Computer Simulation of the Behaviour of an LNG carrier Moored to an Open Jetty

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Picture front page: LNG jetty of the Withnell Bay loading terminal (by courtesy of Shell)

MSc. research report

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Preface

This report contains the results of my MSc. research project at Delft University of Technology, also by order of the Royal/Shell Group. The research has mainly been carried out at De Weger in Rotterdam.

This MSc. research project is part of a larger research programme "Behaviour of Moored Ships in Long Waves", consisting of a number of MSc. studies and future PhD. projects. Main objective of the programme is to generate simple expressions of the motions of moored ships to avoid detailed computer simulations during preliminary harbour design. The research programme has been initiated by Prof. Ir. H. Ligteringen, head of the section Harbours and Waterways of the faculty Civil Engineering and Geosciences.

I would like to thank Ir. J.C.M. de Waal for his effort to collect the measured data from Australia. Furthermore I would like to thank the De Weger company and especially Ir. J.C. van der Lem for the support during my stay.

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Abstract

In the design of oil and gas terminals Six Degree of Freedom (SDF) models are used to calculate the motions of the moored ship as well as forces in mooring lines. TERMSIM II (LNG) is one of those SDF-models, developed by MARIN under a Joint Industry Program with Shell as one of the main sponsors and users. Although the simulation programs have been used for more than twenty years, there is still need for more information about the accuracy of the models.

The research objective is to verify the accuracy of the calculations of the SDF computer model TERMSIM II (LNG) simulating an LNG carrier moored to an open jetty. The accuracy is investigated by comparing calculated forces in mooring legs to prototype measurements.

The prototype measurements have been carried out at the LNG jetty of the Withnell Bay loading terminal, located in the Mermaid Sound, West Australia. The moored ships were 125,000 m^3 Northwest LNG carriers. The measurements consist of average, minimum and maximum values per ten minute interval of the force in each mooring line.
Simultaneously weather conditions were monitored near the terminal. These conditions serve as input for TERMSIM simulations. Simulation runs were carried out for different kinds of environmental loads. The dynamic loads from wind and waves (sea state) appeared to be small and difficult to be compared to the measured data. Dominant loads appeared to be swell waves with peak periods ranging from 14 to 18 s. Simulation under these weather conditions provided good results in case of loaded ships, i.e. the simulation results nearly match the measured data. In case of ships in ballast and partly loaded ships the simulations provide overestimating results. From a sensitivity analysis appeared that the results are rather sensitive to directional spreading of waves and the direction of the incident waves.

From further investigation of the motions of moored ships exposed to swell waves followed that the yaw motion, due to first order wave forces, is dominant for forces in breast lines. A simple empirical expression has been derived to calculate the yaw motion of a moored 125,000 m^3 LNG carrier exposed to swell waves. This expression can be used for preliminary harbour design to estimate maximum yaw motions and mooring forces. Computer simulations can be carried out during further stages of the design process when more detailed input parameters are available.

The main conclusions of this research project are:

- The difference between TERMSIM calculations and measured line forces, concerning a loaded 125,000 m^3 LNG carrier moored to the LNG jetty in Withnell Bay exposed to moderate swell waves, is within reasonable limits. Underestimation of 10% to 20% for the calculated maximum forces in breast lines compared to prototype measurements has been found.

- The prototype measurements show significant dependence between maximum line forces and the loading condition whereas TERMSIM simulations do not show this dependence.

- The influence of directional spreading of waves on line forces is significant in case of wave directions nearly head- or stern-on.

- Yaw motions appear to be dominant for the maximum line forces in breast lines in case of a 125,000 m^3 LNG carrier moored to a jetty exposed to swell waves.

- The yaw motion is dependent on the water depth, wave direction, wave period, wave height and stiffness of the mooring system.

- Maximum allowable wave loads in Withnell Bay appear to be smaller than design wave loads.

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List of Symbols

a	added inertia matrix
$\mathrm{avg}(x)$	average value of x
b	damping matrix
B	breadth of the ship
C	matrix of hydrostatic restoring forces
C_{yaw}	empirical constant for yaw motions
d	water depth
D	depth of the ship
$\mathbf{E}(x)$	expected value of x
F	force
$F^{(1)}$	first order wave force
$F^{(2)}$	second order wave force
$F_{\underline{x}}$	distribution function of x
g	acceleration of gravity
G	centre of gravity
H	wave height
H_s	significant wave height
I	moment of inertia
k	spring coefficient
k_{xx}	transversal radius of gyration in air
k_{yy}, k_{zz}	lateral radius of gyration in air
K_s	shoaling factor
L_{PP}	length between perpendiculars
M	inertia matrix
$\max(x)$	maximum value of x
$\min(x)$	minimum value of x
$\vec{n}$	outward pointing normal vector
p	water pressure
R	retardation function
S	submerged body surface
t	time
T	draft of the ship
T	wave period
T_m	mean wave period or first period
T_p	peak wave period
V	velocity
x_j	displacement or rotation in the j-mode in ship-bound co-ordinate system
X_j	displacement or rotation in the j-mode in earth-fixed co-ordinate system
δ	spreading angle
ε	random phase angle
ζ	wave elevation
$\hat{\zeta}$	wave amplitude
θ	wave direction in earth-fixed co-ordinate system, stern-on: $\theta = 0°$, head-on: $\theta = 180°$
μ_i	mean value of i
ρ	density of water
σ_i	standard deviation of i
Φ	velocity potential
ω	wave angular frequency
ω_e	natural angular frequency
ω_p	peak wave angular frequency
∇	volume displacement

1 Introduction

Research in the seventies and early eighties of the behaviour of moored ships in waves has led to the development of several computer models which calculate wave forces, motions of the moored ship and forces in fenders and mooring lines. The models are so-called Six Degree of Freedom (SDF) models which implies that forces and motions of the ship are calculated in the six degrees of freedom. From the seventies several models have been made and further developed. A few examples of these models are: BAS developed by Delft Hydraulics, TERMSIM developed by MARIN and DIODORE developed by SOGREAH in France.

TERMSIM has been developed by MARIN under a Joint Industry Programme with Shell as one of the main sponsors and users. Shell implements the TERMSIM program in the design of oil and gas terminals. The design process is presented in figure 1.1. In this process the TERMSIM simulation program is used to calculate vessel motions and forces in mooring lines. Before the model can be used, the layout of the mooring facility, as well as spring constants of mooring lines and fenders, need to be defined. After the simulation runs on several design ships, the output is analysed to improve the layout of the mooring facility.

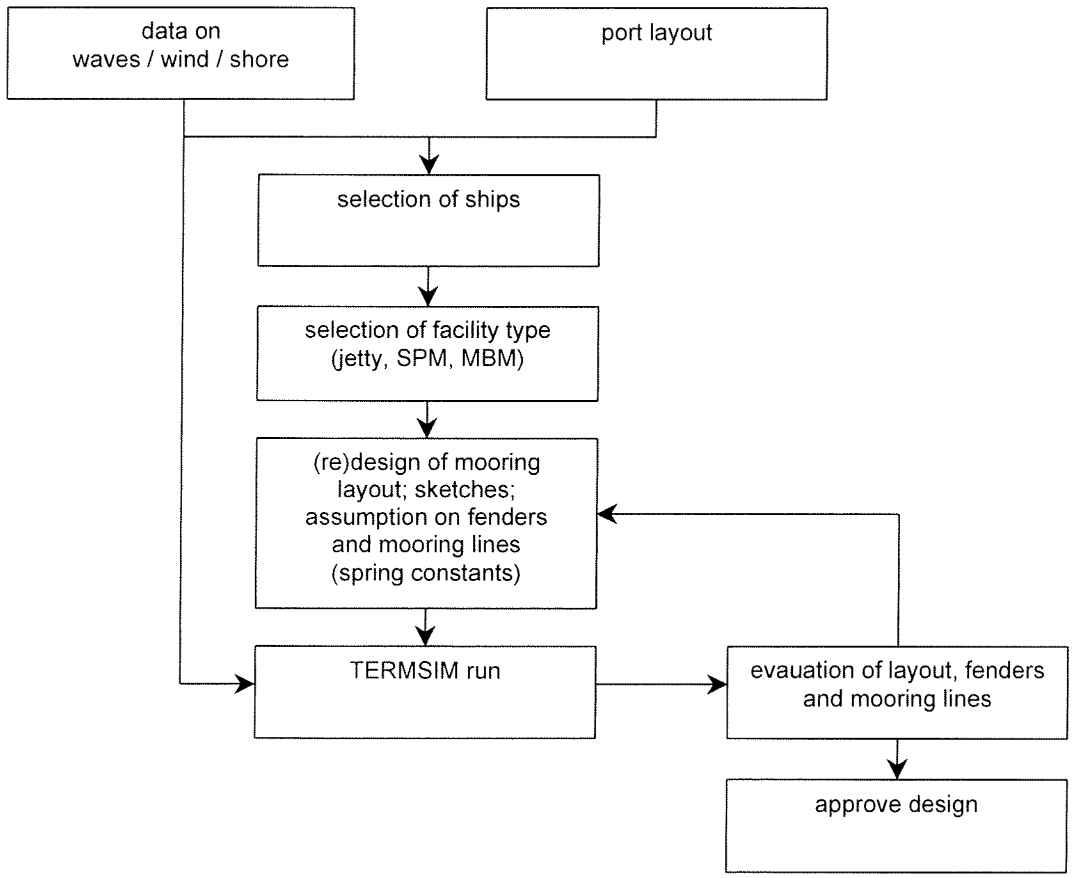


Figure 1.1: calculation scheme for design of mooring facilities

Eventually to improve the design of mooring facilities, Shell appreciates to have more evidence about the validity of the output of TERMSIM simulations. Particular interest is required in the behaviour of moored ships in long waves and the accuracy of TERMSIM modelling this situation. In the past extensive validation of SDF models has been done by comparing the calculated results to scale model measurements. The simulation model then is validated if the differences are within reasonable limits. However, besides the comparison to scale model tests there is demand for validation with use of prototype measurements to verify whether the TERMSIM model resembles the prototype situation.

In this MSc. thesis TERMSIM II (LNG) is validated using prototype measurements consisting of mooring line forces which were monitored at the gas loading terminal Withnell Bay, West Australia. Conclusions will be made about the resemblance of simulations to prototype measurements. Furthermore recommendations will be made with respect to the use of present program and to improvements of the model.

This MSc. research is part of a larger project *"Behaviour of moored ships in long waves"* initiated by Delft University of Technology. Objective of this research programme is to generate simplified expressions to calculate vessel motions and maximum line loads. In order to obtain useful data for this research project, vessel motions have been analysed and a simplified expression for the dominant yaw motion has been derived from further TERMSIM simulations.

This report contains brief descriptions of the research methodology (chapter 2), some useful literature (chapter 3) and a brief description of the TERMSIM model (chapter 4). The analysis of the prototype measurements is presented in chapter 5. A description of the TERMSIM simulation runs are given (chapter 6), after which the results of the simulations are verified to the results of the analysis of prototype measurements (chapter 7). An analysis of the vessel motions and an expression for the yaw motion is described in chapter 8. Conclusions and recommendations are listed in chapter 9.

2 Research Approach

The subject of this thesis has been clarified in the introduction. In this chapter the methodology is described which has been followed to analyse the prototype measurements, to choose the input parameters for TERMSIM simulations and to explain differences between measurements and simulations.

2.1 Problem Definition

For the verification of the process for the design of mooring facilities, more data about the accuracy of existing Six Degree of Freedom (SDF) computer models are necessary. Although the models are used successfully for more then twenty years, the accuracy of the models describing the prototype situation is still not certain enough.

2.2 Research Objective

The objective of the research is to verify the accuracy of the calculations of the SDF computer model TERMSIM II (LNG) simulating an LNG carrier moored to an open jetty. The accuracy is investigated by comparing calculated forces in mooring legs to prototype measurements.

2.3 Research methodology

Prototype measurements

Prototype measurements that serve as reference material for TERMSIM calculations were carried out at the LNG jetty in Withnell Bay, Australia. Before TERMSIM simulations were made, an extensive analysis of prototype measurements had been executed.
The prototype measurements include forces in mooring lines. The measured data consist of average, minimum and maximum forces per ten minute interval. The average force is equal to pretension plus constant loads plus semi-static loads (e.g. as a result of tide). The difference between maximum and average and between minimum and average are the results of dynamic loads, particularly from waves.
The selection of reference periods to which TERMSIM calculations could be compared, has been made with help of the following criteria:

- Certain interesting environmental conditions.
- Constant environmental conditions.
- Rather constant average force.

Interesting environmental conditions are for example relatively high waves, either sea or swell. The environmental conditions must be rather constant, because the conditions cannot be changed during a TERMSIM run. The average force must not vary too much during the reference period because the pretension value during TERMSIM calculations is constant and the behaviour of mooring lines is not constant for different pretension values, because of the non-linear line characteristics.
Certain statistical quantities are calculated from the line force data of the reference period. These quantities will be used to be compared to TERMSIM output. The main quantities are:

- A mean value of maximum forces per ten minutes which is the difference between maximum and average force per interval.

- An estimated value of the maximum force per three hours which follows from the variations of the ten minute maxima.

TERMSIM calculations

The calculations are carried out to be compared to the prototype measurements. Therefore input of data from the jetty, ship and environmental conditions is done as accurately as possible to match the prototype situation. Environmental conditions are obtained from data, monitored by equipment located in the vicinity of the terminal.
Approximation of the pretension value is done by an iteration process. The calculated average force is adjusted to the measured overall average force by changing the pretension per mooring leg in the input. Because of this iteration the dynamic behaviour of calculated line forces takes place in the same range of the (non-linear) line characteristic as the prototype line forces.

From the output of a TERMSIM run the same quantities are calculated as has been done to the prototype measurements. Hence average, minimum and maximum forces per ten minute interval are derived and a mean maximum force per ten minutes and an estimated maximum per three hours is calculated.

Comparison of simulations to measurements

The calculated quantities from simulations are compared to the measured data. If differences occur, then it is verified whether these differences can be explained by incorrect approximations of input parameters. In order to check these approximations, more runs are carried out with the same reference period. Hypotheses can be formulated and verified after simulation with other reference periods.
The verification of input parameters essentially results in a sensitivity analysis executed to verify which input parameters are most significant. With the help of this sensitivity analysis, conclusions can be made about whether differences are due to:

1. Incorrect approximations of input parameters
2. Statistical deviations.
3. Deviations of TERMSIM modelling the prototype situation.

After analysis of the results of the sensitivity analysis, it has been tried to indicate the magnitude of the errors made by TERMSIM in the analysed situation. If the occurring errors can be explained, general conclusions and recommendations can be made about occurring deviations and schematisation of the input.

3 Literature Background

3.1 Validation study of the program MOORSIM

Validation of simulation programmes for moored ships have been validated by means of model tests. An example of such validation study is described by Van Oortmerssen et al. (ref. [1] and ref. [2]). These articles contain summaries of the validation study of the program MOORSIM, which is the precursor of the TERMSIM model. The development of the computer program and the execution of the validation tests were done by MARIN.

The validation study consists of model tests for a 200,000 TDW tanker attached to a jetty and exposed to several wave spectra and wave and wind directions. Particular interest was intended in the modelling of ship behaviour as result of second order wave forces.
An excellent agreement was found in ship motions and mooring forces. Remarkable was the agreement in sway motions in case of beam waves, also because of the non-linear restoring characteristics of the mooring arrangement for sway.

3.2 Design studies to the LNG terminal in Withnell Bay

The design of the LNG jetty in Withnell Bay took place approximately from 1980 to 1983.
As part of the design of the LNG terminal an extensive research program was conducted by Delft Hydraulics Laboratory. A mathematical simulation study (ref. [3]) has been carried out by MARIN to support the physical model tests. The simulation programme MOORSIM was used for the computer simulations.

Comparison of the simulations and model tests for a 125,000 m^3 LNG carrier lead to the following conclusions about the horizontal motions:

- The maximum surge amplitude is lower for the simulation tests.
- The sway motion is small during the simulations when compared to the model test results.
- No consistency for the differences in the yaw mode of motion is found.

Discussions arose about the cause of the differences. The existence of unintended free long waves in the model basin was brought forward as the probable cause for the larger surge and sway motion during the model tests.

Apart from the comparative simulation tests, parameter study tests (ref. [4]) were carried out by MARIN in order to determine the optimum jetty head orientation and a suitable mooring arrangement. The main conclusions, for a moored 125,000 m^3 LNG carrier, were:

- The optimum jetty orientation corresponds to the vessel's head to the waves.
- Line loads stayed within acceptable limits for wave loads H_s = 0.60 m, T_p = 20.0 s.
- Wave loads H_s = 2.30 m, T_p = 14.0 s, provided critical line loads in case of a spherical type LNG carrier.

3.3 Simplified models describing horizontal vessel motions

Computer simulations and physical model tests can provide understanding about moored ship behaviour and maximum line forces under design weather conditions. However computer simulations require detailed input data and physical model tests are suitable to verify a berth design. During early stages of the design process, the detailed data are not available. Moreover a less time consuming prediction method would be appropriate for feasibility studies.

A simplified model has been used by Mol et al. (ref. [5]) to develop a simple expression for the surge motions of a moored ship exposed to long waves. The research has resulted in the following equations:

$$X_s = C_x \cdot H_{sl} \cdot \sqrt{\frac{g \cdot M}{d \cdot k_t}}$$
$$F_m = C_f \cdot H_{sl} \cdot k_i \cdot \sqrt{\frac{g \cdot M}{d \cdot k_t}} \qquad (3.1)$$

where:	X_s	= significant surge motion	[m]
	C_x, C_f	= coefficient	[-]
	M	= mass of vessel	[tons]
	d	= water depth	[m]
	H_{sl}	= long period significant wave height	[m]
	k_t	= stiffness of the mooring system parallel to the quay-line	[Nm]
	F_m	= maximum line force	[N]
	k_i	= stiffness individual mooring line	[Nm]

Values of the C_x coefficient range approximately between 1 and 3, with an average of 1.7. The C_f coefficient ranges between 0.6 and 4, with an average of 1.5. Variations are mainly due to the variations in port geometry.
Long waves are considered as waves with periods larger than 30 seconds (ω < 0.2 rad/s). Long waves occur as bound long waves and free long waves. The bound long wave component in shallow water can be predicted from the wave spectrum using the following relation:

$$H_{sl} = \frac{0.08}{d^2} \cdot T_p \cdot H_s^2 \qquad (3.2)$$

where: d = water depth
T_p = peak period of the short wave spectrum
H_s = significant wave height of the short waves

Sarneel (2000, ref. [6]) has investigated the behaviour of a dry bulk carrier moored to a quay by means of model tests of the Coega harbour in South Africa. The results of the research of the surge motions lead to a confirmation of the expression, developed by Mol et al. A value of 1.8 for the C_x coefficient was found, which is near the average value of 1.7 found by Mol et al..
For the sway motion the following relation was found:

$$Y_s = C(T_p) \cdot H_s \qquad (3.3)$$

where: Y_s = significant sway motion
C = coefficient depending on the peak period
H_s = significant wave height

The coefficient C increases with increasing peak period and appears to be influenced by the natural period of roll.

4 Description of the TERMSIM Model

This section includes a short description of the hydrodynamic theory used in the program TERMSIM. This description is for information only. The background of the mathematics is not included. For derivations of the used hydrodynamic theory is referred to Journée and Massie, "Offshore Hydromechanics" (ref. [7]) and Van Oortmerssen, "The Motions of a Moored Ship in Waves" (ref. [8]).

4.1 Equations of motion

The equation of motion describing a linear mass-damper-spring system for a moored floating body is:

$$\sum_{j=1}^{6}\left\{\left(M_{kj}+a_{kj}\right)\ddot{x}_j+b_{kj}\dot{x}_j+C_{kj}x_j\right\}=F_k \qquad k = 1, 2, \ldots 6 \tag{4.1}$$

in which:
- M = Inertia matrix
- a = added inertia matrix
- b = damping matrix
- C = static restoring matrix
- F_k = external force in the k-mode

In case the right hand side of the equation consists of forces that are linear and independent functions of the body motions x_j and its time derivatives, the equation of motion is linear and can be solved in the frequency domain. The solutions for all frequencies can be calculated separately and then integrated. In most cases the external forces are not linear. Examples of non-linear and dependant behaviour of a mooring system are:

1. Characteristics of fenders and mooring line
2. Second order wave drift forces
3. Non-linear drag

In general these terms play an important role in the behaviour of the system and thus use cannot be made of the linear equation of motion. To overcome the problems of non-linear behaviour use is made of the impulse response theory to describe the fluid reactive forces. This has led to the equation of motion to be solved in the time domain, derived by Cummins (ref. [9]):

$$\sum_{j=1}^{6}\left\{\left(M_{kj}+m_{kj}\right)\cdot\ddot{X}_j(t)+\int_{-\infty}^{t}R_{kj}(t-\tau)\cdot\dot{X}_j(\tau)\cdot d\tau+C_{kj}\cdot X_j(t)\right\}=F_k(t) \qquad k = 1, 2, \ldots 6 \tag{4.2}$$

in which:
- X_j = motion in j-mode
- M = inertia matrix
- m = added inertia matrix
- R = matrix of retardation functions
- C = matrix of hydrostatic restoring forces
- F_k = arbitrarily in time varying external force in the k-mode

The derivation of this equation and the specific equations used for jetty moorings are given in appendix A. The only basic assumption in the approach is the separate treatment of hydrodynamic reactive forces and all other external loads.

4.2 Loads on the moored ship

The external loads on a floating structure consist of exciting environmental loads from waves, current and wind, fluid reactive loads from waves radiating from the body and mooring loads from mooring lines and fenders. The fluid reactive loads are assumed to be proportional to the displacements and its time derivatives, thus incorporated in the left-hand side of equation 3.2. All exciting and mooring loads are approximated separately and incorporated in the right-hand side of equation 3.2.

4.2.1 Waves

The irregular waves are regarded as a summation of a number of long-crested regular waves:

$$\zeta^{(1)}(t)=\sum_{i=1}^{N}\hat{\zeta}_i\cos(\omega_i t+\varepsilon_i) \tag{4.3}$$

where: $\hat{\zeta}_i$ = wave amplitude
ω_i = wave angular frequency
ε_i = random phase angle

The amplitudes of the wave components can be found from the spectral density function $S(\omega)$:

$$\hat{\zeta}_i=\sqrt{2S(\omega_i)\Delta\omega_i} \tag{4.4}$$

where $\Delta\omega_i$ is a small frequency interval partition.

The wave force may be split up into high frequency oscillating or first order components proportional to the wave height and slowly varying wave drift forces proportional to the wave height squared.

First order wave forces

The first order wave forces are theoretically determined by integrating the first order pressures, $p^{(1)}$, over the submerged body surface, S. The first order pressure is found from the first order Bernoulli equation:

$$\begin{aligned} F_k^{(1)} &= -\iint_{S_0} p^{(1)}\cdot n_k\cdot dS \\ &= \iint_{S_0}\rho\frac{\partial\Phi^{(1)}}{\partial t}\cdot n_k\cdot dS \end{aligned} \qquad k = 1, 2, \dots 6 \tag{4.5}$$

where: Φ = velocity potential
n_k = directional cosine of the outward pointing normal vector in the k-mode

The first order velocity potential as function of time and space can be determined using theories of potential flow. The first order wave force can then be related to the incident wave via the amplitude transfer function, which includes the coupling between wave force and incident wave amplitude. The determination of the first order transfer function can be done using the MARIN wave diffraction program DIFFRAC. The results are part of the hydrodynamic file.
Knowing the wave time trace and the transfer functions of first order forces the wave force is determined from summation over all wave frequencies:

$$F^{(1)}(t)=\sum_{i=1}^{N}\zeta_i\cdot\frac{\hat{F}^{(1)}}{\hat{\zeta}}(\omega_i)^{2}\cdot\cos\left(\omega_i t+\varphi^{(1)}(\omega_i)+\varepsilon_i\right) \tag{4.6}$$

where: $\frac{\hat{F}^{(1)}}{\hat{\zeta}}(\omega_i)^{2}$ = amplitude of first order transfer function

$\varphi^{(1)}(\omega_i)$ = phase angle of first order transfer function

Second order wave forces

The wave drift forces can be divided into a mean part and a slowly varying part. Although the second order forces are much smaller then the first order forces, they are often important because of the long periods of the slowly varying part. The following contributions can be distinguished to the wave drift force:

- The product of first order motions and first order inertia forces.
- Second order pressures, containing firstly the squared first order pressure gradient, secondly the product of the first order pressure and the first order motion and thirdly, in case of irregular waves, the second order potential.
- Squared relative wave height which is equal to the wave elevation at the body surface minus vertical displacement of the ship

The formulation of these contributions has been derived by Pinkster (ref. [10]):

$$\begin{aligned}\vec{F}^{(2)} &= m\cdot R^{(1)}\cdot\ddot{\vec{X}}_G^{(1)}\\ &+\iint_{S_0}\left\{\frac{1}{2}\rho\,\vec{\nabla}\Phi^{(1)\,2}+\rho\frac{\partial\Phi^{(2)}}{\partial t}+\rho\vec{X}^{(1)}\cdot\vec{\nabla}\frac{\partial\Phi^{(1)}}{\partial t}\right\}\cdot\vec{n}\cdot dS\\ &-\int_{wl}\frac{1}{2}\rho g\left(\zeta_r^{(1)}\right)^2\cdot\vec{n}\cdot dl\end{aligned} \tag{4.7}$$

in which:
m = mass displacement of the floating structure
R = rotation matrix
G = centre of gravity
$\vec{n}$ = directional cosine of the body surface
wl = waterline surrounding the floating structure
ζ_r = relative wave height

The low frequency wave drift forces, which are linked to wave grouping, may be expressed in terms of transfer functions based on two frequencies. These quadratic functions may be used to calculate the spectral density of the wave drift forces in the frequency domain and then to construct time domain records using direct summation techniques. The second order force as function of all combinations of two frequencies is:

$$F^{(2)}(t)=\sum_{i=1}^{N}\sum_{j=1}^{M}\zeta_i\zeta_j\left\{P_{ij}\cos\left((\omega_i-\omega_j)t+(\varepsilon_i-\varepsilon_j)\right)+Q_{ij}\sin\left((\omega_i-\omega_j)t+(\varepsilon_i-\varepsilon_j)\right)\right\} \tag{4.8}$$

in which:
P_{ij} = in-phase part of the second order transfer function $P(\omega_i, \omega_j)$
Q_{ij} = quadratic part of the second order transfer function $P(\omega_i, \omega_j)$

The second order transfer functions are obtained from the hydrodynamic file.

4.2.2 Current

The current forces are calculated using the following semi-empirical formulae:

$$\begin{aligned}
\text{surge}: \quad & F_1^{\text{current}} = \frac{1}{2}\rho_w V_{cr}^2 C_{c1}(\alpha_{cr}) \cdot T \cdot B \\
\text{sway}: \quad & F_2^{\text{current}} = \frac{1}{2}\rho_w V_{cr}^2 C_{c2}(\alpha_{cr}) \cdot T \cdot L_{PP} \\
\text{yaw}: \quad & F_6^{\text{current}} = \frac{1}{2}\rho_w V_{cr}^2 C_{c6}(\alpha_{cr}) \cdot T \cdot L_{PP}{}^2
\end{aligned} \tag{4.9}$$

in which:
ρ_w = density of water
V_{cr} = relative current velocity with respect to the ship velocity
C_{cj} = current force coefficient
α_{cr} = relative current angle of incidence with respect to the ship heading
T = draft of the vessel
B = width of the vessel
L_{PP} = length between perpendiculars

4.2.3 Wind

The same formulations used to calculate the current loads are used for the aerodynamic loading:

$$\begin{aligned}
\text{surge}: \quad & F_1^{\text{wind}} = \frac{1}{2}\rho_a V_{wr}^2 C_{w1}(\alpha_{wr}) \cdot A_T \\
\text{sway}: \quad & F_2^{\text{wind}} = \frac{1}{2}\rho_a V_{wr}^2 C_{w2}(\alpha_{wr}) \cdot A_L \\
\text{yaw}: \quad & F_6^{\text{wind}} = \frac{1}{2}\rho_a V_{wr}^2 C_{w6}(\alpha_{w}) \cdot A_L \cdot L_{PP}
\end{aligned} \tag{4.10}$$

in which:
ρ_a = density of air
V_{wr} = relative wind velocity with respect to the tanker velocity
C_{wj} = wind force coefficient
α_{wr} = relative wind angle of incidence with respect to the ship heading
A_T = transverse windage area
A_L = lateral windage area
L_{PP} = length between perpendiculars

4.2.4 Fluid reactive forces

The fluid reactive forces to be substituted in the equation of motion are obtained from the frequency dependent hydrodynamic coefficients given in the hydrodynamic file, see appendix A:

$$\begin{aligned}
R_{kj}(t) &= \frac{2}{\pi}\int_0^\infty b_{kj}(\omega)\cos\omega t \cdot d\omega \\
m_{kj} &= a_{kj}(\omega') + \frac{1}{\omega'}\int_0^\infty R_{kj}(t)\sin\omega' t \cdot dt
\end{aligned} \tag{4.11}$$

in which:
R_{kj} = retardation function
m_{kj} = frequency independent inertia coefficient

a_{kj} = frequency dependant added mass coefficient
b_{kj} = frequency dependent damping coefficient
ω' = arbitrarily chosen value of ω

Non-potential fluid reactive forces can be added. These forces may arise from frictional and pressure drag due to viscous effects.

4.2.5 Mooring forces

The restoring forces due to mooring are provided by elongation of mooring lines and compression of fenders. The instantaneous forces are found from the excursions of the vessel at the point of attachment and from the static load-elongation characteristics of lines and fenders.
The behaviour of the jetty is modelled by stiffness of mooring and breasting dolphins. This stiffness is added to the stiffness of mooring lines.
Besides fender forces normal to the ship surface, mechanical friction between vessel and fenders is included in the model by applying a friction coefficient.

4.3 Description of the computer program

The computer program TERMSIM II (LNG), operational since 1998, is used for the simulations carried out for this research. The TERMSIM model is developed at MARIN in succession to MOORSIM, which was available since 1975.
Numerical solution of the equation of motion (eq. 4.2) is done in the time domain for all six degrees of freedom. First a wave, wind and current record is made from a given wave and wind spectrum. Subsequently the added inertia and retardation functions (both functions of time) are calculated from the wave record. The calculation procedure to be processed for all time steps is presented in figure 4.1:

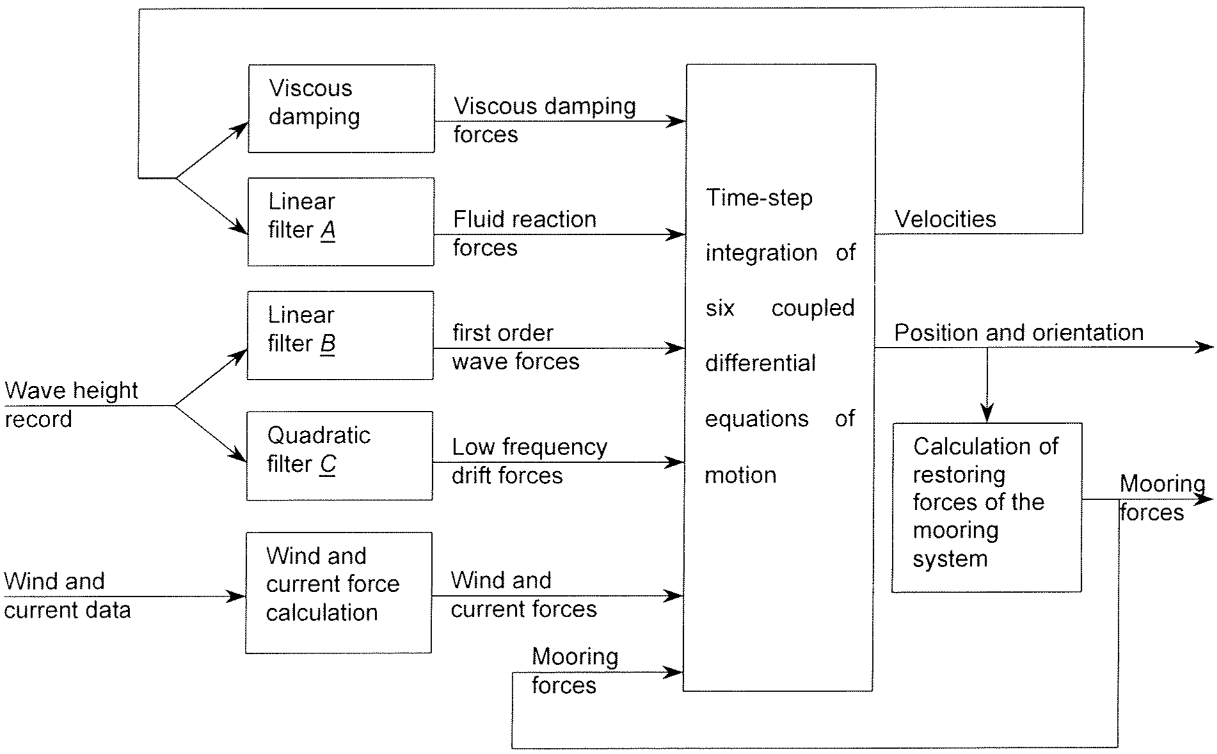


Figure 4.1: Flow diagram of TERMSIM simulations

Calculation of wave, wind and current forces are explained in paragraph 4.2. The evaluation of the convolution integral in the equation of motion is regarded as applying a linear filter, *A*, to the past history of the velocities of the vessel. Viscous damping may be added to the linear damping calculated at *A*.
The linear filters A and B and the quadratic filter C contain the basic hydrodynamic properties of the vessel and are combined in a hydrodynamic file. The hydrodynamic properties are depending on the geometry of the hull, the loading condition and the under keel clearance. The hydrodynamic file contains wind and current forces, first order wave forces, added mass and damping coefficients and low-frequency wave drift forces in the frequency domain. The reaction of the vessel is given to all possible wave frequencies and directions and all wind and current directions.
The restoring forces of the mooring system consist of forces in mooring legs and fender forces. They are calculated from the vessel position and a specific line or fender force characteristic.
After calculation of all forces and hydrodynamic coefficients, the six coupled differential equations of motion are solved by means of time-step integration.
The position and orientation of the vessel, the mooring line and fender forces and all calculated environmental forces are stored for every time step.

5 Prototype Measurements

The line force measurements that were used for this research were executed at the gas loading terminal Withnell Bay from July till December 1996 on its LNG and LPG jetty. Withnell Bay is located in the Mermaid Sound near Dampier, West Australia. The terminal is operated by Mermaid Sound Port & Marine Services Pty. Ltd.

5.1 Withnell Bay gas loading terminal

5.1.1 Terminal location

The Mermaid Sound is a shallow part of the Northwest Australian coast with depths of 10 - 20 meters. The sound is sheltered by a few islands in the west and Burrup Peninsula, on which the terminal is located, and a few islands in the east. Waves from the Indian Ocean enter the sound from the north. From the configuration of the sound follows the direction of penetrated waves from the ocean. The swell waves are refracted and the swell direction is north-west at the terminal regardless of the wave direction at the ocean. The shallow parts of the Mermaid Sound provide damping of incoming waves, especially short period waves.

Maps of the nautical part of the terminal is given in appendix D, figures 1 and 2. The nautical part of the terminal consists of two berths: an LNG/condensate jetty and an LPG/condensate jetty. The heading of vessels moored to the jetties is NNE (330°) for both berths. The jetties are divided by a 500 meter wide manoeuvring basin. The bottom level of the harbour basin is AHD – 16.5 m. Offshore of the berths is a turning circle and an approach channel. Since commissioning of the LPG berth the LNG berth is dedicated to LNG export whereas all condensate export takes place on the LPG berth.

5.1.2 LNG jetty

The LNG jetty (appendix D, figures 3 and 4) has six mooring dolphins (A-C & J-L), equipped with triple quick release hooks, and six breasting dolphins (D-I), equipped with double quick release hooks. The dolphins are spaced such that the berth allows reception of LNG carriers ranging in length from approximately 150 m to 310 m, depending on the offset of the particular ship's manifold. The fenders, attached to the six breasting dolphins, are Yokohama air block fenders. The fender characteristic is given in appendix D, figure 5.
The loading platform is equipped with four 16" loading arms. The centre line of the loading arms is 13.7 m North from the centre line of the jetty.

5.2 Dimensions of the vessels

The vessels moored to the LNG jetty in Withnell Bay in 1996 were the following 125,000 m^3 LNG carriers: Northwest Sanderling, Northwest Sandpiper, Northwest Seaeagle, Northwest Shearwater, Northwest Snipe, Northwest Stormpetrel, Northwest Swallow and Northwest Swift.
All vessels are owned and operated by Northwest Shelf Shipping Service Co. Pty. Ltd. The trade route of the ships is Withnell Bay, Australia to Japan.
The mentioned vessels all have the same dimensions which are given in appendix E.
The ships are equipped with sixteen equal mooring lines. The particulars of the mooring lines are:

- Lines: Galvanised delta filler DF IWRC 6 x WS (36)
  ∅ 42 mm
  Mean breaking strength 124 tons
- Tails: Braided Polyester
  ∅ 64 mm
  length 11 m
  Mean breaking strength 166 tons

Mooring line characteristics are given in appendix D, figures 6 and 7; fairlead positions are given in appendix E.

5.3 Line force measurements

5.3.1 Measurement set-up

A measurement program has been carried out by the operators of Withnell Bay gas terminal, in particular to see whether the line forces are within acceptable limits. The measurement period was July till December 1996.
The line forces were continuously measured by means of gauges fitted to the quick release hooks on top of the dolphins. In order to reduce the data to be recorded, only three values were stored per ten minutes: the average, minimum and maximum. The average is the mean of all measured forces during the ten minute interval. The minimum is the lowest trough value and the maximum the highest peak value during ten minutes.
Vessel motions were not monitored.

Unfortunately, some data were lost during recording, viz. some of the maximum forces from the LPG jetty. Maximum forces from mooring dolphins A and B are available; maximum forces from breasting dolphins and mooring dolphins G and H were lost.

5.3.2 Analysis of line force data

Analysing method

The line force data were studied to identify the effects of ship handling and environmental conditions on the line forces of the moored ship. Characteristic examples of line force-time functions are given in figure 5.1. The numbers in the figure are assessed to correspond with the following influences:

1. Pretension:
   a) provided during berthing of the ship;
   b) adapted during the loading process.
2. A semi-static load as a result of vertical translation of the ship:
   a) due to tidal variations;
   b) due to the loading process of the ship.
3. External loads:
   a) from wind;
   b) from current;
   c) from waves.

Pretension (1) is roughly equal to the average line force immediately after berthing. Adaptations to pretension can be identified as sudden jumps in the average force and are presumably made to avoid excessive line forces or slacking of the lines. These adaptations are made by the winches on the ship deck when the average force is becoming too high or too low. The semi-static load

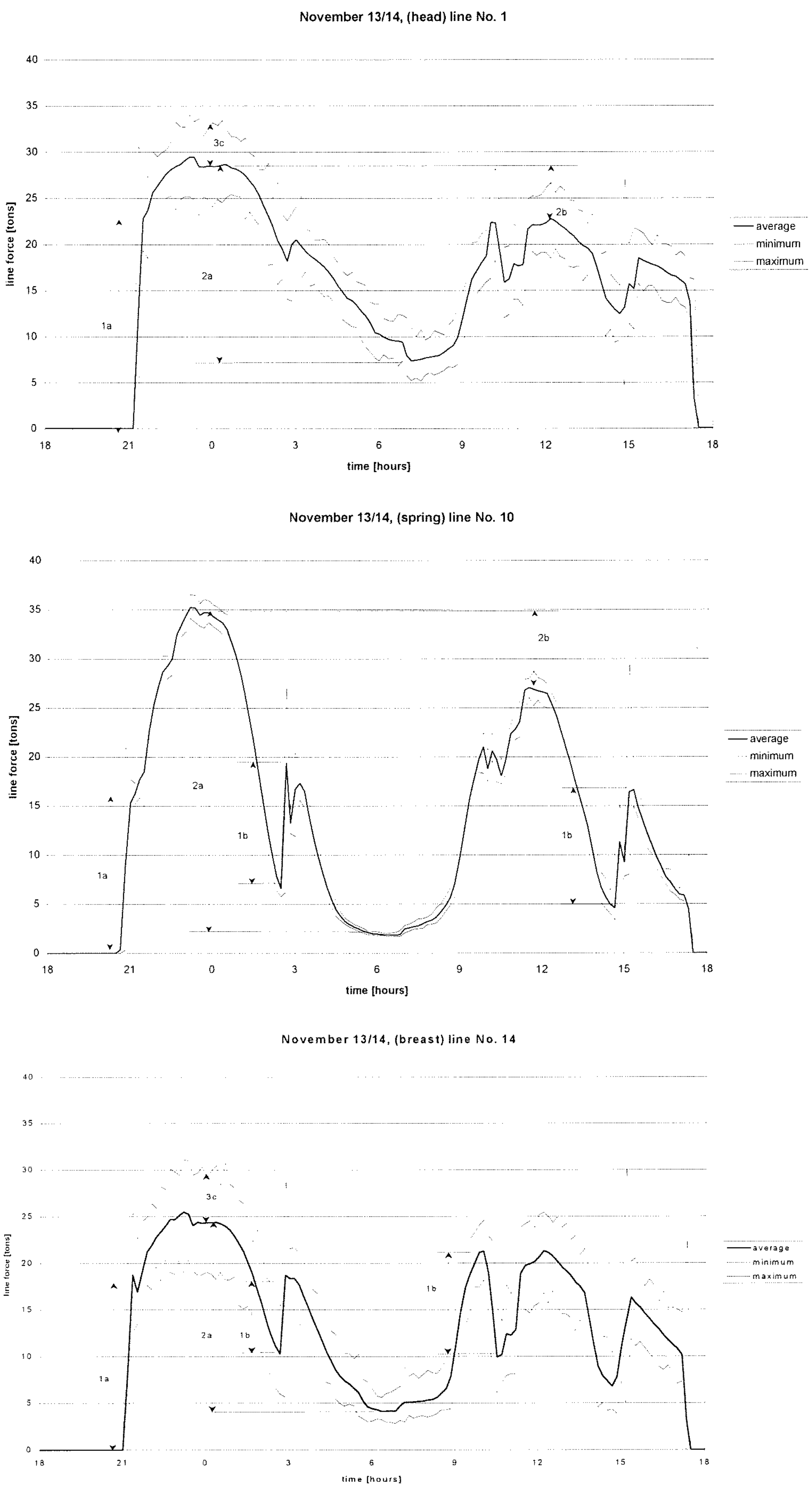


Figure 5.1: Example of measured line force-time functions, LNG jetty Withnell Bay

(2) depends on the difference in height between bollards and fairleads. The larger the difference the larger the tension in mooring lines. So the average force is large at high tide and low at low tide. Mooring lines slack very slowly during the loading process. Forces from current (3a) and wind (3b) are hard to identify in the line force functions, particularly when they are not very large. The wave load (3c) is a dynamic load with a period smaller then the (averaging) interval of ten minutes. Wave loads have little effect on the average force per interval, but have great effect on the difference between average and maximum loads. The line force due to wave loads is a dynamic force superimposed on the average line force. The effect is limited by the range between maximum and minimum force per interval.

When the measured line forces are to be compared with the results of TERMSIM calculations, the effects 'adaptation to pretension' (1b), 'loads due to vertical tide' (2a) and 'loads due to the loading process' (2b) cannot be represented in a single TERMSIM run, which assumes a constant water level. Hence the influence of these loads must be eliminated from the line force data, also since these influences are not of prime interest of the study. If this can be achieved, the remaining line force would still include the effects of pretension and (all other) external loads. By subsequently assessing the line forces due to wind, waves and currents (through TERMSIM) the difference between measured and calculated line forces may then be explained from other environmental sources (e.g. long waves).

In a first attempt to this approach, a method has been developed with which the semi-static loads due to vertical tide and loading of the vessel are eliminated from the measured data. A description of this method is given in appendix B. To develop the method, the line force data from the LNG jetty during October 8-10 have been used. This was a period with apparently small wind and wave loads. The average line forces during this period are given in figure 5.2 and in figure 5.3 vertical tide is presented. It appears that the loading process has not taken place during the first two days, because there is no reduction in line forces in time superimposed on the sinus function due to tide.

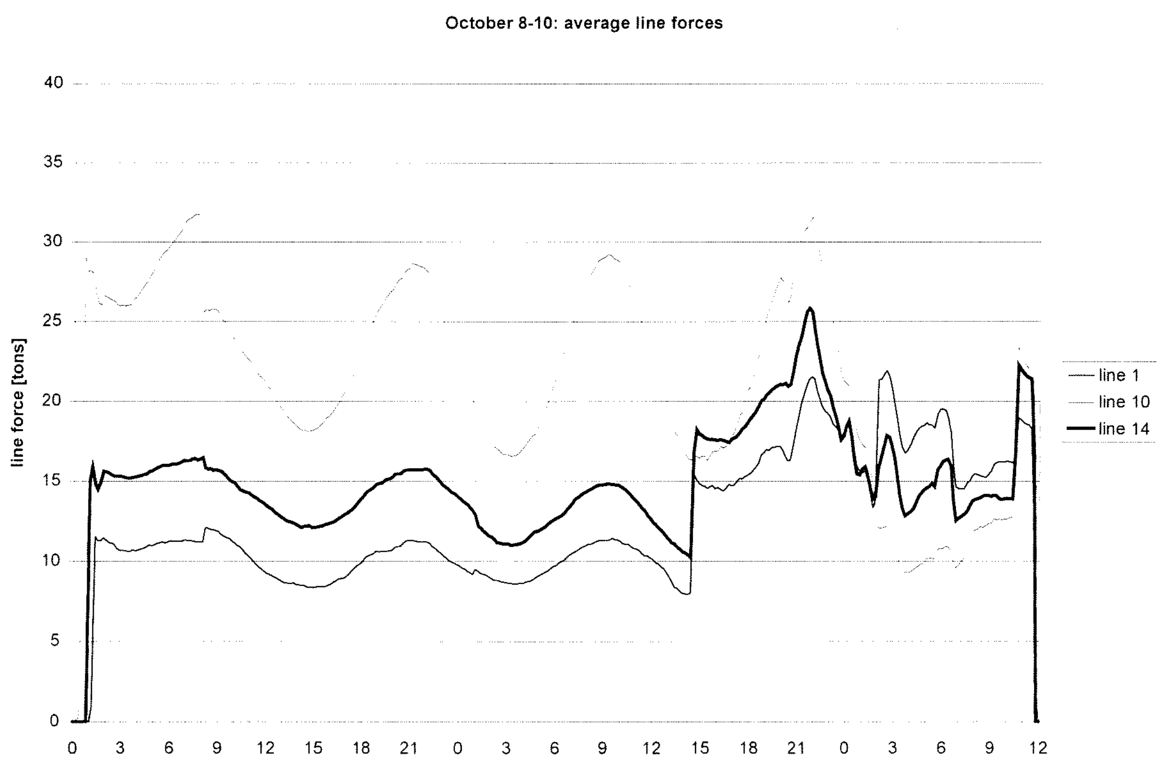


Figure 5.2: Average line forces October 8-10

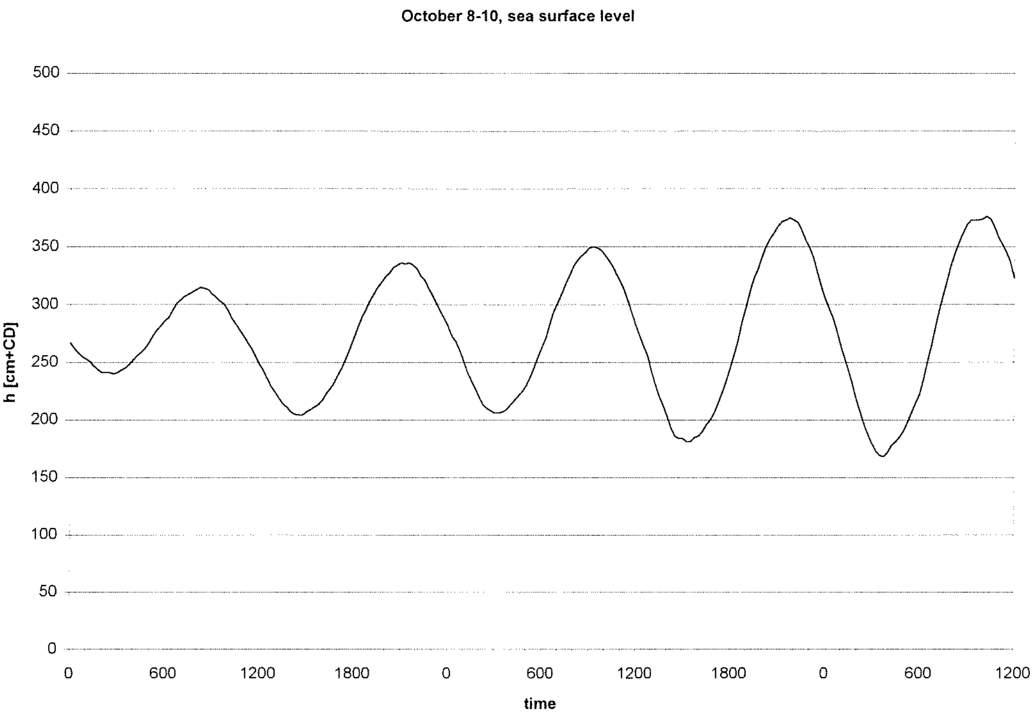


Figure 5.3: Tide data King Bay October 8-10

For October 9 the influence of tide is schematised as a single sine function for a period of nearly three and a half hours around turn of tide to minimise the influence of tidal current. This influence is subtracted from the line force data (average, minimum as well as maximum forces). This proved to be sufficient to eliminate tidal influences significantly; the remaining average forces are nearly constant in time. Only small variations in the average force remain, which may be due to slow wind and wave drift variations. This process is illustrated in figures 5.4 and 5.5.

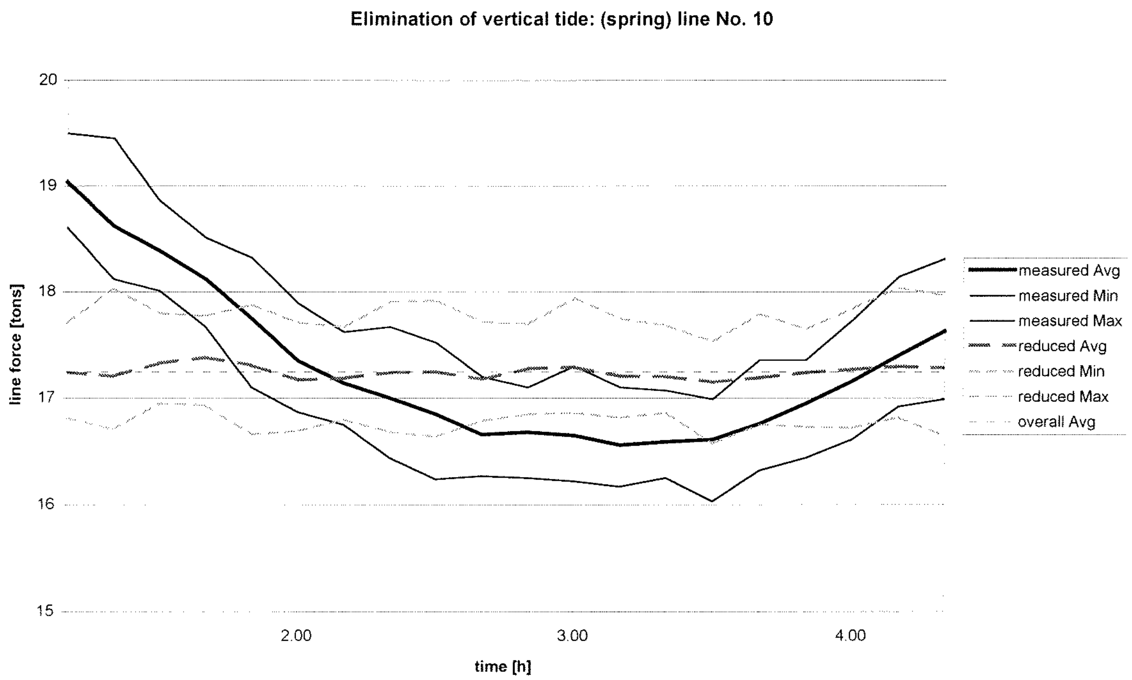


Figure 5.4: Elimination of tidal influences on line forces in a spring line

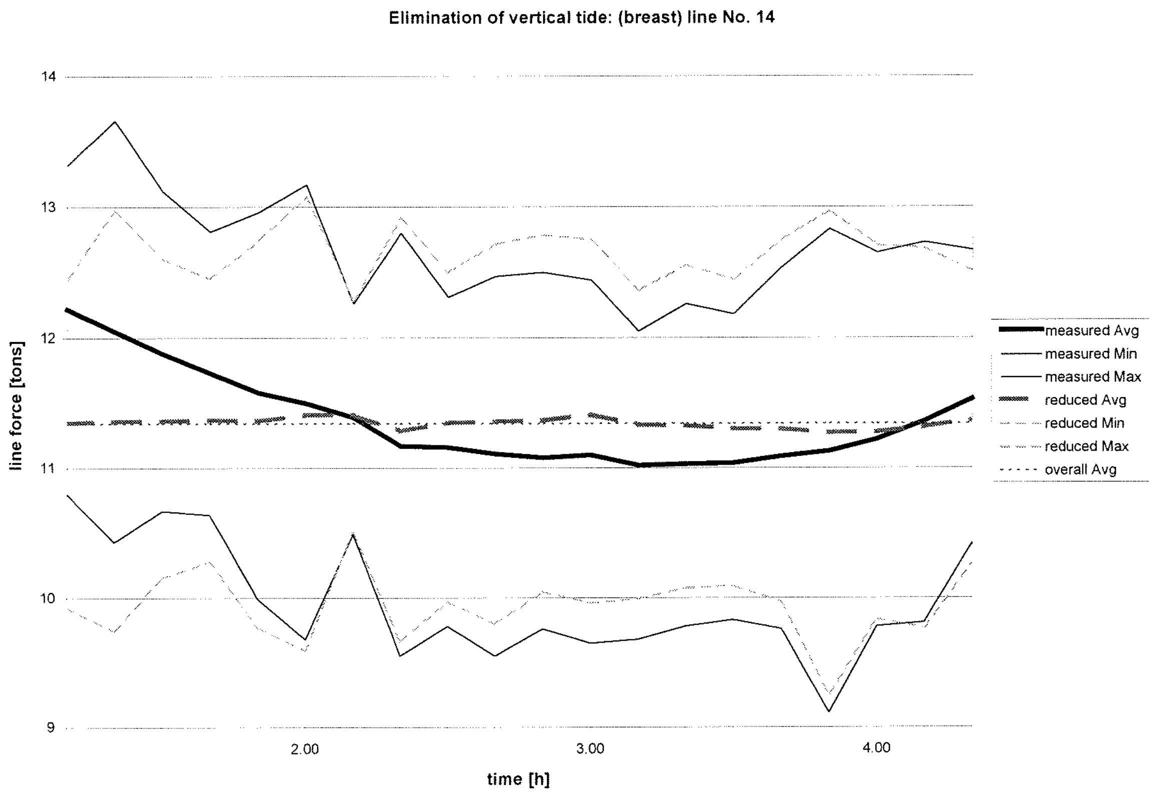


Figure 5.5: Elimination of tidal influences on line forces in a breast line

Figure 5.6: average line forces October 4,5

However, when the same method is applied to October 5 with reduced wind and wave action, a substantial variation in the average force remains. From figure 5.6 it becomes clear that the influences to be eliminated are not as linear as they were approximated for October 9. For example the twists in the line force graphs at about 21:00 is inexplicable. Trying to eliminate the influence of tide by a sine function and the loading process by a straight line does not provide sufficient results: the variations of the average force are too large. It is assessed that this variation originates mainly from difficulties in estimating the draft of the ship. Because the increase of the draft may not be as linear as approximated, variations with periods of a few hours arise. Estimating these variations is nearly impossible.

In view of the results obtained and observing the irregularity of the line force data on days with notable wave action, it was assessed that the proposed method of eliminating semi-static influences from the measured line force signal will not result in workable results, unless accurate and detailed data of tide, current, wind velocity and draft of the ship are made available. Not having these detailed data available, it has been decided to point the attention only to the difference between (10 minutes) average line force and (10 minutes) maximum and minimum line force. Consequently, the variations in the average line force per 10 minutes interval are completely attributed to tide and loading process. The difference between maximum and average and the difference between average and minimum per interval is completely attributed to dynamic effects of waves and wind loads.

This approach can be justified as follows:

- The interval of ten minutes is very short compared to the periods of tide and loading process (both periods are about half a day).
- The variation of loads from tide and loading during ten minutes is small compared to the wave loads, except when wave height is negligible.
- Most important wave loads appear to be long swell waves with peak wave period of 14 - 18 seconds. This period is very short compared to the interval of ten minutes, therefore the influence of waves on the average force per ten minutes is very small.
- Very long components of the time varying drift force and the effects of very long free waves (T> a few minutes) are not accurately observed by the difference between maximum and average per interval. Because occurring wave heights are low, the effect of very long time varying drift force is assumed to be negligible and free long waves were not observed and therefore the effect of these waves has not been taken into account.

Final point of attention are the adaptations of pretension at the winches. The average and maximum force in the specific interval is highly influenced by the adaptation. High dynamic loads occur just after winding of the winches, especially when lines are extended: slacking of lines can cause huge forces as the winch is locked. This process cannot be included in TERMSIM simulations. Furthermore winding of a single winches influences line forces in all lines. Hence the data of all lines from intervals during which adaptations were made to some lines are not taken into account.

Presentation of measured data

The data analysis of prototype measurements is presented in tables in appendix F. In order to obtain appropriate comparison material for TERMSIM simulations the following statistical quantities were derived:

In the formulae the following values are used:

F_k	line force in k^{th} mooring leg
n	number of considered ten minute time intervals
$\mathrm{avg}(F_k)_i$	average line force in k^{th} mooring leg during i^{th} ten minutes time interval
$\min(F_k)_i$	minimum line force in k^{th} mooring leg during i^{th} ten minutes time interval
$\max(F_k)_i$	maximum line force in k^{th} mooring leg during i^{th} ten minutes time interval

Averages per ten minutes

Mean $\mu_{F_k} = \frac{1}{n}\sum_{i=1}^{n} \mathrm{avg}(F_k)_i$

Mean value of all averages per ten minutes.

St. dev. $\sigma_{\mathrm{avg}(F_k)} = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}\left(\mathrm{avg}(F_k)_i - \mu_{F_k}\right)^2}$

Standard deviation of the average per ten minutes. Significant part of this standard deviations is the influence of tide and loading process.

Minima per ten minutes

Mean $\mu_{\min(F_k)} = \frac{1}{n}\sum_{i=1}^{n}\left(\min(F_k)_i - \mathrm{avg}(F_k)_i\right)$

Mean value of all minima per ten minutes. The difference between minimum and average is considered as the negative amplitude of dynamic influences.

St. dev. $\sigma_{\min(F_k)} = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}\left(\min(F_k)_i - \mu_{\min(F_k)}\right)^2}$

Standard deviation of the minima per ten minutes.

Maxima per ten minutes

Mean $\mu_{\max(F_k)} = \frac{1}{n}\sum_{i=1}^{n}\left(\max(F_k)_i - \mathrm{avg}(F_k)_i\right)$

Mean value of all maxima per ten minutes. The difference between maximum and average is considered as the amplitude of dynamic influences.

St. dev. $\sigma_{\max(F_k)} = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}\left(\max(F_k)_i - \mu_{\max(F_k)}\right)^2}$

Standard deviation of the maxima per ten minutes.

The formulae for the given quantities do not count for case 1, October 9. Only in this case the influence of tide has been eliminated from the line force data. The overall average force (after reduction of tidal influences) has been subtracted from the average, maximum and minimum forces instead of the momentary average force.

5.4 Measurements of environmental conditions

5.4.1 Marine environmental monitoring system

Environmental conditions were measured simultaneously to the line force measurements. The system used at the terminal location is the Marine Environmental Monitoring System (MEMS). It exists of measurements of wind speed and wave spectra.
Wind speeds were monitored by means of an RM Young Anemometer. The recorded parameters are average speed and direction per ten minutes and a three seconds gust.
Waves were monitored by means of a Datawell Directional Waverider located near the northernmost mooring dolphin of the LPG jetty. Analysis of the Waverider data has resulted in wave spectra, wave directions and some quantities concerning the shape of the wave spectra, all recorded per ten minutes.

Tidal data were obtained from the Coastal Data Centre, West Australia. Monitoring has been carried out in King Bay near Dampier. Differences in tidal amplitude and phase between King Bay and Withnell Bay are small. The tidal range is 1.00 m during neap tide and 3.60 m during spring tide.

Current monitoring has not been done by the terminal operators or authorities in the surrounding area. Current velocities are estimated from the design of Gorgon LNG terminal near Dampier. The peak tidal currents are 0.30 m/s during neap tide and 0.65 m/s during spring tide.

5.4.2 Analysis of environmental monitoring data

Wind

Analysis of the wind data has led to the following conclusions:

- The main wind direction is south to west, i.e. offshore wind.
- Wind velocities are 0 - 12 m/s.

The most interesting day for investigation of wind effects on moored ships is December 1. During this day wind velocity is 11 m/s while waves and swell are low.

Waves

From the geometry of the Mermaid Sound two effects are important for wave conditions near the terminal:

1. Swell waves generated on the Indian Ocean enter the Mermaid Sound from the north. Refraction of these waves in the sound result in a nearly constant swell direction which is Northwest. Energy dissipation of the swell waves on the shallow parts of the Mermaid Sound reduce the wave height, particularly of shorter waves. Peak period of these wave at the terminal is 13 - 18 s.
2. Waves generated by local wind have got nearly the same direction as the wind. Wave height and peak period is restricted due to the short fetch inside the Mermaid Sound except for northerly wind.

Most dangerous wave conditions are waves from the north due to cyclones and tsunamis generated by earthquakes in the Indian Ocean. A cyclone occurred on April 10, 1996. Maximum significant wave height at the terminal was 3.7 m, peak period 14 s. This event did not happen during the measuring period.

During the second half of 1996 two minor storms took place. July 15, wave height =1.1 m. and December 31, wave height = 1.5 m. During the second storm no ship was moored. Wave conditions during the rest of the period were 0.2 - 0.7 m.

Swell waves during the measuring period range from 0.1 to 0.4 m, peak periods range from 13 to 18 s. Relatively high swell waves combined with LNG berth occupancy occurred on July 18/19, 21/22, 28, 29/30, August 1/2 and September 16/17.

5.5 Analysed periods

The periods analysed in this research can be divided into four categories:

1. Period during which loads due to vertical tide are easy to eliminate from the line force data.
2. Period with significant wind loads combined with low wave conditions.
3. Period with relatively high waves, sea state.
4. Periods with relatively high waves, swell.

Re. 1: During measurements on October 8-10 tidal effects are obvious and easy to eliminate. For verification of these measurements differences between the maximum forces and the overall mean value are considered instead of differences between maxima and average over ten minutes. The environmental conditions though are not severe.

Re. 2: The highest wind loads occurred on December 1. Because the wind direction was offshore, wave height due to the wind was small.

Re. 3: Trying to verify ship behaviour in short period waves (T_p = 6-7 s.) the July 15 case was considered.

Re. 4: Swell waves (T_p = 14-18 s) appear to be the most significant load on the moored ship. Hence most interest of research were periods with high swell waves. these periods were: July 18/19, July 21/22, July 28 and August 1/2.

6 TERMSIM Simulations

6.1 Co-ordinate systems

TERMSIM uses two systems of co-ordinate axes.
The first is an earth-fixed system $O(X_1, X_2, X_3)$. O is an arbitrary point on the sea surface. The co-ordinate axes as used for the LNG jetty in Withnell Bay are included in the jetty layout in appendix D, figure 3 and 4. For the LNG jetty the origin is the intersection of the approach bridge and the centre line of the jetty.
The second co-ordinate system is a ship-bound $G(x_1, x_2, x_3)$ system fixed to the ship. The origin is the ship's centre of gravity. The x_1 axis points towards the ship bow.

The fairlead positions are given in the ship-bound system. All other input as well as output parameters (e.g. ship motions) are given in the earth-fixed system. Input of wave, wind and current directions is done in the direction they are travelling to. For example input of waves head-on = 180°.

6.2 Input parameters

The input of a TERMSIM case exists of the following elements:

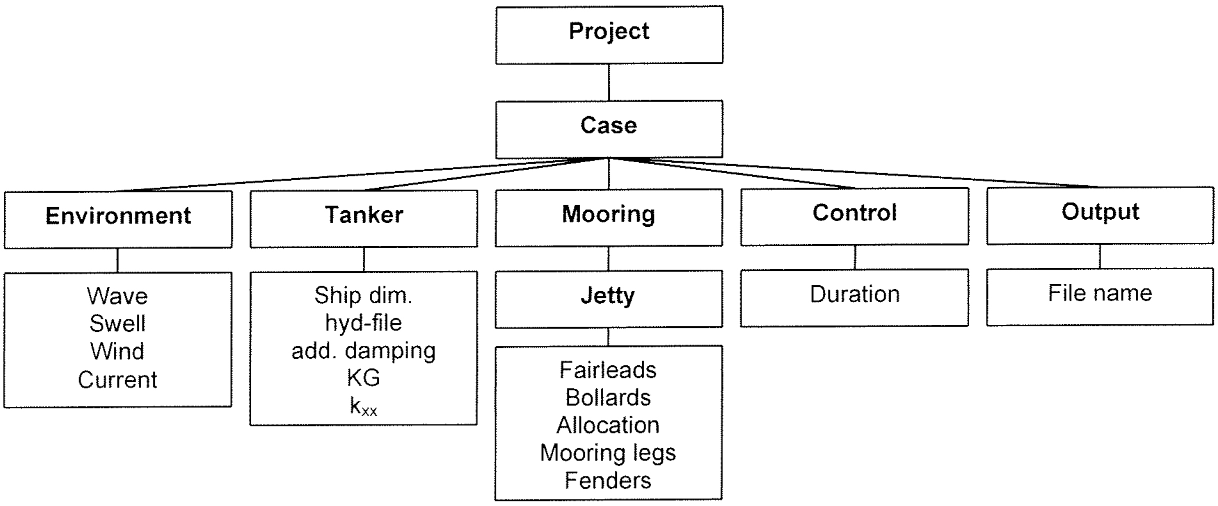


Figure 6.1: Scheme of TERMSIM input data

6.2.1 Environmental data set

It is possible to use two wave spectra as TERMSIM input (waves and swell). These waves are assumed to be long crested and traveling in a constant direction. For most simulations the input wave spectrum is a standard spectrum (in particular a JONSWAP spectrum). The differences between measured spectra and standard spectra, used as simulation input, are very small. The input spectrum is a best fit of the measured spectrum.

For most simulations the wave height and mean direction near the berth is assumed to be equal to the wave conditions measured by the Waverider buoy. However although the bouy is rather close to the LNG jetty, wave directions and wave height near the moored ship might be different due to the presence of the approach channel and harbour basin. Due to this presence, waves might be refracted and the wave height could be smaller inside the harbour basin due to shoaling in the deeper channel and harbour basin. Wave height differences due to refraction in the approach channel are neglected.

Importantly, directional spreading is not included in the model. The possibillity of simulating this spreading is discussed in the paragraph 6.4.4.

Input of wind velocity and direction is in accordance with the measured average wind speed and direction. In most simulations the Harris spectrum for gusting wind was used.

Current velocities were estimated from the tide measurements executed in the King Bay near Dampier. Current loads are small in the Mermaid sound. Velocities range up to 0.65 m/s.

6.2.2 Tanker data set

The following three hydrodynamic files were used for the simulations:

- *S125PAR.hyd*: standard loaded 125,000 m^3 LNG carrier, water depth = 16 m.
- *S125PER.hyd*: standard loaded 125,000 m^3 LNG carrier, water depth = 20 m.
- *NWSandp.hyd*: Northwest-type 125,000 m^3 LNG carrier in ballast, water depth = 17.7 m.

The *S125*-files have been generated by MARIN based on a standard loaded 125,000 m^3 LNG carrier with spherical gas tanks. *NWSandp* has been generated by Delft University of Technology based on the dimensions of a Northwest-type LNG carrier in ballast. The particulars of the ships that were used to determine the hydrodynamic file are:

Table 6.1: Specifications of hydrodynamic files

	Symbol	Unit	*S125*	*NWSandp*
Length between perpendiculars	L_{PP}	m	259	259
Breadth	B	m	48.1	47.2
Depth	D	m	27.0	26.5
Draft	T	m	11.3	9.5
Displacement volume	∇	m^3	103,858	79,015
COG above keel	$\dot{G}K$	m	18.94	16.00
COG forward of station 10	LCG	m	0.41	1.77
Metacentric height	GM	m	3.09	4.70
Transverse radius of gyration in air	k_{xx}	m	17.56	17.80
Longitudinal radius of gyration in air	k_{yy}	m	62.16	62.00
Water depth	d	m	16 / 20 *	17.7

*: water depth = 16 m for *S125PAR.hyd*
water depth = 20 m for *S125PER.hyd*

Concerning the *S125*-files 1,598,000 kNms/rad viscous roll damping was added to 0.30 and 0.35 rad/s by MARIN.

Additional damping for surge, sway and yaw has been neglected for all cases. Additional damping may include wave drift damping or mooring line damping. Wave drift damping is negligible for the occurring wave heights. Mooring line damping is not known, but probably smaller then other uncertainties.

6.2.3 Mooring data set

The fairlead positions have been obtained from SIGGTO LNG data book (ref. [11], appendix E).

Bollard positions have been obtained from the jetty layout (appendix D, figure 3). The level of the quick release hooks is AHD + 6 m.

The horizontal pretension per line is chosen such that the total pretension force in the X_1 direction is equal to zero and that the mean force of the simulation output is approximately equal to the measured mean force.

Mooring line characteristics (appendix D, figure 6) have been obtained from standard mooring line characteristics in OCIMF, Mooring Equipment Guidelines (ref. [12]) and User Manual TERMSIM II (LNG) (ref. [13]).

Fender characteristics have obtained from standard characteristics for Yokohama air block fenders used in the MARIN reports Withnell Bay LNG Terminal project (ref. [4]). The breasting dolphins are equipped with two identical fenders attached to one fender panel. The system is modelled as one fender, located in the middle between the two fenders, with double restoring force characteristic. For all simulation runs a fender friction coefficient of 0.4 was adopted.

6.2.4 Control data set

The duration of all simulation runs is three hours or 10,800 seconds.

6.3 Analysis of the output

The TERMSIM simulations have been made to be compared to the prototype measurements. In order to make the comparison easier to handle, the simulation output is presented the same way as the analysis of measured data, see paragraph 5.3.2. In addition to the measured data the following quantities are presented in the tables:

- Pretension per mooring leg from TERMSIM input
- Overall standard deviation per parameter, computed by TERMSIM
- Vessel motions
- Fender forces

In order to obtain appropriate reference material for the measured data, the TERMSIM output has been analysed the same way as the measured data. Hence average, minimum and maximum are stored for every ten minute interval. The minimum and maximum values are stored as deviations from the average. An example of calculated line forces is given figure 6.2. The variables mentioned in figure 6.2 are the average, maximum and minimum values of the considered parameter in the i^{th} ten minute interval. Noticing that the calculation interval Δt of TERMSIM is 0.5 s, the expressions for the average, minimum and maximum are as follows:

$$
\begin{aligned}
\mathrm{avg}(p)_i &= \frac{1}{1200} \cdot \sum_{j=1200(i-1)+1}^{1200 \cdot i} p_j \\
\max(p)_i &= \max\left[p_{1200(i-1)+1} \cdots p_{1200 \cdot i}\right] - \mathrm{avg}(p)_i \\
\min(p)_i &= \min\left[p_{1200(i-1)+1} \cdots p_{1200 \cdot i}\right] - \mathrm{avg}(p)_i
\end{aligned}
\qquad (6.1)
$$

in which: p_j = considered parameter on time $t = \Delta t \cdot j = 0.5\, j$

The statistical quantities that are calculated from the average, minimum and maximum values are the same as has been done for the measured data (paragraph 5.3.2).

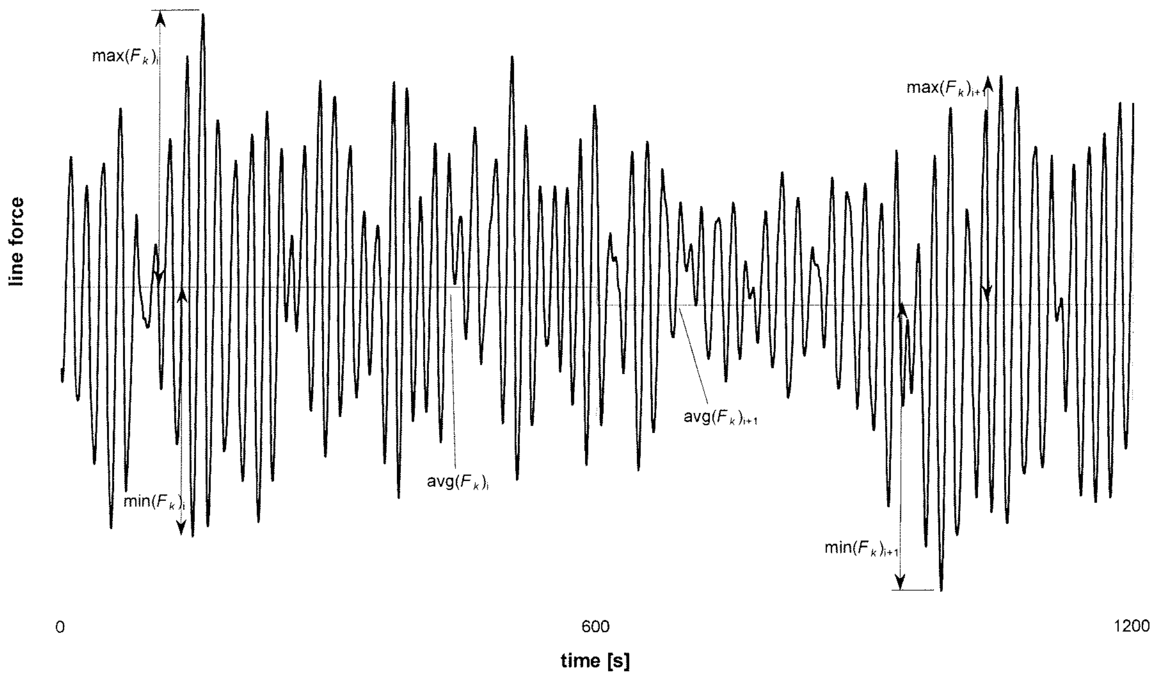


Figure 6.2: calculated line forces during twenty minutes

Beside the mean value of the maxima per ten minutes an expected value of the maximum line force per three hours is given. This is done to obtain more information about the distribution of the maximum forces. Since the overall maximum value per three hours simulation is too much influenced by coincidence, the three hour maxima are estimated in another way.

If the force spectrum of a mooring line is narrow and assuming a linear proportionality between wave height, which is Rayleigh distributed, and line force amplitude, then the amplitudes of line forces are also Rayleigh distributed. The distribution function of line force amplitudes then is:

$$F_a(a) = 1 - e^{-\frac{a^2}{a_{rms}^2}} \tag{6.2}$$

where: a = line force amplitude
a_{rms} = root mean square value of line force amplitude

If a ten minute interval contains a lot of wave motions, the distribution of the maximum forces per ten minute interval can be approximated as follows:

$$F_{\max(F_k)}(a) = \exp\left(-N \cdot e^{-\frac{a^2}{a_{rms}^2}}\right) \tag{6.3}$$

where: $\max(F_k)$ = maximum line force amplitude per ten minutes
N = number of wave motions

Consequently the maxima per ten minutes squared are Gumbel distributed and the expected value of the maximum amplitude per three hours, obtained from eighteen ten minute maxima, is (almost) equal to:

$$\mathbf{E}\left(\max_{3h}(F_k)\right) \approx \sqrt{\left(\mu_{\max(F_k)}\right)^2 + \frac{\sigma_{\max\left(F_k^2\right)} \cdot \sqrt{6}}{\pi} \cdot \ln 18} \tag{6.4}$$

in which: $\mu_{\max(F_k)}$ = mean value of ten minute maxima = $\frac{1}{n}\sum_{i=1}^{n}\left(\max(F_k)_i - \operatorname{avg}(F_k)_i\right)$

$\sigma_{\max\left(F_k^2\right)}$ = standard deviation of ten minute maxima squared

$$= \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}\left(\max\left(F_k^2\right)_i - \mu_{\max\left(F_k^2\right)}\right)^2}$$

$\mu_{\max\left(F_k^2\right)}$ = mean value of ten minute maxima squared

$$= \frac{1}{n}\sum_{i=1}^{n}\left(\max\left(F_k^2\right)_i - \operatorname{avg}\left(F_k^2\right)_i\right)$$

For most cases the line force spectrum of head, breast and stern lines are narrow because of the importance of yaw motion generated by first order wave forces. The spectra of forces in spring lines might not be narrow because of the importance of both first order forces and low frequency surge motions. Because of this there is no theoretical clarification for the distribution of maximum forces in spring lines. The ten minute maxima are assumed to be Gumbel distributed. Then the three hour maxima are also Gumbel distributed and the expected value of the three hour maxima, obtained from eighteen ten minute maxima, is as follows:

$$\mathbf{E}\left(\max_{3h}(F_k)\right) = \mu_{\max(F_k)} + \frac{\sigma_{\max(F_k)} \cdot \sqrt{6}}{\pi} \cdot \ln 18 \tag{6.5}$$

A fit of computed maximum line forces to a distribution derived from Rayleigh distributed amplitudes (Gumbel fit of quadratic maximum line forces per ten minutes) and a Gumbel fit is presented in appendix D. Four TERMSIM runs with the same wave load, but different random seed number, have been carried out to generate to generate 72 ten minute line force maxima. The 72 points have been plotted in the distribution functions of appendix D, The 72 point are assessed to be enough to verify the distribution function.
The horizontal axis consists of scaled line forces squared in case of a "Rayleigh fit" or scaled line forces in case of a Gumbel fit. The scaling means division by the mean value of the plotted (quadratic) maximum line forces.
The vertical axis consists of the double negative logarithmic of the distribution function.
From appendix D appears that the resemblance between the theoretical distribution function and the distribution of calculated maxima is good: R^2 values of the calculated points around the theoretical line are equal to about 0.98.
Equations 6.4 and 6.5 are used in the analysis of both simulations as well as prototype measurements. The distribution of measured maximum forces is assumed to be nearly equal to the simulated distribution. However, verification of this assumption is impossible, because in the prototype situation the environmental conditions and loading condition are not constant over a long period.

Tables containing the processed TERMSIM output are presented in appendix G. Explanation of the quantities mentioned in these tables is done in paragraph 5.3.2. Comparison of the simulation output to the measured data is presented in graphs and tables. The graphs are included in appendix H. The tables are presented in appendix I. In the graphs the mean values of minimum and maximum forces per ten minutes are given. The zero force line is equal to the average force of each line. The minimum and maximum forces are equal to the forces given in the tables of appendices F and G. Also graphs are given of the expected values of three hour maxima, for which also concerns that the zero force line is equal to the average force and the values are equal to the values given in the tables of appendices F and G.

6.4 Description of TERMSIM simulations

In this paragraph the simulations are discussed in order of dominant environmental load:
1. Tide
2. Wind
3. Waves (sea state)
4. Waves (swell)

The simulation runs that have been carried out for the mentioned four cases are discussed below.

6.4.1 Tide

For the first case one run has been executed with input of environmental conditions as measured by the waverider buoy. Wave conditions are modest: significant wave height of swell is 8 cm, direction 195°.

6.4.2 Wind

In this case wind force seems dominant for ship behaviour. A moderate wind speed of 11.6 m/s (5 Beaufort) is present combined with modest wave conditions: $H_{s,\mathrm{swell}}$ = 0.12 m.
In the evaluation the dynamic behaviour of wind loads is considered. Concerning the measured data there is no distinction between static wind loads and pretension load. The dynamic wind loads are modelled by applying a wind spectrum that generates irregular wind velocities. Two wind spectra are used: the Harris-DNV spectrum (ref. [14]) and the API spectrum (ref. [15]).
Input of wave conditions is as measured by the Waverider buoy, direction 192°. Six simulations have been carried out to investigate dynamic ship behaviour with moderate wind conditions lateral to the ship.:

a) wind spectrum Harris-DNV, no wave input
b) wind spectrum API, no wave input
c) no wind input, wave input as monitored
d) wind spectrum Harris-DNV, wave input as monitored
e) wind spectrum API, wave input as monitored
f) wind direction west: 240°, wind spectrum Harris-DNV, wave input as monitored
g) wind direction south-west: 295°, wind spectrum Harris-DNV, wave input as monitored

6.4.3 Waves (sea state)

In this case sea state waves are much higher then swell waves according to the wave spectra in appendix D, figures 10 and 11. $H_{s,\mathrm{sea}}$ = 1.1 m, $H_{s,\mathrm{swell}}$ = 0.2 m. Peak period of the wave spectrum is 6.3 s. The wave direction is almost head-on. Because the waves may not effect ship behaviour when input direction is head-on (180°) the input direction of the third run is fifteen degrees more transversal.
Three runs have been executed to investigate ship behaviour in short period waves. Two reference periods were simulated with slightly different circumstances:

a1) Reference period 17:20 – 19:40, input of monitored conditions.

a2) Reference period 17:20 – 19:40, wave and swell direction parallel to the approach channel (θ = 198°), shoaling factor for swell waves = 0.9.
b1) Reference period 19:50 – 21:30, input of monitored conditions.
b2) Reference period 19:50 – 21:30, wave and swell direction parallel to the approach channel (θ = 198°), shoaling factor for swell waves = 0.9.
b3) Reference period 19:50 – 21:30, no swell, wave direction = 198°.

6.4.4 Waves (swell)

This is the most important case, because the largest line forces occur when swell waves are relatively high. Six reference periods were used for verification:

Table 6.2: Conditions during reference periods

Date (1996)	Time	loading cond.	$H_{s,swell}$ [m]	T_m [s]	θ_{swell} [°]	spreading [°]
July 21	17:40 – 19:30	0%	0.24	15.7	183	33
July 22	7:50 – 10:50	100%	0.26	14.0	189	30
July 28	7:00 – 10:00	40%	0.24	14.5	188	30
August 1/2	23:50 – 2:10	30%	0.31	14.4	192	34
August 2	11:00 – 12:50	100%	0.31	14.0	185	39
July 19	7:10 – 10:30	80%	0.30	14.0	189	30

For all periods in time swell waves are far more important then wind and short waves.
To verify the importance of some input parameters a sensitivity analysis has been carried out. The elements that were verified in the sensitivity analysis are:

- Loading condition
- Directional spreading of waves
- Wave angle of incidence
- Mooring line characteristics
- Additional damping for yaw

The elements are described separately below. Per element is explained what the variations are and how these variations were modelled in the sensitivity analysis.

Loading condition

The loading condition of the moored ship is different for the simulated periods. The loading condition effects several vessel behaviour characteristics in the prototype situation such as displacement mass, draft, roll frequency and under keel clearance.

The parameters in TERMSIM input that can be modified with different loading conditions are:

- Z-position of fairleads as a result of different freeboard
- The transversal radius of gyration in air k_{xx}
- The height of the centre of gravity KG
- When available a different hydrodynamic file can be used based on different loading condition or water depth

For every TERMSIM run the fairlead positions were altered for the simulated loading condition. The radius of gyration and position of the centre of gravity were estimated. The choice of the hydrodynamic file is part of the sensitivity analysis. Three hydrodynamic files were used: *S125PAR.hyd*, *S125PER.hyd* and *NWSandp.hyd*. The details of these files were discussed in paragraph 6.2.2.

For several simulations of partly loaded vessels, runs were carried out using different hydrodynamic files. This has particularly been done simulating the July 28 period. The loading condition was 40%. Further point of interest is investigation of the difference between line forces of loaded vessels and vessels in ballast for both prototype measurements as simulations.

Directional spreading of waves

Ship motions are very sensitive for wave directions, especially when the angle of incidence is almost head-on. Simulations with wave directions approximately 180° would lead to small sway and yaw motions, because the waves are modelled long-crested and travelling in a constant direction.

In the prototype situation wave direction is not constant, so input of almost transversal waves would certainly lead to underestimating results when surge motion is not most significant.

Investigation of the sensitivity of directional spreading to the line forces has been done using the possibility of input of two waves: the spectrum is split into an equal wave and swell spectrum. The individual wave height of wave and swell is chosen such that the total wave energy does not change: $H_s = \frac{1}{2}\sqrt{2} \cdot H_{s,total}$. Directions are chosen such that the average direction does not change: $\frac{\theta_1 + \theta_2}{2} = \theta_{total}$.

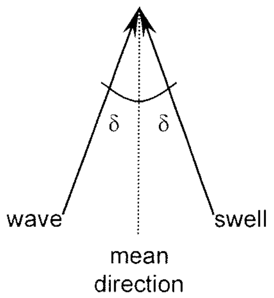


Figure 6.3: modelled directional spreading of waves

The angle δ in figure 6.3 is chosen as a specific percentage of the measured spreading by the Waverider buoy.

Two waves with the same frequency and different directions would introduce an additional second order force, directed in the mean direction, as a result of interaction between the two waves. This additional force which is present in the prototype situation, but it is not included in the TERMSIM model. However, this force would be very small because the angle between the wave directions, 2δ, is small (10° - 40°) and because the second order forces are not most important for ship behaviour in the simulated cases.

An extensive analysis of the effect of wave spreading modelled by two waves has been done for simulations of July 21 and July 22.

Wave direction

As described above, ship behaviour is sensitive to wave directions. Input of slightly different wave directions has been carried out for the July 21&22 periods to investigate the sensitivity.
Because of the sensitivity, knowing the exact wave direction near the moored ship is important. The Waverider buoy that measured the waves near the Withnell Bay terminal is located close to

the harbour basin (see appendix D, figure 2) although not inside it. Wave height and direction may be effected by the existence of the approach channel and turning circle in front of the harbour basin. Waves are refracted on the sides of the approach channel and shoaling causes reduction of wave height.

The shoaling factor for waves travelling from water depth = 8.5 m to 15.5 m (low tide) or 10.5 m to 17.5 m. (high tide), K_s = 0.9. Besides shoaling wave height is influenced by contraction or divergence of waves travelling into the channel and basin. This process has not been taken into account because quantification is hardly possible without the execution of a detailed investigation, preferably with help of a computer model.

A theoretical pattern of wave rays using the refraction theory is presented in figure 5.4. The refraction theory uses the same equation as done to calculate light rays:

$$\frac{d}{ds}\left(\frac{\sin\mu}{c}\right)=0 \qquad (6.6)$$

where: s = axis parallel to the wave ray
μ = angle between wave ray and gradient vector of the bottom slope
c = phase celerity of the wave

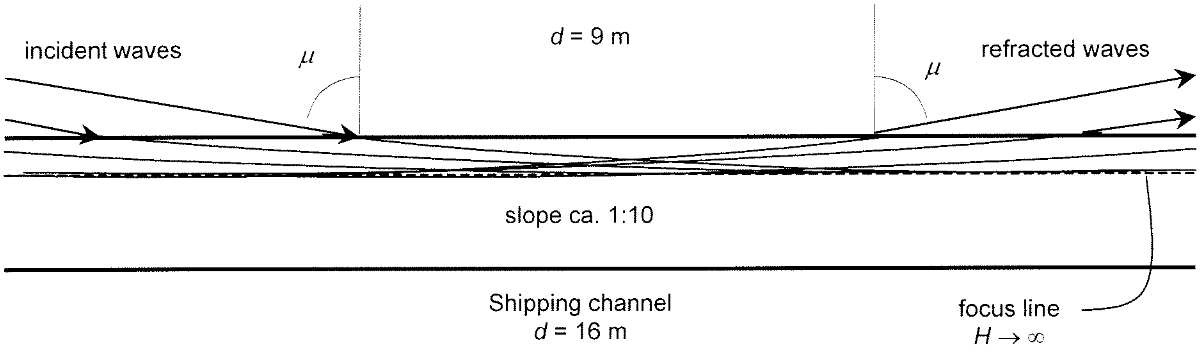


Figure 6.4: Pattern of wave rays according to diffraction theory.

According to the pattern in figure 6.4 all waves travel back to the incident side of the shipping channel as long as the direction of the incident waves $\mu_i > \mu_{limit}$, the limit angle. For waves with wave period T = 16 seconds travelling from water depth h = 9 meters to h = 16 meters, the limit angle is equal to 50°. The occurring incident wave directions range from 70° to 90°. Hence, the drawn wave pattern is valid for all cases.
Along the focus line the theoretical wave height would become infinite, whereas no wave action would be present inside the channel. Diffraction causes smoothing of this unstable situation.
Inside the shipping channel waves are directed almost parallel to the channel axis, because waves travelling in other directions are refracted away from the channel axis at the side slopes. This process is illustrated in figure 6.5.

The assumed wave conditions near the LNG berth are:

- Wave height of swell waves is equal to the measured wave height multiplied by a shoaling factor K_s = 0.9.
- Direction of swell waves is parallel to the channel axis regardless of the measured wave direction: θ = 198°.

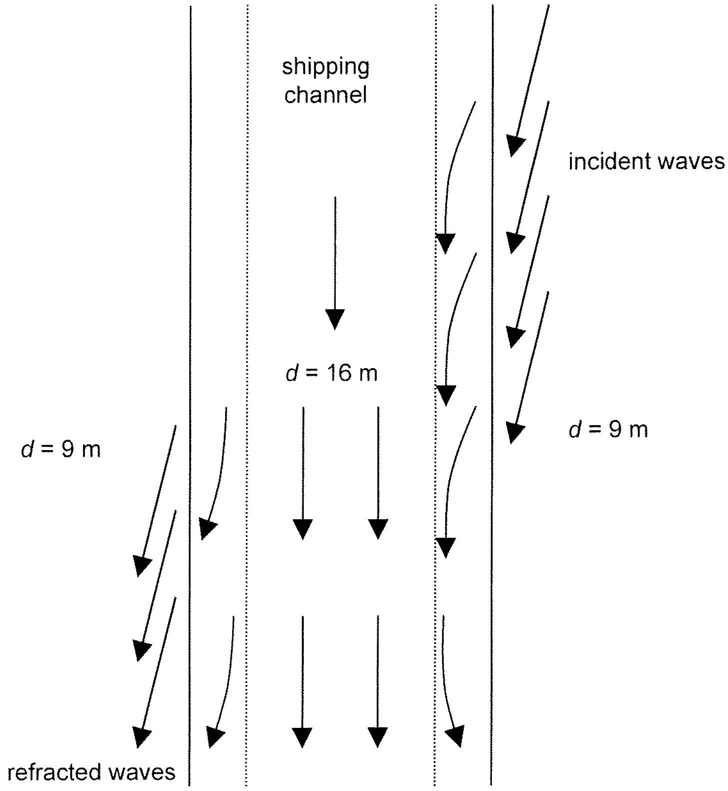


Figure 6.5: wave refraction in approach channel

Simulations including these assumed environmental conditions were carried out for all considered reference periods. Shoaling and refraction are not included in all other simulation runs.

Mooring line characteristics

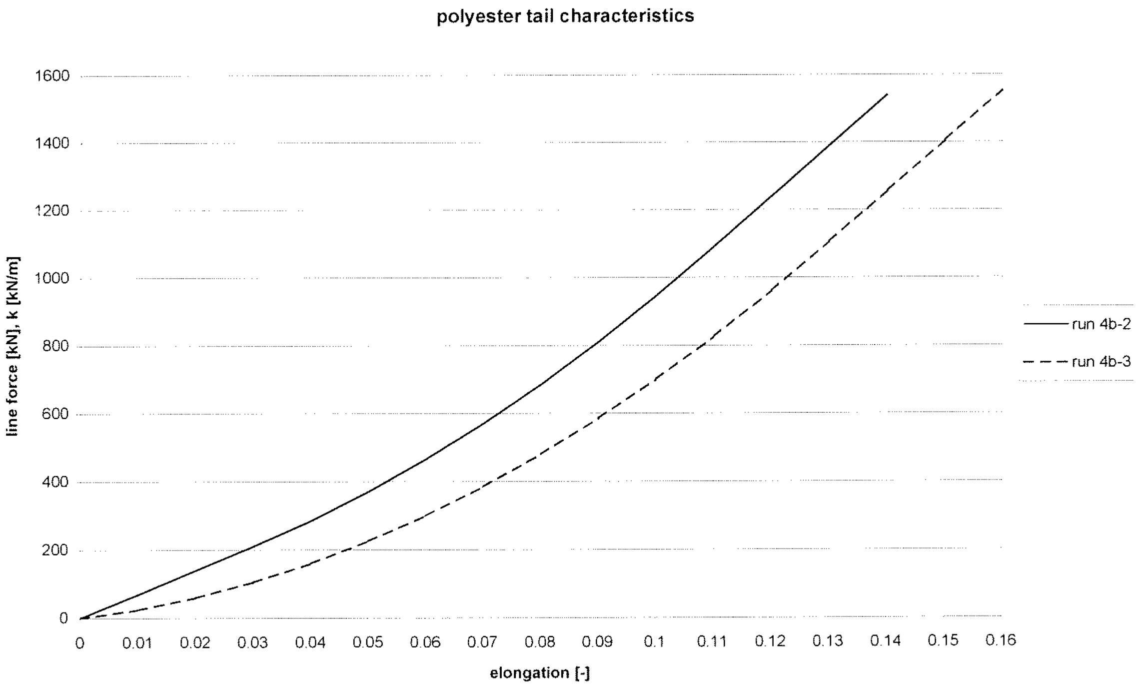


Figure 6.6: Characteristics of polyester tails

Mooring line characteristics are not precisely known, so some differences between measurements and simulations can be explained by the line elasticity. The sensitivity of the elasticity of tails has been investigated for July 22. Input was a softer tail characteristic. The difference of this characteristic with respect to the characteristic used for the other cases is presented in figure 6.6. The ratio of stiffness between the used stiff and soft characteristics is 1.25 (F=40 tn) to 3 (F=0).

An overview of all simulations carried out with dominant swell loads is presented below:

a) July 21

Loading condition 0%. Hyd-file *NWSandp.hyd*.

1. input of monitored conditions, wave direction θ = 183°
2. wave direction θ = 194°
3. wave direction θ = 205°
4. two wave directions, spread = 6°: θ_1 = 177°, θ_2 = 189°
5. two wave directions, spread = 11°: θ_1 = 172°, θ_2 = 194°
6. two wave directions, spread = 17°: θ_1 = 166°, θ_2 = 200°
7. two wave directions, spread = 22°: θ_1 = 161°, θ_2 = 205°
8. wave direction parallel to the approach channel (θ = 198°), shoaling factor 0.9

b) July 22

Loading condition 100%. Hyd-file *S125PAR.hyd*.

1. input of monitored conditions, wave direction θ = 189°
2. wave direction θ = 197°
3. wave direction θ = 197°, softer mooring lines
4. two wave directions, spread = 5°: θ_1 = 184°, θ_2 = 194°, softer mooring lines
5. two wave directions, spread = 10°: θ_1 = 179°, θ_2 = 199°, softer mooring lines
6. two wave directions, spread = 16°: θ_1 = 173°, θ_2 = 205°, softer mooring lines
7. two wave directions, spread = 20°: θ_1 = 169°, θ_2 = 209°, softer mooring lines
8. wave direction parallel to the approach channel (θ = 198°), shoaling factor 0.9, softer mooring lines

c) July 28

Loading condition 40%. Measured wave direction 188°.

1. hyd-file *NWSandp.hyd* (ship in ballast, water depth 17.7 m) , wave direction θ = 188°
2. hyd-file *NWSandp.hyd*, two wave directions, spread = 10°: θ_1 = 178°, θ_2 = 198°
3. hyd-file *S125PAR.hyd* (loaded ship, water depth 16 m), wave direction θ = 188°
4. hyd-file *S125PER.hyd* (loaded ship, water depth 20 m), wave direction θ = 188°
5. hyd-file *S125PER.hyd*, two wave directions, spread = 6°: θ_1 = 182°, θ_2 = 194°
6. hyd-file *NWSandp.hyd*, wave direction parallel to the approach channel (θ = 198°), shoaling factor 0.9
7. hyd-file *S125PER.hyd*, wave direction parallel to the approach channel (θ = 198°), shoaling factor 0.9

d) August 1/2

Loading condition 30%. Hyd-file *S125PER.hyd*. Measured wave direction 192°.

1. input of monitored conditions, wave direction θ = 192°
2. two wave directions, spread = 5°: θ_1 = 187°, θ_2 = 197°
3. two wave directions, spread = 11°: θ_1 = 181°, θ_2 = 203°

4. wave direction parallel to the approach channel (θ = 198°), shoaling factor 0.9
5. wave direction parallel to the approach channel (θ = 198°), shoaling factor 0.9, hyd-file *NWSandp.hyd*

e) August 2

Loading condition 100%. Hyd-file *S125PER.hyd*. Measured wave direction 185°.

1. two wave directions, spread = 13°: θ_1 = 172°, θ_2 = 198°
2. wave direction parallel to the approach channel (θ = 198°), shoaling factor 0.9

f) July 19

Loading condition 80%. Hyd-file *S125PAR.hyd*. Measured wave direction 189°.

1. two wave directions, spread = 12°: θ_1 = 177°, θ_2 = 201°
2. wave direction parallel to the approach channel (θ = 198°), shoaling factor 0.9

6.4.5 Overview of simulation runs

In table 6.3 the most important input parameters of all simulation runs are presented:

Table 6.3: Full overview of input parameters of all TERMSIM runs

run N°	ref. period	water level [m +AHD]	hyd-file	V_{wind} [m/s]	θ_{wind} [°]	$V_{current}$ [m/s]	$\theta_{current}$ [°]	wave spectrum N°	$H_{s,swell}$ [m]	$T_{m,swell}$ [s]	θ_{swell} [°]	θ_{sea} [°]
1	Oct. 9	-0.5	S125PAR	6.9	285	0	-	1	0.08	13.4	195	260
2a	Dec. 1	+1.3	S125PER	11.6 (Har.)	273	0	-	-	0	-	-	-
2b	Dec. 1	+1.3	S125PER	11.6 (API)	273	0	-	-	0	-	-	-
2c	Dec. 1	+1.3	S125PER	0	-	0	-	2	0.12	13.0	192	255
2d	Dec. 1	+1.3	S125PER	11.6 (Har.)	273	0	-	2	0.12	13.0	192	255
2e	Dec. 1	+1.3	S125PER	11.6 (API)	273	0	-	2	0.12	13.0	192	255
2f	Dec. 1	+1.3	S125PER	11.6 (Har.)	240	0	-	2	0.12	13.0	192	255
2g	Dec. 1	+1.3	S125PER	11.6 (Har.)	295	0	-	2	0.12	13.0	192	255
3a-1	Jul. 15 (a)	-0.4	NWSandp	6.1	170	0.3	120	3a	0.19	12.0	193	179
3a-2	Jul. 15 (a)	-0.4	NWSandp	6.1	170	0.3	120	3a	0.17	12.0	198	198
3b-1	Jul. 15 (b)	+0.9	NWSandp	5.7	173	0.5	120	3b	0.21	11.5	191	182
3b-2	Jul. 15 (b)	+0.9	NWSandp	5.7	173	0.5	120	3b	0.19	11.5	198	198
3b-3	Jul. 15 (b)	+0.9	NWSandp	5.7 (const.)	173	0.5	120	3b, no swell	0	-	-	198
4a-1	Jul. 21	-1.3	NWSandp	0	-	0.4	300	4a	0.24	15.7	183	-
4a-2	Jul. 21	-1.3	NWSandp	0	-	0.4	300	4a	0.24	15.7	194	-
4a-3	Jul. 21	-1.3	NWSandp	0	-	0.4	300	4a	0.24	15.7	205	-
4a-4	Jul. 21	-1.3	NWSandp	0	-	0.4	300	4a	0.24	15.7	177	189
4a-5	Jul. 21	-1.3	NWSandp	0	-	0.4	300	4a	0.24	15.7	172	194
4a-6	Jul. 21	-1.3	NWSandp	0	-	0.4	300	4a	0.24	15.7	166	200
4a-7	Jul. 21	-1.3	NWSandp	0	-	0.4	300	4a	0.24	15.7	161	205
4a-8	Jul. 21	-1.3	NWSandp	0	-	0.4	300	4a	0.22	15.7	198	-
4b-1	Jul. 22	-1.1	S125PAR	0	-	0.2	120	4b	0.27	14.0	189	-
4b-2	Jul. 22	-1.1	S125PAR	0	-	0.2	120	4b	0.27	14.0	197	-
4b-3 *	Jul. 22	-1.1	S125PAR	0	-	0.2	120	4b	0.27	14.0	197	-
4b-4 *	Jul. 22	-1.1	S125PAR	0	-	0.2	120	4b	0.27	14.0	184	194
4b-5 *	Jul. 22	-1.1	S125PAR	0	-	0.2	120	4b	0.27	14.0	179	199
4b-6 *	Jul. 22	-1.1	S125PAR	0	-	0.2	120	4b	0.27	14.0	173	205
4b-7 *	Jul. 22	-1.1	S125PAR	0	-	0.2	120	4b	0.27	14.0	169	209
4b-8 *	Jul. 22	-1.1	S125PAR	0	-	0.2	120	4b	0.24	14.0	198	-
4c-1	Jul. 28	+1.0	NWSandp	2.0	75	0	-	5	0.24	14.5	188	-
4c-2	Jul. 28	+1.0	NWSandp	2.0	75	0	-	5	0.24	14.5	178	198
4c-3	Jul. 28	+1.0	S125PAR	2.0	75	0	-	5	0.24	14.5	188	-
4c-4	Jul. 28	+1.0	S125PER	2.0	75	0	-	5	0.24	14.5	188	-
4c-5	Jul. 28	+1.0	S125PER	2.0	75	0	-	5	0.24	14.5	182	194
4c-6	Jul. 28	+1.0	NWSandp	2.0	75	0	-	5	0.22	14.5	198	-
4c-7	Jul. 28	+1.0	S125PER	2.0	75	0	-	5	0.22	14.5	198	-
4d-1	Aug. 1/2	+1.6	S125PER	5.6	321	0.2	300	6a	0.31	14.4	192	-
4d-2	Aug. 1/2	+1.6	S125PER	5.6	321	0.2	300	6a	0.31	14.4	187	197
4d-3	Aug. 1/2	+1.6	S125PER	5.6	321	0.2	300	6a	0.31	14.4	181	203
4d-4	Aug. 1/2	+1.6	S125PER	5.6	321	0.2	300	6a	0.28	14.4	198	-
4d-5	Aug. 1/2	+1.6	NWSandp	5.6	321	0.2	300	6a	0.28	14.4	198	-
4e-1	Aug. 2	+1.8	S125PER	7.4	80	0.2	120	6b	0.31	14.0	172	198
4e-2	Aug. 2	+1.8	S125PER	7.4	80	0.2	120	6b	0.28	14.0	198	-
4f-1	Jul. 19	-0.5	S125PAR	4.0	80	0.4	120	7	0.30	14.0	177	201
4f-2	Jul. 19	-0.5	S125PAR	4.0	80	0.4	120	7	0.27	14.0	198	-

*: softer mooring lines

7 Comparison of TERMSIM Calculations to Measured Data

In this chapter the results of the simulation runs are discussed and compared to the measured data. The method of the analysis of prototype measurements is described in paragraph 5.3.2; the results can be found in appendix F. The description of the TERMSIM runs is found in paragraph 6.4; the results are presented in appendix G. In this chapter the comparison for several dominant environmental loads is discussed in separate paragraphs.

7.1 Tide

During the reference period of October 9, 1996 environmental loads were small. The effects of vertical tide were eliminated successfully from the measured line force data. The remaining variation of average line forces per ten minutes is very small and of the same order of magnitude as the simulation output. Hence no significant very long wave components are assessed to be present in the measurement data.

