Side by Side Tanker Mooring Analysis

Offshore Mexico

Prepared for

XXX Exploration

by

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Contents

I. Introduction

This report contains the results of an analysis of a storage tanker with different sizes of export tankers moored along the side. The primary objectives of this analysis are:

- Find the envelope of relative motion at the end of the loading arm connected to the export tanker,
- Find the absolute acceleration at the end of the loading arm connected to the storage tanker, and
- Find the maximum relative acceleration at the two ends of the loading arm.

This is a preliminary study and thus the emphasis was on breadth rather than detail. Strip theory was used rather than three dimensional diffraction so that more cases could be considered. Pretensions and the connection line arrangement were estimated.

II. Analysis Procedure

In essence, this analysis consisted of taking various export tankers, fixing the drafts of the two vessels, connecting them together, and investigating the behavior when the system is subjected to a set of environments. In particular, for each condition, an equilibrium configuration was found when the system was subjected to the mean force of the environment. Then, a frequency response technique was used to approximate the dynamics of the system about the mean position. The frequency response technique considers: direct wave excitation forces, second order wave forces, and the variation of wind gusts. It is important to notice that the effect of the connection was included in the motions of the tankers, and that there is some consideration of slowly varying drift forces.

The basic results for each tanker pair, draft and environmental set are a mean position and a set of maximum deviations about this mean. In essence, our procedure yields 1 sets of results, one for each pair of tankers and each set of drafts. Within each large set, there are 10 small sets. The small sets are each applicable to a given set of environments.

III. Position and Connections

For each pair of tankers and each draft combination, the analysis was initiated by positioning the storage tanker at the desired draft and aligning it with the wind and current. The export tanker was then place by the side of the storage tanker at its corresponding draft so that the two amidship points were at the same longitudinal location, and at the transverse position where the fender was touching the two tankers, but had no load.

Mooring lines were then connected to the turret of the storage tanker. There were 10 mooring lines composed of 150 meters of 125 mm diameter chain, 175 meters of 152 mm diameter chain, and 1250 meters of 130 mm diameter wire. The anchor location of these lines were computed so that each of the lines had a pretension of 75 tonnes. No further action was taken with these lines.

The two tankers were connected by lines and fenders. We considered two types of connection lines: tweleve mooring lines composed of 100 meters of 75 mm diameter polypropolene, and four spring lines made of 100 meters of 40 mm diameter wire and 10 meters of 75 mm diameter polypropolene. One should take the lengths specified here as nominal ones, since once the lines were connected the lengths were changed to achieve a pretension of 20 tonnes in the mooring lines and 1 tonne in the spring lines. This procedure results in the spring lines having a fixed length of polypropolene and a variable amount of wire.

It was assumed that there were 7 fenders of 3.3 meter diameter and 10 meter length. The stiffness of the fenders was estimated from the vendor data. The fenders were placed at the sea surface, arranged symmetrically about amidship and pretensioned to 1 tonne.

A picture showing the relative position of the tankers and the lines is included in the Appendix for each tanker pair. The location of the attachments of the connecting lines varies with the tankers being considered. In general, the arrangement was chosen so that it "looks reasonable". In particular, the arrangement is quite satisfactory for the smaller tankers, but for big export tankers, one could probably design a better scheme for any given condition.

The maximum tension in the lines and fenders is computed for each set of data. This maximum is deduced by computing the RMS of frequency response of the line and multiplying this by 3.72. Thus, what we are calling a maximum is actually the average of the 1/1000 highest peaks of the tension. The maxima reported include both the dynamic effects of vessel motion and the statics of the wind and current, but not any true structural dynamics of the lines themselves. Plots are attached in the appendix which show the maxima of the turrent mooring line loads, the maximum connection mooring line loads, and the maximum fender loads vs heading. There is one plot for each pair of tankers and each draft set.

IV. Results

Results will be presented for 1 drafts condition of each of the two vessels. For each case, there will be four plots:

1.) Loading Arm Relative Motions,
2.) Bow and Stern Relative Motions,
3.) Mooring, Spring, and Fender loads, and
4.) Loading Arm Accelerations.

