAL FORCE 359 LONG TONS: TIME FRAME 47: REAL TIME 1.47
FRAME 39: ROW 2

AVERAGE PRESSURE (psi) vs AREA (square feet)

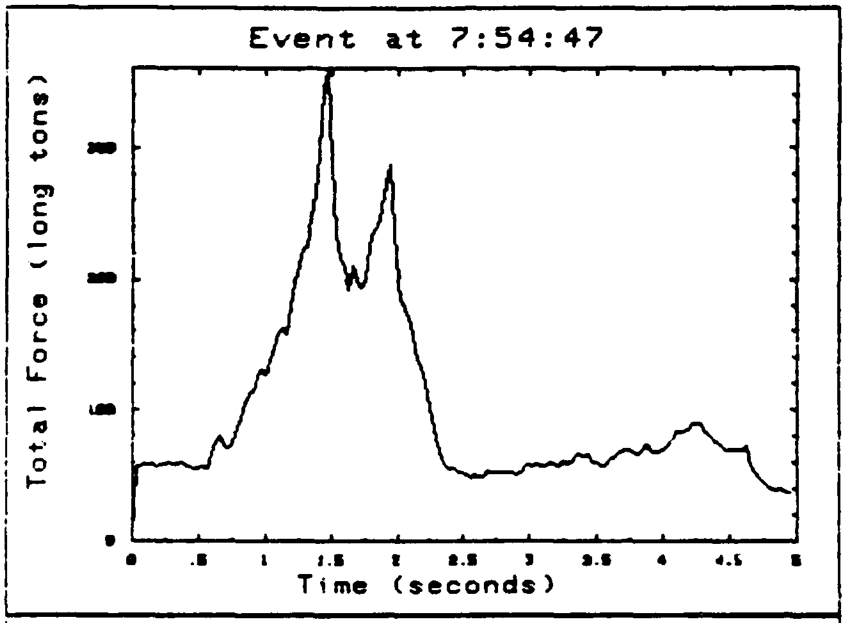
Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	660.00	622.00	553.00	489.00	429.00	387.00	345.00
Area	13.06	14.69	16.32	17.95	19.58	21.22	22.85
Pressure	313.00	295.00	271.00	250.00	234.00	219.00	207.00
Area	24.48	26.11	27.74	29.38	31.01	32.64	34.27
Pressure	195.00	184.00	175.00	166.00	161.00	154.00	147.00
Area	35.90	37.53	39.17	40.80	42.43	44.06	45.69
Pressure	142.00	136.00	131.00	127.00	123.00	118.00	115.00
Area	47.33	48.96	50.59	52.22	53.85	55.49	57.12
Pressure	111.00	108.00	105.00	101.00	99.00	96.00	93.00
Area	58.75	60.38	62.01	63.65	65.28		
Pressure	91.00	88.00	86.00	84.00	82.00		

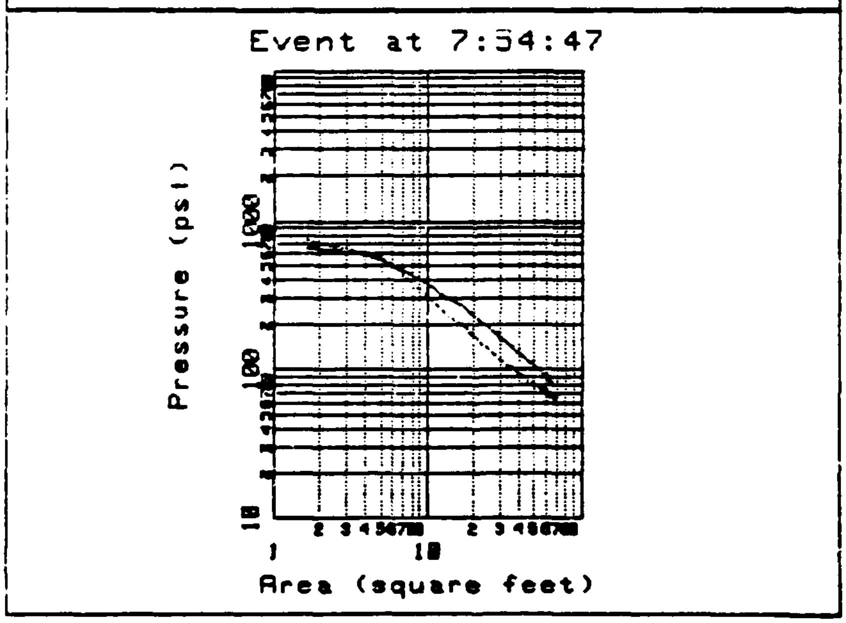
PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

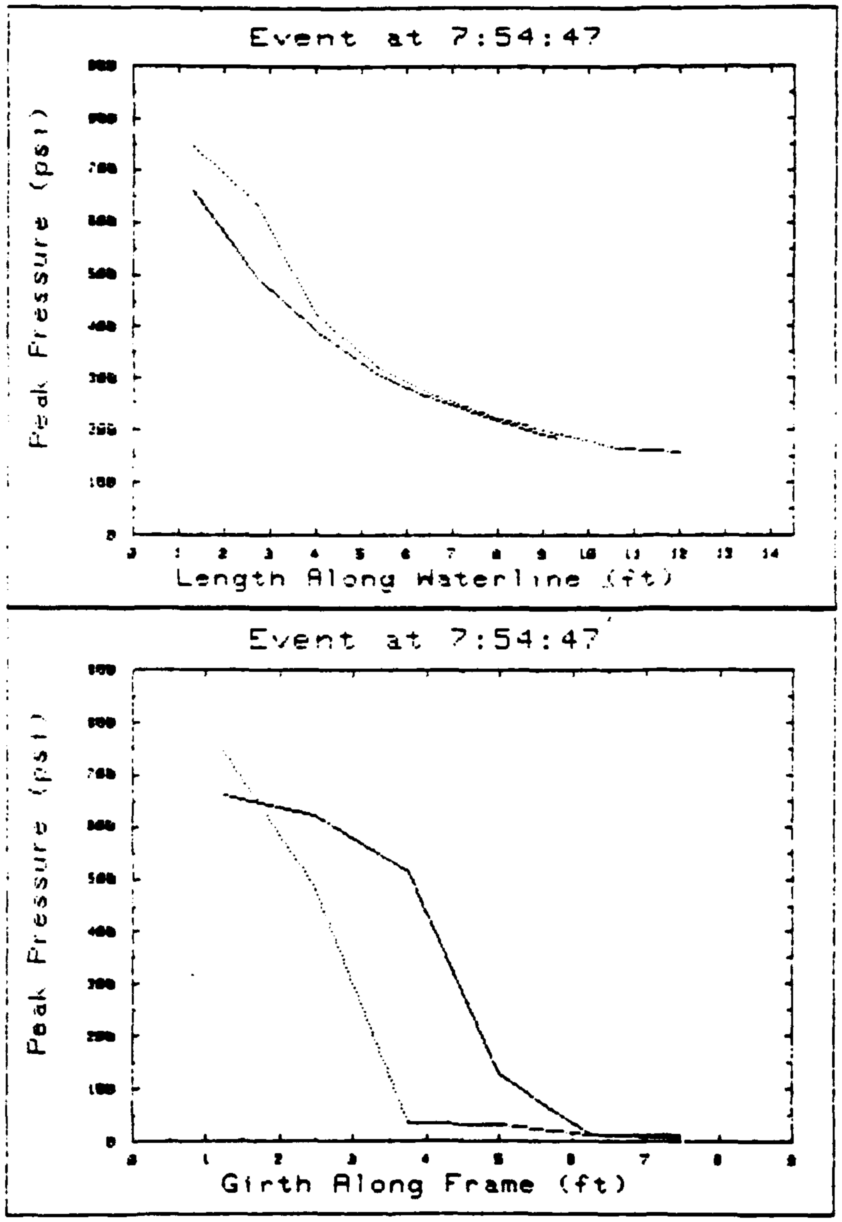
GIRTH	1.25	2.50	3.75	5.00	6.25	7.50
PRESSURE	660.00	622.00	513.00	126.00	12.00	11.00

PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

LENGTH	1.33	2.67	4.00	5.33	6.67	8.00	9.33
PRESSURE	660.00	499.00	395.00	308.00	256.00	215.00	187.00


Event at 7:54:47
Total Force (long tons)
Time (seconds)
0
.5
1
1.5
2
2.5
3
3.5
4
4.5
5


Event at 7:54:47
Pressure (psi)
Area (square feet)
1000
100
10
1
10


Event at 7:54:47
Peak Pressure (psi)
Length Along Waterline (ft)
Event at 7:54:47
Peak Pressure (psi)
Girth Along Frame (ft)

EVENT ON 28 MAR AT 19:41:14
TAPE NUMBER 3 : TRACK NUMBER 2 ; FILE NUMBER 41
PEAK STRAIN 271; THRESHOLD 120
RELATIONSHIPS FOR TIME OF PEAK PRESSURE

MAX PRESSURE 59[illegible] PSI; TIME FRAME 33; REAL TIME 1.03
FRA[illegible] 3[illegible]: ROW

[illegible]VE[illegible]AGE PRES[illegible]E (psi) vs AREA (square feet)

Ar[illegible]	[illegible]63	3.26	4.90	6.53	8.16	9.79	11.42
Pr[illegible]ure	5[illegible].00	380.00	275.00	222.00	179.00	150.00	133.00

Ar[illegible]	13.06	14.69
Pr[illegible]ure	[illegible]18.00	106.00

[illegible]URE (PSI) VERSUS GIRTH ALONG FRAME (FT)

[illegible]H	1.25	2.50	3.75
[illegible]SURE	599.00	380.00	15.00

[illegible]RESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

LENGTH	1.33	2.67	4.00
PRESSURE	599.00	333.00	223.00

RELATIONSHIPS FOR TIME OF PEAK FORCE

MAX TOTAL FORCE 123 LONG TONS: TIME FRAME 33: REAL TIME 1.03
FRAME 38: ROW 5

AVERAGE PRESSURE (psi) vs AREA (square feet)

Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	599.00	380.00	275.00	222.00	179.00	150.00	133.00

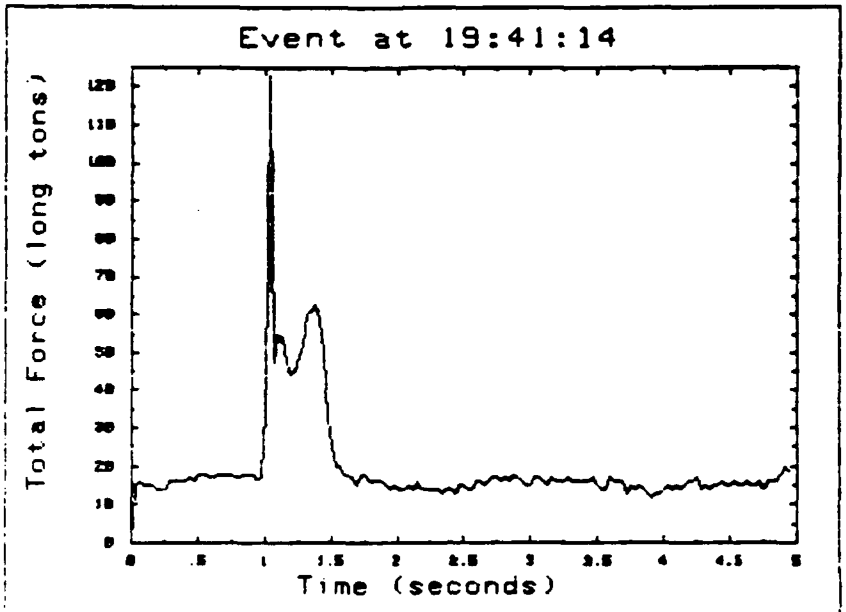
Area	13.06	14.69
Pressure	118.00	106.00

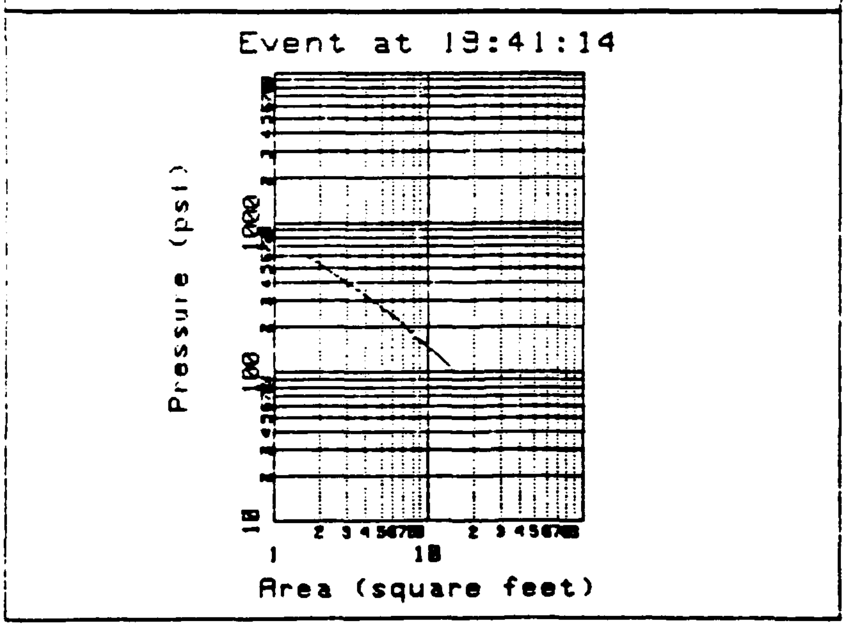
PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

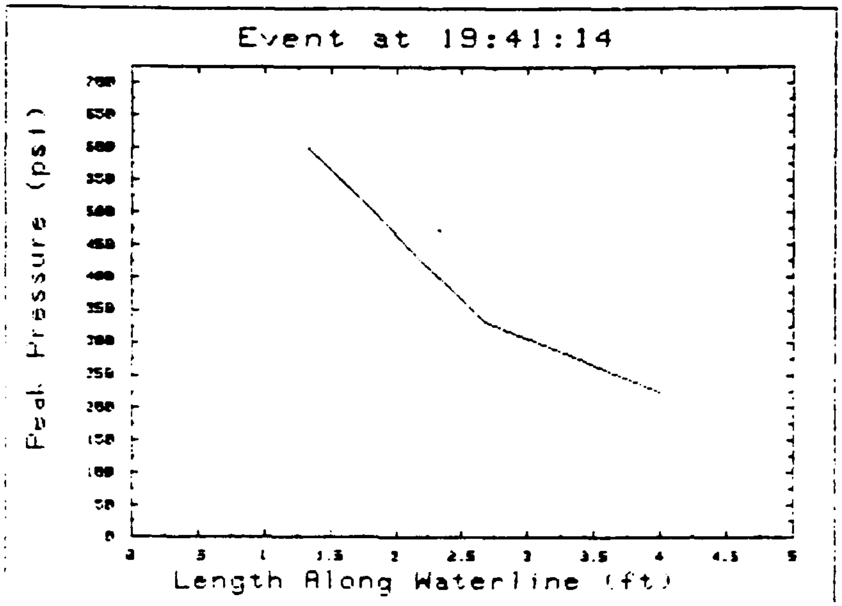
GIRTH	1.25	2.50	3.75
PRESSURE	599.00	380.00	15.00

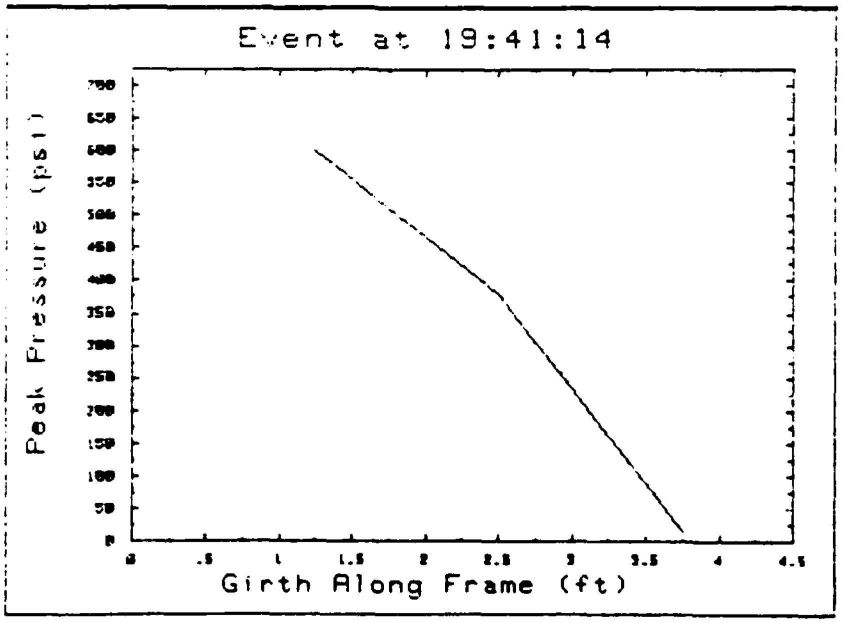
PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

LENGTH	1.33	2.67	4.00
PRESSURE	599.00	333.00	223.00


Event at 19:41:14
Total Force (long tons)
Time (seconds)


Event at 19:41:14
Pressure (psi)
Area (square feet)


Event at 19:41:14
Peak Pressure (psi)
Length Along Waterline (ft)


Event at 19:41:14
Peak Pressure (psi)
Girth Along Frame (ft)

EVENT ON 27 MAR AT 1:3:25
TAPE NUMBER 2 : TRACK NUMBER 3 ; FILE NUMBER 74
PEAK STRAIN 260: THRESHOLD 100
RELATIONSHIPS FOR TIME OF PEAK PRESSURE

MAX PRESSURE 584 PSI: TIME FRAME 57: REAL TIME 1.78
FRAME 35; ROW 3

AVERAGE PRESSURE (psi) vs AREA (square feet)

Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	584.00	319.00	246.00	208.00	177.00	177.00	161.00
Area	13.06	14.69	16.32	17.95	19.58	21.22	22.85
Pressure	151.00	142.00	131.00	123.00	116.00	109.00	103.00
Area	24.48	26.11	27.74	29.38	31.01	32.64	34.27
Pressure	97.00	93.00	90.00	88.00	87.00	88.00	87.00
Area	35.90	37.53	39.17	40.80	42.43	44.06	45.69
Pressure	86.00	85.00	84.00	82.00	81.00	79.00	78.00
Area	47.33	48.96	50.59	52.22	53.85	55.49	57.12
Pressure	76.00	75.00	73.00	72.00	70.00	69.00	67.00
Area	58.75	60.38	62.01	63.65	65.28	66.91	68.54
Pressure	66.00	64.00	63.00	62.00	61.00	60.00	59.00
Area	70.17	71.81	73.44	75.07	76.70	78.33	79.97
Pressure	58.00	57.00	56.00	55.00	54.00	54.00	53.00
Area	81.60	83.23	84.86				
Pressure	52.00	51.00	50.00				

PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

GIRTH	1.25	2.50	3.75	5.00	6.25	7.50
PRESSURE	584.00	319.00	246.00	62.00	51.00	46.00

PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

LENGTH	1.33	2.67	4.00	5.33	6.67	8.00	9.33
PRESSURE	584.00	318.00	107.00	98.00	83.00	74.00	64.00
LENGTH	10.67	12.00					
PRESSURE	58.00	52.00					

RELATIONSHIPS FOR TIME OF PEAK FORCE

MAX TOTAL FORCE 301 LONG TONS: TIME FRAME 35: REAL TIME 1.09
FRAME 35: ROW 3

AVERAGE PRESSURE (psi) vs AREA (square feet)

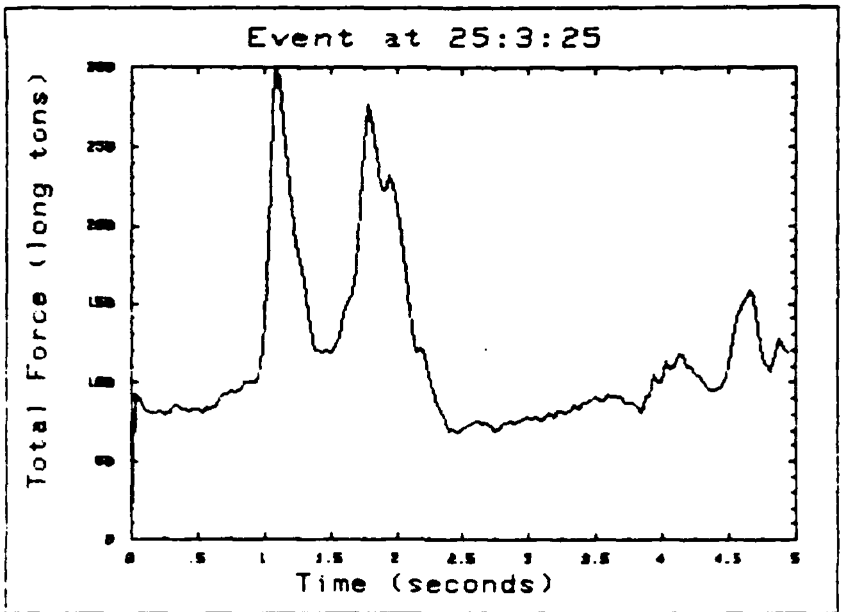
Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	261.00	224.00	216.00	206.00	190.00	201.00	183.00
Area	13.06	14.69	16.32	17.95	19.58	21.22	22.85
Pressure	170.00	158.00	148.00	139.00	135.00	134.00	129.00
Area	24.48	26.11	27.74	29.38	31.01	32.64	34.27
Pressure	124.00	119.00	114.00	109.00	107.00	103.00	100.00
Area	35.90	37.53	39.17	40.80	42.43	44.06	45.69
Pressure	98.00	95.00	93.00	90.00	89.00	88.00	86.00
Area	47.33	48.96	50.59	52.22	53.85	55.49	57.12
Pressure	84.00	82.00	80.00	79.00	77.00	75.00	74.00
Area	58.75	60.38	62.01	63.65	65.28	66.91	68.54
Pressure	72.00	71.00	70.00	68.00	68.00	67.00	66.00
Area	70.17	71.81	73.44	75.07	76.70	78.33	79.97
Pressure	65.00	64.00	63.00	61.00	60.00	59.00	58.00
Area	81.60	83.23	84.86	86.49	88.12		
Pressure	57.00	56.00	55.00	54.00	53.00		

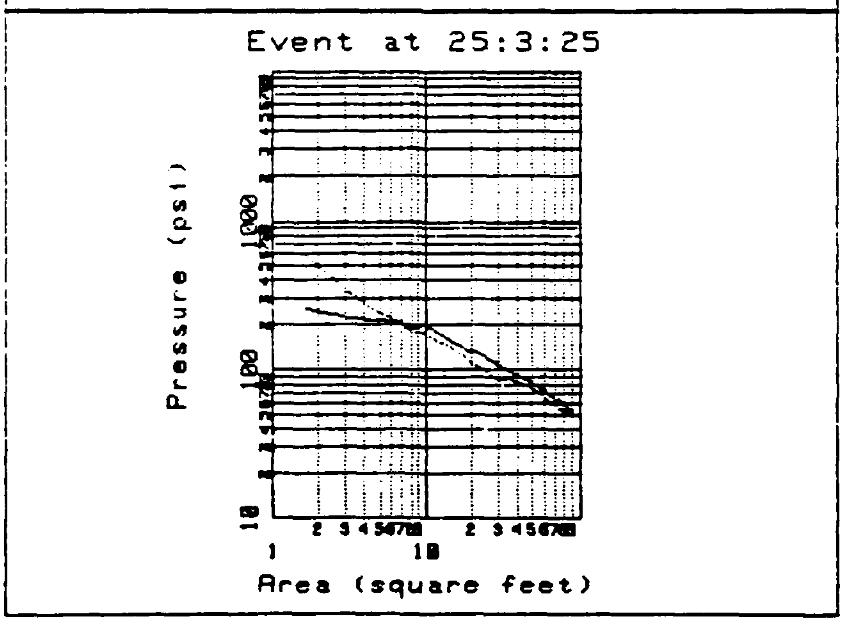
PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

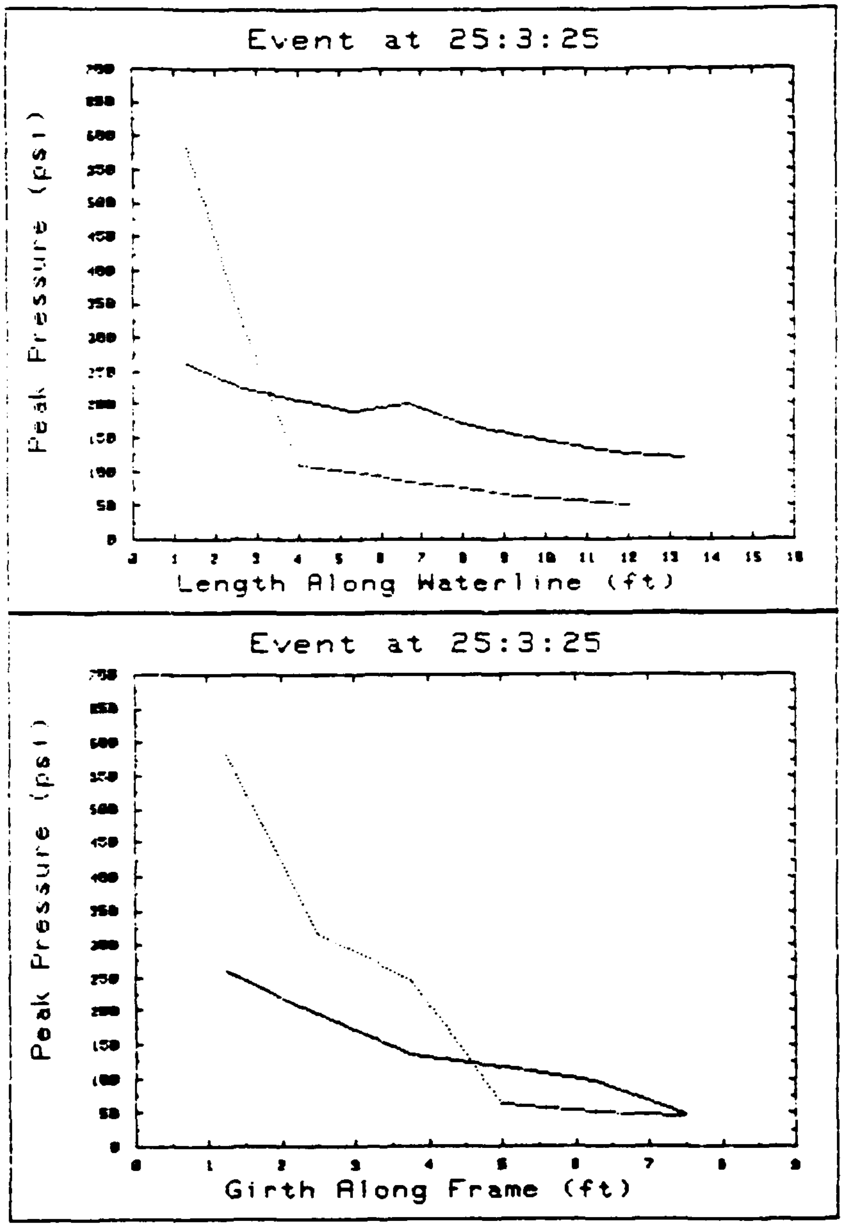
GIRTH	1.25	2.50	3.75	5.00	6.25	7.50
PRESSURE	261.00	194.00	135.00	117.00	95.00	49.00

PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

LENGTH	1.33	2.67	4.00	5.33	6.67	8.00	9.33
PRESSURE	261.00	224.00	208.00	188.00	201.00	172.00	152.00
LENGTH	10.67	12.00	13.33				
PRESSURE	137.00	125.00	119.00				


Event at 25:3:25
Total Force (long tons)
Time (seconds)


Event at 25:3:25
Pressure (psi)
Area (square feet)


Event at 25:3:25
Peak Pressure (psi)
Length Along Waterline (ft)
Event at 25:3:25
Peak Pressure (psi)
Girth Along Frame (ft)

EVENT ON 27 MAR AT 16:0:0
TAPE NUMBER 2 ; TRACK NUMBER 4 ; FILE NUMBER 57
PEAK STRAIN 255: THRESHOLD 120
RELATIONSHIPS FOR TIME OF PEAK PRESSURE

MAX PRESSURE 462 PSI: TIME FRAME 49; REAL TIME 1.53
FRAME 43; ROW 6

AVERAGE PRESSURE (psi) vs AREA (square feet)

Area	1.63	3.26	4.90	6.53
Pressure	462.00	265.00	192.00	146.00

PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

GIRTH	1.25	2.50
PRESSURE	462.00	27.00

PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

LENGTH	1.33	2.67	4.00
PRESSURE	462.00	265.00	192.00

RELATIONSHIPS FOR TIME OF PEAK FORCE

MAX TOTAL FORCE 87 LONG TONS: TIME FRAME 45: REAL TIME 1.41
FRAME 43: ROW 6

AVERAGE PRESSURE (psi) vs AREA (square feet)

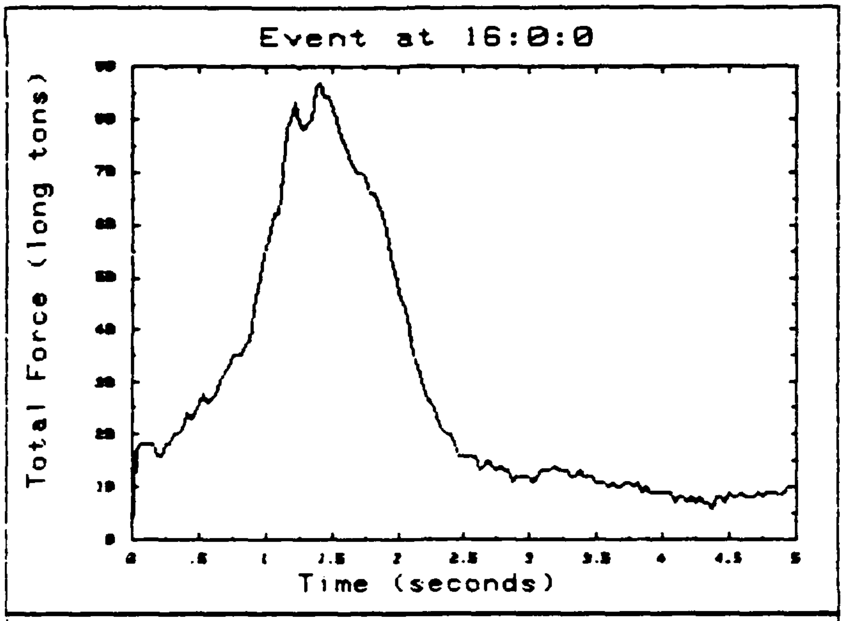
Area	1.63	3.26
Pressure	413.00	306.00

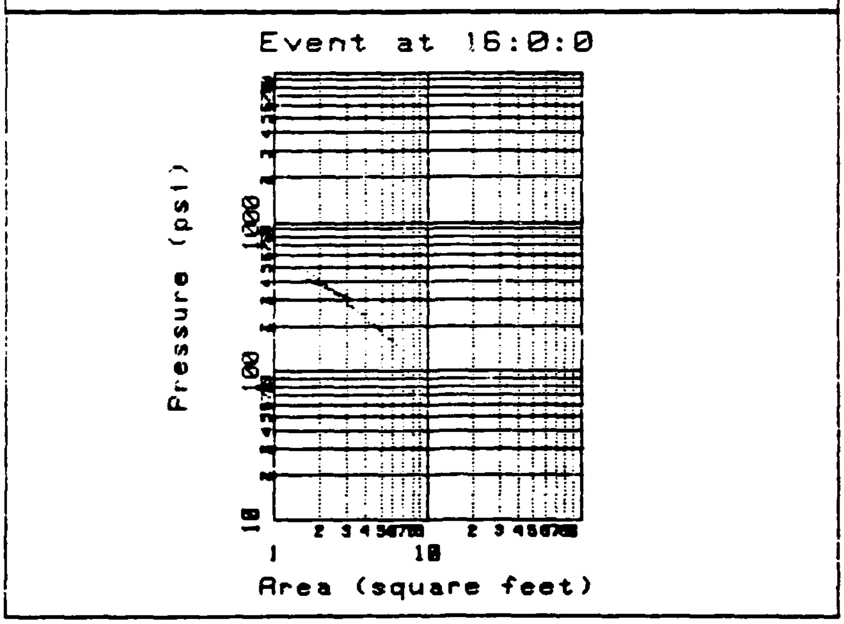
PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

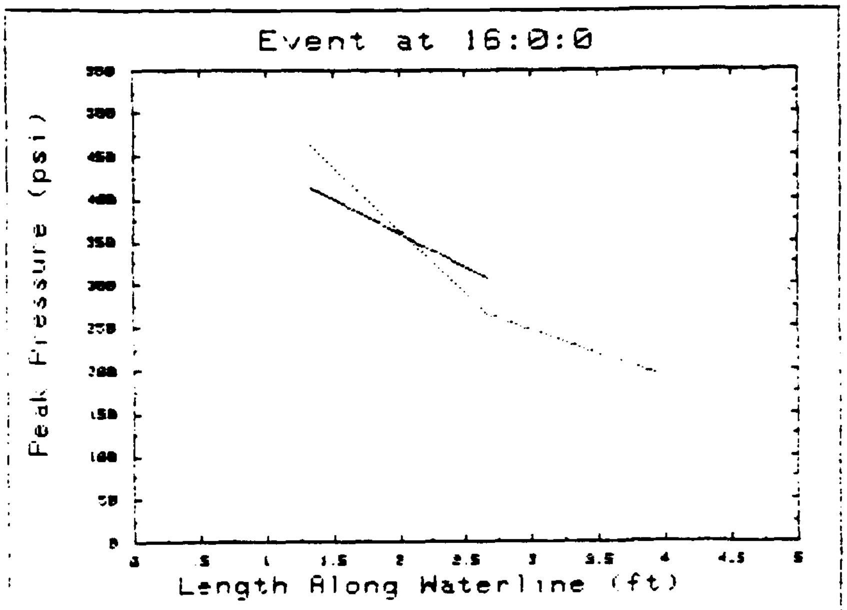
GIRTH	1.25
PRESSURE	413.00

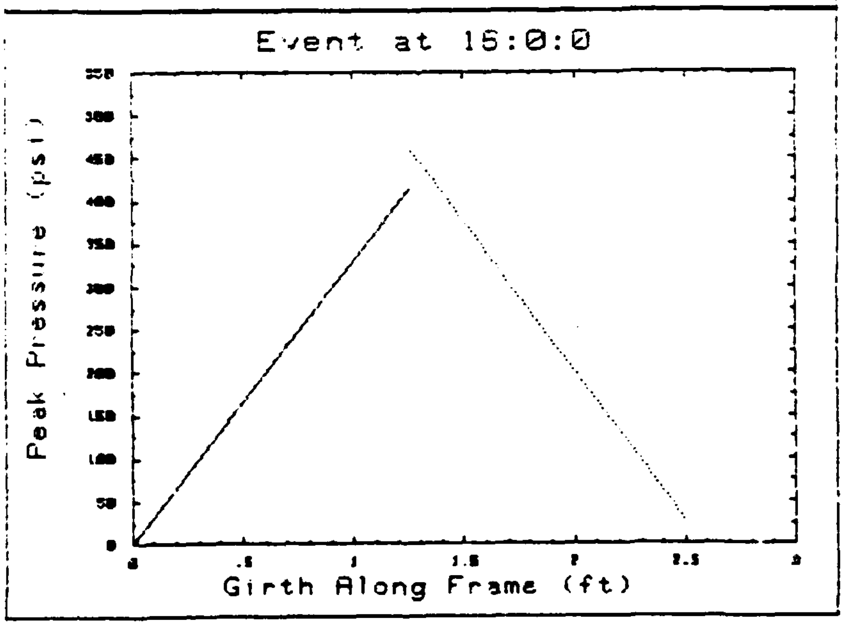
PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

LENGTH	1.33	2.67
PRESSURE	413.00	306.00


Event at 16:0:0
Total Force (long tons)
Time (seconds)


Event at 16:0:0
Pressure (psi)
Area (square feet)


Event at 16:0:0
Peak Pressure (psi)
Length Along Waterline (ft)


Event at 16:0:0
Peak Pressure (psi)
Girth Along Frame (ft)

EVENT ON 28 MAR AT 19:9:5
TAPE NUMBER 3 : TRACK NUMBER 2 : FILE NUMBER 40
PEAK STRAIN 245: THRESHOLD 120
RELATIONSHIPS FOR TIME OF PEAK PRESSURE

MAX PRESSURE 475 PSI; TIME FRAME 107: REAL TIME 3.34
FRAME 41: ROW 5

AVERAGE PRESSURE (psi) vs AREA (square feet)

Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	475.00	301.00	209.00	162.00	132.00	113.00	101.00
Area	13.06	14.69	16.32	17.95	19.58	21.22	22.85
Pressure	90.00	81.00	73.00	70.00	65.00	60.00	56.00
Area	24.48	26.11	27.74	29.38	31.01	32.64	34.27
Pressure	55.00	55.00	53.00	51.00	49.00	49.00	47.00
Area	35.90	37.53	39.17	40.80	42.43		
Pressure	45.00	46.00	45.00	44.00	43.00		

PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

GIRTH	1.25	2.50	3.75	5.00
PRESSURE	475.00	251.00	53.00	41.00

PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

LENGTH	1.33	2.67	4.00	5.33	6.67	8.00	9.33
PRESSURE	475.00	301.00	23.00	21.00	19.00	18.00	20.00
LENGTH	10.67	12.00	13.33				
PRESSURE	18.00	16.00	15.00				

RELATIONSHIPS FOR TIME OF PEAK FORCE

MAX TOTAL FORCE 162 LONG TONS: TIME FRAME 32: REAL TIME 1.00
FRAME 41: ROW 4

AVERAGE PRESSURE (psi) vs AREA (square feet)

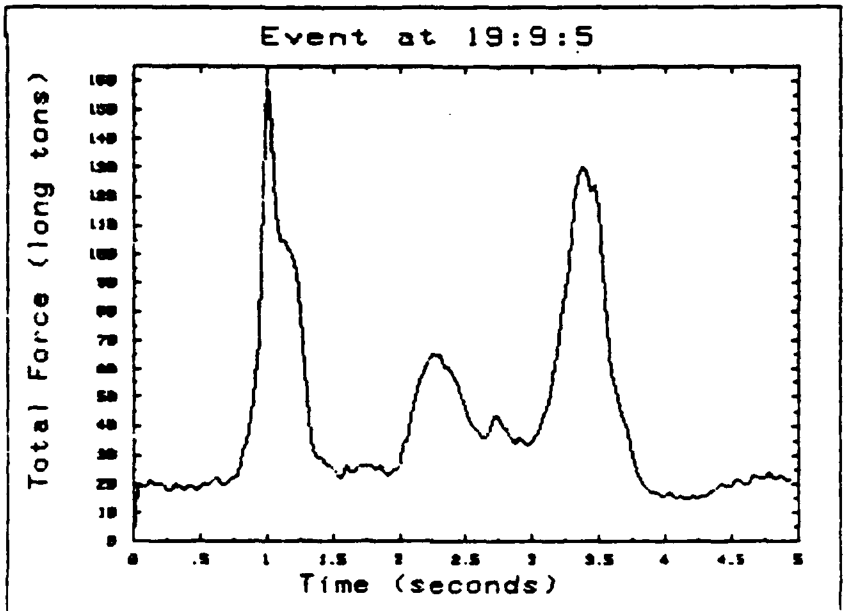
Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	211.00	176.00	171.00	167.00	163.00	157.00	151.00
Area	13.06	14.69	16.32	17.95	19.58	21.22	22.85
Pressure	137.00	126.00	126.00	117.00	109.00	102.00	95.00
Area	24.48	26.11	27.74	29.38	31.01	32.64	34.27
Pressure	89.00	84.00	79.00	75.00	72.00	68.00	65.00
Area	35.90	37.53					
Pressure	63.00	60.00					

PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

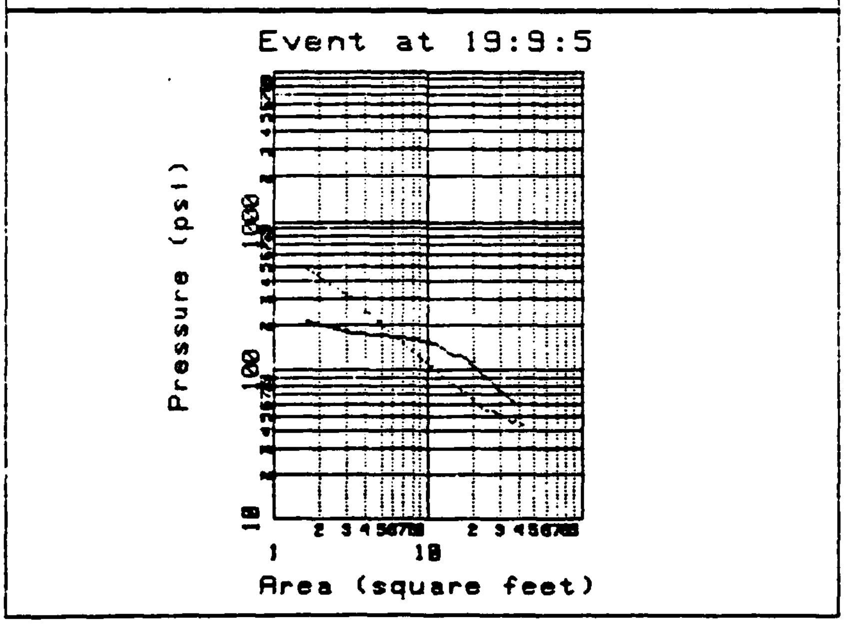
GIRTH	1.25	2.50	3.75	5.00
PRESSURE	211.00	152.00	103.00	76.00

PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

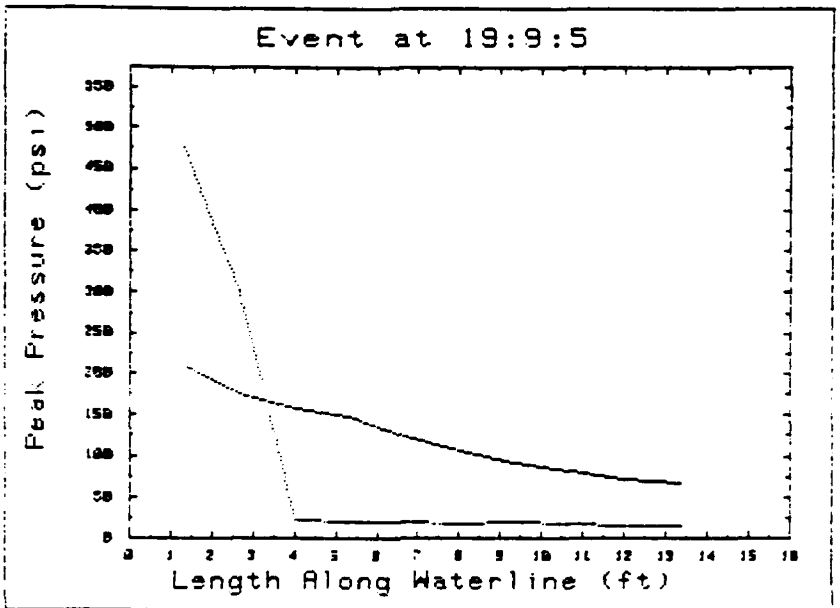
LENGTH	1.33	2.67	4.00	5.33	6.67	8.00	9.33
PRESSURE	211.00	176.00	159.00	148.00	124.00	107.00	92.00
LENGTH	10.67	12.00	13.33				
PRESSURE	81.00	73.00	67.00				

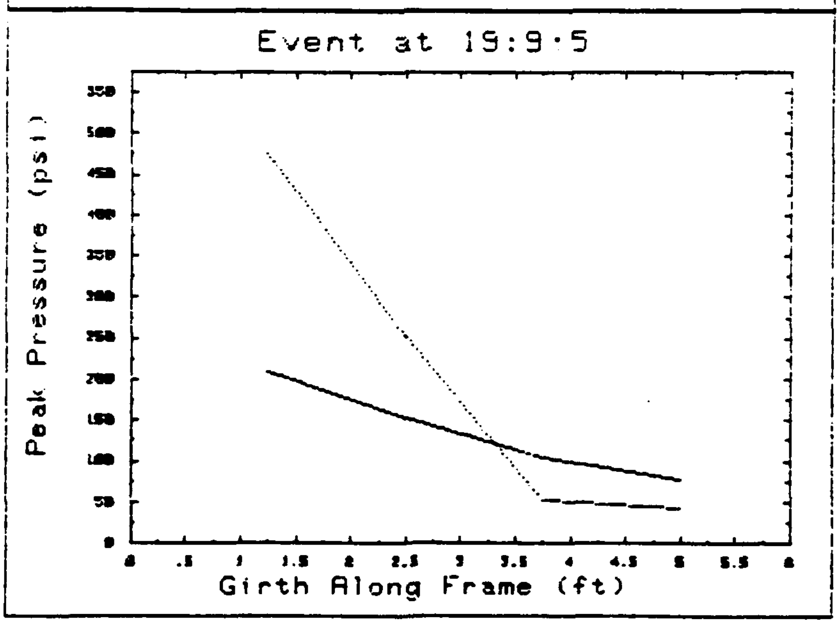


Event at 19:9:5
Total Force (long tons)
Time (seconds)



Event at 19:9:5
Pressure (psi)
Area (square feet)


Event at 19:9:5
Peak Pressure (psi)
Length Along Waterline (ft)


Event at 19:9·5
Peak Pressure (psi)
Girth Along Frame (ft)

WINTER DEPLOYMENT - SOUTH CHUKCHI SEA

EVENT ON 30 APR AT 12:16:55
TAPE NUMBER 7 ; TRACK NUMBER 3 ; FILE NUMBER 62
PEAK STRAIN 502; THRESHOLD 150
AVERAGE SHIP SPEED 5.60 Knots

RELATIONSHIPS FOR TIME OF PEAK PRESSURE

MAX PRESSURE 851 PSI: TIME FRAME 38; REAL TIME 1.19
FRAME 36: ROW 6

AVERAGE PRESSURE (psi) vs AREA (square feet)

Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	851.00	572.00	454.00	414.00	353.00	302.00	263.00

Area	13.06	14.69	16.32
Pressure	233.00	209.00	189.00

PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

GIRTH	1.25	2.50	3.75
PRESSURE	851.00	535.00	149.00

PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

LENGTH	1.33	2.67	4.00
PRESSURE	851.00	572.00	416.00

RELATIONSHIPS FOR TIME OF PEAK FORCE

MAX TOTAL FORCE 204 LONG TONS: TIME FRAME 38: REAL TIME 1.19
FRAME 36: ROW 6

AVERAGE PRESSURE (psi) vs AREA (square feet)

Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	851.00	572.00	454.00	414.00	353.00	302.00	263.00

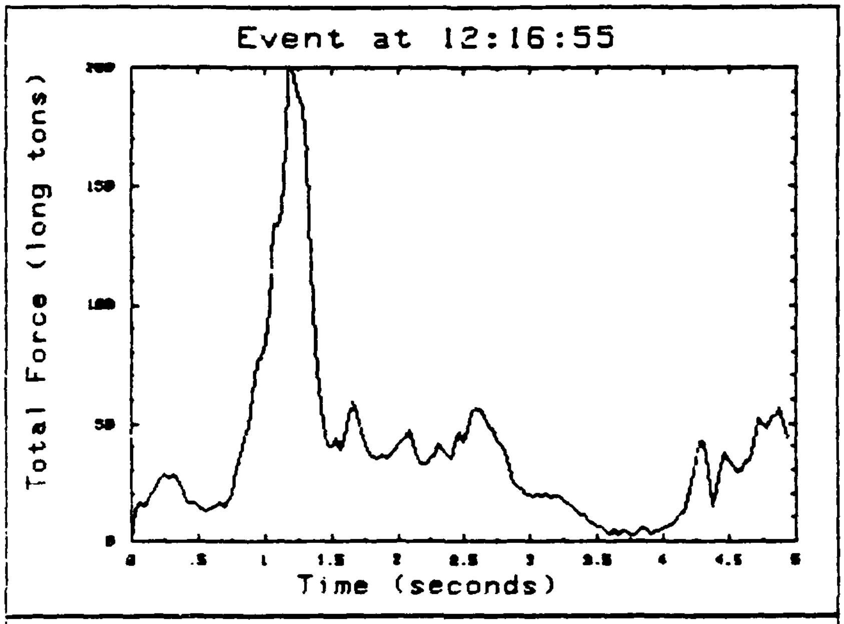
Area	13.06	14.69	16.32
Pressure	233.00	209.00	189.00

PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

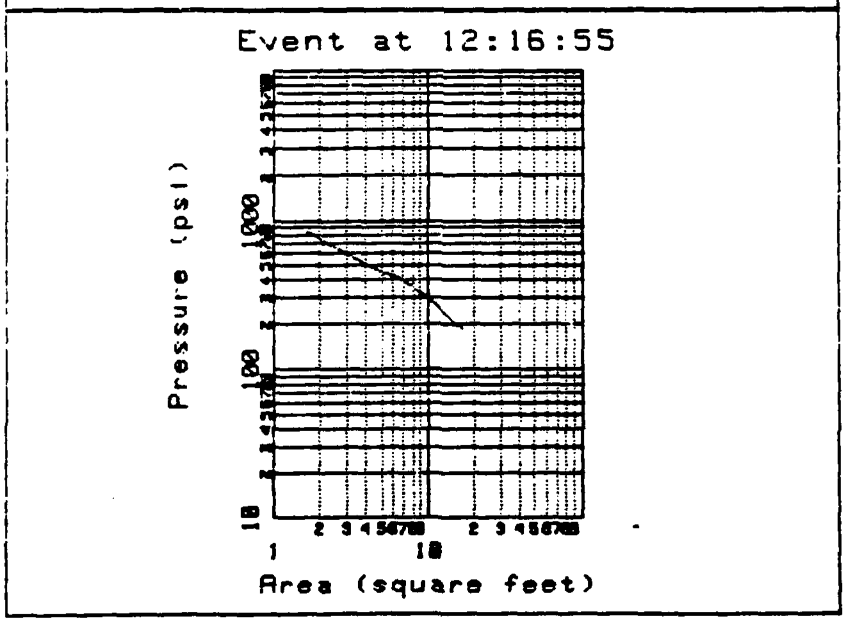
GIRTH	1.25	2.50	3.75
PRESSURE	851.00	535.00	149.00

PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

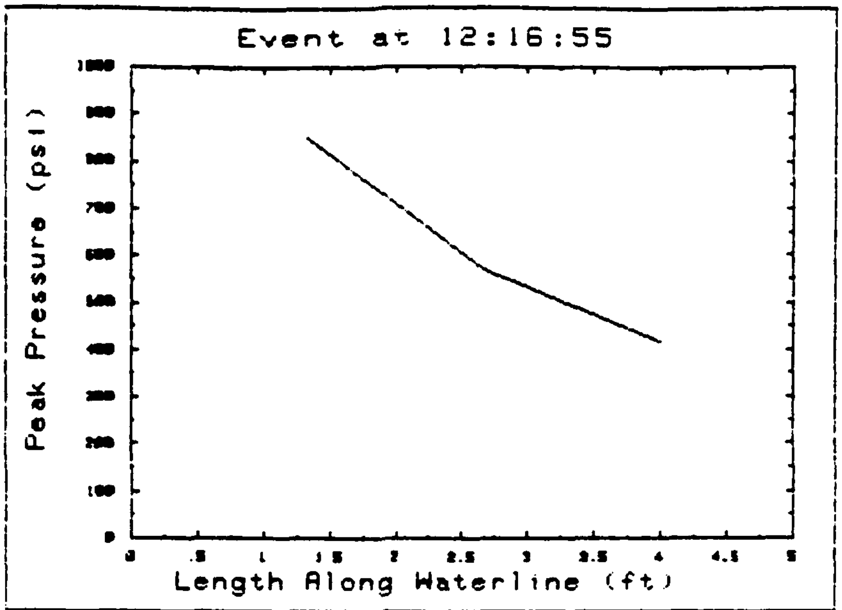
LENGTH	1.33	2.67	4.00
PRESSURE	851.00	572.00	416.00

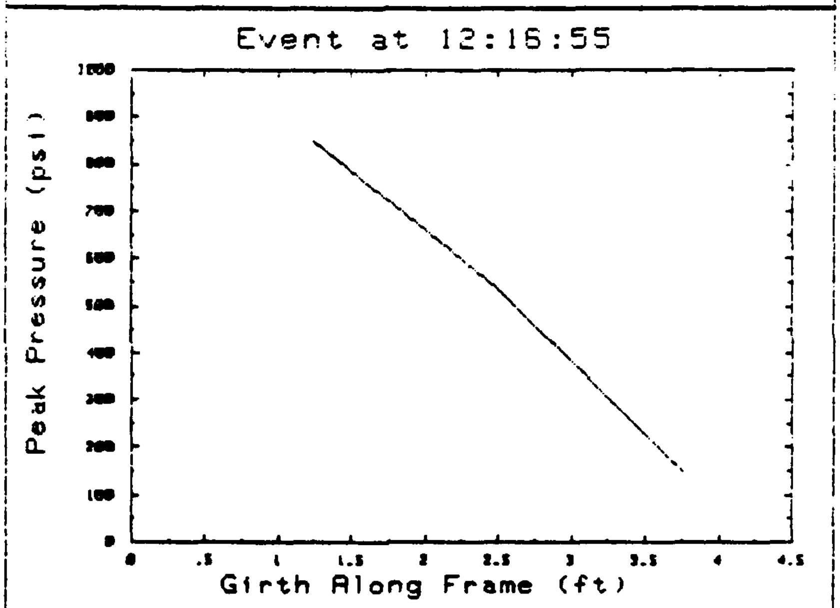


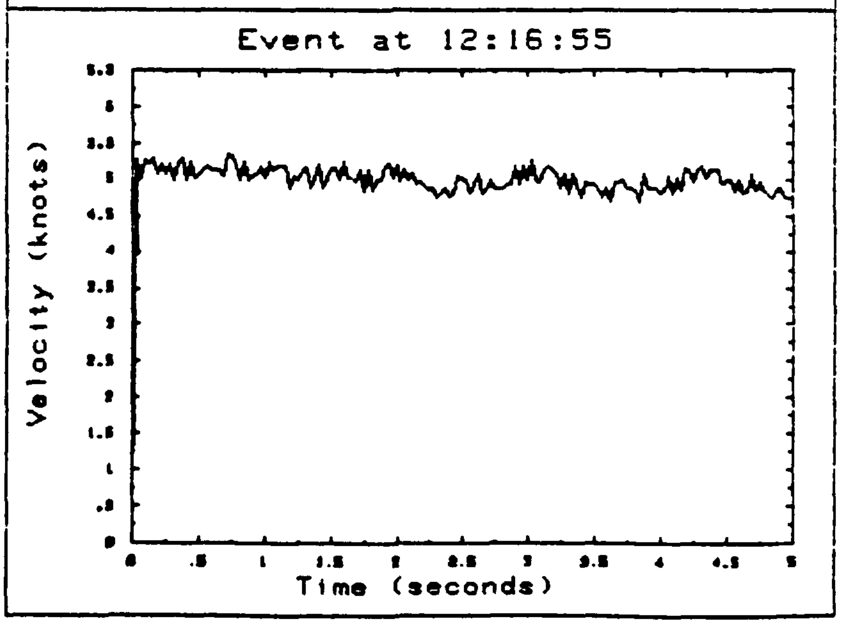
Event at 12:16:55
Total Force (long tons)
Time (seconds)



Event at 12:16:55
Pressure (psi)
Area (square feet)


Event at 12:16:55
Peak Pressure (psi)
Length Along Waterline (ft)


Event at 12:16:55
Peak Pressure (psi)
Girth Along Frame (ft)


Event at 12:16:55
Velocity (knots)
Time (seconds)

EVENT ON 2 APR AT 21:28:46
TAPE NUMBER 4 : TRACK NUMBER 2 ; FILE NUMBER 25
PEAK STRAIN 426; THRESHOLD 150
RELATIONSHIPS FOR TIME OF PEAK PRESSURE

MAX PRESSURE 1010 PSI; TIME FRAME 35: REAL TIME 1.09
FRAME 44: ROW 5

AVERAGE PRESSURE (psi) vs AREA (square feet)

Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	1010.00	513.00	415.00	312.00	253.00	214.00	187.00
Area	13.06	14.69	16.32	17.95	19.58	21.22	22.85
Pressure	166.00	150.00	137.00	128.00	120.00	112.00	106.00
Area	24.48	26.11	27.74	29.38	31.01	32.64	34.27
Pressure	100.00	95.00	90.00	86.00	82.00	78.00	75.00
Area	35.90	37.53	39.17	40.80	42.43	44.06	45.69
Pressure	73.00	70.00	68.00	67.00	65.00	64.00	62.00
Area	47.33	48.96	50.59	52.22	53.85	55.49	57.12
Pressure	60.00	58.00	57.00	56.00	57.00	56.00	54.00
Area	58.75	60.38	62.01	63.65	65.28	66.91	68.54
Pressure	54.00	53.00	53.00	52.00	51.00	50.00	49.00
Area	70.17	71.81	73.44	75.07	76.70	78.33	79.97
Pressure	48.00	47.00	47.00	46.00	45.00	44.00	44.00
Area	81.60	83.23	84.86	86.49			
Pressure	43.00	43.00	42.00	41.00			

PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

GIRTH	1.25	2.50	3.75	5.00	6.25	7.50
PRESSURE	1010.00	513.00	42.00	21.00	21.00	23.00

PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

LENGTH	1.33	2.67	4.00	5.33	6.67	8.00	9.33
PRESSURE	1010.00	117.00	80.00	65.00	56.00	49.00	43.00
LENGTH	10.67	12.00	13.33				
PRESSURE	40.00	38.00	36.00				

RELATIONSHIPS FOR TIME OF PEAK FORCE

MAX TOTAL FORCE 287 LONG TONS: TIME FRAME 41; REAL TIME 1.28
FRAME 44: ROW 7

AVERAGE PRESSURE (psi) vs AREA (square feet)

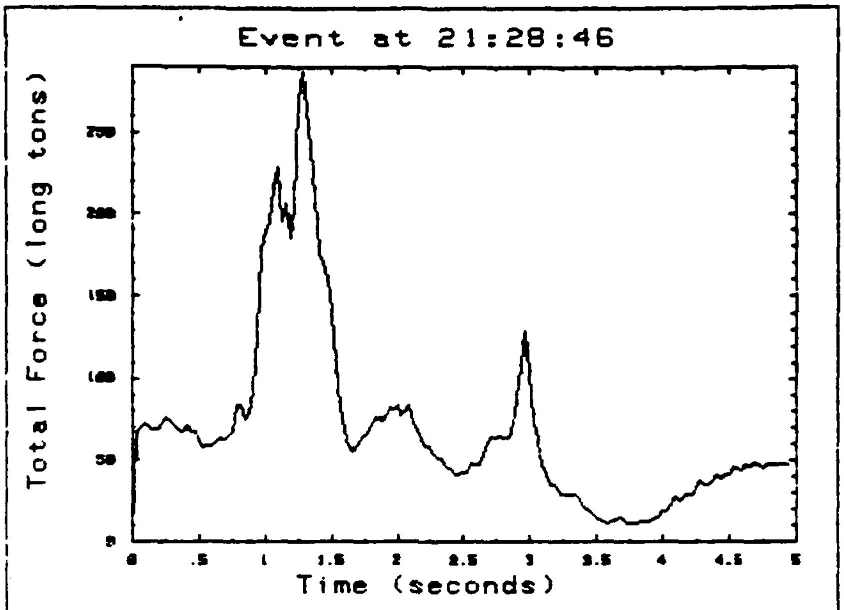
Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	319.00	174.00	141.00	123.00	113.00	109.00	120.00
Area	13.06	14.69	16.32	17.95	19.58	21.22	22.85
Pressure	122.00	129.00	129.00	128.00	125.00	121.00	117.00
Area	24.48	26.11	27.74	29.38	31.01	32.64	34.27
Pressure	113.00	110.00	107.00	104.00	103.00	100.00	97.00
Area	35.90	37.53	39.17	40.80	42.43	44.06	45.69
Pressure	95.00	93.00	90.00	88.00	86.00	84.00	82.00
Area	47.33	48.96	50.59	52.22	53.85	55.49	57.12
Pressure	30.00	79.00	77.00	75.00	74.00	72.00	71.00
Area	58.75	60.38	62.01	63.65	65.28	66.91	68.54
Pressure	70.00	68.00	67.00	66.00	65.00	63.00	62.00
Area	70.17	71.81	73.44	75.07	76.70	78.33	79.97
Pressure	61.00	60.00	59.00	58.00	57.00	56.00	55.00
Area	81.60	83.23	84.86	86.49	88.12		
Pressure	54.00	53.00	52.00	51.00	51.00		

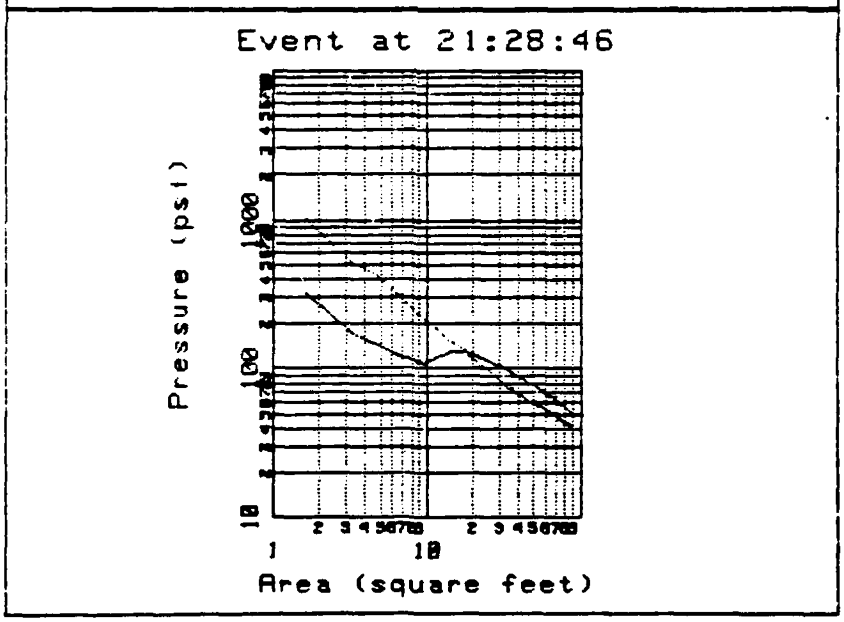
PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

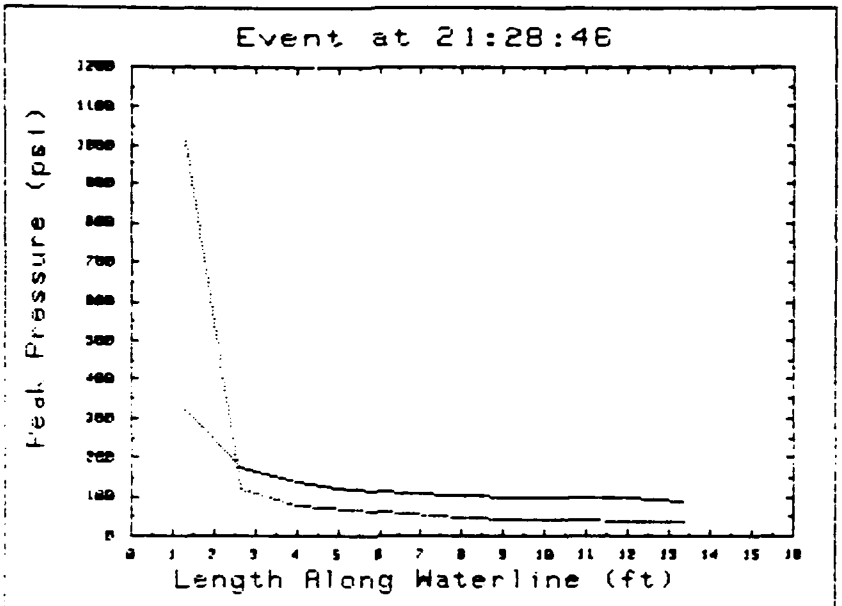
GIRTH	1.25	2.50	3.75	5.00	6.25	7.50
PRESSURE	319.00	174.00	146.00	124.00	102.00	65.00

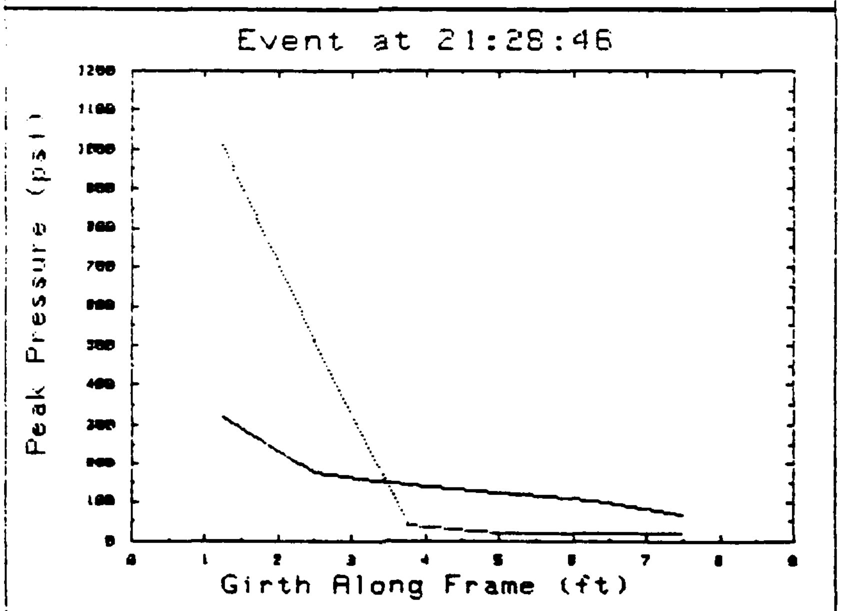
PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

LENGTH	1.33	2.67	4.00	5.33	6.67	8.00	9.33
PRESSURE	319.00	173.00	138.00	121.00	111.00	105.00	97.00
LENGTH	10.67	12.00	13.33				
PRESSURE	100.00	96.00	87.00				


Event at 21:28:46
Total Force (long tons)
Time (seconds)


Event at 21:28:46
Pressure (psi)
Area (square feet)


Event at 21:28:46
Peak Pressure (psi)
Length Along Waterline (ft)


Event at 21:28:46
Peak Pressure (psi)
Girth Along Frame (ft)

EVENT ON 30 APR AT 1:39:50
TAPE NUMBER 7 ; TRACK NUMBER 3 ; FILE NUMBER 5
PEAK STRAIN 419; THRESHOLD 150
AVERAGE SHIP SPEED 3.64 Knots

RELATIONSHIPS FOR TIME OF PEAK PRESSURE

MAX PRESSURE 764 PSI; TIME FRAME 57; REAL TIME 1.78
FRAME 39; ROW 8

AVERAGE PRESSURE (psi) vs AREA (square feet)

Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	764.00	630.00	496.00	386.00	318.00	270.00	235.00
Area	13.06	14.69	16.32	17.95	19.58	21.22	22.85
Pressure	213.00	198.00	183.00	168.00	155.00	143.00	133.00
Area	24.48	26.11					
Pressure	125.00	117.00					

PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

GIRTH	1.25	2.50	3.75
PRESSURE	764.00	410.00	289.00

PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

LENGTH	1.33	2.67	4.00	5.33	6.67	8.00	9.33
PRESSURE	764.00	630.00	496.00	378.00	315.00	275.00	236.00

RELATIONSHIPS FOR TIME OF PEAK FORCE

MAX TOTAL FORCE 214 LONG TONS: TIME FRAME 59: REAL TIME 1.84
FRAME 39: ROW 8

AVERAGE PRESSURE (psi) vs AREA (square feet)

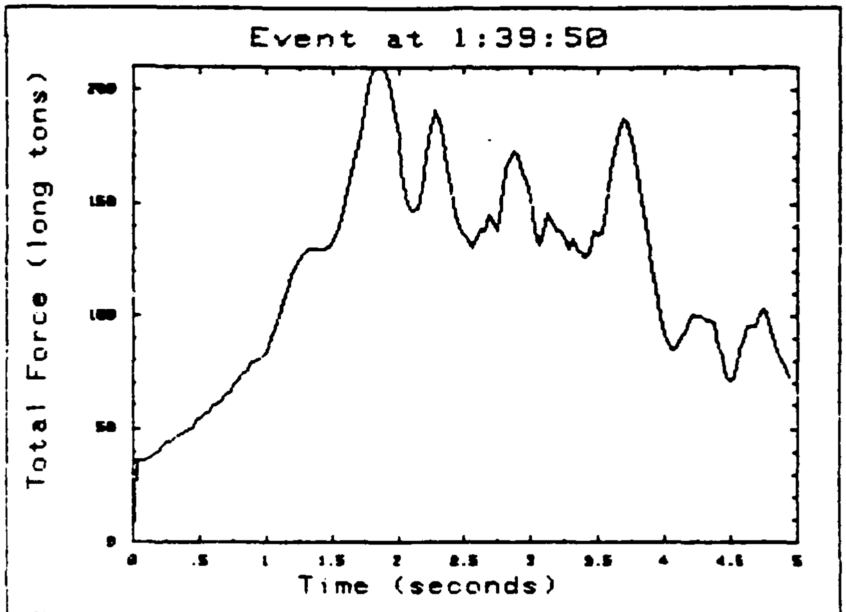
Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	696.00	545.00	485.00	406.00	330.00	287.00	254.00
Area	13.06	14.69	16.32	17.95	19.58	21.22	22.85
Pressure	230.00	207.00	189.00	174.00	161.00	150.00	140.00
Area	24.48						
Pressure	131.00						

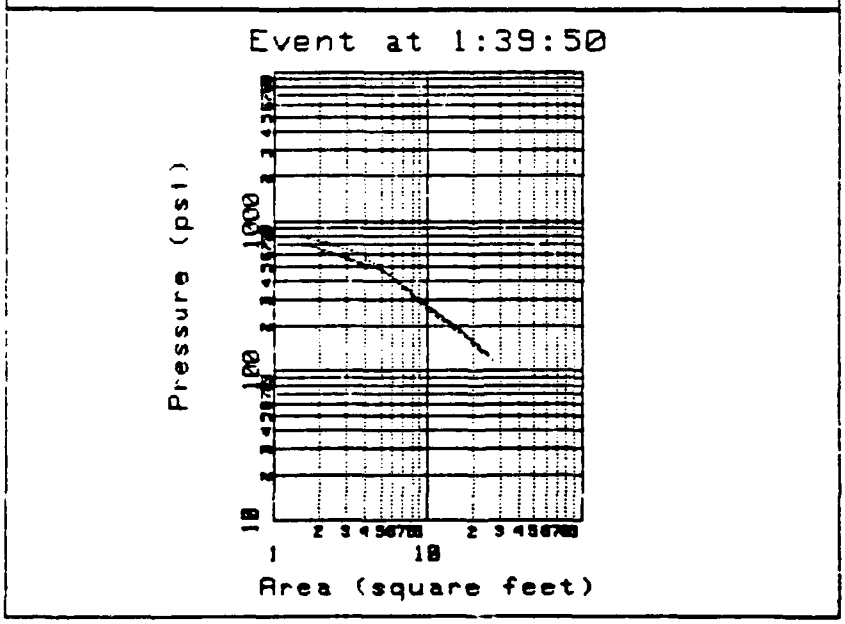
PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

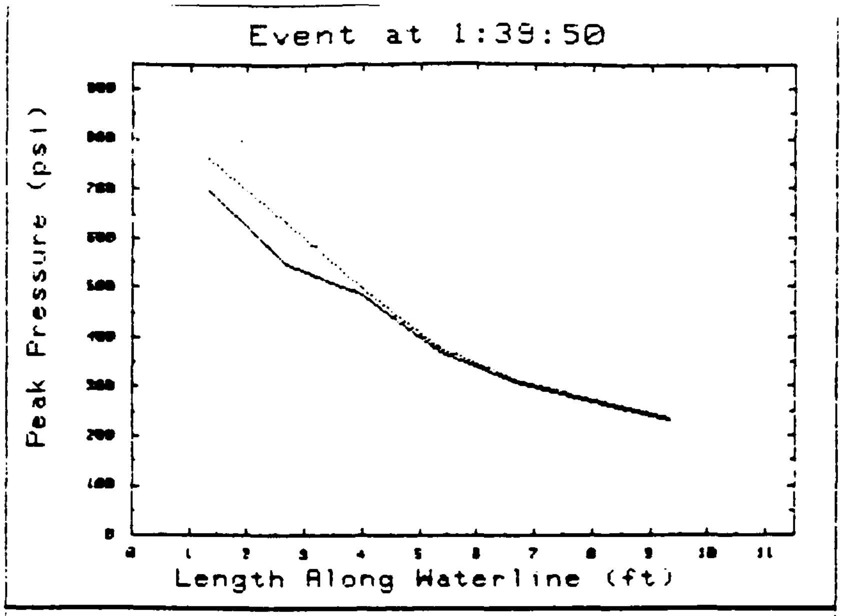
GIRTH	1.25	2.50	3.75
PRESSURE	696.00	433.00	297.00

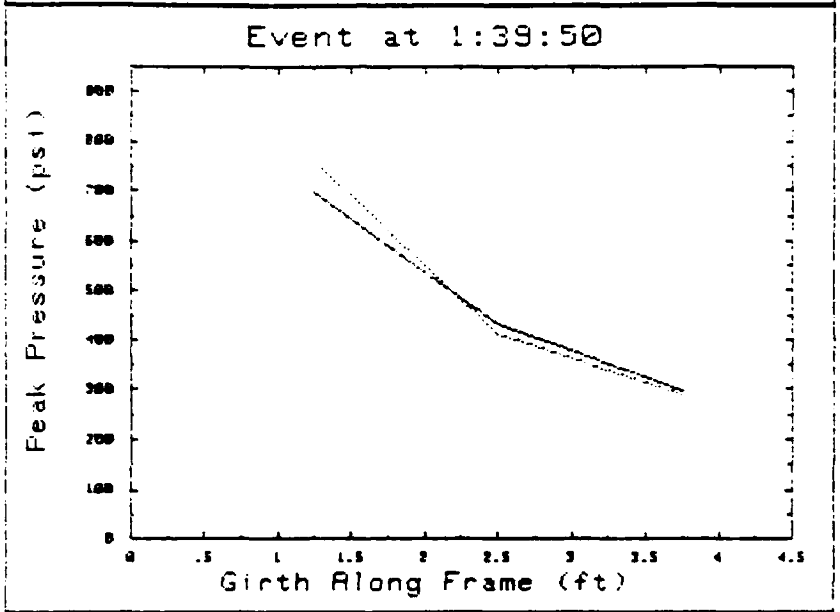
PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

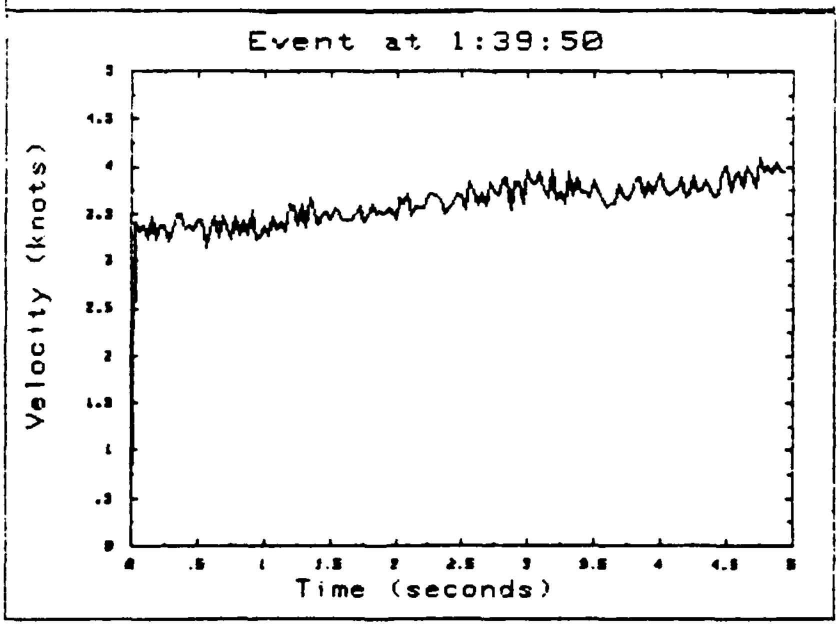
LENGTH	1.33	2.67	4.00	5.33	6.67	8.00	9.33
PRESSURE	696.00	545.00	485.00	370.00	310.00	268.00	232.00


Event at 1:39:50
Total Force (long tons)
Time (seconds)


Event at 1:39:50
Pressure (psi)
Area (square feet)


Event at 1:39:50
Peak Pressure (psi)
Length Along Waterline (ft)


Event at 1:39:50
Peak Pressure (psi)
Girth Along Frame (ft)


Event at 1:39:50
Velocity (knots)
Time (seconds)

EVENT ON 2 APR AT 23:0:25
TAPE NUMBER 4 : TRACK NUMBER 2 ; FILE NUMBER 47
PEAK STRAIN 398: THRESHOLD 150
RELATIONSHIPS FOR TIME OF PEAK PRESSURE

MAX PRESSURE 783 PSI; TIME FRAME 49; REAL TIME 1.53
FRAME 42: ROW 8

AVERAGE PRESSURE (psi) vs AREA (square feet)

Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	783.00	447.00	409.00	393.00	328.00	282.00	290.00

Area	13.06	14.69
Pressure	258.00	232.00

PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

GIRTH	1.25	2.50	3.75	5.00
PRESSURE	783.00	339.00	263.00	210.00

PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

LENGTH	1.33	2.67	4.00
PRESSURE	783.00	447.00	322.00

RELATIONSHIPS FOR TIME OF PEAK FORCE

MAX TOTAL FORCE 254 LONG TONS: TIME FRAME 47: REAL TIME 1.47
FRAME 42: ROW 8

AVERAGE PRESSURE (psi) vs AREA (square feet)

Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	525.00	474.00	441.00	362.00	365.00	340.00	302.00

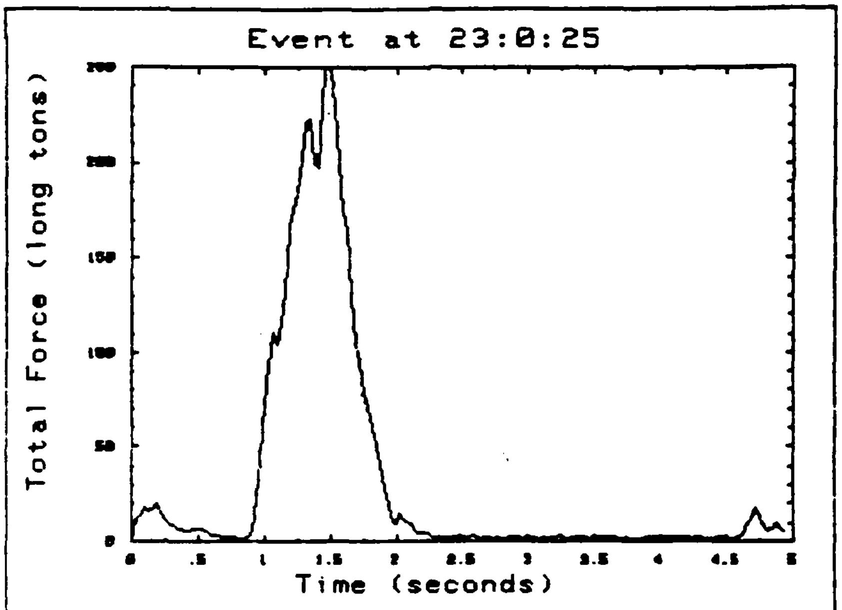
Area	13.06	14.69
Pressure	268.00	245.00

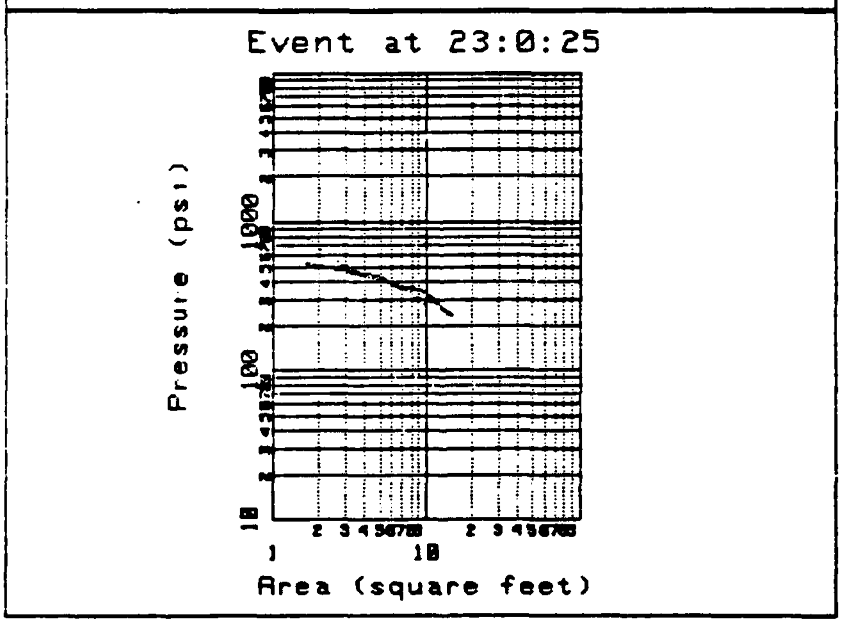
PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

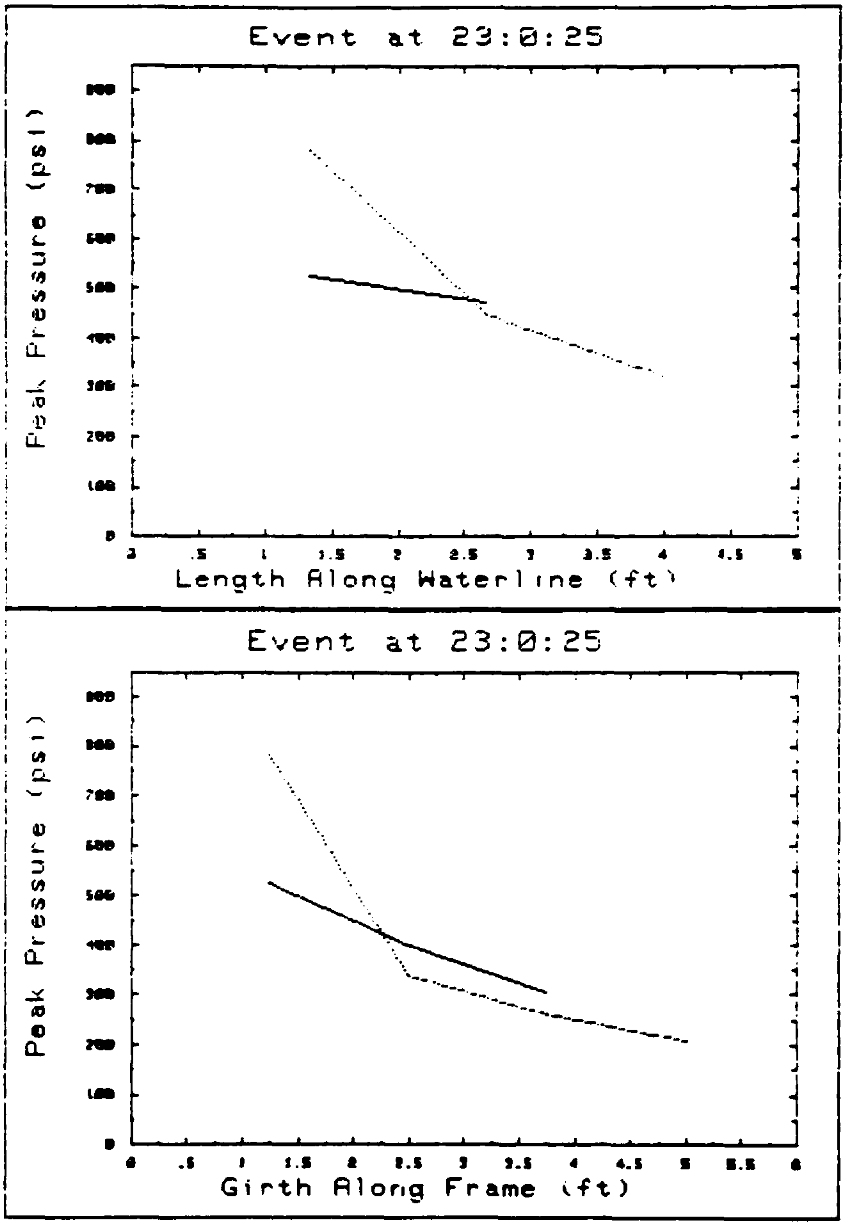
GIRTH	1.25	2.50	3.75
PRESSURE	525.00	399.00	307.00

PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

LENGTH	1.33	2.67
PRESSURE	525.00	474.00


Event at 23:0:25
Total Force (long tons)
Time (seconds)


Event at 23:0:25
Pressure (psi)
Area (square feet)



Event at 23:0:25
Peak Pressure (psi)
Length Along Waterline (ft)
Event at 23:0:25
Peak Pressure (psi)
Girth Along Frame (ft)

EVENT ON 2 APR AT 21:28:53
TAPE NUMBER 4 ; TRACK NUMBER 2 : FILE NUMBER 26
PEAK STRAIN 310; THRESHOLD 150
RELATIONSHIPS FOR TIME OF PEAK PRESSURE

MAX PRESSURE 611 PSI; TIME FRAME 40; REAL TIME 1.25
FRAME 35: ROW 7

AVERAGE PRESSURE (psi) vs AREA (square feet)

Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	611.00	449.00	386.00	346.00	311.00	284.00	252.00
Area	13.06	14.69	16.32	17.95	19.58	21.22	22.85
Pressure	238.00	220.00	210.00	201.00	197.00	200.00	189.00
Area	24.48	26.11	27.74	29.38	31.01	32.64	34.27
Pressure	179.00	173.00	164.00	156.00	148.00	142.00	135.00

PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

GIRTH	1.25	2.50	3.75
PRESSURE	611.00	307.00	62.00

PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

LENGTH	1.33	2.67	4.00	5.33	6.67	8.00	9.33
PRESSURE	611.00	449.00	374.00	162.00	138.00	134.00	136.00
LENGTH	10.67	12.00	13.33				
PRESSURE	150.00	136.00	123.00				

RELATIONSHIPS FOR TIME OF PEAK FORCE

MAX TOTAL FORCE 310 LONG TONS: TIME FRAME 40: REAL TIME 1.25
FRAME 35: ROW 7

AVERAGE PRESSURE (psi) vs AREA (square feet)

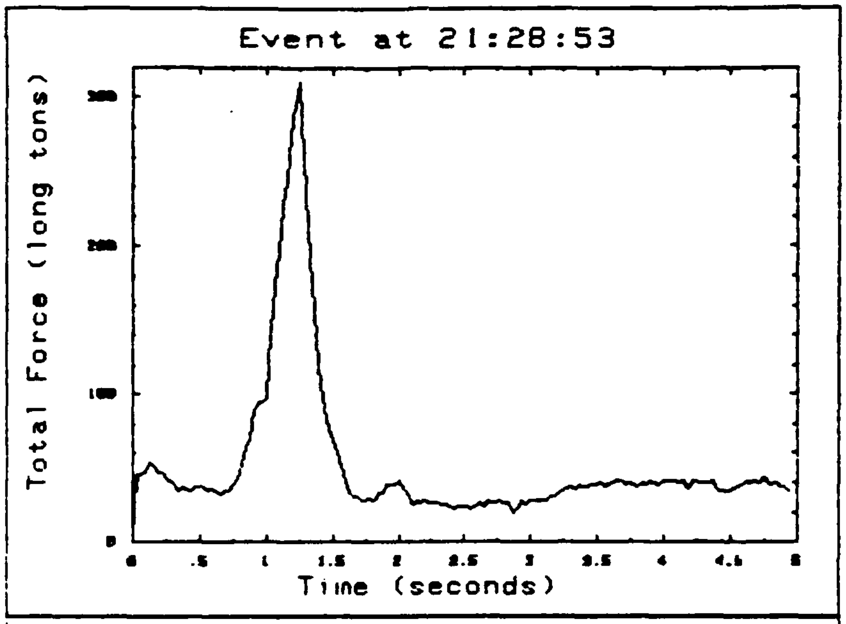
Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	611.00	449.00	386.00	346.00	311.00	284.00	252.00
Area	13.06	14.69	16.32	17.95	19.58	21.22	22.85
Pressure	238.00	220.00	210.00	201.00	197.00	200.00	189.00
Area	24.48	26.11	27.74	29.38	31.01	32.64	34.27
Pressure	179.00	173.00	164.00	156.00	148.00	142.00	135.00

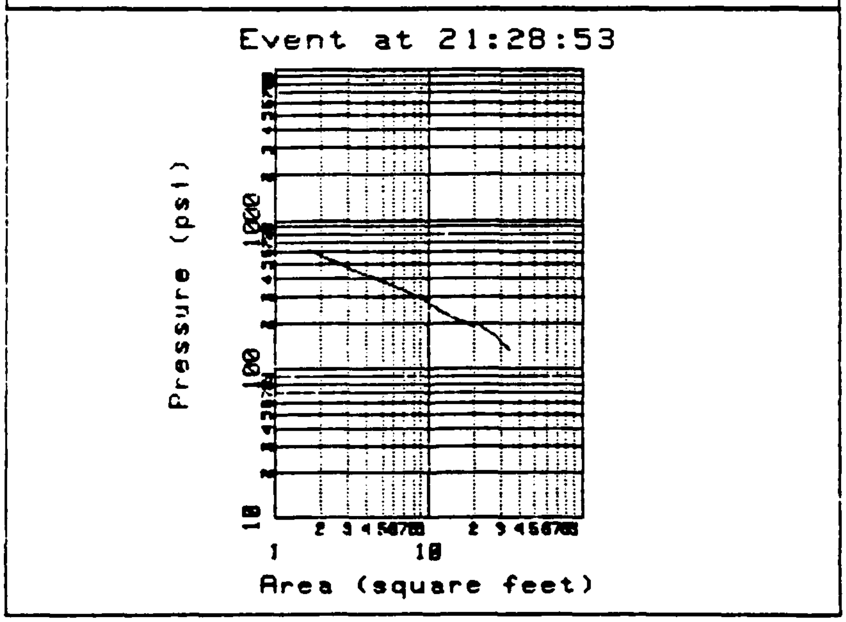
PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

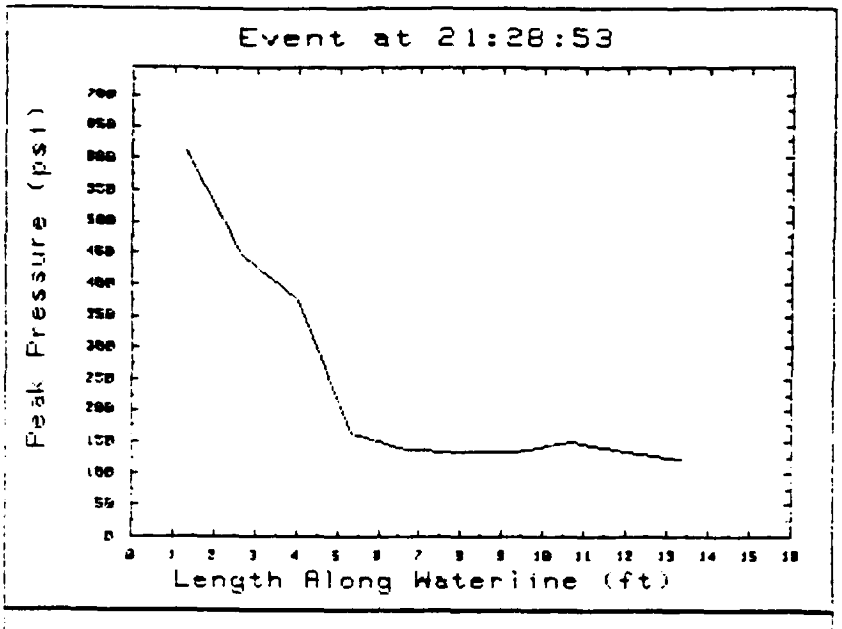
GIRTH	1.25	2.50	3.75
PRESSURE	611.00	307.00	62.00

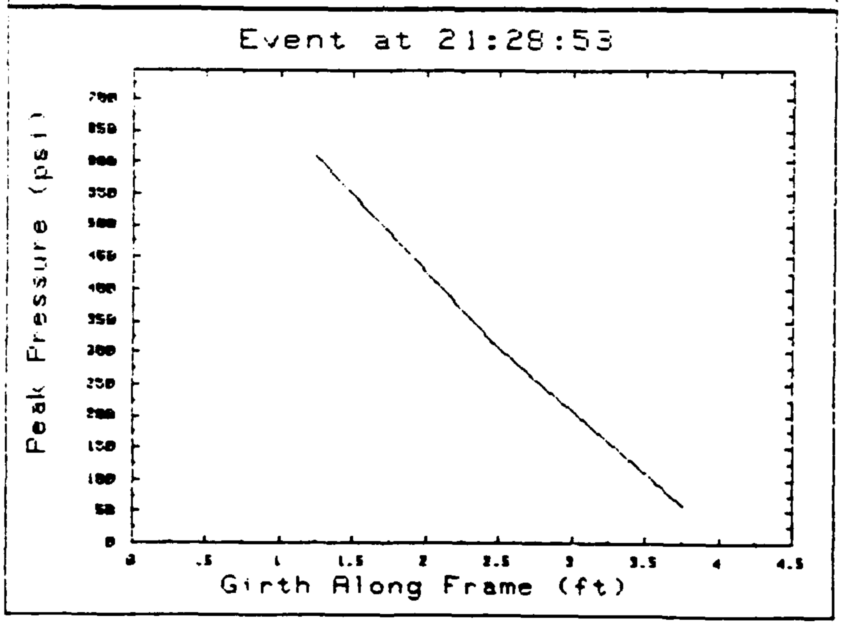
PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

LENGTH	1.33	2.67	4.00	5.33	6.67	8.00	9.33
PRESSURE	611.00	449.00	374.00	162.00	138.00	134.00	136.00
LENGTH	10.67	12.00	13.33				
PRESSURE	150.00	136.00	123.00				


Event at 21:28:53
Total Force (long tons)
Time (seconds)


Event at 21:28:53
Pressure (psi)
1000
100
10
1
10
Area (square feet)


Event at 21:28:53
Peak Pressure (psi)
Length Along Waterline (ft)


Event at 21:28:53
Peak Pressure (psi)
Girth Along Frame (ft)

WINTER DEPLOYMENT - NORTH CHUKCHI SEA

EVENT ON 8 APR AT 17:22:20
TAPE NUMBER 5 ; TRACK NUMBER 1 ; FILE NUMBER 42
PEAK STRAIN 763; THRESHOLD 150
AVERAGE SHIP SPEED -.25 Knots

RELATIONSHIPS FOR TIME OF PEAK PRESSURE

MAX PRESSURE 1640 PSI: TIME FRAME 56; REAL TIME 1.75
FRAME 36; ROW 7

AVERAGE PRESSURE (psi) vs AREA (square feet)

Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	1640.00	1004.00	739.00	569.00	457.00	382.00	331.00

Area	13.06	14.69
Pressure	290.00	261.00

PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

GIRTH	1.25	2.50	3.75	5.00
PRESSURE	1640.00	214.00	143.00	115.00

PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

LENGTH	1.33	2.67	4.00
PRESSURE	1640.00	1004.00	739.00

RELATIONSHIPS FOR TIME OF PEAK FORCE

MAX TOTAL FORCE 273 LONG TONS: TIME FRAME 73: REAL TIME 2.28
FRAME 37: ROW 7

AVERAGE PRESSURE (psi) vs AREA (square feet)

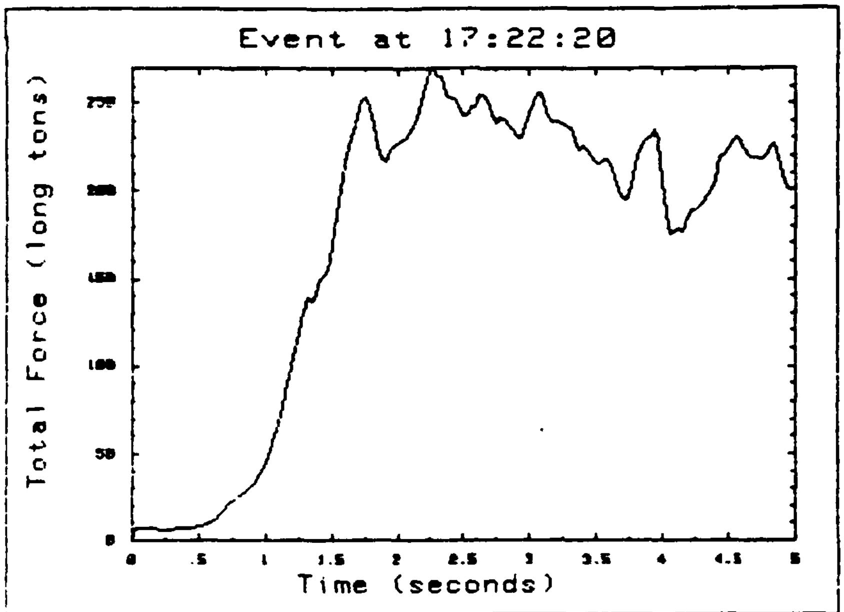
Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	1273.00	1049.00	759.00	585.00	469.00	393.00	343.00

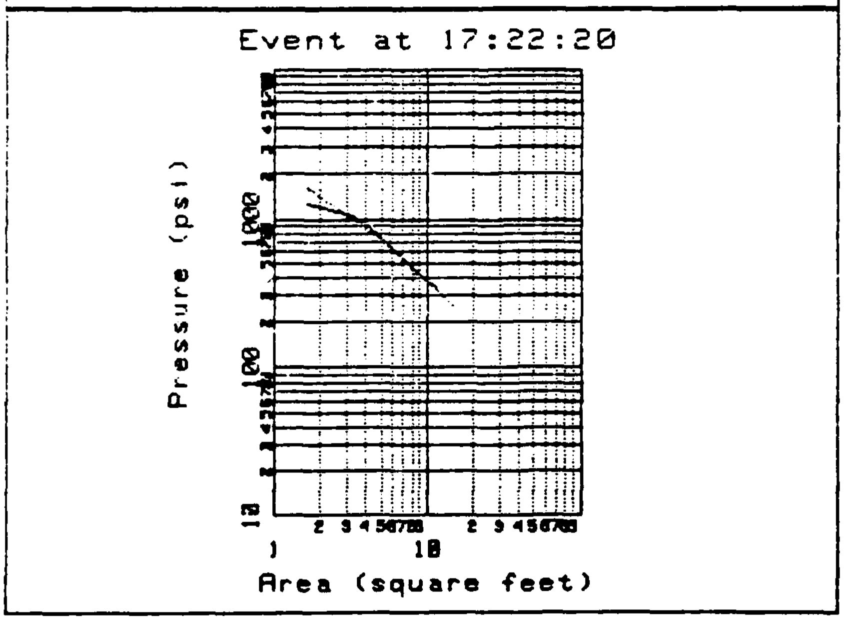
PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

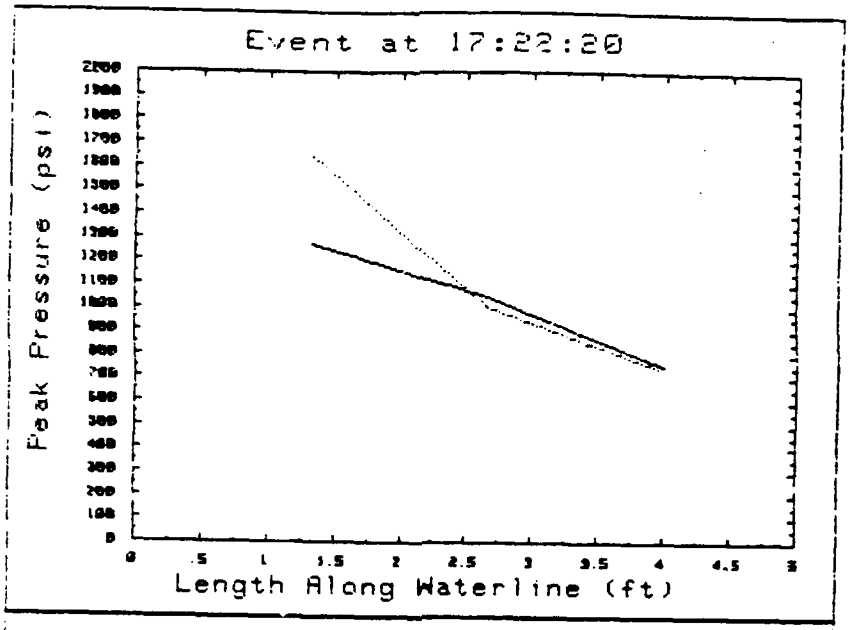
GIRTH	1.25	2.50	3.75
PRESSURE	1273.00	444.00	298.00

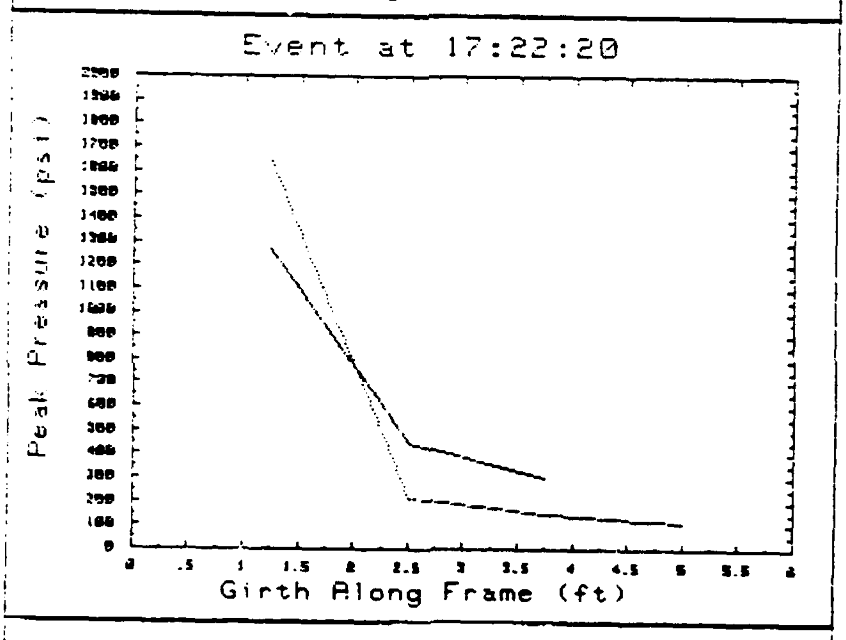
PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

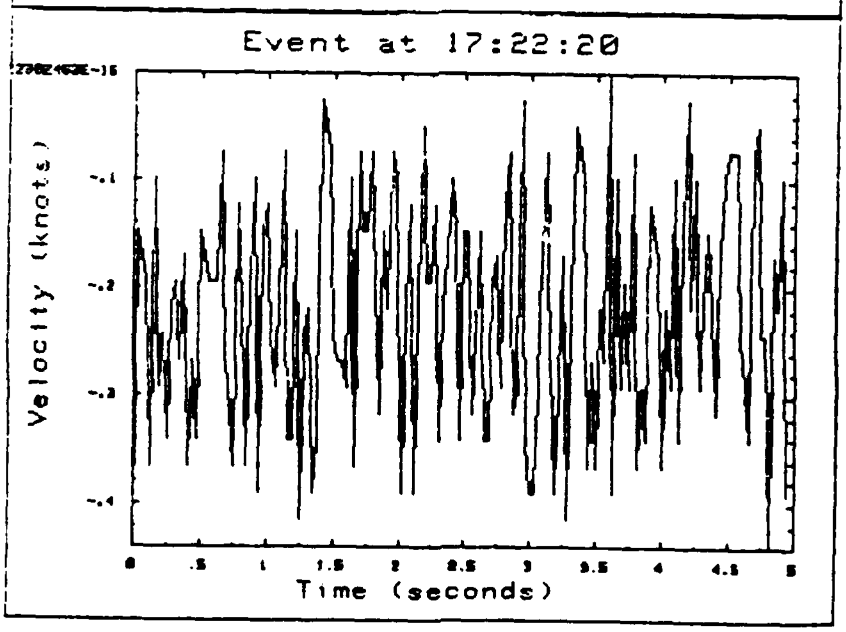
LENGTH	1.33	2.67	4.00
PRESSURE	1273.00	1049.00	759.00


Event at 17:22:20
Total Force (long tons)
Time (seconds)


Event at 17:22:20
Pressure (psi)
Area (square feet)


Event at 17:22:20
Peak Pressure (psi)
Length Along Waterline (ft)
0 .5 1 1.5 2 2.5 3 3.5 4 4.5 5


Event at 17:22:20
Peak Pressure (psi)
Girth Along Frame (ft)
0 .5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6


Event at 17:22:20
Velocity (knots)
-.1
-.2
-.3
-.4
Time (seconds)
0 .5 1 1.5 2 2.5 3 3.5 4 4.5 5

EVENT ON 8 APR AT 18:39:39
TAPE NUMBER 5 : TRACK NUMBER 1 : FILE NUMBER 77
PEAK STRAIN 666; THRESHOLD 150
AVERAGE SHIP SPEED -.27 Knots

RELATIONSHIPS FOR TIME OF PEAK PRESSURE

MAX PRESSURE 1327 PSI; TIME FRAME 35; REAL TIME 1.09
FRAME 37; ROW 7

AVERAGE PRESSURE (psi) vs AREA (square feet)

Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	1327.00	835.00	607.00	507.00	428.00	371.00	325.00

PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

GIRTH	1.25	2.50	3.75
PRESSURE	1327.00	687.00	156.00

PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

LENGTH	1.33	2.67	4.00
PRESSURE	1327.00	835.00	607.00

RELATIONSHIPS FOR TIME OF PEAK FORCE

MAX TOTAL FORCE 260 LONG TONS: TIME FRAME 35: REAL TIME 1.09
FRAME 37: ROW 7

AVERAGE PRESSURE (psi) vs AREA (square feet)

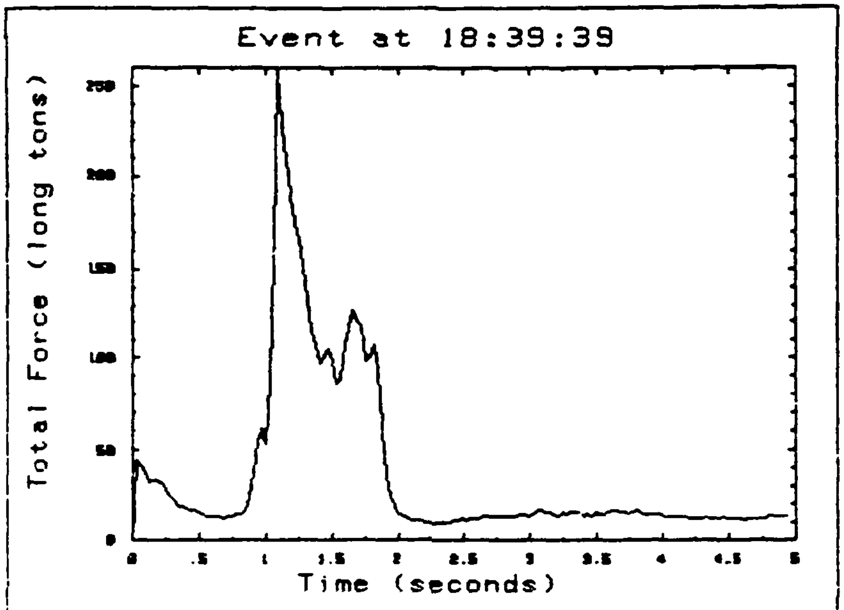
Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	1327.00	835.00	607.00	507.00	428.00	371.00	325.00

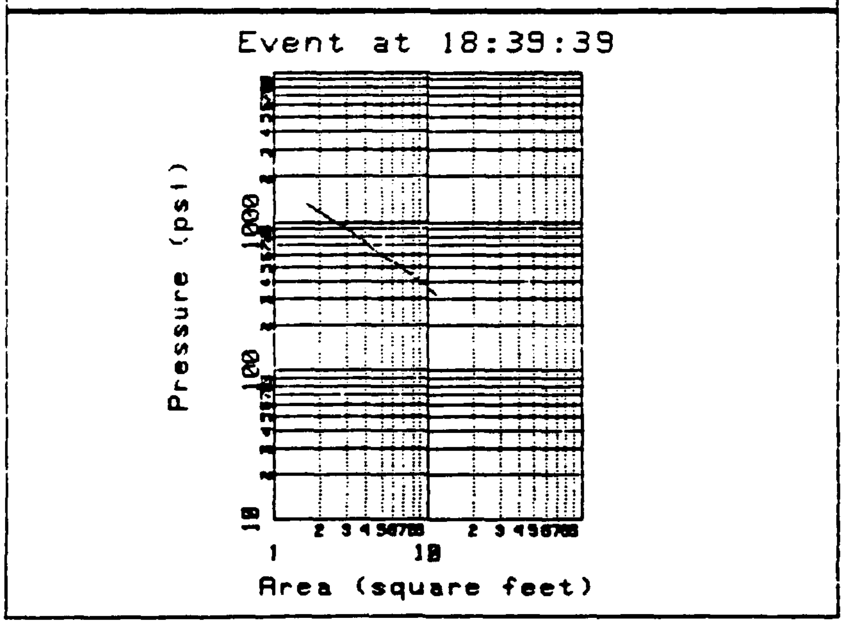
PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

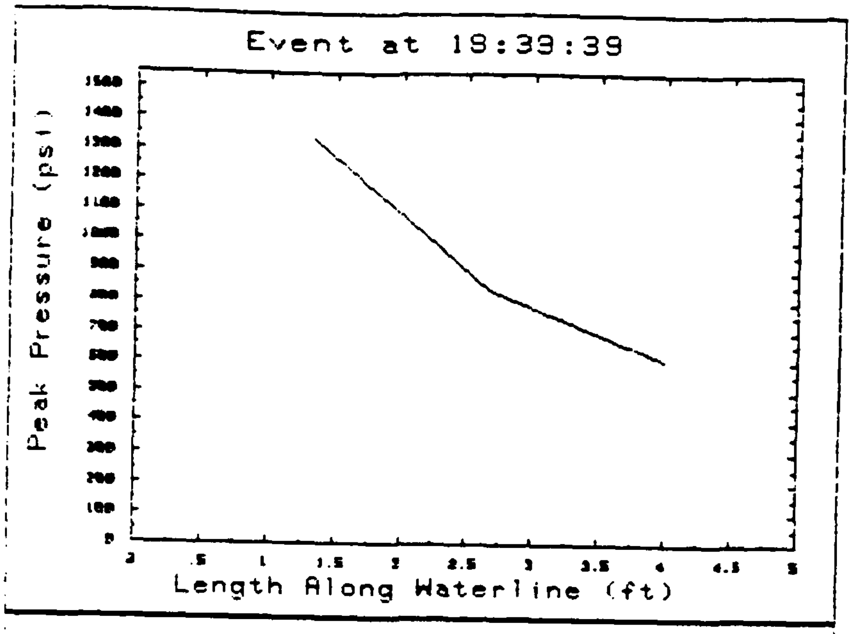
GIRTH	1.25	2.50	3.75
PRESSURE	1327.00	687.00	156.00

PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

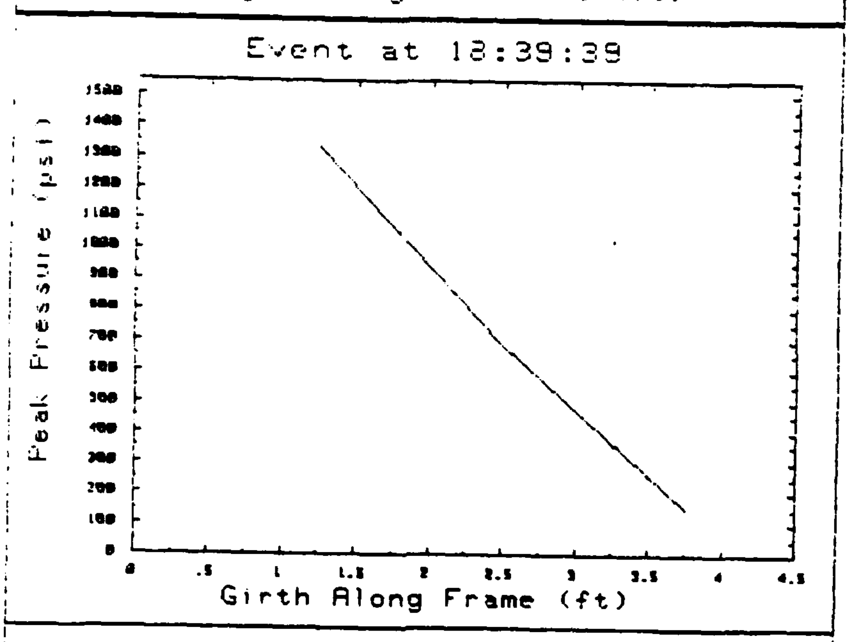
LENGTH	1.33	2.67	4.00
PRESSURE	1327.00	835.00	607.00