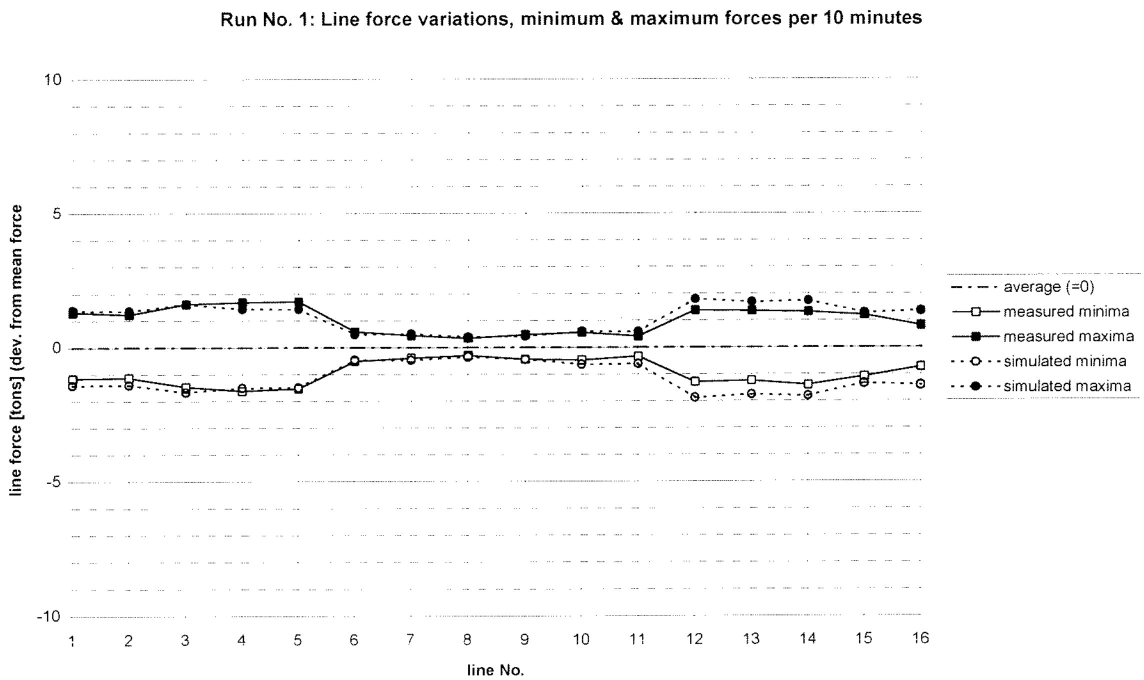


Figure 7.1: Comparison of line forces; October 9 and run 1

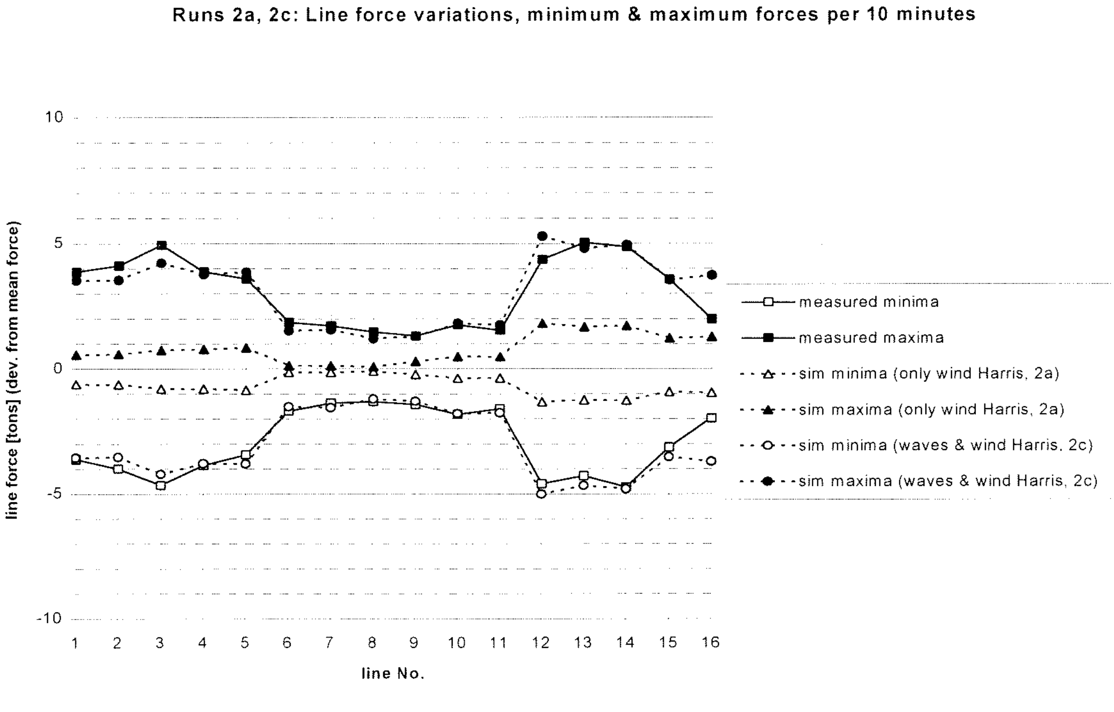
In figure 7.1 the results of run 1 are presented together with the measured data. The zero force line is equal to the average line force, both for the measured and the simulated results. The maxima and minima are mean values of maximum and minimum values per ten minutes. The line numbers correspond with the following mooring legs (see the jetty layout, appendix D, figure 3):

1, 2: head lines
3 - 5: breast lines forward
6 - 8: spring lines forward
9 - 11: spring lines aft
12 - 14: breast lines aft
15 - 16: stern lines

Comparing the maximum forces the general resemblance is very good. However there is an overestimation of 30% of maximum forces in breast lines aft and stern lines.

7.2 Wind

Wind loads may be dominant on December 1, 1996, as low wave conditions are combined with moderate wind loads. Wind velocity is 11.6 m/s in almost transverse direction; swell wave height is only 12 cm. Although swell wave height is small, the dynamical forces from waves are larger than the dynamical forces from wind (comparing runs 2a and 2b). This is not only due to the fact that waves are very often dominant compared to wind loads, but also because wind forces are proportional to wind speed squared and wind speed is only 5 Beaufort.



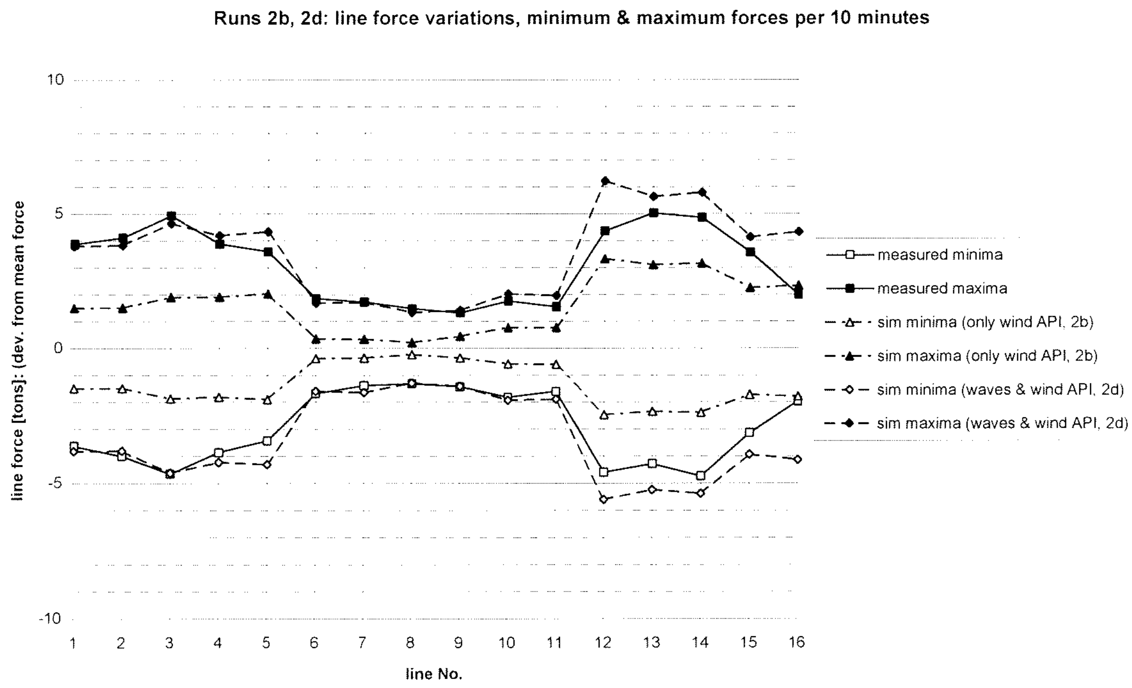


Figure 7.2: Comparison of line forces; runs 2a - 2d and measurements December 1

From results of TERMSIM runs 2a-2d it follows that wave loads are dominant over dynamic wind loads. A well-founded verification of TERMSIM modelling wind forces is not possible because wave loads are too dominant. The effects of the wind spectra Harris-DNV and API are presented in table 7.1; the effects of different wind direction is presented in table 7.2.

Table 7.1: Maximum forces in breast lines for different wind spectra and the same wave spectra.

		Measurements [tn]	**Simulations** [tn]		
			no wind (2b)	Harris-DNV (2c)	API (2d)
10 min.	breast lines forward	4.13	3.36	3.95	4.39
	breast lines aft	4.75	3.93	5.01	5.88
3 hrs.	breast lines forward	5.53	4.47	5.26	5.53
	breast lines aft	6.35	5.03	7.30	8.98

Table 7.2: Maximum forces in breast lines for different wind directions

		Measurements [tn]	**Simulations** [tn]		
			240° (2e)	273° (2c)	295° (2f)
10 min.	breast lines forward	4.13	4.20	3.95	3.94
	breast lines aft	4.75	4.55	5.01	5.35
3 hrs.	breast lines forward	5.53	5.45	5.26	5.39
	breast lines aft	6.35	6.25	7.30	7.98

Results of the sensitivity analysis are:

- The API wind spectrum includes stronger wind gusts than the Harris-DNV spectrum. The effect of wind on maximum forces per three hours is (comparing runs 2c and 2d to 2b, see table 6.1): 0.8 tn (Harris-DNV), 1.1 tn (API) for breast lines forward; 2.3 tn (Harris-DNV), 4.0 tn (API) for breast lines aft.
- The sensitivity for wind direction is small (runs 2c, 2e and 2f): differences are approximately 7% with division of 22° in wind direction. This may also be the result of the transverse wind direction.

Modelling the wind situation during the reference period, Harris-DNV is probably the better spectrum, because the difference between monitored average wind speeds and three seconds gusts are small.

7.3 Waves (sea state)

During July 15, the highest waves of the monitoring period occurred: H_s = 1.2 m, T_p = 6.5 s. Although the sea waves are far larger than the small swell components included in the same spectrum (appendix D, figures 16 and 17) they hardly effect vessel motions and line forces according to run 3b-3 (without swell), see figure 7.3. The influence of waves (sea state) might become dominant over swell waves if wave height is much larger and second order wave forces become significant. Low-frequency wave drift forces are proportional to wave height squared; these forces would probably only be significant if H_s > about 2 m.

Table 7.2: Summary of run 3a-2, July 15 (a)

	Measurements [tn]	**Simulation** [tn]	**Difference**
breast lines forward	4.77	5.49	15.0%
spring lines forward	2.07	1.68	-18.7%
spring lines aft	2.41	2.00	-16.7%
breast lines aft	4.55	5.77	26.8%

Table 7.3: Summary of run 3b-2, July 15 (b)

	Measurements [tn]	**Simulation** [tn]	**Difference**
breast lines forward	4.45	4.66	4.6%
spring lines forward	1.53	1.49	-2.6%
spring lines aft	1.99	1.60	-19.8%
breast lines aft	4.13	4.91	19.0%

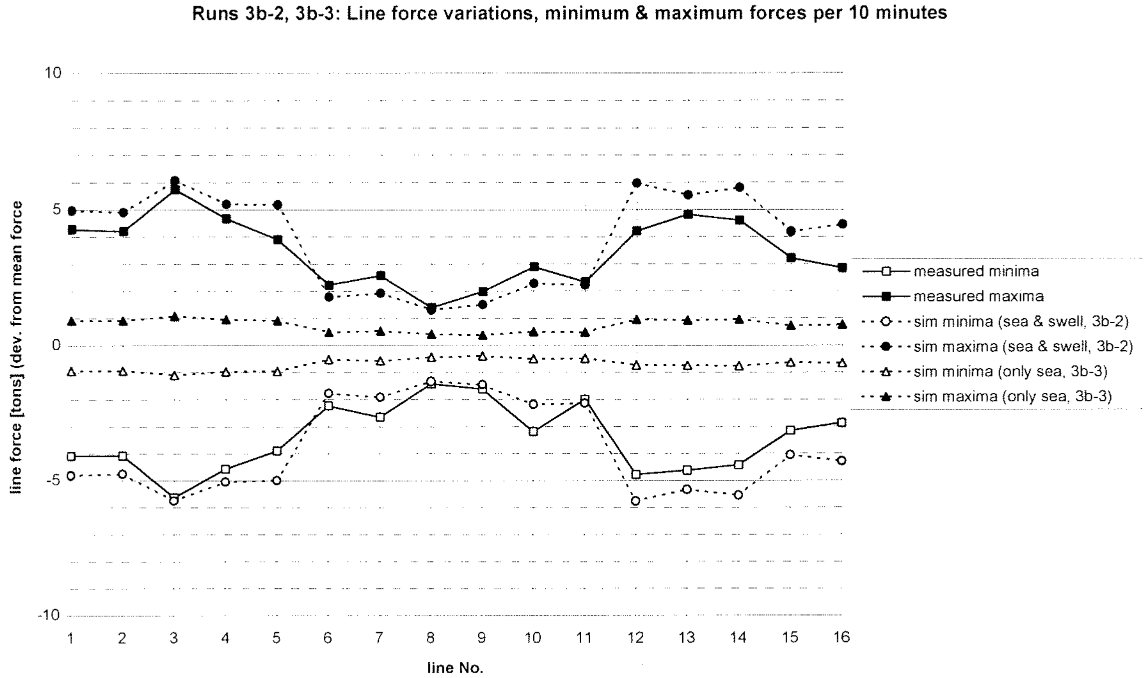


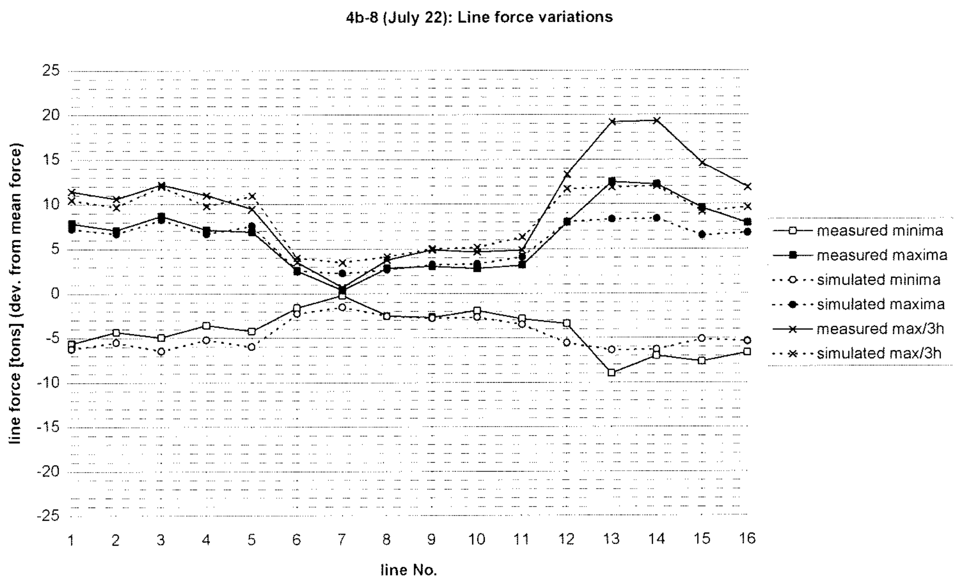
Figure 7.3: Comparison of line forces, runs 3a-2, 3b-2&3, measurements July 15

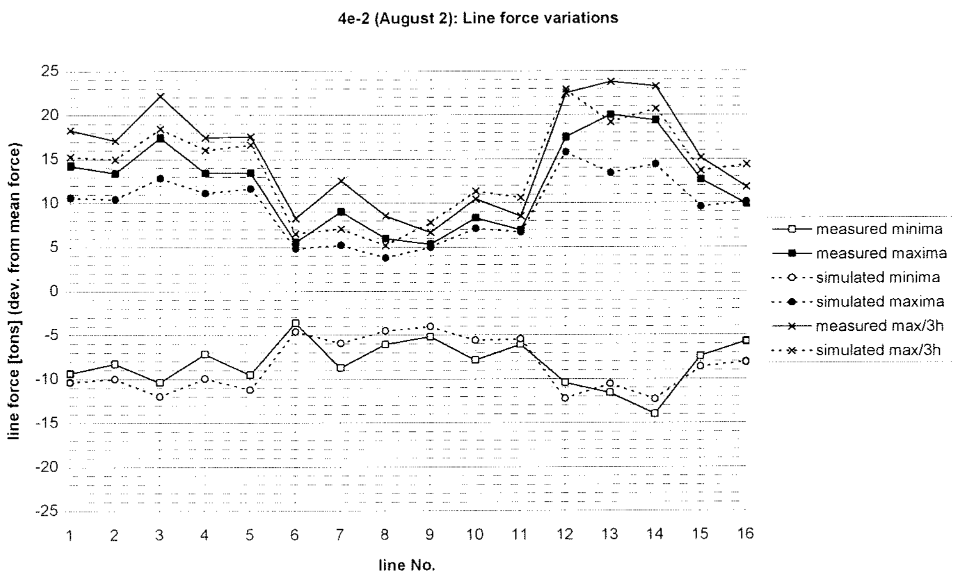
Comparing the runs containing both sea state waves and swell (3a-2, 3b-2) to the measured data, forces in breast lines are overestimated (forward: 10%, aft: 20-25%) and forces in spring lines are slightly underestimated (15%), see tables 7.2 and 7.3.

7.4 Waves (swell)

Swell waves (T_p = 14-18 s) appear to be the dominant loads on the moored LNG carrier in Withnell Bay, because large variations of measured line forces only occurred when relatively high swell waves were present. In figure 7.4 the results of simulation runs for different reference periods are presented. The ships were loaded or nearly loaded during the reference periods. Assumption of input of swell waves is the same for all runs in the graphs. Wave direction is 198°, parallel to the approach channel, for all runs and wave height is equal to 0.9 * measured wave height (0.9 is shoaling factor), according to the assumption that incident waves are refracted in the approach channel, see paragraph 6.4.4.

The maximum line forces in the breast lines for the runs presented in figure 7.4 are given in tables 7.4 - 7.6:





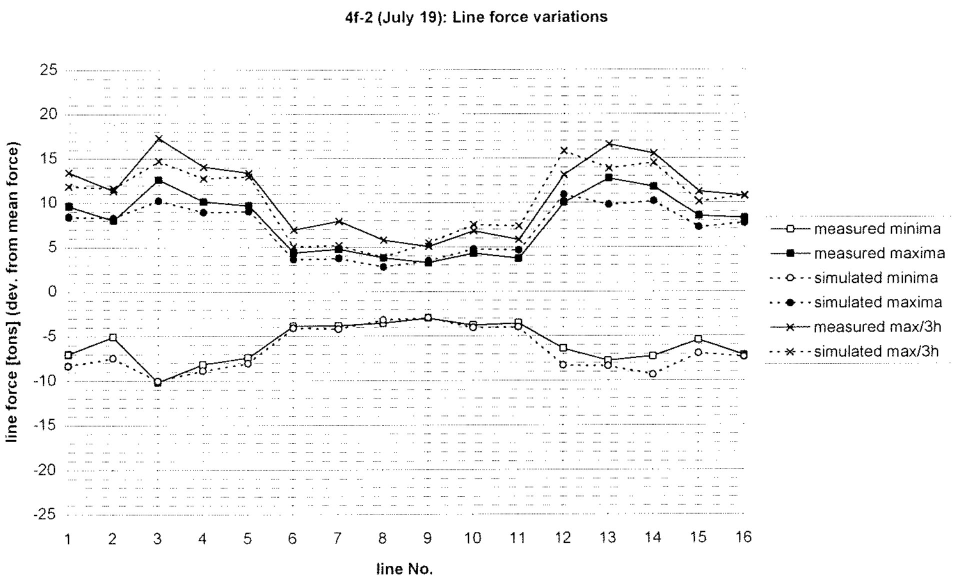


Figure 7.4: Comparison of line forces on loaded ships

Table 7.4: Summary of run 4b-8, July 22 (softer mooring lines)

		Measurements [tn]	**Simulation** [tn]	**Difference**
10 min.	breast lines forward	7.56	7.50	-0.8%
	breast lines aft	10.88	8.24	-24.2%
3 hrs.	breast lines forward	10.88	10.90	0.2%
	breast lines aft	17.25	11.86	-31.3%

Table 7.5: Summary of run 4e-2, August 2

		Measurements [tn]	**Simulation** [tn]	**Difference**
10 min.	breast lines forward	14.75	11.87	-19.5%
	breast lines aft	18.95	14.52	-23.3%
3 hrs.	breast lines forward	19.05	17.03	-10.6%
	breast lines aft	23.16	20.92	-9.7%

Table 7.6: Summary of run 4f-2, July 19

		Measurements [tn]	**Simulation** [tn]	**Difference**
10 min.	breast lines forward	10.81	9.41	-12.9%
	breast lines aft	11.50	10.26	-10.7%
3 hrs.	breast lines forward	14.90	13.47	-9.6%
	breast lines aft	15.07	14.72	-2.3%

The average underestimation for breast lines forward is approximately 10%; the underestimation for breast lines aft is about 20%. The differences between ten minute maxima and three hour maxima show good resemblance. Notice that this difference is slightly higher for simulations than measurements, although the environmental conditions are constant in time for the simulated situation and may slightly vary in time for the prototype situation.

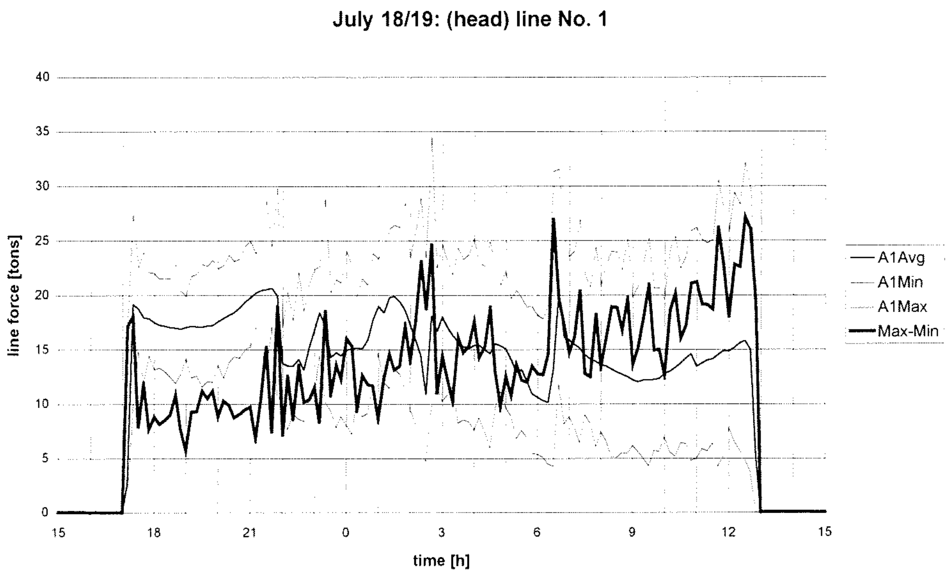
An extensive sensitivity analysis has been carried out to verify the sensitivity of some input parameters. These parameters are:

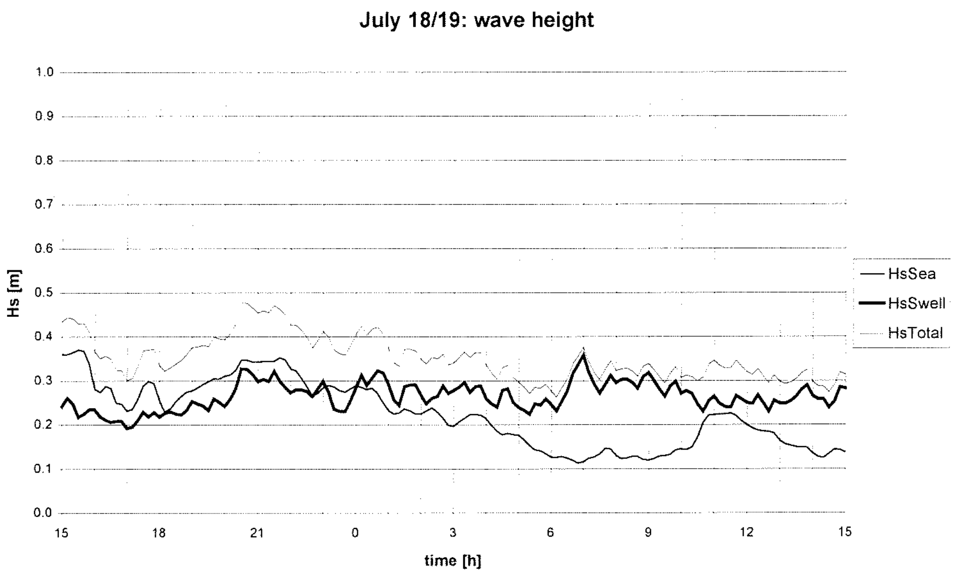
- Loading condition
- Directional spreading of waves
- Wave direction
- Mooring line characteristics

The results of the sensitivity analysis on these parameters are discussed below in separate paragraphs.

7.4.1 Loading condition

Using a different hydrodynamic file to represent a different loading condition especially affects the simulated roll motion (comparing runs 4c-1, 4c-3 and 4c-4). This is particularly the result of the larger metacentric height for ships in ballast. Therefore roll motions are larger for loaded ships. However because the simulated line forces are mainly influenced by the yaw motion and simulated yaw motion is slightly larger using *NWSandp.hyd* (hydrodynamic file for the ship in ballast), the simulated line forces are also slightly larger for runs using *NWSandp.hyd*.
Another variable of different loading condition is the displacement mass of the ship. As a result of different mass, maximum line forces are lower for ships in ballast. However TERMSIM reads the ship's displacement mass from the hydrodynamic file. Therefore the mass cannot be altered for different loading conditions.





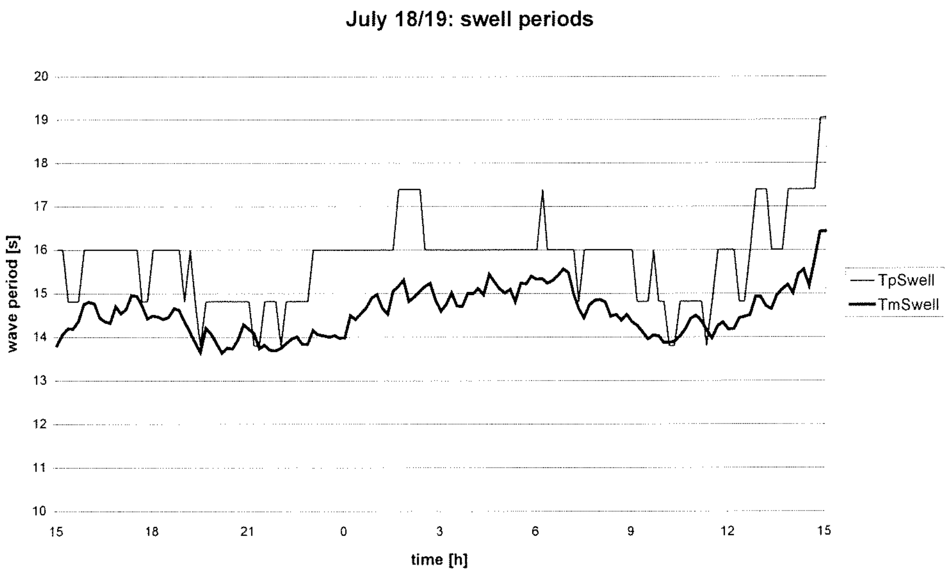
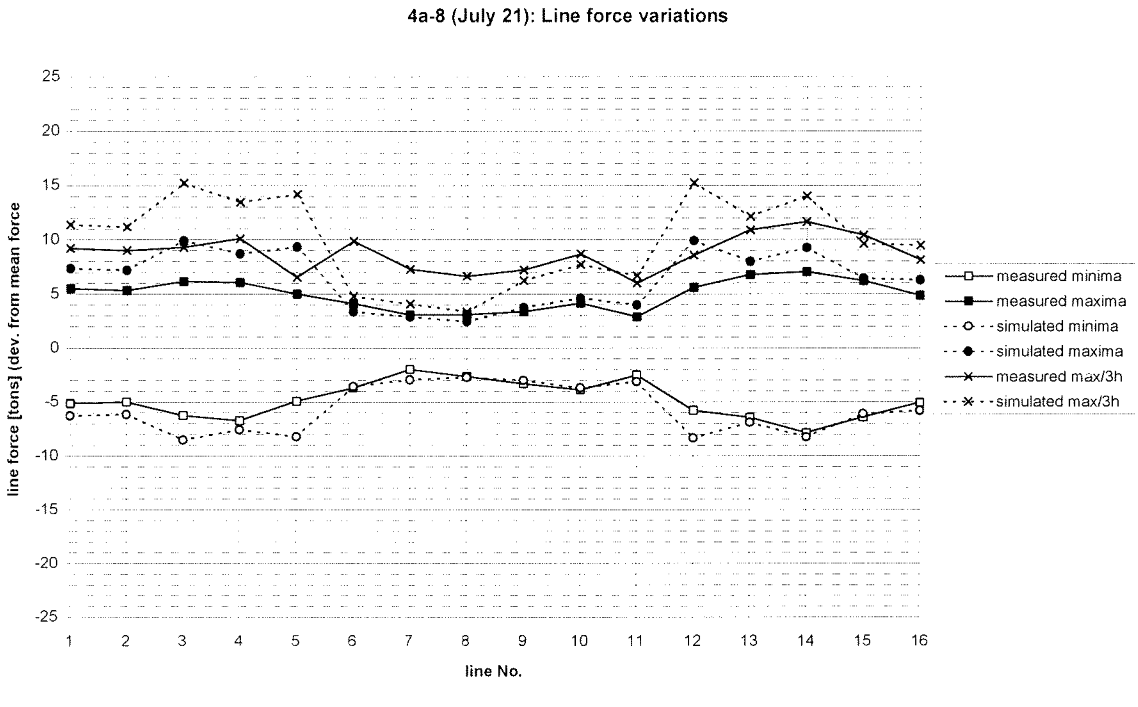


Figure 7.5: Dependence of Measured line force to loading condition, July 18/19

The dependence of measured line forces on the loading condition is illustrated in figure 7.5. The dynamic component of the line forces, "*Max-Min*" is equal to the maximum line force minus the minimum line force during the same ten minute interval. This *Max-Min-value* increases from ten to twenty tons during the loading process of the ship. This increase cannot be explained from increasing wave height or wave period, because these variables are almost constant in time.



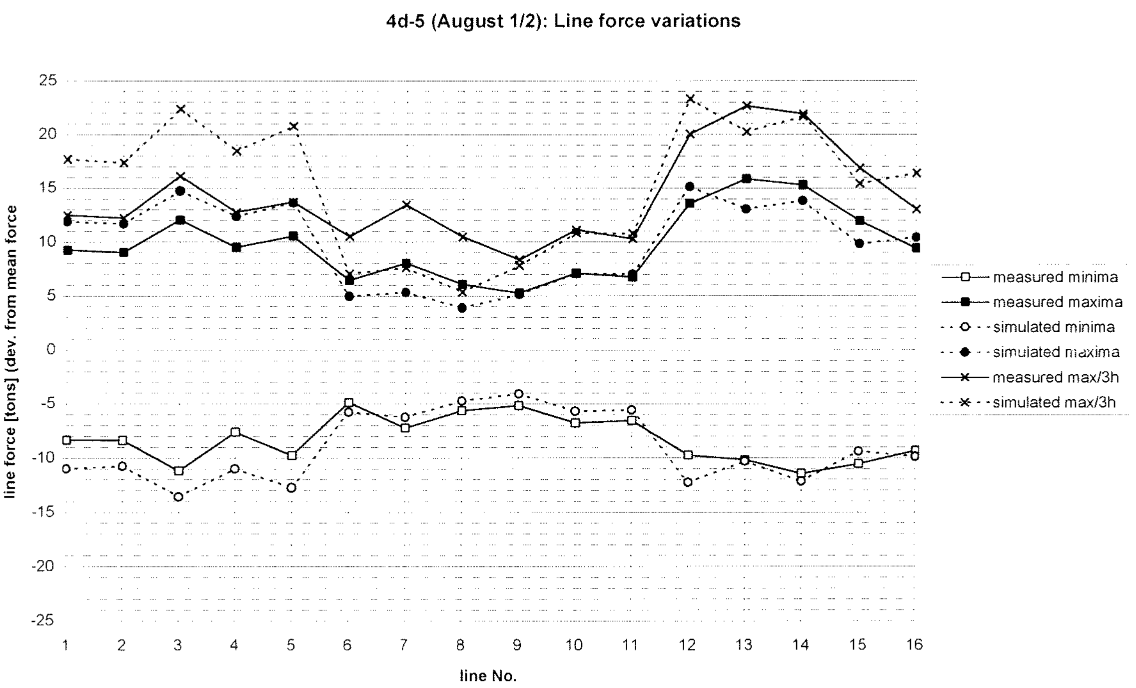


Figure 7.6: comparison of line forces on a ships in ballast and a partly loaded ship

The dependence of maximum line forces is presented In table 7.7. The maximum line forces per ten minutes and per three hours are given for four loading conditions. The data have been originated from runs 4a-8, 4d-5, 4f-2 and 4e-2. Graphs of runs 4a-8 (in ballast) and 4d-5 (30% loaded) are given in figure 6.6; graphs of 4f-2 and 4e-2 are presented in figure 7.4. These runs are chosen because environmental conditions are almost equal (with the exception of the wave period in 4a-8) and the assumption of input of wave direction is equal for all runs: wave direction = 198°, shoaling factor = 0.9. This is the same assumption of wave input as has been used for the loaded ships, discussed above. Input of the different loading condition mainly consists of different height of fairleads and use of the hydrodynamic file for ships in ballast used in 4a-8 and 4d-5.

Table 7.7: Dependence of maximum line forces on loading condition.

		Measurements				**Simulations**			
	date	7-21	8-1/2	7-19	8-2	7-21	8-1/2	7-19	8-2
	run N°					4a-8	4d-5	4f-2	4e-2
	loading condition	0%	30%	80%	100%	0%	30%	80%	100%
	$H_{s,swell}$ [m]	0.24	0.31	0.29	0.30	0.22	0.28	0.26	0.28
	T_m [s]	15.7	14.4	14.0	14.0	15.7	14.4	14.0	14.0
10 min.	breast lines forward [tn]	5.72	10.71	10.81	14.75	9.31	13.60	9.41	11.87
	breast lines aft [tn]	6.46	14.91	11.50	18.97	9.05	14.00	10.26	14.52
3 hrs.	breast lines forward [tn]	8.64	14.20	14.90	19.05	14.27	20.54	13.47	17.03
	breast lines aft [tn]	10.36	21.53	15.07	23.16	13.80	21.74	14.72	20.92

The values in table 7.7 demonstrate an obvious dependence of measured maximum line forces on the loading condition. The simulation output does not demonstrate this dependence. The lower forces for both measurements and simulations during July 21, 1996 are influenced by the lower wave height. The higher forces during August 1/2 and August 2, 1996 are probably influenced by the high water level. Because of high tide and spring tide during the reference period, the vertical angles of mooring lines are large causing increasing line forces.

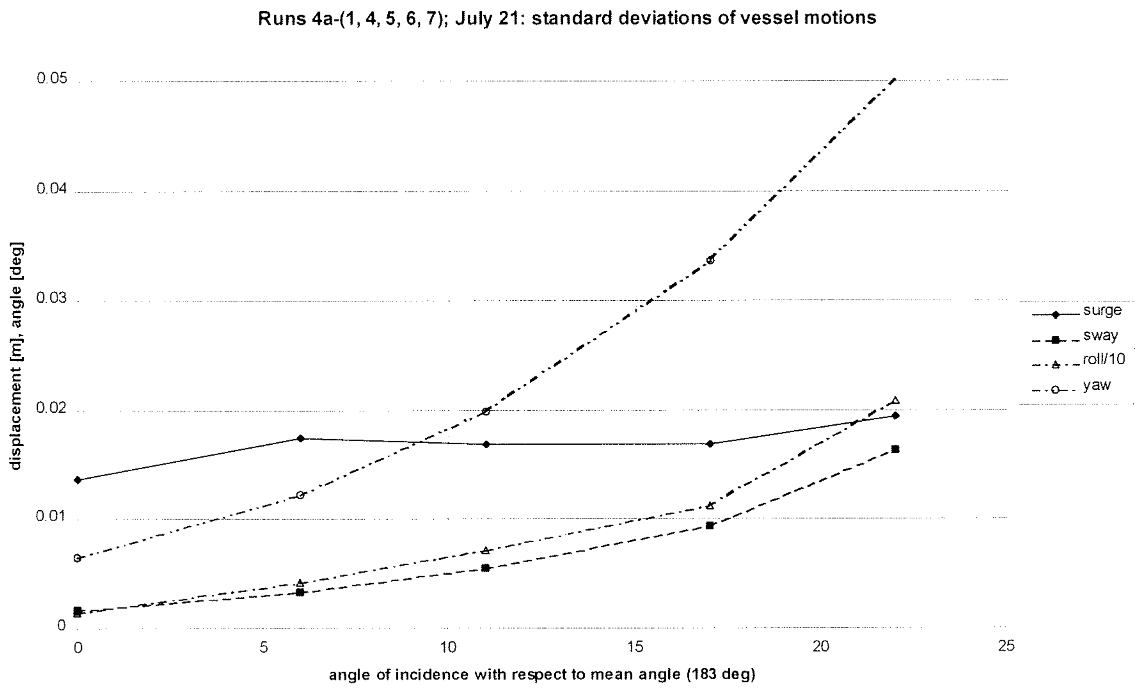
Conclusion from the runs on loaded ships (tables 7.4 – 7.6) was an underestimation of forces in breast lines forward of 10% and breast lines aft 20%. From table 7.7 and figure 7.6 appears that line forces are overestimated for ships in ballast and partly loaded ships. The overestimation is equal to about 45% in breast lines forward and 20% in breast lines aft.

7.4.3 Directional spreading of waves

Directional spreading of waves is not included in the TERMSIM model. However wave propagation on oceans is not unidirectional. Modelling this spreading in TERMSIM input is explained in paragraph 6.4.4. An analysis of the influence of directional spreading has been carried out for simulations of July 21 and July 22, 1996. Mean wave direction is the direction measured by the Waverider buoy, which is 183° for July 21 and 189° for July 22, 1996. The graphs of vessel motions and forces in breast line N° 14 are presented in figure 7.7. In the graphs the *"angle of incidence with respect to mean angle"* is the spreading of the input wave direction. If *"angle of incidence with respect to mean angle"* is δ then the input wave directions were 183°– δ and 183° + δ.

Obviously maximum line forces are very sensitive for wave directions. For directions within thirty degrees from lateral to the ship (180°) the proportionality is between linear and quadratic. Fitting the calculated results to the measured data, input of spreading angle between 30% and 50% of the measured spreading provides the best results.

In order to verify whether the hypothesis *"input of spreading angle is 30-50% of measured spreading"* holds true, a spreading angle of about 33% of the measured spreading was applied as input for all other reference periods. A summary of the results is presented in tables 7.8 – 7.13. θ_{mean} is the measured wave direction which is the average of the directions in the input. δ is the spreading in the input.



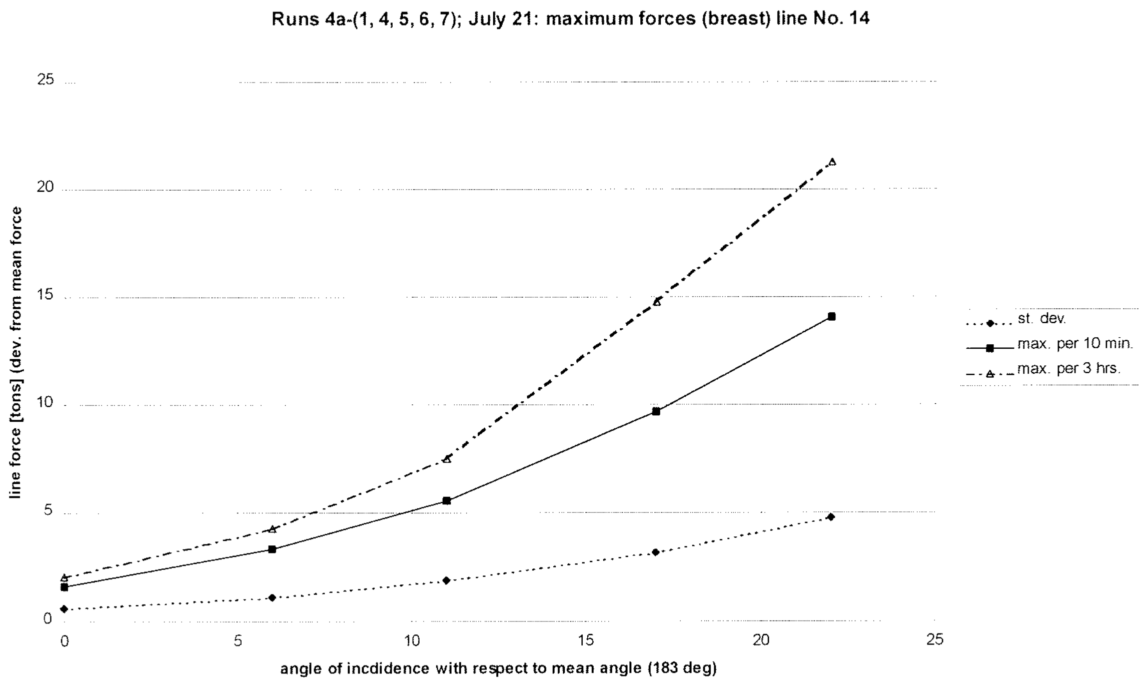


Figure 7.7: Dependence of vessel motions and maximum line forces on directional spreading of waves

Table 7.8: summary of run 4a-5, $\theta_{mean} = 183°$, $\delta = 11°$

		Measurements [tn]	**Simulation** [tn]	**Difference**
10 min.	breast lines forward	5.72	5.62	-1.8%
	breast lines aft	6.46	6.22	-3.7%
3 hrs.	breast lines forward	8.64	7.69	-10.9%
	breast lines aft	10.36	8.63	-16.7%

Table 7.9: summary of run 4b-5, $\theta_{mean} = 189°$, $\delta = 10°$

		Measurements [tn]	**Simulation** [tn]	**Difference**
10 min.	breast lines forward	7.47	6.49	-14.2%
	breast lines aft	10.88	6.68	-38.6%
3 hrs.	breast lines forward	10.88	8.77	-19.4%
	breast lines aft	17.25	9.06	-47.5%

Table 7.10: summary of run 4c-2, $\theta_{mean} = 188°$, $\delta = 10°$

		Measurements [tn]	**Simulation** [tn]	**Difference**
10 min.	breast lines forward	6.22	7.34	18.1%
	breast lines aft	7.44	8.41	13.1%
3 hrs.	breast lines forward	8.37	10.14	21.1%
	breast lines aft	9.47	12.01	26.9%

Table 7.11: summary of run 4d-3, $\theta_{mean} = 192°$, $\delta = 11°$

		Measurements [tn]	**Simulation** [tn]	**Difference**
10 min.	breast lines forward	10.71	15.41	44.0%
	breast lines aft	14.91	19.65	31.8%
3 hrs.	breast lines forward	14.20	23.42	65.0%
	breast lines aft	21.53	27.85	29.3%

Table 7.12: summary of run 4e-1, $\theta_{mean} = 185°$, $\delta = 13°$

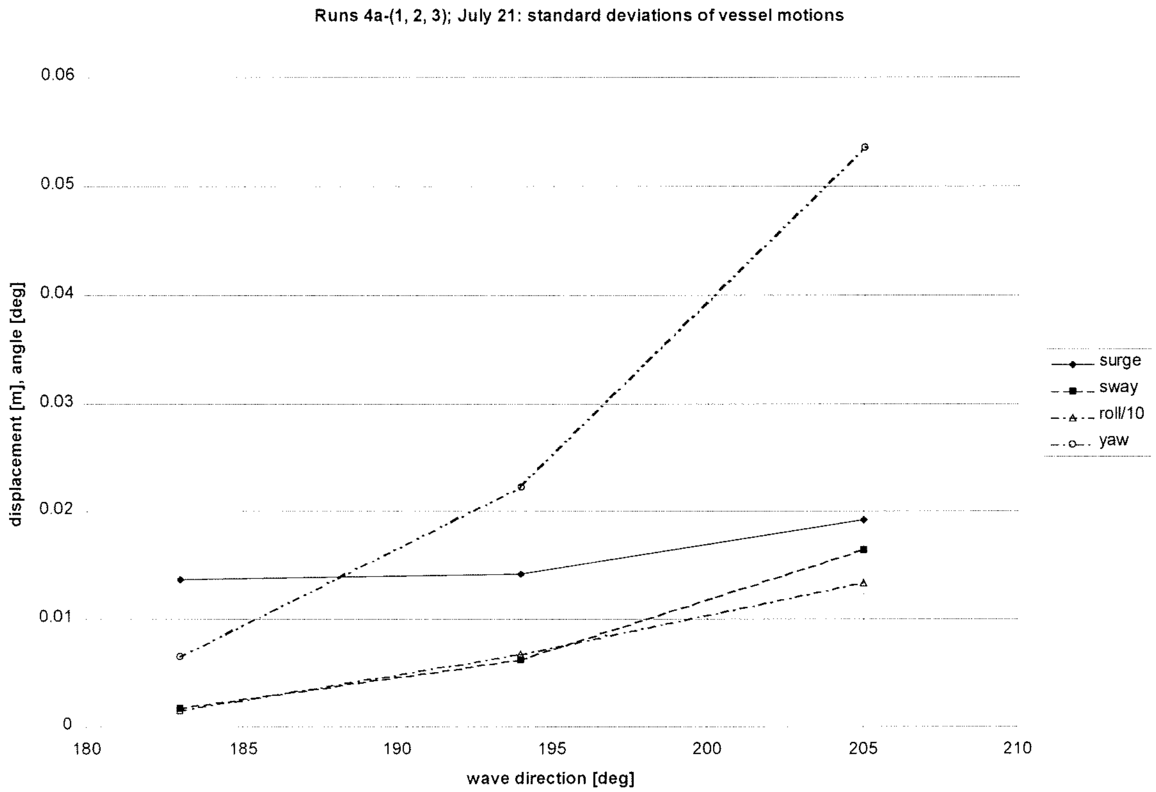
		Measurements [tn]	**Simulation** [tn]	**Difference**
10 min.	breast lines forward	14.75	11.67	-20.9%
	breast lines aft	18.97	14.51	-23.5%
3 hrs.	breast lines forward	19.05	16.32	-14.3%
	breast lines aft	23.16	20.10	-13.2%

Table 7.13: summary of run 4f-1, $\theta_{mean} = 189°$, $\delta = 12°$

		Measurements [tn]	**Simulation** [tn]	**Difference**
10 min.	breast lines forward	10.81	9.05	-16.3%
	breast lines aft	11.50	9.77	-15.0%
3 hrs.	breast lines forward	14.90	12.49	-16.2%
	breast lines aft	15.07	13.69	-9.4%

The difference values show great variance. Comparing runs 4d-3 and 4e-1 (tables 7.11 and 7.12) the influence of the mean direction is evident. Although spreading is larger for 4e-1, line forces are less because of the mean angle which is closer to 180° (head-on).
The measured forces do not show such great variance with mean angle monitored by the Waverider buoy.
Furthermore differences between measurements and simulations are explained by the simulation of the moored ship in ballast, see paragraph 7.4.1, and estimation of the mean wave direction, paragraph 7.4.3.

Directional spreading of waves does influence ship behaviour significantly when mean wave direction is almost lateral. Directional spreading can be modelled in TERMSIM as two waves (wave and swell). Selection of the input of the angle between these two input waves is still uncertain.



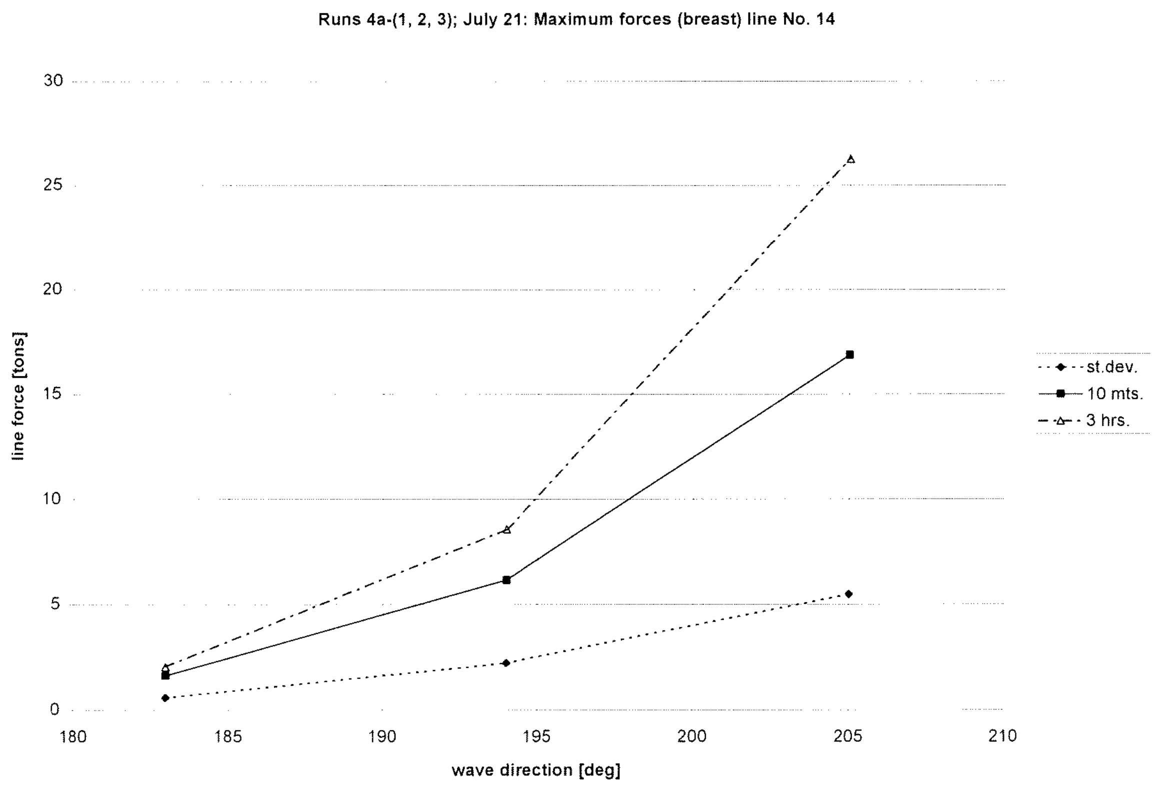


Figure 7.8: Dependence of vessel motions and maximum line forces on wave directions.

7.4.3 Wave direction

As also appeared from the analysis discussed in the previous paragraph, the influence of wave directions on ship behaviour is important. Therefore knowing the exact wave direction near the berth is important for design or research purposes. A sensitivity analysis has been carried out in runs 4a-1, 4a-2 and 4a-3. A summary of the results is given in table 7.14 and figure 7.8.

Table 7.14: Maximum forces in breast lines for different wave directions

		Measurements [tn]	Simulations [tn]		
			183°	194°	204°
10 min.	breast lines forward	5.72	1.92	5.62	14.80
	breast lines aft	6.46	1.68	6.22	16.93
3 hrs.	breast lines forward	8.64	2.36	7.69	22.54
	breast lines aft	10.36	2.13	8.63	26.35

Just like the results of the sensitivity analysis on directional spreading, the proportionality of line forces to wave directions is between linear and quadratic for wave directions below 30° from lateral to the ship (180°). Within the area of interest around 195° maximum line forces become twice as large as wave direction increases with only five degrees.

This sensitivity analysis to the influence of wave directions confirms the assumption of input of waves directions made in paragraph 6.4.4. The wave direction near the moored ship is 198° regardless of the wave direction monitored by the Waverider buoy. This has lead to compromising results for all reference periods, viz. good similarity between simulations and measurements for loaded ships and overestimation for ships in ballast. An other assumption would not have lead to compromising results, because of the large sensitivity of line forces to wave directions.

7.4.4 Mooring line characteristics

A sensitivity analysis on mooring line elasticity has been carried out for simulation of July 22. This is done for this case because pretension of mooring lines appears important as the characteristics of mooring lines are extremely non-linear. The results are given in table 7.15 and figure 7.9.

Table 7.15: Comparison of ten minute maximum vessel motions and ten minute maximum forces in mooring lines for different mooring line characteristics.

	unit	pretension	Measurements	Simulations stiff	difference	soft	difference
surge	m			0.038		0.038	
sway	m			0.038		0.045	
roll	°			0.200		0.185	
yaw	°			0.086		0.087	
ml 7	tn	3	0.35	2.44	597%	1.62	363%
ml 10	tn	6	2.76	4.32	65.5%	2.92	5.8%
ml 12	tn	9	7.94	9.16	15.4%	6.82	-14.1%
ml 3	tn	12	8.65	8.71	0.7%	7.41	-16.7%
ml 16	tn	16	7.86	6.56	-16.5%	5.88	-25.2%

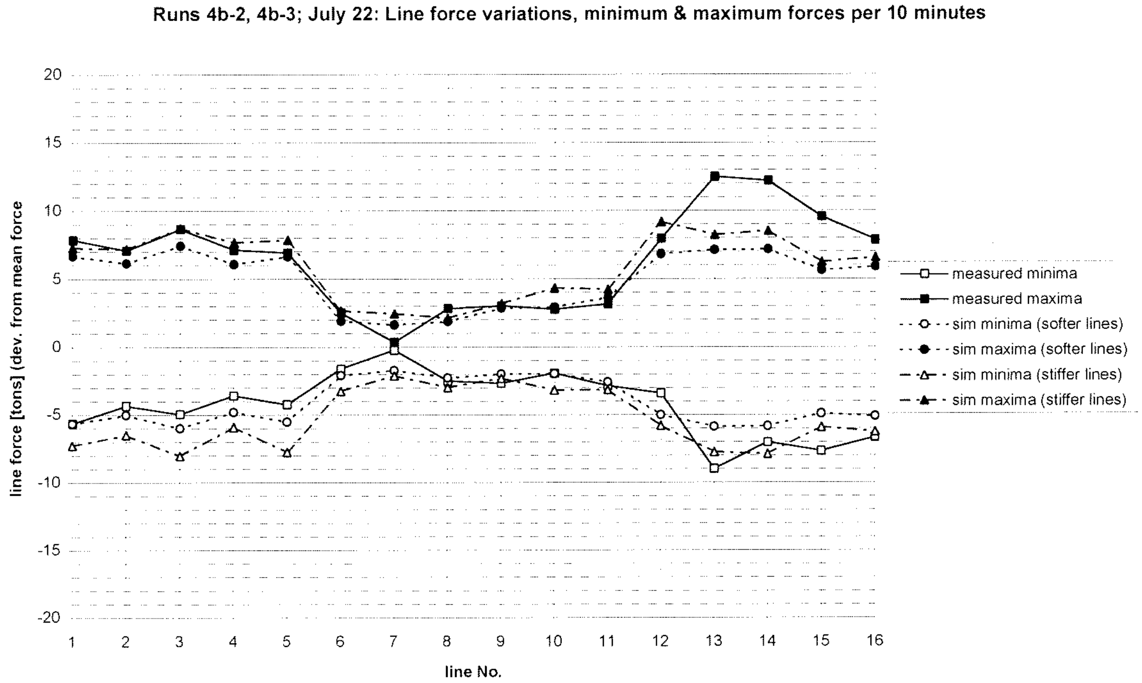


Figure 7.9: Line forces for different line characteristics

Comparing the results to the measured data, the characteristics of mooring lines in the prototype situation seem even more non-linear than assumed in the given characteristics. The measured maximum line forces are very low for low pretension values, indicating low stiffness for low line loads.

The values in table 7.15 seem to show that the lines in prototype situation are stiffer than simulated for pretension values exceeding fifteen tons. However, this is probably the result of high measured forces in the aft lines of the ship (lines 13-16), caused by other effects.

Vessel motions do not appear very sensitive to stiffness of mooring lines in this case according to table 7.15. A simplified equation to calculate the line force in line i is:

$$F_i = k_i \cdot u_i \qquad (7.1)$$

where: k_i = stiffness of line i
u_i = elongation of line i

Comparing two runs with different line characteristics, the variation of maximum line forces is almost proportional to the variation of line stiffness, If the variation of vessel motions can be neglected.

8 Analysis of Vessel Motions

In addition to the verification study of the simulation program TERMSIM II (LNG), there is need for simple expressions which describe vessel motions of moored ships in waves. These expression can be used in preliminary designs for a quick estimation of vessel motions and maximum line forces. Two earlier studies to this subject are briefly described in the literature background, paragraph 3.3.
Objective of the research described in this section is to generate a simple expression for the dominant vessel motion which appears from the simulation runs that were carried out for the verification study.

8.1 Dominant vessel motion

Vessel motions were not included in the prototype measurements. The output of TERMSIM simulations includes detailed data of the motions of the moored ship. These motion data are assumed to represent the motions of the prototype ship in case of good resemblance of the measured and simulated line force data. In other words the simulated motion data are used to calculate the motions of the moored ship. However, the resemblance of the calculated and prototype motions is restricted to the dominant vessel motions. The dominant vessel motions are the motions which mainly influence the maximum line forces. For example if roll is not dominant for the maximum line forces, it is not certain that the calculated roll motions equal the roll of the prototype ship.

Therefore only the dominant vessel motions are analysed. Most important external loads in Withnell Bay are swell waves with peak periods ranging from 14 to 18 seconds. The motions of moored ship exposed to these loads are considered. The dominant motion can be derived from the motion and line force spectra in figures 8.1 and 8.2. These are the spectra of run 4e-2 (August 2), wave spectrum 6b. Peak frequency of the wave spectrum is 0.375 rad/s (T_p = 16.8 s).

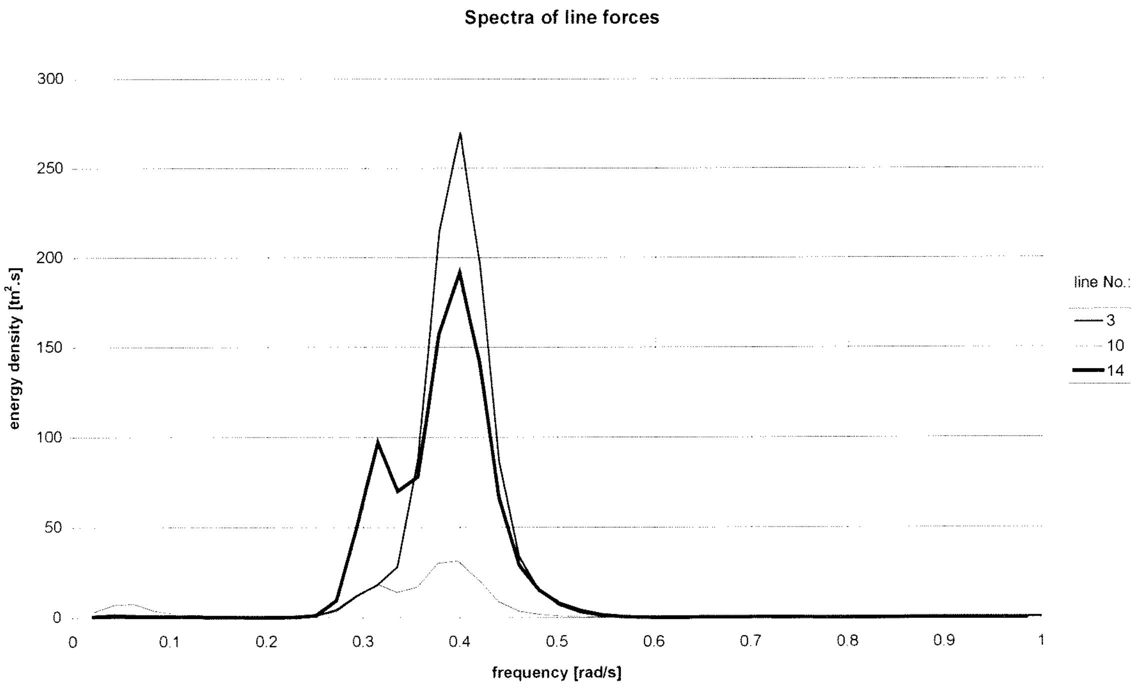
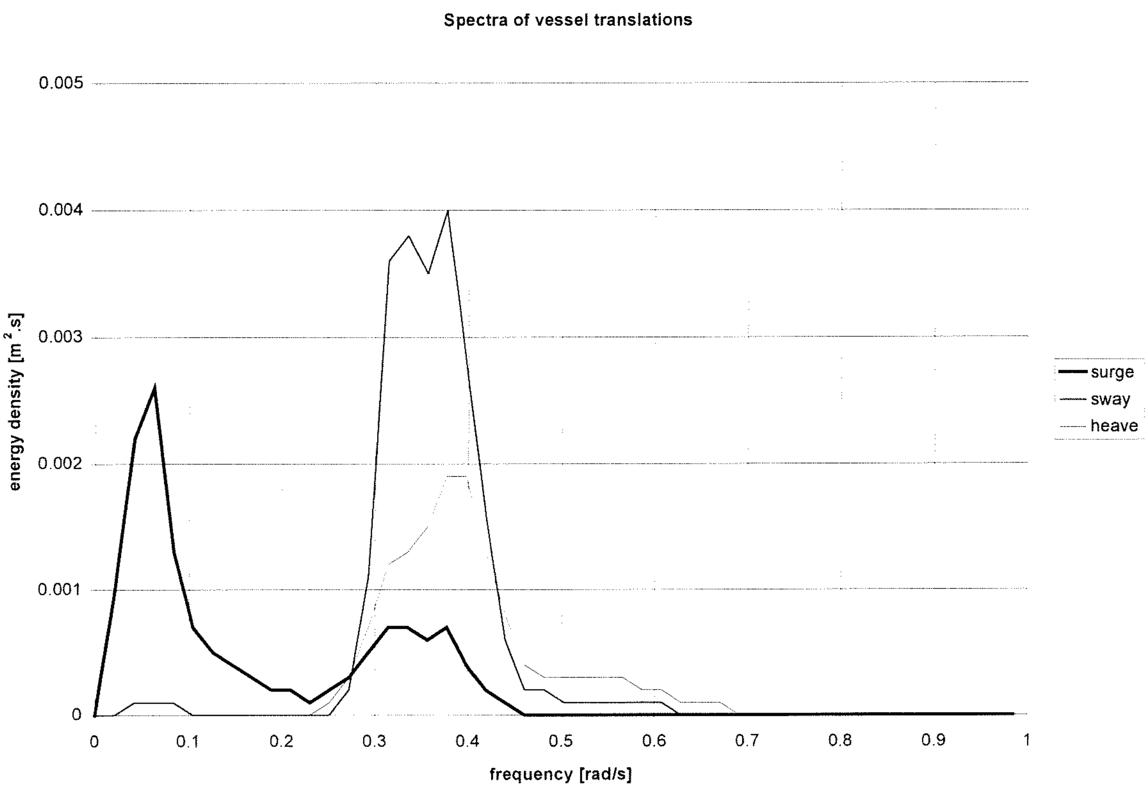


Figure 8.1: Line force spectra, run 4e-2.



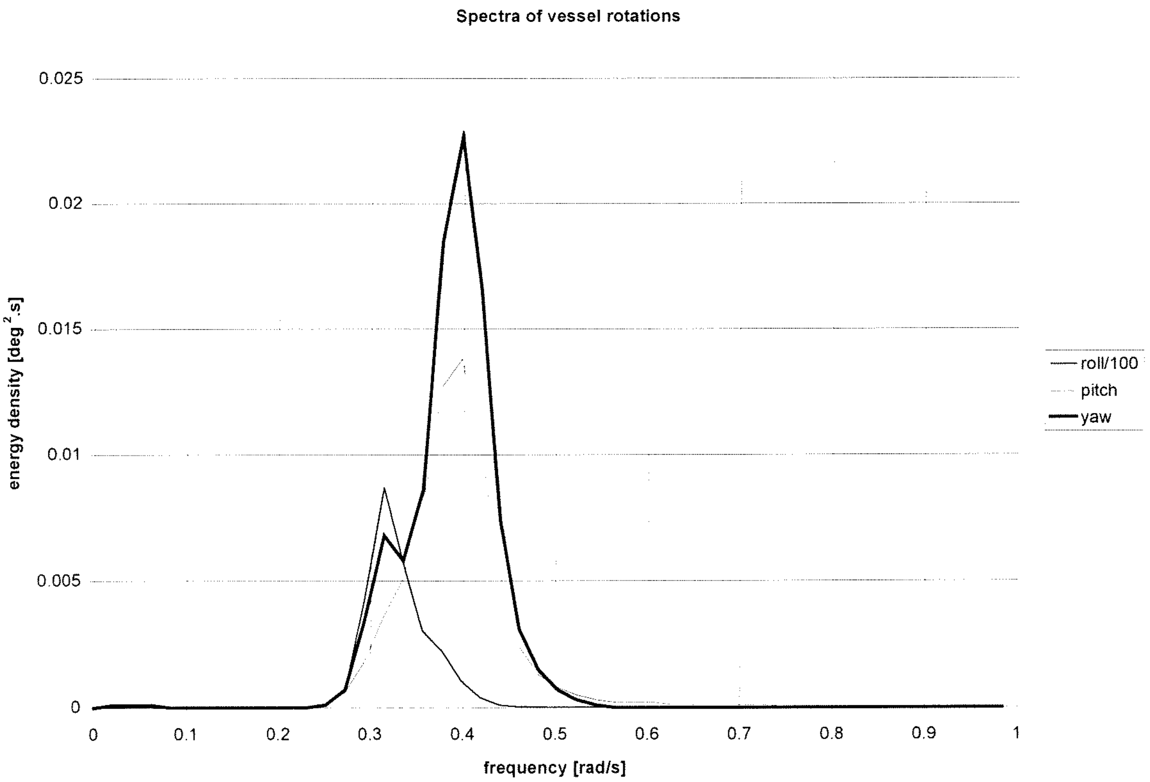


Figure 8.2: Motion spectra, run 4e-2.

The shape of the spectrum of forces in breast lines is equal to the yaw or pitch spectrum. The forces in breast lines are hardly influenced by pitch motions because the direction of breast lines

is almost perpendicular to the pitch motion. The forces in spring lines are influenced by more motions.
Further evidence for the dependence of line forces has been done using the calculated minimum and maximum motions per ten minutes. The forces in breast lines are mainly influenced by sway, roll and pitch. The calculation of line elongation as result of the motions can be estimated using equation 8.1.

$$\begin{aligned} \text{sway}:&\quad \Delta l \approx -x_2 \\ \text{roll}:&\quad \Delta l \approx x_4 \cdot \left(z_{\text{fairlead}} - z_{\text{fender}}\right) \\ \text{yaw}:&\quad \Delta l \approx -x_6 \cdot x_{\text{fairlead}} \end{aligned} \tag{8.1}$$

where: Δl = line elongation
x, z = co-ordinates in ship-bound co-ordinate system

The estimated line elongation as result of sway, roll and yaw applied for run 4e-2 are presented in table 8.1:

Table 8.1: Estimations of line elongation in breast lines.

		min or max per 10 minutes	Δl	$F = k \cdot \Delta l$	F (run 4e-2)
line 3	sway	-0.086 m	0.086 m	3.6 tn	12.83 tn
	roll	0.688°	0.213 m	8.9 tn	
	yaw	-0.137°	0.311 m	13.0 tn	
line 14	sway	-0.086 m	0.086 m	3.6 tn	14.40 tn
	roll	0.688°	0.170 m	7.7 tn	
	yaw	0.146°	0.321 m	14.5 tn	

The estimated maximum forces in breast lines can almost entirely be explained by the maximum yaw angles.

8.2 Expression of the yaw motion

8.2.1 First order model for yaw motions

From figure 8.1 follows that the peak frequency of the yaw spectrum is almost equal to the peak frequency of the wave spectrum. Because of this, the yaw motion is the result of first order wave forces. The expression of the first order wave force in the yaw direction is:

$$F_6^{(1)}(t) = \sum_{i=1}^{N} \zeta_i \cdot \left|\frac{\hat{F}_6^{(1)}}{\zeta}(\omega_i)\right|^2 \cdot \cos\left(\omega_i t + \varphi_6^{(1)}(\omega_i) + \varepsilon_i\right) \tag{8.2}$$

where: $\left|\frac{\hat{F}_6^{(1)}}{\zeta}(\omega_i)\right|^2$ = amplitude of first order transfer function in yaw direction

$\varphi_6^{(1)}(\omega_i)$ = phase angle of first order transfer function in yaw direction

The transfer function depends on the hydrodynamic file, the wave frequency and wave direction.

In order to obtain the effects that influence the yaw motion, the six degrees of freedom system is simplified to a linear mass-spring system (figure 8.3), which may be correct when only yaw is the dominant vessel motion.

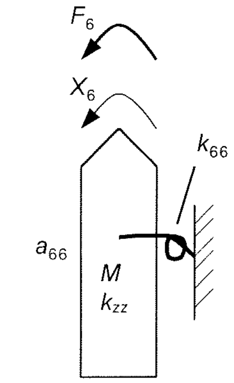


Figure 8.3: Linear mass-spring-system of a ship moored to a jetty

The simplified equation of motion is:

$$(I_{66} + a_{66}) \cdot \ddot{X}_6 + k_{66} X_6 = F_6^{(1)} \tag{8.3}$$

where:
- I_{66} = moment of inertia in the 6th mode
- a_{66} = added mass coefficient
- k_{66} = spring coefficient in the 6th mode
- $F_6^{(1)}$ = first order wave force

- The moment of inertia I_{66} is equal to $\rho\nabla \cdot k_{zz}^2$.
- The frequency independent added mass coefficient a_{66} is obtained from the hydrodynamic file (appendix A, equation A.7).
- The spring coefficient k_{66} is obtained from the stiffness of mooring lines and fenders (appendix B, equation B.4).
- The first order force in the yaw direction $F_6^{(1)}$ is obtained from equation 7.2. In this equation the transfer functions are obtained from the hydrodynamic file.

The particular solution of equation 8.3 is:

$$X_6 = \sum_{i=1}^{n} \frac{\hat{\zeta}_i \cdot \left|\frac{\hat{F}_6^{(1)}}{\hat{\zeta}}(\omega_i)\right|^2}{k_{66} - \omega_i^2 (I_{66} + a_{66})} \cdot \cos\left(\omega_i t + \varphi_6^{(1)} + \varepsilon_i\right) \tag{8.4}$$

According to equation 8.4, the yaw motion becomes infinite if the wave spectrum is non-zero for the natural frequency of the system. This will not be the case because of damping terms and non-linear spring coefficients, not included in the simplified model.

According to equation 8.4 the yaw motion is linearly proportional to the wave height. Yaw motions increase as the wave frequency direction are in ranges of larger transfer functions and motions increase as the wave frequency is near the natural frequency of the system. The system's natural frequency is:

$$\omega_e = \sqrt{\frac{k_{66}}{I_{66} + a_{66}}} \tag{8.5}$$

The parameters that influence the yaw motion are:

1. Ship size: mass displacement and length

2. Stiffness of fenders and mooring lines
3. Wave height
4. Wave period
5. Wave direction
6. Water depth

8.2.2 Investigation of the parameters that influence yaw motions

Investigation of the mentioned six influences has been done for the LNG jetty in Withnell Bay. The above given six influences have been taken into account. The investigation has led to the following expression:

$$X_{6,s} = C_{\text{yaw}} \cdot d \cdot \theta - 180^\circ \cdot T_p \left(T_p - 8\text{ s}\right) \cdot H_s \qquad (8.6)$$

in which:
- C_{yaw} = constant obtained from the simulations [$m^{-2} \cdot s^{-2}$]
- d = water depth
- θ = wave direction
- T_p = peak period of JONSWAP swell spectrum
- H_s = significant wave height of JONSWAP swell spectrum

Below the terms in equation 8.6 are clarified.

Wave height

From equation 8.4 follows a linear proportionality of yaw and wave height. The verification of this hypothesis is given in figure 8.4.

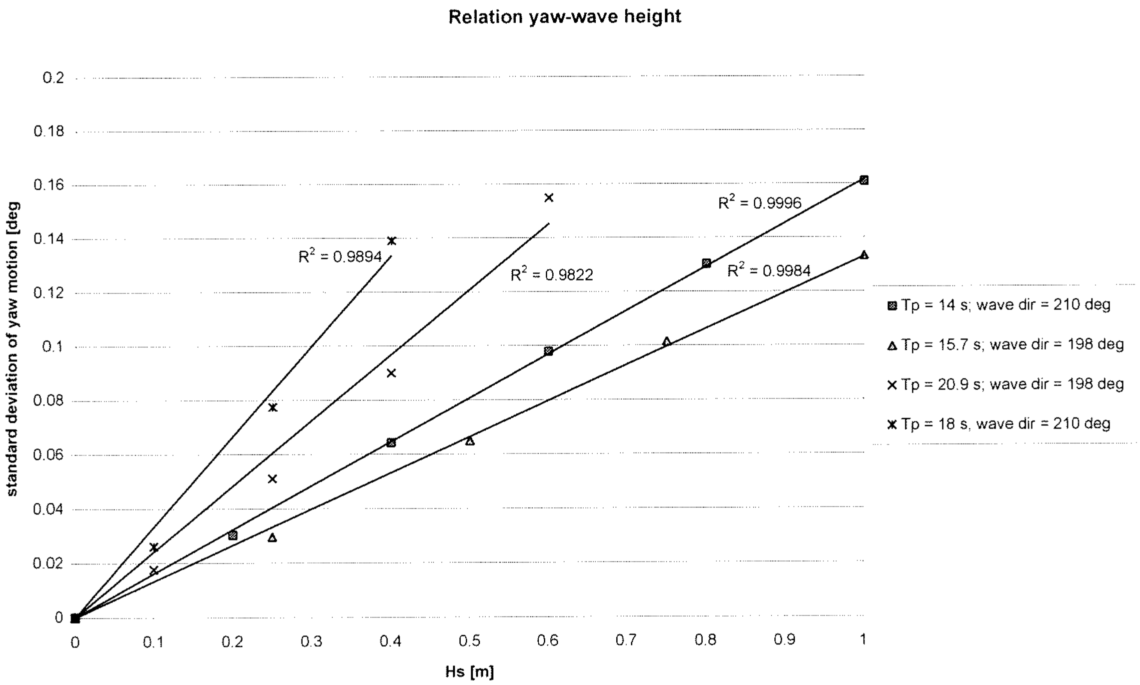


Figure 8.4: Relation between standard deviation of yaw and significant wave height

The relation between wave height and yaw is linear for the higher wave frequencies, $\omega_p \geq 0.40$ rad/s, $T_p \leq 16$ s. For the lower wave frequencies, second order quadratic effects become significant; for a rough estimation of the yaw motion, linearisation of the dependence is allowable:

$$X_6 \propto H_s$$

Because of the linear relationship between wave height and yaw motion, the trough-crest values of the yaw motion are assumed to be Rayleigh distributed, the distribution which is used for wave heights. In the further mentioned values, $X_{6,s}$ is calculated, which is the significant value of mean-crest values of the yaw motion. Assuming Rayleigh distributed yaw amplitudes, the significant yaw amplitude is:

$$X_{6,s} \approx 2.0 \cdot \sigma_{X_6} \tag{8.7}$$

where: σ_{X_6} = standard deviation of the yaw motion

Size of the ship

In appendix D, figures 24 – 27, the amplitude of first order transfer functions of three ships are considered.

Table 8.2: Considered ships in appendix D, figures 24 - 27.

hyd-file	capacity [m³]	L_{pp} [m]	mass displacement [tn]	water depth [m]
L65000	65,000	205	47,970	15
S125PAR	125,000	259	106,454	16
S125PER	125,000	259	106,454	20
S165PAR	165,000	283	125,845	16

The frequency of maximum yaw transfer function is much lower for larger ships, probably resulting in larger yaw motions in long waves and smaller yaw motions in shorter waves. The yaw motions of a larger moored ship cannot be calculated directly from the motions of a smaller ship.

Therefore the formula for the calculation of yaw motions (equation 8.6) is valid only for LNG carriers with capacity of about 125,000 m^3. Further investigation is necessary to generate expressions for larger and smaller vessels.

Stiffness of the mooring system

From equation 8.4 follows that yaw motions increase as the frequency of the yaw motions is close to the natural frequency of the mooring facility. The stiffness of the mooring system used for the calculations in this report is equal to 100 · 10^6 kNm/rad. The added mass coefficient, obtained from the hydrodynamic file, is roughly equal to 3.2 · 10^{11} kgm^2 The natural frequency of the mooring system then is:

$$\omega_e = \sqrt{\frac{k_{66}}{I_{66} + a_{66}}} \quad \text{with} \quad I_{66} = k_{zz}^2 \cdot \rho \nabla$$

$$\omega_e = 0.382 \text{ rad/s} \tag{8.8}$$

$$T_e = 16.4 \text{ s}$$

In figure 8.5 the influence of the stiffness k_{66} is presented. The stiffness is altered in TERMSIM by changing the stiffness of mooring lines and changing the fender type. Input wave spectrum was a JONSWAP spectrum, wave direction is 198°.

ω_p = 0.30 rad/s: H_s = 0.25 m
ω_p = 0.40 rad/s: H_s = 0.50 m
ω_p = 0.30 rad/s: H_s = 1.00 m

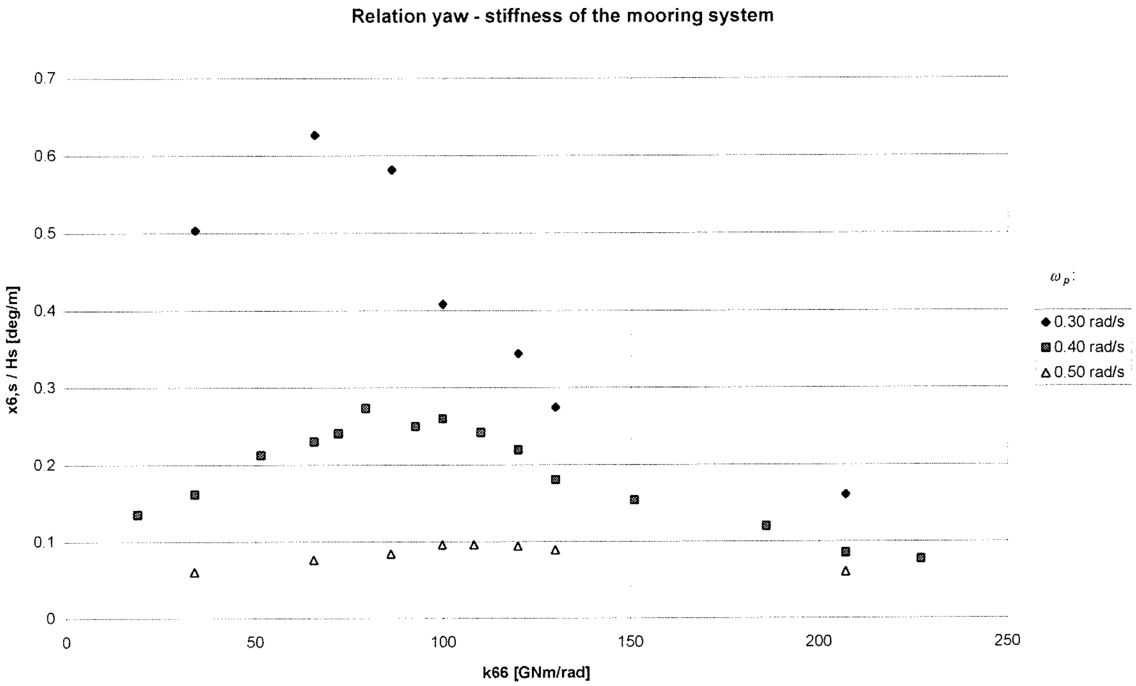


Figure 8.5: Relation between yaw and stiffness in the 6th mode.

From figure 8.5 follows that for peak frequency 0.40 rad/s which is close to the natural frequency of the mooring system, the yaw motions are largest for $k_{66} \approx 100$ GNm/rad. Hence the stiffness of the mooing system in Withnell Bay is unfavourable for wave frequencies of about 0.4 rad/s, because the present stiffness is equal to the most unfavourable stiffness.
The runs described to analyse the effect of wave period and wave direction have all been carried out for $k_{66} = 100$ GNm/rad. For peak frequencies 0.4 - 0.5 rad/s the calculated significant yaw motion is equal to the maximum of possible yaw motions. For peak frequency 0.3 rad/s the maximum possible significant yaw motion is approximately 1.5 times the calculated motion in case of a softer mooring system, $k_{66} = 70$ GNm/rad.
The formulated relation for yaw motions, equation 8.6, is given as an upper limit approach, because to bring the stiffness into account, it would lead to a too difficult relation. Such a difficult relation will not be appropriate for use in the early stages of harbour design. Estimation of the amount of reduction as result of a more conveniently chosen stiffness, can be done in later stages with help of computer simulations.

Wave period

The influence of wave period is presented in figure 8.6. In this figure the significant yaw motion is plotted for different peak periods and wave directions.
The yaw motions calculated for $T_p = 20.9$ s are not the maximum possible motions needed for an upper limit approach, as described above for the influence of the stiffness of the mooring system. Taking into account that these motion can become higher for a softer mooring system, the relation yaw motion - peak period is almost quadratic. A best fit of the relation is:

$$X_6 \propto T_p \cdot (T_p - 8 \text{ s})$$

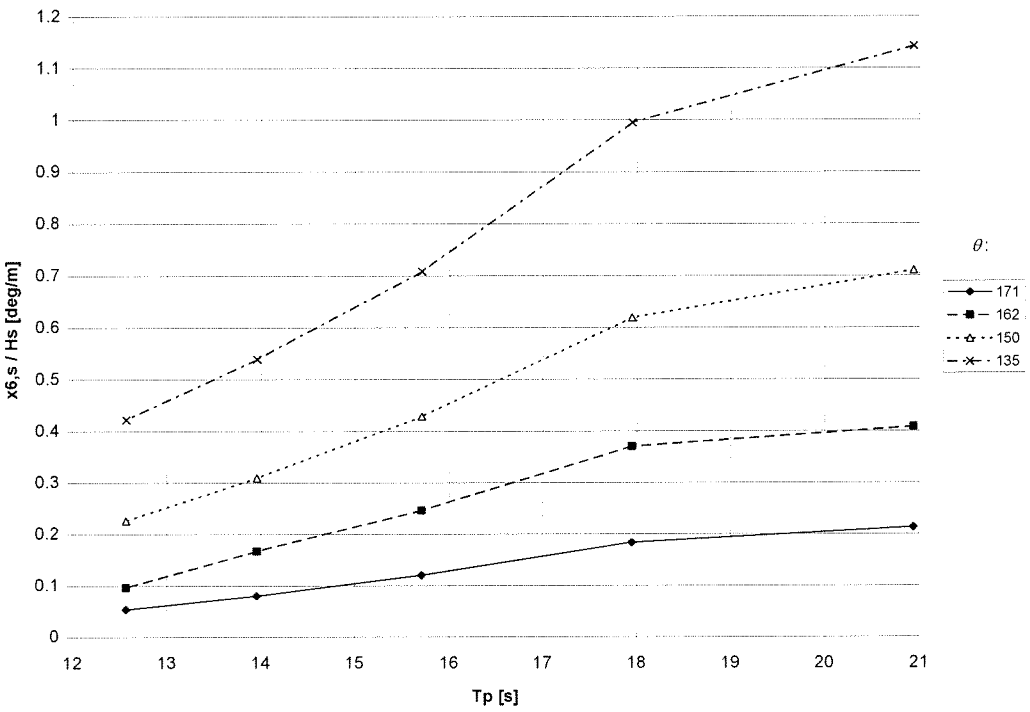


Figure 8.6: Relation between yaw and peak period.

Wave direction

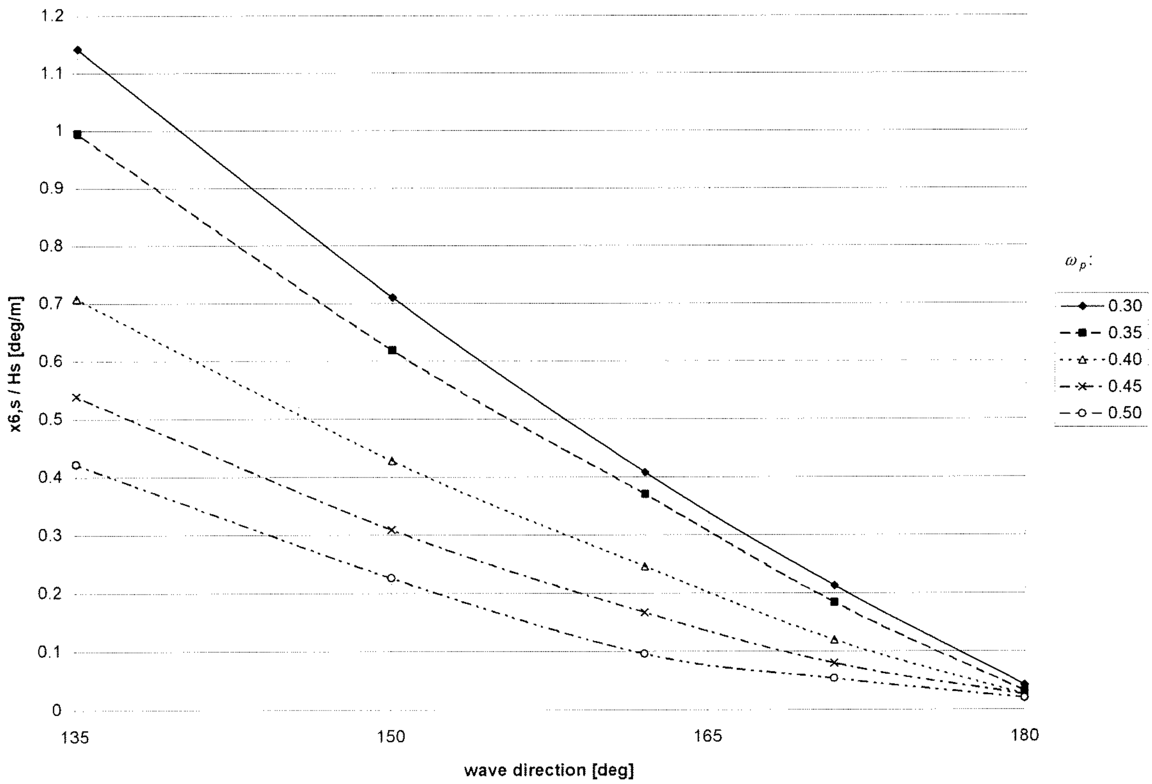


Figure 8.7: Relation between yaw and wave direction

In figure 8.7 the influence of wave direction is presented for different peak frequencies. It appears that the proportionality between yaw motion and wave direction is almost linear for the

lower peak frequencies. For the higher peak frequencies a linear estimation would lead to significant, but not very high deviations.
In order to obtain an easy expression for the yaw motions, the proportionality is assumed to be linear for all peak periods:

$$X_6 \propto |\theta - 180\,^\circ|$$

The relation is valid for both sides of the ship bow ranging from 10° to 50° with respect to the bow, i.e. 130° - 170° and 190° - 230° (with respect to the stern). It is not certain that the relation is valid for wave directions less than 10° with respect to the bow, because of directional spreading. Only a little spreading would lead to higher yaw motions in the prototype situation.

In figure 8.8 a full overview is given of the yaw motions for different wave directions for peak period 15.7 seconds. Maximum values occur at 60° and 120°. Incident waves from the aft side of the ship appear more inconvenient. Yaw motions are 10-20% larger than due to waves from the forward side.

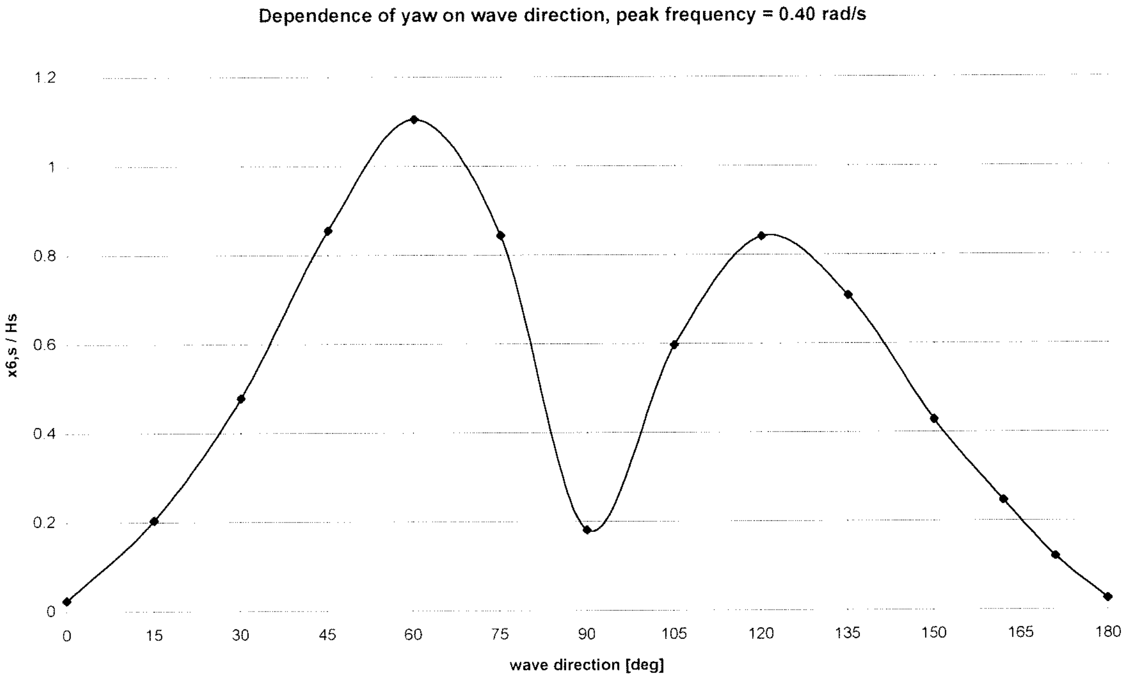


Figure 8.8: Relation between yaw and wave direction from stern to bow. Peak period = 15.7 s.

Water depth

The influence of water depth has been investigated using a different hydrodynamic file. Two files were used, modelling depths of 16 and 20 meters. The results are presented in tables 8.3 and 8.4.

Table 8.3: Dependence of depth on yaw motions for different peak periods. Wave direction = 162 °.

ω_p [rad/s]	T_p [s]	$X_{6,s} / H_s$ (d=16 m) [°/m]	$X_{6,s} / H_s$ (d=20 m) [°/m]	d=20 m / d=16 m
0.30	20.9	0.408	0.495	1.213
0.35	18.0	0.370	0.460	1.243
0.40	15.7	0.246	0.304	1.236
0.45	14.0	0.167	0.224	1.341
0.50	12.6	0.096	0.161	1.677

Table 8.4: Dependence of depth on yaw motions for different wave directions. Peak period = 15.7 s.

θ [°]	$X_{6,s}$ / H_s (d=16 m) [°/m]	$X_{6,s}$ / H_s (d=20 m) [°/m]	d=20 m / d=16 m
171	0.120	0.153	1.278
162	0.246	0.304	1.236
150	0.428	0.498	1.164
135	0.708	0.784	1.107

From tables 8.2 and 8.3 appears that the ratio between the calculated yaw values for 16 and 20 meters water depth is not constant for all wave conditions. The mean ratio is nearly equal to the depth ratio, which is 1.25. Concerning depths ranging from 1.25 * draft (14 m) to 2 * draft (22 m) the yaw motions are proportional to the water depth:

$$\boldsymbol{X_6 \propto d}$$

Determination of the yaw coefficient

In equation 8.6 a constant C_{yaw} is present, which relates the significant yaw motion to the mentioned wave conditions and water depth. The constant has been determined for

$$C_{yaw} = \frac{X_{6,s}}{d \cdot \theta - 180^\circ \cdot T_p (T_p - 8\ \mathrm{s}) \cdot H_s} \tag{8.9}$$

The coefficient has been determined for several peak periods and wave directions. The values for ωp = 0.30 rad/s have been multiplied by 1.5 in order to obtain an upper limit approach with respect to the stiffness of the mooring system.

Table 8.5: Yaw coefficients for different wave directions and peak frequencies [10^{-6} $m^{-2} \cdot s^{-2}$]*

θ [°] \ ω_p [rad/s]	0.30	0.35	0.40	0.45	0.50
171	8.19	7.15	6.88	6.68	6.53
162	7.84	7.19	7.05	6.97	5.80
150	8.19	7.22	7.36	7.74	8.20
135	8.78	7.74	8.12	9.00	10.20

The chosen value for C_{yaw} is $7.5 \cdot 10^{-6}$ $m^{-2}s^{-2}$ which is nearly equal to the mean value of the coefficients in table 8.5.

8.2.3 Summary of the expression of yaw motion and line forces

An estimation of the yaw motions of a large LNG carrier exposed to swell waves can be done using equation 8.6:

$$X_{6,s} = C_{yaw} \cdot d \cdot \theta - 180^\circ \cdot T_p (T_p - 8\ \mathrm{s}) \cdot H_s \tag{8.6}$$

in which:
- C_{yaw} = constant obtained from the simulations [$m^{-2} \cdot s^{-2}$]
- d = water depth
- θ = wave direction
- T_p = peak period of JONSWAP swell spectrum
- H_s = significant wave height of JONSWAP swell spectrum

Notes:

- The unit of the calculated significant yaw motion is degrees, if $|\theta - 180°|$ is expressed in degrees.
- C_{yaw} = $7.5 \cdot 10^{-6}$ $m^{-2}s^{-2}$

- The expression is an upper limit approach with respect to the stiffness of the mooring system. Reduction ranging up to 30% to 60% is possible for a more conveniently chosen stiffness.
- The expression is valid for LNG carriers with capacities of about 125,000 m^3.
- The range of validity for water depth is: 1.25 * draft (14 m) $< d <$ 2 * draft (22 m).
- The range of validity for wave direction is: $130^\circ < \theta < 170^\circ$ and $190^\circ < \theta < 225^\circ$. For values of wave direction almost head-on, equation 7.7 would give underestimating results because of directional spreading of the incident waves.
  Incident waves from the aft side would lead to about 10-20% larger yaw motions.
- The range of validity for peak periods is: 12 s $< T_p <$ 22 s.

The objective the estimation of vessel motions in preliminary designs is to calculate the maximum forces that must stay within specific design values. The calculated significant yaw motion can be used to estimate the significant line forces in breast lines:

$$F_{i,s} = F_{\text{pretension,i}} + k_i \cdot X_{6,s} \cdot x_i \tag{8.10}$$

in which:
$F_{i,s}$ = significant force in (breast) line i.
$F_{pretension,i}$ = pretension in line i.
k_i = lateral stiffness of line i.
$X_{6,s}$ = significant yaw motion [rad].
x_i = x-position of fairlead.

This equation is only valid for breast lines that are directed almost transversal to the ship.

In appendix C the estimation of yaw motions is used to verify the design studies "Withnell Bay LNG Terminal Project" carried out by MARIN in the begin eighties.

8.3 Verification of the expression of the yaw motion to prototype measurements

Using equations 8.6 and 8.10 the significant line forces in breast lines can be related to the swell waves. The measurements include maxima per ten minutes.

Estimating the mean of maximum yaw amplitudes per ten minutes, the yaw amplitudes are assumed to be Rayleigh distributed. Then the quadratic maximum yaw amplitudes per ten minutes are Gumbel distributed:

$$F_{\hat{X}_6}(X_6) = \exp\left(-e^{-\frac{X_6^2 - 2\sigma_{\text{yaw}}^2 \ln N}{2\sigma_{\text{yaw}}^2}} \right) \tag{8.11}$$

where:
$\hat{X}_6$ = yaw amplitude
σ_{yaw} = standard deviation of yaw motion
N = number of waves

The root mean square value of this distribution is equal to:

$$X_{6,\text{max,rms}} = \sqrt{2\sigma_{\text{yaw}}^2 \ln N + 0.577 \cdot 2\sigma_{\text{yaw}}^2} \tag{8.12}$$

where: $X_{6,max,rms}$ = root mean square value of maxima per ten minutes.

Because the probability density function is very narrow, the root mean square value is almost equal to the mean value. The formulation is used to verify the maximum yaw amplitude per ten minutes. For run 4e-2 the average zero upcrossing period T_2 is 17.0 s. Then the number of waves per ten minutes is equal to 35. From equations 8.12 and 8.7, the relation between the mean value of maximum yaw amplitudes per ten minutes and the significant yaw motion becomes:

$$\overline{X_{6,\max}} = 1.44 \cdot X_{6,s} \tag{8.13}$$

In table 8.6 the circumstances for three runs are presented. The significant yaw motion has been calculated by substitution of the given parameters in equation 8.6.
In order to verify the formulae for the significant yaw motions and line forces to the prototype measurements and the TERMSIM simulations, the mean value of the maximum line force per ten minutes is calculated using equations 8.10 and 8.13. The lateral stiffness of a single breast line is 47 ton/m and the eccentricity x_i of the fairlead positions is about 120 m. The comparison of maximum line forces is given in table 8.7.

Table 8.6: Estimation of the significant yaw motion for three cases.

run N°	date	d [m]	θ [°]	T_p [s]	H_s[m]	$X_{6,s}$ [°]
4b-8	July 22	17.6	198	16.8	0.24	0.0723
4e-2	August 2	18.3	198	16.8	0.28	0.0885
4f-2	July 19	16.0	198	16.8	0.27	0.0746

Table 8.7: Comparison of the mean value of maximum line force variations per ten minutes in breast lines. All forces in tons. "Difference" is the difference with respect to the measured value.

run N°	date	measurements	simulation	difference	estimation	difference
4b-8	July 22	9.2	7.9	-14%	10.6	15%
4e-2	August 2	16.9	13.2	-22%	12.8	-24%
4f-2	July 19	11.2	9.8	-13%	10.8	-4%

The estimation of July 22 is much larger than the simulation, also as result of the input of softer mooring lines for run 4b-8. The difference between estimation and measurements is large for August 2, but that is also valid for the simulation. Probably the waves on August 2 were different than assumed.

Conclusion from the verification to the prototype measurements and simulations is: the resemblance between the estimated line forces and measured forces is rather good, particularly because the estimation is only an indication of the magnitude of yaw motions and line forces.

9 Conclusions and Recommendations

The conclusions and recommendations are divided into four categories respectively mentioned in the following paragraphs. Conclusions are written next to bullets. Recommendations are written in italics.

9.1 Validity study TERMSIM II (LNG)

- The difference between TERMSIM calculations and measured line forces, concerning a loaded 125,000 m^3 LNG carrier moored to a jetty exposed to moderate swell waves, is within reasonable limits. Underestimation of 10% to 20% for the calculated maximum forces in breast lines compared to prototype measurements has been found.

- The prototype measurements show significant dependence between maximum line forces and the loading condition whereas TERMSIM simulations do not show this dependence.

More detailed verification of SDF computer models requires more accurate measured data. The data are to consist of the following elements:

- *Ship motion spectra in the six degrees of freedom.*
- *Line force spectra.*
- *Wave spectrum and directional spectrum, measured within the harbour basin, preferably measured with an instrument which also measures long waves (e.g. a wave gauge or pressure transducer).*
- *Wind velocity and direction.*
- *Current velocity and direction.*
- *Still water level.*
- *Draft of the ship.*

The ship motion spectra and line force spectra are easy to be compared to the spectra generated by TERMSIM. Wave data measured within the harbour basin are easier to handle and more accurate, because differences caused by refraction at bottom slopes does not influence the difference of the wave circumstances between the measurement spot and the berth.

9.2 Directional spreading of waves

- The influence of directional spreading of waves on line forces is significant in case of wave directions nearly head- or stern-on.

Research to the influence of directional spreading of waves to wave forces on the moored ship may be profitable, because of the importance of directional spreading in case of wave directions nearly head-on. This will often be the case as jetty head orientation generally is head to the waves. Implementation of directional spreading into the computer model is probably possible, also because run time or memory allocation will not be a problem as personal computers in the near future can probably easily deal with the extra amount of calculations needed to model directional spreading in the computer program.

9.3 Motions of the moored ship

- Yaw motions appear to be dominant for the maximum line forces in breast lines in case of a 125,000 m^3 LNG carrier moored to a jetty exposed to swell waves.

- The yaw motion is dependent on the water depth, wave direction, wave period, wave height and stiffness of the mooring system.

- An inconveniently chosen value for the stiffness of the mooring system can lead to relatively large yaw motions, because of excitation in the system's natural frequency.

The expressions for the significant yaw motion and line forces can be used in preliminary design studies to LNG terminals.

9.4 Design studies LNG terminal Withnell Bay

- Estimated values of yaw motions – based on calculations using TERMSIM II (LNG) and verified to prototype measurements – for a moored LNG carrier exposed to design wave loads do not match the calculated values using MOORSIM. The estimated motions are much larger.

- Maximum allowable wave loads in Withnell Bay appear to be smaller than design wave loads.

Further research to ships moored to the LNG jetty in Withnell Bay can lead to the determination of maximum allowable wave loads.

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Appendix A

Equations of Motion in the Time Domain Applied for a Jetty Terminal

The formulation of the equations of motion in the time domain has been done by Cummins (ref. A-1). He has used the impulse response theory to formulate the equations of motion. An arbitrarily motion is described as a succession of small impulsive displacements. The basic assumption is that at any time the total fluid reactive force is the sum of the reactions to the individual impulsive displacements. The impulsive displacements are considered as moving the ship at a constant velocity for a certain small time interval:

$$\Delta X_j = V_j \cdot \Delta t \tag{A.1}$$

During the impulse the flow is characterised by a velocity potential proportional to the ship velocity:

$$\Phi = \sum_{j=1}^{6} V_j \cdot \psi_j \tag{A.2}$$

in which ψ_j is a normalised velocity potential which is independent of the vessel movement.

During the impulse a wave is formed which will dissipate as a radiated disturbance of the free surface. Since the problem is assumed to be linear the potential of this decaying wave will be proportional to the impulsive displacement. The velocity potential due to the impulsive displacement on 0 < t < Δt is:

$$\Phi(t) = \sum_{j=1}^{6} \chi_j(t) \cdot \Delta X_j \quad \text{for: } t > \Delta t \tag{A.3}$$

in which χ_j is a normalised velocity potential.

When the ship performs an arbitrarily in time varying motion, it can be considered as a succession of small impulsive motions. The resulting velocity potential due to the ship motions is affected by the motion at the same time as well as by the motions in the past.

$$\Phi(t) = \sum_{j=1}^{6} \left\{ V_{jn} \cdot \psi_j + \sum_{i=1}^{n} \chi_j((n-i)\Delta t) \cdot V_{ji} \cdot \Delta t \right\} \tag{A.4}$$

in which: V_{jn} = ship velocity on time $t = n\Delta t = t$
V_{ji} = ship velocity on time $t = i\Delta t$

The hydrodynamic force on time t is found by integrating the hydrodynamic pressures over the submerged surface:

$$\begin{aligned} F_k &= -\iint_S p \cdot n_k \cdot dS \\ &= \iint_S \rho \frac{\partial \Phi}{\partial t} \cdot n_k \cdot dS \\ &= \sum_{j=1}^{6} \left\{ \rho \ddot{X}_j \iint_S \psi_j n_k \cdot dS + \int_{-\infty}^{t} \rho \dot{X}_j(\tau) \iint_S \frac{\partial \chi_j(t-\tau)}{\partial t} \cdot n_k \cdot dS \cdot d\tau \right\} \end{aligned} \tag{A.5}$$

Applying this relation into Newton's law of dynamics, together with the hydrostatic restoring forces, results in the equation of motion in the time domain:

$$\sum_{j=1}^{6}\left\{\left(M_{kj}+m_{kj}\right)\cdot \ddot{X}_j(t)+\int_{-\infty}^{t}R_{kj}(t-\tau)\cdot \dot{X}_j(\tau)\cdot d\tau+C_{kj}\cdot X_j(t)\right\}=F_k(t) \quad \text{for: } k = 1, 2, \dots 6 \tag{A.6}$$

in which: M = inertia matrix

$m_{kj}=\rho\iint_S \psi_j n_k \cdot dS =$ added mass coefficient

$R_{kj}=\rho\iint_S \frac{\partial \chi_j}{\partial t}\cdot n_k \cdot dS =$ retardation function

C = matrix of hydrostatic restoring coefficients

F = arbitrarily in time varying external force

If the exciting force is linear then the Cummins equation must be equal to the equation of motion in the frequency domain. Ogilvie (ref. A-2) has related the coefficients in the equation of motion in the time domain to the frequency dependent coefficients in the equation of motion in the frequency domain:

$$\begin{aligned} R_{kj}(t) &= \frac{2}{\pi}\int_0^{\infty} b_{kj}(\omega)\cos\omega t\cdot d\omega \\ m_{kj} &= a_{kj}(\omega')+\frac{1}{\omega'}\int_0^{\infty}R_{kj}(t)\sin\omega' t\cdot dt \end{aligned} \tag{A.7}$$

in which: a_{kj} = frequency dependent added mass coefficient

b_{kj} = frequency dependent damping coefficient

ω' = arbitrarily chosen value of ω

Under normal circumstances, a number of coefficients can be neglected; the equations of motion for a tanker moored to a jetty is given by the following set of equations:

$$\begin{aligned}
m\ddot{X}_1+\sum_{k=1}^{6}a_{1k}\ddot{X}_k+\sum_{k=1}^{6}\int_{-\infty}^{t}R_{1k}(t-\tau)\cdot\dot{X}_k(\tau)\cdot d\tau+b_{11}\dot{X}_1 &= F_1^{\text{wind}}+F_1^{\text{current}}+F_1^{\text{wave}}+F_1^{\text{mooring}}\\
m\ddot{X}_2+\sum_{k=1}^{6}a_{2k}\ddot{X}_k+\sum_{k=1}^{6}\int_{-\infty}^{t}R_{2k}(t-\tau)\cdot\dot{X}_k(\tau)\cdot d\tau+b_{22}\dot{X}_2 &= F_2^{\text{wind}}+F_2^{\text{current}}+F_2^{\text{wave}}+F_2^{\text{mooring}}\\
m\ddot{X}_3+\sum_{k=1}^{6}a_{3k}\ddot{X}_k+\sum_{k=1}^{6}\int_{-\infty}^{t}R_{3k}(t-\tau)\cdot\dot{X}_k(\tau)\cdot d\tau+c_{33}X_3+c_{35}X_5 &= F_3^{\text{wave}}+F_3^{\text{mooring}}\\
I_{44}\ddot{X}_4+\sum_{k=1}^{6}a_{4k}\ddot{X}_k+\sum_{k=1}^{6}\int_{-\infty}^{t}R_{4k}(t-\tau)\cdot\dot{X}_k(\tau)\cdot d\tau+c_{44}X_4 &= F_4^{\text{wave}}+F_4^{\text{mooring}}\\
I_{55}\ddot{X}_5+\sum_{k=1}^{6}a_{5k}\ddot{X}_k+\sum_{k=1}^{6}\int_{-\infty}^{t}R_{5k}(t-\tau)\cdot\dot{X}_k(\tau)\cdot d\tau+c_{53}X_3+c_{55}X_5 &= F_5^{\text{wave}}+F_5^{\text{mooring}}\\
I_{66}\ddot{X}_6+\sum_{k=1}^{6}a_{6k}\ddot{X}_k+\sum_{k=1}^{6}\int_{-\infty}^{t}R_{6k}(t-\tau)\cdot\dot{X}_k(\tau)\cdot d\tau+b_{66}\dot{X}_6 &= F_6^{\text{wind}}+F_6^{\text{current}}+F_6^{\text{wave}}+F_6^{\text{mooring}}
\end{aligned} \tag{A.9}$$

in which: m = mass displacement of the ship

I_{kk} = moment of inertia in the k-mode

a_{kj} = frequency independent hydrodynamic mass coefficient

b_{kk} = additional viscous damping coefficient

c_{kj} = hydrostatic restoring coefficient

This set of equations is used by TERMSIM to calculate the displacements and velocities of the moored ship.

