CTX Mate, An Open Source, Combined Loading Instrument and Spill Reduction Program.

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Abstract

This paper describes CTX Mate, a program which has been released by the Center for Tankship Excellence under the Gnu Public Licence. CTX Mate is a full featured tanker loading instrument. However, in the event of a casualty, it can be converted to a salvage program and spill reduction package with a single click. Not only is the program instantly available at the site of the spill but almost all the relevent data are already entered including the current loading pattern. All the crew has to do is enter the location of the damage and Mate will do all normal salvage calculations, plus compute the equilibrium oil outflow. The crew can then immediately use Mate to try out various ballast and cargo transfers. Mate will check strength and stability for these possible moves and compute the resulting oil spill. As the paper demonstrates, it is often possible to reduce spillage by a factor of three or more simply by trimming and listing the ship properly, provided it is done quickly enough. The Open Source Mate library has a number of other applications which are discussed in the paper.

Keywords

Tanker; Loading Instrument; Salvage Program; Spill Reduction

1 Introduction

CTX Mate is a tanker salvage and spill reduction program disguised as a Loading Instrument. CTX Mate is both an old program and a new program. Mate is a version of MLOAD, a similar proprietary package which was used successfully on 13 VLCC's and ULCC's for a total of over 80 ship-years between 1995 and 2002. MLOAD was approved as a Loading Instrument by both ABS and Lloyds.

The MLOAD code was donated to the Center for Tankship Excellence (CTX) and thanks to the generosity of all the people who contributed to MLOAD has now been released as Open Source. The contributors include Halsey Herreshoff and Jake Kerwin who developed the immersed section area algorithm used by Mate, Mike Kennedy at Hellespont Shipping who made major improvements and corrections, and dozens of tankermen at Hellespont Shipping and Tankship Transport, who turned an academic exercise into a practical tool.

The CTX reorganized the MLOAD code base to make it easier to maintain, inspect, and reuse, added some visualization features, improved the documentation, and renamed the program CTX Mate. Anyone can download the package from the CTX web site, www.c4tx.org, and use it without charge. Far more importantly, anyone can inspect the code, find bugs, and contribute improvements. The download package includes a Demo ship, and the following documentation:

1. Users Manual
2. Ship Data Preparation Guide
3. Installation and Administration Manual
4. Programmer's Manual

Currently Mate has only been run on Linux, but should build on most Unix-like Operating Systems. The first public release was 2007-09-01.

2 Normal Mode

Perhaps the best way to get an idea of CTX Mate's capabilities is by example. Figure 1 shows a typical screenshot of Mate in Normal mode. It looks pretty much like any Loading Instrument. A table allows the user to change the parcel, the liquid volume and the temperature in any tank. He can enter ullage, innage, percent full, etc as he chooses. A subsidiary table allows the user to change parcel characteristics. CTX Mate uses a flexible description of each liquid parcel on-board including engine room fluids. The user can specify not only the density/API at standard temperature, but VCF method, vapor pressure, sulfur, ash and water content as well. Mate implements Tables 6A, 6B, 54A, and 54B. Buttons allow the user to rebalance the ship, compare bending moment and shear force with allowables and compute righting arms. The righting arm calculations take a few seconds because Mate rebalances the ship in draft and trim at each imposed heel. Mate accepts free water and non-liquid innages and computes all the commercially required cargo information. A full set of cargo survey reports are available. Mate can accept ullage/innage/temperature data from an automatic gauging system. Mostly pretty standard stuff.

But under the hood, Mate is quite different from most Loading Instruments. Mate makes no use of pre-computed tank tables. Rather Mate computes tank liquid volume by direct integration from the compartment's description just like a preliminary design program. This makes for a more accurate, far more flexible Loading Instrument. There is no wedge problem when a tank is nearly empty. There is no need to make a bad guess at the waterplane moment of inertia when the tank is nearly full. Longitudinal as well as transverse shifts in the tank liquids are accounted for. The results are as accurate at large heel and trim as they are at even keel. Even without damage, this is crucial in doing the righting arms and the IMO Reg 25 check. Multiple dipping points/gauging systems are easy to implement and add. CTX Mate understands the difference between tank gauging systems that work in ship coordinates (radar, floats, etc) and systems that work in earth coordinates (surveyor tapes, UTI, pressure, etc).

Even design programs don't get this right. During a Korean newbuilding project, we found that SIKOB, the design program most Korean yards were using to create the tank tables, assumed that a surveyor's tape worked in ship coordinates. With trim, the actual tank waterline at any measured ullage was lower than SIKOB claimed. The error was nil at low ullages; but, at high trim and high ullages, averaged 9 m3 per tank. Commercially, this is the worst kind of error from the point of the ship, since on discharge it looks to the charterer like the ship has kept 9 m3 of his oil per tank. The only reason we discovered this error was that we had a program that did do the calculation correctly. The yard, Daewoo, pointed out that they had delivered hundreds of tankers using this program, and no one had ever complained.

3 Damage Mode

Of course, the real reason why Mate works directly from the compartment description is that it allows the program to handle damage. The loading pattern in Figure 1 represents a typical full load departure. Let's suppose that the ship in Figure 1 sustains damage in the forward port ballast tank, 1B_P. The damage extends into the 1P cargo tank. The crew ascertains that the damage extends about 13 meters up the side and longitudinally most of the aft half of 1B_P.

The Chief Officer flips CTX Mate to Damage mode, Figure 2, by clicking on the Damage button. Many of the commercially important columns disappear and are replaced by columns related to the damage. He enters the location of the damage in 1B_P. He needs to enter six numbers: the location of the high point of the damage and the low point in the six rightmost columns in the 1B_P row. He marks 1B_P as damaged by putting a D in the 1B_P OPT column. He doesn't know much about the internal damage between 1P and 1B_P but the rapid increase in ullage in 1P tells him it is considerable, so he decides to "group" 1P with 1B_P, that is treat the two tanks as if they are fully communicating. He does this by putting a G in the 1P OPT column and changing the 1P GROUP column to 1B_P. And then he rebalances. Figure 2 shows the resulting screen.

The Chief Officer's first check should be for vessel survivability. The worst case bending moment and shear forces are well below the allowables so strength is probably OK, especially if the ship's in a low wave environment. The equilibrium heel after flooding is 2.8 degrees to port and he will have a trim of 2.3 meters by the bow. GM looks OK and he can recompute the righting arms, Figure 3, to confirm that he still has plenty of stability, although the port righting arm is considerably lower than the starboard reflecting the flooding.[1] The hull low point will be 27 m below sea level, and we'll assume he has enough water so that the ship will remain afloat.

Now he can turn his attention to the spillage. The HYDROLOSS and EXCHGLOSS numbers tell him that if he does nothing he will lose 3735 cubic meters of cargo all to exchange flow. A very bad spill. Clicking on the Section button brings up a transverse view of the situation at equilibrium, Figure 4.

Being well schooled in hydrostatic balance, he realizes he need to get the top of the damage as deep into the water as possible. He needs to list and trim the ship toward the damage. He decides to ask Mate what will happen if he ballasts 2B_P. So he goes back to the main tank table, sets the percentage full of 2B_P to 90%, and rebalances. Figure 5 shows the resulting equilibrium.

The ship will have a heel of 7 degrees to port and a trim of 5 m by the bow; but strength and stability still look OK. The low point of the hull will be 30.5 meters deep. I'll assume he has enough water. Most importantly, ***the spill numbers have gone to zero***. A click on the Section button shows him

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[1] There is no difference between Mate's intact stability and damaged stability calculations. In both cases, the program is simply rebalancing the ship in draft and trim at each imposed heel. But rebalance to Mate means recomputing the location and, in the case of damage, the amount of all the tank liquids. So Mate's damaged stability calculations redo the hydrostatic balance in each damaged tank at each heel.

[2] Figure 6 makes another important point. The oil level in the damaged tanks is 3.62 m above sea level. This better be below the top of the vents in 1B_P or we will have *deckloss*, oil flow through the deck openings. Currently, Mate does not

that the equilibrium Live Bottom will now be 1.2 meters above the top of the damage, Figure 6.[2] He immediately starts ballasting 2B_P.

There are a number of points to make about this little saga.

- The time required to type in the data and do the numbers is less than a minute. We are talking a few dozen keystrokes in total. This is largely due to the fact that almost all the required data, the description of the ship and the current loading pattern, were already in the computer and ready to go. I have been involved in shoreside spill responses where *after getting up and running*, it took us over 40 minutes to get the data in from the ship and enter it in the computer, and even then we couldn't be sure we had it right.
- The calculations were done as soon as the crew forward gave the Chief Officer an idea of the location of the damage. With a switched on crew, this should be within 15 minutes of the casualty. Contrast this with multi-hour start up lag of the Emergency Response Services.
- The job was done with a program the Chief Officer was initimately familiar with and facile in from hundreds of hours of practice in the normal tanker routine. Switching to a program he doesn't know in the middle of a crisis, simply isn't going to work.
- The specific combination of this ship's data and the program has been tested daily, probably for several years on hundreds if not thousands of loading patterns. Whenever you are dealing with a complex software package and a database as complex as the description of a tanker and all its compartmentation, you must have this kind of testing to have any confidence in the results. When I was active in tankers, we always found significant unexplained differences between the response service's numbers and our own whenever we compared the two.
- ***Notice the importance of side capture in this scenario.*** A double side can often be an extremely effective spill reduction device in the face of bottom damage. Conversely, there will almost always be little or no bottom capture. Yet IMO's design evaluation procedure assumes that 50% of the spilled oil in grounding will be captured in the double bottom and ignores any double side capture. This is not only totally inaccurate; but much worse hopelessly biased in favor of double bottoms and against double sides. Much better to have no design evaluation than such a misleading system.
- Notice also that the actual spillage depends critically on the equilibrium drafts and heel. Yet IMO assumes even keel at the pre-damage draft. Once again inaccurate and misleading.
- Of course, how much of the saving the crew will actually obtain from the ballasting will depend on how rapidly they are able to ballast down relative to the oil outflow from 1P. But all that is saying is that you must start the process ASAP, and that can only be done by the guys on-board. Since Mate is an equilibrium only model, it gives the crew no information on the rapidity of the flows, other than its separation of Hydrostatic flow and Exchange flow.[3]

4 Outside In Flow

Internal damage is both a difficult practical problem and a difficult theoretical problem. Practically the problem is you usually don't know the extent of the damage. Theoretically, the problem is that even the equilibrium spillage depends on the relative speed of the external and internal flows. Consider our example casualty. If the external hole between 1B_P and the sea is much larger than the internal hole between 1P and 1B_P, then seawater will flow into 1B_P much faster than oil will flow from 1P to 1B_P. This will allow hydrostatic pressure to keep oil in 1P. In the extreme case, the outflow from 1P to 1B_P will be the same as if the 1P to 1B_P damage were external. This is known as *outside-in* flow. Normally, assuming outside-in flow will produce a lower bound on the spill.

The other extreme is that the damage between 1P and 1B_P is extensive enough so that the flow from 1P to 1B_P is much faster than the seawater inflow. In this case the equilibrium situation is the same as if the two tanks were really a single tank. (This will also eventually happen if the internal damage between 1P and 1B_P straddles the equilibrium oil/water interface.) This is known as *inside-out* flow. Normally, assuming inside-out flow will produce an upper bound on the spill.

Mate handles both inside-out and outside-in flow, but nothing in between. Inside-out flow is handled by "tank grouping". The crew designates two or more tanks as "grouped" and Mate then treats the grouped tanks as if they were a single tank. This is what we did in the example casualty. One nice thing about tank grouping is that you don't have to say anything about the location of the internal damage. Grouping is also the key to Mate's ability to model systems which purposely combine tanks to limit damage, such as the Coulombi Egg. In the case of the Coulombi Egg, a damaged wing cargo tank

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handle deckloss. But the downflooding report tells the Chief Officer that the critical 1B_P vent is 3.87 m above sea level, so he is marginally OK with respect to deck loss.

[3] Hydrostatic flow is the outflow required to equilibrate the internal and external pressure at the top of the damage. Any oil that remains in the tank below the top of the damage after this equilibrium is reached will eventually be replaced by seawater. This is known as Exchange flow. Exchange flow is usually an order of magnitude slower than Hydrostatic flow.

would be grouped with the overlying ballast tank.

Outside-in flow requires that the crew specify the location of the internal damage. As long as the internal damage is all below the waterline, the key is the high point of the damage. Going back to our example casualty, let's assume that somehow the crew knows that the damage in the double side in 1P extends up to 11 m above the baseline. The Chief Officer enters the 1P inner side damage just as he would for external shell damage, but designates 1B_P as the outside tank for 1P by entering 1B_P in 1P's Outer column.

Mate first computes the hydrostatic balance in 1P just as if it were an external tank facing seawater pressure externally. However, it directs any oil outflow into 1B_P rather than the sea. It adds that outflow to any oil that was already in 1B_P, and then computes the hydrostatic balance in 1B_P. This time, however, any outflow is directed to the sea. Under these assumptions, Figure 7 tell us the do-nothing spill is 2104 m3, about 1500 m3 less than that in Figure 4 where we assumed inside-out flow. In most cases where the damage is known to be low in both tanks, outside-in will yield a better estimate than grouping.