Event at 18:39:39
Total Force (long tons)
Time (seconds)

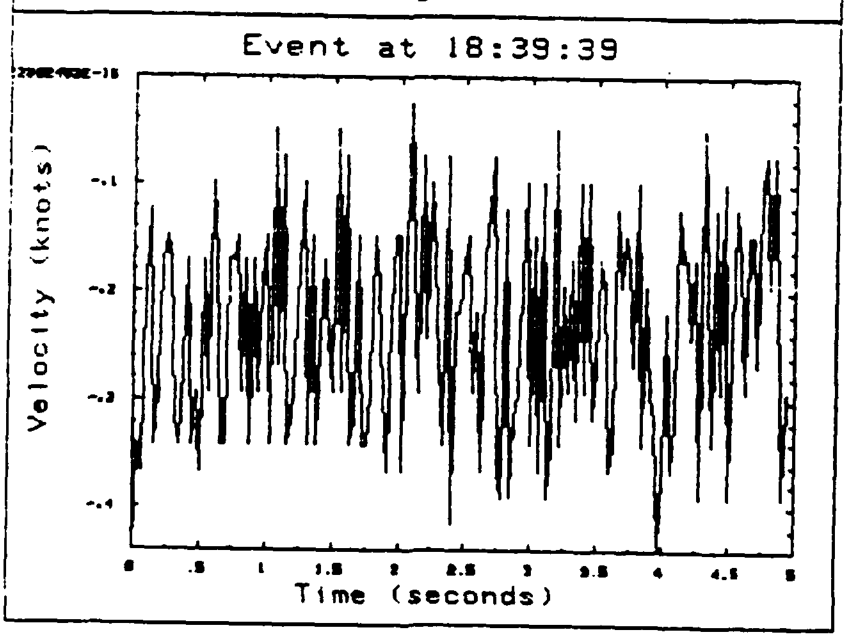

Event at 18:39:39
Pressure (psi)
Area (square feet)



Event at 18:39:39
Peak Pressure (psi)
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Length Along Waterline (ft)



Event at 18:39:39
Peak Pressure (psi)
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
0
.5
1
1.5
2
2.5
3
3.5
4
4.5
Girth Along Frame (ft)



Event at 18:39:39
Velocity (knots)
-.1
-.2
-.3
-.4
0
.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (seconds)

EVENT ON 20 APR AT 13:6:18
TAPE NUMBER 6 ; TRACK NUMBER 4 ; FILE NUMBER 5
PEAK STRAIN 685: THRESHOLD 150
AVERAGE SHIP SPEED 3.20 Knots

RELATIONSHIPS FOR TIME OF PEAK PRESSURE

MAX PRESSURE 1319 PSI: TIME FRAME 113; REAL TIME 3.53
FRAME 44: ROW 8

AVERAGE PRESSURE (psi) vs AREA (square feet)

Area	1.63	3.26	4.90	6.53	8.16	9.79
Pressure	1319.00	1077.00	861.00	717.00	588.00	496.00

PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

GIRTH	1.25	2.50
PRESSURE	1319.00	251.00

PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

LENGTH	1.33	2.67	4.00	5.33
PRESSURE	1319.00	1077.00	861.00	717.00

RELATIONSHIPS FOR TIME OF PEAK FORCE

MAX TOTAL FORCE 443 LONG TONS: TIME FRAME 92; REAL TIME 2.88
FRAME 42: ROW 7

AVERAGE PRESSURE (psi) vs AREA (square feet)

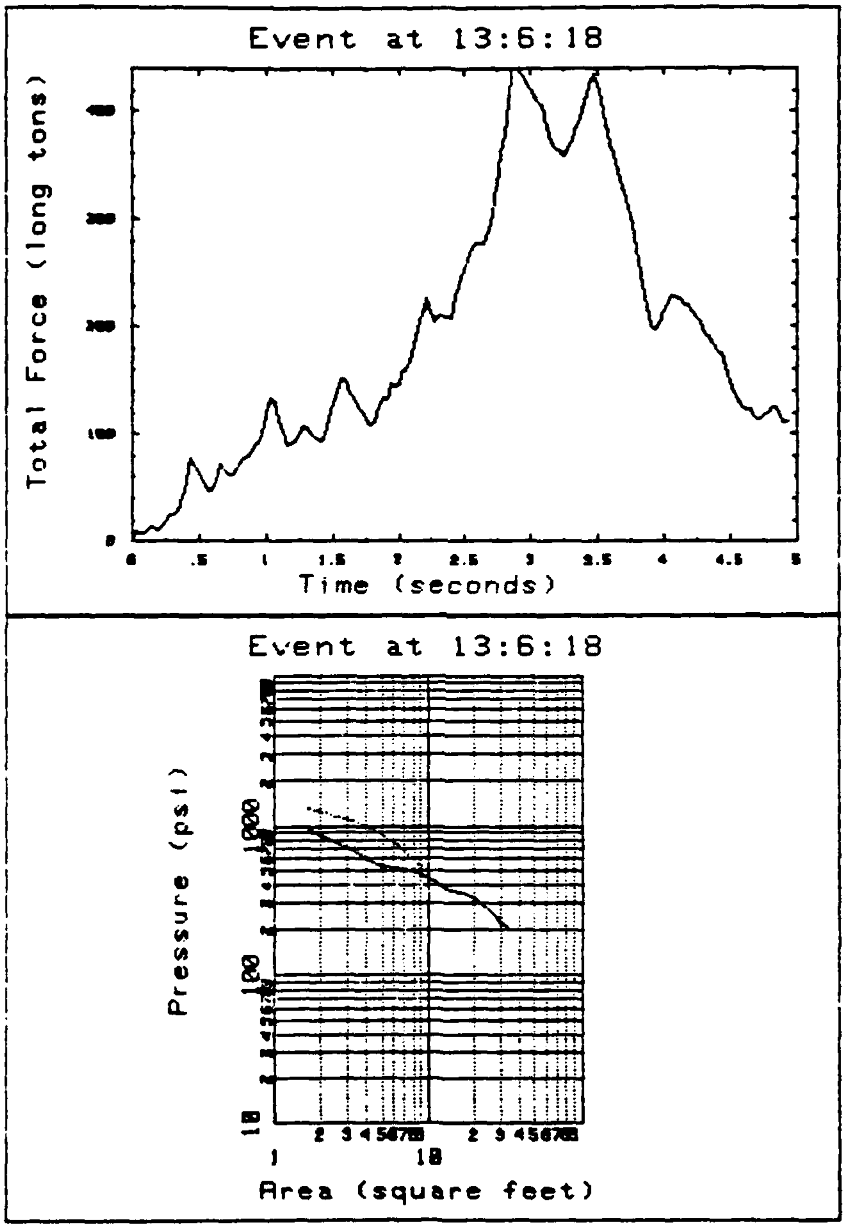
Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	956.00	680.00	537.00	519.00	491.00	450.00	415.00
Area	13.06	14.69	16.32	17.95	19.58	21.22	22.85
Pressure	378.00	369.00	358.00	345.00	330.00	312.00	292.00
Area	24.48	26.11	27.74	29.38	31.01	32.64	
Pressure	274.00	258.00	243.00	231.00	220.00	209.00	

PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

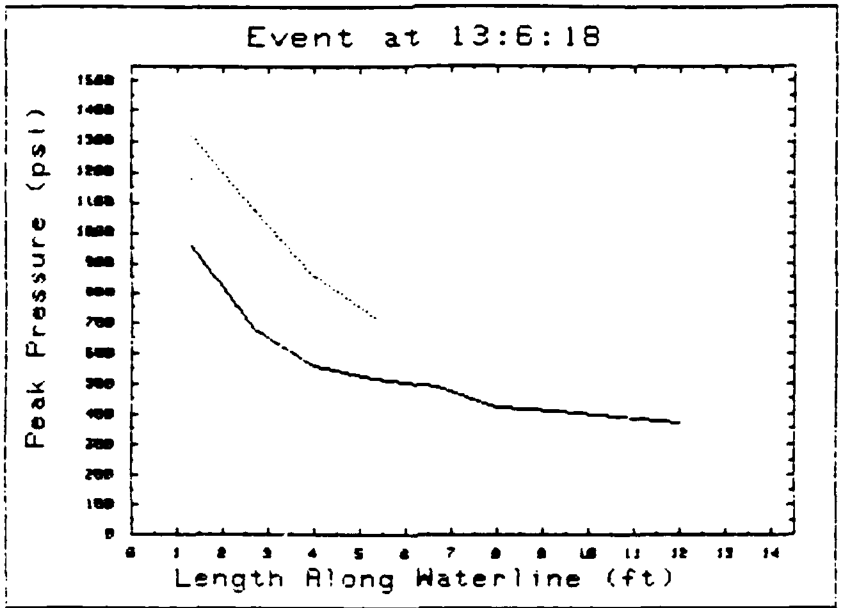
GIRTH	1.25	2.50	3.75	5.00
PRESSURE	956.00	580.00	171.00	133.00

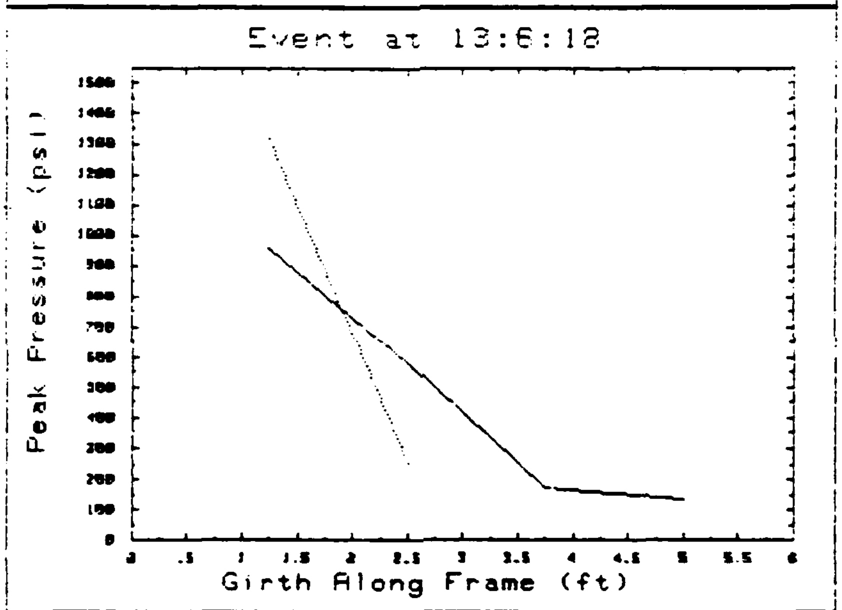
PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

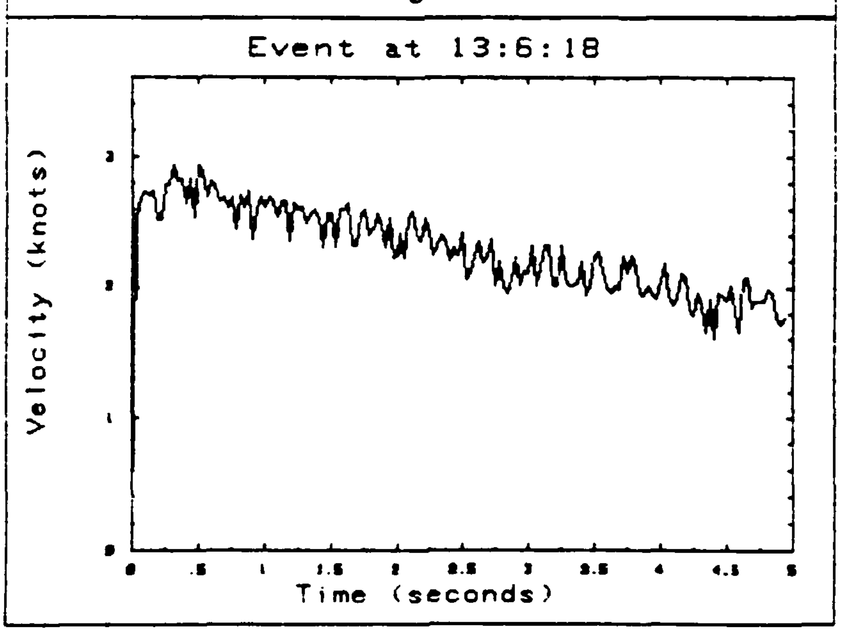
LENGTH	1.33	2.67	4.00	5.33	6.67	8.00	9.33
PRESSURE	956.00	680.00	557.00	519.00	491.00	429.00	410.00
LENGTH	10.67	12.00					
PRESSURE	391.00	372.00					



Event at 13:6:18
Total Force (long tons)
Time (seconds)
Event at 13:6:18
Pressure (psi)
Area (square feet)


Event at 13:6:18
Peak Pressure (psi)
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Length Along Waterline (ft)


Event at 13:6:18
Peak Pressure (psi)
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
0
.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6
Girth Along Frame (ft)


Event at 13:6:18
Velocity (knots)
0
1
2
3
0
.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (seconds)

EVENT ON 24 APR AT 16:11:59
TAPE NUMBER 6 : TRACK NUMBER 4 ; FILE NUMBER 50
PEAK STRAIN 637: THRESHOLD 150
AVERAGE SHIP SPEED 7.80 Knots

RELATIONSHIPS FOR TIME OF PEAK PRESSURE

MAX PRESSURE 1141 PSI: TIME FRAME 56; REAL TIME 1.75
FRAME 42; ROW 8

AVERAGE PRESSURE (psi) vs AREA (square feet)

Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	1141.00	966.00	899.00	751.00	637.00	599.00	530.00
Area	13.06	14.69	16.32	17.95	19.58	21.22	22.85
Pressure	472.00	429.00	395.00	368.00	353.00	330.00	308.00
Area	24.48	26.11	27.74	29.38	31.01	32.64	34.27
Pressure	289.00	273.00	261.00	251.00	240.00	229.00	219.00
Area	35.90	37.53	39.17	40.80	42.43	44.06	
Pressure	210.00	202.00	194.00	187.00	180.00	173.00	

PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

GIRTH	1.25	2.50	3.75	5.00
PRESSURE	1141.00	475.00	325.00	246.00

PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

LENGTH	1.33	2.67	4.00	5.33	6.67	8.00	9.33
PRESSURE	1141.00	966.00	899.00	751.00	166.00	169.00	148.00
LENGTH	10.67	12.00	13.33				
PRESSURE	63.00	59.00	53.00				

RELATIONSHIPS FOR TIME OF PEAK FORCE

MAX TOTAL FORCE 491 LONG TONS: TIME FRAME 56: REAL TIME 1.75
FRAME 42: ROW 8

AVERAGE PRESSURE (psi) vs AREA (square feet)

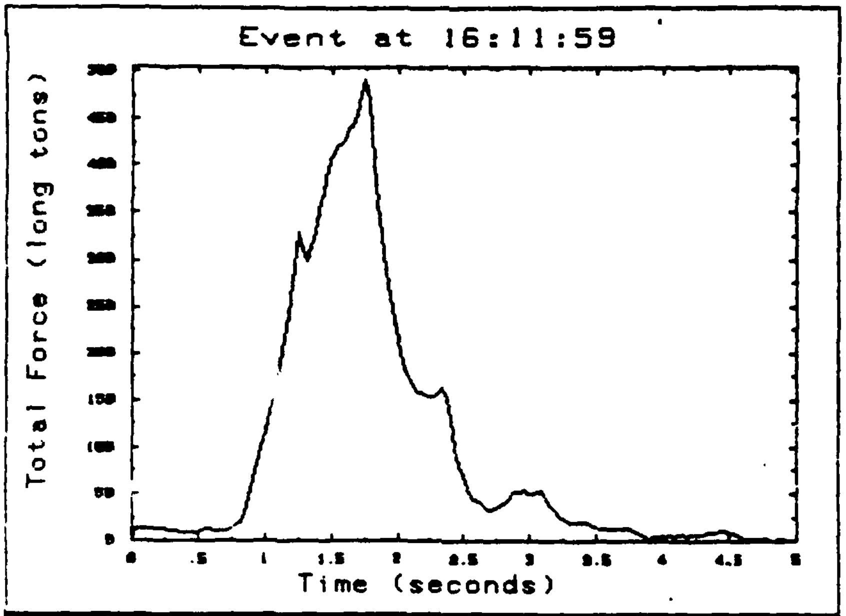
Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	1141.00	966.00	899.00	751.00	637.00	599.00	530.00
Area	13.06	14.69	16.32	17.95	19.58	21.22	22.85
Pressure	472.00	429.00	395.00	368.00	353.00	330.00	308.00
Area	24.48	26.11	27.74	29.38	31.01	32.64	34.27
Pressure	289.00	273.00	261.00	251.00	240.00	229.00	219.00
Area	35.90	37.53	39.17	40.80	42.43	44.06	
Pressure	210.00	202.00	194.00	187.00	180.00	173.00	

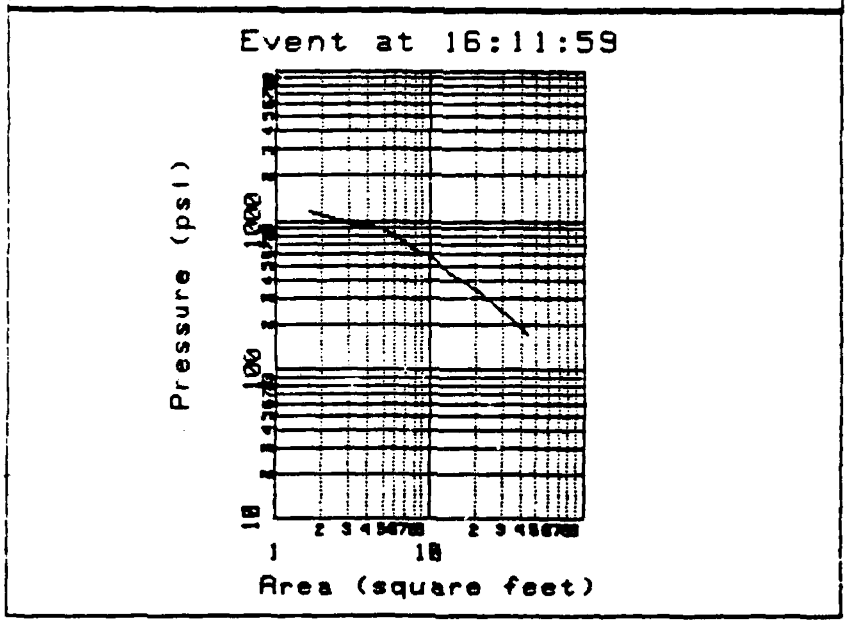
PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

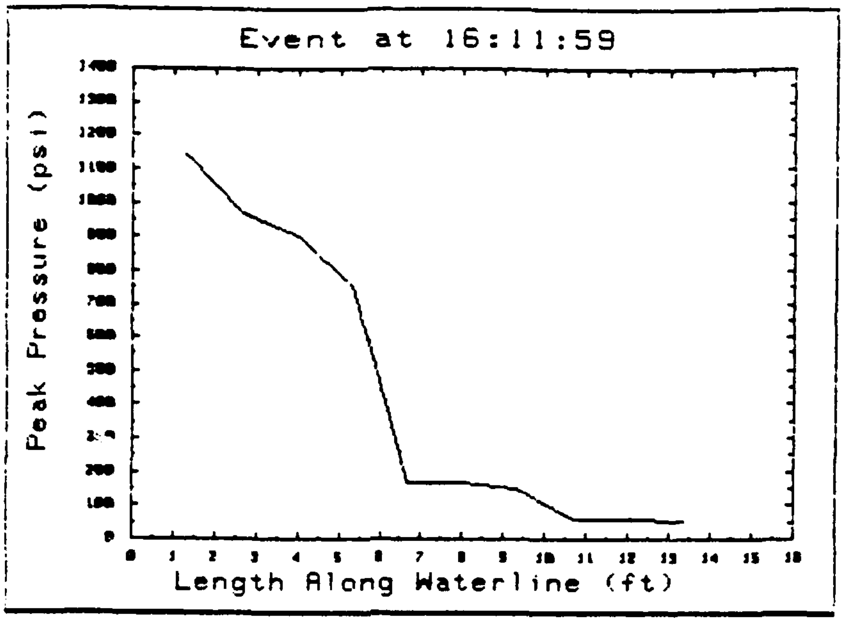
GIRTH	1.25	2.50	3.75	5.00
PRESSURE	1141.00	475.00	325.00	246.00

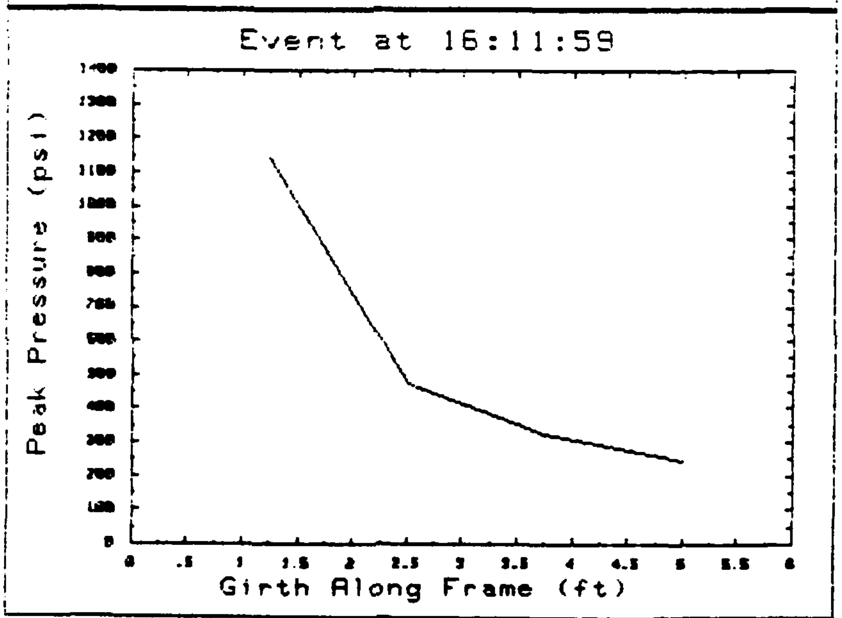
PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

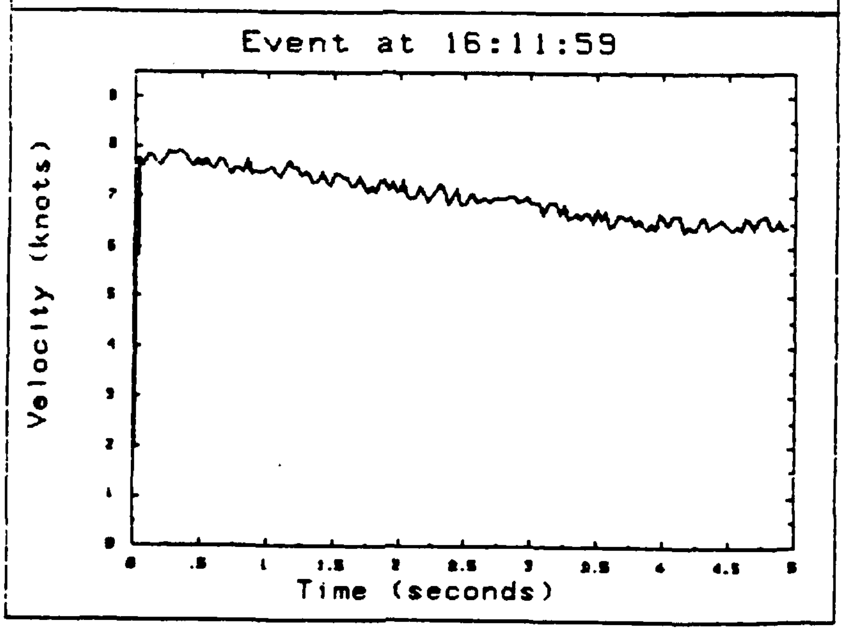
LENGTH	1.33	2.67	4.00	5.33	6.67	8.00	9.33
PRESSURE	1141.00	966.00	899.00	751.00	166.00	169.00	148.00
LENGTH	10.67	12.00	13.33				
PRESSURE	63.00	59.00	53.00				


Event at 16:11:59
Total Force (long tons)
Time (seconds)


Event at 16:11:59
Pressure (psi)
Area (square feet)


Event at 16:11:59
Peak Pressure (psi)
Length Along Waterline (ft)


Event at 16:11:59
Peak Pressure (psi)
Girth Along Frame (ft)


Event at 16:11:59
Velocity (knots)
Time (seconds)

EVENT ON 19 APR AT 13:3:53
TAPE NUMBER 6 : TRACK NUMBER 3 ; FILE NUMBER 38
PEAK STRAIN 549: THRESHOLD 150
AVERAGE SHIP SPEED 5.63 Knots

RELATIONSHIPS FOR TIME OF PEAK PRESSURE

MAX PRESSURE 1243 PSI; TIME FRAME 84: REAL TIME 2.63
FRAME 44; ROW 5

AVERAGE PRESSURE (psi) vs AREA (square feet)

Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	1243.00	760.00	599.00	498.00	412.00	351.00	305.00

PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

GIRTH	1.25	2.50	3.75
PRESSURE	1243.00	760.00	530.00

PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

LENGTH	1.33	2.67
PRESSURE	1243.00	277.00

RELATIONSHIPS FOR TIME OF PEAK FORCE

MAX TOTAL FORCE 294 LONG TONS: TIME FRAME 71: REAL TIME 2.22
FRAME 41: ROW 4

AVERAGE PRESSURE (psi) vs AREA (square feet)

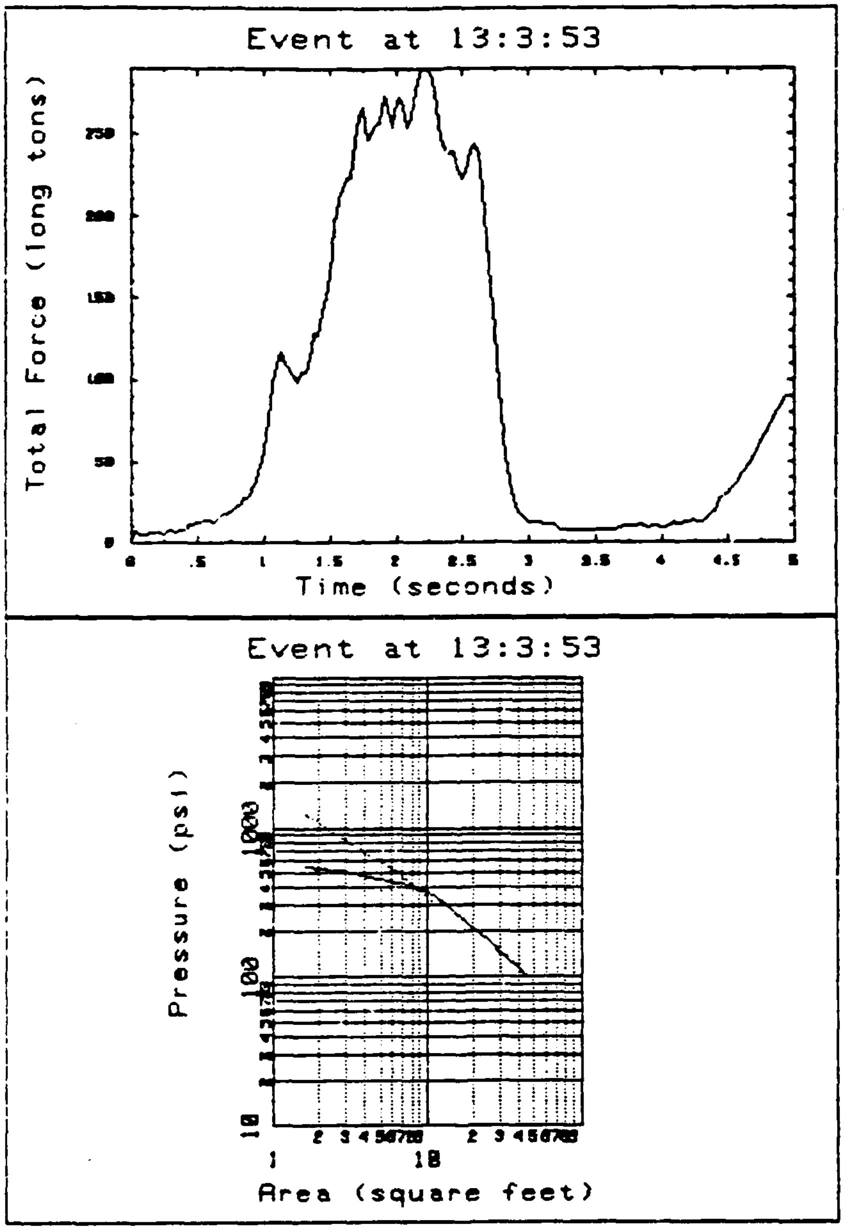
Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	548.00	492.00	449.00	432.00	418.00	375.00	338.00
Area	13.06	14.69	16.32	17.95	19.58	21.22	22.85
Pressure	307.00	276.00	252.00	231.00	216.00	201.00	187.00
Area	24.48	26.11	27.74	29.38	31.01	32.64	34.27
Pressure	176.00	165.00	156.00	148.00	143.00	138.00	132.00
Area	35.90	37.53	39.17	40.80	42.43	44.06	45.69
Pressure	126.00	121.00	116.00	111.00	107.00	103.00	100.00

PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

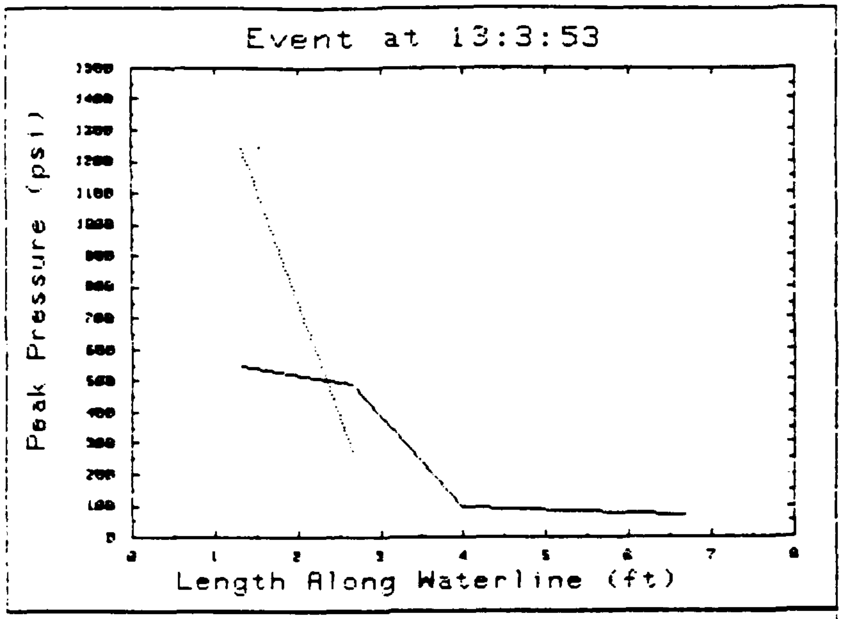
GIRTH	1.25	2.50	3.75	5.00	6.25	7.50
PRESSURE	548.00	457.00	430.00	352.00	287.00	244.00

PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

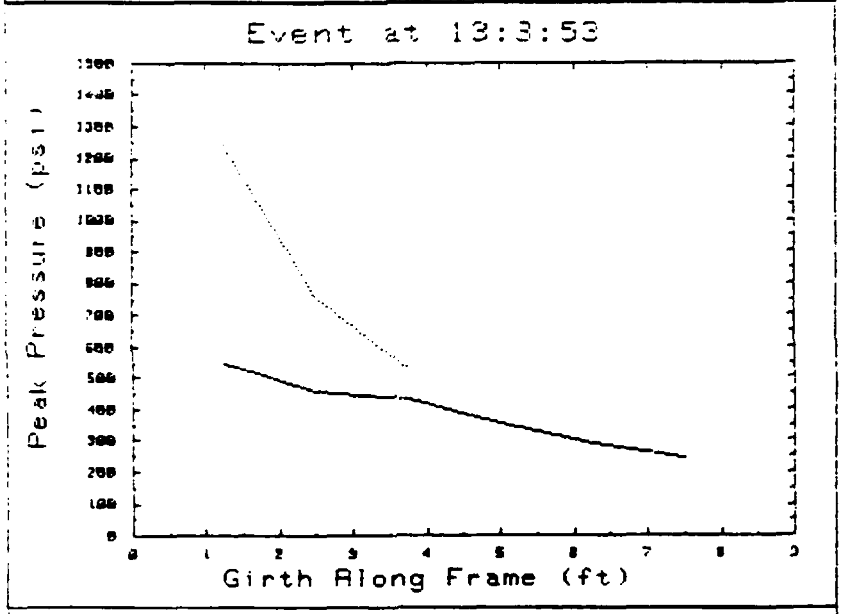
LENGTH	1.33	2.67	4.00	5.33	6.67
PRESSURE	548.00	492.00	96.00	86.00	71.00



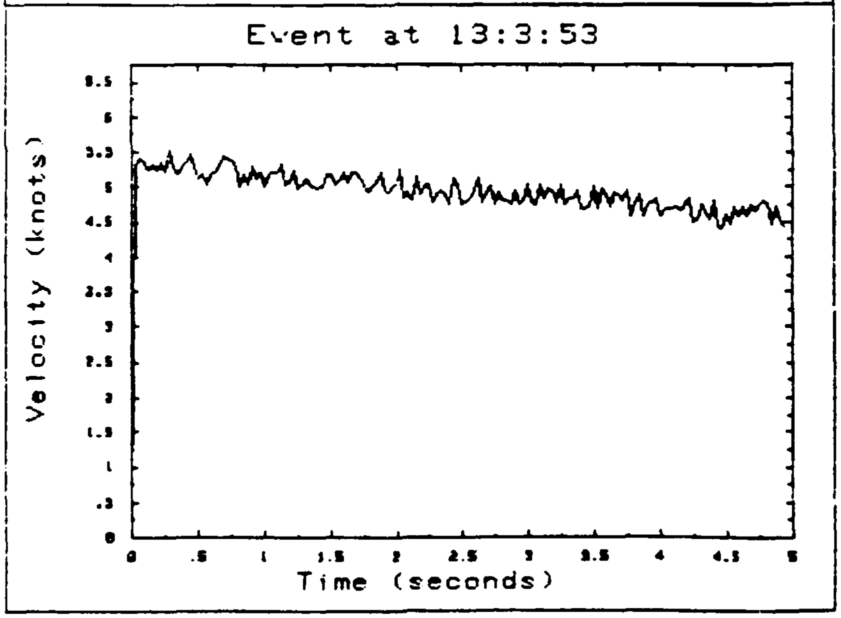
Event at 13:3:53
Total Force (long tons)
Time (seconds)
Event at 13:3:53
Pressure (psi)
Area (square feet)



Event at 13:3:53
Peak Pressure (psi)
Length Along Waterline (ft)



Event at 13:3:53
Peak Pressure (psi)
Girth Along Frame (ft)



Event at 13:3:53
Velocity (knots)
Time (seconds)

EVENT ON 11 APR AT 8:55:30
TAPE NUMBER 6 : TRACK NUMBER 1 ; FILE NUMBER 9
PEAK STRAIN 499; THRESHOLD 150
AVERAGE SHIP SPEED 5.57 Knots

RELATIONSHIPS FOR TIME OF PEAK PRESSURE

MAX PRESSURE 1011 PSI; TIME FRAME 132; REAL TIME 4.13
FRAME 39; ROW 8

AVERAGE PRESSURE (psi) vs AREA (square feet)

Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	1011.00	629.00	458.00	362.00	326.00	317.00	280.00
Area	13.06	14.69	16.32	17.95	19.58	21.22	22.85
Pressure	249.00	233.00	246.00	260.00	241.00	224.00	208.00

PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

GIRTH	1.25	2.50	3.75
PRESSURE	1011.00	146.00	101.00

PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

LENGTH	1.33	2.67	4.00	5.33	6.67	8.00	9.33
PRESSURE	1011.00	629.00	458.00	362.00	352.00	360.00	325.00
LENGTH	10.67	12.00	13.33				
PRESSURE	294.00	281.00	281.00				

RELATIONSHIPS FOR TIME OF PEAK FORCE

MAX TOTAL FORCE 393 LONG TONS: TIME FRAME 62: REAL TIME 1.94
FRAME 41: ROW 8

AVERAGE PRESSURE (psi) vs AREA (square feet)

Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	642.00	401.00	450.00	437.00	385.00	353.00	320.00

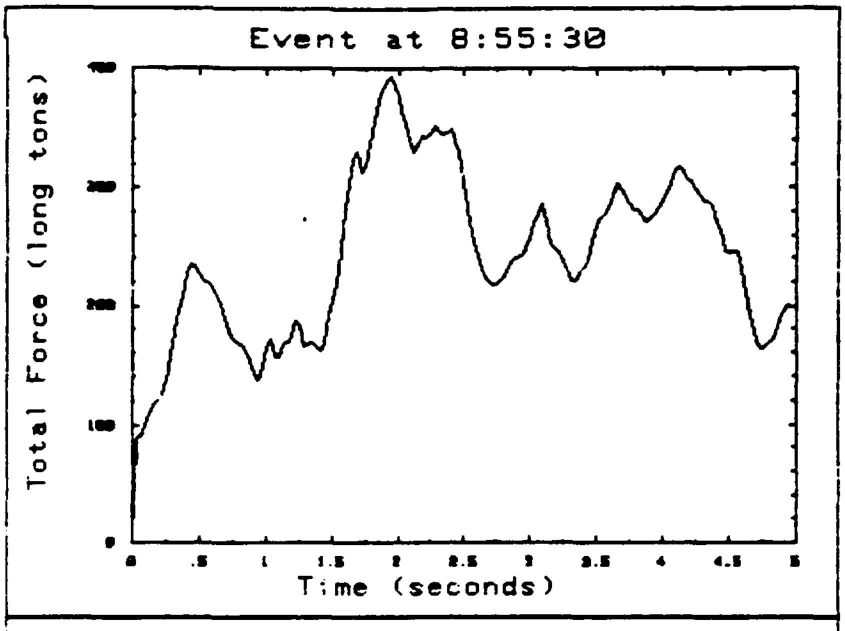
Area	13.06	14.69	16.32
Pressure	283.00	253.00	229.00

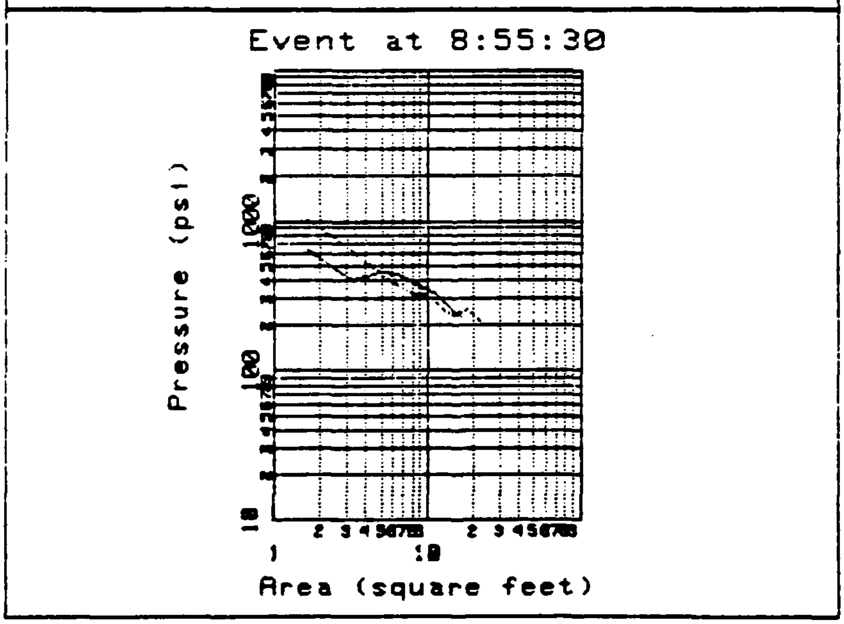
PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

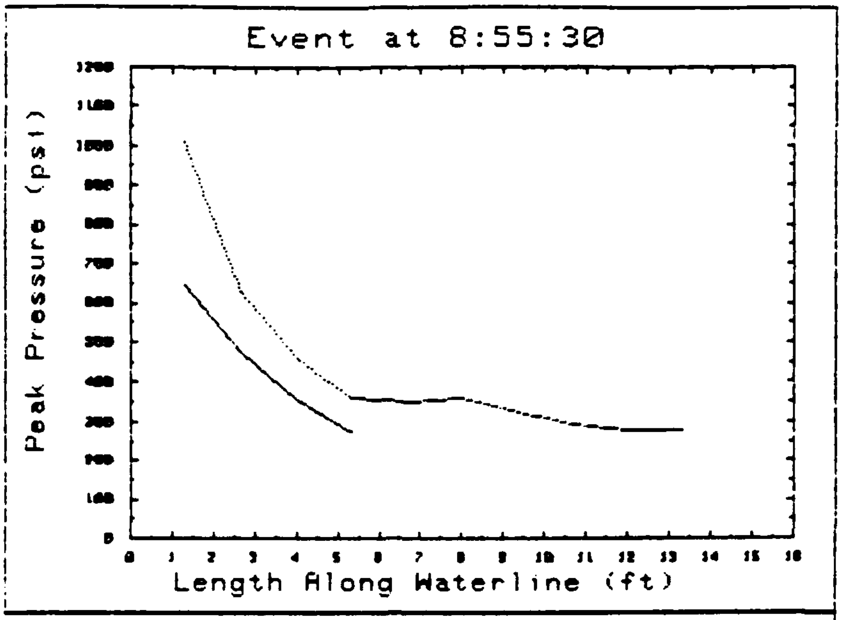
GIRTH	1.25	2.50	3.75
PRESSURE	642.00	354.00	227.00

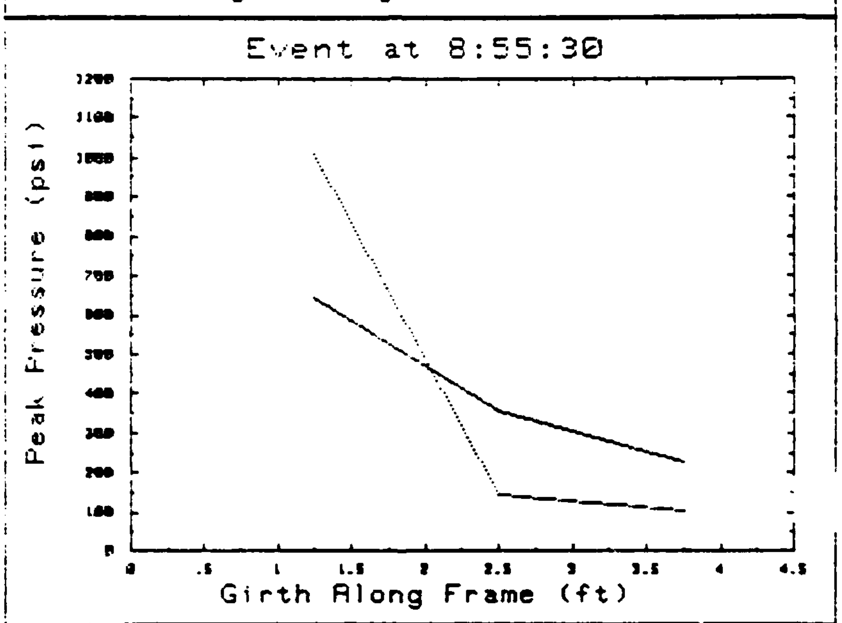
PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

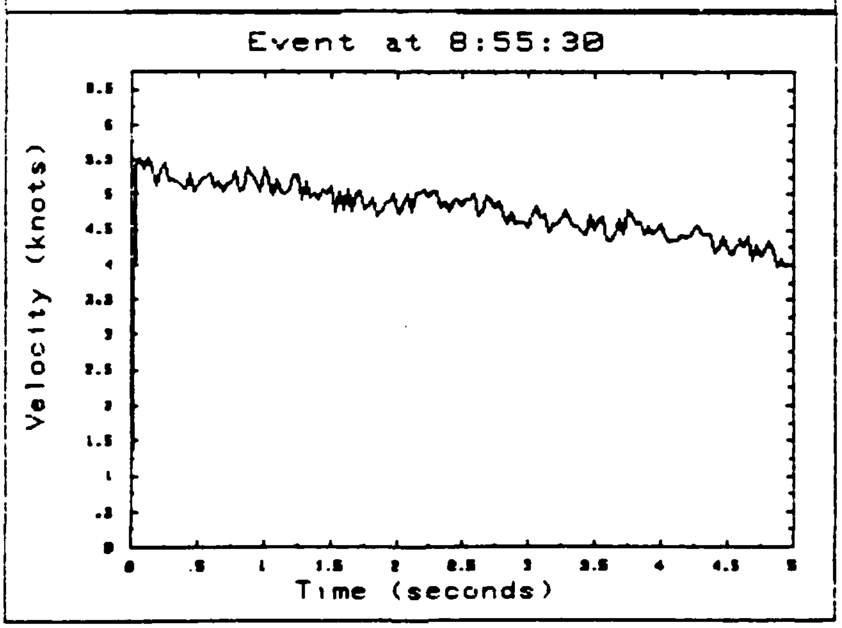
LENGTH	1.33	2.67	4.00	5.33
PRESSURE	642.00	473.00	355.00	272.00


Event at 8:55:30
Total Force (long tons)
Time (seconds)


Event at 8:55:30
Pressure (psi)
Area (square feet)


Event at 8:55:30
Peak Pressure (psi)
Length Along Waterline (ft)


Event at 8:55:30
Peak Pressure (psi)
Girth Along Frame (ft)


Event at 8:55:30
Velocity (knots)
Time (seconds)

EVENT ON 19 APR AT 12:25:12
TAPE NUMBER 6 ; TRACK NUMBER 3 : FILE NUMBER 25
PEAK STRAIN 496; THRESHOLD 150
AVERAGE SHIP SPEED 4.37 Knots

RELATIONSHIPS FOR TIME OF PEAK PRESSURE

MAX PRESSURE 848 PSI; TIME FRAME 78; REAL TIME 2.44
FRAME 44; ROW 6

AVERAGE PRESSURE (psi) vs AREA (square feet)

Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	848.00	614.00	478.00	388.00	316.00	269.00	233.00
Area	13.06	14.69	16.32	17.95	19.58	21.22	22.85
Pressure	218.00	201.00	191.00	175.00	162.00	151.00	141.00
Area	24.48	26.11	27.74	29.38	31.01	32.64	34.27
Pressure	132.00	125.00	118.00	112.00	106.00	101.00	96.00
Area	35.90	37.53	39.17				
Pressure	91.00	88.00	84.00				

PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

GIRTH	1.25	2.50	3.75
PRESSURE	848.00	527.00	175.00

PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

LENGTH	1.33	2.67	4.00	5.33	6.67	8.00	9.33
PRESSURE	848.00	614.00	414.00	339.00	285.00	254.00	220.00
LENGTH	10.67	12.00	13.33				
PRESSURE	194.00	173.00	159.00				

RELATIONSHIPS FOR TIME OF PEAK FORCE

MAX TOTAL FORCE 252 LONG TONS: TIME FRAME 67: REAL TIME 2.09
FRAME 42: ROW 5

AVERAGE PRESSURE (psi) vs AREA (square feet)

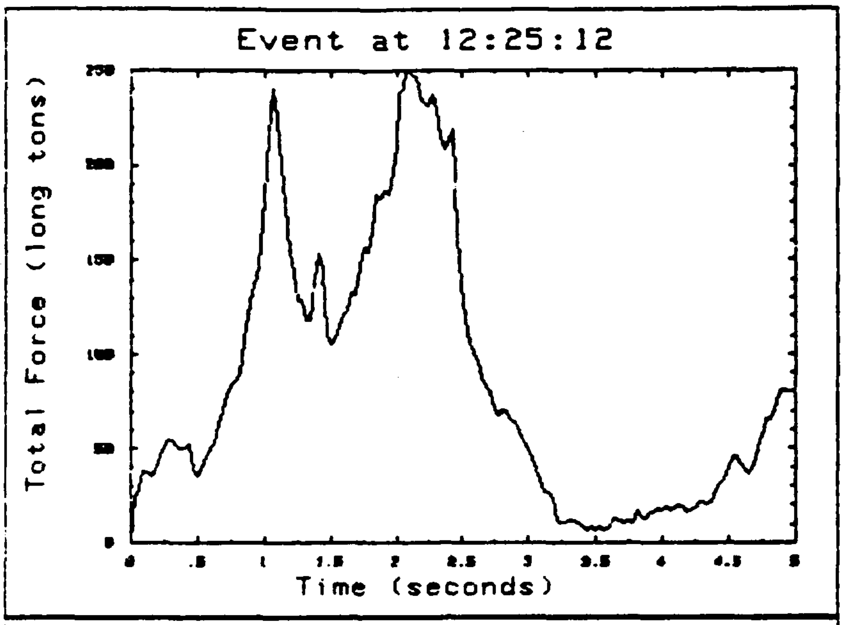
Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	488.00	473.00	420.00	363.00	316.00	276.00	250.00
Area	13.06	14.69	16.32	17.95	19.58	21.22	22.85
Pressure	230.00	212.00	198.00	184.00	172.00	162.00	152.00
Area	24.48	26.11	27.74	29.38	31.01	32.64	34.27
Pressure	143.00	135.00	128.00	122.00	117.00	112.00	108.00
Area	35.90	37.53	39.17	40.80	42.43	44.06	45.69
Pressure	103.00	99.00	95.00	92.00	89.00	86.00	83.00
Area	47.33	48.96	50.59	52.22	53.85	55.49	
Pressure	80.00	78.00	75.00	73.00	71.00	69.00	

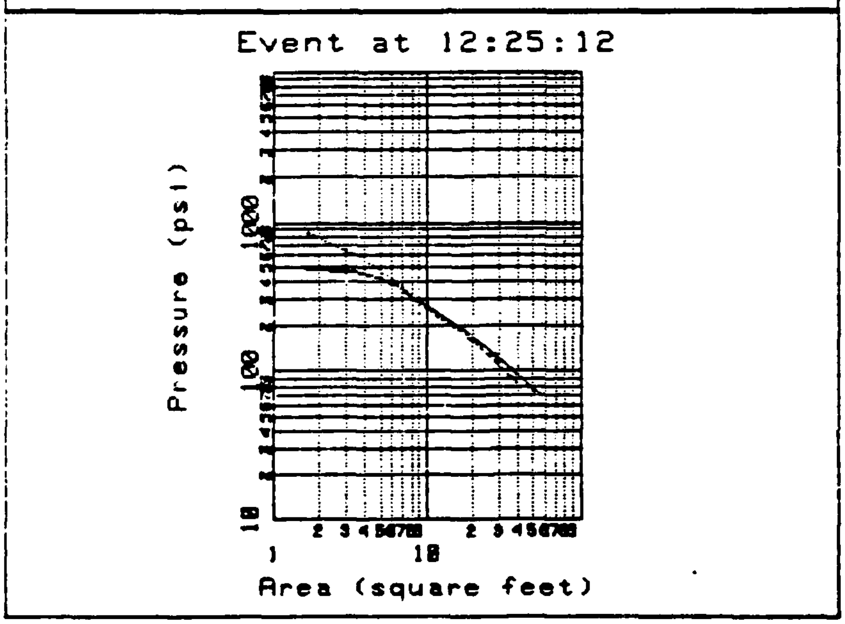
PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

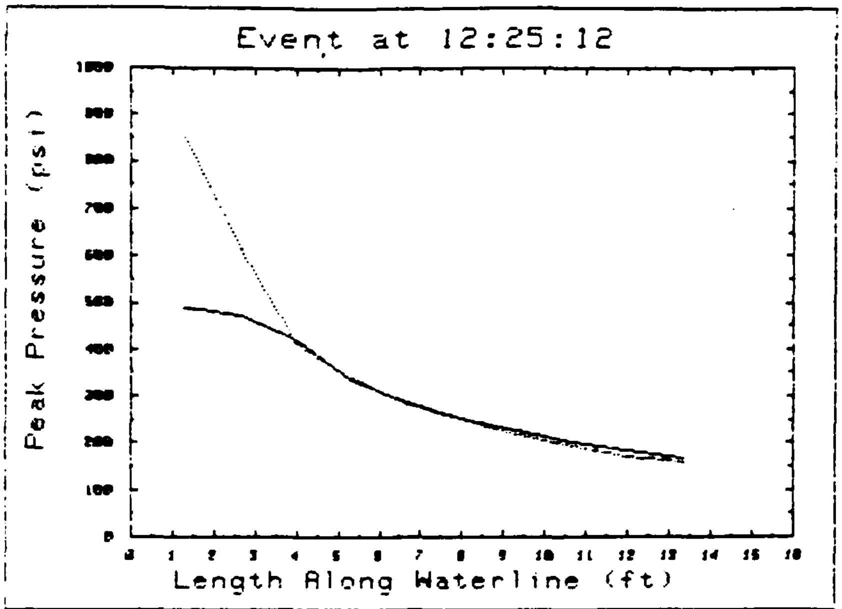
GIRTH	1.25	2.50	3.75	5.00	6.25
PRESSURE	488.00	340.00	199.00	150.00	131.00

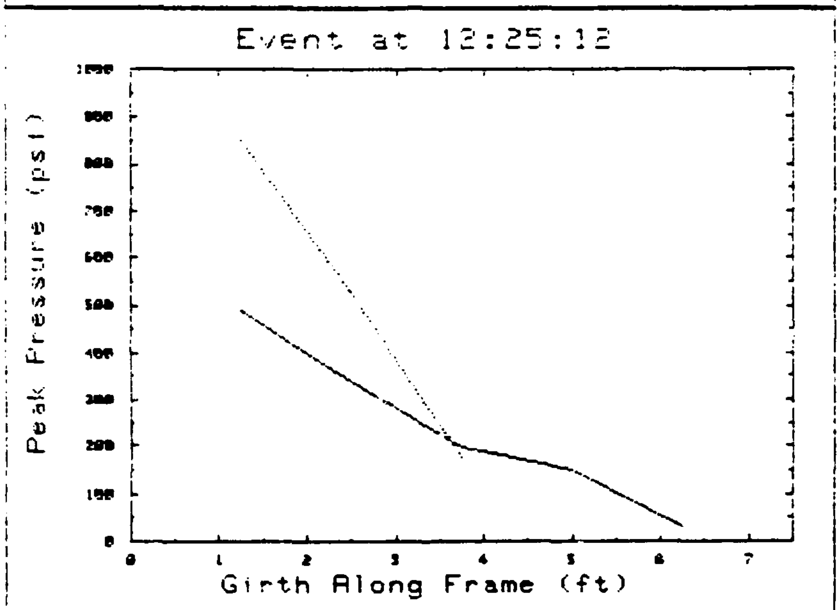
PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

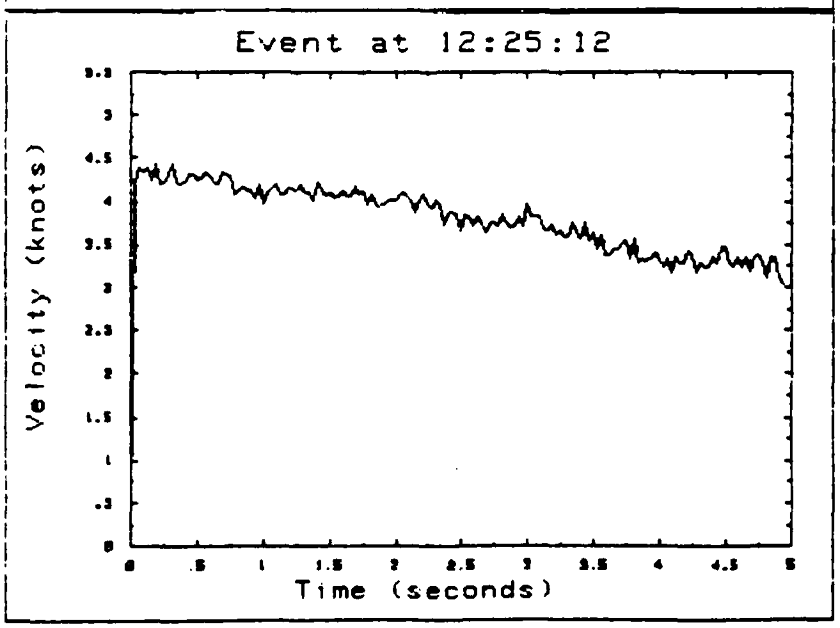
LENGTH	1.33	2.67	4.00	5.33	6.67	8.00	9.33
PRESSURE	488.00	473.00	420.00	334.00	287.00	254.00	228.00
LENGTH	10.67	12.00	13.33				
PRESSURE	204.00	184.00	167.00				


Event at 12:25:12
Total Force (long tons)
Time (seconds)