For all of these plots, results are plotted vs "environmental case". The cases are defined in an appendix. The dimensions here are degrees, meters and seconds except that the wind speed is in knots. Also, the heading here is the direction from which the environment comes. The wind gusts effect the low frequency behavior of the tankers and were assumed to be described by the API wind gust spectrum. A JONSWAP sea spectrum was used for all cases.

With plot 1, the results plotted are:

- the storage tanker yaw angle,
- the wind, current, and wave headings relative to the storage tanker, and
- the loading arm relative motion.

The second plot is of the bow and stern relative motions, the third the maximum force in the mooring lines, spring lines, and fenders, and the last one is the acceleration and relative acceleration of the loading arm.

After these figures, a table of maxima over the cases is presented.

IV.A Storage = st:350 Export = ex:80

The results in this section were obtained with a storage tanker:

st:350 Particulars

Vessel length =	348.110 Meters
Vessel beam =	63.625 Meters
Vessel depth =	27.915 Meters

and an export tanker:

ex:80 Particulars

Vessel length =	242.000 Meters
Vessel beam =	42.000 Meters
Vessel depth =	18.700 Meters

Figure 1 shows the nominal position of the two vessels when connected.

Results will be presented for relative drafts of:

Relative Drafts

Storage	Export
0.	1.0

Here, relative drafts are the fraction of the maximum draft above the minimum draft; i.e. a value of 1 is the maximum draft, a value of zero is the minimum draft, and .5 is halfway in between. For each case, there will be the four plots discussed above for each draft set. After these figures, a table of maxima over the cases is presented.

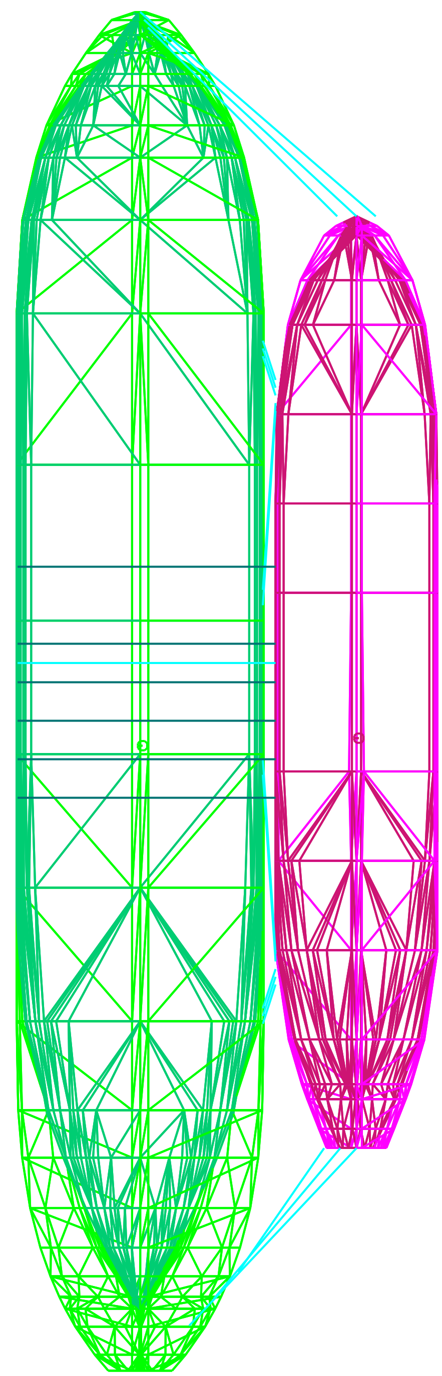
Side By Side - Storage = st:350 Export = ex:80
Storage Tanker Draft = 9.458, Export Tanker Draft = 14.586