5 Sealing a Tank

Mate implements two options with respect to ullage space pressure:

Constant Pressure Mate holds the ullage space pressure constant at the user specified level. Usually this is only appropriate for vented tanks or situations where the IG system is running, although it could be used to model active vacuum systems. Constant pressure can also be used to model "blowing out" a tank later in the salvage process. So far we have assumed constant pressure in our example casualties.

Sealed Tank In this option, the tank is assumed to be isolated. Mate computes the vapor pressure of the cargo at the tank temperature and keeps that constant. The air/inert gas in the ullage space is assumed to behave as a perfect gas. Part of Mate's input for each tank is the high and low settings of the tank's P/V valves. (Zero for vented tanks.) If the tank pressure/vacuum exceeds these numbers, then Mate holds the pressure in the ullage space at these limits. This capability allows Mate to model a Full Vacuum Tanker — a ship designed to take 0 bar absolute in the ullage space. Simply set the tank low P/V settings to -10m gage.

For a conventional tanker, the low P/V setting would typically be about -0.4m. But even this mild vacuum can be surprisingly useful. If in the case of Figure 7, the crew quickly seals 1P and tells Mate it is sealed by entering S instead of D in the Opt column, then the result is shown in Figure 8. The new do-nothing spillage is down to 1640 m3, a reduction of nearly 500 m3 over the constant pressure outcome, despite the very mild vacuum. Notice that the extra liquid in 1P automatically gives us a little more beneficial trim and heel.

6 Stranding

Mate has a limited stranding capability. If the ship is stranded, the crew can enter the fore and aft drafts (or fore and aft water depths) and the ship's heel. Mate will compute the corresponding ground reaction force and centers. All calculations, including oil outflows, are available when stranded. Since Mate does not model the sea bottom, the resulting strength numbers are pretty much useless; but the seawater inflows and oil outflows will be as accurate as the damage location data. The relationship between stranding and spillage can be crucial. For a given damage, oil spillage will generally be much larger in stranded situations than in unstranded. The prototypical example is the Exxon Valdez.

Figure 9 shows an attempt to reconstruct the Valdez spill. It is not a particularly accurate attempt, for I had very limited data on the ship. I did not have hull offsets for the Valdez so I had to morph a hull for which I do have offsets to match the Valdez's overall particulars. Unfortunately, my hull is considerably finer than the Valdez and the resulting summer deadweight is about 2600 tons low. Also it appears that my wings tanks are smaller and center tanks bigger than the actual Valdez. But Figure 9 is close enough for our purposes. It shows the situation at low tide, about 8 hours after the grounding. In this figure I've used the probably optimistic NTSB (NTSB, 1990) damage heights and assumed outside-in flow with vented tanks.

Because of the extensive damage, the Valdez is a real test of a tanker spillage program. Even Mate can't handle the Valdez completely. For example, in outside-in flow, Mate only allows one outside tank for each inside tank. In Figure 9 I've assumed 1C flowed only into the Forepeak tank when in fact it flowed into both the FP and 1S. Anyway under the Figure 9 assumptions, Mate predicts a spill of just under 40,000 m3. According to the NTSB, the actual spill was about 36,000 m3. This level of agreement is more a result of counter-vailing errors than real accuracy; but at least we are in the ball park.

An interesting question is what would have happened if Hazelwood et al had been able to seal the tanks. Figure 10 indicates that successfully sealing the cargo tanks would have reduced the spill to about 13,000 m3. In The Tankship Tromedy (Devanney, 2006), I opined without doing any calculations that a Full Vacuum Valdez would have kept 90% of the spill onboard. I was wrong as people always are when they make pronouncements about spillage without doing the numbers correctly. Mate's Full Vacuum Valdez keeps only two-thirds of the spill onboard. The two main reasons are:

1. Roughly 20% of the spill was exchange flow. Vacuum can have little impact on exchange flow in a stranding.
2. The Valdez was only loaded to 56 feet or about 84% of its cubic. So the initial ullage volumes were much larger than they would have been if the ship had been full loaded. Thus the vacuum at equilibrium is fairly mild.[4] According to the Ull_h_m column in Figure 10, the equilibrium vacuum in most of the cargo tanks is only about -3.5 meters. On the plus side, this means that the upper bulkheads almost certainly would have held.

In any event, keeping two-thirds of the spill on-board would have made a massive difference. It still blows my mind that nobody onboard the Valdez had the presence of mind to try and jam the P/V valves shut. They had 8 hours between the time the ship grounded and low tide. During that whole period, they just sat and watched the oil bubble out.

Several Exxon people have told me that the Valdez would have sunk if she had come off Bligh Reef. CTX Mate is not so sure. Mate says the ship would have floated with a starboard heel of 22 degrees and a trim by the bow of 14 meters. Stability would have been OK with a GM to starboard of over 4 m. Bending moment in the forward part of the ship would have been very low, so she probably would have survived structurally in the flat calm that prevailed. The problem would have been progressive flooding. 1S would have been 7 meters under water at the rail. But Mate claims that, if the crew were able to blank off the downflooding points forward on the starboard side, she probably would have survived. Interestingly the spill would have been about 2,500 m3 — once again assuming the vents were blanked — about 7% of the actual spill. The point is, if Mate had been on-board, all this information would have been available to the crew.

7 Residual Strength

Mate has a residual strength capability based on classical beam theory. At any point after the damage box has been entered, with a couple of clicks, the Chief Officer can bring up a screen showing a transverse view of the longitudinal structure in way the damage. This drawing indicates the members that Mate has eliminated, displays the neutral axes, and highlights the points of maximum longitudinal stress and the max stress to yield point.

However, for a double bottom ship, a strong argument can be made that these results can be so misleading that this stress capability should be disabled when Mate is used as a Loading Instrument. There are two major problems.

1. Beam theory is at best approximately correct for an undamaged tanker, and can be wildly inaccurate in way of the damage.
2. Even worse, in double hull tankers, the double bottom design is not driven by longitudinal stress. It is driven by local hydrostatic pressures. A tanker double bottom will have roughly twice as much steel as required by longitudinal strength. Thus the longitudinal stresses in a tanker double bottom are almost always very low regardless of the loading pattern or the damage. This could easily give the crew a false sense of security.

If a loaded double hull tanker floods anywhere near midships, by far the most likely failure mode is deck buckling. Classical beam theory can give us an inaccurate estimate of the compressive stress in the deck; but, until that is combined with some measure of buckling strength, the number is nearly meaningless. We need to couple Mate with a finite element model, or some sort of beam-column approach. Mate has been designed with this in mind. Mate implements a 3-D distribution of the lightweight and can take as input a longitudinal wave profile; but the actual coupling has not yet been done.

8 Mate as a Teaching Tool

CTX Mate's applications are not limited to being a Loading Instrument. It is safe to say most crews and owners are unaware of the power of properly trimming and listing the ship to reduce spillage. The calculations are far too tedious to do by hand, so nobody does them. Whenever I show something like Figures 2 and 5 to even experienced tankermen or governmental authorities, I invariably get a "Wow!" or at least an "I don't believe it!". The same thing is true with respect to the power of vacuum.

It's not just crew who don't understand hydrostatic balance. The report of the On-Scene Commander at the million liter Diamond Grace spill in Tokyo Bay includes a sketch he made which shows be believed that the equilibrium level in every damaged tank is sea level regardless of the density of the tank contents. Nor do they understand the negative ramifications of mishandling hydrostatic balance. The only major spill at which I have been physically present, the Tamano in Casco Bay, was more than doubled when well after the casualty, the decision was made to start discharging intact tanks. Something similar happened at the Imperial Sarnia spill in the St. Lawrence and the Oceanic Grandeur in the Torres Strait.

By running through a series of drills with a pro-

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[4] The actual vacuum might have been higher. The first thing that happened when the Valdez went aground is that the sea bottom pushed into the forward tanks, compressing the ullage space, resulting in the P/V valves venting strongly. So the actual "initial" ullage space was lower than that assumed in Figure 10.

gram like CTX Mate, everybody learns about the true power of hydrostatic balance in a very concrete context. For the first time, they really understand that in many cases by simply trimming and listing the ship or sealing the tanks, they can cut the spillage in half or more, or in some cases eliminate it entirely. And Mate's simple drawings are far easier to understand and believe than a table of strange numbers and arcane formulae.

However, the real goal here is 3-D visualization. When this is available, we should have a truly effective pedagogic tool.

9 Mate as a Design Tool

CTX Mate is a tanker design program mascarading as a Loading Instrument. As such, it is obvious it can be used a design tool. To faciliate this Mate can be used in non-interactive mode. This allows the program to be embedded in a much larger analysis. For example, one can implement a search over the design space (length, beam, compartmentation, etc) and, for each possible design, use Mate to compute the hydrostatics, create tank tables, check stability, calculate shear force, bending moment, etc.

The Center for Tankship Excellence's Tanker Design Toolkit, CTX DNA, uses Mate in this way. CTX DNA is a set of Perl scripts which creates and evaluates candidate designs. CTX DNA uses a compact, parametric description of a tanker, which it converts into the XML input that Mate needs. Whenever CTX DNA needs the kind of information on a design that Mate can provide, it runs Mate in non-interactive mode; and then examines the resulting XML reports and extracts the information it needs to evaluate that particular design. And then goes on to the next design and repeats the process.

To support this design role, Mate implements Sub-bodies. Each (normally) watertight volume (a Body) in a tanker is divided into one or more sub-volumes or Sub-bodies. Sub-bodies can be combined by addition or subtraction. This allows preliminary design programs to build up complicated compartments from a number of simpler six sided "boxes".

Similary, the hull can be divided into as many buoyant Sub-bodies as makes sense. For obvious example, the rudder(s) can be separated out from the main hull. Among other things, this allows relative movement between the sub-hulls.

10 Mate as a Spill Resistance Evaluator

CTX Mate is a tanker design program, but with special capabilities with respect to damage. Mate can accurately estimate equilibrium oil spillage in a wide range of damage scenarios. As we have seen, in order to do even a reasonably good job of estimating spillage in a particular situation, we must:

- Have a decent model of hydrostatic balance coupled to the sinkage, heel, and trim associated with the damage.
- Correctly model the inter-compartment flows, including most importantly double side capture in the case of double hulls.
- Model what is happening to pressure in the ullage space.
- Allow systems which depend on inter-tank flows, vacuum, etc to do their thing.

CTX Mate can do all these things. (The IMO evaluation scheme does none of the above.)

If we were ever to agree on a reasonable set of damage scenarios — and non-dimensionalizing collision damage to preserve Class confidentiality and then re-constituting non-dimensionalized numbers on the basis of the hittee's particulars is not just unreasonable, it is ridiculous — we could use CTX Mate to subject a potential design to this set of damage scenarios; and come up with whatever statistics are deemed appropriate, hopefully statistics that focus on the amount of oil spilled, rather than the probability of zero spill.

Mate's ability to be scripted, that is, embedded in a larger analysis is critical in this regard. In this case, the evaluation program would simply loop thru all combinations of loading pattern and damage scenarios, calling Mate in non-interactive mode for each such combination, inspect the XML results extracting the information it needs, and then move on to the next combination.

11 Mate as a Benchmark

CTX Mate is Open Source. All the code is inspectable by anyone. In my opinion, this transparency is required of any software package that purports to be in the public interest, or purports to determine the legality of anything as important as tanker operations. I don't trust code I can't see, and neither should anyone else, especially regulatory bodies.

Along with transparency comes the other benefits of Open Source, a hundred minds looking for bugs, a hundred minds looking for ways to improve the code, a hundred minds contributing new functionality. I call this buildability. It is the whole key to science and to progress in general. Without buildability, there would be no such thing as civilization.

But for tanker regulatory purposes, we need more than just inspectable code. The program must be understandable by experts who are not programmers. Mate has a flexible debugging and introspection facility. There is no need to re-compile to use this capability. It is controlled via configuration files, which allow the user to generate various levels of output by subroutine. With this facility a non-programmer can drill in on a particular function and follow Mate's calculations in as much detail as he needs.

This suggests another use for a program like Mate: a benchmark. Currently, there is no real standard in Loading Instruments. For a program to be Class approved for a ship, the normal process is to compare its overall results on a handful of loading patterns with the yard's results in the Trim and Stability booklet for the same loading patterns. Almost nobody knows, usually including the yard, how the yard's program works, what approximations it made, what bugs it has. Almost nobody knows how the owner's program works, what approximations it made, what bugs it has. The only criteria is that a few numbers match within 5%. Presumably, the program the yard is using has been compared with the program that Class is using, also a blackbox, within 5%.

Think about it. There is no way of auditing the accuracy of any of these programs. If the Class program errs 5% on say bending moment, and the yard program errs another 5% in the same direction, and the owners program errs another 5%, we could end up 15% off. Or it could be worse. We just don't know. And whatever the ***relative*** accuracy of these programs is, it is tested only on a handful of tame loading patterns, none of which have any material heel, and at best modest trim.