References

[A-1] W.E. Cummins, "The Impulse Response Function and Ship Motions", *D.T.M.B. Report 1661*, Washington D.C., 1962.

[A-2] T. Ogilvie, "Recent Progress Towards the Understanding and Prediction of Ship Motions", *Proceedings Fifth Symposium on Naval Mechanics*, 1964.

Appendix B

Effects of Slowly Varying Vertical Vessel Motions on Forces in Mooring Lines

Concerning a moored ship in waves, the effect of vertical motions on line forces is small, because the positions of mooring lines are nearly horizontal. The vertical motions have the same order of magnitude as horizontal ship motions. All motions are within a few decimetres.
Concerning vertical motions due to tide or loading process, line force variations become significant because the magnitude of the motions are a few metres in areas with a considerable tidal range. The order of magnitude is larger than vertical motions due to waves.

The computer model TERMSIM, used in this research to calculate vessel displacements and mooring forces, includes forces due to waves, wind and current. Vertical displacements due to tide and loading process are not included in the model.

Description of the static model

In order to verify the measured variations of forces in mooring lines due to tide and loading, a static model has been developed, which calculates mooring forces due to initial vertical vessel displacements. The model can also be used to calculate displacements and mooring forces due to an arbitrary static force.

The system is modelled using a linear mass-damper-spring system. The equation of motion is:

$$\sum_{j=1}^{6}\left\{\left(M_{kj}+a_{kj}\right)\ddot{x}_j+b_{kj}\dot{x}_j+C_{kj}x_j\right\}=F_k \qquad k = 1, 2, \ldots 6 \tag{B.1}$$

in which:
M = Inertia matrix
a = added inertia matrix
b = damping matrix
C = static restoring matrix
F_k = external force in the k-mode

Only very slowly varying motions are considered in the model. Hence accelerations and velocities are almost equal to zero, which reduces the equation of motion to a static model:

$$K \cdot \vec{x} = \vec{F} \tag{B.2}$$

The static restoring matrix K consists of the following elements:

1. Hydrostatic restoring of the moored ship.
2. Stiffness of mooring lines.
3. Stiffness of fenders.

The non-zero hydrostatic restoring components are:

$$\begin{aligned} k_{33} &= -\rho A_s \\ k_{44} &= -\rho\nabla \cdot GM \\ k_{55} &\approx -k_{yy}^2 \cdot \rho A_s \end{aligned} \tag{B.3}$$

in which:
ρ = density of water
A_s = water plane area
∇ = displacement volume
GM = metacentric height
k_{yy} = lateral radius of gyration in air

The forces in mooring lines act on the ship at the fairleads. The position of the fairlead is given by the vector $\vec{x}$ (x, y, z) in the ship-bound co-ordinate system. The direction of the force is given by the angles φ, θ and ψ which are the angles between the mooring line and the x, y and z-axis respectively. The components of the static restoring matrix for forces in mooring lines are:

$$k_{kj} = \sum_{i=1}^{n} -k_{ml,i} \cdot f_k \cdot f_j \qquad k, j = 1, 2 \ldots 6 \tag{B.4}$$

in which: n = number of mooring lines
$k_{ml,i}$ = stiffness of mooring line i

The directional cosines f_k and f_j depend on the fairlead positions and directions of mooring lines:

$$\begin{aligned}
\text{surge:} &\quad f_1 = \cos\varphi \\
\text{sway:} &\quad f_2 = \cos\theta \\
\text{heave:} &\quad f_3 = \cos\psi \\
\text{roll:} &\quad f_4 = y\cos\psi - z\cos\theta = yf_3 - zf_2 \\
\text{pitch:} &\quad f_5 = z\cos\varphi - x\cos\psi = zf_1 - xf_3 \\
\text{yaw:} &\quad f_6 = x\cos\theta - y\cos\varphi = xf_2 - yf_1
\end{aligned} \tag{B.5}$$

where: (x, y, z) = co-ordinates of fairlead in ship-bound co-ordinate system
φ, θ, ψ = angles of mooring leg with x-, y-, z-axis respectively

The same theory is applied to the components of the restoring matrix for fender forces. Because fender forces are directed in the y-direction, all terms containing 1, 3 and 5 are equal to zero.

The total static restoring matrix is equal to the sum of the contributions from hydrostatic forces, forces in mooring lines and fender forces.

Equation B.2 is used to calculate forces in mooring lines due to an initial vertical displacement dx_3. This displacement is either a variation of the ship's draft or a variation of the water level. All external forces are equal to zero. In order to calculate the displacement of the moored ship, equation B.2 is written as:

$$\begin{bmatrix} k_{11} & k_{12} & k_{14} & k_{15} & k_{16} \\ k_{21} & k_{22} & k_{24} & k_{25} & k_{26} \\ k_{41} & k_{42} & k_{44} & k_{45} & k_{46} \\ k_{51} & k_{52} & k_{54} & k_{55} & k_{56} \\ k_{61} & k_{62} & k_{64} & k_{65} & k_{66} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_4 \\ x_5 \\ x_6 \end{bmatrix} = -dx_3 \cdot \begin{bmatrix} k_{13} \\ k_{23} \\ k_{43} \\ k_{53} \\ k_{63} \end{bmatrix} \tag{B.6}$$

From equation B.6 the other displacements can be calculated. The forces in an individual mooring line follow from the calculated ship displacement.

Calculated results

The static model is used to verify measured variations of line forces due to tide and loading concerning a Northwest 125,000 m^3 LNG carrier moored to the LNG jetty in Withnell Bay. The stiffness per mooring line is approximately 40 tn/m; stiffness of each fender is approximately 270 tn/m.

The effect of vertical motions is largest for spring lines N° 6, 7, 10 and 11, which are connected to the outer breasting dolphins D and I. The large effect is the result of the larger vertical angle ψ.
Some results are presented in table B.1. The given forces are variations with respect to the force at water level = AHD and loading condition = 50%.

Table B.1: Variations of line forces due to vertical motions (all forces in tons).

	neap tide		spring tide		loading process	
	LT	HT	LT	HT	Ballast	Laden
h [m+AHD]	-0.52	0.45	-1.89	1.78	0	0
loading condition	50%	50%	50%	50%	0%	100%
mooring leg 1	-1.66	1.47	-5.80	6.01	3.28	-3.17
mooring leg 2	-1.79	1.59	-6.25	6.47	3.54	-3.41
mooring leg 3	-2.21	1.97	-7.71	8.04	4.39	-4.23
mooring leg 4	-2.74	2.43	-9.57	9.90	5.41	-5.22
mooring leg 5	-2.69	2.39	-9.38	9.76	5.33	-5.13
mooring leg 6	-3.42	3.09	-11.73	12.87	6.86	-6.33
mooring leg 7	-4.83	4.35	-16.60	18.09	9.65	-8.94
mooring leg 8	-2.39	2.17	-8.16	9.09	4.83	-4.41
mooring leg 9	-2.65	2.39	-9.06	9.98	5.32	-4.90
mooring leg 10	-4.31	3.90	-14.67	16.33	8.69	-7.96
mooring leg 11	-3.44	3.11	-11.72	13.00	6.92	-6.35
mooring leg 12	-2.40	2.14	-8.29	8.82	4.79	-4.56
mooring leg 13	-1.99	1.79	-6.85	7.42	4.03	-3.80
mooring leg 14	-2.03	1.82	-6.97	7.54	4.09	-3.87
mooring leg 15	-1.06	0.96	-3.62	4.01	2.18	-2.04
mooring leg 16	-1.12	1.01	-3.81	4.20	2.28	-2.14

The calculated range of forces is 10-30 tons in case of a tidal range of 3.5 m. These high variations of forces clarify the necessity of adaptation of pretension at the winches, because large variations of pretension are not allowed.

Appendix C

Verification of the Design Studies "Withnell Bay LNG Terminal Project"

A research program for the design of the LNG jetty in Withnell Bay has been carried out by Delft Hydraulics and MARIN in the begin eighties. The main conclusions of the MARIN studies applied for a 125,000 m3 LNG carrier (ref. [C-1] and [C-2]) are mentioned in paragraph 3.2.

An important difference between the design studies and the measured weather circumstances is the wave height. The wave heights for design conditions were equal to:

- Spectrum I: $H_{s,swell}$ = 0.65 m, $T_{m,swell}$ = 20.0 s; $H_{s,sea}$ = 1.40 m, $T_{m,sea}$ = 7.0 s.
- Spectrum II: $H_{s,swell}$ = 0.60 m, $T_{m,swell}$ = 16.0 s; $H_{s,sea}$ = 2.60 m, $T_{m,sea}$ = 10.0 s.
- Spectrum III: H_s = 2.30 m, T_m = 14.0 s.

These wave conditions are much more severe than the measured conditions in 1996. The maximum wave loads during the measured period were $H_{s,swell}$ equal to approximately 0.35 m, $T_{m,swell}$ = 14 s.

In spite of the low wave conditions, measured line forces are relatively high compared to the calculated results in the design study tests. Clarification of the differences could be an underestimation of yaw motions for the simulation tests. In table C.1 the comparison of significant yaw motions between computer calculations and estimations using equation 8.6 are given. The computer calculations were carried out using MOORSIM; the estimations are based on TERMSIM II calculations (paragraph 8.2).

Table C.1: Comparison of yaw motions between design simulation tests and estimations

test N°	wave direction [°]	wave spectrum	$X_{6,s}$ (MOORSIM) [°]	$X_{6,s}$ (estimation) [°]
1829	195	I	0.0358	0.405
1815	195	II	0.0397	0.210
1813	195	III	0.0667	0.553

Large differences occur between the simulated and estimated significant yaw motions. A part of this difference can be explained by the fact that the estimation is an upper limit approach. A reduction of 30% - 60% to the estimated value is possible. Nevertheless the differences are larger (up to 90%), so that a significant difference remains. Two probable clarifications for this remaining difference are:

1. Errors in the hydrodynamic files used for the simulation tests, i.e. the amplitude of first order transfer function in the 6th mode.
2. Calculation errors of the program MOORSIM.

Taking into account the underestimation of calculated yaw motions, not the low frequency surge and sway motions are dominant concerning maximum line forces, but the first order yaw motions are dominant. Because of this the maximum wave loads, which can be exposed to the moored ship, are smaller than the design wave conditions.

Further research to ships moored to the LNG jetty in Withnell Bay can lead to the determination of the maximum allowable wave loads on the moored ship.

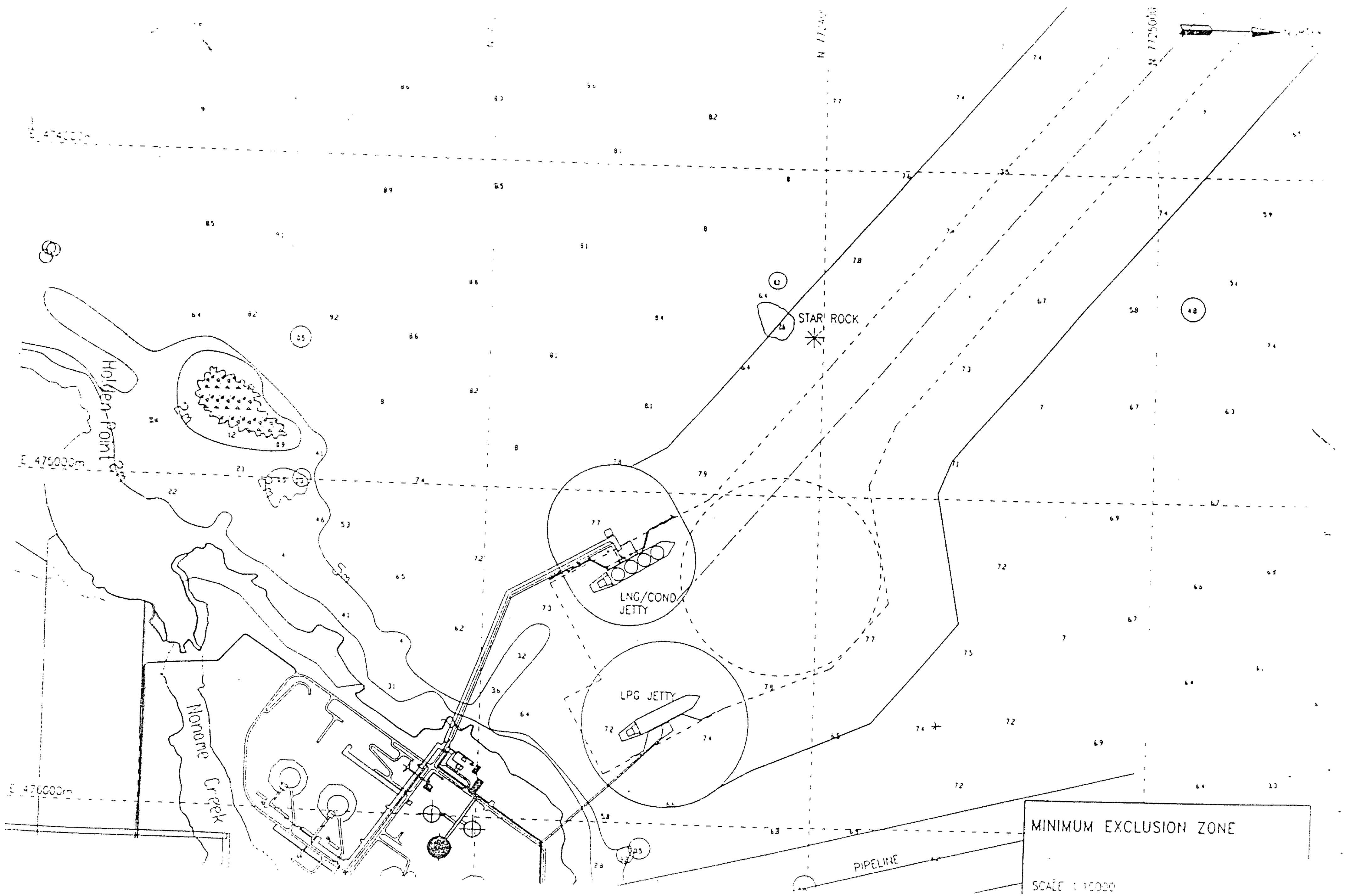
References

[C-1] Netherlands Ship Model Basin (N.S.M.B.), "Discussion on the Comparative Simulation Tests", *Withnell Bay LNG Terminal Project*, Part II-B, N.S.M.B. Report N° 03193-1-OE, June 1981.

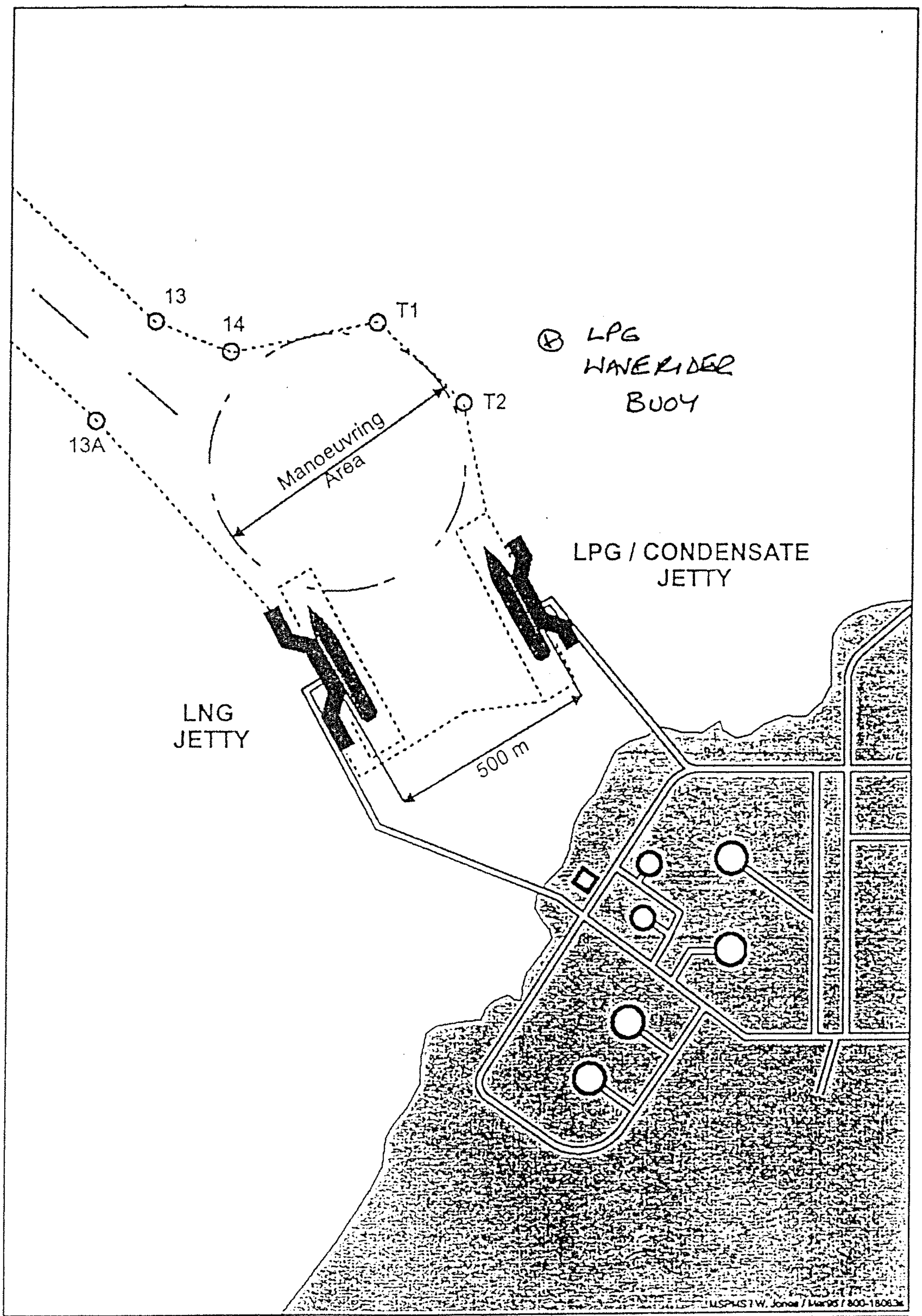
[C-2] Netherlands Ship Model Basin (N.S.M.B.), "Mathematical Simulation of the Behaviour of a Loaded LNG Carrier Moored to a Jetty", *Withnell Bay LNG Terminal Project*, Part II, N.S.M.B. Report N° 03193-1-OE, December 1981.

Appendix D

Figures

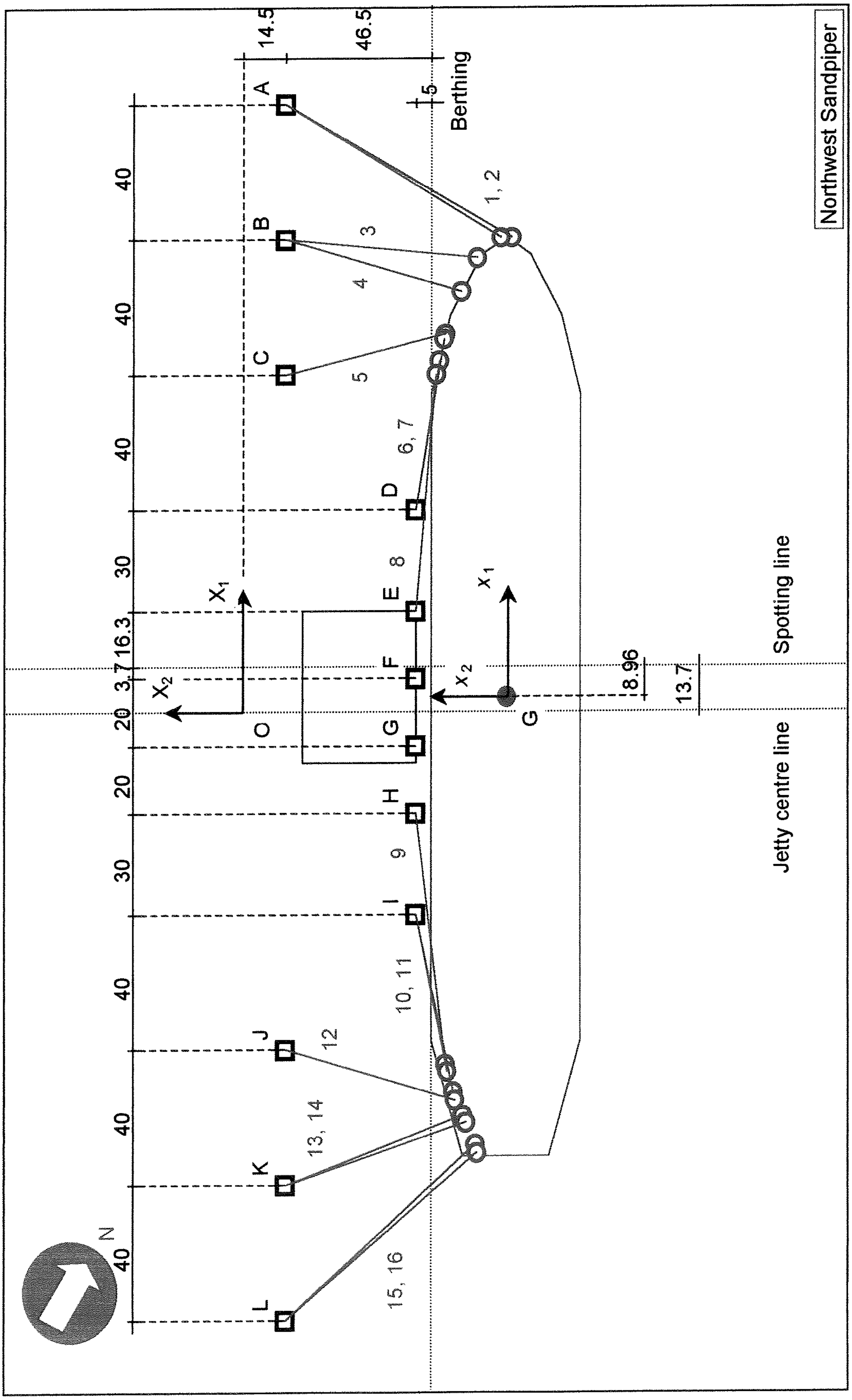


STAR ROCK
LNG/COND JETTY
LPG JETTY
Holden Point
Noname Creek
PIPELINE
E 474000m
E 475000m
E 476000m
MINIMUM EXCLUSION ZONE
SCALE 1:10000



WITHNELL BAY LOADING TERMINAL - GENERAL LAYOUT

Figure 3: LNG jetty Withnell Bay - plan view



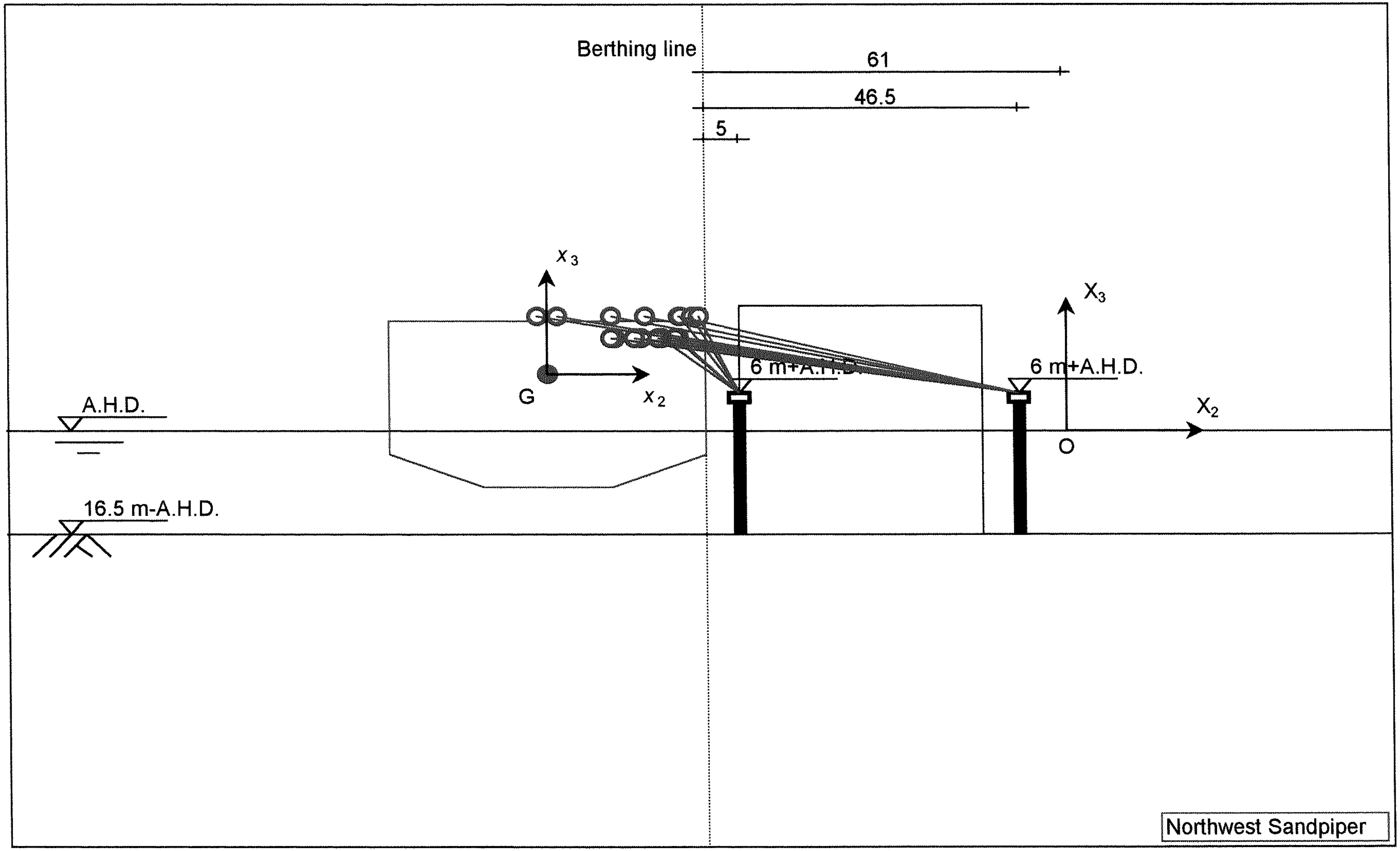


Figure 4: LNG jetty Withnell Bay - front view

Figure 5:

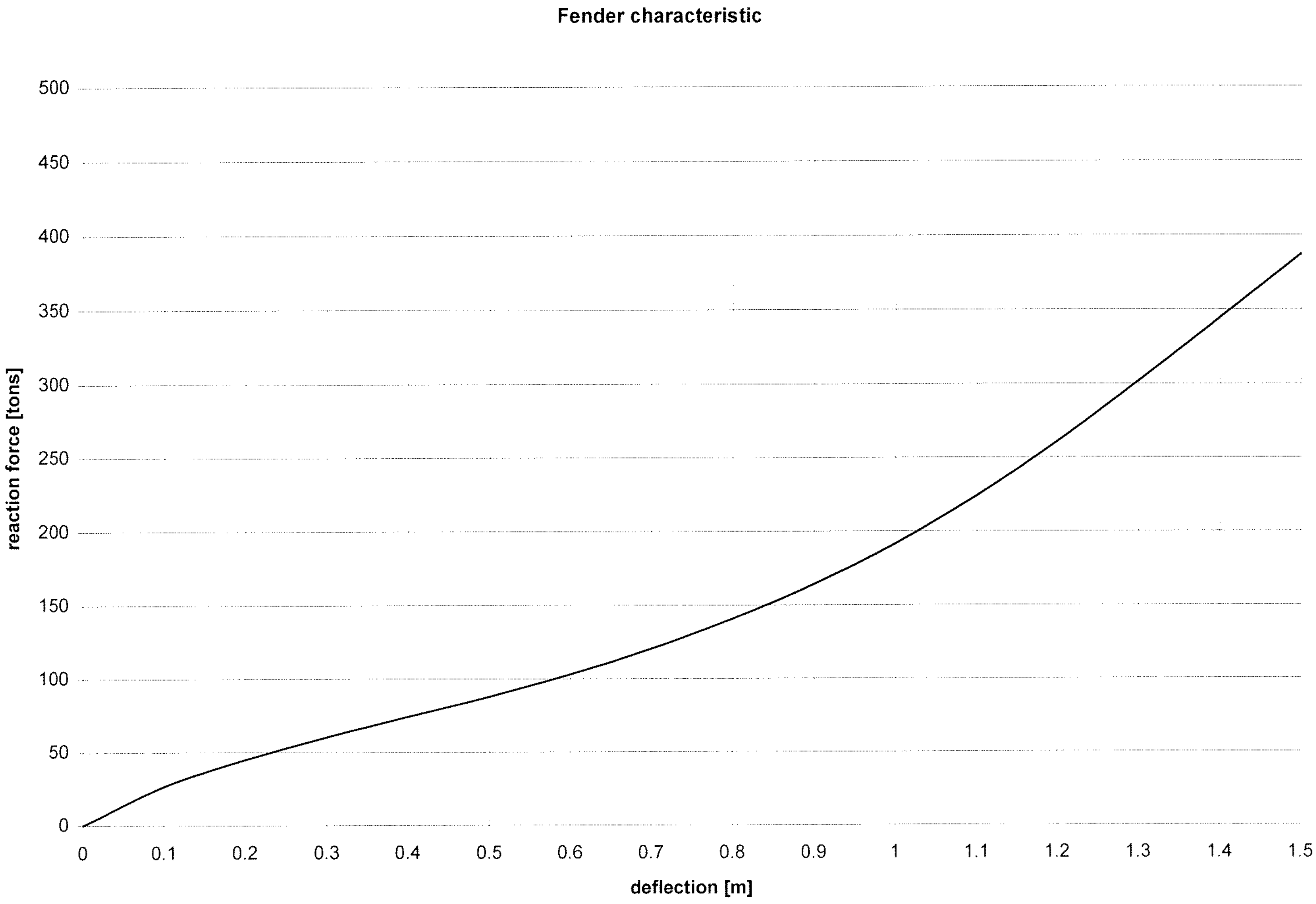
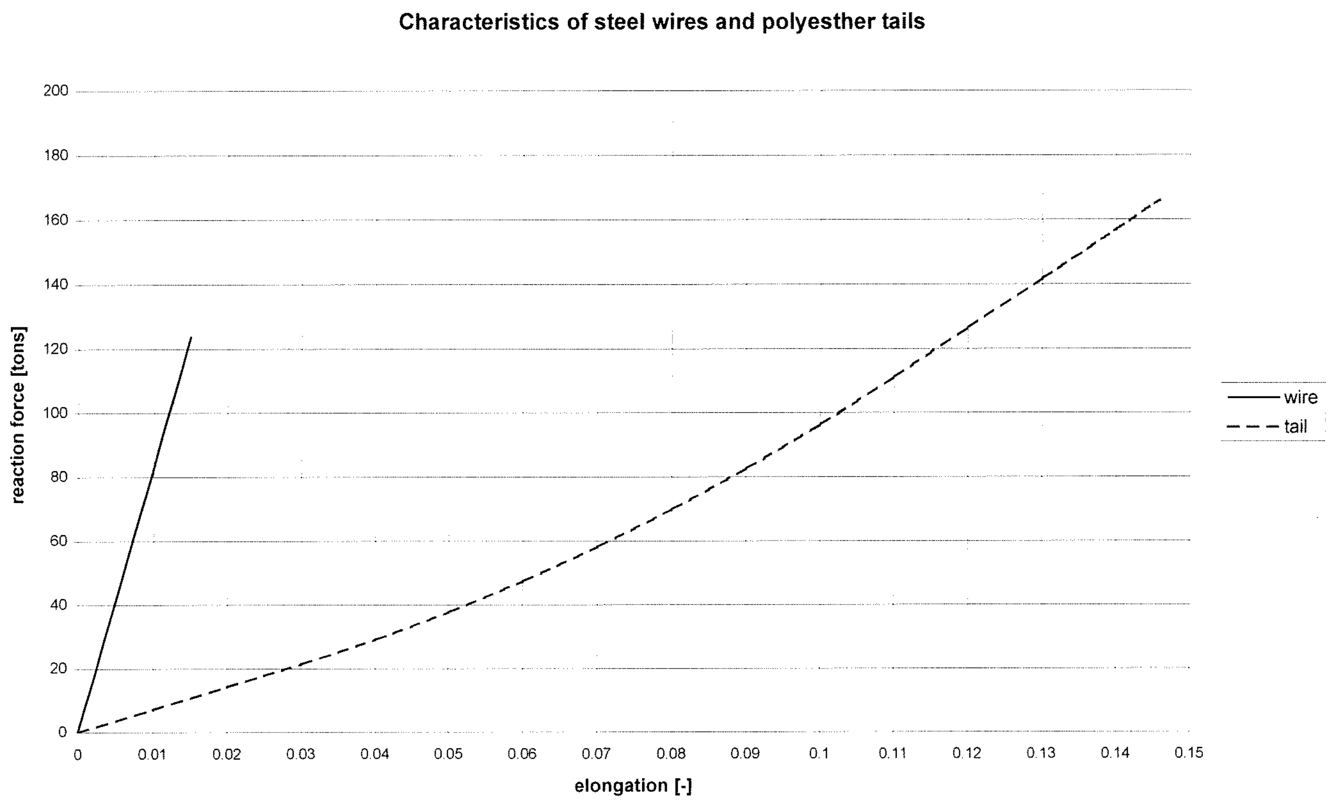

Fender characteristic
reaction force [tons]
500
450
400
350
300
250
200
150
100
50
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
1.5
deflection [m]

Figure 6:



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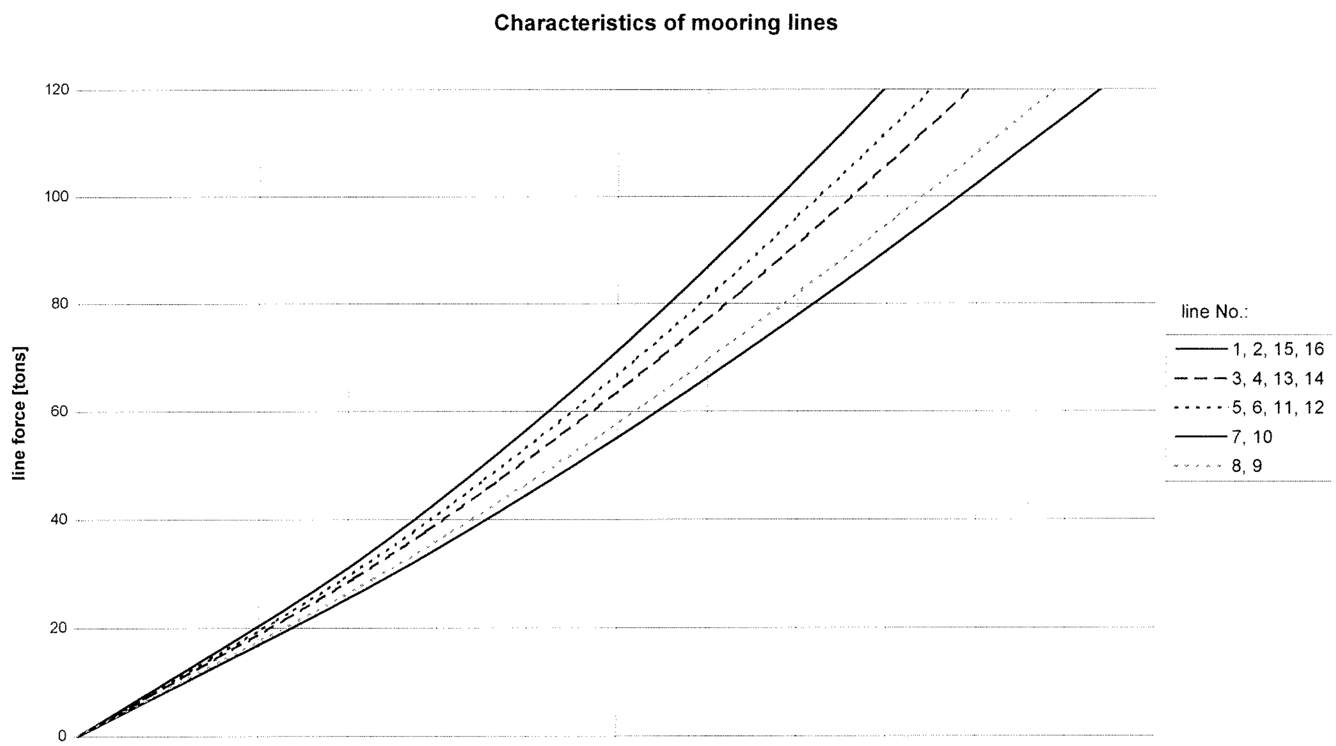

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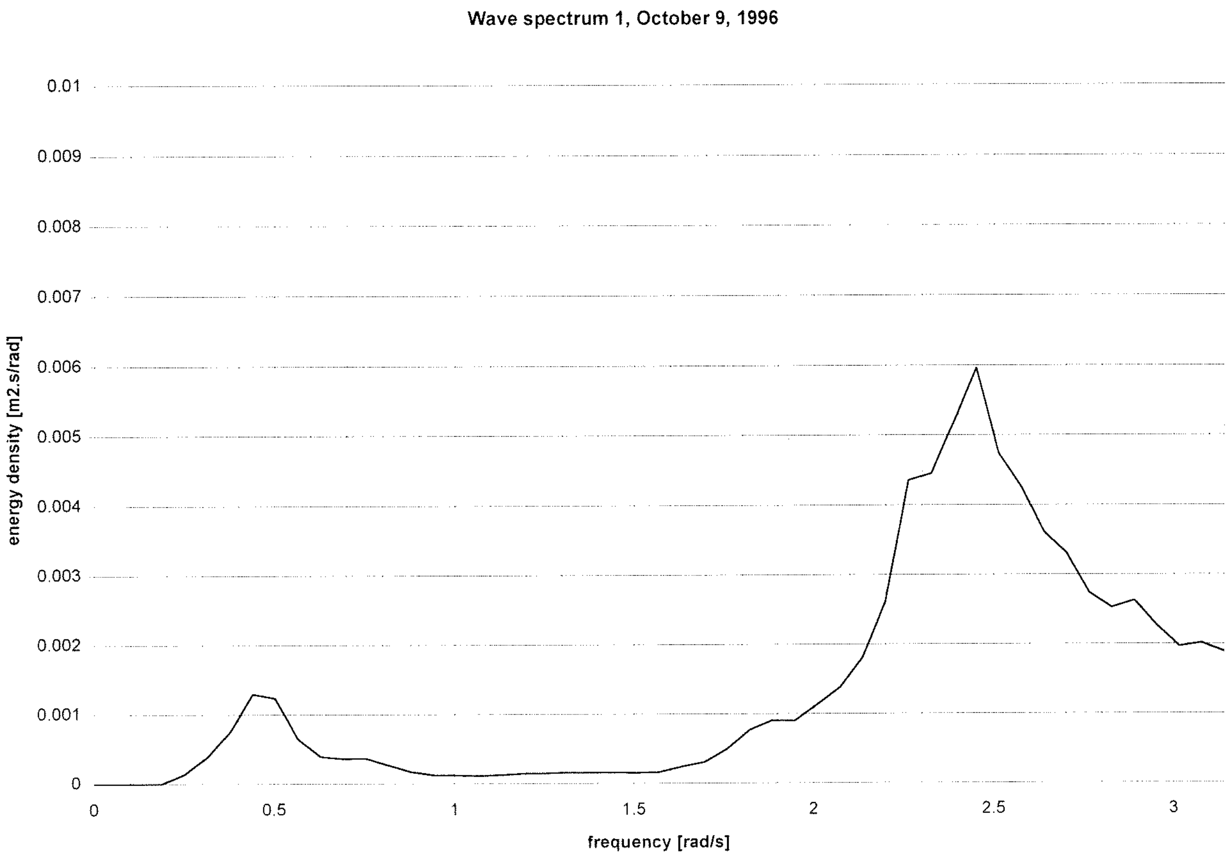

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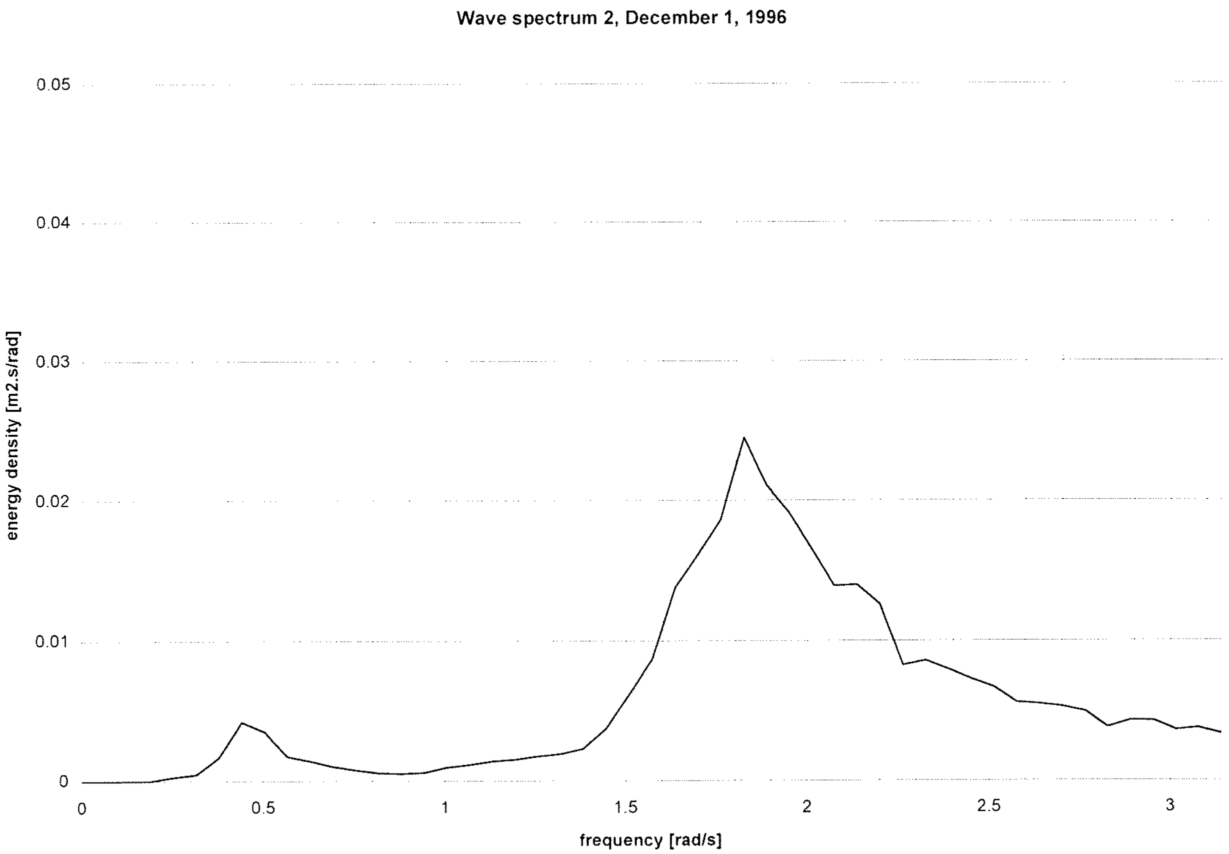

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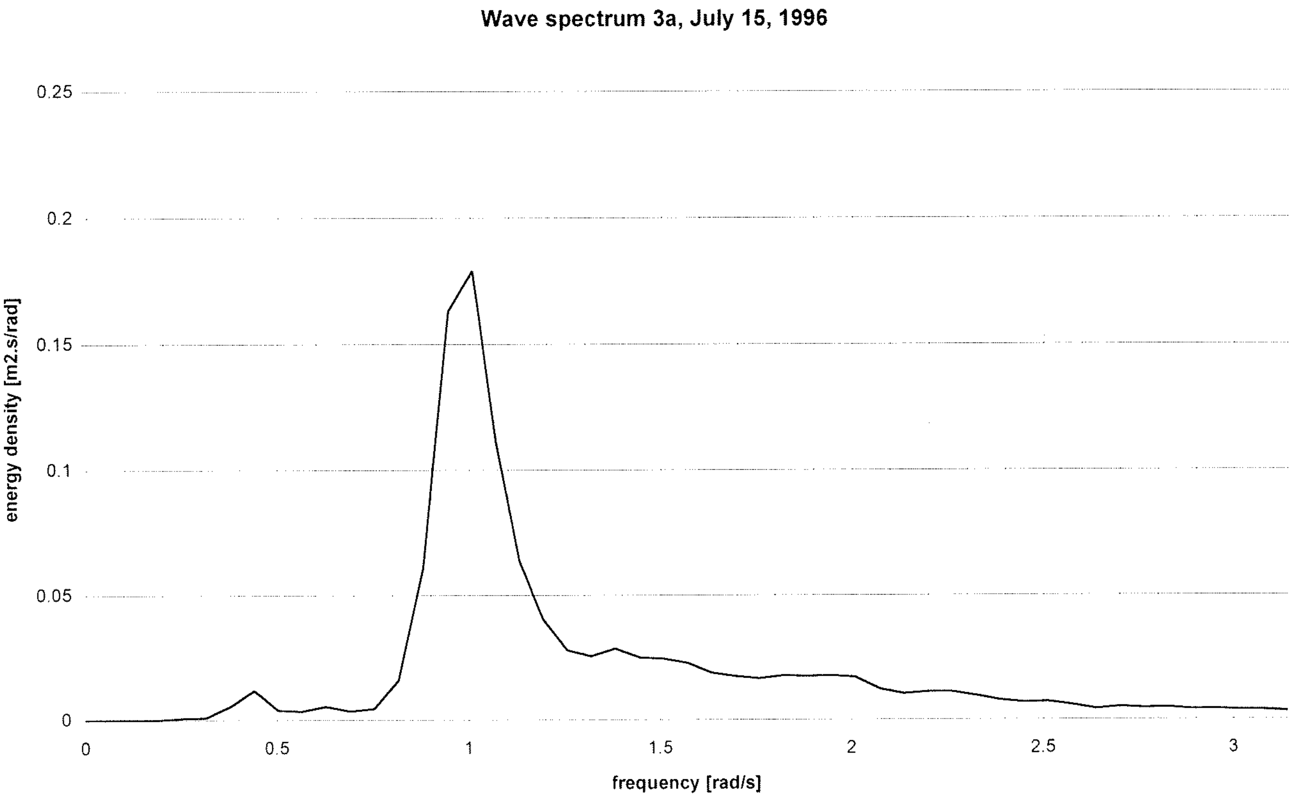

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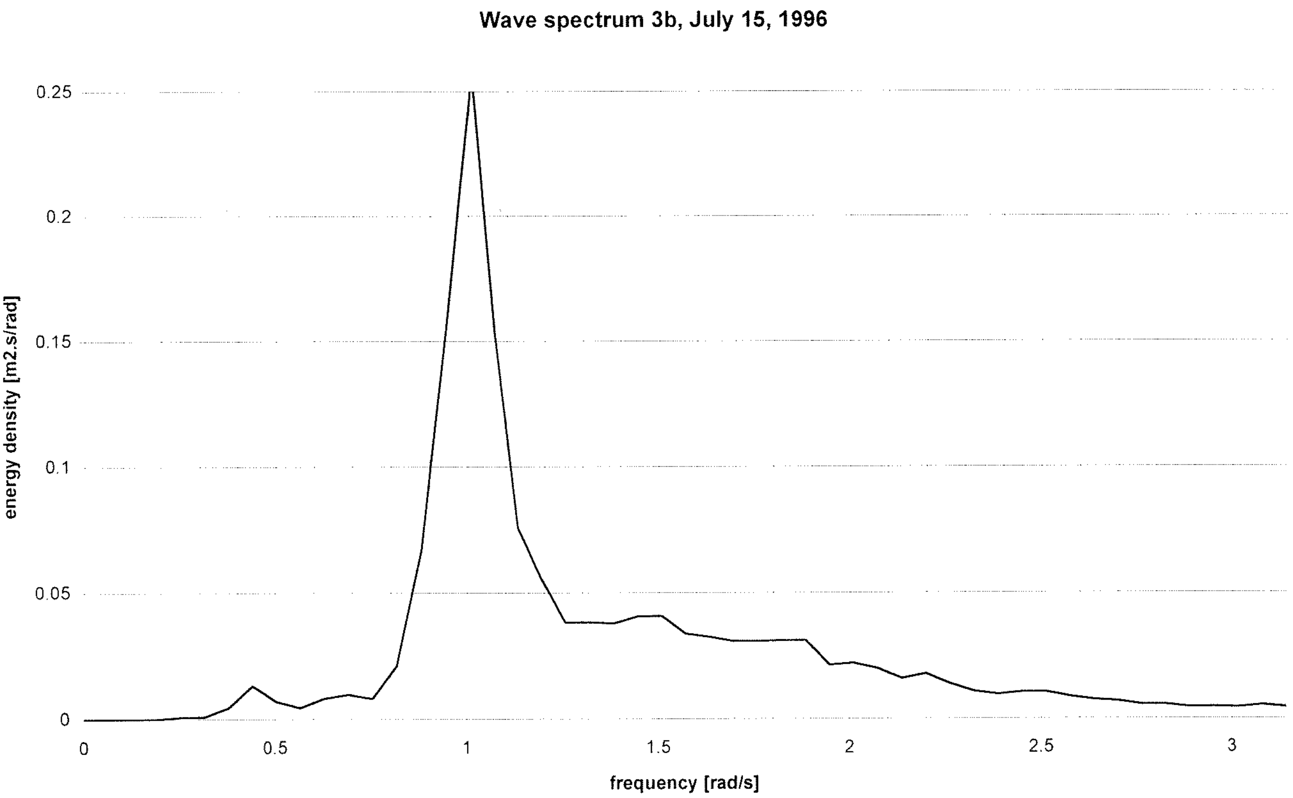

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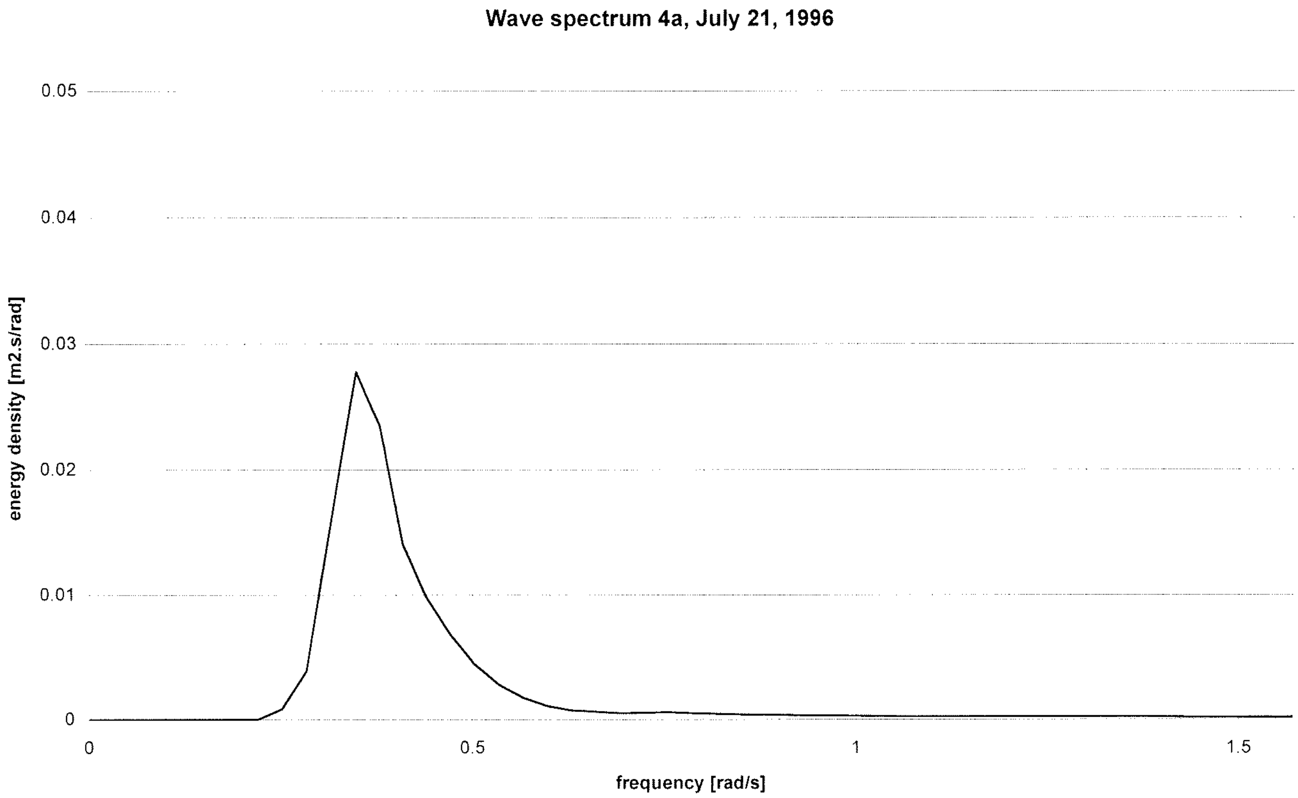

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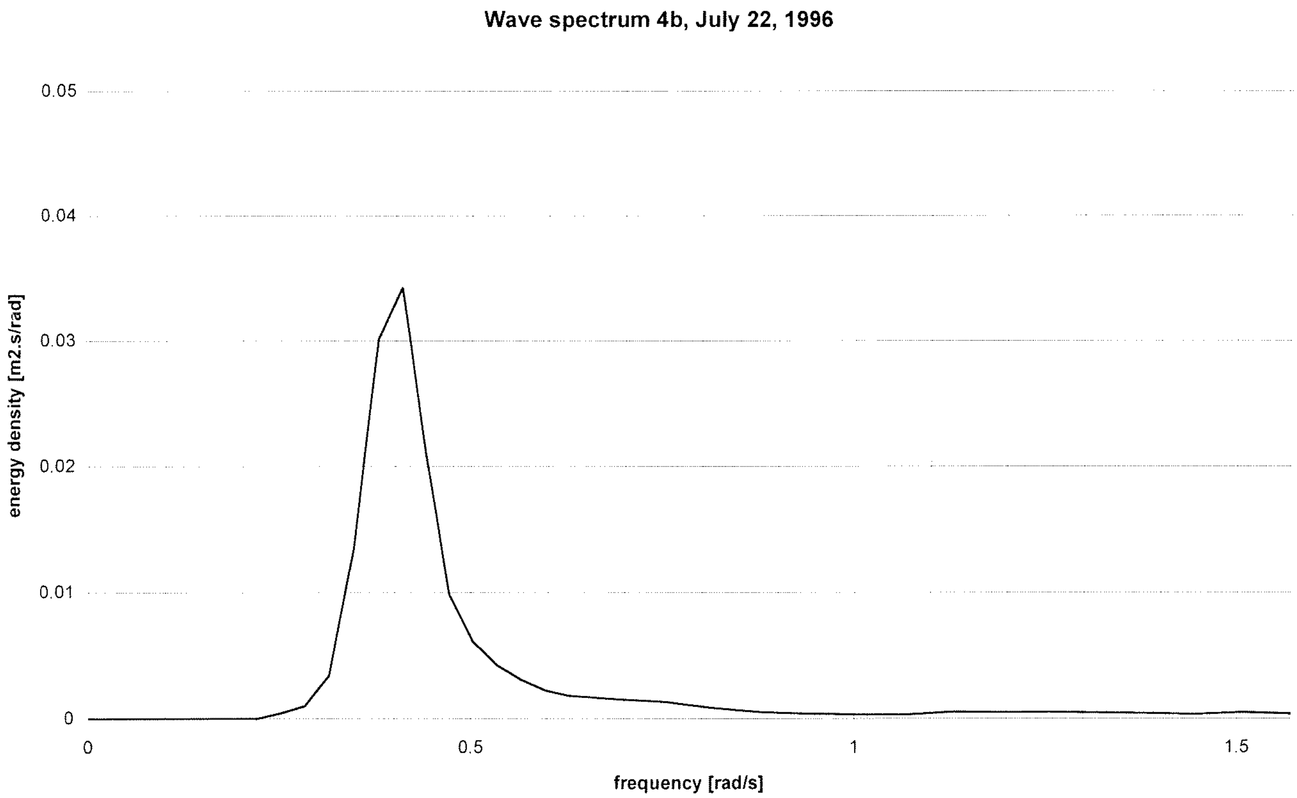

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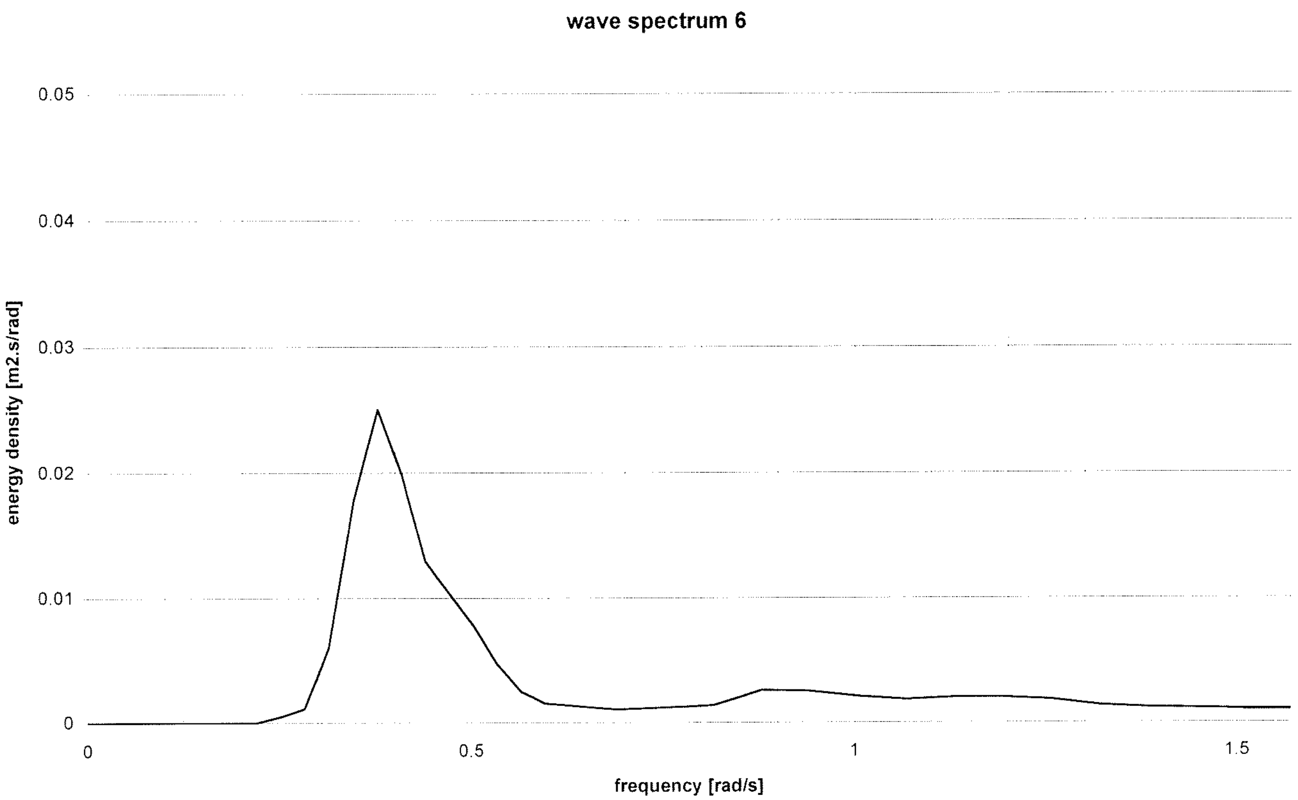

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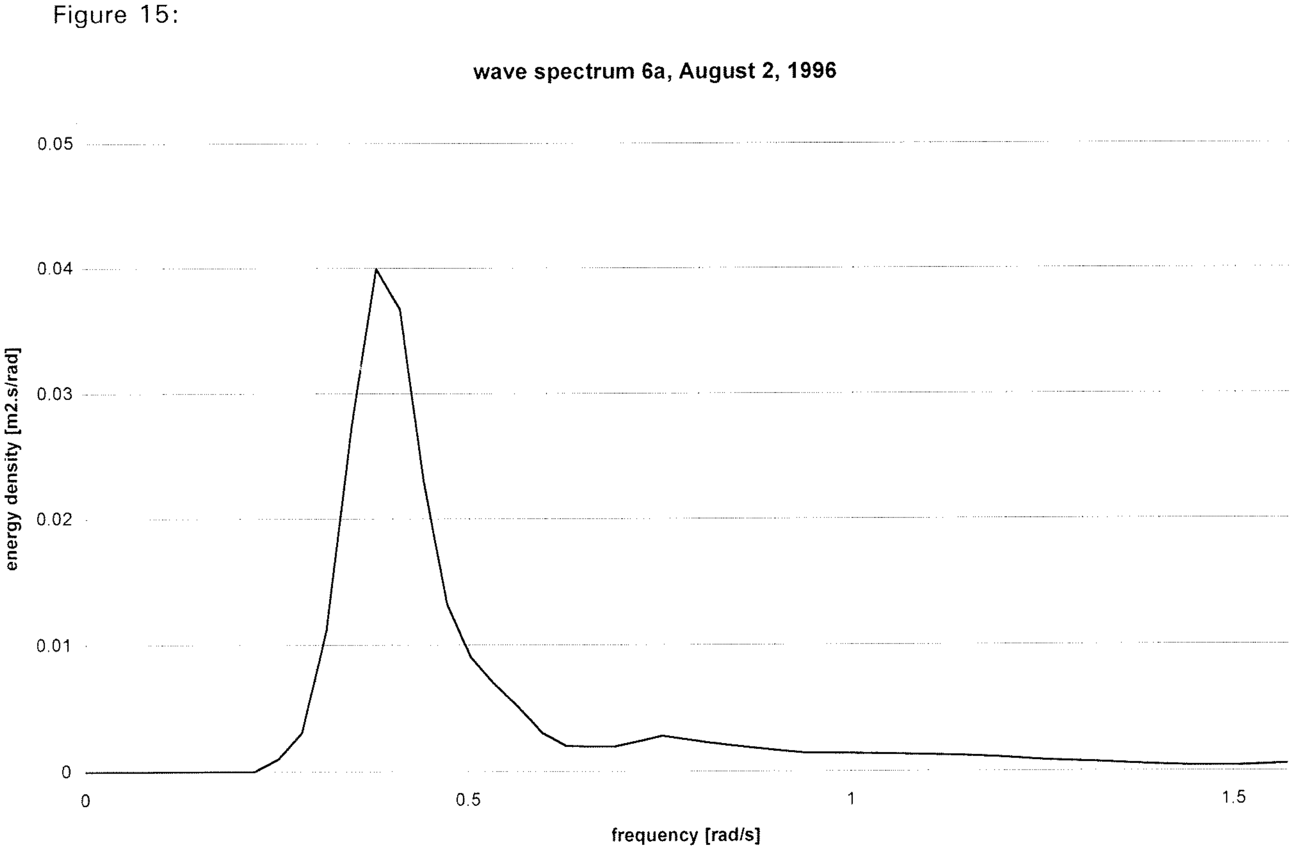

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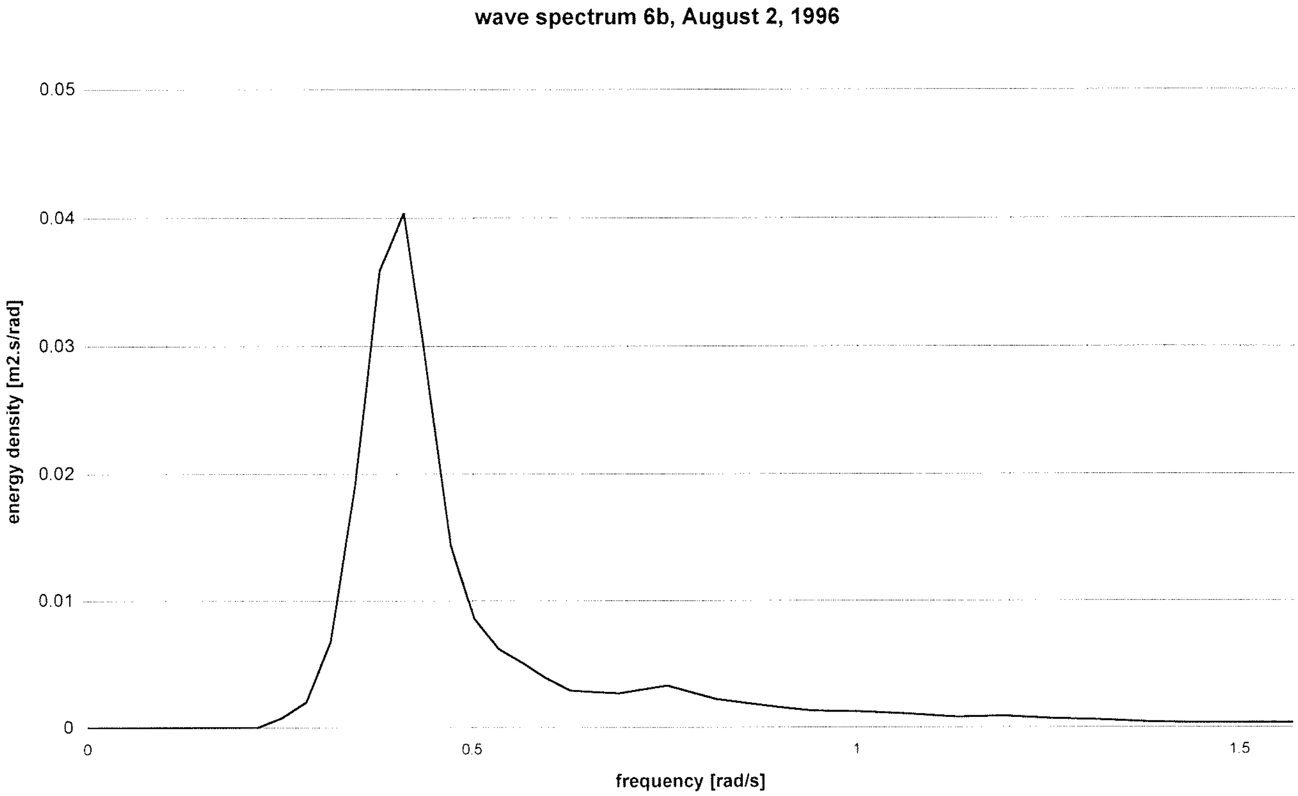

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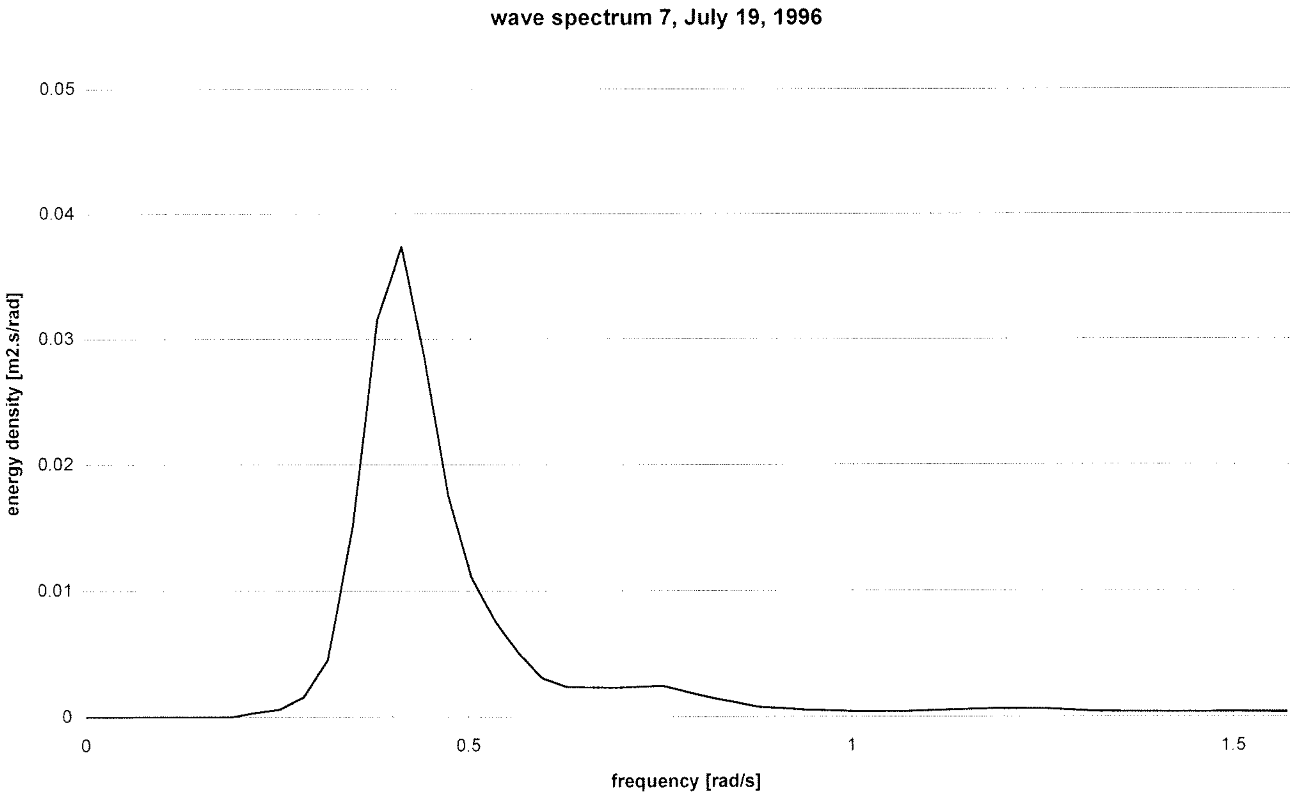

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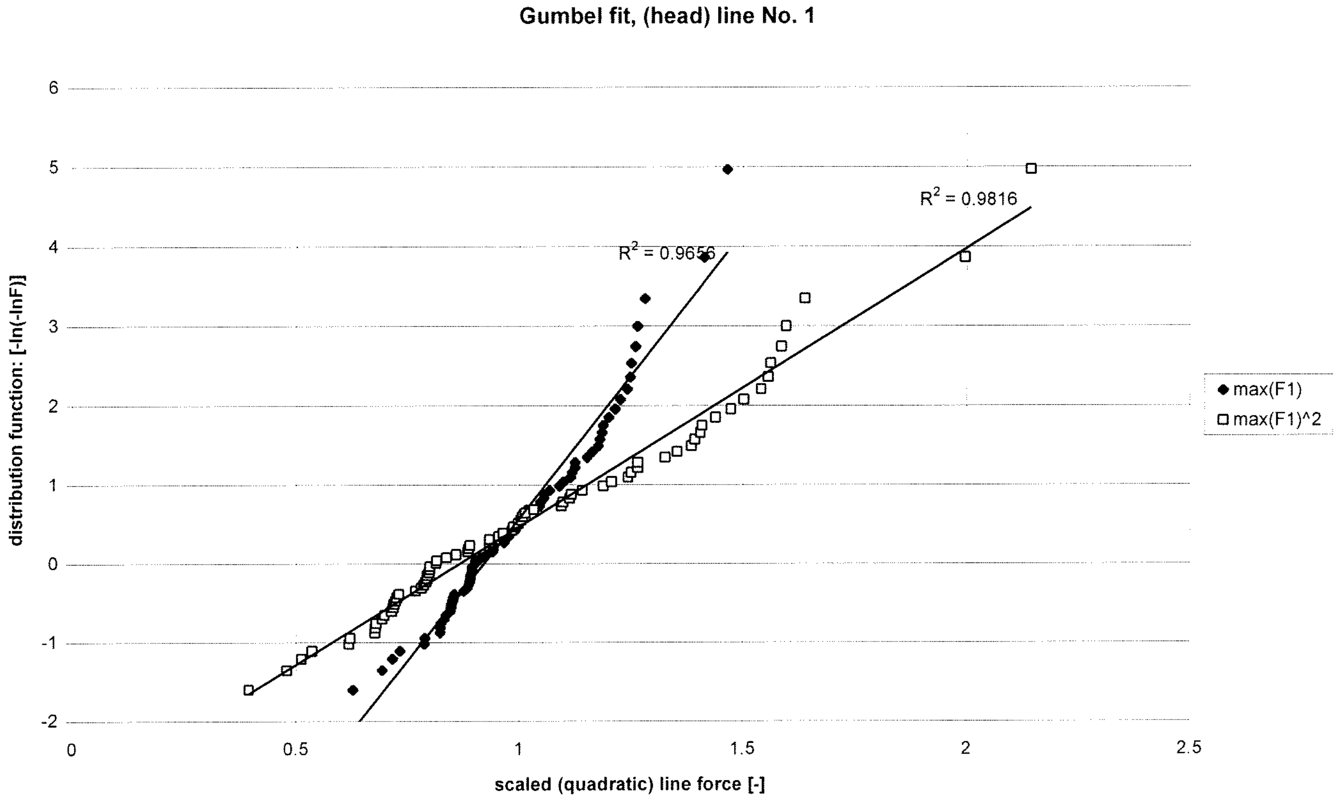

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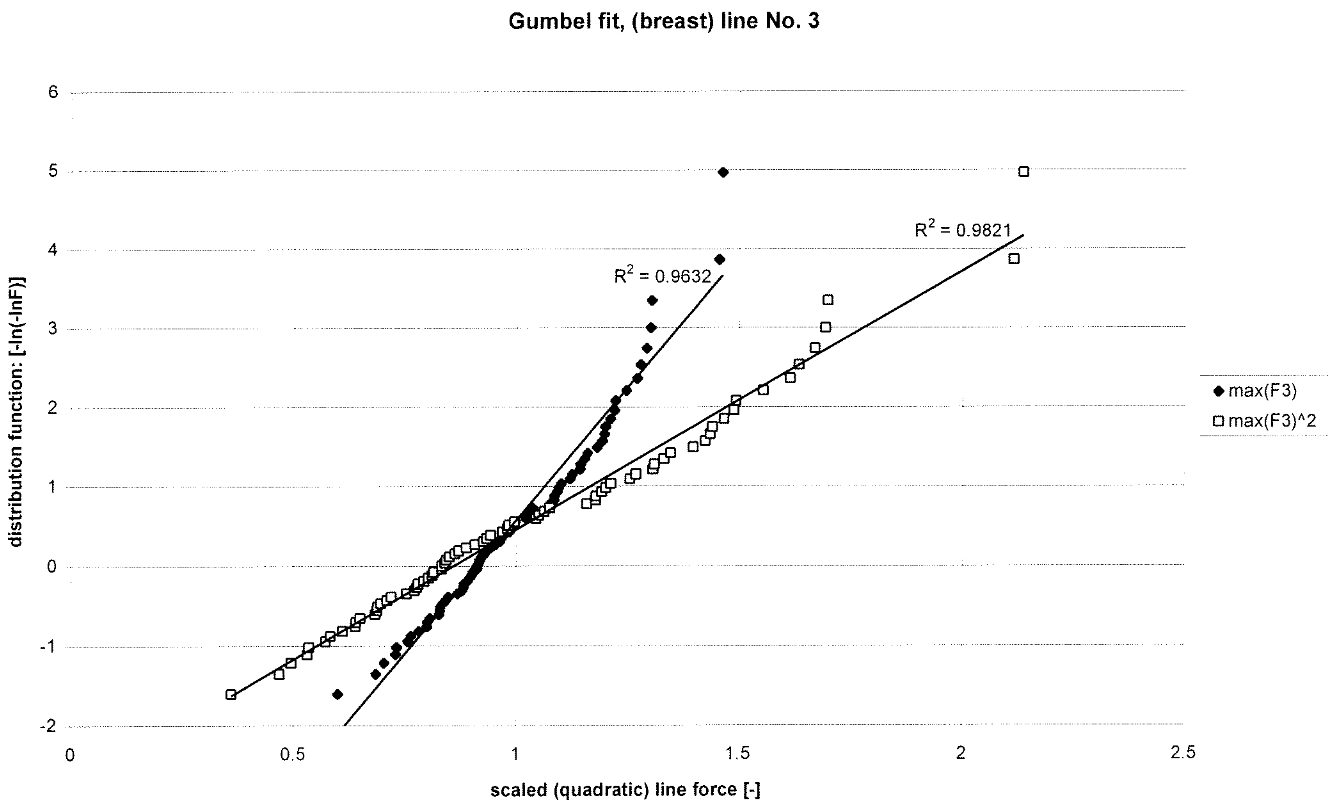

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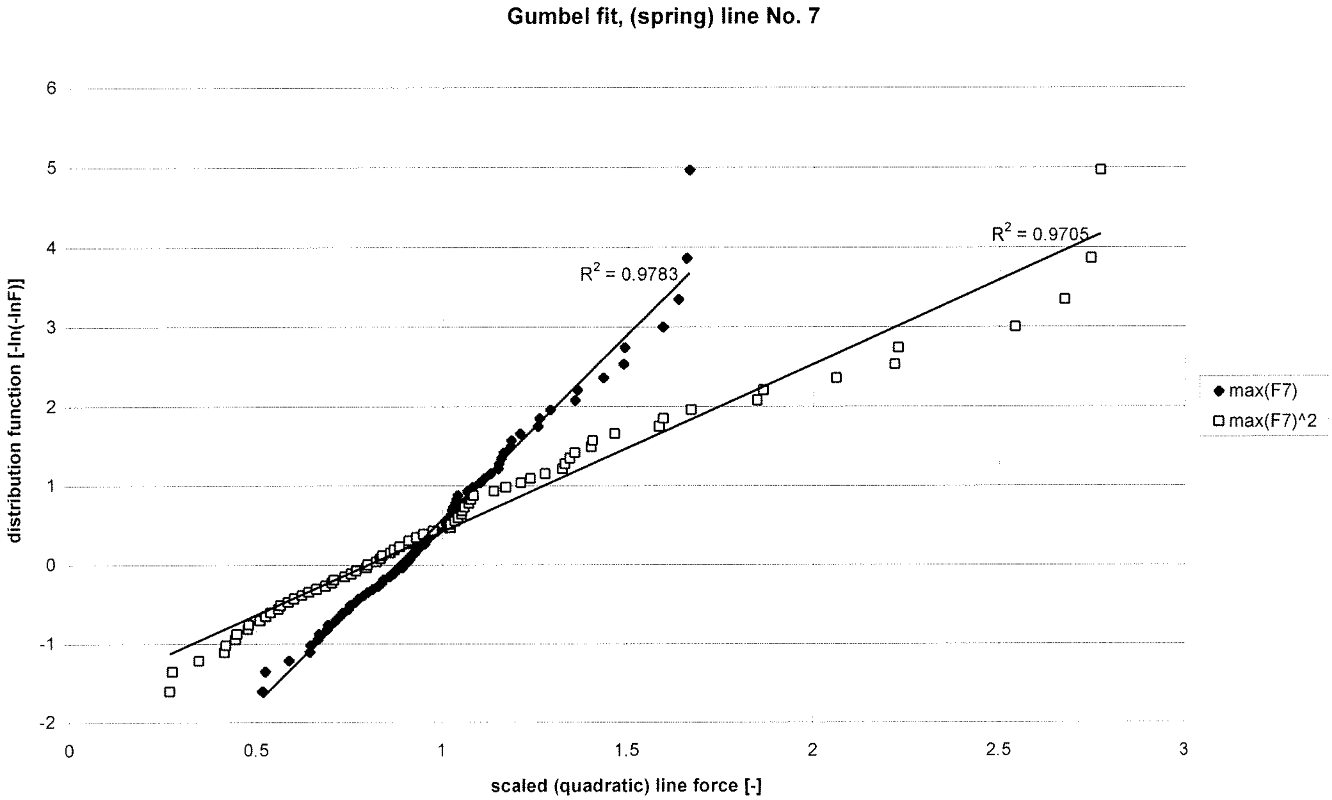

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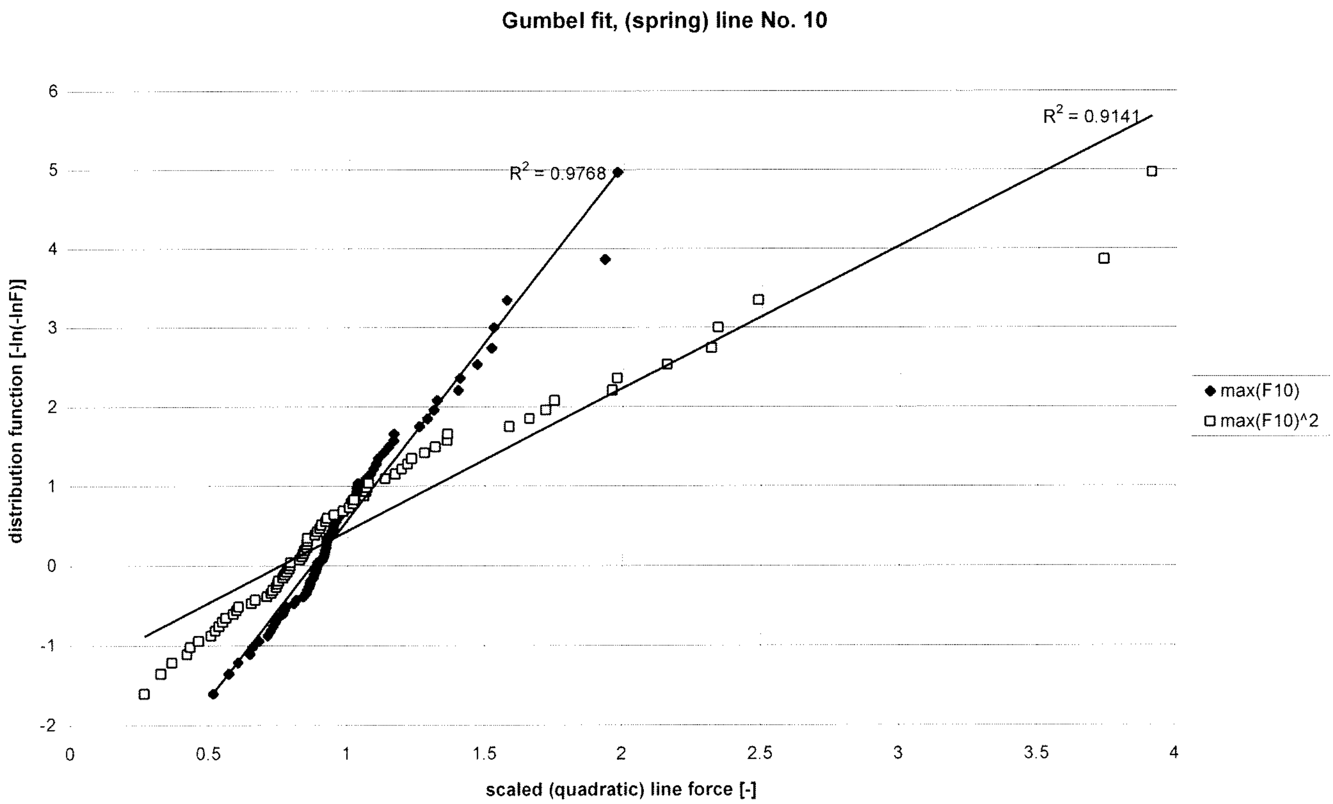

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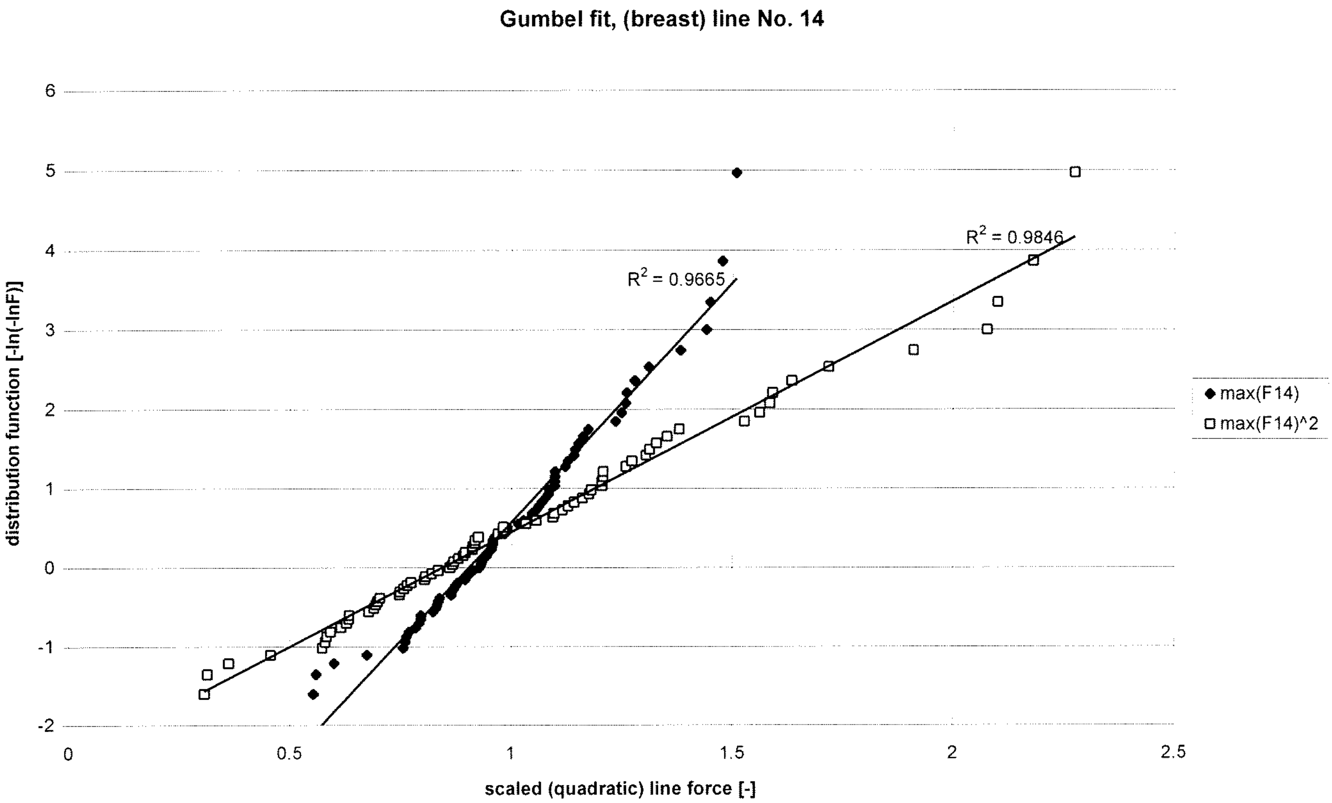

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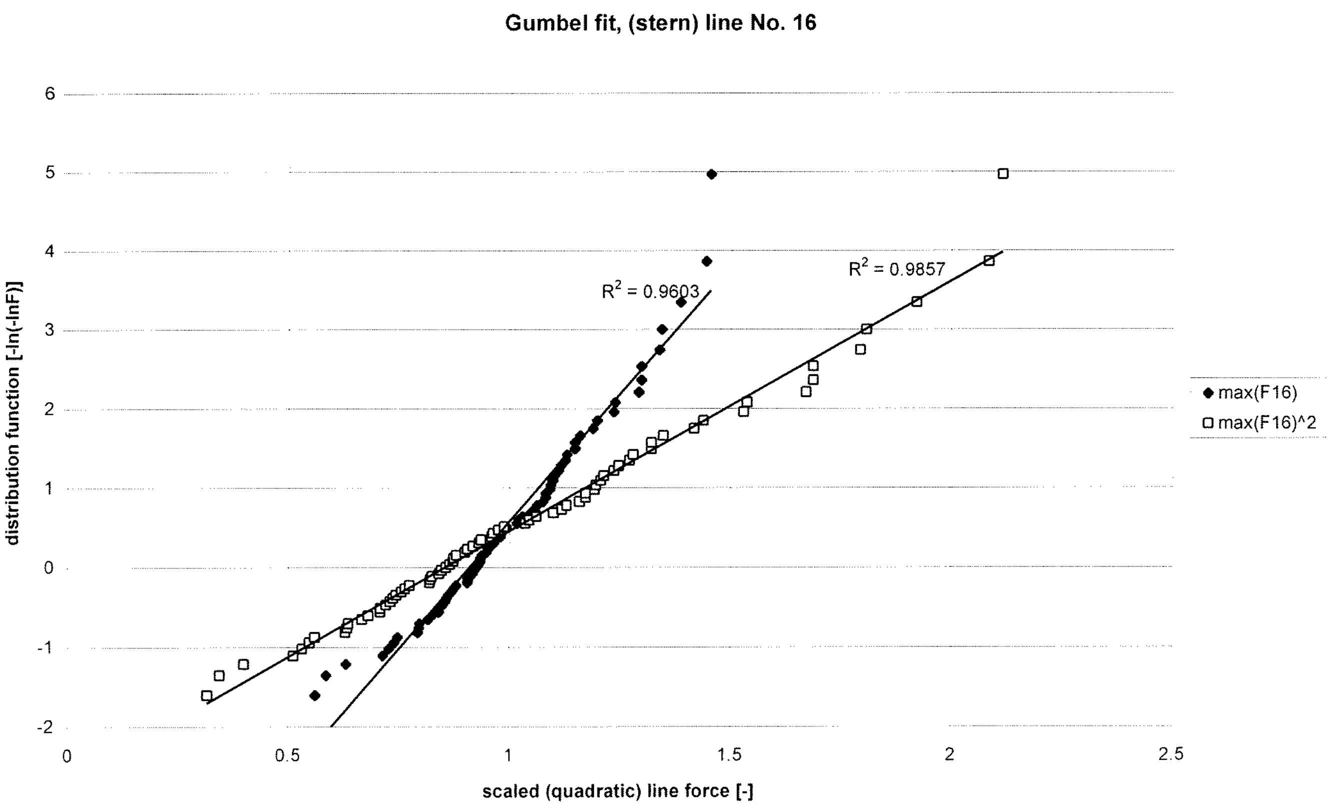

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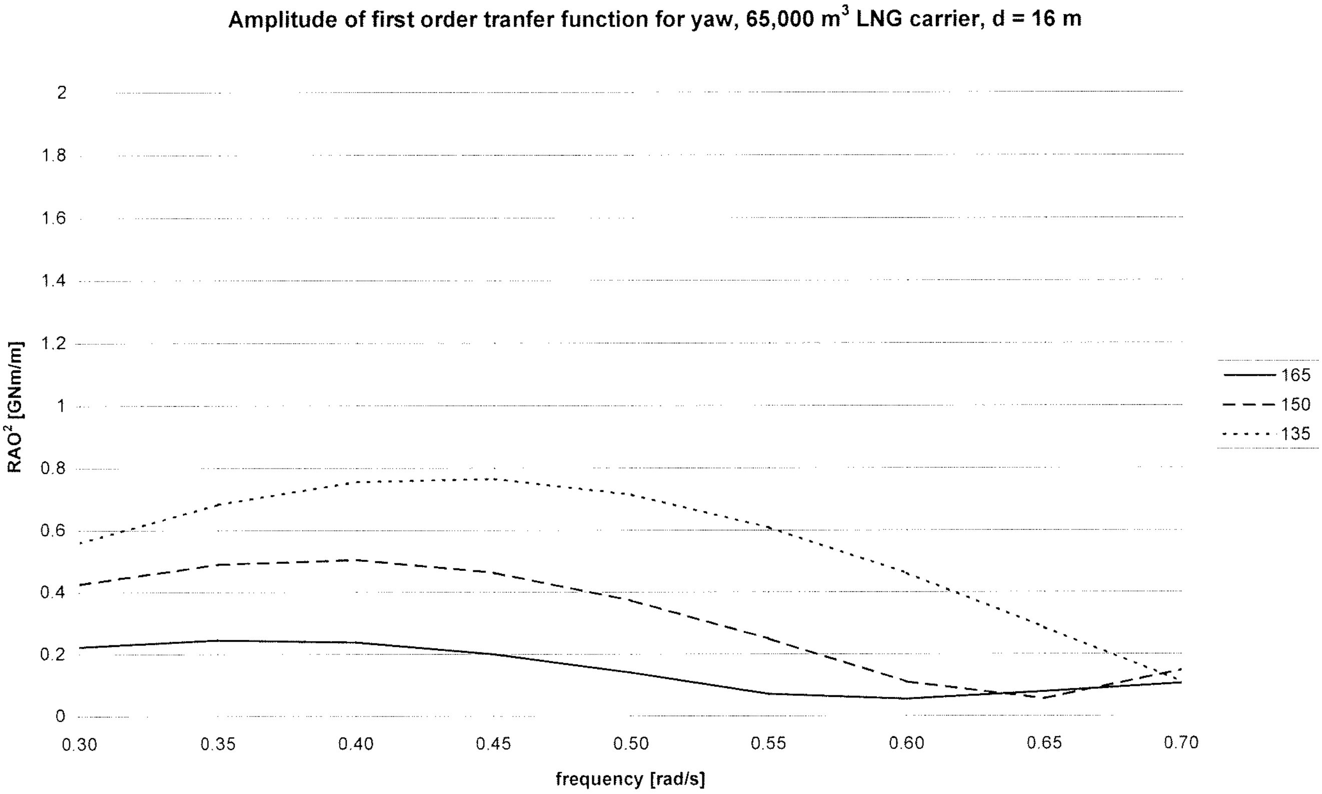

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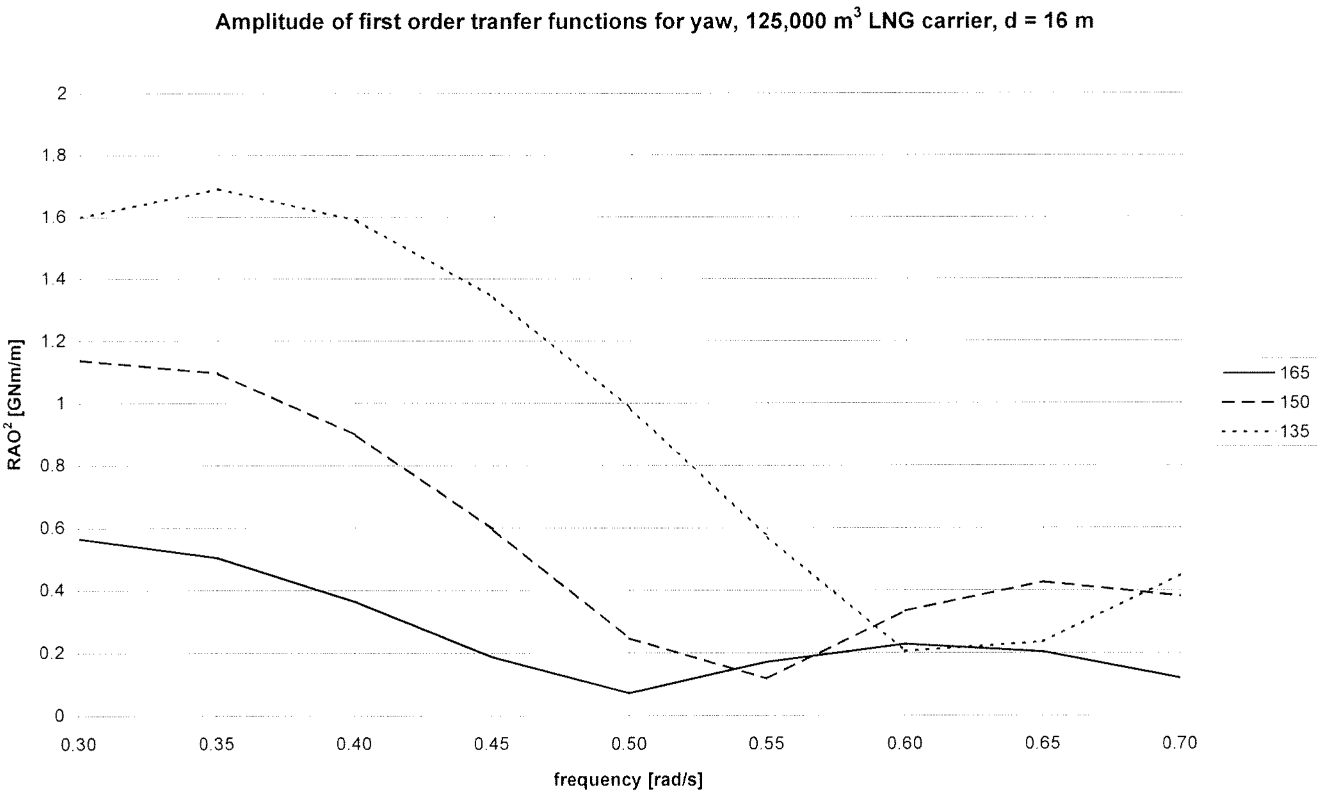

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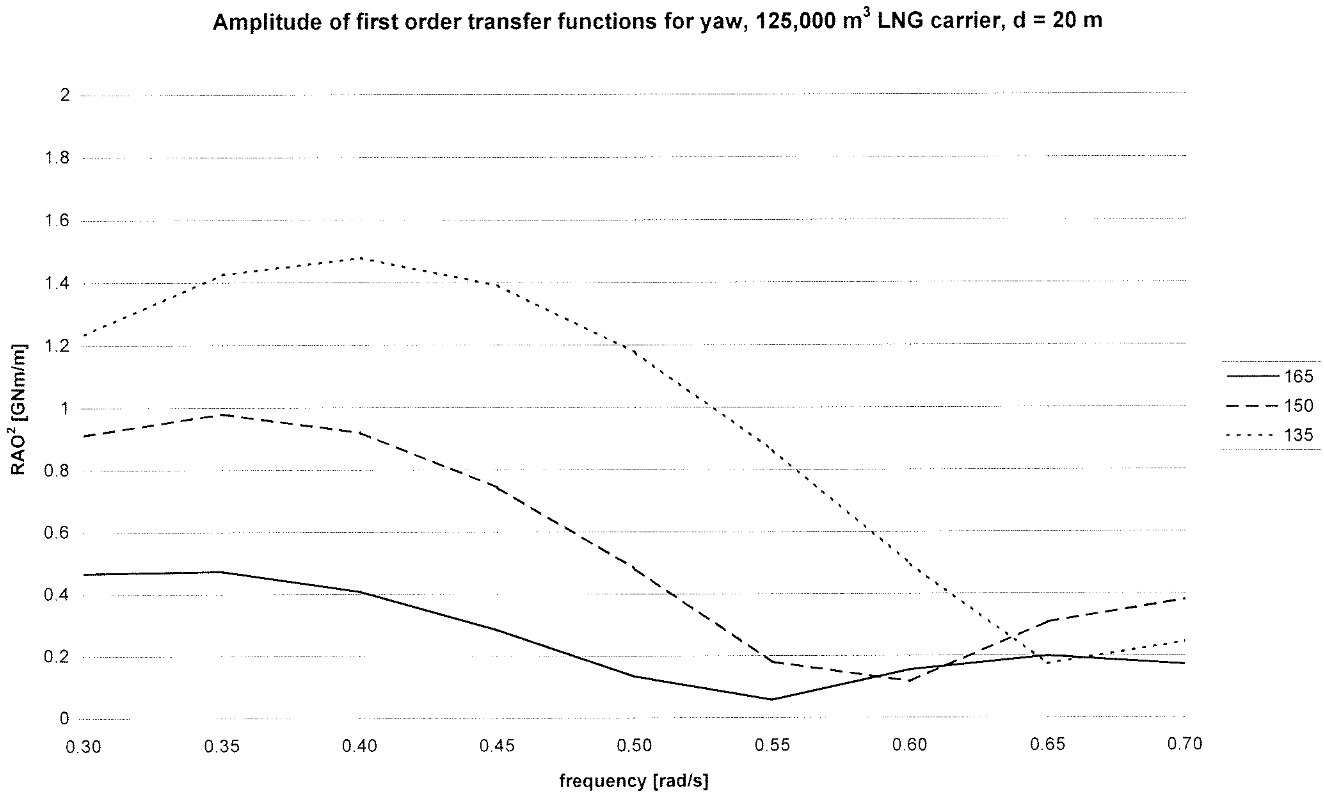

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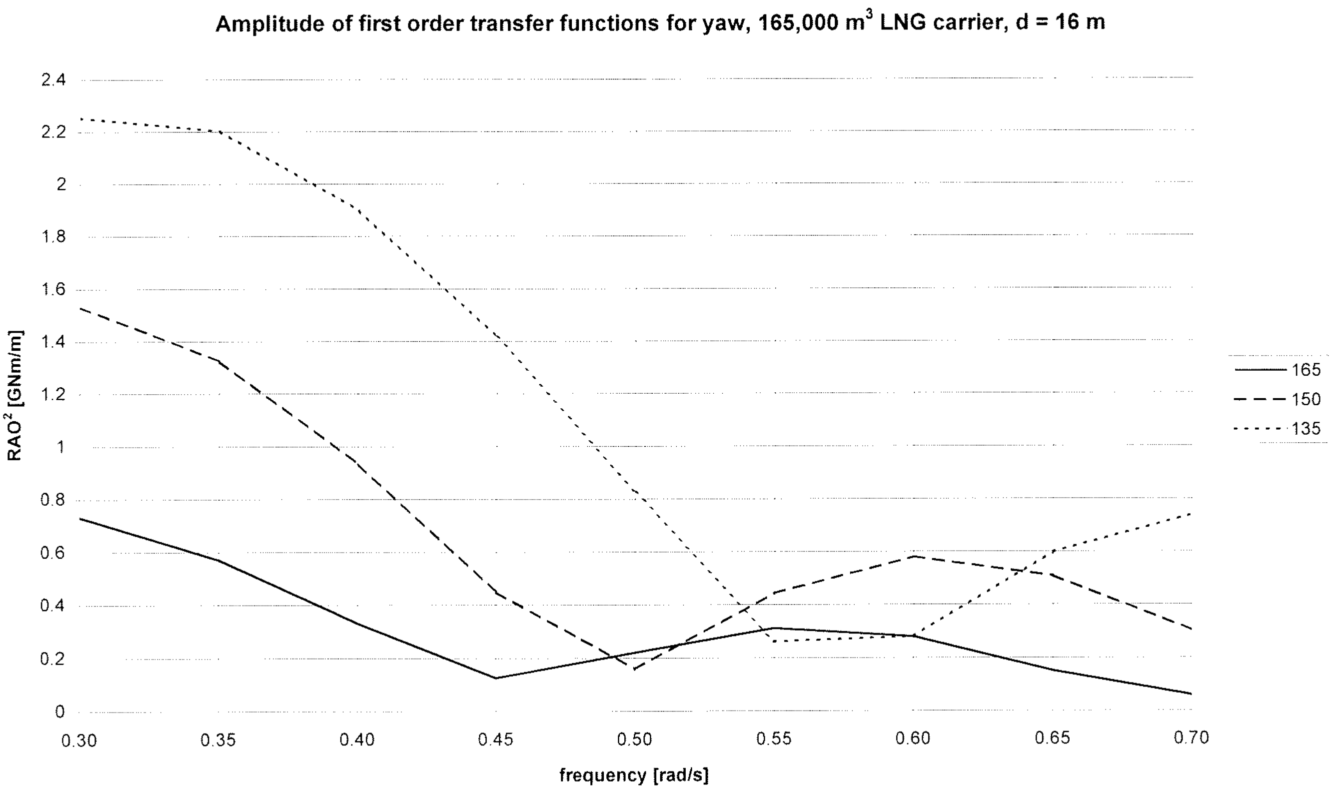


Appendix E

Characteristics of Northwest LNG Carriers

Table 1:	Ship dimensions
Table 2:	Fairlead positions

Drawing Northwest Sandpiper

Table 1: Ship dimensions

	Symbol	Unit	
Cargo capacity	C	m^3	125,000
Dead weight tonnage	DWT	tons	64,088
Displacement laden	Δ	tons	93,240
Displacement ballast	Δ	tons	76,636
Length over all	LOA	m	272
Length between perpendiculars	L_{pp}	m	259
Beam	B	m	47.20
Depth	H	m	26.50
Draft laden	T	m	10.95
Draft ballast	T	m	9.00
Block coefficient	C_B	-	0.680
Manifold distance to fore perp	FP-mf	m	119.04

Table 2: Fairlead positions

Forward

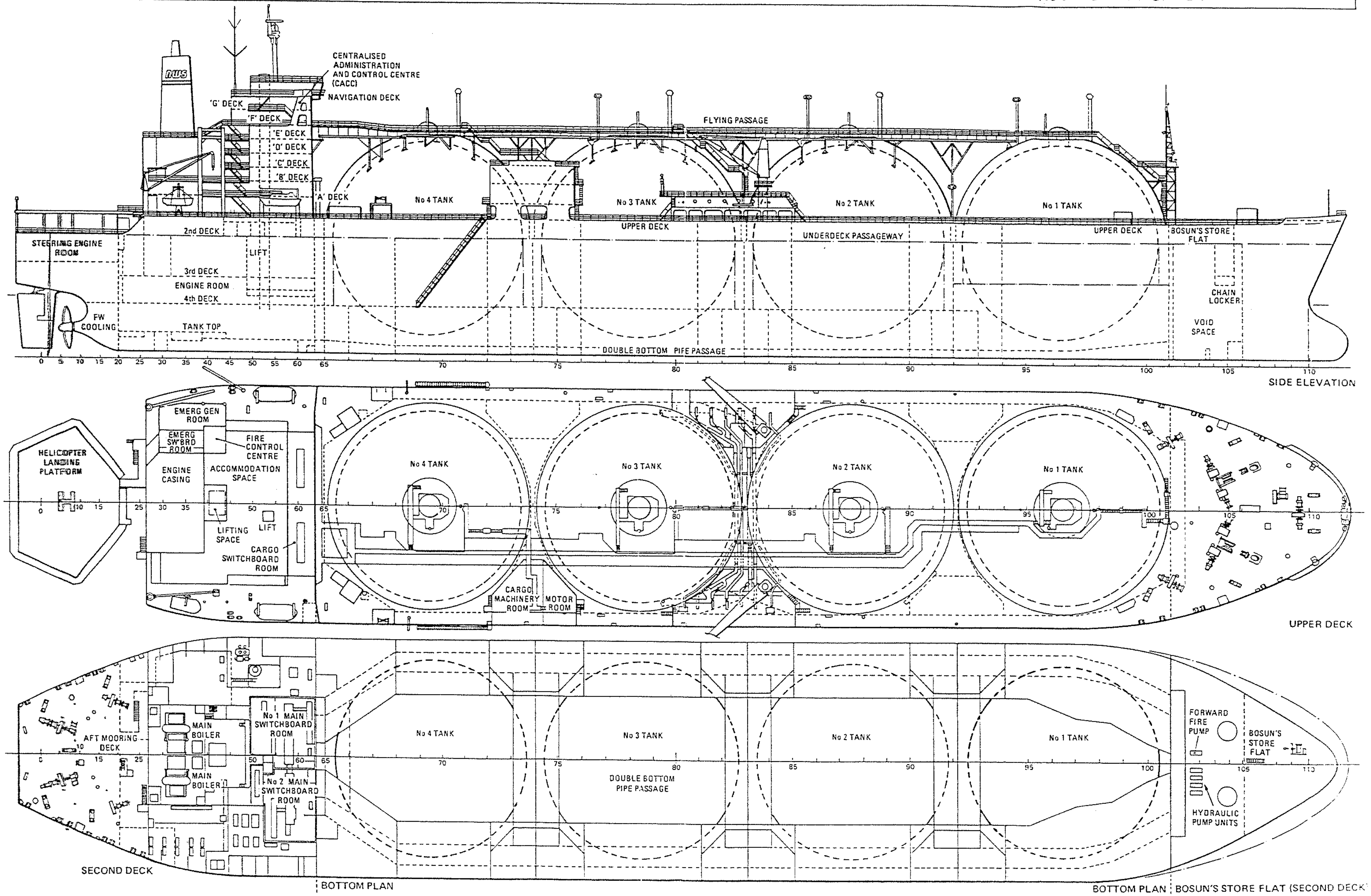
Mooring line N°	1	2	3	4	5	6	7	8
Midship to fairlead [m]	136	136	130	120	107.5	106	99.5	95.5
Centreline to fairlead [m]	-1.6	1.6	9.5	14.5	19.5	19.7	21.5	22.5
upper deck to fairlead [m]	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9