FIGURE 1

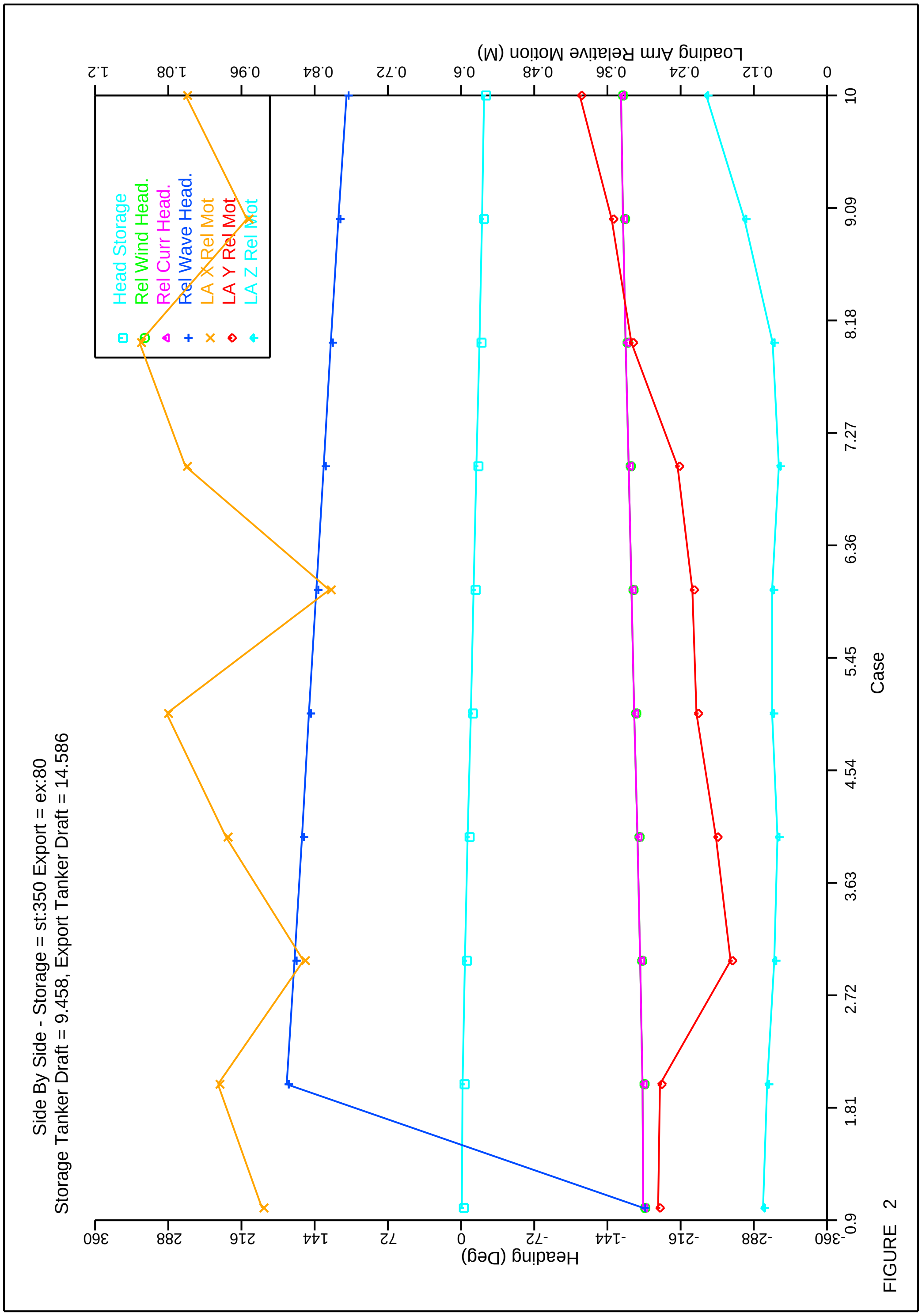
Side By Side - Storage = st:350 Export = ex:80
Storage Tanker Draft = 9.458, Export Tanker Draft = 14.586
Heading (Deg)
Loading Arm Relative Motion (M)
Case
Head Storage
Rel Wind Head.
Rel Curr Head.
Rel Wave Head.
LA X Rel Mot
LA Y Rel Mot
LA Z Rel Mot