This kind of quality control would be laughed at for any normal commercial software. Yet we use it when lives and immense environmental damage are at stake. Loading Instruments should be tested against a known, open standard. And they must be exercised under at least the most extreme input they can ever be expected to face, preferably far more extreme. It is these "corner conditions" that reveal weaknesses in the code. Testing only in the middle of the input space automatically covers up bugs and bad approximations.

We need a open standard. Mate is both open and inspectable. It could be the basis for that standard.

12 Future Work

There are any number of improvements to CTX Mate that should be implemented. Highest on CTX's priority list are:

FE for strength The biggest and perhaps most important job is to couple Mate with a finite element capability. The loads generated by Mate's equilibrium drafts, heel, and tank waterlines (including run-off and flooding for damaged spaces) would be fed to a finite element model to assess strength.

3D Visualization Both for pedagogic purposes, and to do a better job of showing the crew what's happening we need 3D visualization.

GTK User Interface Currently only one graphical interface has been implemented for Mate. It is based on the TCL language which has a number of limitations; most importantly, it is hard to port to non-Linux operating systems. CTX intends to create a GUI for Mate based on the GTK toolkit. It will be very similar to the current GUI, but be much easier to port to Apple and Microsoft operating systems.

Spill Rate We need to give the crew as much insight as we can on how rapidly the spillage will occur. Mate has a project under way based on a simple Torricelli-like model. It may not be very accurate, but it is better than nothing. What we really need here is a good model of exchange flow. I could easily see two or three Ph.D. thesis subjects in this area.

This is just the top of the list. Mate has a large number of other features that need implementation. See our To Do list at www.c4tx.ofg/job/mate/todo.html. CTX will happily accept applications from anyone who wants to take on any of these jobs.

13 Conclusion

CTX Mate can be a useful, expandable tool in a variety of contexts. It can be a substantial aid in teaching us how tankers spill oil. It has certainly taught me a great deal. And properly deployed as a Loading Instrument, Mate could actually reduce spillage in many casualties.

Having said all this I feel compelled to add one basic caveat to the whole CTX Mate project. Far too much effort, most of it misdirected, has been spent on reducing spillage after a casualty has occurred. Far, far too little effort has been spend on preventing the casualty in the first place. Stronger, more manueverable ships, ballast tank inerting, and twin screw will be orders of magnitude more important than a Loading Instrument that sometimes allows the crew to reduce spillage after the fact. CTX Mate can be useful; but we must focus on the real issue which is preventing the casualty in the first place.

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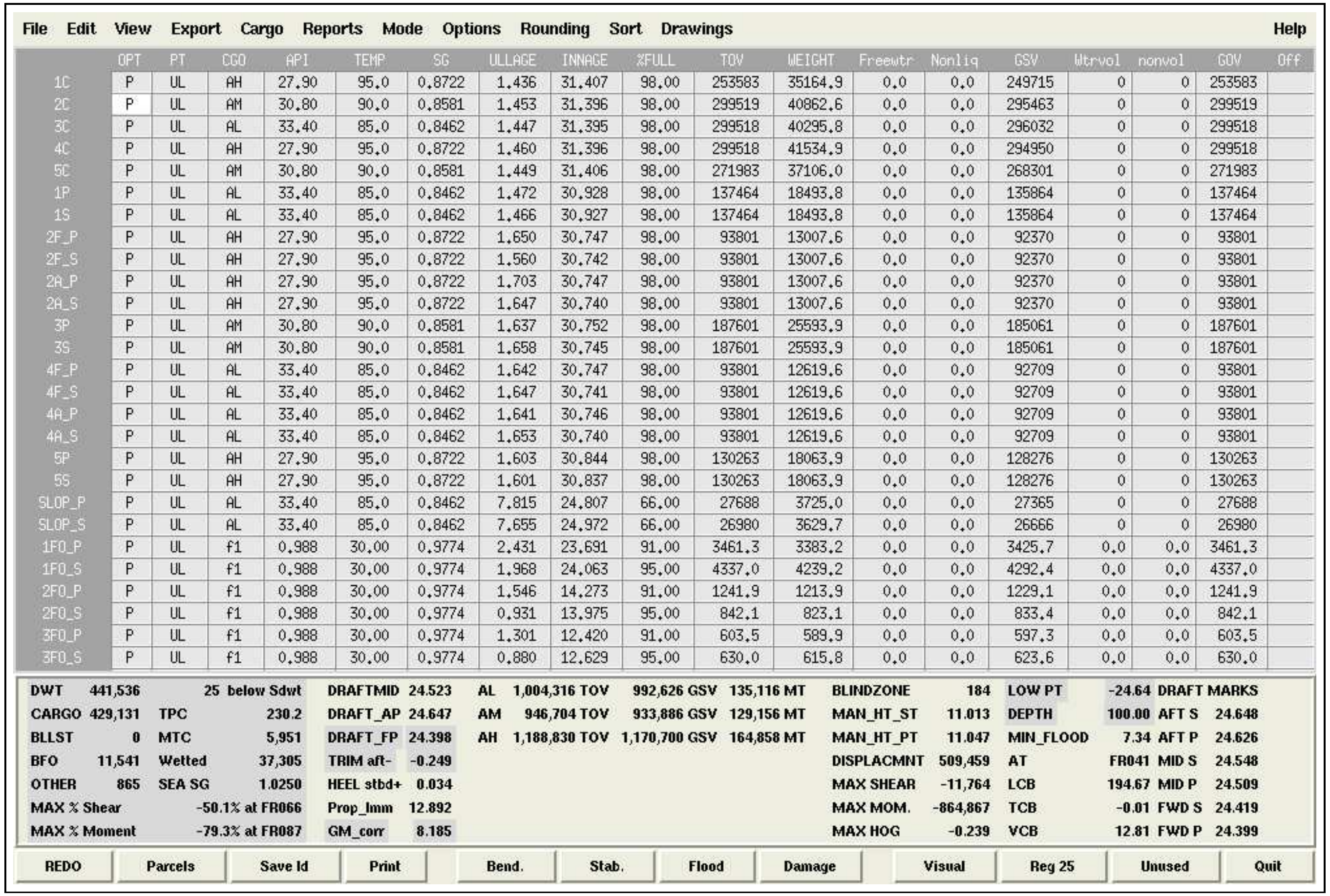
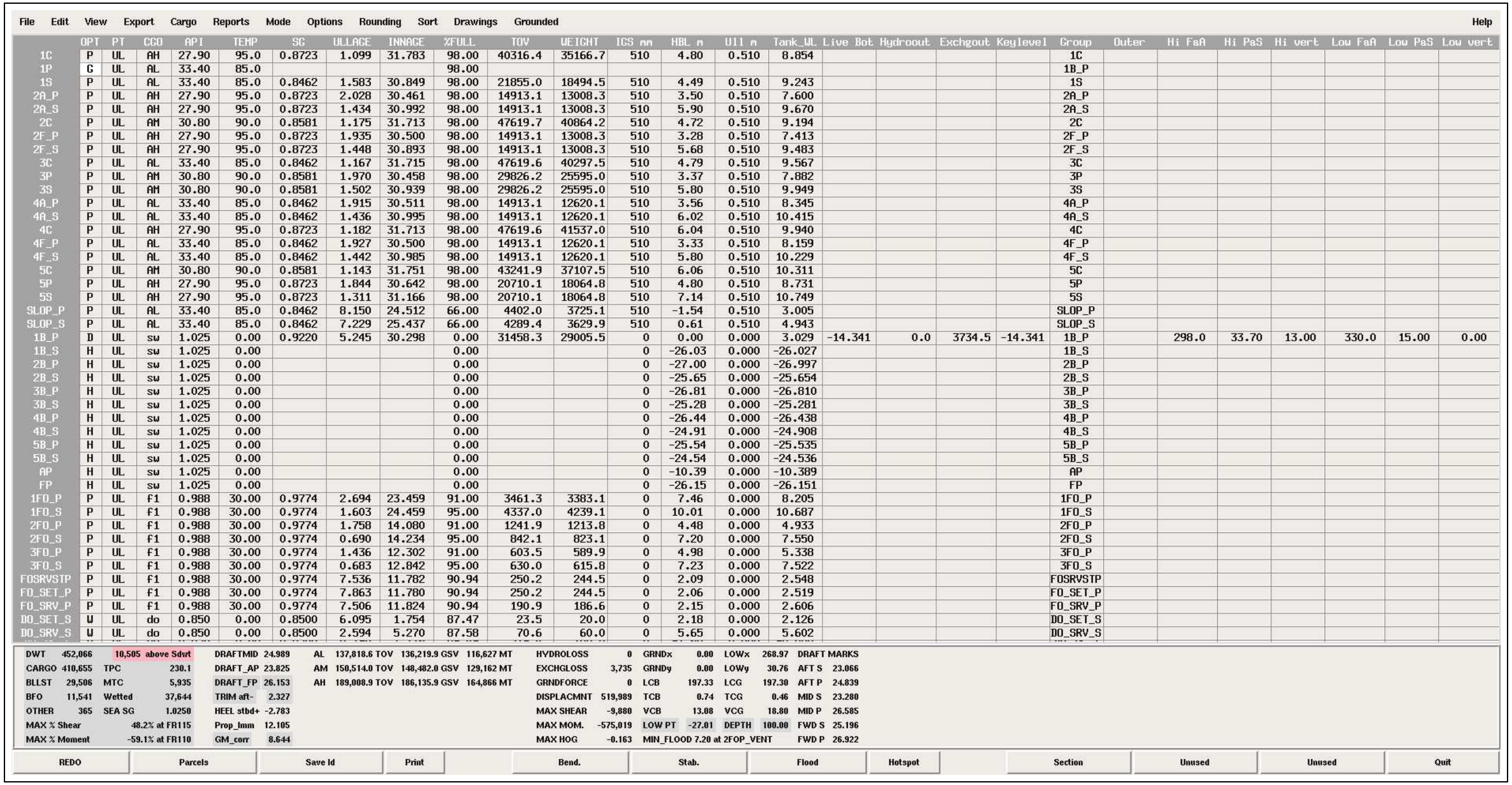


	OPT	PT	CGO	API	TEMP	SG	ULLAGE	INNAGE	%FULL	TOV	WEIGHT	Freewtr	Nonliq	GSV	Wtrvol	nonvol	GOV	Off
1C	P	UL	AH	27.90	95.0	0.8722	1.436	31.407	98.00	253583	35164.9	0.0	0.0	249715	0	0	253583	
2C	P	UL	AM	30.80	90.0	0.8581	1.453	31.396	98.00	299519	40862.6	0.0	0.0	295463	0	0	299519	
3C	P	UL	AL	33.40	85.0	0.8462	1.447	31.395	98.00	299518	40295.8	0.0	0.0	296032	0	0	299518	
4C	P	UL	AH	27.90	95.0	0.8722	1.460	31.396	98.00	299518	41534.9	0.0	0.0	294950	0	0	299518	
5C	P	UL	AM	30.80	90.0	0.8581	1.449	31.406	98.00	271983	37106.0	0.0	0.0	268301	0	0	271983	
1P	P	UL	AL	33.40	85.0	0.8462	1.472	30.928	98.00	137464	18493.8	0.0	0.0	135864	0	0	137464	
1S	P	UL	AL	33.40	85.0	0.8462	1.466	30.927	98.00	137464	18493.8	0.0	0.0	135864	0	0	137464	
2F_P	P	UL	AH	27.90	95.0	0.8722	1.650	30.747	98.00	93801	13007.6	0.0	0.0	92370	0	0	93801	
2F_S	P	UL	AH	27.90	95.0	0.8722	1.560	30.742	98.00	93801	13007.6	0.0	0.0	92370	0	0	93801	
2A_P	P	UL	AH	27.90	95.0	0.8722	1.703	30.747	98.00	93801	13007.6	0.0	0.0	92370	0	0	93801	
2A_S	P	UL	AH	27.90	95.0	0.8722	1.647	30.740	98.00	93801	13007.6	0.0	0.0	92370	0	0	93801	
3P	P	UL	AM	30.80	90.0	0.8581	1.637	30.752	98.00	187601	25593.9	0.0	0.0	185061	0	0	187601	
3S	P	UL	AM	30.80	90.0	0.8581	1.658	30.745	98.00	187601	25593.9	0.0	0.0	185061	0	0	187601	
4F_P	P	UL	AL	33.40	85.0	0.8462	1.642	30.747	98.00	93801	12619.6	0.0	0.0	92709	0	0	93801	
4F_S	P	UL	AL	33.40	85.0	0.8462	1.647	30.741	98.00	93801	12619.6	0.0	0.0	92709	0	0	93801	
4A_P	P	UL	AL	33.40	85.0	0.8462	1.641	30.746	98.00	93801	12619.6	0.0	0.0	92709	0	0	93801	
4A_S	P	UL	AL	33.40	85.0	0.8462	1.653	30.740	98.00	93801	12619.6	0.0	0.0	92709	0	0	93801	
5P	P	UL	AH	27.90	95.0	0.8722	1.603	30.844	98.00	130263	18063.9	0.0	0.0	128276	0	0	130263	
5S	P	UL	AH	27.90	95.0	0.8722	1.601	30.837	98.00	130263	18063.9	0.0	0.0	128276	0	0	130263	
SLOP_P	P	UL	AL	33.40	85.0	0.8462	7.815	24.807	66.00	27688	3725.0	0.0	0.0	27365	0	0	27688	
SLOP_S	P	UL	AL	33.40	85.0	0.8462	7.655	24.972	66.00	26980	3629.7	0.0	0.0	26666	0	0	26980	
1FO_P	P	UL	f1	0.988	30.00	0.9774	2.431	23.691	91.00	3461.3	3383.2	0.0	0.0	3425.7	0.0	0.0	3461.3	
1FO_S	P	UL	f1	0.988	30.00	0.9774	1.968	24.063	95.00	4337.0	4239.2	0.0	0.0	4292.4	0.0	0.0	4337.0	
2FO_P	P	UL	f1	0.988	30.00	0.9774	1.546	14.273	91.00	1241.9	1213.9	0.0	0.0	1229.1	0.0	0.0	1241.9	
2FO_S	P	UL	f1	0.988	30.00	0.9774	0.931	13.975	95.00	842.1	823.1	0.0	0.0	833.4	0.0	0.0	842.1	
3FO_P	P	UL	f1	0.988	30.00	0.9774	1.301	12.420	91.00	603.5	589.9	0.0	0.0	597.3	0.0	0.0	603.5	
3FO_S	P	UL	f1	0.988	30.00	0.9774	0.880	12.629	95.00	630.0	615.8	0.0	0.0	623.6	0.0	0.0	630.0	