Event at 12:25:12
Pressure (psi)
1000
100
10
1
10
Area (square feet)


Event at 12:25:12
Peak Pressure (psi)
Length Along Waterline (ft)


Event at 12:25:12
Peak Pressure (psi)
Girth Along Frame (ft)


Event at 12:25:12
Velocity (knots)
Time (seconds)

EVENT ON 8 APR AT 18:23:31
TAPE NUMBER 5 ; TRACK NUMBER 1 ; FILE NUMBER 63
PEAK STRAIN 477; THRESHOLD 150
AVERAGE SHIP SPEED -.21 Knots

RELATIONSHIPS FOR TIME OF PEAK PRESSURE

MAX PRESSURE 906 PSI; TIME FRAME 158; REAL TIME 4.94
FRAME 39; ROW 8

AVERAGE PRESSURE (psi) vs AREA (square feet)

Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	906.00	545.00	391.00	307.00	263.00	251.00	226.00

Area	13.06	14.69	16.32	17.95	19.58	21.22
Pressure	202.00	182.00	164.00	152.00	140.00	130.00

PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

GIRTH	1.25	2.50	3.75	5.00
PRESSURE	906.00	109.00	40.00	33.00

PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

LENGTH	1.33	2.67	4.00	5.33	6.67
PRESSURE	906.00	545.00	391.00	307.00	250.00

RELATIONSHIPS FOR TIME OF PEAK FORCE

MAX TOTAL FORCE 227 LONG TONS: TIME FRAME 78; REAL TIME 2.44
FRAME 36: ROW 7

AVERAGE PRESSURE (psi) vs AREA (square feet)

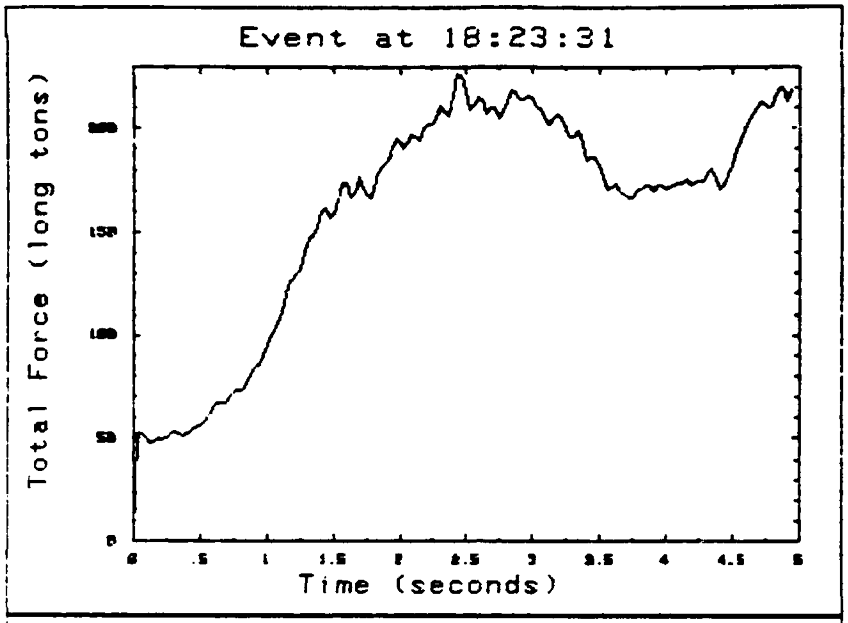
Area	1.63	3.26	4.90	6.53
Pressure	745.00	561.00	462.00	410.00

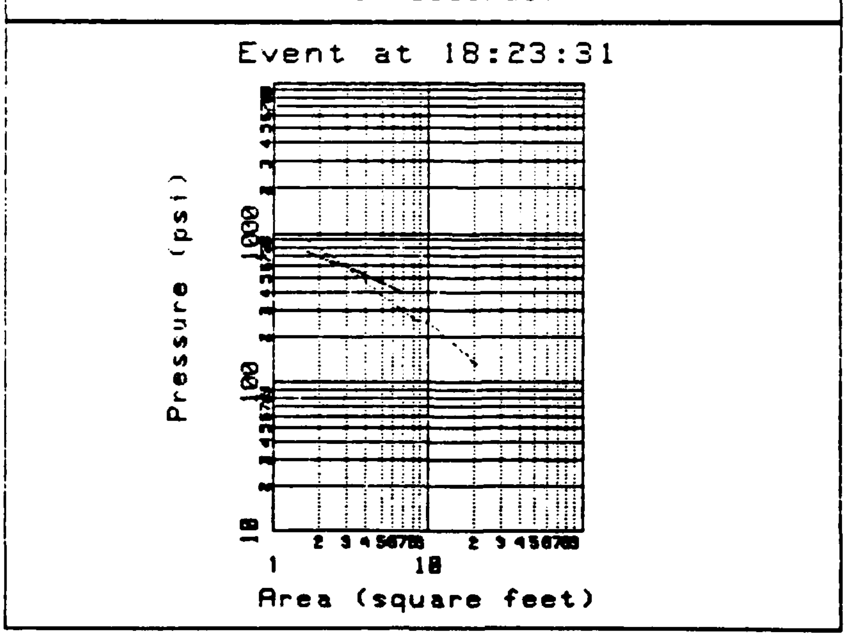
PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

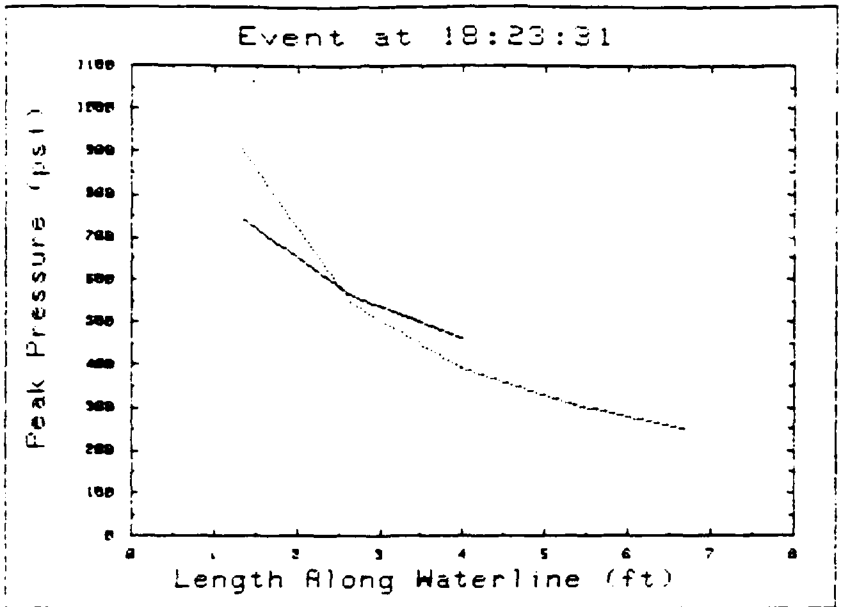
GIRTH	1.25	2.50
PRESSURE	745.00	499.00

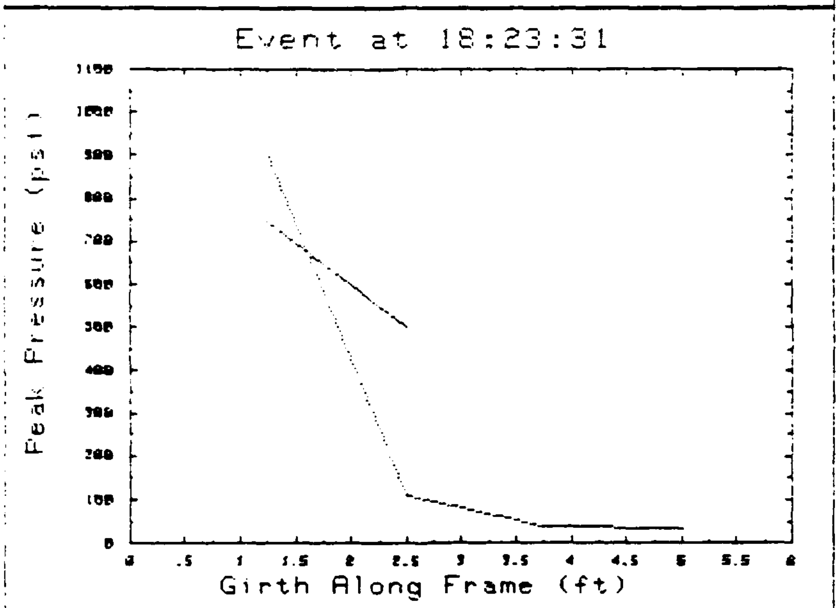
PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

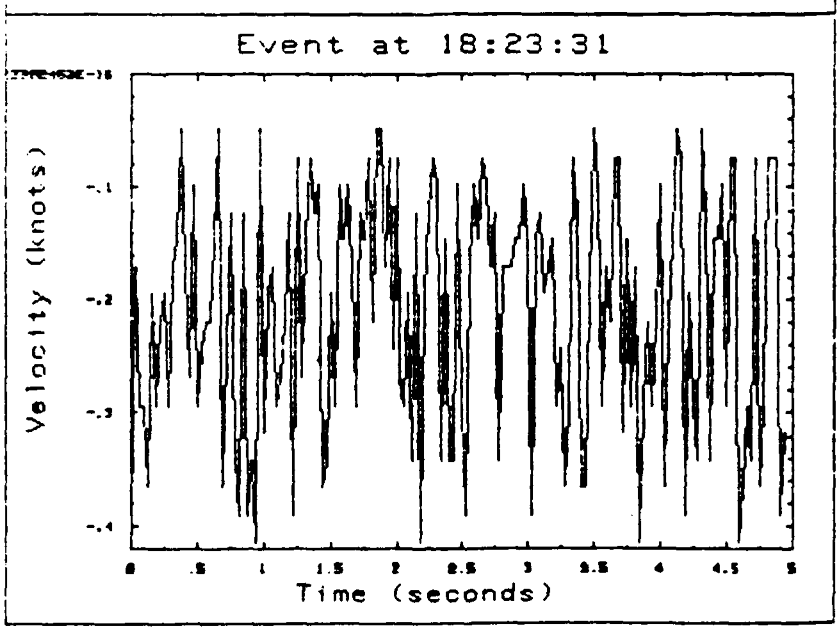
LENGTH	1.33	2.67	4.00
PRESSURE	745.00	561.00	462.00


Event at 18:23:31
Total Force (long tons)
Time (seconds)


Event at 18:23:31
Pressure (psi)
Area (square feet)


Event at 18:23:31
Peak Pressure (psi)
Length Along Waterline (ft)


Event at 18:23:31
Peak Pressure (psi)
Girth Along Frame (ft)


Event at 18:23:31
Velocity (knots)
Time (seconds)

EVENT ON 24 APR AT 18:38:32
TAPE NUMBER 6 ; TRACK NUMBER 4 : FILE NUMBER 64
PEAK STRAIN 469: THRESHOLD 150
AVERAGE SHIP SPEED 3.18 Knots

RELATIONSHIPS FOR TIME OF PEAK PRESSURE

MAX PRESSURE 1008 PSI; TIME FRAME 51; REAL TIME 1.59
FRAME 37; ROW 5

AVERAGE PRESSURE (psi) vs AREA (square feet)

Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	1008.00	684.00	559.00	444.00	362.00	306.00	270.00
Area	13.06	14.69	16.32	17.95	19.58	21.22	22.85
Pressure	249.00	224.00	203.00	186.00	172.00	159.00	151.00
Area	24.48	26.11	27.74				
Pressure	141.00	133.00	125.00				

PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

GIRTH	1.25	2.50	3.75	5.00	6.25	7.50
PRESSURE	1008.00	684.00	461.00	123.00	98.00	24.00

PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

LENGTH	1.33	2.67	4.00	5.33
PRESSURE	1008.00	553.00	380.00	173.00

RELATIONSHIPS FOR TIME OF PEAK FORCE

MAX TOTAL FORCE 257 LONG TONS: TIME FRAME 46; REAL TIME 1.44
FRAME 36: ROW 4

AVERAGE PRESSURE (psi) vs AREA (square feet)

Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	658.00	623.00	531.00	478.00	429.00	365.00	321.00

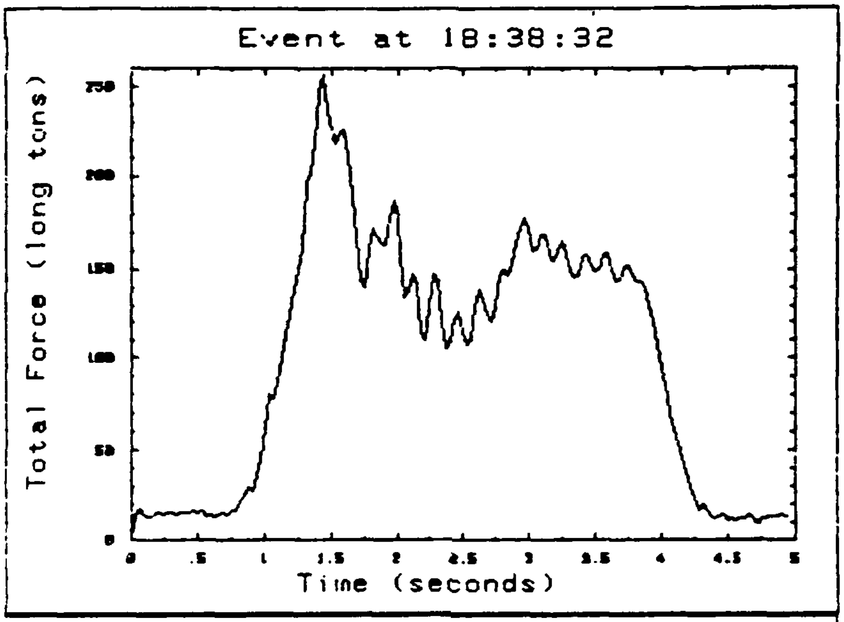
Area	13.06	14.69	16.32	17.95	19.58
Pressure	291.00	262.00	238.00	217.00	200.00

PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

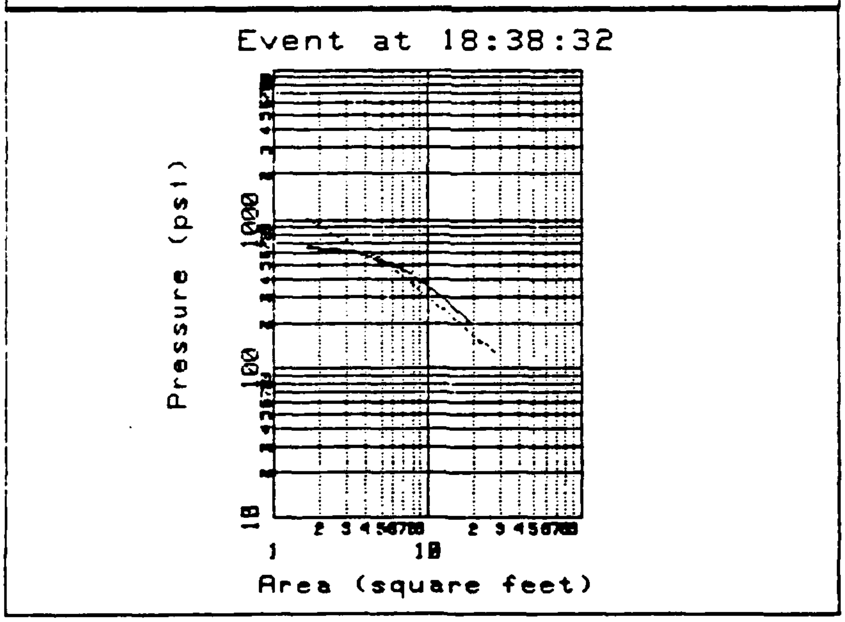
GIRTH	1.25	2.50	3.75	5.00
PRESSURE	658.00	623.00	418.00	333.00

PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

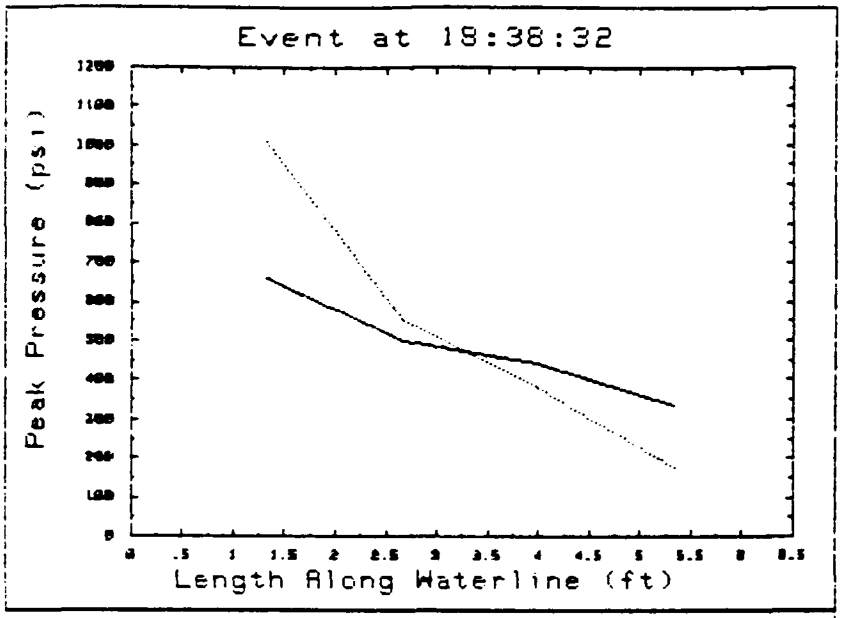
LENGTH	1.33	2.67	4.00	5.33
PRESSURE	658.00	502.00	441.00	333.00

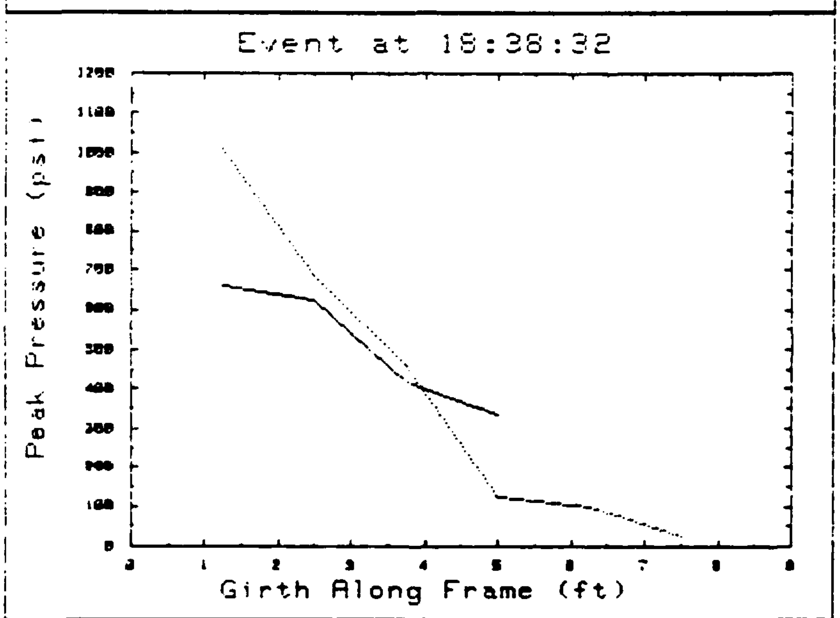


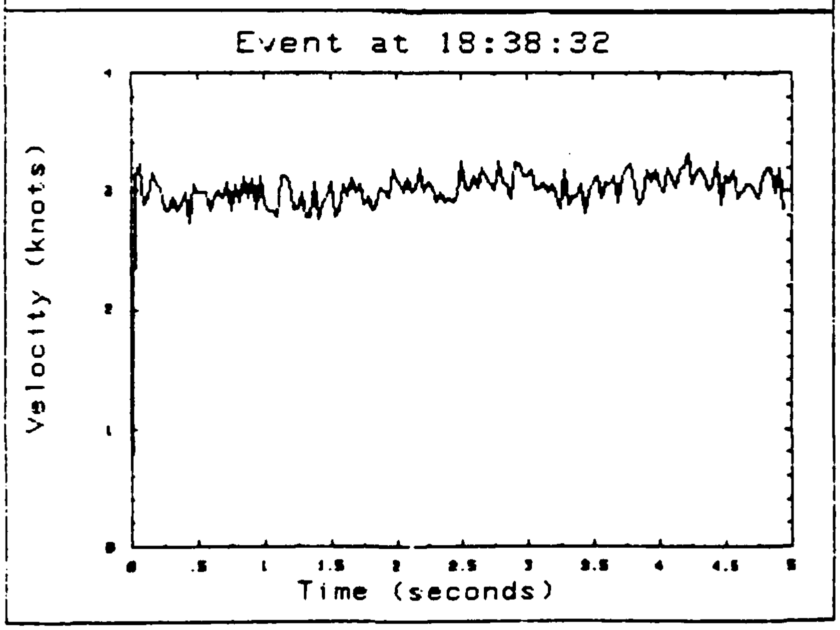
Event at 18:38:32
Total Force (long tons)
250
200
150
100
50
0
0
.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (seconds)



Event at 18:38:32
Pressure (psi)
1000
100
10
1
10
Area (square feet)


Event at 18:38:32
Peak Pressure (psi)
Length Along Waterline (ft)


Event at 18:38:32
Peak Pressure (psi)
Girth Along Frame (ft)


Event at 18:38:32
Velocity (knots)
Time (seconds)

EVENT ON 11 APR AT 8:55:50
TAPE NUMBER 6 : TRACK NUMBER 1 ; FILE NUMBER 12
PEAK STRAIN 450; THRESHOLD 150
AVERAGE SHIP SPEED 2.49 Knots

RELATIONSHIPS FOR TIME OF PEAK PRESSURE

MAX PRESSURE 1006 PSI; TIME FRAME 46; REAL TIME 1.44
FRAME 37; ROW 7

AVERAGE PRESSURE (psi) vs AREA (square feet)

Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	1006.00	573.00	562.00	431.00	348.00	291.00	250.00

Area	13.06	14.69	16.32
Pressure	219.00	198.00	180.00

PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

GIRTH	1.25	2.50	3.75
PRESSURE	1006.00	90.00	64.00

PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

LENGTH	1.33	2.67	4.00	5.33
PRESSURE	1006.00	573.00	562.00	7.00

RELATIONSHIPS FOR TIME OF PEAK FORCE

MAX TOTAL FORCE 234 LONG TONS: TIME FRAME 101: REAL TIME 3.16
FRAME 37: ROW 7

AVERAGE PRESSURE (psi) vs AREA (square feet)

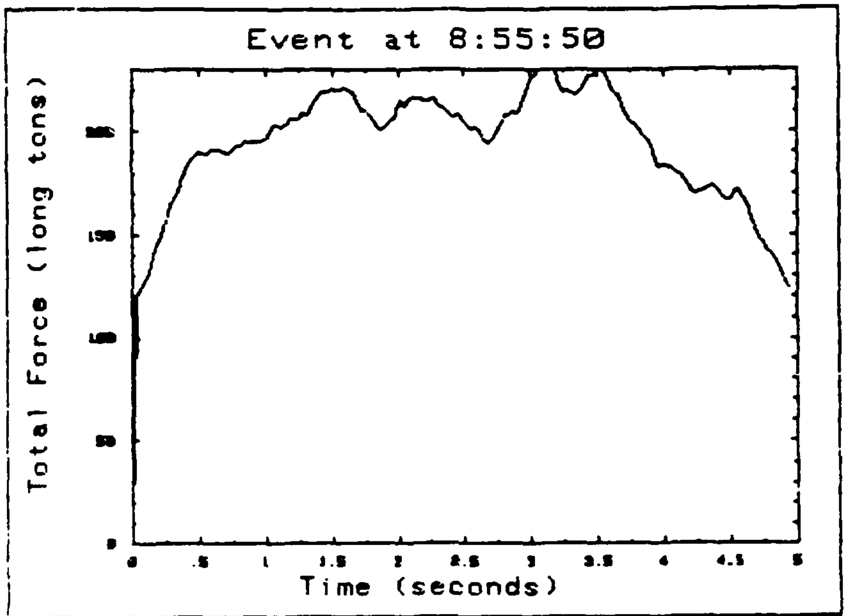
Area	1.63	3.26	4.90	6.53	8.16
Pressure	740.00	656.00	492.00	399.00	323.00

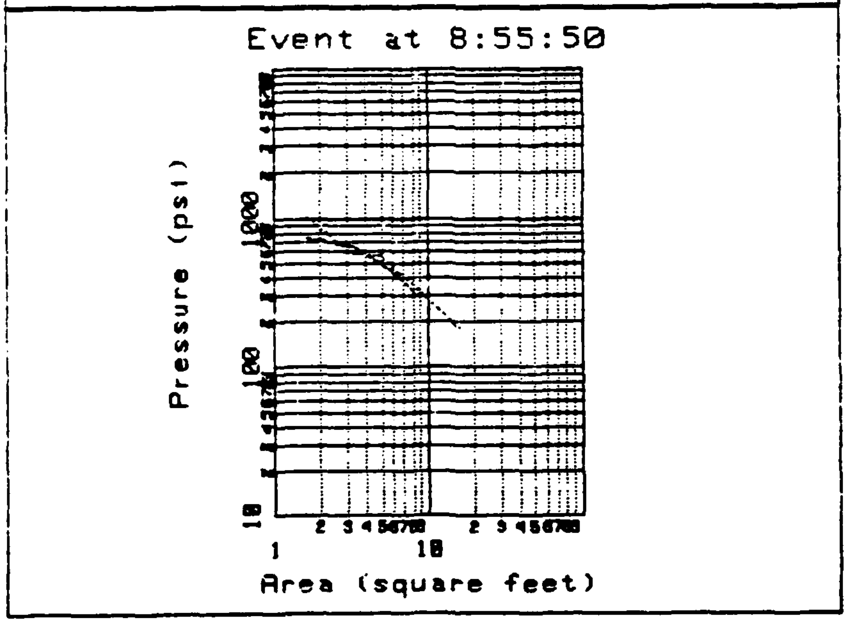
PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

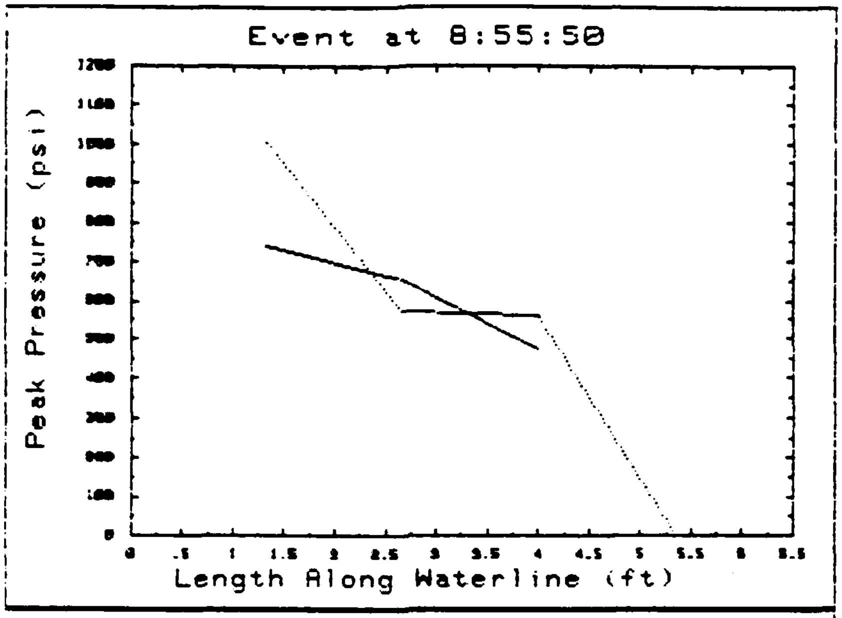
GIRTH	1.25	2.50
PRESSURE	740.00	369.00

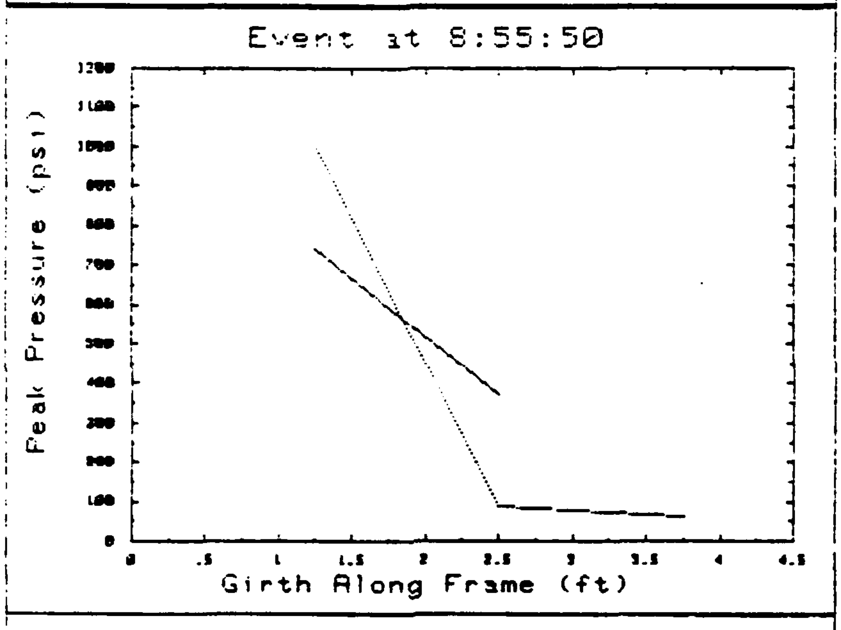
PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

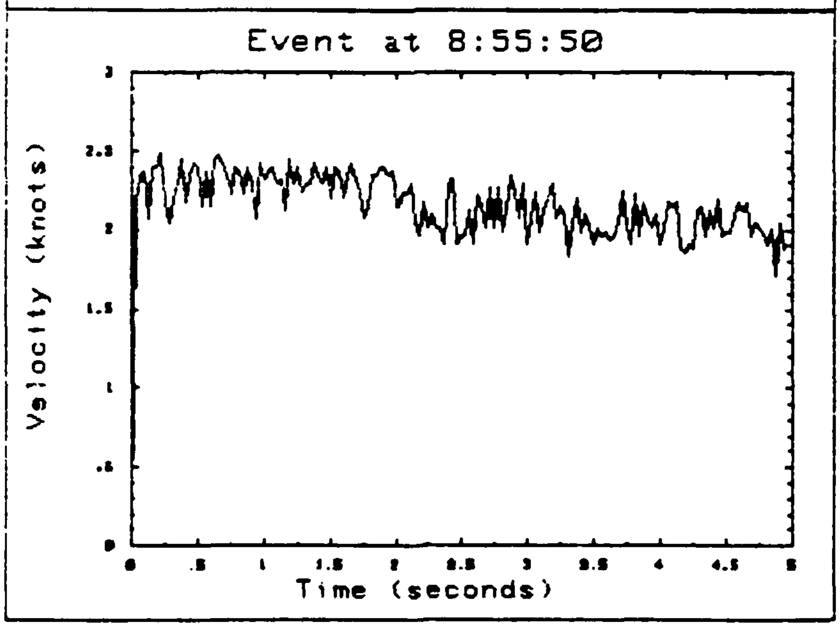
LENGTH	1.33	2.67	4.00
PRESSURE	740.00	656.00	476.00


Event at 8:55:50
Total Force (long tons)
Time (seconds)


Event at 8:55:50
Pressure (psi)
1000
100
10
1
10
Area (square feet)


Event at 8:55:50
Peak Pressure (psi)
Length Along Waterline (ft)


Event at 8:55:50
Peak Pressure (psi)
Girth Along Frame (ft)


Event at 8:55:50
Velocity (knots)
Time (seconds)

EVENT ON 8 APR AT 17:41:16
TAPE NUMBER 5 : TRACK NUMBER 1 : FILE NUMBER 48
PEAK STRAIN 430; THRESHOLD 150
AVERAGE SHIP SPEED -.24 Knots

RELATIONSHIPS FOR TIME OF PEAK PRESSURE

MAX PRESSURE 762 PSI: TIME FRAME 36: REAL TIME 1.13
FRAME 36; ROW 5

AVERAGE PRESSURE (psi) vs AREA (square feet)

Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	762.00	521.00	439.00	370.00	308.00	260.00	227.00
Area	13.06	14.69	16.32	17.95	19.58	21.22	22.85
Pressure	203.00	182.00	167.00	157.00	146.00	135.00	129.00
Area	24.48	26.11					
Pressure	124.00	118.00					

PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

GIRTH	1.25	2.50	3.75
PRESSURE	762.00	382.00	271.00

PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

LENGTH	1.33	2.67	4.00	5.33	6.67	8.00	9.33
PRESSURE	762.00	521.00	439.00	370.00	33.00	32.00	35.00
LENGTH	10.67						
PRESSURE	34.00						

RELATIONSHIPS FOR TIME OF PEAK FORCE

MAX TOTAL FORCE 238 LONG TONS: TIME FRAME 46: REAL TIME 1.44
FRAME 37: ROW 5

AVERAGE PRESSURE (psi) vs AREA (square feet)

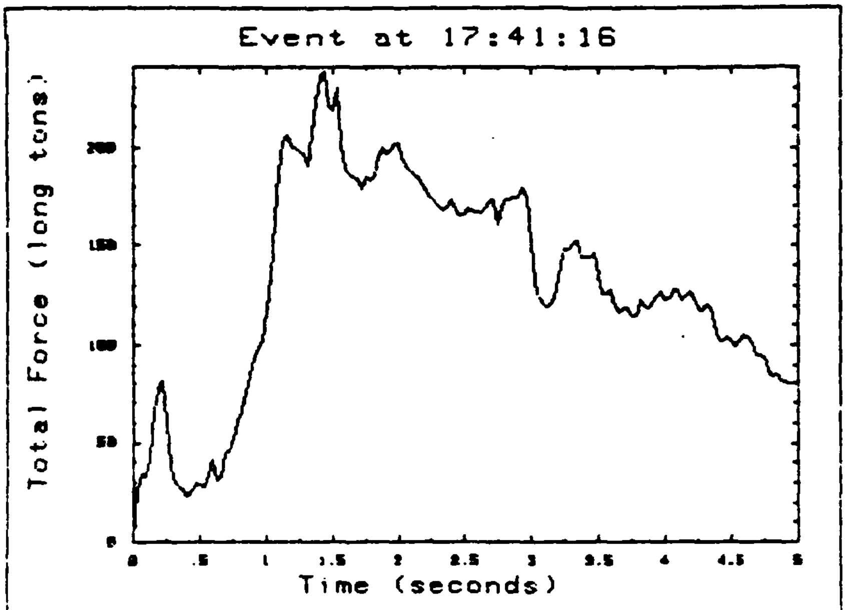
Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	565.00	514.00	412.00	363.00	328.00	298.00	262.00
Area	13.06	14.69	16.32	17.95	19.58	21.22	22.85
Pressure	235.00	227.00	205.00	188.00	174.00	161.00	150.00
Area	24.48	26.11	27.74				
Pressure	141.00	134.00	126.00				

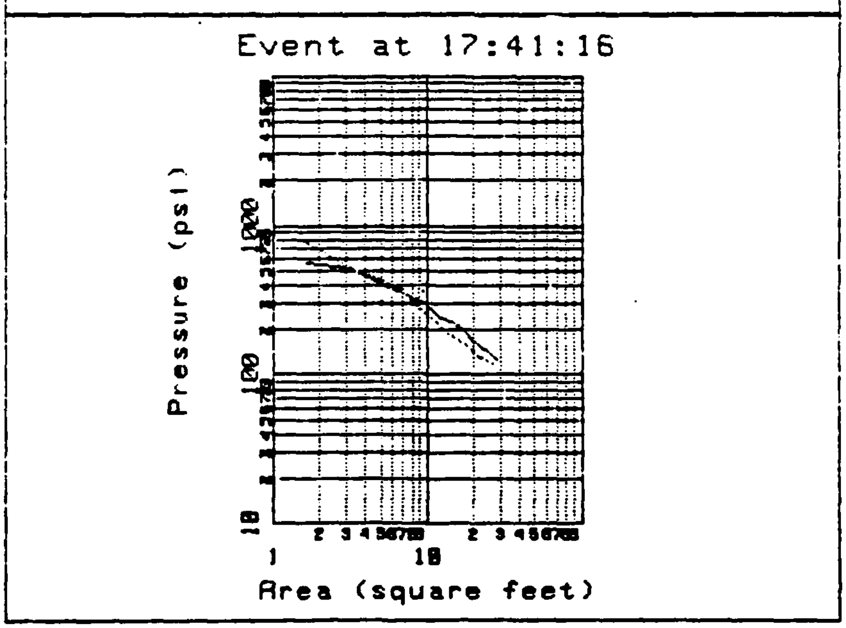
PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

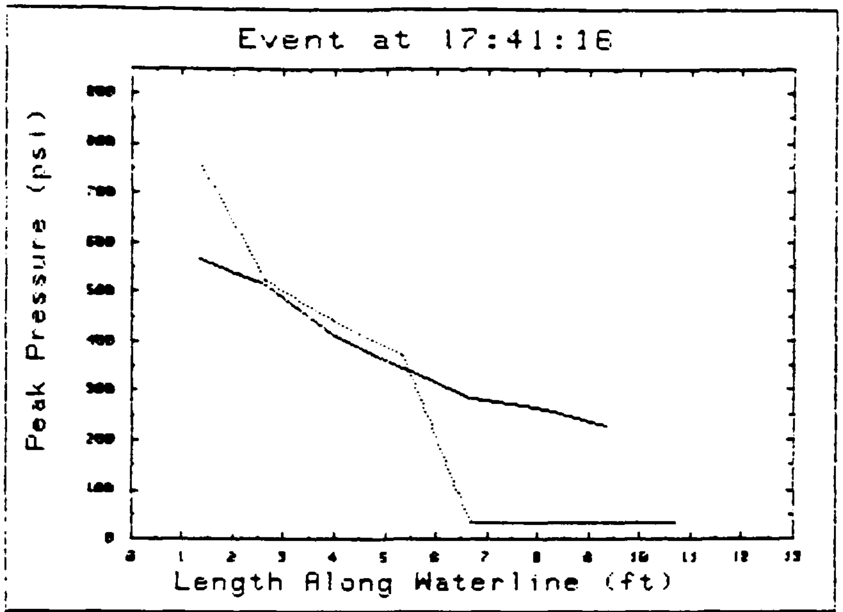
GIRTH	1.25	2.50	3.75
PRESSURE	565.00	377.00	267.00

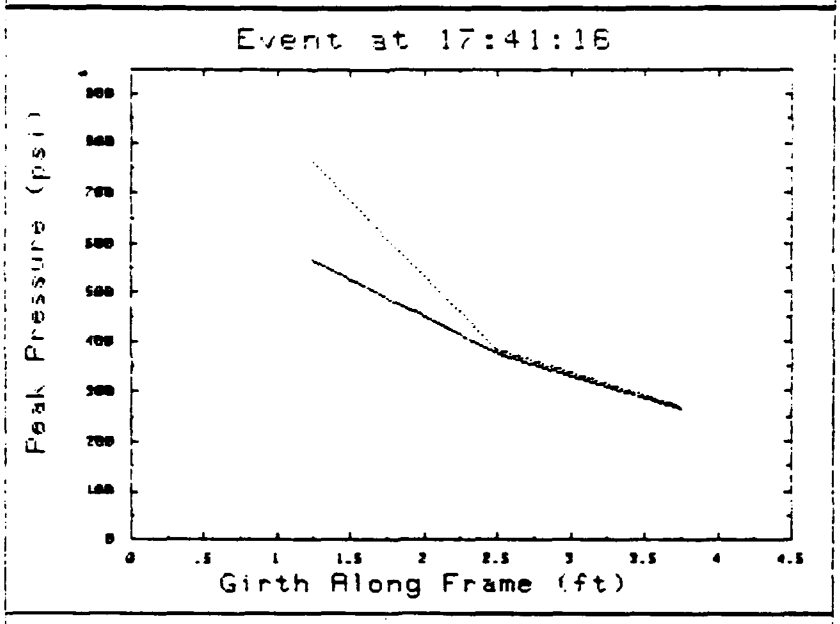
PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

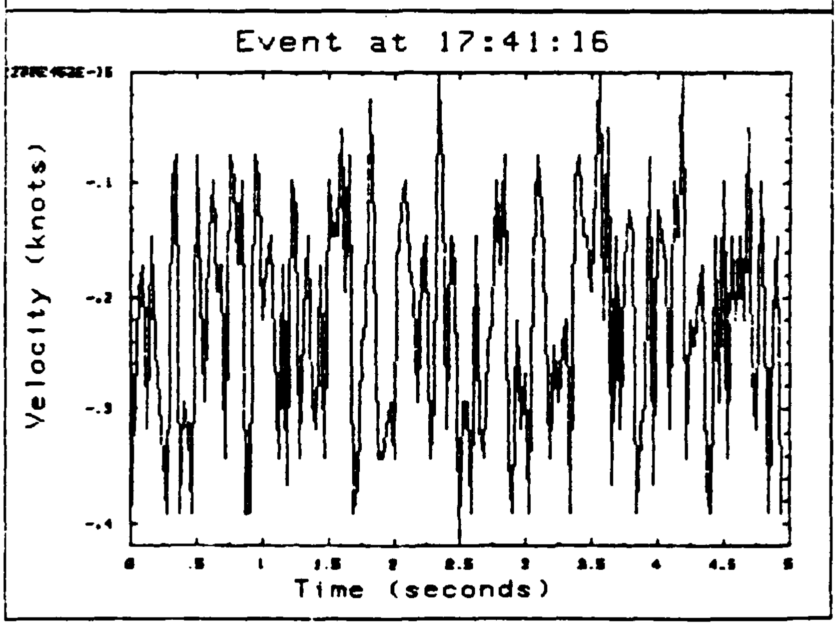
LENGTH	1.33	2.67	4.00	5.33	6.67	8.00	9.33
PRESSURE	565.00	514.00	412.00	346.00	286.00	265.00	228.00


Event at 17:41:16
Total Force (long tons)
Time (seconds)


Event at 17:41:16
Pressure (psi)
Area (square feet)


Event at 17:41:16
Peak Pressure (psi)
Length Along Waterline (ft)


Event at 17:41:16
Peak Pressure (psi)
Girth Along Frame (ft)


Event at 17:41:16
Velocity (knots)
Time (seconds)

EVENT ON 8 APR AT 17:22:32
TAPE NUMBER 5 : TRACK NUMBER 1 ; FILE NUMBER 44
PEAK STRAIN 430: THRESHOLD 150
AVERAGE SHIP SPEED -.26 Knots

RELATIONSHIPS FOR TIME OF PEAK PRESSURE

MAX PRESSURE 1235 PSI; TIME FRAME 101; REAL TIME 3.16
FRAME 39; ROW 3

AVERAGE PRESSURE (psi) vs AREA (square feet)

Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	1235.00	843.00	623.00	501.00	413.00	354.00	310.00
Area	13.06	14.69	16.32	17.95	19.58	21.22	22.85
Pressure	274.00	246.00	223.00	205.00	189.00	176.00	164.00
Area	24.48	26.11	27.74	29.38	31.01	32.64	34.27
Pressure	153.00	145.00	137.00	130.00	125.00	120.00	114.00
Area	35.90	37.53	39.17	40.80	42.43	44.06	45.69
Pressure	109.00	105.00	101.00	97.00	94.00	92.00	89.00
Area	47.33	48.96	50.59	52.22	53.85		
Pressure	86.00	83.00	81.00	78.00	76.00		

PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

GIRTH	1.25	2.50	3.75	5.00	6.25	7.50
PRESSURE	1235.00	255.00	83.00	68.00	56.00	47.00

PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

LENGTH	1.33	2.67	4.00	5.33	6.67	8.00	9.33
PRESSURE	1235.00	843.00	623.00	501.00	403.00	13.00	12.00

RELATIONSHIPS FOR TIME OF PEAK FORCE

MAX TOTAL FORCE 347 LONG TONS: TIME FRAME 123; REAL TIME 3.84
FRAME 43: ROW 3

AVERAGE PRESSURE (psi) vs AREA (square feet)

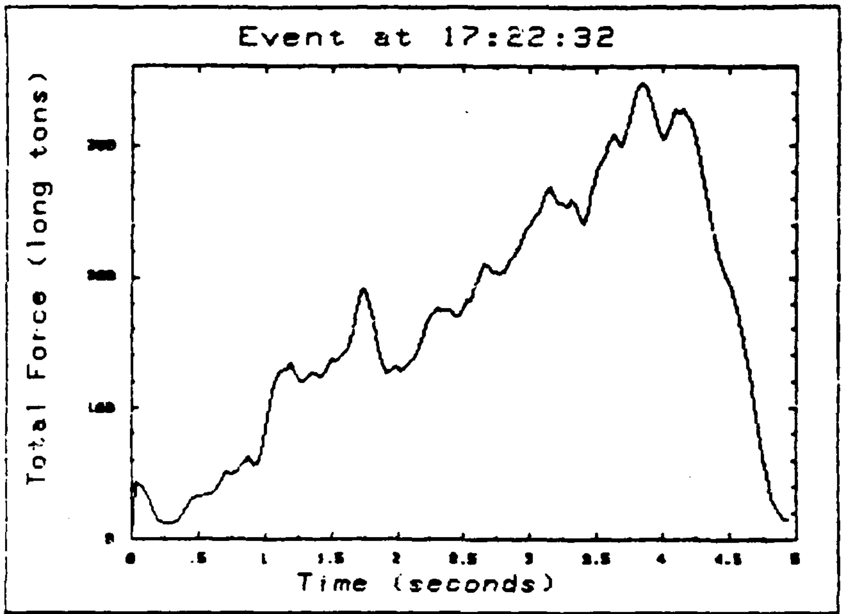
Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	1014.00	986.00	821.00	654.00	540.00	464.00	408.00
Area	13.06	14.69	16.32	17.95	19.58	21.22	22.85
Pressure	361.00	322.00	292.00	268.00	250.00	236.00	220.00
Area	24.48	26.11	27.74	29.38	31.01	32.64	34.27
Pressure	206.00	194.00	183.00	173.00	165.00	157.00	150.00
Area	35.90	37.53	39.17	40.80	42.43	44.06	45.69
Pressure	144.00	138.00	133.00	129.00	124.00	120.00	116.00
Area	47.33	48.96	50.59	52.22	53.85	55.49	57.12
Pressure	112.00	109.00	105.00	102.00	99.00	96.00	94.00

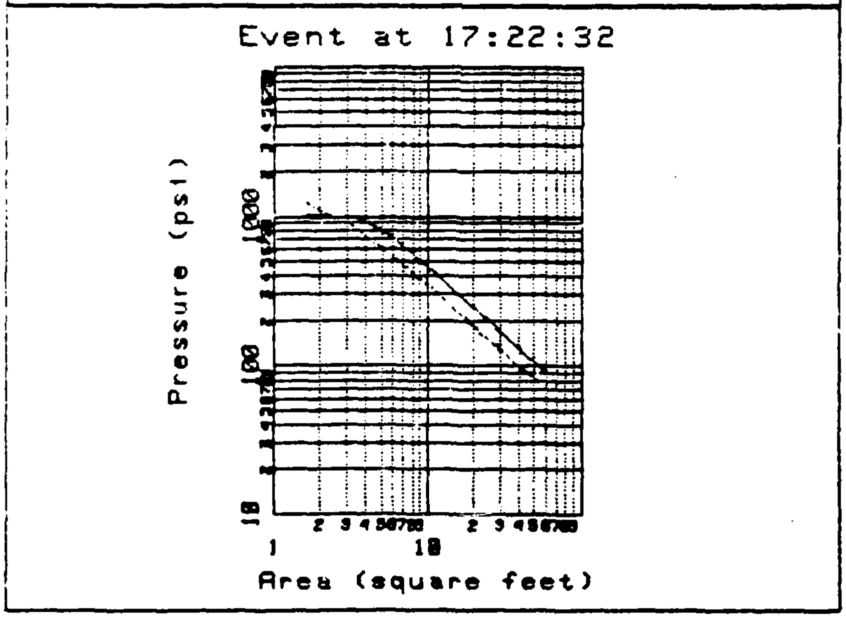
PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

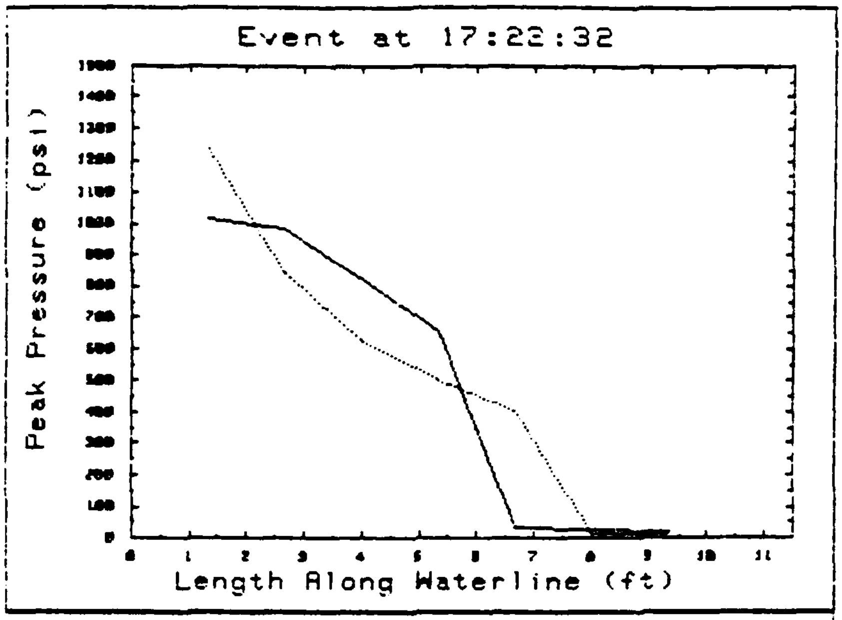
GIRTH	1.25	2.50	3.75	5.00
PRESSURE	1014.00	550.00	29.00	6.00

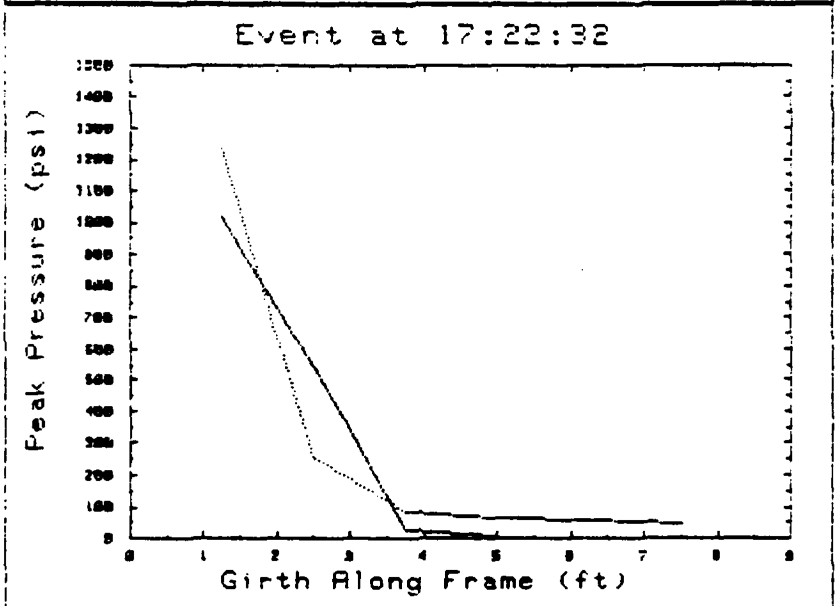
PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

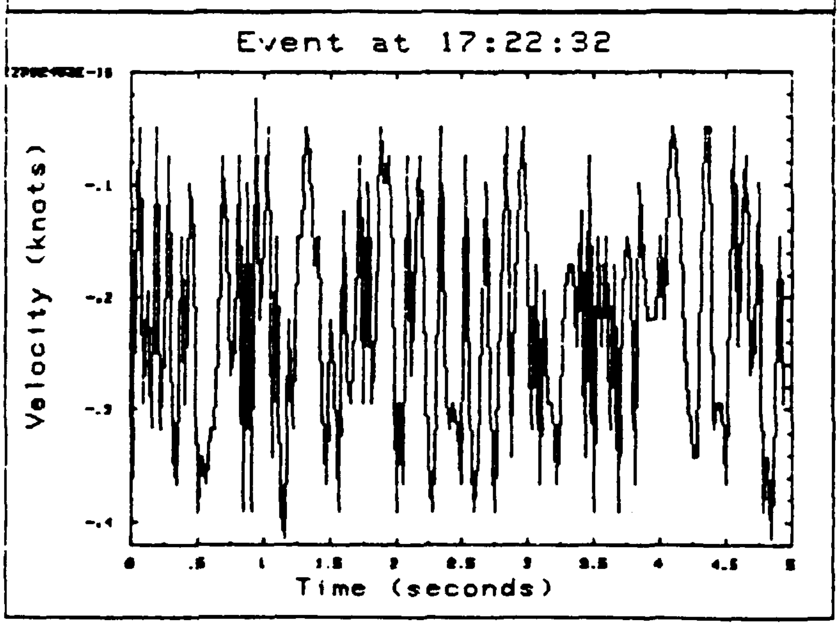
LENGTH	1.33	2.67	4.00	5.33	6.67	8.00	9.33
PRESSURE	1014.00	986.00	821.00	654.00	35.00	24.00	23.00


Event at 17:22:32
Total Force (long tons)
Time (seconds)


Event at 17:22:32
Pressure (psi)
1000
100
10
1
10
Area (square feet)


Event at 17:22:32
Peak Pressure (psi)
Length Along Waterline (ft)


Event at 17:22:32
Peak Pressure (psi)
Girth Along Frame (ft)


Event at 17:22:32
Velocity (knots)
Time (seconds)

EVENT ON 8 APR AT 16:12:57
TAPE NUMBER 5 : TRACK NUMBER 1 ; FILE NUMBER 38
PEAK STRAIN 421: THRESHOLD 150
AVERAGE SHIP SPEED -.32 Knots

RELATIONSHIPS FOR TIME OF PEAK PRESSURE

MAX PRESSURE 937 PSI; TIME FRAME 35; REAL TIME 1.09
FRAME 37; ROW 5

AVERAGE PRESSURE (psi) vs AREA (square feet)

Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	937.00	579.00	412.00	329.00	277.00	251.00	224.00
Area	13.06	14.69	16.32	17.95	19.58	21.22	22.85
Pressure	202.00	182.00	165.00	151.00	138.00	133.00	127.00
Area	24.48	26.11					
Pressure	121.00	114.00					

PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

GIRTH	1.25	2.50	3.75	5.00	6.25
PRESSURE	937.00	508.00	358.00	58.00	52.00

PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

LENGTH	1.33	2.67	4.00	5.33	6.67
PRESSURE	937.00	579.00	408.00	59.00	47.00

RELATIONSHIPS FOR TIME OF PEAK FORCE

MAX TOTAL FORCE 214 LONG TONS; TIME FRAME 35; REAL TIME 1.09
FRAME 37; ROW 5

AVERAGE PRESSURE (psi) vs AREA (square feet)

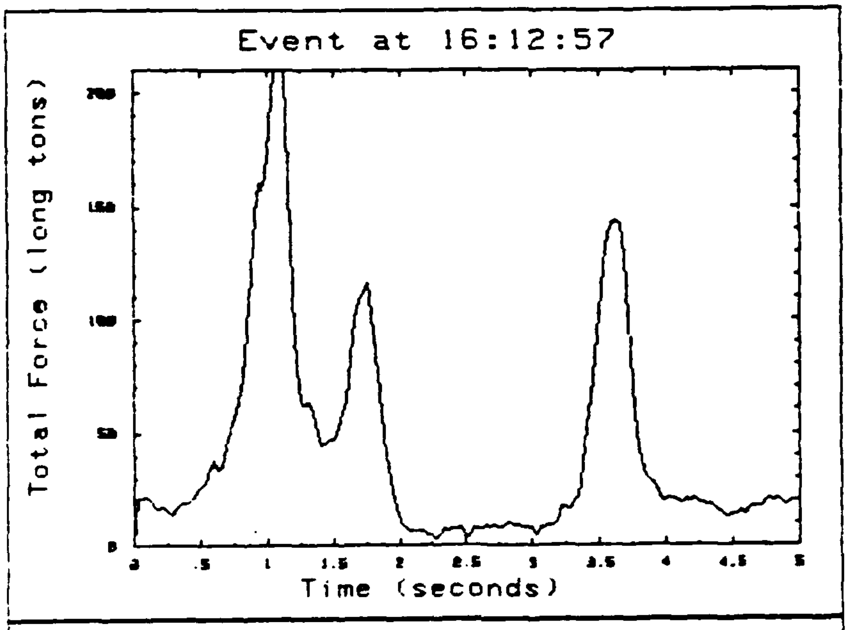
Area	1.63	3.26	4.90	6.53	8.16	9.79	11.42
Pressure	937.00	579.00	412.00	329.00	277.00	251.00	224.00
Area	13.06	14.69	16.32	17.95	19.58	21.22	22.85
Pressure	202.00	182.00	165.00	151.00	138.00	133.00	127.00
Area	24.48	26.11					
Pressure	121.00	114.00					