FIGURE 2

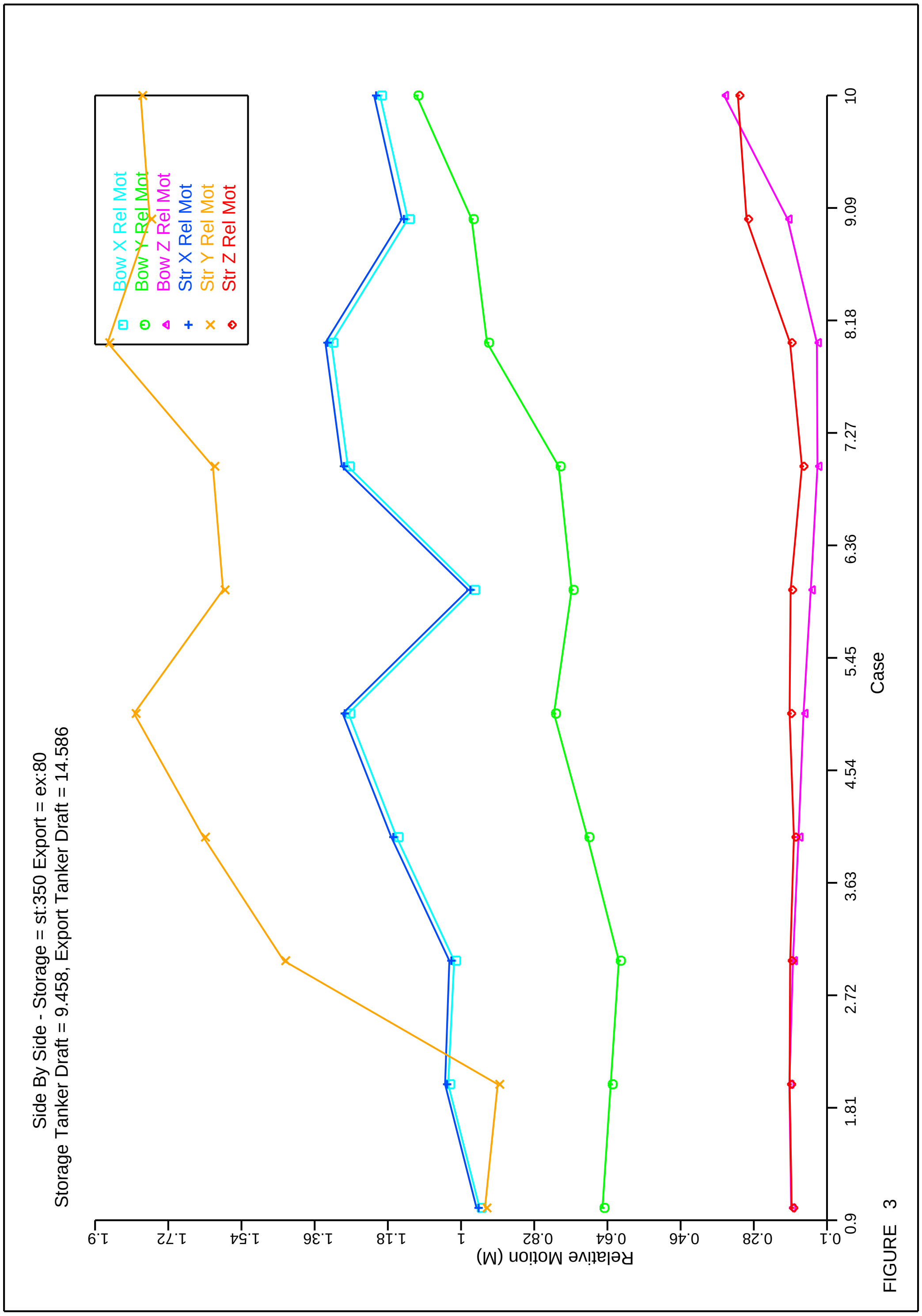
Side By Side - Storage = st:350 Export = ex:80
Storage Tanker Draft = 9.458, Export Tanker Draft = 14.586
Bow X Rel Mot
Bow Y Rel Mot
Bow Z Rel Mot
Str X Rel Mot
Str Y Rel Mot
Str Z Rel Mot
Relative Motion (M)
0.1
0.28
0.46
0.64
0.82
1
1.18
1.36
1.54
1.72
1.9
Case
0.9
1.81
2.72
3.63
4.54
5.45
6.36
7.27
8.18
9.09
10