DWT	441,536		25 below Sdwt	DRAFTMID	24.523	AL	1,004,316 TOV	992,626 GSV	135,116 MT	BLINDZONE	184	LOW PT	-24.64	DRAFT MARKS	
CARGO	429,131	TPC	230.2	DRAFT_AP	24.647	AM	946,704 TOV	933,886 GSV	129,156 MT	MAN_HT_ST	11.013	DEPTH	100.00	AFT S	24.648
BLLST	0	MTC	5,951	DRAFT_FP	24.398	AH	1,188,830 TOV	1,170,700 GSV	164,858 MT	MAN_HT_PT	11.047	MIN_FLOOD	7.34	AFT P	24.626
BFO	11,541	Wetted	37,305	TRIM aft-	-0.249					DISPLACMNT	509,459	AT	FR041	MID S	24.548
OTHER	865	SEA SG	1.0250	HEEL stbd+	0.034					MAX SHEAR	-11,764	LCB	194.67	MID P	24.509
MAX % Shear			-50.1% at FR066	Prop_Imm	12.892					MAX MOM.	-864,867	TCB	-0.01	FWD S	24.419
MAX % Moment			-79.3% at FR087	GM_corr	8.185					MAX HOG	-0.239	VCB	12.81	FWD P	24.399

Figure 1: Typical departure full load, Normal Mode.



	OPT	PT	CGO	API	TEMP	SG	ULLAGE	INNAGE	%FULL	TOV	WEIGHT	IGS mm	HBL m	Ull m	Tank_WL	Live Bot	Hydroout	Exchgout	Keylevel	Group	Outer	Hi FaA	Hi PaS	Hi vert	Low FaA	Low PaS	Low vert
1C	P	UL	AH	27.90	95.0	0.8723	1.099	31.783	98.00	40316.4	35166.7	510	4.80	0.510	8.854					1C							
1P	G	UL	AL	33.40	85.0				98.00											1B_P							
1S	P	UL	AL	33.40	85.0	0.8462	1.583	30.849	98.00	21855.0	18494.5	510	4.49	0.510	9.243					1S							
2A_P	P	UL	AH	27.90	95.0	0.8723	2.028	30.461	98.00	14913.1	13008.3	510	3.50	0.510	7.600					2A_P							
2A_S	P	UL	AH	27.90	95.0	0.8723	1.434	30.992	98.00	14913.1	13008.3	510	5.90	0.510	9.670					2A_S							
2C	P	UL	AM	30.80	90.0	0.8581	1.175	31.713	98.00	47619.7	40864.2	510	4.72	0.510	9.194					2C							
2F_P	P	UL	AH	27.90	95.0	0.8723	1.935	30.500	98.00	14913.1	13008.3	510	3.28	0.510	7.413					2F_P							
2F_S	P	UL	AH	27.90	95.0	0.8723	1.448	30.893	98.00	14913.1	13008.3	510	5.68	0.510	9.483					2F_S							
3C	P	UL	AL	33.40	85.0	0.8462	1.167	31.715	98.00	47619.6	40297.5	510	4.79	0.510	9.567					3C							
3P	P	UL	AM	30.80	90.0	0.8581	1.970	30.458	98.00	29826.2	25595.0	510	3.37	0.510	7.882					3P							
3S	P	UL	AM	30.80	90.0	0.8581	1.502	30.939	98.00	29826.2	25595.0	510	5.80	0.510	9.949					3S							
4A_P	P	UL	AL	33.40	85.0	0.8462	1.915	30.511	98.00	14913.1	12620.1	510	3.56	0.510	8.345					4A_P							
4A_S	P	UL	AL	33.40	85.0	0.8462	1.436	30.995	98.00	14913.1	12620.1	510	6.02	0.510	10.415					4A_S							
4C	P	UL	AH	27.90	95.0	0.8723	1.182	31.713	98.00	47619.6	41537.0	510	6.04	0.510	9.940					4C							
4F_P	P	UL	AL	33.40	85.0	0.8462	1.927	30.500	98.00	14913.1	12620.1	510	3.33	0.510	8.159					4F_P							
4F_S	P	UL	AL	33.40	85.0	0.8462	1.442	30.985	98.00	14913.1	12620.1	510	5.80	0.510	10.229					4F_S							
5C	P	UL	AM	30.80	90.0	0.8581	1.143	31.751	98.00	43241.9	37107.5	510	6.06	0.510	10.311					5C							
5P	P	UL	AH	27.90	95.0	0.8723	1.844	30.642	98.00	20710.1	18064.8	510	4.80	0.510	8.731					5P							
5S	P	UL	AH	27.90	95.0	0.8723	1.311	31.166	98.00	20710.1	18064.8	510	7.14	0.510	10.749					5S							
SLOP_P	P	UL	AL	33.40	85.0	0.8462	8.150	24.512	66.00	4402.0	3725.1	510	-1.54	0.510	3.005					SLOP_P							
SLOP_S	P	UL	AL	33.40	85.0	0.8462	7.229	25.437	66.00	4289.4	3629.9	510	0.61	0.510	4.943					SLOP_S							
1B_P	D	UL	sw	1.025	0.00	0.9220	5.245	30.298	0.00	31458.3	29005.5	0	0.00	0.000	3.029	-14.341	0.0	3734.5	-14.341	1B_P		298.0	33.70	13.00	330.0	15.00	0.00
1B_S	H	UL	sw	1.025	0.00				0.00			0	-26.03	0.000	-26.027					1B_S							
2B_P	H	UL	sw	1.025	0.00				0.00			0	-27.00	0.000	-26.997					2B_P							
2B_S	H	UL	sw	1.025	0.00				0.00			0	-25.65	0.000	-25.654					2B_S							
3B_P	H	UL	sw	1.025	0.00				0.00			0	-26.81	0.000	-26.810					3B_P							
3B_S	H	UL	sw	1.025	0.00				0.00			0	-25.28	0.000	-25.281					3B_S							
4B_P	H	UL	sw	1.025	0.00				0.00			0	-26.44	0.000	-26.438					4B_P							
4B_S	H	UL	sw	1.025	0.00				0.00			0	-24.91	0.000	-24.908					4B_S							
5B_P	H	UL	sw	1.025	0.00				0.00			0	-25.54	0.000	-25.535					5B_P							
5B_S	H	UL	sw	1.025	0.00				0.00			0	-24.54	0.000	-24.536					5B_S							
AP	H	UL	sw	1.025	0.00				0.00			0	-10.39	0.000	-10.389					AP							
FP	H	UL	sw	1.025	0.00				0.00			0	-26.15	0.000	-26.151					FP							
1FO_P	P	UL	f1	0.988	30.00	0.9774	2.694	23.459	91.00	3461.3	3383.1	0	7.46	0.000	8.205					1FO_P							
1FO_S	P	UL	f1	0.988	30.00	0.9774	1.603	24.459	95.00	4337.0	4239.1	0	10.01	0.000	10.687					1FO_S							
2FO_P	P	UL	f1	0.988	30.00	0.9774	1.758	14.080	91.00	1241.9	1213.8	0	4.48	0.000	4.933					2FO_P							
2FO_S	P	UL	f1	0.988	30.00	0.9774	0.690	14.234	95.00	842.1	823.1	0	7.20	0.000	7.550					2FO_S							
3FO_P	P	UL	f1	0.988	30.00	0.9774	1.436	12.302	91.00	603.5	589.9	0	4.98	0.000	5.338					3FO_P							
3FO_S	P	UL	f1	0.988	30.00	0.9774	0.683	12.842	95.00	630.0	615.8	0	7.23	0.000	7.522					3FO_S							
FOSRVSTP	P	UL	f1	0.988	30.00	0.9774	7.536	11.782	90.94	250.2	244.5	0	2.09	0.000	2.548					FOSRVSTP							
FO_SET_P	P	UL	f1	0.988	30.00	0.9774	7.863	11.780	90.94	250.2	244.5	0	2.06	0.000	2.519					FO_SET_P							
FO_SRV_P	P	UL	f1	0.988	30.00	0.9774	7.506	11.824	90.94	190.9	186.6	0	2.15	0.000	2.606					FO_SRV_P							
DO_SET_S	W	UL	do	0.850	0.00	0.8500	6.095	1.754	87.47	23.5	20.0	0	2.18	0.000	2.126					DO_SET_S							
DO_SRV_S	W	UL	do	0.850	0.00	0.8500	2.594	5.270	87.58	70.6	60.0	0	5.65	0.000	5.602					DO_SRV_S							

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DWT     452,066    10,505  above Sdwt   DRAFTMID  24.989   AL  137,818.6 TOV  136,219.9 GSV  116,627 MT   HYDROLOSS          0   GRNDx      0.00   LOWx   268.97   DRAFT MARKS
CARGO   410,655    TPC           230.1  DRAFT_AP  23.825   AM  150,514.0 TOV  148,482.0 GSV  129,162 MT   EXCHGLOSS      3,735   GRNDy      0.00   LOWy    30.76   AFT S  23.066
BLLST    29,506    MTC           5,935  DRAFT_FP  26.153   AH  189,008.9 TOV  186,135.9 GSV  164,866 MT   GRNDFORCE          0   LCB      197.33   LCG    197.30   AFT P  24.839
BFO      11,541    Wetted       37,644  TRIM aft-  2.327                                                  DISPLACMNT   519,989   TCB        0.74   TCG      0.46   MID S  23.280
OTHER       365    SEA SG       1.0250  HEEL stbd+ -2.783                                                 MAX SHEAR     -9,880   VCB       13.08   VCG     18.80   MID P  26.585
MAX % Shear          48.2% at FR115     Prop_Imm  12.105                                                  MAX MOM.    -575,019   LOW PT   -27.01   DEPTH  100.00   FWD S  25.196
MAX % Moment        -59.1% at FR110     GM_corr    8.644                                                  MAX HOG       -0.163   MIN_FLOOD 7.20 at 2FOP_VENT      FWD P  26.922
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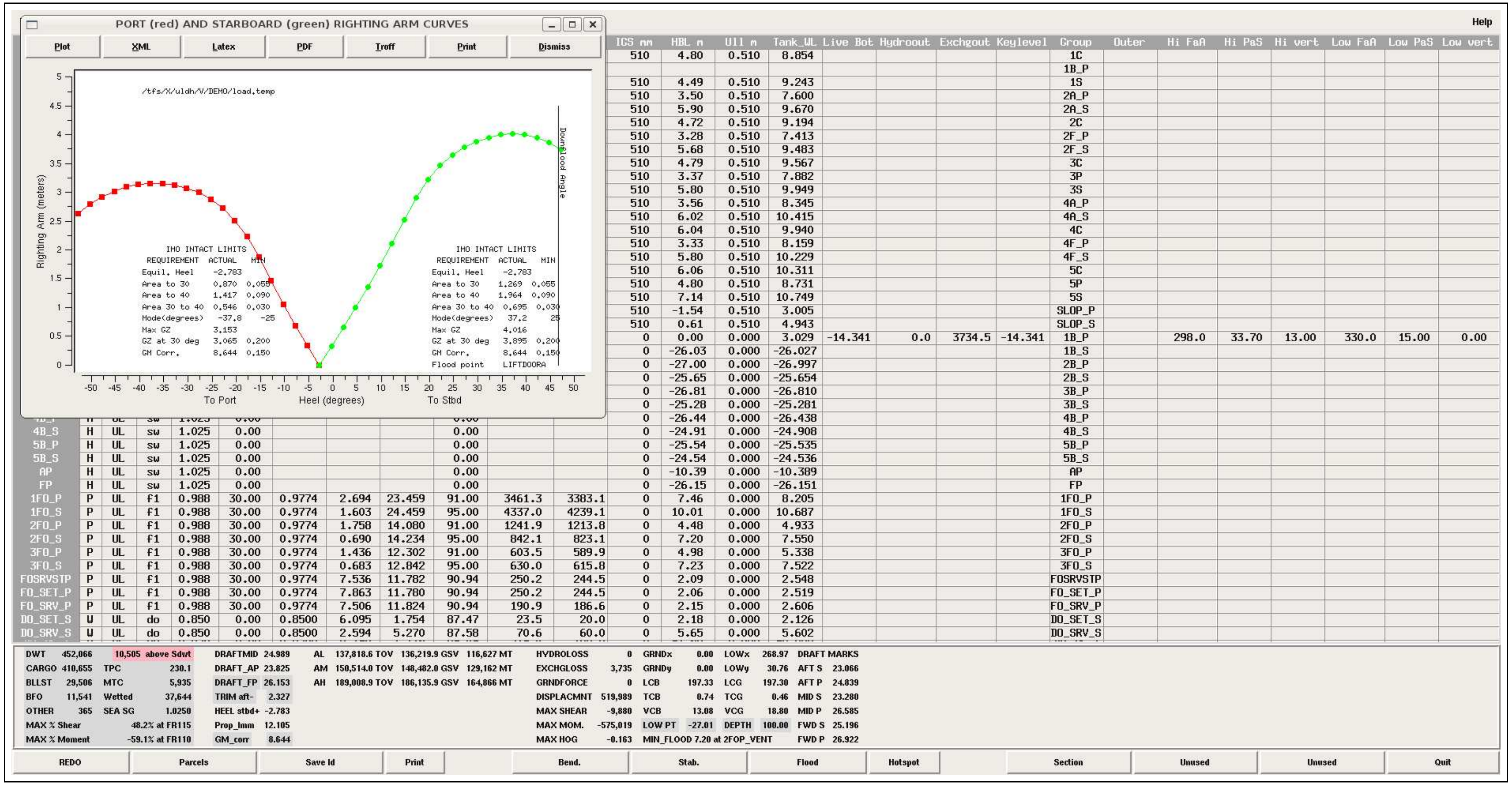
Figure 2: Damage to 1B_P up to 13 m. 1P grouped with 1B_P. Crew does nothing.