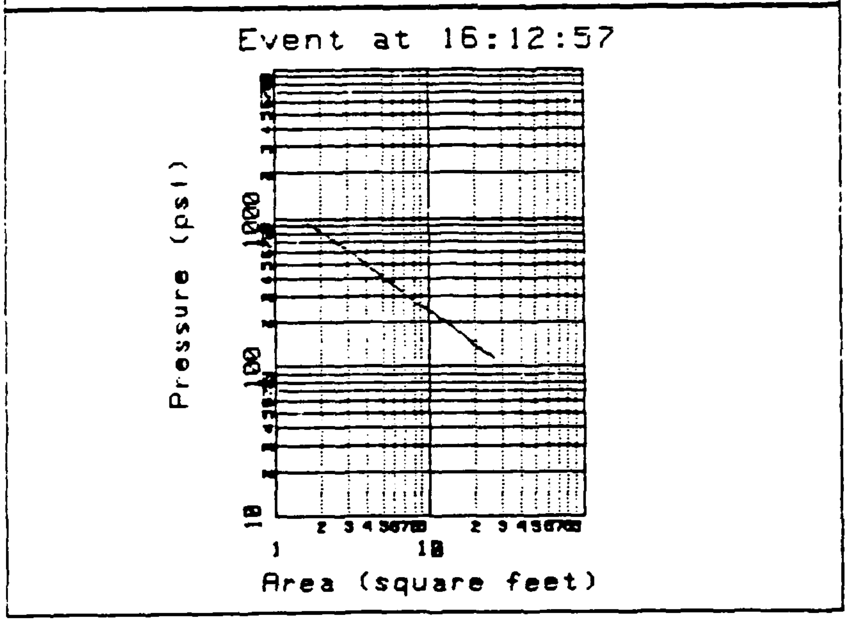
PRESSURE (PSI) VERSUS GIRTH ALONG FRAME (FT)

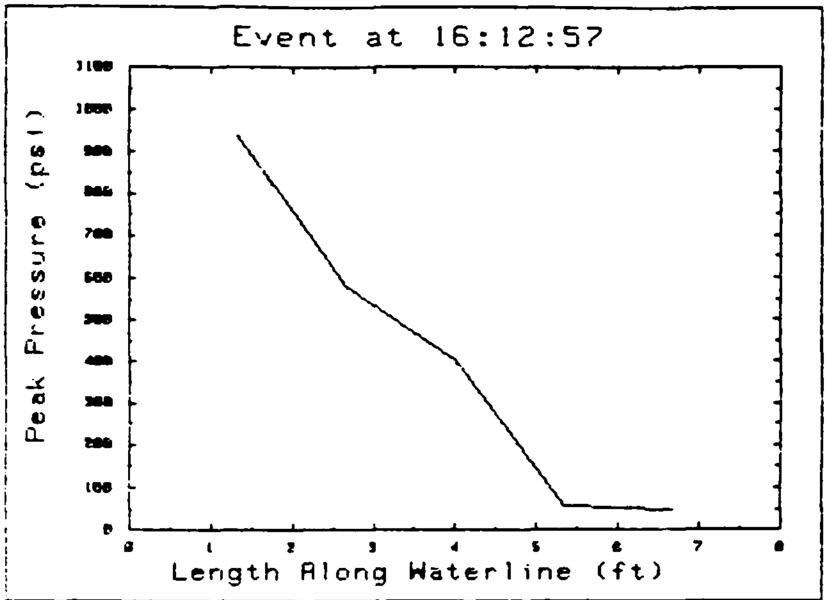
GIRTH	1.25	2.50	3.75	5.00	6.25
PRESSURE	937.00	508.00	358.00	58.00	52.00

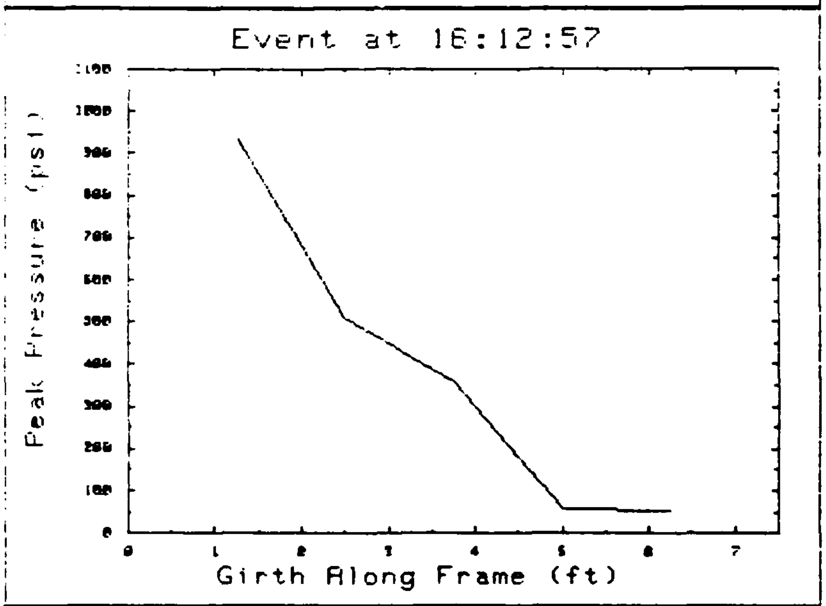
PRESSURE (PSI) VERSUS LENGTH ALONG WATERLINE (FT)

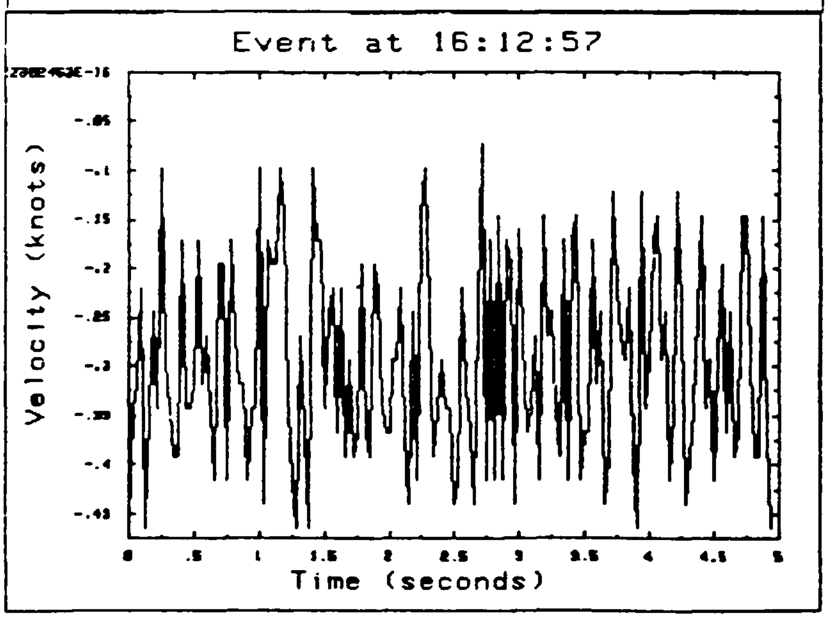
LENGTH	1.33	2.67	4.00	5.33	6.67
PRESSURE	937.00	579.00	408.00	59.00	47.00


Event at 16:12:57
Total Force (long tons)
Time (seconds)


Event at 16:12:57
Pressure (psi)
Area (square feet)


Event at 16:12:57
Peak Pressure (psi)
Length Along Waterline (ft)


Event at 16:12:57
Peak Pressure (psi)
Girth Along Frame (ft)


Event at 16:12:57
Velocity (knots)
Time (seconds)

APPENDIX E

FREQUENCY OF HIGHEST AVERAGE PRESSURE VERSUS IMPACT AREA AT DIFFERENT THRESHOLDS IN EACH GEOGRAPHICAL AREA

SOUTH BERING SEA

FRECUENCY OF IMPACTS VERSUS HIGHEST AVERAGE PRESSURE
FOR SOUTH BERING SEA

THRESHOLD LEVEL IS 50

NO OF SUB-PANELS	1	6	15	31	46	60
PRES (PSI)						
0 - 50	0	20	37	35	23	0
50 - 100	0	29	5	0	0	0
100 - 150	18	2	0	0	0	0
150 - 200	25	0	0	0	0	0
200 - 250	3	0	0	0	0	0
250 - 300	2	0	0	0	0	0
300 - 350	3	0	0	0	0	0
350 - 400	1	0	0	0	0	0
TOTALS	52	51	42	35	23	0

FREQUENCY OF IMPACTS VERSUS HIGHEST AVERAGE PRESSURE
FOR SOUTH BERING SEA

THRESHOLD LEVEL IS 75

NO OF SUB-PANELS	1	6	15	31	46	60
PRES (PSI)						
0 - 50	0	6	36	70	63	1
50 - 100	0	48	41	5	2	0
100 - 150	0	26	4	0	0	0
150 - 200	26	4	0	0	0	0
200 - 250	31	0	0	0	0	0
250 - 300	19	0	0	0	0	0
300 - 350	4	1	0	0	0	0
350 - 400	4	0	0	0	0	0
400 - 450	1	0	0	0	0	0
450 - 500	1	0	0	0	0	0
500 - 550	0	0	0	0	0	0
550 - 600	0	0	0	0	0	0
600 - 650	0	0	0	0	0	0
650 - 700	0	0	0	0	0	0
700 - 750	0	0	0	0	0	0
750 - 800	0	0	0	0	0	0
800 - 850	0	0	0	0	0	0
850 - 900	0	0	0	0	0	0
900 - 950	0	0	0	0	0	0
950 -1000	0	0	0	0	0	0
1000 -1050	0	0	0	0	0	0
1050 -1100	0	0	0	0	0	0
1100 -1150	1	0	0	0	0	0
TOTALS	87	85	81	75	65	1

FREQUENCY OF IMPACTS VERSUS HIGHEST AVERAGE PRESSURE
FOR SOUTH BERING SEA

THRESHOLD LEVEL IS 100

NO OF SUB-PANELS	1	6	15	31	46	60
PRES (PSI)						
0 - 50	0	0	3	1	0	0
50 - 100	0	3	3	0	0	0
100 - 150	0	2	0	0	0	0
150 - 200	0	1	0	0	0	0
200 - 250	1	0	0	0	0	0
250 - 300	1	0	0	0	0	0
300 - 350	1	0	0	0	0	0
350 - 400	2	0	0	0	0	0
400 - 450	1	0	0	0	0	0
TOTALS	6	6	6	1	0	0

NORTH BERING SEA

FREQUENCY OF IMPACTS VERSUS HIGHEST AVERAGE PRESSURE
FOR NORTH BERING SEA

THRESHOLD LEVEL IS 55

NO OF SUB-PANELS	1	6	15	31	46	60
PRES (PSI)						
0 - 50	0	3	6	8	11	0
50 - 100	0	3	5	5	1	0
100 - 150	1	4	2	0	0	0
150 - 200	6	2	0	0	0	0
200 - 250	1	1	0	0	0	0
250 - 300	1	0	0	0	0	0
300 - 350	1	0	0	0	0	0
350 - 400	1	0	0	0	0	0
400 - 450	1	0	0	0	0	0
450 - 500	0	0	0	0	0	0
500 - 550	1	0	0	0	0	0
TOTALS	13	13	13	13	12	0

FREQUENCY OF IMPACTS VERSUS HIGHEST AVERAGE PRESSURE
FOR NORTH BERING SEA

THRESHOLD LEVEL IS 75

NO OF SUB-PANELS	1	6	15	31	46	60
PRES (PSI)						
0 - 50	0	5	7	10	7	0
50 - 100	0	14	8	1	0	0
100 - 150	0	6	1	0	0	0
150 - 200	8	5	0	0	0	0
200 - 250	7	1	0	0	0	0
250 - 300	10	0	0	0	0	0
300 - 350	5	0	0	0	0	0
350 - 400	2	0	0	0	0	0
400 - 450	1	0	0	0	0	0
450 - 500	2	0	0	0	0	0
TOTALS	35	31	16	11	7	0

FREQUENCY OF IMPACTS VERSUS HIGHEST AVERAGE PRESSURE
FOR NORTH BERING SEA

THRESHOLD LEVEL IS 100

NO OF SUB-PANELS	1	6	15	31	46	60
PRES (PSI)						
0 - 50	0	0	2	15	17	0
50 - 100	0	6	16	7	2	0
100 - 150	0	12	4	0	0	0
150 - 200	1	4	0	0	0	0
200 - 250	6	1	0	0	0	0
250 - 300	8	0	0	0	0	0
300 - 350	0	0	0	0	0	0
350 - 400	6	0	0	0	0	0
400 - 450	0	0	0	0	0	0
450 - 500	1	0	0	0	0	0
500 - 550	0	0	0	0	0	0
550 - 600	1	0	0	0	0	0
TOTALS	23	23	22	22	19	0

FREQUENCY OF IMPACTS VERSUS HIGHEST AVERAGE PRESSURE
FOR NORTH BERING SEA

THRESHOLD LEVEL IS 120

NO OF SUB-PANELS	1	6	15	31	46	60
PRES (PSI)						
0 - 50	0	2	21	42	27	0
50 - 100	0	36	74	17	4	0
100 - 150	0	69	7	3	0	0
150 - 200	0	27	3	0	0	0
200 - 250	6	5	1	0	0	0
250 - 300	42	3	0	0	0	0
300 - 350	31	0	0	0	0	0
350 - 400	33	3	0	0	0	0
400 - 450	22	0	0	0	0	0
450 - 500	8	0	0	0	0	0
500 - 550	6	0	0	0	0	0
550 - 600	7	0	0	0	0	0
600 - 650	0	0	0	0	0	0
650 - 700	0	0	0	0	0	0
700 - 750	2	0	0	0	0	0
TOTALS	157	145	106	62	31	0

APPENDIX E (CONTINUED)

SOUTH CHUKCHI SEA

FREQUENCY OF IMPACTS VERSUS HIGHEST AVERAGE PRESSURE
FOR SOUTH CHUKCHI SEA

THRESHOLD LEVEL IS 120

NO OF SUB-PANELS	1	6	15	31	46	60
PRES (PSI)						
0 - 50	0	1	19	28	11	0
50 - 100	0	36	41	6	1	0
100 - 150	0	62	8	0	0	0
150 - 200	0	18	0	0	0	0
200 - 250	19	4	0	0	0	0
250 - 300	45	2	0	0	0	0
300 - 350	39	0	0	0	0	0
350 - 400	21	0	0	0	0	0
400 - 450	12	0	0	0	0	0
450 - 500	4	0	0	0	0	0
500 - 550	2	0	0	0	0	0
550 - 600	3	0	0	0	0	0
600 - 650	2	0	0	0	0	0
650 - 700	1	0	0	0	0	0
TOTALS	148	123	68	34	12	0

FREQUENCY OF IMPACTS VERSUS HIGHEST AVERAGE PRESSURE
FOR SOUTH CHUKCHI SEA

THRESHOLD LEVEL IS 150

NO OF SUB-PANELS	1	6	15	31	46	60
PRES (PSI)						
0 - 50	0	0	5	14	2	0
50 - 100	0	9	39	7	1	0
100 - 150	0	39	10	0	0	0
150 - 200	0	18	2	0	0	0
200 - 250	1	5	0	0	0	0
250 - 300	7	4	0	0	0	0
300 - 350	23	2	0	0	0	0
350 - 400	18	0	0	0	0	0
400 - 450	14	0	0	0	0	0
450 - 500	7	0	0	0	0	0
500 - 550	2	0	0	0	0	0
550 - 600	5	0	0	0	0	0
600 - 650	1	0	0	0	0	0
650 - 700	1	0	0	0	0	0
700 - 750	0	0	0	0	0	0
750 - 800	2	0	0	0	0	0
800 - 850	0	0	0	0	0	0
850 - 900	1	0	0	0	0	0
900 - 950	0	0	0	0	0	0
950 -1000	0	0	0	0	0	0
1000 -1050	1	0	0	0	0	0
TOTALS	83	77	56	21	3	0

APPENDIX E (CONTINUED)

NORTH CHUKCHI SEA

FREQUENCY OF IMPACTS VERSUS HIGHEST AVERAGE PRESSURE
FOR NORTH CHUKCHI SEA

THRESHOLD LEVEL IS 75

NO OF SUB-PANELS	1	6	15	31	46	60
PRES (PSI)						
0 - 50	0	0	0	1	0	0
50 - 100	0	1	1	0	0	0
100 - 150	0	1	0	0	0	0
150 - 200	1	0	0	0	0	0
200 - 250	0	0	0	0	0	0
250 - 300	0	0	0	0	0	0
300 - 350	0	0	0	0	0	0
350 - 400	1	0	0	0	0	0
TOTALS	2	2	1	1	0	0

FREQUENCY OF IMPACTS VERSUS HIGHEST AVERAGE PRESSURE
FOR NORTH CHUKCHI SEA

THRESHOLD LEVEL IS 100

NO OF SUB-PANELS	1	6	15	31	46	60
PRES (PSI)						
0 - 50	0	0	1	0	0	0
50 - 100	0	1	5	0	0	0
100 - 150	0	5	0	0	0	0
150 - 200	0	4	0	0	0	0
200 - 250	1	0	0	0	0	0
250 - 300	5	0	0	0	0	0
300 - 350	5	0	0	0	0	0
350 - 400	1	0	0	0	0	0
400 - 450	1	0	0	0	0	0
450 - 500	1	0	0	0	0	0
TOTALS	14	10	6	0	0	0

FREQUENCY OF IMPACTS VERSUS HIGHEST AVERAGE PRESSURE
FOR NORTH CHUKCHI SEA

THRESHOLD LEVEL IS 150

NO OF SUB-PANELS	1	6	15	31	46	60
PRES (PSI)						
0 - 50	0	0	14	45	20	0
50 - 100	0	24	152	81	50	0
100 - 150	0	149	95	4	0	0
150 - 200	0	129	15	0	0	0
200 - 250	0	60	1	0	0	0
250 - 300	33	29	2	0	0	0
300 - 350	85	5	0	0	0	0
350 - 400	76	8	0	0	0	0
400 - 450	62	0	0	0	0	0
450 - 500	59	2	0	0	0	0
500 - 550	34	0	0	0	0	0
550 - 600	34	1	0	0	0	0
600 - 650	15	0	0	0	0	0
650 - 700	14	0	0	0	0	0
700 - 750	11	0	0	0	0	0
750 - 800	8	0	0	0	0	0
800 - 850	3	0	0	0	0	0
850 - 900	2	0	0	0	0	0
900 - 950	4	0	0	0	0	0
950 -1000	0	0	0	0	0	0
1000 -1050	4	0	0	0	0	0
1050 -1100	0	0	0	0	0	0
1100 -1150	1	0	0	0	0	0
1150 -1200	0	0	0	0	0	0
1200 -1250	2	0	0	0	0	0
1250 -1300	0	0	0	0	0	0
1300 -1350	2	0	0	0	0	0
1350 -1400	0	0	0	0	0	0
1400 -1450	0	0	0	0	0	0
1450 -1500	0	0	0	0	0	0
1500 -1550	0	0	0	0	0	0
1550 -1600	0	0	0	0	0	0
1600 -1650	1	0	0	0	0	0
TOTALS	450	407	279	130	70	0

APPENDIX F

FREQUENCY OF IMPACTS VERSUS LOCATION FOR EACH GEOGRAPHIC LOCATION

FREQUENCY OF IMPACTS VERSUS LOCATION AT TIME OF PEAK PRESSURE FOR SOUTH BERING SEA

Frame Numbers

	44	43	42	41	40	39	38	37	36	35
Row 1	2	2	1	0	2	3	0	0	3	3
Row 2	0	1	4	0	0	0	3	0	0	0
Row 3	5	11	6	1	1	2	5	2	3	1
Row 4	1	7	0	6	1	7	1	1	2	1
Row 5	1	31	5	6	2	1	8	4	10	1
Row 6	3	1	4	1	0	2	0	2	2	1
Row 7	0	0	0	0	0	0	0	0	0	0
Row 8	0	0	0	0	0	0	0	0	0	0

FREQUENCY OF IMPACTS VERSUS LOCATION AT TIME OF PEAK FORCE FOR SOUTH BERING SEA

Frame Numbers

	44	43	42	41	40	39	38	37	36	35
Row 1	2	3	2	3	2	3	0	0	1	0
Row 2	2	1	4	0	0	1	3	0	0	0
Row 3	3	8	5	2	1	2	6	3	1	2
Row 4	2	6	0	10	2	10	2	1	3	1
Row 5	2	29	4	6	5	1	8	4	4	0
Row 6	1	0	1	0	0	0	6	1	3	1
Row 7	0	0	0	0	0	0	0	0	0	0
Row 8	0	0	0	0	0	0	0	0	0	0

FREQUENCY OF IMPACTS VERSUS LOCATION AT TIME OF PEAK PRESSURE
FOR NORTH BERING SEA

	Frame Numbers									
	44	43	42	41	40	39	38	37	36	35
Row 1	0	1	1	2	0	0	0	0	0	0
Row 2	2	0	0	2	1	2	0	0	0	2
Row 3	8	7	2	4	3	2	3	5	2	4
Row 4	3	12	0	8	2	3	2	2	5	4
Row 5	15	21	15	5	8	0	12	10	10	4
Row 6	2	5	16	3	4	6	0	4	5	0
Row 7	0	0	0	0	0	0	0	0	0	0
Row 8	0	0	0	0	0	0	0	0	0	0

FREQUENCY OF IMPACTS VERSUS LOCATION AT TIME OF PEAK FORCE
FOR NORTH BERING SEA

	Frame Numbers									
	44	43	42	41	40	39	38	37	36	35
Row 1	1	1	2	1	0	0	0	0	0	1
Row 2	4	2	0	2	1	6	1	1	0	1
Row 3	9	7	3	5	2	3	6	6	3	3
Row 4	5	9	1	12	2	3	3	3	11	4
Row 5	7	17	10	6	8	0	13	8	9	3
Row 6	0	2	8	4	1	5	3	4	8	1
Row 7	0	0	0	0	0	0	0	0	0	0
Row 8	0	0	0	0	0	0	0	0	0	0

FREQUENCY OF IMPACTS VERSUS LOCATION AT TIME OF PEAK PRESSURE FOR SOUTH CHUKCHI SEA

Frame Numbers

	44	43	42	41	40	39	38	37	36	35
Row 1	0	0	1	0	0	2	0	0	0	0
Row 2	0	1	0	0	0	0	0	0	0	0
Row 3	2	1	4	1	0	5	0	0	0	0
Row 4	6	9	0	6	4	1	1	1	1	3
Row 5	9	34	16	6	8	0	15	19	11	1
Row 6	12	4	25	7	3	10	3	1	12	5
Row 7	1	3	1	1	0	2	1	1	14	1
Row 8	2	5	6	0	1	6	1	2	1	0

FREQUENCY OF IMPACTS VERSUS LOCATION AT TIME OF PEAK FORCE FOR SOUTH CHUKCHI SEA

Frame Numbers

	44	43	42	41	40	39	38	37	36	35
Row 1	0	0	1	0	0	2	0	0	0	0
Row 2	1	1	0	0	0	0	0	0	0	0
Row 3	4	0	5	1	0	4	2	1	0	0
Row 4	3	11	1	6	3	1	2	2	1	3
Row 5	5	35	18	15	6	1	17	19	7	3
Row 6	9	6	19	10	2	5	2	2	12	4
Row 7	2	2	3	2	0	3	1	1	9	1
Row 8	1	4	3	1	0	5	2	4	3	0

FREQUENCY OF IMPACTS VERSUS LOCATION AT TIME OF PEAK PRESSURE FOR SOUTH CHUKCHI SEA

Frame Numbers

	44	43	42	41	40	39	38	37	36	35
Row 1	0	0	0	0	0	0	0	0	0	0
Row 2	0	0	0	0	0	0	0	0	0	0
Row 3	1	0	1	0	0	1	0	0	0	0
Row 4	2	1	0	3	1	0	0	0	0	2
Row 5	2	4	5	1	4	0	7	7	4	1
Row 6	6	0	3	0	0	1	1	0	2	1
Row 7	1	3	1	1	0	2	1	1	14	1
Row 8	2	5	6	0	1	6	1	2	1	0

FREQUENCY OF IMPACTS VERSUS LOCATION AT TIME OF PEAK FORCE FOR SOUTH CHUKCHI SEA

Frame Numbers

	44	43	42	41	40	39	38	37	36	35
Row 1	0	0	0	0	0	0	0	0	0	0
Row 2	0	0	0	0	0	0	0	0	0	0
Row 3	1	0	1	0	0	1	1	0	0	0
Row 4	1	2	0	2	1	1	0	0	0	2
Row 5	1	5	3	5	2	0	8	9	2	1
Row 6	5	1	1	1	0	1	1	0	3	1
Row 7	2	2	3	2	0	3	1	1	9	1
Row 8	1	4	3	1	0	5	2	4	3	0

FREQUENCY OF IMPACTS VERSUS LOCATION AT TIME OF PEAK PRESSURE FOR SOUTH CHUKCHI SEA

Frame Numbers

	44	43	42	41	40	39	38	37	36	35
Row 1	0	0	1	0	0	2	0	0	0	0
Row 2	0	1	0	0	0	0	0	0	0	0
Row 3	1	1	3	1	0	4	0	0	0	0
Row 4	4	8	0	3	3	1	1	1	1	1
Row 5	7	30	11	5	4	0	8	12	7	0
Row 6	6	4	22	7	3	9	2	1	10	4
Row 7	0	0	0	0	0	0	0	0	0	0
Row 8	0	0	0	0	0	0	0	0	0	0

FREQUENCY OF IMPACTS VERSUS LOCATION AT TIME OF PEAK FORCE FOR SOUTH CHUKCHI SEA

Frame Numbers

	44	43	42	41	40	39	38	37	36	35
Row 1	0	0	1	0	0	2	0	0	0	0
Row 2	1	1	0	0	0	0	0	0	0	0
Row 3	3	0	4	1	0	3	1	1	0	0
Row 4	2	9	1	4	2	0	2	2	1	1
Row 5	4	30	15	10	4	1	9	10	5	2
Row 6	4	5	18	9	2	4	1	2	9	3
Row 7	0	0	0	0	0	0	0	0	0	0
Row 8	0	0	0	0	0	0	0	0	0	0

FREQUENCY OF IMPACTS VERSUS LOCATION AT TIME OF PEAK PRESSURE FOR NORTH CHUKCHI SEA

Frame Numbers

	44	43	42	41	40	39	38	37	36	35
Row 1	0	0	0	0	0	0	0	0	0	0
Row 2	0	0	0	0	0	0	0	0	0	0
Row 3	5	7	5	0	2	5	2	7	2	4
Row 4	14	15	0	5	0	8	2	9	2	1
Row 5	10	36	8	5	14	0	17	23	18	8
Row 6	7	4	11	0	1	2	1	4	4	0
Row 7	5	4	3	2	1	11	4	31	45	17
Row 8	13	14	24	6	0	36	18	6	5	0

FREQUENCY OF IMPACTS VERSUS LOCATION AT TIME OF PEAK FORCE FOR NORTH CHUKCHI SEA

Frame Numbers

	44	43	42	41	40	39	38	37	36	35
Row 1	0	0	0	0	0	0	0	0	0	0
Row 2	0	0	0	0	0	0	0	0	0	0
Row 3	4	10	3	1	1	8	4	7	1	2
Row 4	9	18	0	11	2	5	2	9	8	2
Row 5	11	37	14	7	17	1	13	26	11	3
Row 6	3	2	8	1	1	6	2	8	7	0
Row 7	2	5	4	8	2	13	4	39	34	12
Row 8	7	7	12	12	4	24	20	4	15	0

APPENDIX G
SUMMARY DATA FOR DEDICATED RIDGE RAMS

RIDGE	DATE	TIME	PRESSURE (PSI)	FORCE (LT)	MAXIMUM AREA (FT^2)	RAM	VEL (KTS)	P_{AVG} (PSI)
1	4/7	14:40:22	274	111	32.6	1	--	50
		14:44:25	281	159	32.6	2	--	69
		14:44:37	359	105	32.6	2	--	43
5	4/11	8:36:01	358	69	18.0	1	3.9	54
3	4/11	8:50:10	364	143	60.4	1	7.3	37
		8:50:15	591	221	63.7	1	6.8	54
		8:50:37	561	224	34.3	1	4.4	99
		8:50:43	600	116	9.8	1	3.4	154
		8:55:08	462	176	32.6	2	7.9	78
		8:55:18	629	169	3.3	2	6.3	402
		8:55:25	666	192	22.9	2	6.1	116
		8:55:35	799	274	24.5	2	4.2	166
		8:55:45	501	132	14.7	2	3.7	130
		8:55:57	416	122	8.2	2	1.5	197
4	4/11	9:38:31	449	236	47.3	1	8.4	76
		9:38:49	333	78	14.7	1	4.5	66
		9:42:52	496	125	4.9	2	8.2	259
7	4/12	14:15:38	419	142	57.1	1	6.6	38
9	4/19	12:25:12	848	252	55.5	1	4.4	69
		12:29:54	382	200	55.5	2	5.2	56
		12:34:02	472	191	76.7	3	4.3	39
		12:36:34	441	126	49.0	4	3.1	37
		12:38:48	559	172	47.3	5	3.5	55
		12:39:02	575	264	73.4	5	2.9	56
		12:42:37	496	168	26.1	6	1.9	80
		12:50:09	434	118	75.1	7	4.6	24
		12:50:16	573	126	31.0	7	3.2	63
		12:51:52	338	123	32.6	7	0.8	57
		12:58:33	390	154	18.0	8	3.5	127
		13:01:43	627	172	21.2	9	4.0	99
		13:03:44	483	168	70.2	10	5.2	37
		13:03:53	1243	294	45.7	10	5.2	100
		13:05:56	741	329	55.5	11	4.6	92
		13:06:23	336	123	29.4	11	0.8	63
		13:08:02	312	126	39.2	12	5.0	50
		13:10:13	838	314	71.8	13	6.2	68
		13:10:18	443	225	45.7	13	6.4	76
		13:12:30	309	62	4.9	14	6.6	175
		13:12:42	718	319	39.2	14	6.3	126
		13:17:15	456	130	13.0	15	7.0	146
		13:17:26	581	113	34.3	15	5.7	51
		13:20:51	416	175	47.3	16	1.7	56

RIDGE	DATE	TIME	PRESSURE (PSI)	FORCE (LT)	MAXIMUM AREA (FT^2)	RAM	VEL (KTS)	P_{AVG} (PSI)
11	4/20	12:43:51	435	93	34.3	1	5.2	41
		12:54:37	554	230	71.8	2	5.9	50
		12:55:17	453	71	13.1	2	0.9	78
		12:58:25	607	174	55.5	3	7.0	47
		13:06:18	1319	443	32.6	4	2.7	209
		13:06:27	485	240	35.9	4	1.1	104
		13:06:47	435	207	50.6	4	0.3	63
		13:06:52	480	134	42.4	4	1.1	46
		13:09:55	706	313	58.8	5	7.4	83
		13:10:11	380	142	37.5	5	3.4	57
13-14-15	4/24	15:51:44	453	195	40.8	1	3.2	47
		16:04:14	425	170	39.2	2	4.2	67
		16:04:39	551	162	62.0	2	1.1	40
		16:11:59	1141	491	44.1	3	7.6	173
		16:16:27	494	266	53.9	4	7.2	75
		16:16:38	320	110	11.4	4	5.5	138
		16:16:52	329	98	9.8	4	1.2	122
		16:16:58	312	108	26.1	4	0.7	60
		16:17:44	414	102	18.0	4	3.6	81
		16:20:12	715	150	13.1	5	6.4	167

APPENDIX H
SUMMARY OF STRENGTHS FOR CORES TAKEN IN FIRST YEAR ICE

DATE CORE WAS TAKEN	CORE NUMBER	FLEXURAL STRENGTH (PSI)	UNCONSTRAINED CRUSHING STRENGTH (PSI)
4/7	1	93.0	508
	2	93.4	511
4/8	4	86.0	460
	5	100.2	558
4/12	23	101.2	564
4/13	24	97.7	540
	26	102.9	576
	27	101.4	566
4/16	28	87.5	471
Average		95.9	528
Standard Deviation		6.25	42.8

APPENDIX I
RIDGE STRENGTHS AND THICKNESSES FOR DEDICATED TESTS

RIDGE	FLEXURAL* STRENGTH (PSI)	UNCONSTRAINED** CRUSHING STRENGTH (PSI)	AVERAGE* CONSOLIDATED THICKNESS (FT)	MAXIMUM* CONSOLIDATED THICKNESS (FT)
3	127.2	742.5	19.9	27.0
4	126.4	736.5	21.0	28.0
5	127.3	743.0	15.0	24.4
7	126.4	736.5	12.3	17.1
9	122.1	707.8	17.3	24.6
11	115.6	663.0	16.4	24.5
13	115.3	660.5	19.5	32.9
14***	114.5	655.5	19.2	30.2
15	113.8	650.5	18.8	27.6

* From reference
** Computed from brine volumes used for flexural strength using reference
*** Averaged from adjacent ridges 13 and 15

APPENDIX J

VARIATION OF PRESSURE AND AREA WITH TIME - SELECTED EVENTS

FIGURE .1a

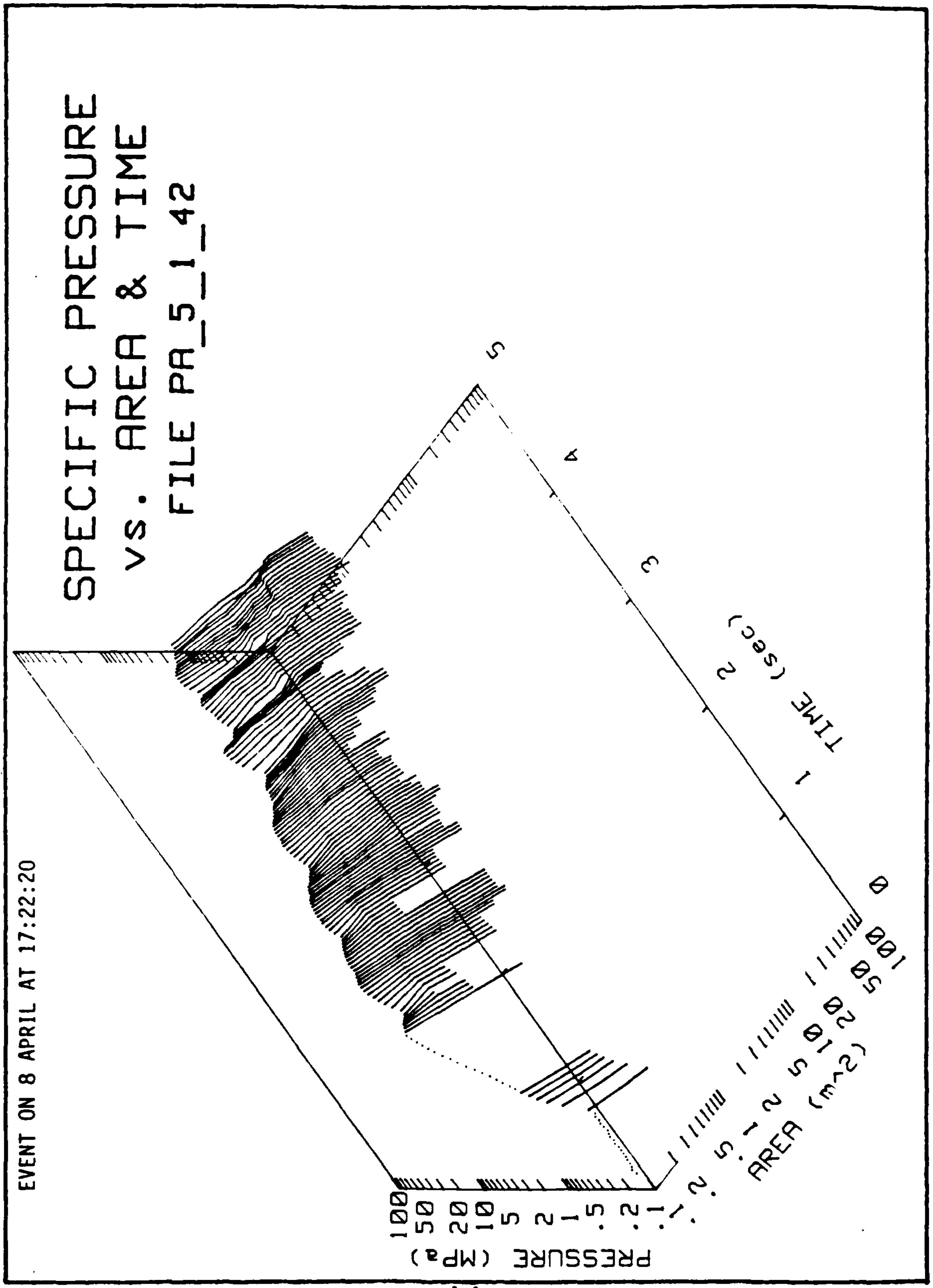


FIGURE .1b

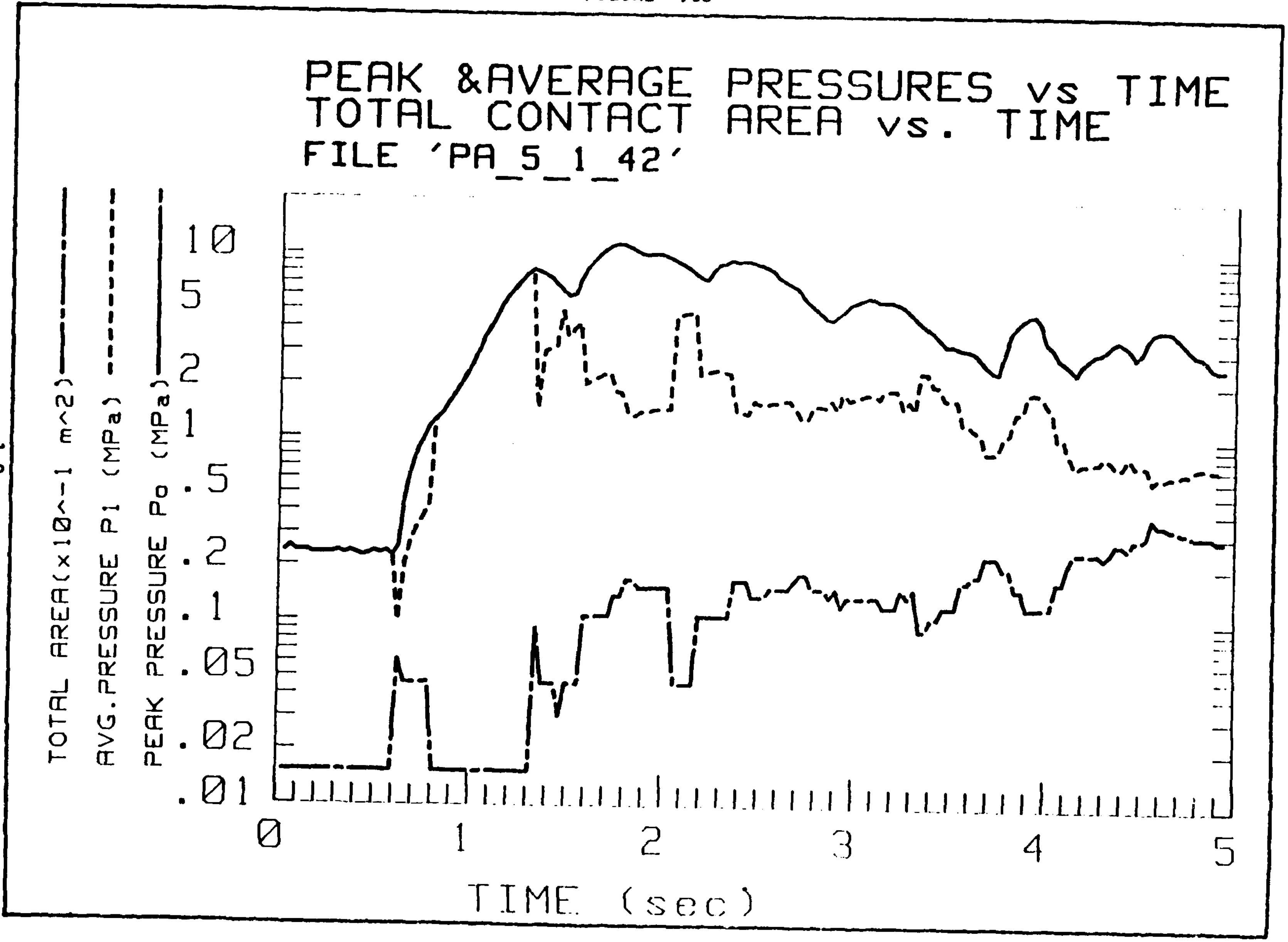

PEAK &AVERAGE PRESSURES vs TIME
TOTAL CONTACT AREA vs. TIME
FILE 'PA_5_1_42'
TOTAL AREA(x10^-1 m^2)
AVG.PRESSURE P1 (MPa)
PEAK PRESSURE Po (MPa)
10
5
2
1
.5
.2
.1
.05
.02
.01
0
1
2
3
4
5
TIME (sec)

FIGURE .1c

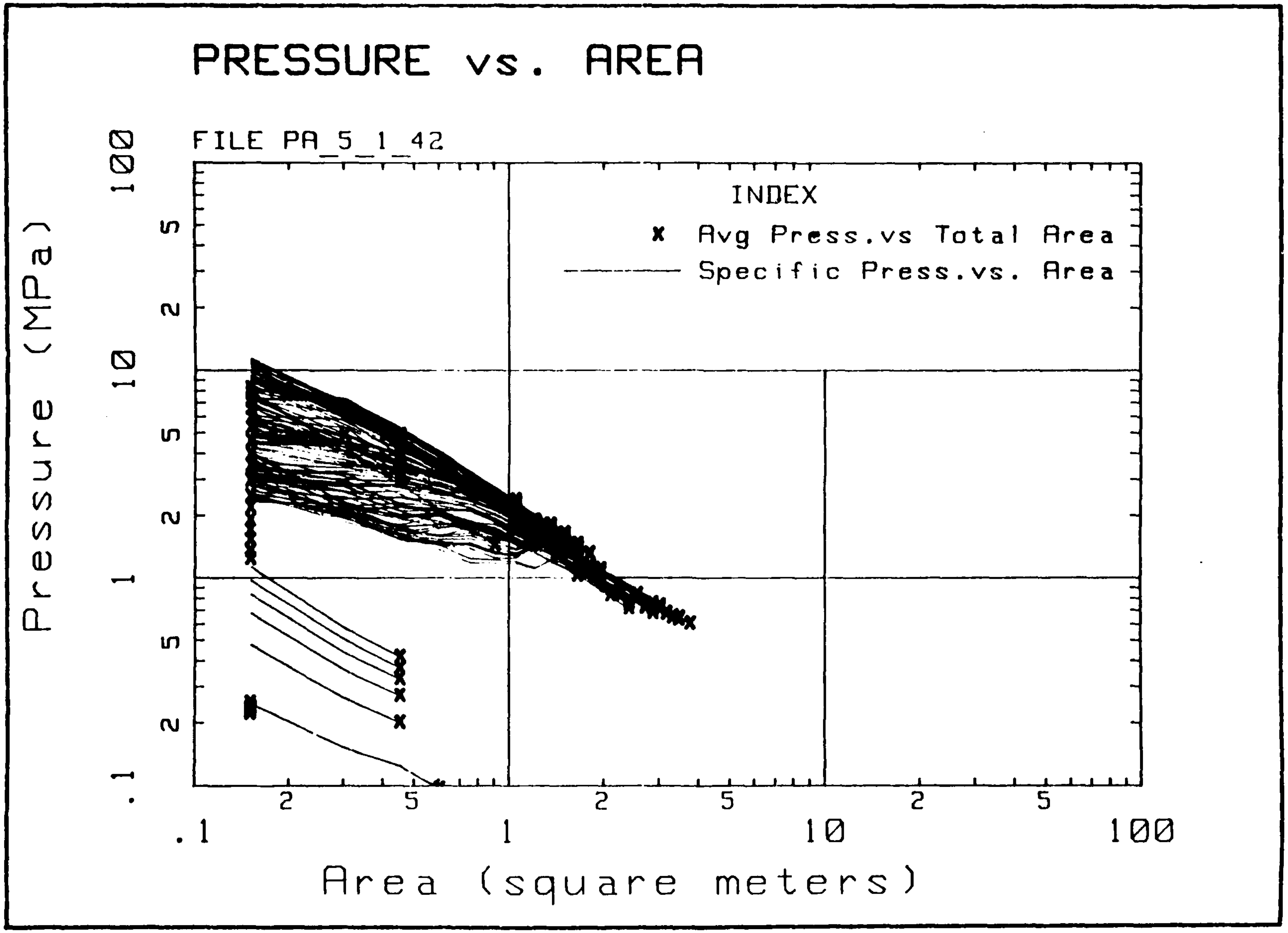

PRESSURE vs. AREA
FILE PA_5_1_42
INDEX
Avg Press.vs Total Area
Specific Press.vs. Area
Pressure (MPa)
Area (square meters)
.1
1
10
100
2
5

FIGURE .1d

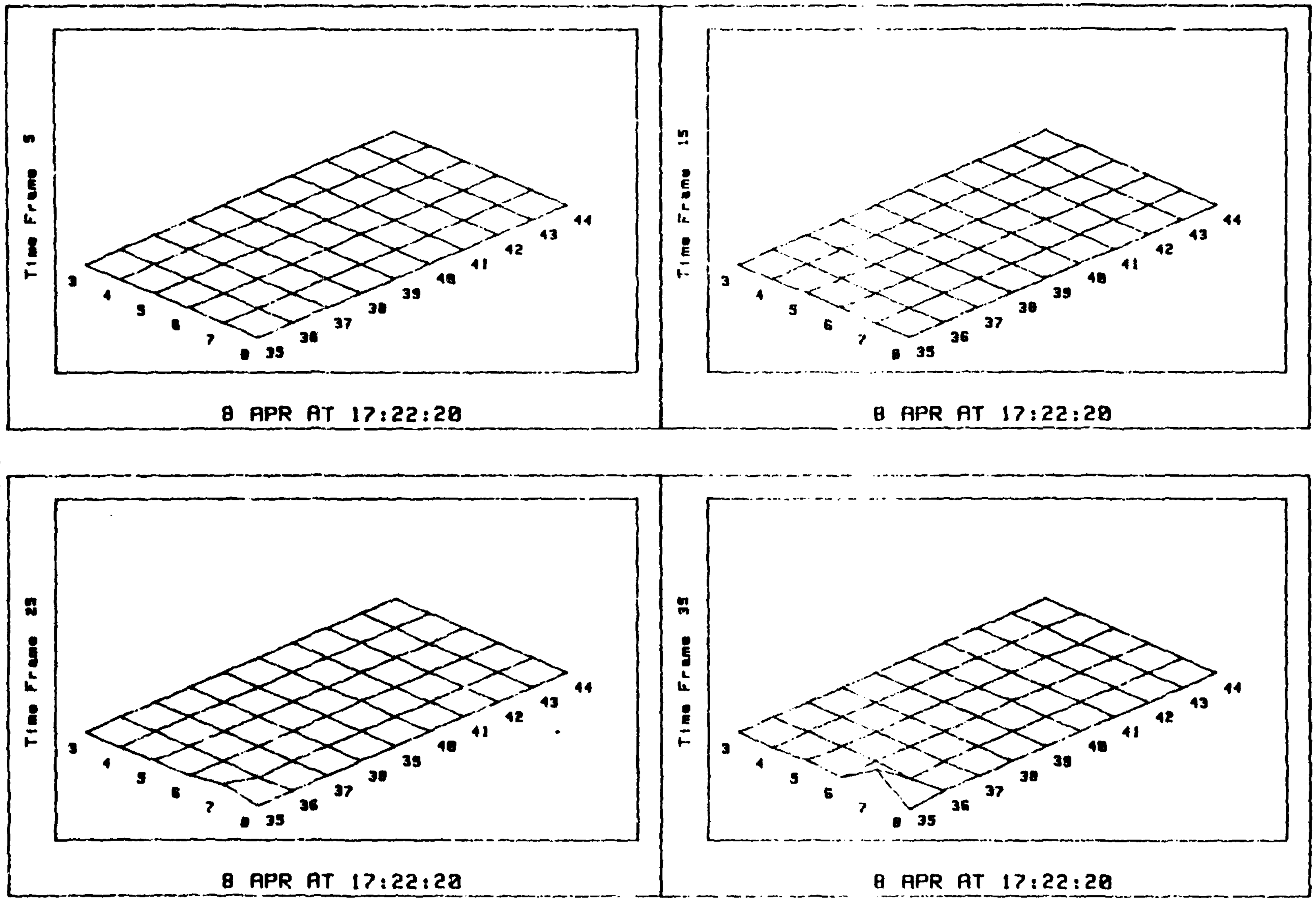

Time Frame 5
3
4
5
6
7
8
35
36
37
38
39
40
41
42
43
44
8 APR AT 17:22:20
Time Frame 15
8 APR AT 17:22:20
Time Frame 25
8 APR AT 17:22:20
Time Frame 35
8 APR AT 17:22:20

FIGURE .1e

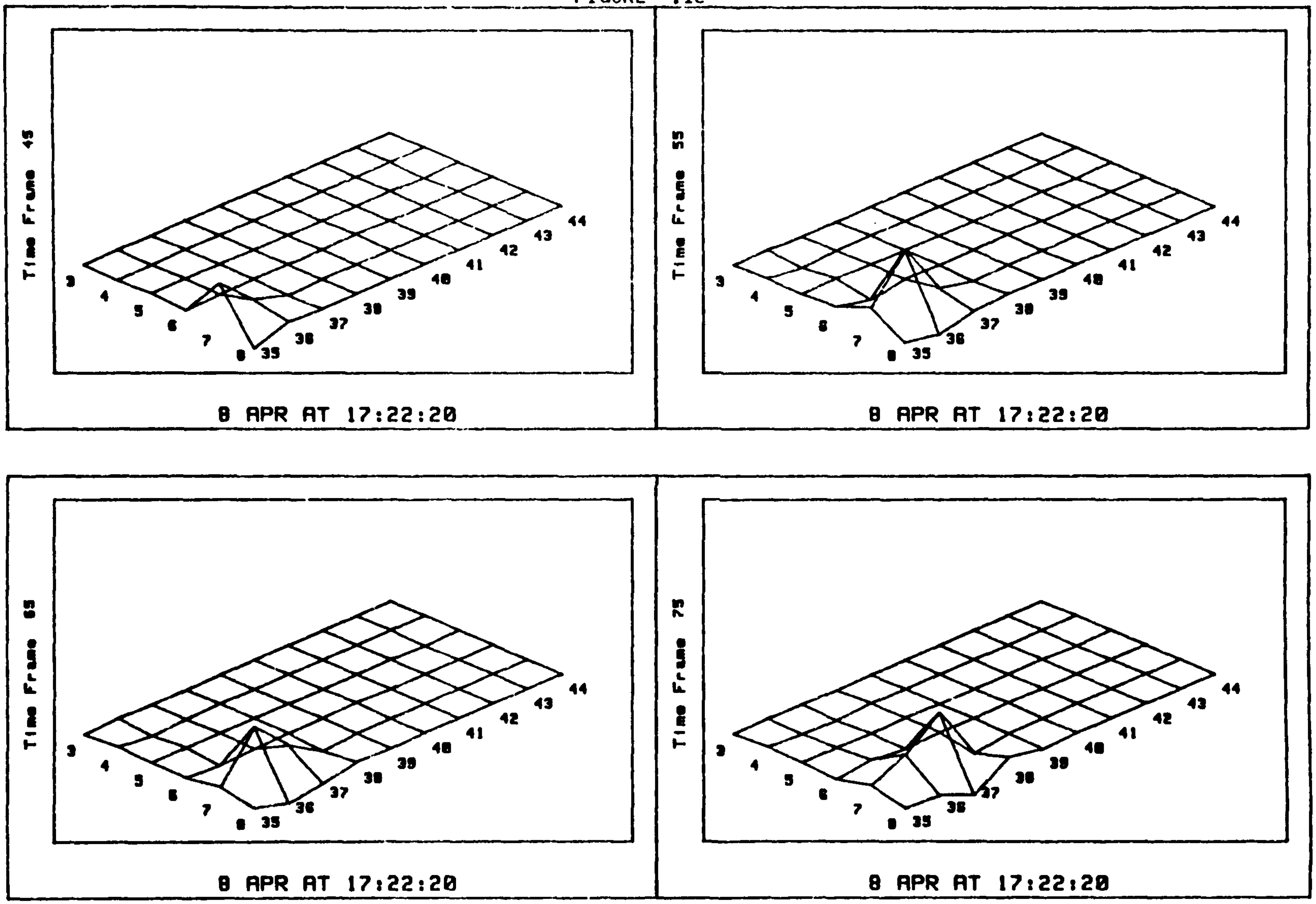
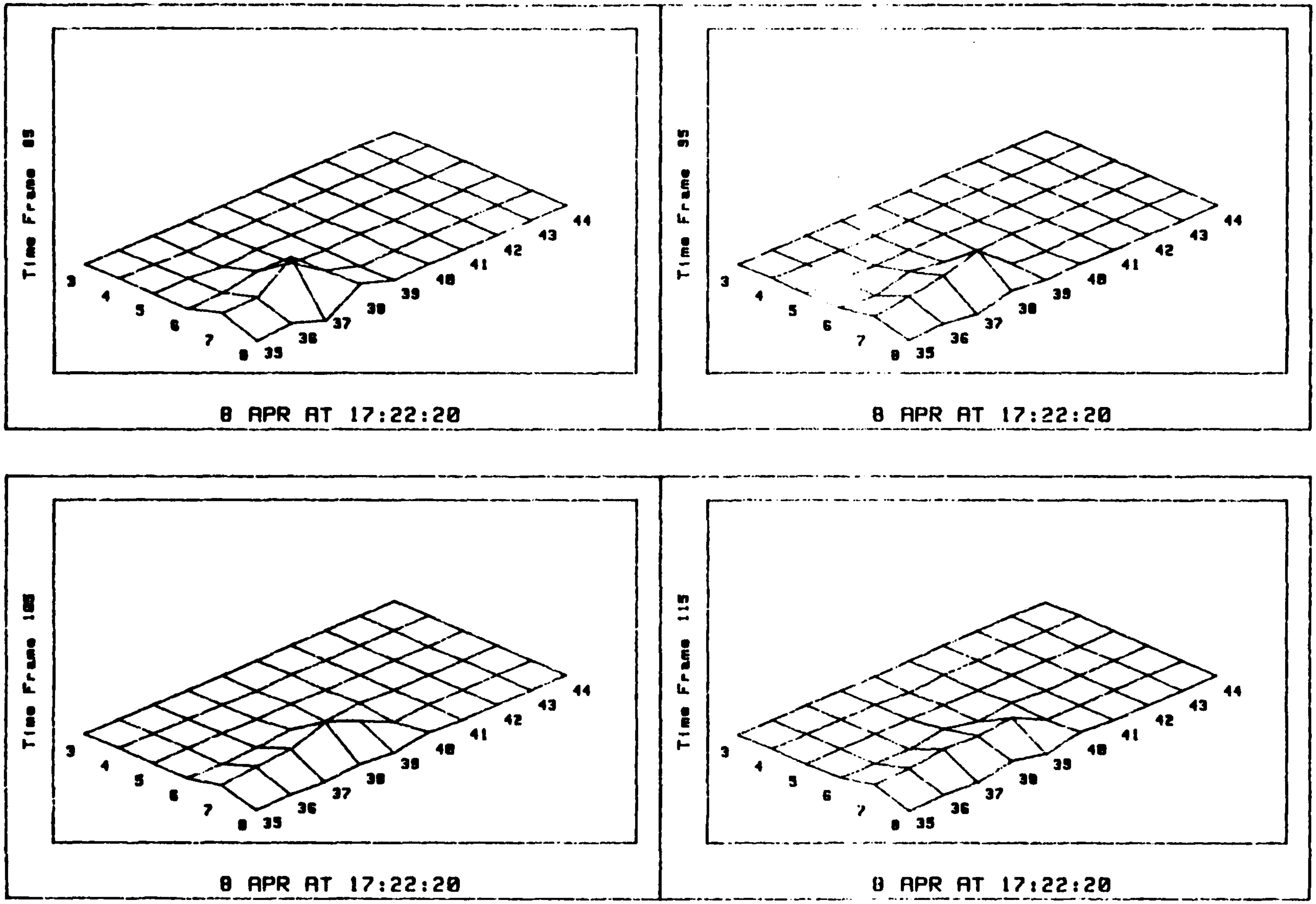