Aft

Mooring line N°	9	10	11	12	13	14	15	16
Midship to fairlead [m]	-109	-111	-117	-119.5	-124	-126	-132.5	-135
Centreline to fairlead [m]	19.5	19	17	16.5	14	13	10	9.5
upper deck to fairlead [m]	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7

A1.6 SHIP'S GENERAL ARRANGEMENT (1)

NORTHWEST SANDPIPER



Appendix F

Results of Statistical Analysis of Line Force Measurements

Measurements

date: 9-10-96
time: 1:00 - 4:20
jetty: LNG jetty Withnell Bay
ship: Northwest

wave spectrum: 1
sign. wave height swell: 0.08 m.
wave direction (swell): 195 deg
wind speed: 6.9 m/s

parameter	unit	overall mean	averages per 10 min. mean	averages per 10 min. st. dev.	minima per 10 min. mean	minima per 10 min. st. dev.	maxima per 10 min. mean	maxima per 10 min. st. dev.	max. per 3 hrs. mean
mooring leg 1	ton	8.63	0.00	0.05	-1.16	0.28	1.31	0.31	1.92
mooring leg 2	ton	9.48	0.00	0.04	-1.14	0.28	1.22	0.30	1.80
mooring leg 3	ton	9.12	0.00	0.03	-1.47	0.35	1.62	0.36	2.33
mooring leg 4	ton	12.34	0.00	0.05	-1.63	0.39	1.68	0.34	2.35
mooring leg 5	ton	10.68	0.00	0.04	-1.53	0.33	1.71	0.36	2.39
mooring leg 6	ton	15.58	0.00	0.08	-0.52	0.11	0.58	0.17	0.97
mooring leg 7	ton	12.16	0.00	0.07	-0.40	0.10	0.44	0.12	0.71
mooring leg 8	ton	10.88	0.00	0.07	-0.30	0.09	0.34	0.11	0.58
mooring leg 9	ton	17.81	0.00	0.07	-0.45	0.09	0.47	0.13	0.76
mooring leg 10	ton	17.25	0.00	0.06	-0.48	0.10	0.55	0.14	0.86
mooring leg 11	ton	11.13	0.00	0.06	-0.34	0.11	0.40	0.10	0.62
mooring leg 12	ton	12.76	0.00	0.04	-1.30	0.20	1.37	0.21	1.79
mooring leg 13	ton	9.41	0.00	0.04	-1.25	0.22	1.35	0.23	1.80
mooring leg 14	ton	11.63	0.00	0.04	-1.41	0.28	1.32	0.22	1.75
mooring leg 15	ton	12.80	0.00	0.05	-1.10	0.21	1.20	0.29	1.82
mooring leg 16	ton	10.45	0.00	0.06	-0.75	0.17	0.80	0.15	1.08

Measurements

date: 1-12-96
time: 23:40 - 1:50
jetty: LNG jetty Whitnell Bay
ship: Northwest

wave spectrum: 2
sign. wave height swell: 0.12 m.
wave direction (swell): 192 deg
wind speed: 11.6 m/s

parameter	unit	averages per 10 min. mean	averages per 10 min. st. dev.	minima per 10 min. mean	minima per 10 min. st. dev.	maxima per 10 min. mean	maxima per 10 min. st. dev.	max per 3 h
mooring leg 1	ton	17.15	0.98	-3.62	0.59	3.87	0.88	5.46
mooring leg 2	ton	19.06	1.32	-4.00	0.66	4.11	0.91	5.75
mooring leg 3	ton	17.78	1.21	-4.65	0.68	4.93	0.93	6.67
mooring leg 4	ton	17.38	1.73	-3.86	0.59	3.87	0.69	5.19
mooring leg 5	ton	16.51	1.27	-3.43	0.54	3.59	0.58	4.73
mooring leg 6	ton	20.73	2.31	-1.68	0.28	1.85	0.51	3.01
mooring leg 7	ton	11.90	6.31	-1.38	0.20	1.71	0.41	2.64
mooring leg 8	ton	17.73	1.59	-1.31	0.20	1.48	0.41	2.41
mooring leg 9	ton	16.27	1.40	-1.43	0.31	1.31	0.18	1.73
mooring leg 10	ton	16.95	1.75	-1.82	0.38	1.75	0.26	2.34
mooring leg 11	ton	13.59	1.46	-1.60	0.33	1.54	0.21	2.01
mooring leg 12	ton	19.07	1.70	-4.60	0.66	4.36	0.75	5.81
mooring leg 13	ton	13.39	1.07	-4.28	0.59	5.02	0.93	6.81
mooring leg 14	ton	14.84	1.17	-4.73	0.62	4.86	0.80	6.43
mooring leg 15	ton	13.48	0.52	-3.13	0.45	3.57	0.60	4.76
mooring leg 16	ton	10.54	0.29	-1.96	0.29	1.98	0.32	2.61

Measurements

date: 15-07-96
time: 17:20 - 19:40
jetty: LNG jetty Whitnell Bay
ship: Northwest

wave spectrum: 3a
sign. wave height swell: 0.19 m.
wave direction (swell): 193 deg
wind speed: 6.1 m/s

parameter	unit	averages per 10 min. mean	averages per 10 min. st. dev.	minima per 10 min. mean	minima per 10 min. st. dev.	maxima per 10 min. mean	maxima per 10 min. st. dev.	max per 3 h
mooring leg 1	ton	15.68	0.94	-3.79	0.57	4.20	0.63	5.46
mooring leg 2	ton	14.35	1.10	-3.64	0.54	4.00	0.59	5.17
mooring leg 3	ton	15.90	1.45	-5.06	0.69	5.58	0.77	7.15
mooring leg 4	ton	11.35	1.69	-3.74	0.57	4.17	0.61	5.41
mooring leg 5	ton	11.27	1.51	-3.05	0.48	3.60	0.63	4.85
mooring leg 6	ton	12.75	2.19	-1.89	0.48	1.70	0.31	2.39
mooring leg 7	ton	12.14	3.93	-1.90	0.50	1.89	0.47	2.96
mooring leg 8	ton	9.31	1.31	-1.02	0.24	0.99	0.26	1.58
mooring leg 9	ton	14.26	2.24	-1.15	0.21	1.52	0.41	2.45
mooring leg 10	ton	24.39	3.73	-1.95	0.27	2.47	0.55	3.71
mooring leg 11	ton	17.40	2.49	-1.65	0.31	1.99	0.48	3.07
mooring leg 12	ton	13.43	1.67	-3.56	0.53	3.77	0.79	5.33
mooring leg 13	ton	10.21	1.45	-3.65	0.55	4.28	0.86	5.95
mooring leg 14	ton	18.26	1.49	-4.24	0.65	4.33	0.83	5.93
mooring leg 15	ton	13.79	0.62	-2.77	0.41	3.04	0.53	4.07
mooring leg 16	ton	15.52	0.58	-2.69	0.43	2.83	0.49	3.79

Measurements

date: 15-07-96
time: 19:50 - 21:30
jetty: LNG jetty Whitnell Bay
ship: Northwest

wave spectrum: 4b
sign. wave height total: 1.21 m.
sign. wave height swell: 0.22 m.
wind speed: 5.7 m/s

parameter	dim.	averages per 10 min. mean	averages per 10 min. st. dev.	minima per 10 min. mean	minima per 10 min. st. dev.	maxima per 10 min. mean	maxima per 10 min. st. dev.	max per 3 h
mooring leg 1	ton	20.16	0.38	-4.07	0.68	4.28	0.50	5.30
mooring leg 2	ton	19.65	1.34	-4.07	0.72	4.20	0.53	5.27
mooring leg 3	ton	22.51	2.30	-5.62	0.89	5.75	0.73	7.25
mooring leg 4	ton	17.94	1.42	-4.56	0.70	4.66	0.63	5.95
mooring leg 5	ton	17.41	2.27	-3.90	0.64	3.90	0.52	5.00
mooring leg 6	ton	19.69	2.51	-2.24	0.45	2.23	0.42	3.18
mooring leg 7	ton	24.83	3.38	-2.65	0.57	2.57	0.46	3.60
mooring leg 8	ton	12.34	1.16	-1.42	0.35	1.40	0.23	1.91
mooring leg 9	ton	22.57	3.74	-1.61	0.23	1.98	0.46	3.02
mooring leg 10	ton	27.71	1.79	-3.19	1.06	2.90	0.49	4.00
mooring leg 11	ton	27.92	4.09	-1.99	0.27	2.34	0.36	3.16
mooring leg 12	ton	21.15	1.11	-4.78	1.55	4.22	0.61	5.43
mooring leg 13	ton	17.72	1.37	-4.63	0.69	4.82	0.70	6.16
mooring leg 14	ton	19.59	2.43	-4.43	0.72	4.60	0.62	5.83
mooring leg 15	ton	16.05	0.52	-3.15	0.37	3.21	0.43	4.01
mooring leg 16	ton	17.65	0.46	-2.86	0.34	2.84	0.39	3.55

Measurements

date: 21-07-96
time: 17:40 - 19:30
jetty: LNG jetty Whitnell Bay
ship: Northwest

wave spectrum: 4a
sign. wave height total: 0.25 m.
sign. wave height swell: 0.24 m.
wind speed: -

parameter	unit	averages per 10 min.		minima per 10 min.		maxima per 10 min.		max per 3 h
		mean	st. dev.	mean	st. dev.	mean	st. dev.	
mooring leg 1	ton	15.34	0.89	-5.13	1.12	5.50	1.82	9.22
mooring leg 2	ton	13.97	0.97	-4.99	1.08	5.32	1.79	9.00
mooring leg 3	ton	20.11	3.09	-6.24	0.80	6.15	1.42	9.29
mooring leg 4	ton	20.97	3.04	-6.74	1.31	6.05	1.83	10.10
mooring leg 5	ton	22.20	4.73	-4.93	0.67	4.98	0.74	6.52
mooring leg 6	ton	13.38	7.55	-3.70	2.63	4.08	2.56	9.86
mooring leg 7	ton	6.09	1.77	-1.96	1.05	3.06	1.87	7.28
mooring leg 8	ton	10.57	1.46	-2.63	1.30	3.09	1.57	6.63
mooring leg 9	ton	21.66	1.91	-3.30	1.88	3.36	1.71	7.20
mooring leg 10	ton	16.81	2.39	-3.87	2.08	4.14	2.01	8.68
mooring leg 11	ton	11.59	1.32	-2.50	1.23	2.87	1.38	5.99
mooring leg 12	ton	16.63	1.42	-5.79	0.97	5.58	1.43	8.56
mooring leg 13	ton	14.23	2.52	-6.44	1.26	6.76	2.07	10.90
mooring leg 14	ton	20.65	2.91	-7.86	2.03	7.03	2.34	11.63
mooring leg 15	ton	22.79	3.10	-6.41	2.09	6.21	2.20	10.41
mooring leg 16	ton	15.93	2.30	-5.05	1.28	4.86	1.71	8.14

Measurements

date: 22-07-96
time: 7:50 - 10:50
jetty: LNG jetty Whitnell Bay
ship: Northwest

wave spectrum: 4b
sign. wave height swell: 0.27 m.
wave direction: 189 deg
wind speed: -

parameter	unit	averages per 10 min.		minima per 10 min.		maxima per 10 min.		max per 3 h
		mean	st. dev.	mean	st. dev.	mean	st. dev.	
mooring leg 1	ton	11.58	0.95	-5.65	0.99	7.86	1.78	11.42
mooring leg 2	ton	8.32	0.93	-4.35	0.87	7.08	1.75	10.61
mooring leg 3	ton	8.88	0.77	-4.95	0.72	8.65	1.73	12.20
mooring leg 4	ton	6.40	1.11	-3.58	1.00	7.12	1.86	10.98
mooring leg 5	ton	9.34	0.83	-4.23	0.69	6.91	1.23	9.46
mooring leg 6	ton	4.51	1.12	-1.61	0.45	2.50	0.44	3.50
mooring leg 7	ton	2.07	0.29	-0.23	0.10	0.35	0.14	0.66
mooring leg 8	ton	11.29	1.30	-2.52	0.65	2.82	0.42	3.76
mooring leg 9	ton	13.73	1.02	-2.69	0.67	3.02	0.82	4.86
mooring leg 10	ton	5.93	1.10	-1.95	0.53	2.76	0.83	4.62
mooring leg 11	ton	12.92	0.92	-2.87	0.75	3.13	0.76	4.84
mooring leg 12	ton	5.99	0.53	-3.41	0.50	7.94	2.60	13.31
mooring leg 13	ton	11.81	0.92	-8.99	1.43	12.49	3.35	19.17
mooring leg 14	ton	10.65	0.69	-7.03	0.88	12.19	3.49	19.28
mooring leg 15	ton	14.13	0.43	-7.68	1.40	9.56	2.52	14.57
mooring leg 16	ton	13.41	0.38	-6.67	1.18	7.86	2.01	11.85

Measurements

date: 28-07-96
time: 7:00 - 10:00
jetty: LNG jetty Whitnell Bay
ship: Northwest

wave spectrum: 5
sign. wave height swell: 0.24 m.
wave direction 188 deg
wind speed: 2 m/s

parameter	unit	averages per 10 min.		minima per 10 min.		maxima per 10 min.		max per 3 h
		mean	st. dev.	mean	st. dev.	mean	st. dev.	
mooring leg 1	ton	19.50	0.85	-5.40	1.03	5.45	0.79	7.01
mooring leg 2	ton	16.75	0.86	-5.12	0.89	5.32	0.77	6.86
mooring leg 3	ton	18.76	1.31	-6.60	1.03	6.94	1.15	9.26
mooring leg 4	ton	19.95	1.57	-5.92	1.06	5.91	0.99	7.90
mooring leg 5	ton	17.63	1.40	-5.31	0.85	5.81	1.09	7.95
mooring leg 6	ton	18.85	1.48	-2.47	0.79	2.83	1.27	5.70
mooring leg 7	ton	22.59	2.26	-2.78	0.78	2.90	0.90	4.92
mooring leg 8	ton	16.39	1.02	-1.95	0.56	2.12	0.83	4.00
mooring leg 9	ton	19.20	0.76	-2.13	0.64	2.24	0.51	3.38
mooring leg 10	ton	21.31	2.18	-2.62	0.68	2.89	0.49	4.00
mooring leg 11	ton	18.86	1.45	-2.23	0.53	2.51	0.41	3.43
mooring leg 12	ton	21.41	1.22	-8.01	1.33	7.22	0.71	8.69
mooring leg 13	ton	10.85	1.16	-6.96	0.97	8.06	1.21	10.53
mooring leg 14	ton	16.35	1.10	-7.48	1.27	7.03	1.05	9.19
mooring leg 15	ton	11.12	1.26	-4.27	0.63	4.89	1.08	7.15
mooring leg 16	ton	11.50	1.60	-4.39	0.67	4.41	0.86	6.14

Measurements

date: 2-08-96
time: 23:50 (1-8) - 2:10 (2-8)
jetty: LNG jetty Whitnell Bay
ship: Northwest

wave spectrum: 6a
sign. wave height swell: 0.31 m.
wave direction: 192 deg
wind speed: 5.6 m/s

parameter	unit	averages per 10 min. mean	averages per 10 min. st. dev.	minima per 10 min. mean	minima per 10 min. st. dev.	maxima per 10 min. mean	maxima per 10 min. st. dev.	max per 3 h
mooring leg 1	ton	19.46	0.34	-8.35	1.34	9.25	1.78	12.49
mooring leg 2	ton	18.40	0.39	-8.36	1.27	9.05	1.76	12.23
mooring leg 3	ton	22.59	0.68	-11.17	1.83	12.06	2.29	16.12
mooring leg 4	ton	14.47	0.72	-7.62	1.00	9.50	1.80	12.77
mooring leg 5	ton	25.79	1.20	-9.78	1.51	10.55	1.64	13.70
mooring leg 6	ton	10.60	2.33	-4.87	1.32	6.43	1.82	10.52
mooring leg 7	ton	22.09	4.67	-7.23	2.17	8.04	2.41	13.46
mooring leg 8	ton	20.62	2.87	-5.62	1.78	6.07	1.96	10.49
mooring leg 9	ton	17.74	2.36	-5.15	1.54	5.26	1.37	8.34
mooring leg 10	ton	18.64	4.55	-6.77	1.99	7.10	1.79	11.13
mooring leg 11	ton	22.48	3.47	-6.55	1.68	6.74	1.57	10.29
mooring leg 12	ton	14.49	0.93	-9.75	1.61	13.57	3.44	20.03
mooring leg 13	ton	11.60	0.88	-10.19	1.45	15.86	3.60	22.67
mooring leg 14	ton	15.82	0.91	-11.45	1.63	15.30	3.48	21.90
mooring leg 15	ton	18.78	0.55	-10.56	1.93	11.96	2.60	16.86
mooring leg 16	ton	18.18	0.41	-9.34	1.68	9.40	1.92	13.03

TERMSIM simulation

No.: 4e-1
date: 2-8-1996
jetty: LNG jetty Withnell Bay
ship: Northwest

wave spectrum: 6b
sign. wave height swell: 0.31 m.
wave direction: 172 & 198 deg
wind speed: 7.4 m/s

parameter	unit	pretens.	st. dev.	averages per 10 min. mean	averages per 10 min. st. dev.	minima per 10 min. mean	minima per 10 min. st. dev.	maxima per 10 min. mean	maxima per 10 min. st. dev.	max per 3 h
surge	m		0.019	-0.004	0.004	-0.059	0.013	0.055	0.013	
sway	m		0.020	0.052	0.001	-0.072	0.017	0.059	0.012	
heave	m		0.019	0.005	0.000	-0.051	0.008	0.048	0.004	
roll	deg		0.203	-0.376	0.002	-0.571	0.116	0.570	0.120	
pitch	deg		0.041	0.000	0.000	-0.106	0.013	0.104	0.013	
yaw	deg		0.041	0.020	0.000	-0.123	0.027	0.129	0.028	
mooring leg 1	ton	21	3.48	15.11	0.06	-9.97	1.82	10.03	1.92	14.00
mooring leg 2	ton	19	3.43	12.89	0.07	-9.65	1.61	9.87	1.85	13.71
mooring leg 3	ton	21	4.16	14.44	0.02	-11.40	1.45	12.26	2.51	17.45
mooring leg 4	ton	18	3.63	10.96	0.04	-9.44	1.07	10.66	2.00	14.83
mooring leg 5	ton	22	3.76	14.85	0.07	-10.43	1.53	11.14	2.38	16.03
mooring leg 6	ton	8	1.56	6.30	0.20	-4.43	0.60	4.66	1.09	7.12
mooring leg 7	ton	23	1.66	21.86	0.21	-5.07	1.04	5.03	1.21	7.75
mooring leg 8	ton	17	1.25	16.36	0.18	-3.93	0.86	3.68	0.85	5.59
mooring leg 9	ton	13	1.29	13.29	0.17	-3.71	0.85	4.11	0.94	6.24
mooring leg 10	ton	19	1.80	19.77	0.21	-5.16	1.13	5.81	1.34	8.83
mooring leg 11	ton	14	1.73	14.23	0.19	-5.02	1.09	5.49	1.25	8.31
mooring leg 12	ton	17	4.37	13.58	0.10	-11.46	1.42	14.17	3.00	20.11
mooring leg 13	ton	14	4.02	11.35	0.10	-10.04	0.91	13.00	2.68	18.53
mooring leg 14	ton	20	4.21	16.67	0.09	-11.77	2.01	13.85	2.93	19.87
mooring leg 15	ton	13	3.07	10.73	0.12	-8.37	1.20	9.75	2.07	14.12
mooring leg 16	ton	11	3.16	8.68	0.12	-7.83	0.92	10.23	2.15	14.74
fender 1	ton		18.90	20.34	0.49	-20.34	0.49	63.32	13.30	
fender 2	ton		14.16	22.57	0.36	-22.57	0.36	45.10	9.50	
fender 3	ton		10.87	25.43	0.42	-25.43	0.42	34.23	6.19	
fender 4	ton		10.46	28.90	0.41	-28.71	0.45	29.14	4.67	
fender 5	ton		13.90	32.48	0.36	-32.48	0.36	36.07	5.84	
fender 6	ton		20.62	37.52	0.29	-37.52	0.29	54.16	7.15	

Measurements

date: 19-07-96
time: 7:10 - 10:30
jetty: LNG jetty Whitnell Bay
ship: Northwest

wave spectrum: 7
sign. wave height swell: 0.30 m.
wave direction: 189 deg
wind speed: 4 m/s

parameter	unit	averages per 10 min. mean	averages per 10 min. st. dev.	minima per 10 min. mean	minima per 10 min. st. dev.	maxima per 10 min. mean	maxima per 10 min. st. dev.	max per 3 h
mooring leg 1	ton	13.12	0.86	-7.03	0.89	9.61	2.00	13.42
mooring leg 2	ton	9.49	0.68	-5.09	0.65	8.00	1.76	11.35
mooring leg 3	ton	16.47	1.05	-10.19	1.27	12.60	2.45	17.28
mooring leg 4	ton	14.29	1.32	-8.18	1.24	10.13	2.07	14.05
mooring leg 5	ton	10.10	1.21	-7.40	1.18	9.68	1.98	13.36
mooring leg 6	ton	11.11	2.63	-3.87	0.88	4.37	1.15	6.95
mooring leg 7	ton	10.78	4.05	-3.83	1.12	4.76	1.40	7.91
mooring leg 8	ton	12.74	2.13	-3.54	0.75	3.78	0.89	5.78
mooring leg 9	ton	12.87	2.07	-2.97	0.56	3.24	0.81	5.07
mooring leg 10	ton	11.81	3.99	-3.77	0.80	4.28	1.12	6.80
mooring leg 11	ton	14.32	2.77	-3.55	0.64	3.71	0.94	5.82
mooring leg 12	ton	8.13	0.98	-6.42	0.67	10.00	1.52	13.13
mooring leg 13	ton	8.81	0.84	-7.78	0.73	12.72	1.93	16.57
mooring leg 14	ton	10.75	0.80	-7.28	0.66	11.77	1.88	15.52
mooring leg 15	ton	11.18	0.32	-5.44	0.52	8.47	1.40	11.21
mooring leg 16	ton	13.93	0.35	-7.17	0.76	8.24	1.25	10.71

Appendix G

Results of Statistical Analysis of Simulation Output

TERMSIM simulation

No.: 1
date: 9-10-1996
jetty: LNG jetty Withnell Bay
ship: Northwest

wave spectrum: 1
sign. wave height swell: 0.08 m.
wave direction (swell): 195 deg
wind speed: 6.9 m/s

parameter	unit	pretens.	overall mean	overall st. dev.	averages per 10 min. mean	averages per 10 min. st. dev.	minima per 10 min. mean	minima per 10 min. st. dev.	maxima per 10 min. mean	maxima per 10 min. st. dev.	max. per 3 hrs. mean
surge	m		0.000	0.002	0.000	0.001	-0.005	0.002	0.006	0.001	
sway	m		0.053	0.004	0.000	0.001	-0.010	0.002	0.011	0.001	
heave	m		0.004	0.004	0.000	0.000	-0.012	0.001	0.011	0.001	
roll	deg		-0.229	0.014	0.000	0.001	-0.038	0.006	0.037	0.007	
pitch	deg		-0.002	0.007	0.000	0.000	-0.019	0.003	0.019	0.003	
yaw	deg		0.002	0.006	0.000	0.000	-0.017	0.003	0.016	0.003	
mooring leg 1	ton	12	8.93	0.52	0.00	0.02	-1.41	0.30	1.37	0.28	1.95
mooring leg 2	ton	12	8.93	0.51	0.00	0.02	-1.40	0.29	1.36	0.28	1.93
mooring leg 3	ton	15	10.90	0.60	0.00	0.02	-1.67	0.33	1.62	0.33	2.28
mooring leg 4	ton	16	11.48	0.54	0.00	0.02	-1.50	0.29	1.44	0.30	2.03
mooring leg 5	ton	15	10.31	0.53	0.00	0.03	-1.49	0.27	1.43	0.29	2.00
mooring leg 6	ton	18	16.86	0.17	0.00	0.04	-0.47	0.10	0.49	0.06	0.63
mooring leg 7	ton	15	13.97	0.18	0.00	0.04	-0.48	0.10	0.50	0.07	0.65
mooring leg 8	ton	12	11.43	0.13	0.00	0.03	-0.36	0.07	0.38	0.05	0.49
mooring leg 9	ton	20	18.92	0.16	0.00	0.03	-0.45	0.06	0.41	0.09	0.61
mooring leg 10	ton	20	18.36	0.22	0.00	0.04	-0.63	0.09	0.59	0.13	0.89
mooring leg 11	ton	12	11.17	0.22	0.00	0.04	-0.63	0.09	0.58	0.13	0.88
mooring leg 12	ton	17	13.35	0.67	0.00	0.06	-1.88	0.33	1.79	0.37	2.49
mooring leg 13	ton	13	9.85	0.63	0.00	0.06	-1.77	0.30	1.68	0.31	2.33
mooring leg 14	ton	13	10.12	0.65	0.00	0.06	-1.82	0.31	1.73	0.33	2.40
mooring leg 15	ton	16	13.82	0.48	0.00	0.04	-1.35	0.23	1.28	0.23	1.77
mooring leg 16	ton	14	11.22	0.51	0.00	0.05	-1.42	0.24	1.35	0.24	1.86
fender 1	ton		13.52	23.93	0.00	0.24	-6.40	1.15	6.87	0.94	
fender 2	ton		13.83	16.53	0.00	0.22	-4.31	0.74	4.76	0.60	
fender 3	ton		14.03	12.16	0.00	0.20	-3.14	0.62	3.56	0.44	
fender 4	ton		14.23	9.05	0.00	0.18	-2.44	0.50	2.67	0.33	
fender 5	ton		14.43	8.70	0.00	0.16	-2.43	0.56	2.57	0.41	
fender 6	ton		14.73	13.33	0.00	0.14	-3.54	0.63	3.96	0.49	

TERMSIM simulation

No.: 2a
date: 1-12-1996
jetty: LNG jetty Withnell Bay
ship: Northwest

wave spectrum: -
sign. wave height swell: -
wave direction (swell): -
wind speed: 11.6 m/s, Harris

parameter	unit	pretens.	st. dev.	averages per 10 min. mean	averages per 10 min. st. dev.	minima per 10 min. mean	minima per 10 min. st. dev.	maxima per 10 min. mean	maxima per 10 min. st. dev.	max per 3 h
surge	m		0.000	-0.005	0.000	0.000	0.000	0.000	0.000	
sway	m		0.006	0.032	0.001	-0.018	0.003	0.013	0.002	
heave	m		0.000	0.005	0.000	0.000	0.000	0.000	0.000	
roll	deg		0.057	-0.323	0.004	-0.141	0.023	0.146	0.031	
pitch	deg		0.000	-0.003	0.000	0.000	0.000	0.000	0.000	
yaw	deg		0.003	0.030	0.000	-0.006	0.001	0.008	0.001	
mooring leg 1	ton	24	0.22	18.16	0.03	-0.61	0.08	0.57	0.09	0.75
mooring leg 2	ton	26	0.23	20.97	0.03	-0.63	0.09	0.59	0.10	0.78
mooring leg 3	ton	24	0.29	17.39	0.04	-0.79	0.11	0.74	0.12	0.99
mooring leg 4	ton	23	0.30	16.77	0.04	-0.80	0.10	0.78	0.12	1.03
mooring leg 5	ton	23	0.32	16.57	0.05	-0.85	0.11	0.84	0.13	1.10
mooring leg 6	ton	22	0.05	20.79	0.01	-0.14	0.03	0.13	0.02	0.17
mooring leg 7	ton	14	0.05	13.14	0.01	-0.14	0.03	0.13	0.02	0.17
mooring leg 8	ton	20	0.03	18.94	0.00	-0.09	0.01	0.09	0.01	0.11
mooring leg 9	ton	17	0.10	17.18	0.01	-0.22	0.04	0.30	0.05	0.41
mooring leg 10	ton	18	0.16	18.74	0.02	-0.37	0.06	0.49	0.09	0.68
mooring leg 11	ton	14	0.16	14.98	0.02	-0.37	0.06	0.48	0.08	0.67
mooring leg 12	ton	21	0.59	20.83	0.08	-1.32	0.22	1.81	0.32	2.45
mooring leg 13	ton	17	0.55	16.92	0.08	-1.24	0.21	1.68	0.29	2.27
mooring leg 14	ton	17	0.56	17.20	0.08	-1.27	0.21	1.72	0.30	2.32
mooring leg 15	ton	15	0.40	14.94	0.06	-0.92	0.15	1.23	0.21	1.66
mooring leg 16	ton	11	0.42	11.14	0.06	-0.96	0.16	1.28	0.22	1.73
fender 1	ton		1.58	1.08	0.26	-1.08	0.26	5.90	0.94	
fender 2	ton		3.13	7.61	0.51	-7.59	0.49	7.02	0.90	
fender 3	ton		3.04	13.08	0.49	-9.88	1.60	6.79	1.00	
fender 4	ton		2.89	18.59	0.44	-9.19	1.43	6.73	1.07	
fender 5	ton		2.82	24.10	0.39	-8.66	1.19	6.77	1.15	
fender 6	ton		2.86	32.36	0.32	-8.34	1.02	7.13	1.21	

TERMSIM simulation

No.: 2b
date: 1-12-1996
jetty: LNG jetty Whitnell Bay
ship: Northwest

wave spectrum: -
sign. wave height swell: -
wave direction (swell): -
wind speed: 11.6 m/s, API

parameter	unit	pretens.	st. dev.	averages per 10 min.		minima per 10 min.		maxima per 10 min.		max per 3 h
				mean	st. dev.	mean	st. dev.	mean	st. dev.	
surge	m		0.000	-0.007	0.000	-0.001	0.000	0.001	0.000	
sway	m		0.016	0.060	0.002	-0.050	0.012	0.038	0.005	
heave	m		0.000	0.006	0.000	0.000	0.000	0.001	0.000	
roll	deg		0.041	-0.274	0.002	-0.103	0.020	0.106	0.028	
pitch	deg		0.000	0.000	0.000	-0.001	0.000	0.001	0.000	
yaw	deg		0.004	0.043	0.000	-0.010	0.001	0.011	0.003	
mooring leg 1	ton	24	0.58	17.91	0.07	-1.48	0.15	1.50	0.23	1.91
mooring leg 2	ton	26	0.58	19.34	0.07	-1.48	0.15	1.50	0.24	1.92
mooring leg 3	ton	24	0.74	16.31	0.09	-1.87	0.19	1.90	0.30	2.42
mooring leg 4	ton	23	0.73	15.79	0.09	-1.80	0.18	1.90	0.33	2.48
mooring leg 5	ton	23	0.77	15.48	0.10	-1.89	0.19	2.02	0.36	2.64
mooring leg 6	ton	22	0.14	19.41	0.01	-0.37	0.05	0.35	0.05	0.46
mooring leg 7	ton	14	0.13	12.15	0.01	-0.36	0.05	0.34	0.04	0.44
mooring leg 8	ton	20	0.08	17.29	0.01	-0.23	0.02	0.21	0.03	0.27
mooring leg 9	ton	17	0.14	16.67	0.02	-0.35	0.06	0.45	0.14	0.77
mooring leg 10	ton	18	0.24	18.25	0.04	-0.58	0.11	0.77	0.24	1.32
mooring leg 11	ton	14	0.24	14.46	0.04	-0.59	0.11	0.78	0.24	1.32
mooring leg 12	ton	21	1.03	20.58	0.16	-2.46	0.46	3.32	0.99	5.03
mooring leg 13	ton	17	0.97	16.89	0.15	-2.34	0.44	3.10	0.91	4.68
mooring leg 14	ton	17	0.99	16.98	0.15	-2.38	0.45	3.15	0.92	4.76
mooring leg 15	ton	15	0.71	15.11	0.11	-1.72	0.33	2.25	0.65	3.39
mooring leg 16	ton	11	0.74	12.53	0.11	-1.78	0.34	2.33	0.68	3.50
fender 1	ton		3.39	3.87	0.48	-3.87	0.48	10.60	1.82	
fender 2	ton		4.22	9.17	0.61	-9.17	0.61	10.60	1.51	
fender 3	ton		4.26	13.10	0.62	-12.19	0.60	10.26	1.36	
fender 4	ton		4.18	17.08	0.61	-12.60	1.98	9.64	0.99	
fender 5	ton		4.01	21.04	0.58	-12.40	2.75	8.31	0.84	
fender 6	ton		3.35	26.50	0.47	-10.97	2.32	6.82	0.88	

TERMSIM simulation

No.: 2c
date: 1-12-1996
jetty: LNG jetty Whitnell Bay
ship: Northwest

wave spectrum: 2
sign. wave height swell: 0.12 m.
wave direction (swell): 192 deg
wind speed: -

parameter	unit	pretens.	st. dev.	averages per 10 min. mean	averages per 10 min. st. dev.	minima per 10 min. mean	minima per 10 min. st. dev.	maxima per 10 min. mean	maxima per 10 min. st. dev.	max per 3 h
surge	m		0.006	-0.005	0.002	-0.019	0.004	0.019	0.004	
sway	m		0.009	0.095	0.000	-0.025	0.005	0.026	0.005	
heave	m		0.007	0.005	0.000	-0.020	0.004	0.019	0.003	
roll	deg		0.033	-0.295	0.000	-0.090	0.021	0.091	0.021	
pitch	deg		0.015	0.000	0.000	-0.041	0.005	0.043	0.006	
yaw	deg		0.014	0.037	0.000	-0.037	0.005	0.037	0.005	
mooring leg 1	ton	24	1.19	15.43	0.03	-3.16	0.52	3.04	0.50	4.09
mooring leg 2	ton	26	1.18	18.23	0.03	-3.14	0.52	3.04	0.51	4.10
mooring leg 3	ton	24	1.40	13.97	0.01	-3.65	0.65	3.63	0.59	4.80
mooring leg 4	ton	23	1.25	13.48	0.01	-3.29	0.57	3.21	0.53	4.27
mooring leg 5	ton	23	1.24	13.12	0.03	-3.22	0.58	3.25	0.54	4.34
mooring leg 6	ton	22	0.48	19.39	0.09	-1.41	0.24	1.40	0.29	2.06
mooring leg 7	ton	14	0.49	12.05	0.10	-1.45	0.25	1.44	0.30	2.12
mooring leg 8	ton	20	0.38	17.97	0.08	-1.15	0.20	1.12	0.25	1.68
mooring leg 9	ton	17	0.40	16.57	0.08	-1.18	0.26	1.22	0.22	1.71
mooring leg 10	ton	18	0.55	18.02	0.09	-1.61	0.31	1.65	0.28	2.29
mooring leg 11	ton	14	0.54	14.22	0.09	-1.58	0.30	1.59	0.27	2.20
mooring leg 12	ton	21	1.49	18.40	0.04	-4.13	0.51	4.09	0.57	5.27
mooring leg 13	ton	17	1.39	14.47	0.02	-3.82	0.57	3.78	0.46	4.83
mooring leg 14	ton	17	1.44	14.73	0.02	-3.93	0.58	3.91	0.48	4.99
mooring leg 15	ton	15	1.07	13.11	0.04	-2.90	0.50	2.88	0.38	3.71
mooring leg 16	ton	11	1.12	9.23	0.04	-3.05	0.52	3.03	0.39	3.89
fender 1	ton		5.55	14.14	0.05	-13.67	1.11	14.44	1.48	
fender 2	ton		3.86	19.29	0.04	-10.71	1.81	9.72	1.03	
fender 3	ton		2.86	22.70	0.03	-8.03	1.46	6.80	0.92	
fender 4	ton		2.04	25.94	0.03	-6.04	1.12	4.84	0.83	
fender 5	ton		1.74	28.62	0.03	-5.53	1.28	4.86	0.81	
fender 6	ton		2.46	32.23	0.04	-7.30	1.66	6.94	1.19	

TERMSIM simulation

No.: 2d
date: 1-12-1996
jetty: LNG jetty Whitnell Bay
ship: Northwest

wave spectrum: 2
sign. wave height swell: 0.12 m.
wave direction (swell): 192 deg
wind speed: 11.6 m/s, Harris

parameter	unit	pretens.	st. dev.	averages per 10 min. mean	averages per 10 min. st. dev.	minima per 10 min. mean	minima per 10 min. st. dev.	maxima per 10 min. mean	maxima per 10 min. st. dev.	max per 3 h
surge	m		0.006	-0.006	0.002	-0.018	0.004	0.017	0.003	
sway	m		0.013	0.057	0.002	-0.038	0.011	0.036	0.008	
heave	m		0.007	0.006	0.000	-0.021	0.005	0.020	0.003	
roll	deg		0.048	-0.261	0.002	-0.131	0.042	0.129	0.037	
pitch	deg		0.016	0.000	0.000	-0.041	0.005	0.043	0.006	
yaw	deg		0.016	0.041	0.000	-0.041	0.005	0.044	0.006	
mooring leg 1	ton	24	1.38	16.72	0.07	-3.55	0.55	3.52	0.56	4.69
mooring leg 2	ton	26	1.37	19.53	0.07	-3.53	0.55	3.54	0.56	4.71
mooring leg 3	ton	24	1.64	15.62	0.07	-4.21	0.65	4.22	0.64	5.62
mooring leg 4	ton	23	1.47	15.14	0.07	-3.79	0.61	3.77	0.59	5.00
mooring leg 5	ton	23	1.48	14.87	0.07	-3.80	0.59	3.86	0.52	5.14
mooring leg 6	ton	22	0.54	19.59	0.09	-1.52	0.32	1.53	0.20	1.98
mooring leg 7	ton	14	0.55	12.23	0.09	-1.55	0.33	1.56	0.20	2.02
mooring leg 8	ton	20	0.42	18.01	0.08	-1.20	0.28	1.21	0.17	1.59
mooring leg 9	ton	17	0.45	16.87	0.09	-1.29	0.20	1.29	0.38	2.14
mooring leg 10	ton	18	0.63	18.55	0.11	-1.79	0.28	1.82	0.54	3.03
mooring leg 11	ton	14	0.62	14.76	0.10	-1.75	0.28	1.76	0.51	2.91
mooring leg 12	ton	21	1.79	20.75	0.15	-5.01	0.74	5.28	1.29	7.82
mooring leg 13	ton	17	1.64	16.68	0.11	-4.67	0.70	4.79	1.06	6.94
mooring leg 14	ton	17	1.70	16.97	0.12	-4.80	0.72	4.95	1.09	7.15
mooring leg 15	ton	15	1.24	14.71	0.08	-3.51	0.54	3.55	0.70	5.05
mooring leg 16	ton	11	1.30	10.88	0.08	-3.69	0.57	3.73	0.74	5.30
fender 1	ton		4.70	4.44	0.36	-4.44	0.36	16.66	2.77	
fender 2	ton		4.54	8.83	0.48	-8.76	0.47	13.20	2.40	
fender 3	ton		3.80	12.50	0.49	-10.57	2.14	10.60	2.24	
fender 4	ton		3.30	16.24	0.47	-9.62	2.71	9.12	2.04	
fender 5	ton		3.37	19.98	0.44	-9.56	1.93	8.63	1.75	
fender 6	ton		3.98	25.19	0.39	-11.91	1.75	9.56	2.10	

TERMSIM simulation

No.:	2e	wave spectrum:	2
date:	1-12-1996	sign. wave height swell:	0.12 m.
jetty:	LNG jetty Whitnell Bay	wave direction (swell):	192 deg
ship:	Northwest	wind speed:	11.6 m/s, API

				averages per 10 min.		minima per 10 min.		maxima per 10 min.		max per 3 h
parameter	**unit**	**pretens.**	**st. dev.**	**mean**	**st. dev.**	**mean**	**st. dev.**	**mean**	**st. dev.**	
surge	m		0.007	-0.006	0.001	-0.020	0.006	0.019	0.007	
sway	m		0.018	0.056	0.002	-0.058	0.018	0.049	0.010	
heave	m		0.007	0.006	0.000	-0.021	0.005	0.020	0.003	
roll	deg		0.059	-0.261	0.002	-0.156	0.045	0.150	0.045	
pitch	deg		0.016	0.000	0.000	-0.041	0.005	0.043	0.006	
yaw	deg		0.016	0.041	0.001	-0.042	0.006	0.045	0.007	
mooring leg 1	ton	24	1.46	16.71	0.08	-3.82	0.61	3.80	0.52	4.82
mooring leg 2	ton	26	1.46	19.53	0.08	-3.80	0.61	3.82	0.52	4.85
mooring leg 3	ton	24	1.75	15.62	0.08	-4.62	0.68	4.64	0.61	5.89
mooring leg 4	ton	23	1.59	15.14	0.09	-4.23	0.67	4.19	0.54	5.23
mooring leg 5	ton	23	1.61	14.88	0.08	-4.30	0.62	4.33	0.55	5.47
mooring leg 6	ton	22	0.57	19.60	0.05	-1.60	0.34	1.68	0.28	2.31
mooring leg 7	ton	14	0.58	12.24	0.05	-1.64	0.36	1.71	0.30	2.38
mooring leg 8	ton	20	0.44	18.02	0.05	-1.28	0.34	1.33	0.27	1.94
mooring leg 9	ton	17	0.48	16.87	0.06	-1.40	0.32	1.41	0.50	2.54
mooring leg 10	ton	18	0.68	18.56	0.09	-1.92	0.41	2.02	0.72	3.64
mooring leg 11	ton	14	0.66	14.76	0.08	-1.89	0.40	1.95	0.69	3.51
mooring leg 12	ton	21	2.00	20.80	0.19	-5.59	0.84	6.22	1.81	9.63
mooring leg 13	ton	17	1.85	16.73	0.16	-5.24	0.79	5.63	1.48	8.53
mooring leg 14	ton	17	1.90	17.03	0.16	-5.38	0.80	5.79	1.52	8.79
mooring leg 15	ton	15	1.38	14.75	0.10	-3.93	0.58	4.13	0.98	6.14
mooring leg 16	ton	11	1.45	10.93	0.11	-4.13	0.61	4.32	1.02	6.43
fender 1	ton		5.16	4.65	0.42	-4.65	0.42	19.56	2.87	
fender 2	ton		5.39	8.83	0.57	-8.83	0.57	16.14	2.53	
fender 3	ton		5.05	12.38	0.63	-11.63	1.03	13.77	2.42	
fender 4	ton		4.71	16.11	0.62	-13.51	2.71	11.85	2.06	
fender 5	ton		4.66	19.83	0.60	-14.44	3.03	10.89	1.94	
fender 6	ton		4.89	25.00	0.52	-15.12	2.15	11.22	2.26	

TERMSIM simulation

No.: 2f
date: 1-12-1996
jetty: LNG jetty Whitnell Bay
ship: Northwest

wave spectrum: 2
sign. wave height swell: 0.56 m.
wave direction (swell): 0.12 m.
wind speed: 11.6 m/s, Harris
wind direction: SW

parameter	unit	pretens.	st. dev.	averages per 10 min. mean	averages per 10 min. st. dev.	minima per 10 min. mean	minima per 10 min. st. dev.	maxima per 10 min. mean	maxima per 10 min. st. dev.	max per 3 h
surge	m		0.006	0.007	0.002	-0.020	0.003	0.015	0.001	
sway	m		0.012	0.061	0.002	-0.035	0.010	0.032	0.007	
heave	m		0.007	0.006	0.000	-0.020	0.004	0.019	0.003	
roll	deg		0.042	-0.263	0.001	-0.117	0.037	0.113	0.033	
pitch	deg		0.015	0.000	0.000	-0.041	0.005	0.043	0.006	
yaw	deg		0.017	0.050	0.001	-0.044	0.005	0.047	0.007	
mooring leg 1	ton	24	1.40	15.54	0.03	-3.59	0.49	3.61	0.53	4.92
mooring leg 2	ton	26	1.39	18.34	0.03	-3.55	0.49	3.61	0.54	4.93
mooring leg 3	ton	24	1.66	14.42	0.02	-4.28	0.57	4.26	0.62	5.80
mooring leg 4	ton	23	1.48	13.96	0.03	-3.77	0.52	3.79	0.58	5.18
mooring leg 5	ton	23	1.49	13.96	0.04	-3.83	0.55	3.78	0.57	5.19
mooring leg 6	ton	22	0.52	19.86	0.09	-1.64	0.30	1.40	0.15	1.75
mooring leg 7	ton	14	0.53	12.53	0.09	-1.68	0.31	1.43	0.16	1.79
mooring leg 8	ton	20	0.41	18.33	0.08	-1.31	0.26	1.09	0.12	1.37
mooring leg 9	ton	17	0.43	16.55	0.08	-1.21	0.15	1.42	0.35	2.21
mooring leg 10	ton	18	0.62	18.22	0.11	-1.71	0.23	1.97	0.52	3.15
mooring leg 11	ton	14	0.60	14.45	0.10	-1.68	0.22	1.90	0.50	3.03
mooring leg 12	ton	21	1.88	21.28	0.18	-5.18	0.66	5.65	1.36	8.41
mooring leg 13	ton	17	1.75	17.50	0.15	-4.92	0.68	5.13	1.12	7.64
mooring leg 14	ton	17	1.80	17.80	0.15	-5.06	0.69	5.29	1.16	7.88
mooring leg 15	ton	15	1.32	15.52	0.11	-3.77	0.55	3.80	0.75	5.66
mooring leg 16	ton	11	1.39	11.72	0.11	-3.96	0.57	3.99	0.79	5.93
fender 1	ton		4.33	3.51	0.38	-3.51	0.38	16.90	2.41	
fender 2	ton		4.53	8.55	0.51	-8.55	0.51	13.31	2.08	
fender 3	ton		3.66	13.02	0.49	-10.49	2.25	10.16	1.88	
fender 4	ton		2.97	17.61	0.42	-8.68	2.51	8.04	1.71	
fender 5	ton		2.92	22.16	0.36	-8.35	1.54	7.16	1.44	
fender 6	ton		3.30	28.07	0.22	-10.40	1.75	8.38	1.54	

TERMSIM simulation

No.: 2g
date: 1-12-1996
jetty: LNG jetty Whitnell Bay
ship: Northwest

wave spectrum: 2
sign. wave height swell: 0.12 m.
wave direction (swell): 192 deg
wind speed: 11.6 m/s, Harris
wind direction: W

parameter	unit	pretens.	st. dev.	averages per 10 min. mean	averages per 10 min. st. dev.	minima per 10 min. mean	minima per 10 min. st. dev.	maxima per 10 min. mean	maxima per 10 min. st. dev.	max per 3 h
surge	m		0.006	-0.012	0.002	-0.017	0.004	0.015	0.003	
sway	m		0.012	0.057	0.002	-0.033	0.008	0.033	0.007	
heave	m		0.007	0.006	0.000	-0.020	0.004	0.019	0.003	
roll	deg		0.041	-0.263	0.002	-0.113	0.038	0.113	0.034	
pitch	deg		0.016	-0.001	0.000	-0.041	0.005	0.043	0.006	
yaw	deg		0.016	0.030	0.000	-0.040	0.006	0.041	0.006	
mooring leg 1	ton	24	1.44	17.72	0.11	-3.80	0.72	3.70	0.63	4.91
mooring leg 2	ton	26	1.44	20.54	0.12	-3.79	0.72	3.73	0.64	4.95
mooring leg 3	ton	24	1.71	16.71	0.12	-4.49	0.82	4.49	0.70	5.85
mooring leg 4	ton	23	1.53	16.15	0.12	-4.06	0.75	4.00	0.65	5.24
mooring leg 5	ton	23	1.54	15.76	0.10	-4.04	0.72	4.11	0.59	5.26
mooring leg 6	ton	22	0.52	19.62	0.06	-1.48	0.22	1.41	0.25	1.98
mooring leg 7	ton	14	0.53	12.26	0.06	-1.51	0.23	1.43	0.26	2.02
mooring leg 8	ton	20	0.40	17.99	0.06	-1.16	0.19	1.10	0.20	1.54
mooring leg 9	ton	17	0.42	16.88	0.07	-1.17	0.20	1.22	0.23	1.73
mooring leg 10	ton	18	0.58	18.49	0.09	-1.63	0.27	1.70	0.31	2.40
mooring leg 11	ton	14	0.57	14.70	0.08	-1.60	0.26	1.63	0.30	2.31
mooring leg 12	ton	21	1.64	19.80	0.09	-4.58	0.60	4.78	0.92	6.64
mooring leg 13	ton	17	1.52	15.65	0.05	-4.22	0.58	4.38	0.75	5.96
mooring leg 14	ton	17	1.57	15.92	0.05	-4.35	0.59	4.51	0.77	6.15
mooring leg 15	ton	15	1.16	13.84	0.03	-3.16	0.45	3.29	0.51	4.41
mooring leg 16	ton	11	1.22	9.98	0.03	-3.33	0.48	3.46	0.53	4.64
fender 1	ton		5.14	6.55	0.30	-6.55	0.30	15.81	2.16	
fender 2	ton		4.21	10.30	0.41	-10.01	0.88	11.98	1.82	
fender 3	ton		3.43	13.08	0.44	-9.48	1.84	9.72	1.80	
fender 4	ton		3.09	15.89	0.46	-8.67	2.11	8.65	1.71	
fender 5	ton		3.38	18.68	0.48	-9.54	1.67	8.68	1.73	
fender 6	ton		4.43	22.71	0.50	-12.66	1.67	10.28	2.02	

TERMSIM simulation

No.:	4a-1	wave spectrum:	3a
date:	15-7-1996	sign. wave height swell:	0.19 m.
jetty:	LNG jetty Whitnell Bay	wave direction (swell):	193 deg
ship:	Northwest	wind speed:	6.1 m.

parameter	unit	pretens.	st. dev.	averages per 10 min. mean	st. dev.	minima per 10 min. mean	st. dev.	maxima per 10 min. mean	st. dev.	max per 3 h
surge	m		0.005	-0.015	0.002	-0.015	0.004	0.013	0.003	
sway	m		0.005	0.049	0.000	-0.014	0.002	0.014	0.002	
heave	m		0.009	0.004	0.000	-0.028	0.004	0.028	0.004	
roll	deg		0.062	-0.149	0.000	-0.178	0.028	0.175	0.027	
pitch	deg		0.018	-0.001	0.000	-0.050	0.007	0.052	0.009	
yaw	deg		0.013	0.009	0.000	-0.035	0.006	0.035	0.005	
mooring leg 1	ton	19	1.09	16.20	0.02	-2.98	0.44	3.13	0.50	4.03
mooring leg 2	ton	18	1.08	14.50	0.02	-2.95	0.43	3.11	0.50	4.01
mooring leg 3	ton	21	1.27	16.74	0.01	-3.53	0.53	3.66	0.54	4.74
mooring leg 4	ton	16	1.14	12.64	0.01	-3.16	0.48	3.29	0.51	4.25
mooring leg 5	ton	16	1.12	11.68	0.03	-3.16	0.50	3.22	0.46	4.26
mooring leg 6	ton	16	0.44	14.41	0.08	-1.28	0.26	1.18	0.26	1.77
mooring leg 7	ton	16	0.45	14.65	0.08	-1.32	0.27	1.22	0.27	1.83
mooring leg 8	ton	11	0.35	10.26	0.07	-1.03	0.21	0.94	0.21	1.40
mooring leg 9	ton	12	0.38	12.48	0.07	-1.01	0.22	1.13	0.26	1.71
mooring leg 10	ton	22	0.54	22.93	0.08	-1.44	0.30	1.64	0.35	2.41
mooring leg 11	ton	15	0.51	15.36	0.08	-1.38	0.29	1.53	0.32	2.24
mooring leg 12	ton	15	1.36	12.93	0.03	-3.69	0.67	3.71	0.69	4.94
mooring leg 13	ton	13	1.27	10.56	0.02	-3.45	0.61	3.39	0.59	4.44
mooring leg 14	ton	22	1.32	19.05	0.01	-3.56	0.63	3.54	0.64	4.66
mooring leg 15	ton	17	0.98	14.50	0.04	-2.68	0.46	2.55	0.43	3.30
mooring leg 16	ton	18	1.03	16.11	0.03	-2.82	0.48	2.70	0.46	3.50
fender 1	ton		7.49	20.84	0.07	-19.99	1.43	21.81	3.05	
fender 2	ton		4.32	23.19	0.04	-13.03	2.37	12.73	2.18	
fender 3	ton		2.76	24.77	0.02	-7.95	1.58	7.93	1.72	
fender 4	ton		2.81	26.35	0.03	-8.17	1.18	8.32	1.37	
fender 5	ton		4.42	27.93	0.04	-12.35	2.33	12.39	2.36	
fender 6	ton		7.63	30.29	0.08	-20.61	3.83	20.13	3.53	

TERMSIM simulation

No.:	3a-2	wave spectrum:	3a
date:	15-7-1996	sign. wave height swell:	0.17 m.
jetty:	LNG jetty Withnell Bay	wave direction:	198 deg
ship:	Northwest	wind speed:	6.1 m.

parameter	unit	pretens.	st. dev.	averages per 10 min. mean	averages per 10 min. st. dev.	minima per 10 min. mean	minima per 10 min. st. dev.	maxima per 10 min. mean	maxima per 10 min. st. dev.	max per 3 h
surge	m		0.005	-0.015	0.002	-0.012	0.005	0.012	0.004	
sway	m		0.007	0.048	0.000	-0.022	0.005	0.022	0.004	
heave	m		0.009	0.004	0.000	-0.027	0.004	0.026	0.003	
roll	deg		0.077	-0.139	0.000	-0.220	0.036	0.220	0.037	
pitch	deg		0.017	-0.001	0.000	-0.047	0.005	0.050	0.007	
yaw	deg		0.018	0.008	0.000	-0.049	0.009	0.049	0.008	
mooring leg 1	ton	19	1.53	16.34	0.03	-4.21	0.64	4.22	0.85	5.89
mooring leg 2	ton	18	1.51	14.64	0.03	-4.18	0.63	4.17	0.84	5.82
mooring leg 3	ton	21	1.80	16.91	0.01	-4.93	0.78	5.04	1.00	7.01
mooring leg 4	ton	16	1.60	12.80	0.02	-4.41	0.69	4.46	0.89	6.19
mooring leg 5	ton	16	1.59	11.84	0.03	-4.34	0.70	4.47	0.88	6.18
mooring leg 6	ton	16	0.56	14.40	0.09	-1.47	0.27	1.60	0.29	2.25
mooring leg 7	ton	16	0.58	14.64	0.09	-1.51	0.28	1.65	0.30	2.32
mooring leg 8	ton	11	0.42	10.24	0.08	-1.11	0.21	1.22	0.23	1.73
mooring leg 9	ton	12	0.47	12.52	0.08	-1.33	0.24	1.23	0.23	1.75
mooring leg 10	ton	22	0.69	22.99	0.09	-1.94	0.32	1.85	0.34	2.61
mooring leg 11	ton	15	0.66	15.42	0.09	-1.87	0.31	1.73	0.32	2.44
mooring leg 12	ton	15	1.88	13.05	0.03	-5.15	0.92	5.01	0.86	6.75
mooring leg 13	ton	13	1.76	10.66	0.02	-4.76	0.89	4.73	0.79	6.32
mooring leg 14	ton	22	1.83	19.15	0.02	-4.93	0.92	4.98	0.86	6.71
mooring leg 15	ton	17	1.35	14.56	0.04	-3.60	0.68	3.64	0.60	4.85
mooring leg 16	ton	18	1.42	16.17	0.04	-3.80	0.72	3.86	0.65	5.15
fender 1	ton		10.28	20.69	0.13	-20.62	0.37	29.64	4.99	
fender 2	ton		6.12	22.91	0.05	-18.57	3.85	18.36	3.70	
fender 3	ton		4.02	24.47	0.05	-12.44	2.58	12.02	2.56	
fender 4	ton		4.21	26.04	0.06	-12.99	2.53	12.80	2.52	
fender 5	ton		6.48	27.60	0.08	-18.84	2.85	18.87	3.67	
fender 6	ton		10.92	29.93	0.12	-27.94	2.62	28.05	3.94	

TERMSIM simulation

No.: 3b-1
date: 15-7-1996
jetty: LNG jetty Whitnell Bay
ship: Northwest

wave spectrum: 3b
sign. wave height swell: 0.21 m.
wave direction (swell): 191 deg
wind speed: 5.7 m/s

				averages per 10 min.		minima per 10 min.		maxima per 10 min.		max per 3 h
parameter	**unit**	**pretens.**	**st. dev.**	**mean**	**st. dev.**	**mean**	**st. dev.**	**mean**	**st. dev.**	
surge	m		0.006	-0.017	0.002	-0.015	0.005	0.013	0.004	
sway	m		0.005	0.070	0.000	-0.013	0.002	0.013	0.002	
heave	m		0.011	0.007	0.000	-0.030	0.004	0.031	0.002	
roll	deg		0.061	-0.216	0.000	-0.160	0.018	0.156	0.019	
pitch	deg		0.018	-0.002	0.000	-0.055	0.007	0.050	0.004	
yaw	deg		0.011	0.016	0.000	-0.030	0.005	0.030	0.006	
mooring leg 1	ton	25	0.98	19.80	0.02	-2.58	0.45	2.67	0.31	3.41
mooring leg 2	ton	24	0.97	19.06	0.03	-2.55	0.44	2.64	0.30	3.37
mooring leg 3	ton	30	1.15	23.63	0.01	-3.00	0.53	3.20	0.42	4.11
mooring leg 4	ton	23	1.02	17.23	0.01	-2.66	0.46	2.76	0.34	3.53
mooring leg 5	ton	24	0.99	17.53	0.03	-2.57	0.45	2.68	0.38	3.53
mooring leg 6	ton	24	0.41	22.17	0.08	-1.15	0.22	1.10	0.17	1.48
mooring leg 7	ton	29	0.45	28.32	0.09	-1.25	0.24	1.20	0.18	1.61
mooring leg 8	ton	16	0.33	14.37	0.07	-0.92	0.20	0.88	0.14	1.20
mooring leg 9	ton	21	0.35	21.52	0.07	-0.89	0.16	0.98	0.20	1.43
mooring leg 10	ton	26	0.50	27.34	0.08	-1.24	0.23	1.40	0.27	2.02
mooring leg 11	ton	27	0.49	27.28	0.08	-1.21	0.22	1.36	0.27	1.96
mooring leg 12	ton	24	1.18	21.26	0.03	-3.21	0.59	3.23	0.62	4.30
mooring leg 13	ton	22	1.10	19.13	0.02	-2.97	0.55	3.03	0.58	3.97
mooring leg 14	ton	24	1.15	20.75	0.02	-3.10	0.57	3.16	0.60	4.15
mooring leg 15	ton	20	0.85	17.88	0.04	-2.25	0.43	2.32	0.44	3.02
mooring leg 16	ton	22	0.90	19.27	0.04	-2.38	0.45	2.45	0.47	3.19
fender 1	ton		6.53	27.74	0.06	-17.05	2.92	17.56	3.13	
fender 2	ton		3.85	32.07	0.03	-9.99	1.47	10.04	1.71	
fender 3	ton		2.58	34.96	0.02	-6.91	1.35	6.94	1.12	
fender 4	ton		2.61	37.85	0.02	-7.34	1.07	7.74	1.28	
fender 5	ton		3.90	40.73	0.04	-10.61	1.58	10.59	1.74	
fender 6	ton		6.36	44.96	0.06	-17.30	2.82	14.89	2.08	

TERMSIM simulation

No.: 3b-2
date: 15-7-1996
jetty: LNG jetty Withnell Bay
ship: Northwest

wave spectrum: 3b
sign. wave height swell: 0.19 m.
wave direction: 198 deg
wind speed: 5.7 m/s

parameter	unit	pretens.	st. dev.	averages per 10 min. mean	averages per 10 min. st. dev.	minima per 10 min. mean	minima per 10 min. st. dev.	maxima per 10 min. mean	maxima per 10 min. st. dev.	max per 3 h
surge	m		0.005	-0.019	0.002	-0.015	0.006	0.014	0.004	
sway	m		0.009	0.069	0.000	-0.025	0.003	0.027	0.005	
heave	m		0.011	0.006	0.000	-0.031	0.003	0.032	0.003	
roll	deg		0.099	-0.202	0.001	-0.274	0.035	0.269	0.037	
pitch	deg		0.019	-0.002	0.000	-0.058	0.008	0.054	0.005	
yaw	deg		0.020	0.016	0.000	-0.056	0.009	0.055	0.009	
mooring leg 1	ton	25	1.74	19.98	0.04	-4.80	0.77	4.97	0.64	6.27
mooring leg 2	ton	24	1.72	19.24	0.04	-4.75	0.76	4.91	0.63	6.17
mooring leg 3	ton	30	2.10	23.85	0.02	-5.74	0.91	6.08	0.84	7.75
mooring leg 4	ton	23	1.82	17.43	0.03	-5.04	0.81	5.20	0.67	6.55
mooring leg 5	ton	24	1.81	17.72	0.03	-5.00	0.78	5.18	0.75	6.68
mooring leg 6	ton	24	0.63	22.14	0.11	-1.77	0.37	1.79	0.38	2.64
mooring leg 7	ton	29	0.68	28.29	0.12	-1.92	0.41	1.93	0.41	2.85
mooring leg 8	ton	16	0.46	14.33	0.09	-1.33	0.31	1.32	0.29	1.97
mooring leg 9	ton	21	0.52	21.60	0.09	-1.45	0.30	1.50	0.32	2.22
mooring leg 10	ton	26	0.79	27.46	0.11	-2.18	0.41	2.28	0.44	3.28
mooring leg 11	ton	27	0.77	27.39	0.11	-2.14	0.39	2.23	0.43	3.19
mooring leg 12	ton	24	2.12	21.45	0.04	-5.76	0.96	5.97	1.05	8.07
mooring leg 13	ton	22	1.96	19.27	0.03	-5.33	0.87	5.53	0.93	7.41
mooring leg 14	ton	24	2.05	20.90	0.02	-5.54	0.90	5.80	0.98	7.77
mooring leg 15	ton	20	1.49	17.96	0.05	-4.05	0.64	4.19	0.70	5.59
mooring leg 16	ton	22	1.58	19.36	0.05	-4.29	0.68	4.45	0.74	5.93
fender 1	ton		11.62	27.48	0.13	-27.14	1.18	31.15	3.80	
fender 2	ton		6.98	31.83	0.09	-19.89	3.59	19.81	2.62	
fender 3	ton		4.87	34.74	0.09	-13.62	2.28	13.79	2.05	
fender 4	ton		5.13	37.64	0.09	-14.42	1.77	15.37	2.39	
fender 5	ton		7.40	40.50	0.09	-20.85	2.15	19.30	2.86	
fender 6	ton		11.45	44.32	0.13	-32.67	4.05	27.11	4.24	

TERMSIM simulation

No.: 3b-3
date: 15-7-1996
jetty: LNG jetty Whitnell Bay
ship: Northwest

wave spectrum: 3b, no swell
sign. wave height swell: -
wave direction: 198 deg
wind speed: 5.7 m/s (const.)

				averages per 10 min.		minima per 10 min.		maxima per 10 min.		max per 3 h
parameter	**unit**	**pretens.**	**st. dev.**	**mean**	**st. dev.**	**mean**	**st. dev.**	**mean**	**st. dev.**	
surge	m		0.004	-0.019	0.002	-0.008	0.002	0.008	0.002	
sway	m		0.002	0.069	0.000	-0.007	0.001	0.005	0.000	
heave	m		0.005	0.006	0.000	-0.016	0.003	0.016	0.003	
roll	deg		0.009	-0.202	0.000	-0.025	0.003	0.029	0.005	
pitch	deg		0.009	-0.002	0.000	-0.031	0.005	0.030	0.005	
yaw	deg		0.003	0.015	0.000	-0.009	0.001	0.010	0.002	
mooring leg 1	ton	25	0.28	20.00	0.03	-0.94	0.18	0.93	0.13	1.18
mooring leg 2	ton	24	0.28	19.26	0.03	-0.93	0.18	0.92	0.13	1.17
mooring leg 3	ton	30	0.31	23.85	0.01	-1.09	0.19	1.09	0.18	1.42
mooring leg 4	ton	23	0.28	17.45	0.02	-0.96	0.18	0.96	0.15	1.24
mooring leg 5	ton	24	0.26	17.74	0.02	-0.95	0.15	0.92	0.18	1.23
mooring leg 6	ton	24	0.19	22.16	0.08	-0.52	0.10	0.49	0.10	0.73
mooring leg 7	ton	29	0.21	28.31	0.09	-0.57	0.10	0.54	0.12	0.80
mooring leg 8	ton	16	0.17	14.34	0.07	-0.43	0.08	0.42	0.09	0.63
mooring leg 9	ton	21	0.16	21.58	0.07	-0.39	0.09	0.39	0.09	0.59
mooring leg 10	ton	26	0.20	27.44	0.09	-0.50	0.11	0.51	0.12	0.77
mooring leg 11	ton	27	0.19	27.37	0.08	-0.48	0.11	0.49	0.11	0.74
mooring leg 12	ton	24	0.25	21.43	0.03	-0.72	0.13	0.97	0.20	1.34
mooring leg 13	ton	22	0.24	19.25	0.02	-0.73	0.11	0.92	0.20	1.28
mooring leg 14	ton	24	0.25	20.88	0.01	-0.76	0.11	0.96	0.21	1.34
mooring leg 15	ton	20	0.21	17.95	0.04	-0.63	0.12	0.72	0.17	1.01
mooring leg 16	ton	22	0.22	19.35	0.04	-0.66	0.12	0.76	0.17	1.06
fender 1	ton		1.20	27.52	0.09	-4.28	0.78	4.09	0.57	
fender 2	ton		0.85	31.82	0.08	-2.60	0.51	2.79	0.34	
fender 3	ton		0.94	34.68	0.07	-2.92	0.37	2.45	0.22	
fender 4	ton		1.25	37.54	0.07	-4.05	0.82	3.32	0.30	
fender 5	ton		1.66	40.40	0.07	-5.38	1.18	4.94	0.72	
fender 6	ton		2.35	44.70	0.07	-7.67	1.52	7.63	1.12	

TERMSIM simulation

No.: 4a-1
date: 21-7-1996
jetty: LNG jetty Whitnell Bay
ship: Northwest

wave spectrum: 4a
sign. wave height swell: 0.24 m.
wave direction: 183 deg
wind speed: -

				averages per 10 min.		minima per 10 min.		maxima per 10 min.		max per 3 h
parameter	**unit**	**pretens.**	**st. dev.**	**mean**	**st. dev.**	**mean**	**st. dev.**	**mean**	**st. dev.**	
surge	m		0.014	0.000	0.003	-0.036	0.004	0.035	0.004	
sway	m		0.002	0.053	0.000	-0.004	0.000	0.004	0.000	
heave	m		0.012	0.004	0.000	-0.032	0.004	0.035	0.006	
roll	deg		0.015	-0.172	0.000	-0.043	0.005	0.041	0.005	
pitch	deg		0.030	-0.001	0.000	-0.084	0.008	0.080	0.009	
yaw	deg		0.007	0.011	0.000	-0.018	0.002	0.018	0.002	
mooring leg 1	ton	18	0.64	14.20	0.04	-1.76	0.22	1.84	0.21	2.25
mooring leg 2	ton	18	0.64	13.81	0.05	-1.76	0.22	1.85	0.21	2.25
mooring leg 3	ton	25	0.71	20.41	0.01	-2.01	0.18	2.05	0.25	2.50
mooring leg 4	ton	26	0.66	21.08	0.02	-1.86	0.21	1.92	0.22	2.33
mooring leg 5	ton	28	0.66	22.73	0.05	-1.84	0.16	1.80	0.23	2.25
mooring leg 6	ton	15	0.70	14.19	0.15	-1.91	0.17	1.84	0.22	2.34
mooring leg 7	ton	8	0.73	7.53	0.16	-2.00	0.18	1.93	0.23	2.44
mooring leg 8	ton	12	0.62	11.13	0.13	-1.71	0.16	1.65	0.18	2.07
mooring leg 9	ton	21	0.62	20.52	0.13	-1.61	0.19	1.73	0.17	2.11
mooring leg 10	ton	16	0.73	15.57	0.15	-1.92	0.22	2.00	0.21	2.47
mooring leg 11	ton	11	0.70	10.48	0.14	-1.85	0.21	1.92	0.20	2.37
mooring leg 12	ton	20	0.69	17.52	0.06	-1.79	0.23	1.86	0.21	2.40
mooring leg 13	ton	17	0.56	14.70	0.03	-1.61	0.18	1.55	0.20	1.96
mooring leg 14	ton	24	0.59	21.66	0.02	-1.69	0.19	1.63	0.20	2.05
mooring leg 15	ton	25	0.51	22.96	0.07	-1.45	0.16	1.36	0.17	1.75
mooring leg 16	ton	18	0.51	16.60	0.06	-1.46	0.16	1.38	0.17	1.76
fender 1	ton		3.36	21.79	0.11	-9.42	0.79	9.24	1.44	
fender 2	ton		1.65	24.77	0.06	-4.67	0.48	4.46	0.78	
fender 3	ton		0.76	26.76	0.02	-2.18	0.38	2.20	0.33	
fender 4	ton		1.14	28.74	0.02	-3.18	0.33	3.07	0.34	
fender 5	ton		2.21	30.73	0.06	-6.16	0.65	6.03	0.79	
fender 6	ton		3.96	33.71	0.11	-10.94	1.33	10.83	1.42	

TERMSIM simulation

No.: 4a-2
date: 21-7-1996
jetty: LNG jetty Whitnell Bay
ship: Northwest

wave spectrum: 4a
sign. wave height swell: 0.24 m.
wave direction: 194 deg
wind speed: -

				averages per 10 min.		minima per 10 min.		maxima per 10 min.		max per 3 h
parameter	**dim.**	**pretens.**	**st. dev.**	**mean**	**st. dev.**	**mean**	**st. dev.**	**mean**	**st. dev.**	
surge	m		0.014	0.000	0.002	-0.041	0.009	0.037	0.005	
sway	m		0.006	0.053	0.000	-0.018	0.003	0.018	0.002	
heave	m		0.012	0.004	0.000	-0.034	0.005	0.037	0.006	
roll	deg		0.068	-0.172	0.000	-0.203	0.031	0.200	0.024	
pitch	deg		0.031	-0.001	0.000	-0.088	0.007	0.085	0.009	
yaw	deg		0.022	0.011	0.000	-0.061	0.009	0.060	0.009	
mooring leg 1	ton	18	1.73	14.21	0.03	-4.90	0.67	4.71	0.81	6.41
mooring leg 2	ton	18	1.71	13.82	0.04	-4.84	0.66	4.66	0.79	6.32
mooring leg 3	ton	25	2.18	20.41	0.02	-6.11	0.83	6.01	1.05	8.24
mooring leg 4	ton	26	1.90	21.09	0.02	-5.34	0.69	5.21	0.91	7.13
mooring leg 5	ton	28	2.02	22.73	0.05	-5.70	0.74	5.64	0.98	7.72
mooring leg 6	ton	15	1.09	14.14	0.13	-3.20	0.44	2.98	0.41	3.89
mooring leg 7	ton	8	1.13	7.48	0.13	-3.32	0.45	3.09	0.42	4.04
mooring leg 8	ton	12	0.90	11.09	0.11	-2.66	0.38	2.45	0.33	3.20
mooring leg 9	ton	21	0.96	20.57	0.11	-2.58	0.36	2.89	0.36	3.71
mooring leg 10	ton	16	1.25	15.62	0.13	-3.39	0.49	3.69	0.43	4.67
mooring leg 11	ton	11	1.22	10.52	0.12	-3.30	0.48	3.56	0.42	4.50
mooring leg 12	ton	20	2.45	17.55	0.06	-6.71	0.94	6.80	1.02	9.43
mooring leg 13	ton	17	2.10	14.70	0.02	-5.71	0.80	5.69	0.82	7.89
mooring leg 14	ton	24	2.23	21.67	0.02	-6.02	0.84	6.16	0.90	8.57
mooring leg 15	ton	25	1.56	22.96	0.06	-4.17	0.61	4.19	0.64	5.88
mooring leg 16	ton	18	1.61	16.59	0.05	-4.34	0.64	4.31	0.64	6.01
fender 1	ton		11.93	21.94	0.23	-21.94	0.23	34.00	4.93	
fender 2	ton		6.72	24.73	0.07	-18.88	3.03	20.40	3.50	
fender 3	ton		3.64	26.73	0.03	-10.50	1.52	10.80	2.30	
fender 4	ton		3.90	28.74	0.04	-10.94	1.73	10.78	1.21	
fender 5	ton		7.15	30.75	0.08	-19.15	3.18	18.73	2.66	
fender 6	ton		12.61	33.65	0.17	-32.22	1.39	29.82	3.57	

TERMSIM simulation

No.: 4a-3
date: 21-7-1996
jetty: LNG jetty Whitnell Bay
ship: Northwest

wave spectrum: 4a
sign. wave height swell: 0.24 m.
wave direction: 205 deg
wind speed: -

				averages per 10 min.		minima per 10 min.		maxima per 10 min.		max per 3 h
parameter	**unit**	**pretens.**	**st. dev.**	**mean**	**st. dev.**	**mean**	**st. dev.**	**mean**	**st. dev.**	
surge	m		0.019	-0.006	0.004	-0.073	0.017	0.040	0.008	
sway	m		0.017	0.052	0.001	-0.060	0.015	0.041	0.008	
heave	m		0.015	0.004	0.000	-0.040	0.005	0.043	0.006	
roll	deg		0.134	-0.173	0.001	-0.390	0.060	0.398	0.064	
pitch	deg		0.035	-0.001	0.000	-0.097	0.008	0.096	0.010	
yaw	deg		0.054	0.012	0.001	-0.148	0.025	0.154	0.026	
mooring leg 1	ton	18	4.25	14.28	0.08	-11.27	1.39	12.30	2.26	19.10
mooring leg 2	ton	18	4.19	13.90	0.08	-11.03	1.32	12.13	2.23	18.86
mooring leg 3	ton	25	5.34	20.43	0.08	-14.46	2.35	15.86	2.94	24.29
mooring leg 4	ton	26	4.67	21.16	0.08	-12.66	2.06	13.90	2.59	21.48
mooring leg 5	ton	28	4.90	22.68	0.09	-13.45	2.29	14.64	2.65	21.85
mooring leg 6	ton	15	2.09	13.85	0.19	-7.02	1.14	5.26	0.94	7.39
mooring leg 7	ton	8	2.08	7.19	0.19	-5.89	0.55	5.40	0.96	7.56
mooring leg 8	ton	12	1.64	10.83	0.17	-5.61	0.90	4.07	0.67	5.57
mooring leg 9	ton	21	1.81	20.85	0.17	-4.41	0.75	6.32	1.10	8.80
mooring leg 10	ton	16	2.46	15.95	0.20	-6.16	1.04	8.34	1.49	11.70
mooring leg 11	ton	11	2.39	10.84	0.19	-5.96	0.93	8.03	1.41	11.20
mooring leg 12	ton	20	5.84	17.86	0.15	-15.19	1.59	18.58	3.62	29.03
mooring leg 13	ton	17	5.08	14.82	0.08	-12.92	1.07	15.33	3.07	23.74
mooring leg 14	ton	24	5.49	21.83	0.09	-14.63	2.10	16.88	3.41	26.27
mooring leg 15	ton	25	3.88	22.96	0.08	-10.72	1.58	11.26	2.40	17.35
mooring leg 16	ton	18	4.00	16.59	0.07	-11.12	1.55	11.51	2.42	17.69
fender 1	ton		21.92	23.92	1.15	-23.92	1.15	67.47	7.10	
fender 2	ton		14.75	24.28	0.17	-24.28	0.17	43.42	4.96	
fender 3	ton		9.31	25.94	0.43	-25.76	0.68	25.92	4.71	
fender 4	ton		9.52	28.16	0.37	-27.78	0.76	24.22	4.39	
fender 5	ton		15.54	30.54	0.21	-30.54	0.21	38.49	5.93	
fender 6	ton		23.94	34.46	0.63	-34.46	0.63	61.40	8.58	

TERMSIM simulation

No.: 4a-4
date: 21-7-1996
jetty: LNG jetty Withnell Bay
ship: Northwest

wave spectrum: 4a
sign. wave height swell: 0.24 m.
wave direction: 177 & 189 deg
wind speed: -

parameter	unit	pretens.	st. dev.	averages per 10 min. mean	averages per 10 min. st. dev.	minima per 10 min. mean	minima per 10 min. st. dev.	maxima per 10 min. mean	maxima per 10 min. st. dev.	max per 3 h
surge	m		0.017	-0.003	0.003	-0.049	0.012	0.042	0.004	
sway	m		0.003	0.055	0.000	-0.009	0.001	0.009	0.001	
heave	m		0.013	0.004	0.000	-0.037	0.005	0.037	0.005	
roll	deg		0.041	-0.171	0.000	-0.106	0.024	0.110	0.019	
pitch	deg		0.030	-0.001	0.000	-0.084	0.016	0.084	0.017	
yaw	deg		0.012	0.012	0.000	-0.036	0.006	0.037	0.007	
mooring leg 1	ton	18	0.97	14.92	0.05	-2.78	0.43	2.86	0.60	3.92
mooring leg 2	ton	18	0.95	14.57	0.05	-2.72	0.42	2.81	0.61	3.86
mooring leg 3	ton	25	1.25	20.91	0.01	-3.65	0.62	3.82	0.59	4.92
mooring leg 4	ton	26	1.13	21.59	0.03	-3.28	0.53	3.42	0.61	4.53
mooring leg 5	ton	28	1.21	23.11	0.05	-3.43	0.66	3.59	0.50	4.49
mooring leg 6	ton	15	0.78	14.32	0.14	-2.14	0.61	2.08	0.28	2.71
mooring leg 7	ton	8	0.66	8.28	0.12	-1.80	0.51	1.79	0.25	2.35
mooring leg 8	ton	12	0.64	11.21	0.11	-1.75	0.49	1.69	0.24	2.22
mooring leg 9	ton	21	0.79	20.77	0.14	-1.95	0.25	2.23	0.63	3.66
mooring leg 10	ton	16	0.87	15.96	0.14	-2.14	0.28	2.49	0.68	4.02
mooring leg 11	ton	11	0.73	10.89	0.12	-1.80	0.23	2.13	0.58	3.44
mooring leg 12	ton	20	1.17	18.20	0.05	-3.33	0.48	3.51	0.74	4.69
mooring leg 13	ton	17	0.95	15.37	0.03	-2.72	0.52	2.84	0.49	3.64
mooring leg 14	ton	24	1.11	22.14	0.03	-3.20	0.58	3.32	0.58	4.26
mooring leg 15	ton	25	0.87	23.23	0.08	-2.43	0.53	2.43	0.33	2.99
mooring leg 16	ton	18	0.83	17.00	0.07	-2.30	0.52	2.34	0.33	2.89
fender 1	ton		6.95	22.22	0.10	-19.90	2.61	20.21	2.84	
fender 2	ton		3.73	25.41	0.05	-10.90	2.04	10.51	1.27	
fender 3	ton		1.98	27.55	0.02	-5.37	0.87	5.59	0.74	
fender 4	ton		2.08	29.68	0.01	-5.62	0.46	5.90	0.59	
fender 5	ton		3.89	31.82	0.04	-11.05	1.55	11.16	1.52	
fender 6	ton		7.12	35.02	0.09	-20.88	3.03	19.98	2.60	

TERMSIM simulation

No.: 4a-5
date: 21-7-1996
jetty: LNG jetty Withnell Bay
ship: Northwest

wave spectrum: 4a
sign. wave height swell: 0.24 m.
wave direction: 172 & 194 deg
wind speed: -

				averages per 10 min.		minima per 10 min.		maxima per 10 min.		max per 3 h
parameter	**unit**	**pretens.**	**st. dev.**	**mean**	**st. dev.**	**mean**	**st. dev.**	**mean**	**st. dev.**	
surge	m		0.017	-0.003	0.004	-0.047	0.011	0.044	0.005	
sway	m		0.006	0.055	0.000	-0.014	0.001	0.016	0.001	
heave	m		0.013							
roll	deg		0.071							
pitch	deg		0.031							
yaw	deg		0.020	0.012	0.000	-0.056	0.010	0.059	0.011	
mooring leg 1	ton	18	1.50	14.92	0.05	-4.17	0.73	4.55	0.92	6.14
mooring leg 2	ton	18	1.47	14.57	0.05	-4.08	0.71	4.47	0.91	6.04
mooring leg 3	ton	25	1.97	20.92	0.01	-5.63	0.89	5.92	1.09	7.82
mooring leg 4	ton	26	1.76	21.59	0.03	-5.01	0.81	5.33	0.99	7.08
mooring leg 5	ton	28	1.86	23.12	0.06	-5.36	0.81	5.45	0.90	7.06
mooring leg 6	ton	15	0.87	14.32	0.15	-2.57	0.43	2.57	0.32	3.30
mooring leg 7	ton	8	0.73	8.29	0.13	-2.15	0.35	2.22	0.28	2.85
mooring leg 8	ton	12	0.68	11.21	0.12	-1.99	0.35	2.01	0.26	2.59
mooring leg 9	ton	21	0.86	20.77	0.15	-2.33	0.30	2.67	0.47	3.73
mooring leg 10	ton	16	0.98	15.96	0.16	-2.67	0.37	3.10	0.54	4.33
mooring leg 11	ton	11	0.84	10.89	0.14	-2.25	0.32	2.66	0.47	3.72
mooring leg 12	ton	20	1.88	18.22	0.07	-5.03	0.84	5.82	1.17	7.66
mooring leg 13	ton	17	1.60	15.39	0.03	-4.29	0.73	4.76	1.02	6.49
mooring leg 14	ton	24	1.86	22.15	0.03	-5.06	0.87	5.54	1.17	7.50
mooring leg 15	ton	25	1.41	23.24	0.08	-3.82	0.78	4.02	0.82	5.54
mooring leg 16	ton	18	1.35	17.01	0.07	-3.64	0.72	3.91	0.79	5.37
fender 1	ton		11.24	22.30	0.12	-22.30	0.12	31.84	4.18	
fender 2	ton		6.35	25.40	0.10	-18.48	3.94	18.14	2.93	
fender 3	ton		3.48	27.55	0.05	-9.84	1.82	10.50	1.81	
fender 4	ton		3.32	29.70	0.02	-8.58	0.50	8.98	0.56	
fender 5	ton		6.10	31.85	0.07	-16.68	2.17	16.70	2.19	
fender 6	ton		11.09	34.99	0.11	-31.20	4.30	27.85	3.28	

TERMSIM simulation

No.: 4a-6
date: 21-7-1996
jetty: LNG jetty Withnell Bay
ship: Northwest

wave spectrum: 4a
sign. wave height swell: 0.24 m.
wave direction: 166 & 200 deg
wind speed: -

parameter	unit	pretens.	st. dev.	averages per 10 min. mean	averages per 10 min. st. dev.	minima per 10 min. mean	minima per 10 min. st. dev.	maxima per 10 min. mean	maxima per 10 min. st. dev.	max per 3 h
surge	m		0.017	-0.004	0.004	-0.049	0.020	0.045	0.008	
sway	m		0.009	0.055	0.000	-0.028	0.007	0.026	0.003	
heave	m		0.014	0.004	0.000	-0.040	0.006	0.043	0.006	
roll	deg		0.113	-0.172	0.001	-0.302	0.050	0.315	0.044	
pitch	deg		0.032	-0.001	0.000	-0.088	0.019	0.091	0.016	
yaw	deg		0.034	0.012	0.000	-0.092	0.016	0.098	0.020	
mooring leg 1	ton	18	2.48	14.93	0.07	-6.67	0.97	7.53	1.30	11.20
mooring leg 2	ton	18	2.43	14.58	0.07	-6.53	0.93	7.40	1.28	11.00
mooring leg 3	ton	25	3.29	20.92	0.02	-8.84	1.42	9.85	1.76	14.75
mooring leg 4	ton	26	2.94	21.60	0.05	-7.96	1.21	8.82	1.53	13.12
mooring leg 5	ton	28	3.09	23.10	0.06	-8.47	1.39	9.07	1.62	13.49
mooring leg 6	ton	15	1.14	14.27	0.18	-3.50	0.93	3.08	0.26	3.66
mooring leg 7	ton	8	0.96	8.24	0.15	-2.89	0.74	2.64	0.22	3.12
mooring leg 8	ton	12	0.85	11.17	0.15	-2.57	0.77	2.30	0.16	2.67
mooring leg 9	ton	21	1.08	20.84	0.18	-2.69	0.27	3.52	1.06	5.90
mooring leg 10	ton	16	1.32	16.04	0.19	-3.26	0.42	4.35	1.23	7.12
mooring leg 11	ton	11	1.13	10.96	0.16	-2.78	0.36	3.75	1.06	6.15
mooring leg 12	ton	20	3.18	18.34	0.08	-8.14	1.33	9.89	2.45	15.30
mooring leg 13	ton	17	2.73	15.47	0.05	-6.99	1.26	8.39	1.90	12.84
mooring leg 14	ton	24	3.19	22.24	0.05	-8.31	1.53	9.68	2.17	14.75
mooring leg 15	ton	25	2.37	23.27	0.11	-6.37	1.22	7.00	1.37	10.41
mooring leg 16	ton	18	2.28	17.05	0.09	-6.03	1.15	6.81	1.37	10.20
fender 1	ton		16.86	22.97	0.34	-22.97	0.34	49.86	6.62	
fender 2	ton		10.75	25.22	0.08	-25.15	0.19	32.11	3.88	
fender 3	ton		6.11	27.42	0.06	-18.35	3.23	18.60	3.08	
fender 4	ton		5.63	29.67	0.05	-17.94	5.06	14.52	2.29	
fender 5	ton		10.05	31.91	0.09	-28.18	3.89	25.87	3.16	
fender 6	ton		17.25	34.98	0.10	-34.98	0.10	43.25	6.67	

TERMSIM simulation

No.: 4a-7
date: 21-7-1996
jetty: LNG jetty Withnell Bay
ship: Northwest

wave spectrum: 4a
sign. wave height swell: 0.24 m.
wave direction: 161 & 205 deg
wind speed: -

parameter	unit	pretens.	st. dev.	averages per 10 min. mean	averages per 10 min. st. dev.	minima per 10 min. mean	minima per 10 min. st. dev.	maxima per 10 min. mean	maxima per 10 min. st. dev.	max per 3 h
surge	m		0.019	-0.005	0.005	-0.065	0.032	0.056	0.024	
sway	m		0.016	0.054	0.000	-0.046	0.010	0.040	0.006	
heave	m		0.015	0.004	0.000	-0.043	0.008	0.044	0.008	
roll	deg		0.208	-0.173	0.001	-0.456	0.105	0.470	0.110	
pitch	deg		0.032	-0.001	0.000	-0.090	0.019	0.090	0.019	
yaw	deg		0.050	0.013	0.001	-0.134	0.025	0.139	0.027	
mooring leg 1	ton	18	3.80	14.98	0.08	-9.39	1.57	10.96	1.89	16.65
mooring leg 2	ton	18	3.73	14.63	0.09	-9.19	1.55	10.76	1.87	16.37
mooring leg 3	ton	25	5.05	20.97	0.05	-12.36	1.76	14.66	2.30	22.26
mooring leg 4	ton	26	4.53	21.65	0.06	-11.27	1.75	13.01	2.13	19.77
mooring leg 5	ton	28	4.75	23.12	0.08	-11.75	1.50	13.75	1.97	20.74
mooring leg 6	ton	15	1.58	14.23	0.21	-4.45	1.12	4.89	1.12	7.43
mooring leg 7	ton	8	1.33	8.21	0.18	-3.65	0.89	4.21	1.01	6.48
mooring leg 8	ton	12	1.13	11.14	0.18	-3.30	1.01	3.52	0.92	5.60
mooring leg 9	ton	21	1.45	20.91	0.22	-4.07	1.17	4.48	1.35	7.52
mooring leg 10	ton	16	1.81	16.13	0.23	-4.93	1.27	5.53	1.47	8.85
mooring leg 11	ton	11	1.56	11.04	0.19	-4.18	1.06	4.79	1.28	7.67
mooring leg 12	ton	20	4.70	18.53	0.12	-11.25	2.10	14.11	3.14	20.84
mooring leg 13	ton	17	4.08	15.62	0.10	-9.52	1.65	12.30	3.31	18.78
mooring leg 14	ton	24	4.75	22.39	0.10	-11.44	2.07	14.06	3.67	21.28
mooring leg 15	ton	25	3.54	23.35	0.13	-8.63	1.58	10.37	3.00	15.81
mooring leg 16	ton	18	3.41	17.14	0.12	-8.14	1.45	10.13	2.94	15.49
fender 1	ton		22.45	24.34	0.56	-24.34	0.56	63.61	9.38	
fender 2	ton		15.82	25.09	0.13	-25.09	0.13	42.22	6.53	
fender 3	ton		10.47	27.04	0.21	-26.03	2.46	28.01	4.55	
fender 4	ton		8.97	29.42	0.16	-25.35	4.16	21.76	2.67	
fender 5	ton		14.07	31.78	0.14	-31.23	1.28	32.91	4.96	
fender 6	ton		22.60	35.32	0.30	-35.32	0.30	55.89	7.64	

TERMSIM simulation

No.:	4a-8	wave spectrum:	4a
date:	21-7-1996	sign. wave height swell:	0.22 m.
jetty:	LNG jetty Withnell Bay	wave direction:	198 deg
ship:	Northwest	wind speed:	-

parameter	unit	pretens.	st. dev.	averages per 10 min. mean	averages per 10 min. st. dev.	minima per 10 min. mean	minima per 10 min. st. dev.	maxima per 10 min. mean	maxima per 10 min. st. dev.	max per 3 h
surge	m		0.016	-0.005	0.003	-0.048	0.013	0.037	0.005	
sway	m		0.010	0.054	0.000	-0.032	0.010	0.028	0.004	
heave	m		0.013	0.004	0.000	-0.035	0.004	0.036	0.005	
roll	deg		0.074	-0.158	0.001	-0.211	0.033	0.206	0.037	
pitch	deg		0.029	-0.001	0.000	-0.076	0.010	0.079	0.013	
yaw	deg		0.033	0.012	0.000	-0.096	0.023	0.096	0.024	
mooring leg 1	ton	18	2.39	14.76	0.05	-6.28	1.44	7.35	2.05	11.39
mooring leg 2	ton	18	2.34	14.41	0.05	-6.15	1.41	7.20	2.01	11.17
mooring leg 3	ton	25	3.22	20.67	0.03	-8.52	1.94	9.91	2.67	15.22
mooring leg 4	ton	26	2.85	21.36	0.03	-7.57	1.76	8.70	2.41	13.44
mooring leg 5	ton	28	3.06	22.82	0.05	-8.22	1.90	9.32	2.44	14.16
mooring leg 6	ton	15	1.19	14.20	0.14	-3.57	0.96	3.35	0.62	4.76
mooring leg 7	ton	8	1.00	8.19	0.12	-2.93	0.77	2.87	0.53	4.07
mooring leg 8	ton	12	0.89	11.13	0.11	-2.69	0.77	2.45	0.40	3.36
mooring leg 9	ton	21	1.17	20.84	0.14	-3.01	0.48	3.74	1.10	6.22
mooring leg 10	ton	16	1.43	16.03	0.15	-3.69	0.64	4.61	1.37	7.70
mooring leg 11	ton	11	1.22	10.94	0.13	-3.13	0.53	3.99	1.19	6.68
mooring leg 12	ton	20	3.19	18.08	0.09	-8.34	1.65	9.90	2.73	15.24
mooring leg 13	ton	17	2.63	15.21	0.05	-6.91	1.46	7.98	2.07	12.14
mooring leg 14	ton	24	3.08	21.94	0.05	-8.26	1.79	9.26	2.37	14.01
mooring leg 15	ton	25	2.21	23.05	0.07	-6.11	1.41	6.42	1.58	9.62
mooring leg 16	ton	18	2.13	16.84	0.07	-5.79	1.30	6.29	1.57	9.46
fender 1	ton		16.14	22.40	0.41	-22.40	0.41	46.74	8.68	
fender 2	ton		10.06	24.67	0.14	-24.25	1.08	29.03	5.38	
fender 3	ton		5.76	26.87	0.13	-16.74	4.41	16.72	2.65	
fender 4	ton		6.11	29.13	0.09	-19.42	4.29	17.33	2.64	
fender 5	ton		10.66	31.38	0.08	-28.56	3.37	28.51	4.87	
fender 6	ton		17.54	34.58	0.22	-34.58	0.22	44.64	8.90	

TERMSIM simulation

No.:	4b-1	wave spectrum:	4b
date:	22-7-1996	sign. wave height swell:	0.27 m.
jetty:	LNG jetty Whitnell Bay	wave direction:	189 deg
ship:	Northwest	wind speed:	-

				averages per 10 min.		minima per 10 min.		maxima per 10 min.		max per 3 h
parameter	**unit**	**pretens.**	**st. dev.**	**mean**	**st. dev.**	**mean**	**st. dev.**	**mean**	**st. dev.**	
surge	m		0.008	-0.004	0.003	-0.026	0.010	0.018	0.005	
sway	m		0.005	0.032	0.000	-0.015	0.002	0.014	0.002	
heave	m		0.014	0.002	0.000	-0.038	0.006	0.039	0.005	
roll	deg		0.033	-0.211	0.000	-0.092	0.011	0.095	0.011	
pitch	deg		0.027	0.000	0.000	-0.075	0.008	0.076	0.008	
yaw	deg		0.015	-0.006	0.000	-0.040	0.006	0.039	0.005	
mooring leg 1	ton	14	1.37	11.85	0.04	-3.63	0.53	3.65	0.52	4.98
mooring leg 2	ton	10	1.35	8.60	0.05	-3.59	0.51	3.63	0.52	4.95
mooring leg 3	ton	12	1.59	9.40	0.02	-4.09	0.50	4.22	0.63	5.82
mooring leg 4	ton	9	1.43	6.77	0.03	-3.71	0.38	3.82	0.56	5.24
mooring leg 5	ton	12	1.41	9.97	0.04	-3.75	0.42	3.72	0.56	5.14
mooring leg 6	ton	5	0.51	4.81	0.11	-1.61	0.39	1.36	0.31	2.07
mooring leg 7	ton	3	0.38	2.78	0.08	-1.05	0.26	1.23	0.29	1.87
mooring leg 8	ton	12	0.45	11.73	0.11	-1.51	0.42	1.17	0.28	1.79
mooring leg 9	ton	14	0.48	13.92	0.11	-1.25	0.30	1.57	0.40	2.47
mooring leg 10	ton	6	0.63	5.81	0.13	-1.64	0.38	2.06	0.48	3.15
mooring leg 11	ton	13	0.62	12.76	0.12	-1.62	0.38	2.01	0.47	3.07
mooring leg 12	ton	9	1.47	5.96	0.06	-3.49	0.43	3.95	0.47	5.35
mooring leg 13	ton	14	1.39	11.51	0.03	-3.72	0.53	3.71	0.58	5.00
mooring leg 14	ton	13	1.43	10.37	0.03	-3.84	0.55	3.83	0.59	5.15
mooring leg 15	ton	16	1.08	13.90	0.06	-2.91	0.40	2.94	0.54	4.03
mooring leg 16	ton	16	1.13	13.22	0.06	-3.06	0.42	3.09	0.55	4.22
fender 1	ton		9.69	20.17	0.12	-20.17	0.12	26.85	3.80	
fender 2	ton		5.96	18.50	0.08	-16.63	1.49	16.78	2.58	
fender 3	ton		3.60	17.45	0.06	-11.00	1.29	10.44	1.48	
fender 4	ton		2.39	16.40	0.04	-7.39	0.99	7.08	0.82	
fender 5	ton		3.72	15.35	0.05	-10.88	1.45	10.21	1.29	
fender 6	ton		7.15	13.88	0.14	-13.88	0.14	20.45	1.53	

TERMSIM simulation

No.: 4b-2
date: 22-7-1996
jetty: LNG jetty Whitnell Bay
ship: Northwest

wave spectrum: 4b
sign. wave height swell: 0.27 m.
wave direction: 197 deg
wind speed: -

parameter	unit	pretens.	st. dev.	averages per 10 min. mean	averages per 10 min. st. dev.	minima per 10 min. mean	minima per 10 min. st. dev.	maxima per 10 min. mean	maxima per 10 min. st. dev.	max per 3 h
surge	m		0.010	-0.008	0.003	-0.038	0.013	0.022	0.007	
sway	m		0.011	0.030	0.001	-0.038	0.006	0.031	0.004	
heave	m		0.014	0.002	0.000	-0.039	0.006	0.040	0.004	
roll	deg		0.067	-0.212	0.001	-0.193	0.024	0.200	0.025	
pitch	deg		0.029	0.000	0.000	-0.081	0.009	0.082	0.008	
yaw	deg		0.031	-0.005	0.000	-0.083	0.014	0.086	0.011	
mooring leg 1	ton	14	2.74	11.92	0.05	-7.28	1.05	7.27	1.15	9.98
mooring leg 2	ton	10	2.67	8.69	0.06	-6.50	0.77	7.17	1.12	9.80
mooring leg 3	ton	12	3.21	9.44	0.04	-8.03	0.79	8.71	1.32	11.99
mooring leg 4	ton	9	2.78	6.88	0.07	-5.90	0.52	7.66	1.14	10.46
mooring leg 5	ton	12	2.91	9.95	0.06	-7.75	0.93	7.84	1.16	10.81
mooring leg 6	ton	5	0.96	4.67	0.13	-3.26	0.59	2.66	0.53	3.85
mooring leg 7	ton	3	0.72	2.74	0.09	-2.12	0.35	2.44	0.52	3.60
mooring leg 8	ton	12	0.81	11.58	0.13	-2.99	0.61	2.11	0.44	3.10
mooring leg 9	ton	14	0.88	14.08	0.13	-2.30	0.47	3.18	0.64	4.62
mooring leg 10	ton	6	1.21	5.99	0.15	-3.19	0.62	4.32	0.80	6.12
mooring leg 11	ton	13	1.20	12.93	0.15	-3.16	0.62	4.23	0.78	5.98
mooring leg 12	ton	9	2.91	6.20	0.16	-5.81	0.43	9.16	1.30	12.95
mooring leg 13	ton	14	2.89	11.55	0.05	-7.75	1.22	8.22	1.22	11.67
mooring leg 14	ton	13	2.99	10.41	0.06	-7.88	0.98	8.52	1.24	12.07
mooring leg 15	ton	16	2.20	13.87	0.06	-5.91	1.01	6.23	1.01	8.70
mooring leg 16	ton	16	2.32	13.20	0.06	-6.24	1.07	6.56	1.05	9.17
fender 1	ton		17.02	21.13	0.66	-21.13	0.66	49.63	5.70	
fender 2	ton		11.54	18.42	0.14	-18.42	0.14	35.64	4.04	
fender 3	ton		7.66	16.95	0.26	-16.95	0.26	23.39	2.92	
fender 4	ton		5.30	15.83	0.37	-15.67	0.57	14.50	1.63	
fender 5	ton		7.27	14.98	0.25	-14.98	0.25	19.21	2.85	
fender 6	ton		12.43	14.91	0.56	-14.91	0.56	36.94	1.92	

TERMSIM simulation

No.: 4b-3
date: 22-7-1996
jetty: LNG jetty Whitnell Bay
ship: Northwest

wave spectrum: 4b
sign. wave height swell: 0.27 m.
wave direction: 197 deg
wind speed: -

parameter	unit	pretens.	st. dev.	averages per 10 min. mean	averages per 10 min. st. dev.	minima per 10 min. mean	minima per 10 min. st. dev.	maxima per 10 min. mean	maxima per 10 min. st. dev.	max per 3 h
surge	m		0.012	-0.007	0.005	-0.038	0.013	0.024	0.008	
sway	m		0.012	0.032	0.001	-0.045	0.007	0.033	0.004	
heave	m		0.014	0.002	0.000	-0.039	0.006	0.040	0.004	
roll	deg		0.062	-0.224	0.001	-0.184	0.023	0.185	0.025	
pitch	deg		0.029	0.000	0.000	-0.080	0.009	0.081	0.008	
yaw	deg		0.032	-0.005	0.001	-0.086	0.010	0.087	0.009	
mooring leg 1	ton	14	2.35	12.24	0.08	-5.66	0.69	6.66	0.75	8.72
mooring leg 2	ton	10	2.13	9.13	0.08	-5.02	0.60	6.13	0.70	8.05
mooring leg 3	ton	12	2.55	10.04	0.05	-5.99	0.61	7.41	0.84	9.86
mooring leg 4	ton	9	2.08	7.57	0.06	-4.81	0.54	6.07	0.69	8.04
mooring leg 5	ton	12	2.30	10.59	0.06	-5.53	0.49	6.64	0.75	8.83
mooring leg 6	ton	5	0.65	4.92	0.14	-2.10	0.35	1.89	0.31	2.59
mooring leg 7	ton	3	0.54	2.76	0.11	-1.73	0.27	1.62	0.27	2.22
mooring leg 8	ton	12	0.66	11.76	0.17	-2.29	0.46	1.86	0.33	2.60
mooring leg 9	ton	14	0.77	14.13	0.19	-2.00	0.33	2.84	0.56	4.10
mooring leg 10	ton	6	0.78	6.17	0.16	-1.97	0.32	2.92	0.52	4.10
mooring leg 11	ton	13	0.99	13.05	0.20	-2.58	0.41	3.61	0.64	5.05
mooring leg 12	ton	9	2.12	7.01	0.12	-5.01	0.53	6.82	0.80	9.65
mooring leg 13	ton	14	2.36	12.08	0.05	-5.88	0.67	7.12	0.96	9.84
mooring leg 14	ton	13	2.36	11.03	0.06	-5.83	0.65	7.16	0.96	9.94
mooring leg 15	ton	16	1.92	14.18	0.08	-4.91	0.54	5.62	0.84	7.68
mooring leg 16	ton	16	2.01	13.53	0.07	-5.11	0.56	5.88	0.87	8.02
fender 1	ton		17.02	21.75	0.51	-21.75	0.51	47.95	4.44	
fender 2	ton		11.39	19.14	0.13	-19.14	0.13	33.99	3.58	
fender 3	ton		7.69	17.75	0.27	-17.75	0.27	22.10	2.78	
fender 4	ton		6.32	16.66	0.30	-16.66	0.30	16.57	1.88	
fender 5	ton		8.78	15.89	0.17	-15.89	0.17	22.52	2.87	
fender 6	ton		13.83	16.02	0.69	-16.02	0.69	39.35	1.72	

TERMSIM simulation

No.:	4b-4	wave spectrum:	4b
date:	22-7-1996	sign. wave height swell:	0.27 m.
jetty:	LNG jetty Withnell Bay	wave direction:	184 & 194 deg
ship:	Northwest	wind speed:	-

				averages per 10 min.		minima per 10 min.		maxima per 10 min.		max per 3 h
parameter	**unit**	**pretens.**	**st. dev.**	**mean**	**st. dev.**	**mean**	**st. dev.**	**mean**	**st. dev.**	
surge	m		0.011	-0.004	0.004	-0.031	0.011	0.032	0.012	
sway	m		0.008	0.033	0.000	-0.027	0.007	0.022	0.004	
heave	m		0.014	0.002	0.000	-0.040	0.006	0.038	0.005	
roll	deg		0.055	-0.222	0.001	-0.148	0.029	0.150	0.033	
pitch	deg		0.029	-0.001	0.000	-0.081	0.014	0.084	0.015	
yaw	deg		0.021	-0.006	0.000	-0.062	0.012	0.061	0.011	
mooring leg 1	ton	14	1.54	12.15	0.05	-4.28	0.80	4.74	1.09	6.58
mooring leg 2	ton	10	1.40	9.04	0.05	-3.82	0.70	4.35	1.01	6.05
mooring leg 3	ton	12	1.67	9.98	0.02	-4.47	0.81	5.24	1.20	7.27
mooring leg 4	ton	9	1.36	7.50	0.03	-3.64	0.67	4.28	1.01	5.98
mooring leg 5	ton	12	1.51	10.59	0.05	-4.08	0.74	4.80	1.18	6.86
mooring leg 6	ton	5	0.48	5.02	0.10	-1.43	0.40	1.67	0.62	3.07
mooring leg 7	ton	3	0.40	2.84	0.09	-1.19	0.33	1.45	0.54	2.67
mooring leg 8	ton	12	0.51	11.88	0.12	-1.57	0.47	1.74	0.64	3.19
mooring leg 9	ton	14	0.58	13.98	0.13	-1.82	0.63	1.89	0.58	3.21
mooring leg 10	ton	6	0.55	6.04	0.11	-1.71	0.55	1.89	0.56	3.16
mooring leg 11	ton	13	0.71	12.88	0.14	-2.24	0.73	2.34	0.68	3.89
mooring leg 12	ton	9	1.36	6.88	0.05	-3.73	0.66	4.34	0.94	6.00
mooring leg 13	ton	14	1.51	12.04	0.03	-4.19	0.68	4.74	0.89	6.40
mooring leg 14	ton	13	1.51	10.98	0.03	-4.17	0.67	4.76	0.90	6.44
mooring leg 15	ton	16	1.22	14.21	0.07	-3.51	0.58	3.87	0.71	5.19
mooring leg 16	ton	16	1.29	13.55	0.07	-3.66	0.60	4.05	0.74	5.43
fender 1	ton		12.06	21.13	0.19	-21.13	0.19	36.35	5.05	
fender 2	ton		7.38	19.23	0.10	-18.73	0.99	22.68	4.06	
fender 3	ton		4.67	18.14	0.11	-15.36	2.67	14.17	3.20	
fender 4	ton		4.24	17.08	0.12	-14.03	2.74	11.88	1.80	
fender 5	ton		6.52	16.07	0.10	-15.98	0.27	17.65	2.68	
fender 6	ton		10.51	15.16	0.26	-15.16	0.26	32.52	5.03	