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IMO INTACT LIMITS
REQUIREMENT    ACTUAL   MIN
Equil. Heel     -2.783
Area to 30      0.870   0.055
Area to 40      1.417   0.090
Area 30 to 40   0.546   0.030
Mode(degrees)   -37.8    -25
Max GZ          3.153
GZ at 30 deg    3.065   0.200
GM Corr.        8.644   0.150
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IMO INTACT LIMITS
REQUIREMENT    ACTUAL   MIN
Equil. Heel     -2.783
Area to 30      1.269   0.055
Area to 40      1.964   0.090
Area 30 to 40   0.695   0.030
Mode(degrees)    37.2     25
Max GZ          4.016
GZ at 30 deg    3.895   0.200
GM Corr.        8.644   0.150
Flood point     LIFTDOORA
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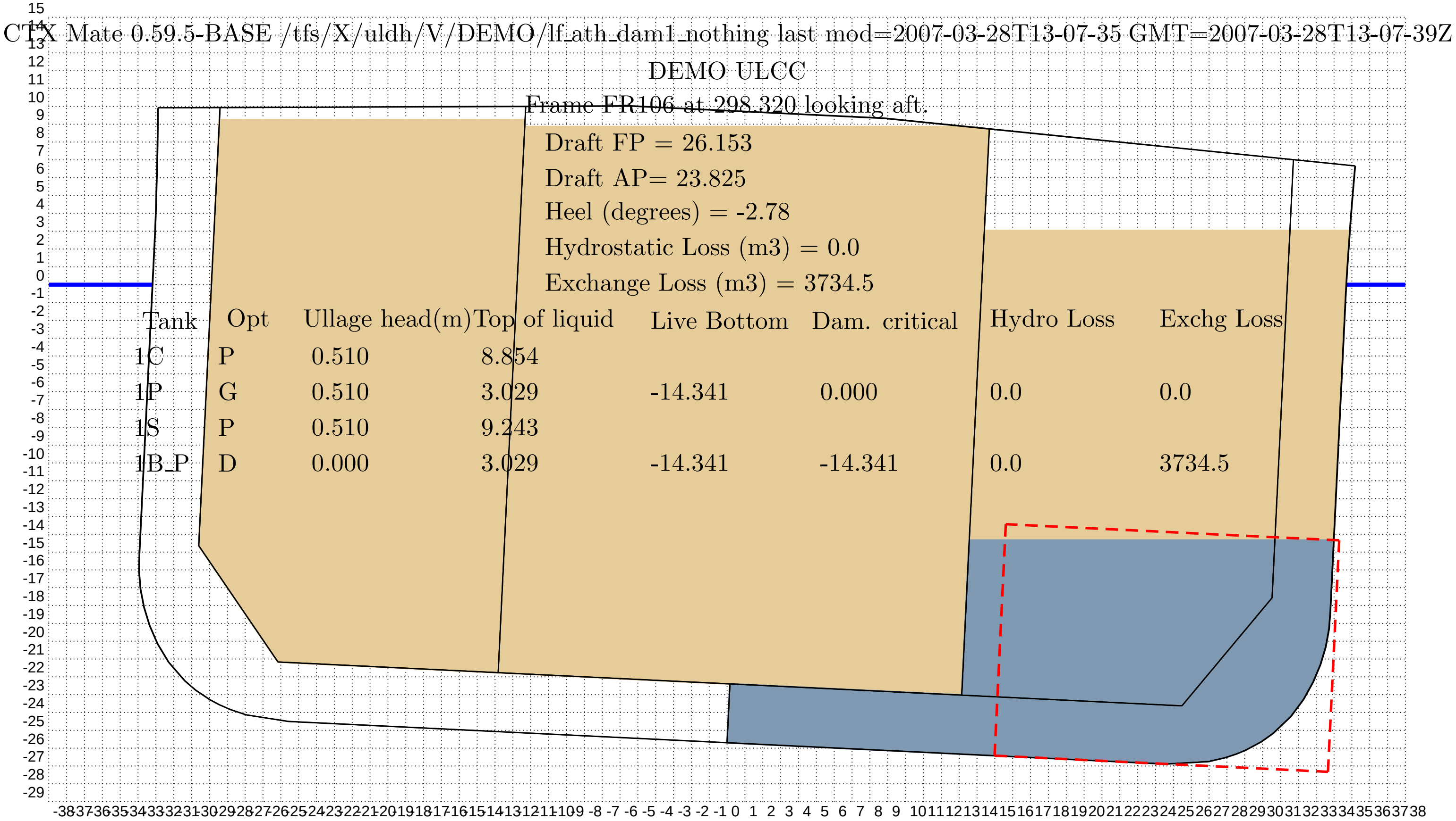
4B_S	H	UL	sw	1.025	0.00				0.00		
5B_P	H	UL	sw	1.025	0.00				0.00		
5B_S	H	UL	sw	1.025	0.00				0.00		
AP	H	UL	sw	1.025	0.00				0.00		
FP	H	UL	sw	1.025	0.00				0.00		
1FO_P	P	UL	f1	0.988	30.00	0.9774	2.694	23.459	91.00	3461.3	3383.1
1FO_S	P	UL	f1	0.988	30.00	0.9774	1.603	24.459	95.00	4337.0	4239.1
2FO_P	P	UL	f1	0.988	30.00	0.9774	1.758	14.080	91.00	1241.9	1213.8
2FO_S	P	UL	f1	0.988	30.00	0.9774	0.690	14.234	95.00	842.1	823.1
3FO_P	P	UL	f1	0.988	30.00	0.9774	1.436	12.302	91.00	603.5	589.9
3FO_S	P	UL	f1	0.988	30.00	0.9774	0.683	12.842	95.00	630.0	615.8
FOSRVSTP	P	UL	f1	0.988	30.00	0.9774	7.536	11.782	90.94	250.2	244.5
FO_SET_P	P	UL	f1	0.988	30.00	0.9774	7.863	11.780	90.94	250.2	244.5
FO_SRV_P	P	UL	f1	0.988	30.00	0.9774	7.506	11.824	90.94	190.9	186.6
DO_SET_S	W	UL	do	0.850	0.00	0.8500	6.095	1.754	87.47	23.5	20.0
DO_SRV_S	W	UL	do	0.850	0.00	0.8500	2.594	5.270	87.58	70.6	60.0

IGS mm	HBL m	Ull m	Tank_WL	Live Bot	Hydroout	Exchgout	Keylevel	Group	Outer	Hi F&A	Hi P&S	Hi vert	Low F&A	Low P&S	Low vert
510	4.80	0.510	8.854					1C							
								1B_P							
510	4.49	0.510	9.243					1S							
510	3.50	0.510	7.600					2A_P							
510	5.90	0.510	9.670					2A_S							
510	4.72	0.510	9.194					2C							
510	3.28	0.510	7.413					2F_P							
510	5.68	0.510	9.483					2F_S							
510	4.79	0.510	9.567					3C							
510	3.37	0.510	7.882					3P							
510	5.80	0.510	9.949					3S							
510	3.56	0.510	8.345					4A_P							
510	6.02	0.510	10.415					4A_S							
510	6.04	0.510	9.940					4C							
510	3.33	0.510	8.159					4F_P							
510	5.80	0.510	10.229					4F_S							
510	6.06	0.510	10.311					5C							
510	4.80	0.510	8.731					5P							
510	7.14	0.510	10.749					5S							
510	-1.54	0.510	3.005					SLOP_P							
510	0.61	0.510	4.943					SLOP_S							
0	0.00	0.000	3.029	-14.341	0.0	3734.5	-14.341	1B_P		298.0	33.70	13.00	330.0	15.00	0.00
0	-26.03	0.000	-26.027					1B_S							
0	-27.00	0.000	-26.997					2B_P							
0	-25.65	0.000	-25.654					2B_S							
0	-26.81	0.000	-26.810					3B_P							
0	-25.28	0.000	-25.281					3B_S							
0	-26.44	0.000	-26.438					4B_P							
0	-24.91	0.000	-24.908					4B_S							
0	-25.54	0.000	-25.535					5B_P							
0	-24.54	0.000	-24.536					5B_S							
0	-10.39	0.000	-10.389					AP							
0	-26.15	0.000	-26.151					FP							
0	7.46	0.000	8.205					1FO_P							
0	10.01	0.000	10.687					1FO_S							
0	4.48	0.000	4.933					2FO_P							
0	7.20	0.000	7.550					2FO_S							
0	4.98	0.000	5.338					3FO_P							
0	7.23	0.000	7.522					3FO_S							
0	2.09	0.000	2.548					FOSRVSTP							
0	2.06	0.000	2.519					FO_SET_P							
0	2.15	0.000	2.606					FO_SRV_P							
0	2.18	0.000	2.126					DO_SET_S							
0	5.65	0.000	5.602					DO_SRV_S							

```
DWT      452,066   10,505  above Sdwt   DRAFTMID  24.989   AL  137,818.6 TOV  136,219.9 GSV  116,627 MT   HYDROLOSS         0   GRNDx   0.00   LOWx  268.97   DRAFT MARKS
CARGO    410,655   TPC          230.1   DRAFT_AP  23.825   AM  150,514.0 TOV  148,482.0 GSV  129,162 MT   EXCHGLOSS     3,735   GRNDy   0.00   LOWy   30.76   AFT S  23.066
BLLST     29,506   MTC          5,935   DRAFT_FP  26.153   AH  189,008.9 TOV  186,135.9 GSV  164,866 MT   GRNDFORCE         0   LCB   197.33   LCG   197.30   AFT P  24.839
BFO       11,541   Wetted      37,644   TRIM aft-  2.327                                                  DISPLACMNT  519,989   TCB     0.74   TCG     0.46   MID S  23.280
OTHER        365   SEA SG      1.0250   HEEL stbd+ -2.783                                                 MAX SHEAR    -9,880   VCB    13.08   VCG    18.80   MID P  26.585
MAX % Shear          48.2% at FR115     Prop_Imm  12.105                                                  MAX MOM.   -575,019   LOW PT -27.01  DEPTH  100.00   FWD S  25.196
MAX % Moment        -59.1% at FR110     GM_corr    8.644                                                  MAX HOG      -0.163   MIN_FLOOD 7.20 at 2FOP_VENT    FWD P  26.922
```

Figure 3: Damaged Righting arms.



CTX Mate 0.59.5-BASE /tfs/X/uldh/V/DEMO/lf_ath_dam1_nothing last mod=2007-03-28T13-07-35 GMT=2007-03-28T13-07-39Z

DEMO ULCC

Frame FR106 at 298.320 looking aft.