Time Frame 45
3 4 5 6 7 8
35 36 37 38 39 40 41 42 43 44
8 APR AT 17:22:20
Time Frame 55
3 4 5 6 7 8
35 36 37 38 39 40 41 42 43 44
8 APR AT 17:22:20
Time Frame 65
3 4 5 6 7 8
35 36 37 38 39 40 41 42 43 44
8 APR AT 17:22:20
Time Frame 75
3 4 5 6 7 8
35 36 37 38 39 40 41 42 43 44
8 APR AT 17:22:20

FIGURE .1f



Time Frame 85
3 4 5 6 7 8
35 36 37 38 39 40 41 42 43 44
8 APR AT 17:22:20
Time Frame 95
3 4 5 6 7 8
35 36 37 38 39 40 41 42 43 44
8 APR AT 17:22:20
Time Frame 105
3 4 5 6 7 8
35 36 37 38 39 40 41 42 43 44
8 APR AT 17:22:20
Time Frame 115
3 4 5 6 7 8
35 36 37 38 39 40 41 42 43 44
8 APR AT 17:22:20

FIGURE .1g

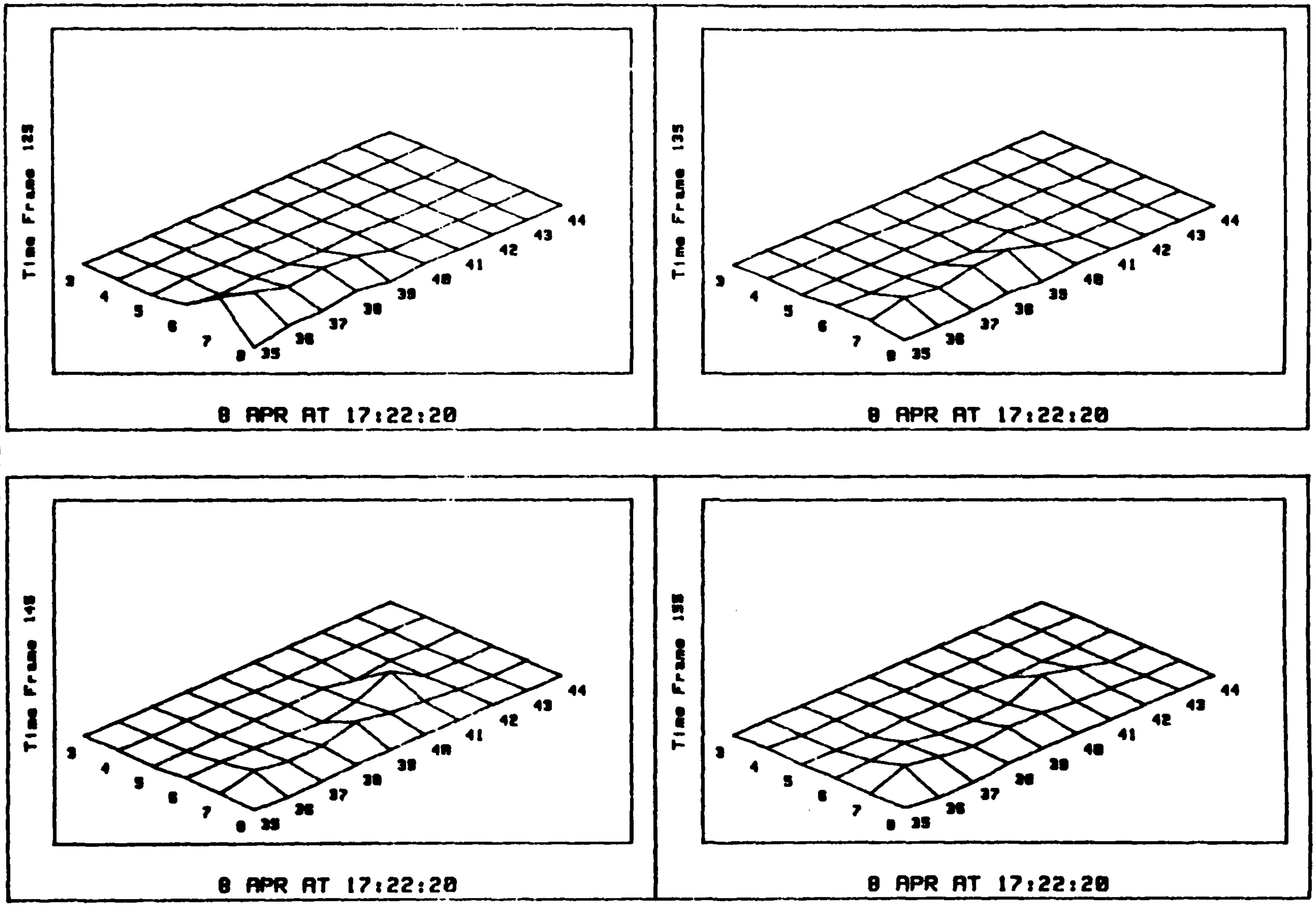

Time Frame 125
8 APR AT 17:22:20
Time Frame 135
8 APR AT 17:22:20
Time Frame 145
8 APR AT 17:22:20
Time Frame 155
8 APR AT 17:22:20

FIGURE .2a

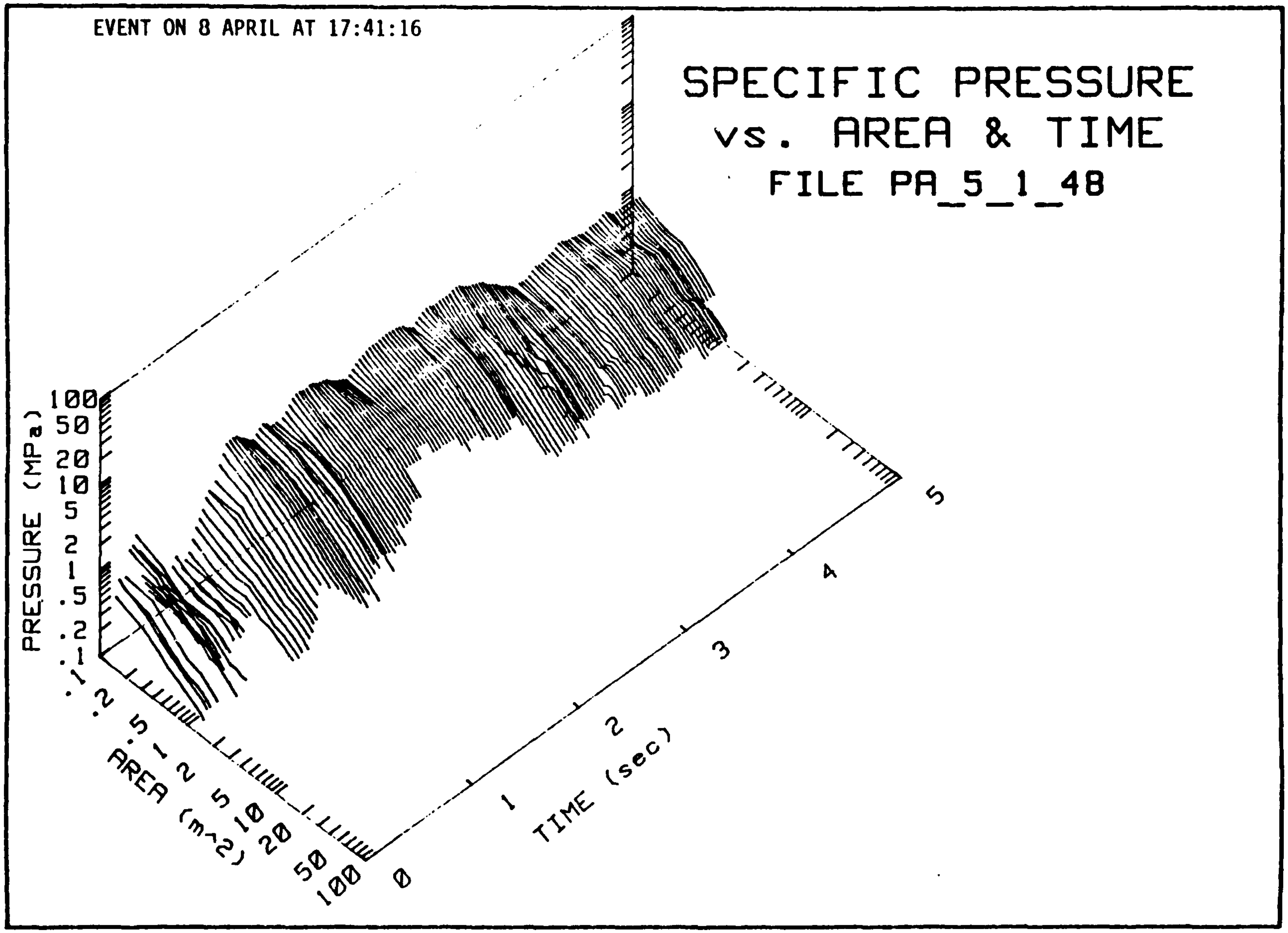
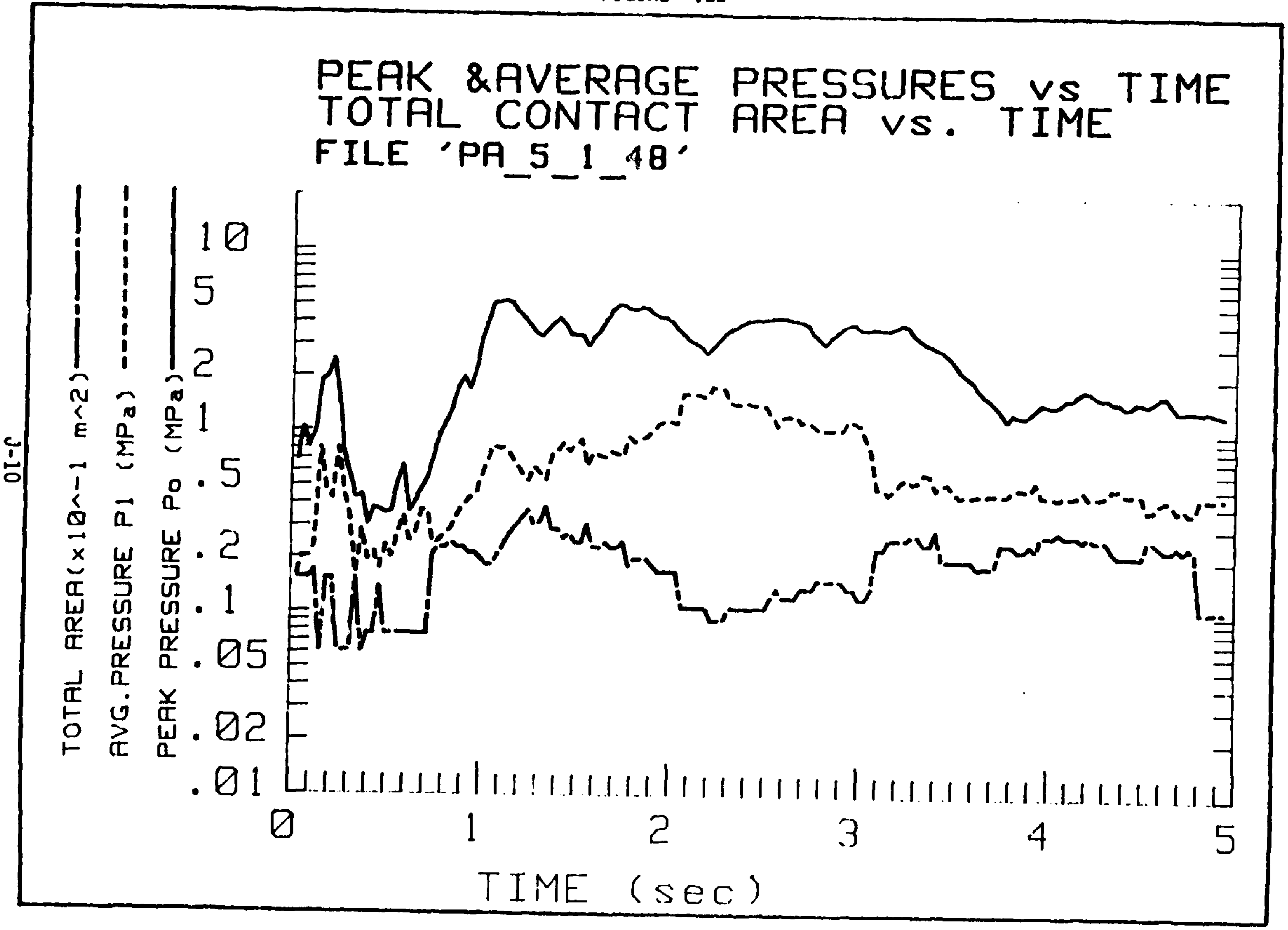
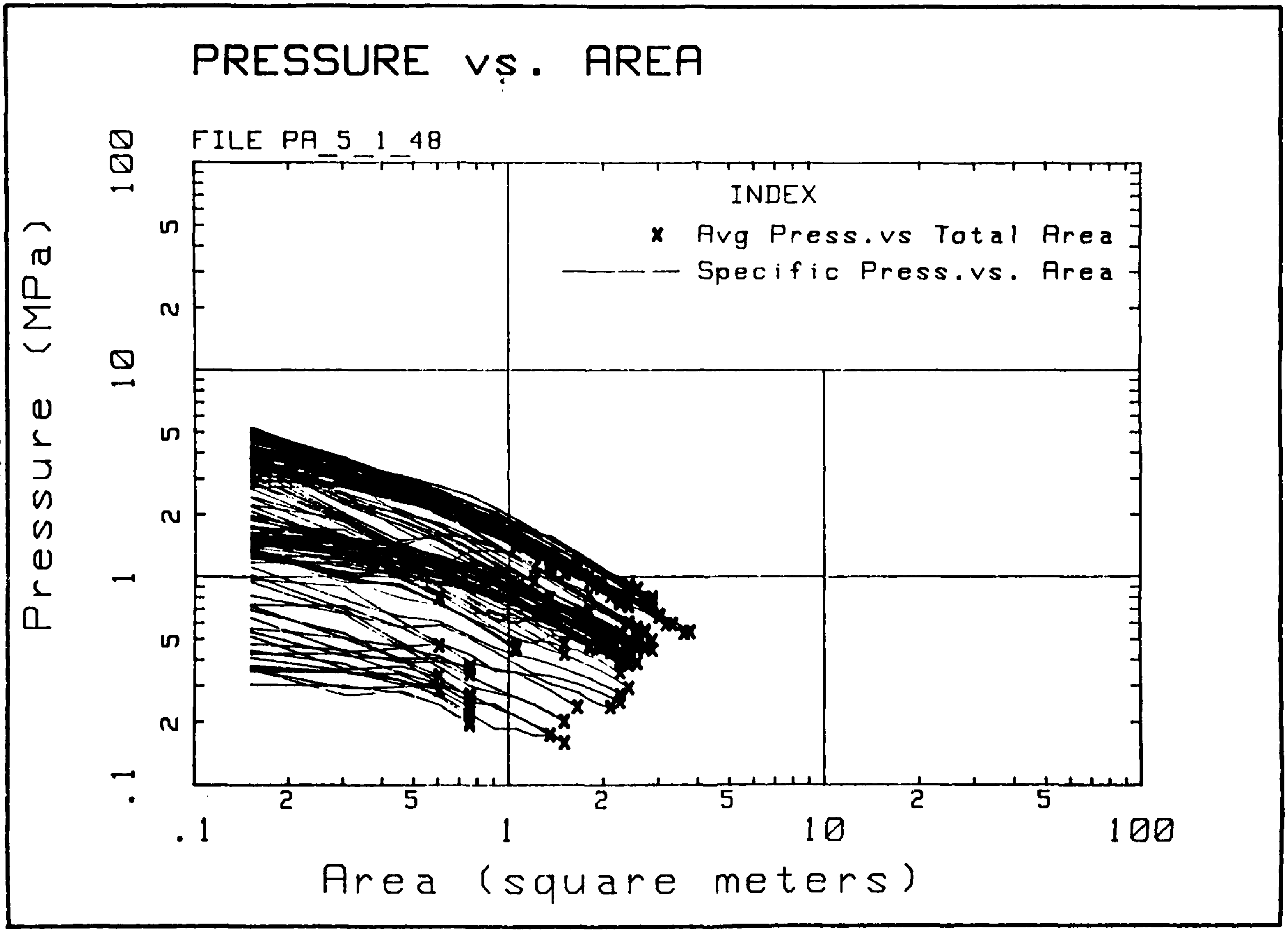

EVENT ON 8 APRIL AT 17:41:16
SPECIFIC PRESSURE
vs. AREA & TIME
FILE PA_5_1_48
PRESSURE (MPa)
100 50 20 10 5 2 1 .5 .2 .1
AREA (m^2)
.1 .2 .5 1 2 5 10 20 50 100
TIME (sec)
0 1 2 3 4 5

FIGURE .2b

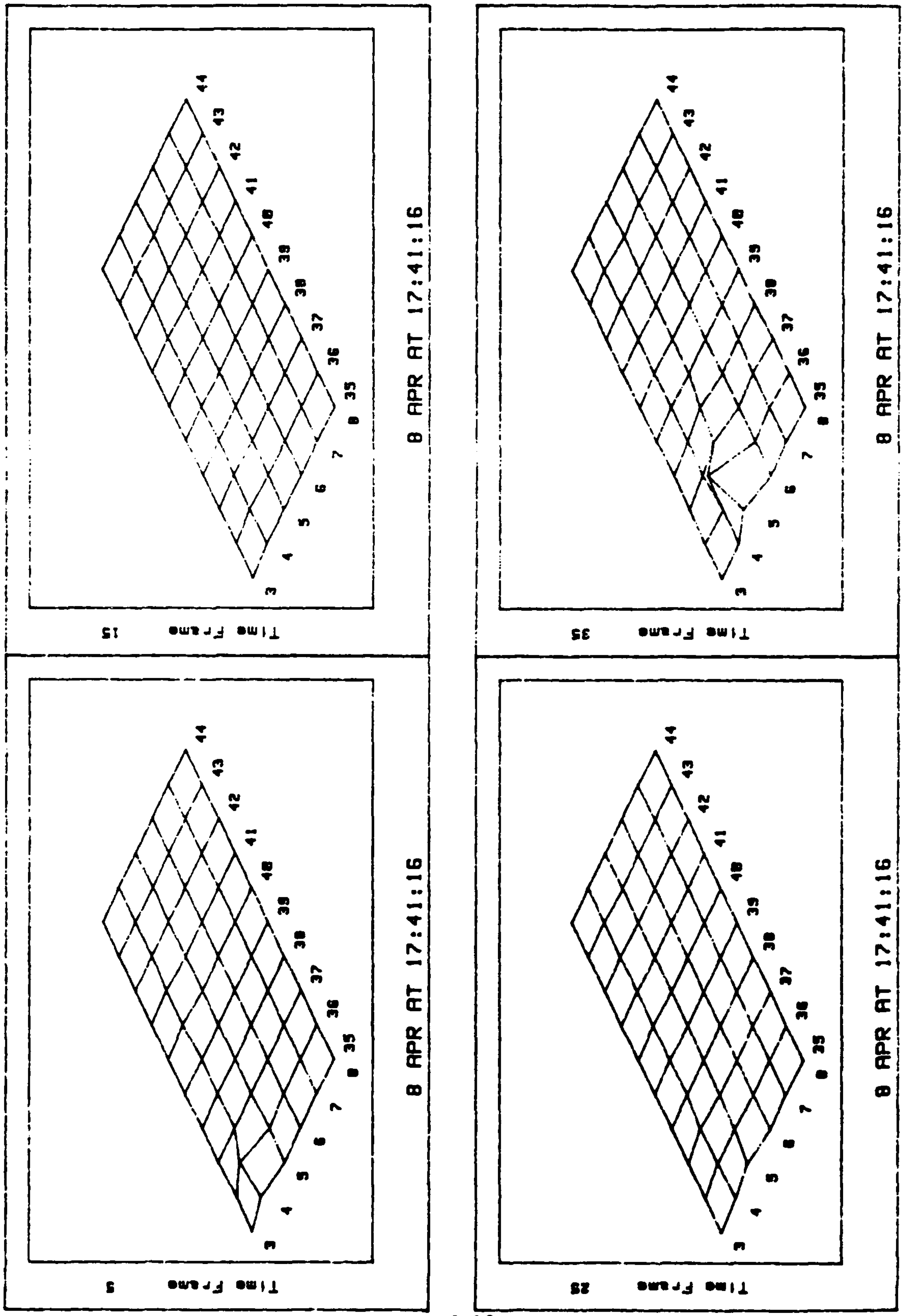


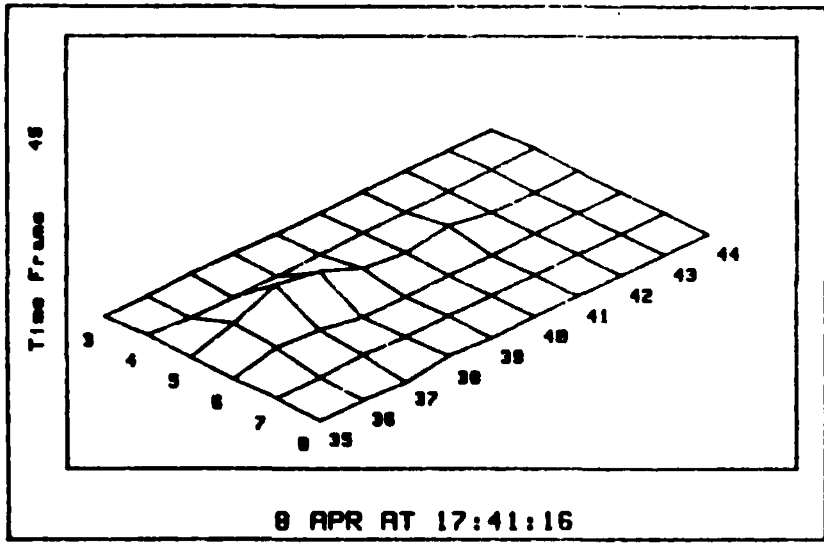
PEAK &AVERAGE PRESSURES vs TIME
TOTAL CONTACT AREA vs. TIME
FILE 'PA_5_1_48'
TOTAL AREA(x10^-1 m^2)
AVG.PRESSURE P1 (MPa)
PEAK PRESSURE Po (MPa)
10
5
2
1
.5
.2
.1
.05
.02
.01
0
1
2
3
4
5
TIME (sec)

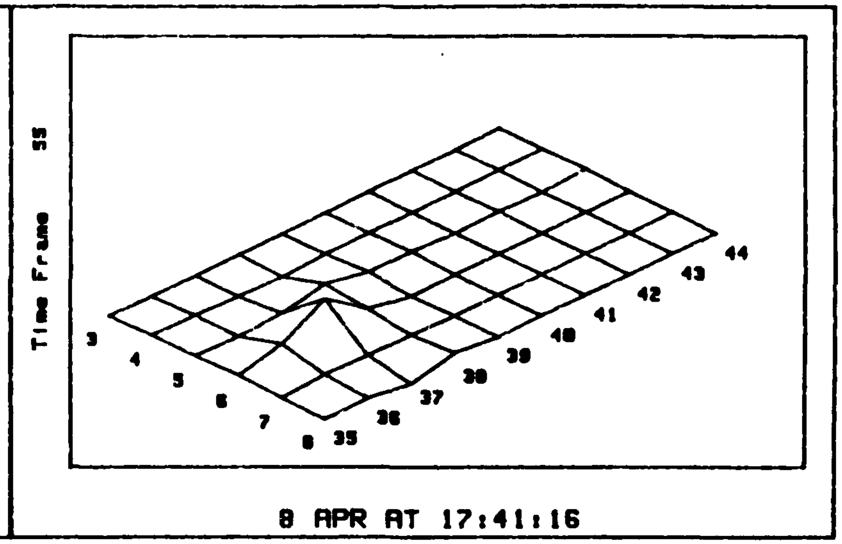
FIGURE .2c

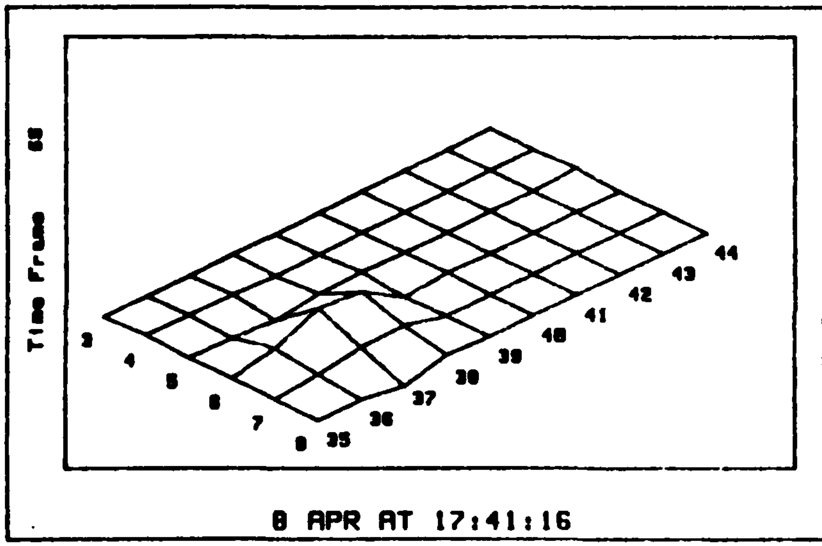


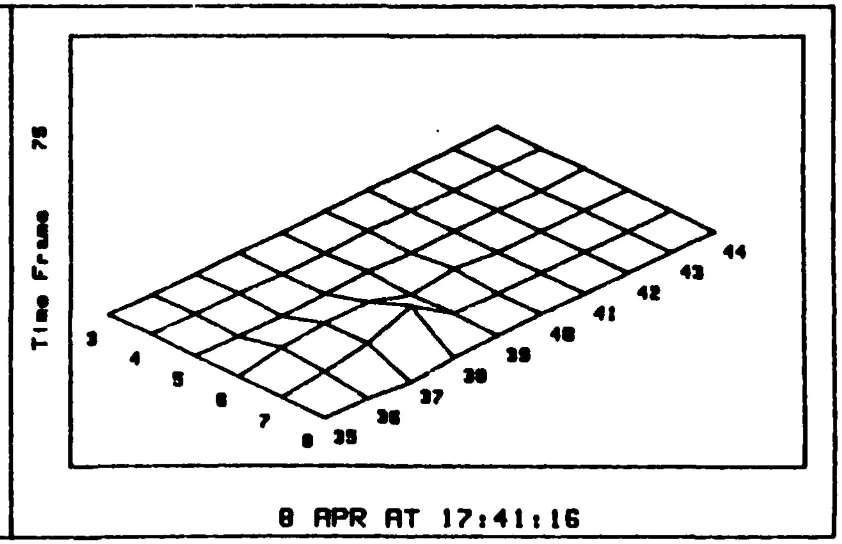
PRESSURE vs. AREA
FILE PA_5_1_48
INDEX
Avg Press.vs Total Area
Specific Press.vs. Area
Pressure (MPa)
Area (square meters)
.1
1
10
100
2
5

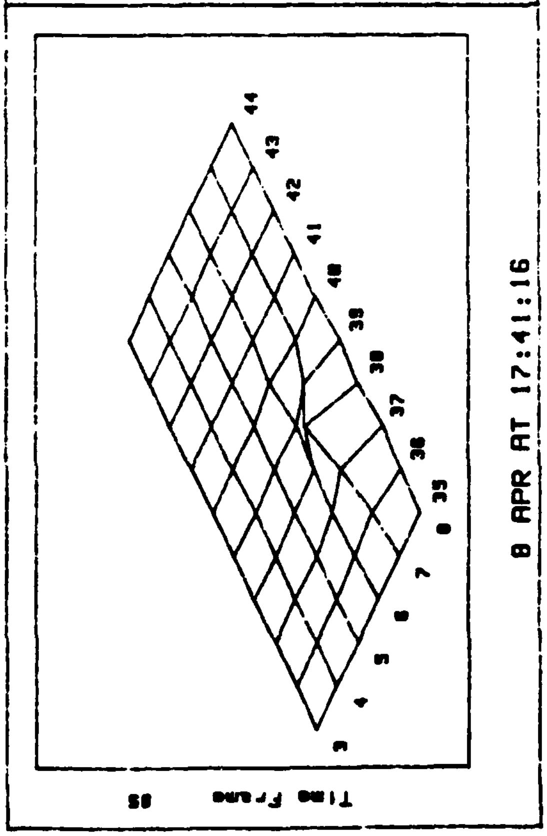

Time Frame 5
8 APR AT 17:41:16
Time Frame 15
8 APR AT 17:41:16
Time Frame 25
8 APR AT 17:41:16
Time Frame 35
8 APR AT 17:41:16

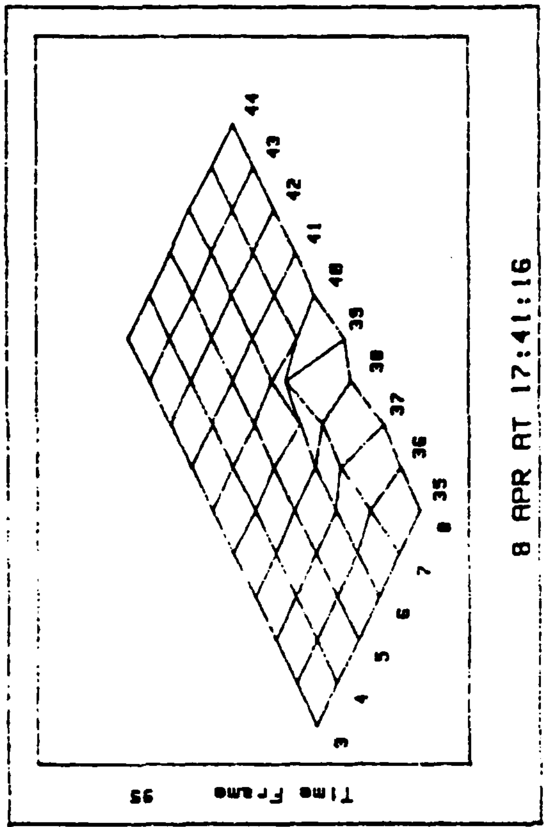

Time Frame 45
3
4
5
6
7
8
35
36
37
38
39
40
41
42
43
44
8 APR AT 17:41:16

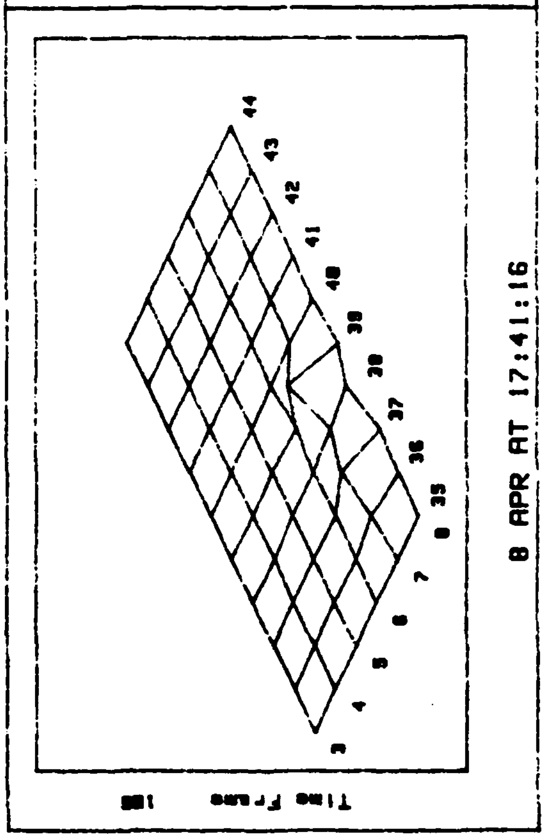

Time Frame 55
3
4
5
6
7
8
35
36
37
38
39
40
41
42
43
44
8 APR AT 17:41:16

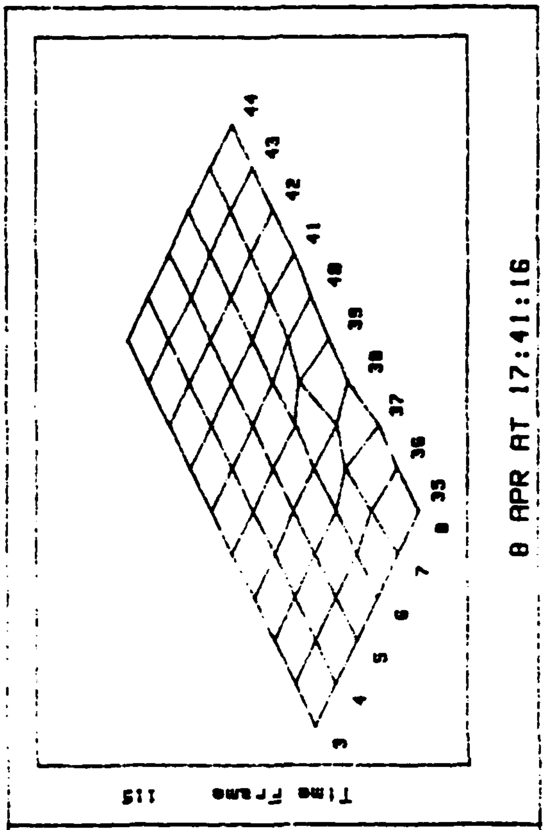

Time Frame 65
3
4
5
6
7
8
35
36
37
38
39
40
41
42
43
44
8 APR AT 17:41:16

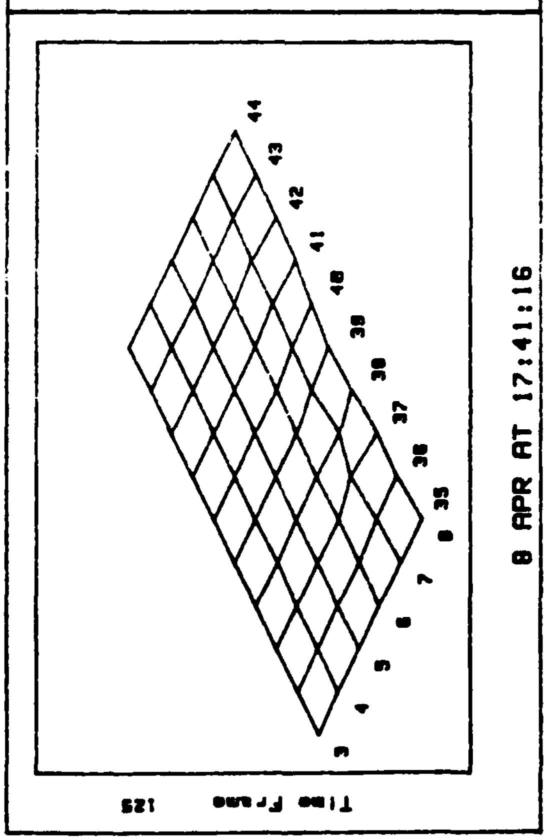

Time Frame 75
3
4
5
6
7
8
35
36
37
38
39
40
41
42
43
44
8 APR AT 17:41:16

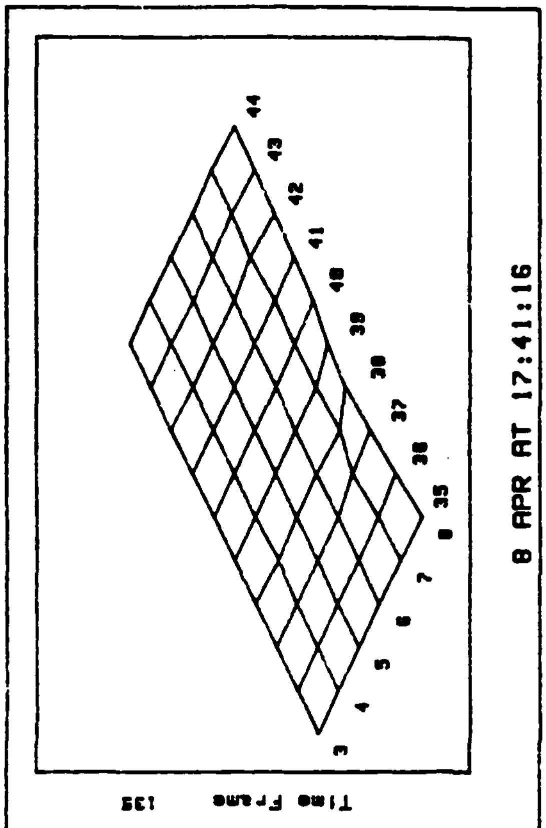

8 APR AT 17:41:16
3 4 5 6 7 8
35 36 37 38 39 40 41 42 43 44
Time Frame 85

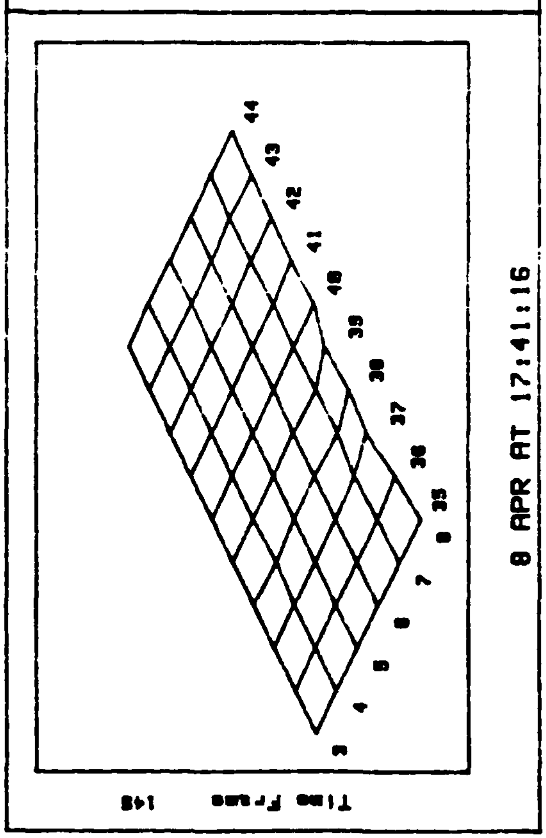

8 APR AT 17:41:16
3 4 5 6 7 8
35 36 37 38 39 40 41 42 43 44
Time Frame 95

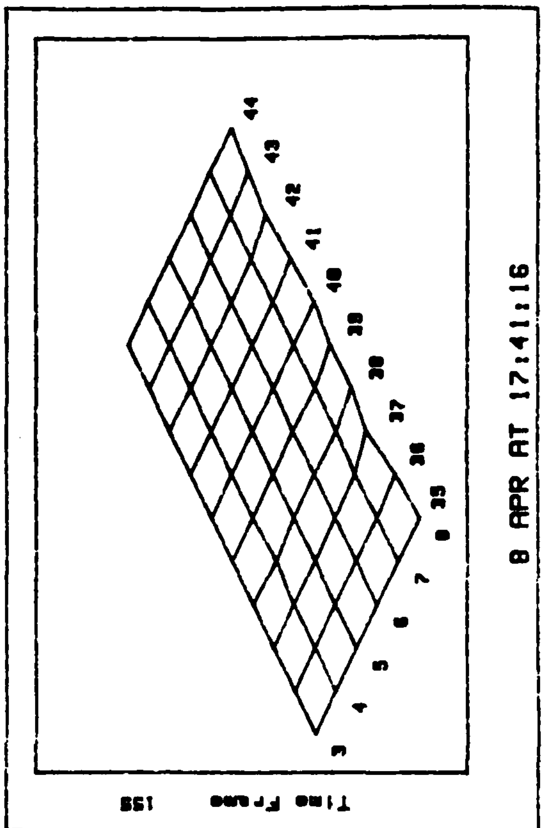

8 APR AT 17:41:16
3 4 5 6 7 8
35 36 37 38 39 40 41 42 43 44
Time Frame 105

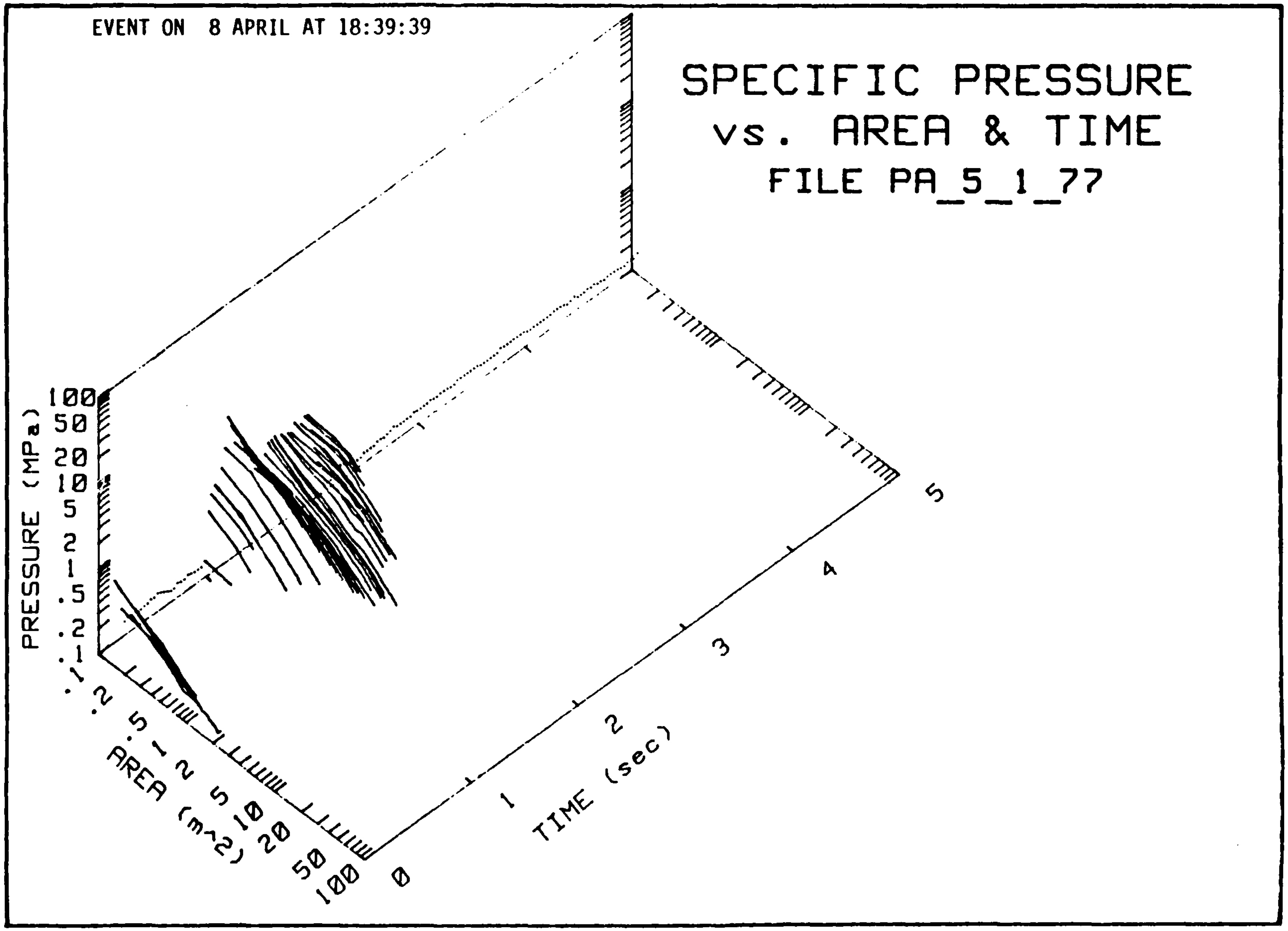

8 APR AT 17:41:16
3 4 5 6 7 8
35 36 37 38 39 40 41 42 43 44
Time Frame 115

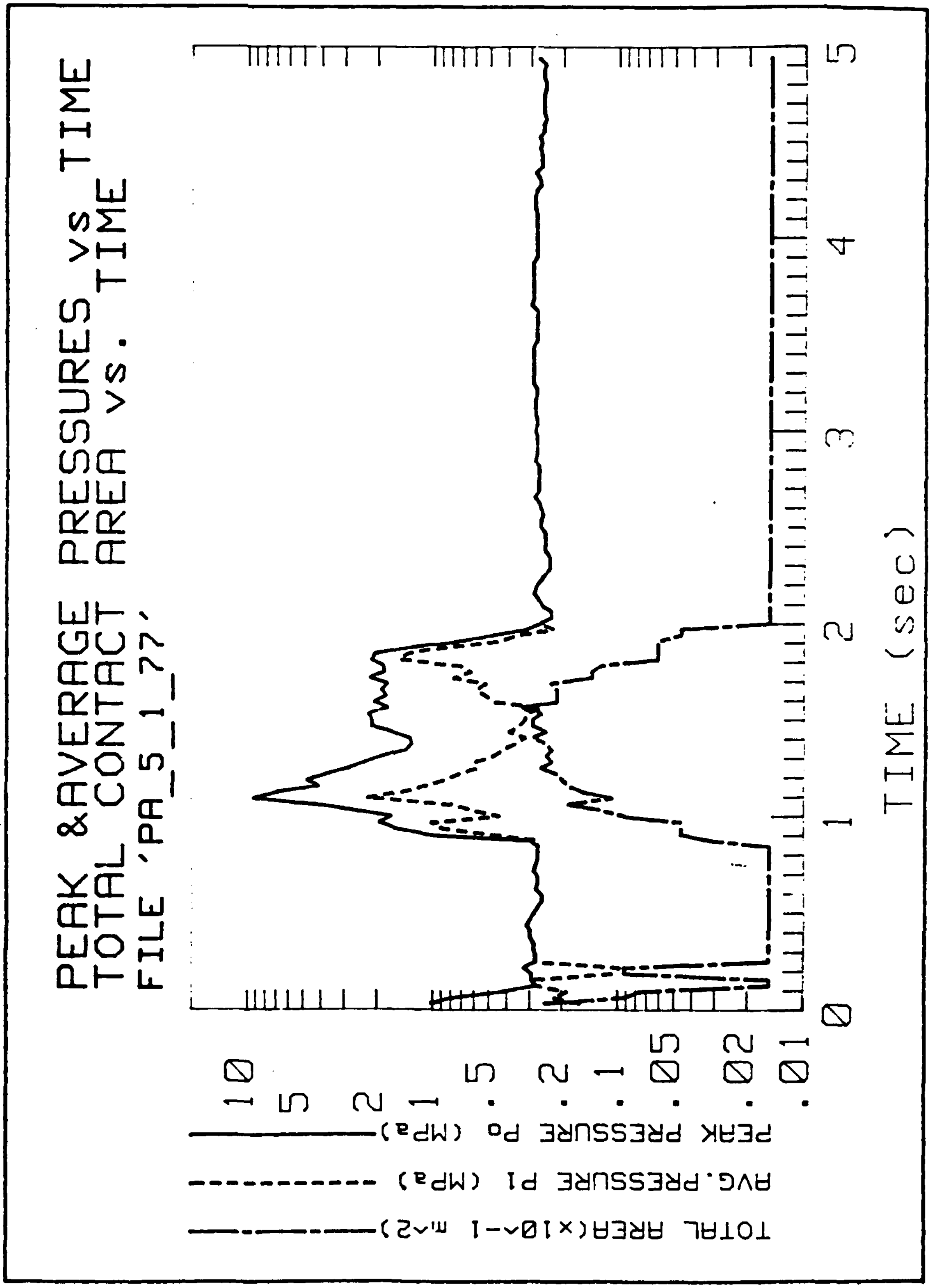

Time Frame 123
8 APR AT 17:41:16

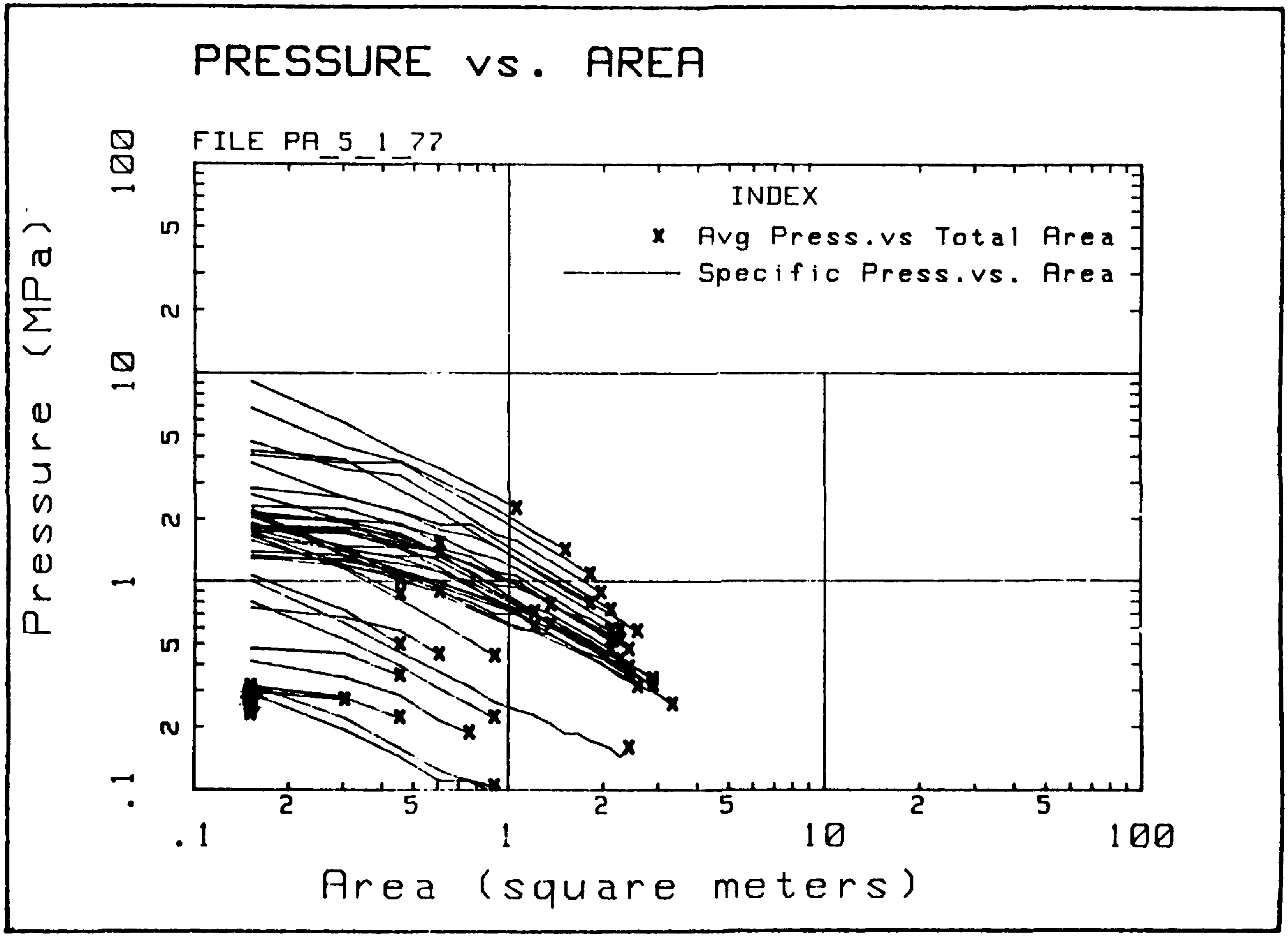

Time Frame 133
8 APR AT 17:41:16

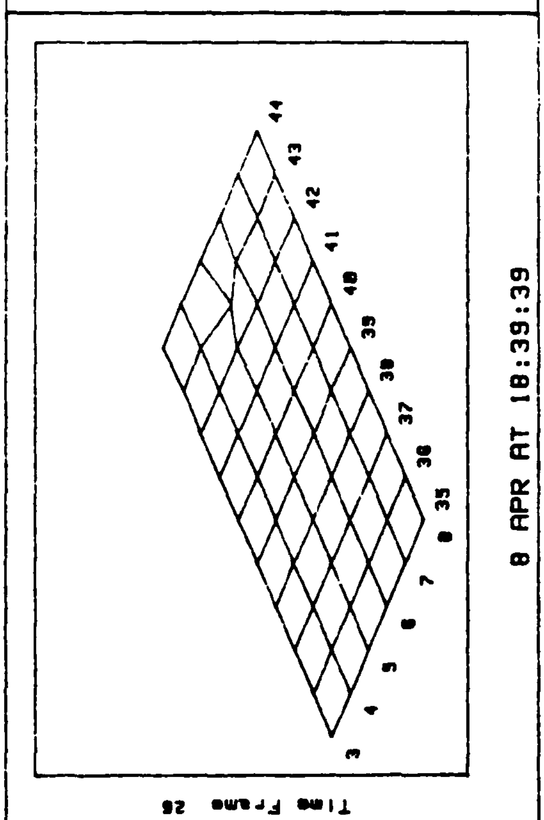

Time Frame 148
8 APR AT 17:41:16

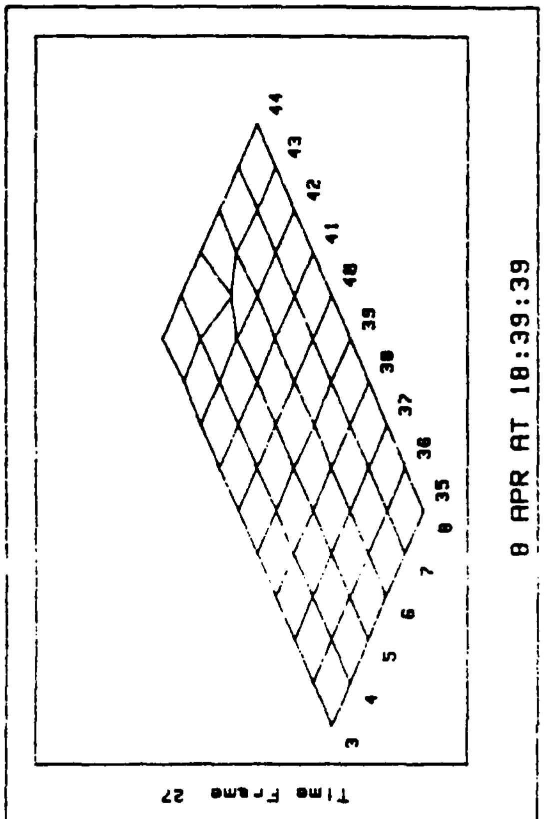

Time Frame 158
8 APR AT 17:41:16

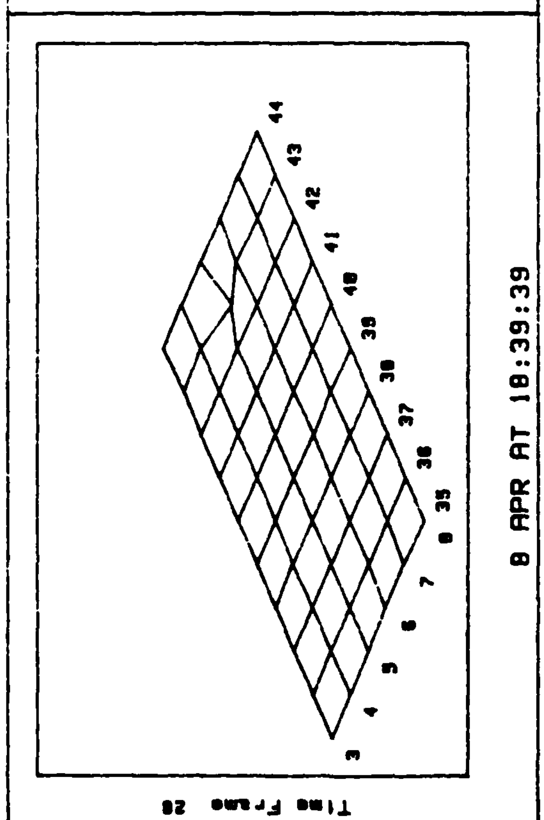

EVENT ON 8 APRIL AT 18:39:39
SPECIFIC PRESSURE
vs. AREA & TIME
FILE PA_5_1_77
PRESSURE (MPa)
100
50
20
10
5
2
1
.5
.2
.1
AREA (m^2)
.1
.2
.5
1
2
5
10
20
50
100
TIME (sec)
0
1
2
3
4
5