FIGURE 3

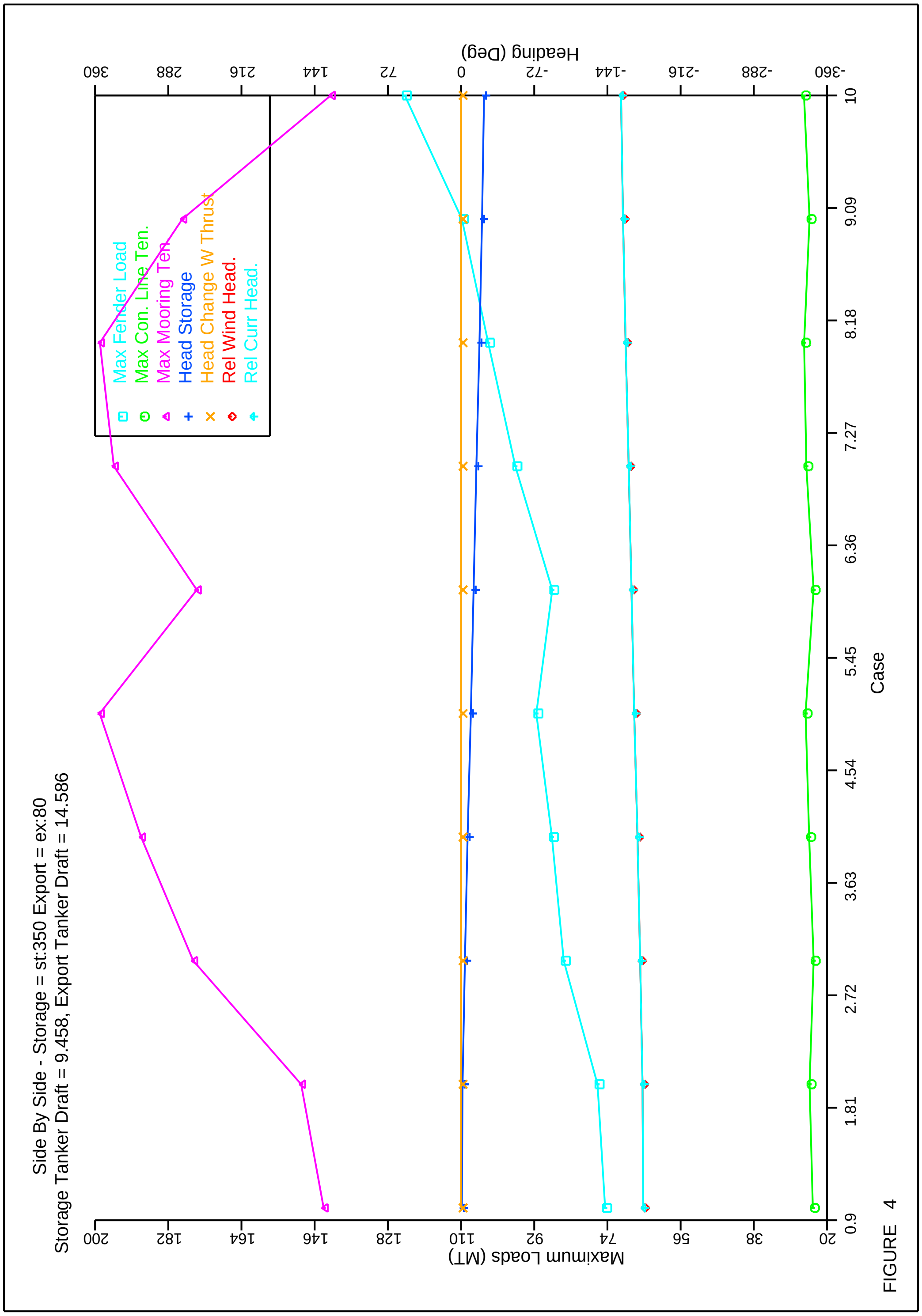
Side By Side - Storage = st:350 Export = ex:80
Storage Tanker Draft = 9.458, Export Tanker Draft = 14.586
Maximum Loads (MT)
Heading (Deg)
Case
Max Fender Load
Max Con. Line Ten.
Max Mooring Ten.
Head Storage
Head Change W Thrust
Rel Wind Head.
Rel Curr Head.