TERMSIM simulation

No.: 4b-5
date: 22-7-1996
jetty: LNG jetty Withnell Bay
ship: Northwest

wave spectrum: 4b
sign. wave height swell: 0.27 m.
wave direction: 179 & 199 deg
wind speed: -

parameter	unit	pretens.	st. dev.	averages per 10 min. mean	averages per 10 min. st. dev.	minima per 10 min. mean	minima per 10 min. st. dev.	maxima per 10 min. mean	maxima per 10 min. st. dev.	max per 3 h
surge	m		0.012	-0.004	0.003	-0.038	0.012	0.039	0.013	
sway	m		0.012	0.032	0.001	-0.048	0.010	0.032	0.005	
heave	m		0.014	0.002	0.000	-0.041	0.007	0.040	0.006	
roll	deg		0.080	-0.223	0.001	-0.223	0.048	0.224	0.052	
pitch	deg		0.030	-0.001	0.000	-0.084	0.014	0.086	0.016	
yaw	deg		0.028	-0.006	0.000	-0.083	0.014	0.083	0.014	
mooring leg 1	ton	14	2.09	12.21	0.06	-5.68	0.98	6.24	1.26	8.30
mooring leg 2	ton	10	1.89	9.10	0.06	-5.04	0.85	5.73	1.17	7.65
mooring leg 3	ton	12	2.28	10.04	0.04	-5.78	0.91	7.13	1.51	9.61
mooring leg 4	ton	9	1.85	7.56	0.05	-4.72	0.77	5.75	1.21	7.73
mooring leg 5	ton	12	2.07	10.63	0.05	-5.18	0.84	6.57	1.43	8.95
mooring leg 6	ton	5	0.63	5.01	0.10	-1.95	0.34	2.23	0.56	3.50
mooring leg 7	ton	3	0.53	2.84	0.08	-1.61	0.26	1.93	0.49	3.04
mooring leg 8	ton	12	0.66	11.87	0.12	-2.14	0.42	2.25	0.61	3.61
mooring leg 9	ton	14	0.73	14.01	0.13	-2.34	0.60	2.61	0.51	3.76
mooring leg 10	ton	6	0.72	6.07	0.11	-2.25	0.51	2.64	0.52	3.82
mooring leg 11	ton	13	0.92	12.92	0.14	-2.95	0.66	3.26	0.64	4.71
mooring leg 12	ton	9	1.85	6.93	0.06	-4.87	0.62	6.34	1.41	8.79
mooring leg 13	ton	14	2.06	12.07	0.03	-5.50	0.85	6.84	1.33	9.18
mooring leg 14	ton	13	2.06	11.01	0.03	-5.47	0.83	6.84	1.35	9.21
mooring leg 15	ton	16	1.67	14.21	0.07	-4.48	0.77	5.77	1.08	7.70
mooring leg 16	ton	16	1.75	13.56	0.06	-4.68	0.79	6.00	1.12	7.99
fender 1	ton		15.28	21.52	0.27	-21.52	0.27	44.83	5.82	
fender 2	ton		9.85	19.13	0.14	-19.13	0.14	30.23	4.98	
fender 3	ton		6.71	17.87	0.21	-17.70	0.49	20.28	3.95	
fender 4	ton		6.35	16.79	0.21	-16.79	0.21	16.91	2.35	
fender 5	ton		8.92	15.98	0.10	-15.98	0.10	24.56	3.02	
fender 6	ton		13.47	15.87	0.39	-15.87	0.39	41.46	3.57	

TERMSIM simulation

No.: 4b-6
date: 22-7-1996
jetty: LNG jetty Withnell Bay
ship: Northwest

wave spectrum: 4b
sign. wave height swell: 0.27 m.
wave direction: 161 & 205 deg
wind speed: -

				averages per 10 min.		minima per 10 min.		maxima per 10 min.		max per 3 h
parameter	**unit**	**pretens.**	**st. dev.**	**mean**	**st. dev.**	**mean**	**st. dev.**	**mean**	**st. dev.**	
surge	m		0.018	-0.005	0.007	-0.046	0.013	0.041	0.015	
sway	m		0.019	0.030	0.001	-0.077	0.017	0.047	0.007	
heave	m		0.015	0.002	0.000	-0.044	0.004	0.043	0.005	
roll	deg		0.115	-0.226	0.001	-0.364	0.061	0.345	0.058	
pitch	deg		0.034	0.000	0.000	-0.090	0.013	0.089	0.012	
yaw	deg		0.039	-0.006	0.001	-0.116	0.016	0.114	0.011	
mooring leg 1	ton	14	2.88	12.31	0.07	-7.02	0.85	8.96	1.05	10.96
mooring leg 2	ton	10	2.62	9.20	0.07	-6.19	0.73	8.27	0.97	10.12
mooring leg 3	ton	12	3.15	10.17	0.09	-7.22	0.78	10.23	1.32	12.71
mooring leg 4	ton	9	2.57	7.68	0.07	-5.83	0.64	8.31	1.03	10.25
mooring leg 5	ton	12	2.87	10.75	0.14	-6.59	0.75	9.19	1.31	11.62
mooring leg 6	ton	5	0.90	5.02	0.20	-2.36	0.28	2.73	0.74	4.39
mooring leg 7	ton	3	0.76	2.85	0.18	-1.95	0.23	2.36	0.66	3.85
mooring leg 8	ton	12	0.94	11.86	0.24	-2.56	0.35	2.72	0.75	4.40
mooring leg 9	ton	14	1.03	14.05	0.25	-2.80	0.67	3.22	0.46	4.25
mooring leg 10	ton	6	1.02	6.12	0.21	-2.70	0.54	3.41	0.47	4.47
mooring leg 11	ton	13	1.30	12.97	0.26	-3.56	0.76	4.23	0.58	5.53
mooring leg 12	ton	9	2.62	7.07	0.10	-6.21	0.70	9.72	1.25	12.52
mooring leg 13	ton	14	2.92	12.18	0.10	-7.51	0.90	10.29	1.46	13.08
mooring leg 14	ton	13	2.92	11.13	0.09	-7.41	0.88	10.36	1.44	13.18
mooring leg 15	ton	16	2.37	14.28	0.15	-6.31	0.83	8.03	1.32	10.23
mooring leg 16	ton	16	2.49	13.63	0.14	-6.57	0.84	8.39	1.33	10.66
fender 1	ton		18.94	22.34	0.74	-22.34	0.74	56.57	6.06	
fender 2	ton		12.95	19.11	0.21	-19.11	0.21	40.42	3.48	
fender 3	ton		9.50	17.40	0.23	-17.40	0.23	30.10	3.43	
fender 4	ton		8.92	16.26	0.34	-16.26	0.34	23.85	3.14	
fender 5	ton		11.52	15.92	0.18	-15.92	0.18	32.07	4.14	
fender 6	ton		16.71	17.09	0.68	-17.09	0.68	47.67	4.33	

TERMSIM simulation

No.: 4b-7
date: 22-7-1996
jetty: LNG jetty Withnell Bay
ship: Northwest

wave spectrum: 4b
sign. wave height swell: 0.27 m.
wave direction: 169 & 209 deg
wind speed: -

parameter	unit	pretens.	st. dev.	averages per 10 min. mean	averages per 10 min. st. dev.	minima per 10 min. mean	minima per 10 min. st. dev.	maxima per 10 min. mean	maxima per 10 min. st. dev.	max per 3 h
surge	m		0.021	-0.004	0.006	-0.063	0.013	0.068	0.026	
sway	m		0.025	0.028	0.002	-0.098	0.014	0.056	0.006	
heave	m		0.015	0.002	0.000	-0.046	0.010	0.046	0.008	
roll	deg		0.147	-0.228	0.003	-0.407	0.087	0.402	0.088	
pitch	deg		0.033	-0.001	0.000	-0.093	0.016	0.095	0.017	
yaw	deg		0.049	-0.006	0.000	-0.133	0.021	0.140	0.022	
mooring leg 1	ton	14	3.55	12.40	0.08	-8.55	1.30	10.32	1.79	13.32
mooring leg 2	ton	10	3.22	9.29	0.08	-7.44	1.05	9.53	1.67	12.36
mooring leg 3	ton	12	3.90	10.31	0.09	-8.43	0.95	11.93	2.21	15.48
mooring leg 4	ton	9	3.17	7.79	0.08	-6.81	0.80	9.66	1.77	12.55
mooring leg 5	ton	12	3.55	10.88	0.13	-7.70	0.93	10.94	2.12	14.29
mooring leg 6	ton	5	1.11	5.07	0.18	-3.02	0.37	3.94	1.08	6.36
mooring leg 7	ton	3	0.94	2.90	0.15	-2.32	0.21	3.44	0.99	5.66
mooring leg 8	ton	12	1.15	11.91	0.21	-3.46	0.52	3.95	1.07	6.37
mooring leg 9	ton	14	1.27	14.03	0.21	-3.94	0.98	4.33	0.71	5.93
mooring leg 10	ton	6	1.27	6.12	0.18	-3.61	0.74	4.50	0.78	6.26
mooring leg 11	ton	13	1.62	12.97	0.22	-4.81	1.05	5.53	0.92	7.61
mooring leg 12	ton	9	3.37	7.22	0.12	-6.83	0.53	12.37	2.26	16.60
mooring leg 13	ton	14	3.76	12.34	0.13	-8.47	1.20	13.74	2.90	18.46
mooring leg 14	ton	13	3.76	11.29	0.13	-8.34	1.14	13.78	2.90	18.53
mooring leg 15	ton	16	3.05	14.40	0.15	-7.17	1.09	11.22	2.53	15.19
mooring leg 16	ton	16	3.19	13.75	0.15	-7.43	1.10	11.67	2.59	15.76
fender 1	ton		22.36	23.44	0.74	-23.44	0.74	66.96	8.21	
fender 2	ton		15.74	19.25	0.28	-19.25	0.28	48.05	5.89	
fender 3	ton		11.69	17.04	0.22	-17.04	0.22	35.82	4.28	
fender 4	ton		10.49	15.77	0.37	-15.77	0.37	27.29	2.33	
fender 5	ton		13.06	15.80	0.24	-15.80	0.24	35.44	3.59	
fender 6	ton		18.92	18.03	0.48	-18.03	0.48	51.99	4.32	

TERMSIM simulation

No.:	4b-8	wave spectrum:	4b
date:	22-7-1996	sign. wave height swell:	0.24 m.
jetty:	LNG jetty Withnell Bay	wave direction:	198 deg
ship:	Northwest	wind speed:	-

parameter	unit	pretens.	st. dev.	averages per 10 min. mean	averages per 10 min. st. dev.	minima per 10 min. mean	minima per 10 min. st. dev.	maxima per 10 min. mean	maxima per 10 min. st. dev.	max per 3 h
surge	m		0.015	-0.010	0.005	-0.043	0.013	0.040	0.012	
sway	m		0.016	0.033	0.001	-0.060	0.015	0.039	0.009	
heave	m		0.014	0.002	0.000	-0.038	0.005	0.039	0.005	
roll	deg		0.116	-0.230	0.001	-0.313	0.070	0.309	0.076	
pitch	deg		0.030	0.000	0.000	-0.081	0.012	0.084	0.015	
yaw	deg		0.036	-0.005	0.000	-0.098	0.017	0.099	0.019	
mooring leg 1	ton	14	2.56	12.18	0.09	-6.24	1.08	7.24	1.58	10.45
mooring leg 2	ton	10	2.32	9.08	0.09	-5.50	0.91	6.66	1.48	9.66
mooring leg 3	ton	12	2.80	9.97	0.07	-6.48	1.00	8.26	1.85	12.00
mooring leg 4	ton	9	2.27	7.52	0.07	-5.21	0.80	6.67	1.52	9.77
mooring leg 5	ton	12	2.54	10.51	0.08	-5.99	0.97	7.57	1.67	10.93
mooring leg 6	ton	5	0.79	4.90	0.14	-2.29	0.46	2.57	0.63	3.99
mooring leg 7	ton	3	0.64	2.74	0.12	-1.54	0.22	2.23	0.54	3.45
mooring leg 8	ton	12	0.83	11.71	0.17	-2.57	0.61	2.63	0.65	4.10
mooring leg 9	ton	14	0.96	14.18	0.18	-2.78	0.67	3.21	0.80	5.01
mooring leg 10	ton	6	0.96	6.23	0.16	-2.69	0.59	3.29	0.82	5.13
mooring leg 11	ton	13	1.21	13.10	0.20	-3.51	0.77	4.06	0.99	6.29
mooring leg 12	ton	9	2.36	7.05	0.09	-5.59	0.75	8.03	1.94	11.68
mooring leg 13	ton	14	2.58	12.08	0.06	-6.37	0.93	8.31	1.81	11.88
mooring leg 14	ton	13	2.58	11.03	0.06	-6.32	0.91	8.39	1.84	12.01
mooring leg 15	ton	16	2.06	14.16	0.10	-5.15	0.84	6.48	1.33	9.17
mooring leg 16	ton	16	2.16	13.51	0.09	-5.39	0.87	6.79	1.40	9.61
fender 1	ton		17.61	22.25	0.42	-22.25	0.42	49.74	7.56	
fender 2	ton		11.71	19.64	0.16	-19.64	0.16	34.61	5.21	
fender 3	ton		8.32	18.40	0.27	-18.24	0.54	24.31	4.81	
fender 4	ton		8.10	17.51	0.26	-17.51	0.26	21.24	4.04	
fender 5	ton		11.04	17.14	0.11	-17.14	0.11	29.86	3.81	
fender 6	ton		16.26	18.00	0.54	-18.00	0.54	45.92	4.90	

TERMSIM simulation

No.: 4c-1
date: 28-7-1996
jetty: LNG jetty Withnell Bay
ship: Northwest

wave spectrum: 5
sign. wave height swell: 0.24 m.
wave direction: 188 deg
wind speed: 2 m/s

				averages per 10 min.		minima per 10 min.		maxima per 10 min.		max per 3 h
parameter	**unit**	**pretens.**	**st. dev.**	**mean**	**st. dev.**	**mean**	**st. dev.**	**mean**	**st. dev.**	
surge	m		0.013	-0.006	0.003	-0.035	0.005	0.034	0.005	
sway	m		0.004	0.054	0.000	-0.012	0.003	0.011	0.002	
heave	m		0.011	0.005	0.000	-0.031	0.003	0.030	0.004	
roll	deg		0.040	-0.153	0.000	-0.114	0.028	0.113	0.023	
pitch	deg		0.026	-0.002	0.000	-0.076	0.010	0.081	0.013	
yaw	deg		0.015	0.027	0.000	-0.045	0.009	0.045	0.010	
mooring leg 1	ton	24	1.26	18.54	0.04	-3.81	0.73	3.72	0.82	5.18
mooring leg 2	ton	21	1.24	15.81	0.04	-3.75	0.72	3.62	0.79	5.05
mooring leg 3	ton	24	1.52	17.95	0.01	-4.62	0.97	4.61	0.94	6.34
mooring leg 4	ton	25	1.34	18.90	0.02	-4.06	0.81	4.03	0.85	5.59
mooring leg 5	ton	23	1.38	16.69	0.04	-4.23	0.90	4.23	0.78	5.74
mooring leg 6	ton	21	0.83	19.96	0.13	-2.36	0.44	2.46	0.40	3.35
mooring leg 7	ton	24	0.88	23.18	0.14	-2.52	0.46	2.63	0.42	3.58
mooring leg 8	ton	18	0.69	16.51	0.12	-1.97	0.36	2.04	0.31	2.74
mooring leg 9	ton	18	0.73	18.67	0.12	-2.15	0.34	2.12	0.38	2.98
mooring leg 10	ton	20	0.94	20.42	0.14	-2.81	0.46	2.78	0.52	3.96
mooring leg 11	ton	18	0.91	19.01	0.13	-2.72	0.45	2.67	0.50	3.80
mooring leg 12	ton	21	1.60	20.96	0.05	-4.82	0.91	4.94	1.15	6.96
mooring leg 13	ton	13	1.35	12.42	0.03	-3.95	0.84	4.00	0.87	5.57
mooring leg 14	ton	18	1.41	17.51	0.03	-4.13	0.87	4.24	0.93	5.92
mooring leg 15	ton	13	1.00	12.33	0.06	-2.80	0.67	2.91	0.57	3.96
mooring leg 16	ton	14	1.06	12.89	0.06	-2.98	0.71	3.09	0.61	4.22
fender 1	ton		7.87	12.98	0.18	-12.98	0.18	25.71	5.13	
fender 2	ton		4.49	20.19	0.07	-13.73	2.54	14.23	3.37	
fender 3	ton		2.41	25.18	0.04	-6.97	1.80	7.32	1.88	
fender 4	ton		2.59	30.18	0.02	-7.61	1.58	7.42	1.09	
fender 5	ton		4.80	35.18	0.04	-13.73	2.26	13.87	2.02	
fender 6	ton		8.41	42.50	0.11	-24.99	4.35	20.90	2.99	

TERMSIM simulation

No.:	4c-2	wave spectrum:	5
date:	28-7-1996	sign. wave height total:	0.24 m.
jetty:	LNG jetty Withnell Bay	wave direction:	178 & 198 deg
ship:	Northwest	wind speed:	2 m/s

parameter	unit	pretens.	st. dev.	averages per 10 min. mean	averages per 10 min. st. dev.	minima per 10 min. mean	minima per 10 min. st. dev.	maxima per 10 min. mean	maxima per 10 min. st. dev.	max per 3 h
surge	m		0.014	-0.006	0.002	-0.038	0.007	0.039	0.009	
sway	m		0.007	0.054	0.000	-0.022	0.006	0.019	0.005	
heave	m		0.011	0.005	0.000	-0.031	0.004	0.030	0.004	
roll	deg		0.067	-0.154	0.001	-0.189	0.042	0.194	0.038	
pitch	deg		0.028	-0.002	0.000	-0.072	0.008	0.074	0.009	
yaw	deg		0.026	0.027	0.000	-0.080	0.018	0.081	0.019	
mooring leg 1	ton	24	2.16	18.48	0.04	-6.61	1.64	6.43	1.40	8.89
mooring leg 2	ton	21	2.11	15.74	0.04	-6.52	1.62	6.26	1.36	8.65
mooring leg 3	ton	24	2.60	17.89	0.03	-7.90	1.88	7.93	1.75	10.93
mooring leg 4	ton	25	2.29	18.84	0.03	-6.97	1.67	6.91	1.52	9.55
mooring leg 5	ton	23	2.34	16.65	0.04	-7.09	1.58	7.20	1.59	9.94
mooring leg 6	ton	21	1.12	19.99	0.11	-3.30	0.37	3.59	1.04	5.92
mooring leg 7	ton	24	1.19	23.21	0.12	-3.50	0.39	3.83	1.12	6.35
mooring leg 8	ton	18	0.90	16.53	0.10	-2.60	0.30	2.85	0.83	4.73
mooring leg 9	ton	18	0.96	18.64	0.10	-3.02	0.84	2.87	0.38	3.73
mooring leg 10	ton	20	1.30	20.39	0.12	-4.07	1.09	4.01	0.56	5.28
mooring leg 11	ton	18	1.26	18.98	0.11	-3.97	1.06	3.87	0.55	5.11
mooring leg 12	ton	21	2.83	20.98	0.07	-8.54	2.02	9.23	2.20	13.07
mooring leg 13	ton	13	2.49	12.46	0.05	-7.54	1.65	7.76	2.02	11.12
mooring leg 14	ton	18	2.60	17.55	0.05	-7.82	1.73	8.24	2.17	11.85
mooring leg 15	ton	13	1.86	12.37	0.06	-5.55	1.14	5.74	1.56	8.28
mooring leg 16	ton	14	1.97	12.93	0.06	-5.89	1.21	6.08	1.64	8.77
fender 1	ton		12.49	14.47	0.53	-14.47	0.53	44.78	8.01	
fender 2	ton		8.27	20.31	0.16	-20.31	0.16	27.67	6.32	
fender 3	ton		4.63	25.29	0.15	-14.16	3.42	14.89	4.29	
fender 4	ton		4.33	30.36	0.09	-12.84	2.90	11.35	1.63	
fender 5	ton		7.95	35.42	0.09	-22.35	3.64	20.91	2.50	
fender 6	ton		13.67	42.36	0.13	-38.22	4.07	33.24	5.85	

TERMSIM simulation

No.:	4c-3	wave spectrum:	5
date:	28-7-1996	sign. wave height total:	0.24 m.
jetty:	LNG jetty Withnell Bay	wave direction:	188 deg
ship:	Northwest	wind speed:	2 m/s

parameter	unit	pretens.	st. dev.	averages per 10 min. mean	averages per 10 min. st. dev.	minima per 10 min. mean	minima per 10 min. st. dev.	maxima per 10 min. mean	maxima per 10 min. st. dev.	max per 3 h
surge	m		0.011	-0.007	0.003	-0.033	0.008	0.035	0.009	
sway	m		0.005	0.050	0.000	-0.014	0.002	0.014	0.002	
heave	m		0.013	0.006	0.000	-0.038	0.004	0.039	0.004	
roll	deg		0.076	-0.442	0.000	-0.200	0.039	0.202	0.046	
pitch	deg		0.032	-0.003	0.000	-0.091	0.014	0.096	0.016	
yaw	deg		0.012	0.024	0.000	-0.035	0.006	0.037	0.006	
mooring leg 1	ton	24	1.02	17.29	0.05	-3.06	0.56	2.99	0.76	4.32
mooring leg 2	ton	21	1.00	14.57	0.05	-3.03	0.55	2.93	0.75	4.24
mooring leg 3	ton	24	1.21	16.32	0.01	-3.56	0.74	3.65	0.80	5.09
mooring leg 4	ton	25	1.08	17.27	0.03	-3.18	0.63	3.24	0.75	4.59
mooring leg 5	ton	23	1.11	14.94	0.05	-3.26	0.72	3.42	0.70	4.64
mooring leg 6	ton	21	0.68	19.65	0.15	-2.17	0.47	2.31	0.49	3.41
mooring leg 7	ton	24	0.72	22.88	0.16	-2.31	0.50	2.46	0.53	3.66
mooring leg 8	ton	18	0.58	16.38	0.13	-1.81	0.40	1.91	0.44	2.90
mooring leg 9	ton	18	0.59	18.51	0.13	-2.01	0.43	1.89	0.39	2.76
mooring leg 10	ton	20	0.75	20.11	0.15	-2.58	0.51	2.41	0.49	3.51
mooring leg 11	ton	18	0.73	18.69	0.14	-2.50	0.49	2.31	0.47	3.36
mooring leg 12	ton	21	1.26	19.54	0.05	-3.96	0.64	4.03	0.65	5.32
mooring leg 13	ton	13	1.11	11.06	0.04	-3.17	0.45	3.61	0.62	4.76
mooring leg 14	ton	18	1.15	16.11	0.03	-3.28	0.46	3.76	0.64	4.97
mooring leg 15	ton	13	0.85	11.31	0.07	-2.40	0.41	2.76	0.54	3.71
mooring leg 16	ton	14	0.89	11.83	0.07	-2.53	0.42	2.91	0.57	3.90
fender 1	ton		7.11	12.80	0.11	-12.80	0.11	23.47	4.58	
fender 2	ton		4.57	19.25	0.07	-14.00	2.88	14.57	3.01	
fender 3	ton		3.03	23.66	0.06	-9.36	1.35	9.80	1.68	
fender 4	ton		2.61	28.08	0.05	-6.97	0.89	7.32	1.20	
fender 5	ton		3.70	32.50	0.06	-10.15	1.01	10.94	1.66	
fender 6	ton		6.41	39.11	0.09	-18.48	1.98	18.06	1.97	

TERMSIM simulation

No.: 4c-4
date: 28-7-1996
jetty: LNG jetty Withnell Bay
ship: Northwest

wave spectrum: 5
sign. wave height total: 0.24 m.
wave direction: 188 deg
wind speed: 2 m/s

				averages per 10 min.		minima per 10 min.		maxima per 10 min.		max per 3 h
parameter	**unit**	**pretens.**	**st. dev.**	**mean**	**st. dev.**	**mean**	**st. dev.**	**mean**	**st. dev.**	
surge	m		0.014	-0.009	0.004	-0.045	0.012	0.040	0.007	
sway	m		0.007	0.050	0.000	-0.019	0.003	0.019	0.003	
heave	m		0.015	0.006	0.000	-0.044	0.005	0.043	0.005	
roll	deg		0.089	-0.442	0.001	-0.230	0.040	0.234	0.038	
pitch	deg		0.035	-0.003	0.000	-0.100	0.017	0.107	0.017	
yaw	deg		0.014	0.024	0.000	-0.042	0.005	0.042	0.007	
mooring leg 1	ton	24	1.18	17.32	0.06	-3.59	0.54	3.36	0.66	4.49
mooring leg 2	ton	21	1.16	14.59	0.07	-3.55	0.53	3.28	0.65	4.39
mooring leg 3	ton	24	1.41	16.31	0.01	-4.18	0.82	4.11	0.82	5.49
mooring leg 4	ton	25	1.25	17.28	0.04	-3.74	0.64	3.58	0.75	4.85
mooring leg 5	ton	23	1.31	14.91	0.06	-3.84	0.95	3.94	0.70	5.16
mooring leg 6	ton	21	0.86	19.56	0.19	-2.82	0.76	2.67	0.42	3.62
mooring leg 7	ton	24	0.92	22.78	0.21	-3.01	0.81	2.86	0.45	3.88
mooring leg 8	ton	18	0.74	16.29	0.17	-2.38	0.64	2.25	0.38	3.10
mooring leg 9	ton	18	0.76	18.59	0.17	-2.36	0.35	2.48	0.62	3.88
mooring leg 10	ton	20	0.96	20.21	0.20	-3.01	0.43	3.15	0.74	4.83
mooring leg 11	ton	18	0.93	18.78	0.19	-2.92	0.42	3.02	0.70	4.61
mooring leg 12	ton	21	1.50	19.58	0.07	-4.67	0.57	4.58	0.72	5.93
mooring leg 13	ton	13	1.28	11.04	0.05	-3.71	0.47	3.92	0.54	5.04
mooring leg 14	ton	18	1.33	16.10	0.04	-3.88	0.49	4.10	0.57	5.27
mooring leg 15	ton	13	0.97	11.28	0.09	-2.68	0.38	2.97	0.44	3.86
mooring leg 16	ton	14	1.02	11.80	0.09	-2.82	0.41	3.14	0.46	4.07
fender 1	ton		7.79	12.83	0.15	-12.83	0.15	25.83	4.83	
fender 2	ton		5.10	19.19	0.08	-15.39	2.86	15.96	3.80	
fender 3	ton		3.66	23.63	0.07	-10.80	2.04	11.60	2.25	
fender 4	ton		3.72	28.08	0.07	-10.60	1.73	10.28	1.59	
fender 5	ton		5.24	32.53	0.09	-15.36	2.07	15.45	2.10	
fender 6	ton		8.39	39.14	0.15	-25.27	3.06	22.37	2.52	

TERMSIM simulation

No.:	4c-5	wave spectrum:	5
date:	28-7-1996	sign. wave height total:	0.24 m.
jetty:	LNG jetty Withnell Bay	wave direction:	182 & 194 deg
ship:	Northwest	wind speed:	2 m/s

parameter	unit	pretens.	st. dev.	averages per 10 min. mean	averages per 10 min. st. dev.	minima per 10 min. mean	minima per 10 min. st. dev.	maxima per 10 min. mean	maxima per 10 min. st. dev.	max per 3 h
surge	m		0.016	-0.009	0.003	-0.053	0.012	0.038	0.006	
sway	m		0.012	0.049	0.000	-0.035	0.006	0.035	0.006	
heave	m		0.016	0.006	0.000	-0.043	0.007	0.041	0.004	
roll	deg		0.161	-0.439	0.002	-0.433	0.074	0.440	0.074	
pitch	deg		0.037	-0.003	0.000	-0.096	0.012	0.094	0.010	
yaw	deg		0.024	0.025	0.001	-0.073	0.015	0.077	0.015	
mooring leg 1	ton	24	2.05	17.30	0.04	-5.94	1.38	6.34	1.69	9.11
mooring leg 2	ton	21	2.01	14.57	0.04	-5.86	1.35	6.20	1.64	8.90
mooring leg 3	ton	24	2.48	16.28	0.04	-7.37	1.85	7.48	2.07	10.81
mooring leg 4	ton	25	2.20	17.27	0.03	-6.45	1.55	6.77	1.84	9.74
mooring leg 5	ton	23	2.27	14.89	0.07	-6.91	1.79	6.73	1.77	9.60
mooring leg 6	ton	21	1.14	19.53	0.16	-4.15	0.88	3.03	0.55	4.27
mooring leg 7	ton	24	1.21	22.74	0.17	-4.39	0.92	3.23	0.58	4.54
mooring leg 8	ton	18	0.94	16.27	0.14	-3.38	0.73	2.46	0.40	3.37
mooring leg 9	ton	18	0.99	18.63	0.14	-2.58	0.43	3.64	0.82	5.49
mooring leg 10	ton	20	1.30	20.27	0.17	-3.42	0.60	4.88	1.09	7.34
mooring leg 11	ton	18	1.26	18.84	0.16	-3.33	0.58	4.70	1.04	7.05
mooring leg 12	ton	21	2.61	19.75	0.09	-7.76	1.33	9.24	1.81	12.72
mooring leg 13	ton	13	2.29	11.19	0.05	-7.06	1.38	7.26	1.43	9.81
mooring leg 14	ton	18	2.39	16.26	0.05	-7.31	1.41	7.69	1.53	10.43
mooring leg 15	ton	13	1.72	11.38	0.07	-5.42	1.08	5.19	1.02	7.04
mooring leg 16	ton	14	1.81	11.91	0.07	-5.71	1.13	5.51	1.08	7.46
fender 1	ton		12.34	13.74	0.47	-13.74	0.47	44.47	9.29	
fender 2	ton		9.50	18.62	0.20	-18.62	0.20	31.62	7.35	
fender 3	ton		7.05	22.98	0.21	-20.41	2.53	23.59	4.97	
fender 4	ton		6.24	27.59	0.15	-18.55	3.45	17.71	2.98	
fender 5	ton		8.18	32.22	0.08	-24.44	4.00	22.43	3.00	
fender 6	ton		12.88	38.84	0.10	-37.18	3.04	32.48	4.26	

TERMSIM simulation

No.:	4c-6	wave spectrum:	5
date:	28-7-1996	sign. wave height total:	0.22 m.
jetty:	LNG jetty Withnell Bay	wave direction:	198 deg
ship:	Northwest	wind speed:	2 m/s

				averages per 10 min.		minima per 10 min.		maxima per 10 min.		max per 3 h
parameter	**unit**	**pretens.**	**st. dev.**	**mean**	**st. dev.**	**mean**	**st. dev.**	**mean**	**st. dev.**	
surge	m		0.013	-0.008	0.002	-0.038	0.006	0.033	0.006	
sway	m		0.011	0.054	0.000	-0.032	0.008	0.028	0.005	
heave	m		0.011	0.005	0.000	-0.030	0.004	0.029	0.004	
roll	deg		0.104	-0.152	0.001	-0.299	0.058	0.301	0.059	
pitch	deg		0.026	-0.002	0.000	-0.070	0.011	0.074	0.014	
yaw	deg		0.037	0.028	0.001	-0.104	0.025	0.107	0.027	
mooring leg 1	ton	24	3.07	18.53	0.04	-8.65	2.19	8.85	2.30	13.68
mooring leg 2	ton	21	3.01	15.79	0.04	-8.50	2.09	8.61	2.22	13.27
mooring leg 3	ton	24	3.75	17.94	0.04	-10.56	2.52	10.97	2.87	16.99
mooring leg 4	ton	25	3.29	18.91	0.03	-9.27	2.34	9.60	2.51	14.83
mooring leg 5	ton	23	3.38	16.67	0.06	-9.61	2.18	9.89	2.55	15.23
mooring leg 6	ton	21	1.44	19.91	0.13	-4.27	0.97	4.17	0.91	6.22
mooring leg 7	ton	24	1.53	23.12	0.14	-4.51	1.01	4.44	0.97	6.63
mooring leg 8	ton	18	1.12	16.45	0.11	-3.33	0.74	3.18	0.66	4.66
mooring leg 9	ton	18	1.22	18.75	0.11	-3.37	0.69	3.65	0.83	5.52
mooring leg 10	ton	20	1.70	20.54	0.14	-4.69	0.98	5.12	1.23	7.89
mooring leg 11	ton	18	1.64	19.12	0.13	-4.57	0.96	4.95	1.18	7.61
mooring leg 12	ton	21	3.98	21.26	0.11	-10.93	2.54	12.07	3.24	18.82
mooring leg 13	ton	13	3.44	12.64	0.07	-9.37	1.66	10.06	2.59	15.45
mooring leg 14	ton	18	3.62	17.75	0.07	-9.97	2.27	10.73	2.83	16.63
mooring leg 15	ton	13	2.54	12.48	0.06	-7.03	1.56	7.33	1.80	11.11
mooring leg 16	ton	14	2.70	13.05	0.06	-7.45	1.64	7.79	1.92	11.82
fender 1	ton		16.08	15.86	0.77	-15.86	0.77	53.48	10.60	
fender 2	ton		11.47	20.22	0.17	-20.22	0.17	35.29	6.96	
fender 3	ton		7.00	25.07	0.25	-21.22	4.10	21.19	4.51	
fender 4	ton		6.13	30.33	0.18	-18.88	4.14	17.46	3.25	
fender 5	ton		10.74	35.50	0.14	-30.35	4.29	27.34	4.03	
fender 6	ton		18.08	42.34	0.18	-42.12	0.74	43.66	8.31	

TERMSIM simulation

No.:	4c-7	wave spectrum:	5
date:	28-7-1996	sign. wave height total:	0.22 m.
jetty:	LNG jetty Withnell Bay	wave direction:	198 deg
ship:	Northwest	wind speed:	2 m/s

				averages per 10 min.		minima per 10 min.		maxima per 10 min.		max per 3 h
parameter	**unit**	**pretens.**	**st. dev.**	**mean**	**st. dev.**	**mean**	**st. dev.**	**mean**	**st. dev.**	
surge	m		0.016	-0.010	0.004	-0.062	0.019	0.035	0.005	
sway	m		0.015	0.048	0.001	-0.045	0.012	0.042	0.008	
heave	m		0.015	0.006	0.000	-0.042	0.006	0.043	0.005	
roll	deg		0.155	-0.422	0.002	-0.425	0.076	0.417	0.071	
pitch	deg		0.034	-0.003	0.000	-0.095	0.015	0.094	0.015	
yaw	deg		0.034	0.026	0.001	-0.090	0.017	0.098	0.022	
mooring leg 1	ton	24	2.91	16.91	0.06	-7.53	1.44	8.10	1.77	11.82
mooring leg 2	ton	21	2.86	14.18	0.06	-7.41	1.41	7.92	1.73	11.56
mooring leg 3	ton	24	3.53	15.77	0.03	-9.52	1.85	9.61	2.02	13.94
mooring leg 4	ton	25	3.13	16.78	0.03	-8.23	1.61	8.69	1.88	12.73
mooring leg 5	ton	23	3.23	14.34	0.07	-9.00	1.81	8.56	1.75	12.33
mooring leg 6	ton	21	1.43	19.36	0.19	-5.27	1.52	3.45	0.44	4.44
mooring leg 7	ton	24	1.52	22.57	0.20	-5.56	1.58	3.67	0.47	4.72
mooring leg 8	ton	18	1.13	16.16	0.17	-4.29	1.23	2.71	0.35	3.50
mooring leg 9	ton	18	1.21	18.65	0.16	-2.89	0.35	4.60	1.34	7.62
mooring leg 10	ton	20	1.65	20.26	0.19	-3.98	0.46	6.19	1.84	10.33
mooring leg 11	ton	18	1.59	18.82	0.19	-3.88	0.44	5.95	1.75	9.90
mooring leg 12	ton	21	3.59	19.35	0.11	-9.54	1.47	11.73	3.13	17.90
mooring leg 13	ton	13	3.13	10.75	0.08	-8.35	1.13	9.31	2.14	13.67
mooring leg 14	ton	18	3.27	15.83	0.08	-8.96	1.68	9.90	2.35	14.66
mooring leg 15	ton	13	2.33	11.05	0.10	-6.54	1.41	6.52	1.31	9.25
mooring leg 16	ton	14	2.46	11.57	0.09	-6.90	1.47	6.94	1.43	9.91
fender 1	ton		15.59	14.83	0.74	-14.83	0.74	51.39	8.34	
fender 2	ton		12.19	18.20	0.19	-18.20	0.19	37.34	6.60	
fender 3	ton		9.04	22.27	0.24	-21.97	0.78	27.32	5.34	
fender 4	ton		7.74	26.94	0.25	-22.89	3.34	21.33	3.91	
fender 5	ton		10.43	31.69	0.18	-29.51	2.16	25.84	3.10	
fender 6	ton		16.76	38.25	0.14	-38.22	0.14	39.78	6.29	

TERMSIM simulation

No.: 4d-1
date: 2-8-1996
jetty: LNG jetty Withnell Bay
ship: Northwest

wave spectrum: 6a
sign. wave height swell: 0.31 m.
wave direction: 192 deg
wind speed: 5.6 m/s

parameter	unit	pretens.	st. dev.	averages per 10 min. mean	averages per 10 min. st. dev.	minima per 10 min. mean	minima per 10 min. st. dev.	maxima per 10 min. mean	maxima per 10 min. st. dev.	max per 3 h
surge	m		0.022	-0.009	0.003	-0.080	0.026	0.055	0.008	
sway	m		0.014	0.045	0.001	-0.043	0.013	0.040	0.007	
heave	m		0.020	0.006	0.000	-0.060	0.007	0.059	0.007	
roll	deg		0.148	-0.454	0.002	-0.406	0.060	0.398	0.056	
pitch	deg		0.048	-0.002	0.000	-0.136	0.024	0.145	0.022	
yaw	deg		0.036	0.040	0.001	-0.105	0.018	0.113	0.024	
mooring leg 1	ton	25	3.03	17.12	0.06	-8.66	1.72	8.70	1.86	11.94
mooring leg 2	ton	24	2.99	16.00	0.06	-8.56	1.64	8.57	1.84	11.77
mooring leg 3	ton	30	3.72	19.36	0.06	-10.75	2.50	10.73	2.60	15.14
mooring leg 4	ton	21	3.22	11.63	0.05	-8.85	1.31	9.10	2.04	12.61
mooring leg 5	ton	32	3.47	22.04	0.07	-10.28	2.78	10.17	2.67	14.60
mooring leg 6	ton	12	1.63	9.37	0.14	-6.10	1.76	4.87	0.93	6.96
mooring leg 7	ton	23	1.73	20.93	0.15	-6.66	2.00	5.22	1.03	7.53
mooring leg 8	ton	21	1.33	19.03	0.13	-5.21	1.60	3.96	0.71	5.56
mooring leg 9	ton	17	1.43	17.81	0.13	-4.17	0.65	5.68	1.68	9.47
mooring leg 10	ton	18	1.91	19.28	0.15	-5.61	0.89	7.67	2.25	12.74
mooring leg 11	ton	22	1.89	22.58	0.15	-5.50	0.86	7.62	2.24	12.67
mooring leg 12	ton	14	3.90	13.06	0.15	-10.98	1.18	13.59	2.84	18.68
mooring leg 13	ton	11	3.39	10.08	0.13	-8.96	0.98	10.81	1.83	14.20
mooring leg 14	ton	16	3.56	14.47	0.13	-10.17	1.31	11.43	2.01	15.14
mooring leg 15	ton	19	2.55	18.07	0.11	-7.11	0.88	7.69	1.06	9.83
mooring leg 16	ton	19	2.70	17.73	0.12	-7.55	0.93	8.17	1.18	10.50
fender 1	ton		13.60	9.55	0.93	-9.55	0.93	55.74	11.13	
fender 2	ton		11.65	13.55	0.36	-13.55	0.36	40.73	8.80	
fender 3	ton		9.16	19.06	0.39	-19.06	0.39	29.41	6.02	
fender 4	ton		6.97	26.22	0.40	-20.97	4.09	18.19	2.44	
fender 5	ton		9.56	33.64	0.25	-29.92	3.46	24.10	2.15	
fender 6	ton		16.19	43.69	0.22	-43.36	1.02	40.31	4.30	

TERMSIM simulation

No.:	4d-2	wave spectrum:	6a
date:	2-8-1996	sign. wave height swell:	0.31 m.
jetty:	LNG jetty Withnell Bay	wave direction:	187 & 197 deg
ship:	Northwest	wind speed:	5.6 m/s

				averages per 10 min.		minima per 10 min.		maxima per 10 min.		max per 3 h
parameter	**unit**	**pretens.**	**st. dev.**	**mean**	**st. dev.**	**mean**	**st. dev.**	**mean**	**st. dev.**	
surge	m		0.025	-0.011	0.004	-0.087	0.019	0.051	0.004	
sway	m		0.023	0.042	0.002	-0.085	0.026	0.067	0.014	
heave	m		0.022	0.006	0.000	-0.059	0.010	0.056	0.007	
roll	deg		0.229	-0.457	0.004	-0.652	0.104	0.637	0.096	
pitch	deg		0.049	-0.002	0.000	-0.129	0.016	0.126	0.014	
yaw	deg		0.053	0.043	0.002	-0.155	0.035	0.174	0.042	
mooring leg 1	ton	25	4.46	17.03	0.06	-12.10	2.34	12.84	3.22	19.70
mooring leg 2	ton	24	4.39	17.03	0.06	-11.76	2.07	12.63	3.14	19.33
mooring leg 3	ton	30	5.47	17.03	0.08	-14.62	2.41	15.85	4.19	24.88
mooring leg 4	ton	21	4.63	17.03	0.05	-10.70	0.80	13.37	3.35	20.55
mooring leg 5	ton	32	5.08	17.03	0.13	-14.05	2.94	14.66	3.98	23.29
mooring leg 6	ton	12	2.16	17.03	0.25	-7.14	1.40	5.60	1.22	8.36
mooring leg 7	ton	23	2.31	17.03	0.27	-7.91	1.68	6.02	1.34	9.04
mooring leg 8	ton	21	1.75	17.03	0.23	-6.20	1.36	4.45	0.96	6.62
mooring leg 9	ton	17	1.89	17.03	0.23	-4.72	0.95	6.80	1.56	10.32
mooring leg 10	ton	18	2.61	17.03	0.28	-6.52	1.31	9.44	2.17	14.33
mooring leg 11	ton	22	2.59	17.03	0.28	-6.41	1.28	9.42	2.19	14.37
mooring leg 12	ton	14	5.78	17.03	0.28	-12.82	0.78	19.61	4.98	29.08
mooring leg 13	ton	11	5.03	17.03	0.22	-10.43	0.26	16.37	4.14	24.42
mooring leg 14	ton	16	5.38	17.03	0.20	-13.17	1.38	17.44	4.54	26.25
mooring leg 15	ton	19	3.89	17.03	0.14	-10.52	2.02	12.14	3.02	18.19
mooring leg 16	ton	19	4.12	17.03	0.15	-11.11	2.10	12.90	3.22	19.33
fender 1	ton		18.75	12.56	1.26	-12.56	1.26	75.60	18.52	
fender 2	ton		15.55	14.55	0.65	-14.55	0.65	57.68	12.77	
fender 3	ton		12.99	18.51	0.41	-18.51	0.41	43.65	7.68	
fender 4	ton		10.94	25.15	0.59	-25.15	0.59	29.31	4.58	
fender 5	ton		13.54	32.84	0.50	-32.84	0.50	32.78	4.31	
fender 6	ton		21.76	43.23	0.19	-43.23	0.19	53.63	5.53	

TERMSIM simulation

No.:	4d-3	wave spectrum:	6a
date:	2-8-1996	sign. wave height swell:	0.31 m.
jetty:	LNG jetty Withnell Bay	wvae direction:	181 & 203 deg
ship:	Northwest	wind speed:	5.6 m/s

				averages per 10 min.		minima per 10 min.		maxima per 10 min.		max per 3 h
parameter	**unit**	**pretens.**	**st. dev.**	**mean**	**st. dev.**	**mean**	**st. dev.**	**mean**	**st. dev.**	
surge	m		0.024	-0.008	0.004	-0.074	0.015	0.045	0.005	
sway	m		0.016	0.045	0.001	-0.045	0.012	0.042	0.007	
heave	m		0.021	0.006	0.000	-0.056	0.008	0.053	0.005	
roll	deg		0.169	-0.454	0.002	-0.436	0.071	0.428	0.071	
pitch	deg		0.048	-0.002	0.000	-0.125	0.016	0.121	0.013	
yaw	deg		0.039	0.040	0.001	-0.108	0.020	0.116	0.023	
mooring leg 1	ton	25	3.29	17.08	0.07	-8.87	1.86	9.02	2.08	12.61
mooring leg 2	ton	24	3.25	15.96	0.08	-8.74	1.73	8.88	2.04	12.39
mooring leg 3	ton	30	4.04	19.34	0.07	-10.96	2.30	11.16	2.63	15.75
mooring leg 4	ton	21	3.49	11.60	0.06	-8.97	1.16	9.46	2.14	13.20
mooring leg 5	ton	32	3.76	22.04	0.09	-10.40	2.23	10.40	2.47	14.80
mooring leg 6	ton	12	1.77	9.41	0.19	-5.75	1.01	4.02	0.83	5.90
mooring leg 7	ton	23	1.88	20.97	0.20	-6.26	1.14	4.28	0.91	6.32
mooring leg 8	ton	21	1.46	19.07	0.17	-4.89	0.90	3.24	0.59	4.56
mooring leg 9	ton	17	1.56	17.78	0.16	-3.43	0.60	5.24	0.95	7.39
mooring leg 10	ton	18	2.09	19.24	0.19	-4.74	0.89	7.10	1.34	10.11
mooring leg 11	ton	22	2.07	22.55	0.19	-4.66	0.88	7.05	1.33	10.05
mooring leg 12	ton	14	4.27	13.09	0.17	-11.14	1.20	13.79	2.61	18.27
mooring leg 13	ton	11	3.71	10.14	0.17	-9.31	0.88	11.43	2.19	15.23
mooring leg 14	ton	16	3.91	14.52	0.16	-10.67	1.35	12.08	2.35	16.13
mooring leg 15	ton	19	2.80	18.13	0.15	-7.76	1.08	8.18	1.70	11.15
mooring leg 16	ton	19	2.97	17.79	0.15	-8.21	1.16	8.70	1.82	11.85
fender 1	ton		14.57	10.10	1.14	-10.10	1.14	55.33	11.38	
fender 2	ton		12.48	13.57	0.39	-13.57	0.39	41.87	8.27	
fender 3	ton		10.00	18.91	0.45	-18.91	0.45	30.31	6.04	
fender 4	ton		7.89	26.11	0.45	-22.30	3.64	19.46	2.62	
fender 5	ton		10.59	33.57	0.28	-31.45	2.73	25.30	2.39	
fender 6	ton		17.58	43.55	0.22	-43.55	0.22	40.99	4.39	

TERMSIM simulation

No.: 4d-4
date: 2-8-1996
jetty: LNG jetty Withnell Bay
ship: Northwest

wave spectrum: 7a-2
sign. wave height swell: 0.29 m.
wave direction: 198 deg
wind speed: 5.6 m/s

				averages per 10 min.		minima per 10 min.		maxima per 10 min.		max per 3 h
parameter	unit	pretens.	st. dev.	mean	st. dev.	mean	st. dev.	mean	st. dev.	
surge	m		0.024	-0.015	0.005	-0.088	0.027	0.047	0.007	
sway	m		0.022	0.057	0.001	-0.069	0.021	0.064	0.014	
heave	m		0.020	0.006	0.000	-0.057	0.007	0.058	0.007	
roll	deg		0.226	-0.500	0.003	-0.627	0.117	0.612	0.110	
pitch	deg		0.045	-0.002	0.000	-0.126	0.020	0.126	0.020	
yaw	deg		0.046	0.035	0.001	-0.125	0.025	0.138	0.032	
mooring leg 1	ton	25	3.96	16.82	0.06	-10.42	2.33	11.10	2.89	16.48
mooring leg 2	ton	24	3.91	15.70	0.06	-10.21	2.11	10.96	2.85	16.27
mooring leg 3	ton	30	4.85	18.84	0.05	-12.81	2.56	13.38	3.45	19.92
mooring leg 4	ton	21	4.17	11.13	0.04	-9.75	0.85	11.63	2.99	17.19
mooring leg 5	ton	32	4.51	21.34	0.09	-12.31	2.91	12.25	3.16	18.25
mooring leg 6	ton	12	1.94	9.08	0.17	-6.65	1.52	4.63	0.66	6.10
mooring leg 7	ton	23	2.06	20.65	0.19	-7.39	1.86	4.92	0.74	6.58
mooring leg 8	ton	21	1.57	18.83	0.16	-5.83	1.44	3.66	0.57	4.95
mooring leg 9	ton	17	1.68	17.82	0.15	-3.92	0.62	6.38	1.69	10.19
mooring leg 10	ton	18	2.29	19.16	0.18	-5.42	0.83	8.65	2.42	14.11
mooring leg 11	ton	22	2.27	22.45	0.17	-5.32	0.82	8.60	2.45	14.12
mooring leg 12	ton	14	4.91	11.67	0.18	-10.93	0.63	16.06	4.84	24.69
mooring leg 13	ton	11	4.22	8.67	0.20	-8.66	0.22	13.18	3.69	19.75
mooring leg 14	ton	16	4.56	12.96	0.16	-11.15	1.26	14.00	4.05	21.20
mooring leg 15	ton	19	3.30	16.87	0.14	-9.22	2.66	9.54	2.60	14.03
mooring leg 16	ton	19	3.50	16.50	0.14	-9.68	2.70	10.14	2.80	15.00
fender 1	ton		19.51	17.25	1.35	-17.25	1.35	63.55	12.31	
fender 2	ton		15.82	21.18	0.39	-21.18	0.39	46.67	10.43	
fender 3	ton		12.50	26.19	0.44	-26.14	0.38	35.78	7.44	
fender 4	ton		11.32	32.39	0.55	-30.75	1.82	28.35	4.74	
fender 5	ton		14.38	38.47	0.44	-38.02	1.03	32.53	5.16	
fender 6	ton		21.60	46.32	0.26	-46.32	0.26	50.59	9.23	

TERMSIM simulation

No.: 4d-5
date: 2-8-1996
jetty: LNG jetty Withnell Bay
ship: Northwest

wave spectrum: 6a
sign. wave height swell: 0.29 m.
wave direction: 198 deg
wind speed: 5.6 m/s

				averages per 10 min.		minima per 10 min.		maxima per 10 min.		max per 3 h
parameter	**unit**	**pretens.**	**st. dev.**	**mean**	**st. dev.**	**mean**	**st. dev.**	**mean**	**st. dev.**	
surge	m		0.019	-0.007	0.003	-0.060	0.017	0.042	0.004	
sway	m		0.028	0.065	0.001	-0.051	0.010	0.049	0.012	
heave	m		0.014	0.005	0.000	-0.042	0.005	0.041	0.005	
roll	deg		0.249	-0.184	0.002	-0.443	0.104	0.439	0.110	
pitch	deg		0.036	-0.002	0.000	-0.096	0.017	0.094	0.014	
yaw	deg		0.055	0.038	0.001	-0.132	0.031	0.138	0.034	
mooring leg 1	ton	25	4.74	18.71	0.07	-10.98	2.66	11.89	2.97	17.70
mooring leg 2	ton	24	4.66	17.59	0.07	-10.75	2.47	11.69	2.90	17.36
mooring leg 3	ton	30	5.85	21.47	0.06	-13.57	3.10	14.76	3.90	22.38
mooring leg 4	ton	21	4.94	13.60	0.06	-11.00	1.63	12.37	3.12	18.46
mooring leg 5	ton	32	5.48	24.28	0.07	-12.73	2.98	13.65	3.65	20.77
mooring leg 6	ton	12	2.08	9.85	0.13	-5.76	1.19	4.97	0.92	7.05
mooring leg 7	ton	23	2.22	21.42	0.14	-6.22	1.35	5.33	1.01	7.62
mooring leg 8	ton	21	1.64	19.30	0.12	-4.73	1.06	3.90	0.65	5.35
mooring leg 9	ton	17	1.75	17.84	0.12	-4.08	0.68	5.13	1.19	7.81
mooring leg 10	ton	18	2.45	19.40	0.14	-5.67	1.06	7.07	1.66	10.82
mooring leg 11	ton	22	2.43	22.72	0.14	-5.57	1.05	7.02	1.67	10.79
mooring leg 12	ton	14	5.67	13.97	0.19	-12.26	1.36	15.13	4.19	23.32
mooring leg 13	ton	11	4.96	11.03	0.19	-10.30	0.87	13.04	3.67	20.24
mooring leg 14	ton	16	5.28	15.40	0.17	-12.15	2.05	13.83	4.00	21.67
mooring leg 15	ton	19	3.81	18.77	0.13	-9.37	2.26	9.80	2.86	15.43
mooring leg 16	ton	19	4.04	18.44	0.14	-9.87	2.37	10.41	3.04	16.37
fender 1	ton		22.39	19.18	1.57	-19.18	1.57	64.58	11.58	
fender 2	ton		17.75	23.61	0.42	-23.61	0.42	45.47	8.18	
fender 3	ton		13.54	29.56	0.55	-28.09	3.09	30.75	5.75	
fender 4	ton		12.04	36.52	0.59	-29.94	5.26	25.14	4.30	
fender 5	ton		15.61	42.92	0.47	-40.15	2.97	36.32	7.40	
fender 6	ton		23.88	50.96	0.32	-50.96	0.32	54.56	10.70	

TERMSIM simulation

No.: 4e-1
date: 2-8-1996
jetty: LNG jetty Withnell Bay
ship: Northwest

wave spectrum: 6b
sign. wave height swell: 0.31 m.
wave direction: 172 & 198 deg
wind speed: 7.4 m/s

parameter	unit	pretens.	st. dev.	averages per 10 min. mean	averages per 10 min. st. dev.	minima per 10 min. mean	minima per 10 min. st. dev.	maxima per 10 min. mean	maxima per 10 min. st. dev.	max per 3 h
surge	m		0.019	-0.004	0.004	-0.059	0.013	0.055	0.013	
sway	m		0.020	0.052	0.001	-0.072	0.017	0.059	0.012	
heave	m		0.019	0.005	0.000	-0.051	0.008	0.048	0.004	
roll	deg		0.203	-0.376	0.002	-0.571	0.116	0.570	0.120	
pitch	deg		0.041	0.000	0.000	-0.106	0.013	0.104	0.013	
yaw	deg		0.041	0.020	0.000	-0.123	0.027	0.129	0.028	
mooring leg 1	ton	21	3.48	15.11	0.06	-9.97	1.82	10.03	1.92	14.00
mooring leg 2	ton	19	3.43	12.89	0.07	-9.65	1.61	9.87	1.85	13.71
mooring leg 3	ton	21	4.16	14.44	0.02	-11.40	1.45	12.26	2.51	17.45
mooring leg 4	ton	18	3.63	10.96	0.04	-9.44	1.07	10.66	2.00	14.83
mooring leg 5	ton	22	3.76	14.85	0.07	-10.43	1.53	11.14	2.38	16.03
mooring leg 6	ton	8	1.56	6.30	0.20	-4.43	0.60	4.66	1.09	7.12
mooring leg 7	ton	23	1.66	21.86	0.21	-5.07	1.04	5.03	1.21	7.75
mooring leg 8	ton	17	1.25	16.36	0.18	-3.93	0.86	3.68	0.85	5.59
mooring leg 9	ton	13	1.29	13.29	0.17	-3.71	0.85	4.11	0.94	6.24
mooring leg 10	ton	19	1.80	19.77	0.21	-5.16	1.13	5.81	1.34	8.83
mooring leg 11	ton	14	1.73	14.23	0.19	-5.02	1.09	5.49	1.25	8.31
mooring leg 12	ton	17	4.37	13.58	0.10	-11.46	1.42	14.17	3.00	20.11
mooring leg 13	ton	14	4.02	11.35	0.10	-10.04	0.91	13.00	2.68	18.53
mooring leg 14	ton	20	4.21	16.67	0.09	-11.77	2.01	13.85	2.93	19.87
mooring leg 15	ton	13	3.07	10.73	0.12	-8.37	1.20	9.75	2.07	14.12
mooring leg 16	ton	11	3.16	8.68	0.12	-7.83	0.92	10.23	2.15	14.74
fender 1	ton		18.90	20.34	0.49	-20.34	0.49	63.32	13.30	
fender 2	ton		14.16	22.57	0.36	-22.57	0.36	45.10	9.50	
fender 3	ton		10.87	25.43	0.42	-25.43	0.42	34.23	6.19	
fender 4	ton		10.46	28.90	0.41	-28.71	0.45	29.14	4.67	
fender 5	ton		13.90	32.48	0.36	-32.48	0.36	36.07	5.84	
fender 6	ton		20.62	37.52	0.29	-37.52	0.29	54.16	7.15	

TERMSIM simulation

No.: 4e-2
date: 2-8-1996
jetty: LNG jetty Withnell Bay
ship: Northwest

wave spectrum: 6b
sign. wave height swell: 0.28 m.
wave direction: 198 deg
wind speed: 7.4 m/s

parameter	unit	pretens.	st. dev.	averages per 10 min. mean	averages per 10 min. st. dev.	minima per 10 min. mean	minima per 10 min. st. dev.	maxima per 10 min. mean	maxima per 10 min. st. dev.	max per 3 h
surge	m		0.018	-0.014	0.004	-0.061	0.013	0.046	0.011	
sway	m		0.022	0.032	0.001	-0.086	0.022	0.066	0.013	
heave	m		0.017	0.003	0.000	-0.052	0.007	0.051	0.006	
roll	deg		0.236	-0.226	0.002	-0.684	0.127	0.668	0.120	
pitch	deg		0.038	-0.001	0.000	-0.109	0.019	0.117	0.018	
yaw	deg		0.046	0.011	0.001	-0.137	0.021	0.146	0.026	
mooring leg 1	ton	21	3.83	15.51	0.06	-10.35	1.61	10.61	2.23	15.27
mooring leg 2	ton	19	3.77	13.30	0.06	-10.00	1.39	10.42	2.18	14.97
mooring leg 3	ton	21	4.60	14.74	0.05	-12.01	1.32	12.83	2.67	18.45
mooring leg 4	ton	18	4.01	11.32	0.04	-9.97	1.07	11.13	2.32	16.02
mooring leg 5	ton	22	4.17	14.98	0.10	-11.21	1.60	11.64	2.35	16.63
mooring leg 6	ton	8	1.67	5.89	0.22	-4.64	0.50	4.84	0.74	6.51
mooring leg 7	ton	23	1.80	21.42	0.25	-5.95	1.39	5.20	0.83	7.08
mooring leg 8	ton	17	1.34	15.96	0.21	-4.54	1.07	3.77	0.63	5.18
mooring leg 9	ton	13	1.45	13.65	0.20	-4.06	0.69	4.98	1.25	7.79
mooring leg 10	ton	19	2.05	19.92	0.24	-5.63	0.95	7.11	1.87	11.32
mooring leg 11	ton	14	1.96	14.58	0.23	-5.47	0.93	6.69	1.73	10.60
mooring leg 12	ton	17	4.75	14.34	0.15	-12.24	1.55	15.76	3.64	22.89
mooring leg 13	ton	14	4.24	11.87	0.09	-10.56	1.00	13.40	2.94	19.15
mooring leg 14	ton	20	4.47	17.13	0.08	-12.31	2.16	14.40	3.23	20.71
mooring leg 15	ton	13	3.17	11.00	0.10	-8.62	1.29	9.57	2.08	13.65
mooring leg 16	ton	11	3.29	9.00	0.10	-8.10	1.01	10.12	2.16	14.36
fender 1	ton		20.38	22.02	0.79	-22.02	0.79	62.00	10.22	
fender 2	ton		15.14	23.80	0.27	-23.80	0.27	43.75	8.75	
fender 3	ton		11.78	26.36	0.35	-26.36	0.35	33.66	6.43	
fender 4	ton		11.72	29.49	0.35	-29.35	0.42	29.98	4.35	
fender 5	ton		15.58	32.68	0.30	-32.68	0.30	37.44	5.32	
fender 6	ton		22.68	37.22	0.30	-37.22	0.30	57.00	6.83	

TERMSIM simulation

No.:	4f-1
date:	19-7-1996
jetty:	LNG jetty Withnell Bay
ship:	Northwest

wave spectrum:	7
sign. wave height swell:	0.30 m.
wave direction:	177 & 201 deg
wind speed:	4 m/s

parameter	unit	pretens.	st. dev.	averages per 10 min. mean	averages per 10 min. st. dev.	minima per 10 min. mean	minima per 10 min. st. dev.	maxima per 10 min. mean	maxima per 10 min. st. dev.	max per 3 h
surge	m		0.011	-0.003	0.003	-0.035	0.013	0.032	0.005	
sway	m		0.012	0.051	0.000	-0.034	0.005	0.032	0.004	
heave	m		0.016	0.003	0.000	-0.044	0.006	0.046	0.008	
roll	deg		0.112	-0.333	0.001	-0.297	0.049	0.300	0.046	
pitch	deg		0.035	-0.001	0.000	-0.092	0.017	0.092	0.018	
yaw	deg		0.034	0.027	0.000	-0.094	0.015	0.097	0.019	
mooring leg 1	ton	19	2.96	12.58	0.06	-8.17	1.49	8.12	1.56	11.23
mooring leg 2	ton	15	2.91	9.25	0.06	-7.37	0.83	8.00	1.51	11.01
mooring leg 3	ton	24	3.55	15.80	0.03	-9.85	1.72	9.85	1.89	13.64
mooring leg 4	ton	20	3.14	13.33	0.04	-8.74	1.63	8.63	1.67	11.96
mooring leg 5	ton	17	3.12	9.63	0.06	-7.98	1.16	8.67	1.58	11.86
mooring leg 6	ton	24	1.17	10.87	0.17	-3.55	0.64	3.20	0.60	4.56
mooring leg 7	ton	12	1.21	10.55	0.18	-3.65	0.66	3.29	0.63	4.71
mooring leg 8	ton	13	0.89	12.33	0.15	-2.74	0.52	2.44	0.50	3.56
mooring leg 9	ton	13	0.94	13.44	0.15	-2.57	0.52	2.92	0.57	4.21
mooring leg 10	ton	12	1.32	12.05	0.17	-3.60	0.68	4.07	0.76	5.79
mooring leg 11	ton	14	1.29	14.60	0.16	-3.53	0.66	3.98	0.75	5.66
mooring leg 12	ton	10	3.35	8.99	0.09	-8.04	0.85	10.19	1.98	14.16
mooring leg 13	ton	11	3.13	9.70	0.06	-8.14	1.11	9.39	1.87	13.18
mooring leg 14	ton	14	3.28	11.88	0.06	-9.05	1.25	9.74	1.97	13.73
mooring leg 15	ton	13	2.41	11.73	0.09	-6.76	1.14	7.15	1.39	10.01
mooring leg 16	ton	16	2.55	14.29	0.09	-7.14	1.19	7.58	1.49	10.64
fender 1	ton		16.11	15.63	0.67	-15.63	0.67	52.19	6.98	
fender 2	ton		12.36	19.39	0.12	-19.39	0.12	37.00	4.30	
fender 3	ton		8.35	23.79	0.20	-22.90	1.21	24.80	3.44	
fender 4	ton		5.84	28.76	0.17	-17.70	2.93	15.37	2.26	
fender 5	ton		8.67	33.75	0.14	-26.07	4.17	21.78	2.42	
fender 6	ton		15.50	40.55	0.18	-39.83	1.23	36.77	4.97	

TERMSIM simulation

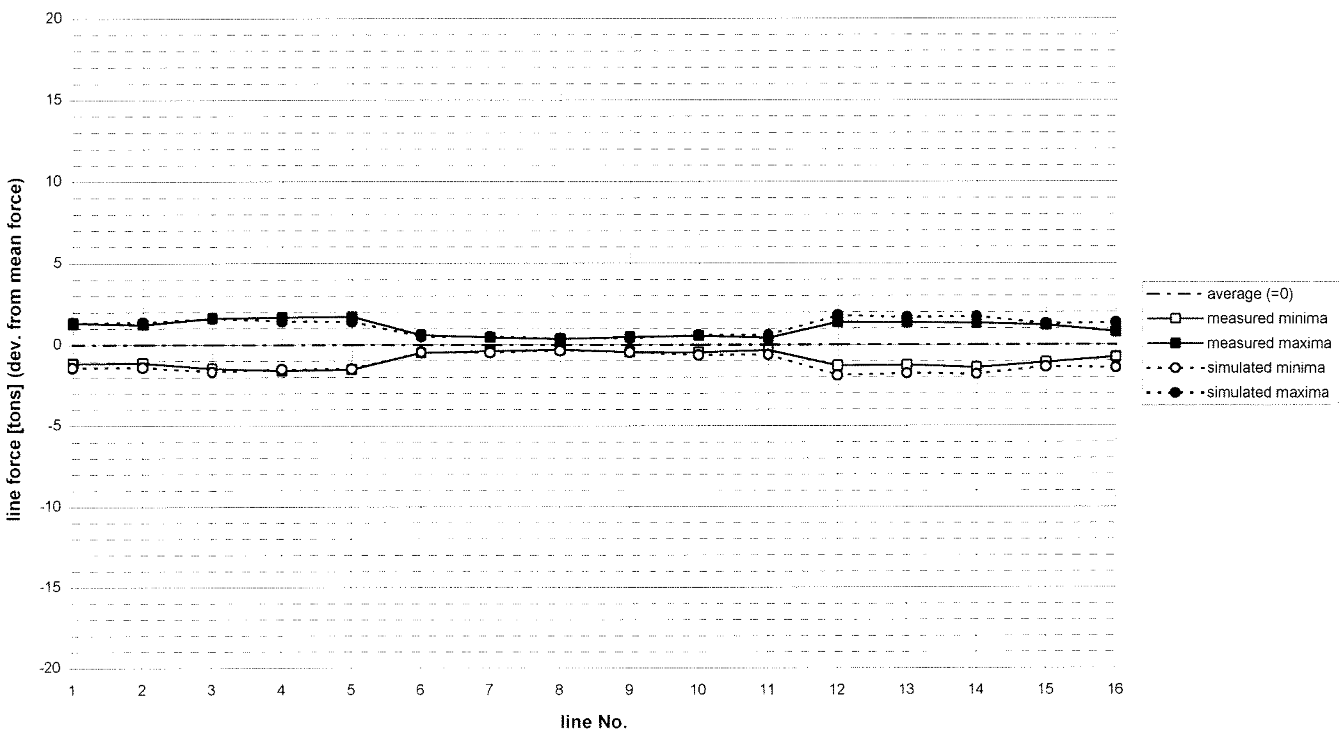
No.:	4f-2	wave spectrum:	7
date:	19-7-1996	sign. wave height swell:	0.27 m.
jetty:	LNG jetty Withnell Bay	wave direction:	198 deg
ship:	Northwest	wind speed:	4 m/s

				averages per 10 min.		minima per 10 min.		maxima per 10 min.		max per 3 h
parameter	**unit**	**pretens.**	**st. dev.**	**mean**	**st. dev.**	**mean**	**st. dev.**	**mean**	**st. dev.**	
surge	m		0.011	-0.004	0.003	-0.038	0.011	0.033	0.007	
sway	m		0.012	0.051	0.000	-0.036	0.005	0.034	0.004	
heave	m		0.015	0.003	0.000	-0.041	0.005	0.043	0.005	
roll	deg		0.117	-0.333	0.001	-0.305	0.054	0.304	0.044	
pitch	deg		0.033	-0.001	0.000	-0.092	0.015	0.089	0.014	
yaw	deg		0.036	0.027	0.001	-0.098	0.018	0.101	0.022	
mooring leg 1	ton	19	3.13	12.57	0.04	-8.33	1.61	8.41	1.68	11.88
mooring leg 2	ton	15	3.07	9.24	0.05	-7.47	0.88	8.28	1.62	11.63
mooring leg 3	ton	24	3.76	15.79	0.03	-10.05	1.80	10.24	2.16	14.71
mooring leg 4	ton	20	3.33	13.32	0.03	-8.90	1.70	8.93	1.85	12.74
mooring leg 5	ton	17	3.29	9.62	0.06	-8.06	1.07	9.05	1.89	12.95
mooring leg 6	ton	24	1.22	10.85	0.16	-4.08	1.02	3.60	0.64	5.04
mooring leg 7	ton	12	1.25	10.53	0.17	-4.20	1.03	3.72	0.66	5.20
mooring leg 8	ton	13	0.92	12.32	0.15	-3.19	0.81	2.75	0.49	3.86
mooring leg 9	ton	13	1.00	13.46	0.14	-2.94	0.55	3.44	0.90	5.46
mooring leg 10	ton	12	1.40	12.08	0.17	-4.07	0.77	4.75	1.23	7.52
mooring leg 11	ton	14	1.38	14.62	0.16	-3.98	0.75	4.64	1.20	7.35
mooring leg 12	ton	10	3.56	9.04	0.11	-8.32	0.75	10.90	2.43	15.83
mooring leg 13	ton	11	3.32	9.73	0.06	-8.38	1.03	9.75	2.01	13.84
mooring leg 14	ton	14	3.48	11.90	0.05	-9.35	1.17	10.15	2.14	14.49
mooring leg 15	ton	13	2.55	11.74	0.07	-6.95	1.13	7.21	1.40	10.08
mooring leg 16	ton	16	2.70	14.31	0.07	-7.36	1.20	7.68	1.52	10.78
fender 1	ton		16.93	16.02	0.73	-16.02	0.73	54.44	8.28	
fender 2	ton		13.08	19.38	0.14	-19.38	0.14	38.61	5.06	
fender 3	ton		8.89	23.67	0.23	-23.48	0.37	25.78	3.98	
fender 4	ton		6.03	28.67	0.20	-17.91	2.77	15.91	2.35	
fender 5	ton		8.91	33.70	0.16	-26.82	3.78	22.27	2.44	
fender 6	ton		16.14	40.51	0.19	-39.99	1.48	38.08	4.99	

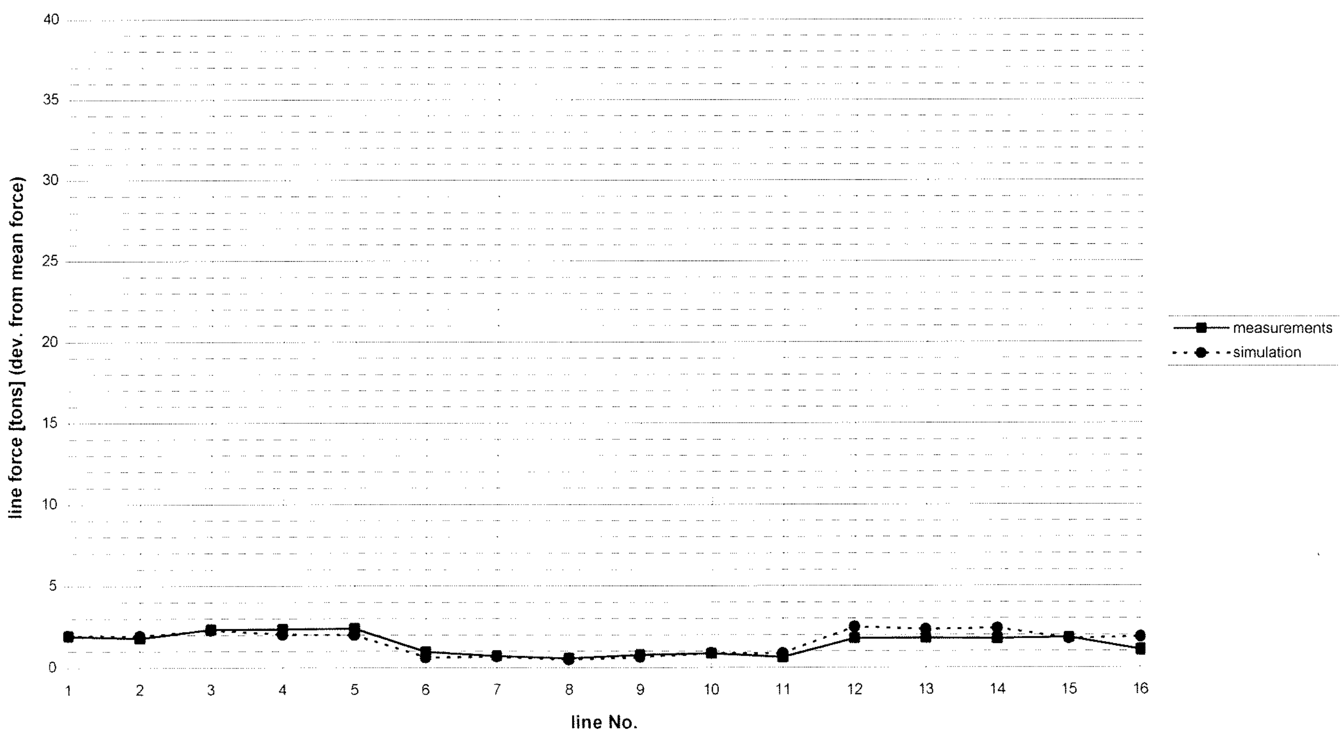
Appendix H

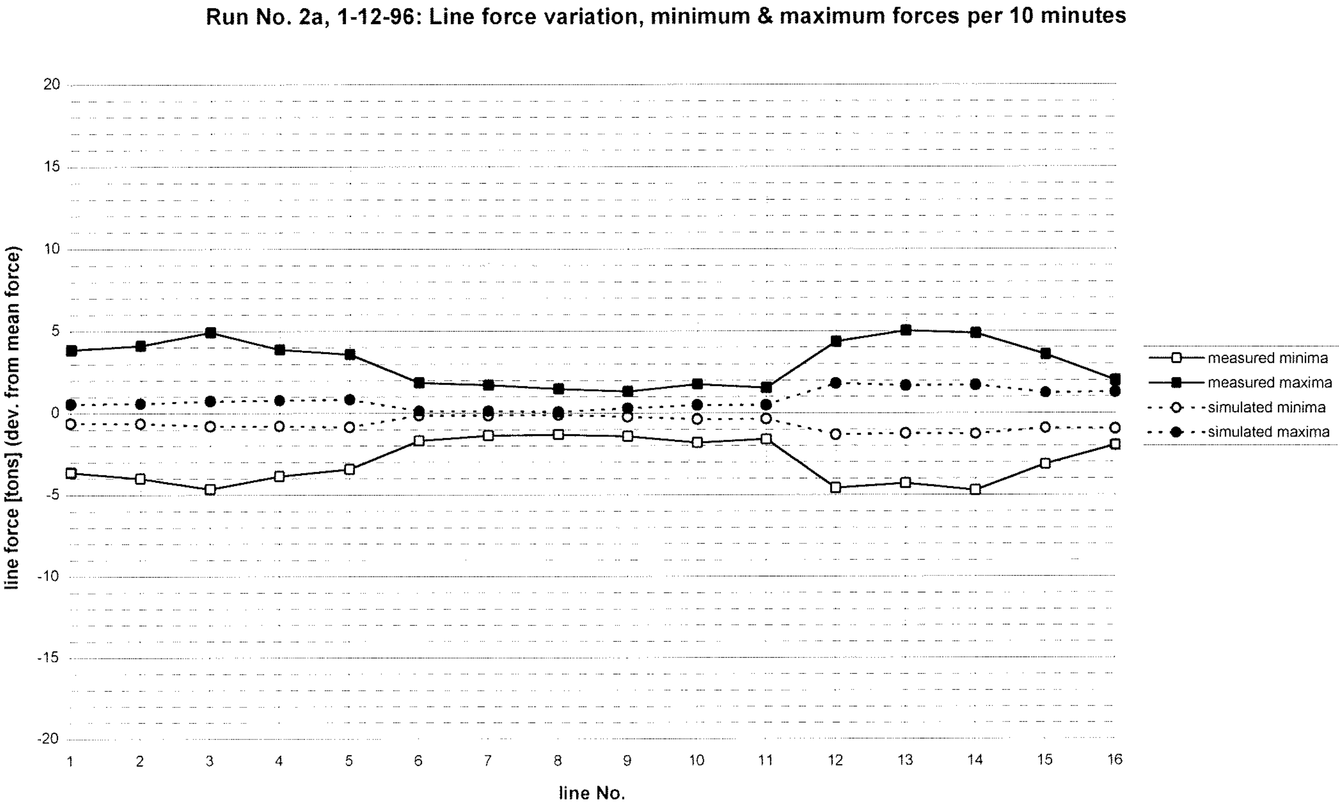
Line Force Graphs

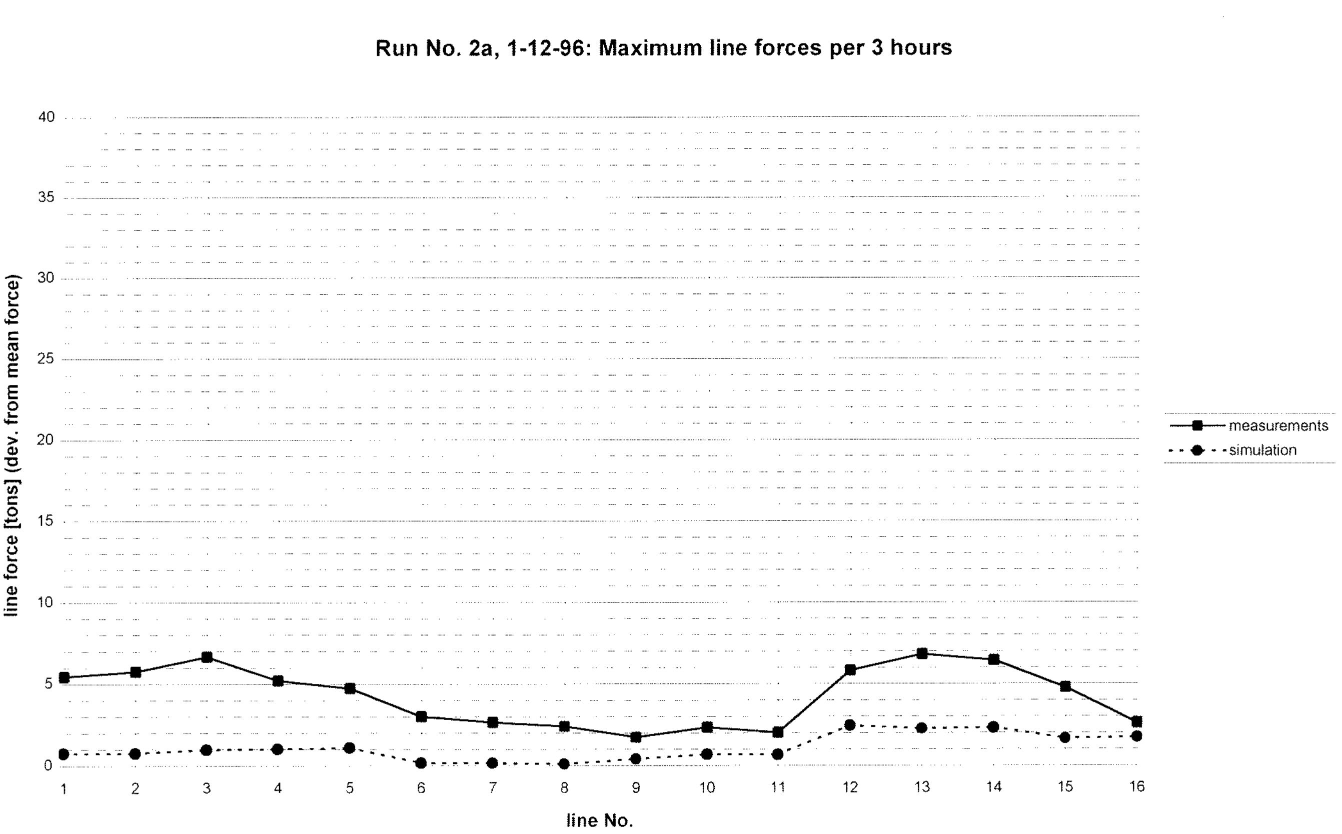
run No. 1, 9-10-96: line force variations, minima & maxima per 10 minutes

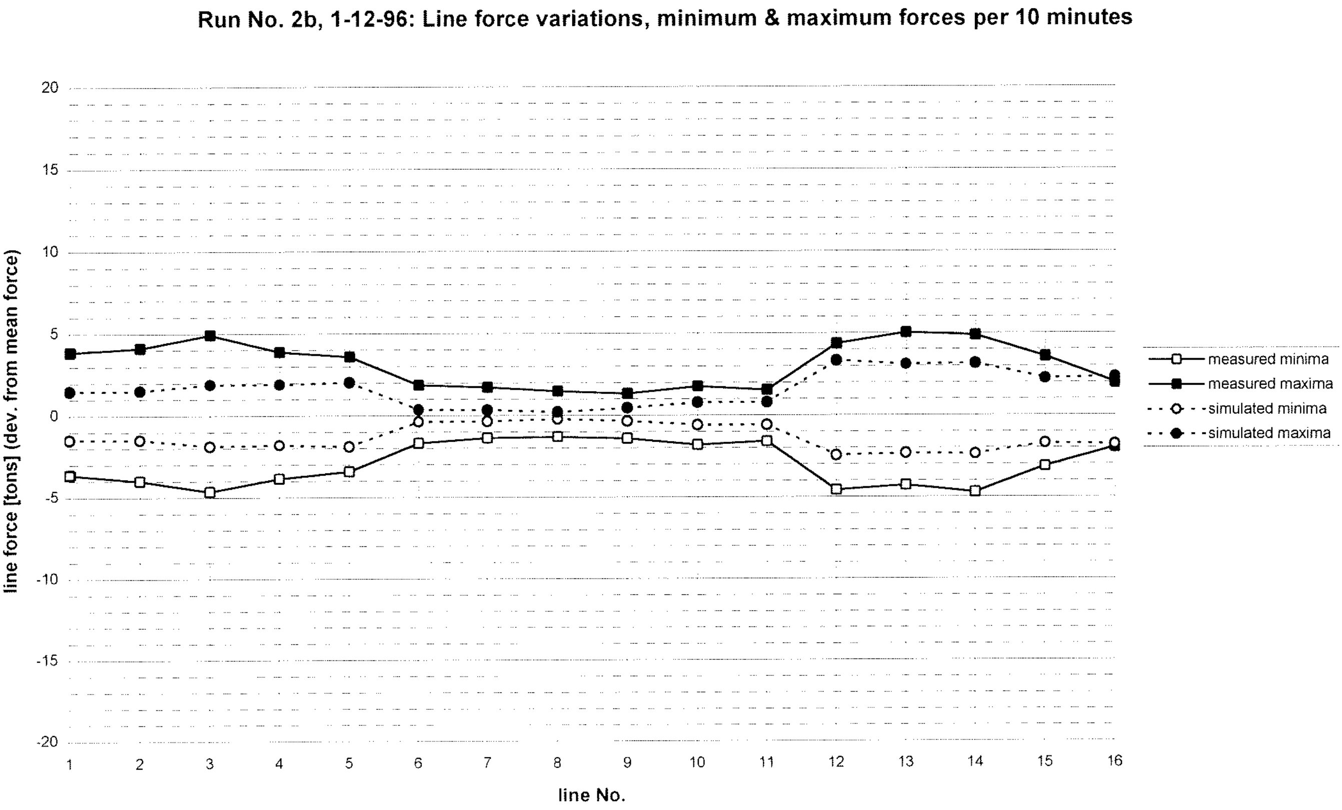


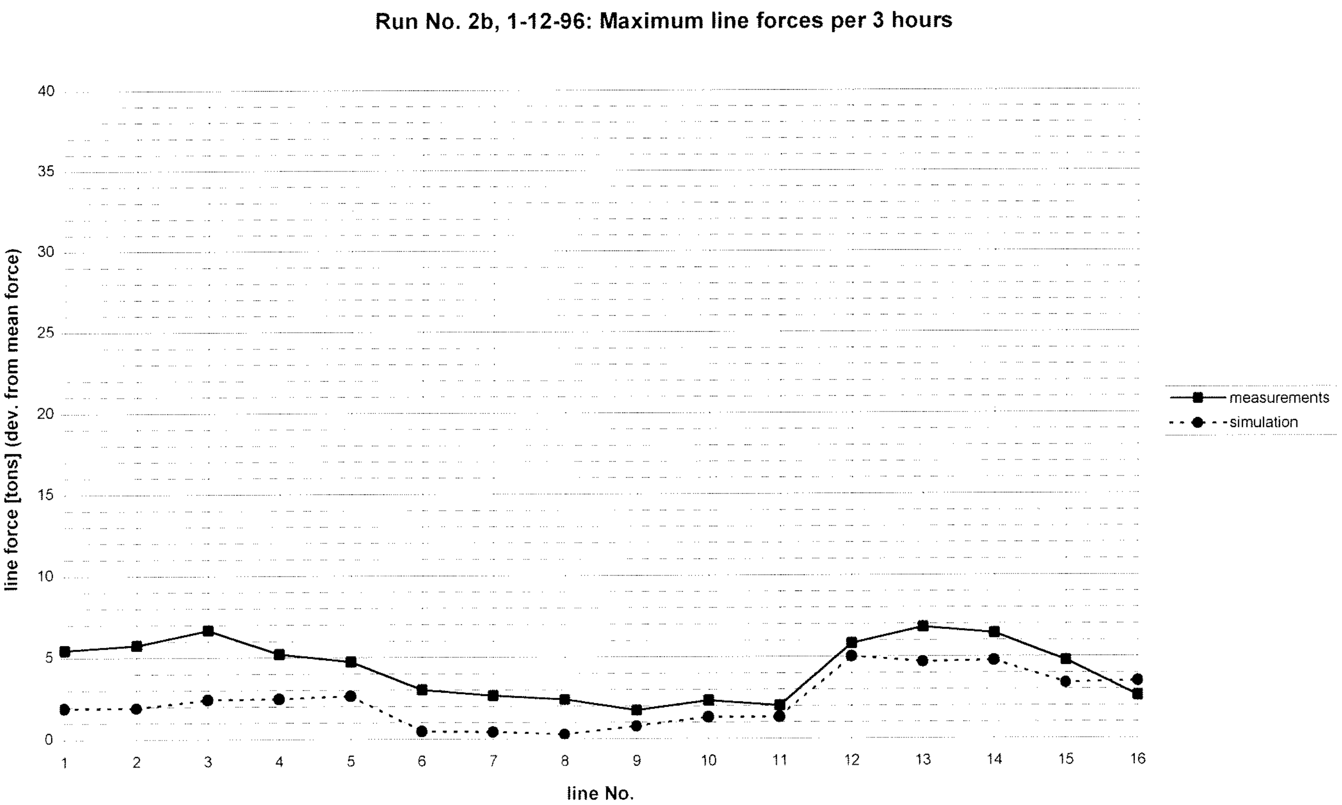
run No. 1, 9-10-96: maximum line forces per 3 hours

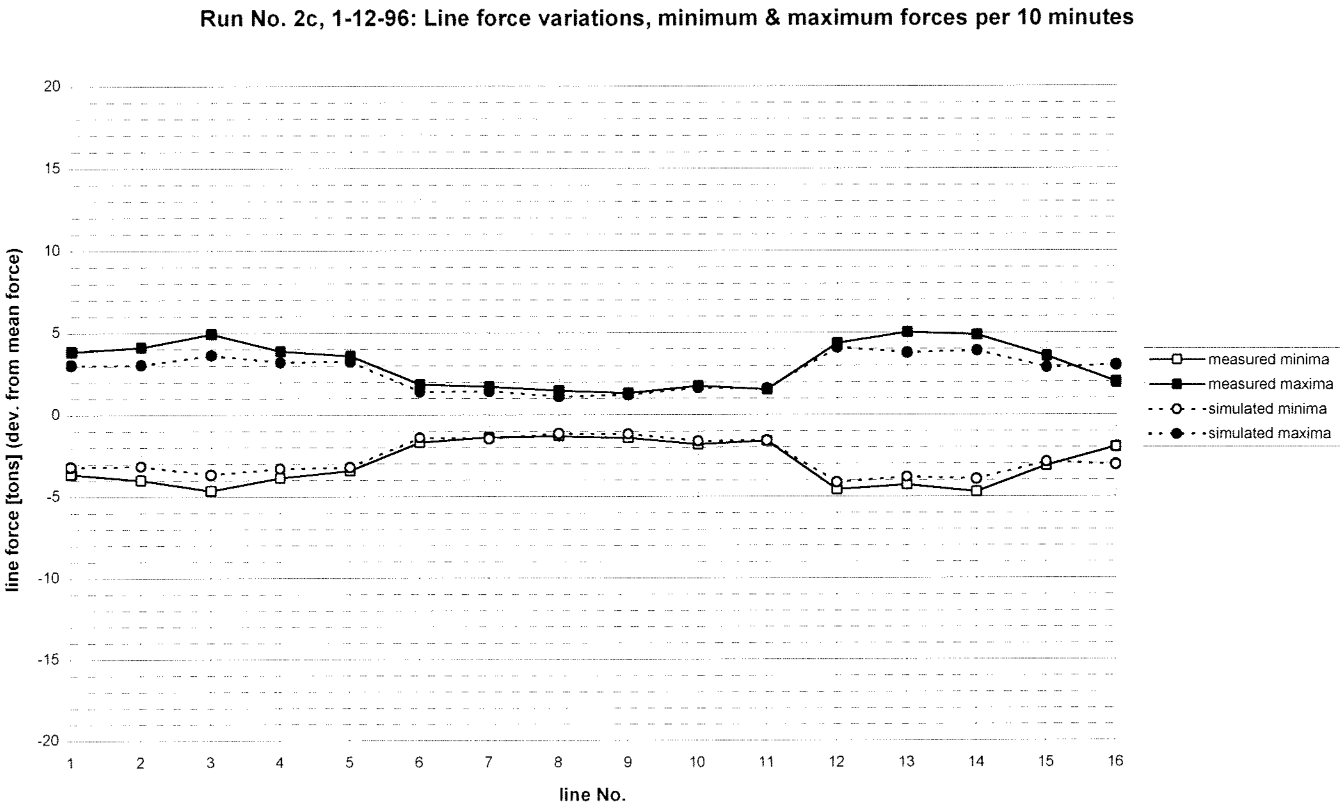


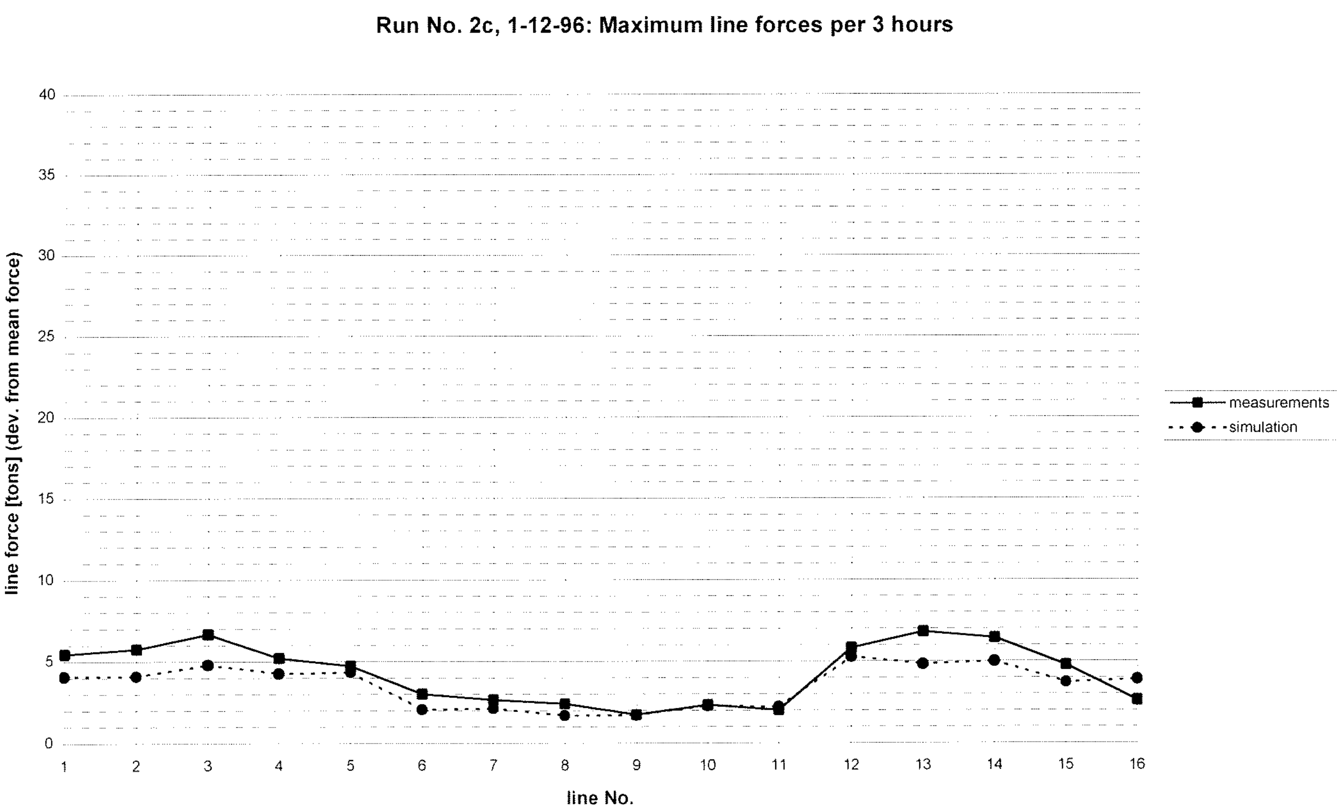

Run No. 2a, 1-12-96: Line force variation, minimum & maximum forces per 10 minutes
line force [tons] (dev. from mean force)
20
15
10
5
0
-5
-10
-15
-20
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
line No.
measured minima
measured maxima
simulated minima
simulated maxima


Run No. 2a, 1-12-96: Maximum line forces per 3 hours
line force [tons] (dev. from mean force)
40
35
30
25
20
15
10
5
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
line No.
measurements
simulation

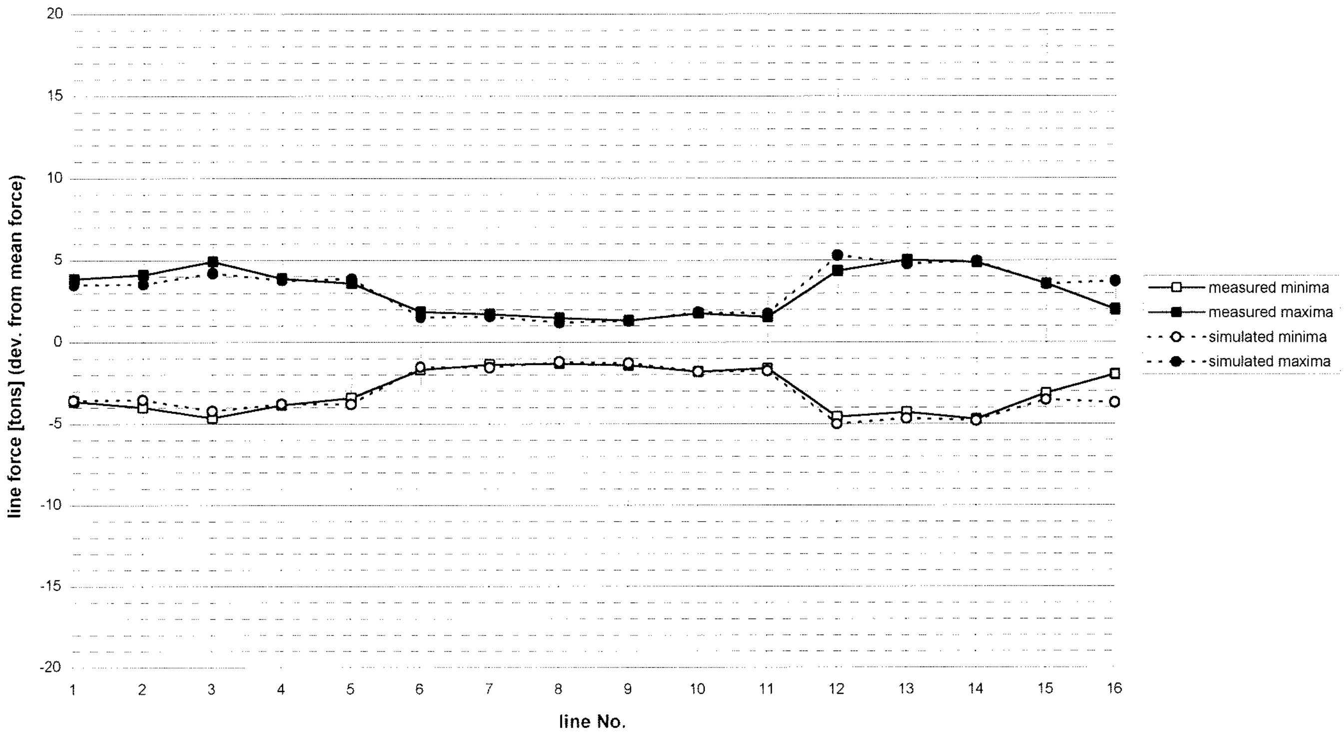

Run No. 2b, 1-12-96: Line force variations, minimum & maximum forces per 10 minutes
line force [tons] (dev. from mean force)
20
15
10
5
0
-5
-10
-15
-20
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
line No.
measured minima
measured maxima
simulated minima
simulated maxima


Run No. 2b, 1-12-96: Maximum line forces per 3 hours
line force [tons] (dev. from mean force)
40
35
30
25
20
15
10
5
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
line No.
measurements
simulation

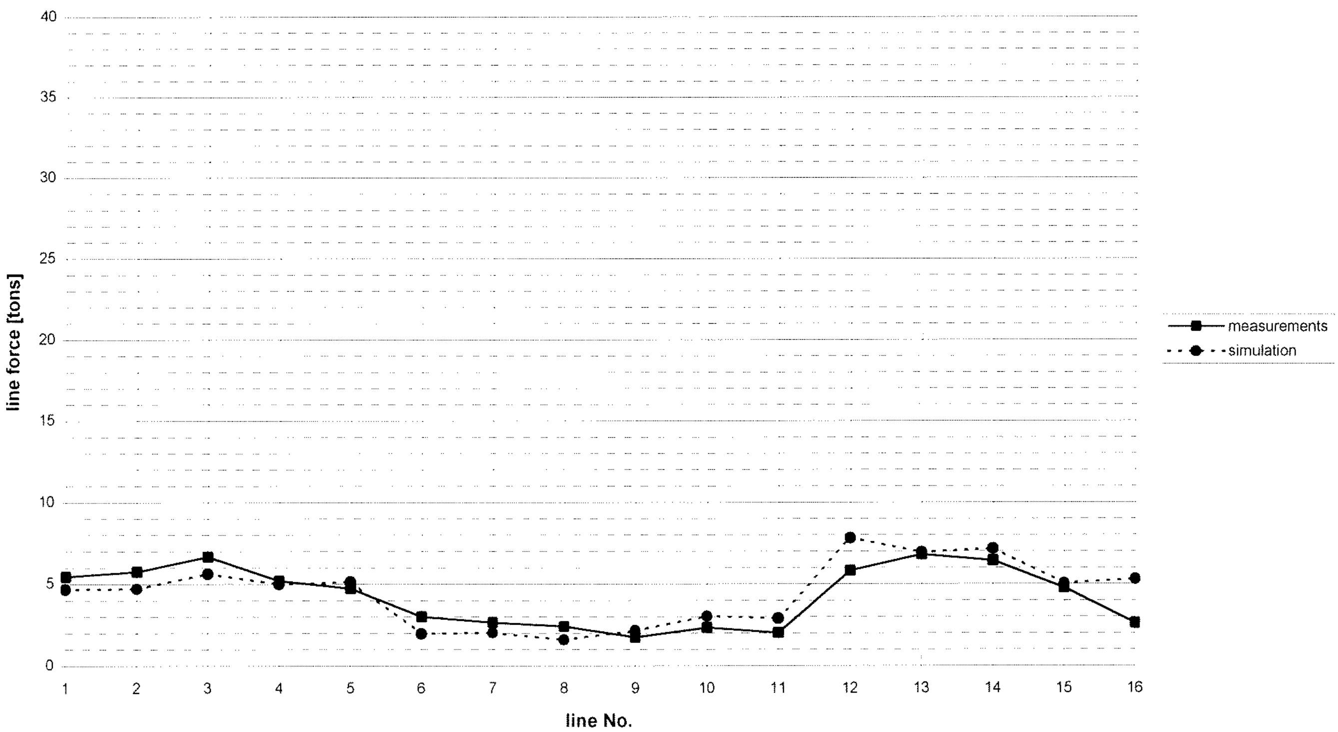

Run No. 2c, 1-12-96: Line force variations, minimum & maximum forces per 10 minutes
20
15
10
5
0
-5
-10
-15
-20
line force [tons] (dev. from mean force)
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
line No.
measured minima
measured maxima
simulated minima
simulated maxima

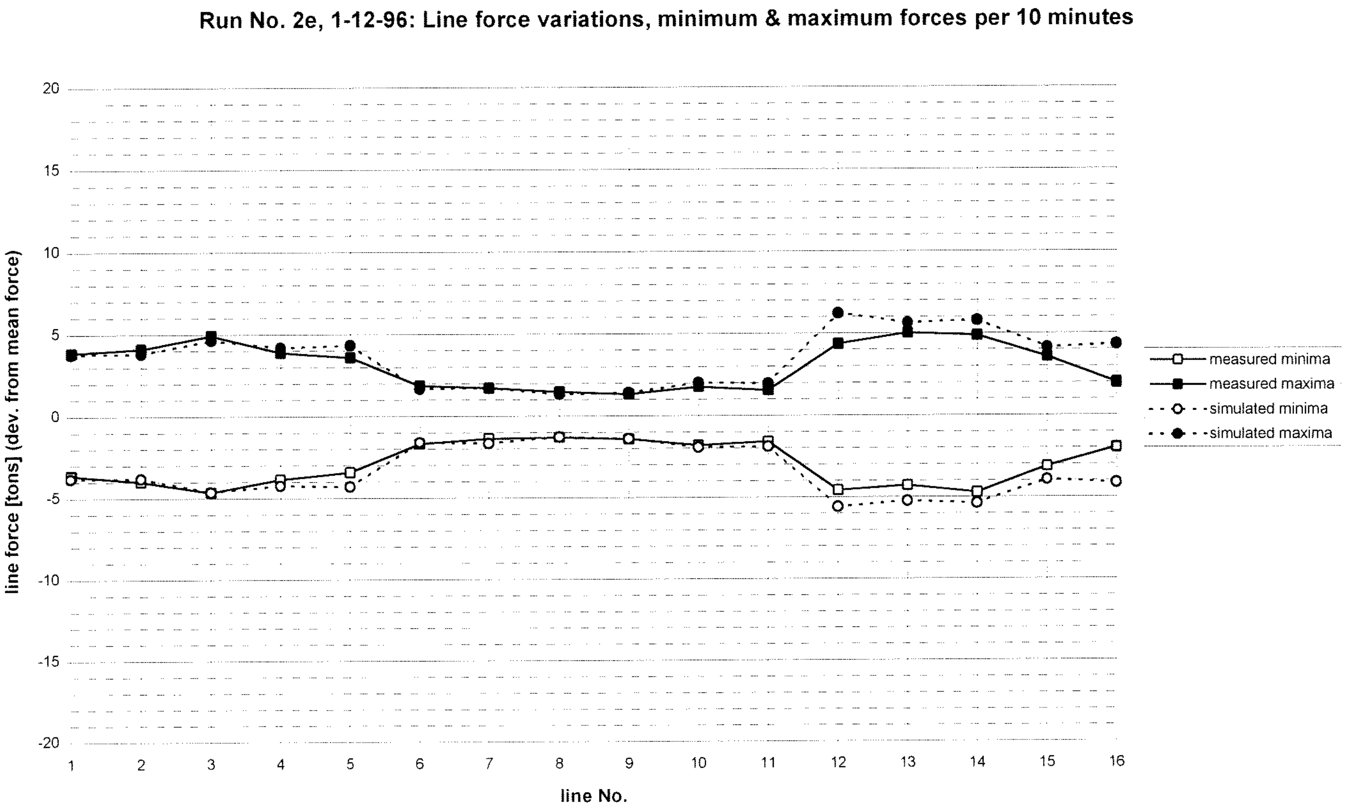

Run No. 2c, 1-12-96: Maximum line forces per 3 hours
40
35
30
25
20
15
10
5
0
line force [tons] (dev. from mean force)
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
line No.
measurements
simulation