Draft FP = 26.153

Draft AP= 23.825

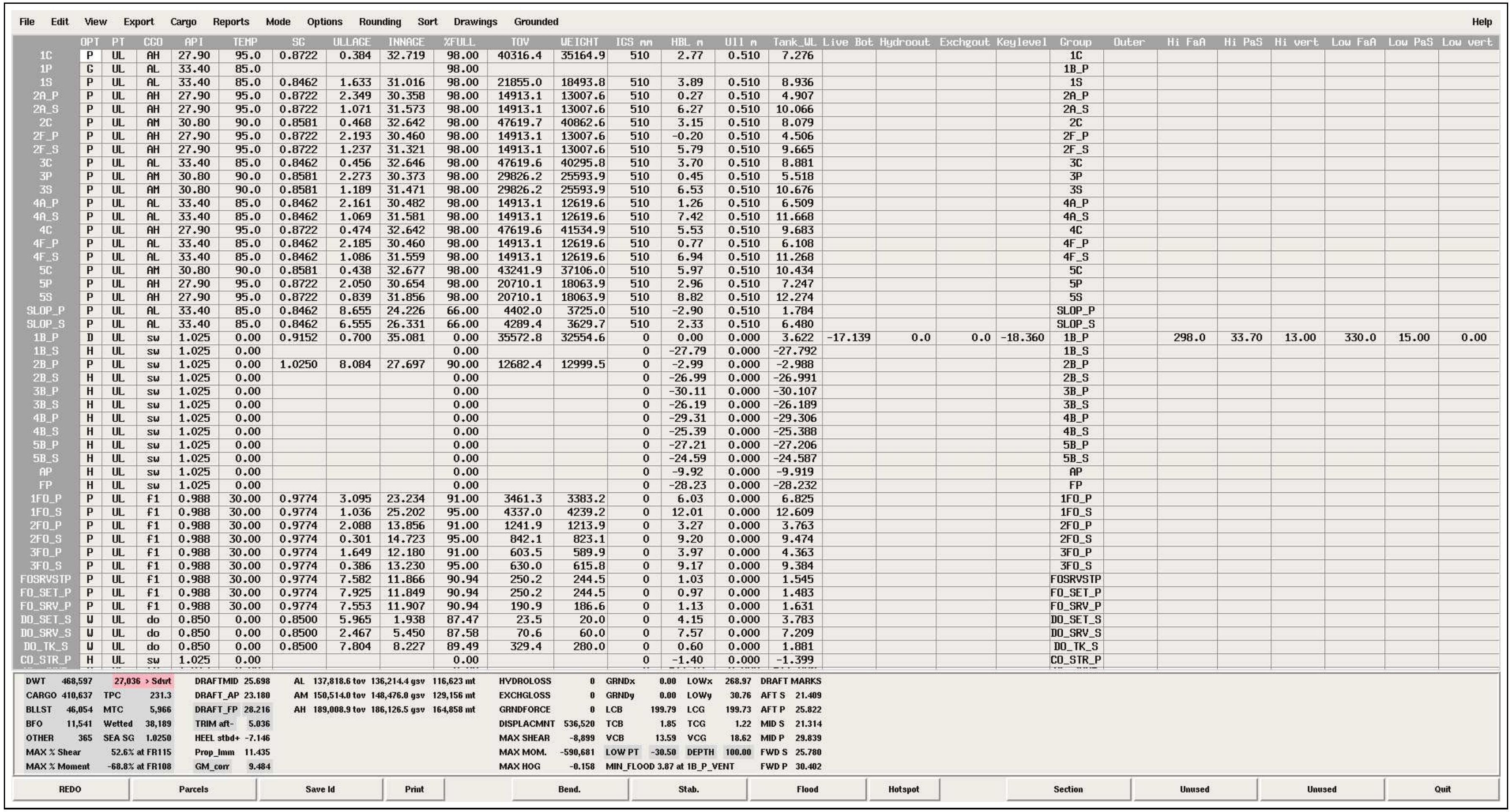
Heel (degrees) = -2.78

Hydrostatic Loss (m3) = 0.0

Exchange Loss (m3) = 3734.5

Tank	Opt	Ullage head(m)	Top of liquid	Live Bottom	Dam. critical	Hydro Loss	Exchg Loss
1C	P	0.510	8.854				
1P	G	0.510	3.029	-14.341	0.000	0.0	0.0
1S	P	0.510	9.243				
1B_P	D	0.000	3.029	-14.341	-14.341	0.0	3734.5

Figure 4: Transverse section in way of damage.



	OPT	PT	CGO	API	TEMP	SG	ULLAGE	INNAGE	%FULL	TOV	WEIGHT	ICS mm	HBL m	Ull m	Tank_WL	Live Bot	Hydroout	Exchgout	Keylevel	Group	Outer	Hi FaA	Hi PaS	Hi vert	Low FaA	Low PaS	Low vert
1C	P	UL	AH	27.90	95.0	0.8722	0.384	32.719	98.00	40316.4	35164.9	510	2.77	0.510	7.276					1C							
1P	G	UL	AL	33.40	85.0				98.00											1B_P							
1S	P	UL	AL	33.40	85.0	0.8462	1.633	31.016	98.00	21855.0	18493.8	510	3.89	0.510	8.936					1S							
2A_P	P	UL	AH	27.90	95.0	0.8722	2.349	30.358	98.00	14913.1	13007.6	510	0.27	0.510	4.907					2A_P							
2A_S	P	UL	AH	27.90	95.0	0.8722	1.071	31.573	98.00	14913.1	13007.6	510	6.27	0.510	10.066					2A_S							
2C	P	UL	AM	30.80	90.0	0.8581	0.468	32.642	98.00	47619.7	40862.6	510	3.15	0.510	8.079					2C							
2F_P	P	UL	AH	27.90	95.0	0.8722	2.193	30.460	98.00	14913.1	13007.6	510	-0.20	0.510	4.506					2F_P							
2F_S	P	UL	AH	27.90	95.0	0.8722	1.237	31.321	98.00	14913.1	13007.6	510	5.79	0.510	9.665					2F_S							
3C	P	UL	AL	33.40	85.0	0.8462	0.456	32.646	98.00	47619.6	40295.8	510	3.70	0.510	8.881					3C							
3P	P	UL	AM	30.80	90.0	0.8581	2.273	30.373	98.00	29826.2	25593.9	510	0.45	0.510	5.518					3P							
3S	P	UL	AM	30.80	90.0	0.8581	1.189	31.471	98.00	29826.2	25593.9	510	6.53	0.510	10.676					3S							
4A_P	P	UL	AL	33.40	85.0	0.8462	2.161	30.482	98.00	14913.1	12619.6	510	1.26	0.510	6.509					4A_P							
4A_S	P	UL	AL	33.40	85.0	0.8462	1.069	31.581	98.00	14913.1	12619.6	510	7.42	0.510	11.668					4A_S							
4C	P	UL	AH	27.90	95.0	0.8722	0.474	32.642	98.00	47619.6	41534.9	510	5.53	0.510	9.683					4C							
4F_P	P	UL	AL	33.40	85.0	0.8462	2.185	30.460	98.00	14913.1	12619.6	510	0.77	0.510	6.108					4F_P							
4F_S	P	UL	AL	33.40	85.0	0.8462	1.086	31.559	98.00	14913.1	12619.6	510	6.94	0.510	11.268					4F_S							
5C	P	UL	AM	30.80	90.0	0.8581	0.438	32.677	98.00	43241.9	37106.0	510	5.97	0.510	10.434					5C							
5P	P	UL	AH	27.90	95.0	0.8722	2.050	30.654	98.00	20710.1	18063.9	510	2.96	0.510	7.247					5P							
5S	P	UL	AH	27.90	95.0	0.8722	0.839	31.856	98.00	20710.1	18063.9	510	8.82	0.510	12.274					5S							
SLOP_P	P	UL	AL	33.40	85.0	0.8462	8.655	24.226	66.00	4402.0	3725.0	510	-2.90	0.510	1.784					SLOP_P							
SLOP_S	P	UL	AL	33.40	85.0	0.8462	6.555	26.331	66.00	4289.4	3629.7	510	2.33	0.510	6.480					SLOP_S							
1B_P	D	UL	sw	1.025	0.00	0.9152	0.700	35.081	0.00	35572.8	32554.6	0	0.00	0.000	3.622	-17.139	0.0	0.0	-18.360	1B_P		298.0	33.70	13.00	330.0	15.00	0.00
1B_S	H	UL	sw	1.025	0.00				0.00			0	-27.79	0.000	-27.792					1B_S							
2B_P	P	UL	sw	1.025	0.00	1.0250	8.084	27.697	90.00	12682.4	12999.5	0	-2.99	0.000	-2.988					2B_P							
2B_S	H	UL	sw	1.025	0.00				0.00			0	-26.99	0.000	-26.991					2B_S							
3B_P	H	UL	sw	1.025	0.00				0.00			0	-30.11	0.000	-30.107					3B_P							
3B_S	H	UL	sw	1.025	0.00				0.00			0	-26.19	0.000	-26.189					3B_S							
4B_P	H	UL	sw	1.025	0.00				0.00			0	-29.31	0.000	-29.306					4B_P							
4B_S	H	UL	sw	1.025	0.00				0.00			0	-25.39	0.000	-25.388					4B_S							
5B_P	H	UL	sw	1.025	0.00				0.00			0	-27.21	0.000	-27.206					5B_P							
5B_S	H	UL	sw	1.025	0.00				0.00			0	-24.59	0.000	-24.587					5B_S							
AP	H	UL	sw	1.025	0.00				0.00			0	-9.92	0.000	-9.919					AP							
FP	H	UL	sw	1.025	0.00				0.00			0	-28.23	0.000	-28.232					FP							
1FO_P	P	UL	f1	0.988	30.00	0.9774	3.095	23.234	91.00	3461.3	3383.2	0	6.03	0.000	6.825					1FO_P							
1FO_S	P	UL	f1	0.988	30.00	0.9774	1.036	25.202	95.00	4337.0	4239.2	0	12.01	0.000	12.609					1FO_S							
2FO_P	P	UL	f1	0.988	30.00	0.9774	2.088	13.856	91.00	1241.9	1213.9	0	3.27	0.000	3.763					2FO_P							
2FO_S	P	UL	f1	0.988	30.00	0.9774	0.301	14.723	95.00	842.1	823.1	0	9.20	0.000	9.474					2FO_S							
3FO_P	P	UL	f1	0.988	30.00	0.9774	1.649	12.180	91.00	603.5	589.9	0	3.97	0.000	4.363					3FO_P							
3FO_S	P	UL	f1	0.988	30.00	0.9774	0.386	13.230	95.00	630.0	615.8	0	9.17	0.000	9.384					3FO_S							
FOSRVSTP	P	UL	f1	0.988	30.00	0.9774	7.582	11.866	90.94	250.2	244.5	0	1.03	0.000	1.545					FOSRVSTP							
FO_SET_P	P	UL	f1	0.988	30.00	0.9774	7.925	11.849	90.94	250.2	244.5	0	0.97	0.000	1.483					FO_SET_P							
FO_SRV_P	P	UL	f1	0.988	30.00	0.9774	7.553	11.907	90.94	190.9	186.6	0	1.13	0.000	1.631					FO_SRV_P							
DO_SET_S	W	UL	do	0.850	0.00	0.8500	5.965	1.938	87.47	23.5	20.0	0	4.15	0.000	3.783					DO_SET_S							
DO_SRV_S	W	UL	do	0.850	0.00	0.8500	2.467	5.450	87.58	70.6	60.0	0	7.57	0.000	7.209					DO_SRV_S							
DO_TK_S	W	UL	do	0.850	0.00	0.8500	7.804	8.227	89.49	329.4	280.0	0	0.60	0.000	1.881					DO_TK_S							
CO_STR_P	H	UL	sw	1.025	0.00				0.00			0	-1.40	0.000	-1.399					CO_STR_P							

DWT 468,597 27,036 > Sdwt
CARGO 410,637 TPC 231.3
BLLST 46,054 MTC 5,966
BFO 11,541 Wetted 38,189
OTHER 365 SEA SG 1.0250
MAX % Shear 52.6% at FR115
MAX % Moment -68.8% at FR108