FIGURE 4

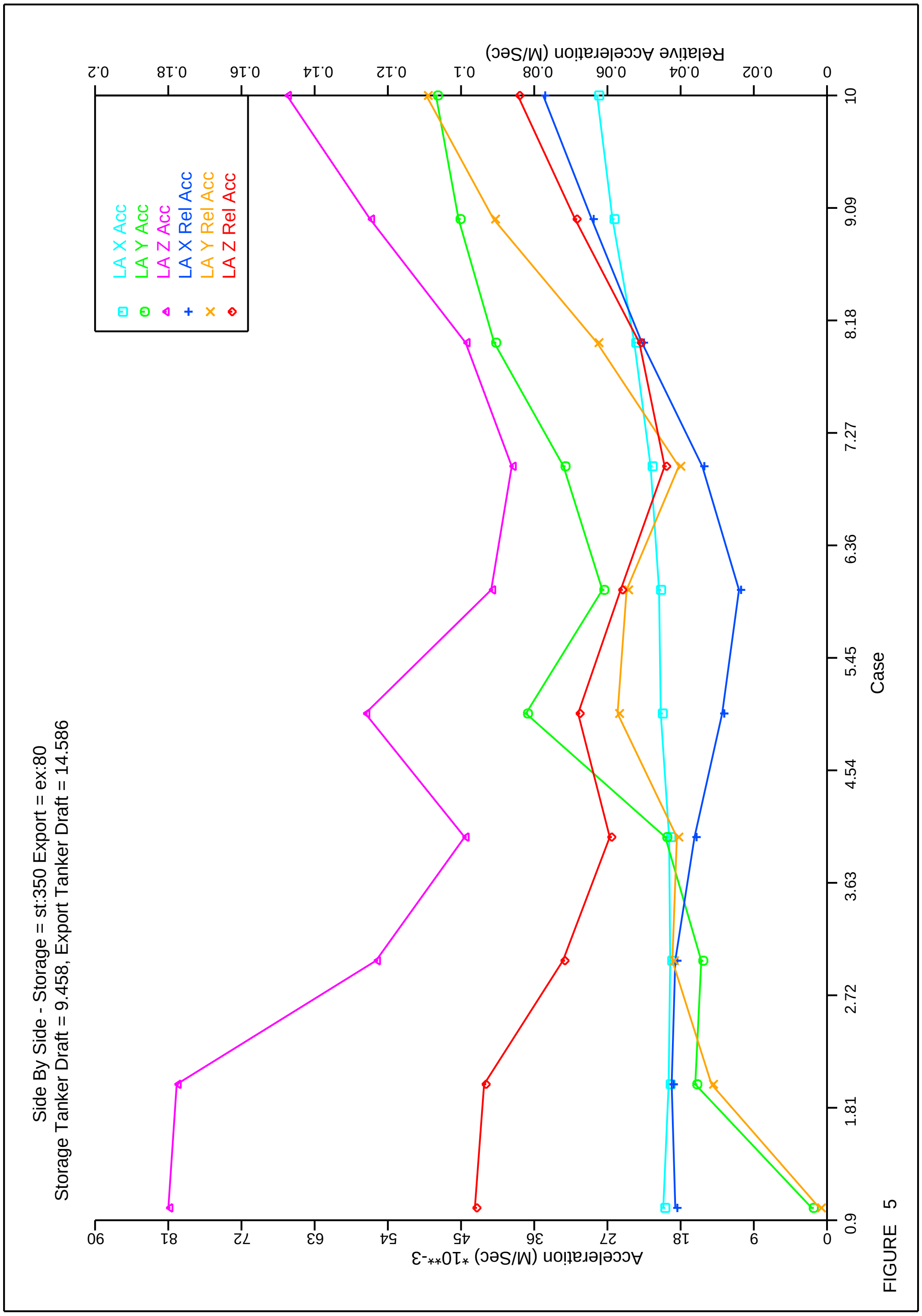
Side By Side - Storage = st:350 Export = ex:80
Storage Tanker Draft = 9.458, Export Tanker Draft = 14.586
LA X Acc
LA Y Acc
LA Z Acc
LA X Rel Acc
LA Y Rel Acc
LA Z Rel Acc
Acceleration (M/Sec) *10**-3
Relative Acceleration (M/Sec)
Case
0.9
1.81
2.72
3.63
4.54
5.45
6.36
7.27
8.18
9.09
10
0
9
18
27
36
45
54
63
72
81
90
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2