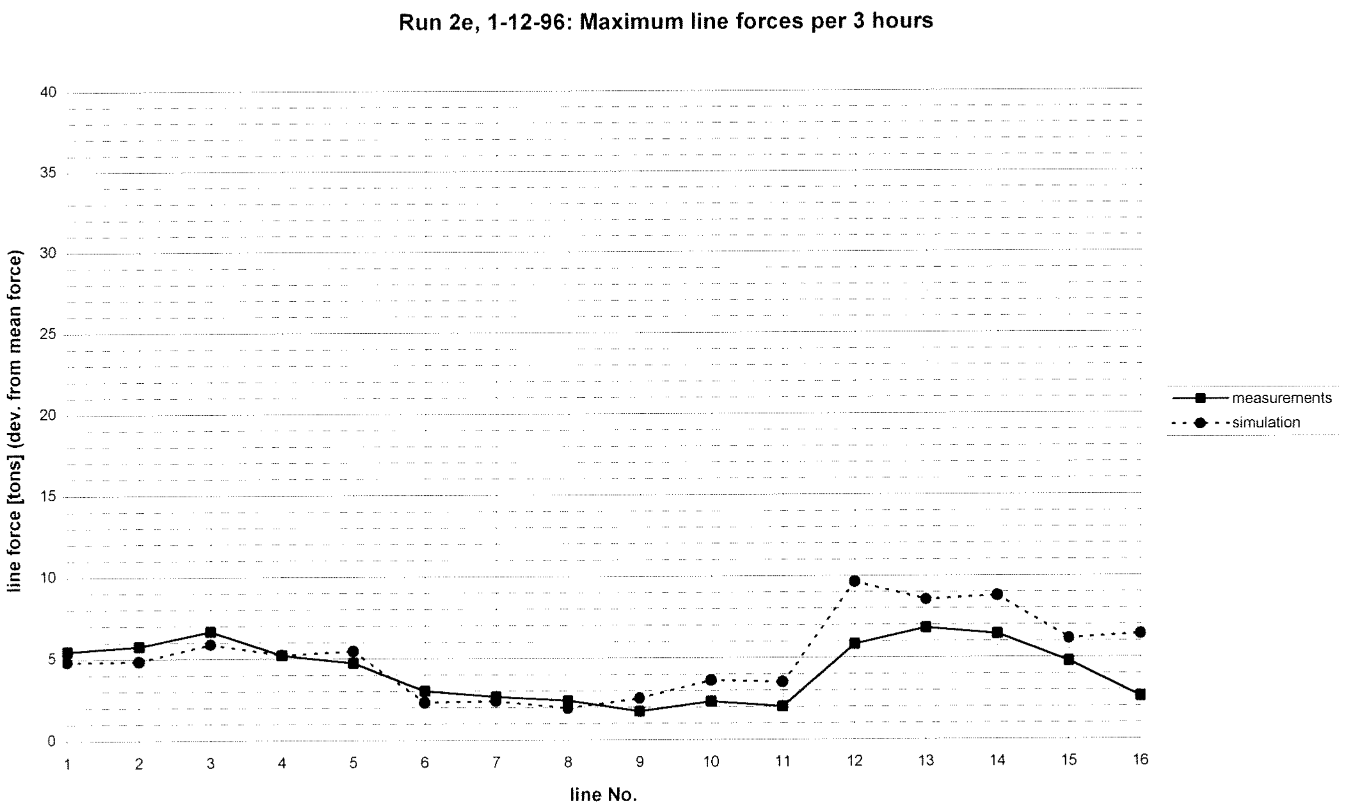
Run No. 2d, 1-12-96: Line force variations, minimum & maximum forces per 10 minutes

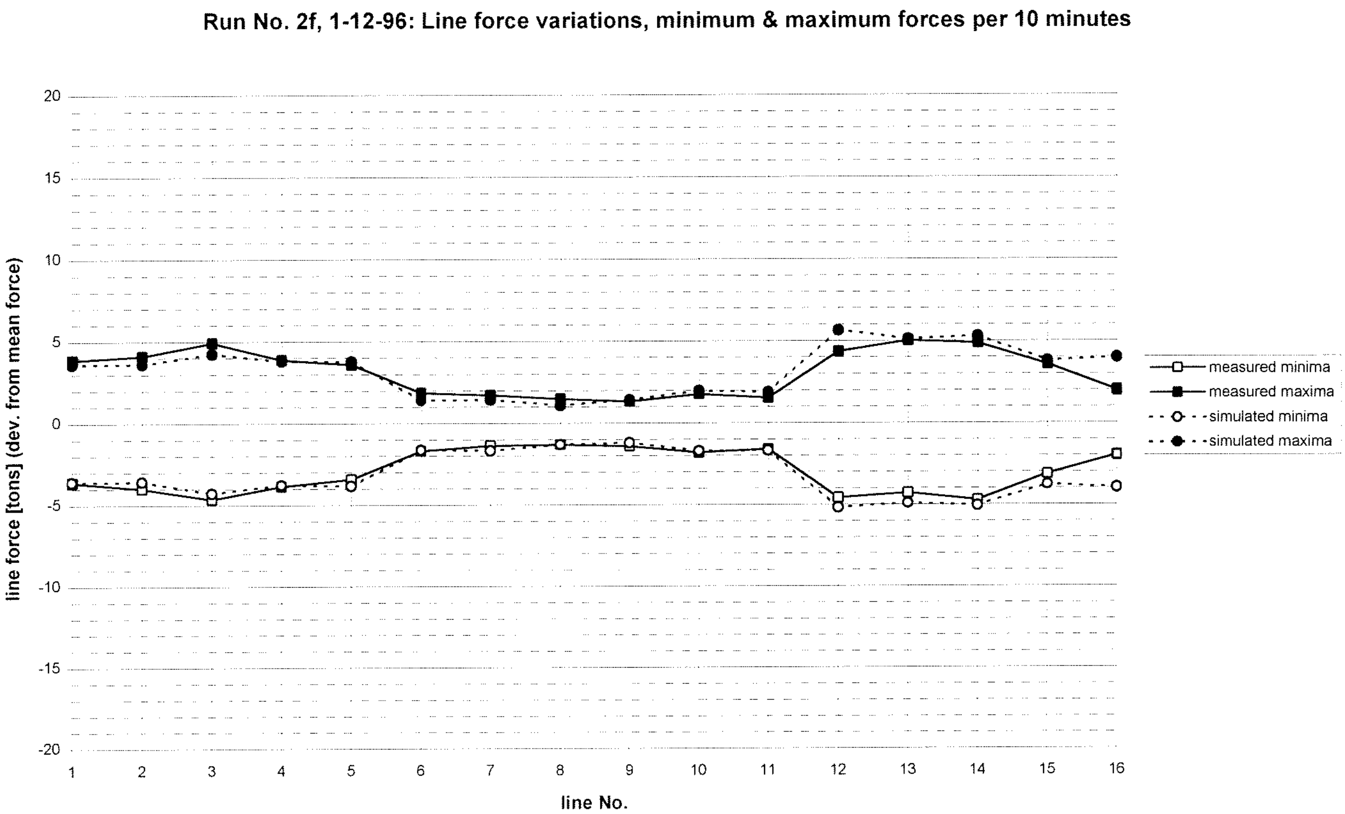


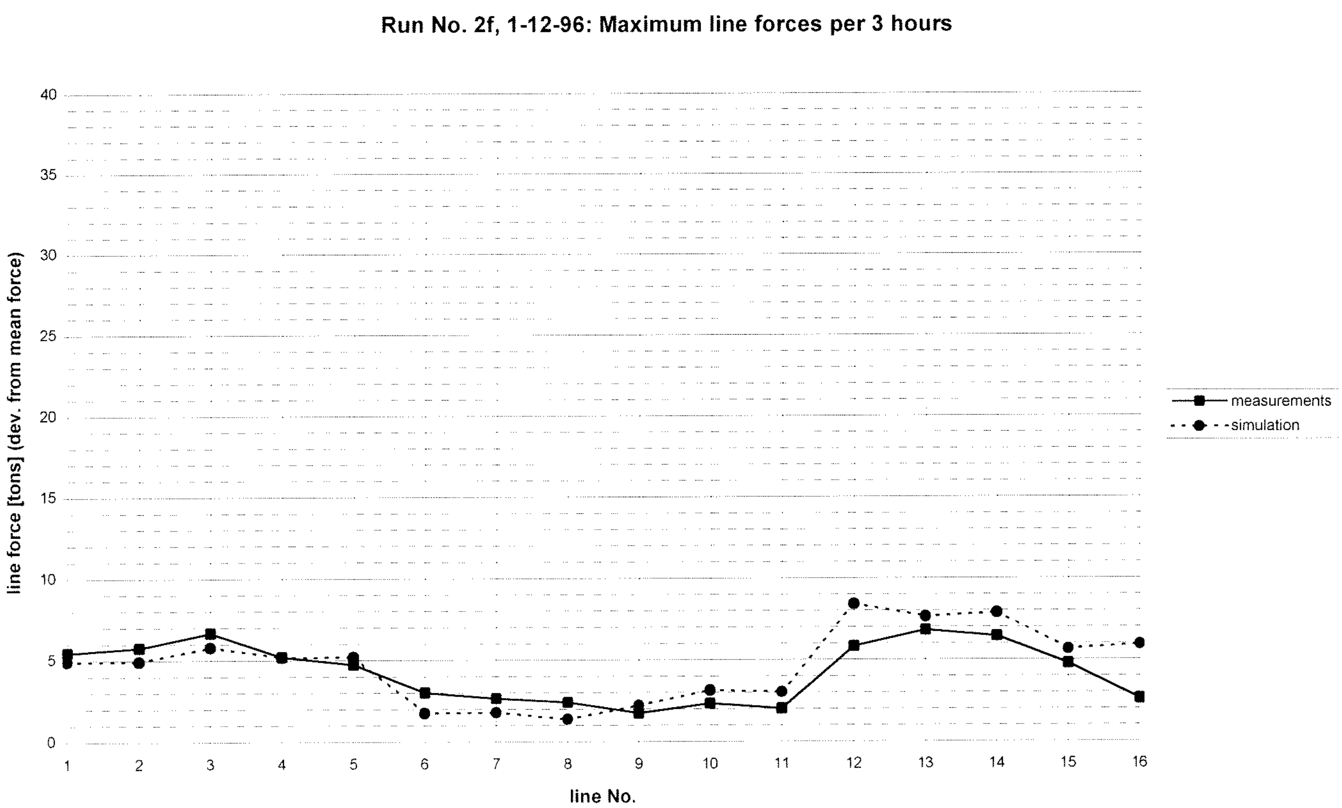
Run No. 2d, 1-12-96: Maximum line forces per 3 hours



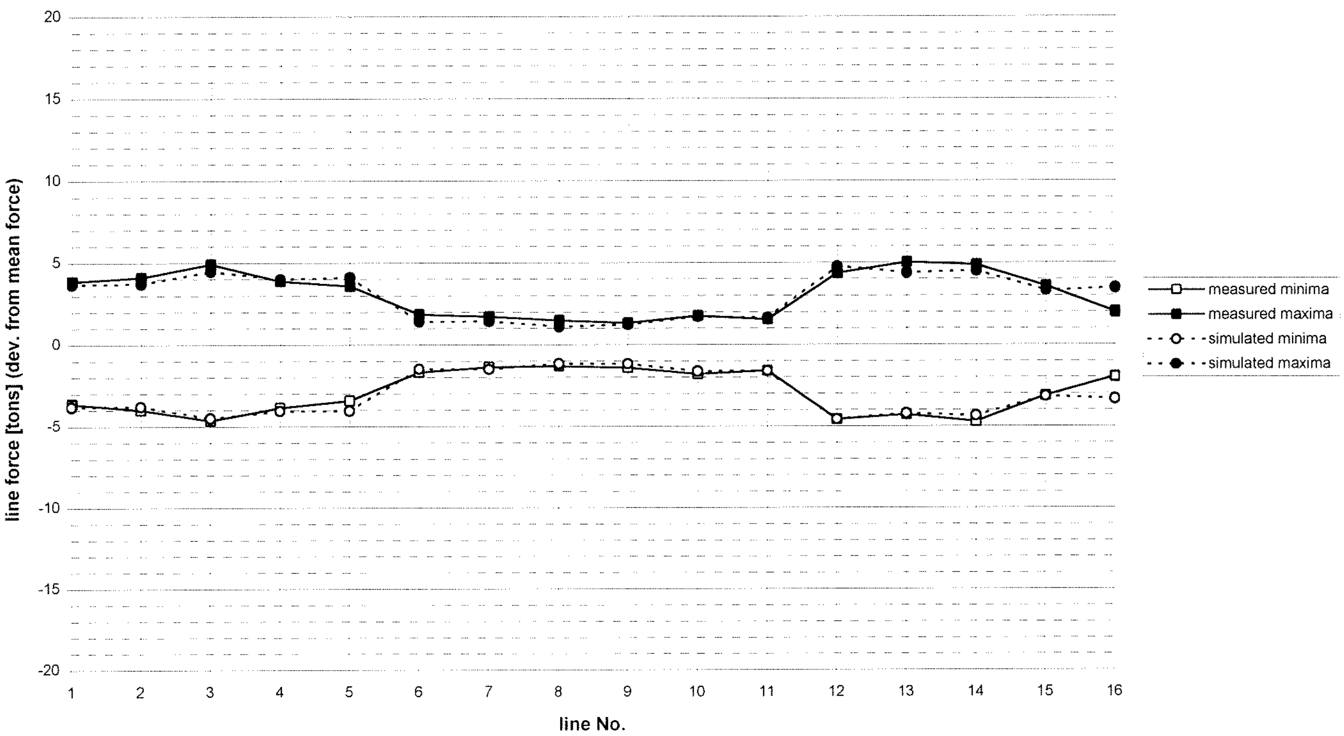

Run No. 2e, 1-12-96: Line force variations, minimum & maximum forces per 10 minutes
line force [tons] (dev. from mean force)
20
15
10
5
0
-5
-10
-15
-20
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
line No.
measured minima
measured maxima
simulated minima
simulated maxima


Run 2e, 1-12-96: Maximum line forces per 3 hours
line force [tons] (dev. from mean force)
40
35
30
25
20
15
10
5
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
line No.
measurements
simulation

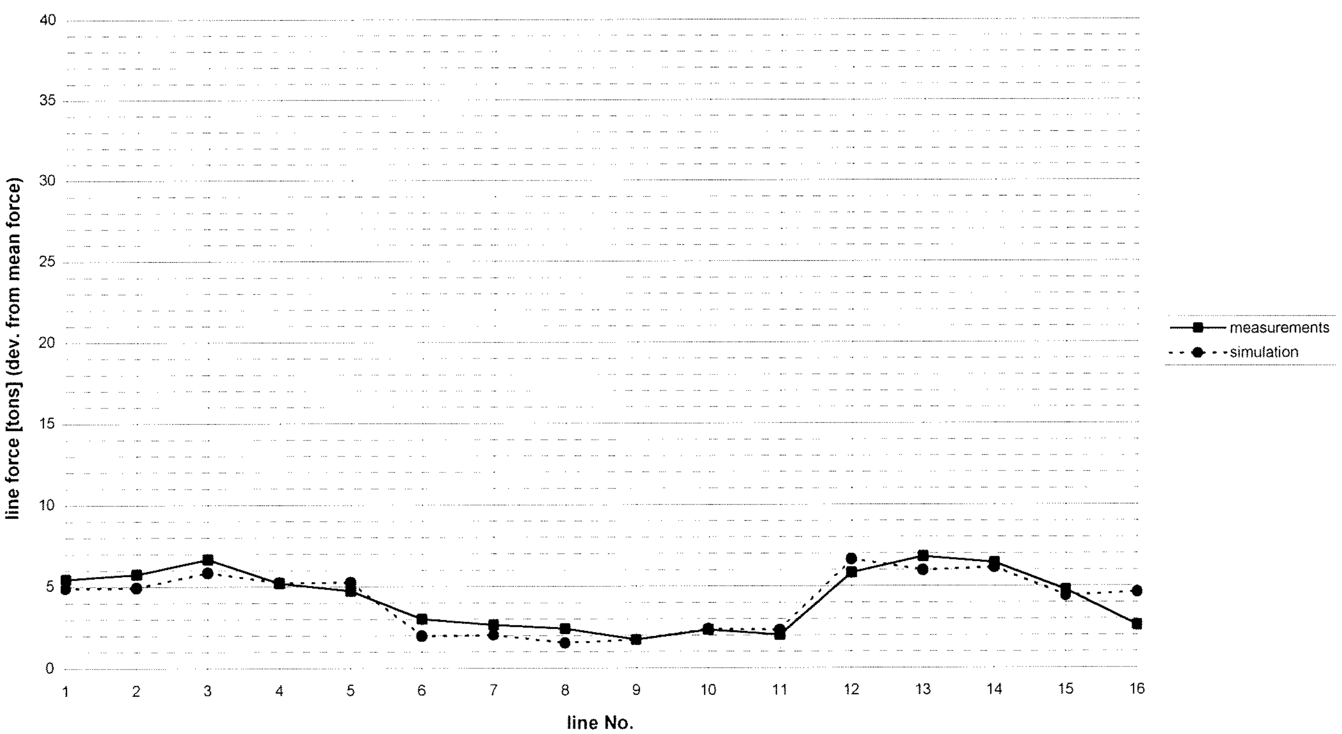

Run No. 2f, 1-12-96: Line force variations, minimum & maximum forces per 10 minutes
line force [tons] (dev. from mean force)
line No.
measured minima
measured maxima
simulated minima
simulated maxima


Run No. 2f, 1-12-96: Maximum line forces per 3 hours
line force [tons] (dev. from mean force)
line No.
measurements
simulation

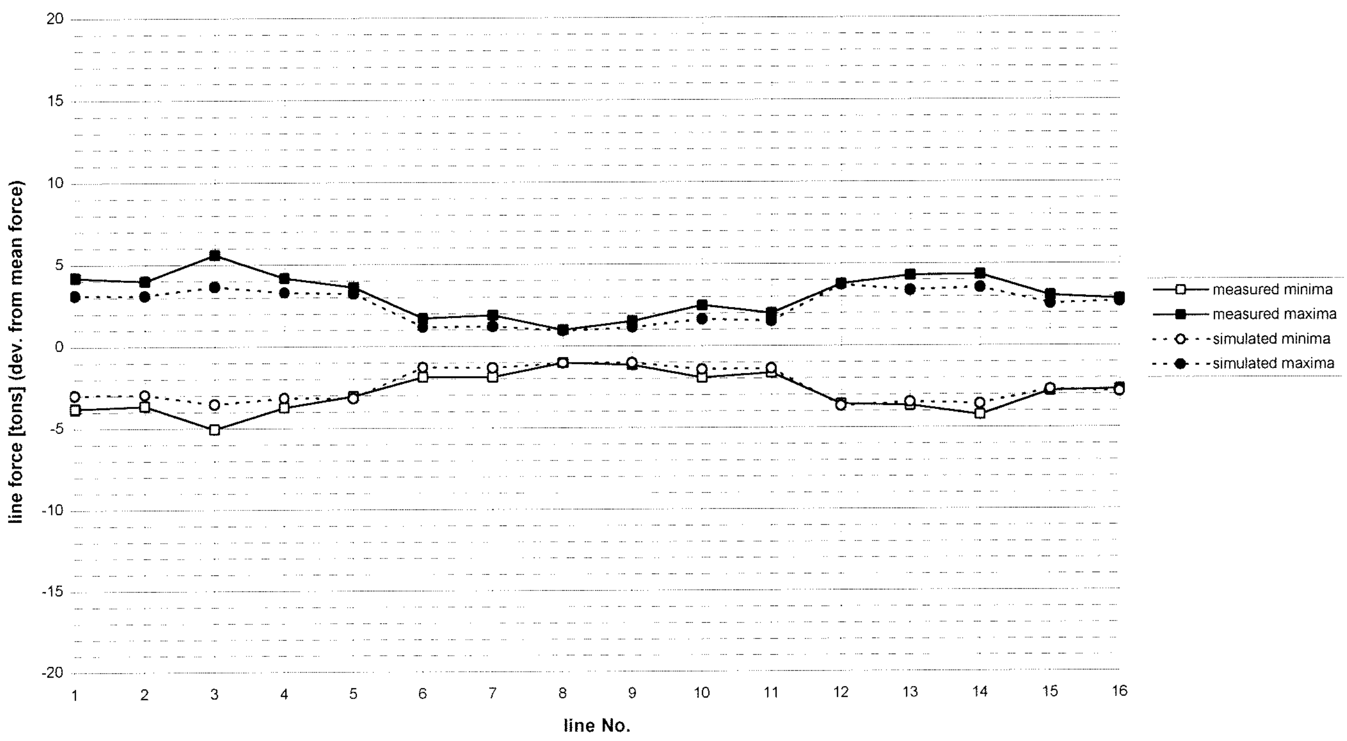
Run No. 2g, 1-12-96: Line force variations, minimum & maximum forces per 10 minutes



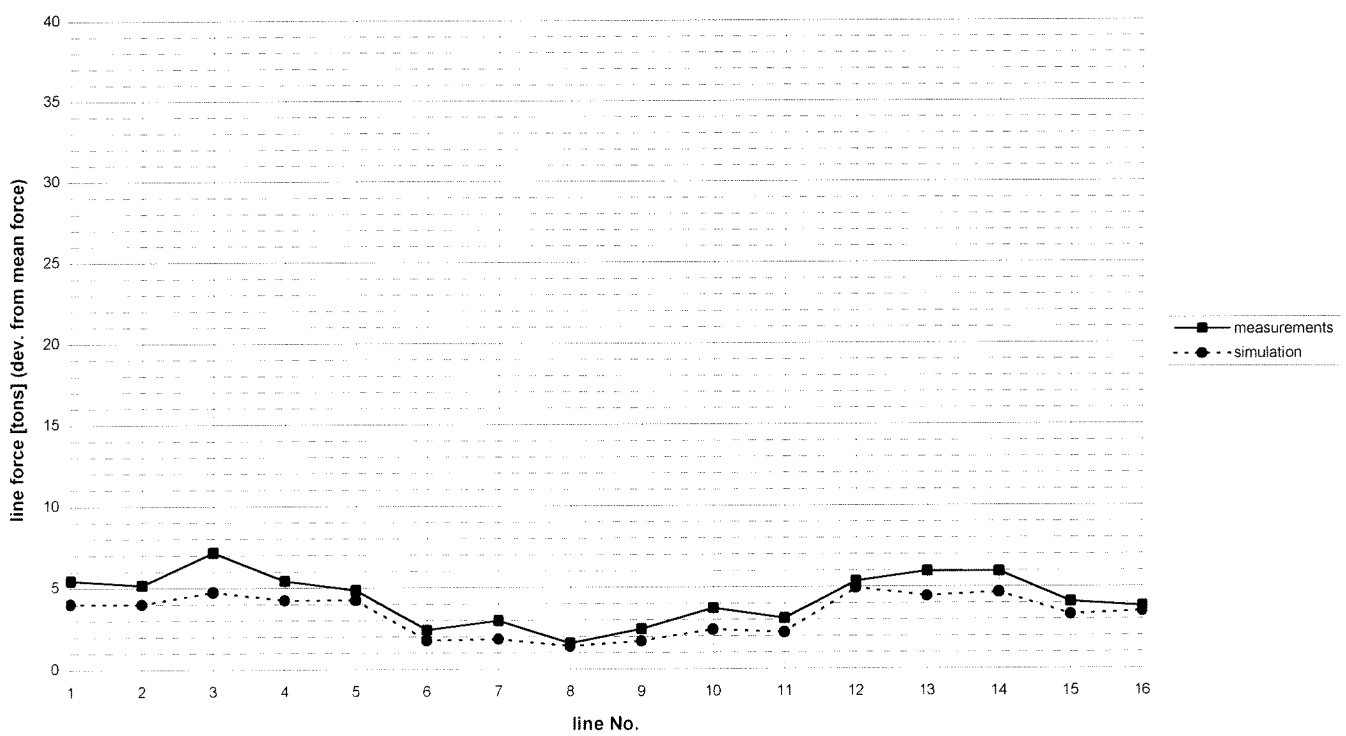
Run No. 2g, 1-12-96: Maximum line forces per 3 hours

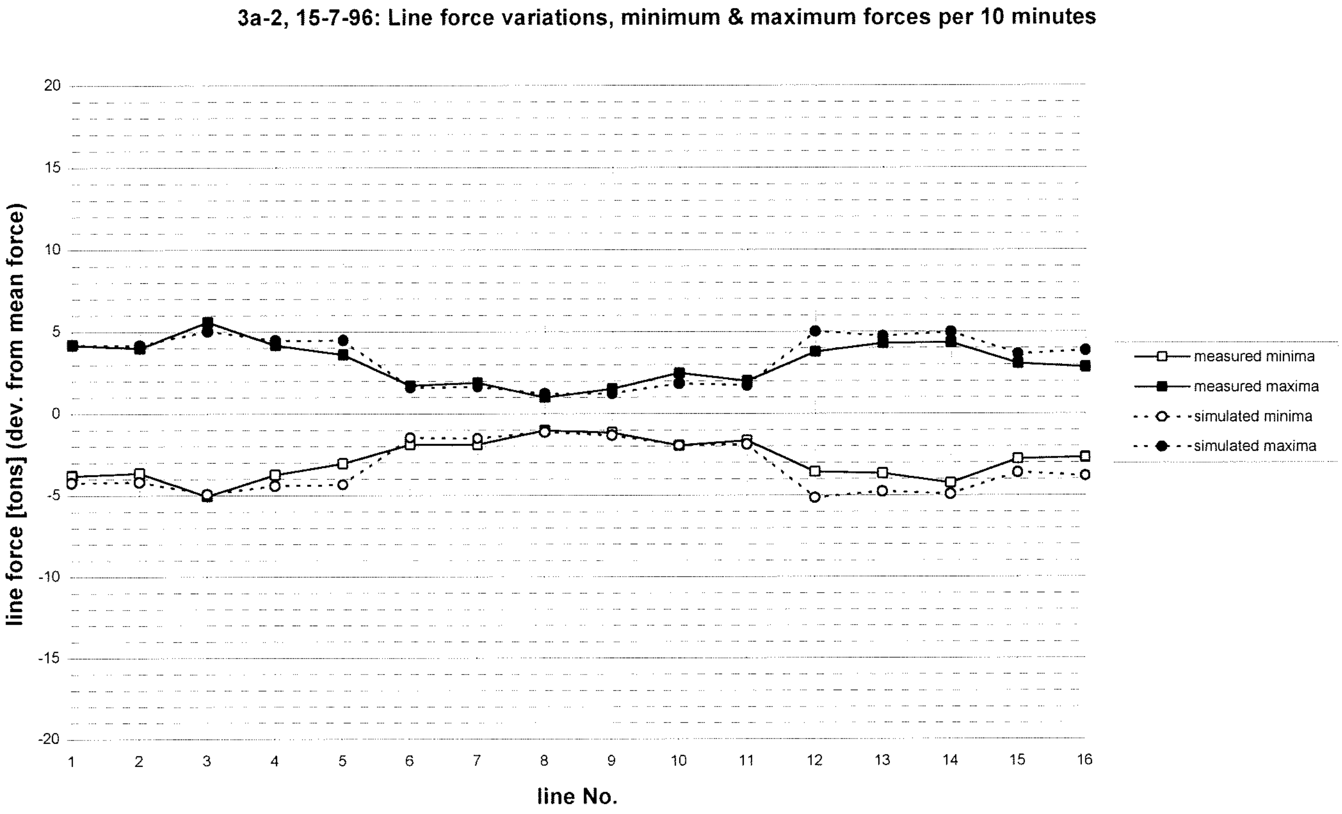


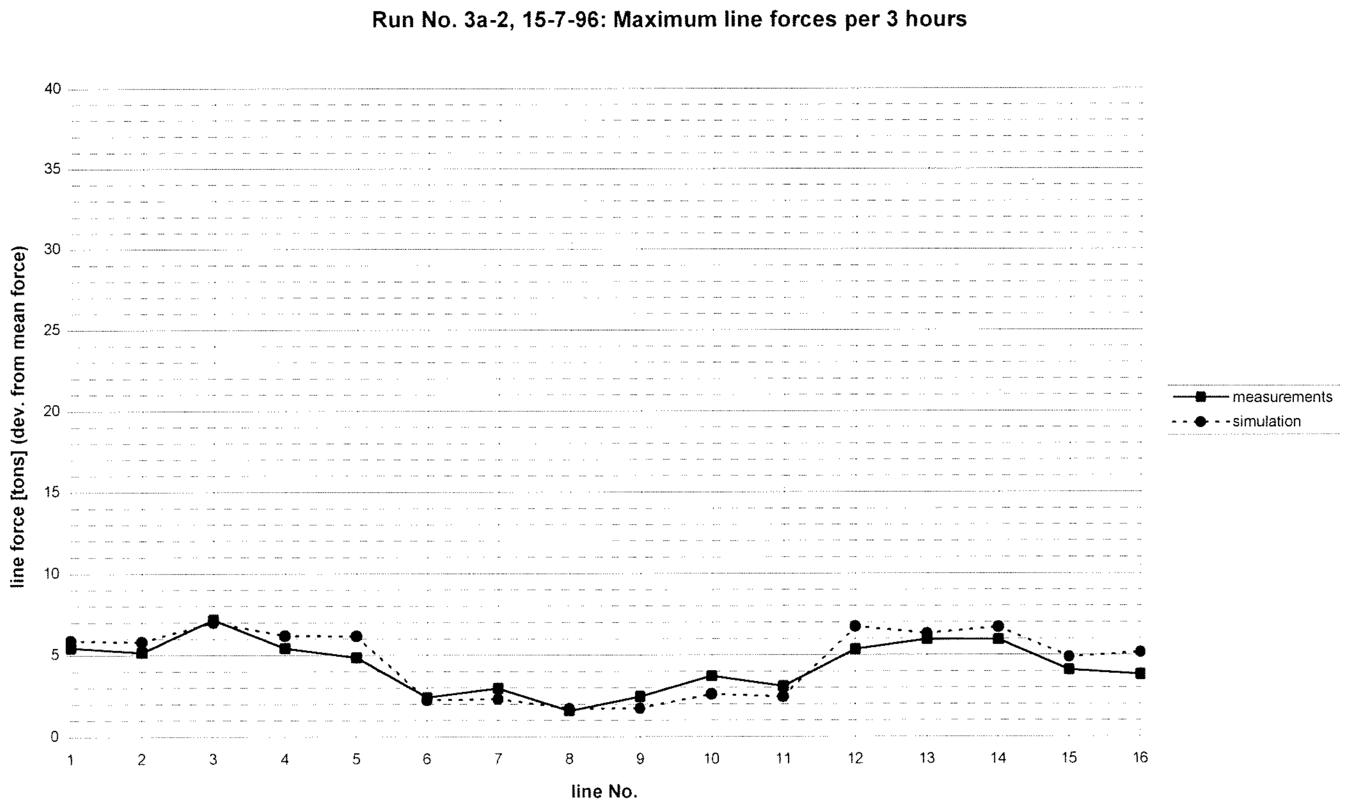
Run No. 3a-1, 15-7-96: Line force variations, minimum & maximum forces per 10 minutes



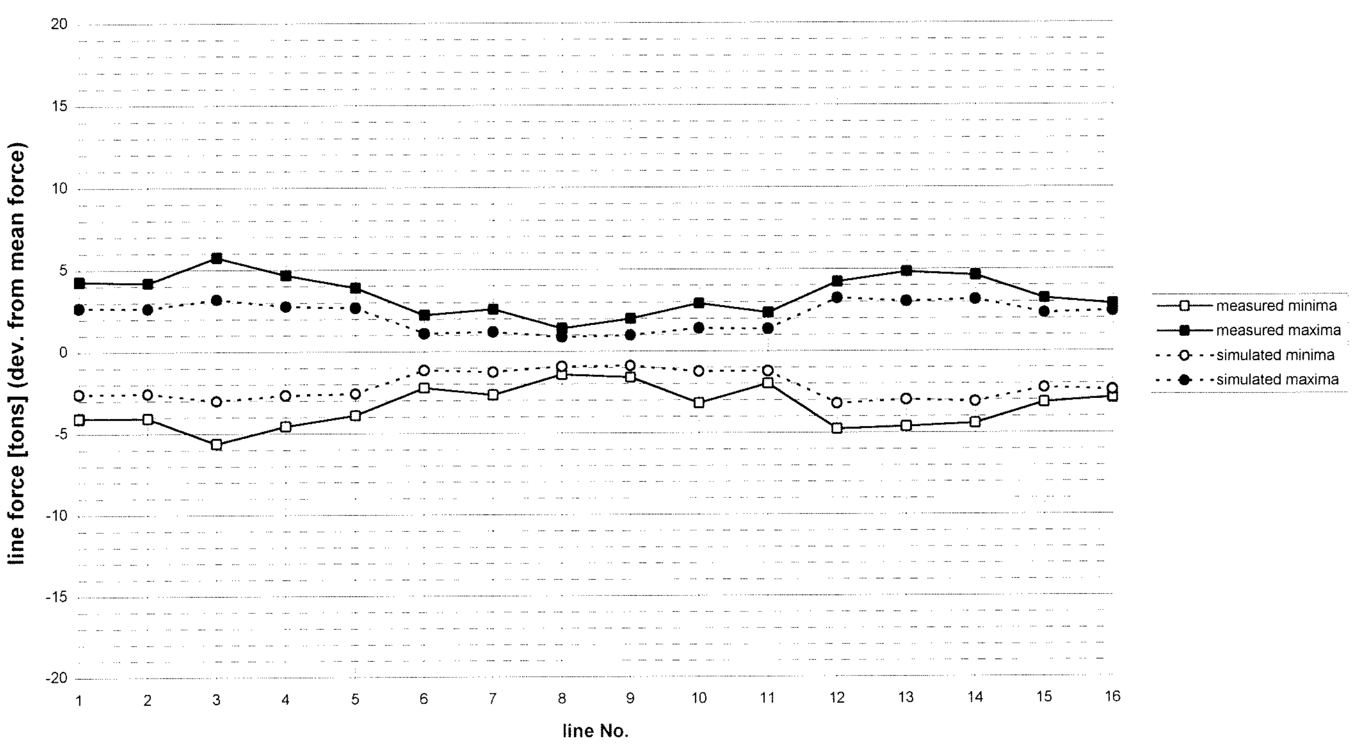
Run No. 3a-1, 15-7-96: Maximum line forces per 3 hours



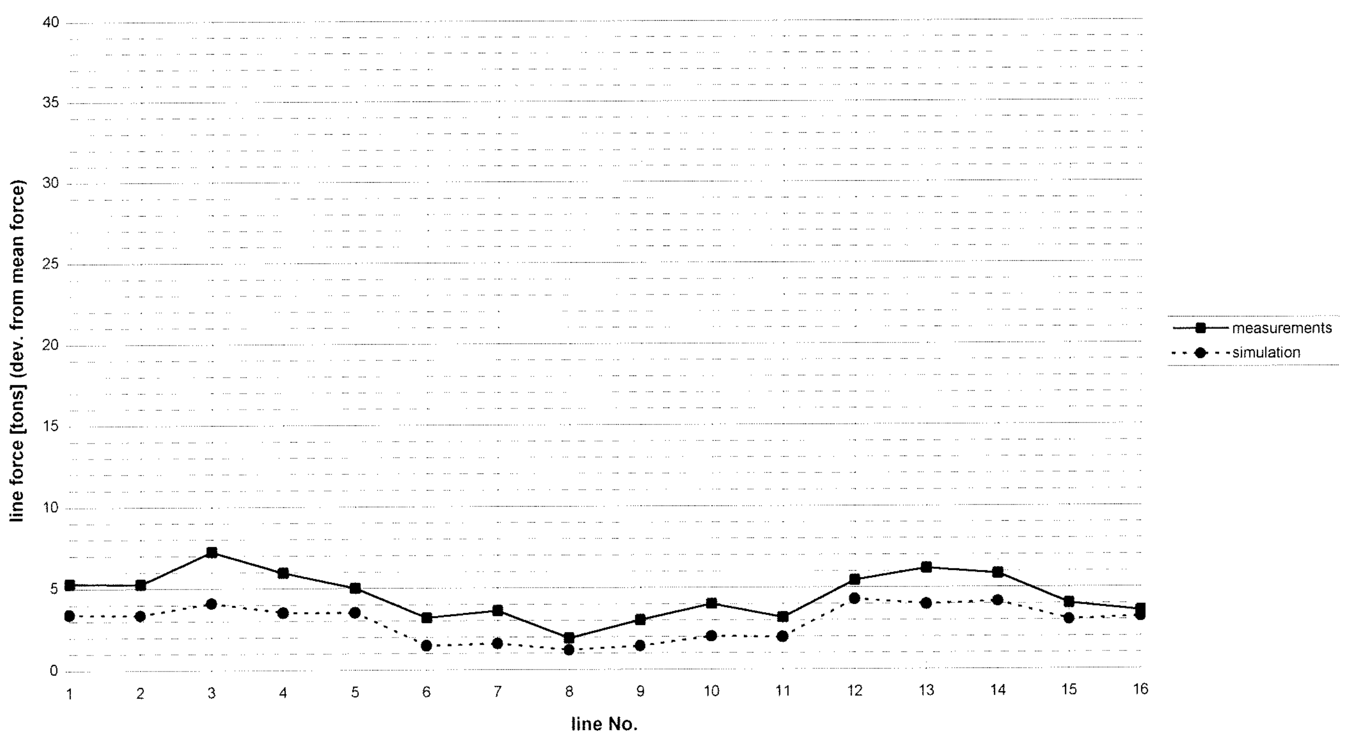

3a-2, 15-7-96: Line force variations, minimum & maximum forces per 10 minutes
line force [tons] (dev. from mean force)
line No.
measured minima
measured maxima
simulated minima
simulated maxima


Run No. 3a-2, 15-7-96: Maximum line forces per 3 hours
line force [tons] (dev. from mean force)
line No.
measurements
simulation

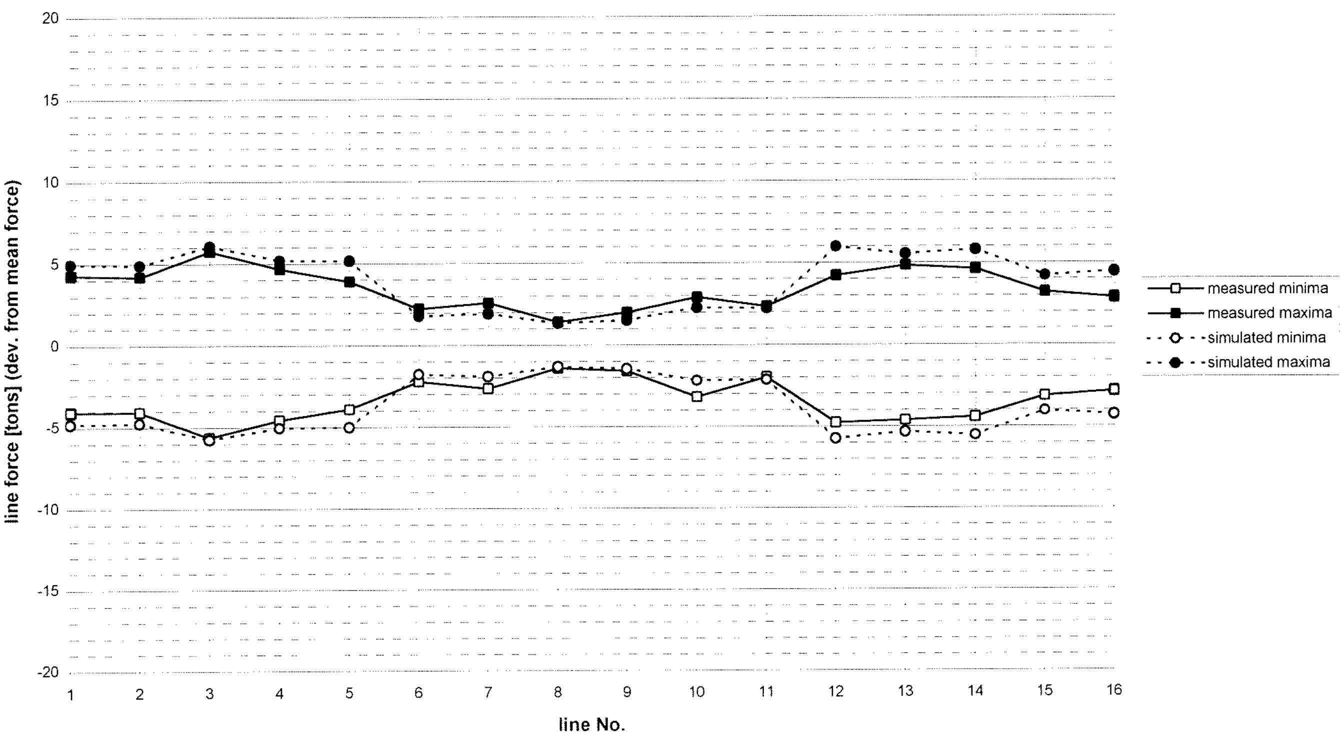
Run No. 3b-1, 15-7-96: Line force variations, minimum & maximum forces per 10 minutes



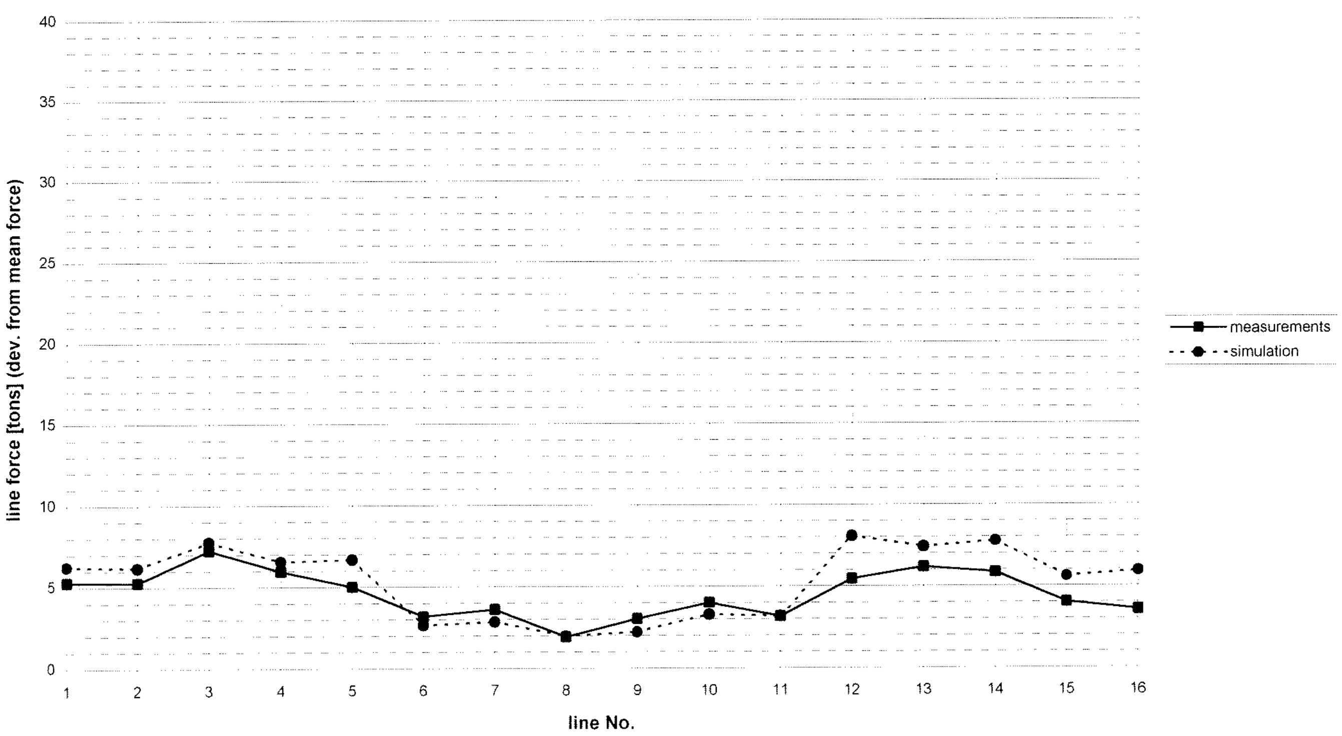
Run No. 3b-1, 15-7-96: Maximum line forces per 3 hours



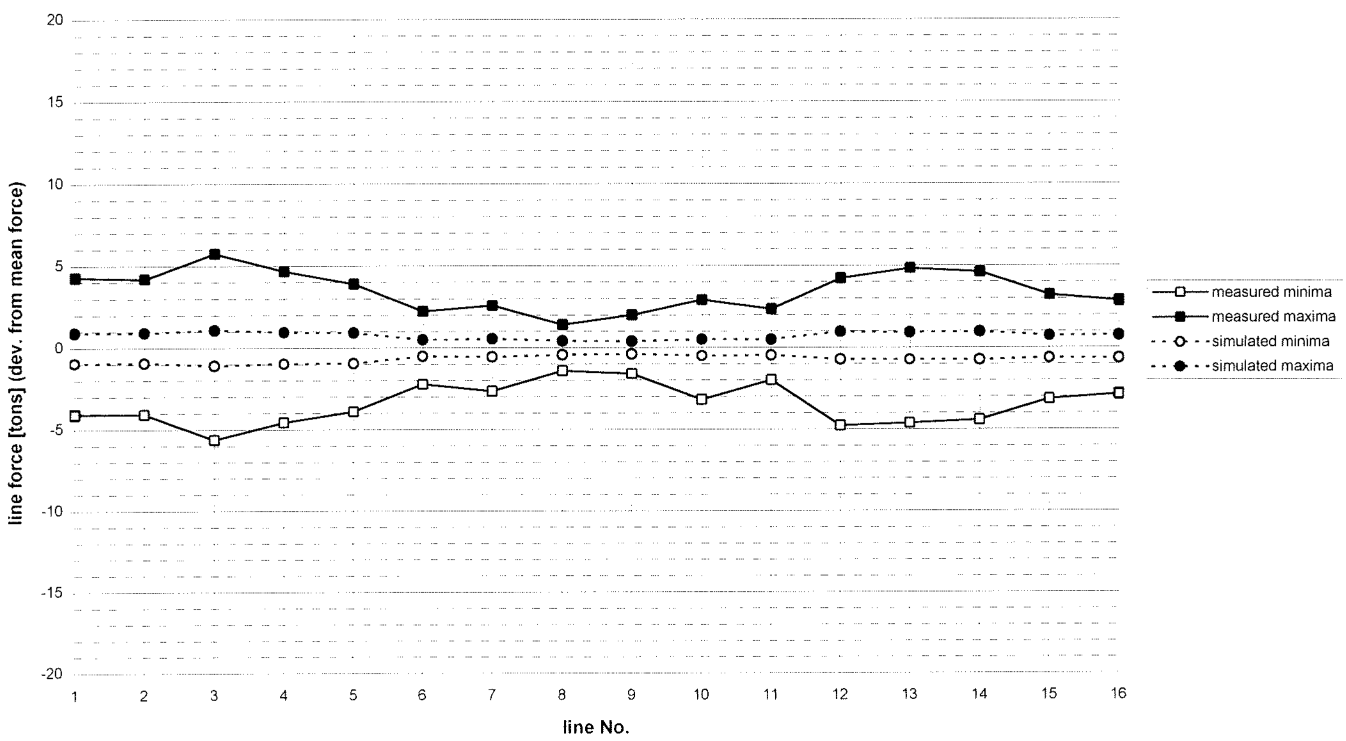
Run No. 3b-2, 15-7-96: Line force variations, minimum & maximum forces per 10 minutes



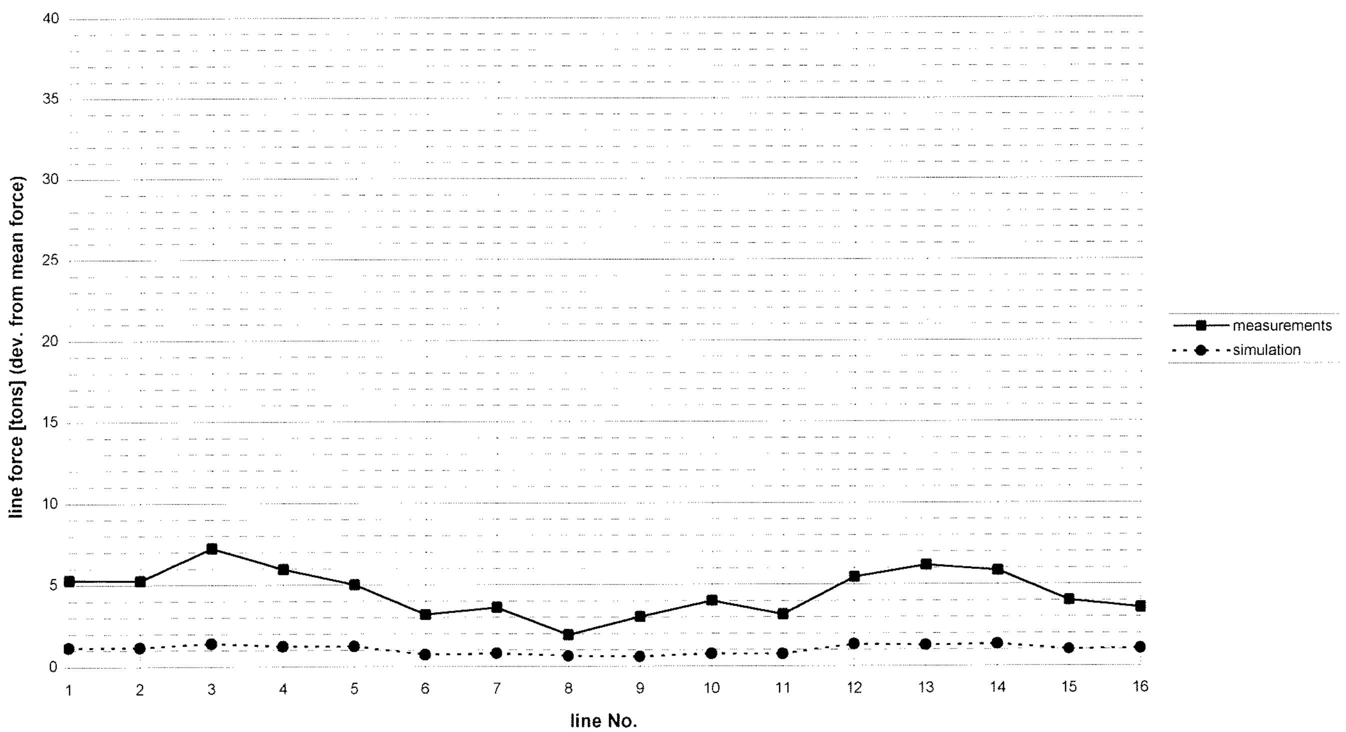
Run No. 3b-2, 15-7-96: Maximum line forces per 3 hours

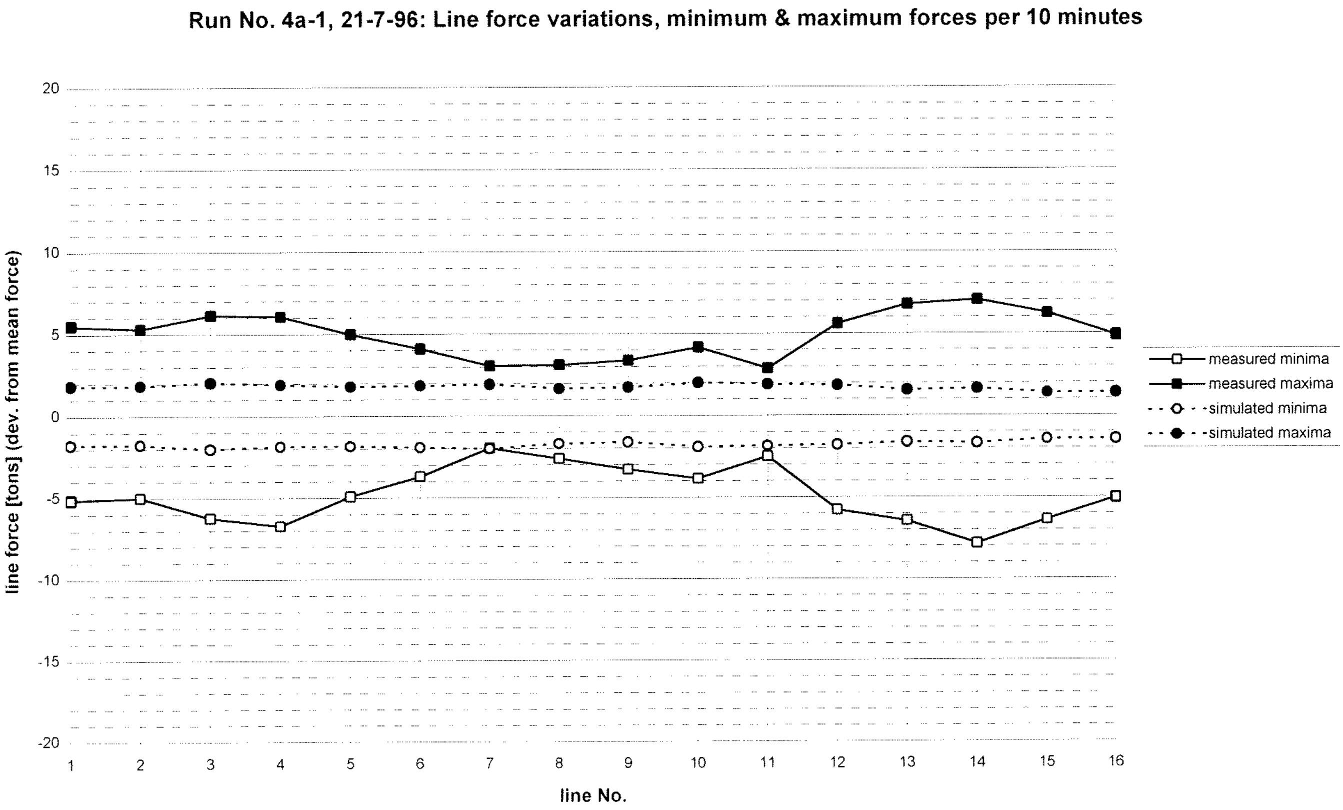


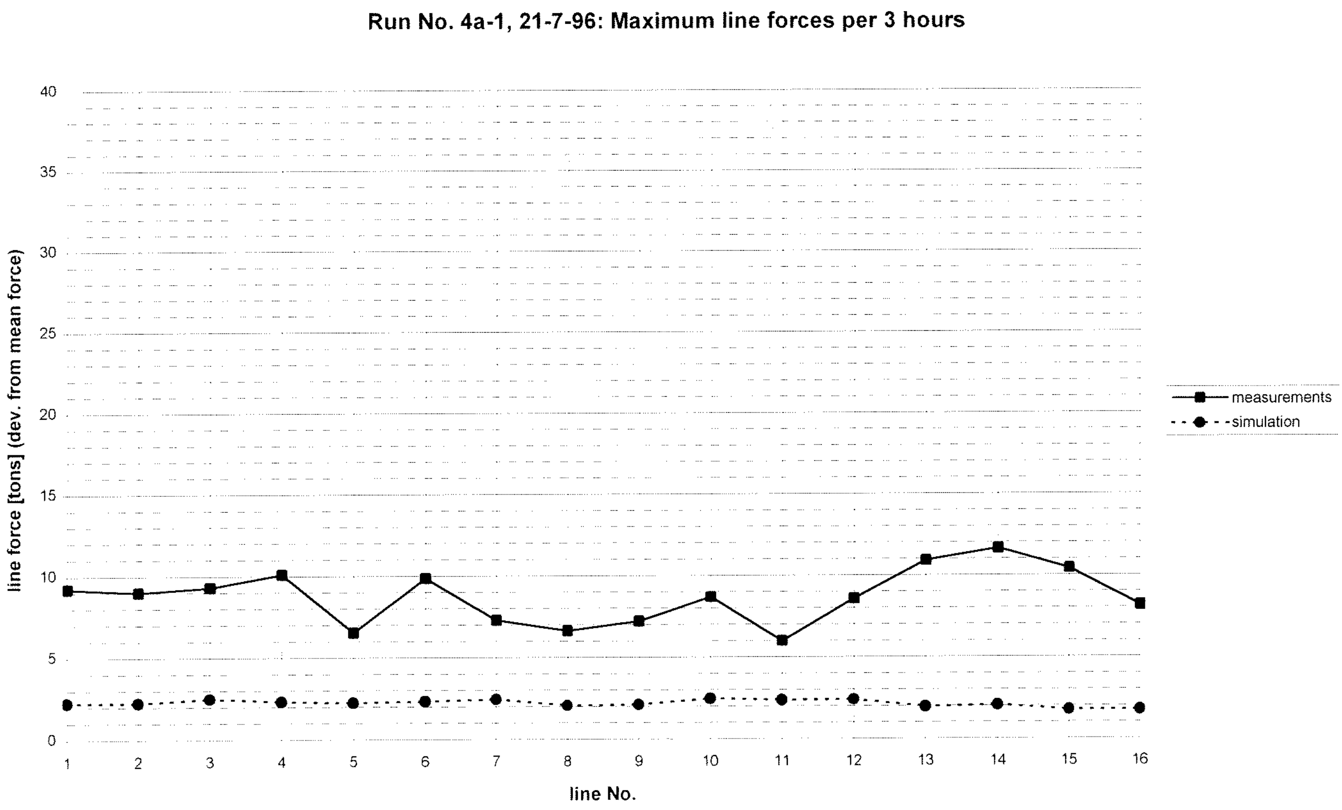
Run No. 3b-3, 15-7-96: Line force variations, minimum & maximum forces per 10 minutes

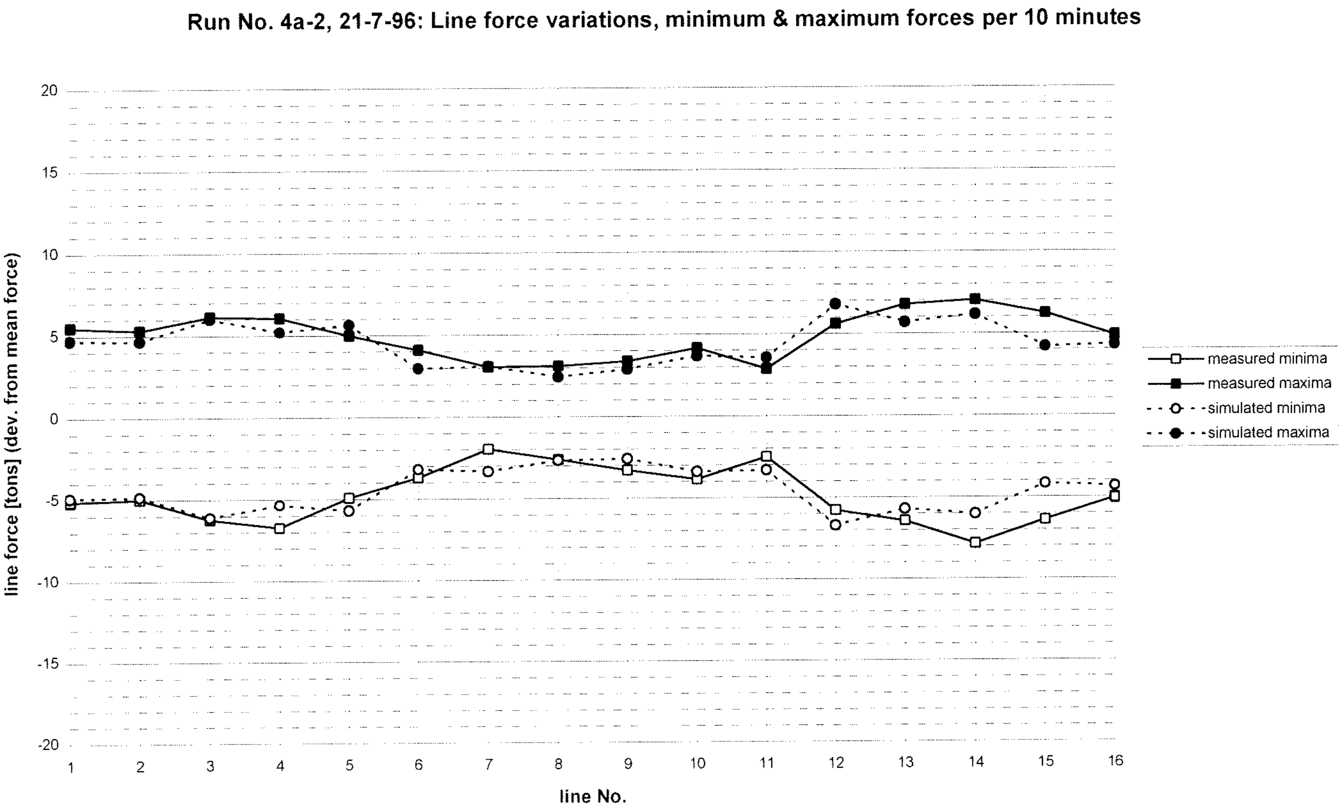


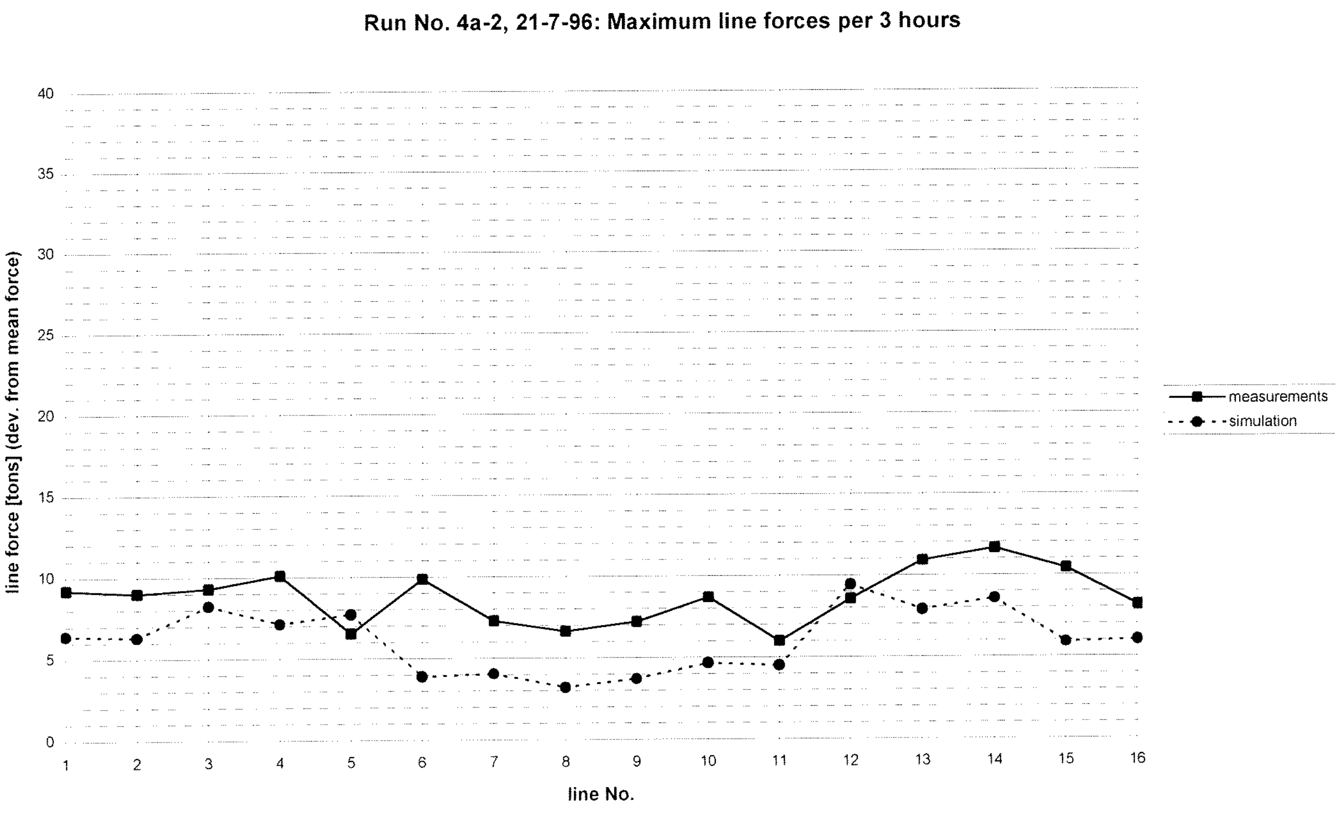
Run No. 3b-3, 15-7-96: Maximum line forces per 3 hours



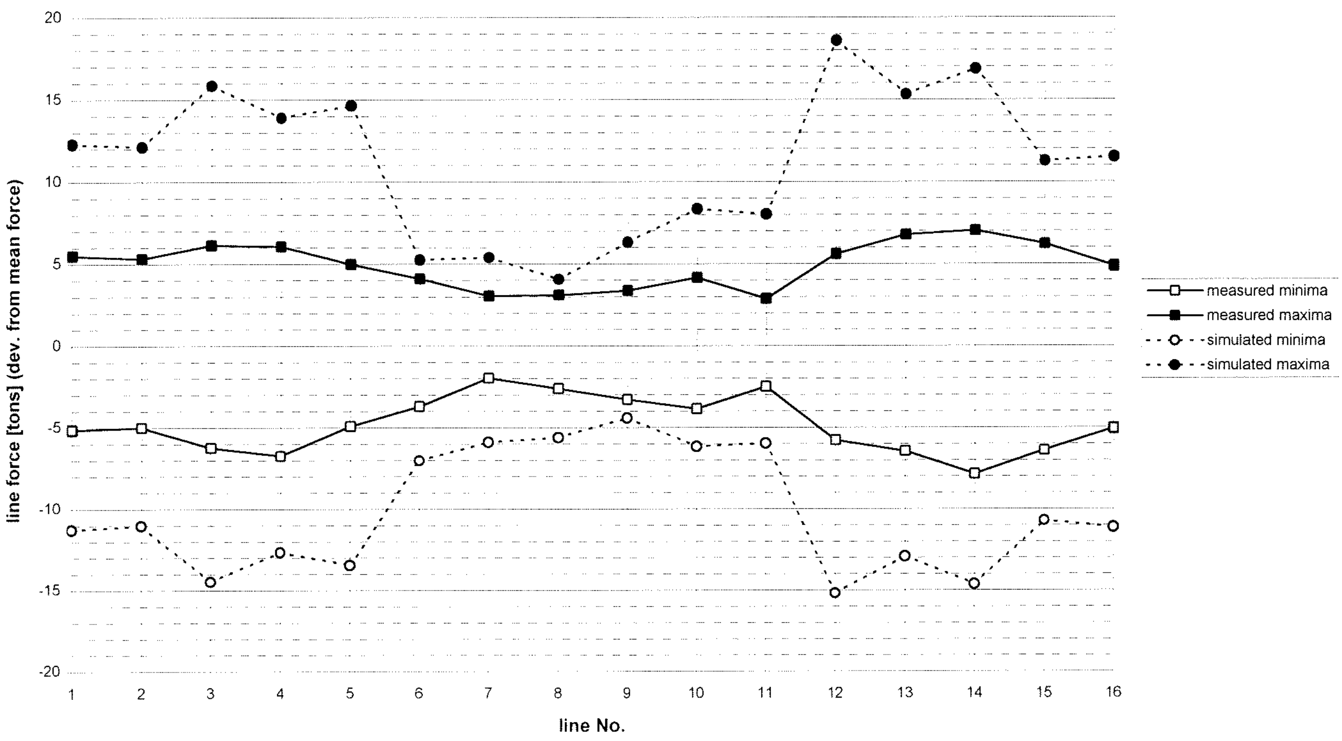

Run No. 4a-1, 21-7-96: Line force variations, minimum & maximum forces per 10 minutes
line force [tons] (dev. from mean force)
20
15
10
5
0
-5
-10
-15
-20
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
line No.
measured minima
measured maxima
simulated minima
simulated maxima


Run No. 4a-1, 21-7-96: Maximum line forces per 3 hours
line force [tons] (dev. from mean force)
40
35
30
25
20
15
10
5
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
line No.
measurements
simulation

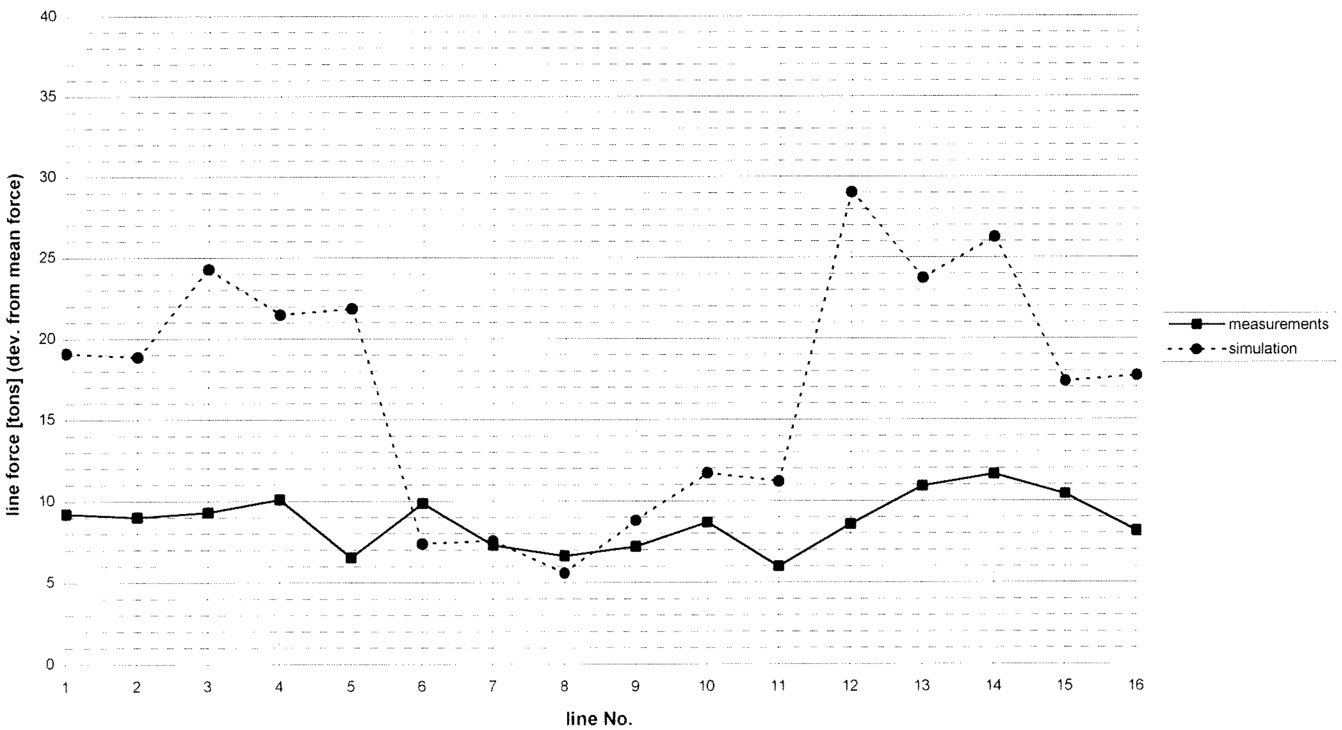

Run No. 4a-2, 21-7-96: Line force variations, minimum & maximum forces per 10 minutes
line force [tons] (dev. from mean force)
20
15
10
5
0
-5
-10
-15
-20
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
line No.
measured minima
measured maxima
simulated minima
simulated maxima


Run No. 4a-2, 21-7-96: Maximum line forces per 3 hours
line force [tons] (dev. from mean force)
40
35
30
25
20
15
10
5
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
line No.
measurements
simulation

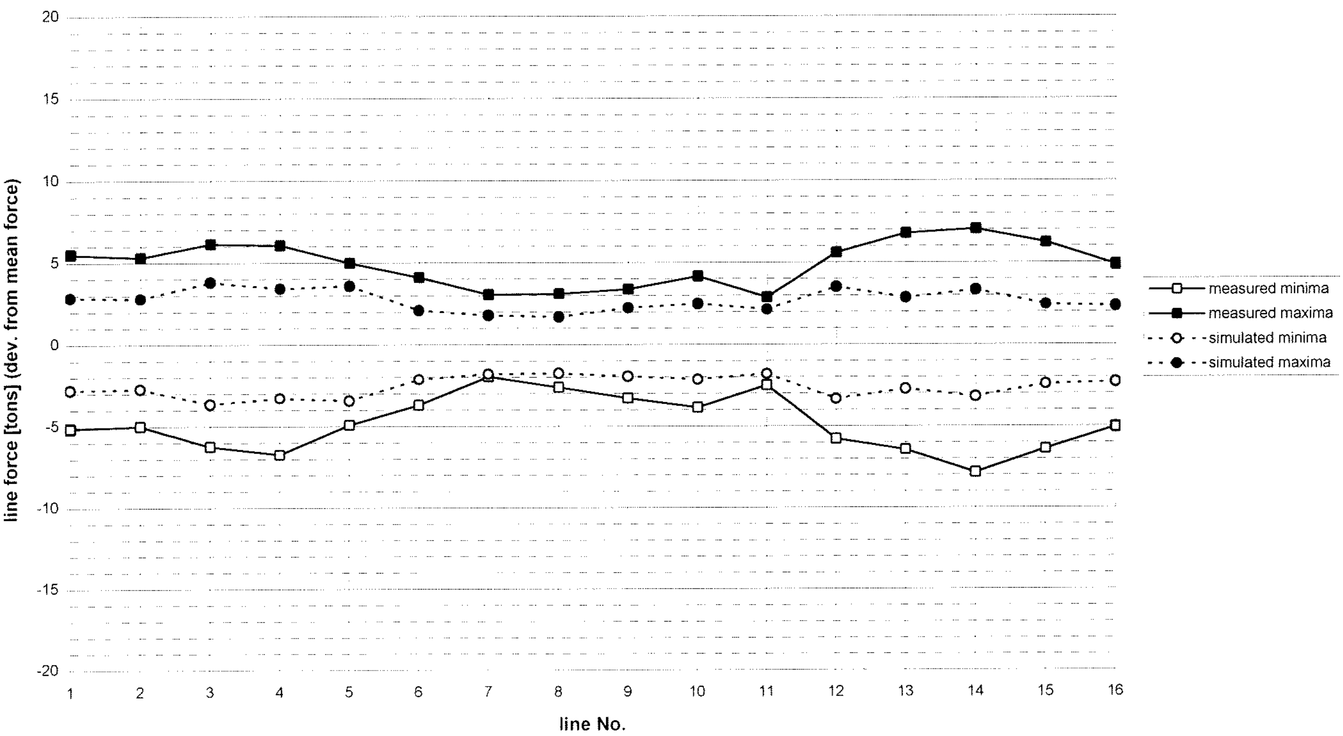
Run No. 4a-3, 21-7-96: Line force variations, minimum & maximum forces per 10 minutes



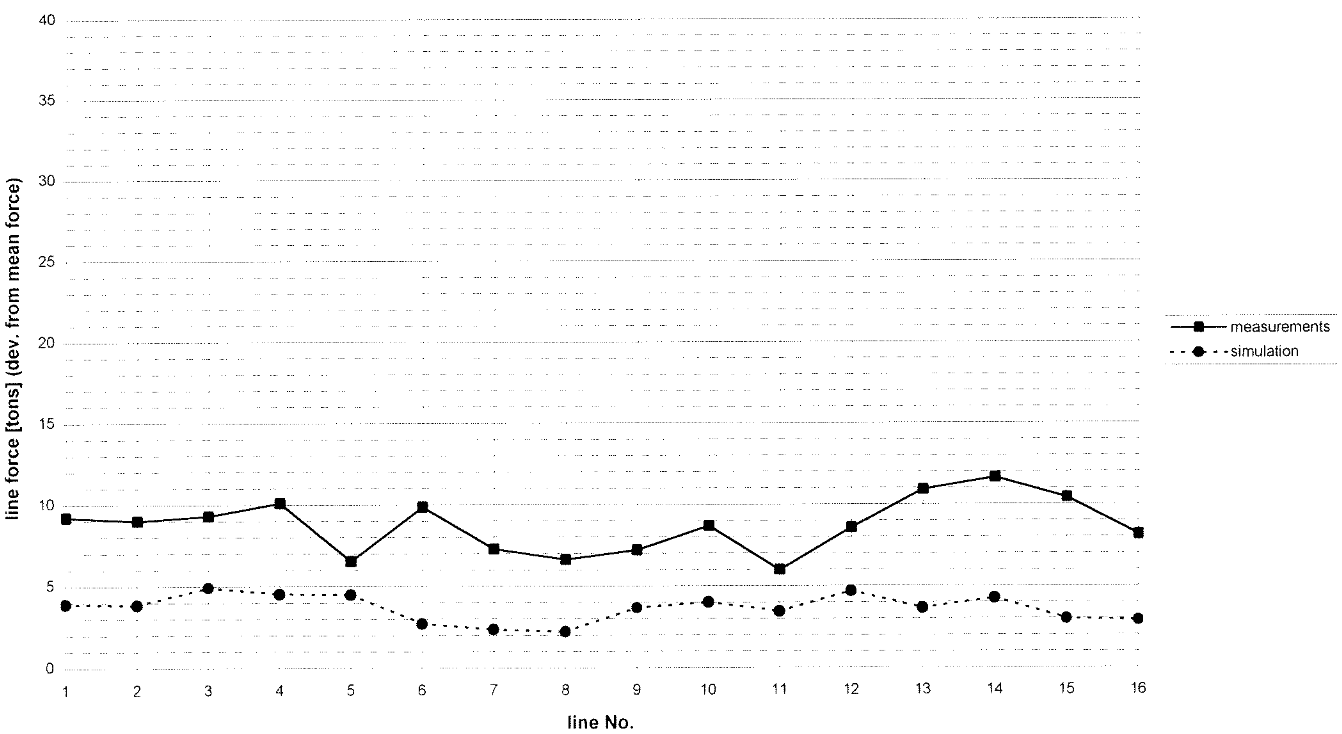
Run No. 4a-3, 21-7-96: Maximum line forces per 3 hours



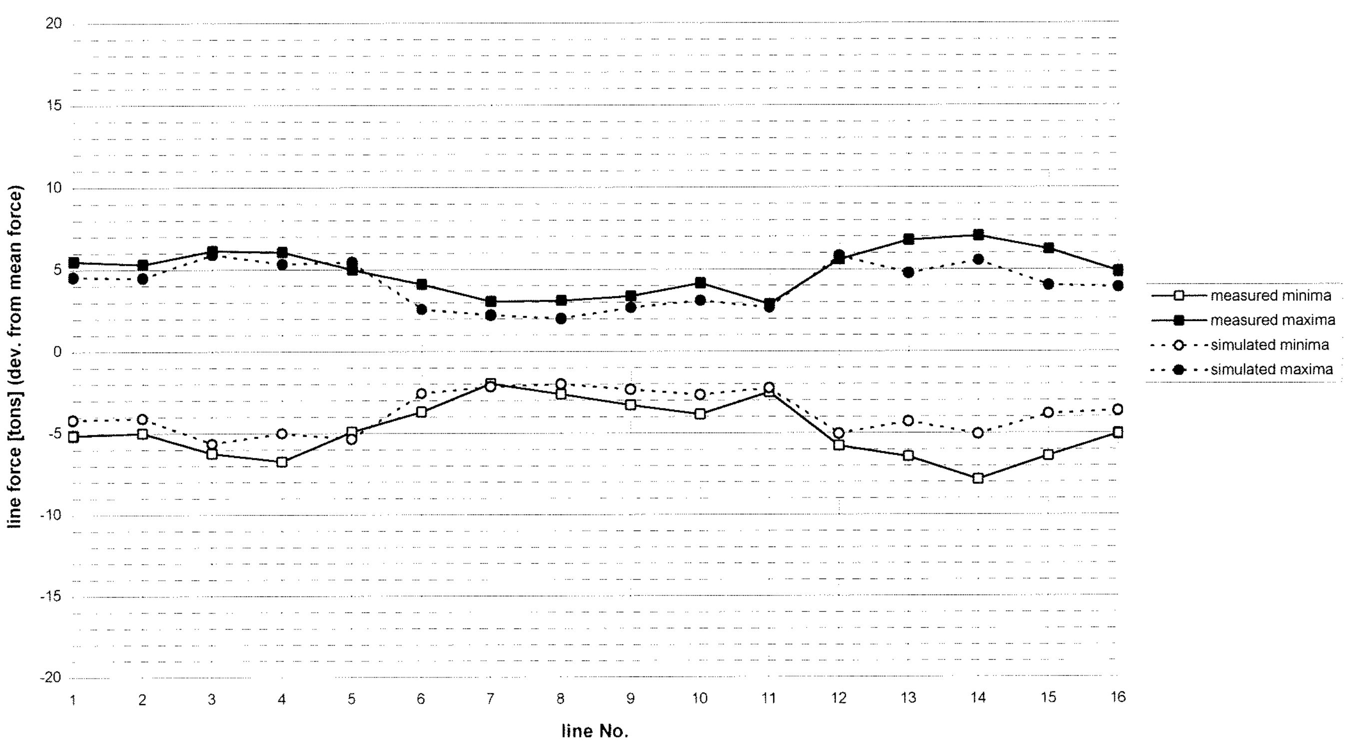
Run No. 4a-4, 21-7-96: Line force variations, minimum & maximum forces per 10 minutes



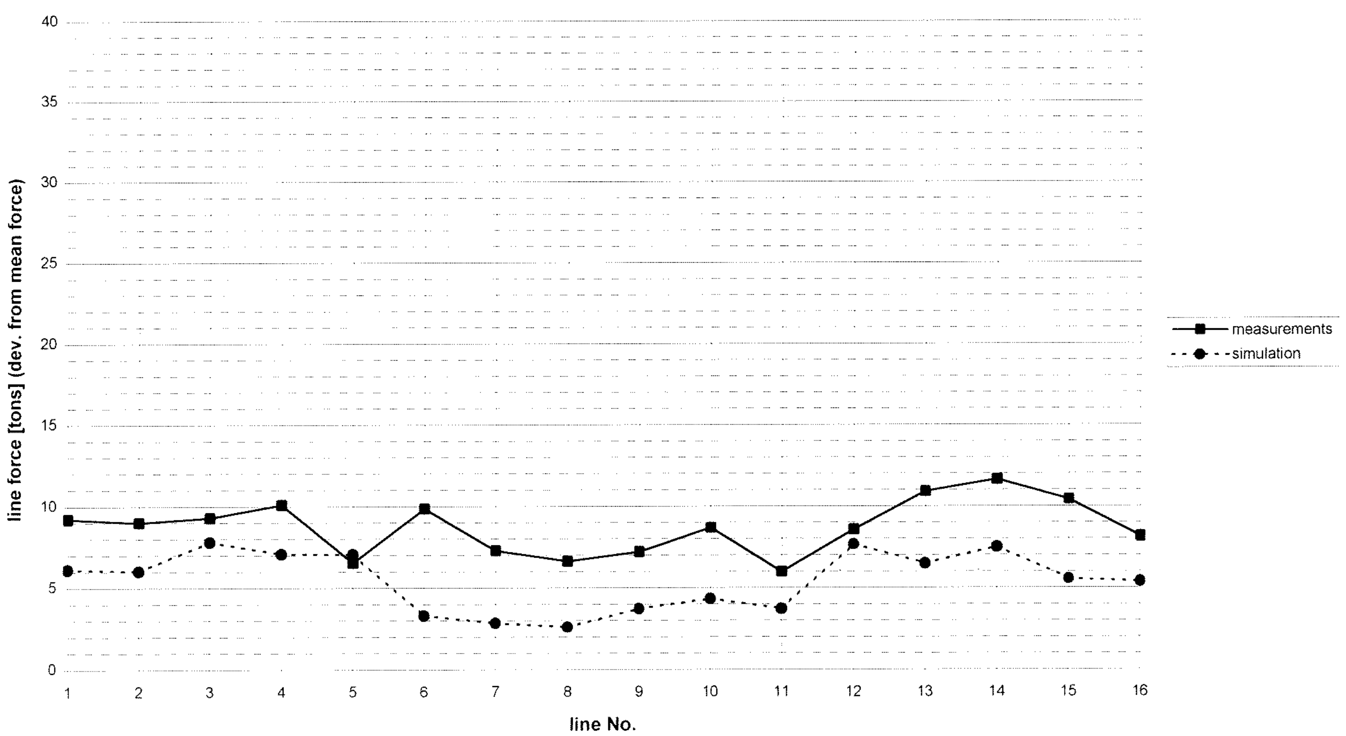
Run No. 4a-4, 21-7-96: Maximum line forces per 3 hours

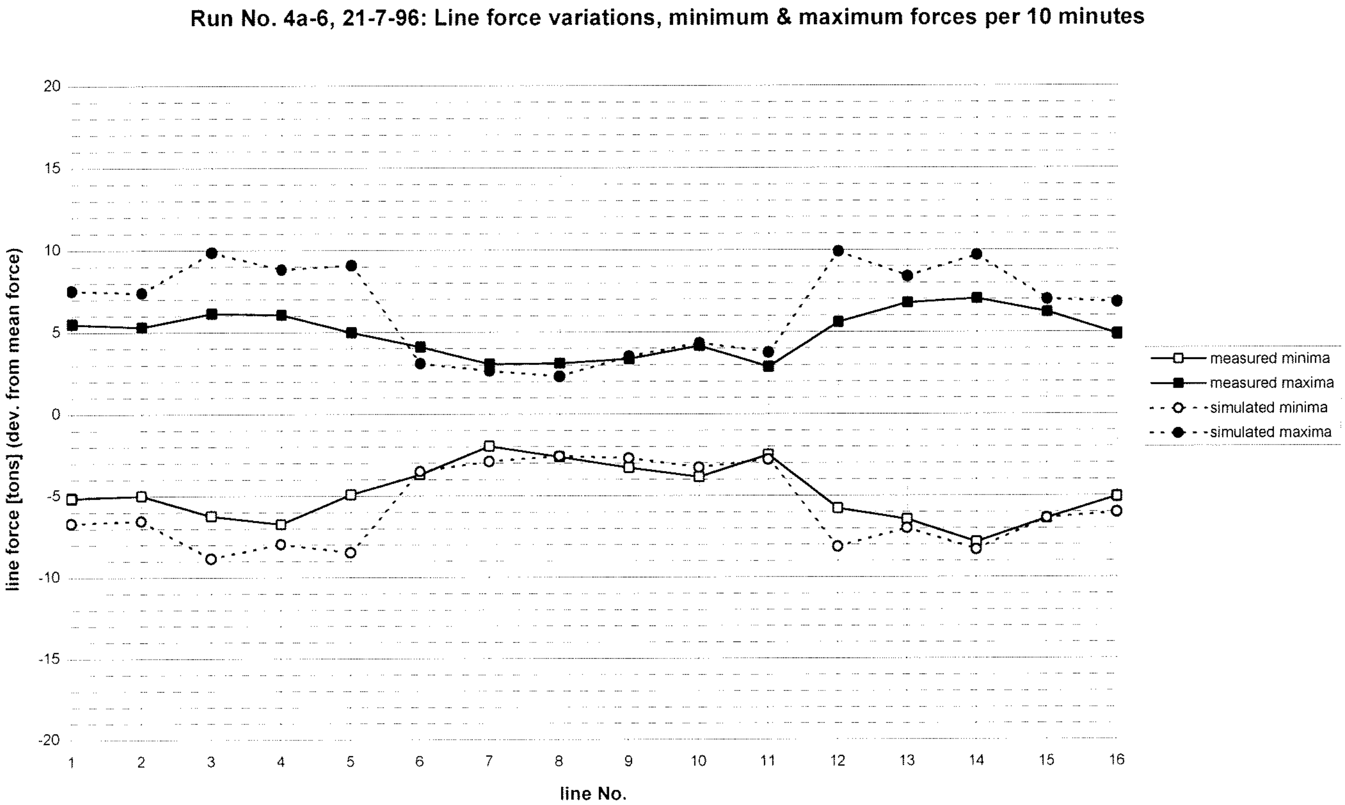


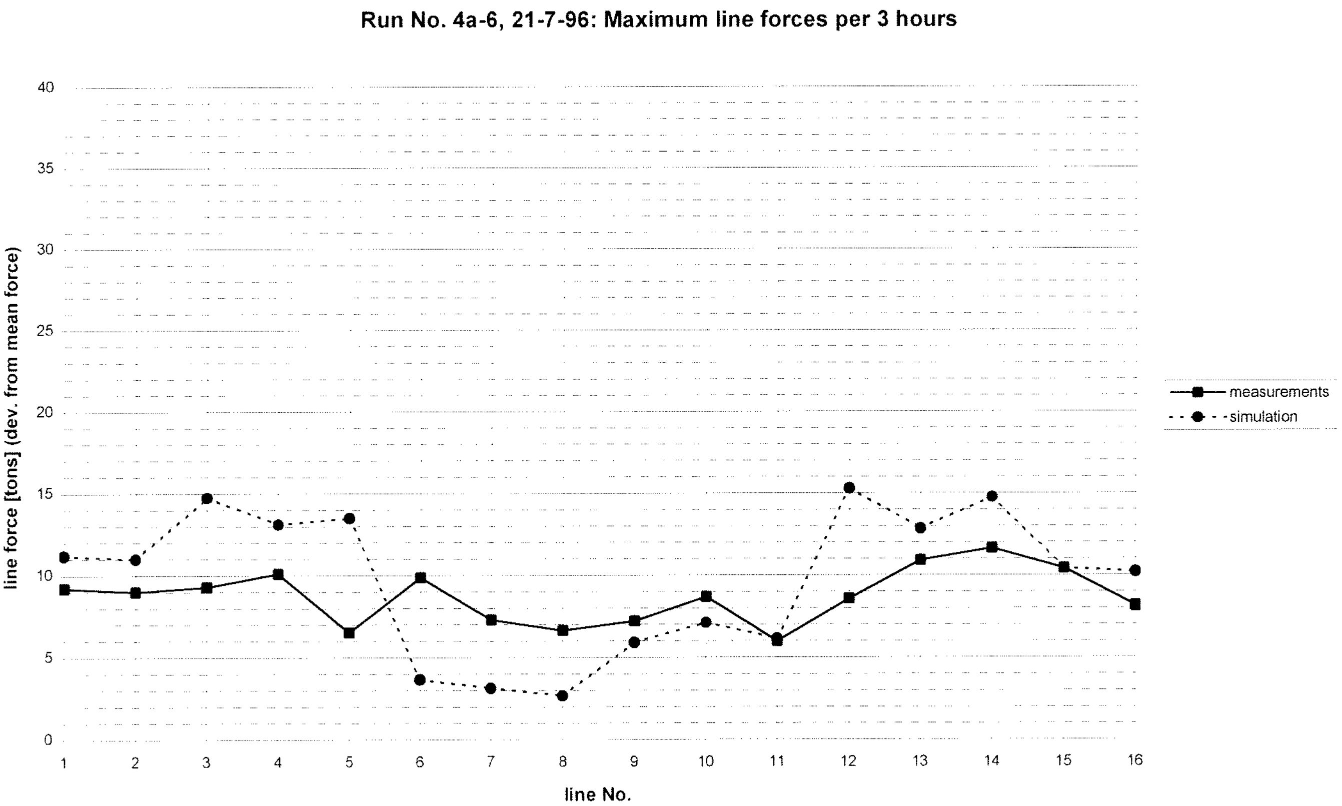
Run No. 4a-5, 21-7-96: Line force variations, minimum & maximum forces per 10 minutes



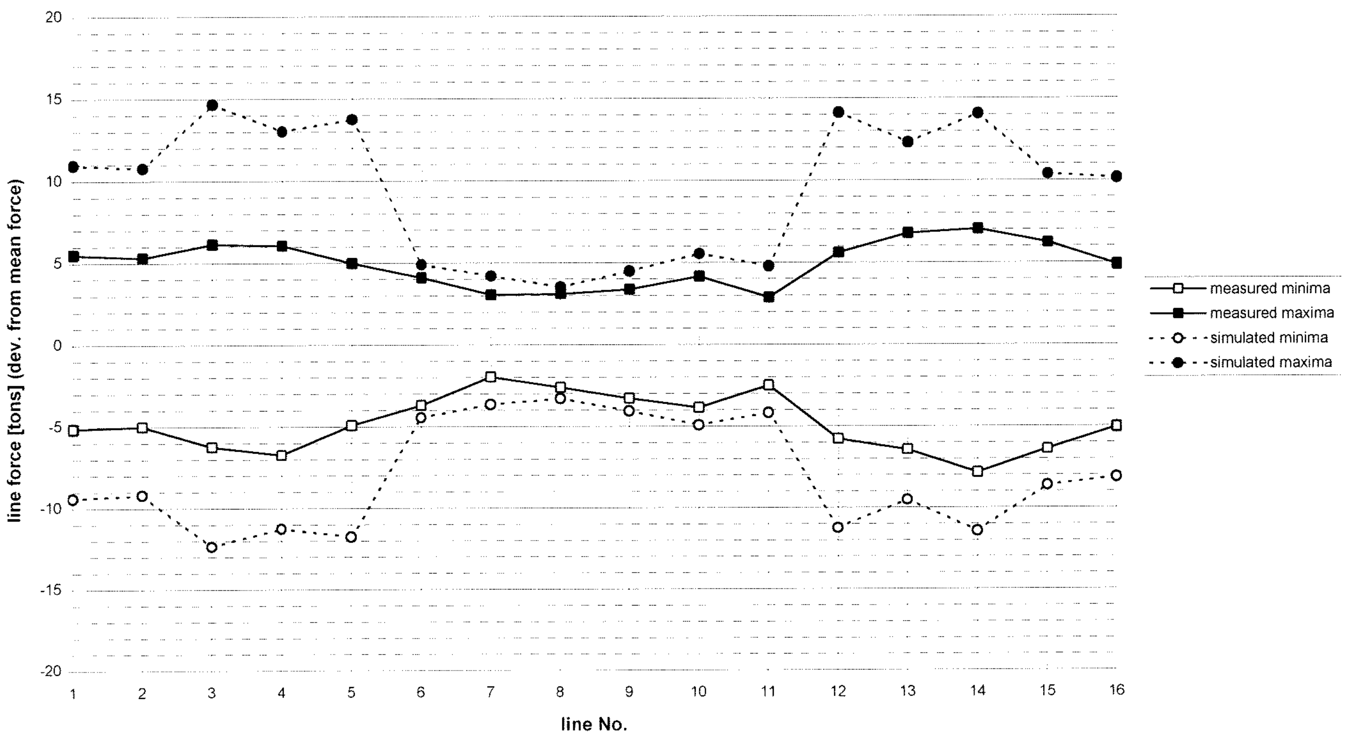
Run No. 4a-5, 21-7-96: Maximum line forces per 3 hours



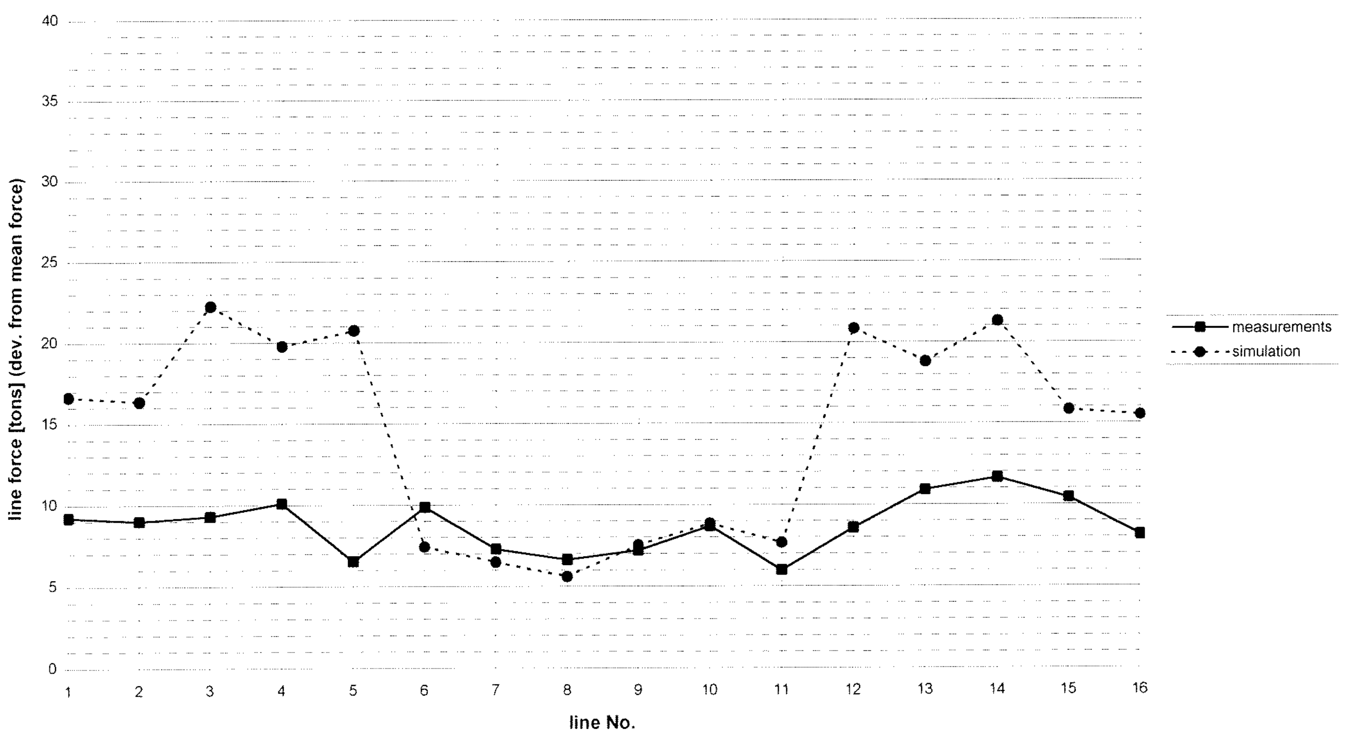

Run No. 4a-6, 21-7-96: Line force variations, minimum & maximum forces per 10 minutes
line force [tons] (dev. from mean force)
line No.
measured minima
measured maxima
simulated minima
simulated maxima


Run No. 4a-6, 21-7-96: Maximum line forces per 3 hours
line force [tons] (dev. from mean force)
line No.
measurements
simulation

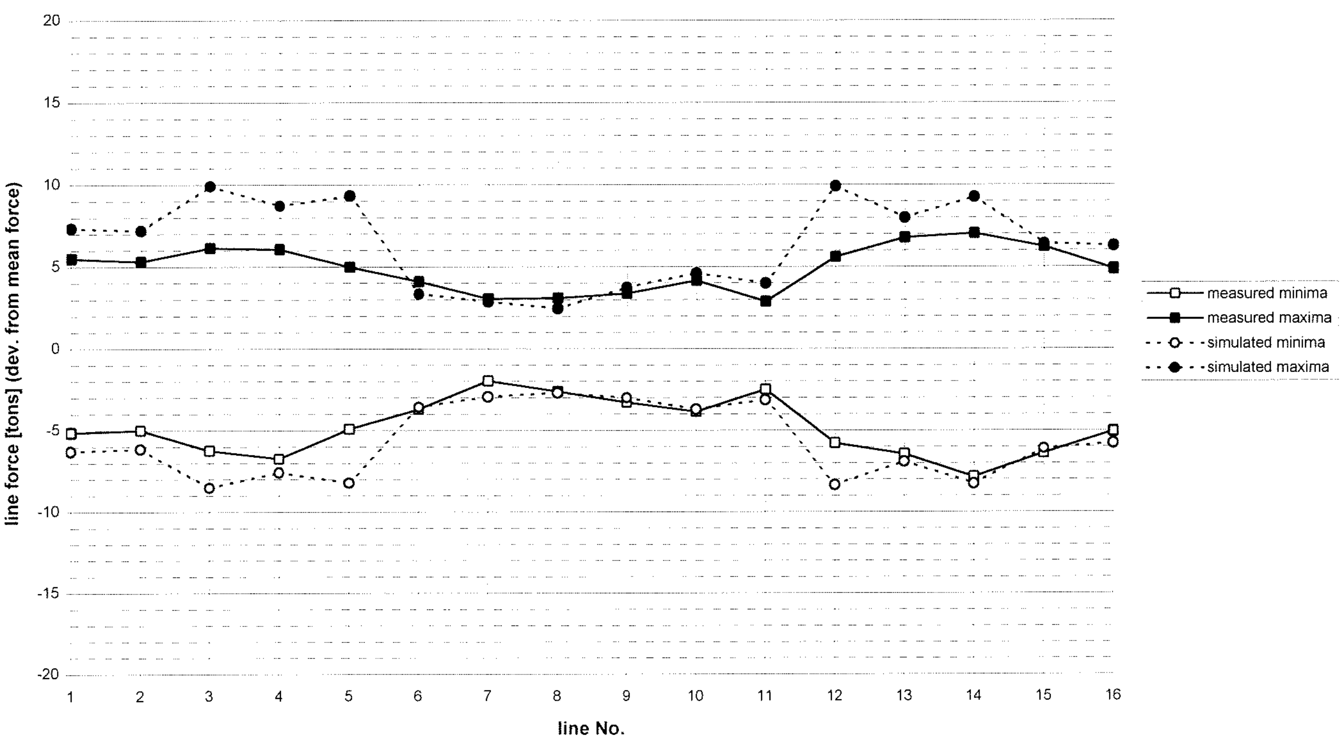
Run No. 4a-7, 21-7-96: Line force variations, minimum & maximum forces per 10 minutes



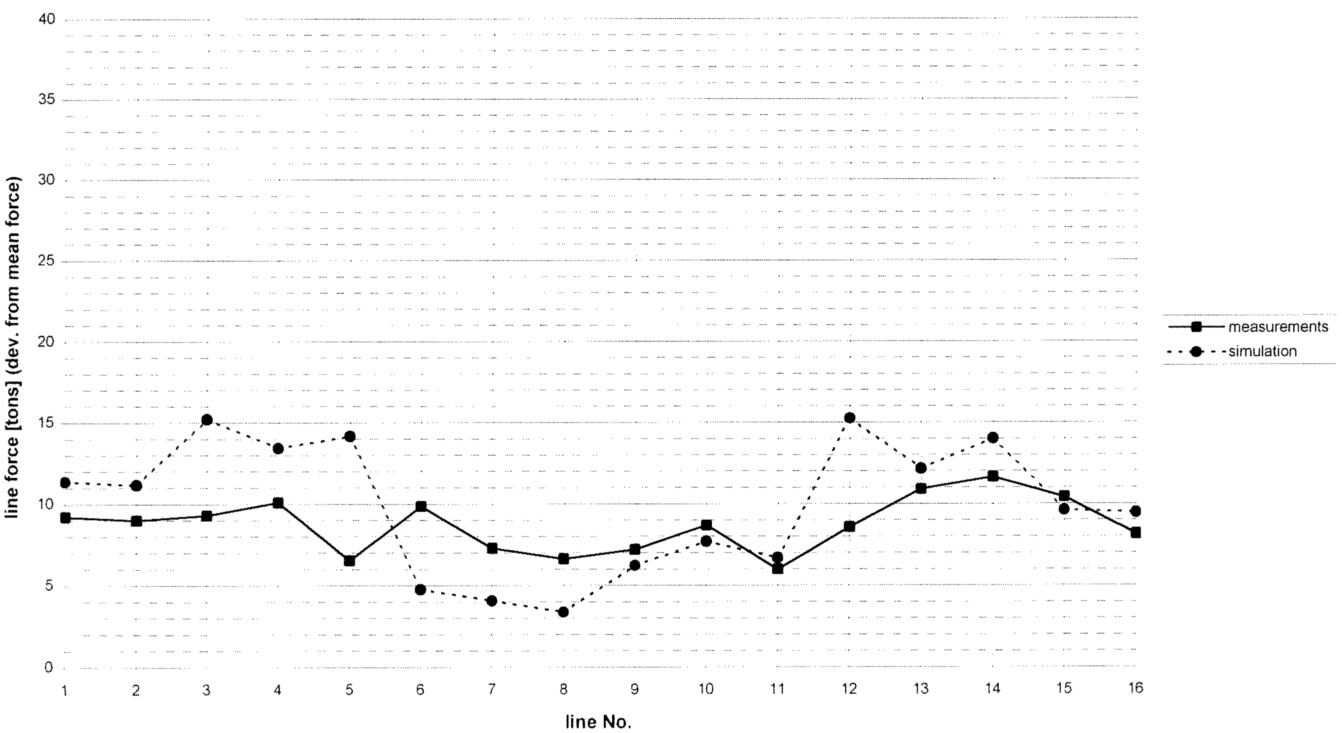
Run No. 4a-7, 21-7-96: Maximum line forces per 3 hours



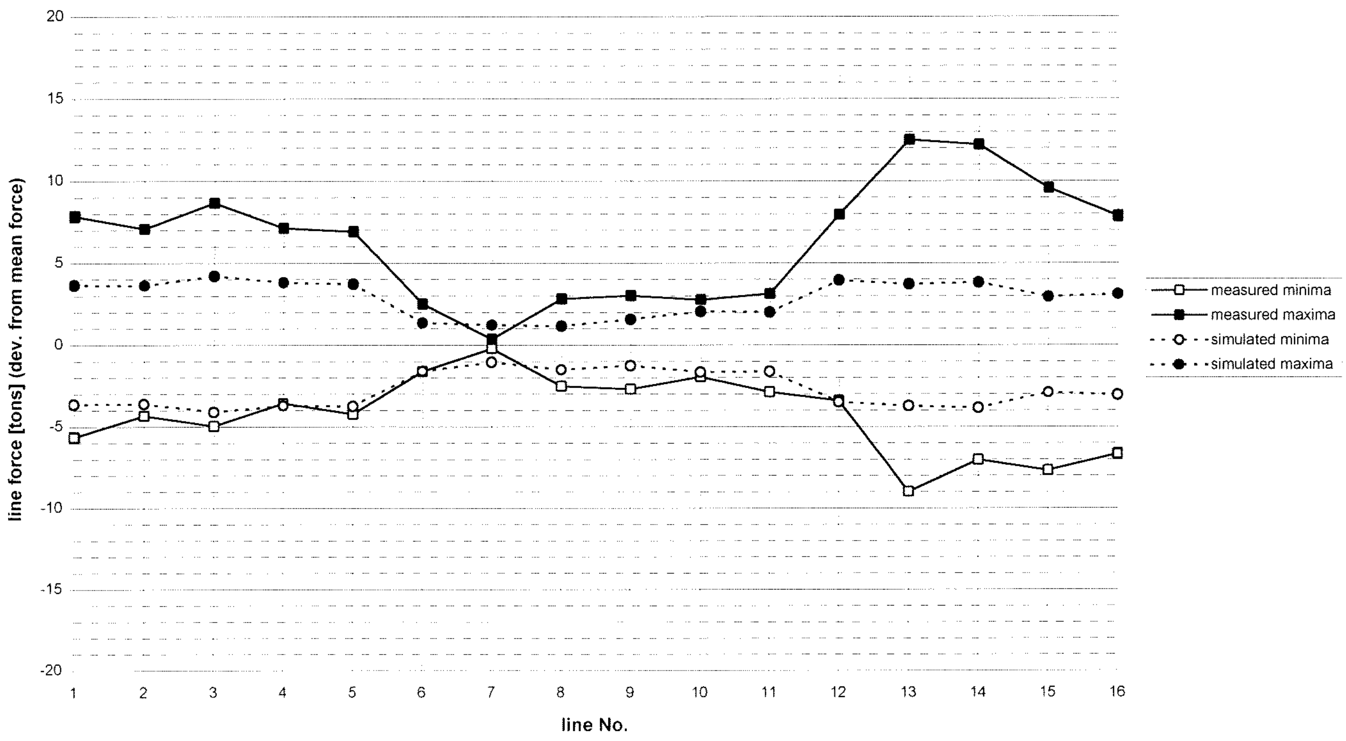
Run No. 4a-8, 21-7-96: Line force variations, minimum & maximum forces per 10 minutes