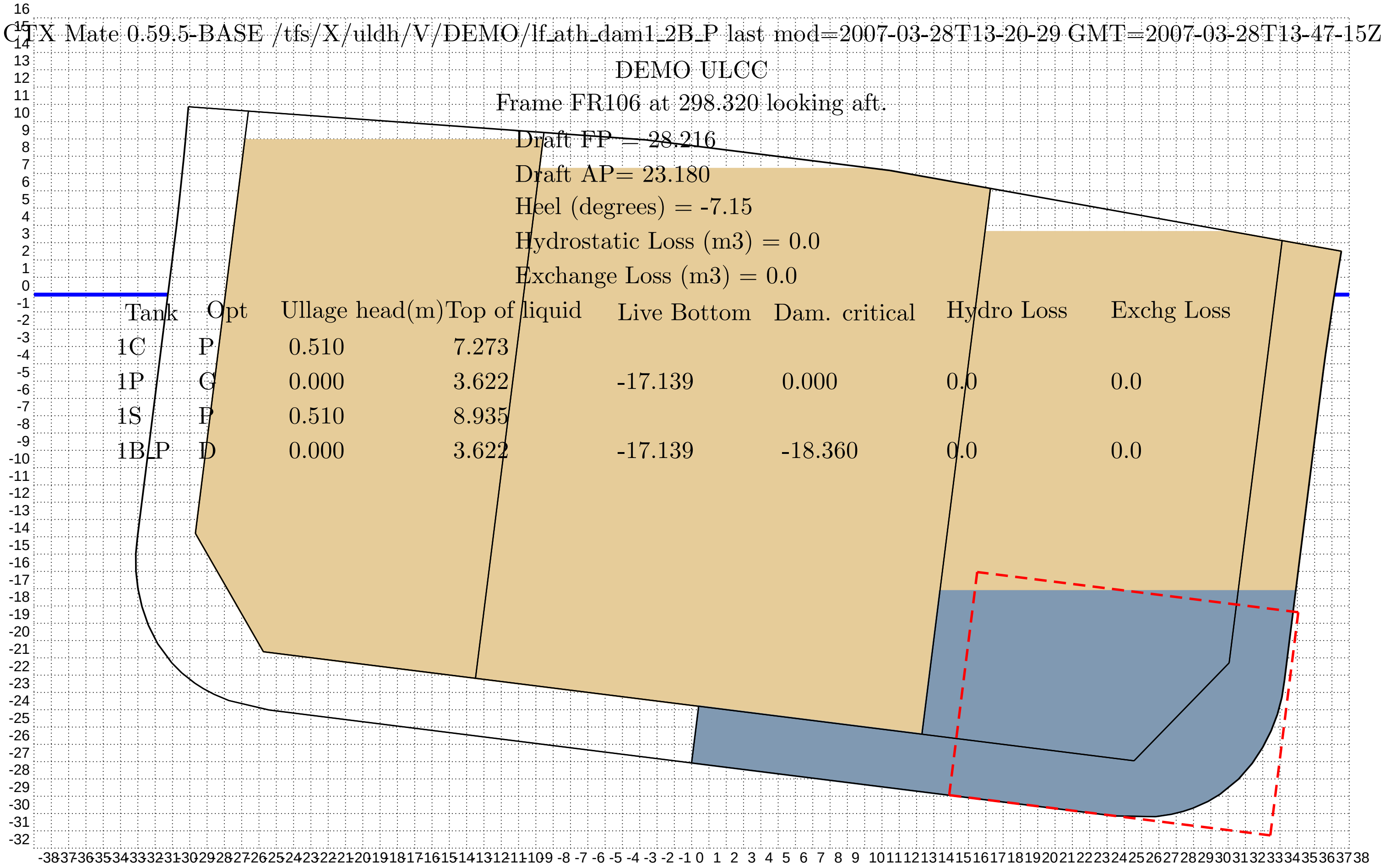
DRAFTMID 25.698
DRAFT_AP 23.180
DRAFT_FP 28.216
TRIM aft- 5.036
HEEL stbd+ -7.146
Prop_Imm 11.435
GM_corr 9.484

AL 137,818.6 tov 136,214.4 gsv 116,623 mt
AM 150,514.0 tov 148,476.0 gsv 129,156 mt
AH 189,008.9 tov 186,126.5 gsv 164,858 mt

HYDROLOSS 0 GRNDx 0.00 LOWx 268.97
EXCHGLOSS 0 GRNDy 0.00 LOWy 30.76
GRNDFORCE 0 LCB 199.79 LCG 199.73
DISPLACMNT 536,520 TCB 1.85 TCG 1.22
MAX SHEAR -8,899 VCB 13.59 VCG 18.62
MAX MOM. -590,681 LOW PT -30.50 DEPTH 100.00
MAX HOG -0.158 MIN_FLOOD 3.87 at 1B_P_VENT

DRAFT MARKS
AFT S 21.409
AFT P 25.822
MID S 21.314
MID P 29.839
FWD S 25.780
FWD P 30.402

Figure 5: Damaged per Figure 2 but 2B_P ballasted.



CTX Mate 0.59.5-BASE /tfs/X/uldh/V/DEMO/lf_ath_dam1_2B_P last mod=2007-03-28T13-20-29 GMT=2007-03-28T13-47-15Z

DEMO ULCC

Frame FR106 at 298.320 looking aft.

Draft FP = 28.216

Draft AP= 23.180

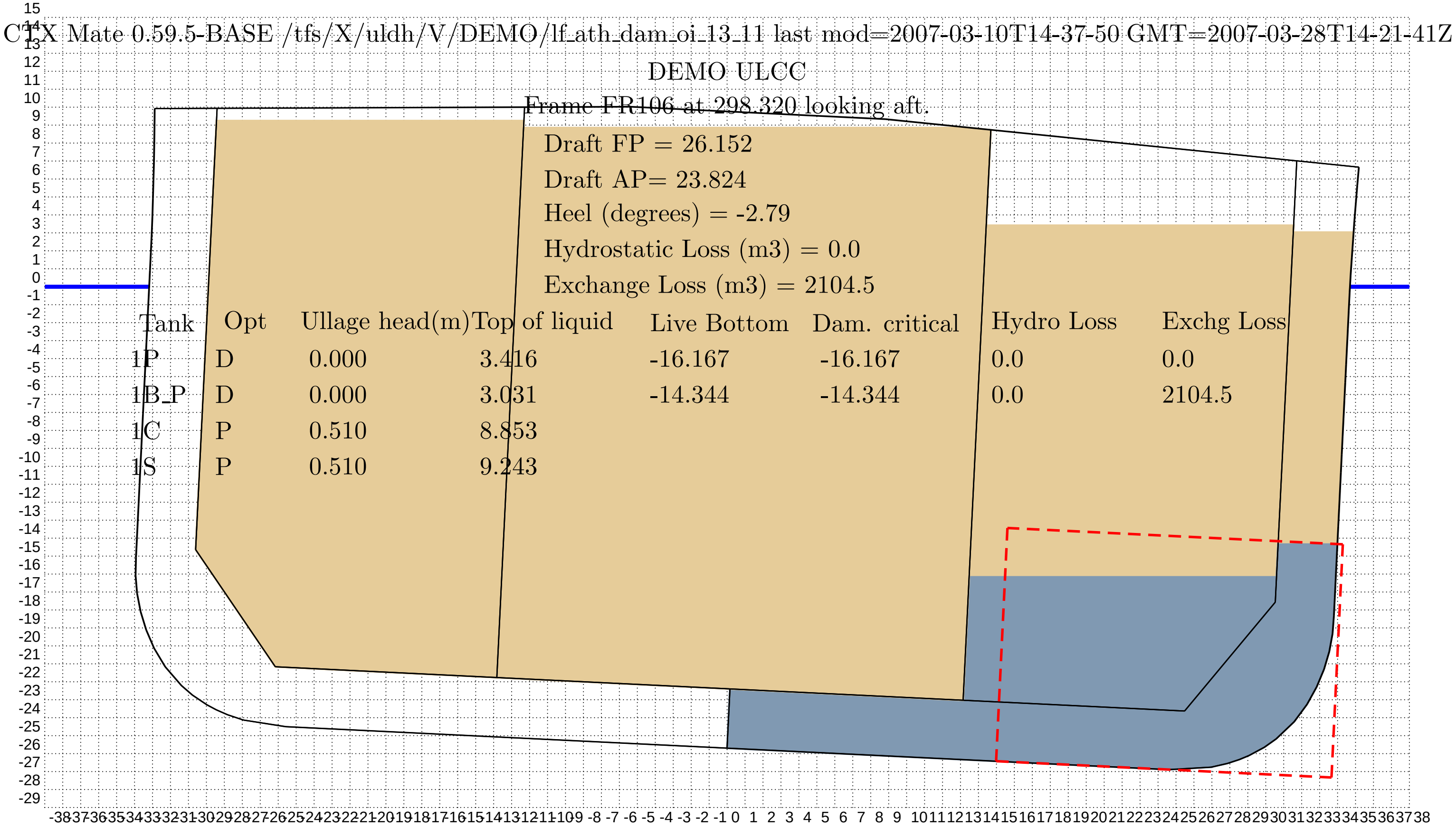
Heel (degrees) = -7.15

Hydrostatic Loss (m3) = 0.0

Exchange Loss (m3) = 0.0

Tank	Opt	Ullage head(m)	Top of liquid	Live Bottom	Dam. critical	Hydro Loss	Exchg Loss
1C	P	0.510	7.273				
1P	G	0.000	3.622	-17.139	0.000	0.0	0.0
1S	P	0.510	8.935				
1B_P	D	0.000	3.622	-17.139	-18.360	0.0	0.0

Figure 6: Section in way of damage with 2B_P ballasted.



CTX Mate 0.59.5-BASE /tfs/X/uldh/V/DEMO/lf_ath_dam_oi_13_11 last mod=2007-03-10T14-37-50 GMT=2007-03-28T14-21-41Z

DEMO ULCC

Frame FR106 at 298.320 looking aft.

Draft FP = 26.152

Draft AP= 23.824

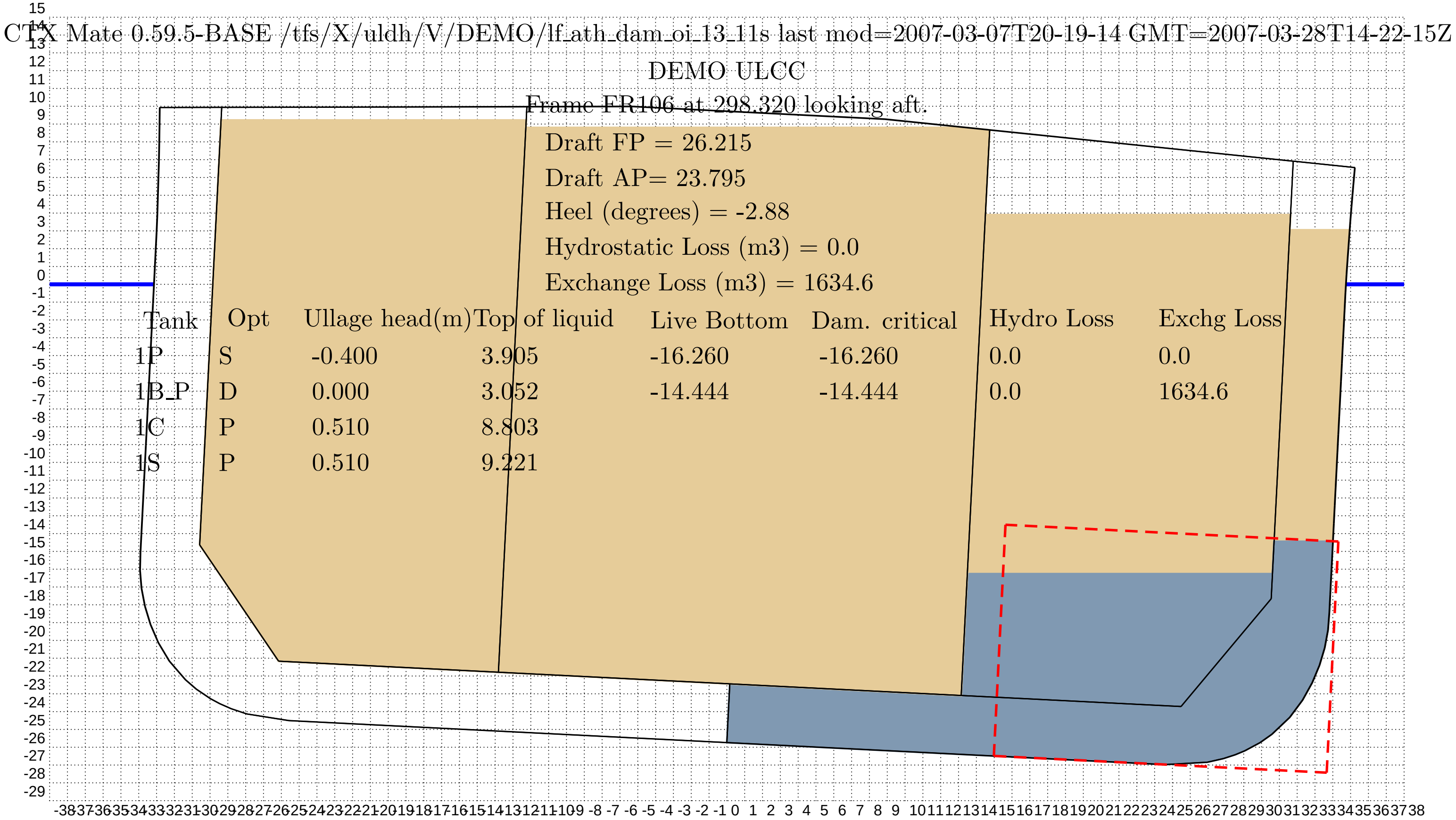
Heel (degrees) = -2.79

Hydrostatic Loss (m3) = 0.0

Exchange Loss (m3) = 2104.5

Tank	Opt	Ullage head(m)	Top of liquid	Live Bottom	Dam. critical	Hydro Loss	Exchg Loss
1P	D	0.000	3.416	-16.167	-16.167	0.0	0.0
1B_P	D	0.000	3.031	-14.344	-14.344	0.0	2104.5
1C	P	0.510	8.853				
1S	P	0.510	9.243				

Figure 7: Example of Outside In Flow, damage in 1P double side up 11 m



CTX Mate 0.59.5-BASE /tfs/X/uldh/V/DEMO/lf_ath_dam_oi_13_11s last mod=2007-03-07T20-19-14 GMT=2007-03-28T14-22-15Z

DEMO ULCC

Frame FR106 at 298.320 looking aft.