FIGURE 5

V. Maxima For all Tanker Cases

The results reported here are the maxima for all cases condisered.

The maximum of the mooring line, connection line, and fender loads are, in tonnes,

Maximum Connecting Line Load	=	25.66
Maximum Fender Load	=	123.83
Maximum Mooring Line Load	=	198.87

As mentioned in the beginning one of the primary objectives of this study was to obtain information on the extremes of the motion of the ends of the loading arm. Here, the location of these ends was assumed to be at amidship on both tankers and 6 meters inboard from each edge. There are three quantities of interest here: the relative position envelope of the two ends of the arm, the relative acceleration envelope of the two ends, and the absolute acceleration of one end of the arm. The results discussed here are in meters and meters/second**2.

The acceleration envelopes found were:

Relative Acceleration

x	0.078
y	0.110
z	0.096

Acceleration of End on Storage Tanker

x	0.028
y	0.048
z	0.081

The coordinate system employed here has its origin at the loading arm end on the *storage* tanker, and the axes are aligned with those of the storage tanker: x is longitudinal, positive toward the stern, y is transverse positive toward starboard, and z is vertical positve up. These are maxima based on the average of the 1/1000th highest peaks, and they are equally likely to be positive or negative.

The relative position envelope is composed of two portions, a static envelope and a dynamic deviation. The static envelope is:

Static Relative Position

	Min	Max
x	–0.29	–0.23
y	15.59	15.61
z	–14.33	–14.32

Notice that this is a position envelope, i.e. it defines the extremes of motion of the ends of the loading arm. In particular, notice that the minimum is not necessarily negative! In addition to the static envelope, we have a dynamic deviation:

Dynamic Relative Position Deviation

x	1.13
y	0.41
z	0.20

To obtain the total envelope, the maxima due to dynamics should be added to the maxima above and subtracted from the minima. Thus, the total envelope is:

Total Position Deviation Envelope

	Min	Max
x	–1.42	–0.03
y	15.18	16.02
z	–14.53	–14.12

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*                                        ***  MOSES  ***                                           *
*                                        ---------------                   August 27, 2001         *
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+++ E N V I R O N M E N T A L   C A S E   S U M M A R Y +++

Units are Tonnes, Meters, and Degrees Unless Otherwise Specified

Case	Wave Height	Wave Headin	Wave P.Peri	Wave Gamma	Wind Speed	Wind Headin	Curr Speed	Curr Headin
1.000	1.620	180.000	6.422	1.000	38.830	180.000	0.500	180.000
2.000	1.620	170.000	6.422	1.000	38.830	180.000	0.500	180.000
3.000	1.620	160.000	6.422	1.000	38.830	180.000	0.500	180.000
4.000	1.620	150.000	6.422	1.000	38.830	180.000	0.500	180.000
5.000	1.620	140.000	6.422	1.000	38.830	180.000	0.500	180.000
6.000	1.620	130.000	6.422	1.000	38.830	180.000	0.500	180.000
7.000	1.620	120.000	6.422	1.000	38.830	180.000	0.500	180.000
8.000	1.620	110.000	6.422	1.000	38.830	180.000	0.500	180.000
9.000	1.620	100.000	6.422	1.000	38.830	180.000	0.500	180.000
10.000	1.620	90.000	6.422	1.000	38.830	180.000	0.500	180.000