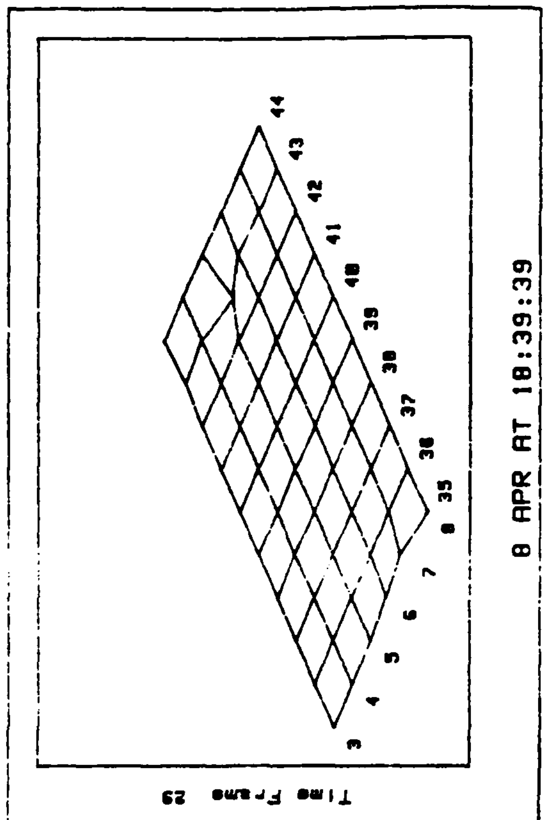

PEAK &AVERAGE PRESSURES vs TIME
TOTAL CONTACT AREA vs. TIME
FILE 'PA_5_1_77'
10
5
2
1
.5
.2
.1
.05
.02
.01
0
1
2
3
4
5
TIME (sec)
PEAK PRESSURE Po (MPa)
AVG.PRESSURE P1 (MPa)
TOTAL AREA(x10^-1 m^2)

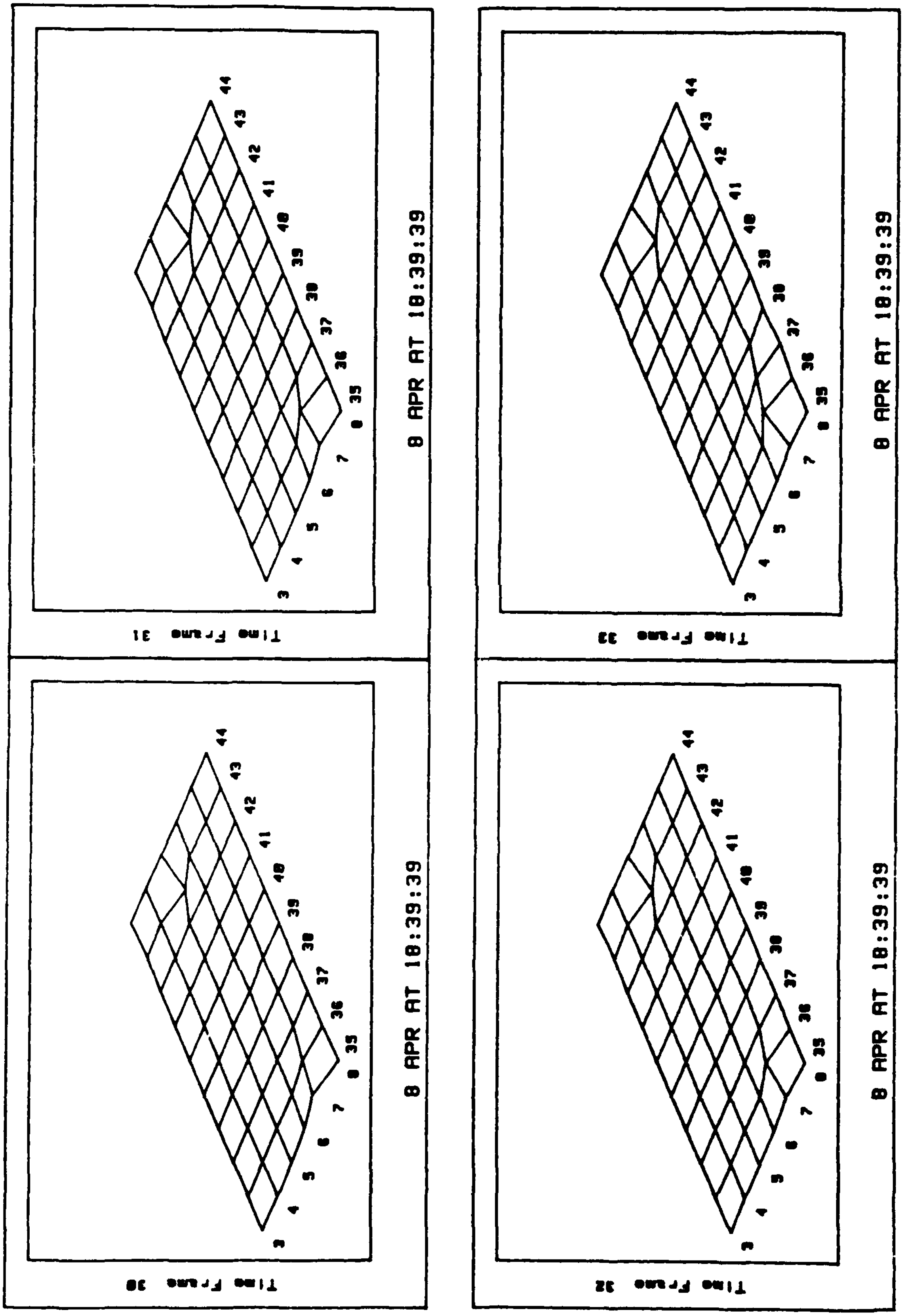

PRESSURE vs. AREA
FILE PA_5_1_77
INDEX
Avg Press.vs Total Area
Specific Press.vs. Area
Pressure (MPa)
Area (square meters)
.1
1
10
100
2
5

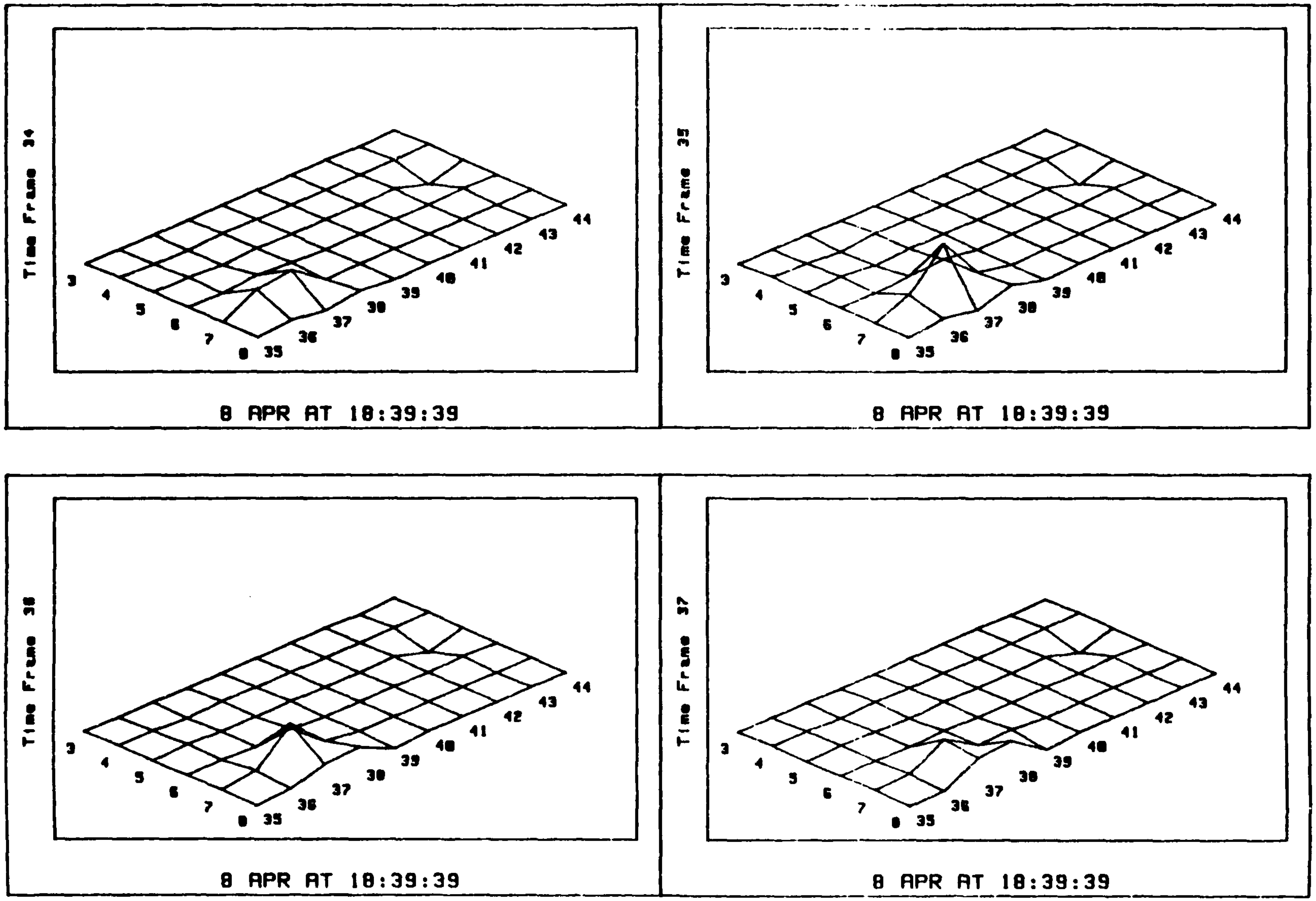

Time Frame 26
3
4
5
6
7
8
35
36
37
38
39
40
41
42
43
44
8 APR AT 18:39:39

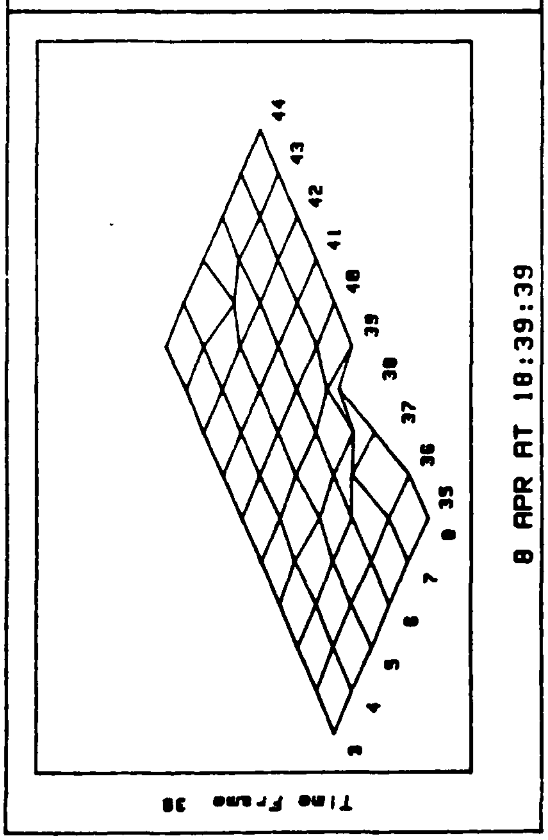

Time Frame 27
3
4
5
6
7
8
35
36
37
38
39
40
41
42
43
44
8 APR AT 18:39:39

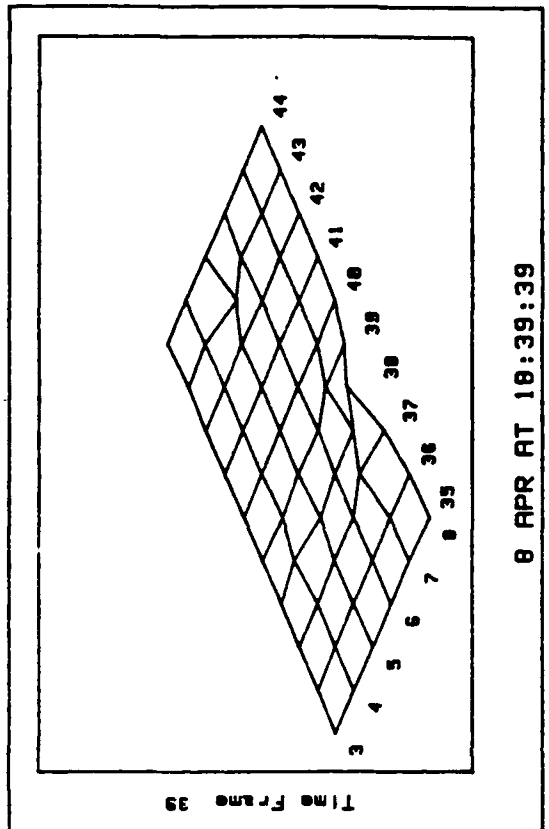

Time Frame 28
3
4
5
6
7
8
35
36
37
38
39
40
41
42
43
44
8 APR AT 18:39:39

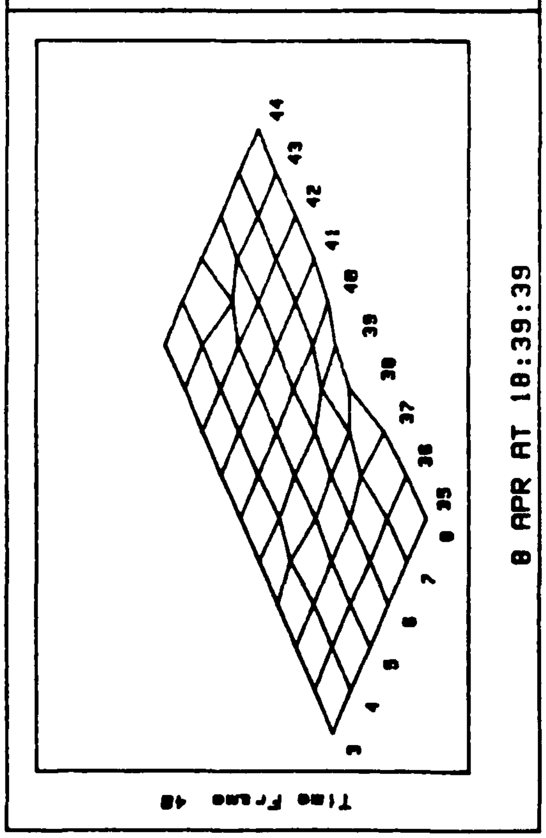

Time Frame 29
3
4
5
6
7
8
35
36
37
38
39
40
41
42
43
44
8 APR AT 18:39:39

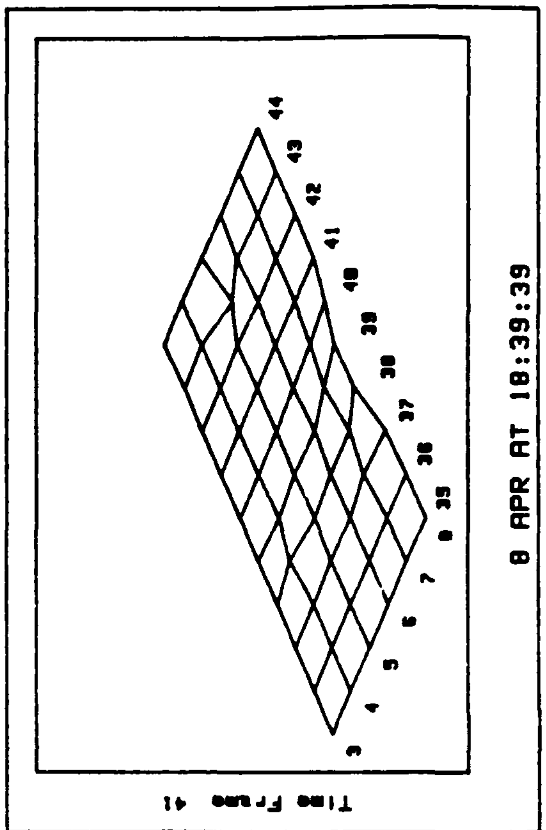

Time Frame 30
8 APR AT 18:39:39
Time Frame 31
8 APR AT 18:39:39
Time Frame 32
8 APR AT 18:39:39
Time Frame 33
8 APR AT 18:39:39
3 4 5 6 7 8 35 36 37 38 39 40 41 42 43 44

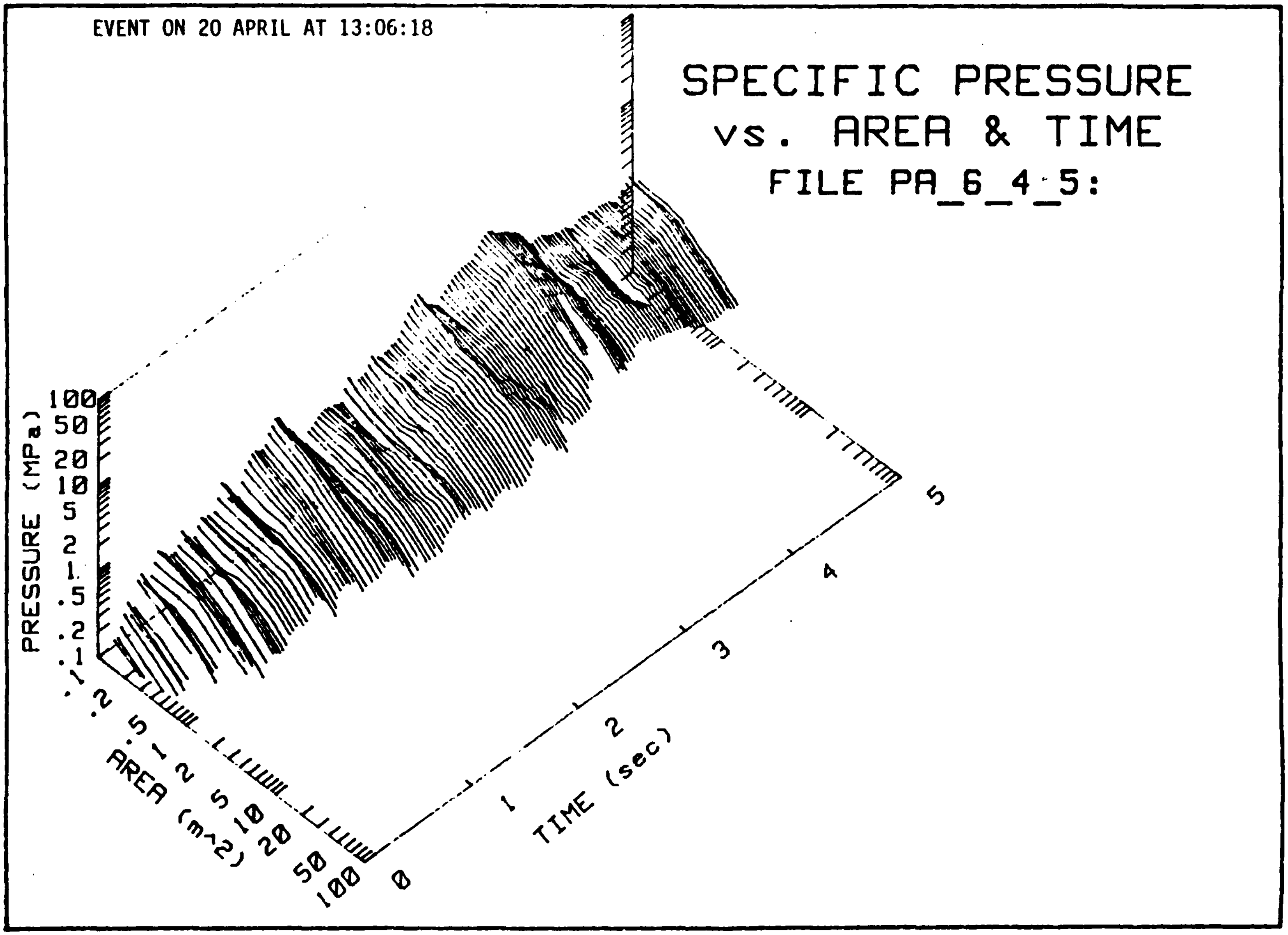

Time Frame 34
8 APR AT 18:39:39
Time Frame 35
8 APR AT 18:39:39
Time Frame 36
8 APR AT 18:39:39
Time Frame 37
8 APR AT 18:39:39

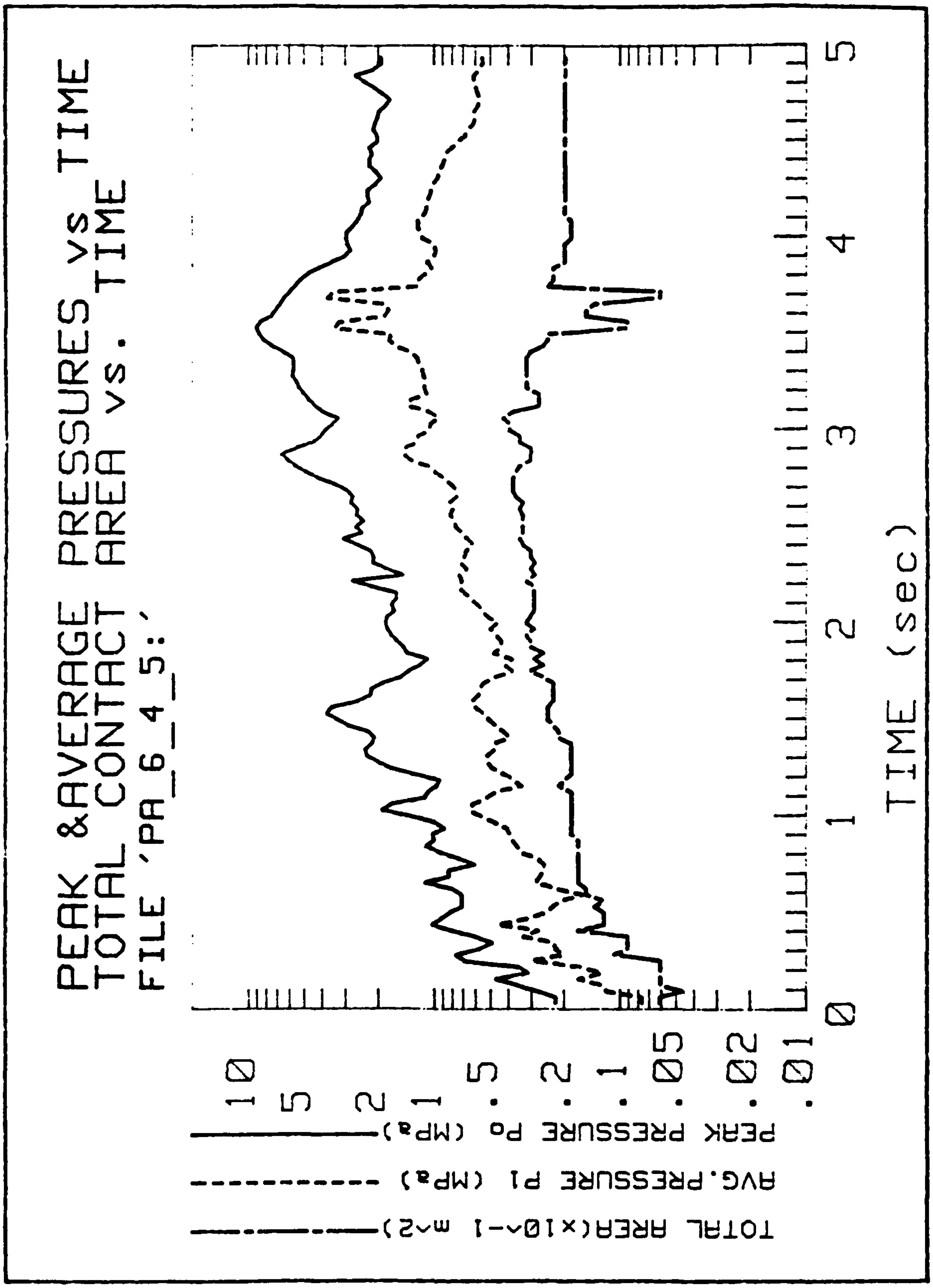

8 APR AT 18:39:39
Time Frame 38

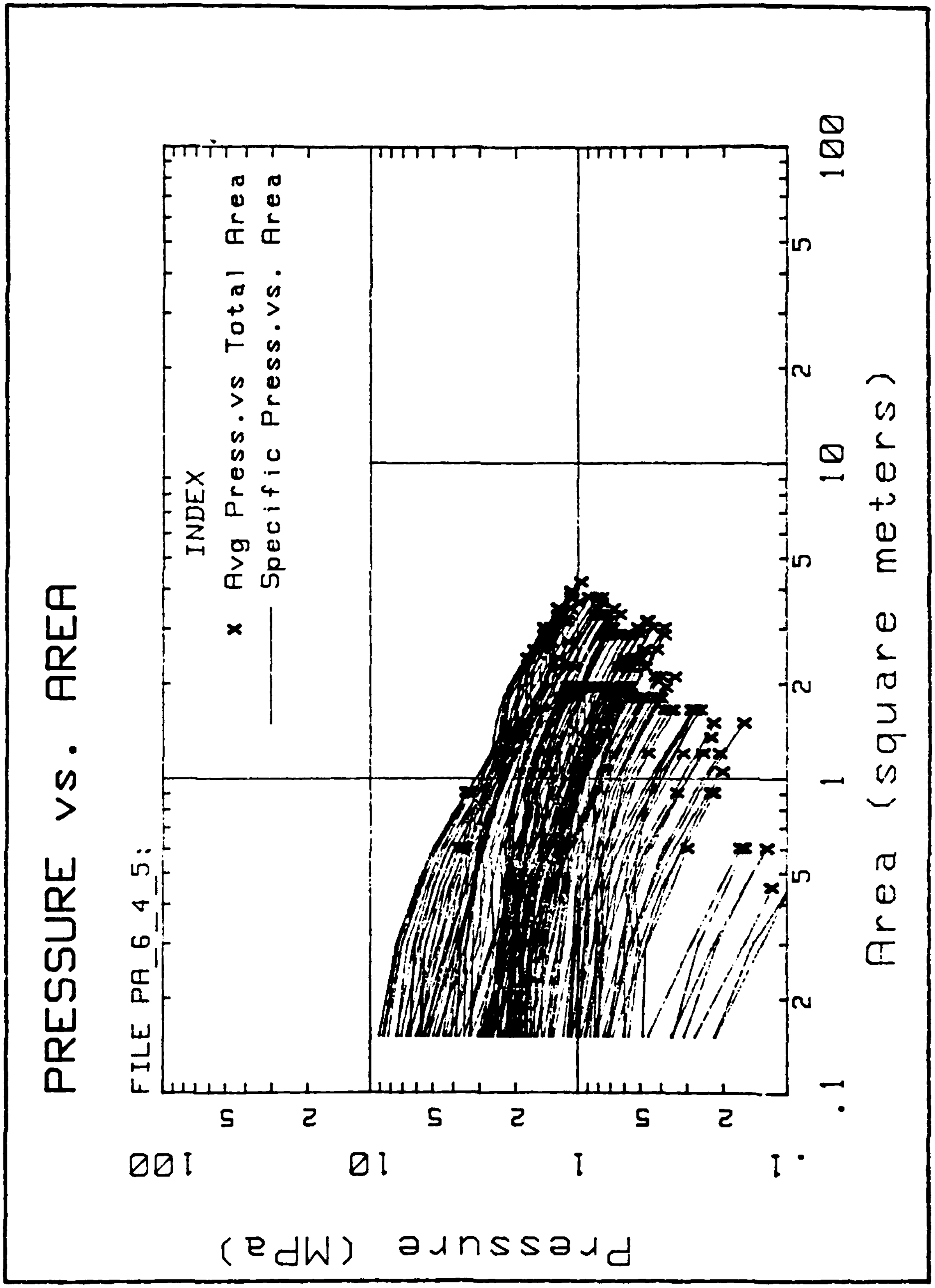

8 APR AT 18:39:39
Time Frame 39

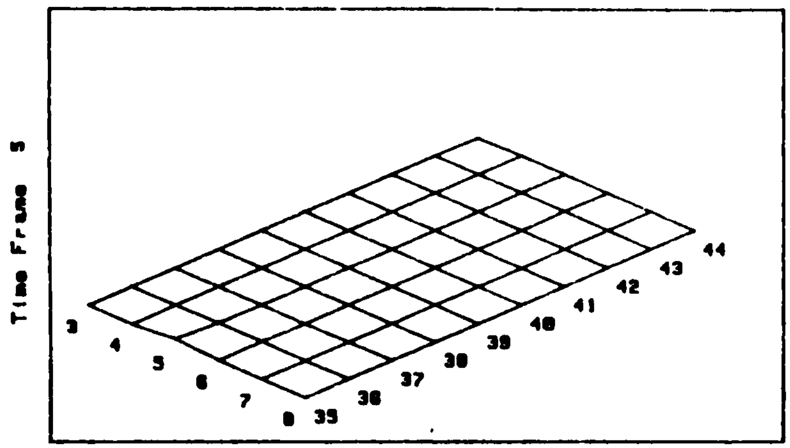

8 APR AT 18:39:39
Time Frame 40


8 APR AT 18:39:39
Time Frame 41

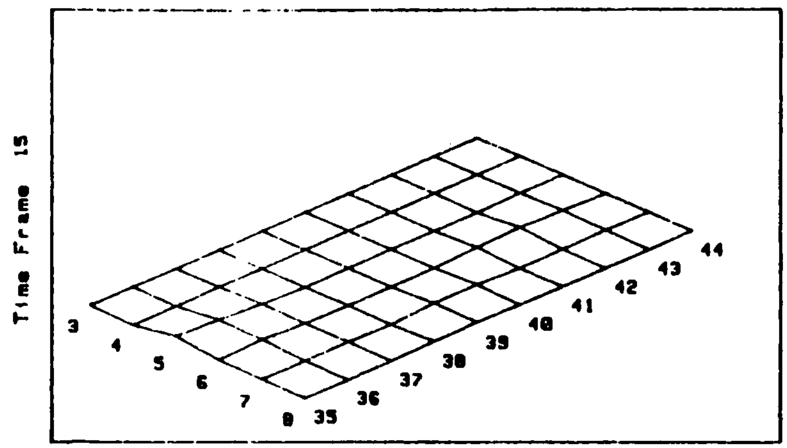

EVENT ON 20 APRIL AT 13:06:18
SPECIFIC PRESSURE
vs. AREA & TIME
FILE PA_6_4_5:
PRESSURE (MPa)
100
50
20
10
5
2
1
.5
.2
.1
AREA (m^2)
.1
.2
.5
1
2
5
10
20
50
100
TIME (sec)
0
1
2
3
4
5


PEAK &AVERAGE PRESSURES vs TIME
TOTAL CONTACT AREA vs. TIME
FILE 'PA_6_4_5:'
TIME (sec)
PEAK PRESSURE Po (MPa)
AVG.PRESSURE P1 (MPa)
TOTAL AREA(x10^-1 m^2)

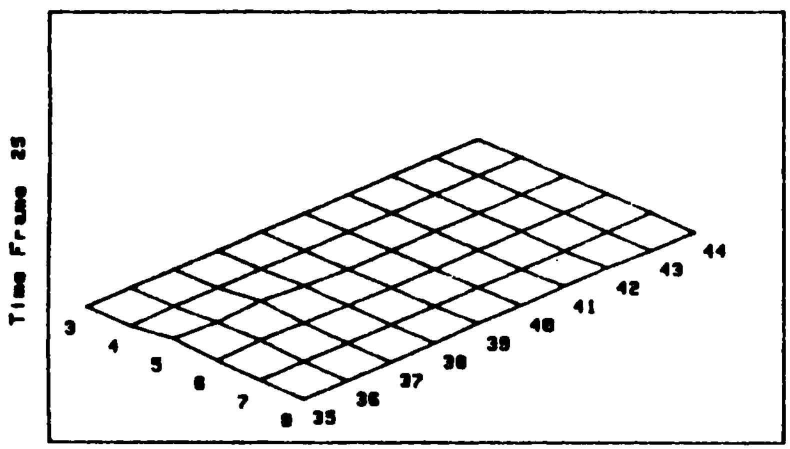

PRESSURE vs. AREA
FILE PA_6_4_5:
INDEX
x Avg Press.vs Total Area
— Specific Press.vs. Area
Area (square meters)
Pressure (MPa)
.1
1
10
100