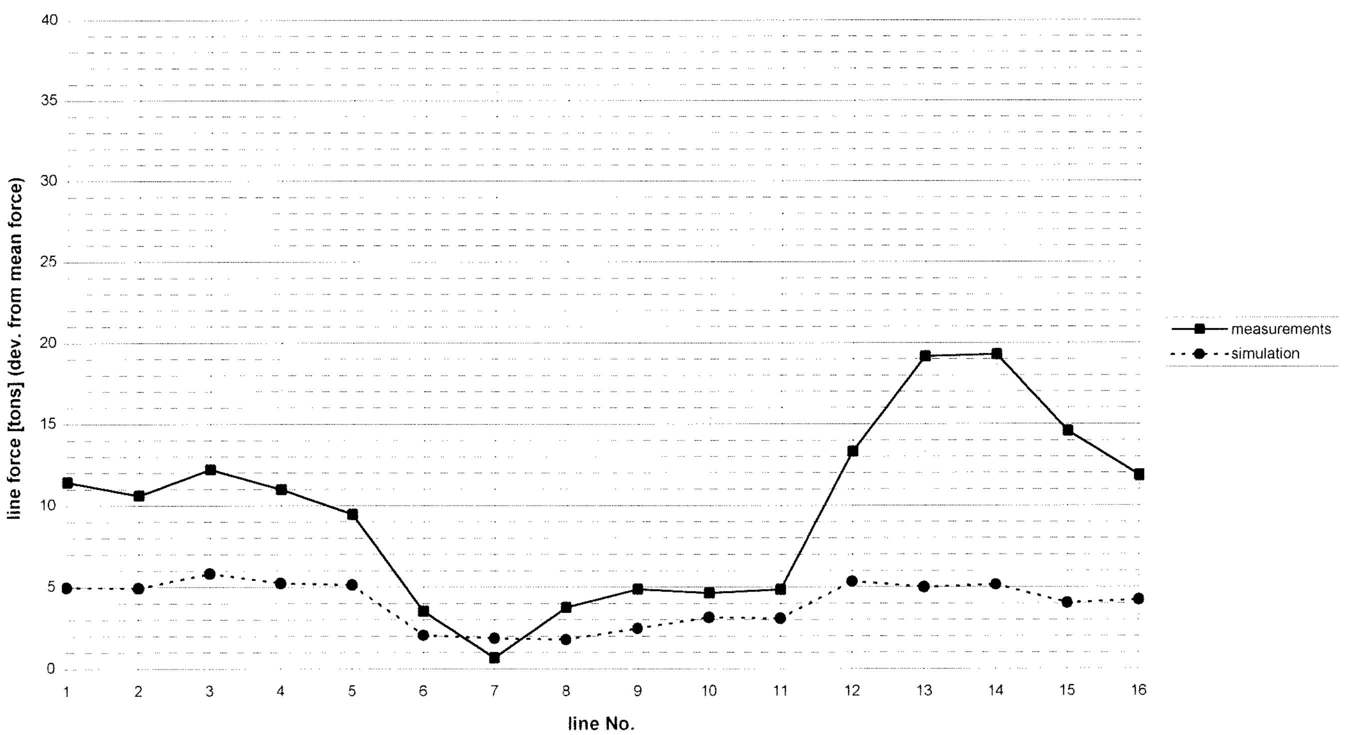
Run No. 4a-8, 21-7-96: Maximum line forces per 3 hours

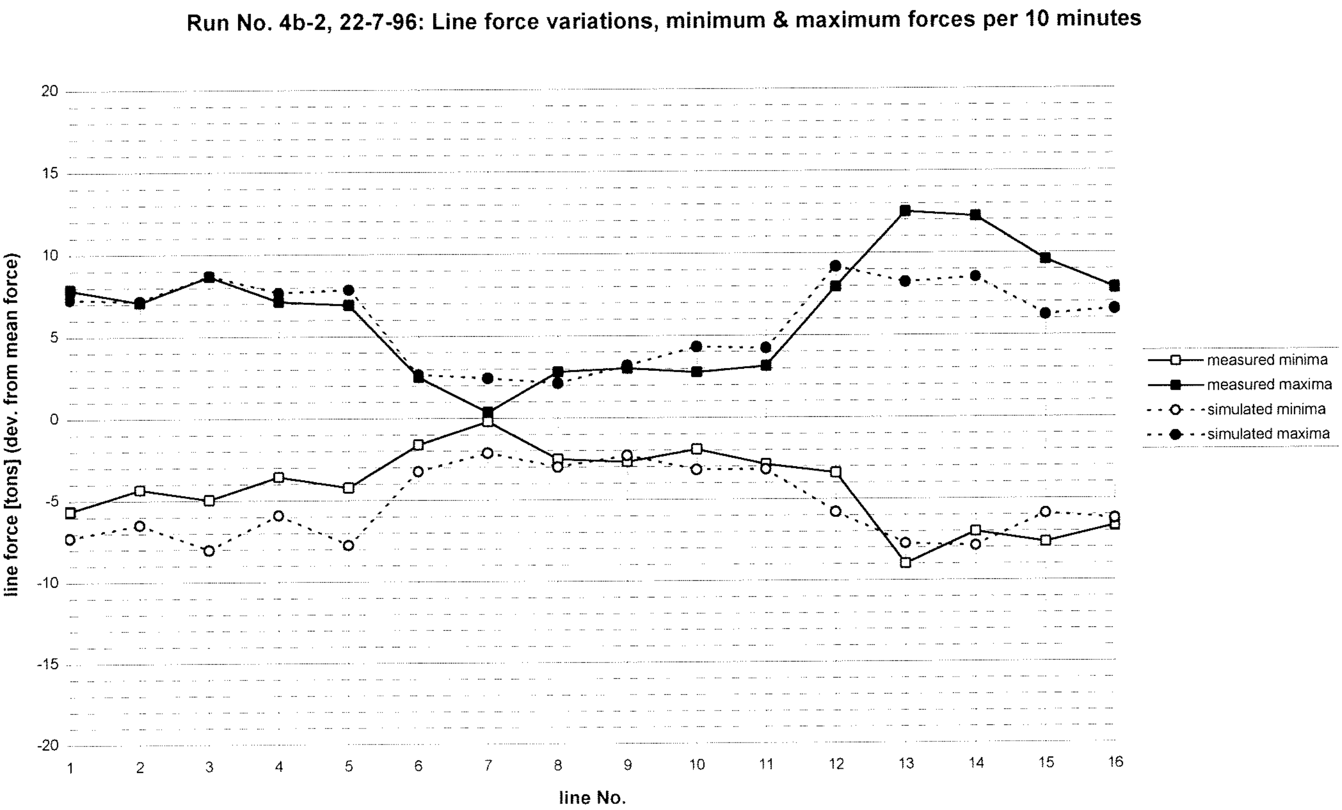


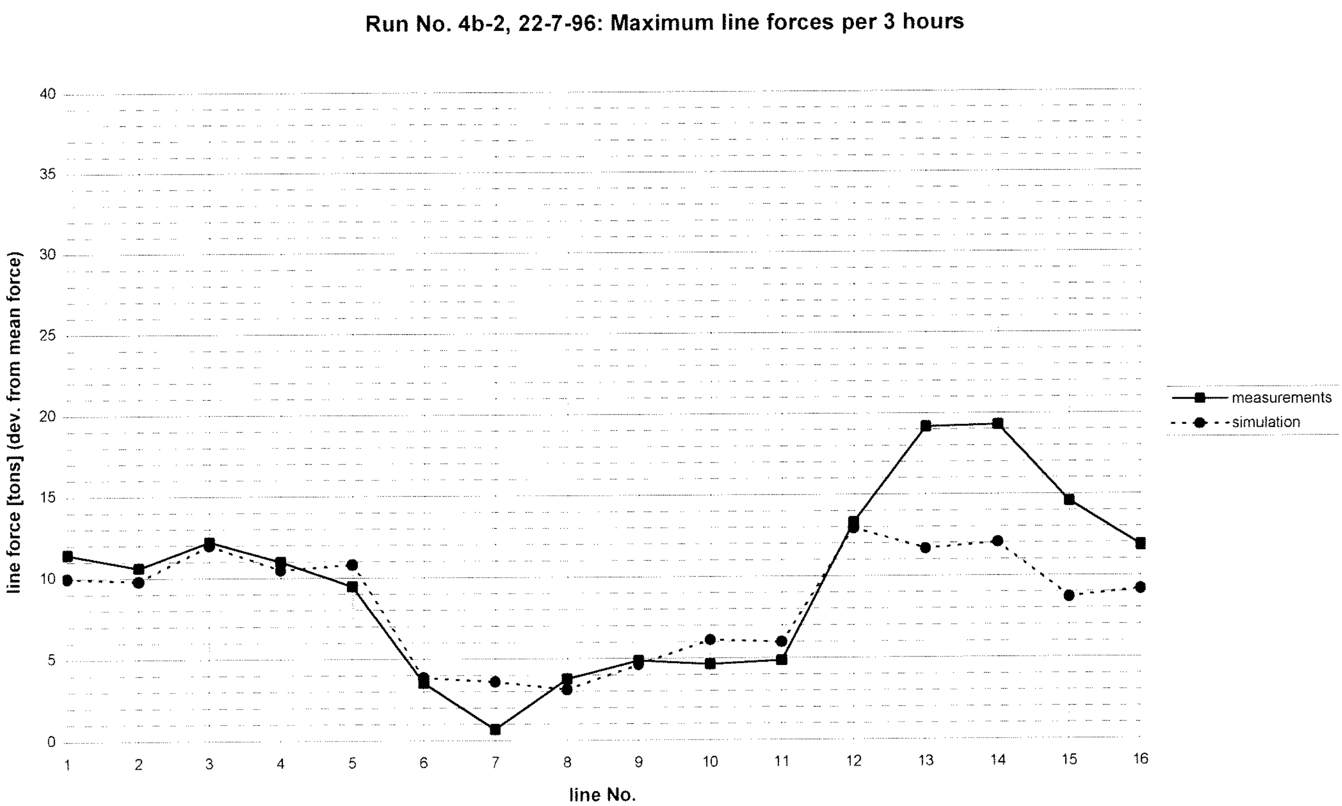
Run No. 4b-1, 22-7-96: Line force variations, minimum & maximum forces per 10 minutes



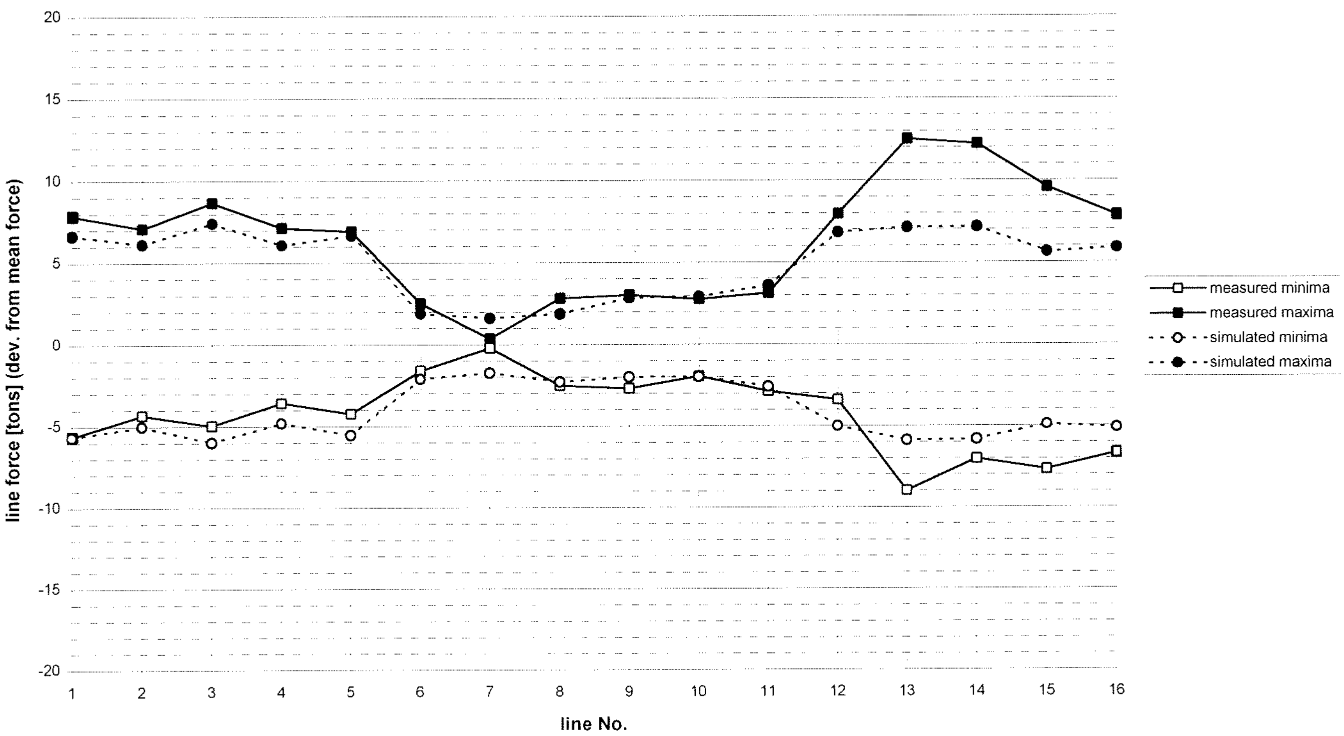
Run No. 4b-1, 22-7-96: Maximum line forces per 3 hours



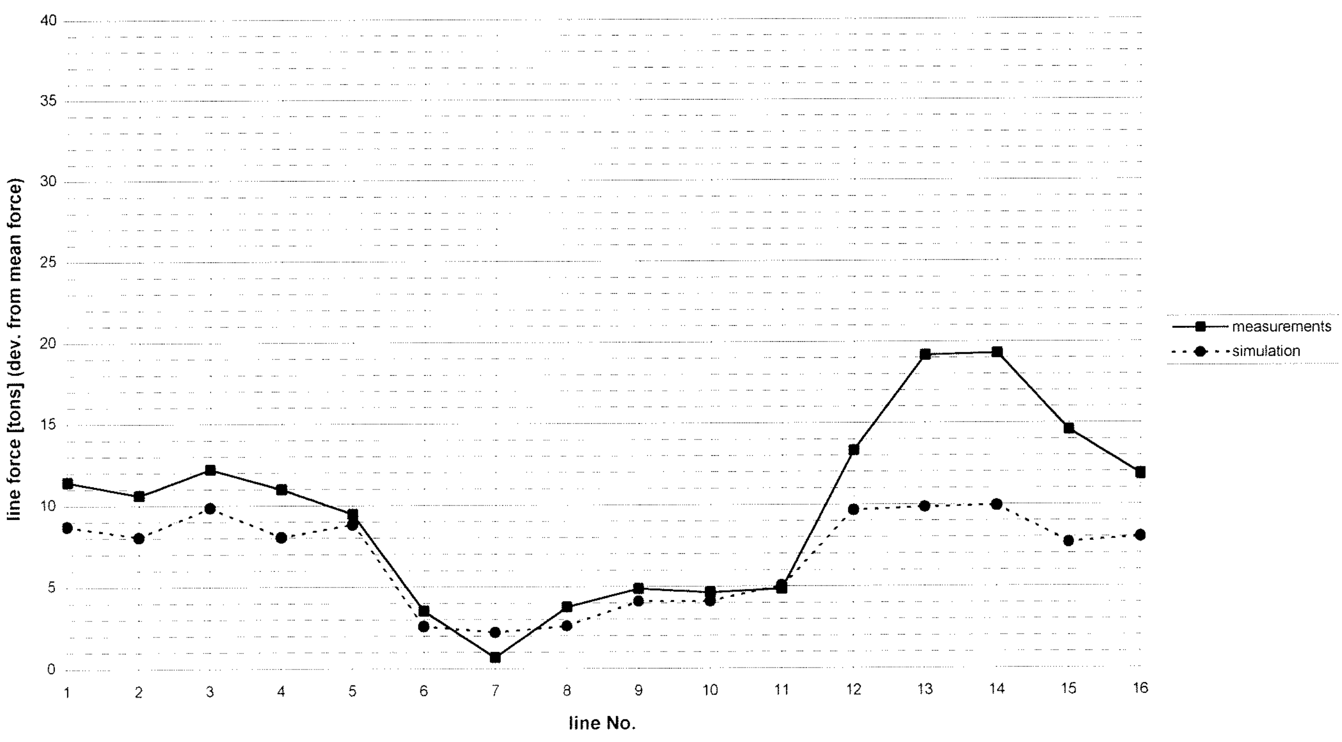

Run No. 4b-2, 22-7-96: Line force variations, minimum & maximum forces per 10 minutes
line force [tons] (dev. from mean force)
20
15
10
5
0
-5
-10
-15
-20
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
line No.
measured minima
measured maxima
simulated minima
simulated maxima

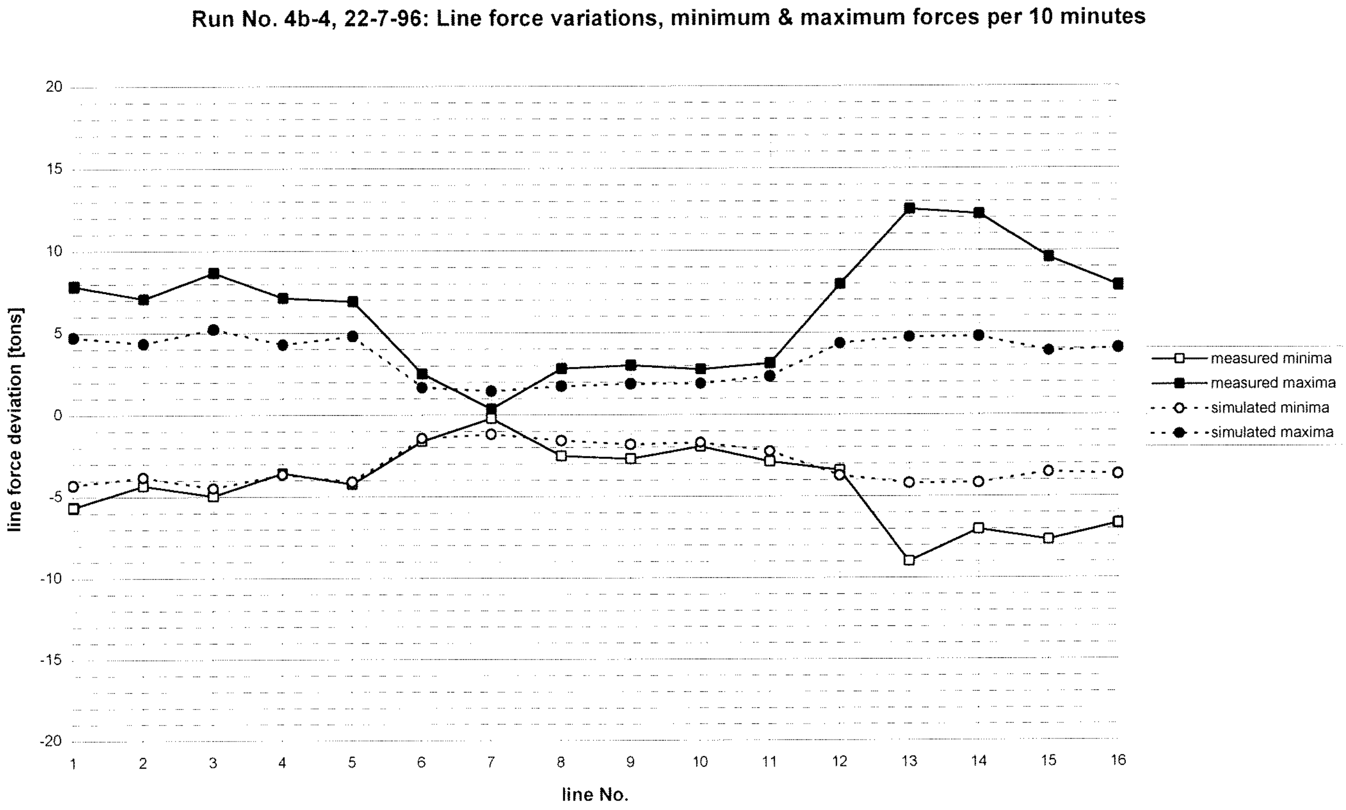

Run No. 4b-2, 22-7-96: Maximum line forces per 3 hours
line force [tons] (dev. from mean force)
40
35
30
25
20
15
10
5
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
line No.
measurements
simulation

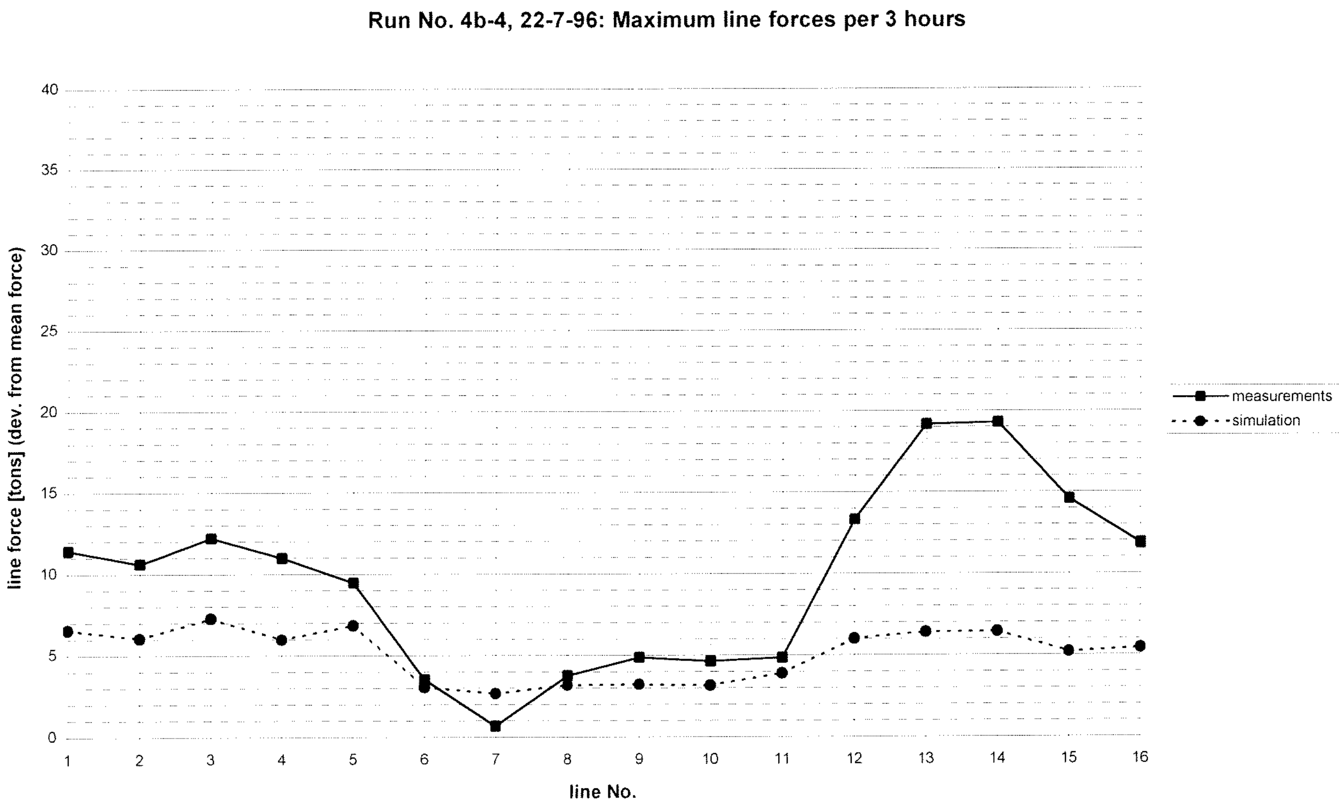
Run No. 4b-3, 22-7-96: Line force variations, minimum & maximum forces per 10 minutes

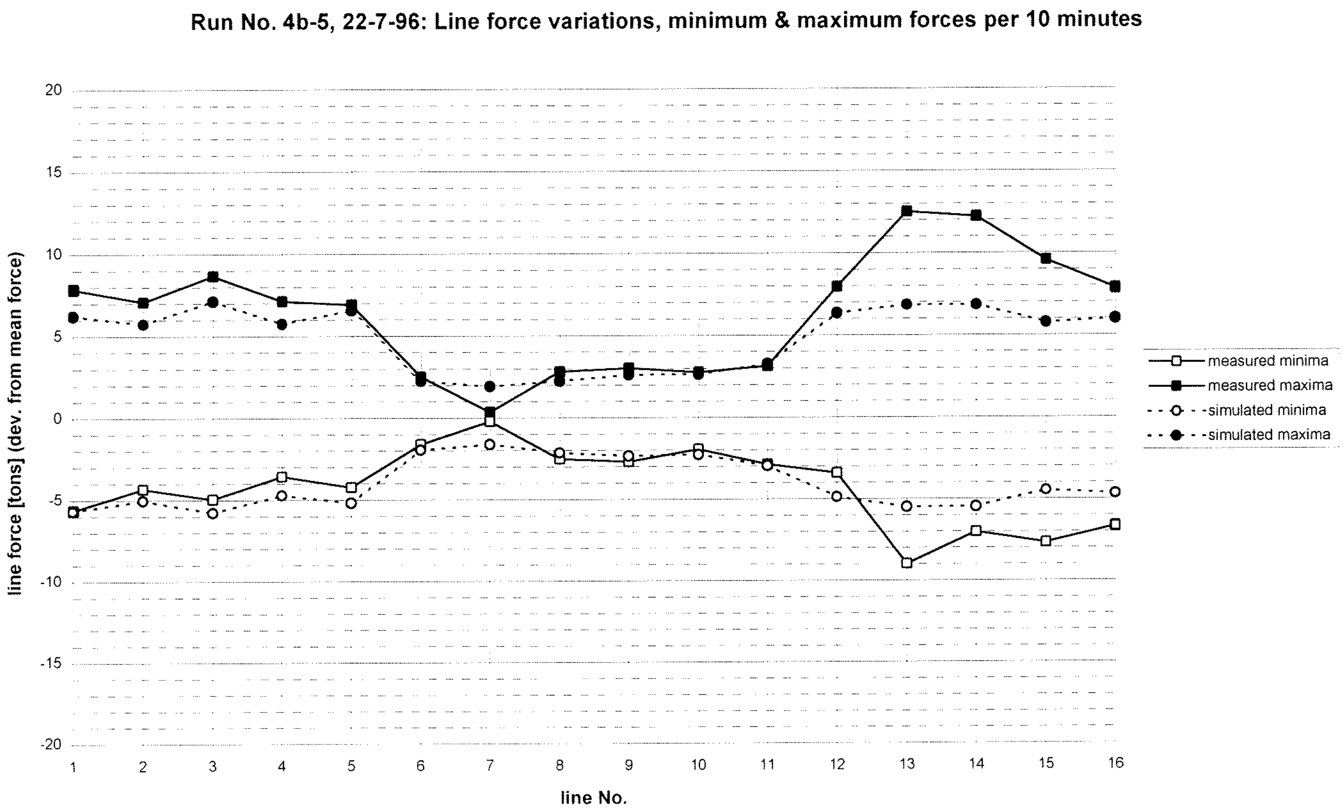


Run No. 4b-3, 22-7-96: Maximum line forces per 3 hours

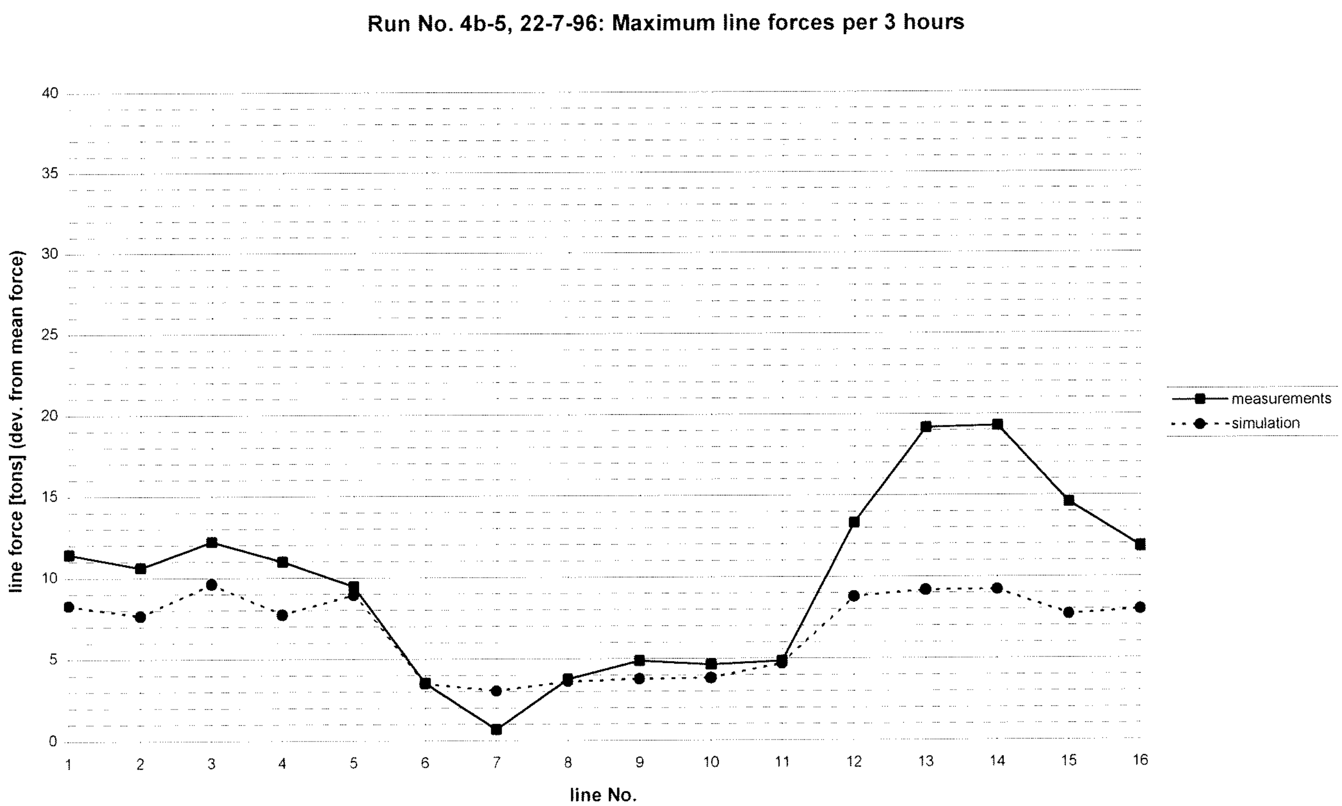



Run No. 4b-4, 22-7-96: Line force variations, minimum & maximum forces per 10 minutes
line force deviation [tons]
line No.
20
15
10
5
0
-5
-10
-15
-20
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
measured minima
measured maxima
simulated minima
simulated maxima


Run No. 4b-4, 22-7-96: Maximum line forces per 3 hours
line force [tons] (dev. from mean force)
line No.
40
35
30
25
20
15
10
5
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
measurements
simulation

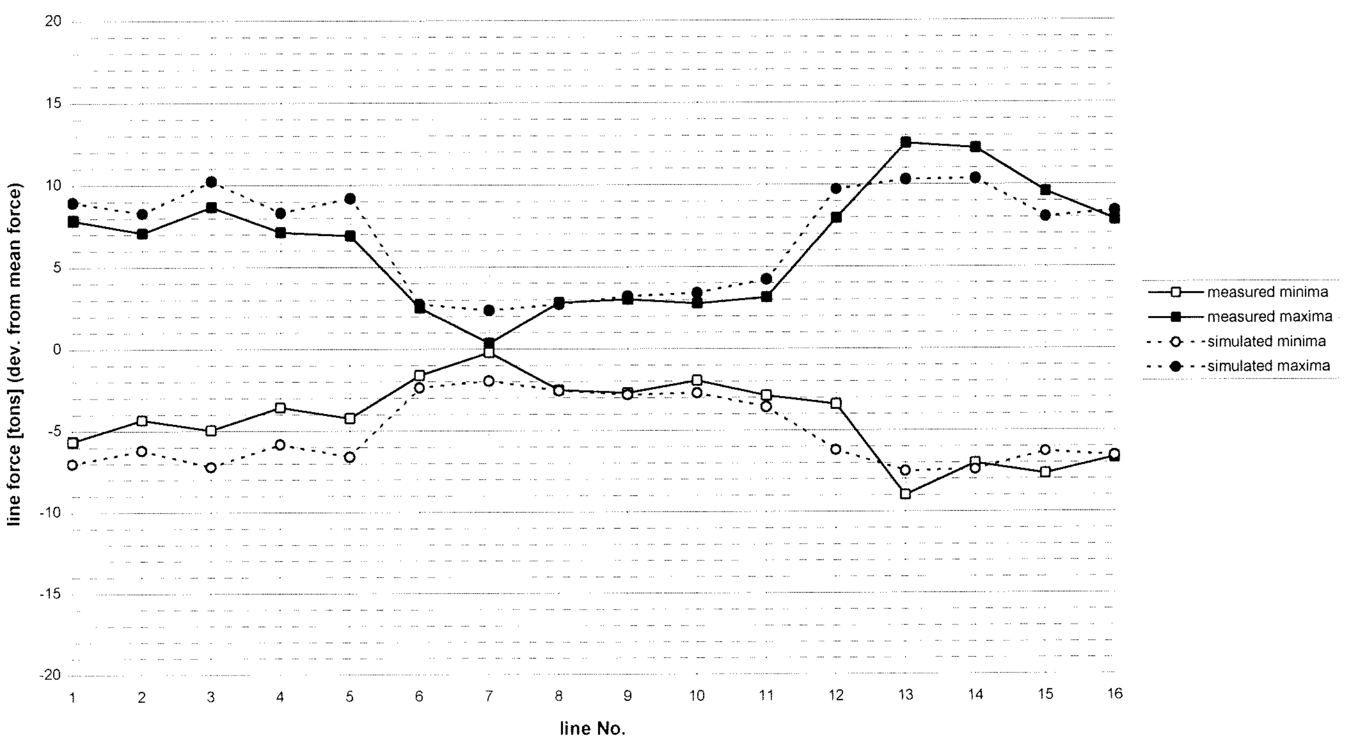


Run No. 4b-5, 22-7-96: Line force variations, minimum & maximum forces per 10 minutes
20
15
10
5
0
-5
-10
-15
-20
line force [tons] (dev. from mean force)
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
line No.
measured minima
measured maxima
simulated minima
simulated maxima

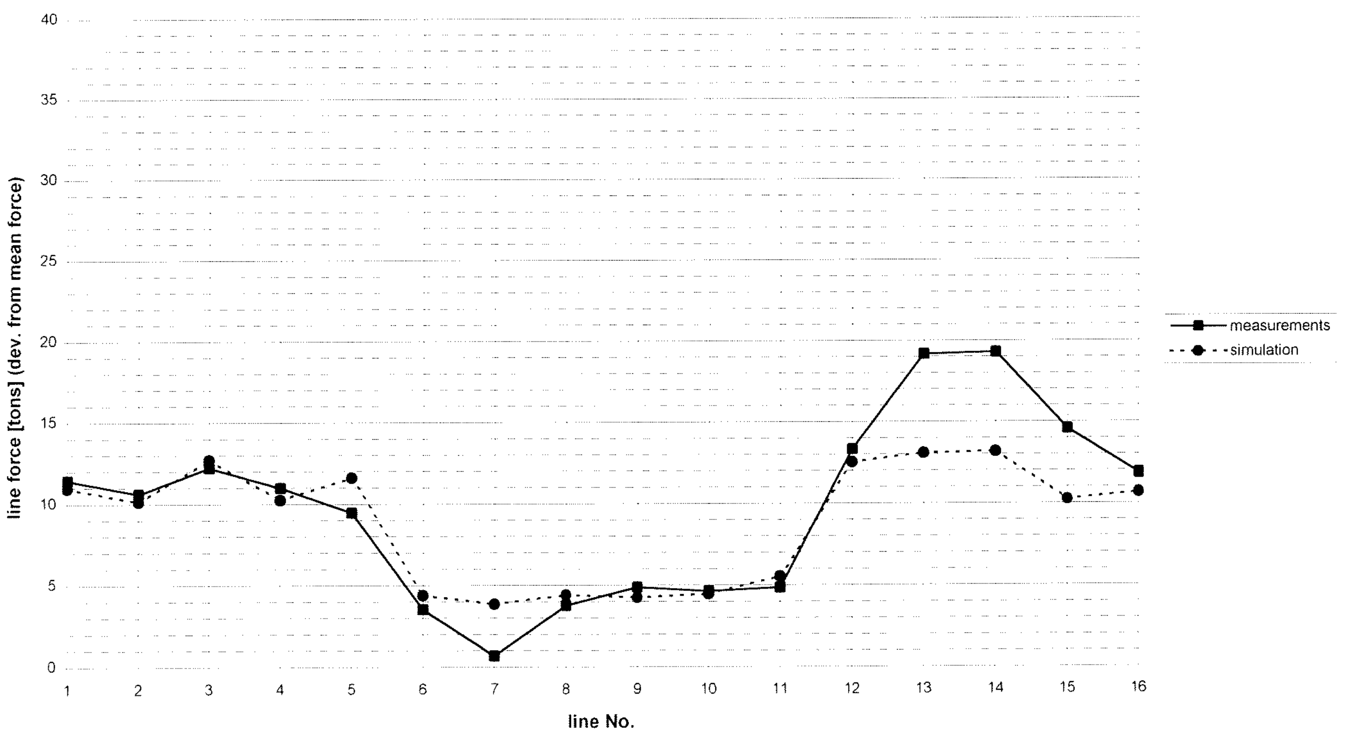


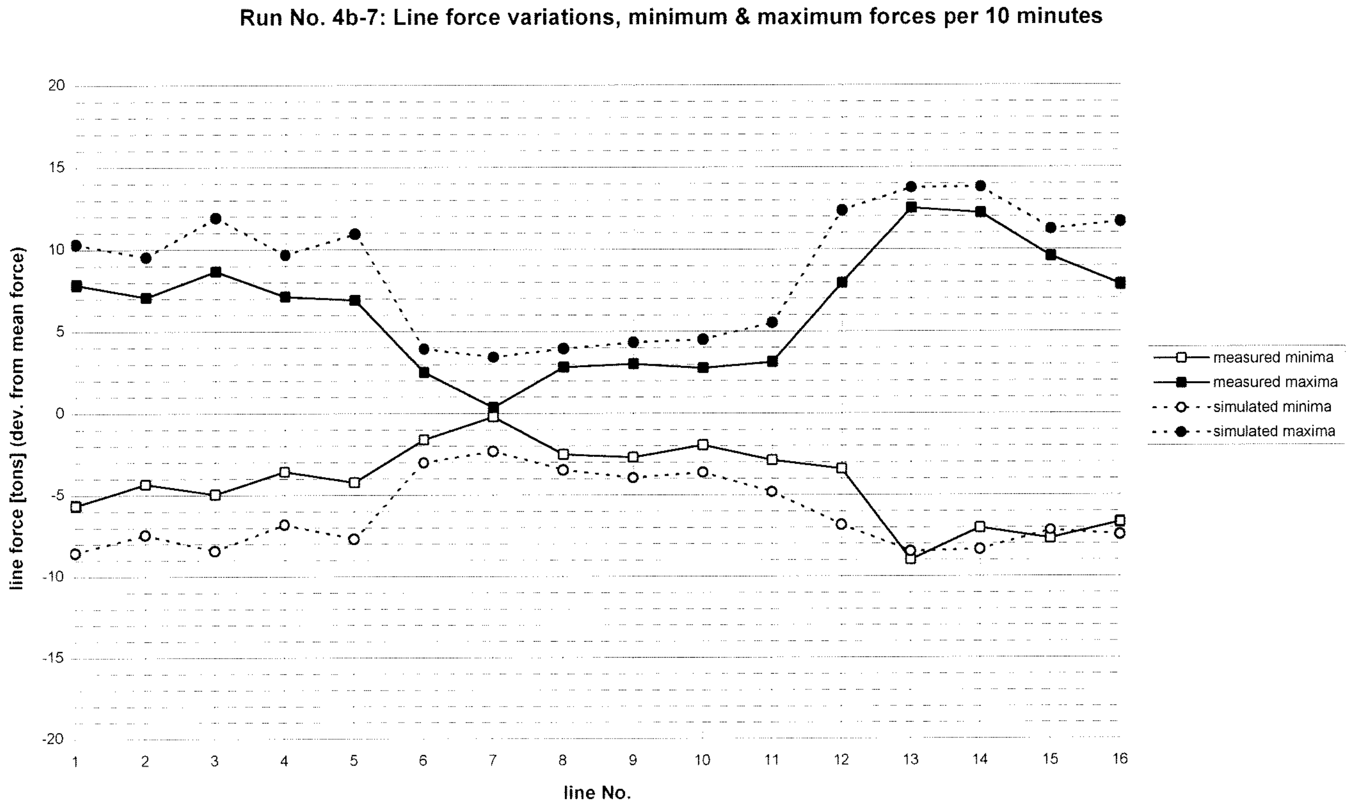
Run No. 4b-5, 22-7-96: Maximum line forces per 3 hours
40
35
30
25
20
15
10
5
0
line force [tons] (dev. from mean force)
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
line No.
measurements
simulation

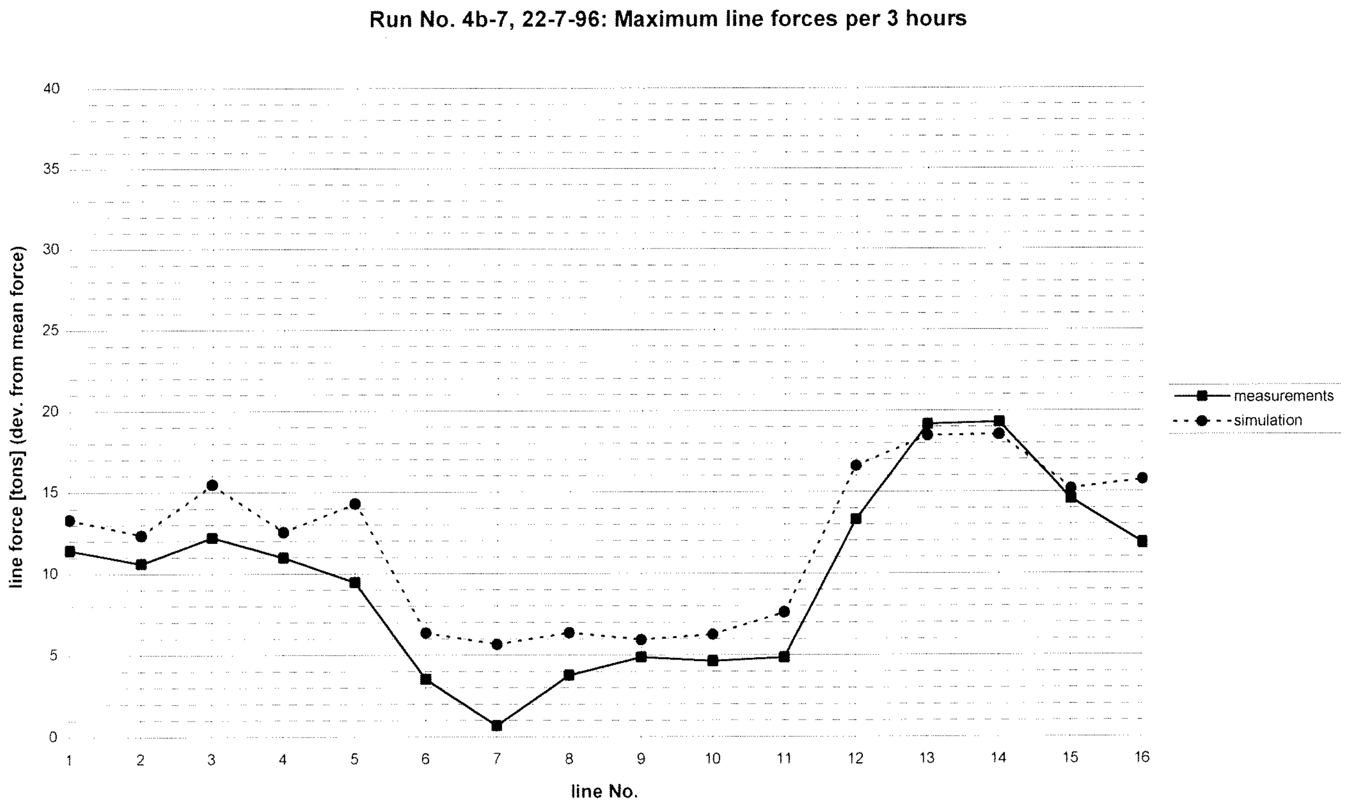
Run No. 4b-6, 22-7-96: Line force variations, minimum & maximum forces per 10 minutes

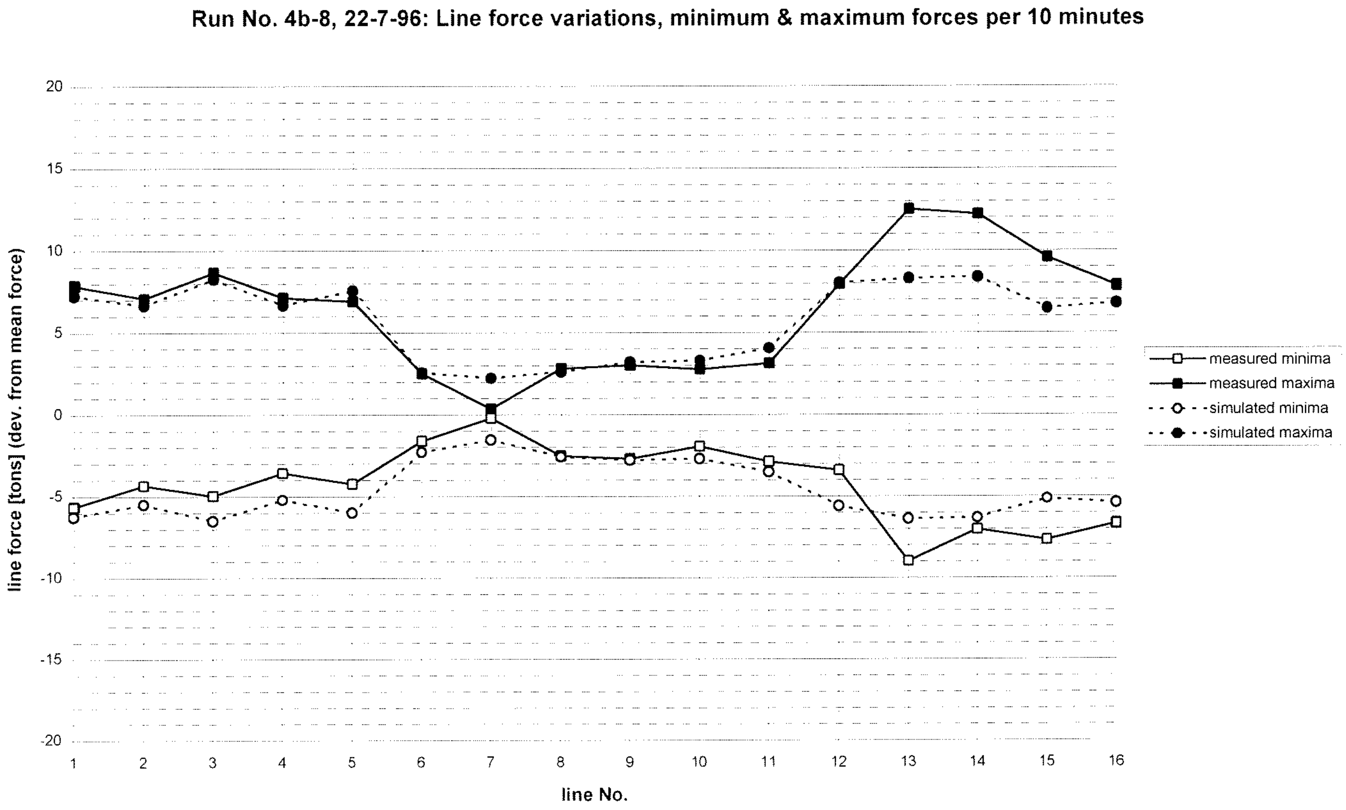


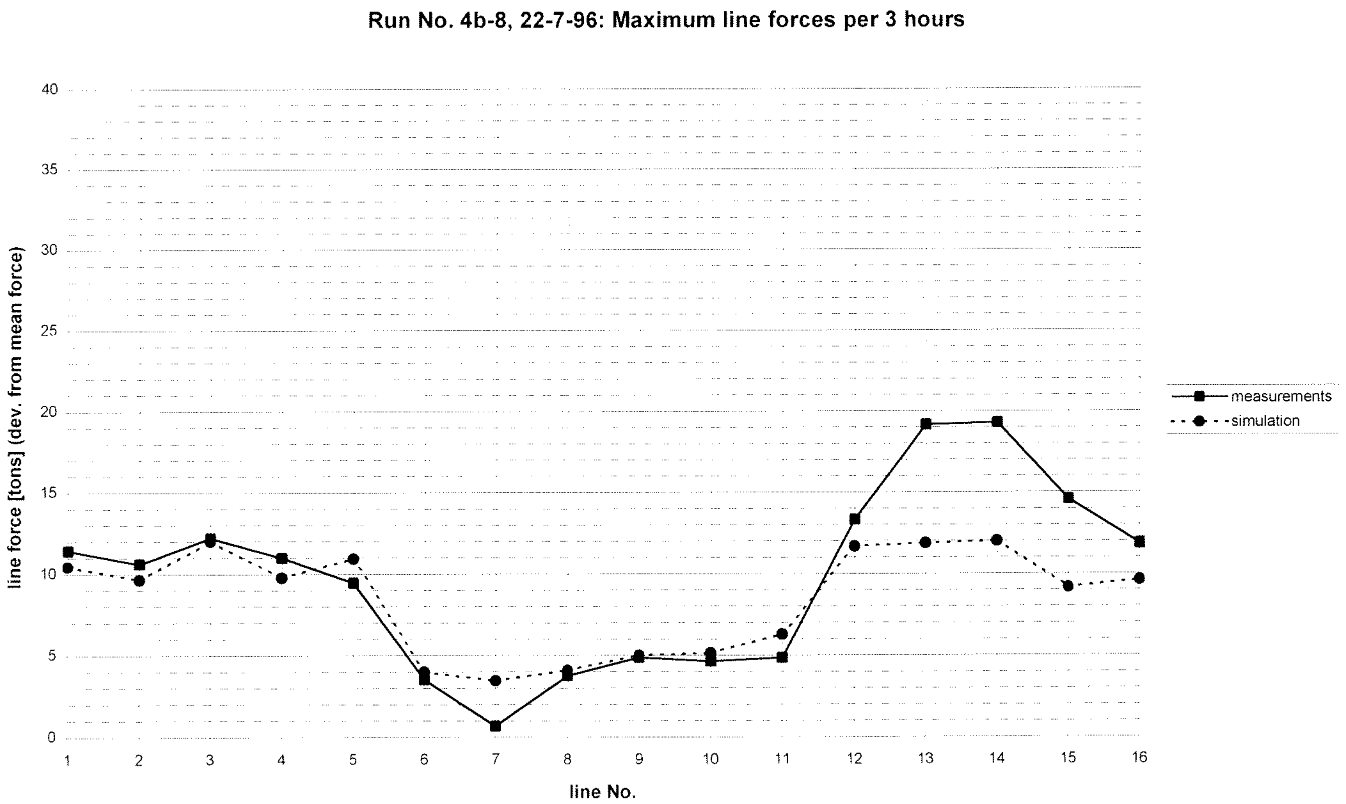
Run No. 4b-6, 22-7-96: Maximum line forces per 3 hours



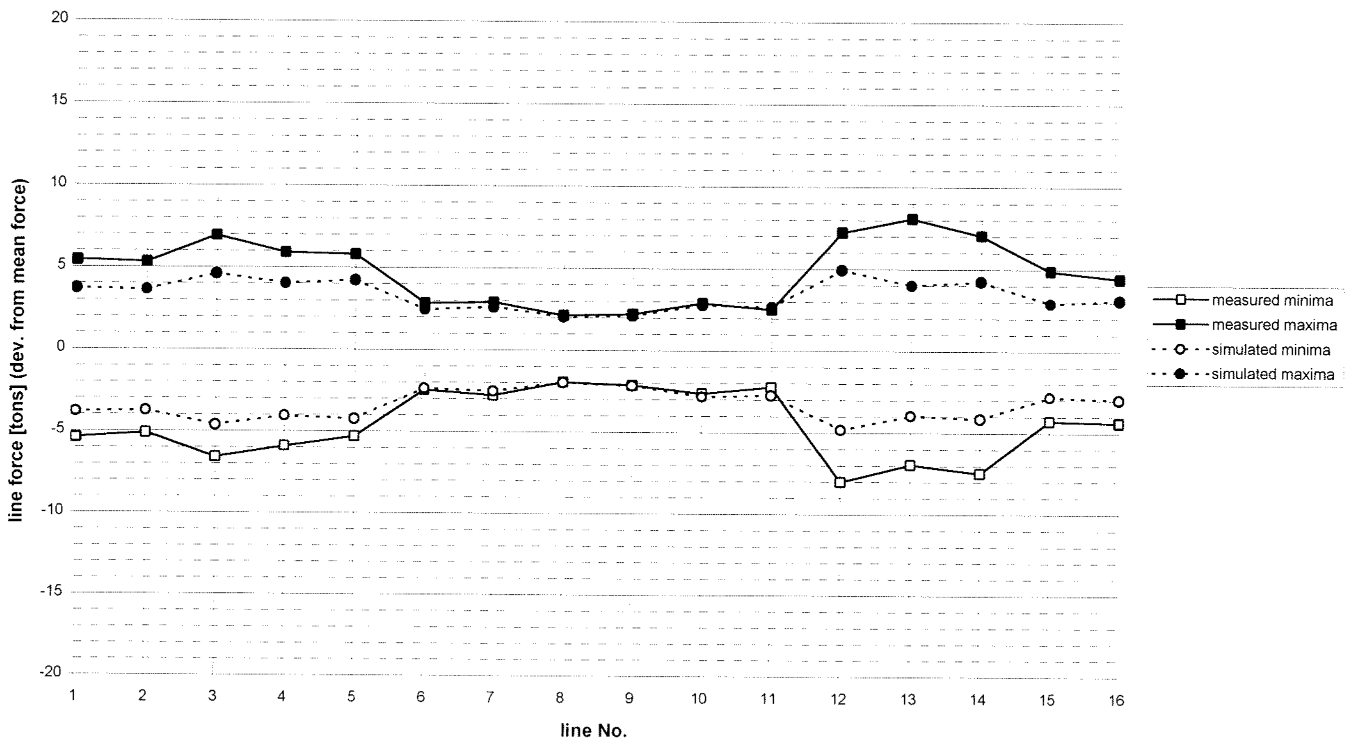

Run No. 4b-7: Line force variations, minimum & maximum forces per 10 minutes
line force [tons] (dev. from mean force)
20
15
10
5
0
-5
-10
-15
-20
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
line No.
measured minima
measured maxima
simulated minima
simulated maxima


Run No. 4b-7, 22-7-96: Maximum line forces per 3 hours
line force [tons] (dev. from mean force)
40
35
30
25
20
15
10
5
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
line No.
measurements
simulation

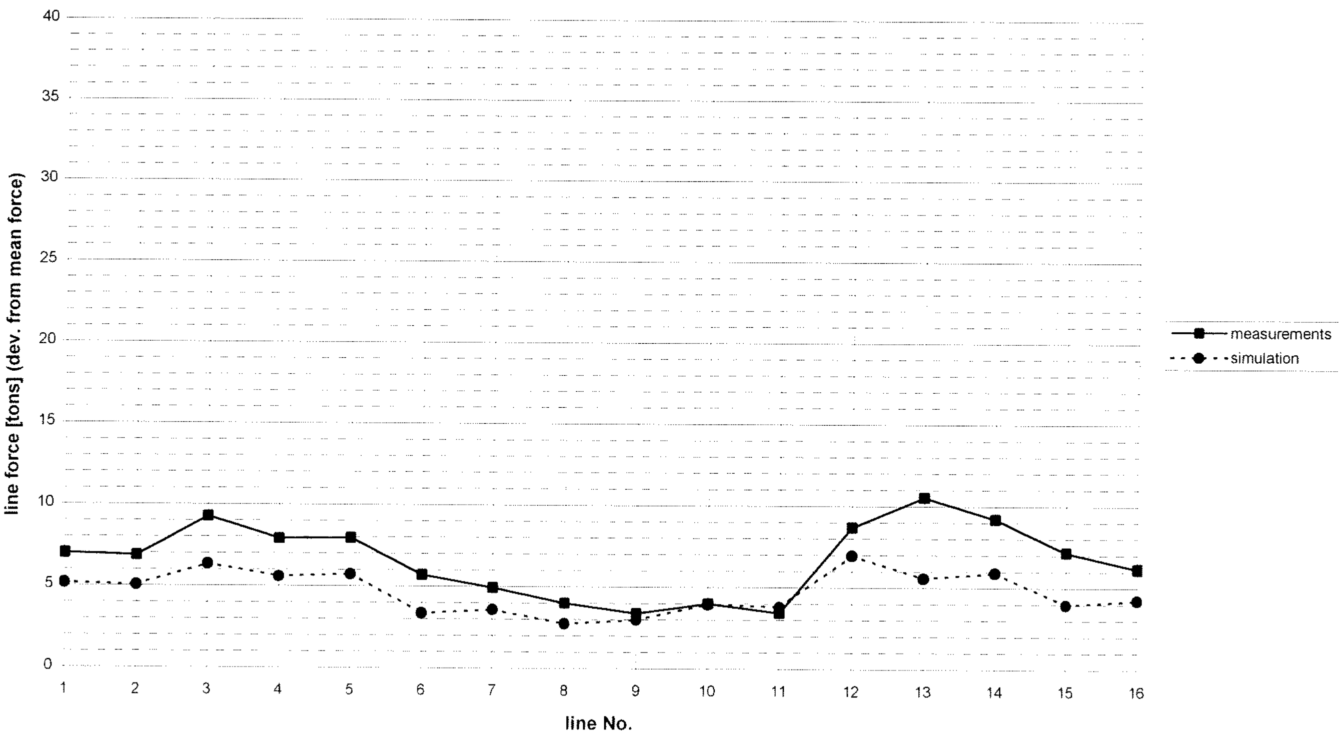

Run No. 4b-8, 22-7-96: Line force variations, minimum & maximum forces per 10 minutes
line force [tons] (dev. from mean force)
20
15
10
5
0
-5
-10
-15
-20
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
line No.
measured minima
measured maxima
simulated minima
simulated maxima

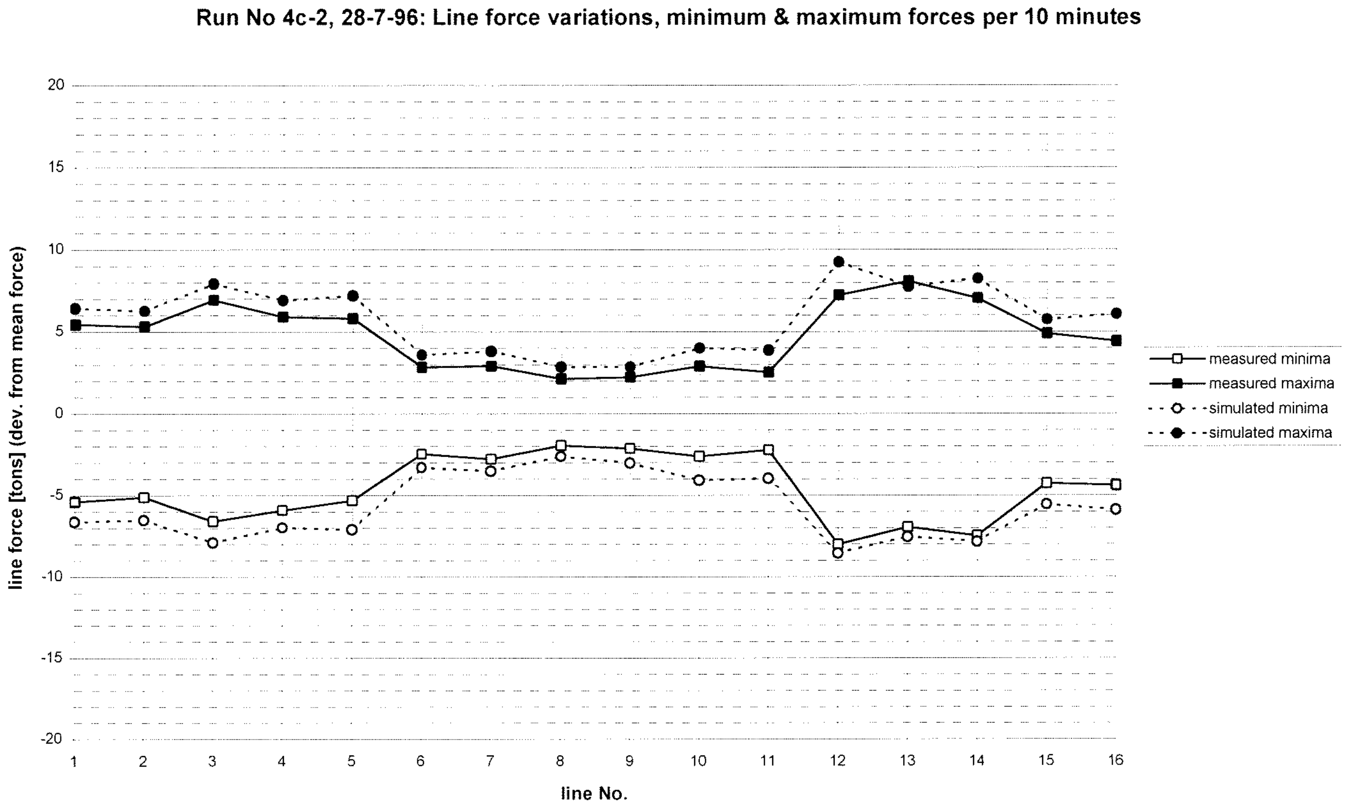

Run No. 4b-8, 22-7-96: Maximum line forces per 3 hours
line force [tons] (dev. from mean force)
40
35
30
25
20
15
10
5
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
line No.
measurements
simulation

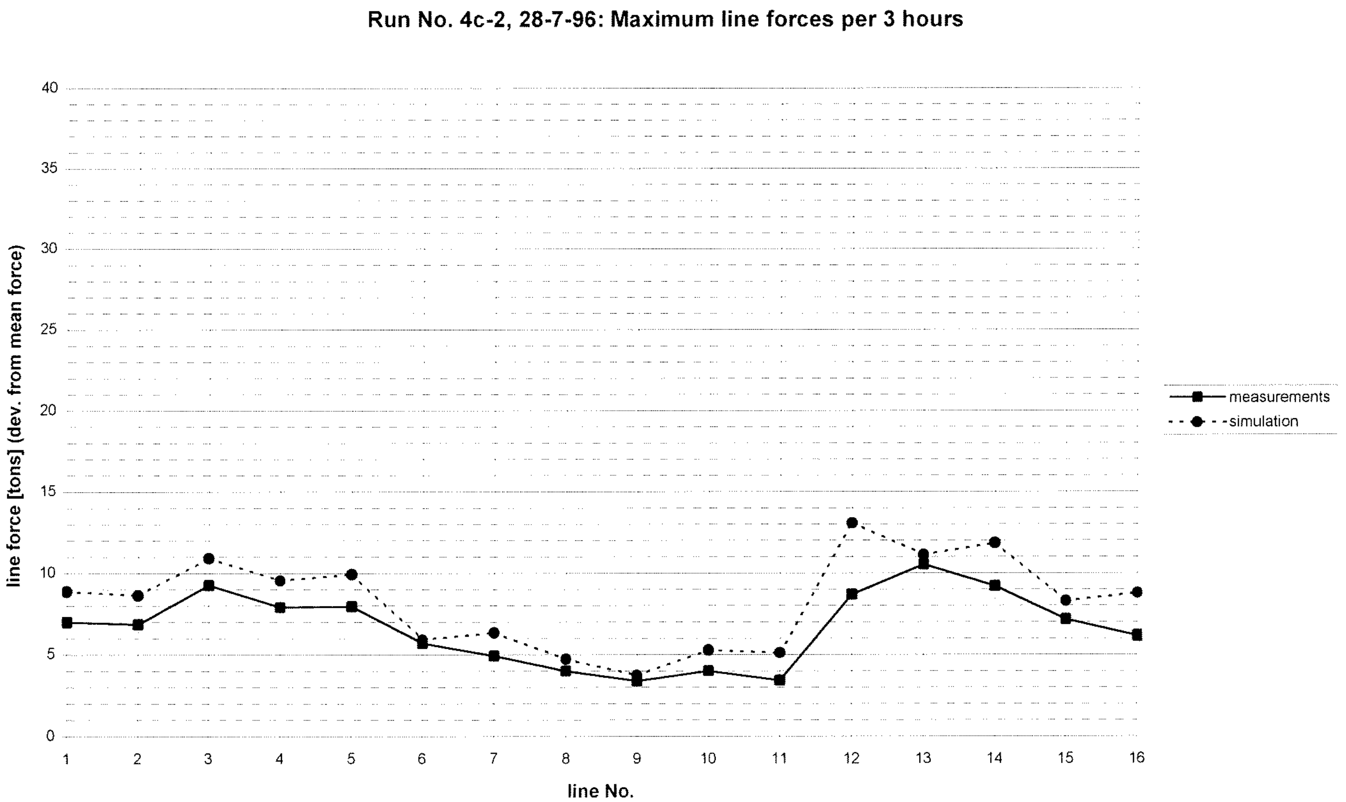
Run No. 4c-1, 28-7-96: Line force variations, minimum & maximum forces per 10 minutes



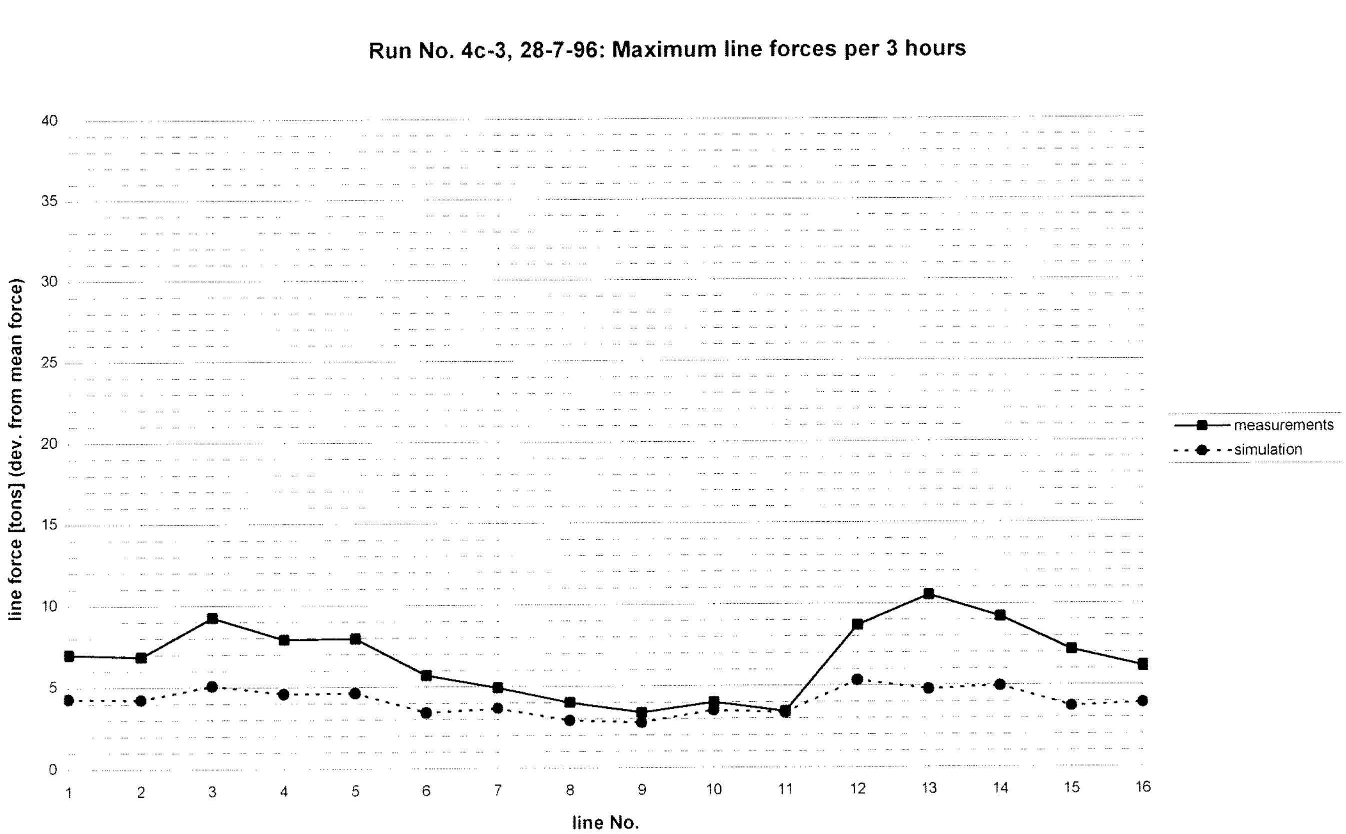
Run No. 4c-1: Maximum line forces per 3 hours



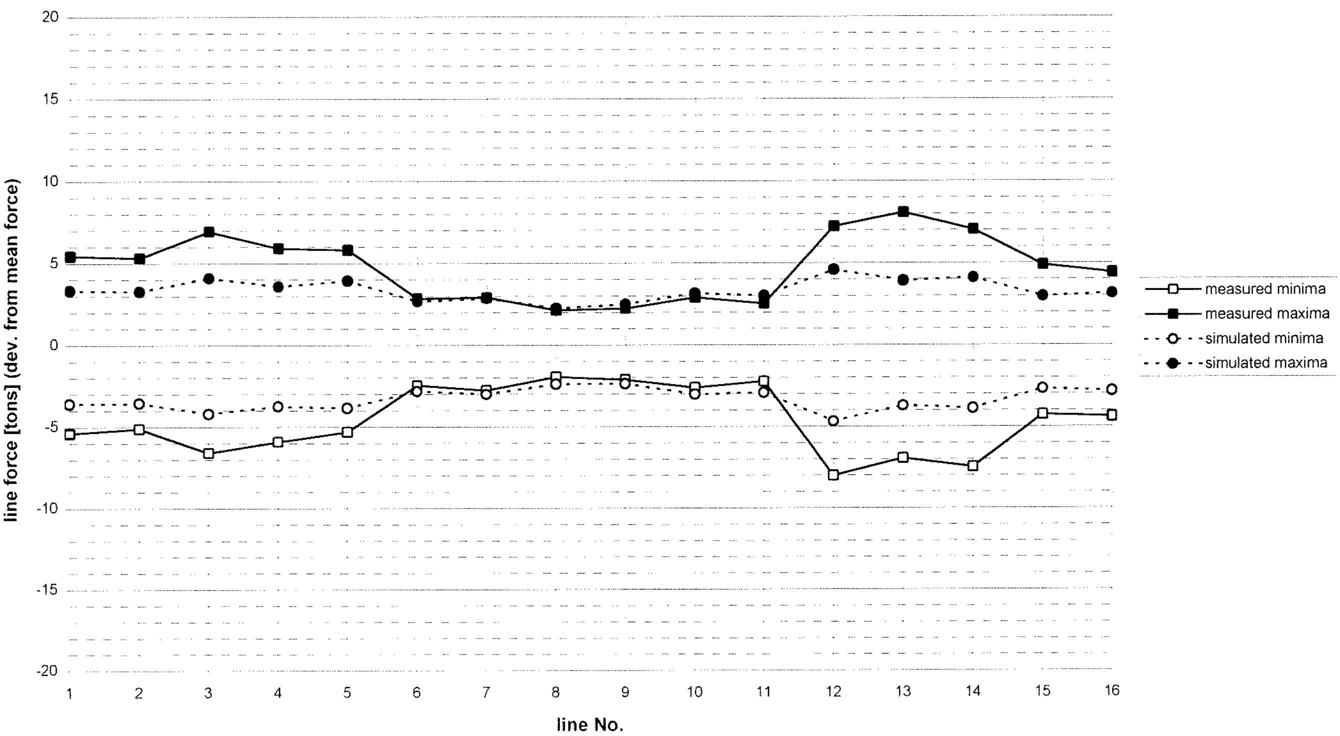

Run No 4c-2, 28-7-96: Line force variations, minimum & maximum forces per 10 minutes
20
15
10
5
0
-5
-10
-15
-20
line force [tons] (dev. from mean force)
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
line No.
measured minima
measured maxima
simulated minima
simulated maxima


Run No. 4c-2, 28-7-96: Maximum line forces per 3 hours
40
35
30
25
20
15
10
5
0
line force [tons] (dev. from mean force)
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
line No.
measurements
simulation

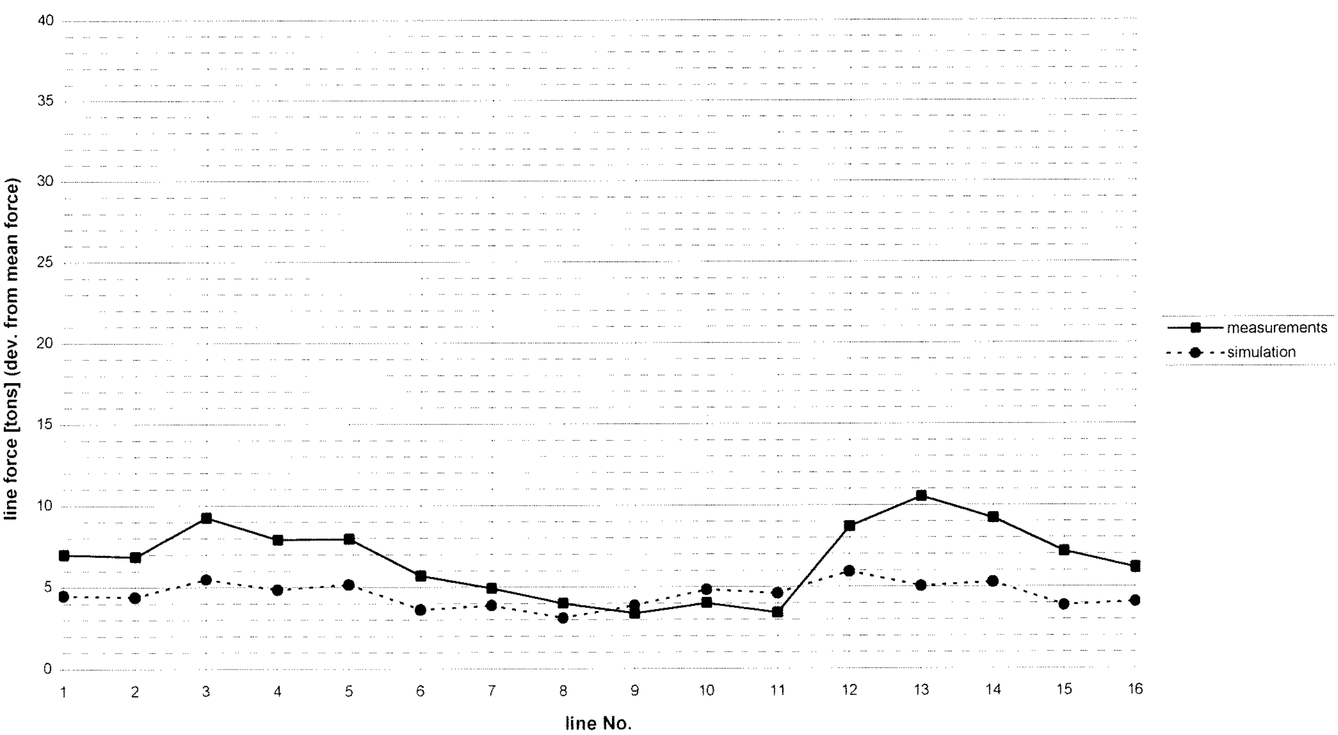

Run No. 4c-3, 28-7-96: Line force variations, minimum & maximum forces per 10 minutes
line force deviation [tons]
20
15
10
5
0
-5
-10
-15
-20
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
line No.
measured minima
measured maxima
simulated minima
simulated maxima


Run No. 4c-3, 28-7-96: Maximum line forces per 3 hours
line force [tons] (dev. from mean force)
40
35
30
25
20
15
10
5
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
line No.
measurements
simulation

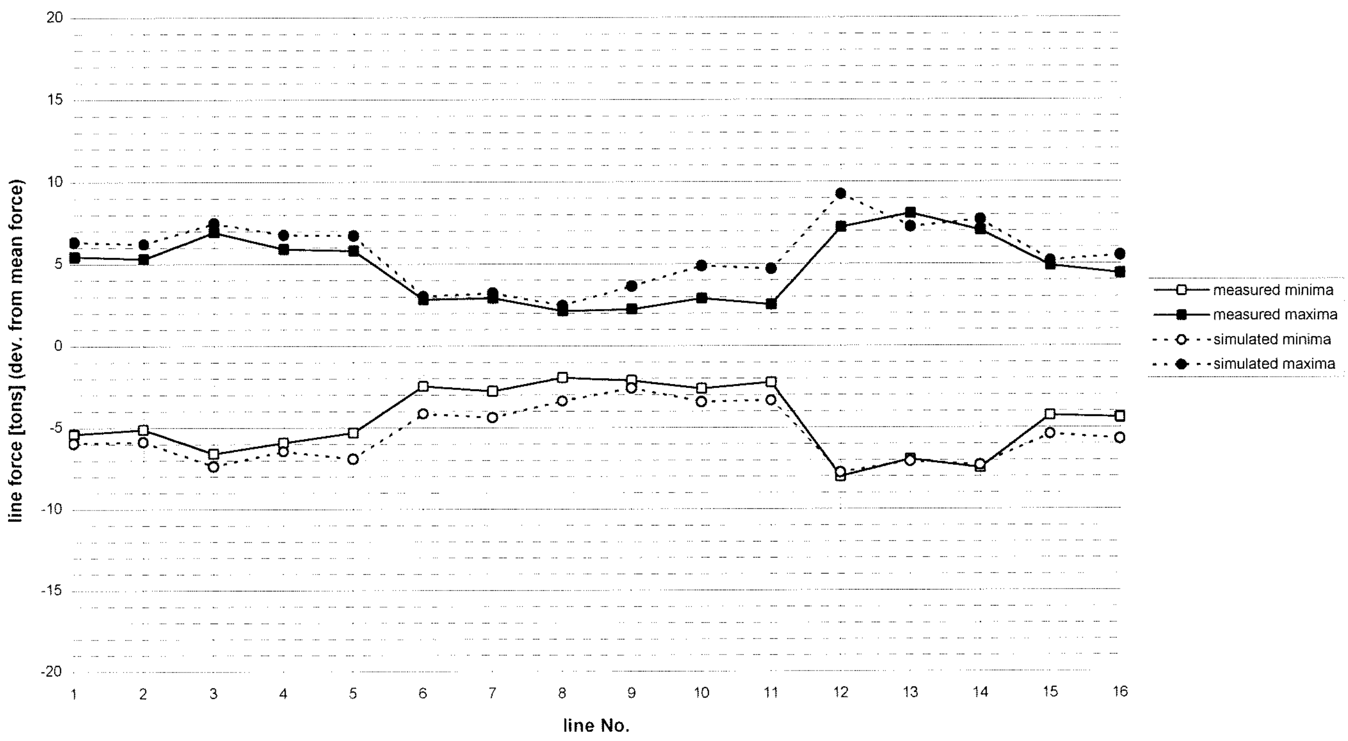
Run No. 4c-4, 28-7-96: Line force variations, minimum & maximum forces per 10 minutes



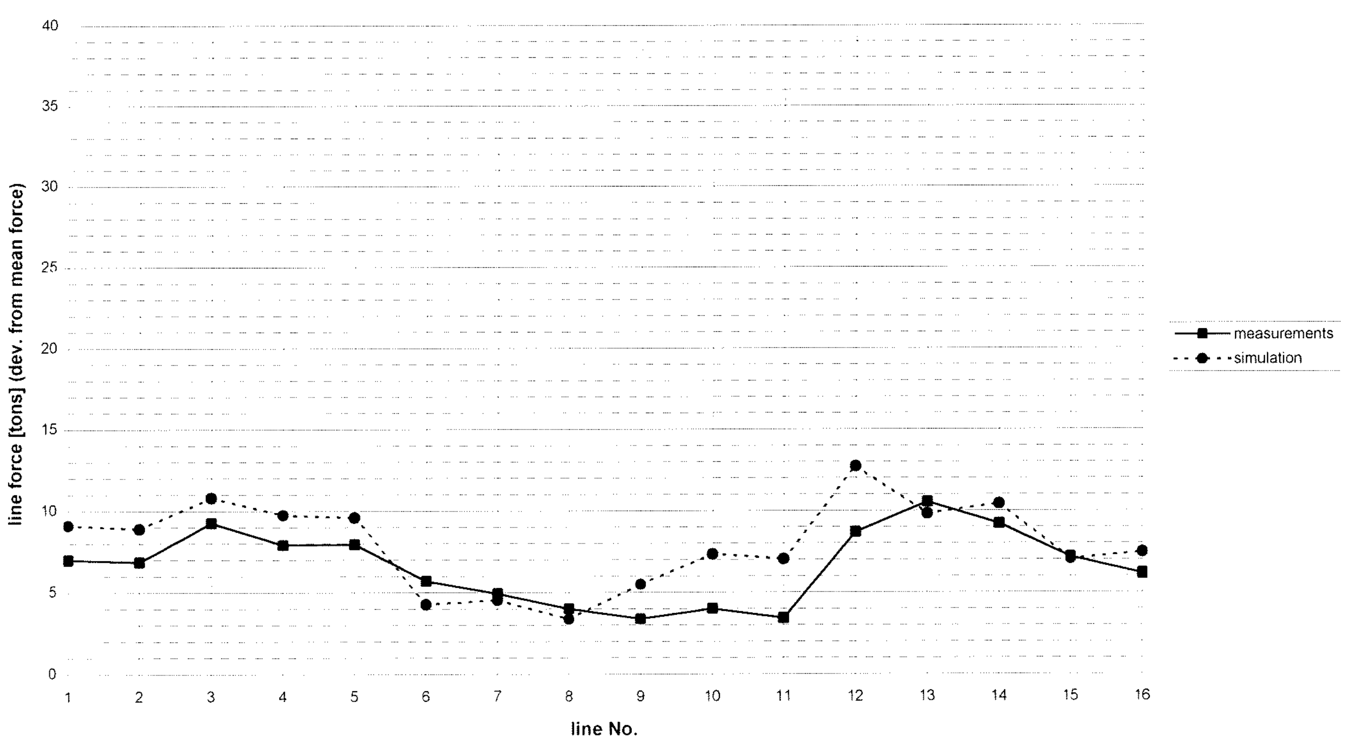
Run No. 4c-4, 28-7-96: Maximum line forces per 3 hours

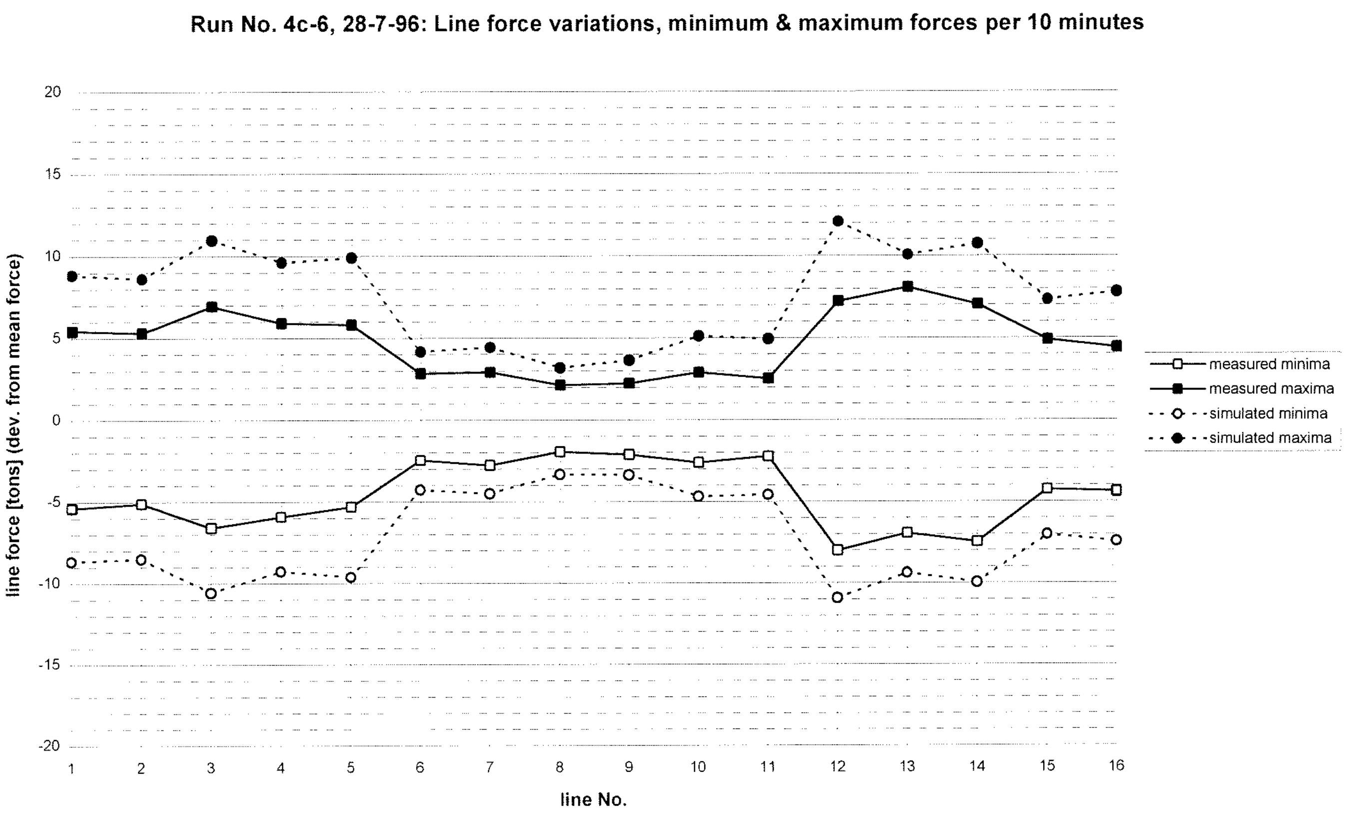


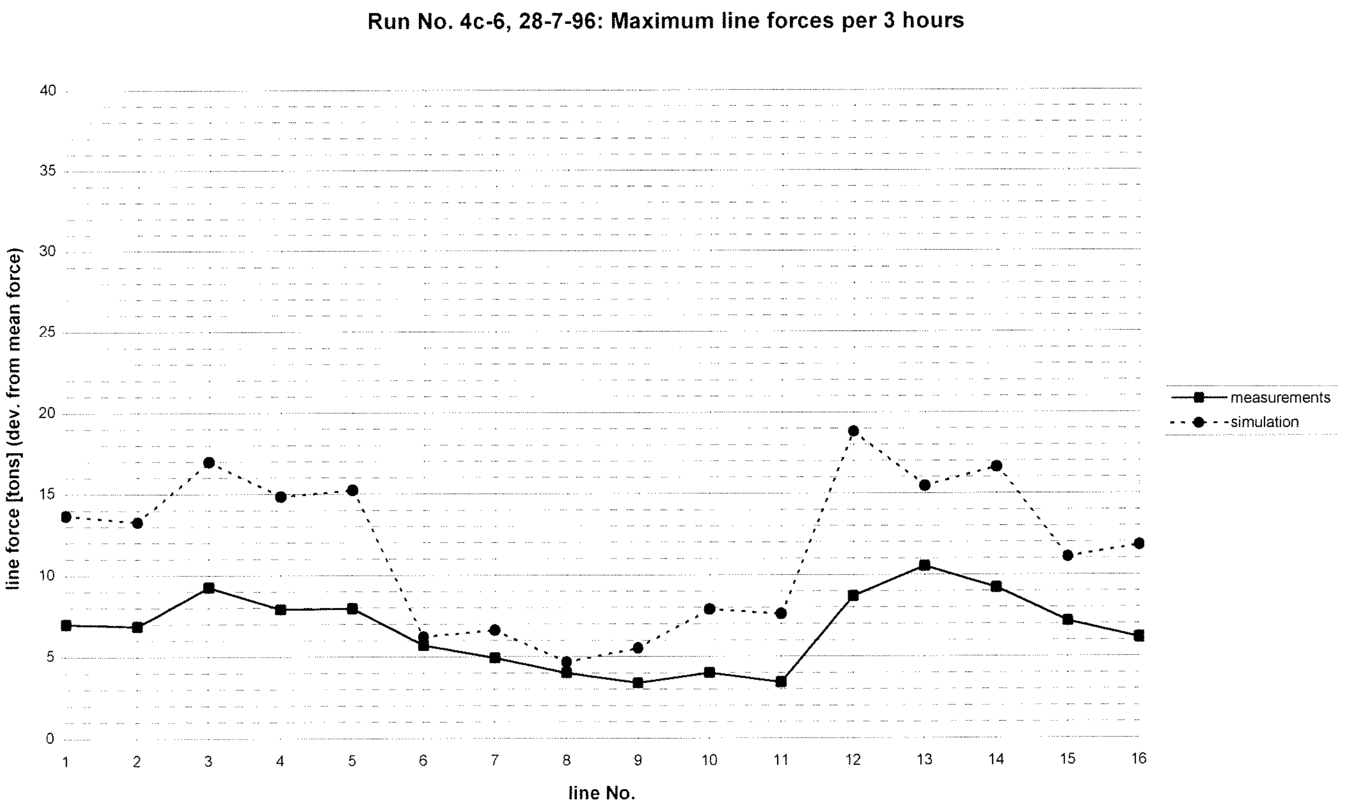
Run No. 4c-5, 28-7-96: Line force variations, minimum & maximum forces per 10 minutes

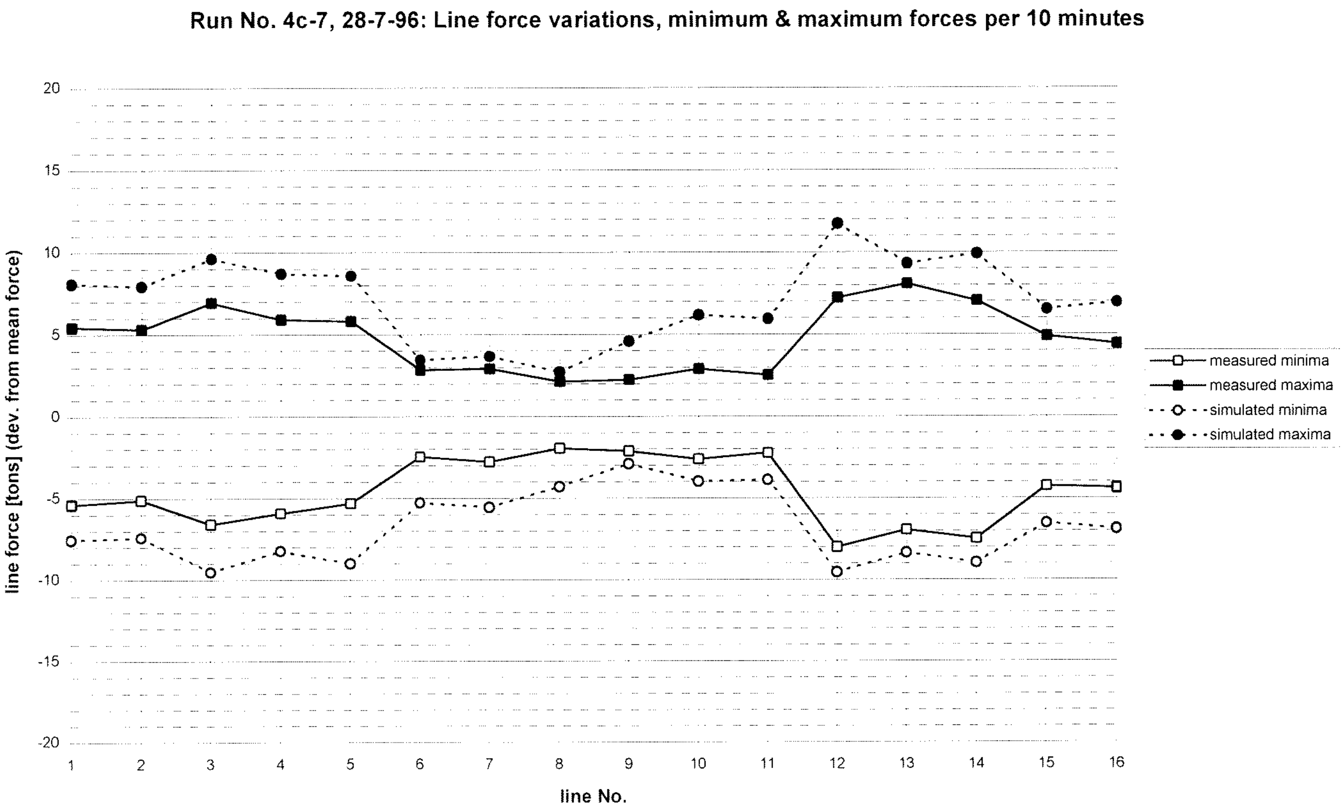


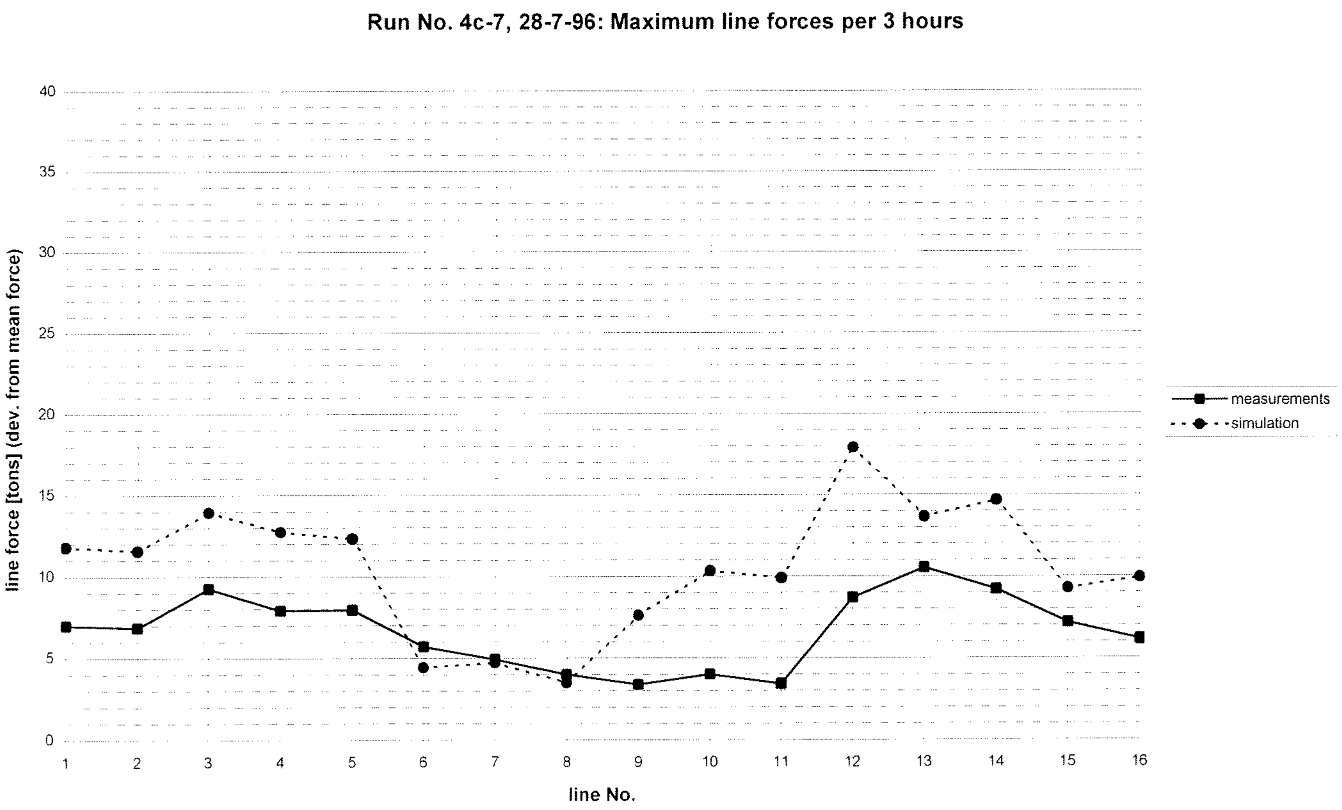
Run No. 4c-5, 28-7-96: Maximum line forces per 3 hours



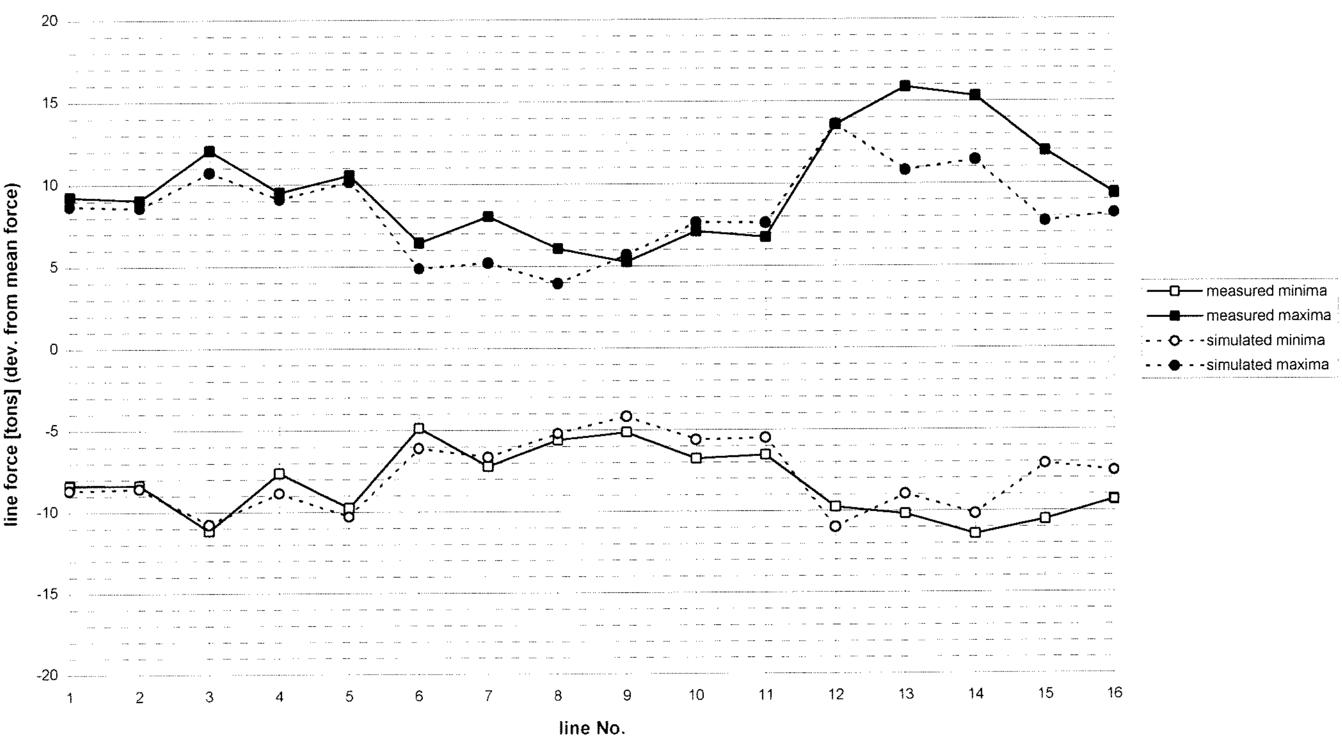

Run No. 4c-6, 28-7-96: Line force variations, minimum & maximum forces per 10 minutes
line force [tons] (dev. from mean force)
line No.
measured minima
measured maxima
simulated minima
simulated maxima


Run No. 4c-6, 28-7-96: Maximum line forces per 3 hours
line force [tons] (dev. from mean force)
line No.
measurements
simulation

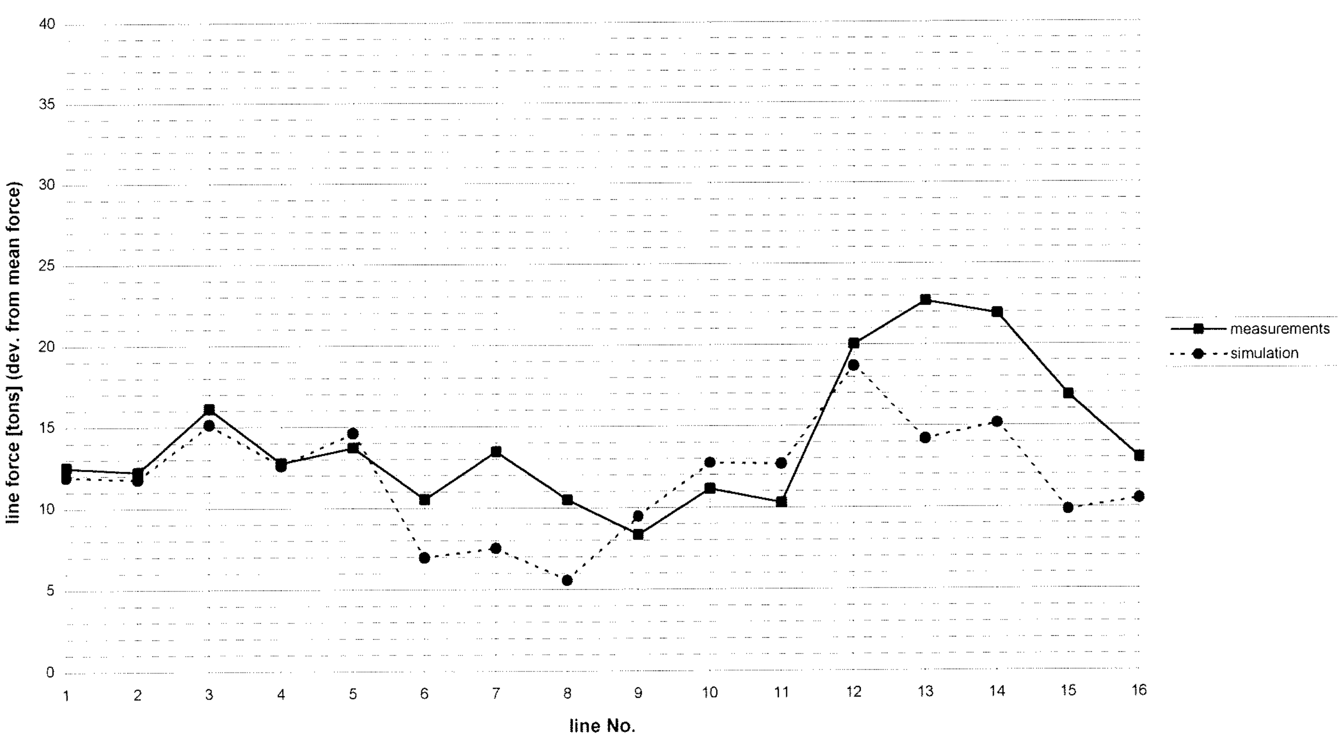

Run No. 4c-7, 28-7-96: Line force variations, minimum & maximum forces per 10 minutes
line force [tons] (dev. from mean force)
line No.
measured minima
measured maxima
simulated minima
simulated maxima


Run No. 4c-7, 28-7-96: Maximum line forces per 3 hours
line force [tons] (dev. from mean force)
line No.
measurements
simulation

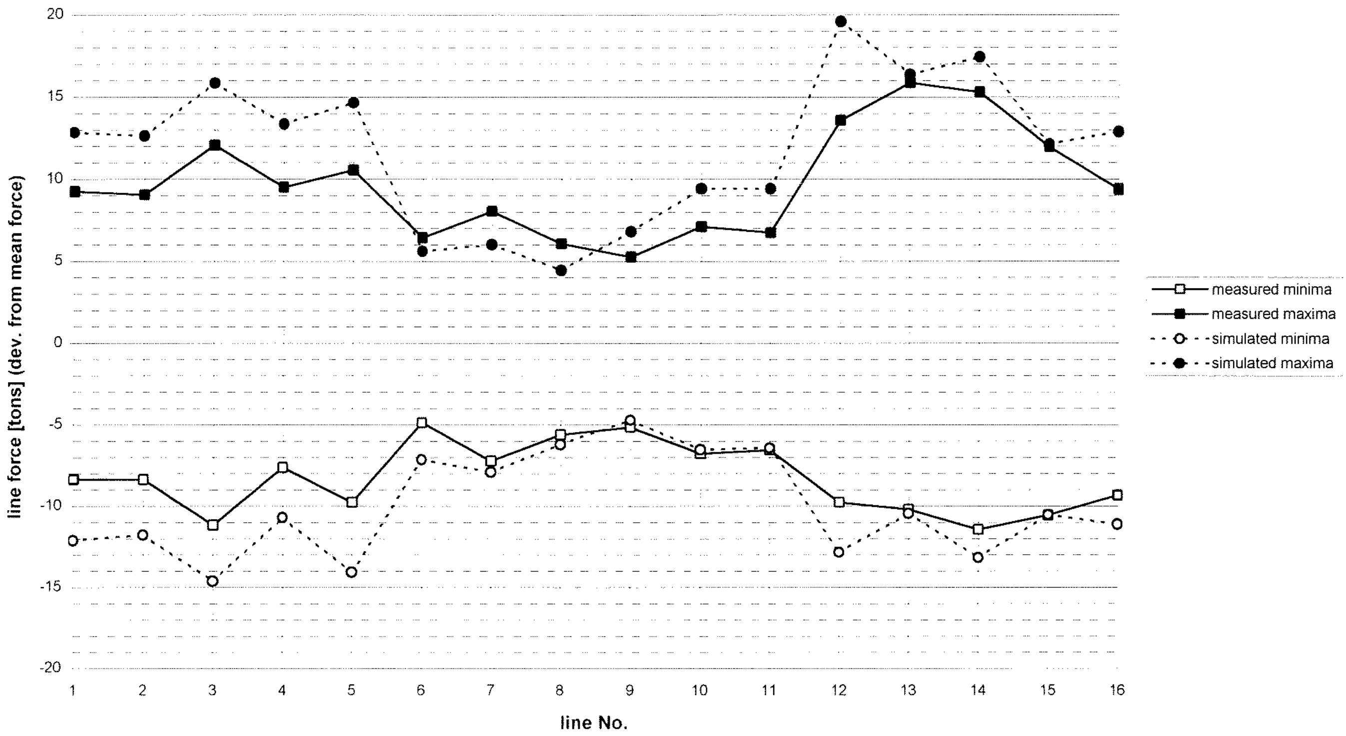
Run No. 4d-1, 2-8-96: Line force variations, minimum & maximum forces per 10 minutes



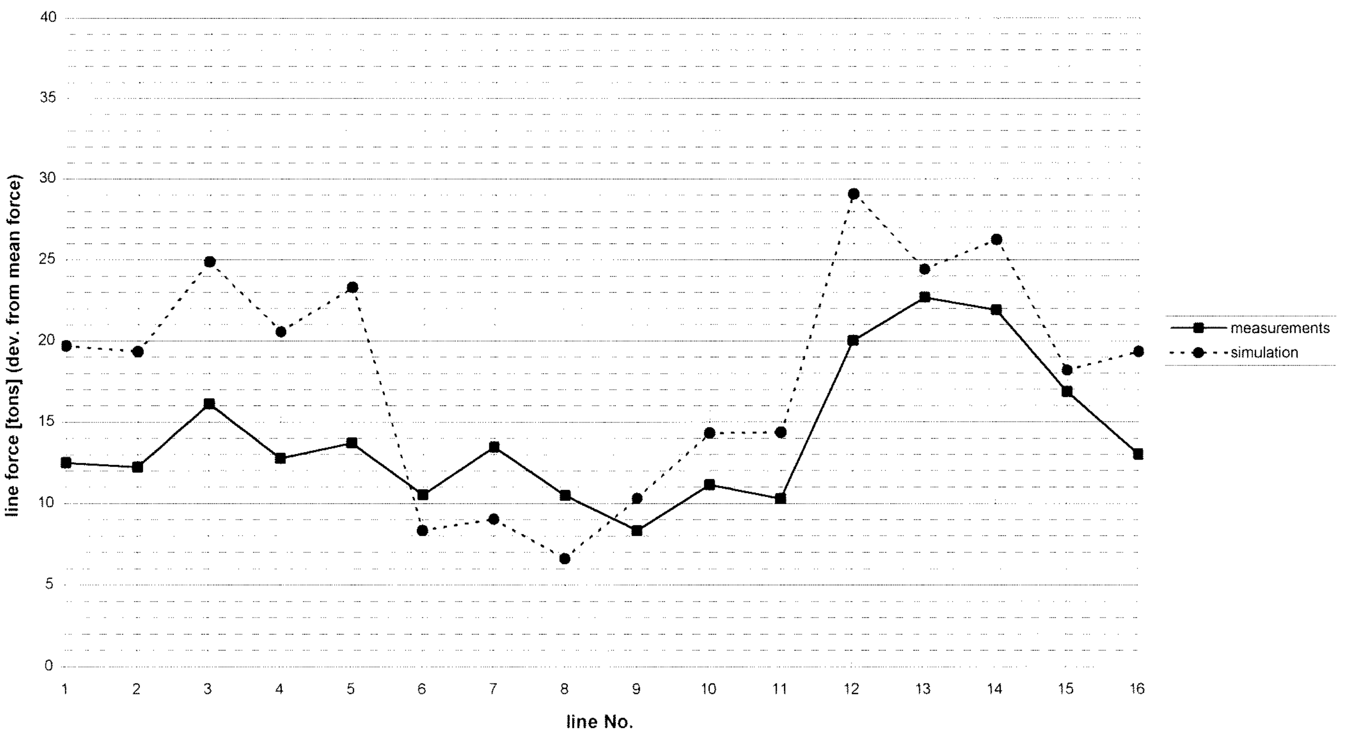
Run No. 4d-1, 2-8-96: Maximum line forces per 3 hours

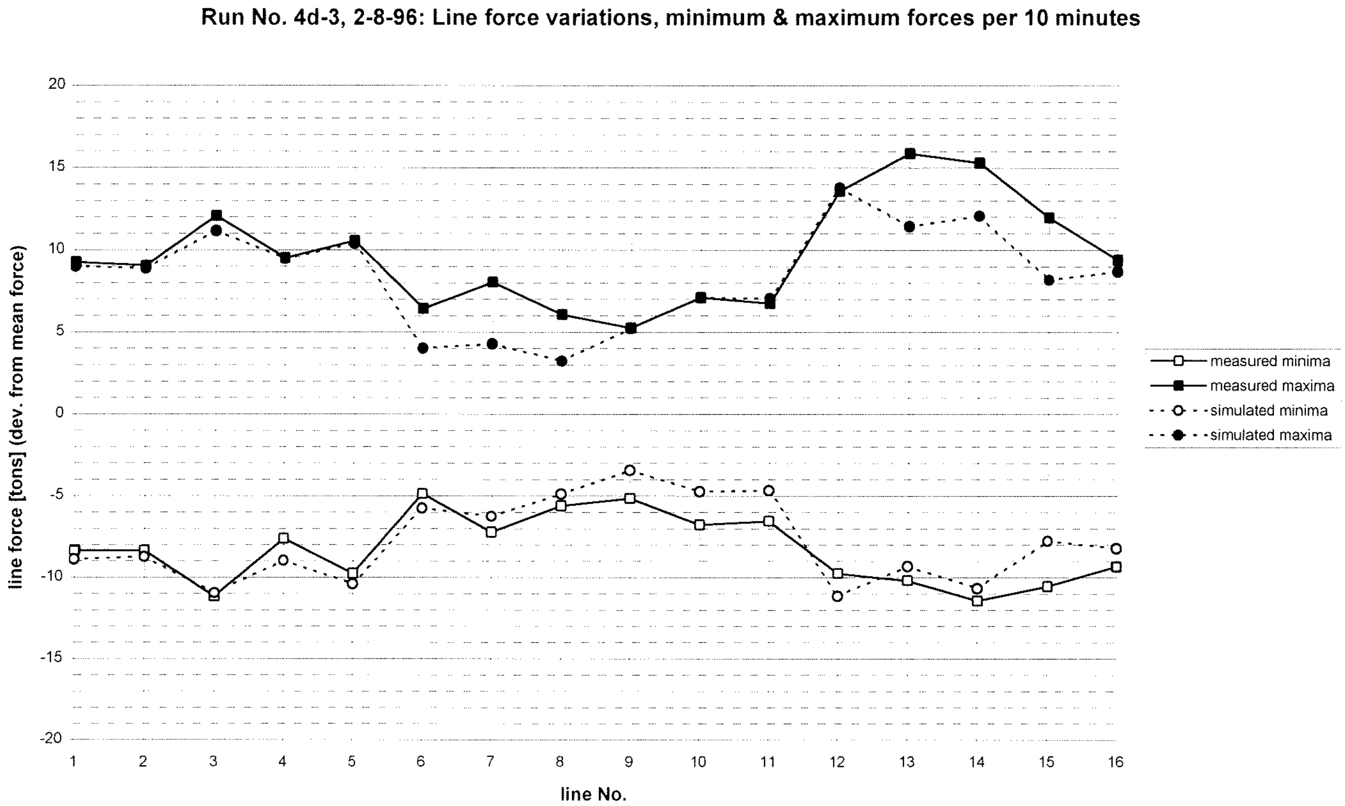


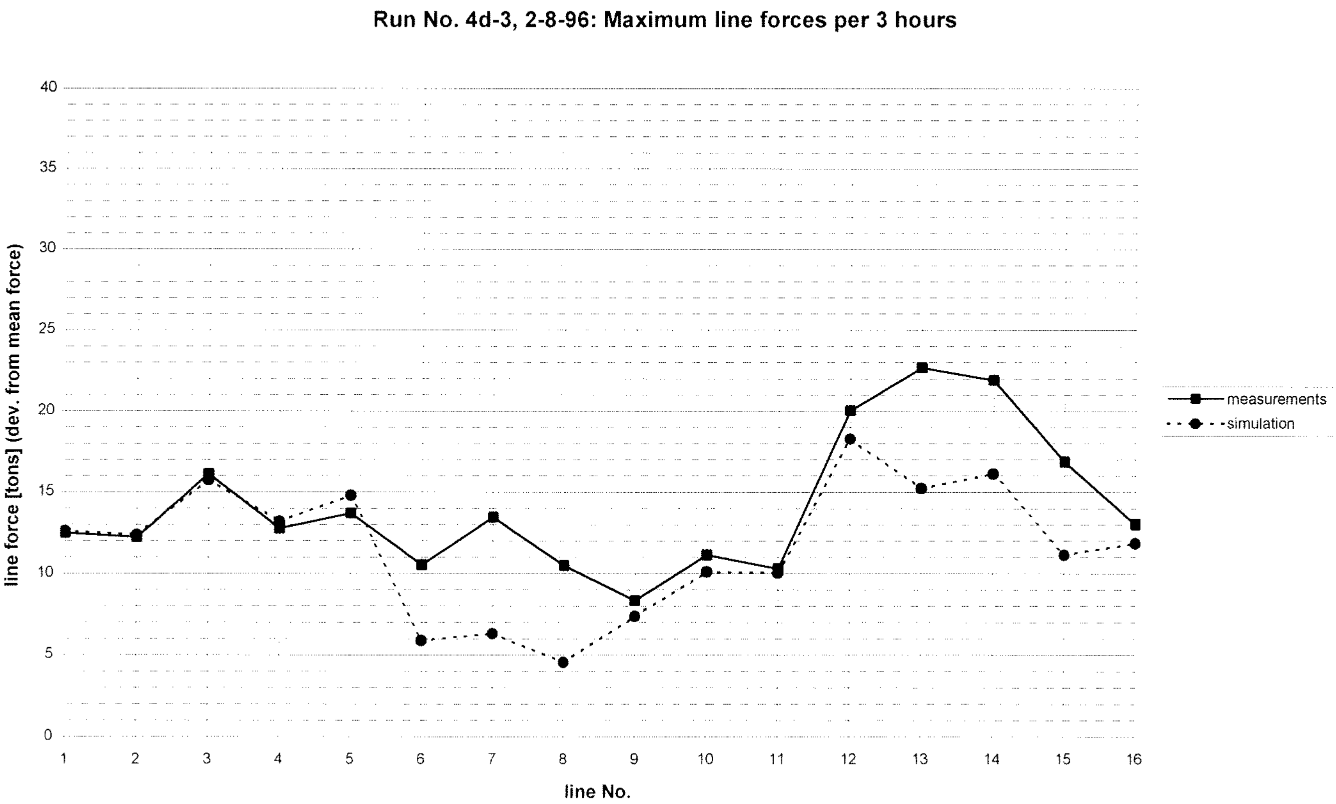
Run No. 4d-2, 2-8-96: Line force variations, minimum & maximum forces per 10 minutes

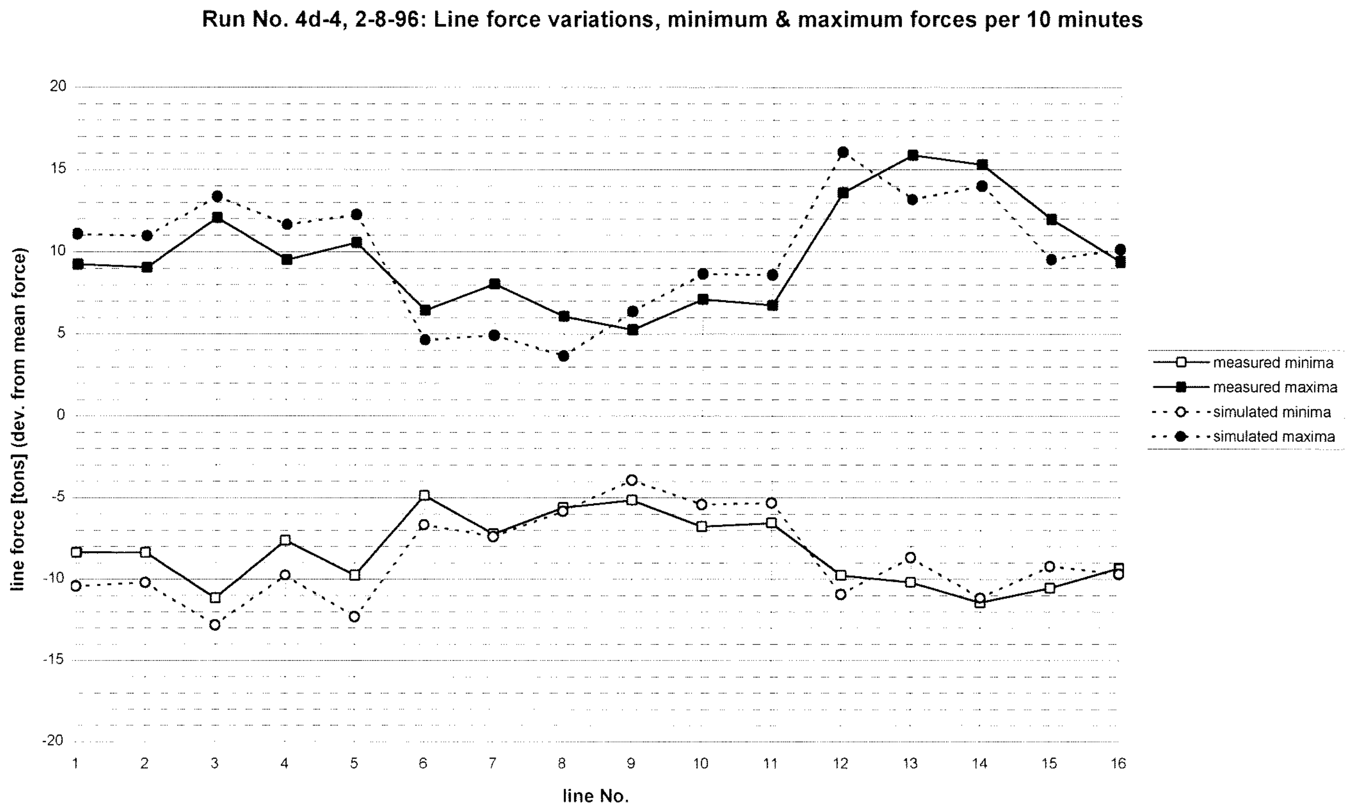


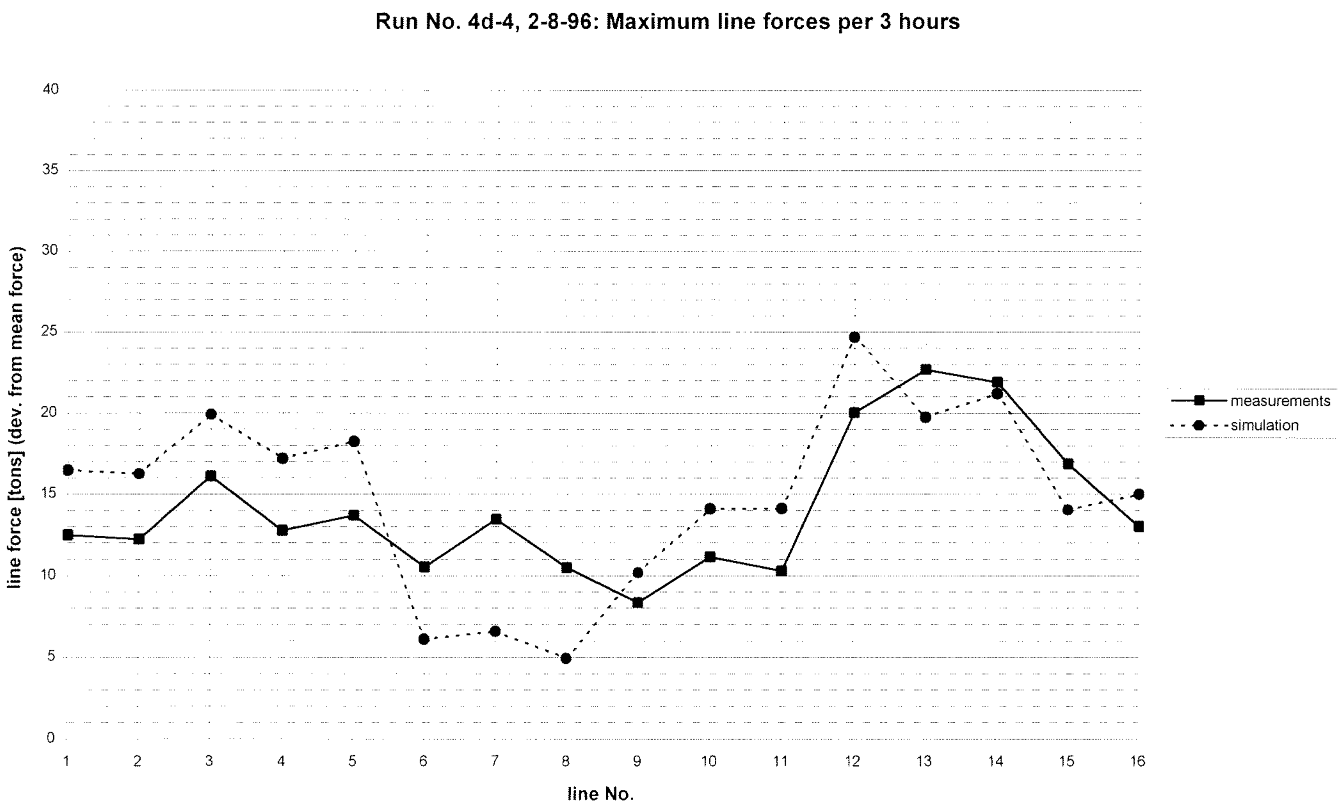
7a-2: Maximum line forces per 3 hours

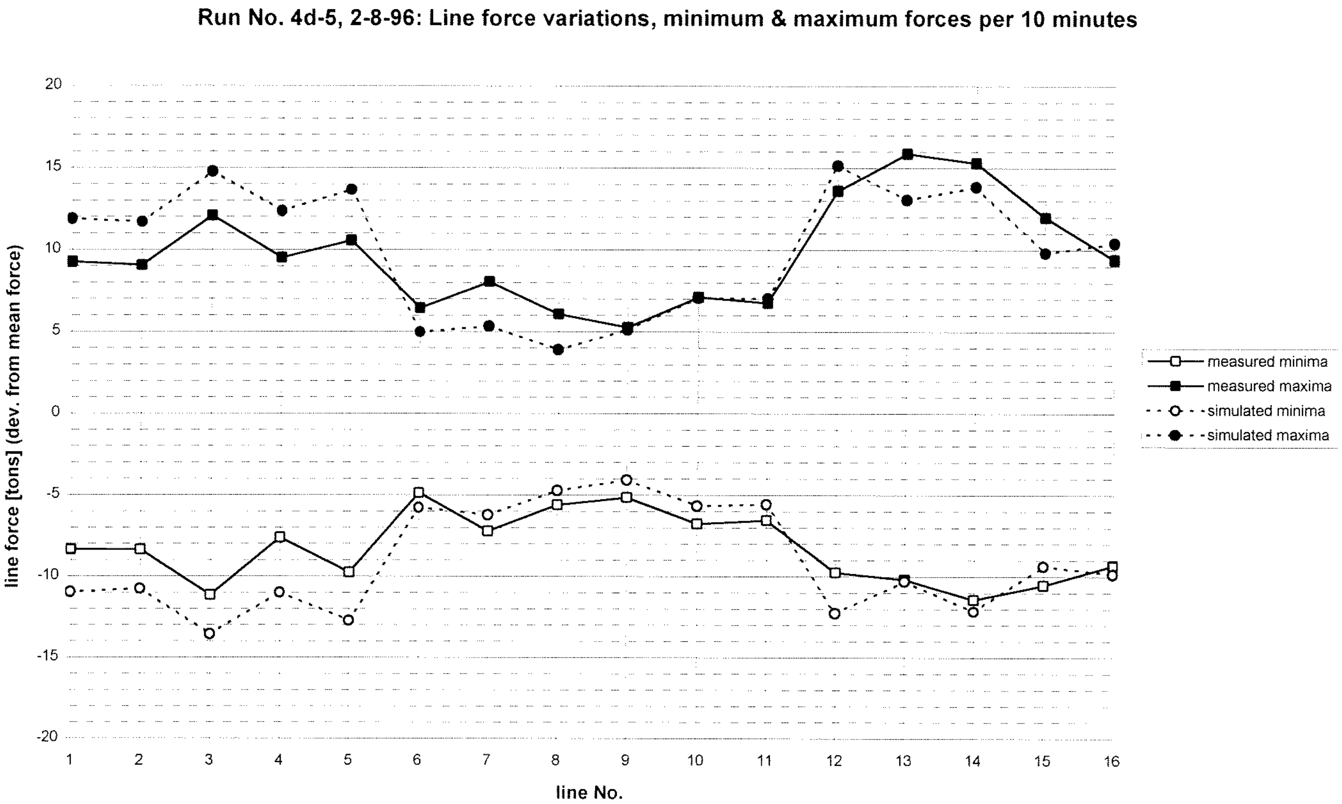


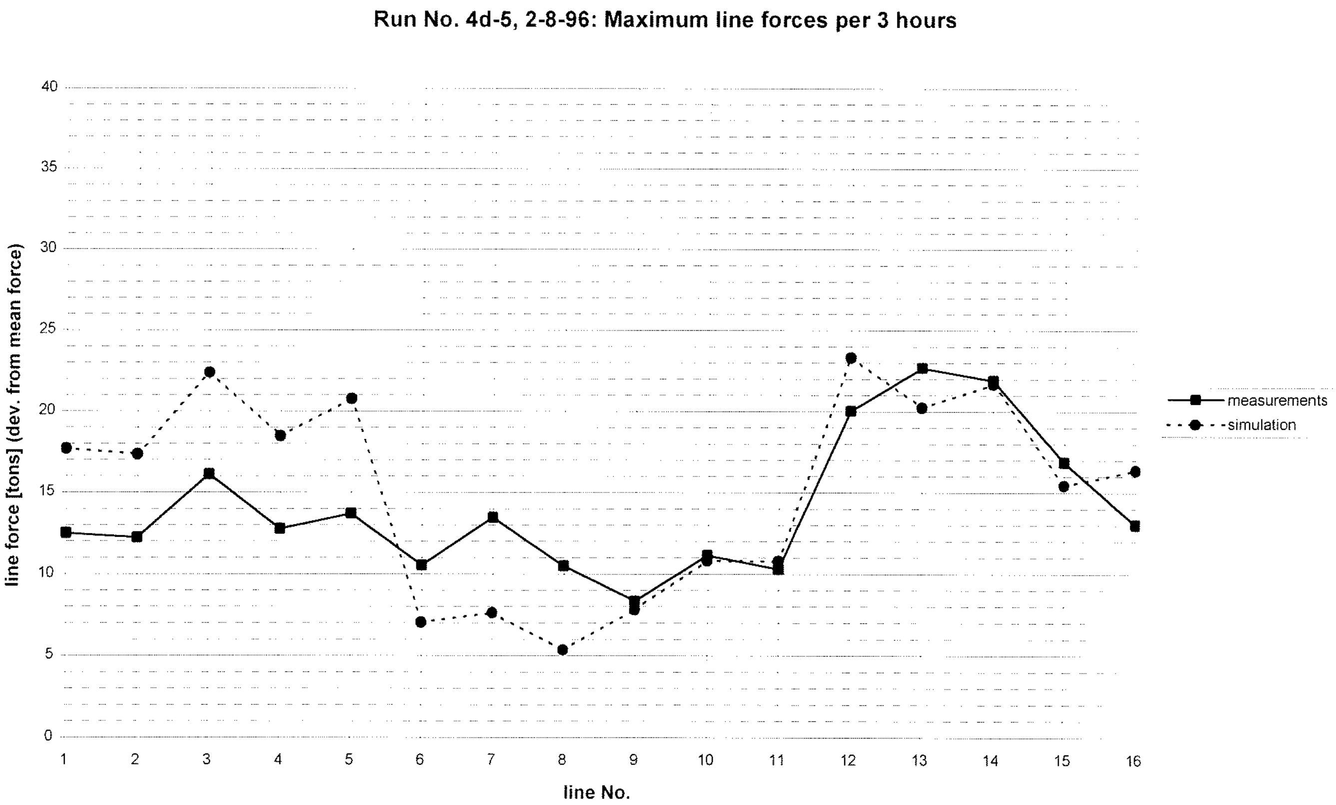

Run No. 4d-3, 2-8-96: Line force variations, minimum & maximum forces per 10 minutes
line force [tons] (dev. from mean force)
line No.
measured minima
measured maxima
simulated minima
simulated maxima

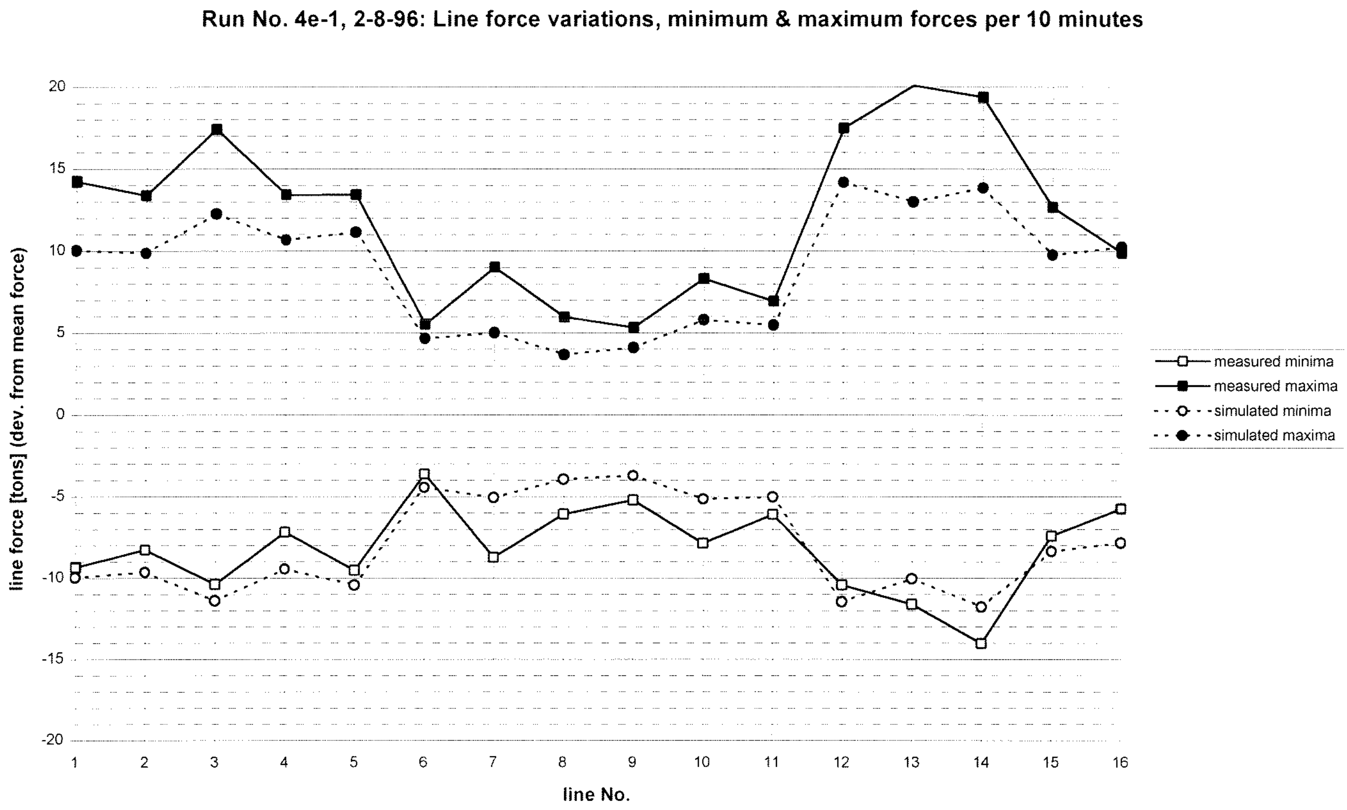

Run No. 4d-3, 2-8-96: Maximum line forces per 3 hours
line force [tons] (dev. from mean force)
line No.
measurements
simulation

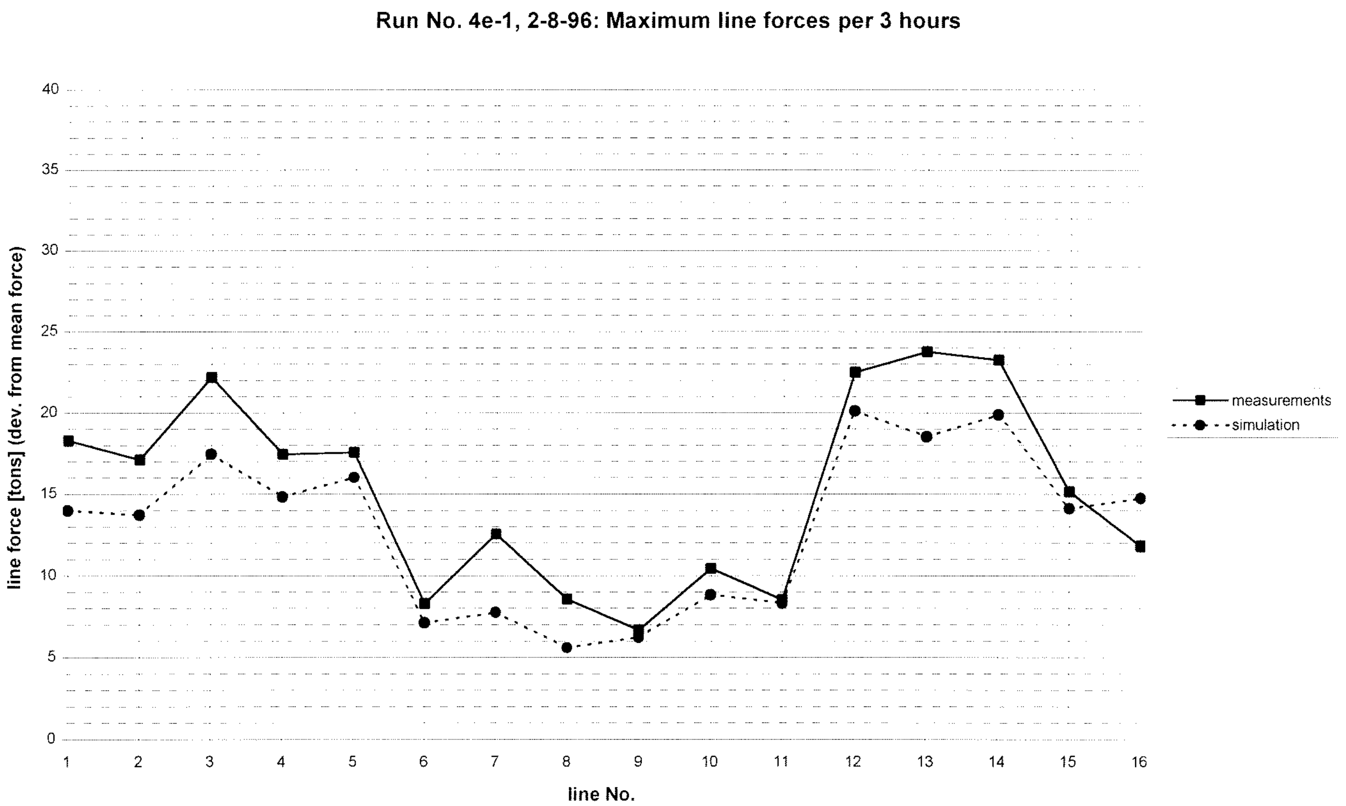

Run No. 4d-4, 2-8-96: Line force variations, minimum & maximum forces per 10 minutes
line force [tons] (dev. from mean force)
line No.
measured minima
measured maxima
simulated minima
simulated maxima


Run No. 4d-4, 2-8-96: Maximum line forces per 3 hours
line force [tons] (dev. from mean force)
line No.
measurements
simulation

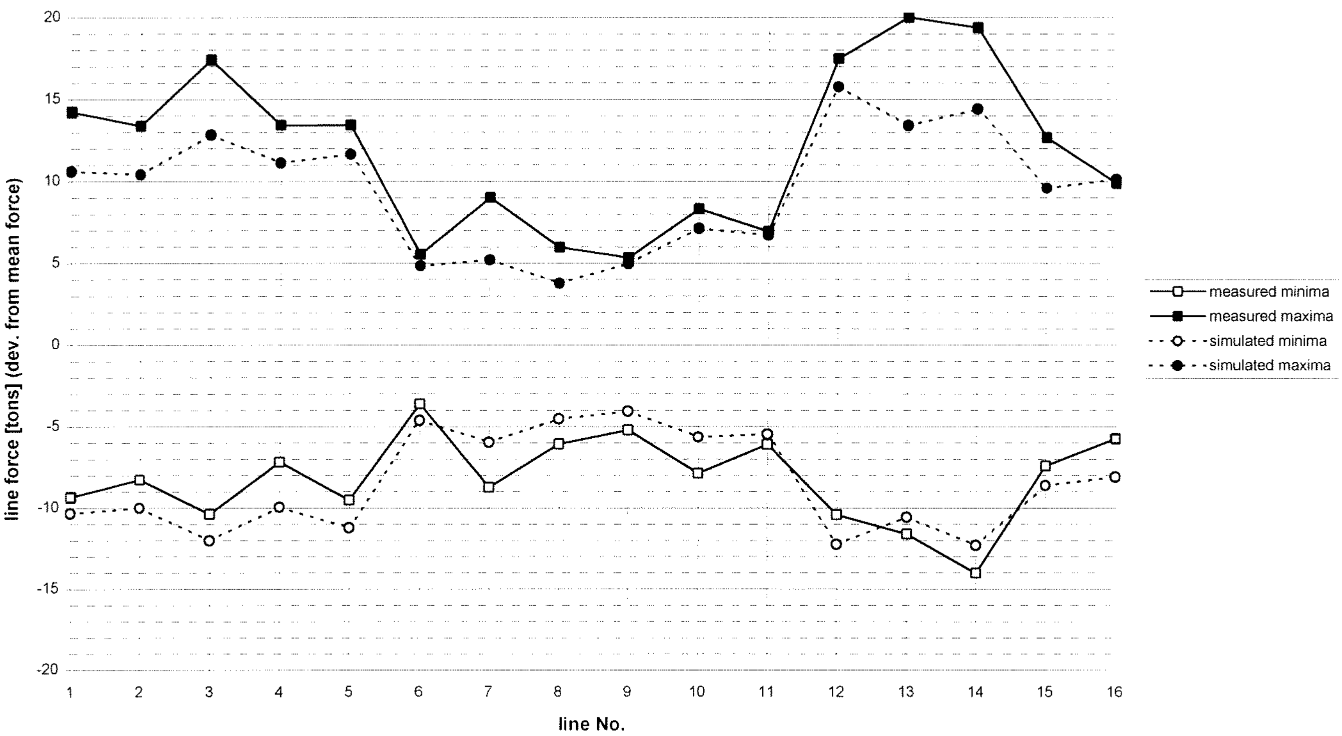

Run No. 4d-5, 2-8-96: Line force variations, minimum & maximum forces per 10 minutes
line force [tons] (dev. from mean force)
line No.
measured minima
measured maxima
simulated minima
simulated maxima


Run No. 4d-5, 2-8-96: Maximum line forces per 3 hours
line force [tons] (dev. from mean force)
line No.
measurements
simulation

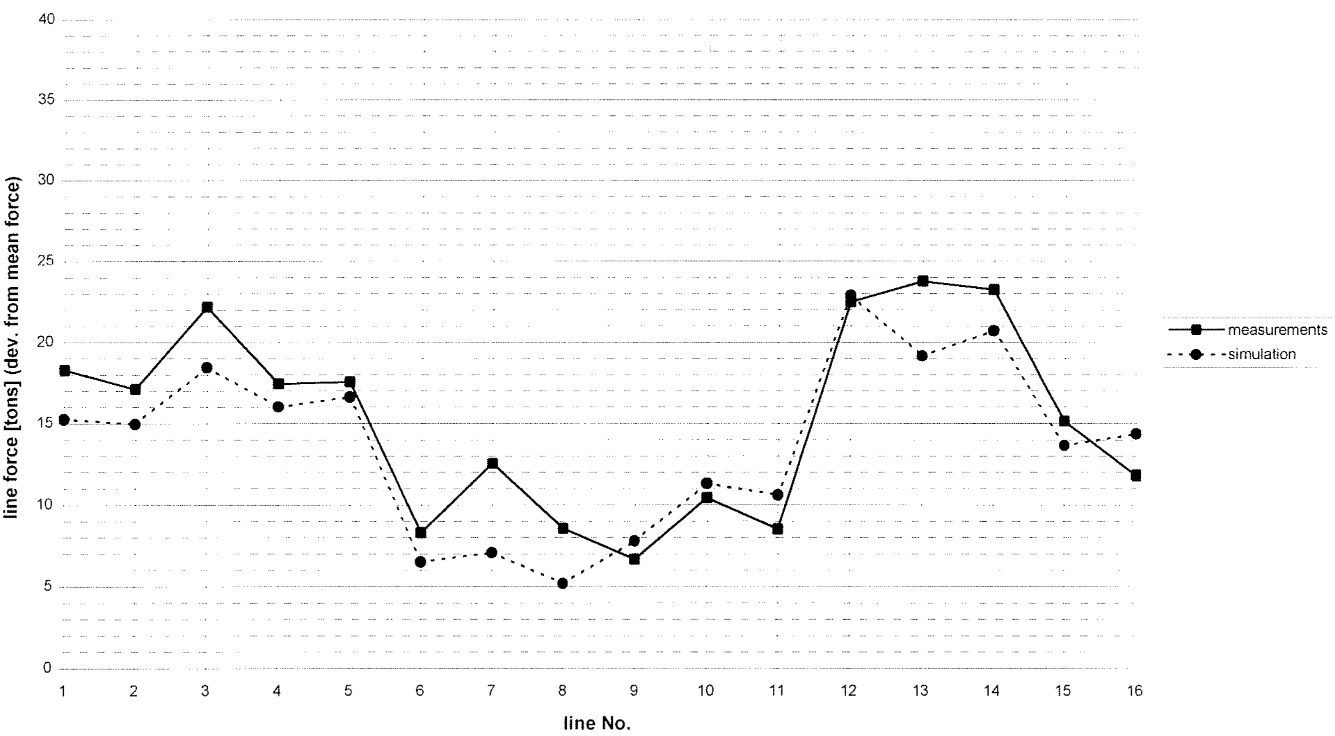

Run No. 4e-1, 2-8-96: Line force variations, minimum & maximum forces per 10 minutes
line force [tons] (dev. from mean force)
line No.
measured minima
measured maxima
simulated minima
simulated maxima

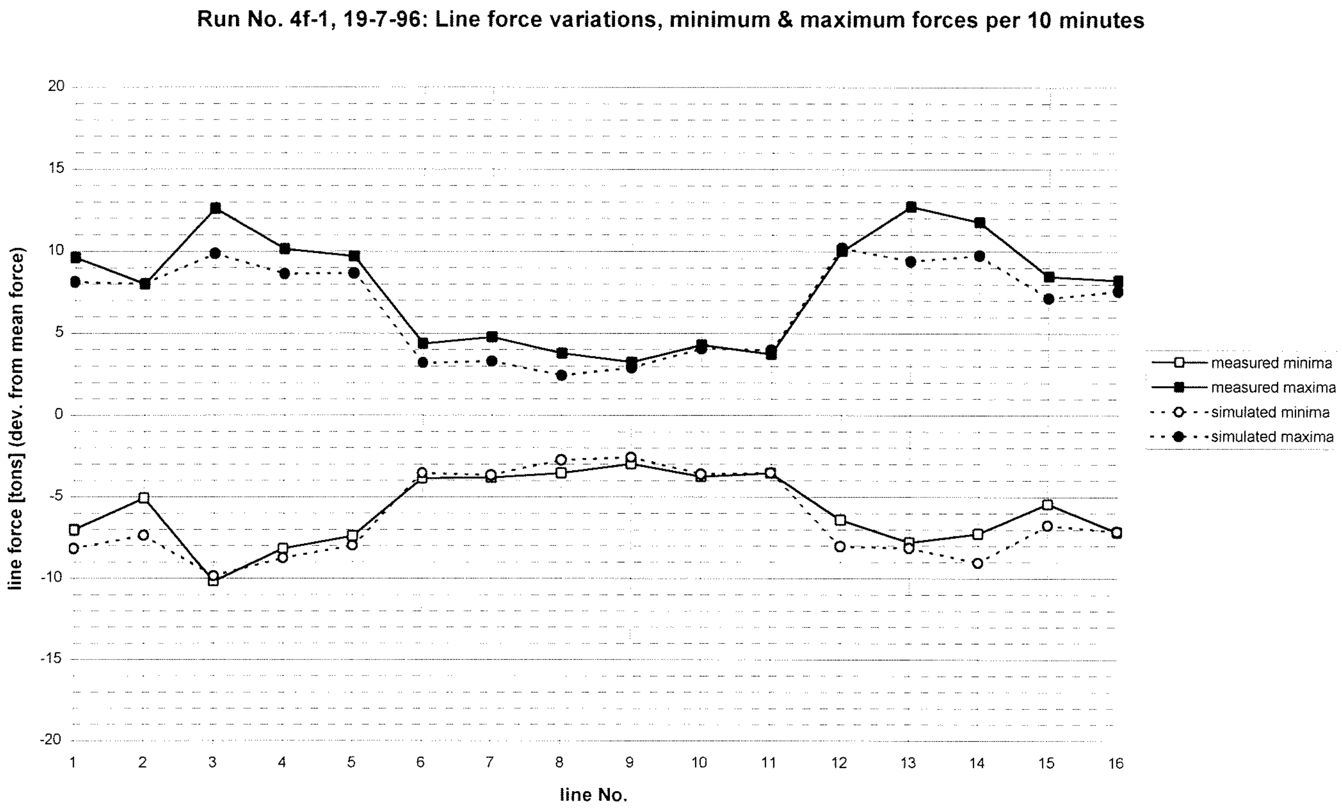

Run No. 4e-1, 2-8-96: Maximum line forces per 3 hours
line force [tons] (dev. from mean force)
line No.
measurements
simulation

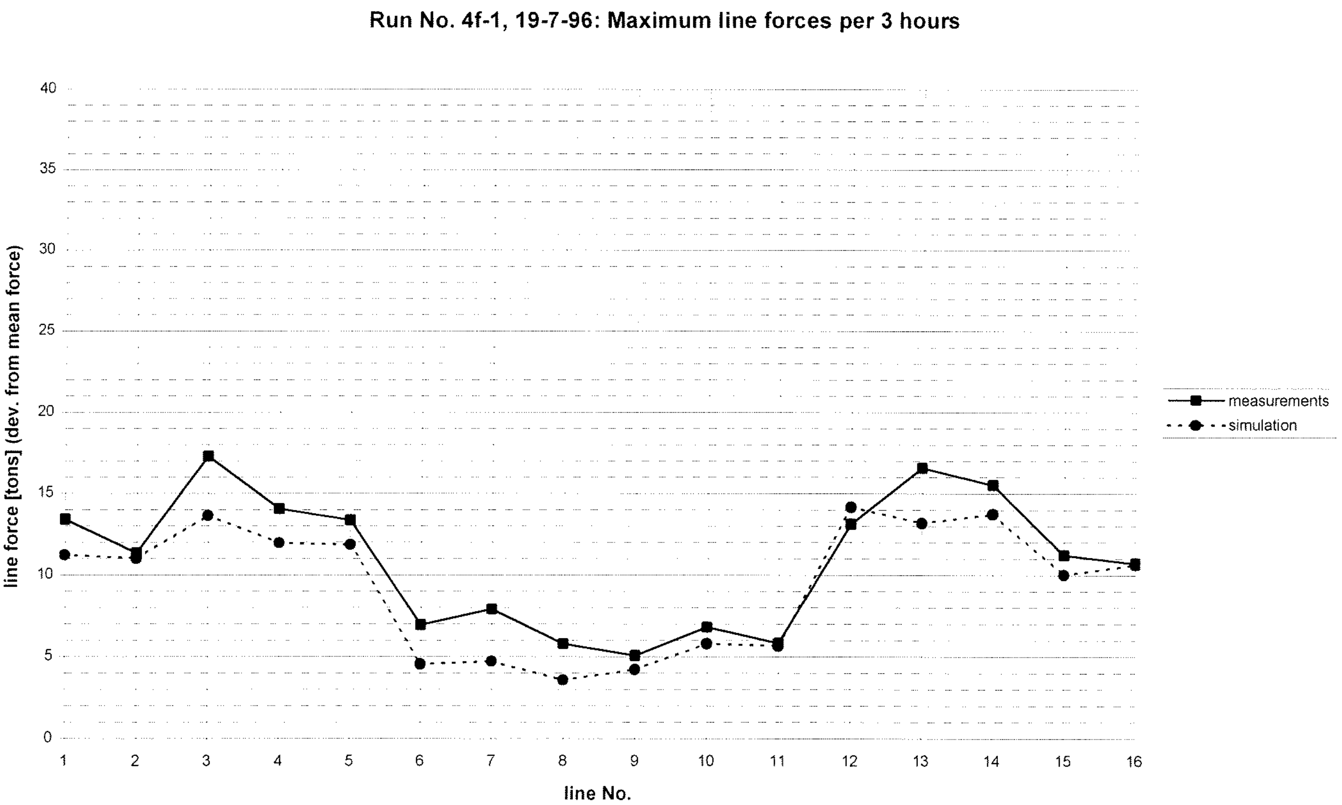
Run No. 4e-2, 2-8-96: Line force variations, minimum & maximum forces per 10 minutes



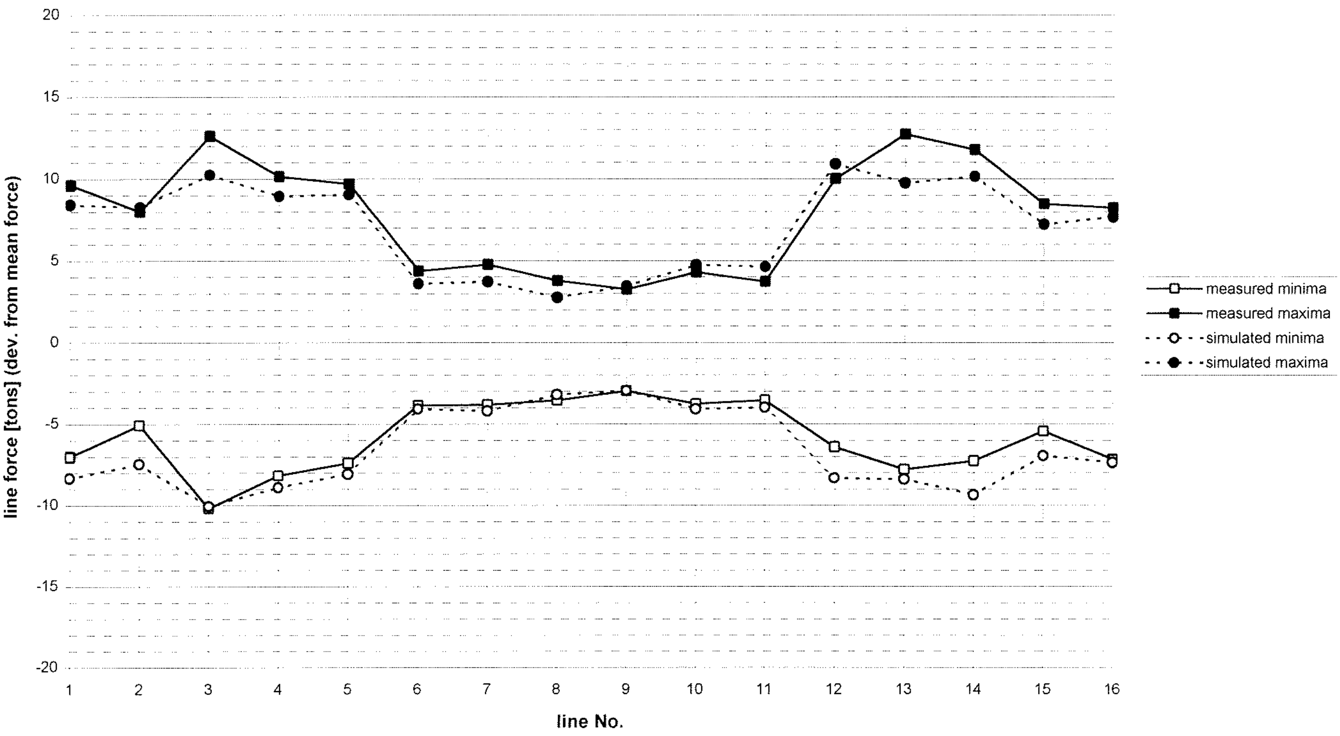
Run No. 4e-2: Maximum line forces per 3 hours



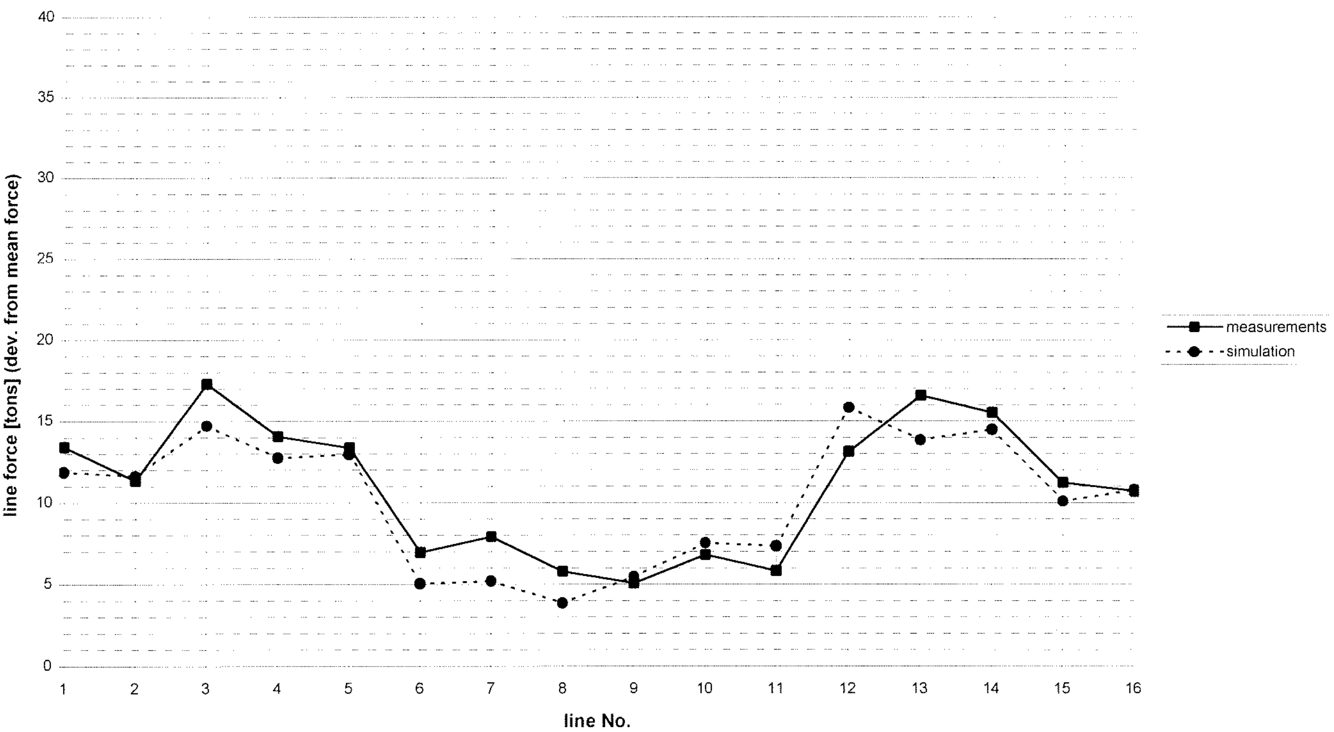

Run No. 4f-1, 19-7-96: Line force variations, minimum & maximum forces per 10 minutes
line force [tons] (dev. from mean force)
line No.
measured minima
measured maxima
simulated minima
simulated maxima


Run No. 4f-1, 19-7-96: Maximum line forces per 3 hours
line force [tons] (dev. from mean force)
line No.
measurements
simulation

Run No. 4f-2, 19-7-96: Line force variations, minimum & maximum forces per 10 minutes



Run No. 4f-2, 19-7-96: Maximum line forces per 3 hours



Appendix I

Comparison of Maximum Forces

Maximum forces per 10 minutes
Maximum forces per 3 hours

Comparison of maximum forces

No.:	1	wave spectrum:	1
date:	9-10-96	sign. wave height swell:	0.08 m.
jetty:	LNG jetty Withnell Bay	wave direction (swell):	195 deg
ship:	Northwest	wind speed:	6.9 m/s

Maximum forces per 10 minutes

parameter	unit	measurements	simulation	difference	
head lines	ton	1.27	1.37	0.10	7.8%
breast lines forward	ton	1.67	1.49	-0.17	-10.4%
spring lines forward	ton	0.46	0.46	0.00	0.0%
spring lines aft	ton	0.47	0.53	0.05	10.8%
breast lines aft	ton	1.35	1.73	0.39	28.6%
stern lines	ton	1.00	1.31	0.31	31.5%

Maximum forces per 3 hours

parameter	unit	measurements	simulation	difference	
head lines	ton	1.86	1.94	0.08	4.5%
breast lines forward	ton	2.36	2.11	-0.25	-10.8%
spring lines forward	ton	0.75	0.59	-0.16	-21.1%
spring lines aft	ton	0.75	0.79	0.05	6.1%
breast lines aft	ton	1.78	2.40	0.63	35.3%
stern lines	ton	1.45	1.82	0.37	25.5%

Comparison of maximum forces

No.:	2a	wave spectrum:	-
date:	1-12-96	sign. wave height swell:	-
jetty:	LNG jetty Withnell Bay	wave direction (swell):	-
ship:	Northwest	wind speed:	11.6 m/s, Harris

Maximum forces per 10 minutes

parameter	unit	measurements	simulation	difference	
head lines	ton	3.99	0.58	-3.41	-85.5%
breast lines forward	ton	4.13	0.79	-3.34	-80.9%
spring lines forward	ton	1.68	0.12	-1.56	-93.2%
spring lines aft	ton	1.54	0.42	-1.11	-72.4%
breast lines aft	ton	4.75	1.74	-3.01	-63.4%
stern lines	ton	2.77	1.26	-1.52	-54.7%

Maximum forces per 3 hours

parameter	unit	measurements	simulation	difference	
head lines	ton	5.60	0.77	-4.84	-86.3%
breast lines forward	ton	5.53	1.04	-4.49	-81.2%
spring lines forward	ton	2.68	0.15	-2.53	-94.4%
spring lines aft	ton	2.02	0.59	-1.44	-70.9%
breast lines aft	ton	6.35	2.34	-4.01	-63.1%
stern lines	ton	3.68	1.69	-1.99	-54.1%

Comparison of maximum forces

No.:	2b	wave spectrum:	-
date:	1-12-96	sign. wave height swell:	-
jetty:	LNG jetty Whitnell Bay	wave direction (swell):	-
ship:	Northwest	wind speed:	11.6 m/s, API

Maximum forces per 10 minutes

parameter	unit	measurements	simulation	difference	
head lines	ton	3.99	1.50	-2.49	-62.4%
breast lines forward	ton	4.13	1.94	-2.19	-53.0%
spring lines forward	ton	1.68	0.30	-1.38	-82.0%
spring lines aft	ton	1.54	0.67	-0.87	-56.6%
breast lines aft	ton	4.75	3.19	-1.56	-32.8%
stern lines	ton	2.77	2.29	-0.49	-17.5%

Maximum forces per 3 hours

parameter	unit	measurements	simulation	difference	
head lines	ton	5.60	1.91	-3.69	-65.8%
breast lines forward	ton	5.53	2.51	-3.02	-54.6%
spring lines forward	ton	2.68	0.39	-2.29	-85.5%
spring lines aft	ton	2.02	1.14	-0.88	-43.7%
breast lines aft	ton	6.35	4.82	-1.53	-24.1%
stern lines	ton	3.68	3.44	-0.24	-6.5%

Comparison of maximum forces

No.:	2c	wave spectrum:	2
date:	1-12-96	sign. wave height swell:	0.12 m.
jetty:	LNG jetty Whitnell Bay	wave direction (swell):	192 deg
ship:	Northwest	wind speed:	-

Maximum forces per 10 minutes

parameter	unit	measurements	simulation	difference	
head lines	ton	3.99	3.04	-0.95	-23.8%
breast lines forward	ton	4.13	3.36	-0.77	-18.6%
spring lines forward	ton	1.68	1.32	-0.36	-21.6%
spring lines aft	ton	1.54	1.49	-0.05	-3.3%
breast lines aft	ton	4.75	3.93	-0.82	-17.3%
stern lines	ton	2.77	2.95	0.18	6.5%

Maximum forces per 3 hours

parameter	unit	measurements	simulation	difference	
head lines	ton	5.60	4.10	-1.51	-26.9%
breast lines forward	ton	5.53	4.47	-1.06	-19.2%
spring lines forward	ton	2.68	1.95	-0.73	-27.3%
spring lines aft	ton	2.02	2.07	0.04	2.1%
breast lines aft	ton	6.35	5.03	-1.32	-20.8%
stern lines	ton	3.68	3.80	0.11	3.1%

Comparison of maximum forces

No.:	2d	wave spectrum:	2
date:	1-12-96	sign. wave height swell:	0.12 m.
jetty:	LNG jetty Whitnell Bay	wave direction (swell):	192 deg
ship:	Northwest	wind speed:	11.6 m/s, Harris

Maximum forces per 10 minutes

parameter	unit	measurements	simulation	difference	
head lines	ton	3.99	3.53	-0.46	-11.6%
breast lines forward	ton	4.13	3.95	-0.18	-4.3%
spring lines forward	ton	1.68	1.43	-0.25	-14.8%
spring lines aft	ton	1.54	1.62	0.09	5.7%
breast lines aft	ton	4.75	5.01	0.26	5.5%
stern lines	ton	2.77	3.64	0.87	31.2%

Maximum forces per 3 hours

parameter	unit	measurements	simulation	difference	
head lines	ton	5.60	4.70	-0.90	-16.1%
breast lines forward	ton	5.53	5.26	-0.27	-5.0%
spring lines forward	ton	2.68	1.86	-0.82	-30.6%
spring lines aft	ton	2.02	2.70	0.67	33.2%
breast lines aft	ton	6.35	7.30	0.95	14.9%
stern lines	ton	3.68	5.18	1.49	40.4%

Comparison of maximum forces

No.:	2e	wave spectrum:	2
date:	1-12-96	sign. wave height swell:	0.12 m.
jetty:	LNG jetty Whitnell Bay	wave direction (swell):	192 deg
ship:	Northwest	wind speed:	11.6 m/s, API

Maximum forces per 10 minutes

parameter	unit	measurements	simulation	difference	
head lines	ton	3.99	3.81	-0.18	-4.5%
breast lines forward	ton	4.13	4.39	0.26	6.2%
spring lines forward	ton	1.68	1.57	-0.11	-6.4%
spring lines aft	ton	1.54	1.79	0.26	16.6%
breast lines aft	ton	4.75	5.88	1.13	23.9%
stern lines	ton	2.77	4.23	1.45	52.3%

Maximum forces per 3 hours

parameter	unit	measurements	simulation	difference	
head lines	ton	5.60	4.83	-0.77	-13.7%
breast lines forward	ton	5.53	5.53	0.00	-0.1%
spring lines forward	ton	2.68	2.21	-0.47	-17.6%
spring lines aft	ton	2.02	3.23	1.21	59.6%
breast lines aft	ton	6.35	8.98	2.63	41.4%
stern lines	ton	3.68	6.29	2.60	70.6%

Comparison of maximum forces

No.:	2f	wave spectrum:	2
date:	1-12-96	sign. wave height swell:	0.56 m.
jetty:	LNG jetty Whitnell Bay	wave direction (swell):	0.12 m.
ship:	Northwest	wind speed:	11.6 m/s, Harris

Maximum forces per 10 minutes

parameter	unit	measurements	simulation	difference	
head lines	ton	3.99	3.61	-0.38	-9.4%
breast lines forward	ton	4.13	3.94	-0.19	-4.6%
spring lines forward	ton	1.68	1.31	-0.37	-22.0%
spring lines aft	ton	1.54	1.76	0.22	14.6%
breast lines aft	ton	4.75	5.35	0.61	12.8%
stern lines	ton	2.77	3.90	1.12	40.4%

Maximum forces per 3 hours

parameter	unit	measurements	simulation	difference	
head lines	ton	5.60	4.92	-0.68	-12.1%
breast lines forward	ton	5.53	5.39	-0.14	-2.6%
spring lines forward	ton	2.68	1.64	-1.04	-38.9%
spring lines aft	ton	2.02	2.79	0.77	38.1%
breast lines aft	ton	6.35	7.98	1.62	25.5%
stern lines	ton	3.68	5.79	2.11	57.3%

Comparison of maximum forces

No.:	2g	wave spectrum:	2
date:	1-12-96	sign. wave height swell:	0.12 m.
jetty:	LNG jetty Whitnell Bay	wave direction (swell):	192 deg
ship:	Northwest	wind speed:	11.6 m/s, Harris

Maximum forces per 10 minutes

parameter	unit	measurements	simulation	difference	
head lines	ton	3.99	3.72	-0.27	-6.9%
breast lines forward	ton	4.13	4.20	0.07	1.7%
spring lines forward	ton	1.68	1.31	-0.37	-21.9%
spring lines aft	ton	1.54	1.52	-0.02	-1.3%
breast lines aft	ton	4.75	4.55	-0.19	-4.1%
stern lines	ton	2.77	3.38	0.60	21.7%

Maximum forces per 3 hours

parameter	unit	measurements	simulation	difference	
head lines	ton	5.60	4.93	-0.68	-12.1%
breast lines forward	ton	5.53	5.45	-0.08	-1.4%
spring lines forward	ton	2.68	1.84	-0.84	-31.2%
spring lines aft	ton	2.02	2.15	0.12	6.1%
breast lines aft	ton	6.35	6.25	-0.10	-1.6%
stern lines	ton	3.68	4.52	0.84	22.8%

Comparison of maximum forces

No.:	4a-1	wave spectrum:	3a
date:	15-07-96	sign. wave height swell:	0.19 m.
jetty:	LNG jetty Whitnell Bay	wave direction (swell):	193 deg
ship:	Northwest	wind speed:	6.1 m.

Maximum forces per 10 minutes

parameter	unit	measurements	simulation	difference	
head lines	ton	4.10	3.12	-0.98	-23.9%
breast lines forward	ton	4.45	3.39	-1.06	-23.8%
spring lines forward	ton	1.53	1.11	-0.42	-27.3%
spring lines aft	ton	1.99	1.43	-0.56	-28.3%
breast lines aft	ton	4.13	3.55	-0.58	-14.0%
stern lines	ton	2.93	2.62	-0.31	-10.6%

Maximum forces per 3 hours

parameter	unit	measurements	simulation	difference	
head lines	ton	5.32	4.02	-1.30	-24.4%
breast lines forward	ton	5.81	4.42	-1.39	-23.9%
spring lines forward	ton	2.31	1.67	-0.64	-27.8%
spring lines aft	ton	3.08	2.12	-0.96	-31.1%
breast lines aft	ton	5.74	4.68	-1.06	-18.4%
stern lines	ton	3.93	3.40	-0.53	-13.4%

Comparison of maximum forces

No.:	3a-2	wave spectrum:	3a
date:	15-07-96	sign. wave height swell:	0.17 m.
jetty:	LNG jetty Withnell Bay	wave direction:	198 deg
ship:	Northwest	wind speed:	6.1 m.

Maximum forces per 10 minutes

parameter	unit	measurements	simulation	difference	
head lines	ton	4.10	4.20	0.10	2.4%
breast lines forward	ton	4.45	4.66	0.20	4.6%
spring lines forward	ton	1.53	1.49	-0.04	-2.6%
spring lines aft	ton	1.99	1.60	-0.39	-19.8%
breast lines aft	ton	4.13	4.91	0.78	19.0%
stern lines	ton	2.93	3.75	0.82	27.8%

Maximum forces per 3 hours

parameter	unit	measurements	simulation	difference	
head lines	ton	5.32	5.86	0.54	10.2%
breast lines forward	ton	5.81	6.46	0.66	11.3%
spring lines forward	ton	2.31	2.10	-0.21	-9.1%
spring lines aft	ton	3.08	2.27	-0.81	-26.4%
breast lines aft	ton	5.74	6.59	0.85	14.8%
stern lines	ton	3.93	5.00	1.07	27.2%

Comparison of maximum forces

No.:	3b-1	wave spectrum:	3b
date:	15-07-96	sign. wave height swell:	0.21 m.
jetty:	LNG jetty Whitnell Bay	wave direction (swell):	191 deg
ship:	Northwest	wind speed:	5.7 m/s

Maximum forces per 10 minutes

parameter	unit	measurements	simulation	difference	
head lines	ton	4.24	2.66	-1.58	-37.3%
breast lines forward	ton	4.77	2.88	-1.89	-39.7%
spring lines forward	ton	2.07	1.06	-1.01	-48.7%
spring lines aft	ton	2.41	1.25	-1.16	-48.2%
breast lines aft	ton	4.55	3.14	-1.41	-31.0%
stern lines	ton	3.03	2.38	-0.64	-21.3%

Maximum forces per 3 hours

parameter	unit	measurements	simulation	difference	
head lines	ton	5.29	3.39	-1.90	-35.9%
breast lines forward	ton	6.07	3.72	-2.34	-38.7%
spring lines forward	ton	2.90	1.43	-1.47	-50.7%
spring lines aft	ton	3.39	1.80	-1.59	-46.9%
breast lines aft	ton	5.81	4.14	-1.67	-28.7%
stern lines	ton	3.78	3.11	-0.68	-17.9%

Comparison of maximum forces

No.:	3b-2	wave spectrum:	3b
date:	15-07-96	sign. wave height swell:	0.19 m.
jetty:	LNG jetty Withnell Bay	wave direction:	198 deg
ship:	Northwest	wind speed:	5.7 m/s

Maximum forces per 10 minutes

parameter	unit	measurements	simulation	difference	
head lines	ton	4.24	4.94	0.70	16.4%
breast lines forward	ton	4.77	5.49	0.72	15.0%
spring lines forward	ton	2.07	1.68	-0.39	-18.7%
spring lines aft	ton	2.41	2.00	-0.40	-16.7%
breast lines aft	ton	4.55	5.77	1.22	26.8%
stern lines	ton	3.03	4.32	1.29	42.8%

Maximum forces per 3 hours

parameter	unit	measurements	simulation	difference	
head lines	ton	5.29	6.22	0.93	17.6%
breast lines forward	ton	6.07	6.99	0.93	15.3%
spring lines forward	ton	2.90	2.49	-0.41	-14.1%
spring lines aft	ton	3.39	2.90	-0.49	-14.6%
breast lines aft	ton	5.81	7.75	1.94	33.4%
stern lines	ton	3.78	5.76	1.98	52.2%

Comparison of maximum forces

No.:	3b-3	wave spectrum:	3b, no swell
date:	15-07-96	sign. wave height swell:	-
jetty:	LNG jetty Whitnell Bay	wave direction:	198 deg
ship:	Northwest	wind speed:	5.7 m/s (const.)

Maximum forces per 10 minutes

parameter	unit	measurements	simulation	difference	
head lines	ton	4.24	0.92	-3.32	-78.2%
breast lines forward	ton	4.77	0.99	-3.78	-79.3%
spring lines forward	ton	2.07	0.48	-1.58	-76.6%
spring lines aft	ton	2.41	0.46	-1.95	-80.9%
breast lines aft	ton	4.55	0.95	-3.60	-79.2%
stern lines	ton	3.03	0.74	-2.29	-75.6%

Maximum forces per 3 hours

parameter	unit	measurements	simulation	difference	
head lines	ton	5.29	1.18	-4.11	-77.7%
breast lines forward	ton	6.07	1.30	-4.77	-78.6%
spring lines forward	ton	2.90	0.72	-2.18	-75.1%
spring lines aft	ton	3.39	0.70	-2.69	-79.4%
breast lines aft	ton	5.81	1.32	-4.49	-77.3%
stern lines	ton	3.78	1.04	-2.75	-72.6%

Comparison of maximum forces

No.:	4a-1	wave spectrum:	4a
date:	21-07-96	sign. wave height swell:	0.24 m.
jetty:	LNG jetty Whitnell Bay	wave direction:	183 deg
ship:	Northwest	wind speed:	-

Maximum forces per 10 minutes

parameter	unit	measurements	simulation	difference	
head lines	ton	5.41	1.84	-3.56	-65.9%
breast lines forward	ton	5.72	1.92	-3.80	-66.4%
spring lines forward	ton	3.41	1.81	-1.60	-47.0%
spring lines aft	ton	3.46	1.88	-1.58	-45.6%
breast lines aft	ton	6.46	1.68	-4.78	-74.0%
stern lines	ton	5.53	1.37	-4.16	-75.2%

Maximum forces per 3 hours

parameter	unit	measurements	simulation	difference	
head lines	ton	9.11	2.25	-6.86	-75.3%
breast lines forward	ton	8.64	2.36	-6.27	-72.7%
spring lines forward	ton	7.92	2.28	-5.64	-71.2%
spring lines aft	ton	7.29	2.32	-4.97	-68.2%
breast lines aft	ton	10.36	2.13	-8.23	-79.4%
stern lines	ton	9.28	1.76	-7.52	-81.1%

Comparison of maximum forces

No.:	4a-2	wave spectrum:	4a
date:	21-07-96	sign. wave height swell:	0.24 m.
jetty:	LNG jetty Whitnell Bay	wave direction:	194 deg
ship:	Northwest	wind speed:	-

Maximum forces per 10 minutes

parameter	unit	measurements	simulation	difference	
head lines	ton	5.41	4.69	-0.72	-13.3%
breast lines forward	ton	5.72	5.62	-0.11	-1.8%
spring lines forward	ton	3.41	2.84	-0.57	-16.8%
spring lines aft	ton	3.46	3.38	-0.08	-2.2%
breast lines aft	ton	6.46	6.22	-0.24	-3.7%
stern lines	ton	5.53	4.25	-1.28	-23.2%

Maximum forces per 3 hours

parameter	unit	measurements	simulation	difference	
head lines	ton	9.11	6.37	-2.74	-30.1%
breast lines forward	ton	8.64	7.69	-0.94	-10.9%
spring lines forward	ton	7.92	3.71	-4.21	-53.2%
spring lines aft	ton	7.29	4.29	-3.00	-41.1%
breast lines aft	ton	10.36	8.63	-1.73	-16.7%
stern lines	ton	9.28	5.94	-3.33	-35.9%

Comparison of maximum forces

No.:	4a-3	wave spectrum:	4a
date:	21-07-96	sign. wave height total:	0.24 m.
jetty:	LNG jetty Whitnell Bay	sign. wave height swell:	205 deg
ship:	Northwest	wind speed:	-

Maximum forces per 10 minutes

parameter	unit	measurements	simulation	difference	
head lines	ton	5.41	12.22	6.81	125.9%
breast lines forward	ton	5.72	14.80	9.07	158.5%
spring lines forward	ton	3.41	4.91	1.50	43.9%
spring lines aft	ton	3.46	7.57	4.11	118.7%
breast lines aft	ton	6.46	16.93	10.47	162.1%
stern lines	ton	5.53	11.39	5.86	105.8%

Maximum forces per 3 hours

parameter	unit	measurements	simulation	difference	
head lines	ton	9.11	18.98	9.87	108.4%
breast lines forward	ton	8.64	22.54	13.90	161.0%
spring lines forward	ton	7.92	6.84	-1.08	-13.7%
spring lines aft	ton	7.29	10.57	3.28	45.0%
breast lines aft	ton	10.36	26.35	15.98	154.2%
stern lines	ton	9.28	17.52	8.24	88.8%

Comparison of maximum forces

No.:	4a-4	wave spectrum:	4a
date:	21-07-96	sign. wave height swell:	0.24 m.
jetty:	LNG jetty Withnell Bay	wave direction:	177 & 189 deg
ship:	Northwest	wind speed:	-

Maximum forces per 10 minutes

parameter	unit	measurements	simulation	difference	
head lines	ton	5.41	2.84	-2.57	-47.5%
breast lines forward	ton	5.72	3.61	-2.12	-37.0%
spring lines forward	ton	3.41	1.85	-1.56	-45.7%
spring lines aft	ton	3.46	2.28	-1.18	-34.0%
breast lines aft	ton	6.46	3.23	-3.23	-50.1%
stern lines	ton	5.53	2.39	-3.14	-56.8%

Maximum forces per 3 hours

parameter	unit	measurements	simulation	difference	
head lines	ton	9.11	3.89	-5.22	-57.3%
breast lines forward	ton	8.64	4.64	-3.99	-46.2%
spring lines forward	ton	7.92	2.43	-5.50	-69.4%
spring lines aft	ton	7.29	3.71	-3.58	-49.2%
breast lines aft	ton	10.36	4.20	-6.17	-59.5%
stern lines	ton	9.28	2.94	-6.34	-68.3%

Comparison of maximum forces

No.:	4a-5	wave spectrum:	4a
date:	21-07-96	sign. wave height swell:	0.24 m.
jetty:	LNG jetty Withnell Bay	wave direction:	172 & 194 deg
ship:	Northwest	wind speed:	-

Maximum forces per 10 minutes

parameter	unit	measurements	simulation	difference	
head lines	ton	5.41	4.51	-0.89	-16.5%
breast lines forward	ton	5.72	5.57	-0.16	-2.8%
spring lines forward	ton	3.41	2.27	-1.15	-33.6%
spring lines aft	ton	3.46	2.81	-0.65	-18.7%
breast lines aft	ton	6.46	5.37	-1.09	-16.8%
stern lines	ton	5.53	3.97	-1.57	-28.3%

Maximum forces per 3 hours

parameter	unit	measurements	simulation	difference	
head lines	ton	9.11	6.09	-3.02	-33.2%
breast lines forward	ton	8.64	7.32	-1.32	-15.3%
spring lines forward	ton	7.92	2.92	-5.01	-63.2%
spring lines aft	ton	7.29	3.92	-3.37	-46.2%
breast lines aft	ton	10.36	7.22	-3.15	-30.4%
stern lines	ton	9.28	5.46	-3.82	-41.2%

Comparison of maximum forces

No.:	4a-6	wave spectrum:	4a
date:	21-07-96	sign. wave height swell:	0.24 m.
jetty:	LNG jetty Withnell Bay	wave direction:	166 & 200 deg
ship:	Northwest	wind speed:	-

Maximum forces per 10 minutes

parameter	unit	measurements	simulation	difference	
head lines	ton	5.41	7.47	2.06	38.1%
breast lines forward	ton	5.72	9.25	3.52	61.5%
spring lines forward	ton	3.41	2.67	-0.74	-21.7%
spring lines aft	ton	3.46	3.87	0.41	11.9%
breast lines aft	ton	6.46	9.32	2.86	44.4%
stern lines	ton	5.53	6.90	1.37	24.8%

Maximum forces per 3 hours

parameter	unit	measurements	simulation	difference	
head lines	ton	9.11	11.10	1.99	21.9%
breast lines forward	ton	8.64	13.79	5.15	59.6%
spring lines forward	ton	7.92	3.15	-4.77	-60.3%
spring lines aft	ton	7.29	6.39	-0.90	-12.4%
breast lines aft	ton	10.36	14.30	3.94	38.0%
stern lines	ton	9.28	10.30	1.03	11.1%

Comparison of maximum forces

No.:	4a-7	wave spectrum:	4a
date:	21-07-96	sign. wave height swell:	0.24 m.
jetty:	LNG jetty Withnell Bay	wave direction:	161 & 205 deg
ship:	Northwest	wind speed:	-

Maximum forces per 10 minutes

parameter	unit	measurements	simulation	difference	
head lines	ton	5.41	10.86	5.45	100.9%
breast lines forward	ton	5.72	13.81	8.08	141.2%
spring lines forward	ton	3.41	4.21	0.79	23.2%
spring lines aft	ton	3.46	4.93	1.47	42.6%
breast lines aft	ton	6.46	13.49	7.03	108.9%
stern lines	ton	5.53	10.25	4.72	85.2%

Maximum forces per 3 hours

parameter	unit	measurements	simulation	difference	
head lines	ton	9.11	16.51	7.40	81.2%
breast lines forward	ton	8.64	20.92	12.29	142.3%
spring lines forward	ton	7.92	6.50	-1.42	-17.9%
spring lines aft	ton	7.29	8.02	0.73	10.0%
breast lines aft	ton	10.36	20.30	9.94	95.9%
stern lines	ton	9.28	15.65	6.37	68.7%

Comparison of maximum forces

No.:	4a-8	wave spectrum:	4a
date:	21-07-96	sign. wave height swell:	0.22 m.
jetty:	LNG jetty Withnell Bay	wave direction:	198 deg
ship:	Northwest	wind speed:	-

Maximum forces per 10 minutes

parameter	unit	measurements	simulation	difference	
head lines	ton	5.41	7.27	1.86	34.5%
breast lines forward	ton	5.72	9.31	3.59	62.7%
spring lines forward	ton	3.41	2.89	-0.52	-15.3%
spring lines aft	ton	3.46	4.11	0.65	18.9%
breast lines aft	ton	6.46	9.05	2.59	40.1%
stern lines	ton	5.53	6.36	0.82	14.9%

Maximum forces per 3 hours

parameter	unit	measurements	simulation	difference	
head lines	ton	9.11	11.28	2.17	23.8%
breast lines forward	ton	8.64	14.27	5.64	65.3%
spring lines forward	ton	7.92	4.06	-3.86	-48.7%
spring lines aft	ton	7.29	6.87	-0.42	-5.8%
breast lines aft	ton	10.36	13.80	3.44	33.2%
stern lines	ton	9.28	9.54	0.26	2.8%

Comparison of maximum forces

No.:	4b-1	wave spectrum:	4b
date:	22-07-96	sign. wave height swell:	0.27 m.
jetty:	LNG jetty Whitnell Bay	wave direction:	189 deg
ship:	Northwest	wind speed:	-

Maximum forces per 10 minutes

parameter	unit	measurements	simulation	difference	
head lines	ton	7.47	3.64	-3.83	-51.2%
breast lines forward	ton	7.56	3.92	-3.64	-48.1%
spring lines forward	ton	1.89	1.25	-0.64	-33.9%
spring lines aft	ton	2.97	1.88	-1.09	-36.7%
breast lines aft	ton	10.88	3.83	-7.05	-64.8%
stern lines	ton	8.71	3.02	-5.69	-65.4%

Maximum forces per 3 hours

parameter	unit	measurements	simulation	difference	
head lines	ton	11.02	4.97	-6.05	-54.9%
breast lines forward	ton	10.88	5.40	-5.48	-50.4%
spring lines forward	ton	2.64	1.91	-0.73	-27.7%
spring lines aft	ton	4.77	2.89	-1.88	-39.4%
breast lines aft	ton	17.25	5.17	-12.08	-70.0%
stern lines	ton	13.21	4.12	-9.08	-68.8%

Comparison of maximum forces

No.:	4b-2	wave spectrum:	4b
date:	22-07-96	sign. wave height swell:	0.27 m.
jetty:	LNG jetty Whitnell Bay	wave direction:	197 deg
ship:	Northwest	wind speed:	-

Maximum forces per 10 minutes

parameter	unit	measurements	simulation	difference	
head lines	ton	7.47	7.22	-0.25	-3.3%
breast lines forward	ton	7.56	8.07	0.51	6.7%
spring lines forward	ton	1.89	2.40	0.51	27.2%
spring lines aft	ton	2.97	3.91	0.94	31.5%
breast lines aft	ton	10.88	8.64	-2.24	-20.6%
stern lines	ton	8.71	6.39	-2.31	-26.6%

Maximum forces per 3 hours

parameter	unit	measurements	simulation	difference	
head lines	ton	11.02	9.89	-1.13	-10.2%
breast lines forward	ton	10.88	11.08	0.21	1.9%
spring lines forward	ton	2.64	3.52	0.87	33.1%
spring lines aft	ton	4.77	5.57	0.80	16.8%
breast lines aft	ton	17.25	12.23	-5.02	-29.1%
stern lines	ton	13.21	8.93	-4.27	-32.4%

Comparison of maximum forces

No.:	4b-3	wave spectrum:	4b
date:	22-07-96	sign. wave height swell:	0.27 m.
jetty:	LNG jetty Whitnell Bay	wave direction:	197 deg
ship:	Northwest	wind speed:	-

Maximum forces per 10 minutes

parameter	unit	measurements	simulation	difference	
head lines	ton	7.47	6.39	-1.07	-14.4%
breast lines forward	ton	7.56	6.71	-0.85	-11.3%
spring lines forward	ton	1.89	1.79	-0.10	-5.3%
spring lines aft	ton	2.97	3.12	0.15	5.1%
breast lines aft	ton	10.88	7.03	-3.84	-35.3%
stern lines	ton	8.71	5.75	-2.95	-33.9%

Maximum forces per 3 hours

parameter	unit	measurements	simulation	difference	
head lines	ton	11.02	8.39	-2.63	-23.9%
breast lines forward	ton	10.88	8.91	-1.96	-18.1%
spring lines forward	ton	2.64	2.47	-0.17	-6.4%
spring lines aft	ton	4.77	4.42	-0.36	-7.5%
breast lines aft	ton	17.25	9.81	-7.44	-43.1%
stern lines	ton	13.21	7.85	-5.36	-40.6%

Comparison of maximum forces

No.:	4b-4	wave spectrum:	4b
date:	22-07-96	sign. wave height swell:	0.27 m.
jetty:	LNG jetty Withnell Bay	wave direction:	184 & 194 deg
ship:	Northwest	wind speed:	-

Maximum forces per 10 minutes

parameter	unit	measurements	simulation	difference	
head lines	ton	7.47	4.55	-2.92	-39.1%
breast lines forward	ton	7.56	4.77	-2.79	-36.9%
spring lines forward	ton	1.89	1.62	-0.27	-14.3%
spring lines aft	ton	2.97	2.04	-0.93	-31.3%
breast lines aft	ton	10.88	4.61	-6.27	-57.6%
stern lines	ton	8.71	3.96	-4.75	-54.5%

Maximum forces per 3 hours

parameter	unit	measurements	simulation	difference	
head lines	ton	11.02	6.32	-4.70	-42.7%
breast lines forward	ton	10.88	6.70	-4.18	-38.4%
spring lines forward	ton	2.64	2.97	0.33	12.6%
spring lines aft	ton	4.77	3.42	-1.36	-28.4%
breast lines aft	ton	17.25	6.28	-10.97	-63.6%
stern lines	ton	13.21	5.31	-7.89	-59.8%

Comparison of maximum forces

No.:	4b-5	wave spectrum:	4b
date:	22-07-96	sign. wave height swell:	0.27 m.
jetty:	LNG jetty Withnell Bay	wave direction:	179 & 199 deg
ship:	Northwest	wind speed:	-

Maximum forces per 10 minutes

parameter	unit	measurements	simulation	difference	
head lines	ton	7.47	5.98	-1.48	-19.8%
breast lines forward	ton	7.56	6.49	-1.07	-14.2%
spring lines forward	ton	1.89	2.13	0.24	12.9%
spring lines aft	ton	2.97	2.84	-0.13	-4.5%
breast lines aft	ton	10.88	6.68	-4.20	-38.6%
stern lines	ton	8.71	5.88	-2.82	-32.4%

Maximum forces per 3 hours

parameter	unit	measurements	simulation	difference	
head lines	ton	11.02	7.97	-3.04	-27.6%
breast lines forward	ton	10.88	8.77	-2.11	-19.4%
spring lines forward	ton	2.64	3.38	0.74	28.1%
spring lines aft	ton	4.77	4.10	-0.68	-14.2%
breast lines aft	ton	17.25	9.06	-8.19	-47.5%
stern lines	ton	13.21	7.85	-5.36	-40.6%

Comparison of maximum forces

No.:	4b-6	wave spectrum:	4b
date:	22-07-96	sign. wave height swell:	0.27 m.
jetty:	LNG jetty Withnell Bay	wave direction:	161 & 205 deg
ship:	Northwest	wind speed:	-

Maximum forces per 10 minutes

parameter	unit	measurements	simulation	difference	
head lines	ton	7.47	8.62	1.15	15.4%
breast lines forward	ton	7.56	9.25	1.69	22.3%
spring lines forward	ton	1.89	2.60	0.71	37.8%
spring lines aft	ton	2.97	3.62	0.65	21.7%
breast lines aft	ton	10.88	10.12	-0.75	-6.9%
stern lines	ton	8.71	8.21	-0.50	-5.7%

Maximum forces per 3 hours

parameter	unit	measurements	simulation	difference	
head lines	ton	11.02	10.54	-0.47	-4.3%
breast lines forward	ton	10.88	11.52	0.65	6.0%
spring lines forward	ton	2.64	4.22	1.57	59.5%
spring lines aft	ton	4.77	4.75	-0.02	-0.5%
breast lines aft	ton	17.25	12.93	-4.32	-25.1%
stern lines	ton	13.21	10.45	-2.76	-20.9%

Comparison of maximum forces

No.:	4b-7	wave spectrum:	4b
date:	22-07-96	sign. wave height swell:	0.27 m.
jetty:	LNG jetty Withnell Bay	wave direction:	169 & 209 deg
ship:	Northwest	wind speed:	-

Maximum forces per 10 minutes

parameter	unit	measurements	simulation	difference	
head lines	ton	7.47	9.93	2.46	32.9%
breast lines forward	ton	7.56	10.84	3.28	43.4%
spring lines forward	ton	1.89	3.78	1.89	99.8%
spring lines aft	ton	2.97	4.79	1.82	61.1%
breast lines aft	ton	10.88	13.30	2.42	22.3%
stern lines	ton	8.71	11.45	2.74	31.4%

Maximum forces per 3 hours

parameter	unit	measurements	simulation	difference	
head lines	ton	11.02	12.84	1.83	16.6%
breast lines forward	ton	10.88	14.11	3.23	29.7%
spring lines forward	ton	2.64	6.13	3.49	132.0%
spring lines aft	ton	4.77	6.60	1.82	38.2%
breast lines aft	ton	17.25	17.86	0.61	3.5%
stern lines	ton	13.21	15.47	2.27	17.2%

Comparison of maximum forces

No.:	4b-8	wave spectrum:	4b
date:	22-07-96	sign. wave height swell:	0.24 m.
jetty:	LNG jetty Withnell Bay	wave direction:	198 deg
ship:	Northwest	wind speed:	-

Maximum forces per 10 minutes

parameter	unit	measurements	simulation	difference	
head lines	ton	7.47	6.95	-0.52	-6.9%
breast lines forward	ton	7.56	7.50	-0.06	-0.8%
spring lines forward	ton	1.89	2.47	0.58	30.9%
spring lines aft	ton	2.97	3.52	0.55	18.5%
breast lines aft	ton	10.88	8.24	-2.64	-24.2%
stern lines	ton	8.71	6.64	-2.07	-23.8%

Maximum forces per 3 hours

parameter	unit	measurements	simulation	difference	
head lines	ton	11.02	10.06	-0.96	-8.7%
breast lines forward	ton	10.88	10.90	0.02	0.2%
spring lines forward	ton	2.64	3.85	1.20	45.5%
spring lines aft	ton	4.77	5.48	0.71	14.8%
breast lines aft	ton	17.25	11.86	-5.39	-31.3%
stern lines	ton	13.21	9.39	-3.81	-28.9%

Comparison of maximum forces

No.:	4c-1	wave spectrum:	5
date:	28-07-96	sign. wave height total:	0.24 m.
jetty:	LNG jetty Withnell Bay	wave direction:	188 deg
ship:	Northwest	wind speed:	2 m/s

Maximum forces per 10 minutes

parameter	unit	measurements	simulation	difference	
head lines	ton	5.38	3.67	-1.71	-31.8%
breast lines forward	ton	6.22	4.29	-1.93	-31.0%
spring lines forward	ton	2.62	2.37	-0.24	-9.3%
spring lines aft	ton	2.55	2.52	-0.02	-1.0%
breast lines aft	ton	7.44	4.40	-3.04	-40.9%
stern lines	ton	4.65	3.00	-1.65	-35.5%

Maximum forces per 3 hours

parameter	unit	measurements	simulation	difference	
head lines	ton	6.93	5.12	-1.82	-26.2%
breast lines forward	ton	8.37	5.89	-2.48	-29.6%
spring lines forward	ton	4.87	3.22	-1.65	-33.9%
spring lines aft	ton	3.60	3.58	-0.02	-0.6%
breast lines aft	ton	9.47	6.15	-3.32	-35.1%
stern lines	ton	6.65	4.09	-2.56	-38.5%

Comparison of maximum forces

No.:	4c-2	wave spectrum:	5
date:	28-07-96	sign. wave height total:	0.24 m.
jetty:	LNG jetty Withnell Bay	wave direction:	178 & 198 deg
ship:	Northwest	wind speed:	2 m/s

Maximum forces per 10 minutes

parameter	unit	measurements	simulation	difference	
head lines	ton	5.38	6.35	0.96	17.9%
breast lines forward	ton	6.22	7.34	1.12	18.1%
spring lines forward	ton	2.62	3.42	0.81	30.9%
spring lines aft	ton	2.55	3.58	1.04	40.8%
breast lines aft	ton	7.44	8.41	0.97	13.1%
stern lines	ton	4.65	5.91	1.26	27.1%

Maximum forces per 3 hours

parameter	unit	measurements	simulation	difference	
head lines	ton	6.93	8.77	1.84	26.5%
breast lines forward	ton	8.37	10.14	1.77	21.1%
spring lines forward	ton	4.87	5.67	0.80	16.3%
spring lines aft	ton	3.60	4.71	1.11	30.7%
breast lines aft	ton	9.47	12.01	2.54	26.9%
stern lines	ton	6.65	8.53	1.88	28.2%

Comparison of maximum forces

No.:	4c-3	wave spectrum:	5
date:	28-07-96	sign. wave height total:	0.24 m.
jetty:	LNG jetty Withnell Bay	wave direction:	188 deg
ship:	Northwest	wind speed:	2 m/s

Maximum forces per 10 minutes

parameter	unit	measurements	simulation	difference	
head lines	ton	5.38	2.96	-2.42	-45.0%
breast lines forward	ton	6.22	3.44	-2.78	-44.7%
spring lines forward	ton	2.62	2.23	-0.39	-15.0%
spring lines aft	ton	2.55	2.20	-0.34	-13.5%
breast lines aft	ton	7.44	3.80	-3.64	-48.9%
stern lines	ton	4.65	2.84	-1.81	-39.0%

Maximum forces per 3 hours

parameter	unit	measurements	simulation	difference	
head lines	ton	6.93	4.28	-2.66	-38.3%
breast lines forward	ton	8.37	4.77	-3.60	-43.0%
spring lines forward	ton	4.87	3.32	-1.55	-31.8%
spring lines aft	ton	3.60	3.21	-0.39	-10.9%
breast lines aft	ton	9.47	5.01	-4.46	-47.1%
stern lines	ton	6.65	3.80	-2.85	-42.8%

Comparison of maximum forces

No.:	4c-4	wave spectrum:	5
date:	28-07-96	sign. wave height total:	0.24 m.
jetty:	LNG jetty Withnell Bay	wave direction:	188 deg
ship:	Northwest	wind speed:	2 m/s

Maximum forces per 10 minutes

parameter	unit	measurements	simulation	difference	
head lines	ton	5.38	3.32	-2.07	-38.4%
breast lines forward	ton	6.22	3.88	-2.34	-37.7%
spring lines forward	ton	2.62	2.59	-0.02	-0.9%
spring lines aft	ton	2.55	2.89	0.34	13.4%
breast lines aft	ton	7.44	4.20	-3.24	-43.5%
stern lines	ton	4.65	3.06	-1.59	-34.2%

Maximum forces per 3 hours

parameter	unit	measurements	simulation	difference	
head lines	ton	6.93	4.44	-2.49	-36.0%
breast lines forward	ton	8.37	5.17	-3.21	-38.3%
spring lines forward	ton	4.87	3.53	-1.34	-27.5%
spring lines aft	ton	3.60	4.44	0.84	23.2%
breast lines aft	ton	9.47	5.41	-4.06	-42.8%
stern lines	ton	6.65	3.97	-2.68	-40.4%

Comparison of maximum forces

No.:	4c-5	wave spectrum:	5
date:	28-07-96	sign. wave height total:	0.24 m.
jetty:	LNG jetty Withnell Bay	wave direction:	182 & 194 deg
ship:	Northwest	wind speed:	2 m/s

Maximum forces per 10 minutes

parameter	unit	measurements	simulation	difference	
head lines	ton	5.38	6.27	0.89	16.5%
breast lines forward	ton	6.22	7.00	0.78	12.5%
spring lines forward	ton	2.62	2.91	0.29	11.1%
spring lines aft	ton	2.55	4.41	1.86	73.1%
breast lines aft	ton	7.44	8.06	0.62	8.4%
stern lines	ton	4.65	5.35	0.70	15.1%

Maximum forces per 3 hours

parameter	unit	measurements	simulation	difference	
head lines	ton	6.93	9.01	2.07	29.9%
breast lines forward	ton	8.37	10.05	1.68	20.1%
spring lines forward	ton	4.87	4.06	-0.81	-16.7%
spring lines aft	ton	3.60	6.63	3.03	84.0%
breast lines aft	ton	9.47	10.98	1.51	16.0%
stern lines	ton	6.65	7.25	0.60	9.0%

Comparison of maximum forces

No.:	4c-6	wave spectrum:	5
date:	28-07-96	sign. wave height total:	0.22 m.
jetty:	LNG jetty Withnell Bay	wave direction:	198 deg
ship:	Northwest	wind speed:	2 m/s

Maximum forces per 10 minutes

parameter	unit	measurements	simulation	difference	
head lines	ton	5.38	8.73	3.35	62.2%
breast lines forward	ton	6.22	10.15	3.93	63.2%
spring lines forward	ton	2.62	3.93	1.31	50.2%
spring lines aft	ton	2.55	4.57	2.03	79.6%
breast lines aft	ton	7.44	10.95	3.51	47.2%
stern lines	ton	4.65	7.56	2.91	62.6%

Maximum forces per 3 hours

parameter	unit	measurements	simulation	difference	
head lines	ton	6.93	13.47	6.54	94.3%
breast lines forward	ton	8.37	15.68	7.31	87.3%
spring lines forward	ton	4.87	5.84	0.96	19.7%
spring lines aft	ton	3.60	7.01	3.41	94.6%
breast lines aft	ton	9.47	16.97	7.50	79.2%
stern lines	ton	6.65	11.46	4.81	72.4%

Comparison of maximum forces

No.:	4c-7	wave spectrum:	5
date:	28-07-96	sign. wave height total:	0.22 m.
jetty:	LNG jetty Withnell Bay	wave direction:	198 deg
ship:	Northwest	wind speed:	2 m/s

Maximum forces per 10 minutes

parameter	unit	measurements	simulation	difference	
head lines	ton	5.38	8.01	2.63	48.8%
breast lines forward	ton	6.22	8.96	2.74	44.0%
spring lines forward	ton	2.62	3.28	0.66	25.2%
spring lines aft	ton	2.55	5.58	3.03	119.0%
breast lines aft	ton	7.44	10.31	2.87	38.6%
stern lines	ton	4.65	6.73	2.08	44.8%

Maximum forces per 3 hours

parameter	unit	measurements	simulation	difference	
head lines	ton	6.93	11.69	4.76	68.6%
breast lines forward	ton	8.37	13.00	4.63	55.3%
spring lines forward	ton	4.87	4.22	-0.66	-13.5%
spring lines aft	ton	3.60	9.28	5.68	157.8%
breast lines aft	ton	9.47	15.41	5.94	62.7%
stern lines	ton	6.65	9.58	2.93	44.1%

Comparison of maximum forces

No.:	4d-1	wave spectrum:	6a
date:	2-08-96	sign. wave height swell:	0.31 m.
jetty:	LNG jetty Withnell Bay	wave direction:	192 deg
ship:	Northwest	wind speed:	5.6 m/s

Maximum forces per 10 minutes

parameter	unit	measurements	simulation	difference	
head lines	ton	9.15	8.63	-0.51	-5.6%
breast lines forward	ton	10.71	10.00	-0.71	-6.6%
spring lines forward	ton	6.85	4.68	-2.16	-31.6%
spring lines aft	ton	6.37	6.99	0.62	9.7%
breast lines aft	ton	14.91	11.94	-2.97	-19.9%
stern lines	ton	10.68	7.93	-2.74	-25.7%

Maximum forces per 3 hours

parameter	unit	measurements	simulation	difference	
head lines	ton	12.36	11.86	-0.51	-4.1%
breast lines forward	ton	14.20	14.12	-0.08	-0.6%
spring lines forward	ton	11.49	6.69	-4.81	-41.8%
spring lines aft	ton	9.92	11.63	1.71	17.2%
breast lines aft	ton	21.53	16.01	-5.52	-25.7%
stern lines	ton	14.95	10.17	-4.78	-32.0%

Comparison of maximum forces

No.:	4d-2	wave spectrum:	6a
date:	2-08-96	sign. wave height swell:	0.31 m.
jetty:	LNG jetty Withnell Bay	wave direction:	187 & 197 deg
ship:	Northwest	wind speed:	5.6 m/s

Maximum forces per 10 minutes

parameter	unit	measurements	simulation	difference	
head lines	ton	9.15	12.74	3.59	39.3%
breast lines forward	ton	10.71	14.63	3.92	36.6%
spring lines forward	ton	6.85	5.36	-1.49	-21.7%
spring lines aft	ton	6.37	8.55	2.19	34.3%
breast lines aft	ton	14.91	17.81	2.89	19.4%
stern lines	ton	10.68	12.52	1.85	17.3%

Maximum forces per 3 hours

parameter	unit	measurements	simulation	difference	
head lines	ton	12.36	19.52	7.15	57.9%
breast lines forward	ton	14.20	22.91	8.71	61.4%
spring lines forward	ton	11.49	8.01	-3.49	-30.3%
spring lines aft	ton	9.92	13.01	3.09	31.1%
breast lines aft	ton	21.53	26.58	5.05	23.5%
stern lines	ton	14.95	18.76	3.81	25.5%

Comparison of maximum forces

No.:	4d-3	wave spectrum:	6a
date:	2-08-96	sign. wave height swell:	0.31 m.
jetty:	LNG jetty Withnell Bay	wvae direction:	181 & 203 deg
ship:	Northwest	wind speed:	5.6 m/s

Maximum forces per 10 minutes

parameter	unit	measurements	simulation	difference	
head lines	ton	9.15	8.95	-0.20	-2.2%
breast lines forward	ton	10.71	10.34	-0.36	-3.4%
spring lines forward	ton	6.85	3.85	-3.00	-43.8%
spring lines aft	ton	6.37	6.46	0.10	1.5%
breast lines aft	ton	14.91	12.43	-2.48	-16.6%
stern lines	ton	10.68	8.44	-2.24	-21.0%

Maximum forces per 3 hours

parameter	unit	measurements	simulation	difference	
head lines	ton	12.36	12.50	0.14	1.1%
breast lines forward	ton	14.20	14.59	0.39	2.7%
spring lines forward	ton	11.49	5.59	-5.90	-51.3%
spring lines aft	ton	9.92	9.19	-0.73	-7.4%
breast lines aft	ton	21.53	16.55	-4.99	-23.2%
stern lines	ton	14.95	11.50	-3.44	-23.0%

Comparison of maximum forces

No.:	4d-4	wave spectrum:	7a-2
date:	2-08-96	sign. wave height swell:	0.29 m.
jetty:	LNG jetty Withnell Bay	wave direction:	198 deg
ship:	Northwest	wind speed:	5.6 m/s

Maximum forces per 10 minutes

parameter	unit	measurements	simulation	difference	
head lines	ton	9.15	11.03	1.88	20.6%
breast lines forward	ton	10.71	12.42	1.71	16.0%
spring lines forward	ton	6.85	4.40	-2.44	-35.7%
spring lines aft	ton	6.37	7.88	1.51	23.7%
breast lines aft	ton	14.91	14.41	-0.50	-3.3%
stern lines	ton	10.68	9.84	-0.84	-7.9%

Maximum forces per 3 hours

parameter	unit	measurements	simulation	difference	
head lines	ton	12.36	16.37	4.01	32.4%
breast lines forward	ton	14.20	18.45	4.26	30.0%
spring lines forward	ton	11.49	5.88	-5.62	-48.9%
spring lines aft	ton	9.92	12.81	2.89	29.1%
breast lines aft	ton	21.53	21.88	0.35	1.6%
stern lines	ton	14.95	14.52	-0.43	-2.9%

Comparison of maximum forces

No.:	4d-5	wave spectrum:	6a
date:	2-08-96	sign. wave height swell:	0.29 m.
jetty:	LNG jetty Withnell Bay	wave direction:	198 deg
ship:	Northwest	wind speed:	5.6 m/s

Maximum forces per 10 minutes

parameter	unit	measurements	simulation	difference	
head lines	ton	9.15	11.79	2.64	28.9%
breast lines forward	ton	10.71	13.60	2.89	27.0%
spring lines forward	ton	6.85	4.73	-2.12	-30.9%
spring lines aft	ton	6.37	6.41	0.04	0.6%
breast lines aft	ton	14.91	14.00	-0.91	-6.1%
stern lines	ton	10.68	10.11	-0.57	-5.3%

Maximum forces per 3 hours

parameter	unit	measurements	simulation	difference	
head lines	ton	12.36	17.53	5.16	41.8%
breast lines forward	ton	14.20	20.54	6.34	44.7%
spring lines forward	ton	11.49	6.67	-4.82	-41.9%
spring lines aft	ton	9.92	9.81	-0.11	-1.1%
breast lines aft	ton	21.53	21.74	0.21	1.0%
stern lines	ton	14.95	15.90	0.95	6.4%

Comparison of maximum forces

No.:	4e-1	wave spectrum:	6b
date:	2-08-96	sign. wave height swell:	0.31 m.
jetty:	LNG jetty Withnell Bay	wave direction:	172 & 198 deg
ship:	Northwest	wind speed:	7.4 m/s

Maximum forces per 10 minutes

parameter	unit	measurements	simulation	difference	
head lines	ton	13.81	9.95	-3.85	-27.9%
breast lines forward	ton	14.75	11.35	-3.40	-23.0%
spring lines forward	ton	6.83	4.45	-2.38	-34.8%
spring lines aft	ton	6.86	5.14	-1.72	-25.1%
breast lines aft	ton	18.97	13.67	-5.30	-27.9%
stern lines	ton	11.27	9.99	-1.28	-11.4%

Maximum forces per 3 hours

parameter	unit	measurements	simulation	difference	
head lines	ton	17.69	13.86	-3.83	-21.7%
breast lines forward	ton	19.05	16.10	-2.95	-15.5%
spring lines forward	ton	9.79	6.82	-2.97	-30.4%
spring lines aft	ton	8.54	7.79	-0.74	-8.7%
breast lines aft	ton	23.16	19.50	-3.66	-15.8%
stern lines	ton	13.47	14.43	0.96	7.1%

Comparison of maximum forces

No.:	4e-2	wave spectrum:	6b
date:	2-08-96	sign. wave height swell:	0.28 m.
jetty:	LNG jetty Withnell Bay	wave direction:	198 deg
ship:	Northwest	wind speed:	7.4 m/s

Maximum forces per 10 minutes

parameter	unit	measurements	simulation	difference	
head lines	ton	13.81	10.51	-3.29	-23.9%
breast lines forward	ton	14.75	11.87	-2.88	-19.5%
spring lines forward	ton	6.83	4.60	-2.23	-32.6%
spring lines aft	ton	6.86	6.26	-0.60	-8.7%
breast lines aft	ton	18.95	14.52	-4.42	-23.3%
stern lines	ton	11.27	9.84	-1.43	-12.7%

Maximum forces per 3 hours

parameter	unit	measurements	simulation	difference	
head lines	ton	17.69	15.12	-2.58	-14.6%
breast lines forward	ton	19.05	17.03	-2.02	-10.6%
spring lines forward	ton	9.79	6.26	-3.53	-36.1%
spring lines aft	ton	8.54	9.91	1.37	16.0%
breast lines aft	ton	23.16	20.92	-2.24	-9.7%
stern lines	ton	13.47	14.01	0.53	4.0%

Comparison of maximum forces

No.:	4f-1	wave spectrum:	7
date:	19-07-96	sign. wave height swell:	0.30 m.
jetty:	LNG jetty Withnell Bay	wave direction:	177 & 201 deg
ship:	Northwest	wind speed:	4 m/s

Maximum forces per 10 minutes

parameter	unit	measurements	simulation	difference	
head lines	ton	8.81	8.06	-0.74	-8.4%
breast lines forward	ton	10.81	9.05	-1.76	-16.3%
spring lines forward	ton	4.30	2.98	-1.33	-30.8%
spring lines aft	ton	3.74	3.66	-0.09	-2.3%
breast lines aft	ton	11.50	9.77	-1.72	-15.0%
stern lines	ton	8.35	7.37	-0.99	-11.8%

Maximum forces per 3 hours

parameter	unit	measurements	simulation	difference	
head lines	ton	12.39	11.12	-1.26	-10.2%
breast lines forward	ton	14.90	12.49	-2.41	-16.2%
spring lines forward	ton	6.88	4.28	-2.61	-37.9%
spring lines aft	ton	5.90	5.22	-0.68	-11.5%
breast lines aft	ton	15.07	13.69	-1.38	-9.2%
stern lines	ton	10.96	10.33	-0.63	-5.8%

Comparison of maximum forces

No.:	4f-2	wave spectrum:	7
date:	19-07-96	sign. wave height swell:	0.27 m.
jetty:	LNG jetty Withnell Bay	wave direction:	198 deg
ship:	Northwest	wind speed:	4 m/s

Maximum forces per 10 minutes

parameter	unit	measurements	simulation	difference	
head lines	ton	8.81	8.35	-0.46	-5.2%
breast lines forward	ton	10.81	9.41	-1.40	-12.9%
spring lines forward	ton	4.30	3.36	-0.94	-21.9%
spring lines aft	ton	3.74	4.28	0.53	14.2%
breast lines aft	ton	11.50	10.26	-1.23	-10.7%
stern lines	ton	8.35	7.45	-0.91	-10.9%

Maximum forces per 3 hours

parameter	unit	measurements	simulation	difference	
head lines	ton	12.39	11.75	-0.63	-5.1%
breast lines forward	ton	14.90	13.47	-1.43	-9.6%
spring lines forward	ton	6.88	4.70	-2.18	-31.7%
spring lines aft	ton	5.90	6.78	0.88	14.9%
breast lines aft	ton	15.07	14.72	-0.35	-2.3%
stern lines	ton	10.96	10.43	-0.53	-4.8%