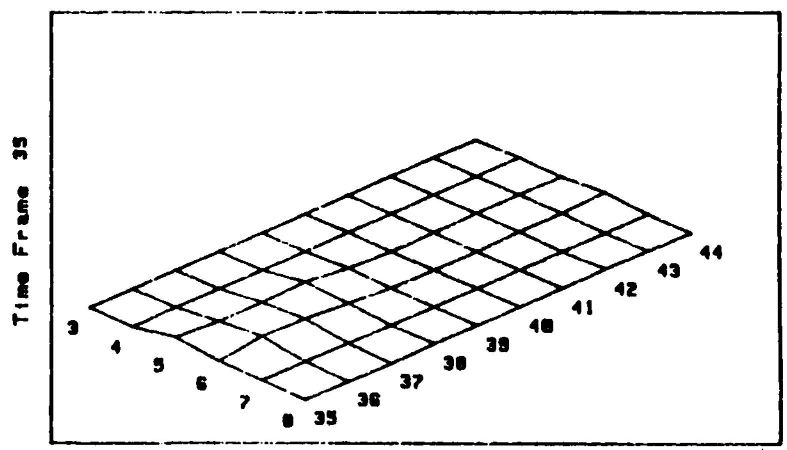
20 APR AT 13:6:18



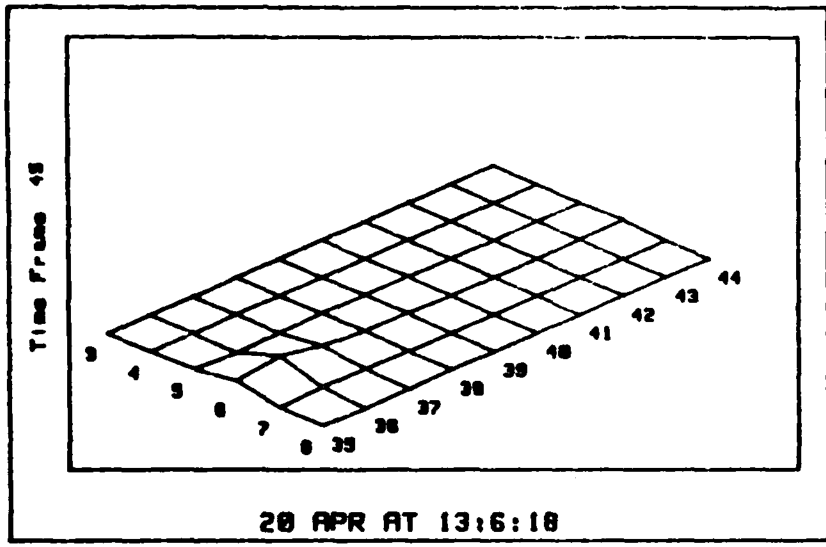
20 APR AT 13:6:18

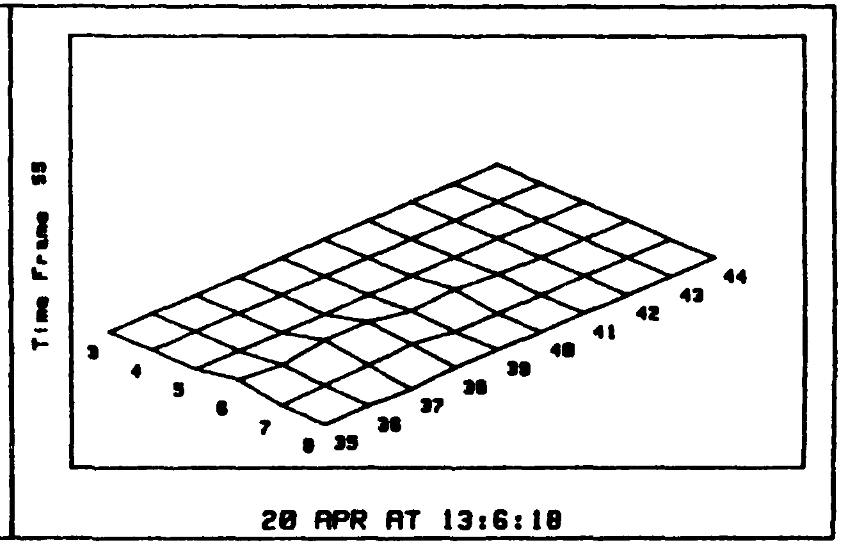


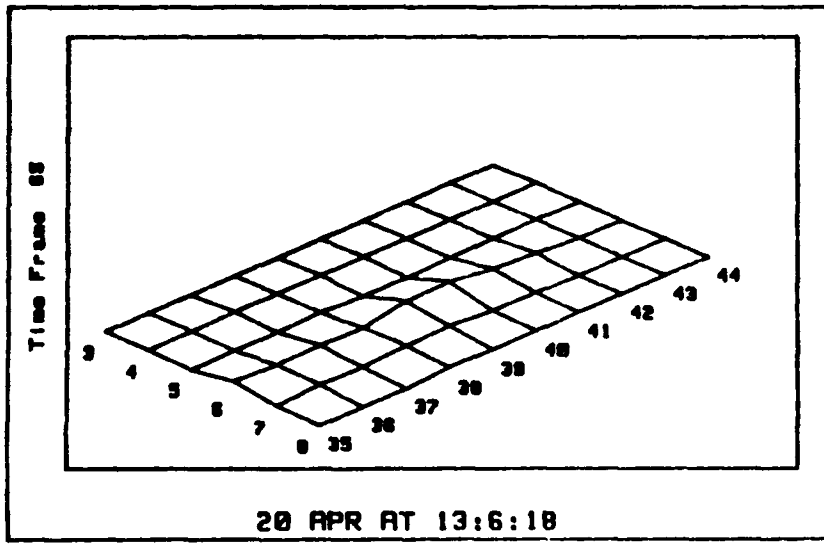
20 APR AT 13:6:18

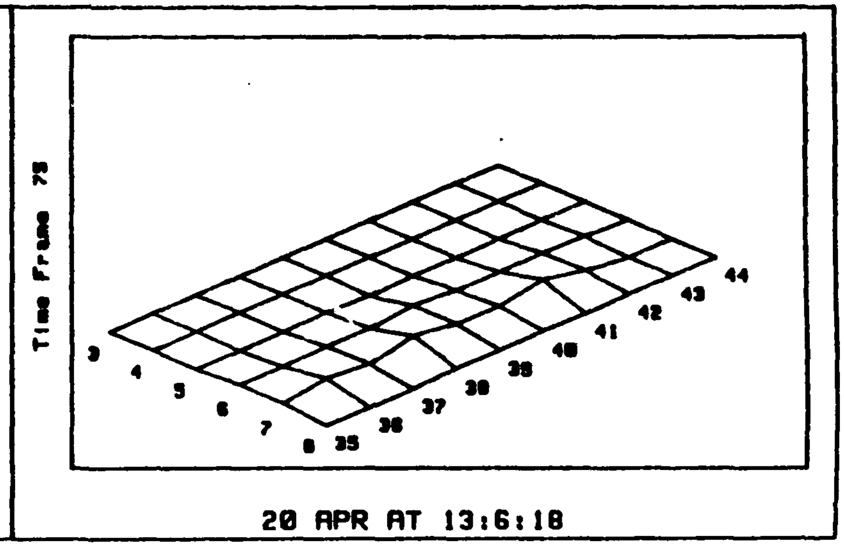


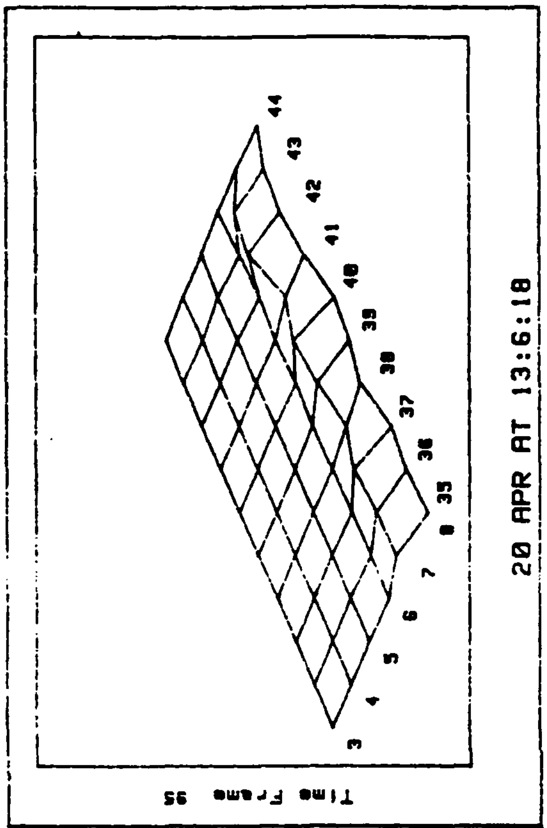
20 APR AT 13:6:18

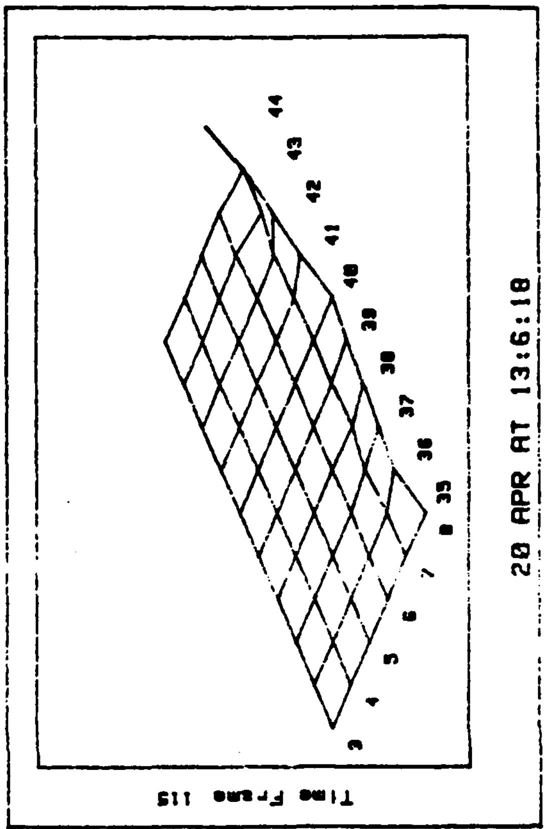

Time Frame 45
3
4
5
6
7
8
35
36
37
38
39
40
41
42
43
44
20 APR AT 13:6:18

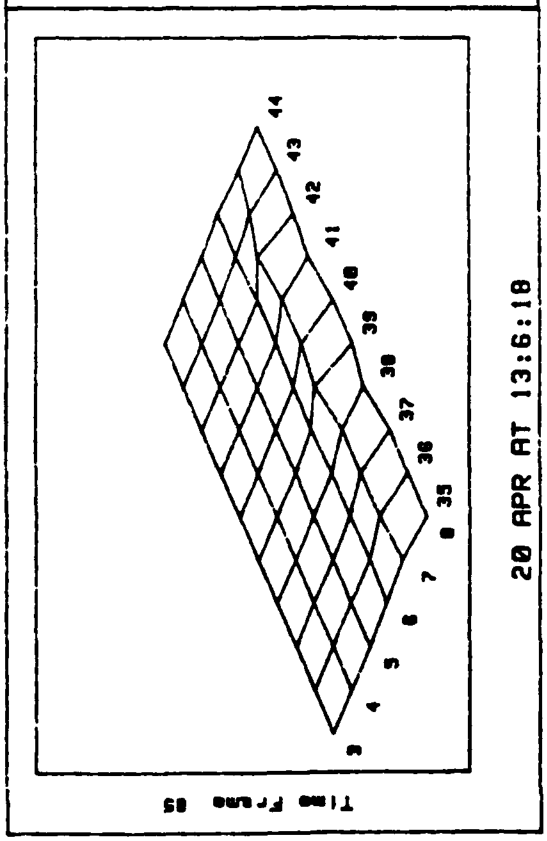

Time Frame 55
3
4
5
6
7
8
35
36
37
38
39
40
41
42
43
44
20 APR AT 13:6:18

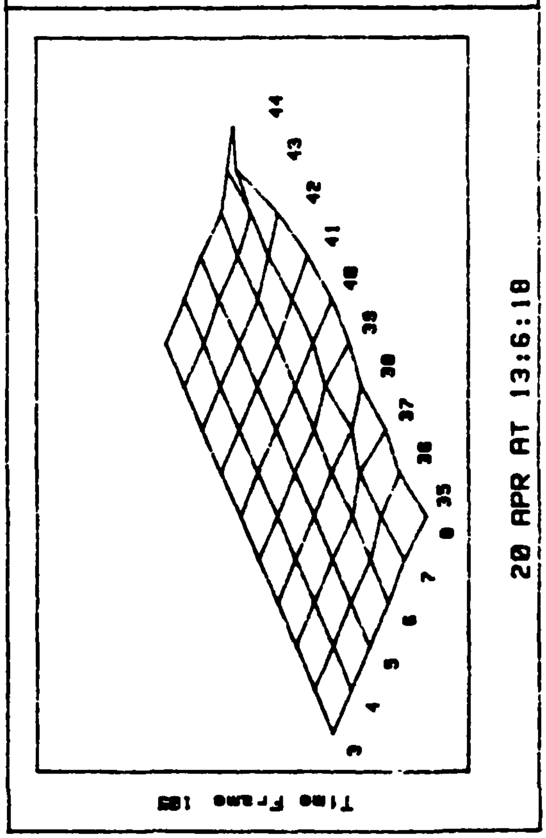

Time Frame 65
3
4
5
6
7
8
35
36
37
38
39
40
41
42
43
44
20 APR AT 13:6:18

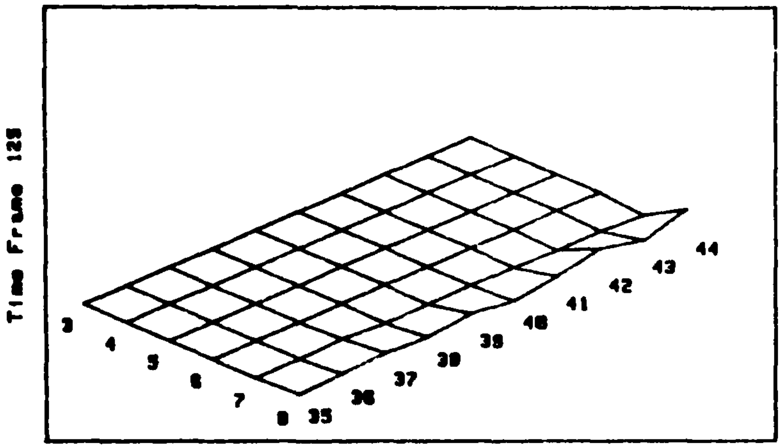

Time Frame 75
3
4
5
6
7
8
35
36
37
38
39
40
41
42
43
44
20 APR AT 13:6:18


Time Frame 95
20 APR AT 13:6:18

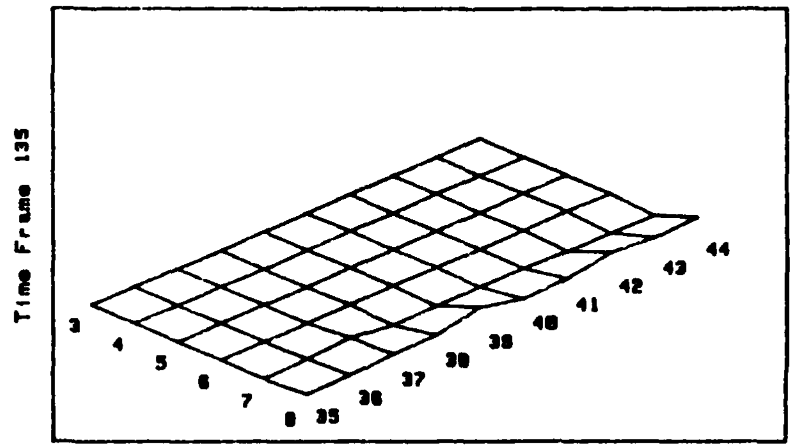

Time Frame 115
20 APR AT 13:6:18


Time Frame 85
20 APR AT 13:6:18

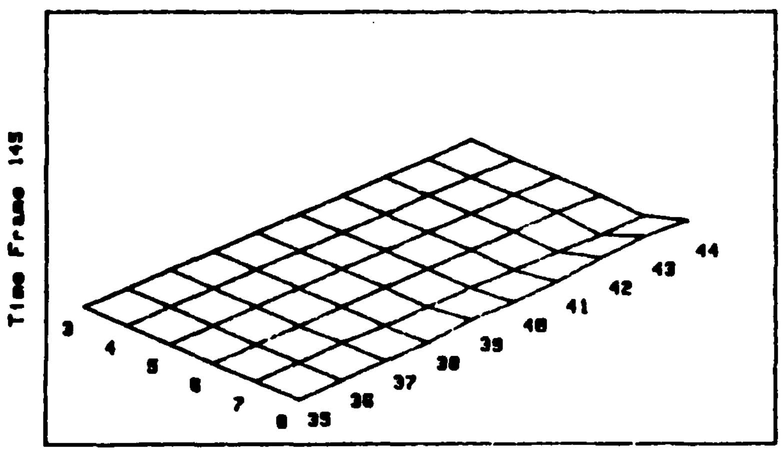

Time Frame
20 APR AT 13:6:18



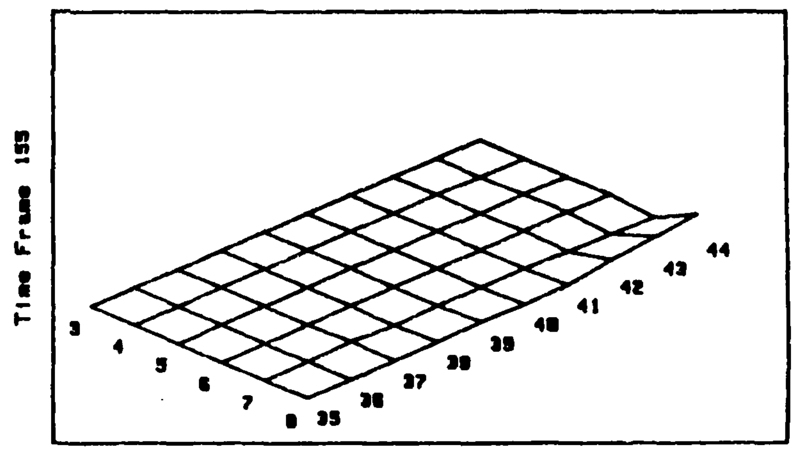
20 APR AT 13:6:18



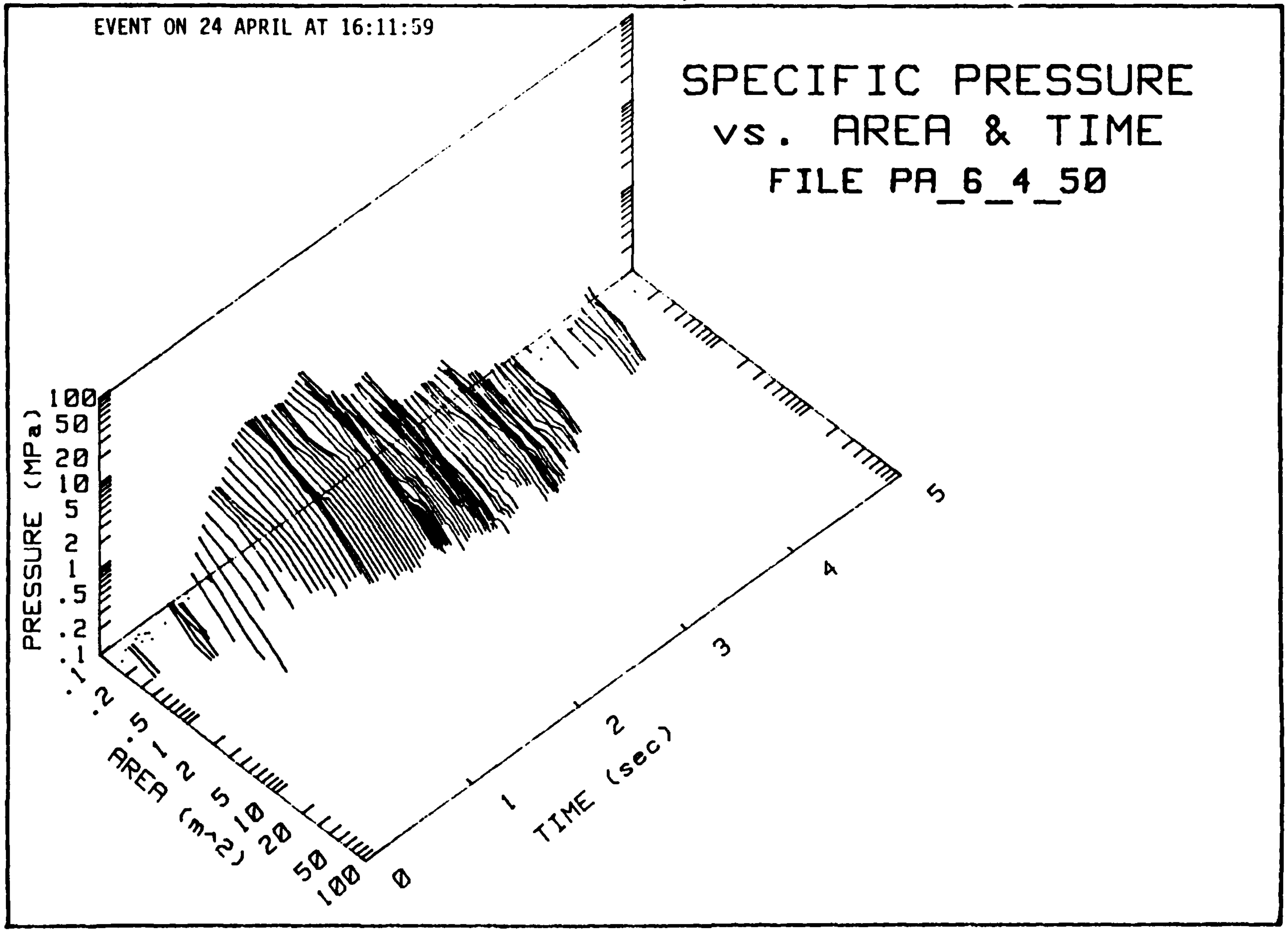
20 APR AT 13:6:18

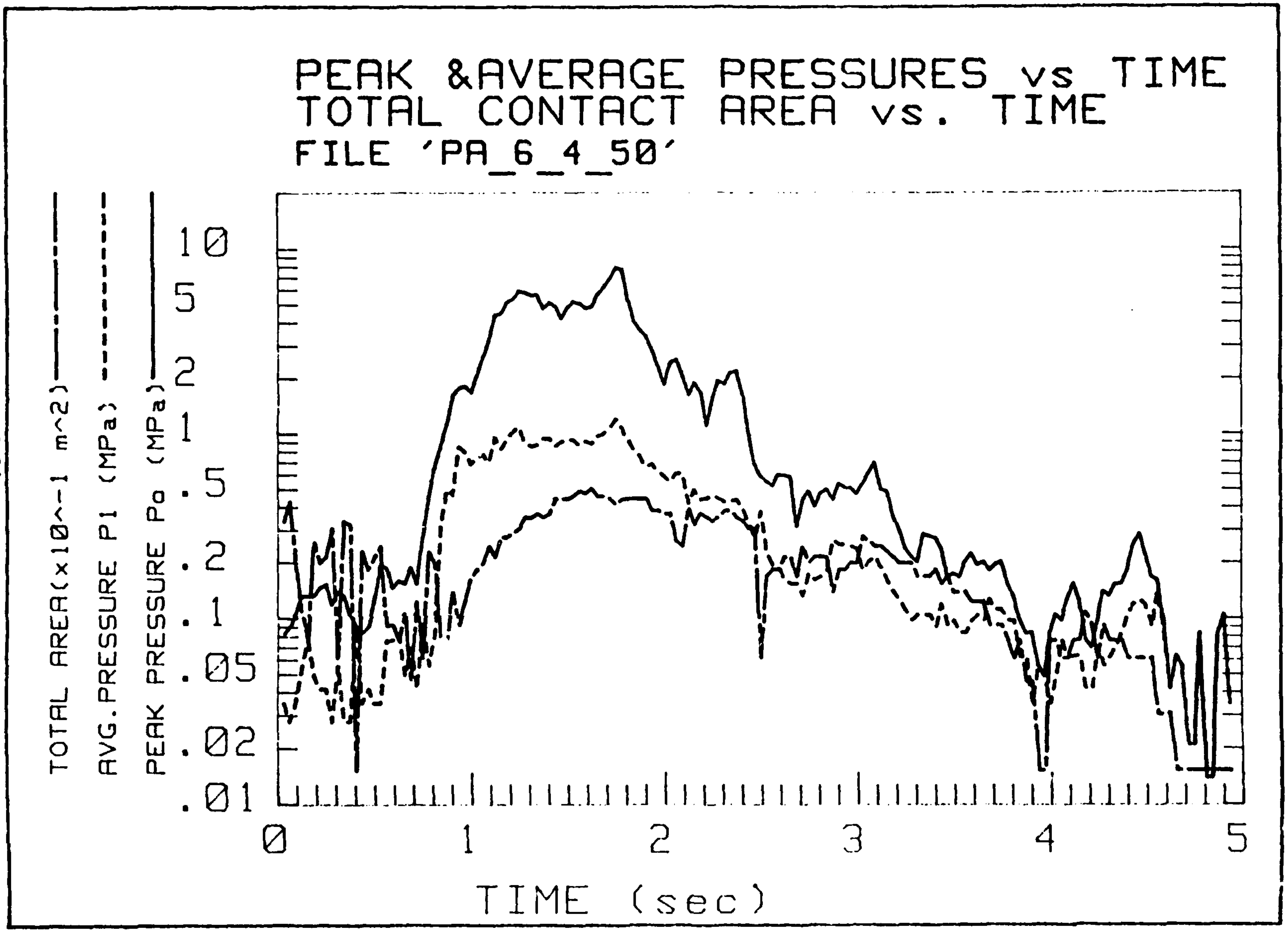


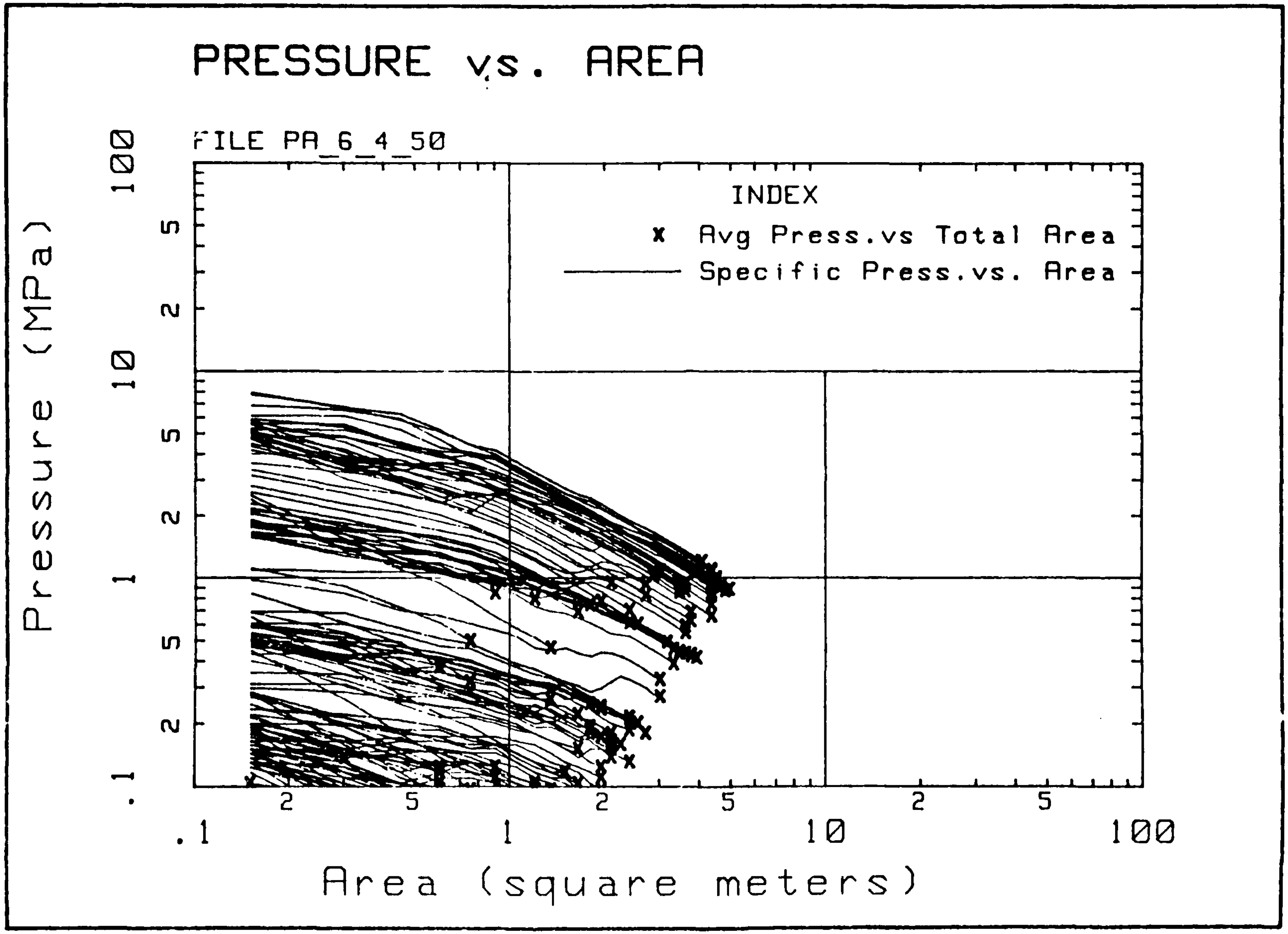
20 APR AT 13:6:18

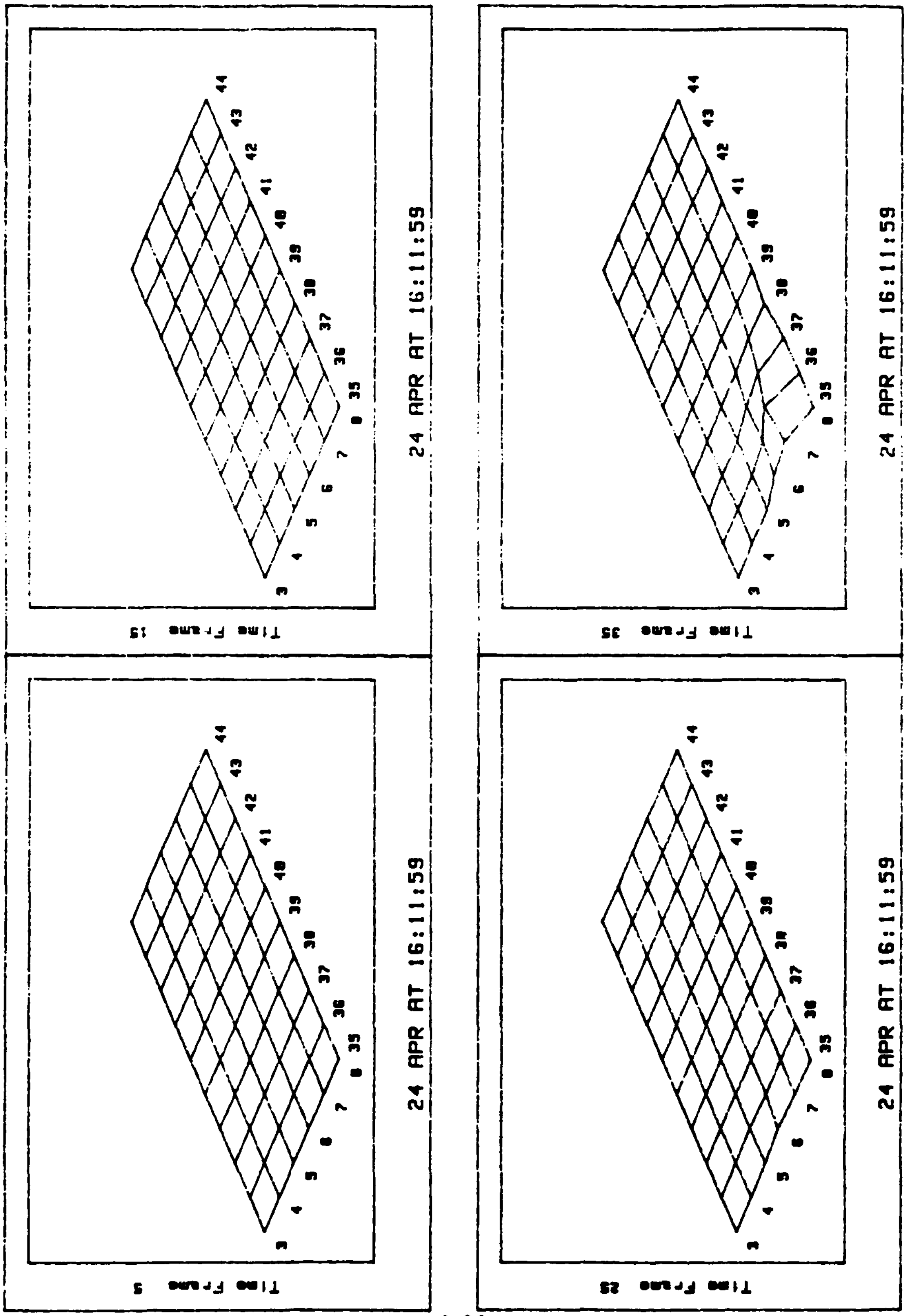


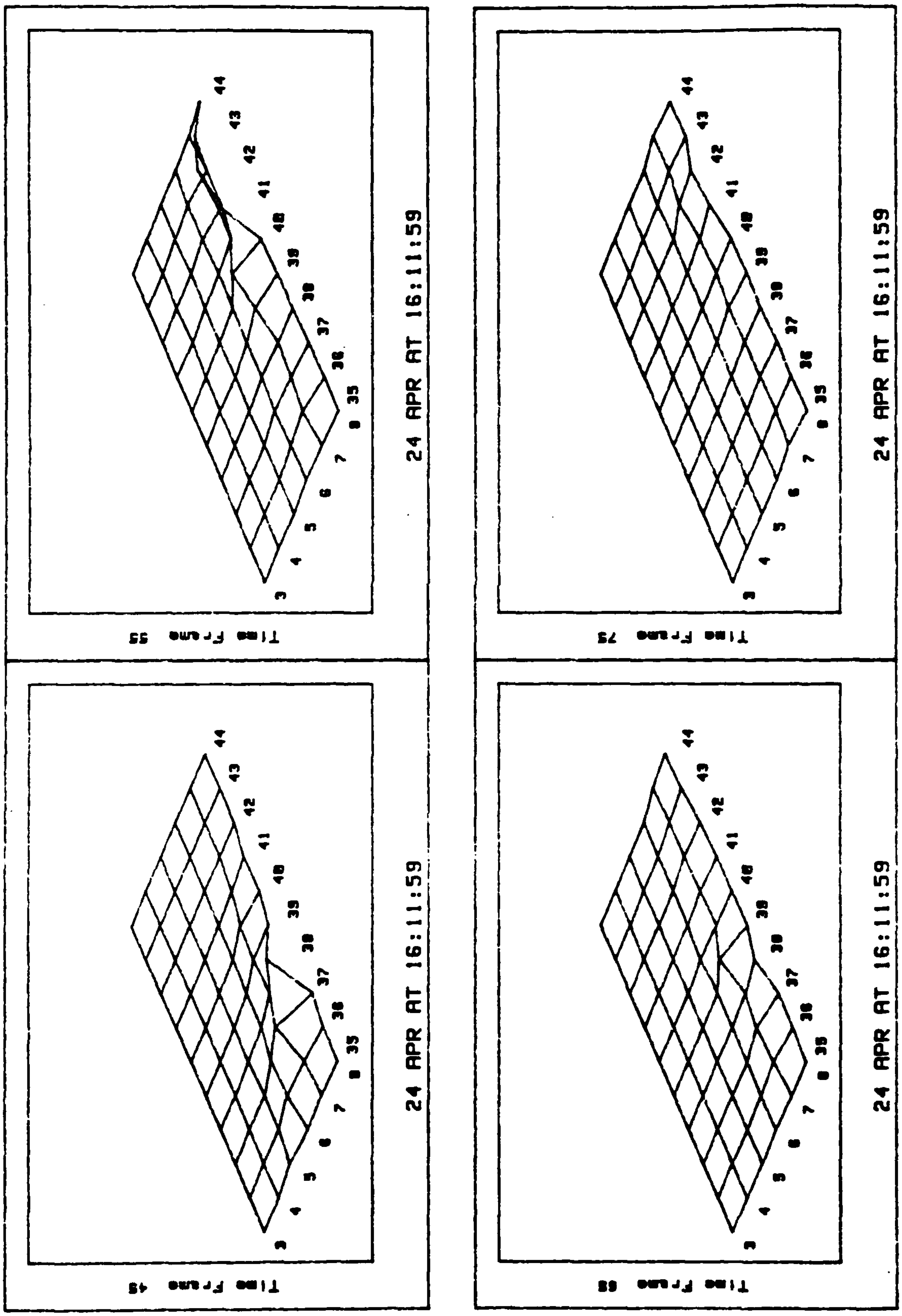
20 APR AT 13:6:18

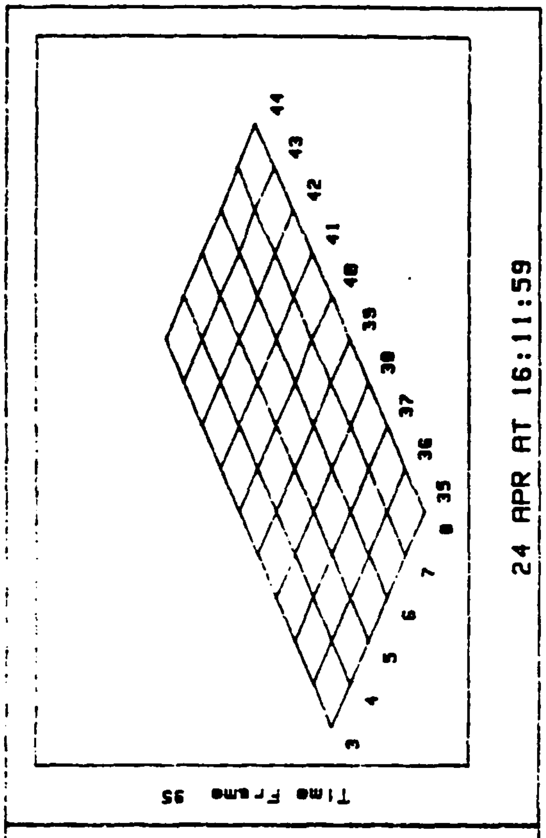

EVENT ON 24 APRIL AT 16:11:59
SPECIFIC PRESSURE
vs. AREA & TIME
FILE PA_6_4_50
PRESSURE (MPa)
100
50
20
10
5
2
1
.5
.2
.1
.1
.2
.5
1
2
5
10
20
50
100
AREA (m^2)
0
1
2
3
4
5
TIME (sec)

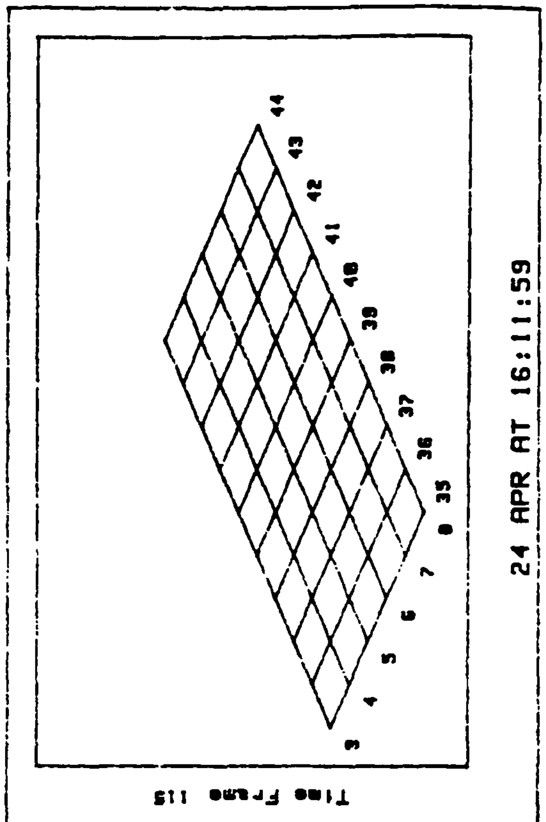

PEAK &AVERAGE PRESSURES vs TIME
TOTAL CONTACT AREA vs. TIME
FILE 'PA_6_4_50'
TOTAL AREA(x10^-1 m^2)
AVG.PRESSURE P1 (MPa)
PEAK PRESSURE Po (MPa)
10
5
2
1
.5
.2
.1
.05
.02
.01
0
1
2
3
4
5
TIME (sec)

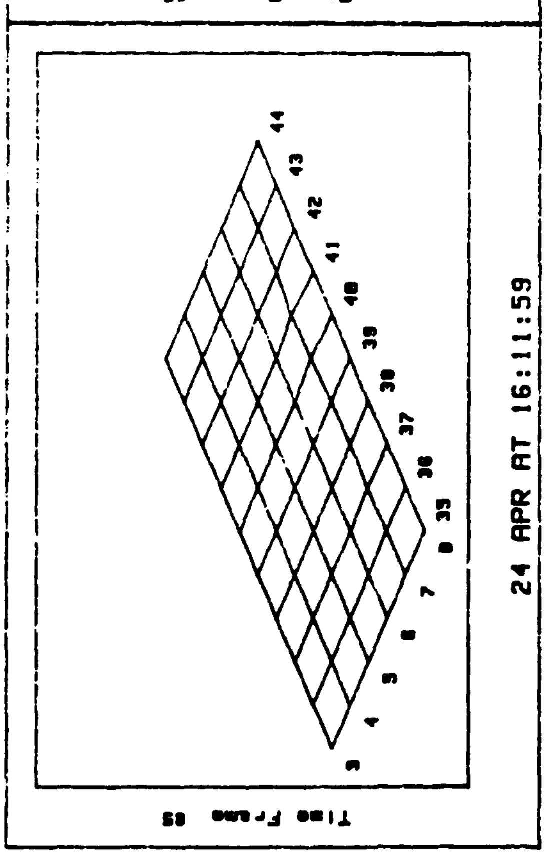

PRESSURE vs. AREA
FILE PA_6_4_50
INDEX
x Avg Press.vs Total Area
Specific Press.vs. Area
Pressure (MPa)
Area (square meters)
.1
1
10
100

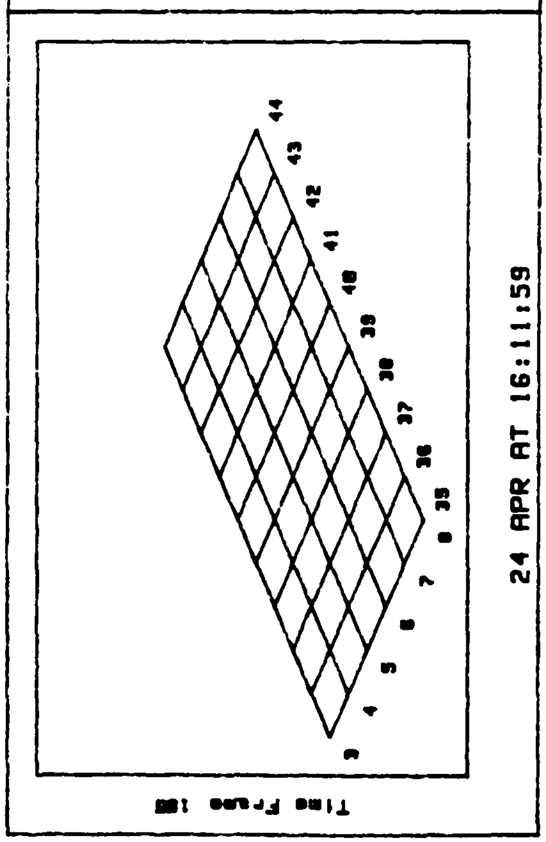

Time Frame 5
24 APR AT 16:11:59
Time Frame 15
24 APR AT 16:11:59
Time Frame 25
24 APR AT 16:11:59
Time Frame 35
24 APR AT 16:11:59
3 4 5 6 7 8 35 36 37 38 39 40 41 42 43 44

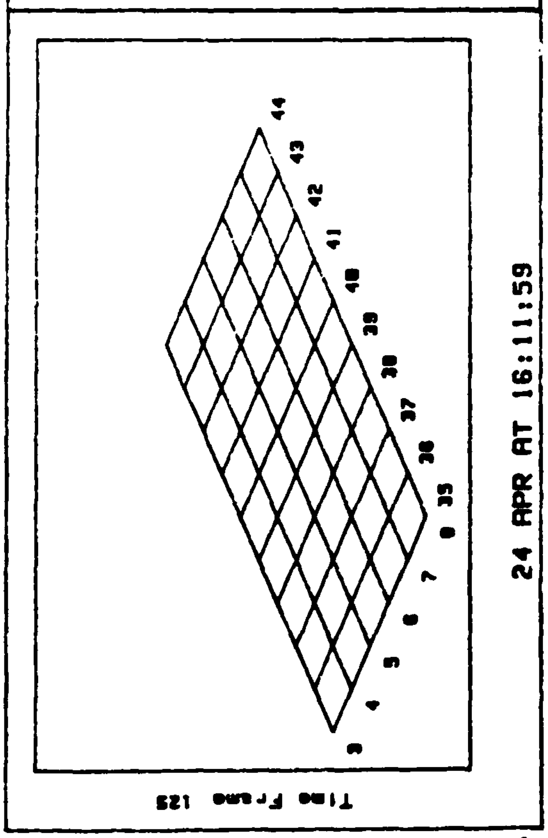

Time Frame 55
24 APR AT 16:11:59
Time Frame 75
24 APR AT 16:11:59
Time Frame 45
24 APR AT 16:11:59
Time Frame 65
24 APR AT 16:11:59

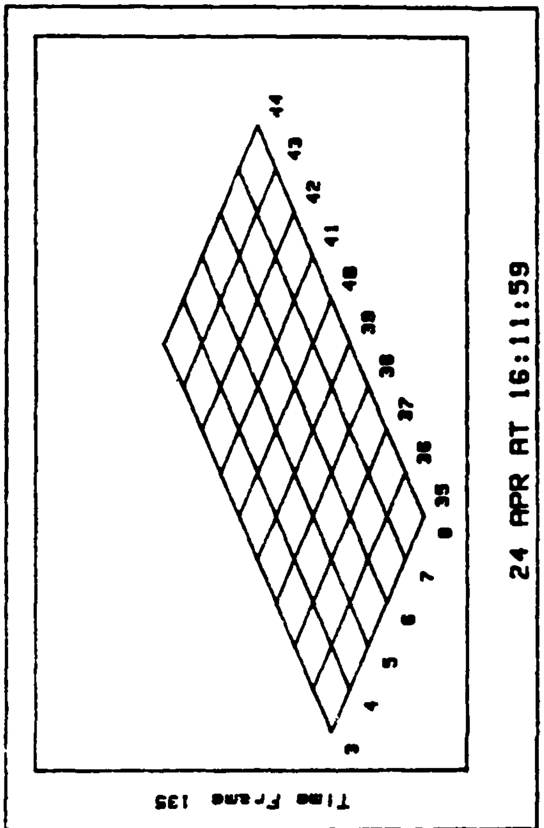

Time Frame 95
24 APR AT 16:11:59
3 4 5 6 7 0
35 36 37 38 39 40 41 42 43 44

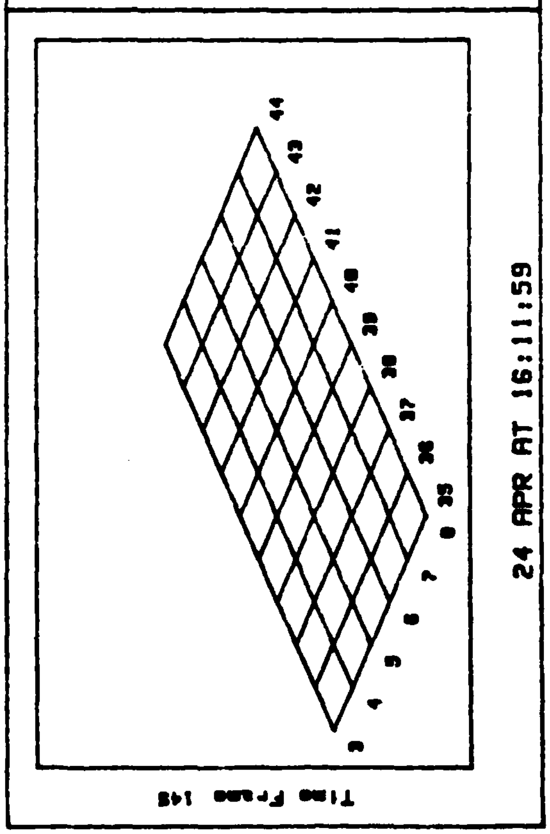

Time Frame 115
24 APR AT 16:11:59
3 4 5 6 7 0
35 36 37 38 39 40 41 42 43 44

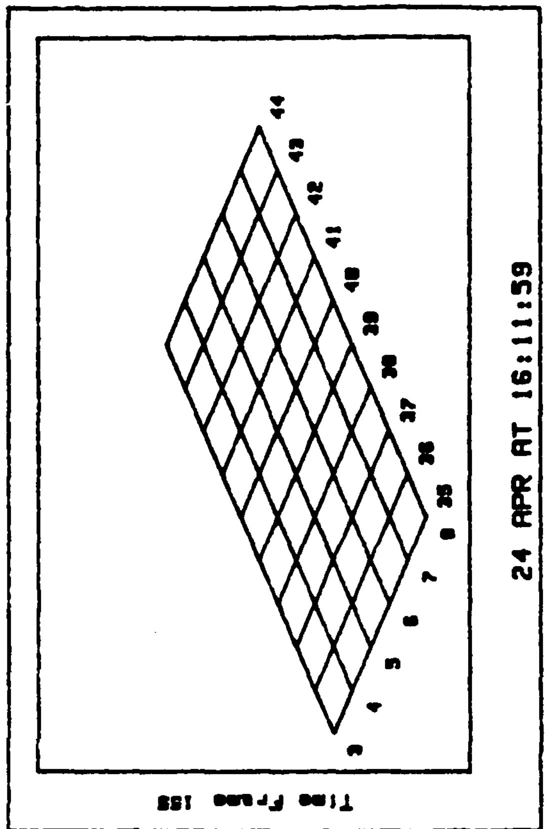

Time Frame 85
24 APR AT 16:11:59
3 4 5 6 7 0
35 36 37 38 39 40 41 42 43 44


Time Frame 105
24 APR AT 16:11:59
3 4 5 6 7 0
35 36 37 38 39 40 41 42 43 44


24 APR AT 16:11:59
Time Frame 125


24 APR AT 16:11:59
Time Frame 135


24 APR AT 16:11:59
Time Frame 145


24 APR AT 16:11:59
Time Frame 155

APPENDIX K

COMPUTER PLOTS OF THE COMPARISON OF MEASURED DATA
WITH EXTREME VALUE DISTRIBUTIONS

FIGURE .1

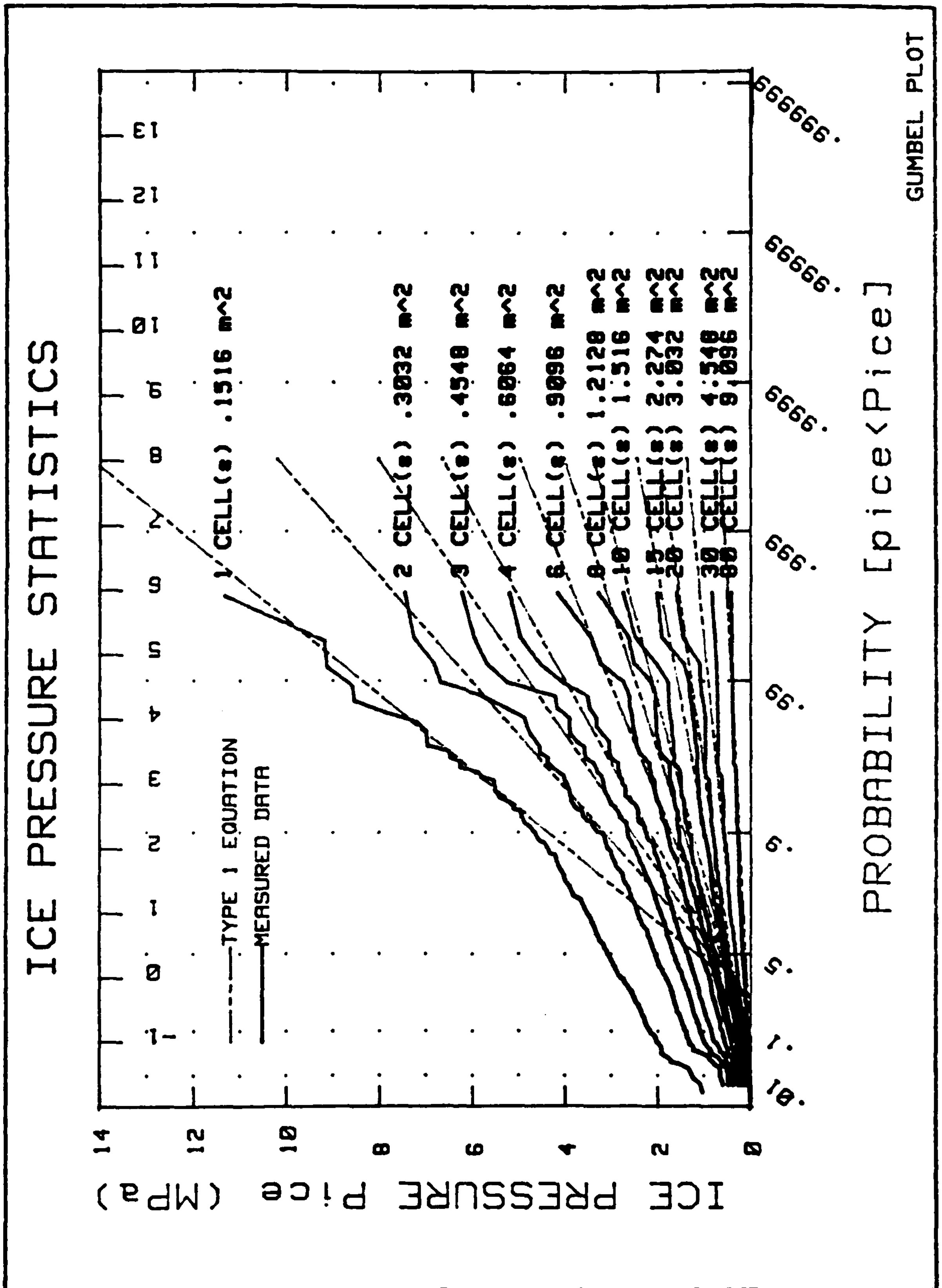
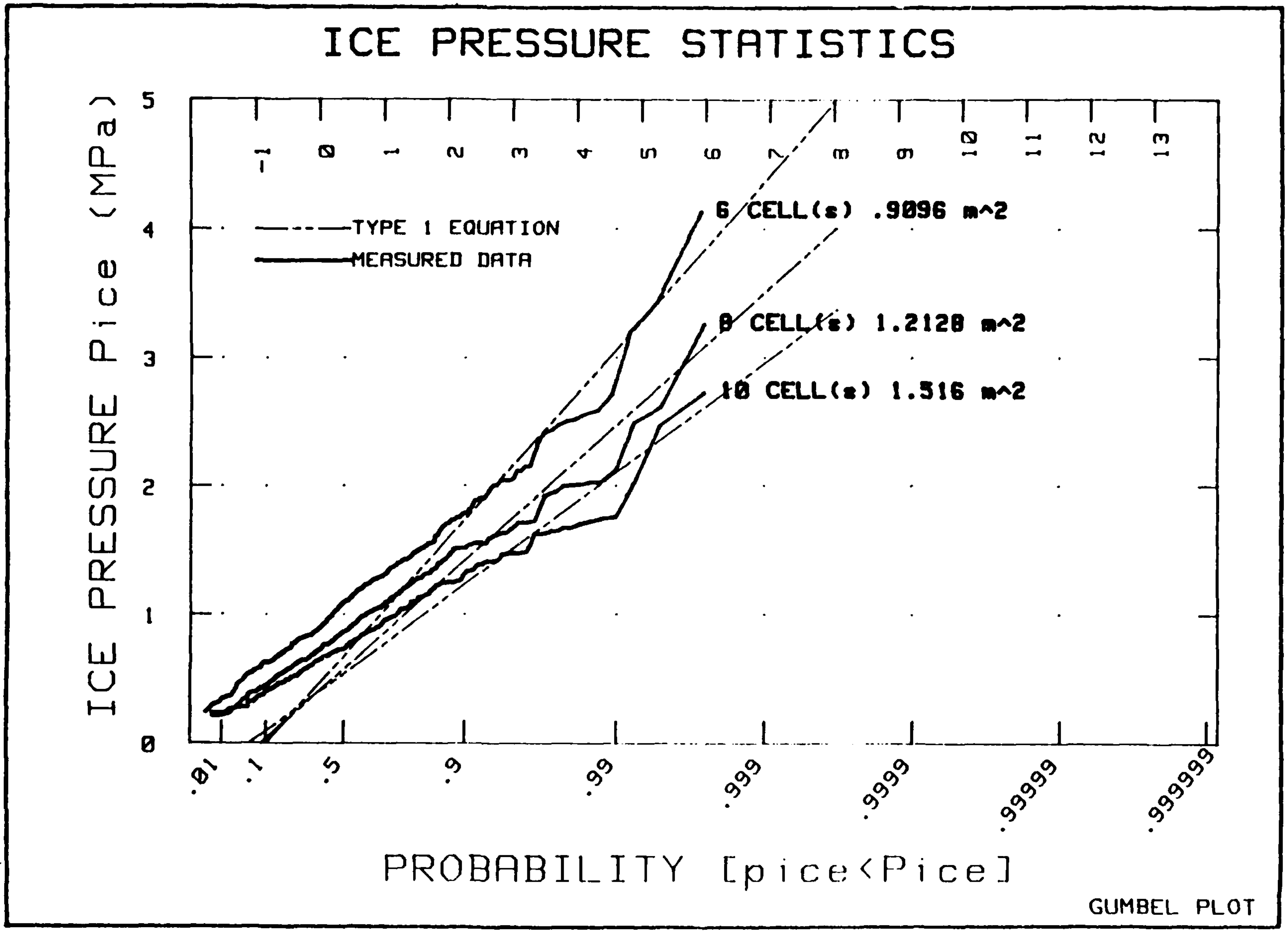


FIGURE .2



ICE PRESSURE STATISTICS
TYPE 1 EQUATION
MEASURED DATA
6 CELL(s) .9096 m^2
8 CELL(s) 1.2128 m^2
10 CELL(s) 1.516 m^2
ICE PRESSURE Pice (MPa)
0
1
2
3
4
5
-1
0
1
2
3
4
5
6
7
8
9
10
11
12
13
.01
.1
.5
.9
.99
.999
.9999
.99999
.999999
PROBABILITY [pice<Pice]
GUMBEL PLOT

FIGURE .3

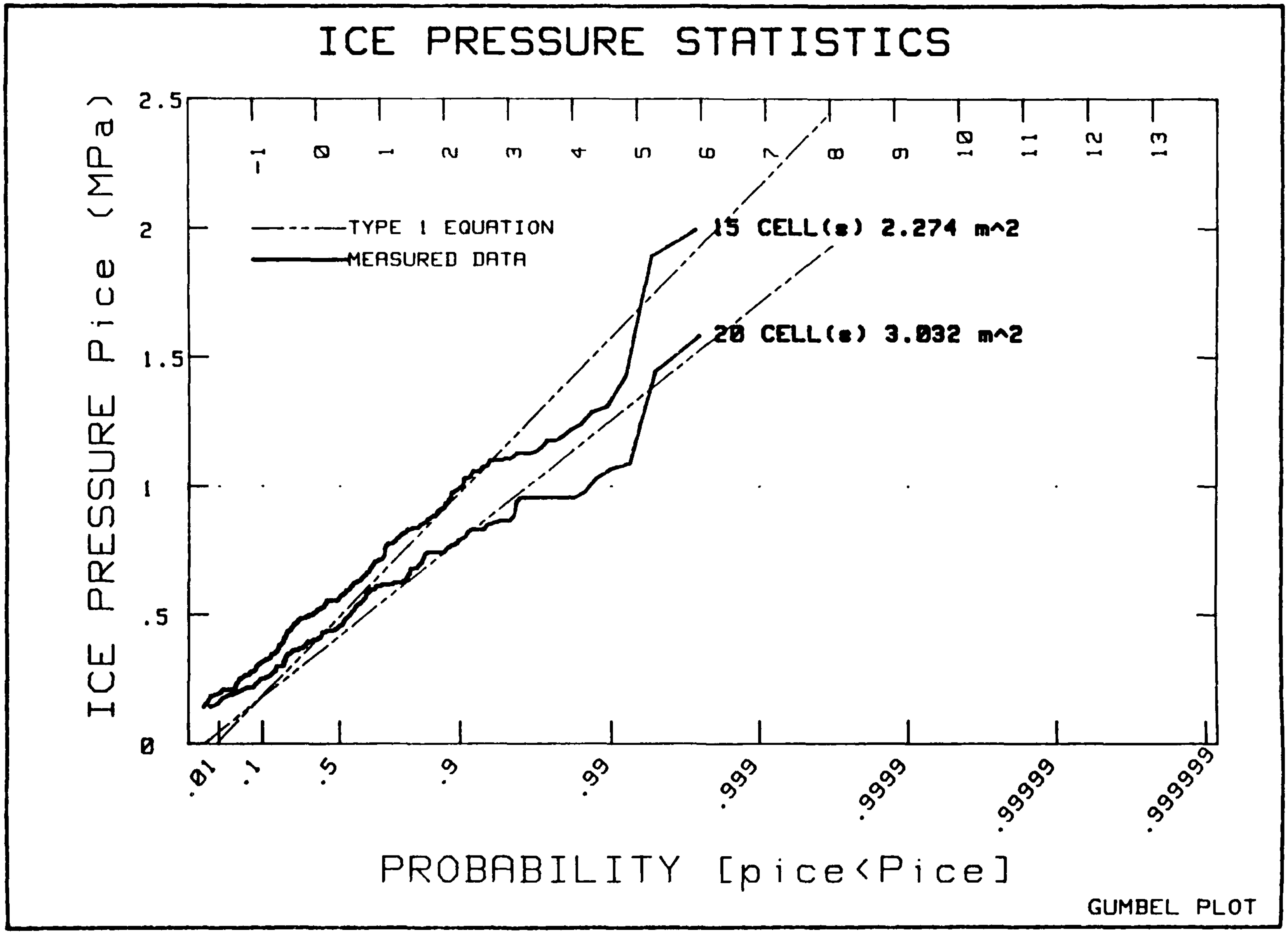
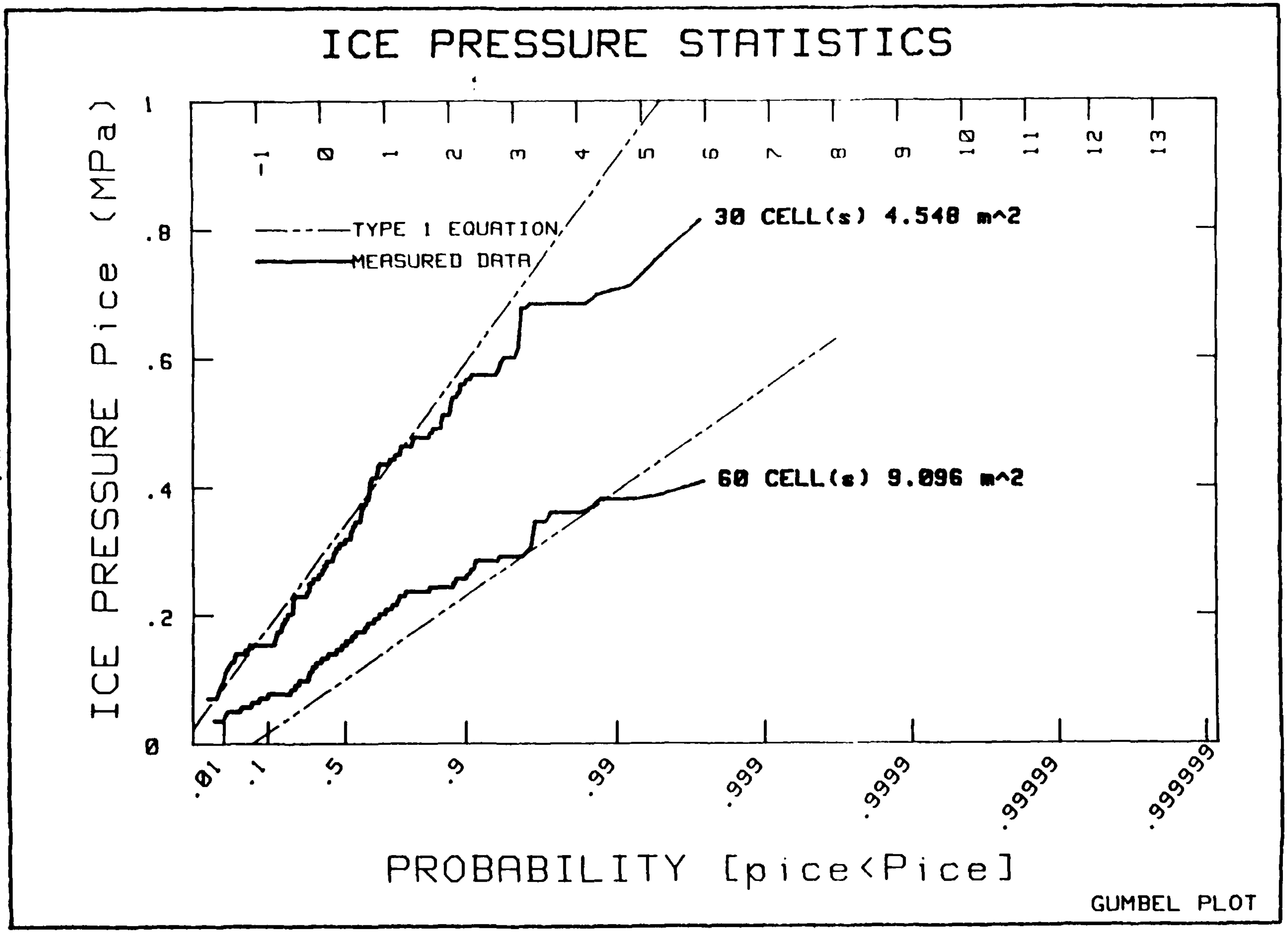
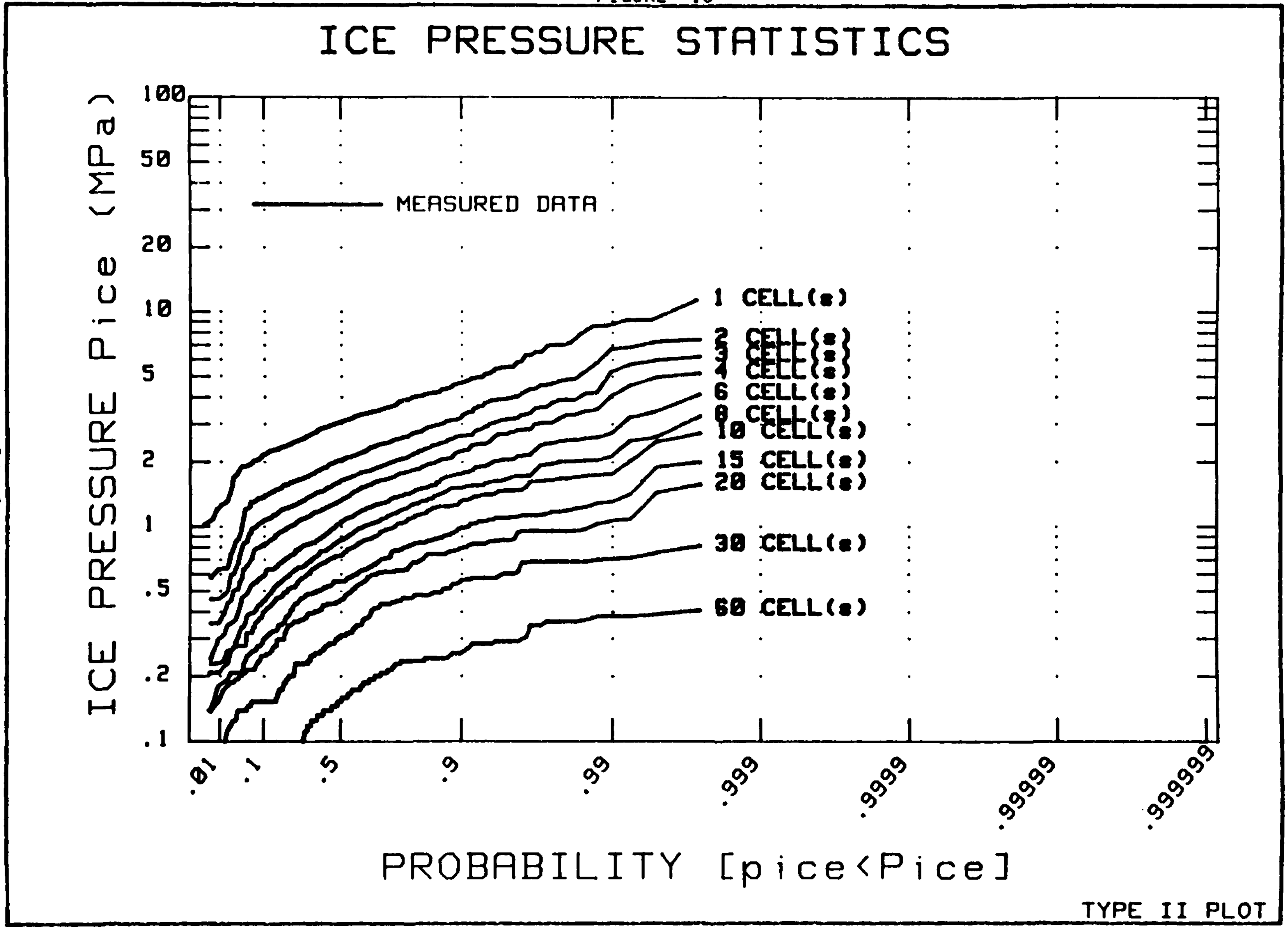

ICE PRESSURE STATISTICS
ICE PRESSURE Pice (MPa)
2.5
2
1.5
1
.5
0
-1
0
1
2
3
4
5
6
7
8
9
10
11
12
13
TYPE I EQUATION
MEASURED DATA
15 CELL(s) 2.274 m^2
20 CELL(s) 3.032 m^2
.01
.1
.5
.9
.99
.999
.9999
.99999
.999999
PROBABILITY [pice<Pice]
GUMBEL PLOT

FIGURE .4



ICE PRESSURE STATISTICS
ICE PRESSURE Pice (MPa)
1
.8
.6
.4
.2
0
-1
0
1
2
3
4
5
6
7
8
9
10
11
12
13
TYPE 1 EQUATION
MEASURED DATA
30 CELL(s) 4.548 m^2
60 CELL(s) 9.096 m^2
.01
.1
.5
.9
.99
.999
.9999
.99999
.999999
PROBABILITY [pice<Pice]
GUMBEL PLOT

FIGURE .5



ICE PRESSURE STATISTICS
ICE PRESSURE Pice (MPa)
100
50
20
10
5
2
1
.5
.2
.1
MEASURED DATA
1 CELL(s)
2 CELL(s)
3 CELL(s)
4 CELL(s)
6 CELL(s)
8 CELL(s)
10 CELL(s)
15 CELL(s)
20 CELL(s)
30 CELL(s)
60 CELL(s)
.01
.1
.5
.9
.99
.999
.9999
.99999
.999999
PROBABILITY [pice<Pice]
TYPE II PLOT

APPENDIX L

NON-DIMENSIONAL DATA USED IN FIGURE 42

NDF = Non-dimensional force = $\frac{F}{\rho g h^3}$

NDV = Non-dimensional normal velocity = $\frac{V_n}{\sqrt{gh}}$

NDS = Non-dimensional flexural strength = $\frac{\sigma_f}{\rho g h}$

FIRST YEAR IMPACTS

DATA FOR FLEXURAL STRENGTH OF 78.4 PSI

IMPACT NO	NDF	NDV	NDS	NDV*NDS
1	7549.63	.12	235.20	27.49
2	2590.00	1.05	176.40	184.49
3	3045.00	.85	176.40	150.20
4	4690.00	.79	176.40	138.74
5	3255.00	.70	176.40	124.08
6	3500.00	.60	176.40	106.60
7	4690.00	.63	176.40	111.50
8	4970.00	.60	176.40	105.29
9	3045.00	.60	176.40	105.05
10	8925.00	.66	176.40	116.66
11	2345.00	.79	176.40	138.99
12	3815.00	.60	176.40	105.37
13	4620.00	.83	176.40	146.51
14	3535.00	.81	176.40	143.17
15	262.50	.37	88.20	32.60
16	463.75	.51	88.20	44.54
17	472.50	.59	88.20	51.96
18	450.62	.56	88.20	49.62
19	686.88	.77	88.20	68.08
20	647.50	.65	88.20	57.32
21	167.22	.19	58.80	11.27
22	149.07	.34	58.80	20.03
23	116.67	.35	58.80	20.45
24	114.07	.38	58.80	22.51
25	163.33	.38	58.80	22.39

FIRST YEAR IMPACTS

DATA FOR FLEXURAL STRENGTH OF 78.4 PSI

IMPACT NO	NDF	NDV	NDS	NDV*NDS
26	197.04	.26	58.80	15.29
27	264.44	.47	58.80	27.54
28	421.30	.26	58.80	15.10
29	112.78	.34	58.80	20.12
30	107.59	.32	58.80	19.02
31	108.89	.46	58.80	27.31
32	187.96	.11	58.80	6.50
33	155.56	.50	58.80	29.26
34	200.93	.09	58.80	5.58
35	232.04	.10	58.80	5.86
36	237.22	.06	58.80	3.63
37	103.70	.21	58.80	12.47
38	130.93	.52	58.80	30.53
39	98.52	.35	58.80	20.36
40	186.67	.24	58.80	14.02
41	277.41	.19	58.80	11.02
42	177.59	.61	58.80	35.99
43	127.04	.56	58.80	32.81
44	64.81	.44	58.80	25.89
45	347.41	.64	58.80	37.74
46	123.15	.58	58.80	34.22
47	142.59	.37	58.80	21.49
48	85.56	.23	58.80	13.39
49	137.41	.51	58.80	29.73
50	93.33	.25	58.80	14.86
51	90.74	.20	58.80	12.05
52	92.04	.27	58.80	15.86
53	81.67	.15	58.80	8.95
54	110.19	.13	58.80	7.92
55	94.63	.32	58.80	19.05
56	186.67	.37	58.80	21.99
57	95.93	.27	58.80	16.17
58	101.11	.27	58.80	16.03
59	129.63	.15	58.80	8.71
60	133.52	.06	58.80	3.53
61	76.48	.36	58.80	21.41
62	155.56	.26	58.80	15.56
63	124.44	.22	58.80	12.72
64	110.19	.17	58.80	9.91
65	98.52	.15	58.80	8.54
66	132.22	.11	58.80	6.68
67	138.70	.16	58.80	9.53
68	162.04	.10	58.80	5.80
69	151.67	.39	58.80	23.21
70	129.63	.07	58.80	4.11

FIRST YEAR IMPACTS

DATA FOR FLEXURAL STRENGTH OF 78.4 PSI

IMPACT NO	NDF	NDV	NDS	NDV*NDS
71	123.15	.43	58.80	25.37
72	98.52	.51	58.80	30.07
73	234.63	.50	58.80	29.34
74	115.37	.46	58.80	26.78
75	263.15	.53	58.80	31.31
76	234.63	.36	58.80	21.41
77	264.44	.29	58.80	16.97
78	123.15	.41	58.80	24.17
79	57.04	.33	58.80	19.67
80	160.74	.38	58.80	22.36
81	79.07	.52	58.80	30.59
82	99.81	.35	58.80	20.45
83	92.04	.29	58.80	17.31
84	76.48	.29	58.80	17.20
85	110.19	.43	58.80	25.04
86	176.30	.35	58.80	20.41
87	106.30	.47	58.80	27.74
88	168.52	.47	58.80	27.91
89	79.07	.25	58.80	14.68
90	97.22	.29	58.80	17.17
91	59.61	.18	44.10	8.08
92	38.83	.40	44.10	17.73
93	59.06	.44	44.10	19.59
94	56.87	.38	44.10	16.58
95	78.20	.49	44.10	21.43
96	44.84	.20	44.10	8.70
97	41.02	.19	44.10	8.35
98	83.13	.16	44.10	7.21
99	45.94	.28	44.10	12.54
100	66.17	.20	44.10	8.65
101	68.36	.37	44.10	16.13
102	54.14	.13	44.10	5.75
103	36.09	.17	44.10	7.43
104	47.58	.14	44.10	6.33
105	44.30	.16	44.10	7.06
106	63.44	.08	44.10	3.58
107	82.58	.25	44.10	10.97
108	43.75	.02	44.10	.71
109	64.53	.06	44.10	2.61
110	80.94	.02	44.10	.90
111	43.75	.41	44.10	18.13
112	17.18	.11	29.40	3.10
113	22.69	.19	29.40	5.53
114	19.28	.34	29.40	9.96
115	16.20	.20	29.40	5.91

FIRST YEAR IMPACTS

DATA FOR FLEXURAL STRENGTH OF 78.4 PSI

IMPACT NO	NDF	NDV	NDS	NDV*NDS
116	19.44	.11	29.40	3.24
117	35.00	.29	29.40	8.66
118	14.75	.28	29.40	8.16
119	17.18	.27	29.40	7.97
120	19.61	.17	29.40	5.00
121	15.72	.32	29.40	9.42
122	11.67	.36	29.40	10.57
123	12.64	.31	29.40	9.00
124	32.73	.23	29.40	6.87
125	24.63	.24	29.40	7.07
126	18.47	.36	29.40	10.63
127	13.61	.19	29.40	5.66
128	32.89	.10	29.40	2.97
129	26.25	.12	29.40	3.47
130	11.50	.08	29.40	2.41
131	26.74	.16	29.40	4.80
132	12.96	.11	29.40	3.34
133	15.56	.22	29.40	6.36
134	31.11	.26	29.40	7.71
135	24.63	.06	29.40	1.71
136	8.75	.24	29.40	6.95
137	36.62	.27	29.40	7.96
138	14.42	.19	29.40	5.54
139	20.25	.33	29.40	9.85
140	13.77	.37	29.40	10.84
141	13.29	.33	29.40	9.75
142	20.74	.18	29.40	5.28
143	21.71	.23	29.40	6.81
144	18.63	.24	29.40	7.10
145	11.18	.26	29.40	7.69
146	23.50	.12	29.40	3.65
147	25.28	.12	29.40	3.49
148	29.65	.28	29.40	8.32
149	10.21	.13	29.40	3.82
150	28.52	.08	29.40	2.35
151	9.88	.27	29.40	7.95

MULTI-YEAR DATA

IMPACT NO	NDF	NDV	NDS	NDV*NDS
1	1.64	.01	15.86	.14
2	.83	.02	15.88	.26
3	.57	.02	13.62	.22
4	.83	.02	15.88	.36
5	1.06	.02	15.86	.39
6	.56	.03	15.86	.43
7	1.90	.03	15.86	.48
8	.76	.03	13.29	.38
9	.52	.03	13.62	.44
10	.54	.03	14.38	.48
11	1.18	.04	15.88	.71
12	1.14	.05	15.88	.75
13	1.04	.05	14.38	.72
14	.59	.06	14.38	.86
15	1.78	.07	15.88	1.08
16	3.52	.07	15.86	1.12
17	.92	.07	13.29	.88
18	1.16	.07	15.88	1.13
19	.85	.07	15.88	1.15
20	.85	.07	15.88	1.17
21	.54	.07	13.62	1.02
22	.52	.07	14.38	1.07
23	1.04	.08	15.88	1.31
24	.72	.09	19.10	1.70
25	1.13	.09	15.86	1.37
26	1.16	.09	15.88	1.45
27	1.70	.09	15.88	1.49
28	.80	.09	13.29	1.18
29	1.22	.09	14.38	1.27
30	1.29	.10	15.88	1.58
31	.80	.10	15.88	1.60
32	.99	.10	14.38	1.40
33	2.22	.10	15.88	1.66
34	.29	.10	13.54	1.32
35	.74	.12	15.86	1.84
36	1.14	.11	15.88	1.81
37	1.35	.12	15.88	1.85
38	1.75	.11	14.38	1.60
39	1.99	.12	15.88	1.92
40	.76	.12	15.88	1.94
41	.58	.12	13.62	1.65
42	1.83	.14	15.86	2.17
43	.79	.13	13.62	1.84
44	.85	.13	14.38	1 89
45	2.16	.14	15.88	2.29
46	2.67	.17	23.12	3.96
47	.75	.14	14.38	1.98
48	1.52	.15	15.88	2.36
49	.42	.15	15.88	2.40
50	1.38	.16	15.86	2.47
51	.98	.14	14.38	2.06
52	2.48	.16	15.86	2.61
53	.88	.16	15.88	2.57

FIRST YEAR IMPACTS

DATA FOR FLEXURAL STRENGTH OF 78.4 PSI

IMPACT NO	NDF	NDV	NDS	NDV*NDS
54	.64	.15	14.38	2.21
55	1.40	.16	13.62	2.16
56	2.59	.16	13.70	2.20
57	.78	.16	14.38	2.34
58	.89	.17	13.54	2.24

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