Draft FP = 26.215

Draft AP= 23.795

Heel (degrees) = -2.88

Hydrostatic Loss (m3) = 0.0

Exchange Loss (m3) = 1634.6

Tank	Opt	Ullage head(m)	Top of liquid	Live Bottom	Dam. critical	Hydro Loss	Exchg Loss
1P	S	-0.400	3.905	-16.260	-16.260	0.0	0.0
1B_P	D	0.000	3.052	-14.444	-14.444	0.0	1634.6
1C	P	0.510	8.803				
1S	P	0.510	9.221				

Figure 8: Same as Figure 7 except 1P is pulled down to -0.4m H20

```
CTX MATE 0.59.2-BASE.  Ship is CTX_VALDEZ.  Load pattern is lf_ntsb_oi_lw_fp. Last modified at 2007-03-08T15-13-13
USING API/SG .01/.0001, F/C .1/.01, VCF_4, O_INN/WEDGE, NO ALLOWABLES, STRANDED! SHIP IS NOT AFLOAT!
ntsb with 1C going to FP
ntsb damage in center tanks pretty optimistic

  TANK  |O|PT|CGO| API | TEMP|  SG  |ULLAGE|INNAGE|%FULL | VOLUME | WEIGHT |IGS_mm| HBL_m |Ull_h m|TANK_WL|OIL/SW |HYDROOUT|EXCHGOUT|KEY_ze | GROUP  | OUTER  |high_xs|high_ys|high_zs|low_xs |low_ys |low_zs |

1C      |D|UL|PB| 26.20|35.00|0.8865|13.135|16.203| 83.24| 14825.5| 13142.7|     0|  0.000|  0.000|  2.176|-13.414|     0.0|   241.8|-13.414|1C      |FP      |236.100|-12.100|  1.000|274.500|  0.000|  0.000|
2C      |D|UL|PB| 26.20|35.00|0.8870|13.135|16.203| 83.24| 19301.5| 17121.2|     0|  0.000|  0.000|  2.176|-13.414|     0.0|     0.0|-13.414|2C      |2S      |186.500|-12.100|  1.000|236.100|  0.000|  0.000|
3C      |D|UL|PB| 26.20|35.00|0.9052|13.459|15.879| 83.24| 20630.5| 18674.6|     0|  0.000|  0.000|  1.852|-11.416|  6734.6|  3354.2|-11.416|3C      |3S      |132.400|-12.100|  3.000|186.500|  0.000|  0.000|
1P      |P|UL|PB| 26.20|35.00|0.8820| 5.528|22.961| 83.24|  7380.7|  6509.4|     0|  7.381|  0.000|  9.582|       |        |        |       |1P      |        |       |       |       |       |       |       |
1S      |D|UL|PB| 26.20|35.00|0.8978|11.943|16.546| 83.24|  5101.1|  4580.0|     0|  0.000|  0.000|  1.873|-11.549|  2279.6|   567.3|-11.549|1S      |        |236.100|-24.500|  3.300|274.500|-12.100|  0.000|
2P      |E|UL|sw|1.0250|     |      |28.065|-0.196|  0.00|     0.0|     0.0|     0|-13.569|  0.000|-13.569|       |        |        |       |2P      |        |       |       |       |       |       |       |
2S      |D|UL|sw|1.0250|     |0.9188|11.524|16.345|  0.00| 10431.6|  9585.0|     0|  0.000|  0.000|  1.667|-10.277|     0.0|  1654.7|-10.277|2S      |        |186.500|-25.300|  4.600|236.100|-12.100|  0.000|
3P      |P|UL|PB| 26.20|35.00|0.8820| 5.481|22.356| 83.24| 15811.4| 13944.9|     0|  6.782|  0.000|  8.983|       |        |        |       |3P      |        |       |       |       |       |       |       |
3S      |D|UL|PB| 26.20|35.00|0.9054|11.232|16.605| 83.24| 11726.5| 10617.1|     0|  0.000|  0.000|  1.927|-11.876|  7268.4|  1922.8|-11.876|3S      |        |132.400|-25.300|  3.000|186.500|-12.100|  0.000|
4C      |D|UL|PB| 26.20|35.00|0.8870|13.135|16.203| 83.24| 11440.8| 10148.5|     0|  0.000|  0.000|  2.176|-13.414|     0.0|     0.0|-13.414|4C      |4S      |103.000|-12.100|  1.000|132.400|  0.000|  0.000|
4P      |E|UL|sw|1.0250|     |      |28.033|-0.196|  0.00|     0.0|     0.0|     0|-13.569|  0.000|-13.569|       |        |        |       |4P      |        |       |       |       |       |       |       |
4S      |D|UL|sw|1.0250|     |0.8994|11.142|16.695|  0.00|  6342.1|  5703.9|     0|  0.000|  0.000|  2.017|-12.431|     0.0|     0.0|-14.414|4S      |        |103.000|-15.000|  0.000|132.400|-12.100|  0.000|
5C      |D|UL|PB| 26.20|35.00|0.8827|13.041|16.297| 83.24| 20794.7| 18355.2|     0|  0.000|  0.000|  2.270|-13.991|  7450.4|   109.4|-13.991|5C      |5S      | 69.200|-12.100|  0.200|103.000|  0.000|  0.000|
5P      |P|UL|PB| 26.20|35.00|0.8820| 5.101|22.736| 83.24|  9039.7|  7972.6|     0|  7.163|  0.000|  9.364|       |        |        |       |5P      |        |       |       |       |       |       |       |
5S      |D|UL|PB| 26.20|35.00|0.8849|10.941|16.896| 83.24|  6448.1|  5705.7|     0|  0.000|  0.000|  2.218|-13.675|  4411.7|   132.2|-13.675|5S      |        | 69.200|-25.300|  1.200|103.000|-12.100|  0.000|
AP      |E|UL|sw|1.0250|     |      |19.218| 0.023|  0.00|     0.0|     0.0|     0|-13.448|  0.000|-13.448|       |        |        |       |AP      |        |       |       |       |       |       |       |
FO_P_A  |W|UL|f1|0.9800|     |0.9800|10.806| 6.168| 15.00|   155.8|   152.7|     0|  4.269|  0.000|  4.358|       |        |        |       |FO_P_A  |        |       |       |       |       |       |       |
FO_P_F  |W|UL|f1|0.9800|     |0.9800|14.633|10.552| 15.00|   525.6|   515.1|     0| -0.305|  0.000|  0.180|       |        |        |       |FO_P_F  |        |       |       |       |       |       |       |
FO_S_A  |W|UL|f1|0.9800|     |0.9800|10.671| 6.303| 15.00|   155.8|   152.7|     0|  3.219|  0.000|  3.347|       |        |        |       |FO_S_A  |        |       |       |       |       |       |       |
FO_S_F  |W|UL|f1|0.9800|     |0.9800|14.448|10.738| 15.00|   525.6|   515.1|     0| -1.442|  0.000| -0.918|       |        |        |       |FO_S_F  |        |       |       |       |       |       |       |
FP      |D|UL|sw|1.0250|     |0.8929|11.943|15.894|  0.00|  4116.9|  3676.1|     0|  0.000|  0.000|  1.868|-11.517|  2874.0|   316.4|-11.517|FP      |        |274.600|-15.000|  3.000|292.000|  0.000|  0.000|
SLOP_P  |P|UL|PB| 26.20|35.00|0.8820| 7.893|19.554| 64.97|  3232.5|  2850.9|     0|  4.489|  0.000|  6.619|       |        |        |       |SLOP_P  |        |       |       |       |       |       |       |
SLOP_S  |P|UL|PB| 26.20|35.00|0.8820| 7.886|19.560| 64.97|  3232.5|  2850.9|     0|  3.054|  0.000|  5.321|       |        |        |       |SLOP_S  |        |       |       |       |       |       |       |
POINT   | | |  |      |     |      |      |      |      |        |   500.0|      |       |       |       |       |        |        |       |        |        |118.550|  0.000| 18.510|       |       |       |

DWT     153274   59273 LT Sdwt DRAFTMID  14.000  PB  163264.4 TOV  160831.8 GSV   143989 MT HYDROLOSS   31019 GRNDxs 162.942 LOWxs -10.915   Draftmarks
CARGO   143989  TPC      129.7 DRAFT AP  14.000                                             EXCHGLOSS    8299 GRNDys  -5.318 LOWys -23.440  Aft-P CANT_DO
BLLST     4309  MTC       2464 DRAFT FP  14.000                                             GRND FORCE -17513 LCB     12.393 LCG    13.018  Aft-S CANT_DO
BFO       1336  WETTED   18764 TRIM       0.000                                             DISPLCMENT 165036 TCB     -0.516 TCG    -0.865  Mid-P CANT_DO
OTHER      500  SEA_SG  1.0250 HEEL       2.000                                             MAX SHEAR   10403 VCB      7.290 VCG     9.767  Mid-S CANT_DO
NO SHEAR FORCE ALLOWABLE!      PROP IMM   4.497                                             MAX BEND   441712 LOW_PT  -14.81 DEPTH  100.00  Fwd-P CANT_DO
NO BENDING MOMENT ALLOWABLE!   GM_corr   10.487                                             NO HULL MOI CURVE NO DOWNFLOOD POINTS!          Fwd-S CANT_DO
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Figure 9: Approximate reconstruction of Exxon Valdez damage. All tanks vented.

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CTX MATE 0.59.2-BASE.  Ship is CTX_VALDEZ.  Load pattern is lf_ntsb_oi_lw_fp_s. Last modified at 2007-03-08T15-14-39
USING API/SG .01/.0001, F/C .1/.01, VCF_4, O_INN/WEDGE, NO ALLOWABLES, STRANDED! SHIP IS NOT AFLOAT!
ntsb with 1C going to FP, all cargo tanks sealed FVT
ntsb damage in center tanks pretty optimistic

  TANK  |O|PT|CGO| API | TEMP|  SG  |ULLAGE|INNAGE|%FULL | VOLUME | WEIGHT |IGS_mm| HBL_m |Ull_h m|TANK_WL|OIL/SW |HYDROOUT|EXCHGOUT|KEY_ze | GROUP  | OUTER  |high_xs|high_ys|high_zs|low_xs |low_ys |low_zs |

1C      |S|UL|PB| 26.20|35.00|0.8856| 9.329|20.009| 83.24| 18342.9| 16244.8|     0|  0.000| -3.349|  5.982|-13.414|     0.0|     0.0|-13.414|1C      |FP      |236.100|-12.100|  1.000|274.500|  0.000|  0.000|
2C      |S|UL|PB| 26.20|35.00|0.8861| 9.343|19.995| 83.24| 23828.1| 21113.3|     0|  0.000| -3.336|  5.968|-13.414|     0.0|     0.0|-13.414|2C      |2S      |186.500|-12.100|  1.000|236.100|  0.000|  0.000|
3C      |S|UL|PB| 26.20|35.00|0.9006| 9.548|19.790| 83.24| 25723.3| 23166.2|     0|  0.000| -3.445|  5.763|-11.416|  1641.7|  3354.2|-11.416|3C      |3S      |132.400|-12.100|  3.000|186.500|  0.000|  0.000|
1P      |P|UL|PB| 26.20|35.00|0.8820| 5.528|22.961| 83.24|  7380.7|  6509.4|     0|  7.381|  0.000|  9.582|       |        |        |       |1P      |        |       |       |       |       |       |       |
1S      |S|UL|PB| 26.20|35.00|0.8947| 8.321|20.168| 83.24|  6360.9|  5691.1|     0|  0.000| -3.189|  5.495|-11.549|  1019.8|   567.3|-11.549|1S      |        |236.100|-24.500|  3.300|274.500|-12.100|  0.000|
2P      |E|UL|sw|1.0250|     |      |28.065|-0.196|  0.00|     0.0|     0.0|     0|-13.569|  0.000|-13.569|       |        |        |       |2P      |        |       |       |       |       |       |       |
2S      |D|UL|sw|1.0250|     |0.9556|12.142|15.727|  0.00| 10030.7|  9584.9|     0|  0.000|  0.000|  1.049| -6.462|     0.0|     0.0|-10.277|2S      |        |186.500|-25.300|  4.600|236.100|-12.100|  0.000|
3P      |P|UL|PB| 26.20|35.00|0.8820| 5.481|22.356| 83.24| 15811.4| 13944.9|     0|  6.782|  0.000|  8.983|       |        |        |       |3P      |        |       |       |       |       |       |       |
3S      |S|UL|PB| 26.20|35.00|0.8972| 2.357|25.480| 83.24| 18030.7| 16177.0|     0|  0.000| -7.837| 10.802|-11.876|   964.2|  1922.8|-11.876|3S      |        |132.400|-25.300|  3.000|186.500|-12.100|  0.000|
4C      |S|UL|PB| 26.20|35.00|0.8861| 9.343|19.995| 83.24| 14123.9| 12514.8|     0|  0.000| -3.336|  5.968|-13.414|     0.0|     0.0|-13.414|4C      |4S      |103.000|-12.100|  1.000|132.400|  0.000|  0.000|
4P      |E|UL|sw|1.0250|     |      |28.033|-0.196|  0.00|     0.0|     0.0|     0|-13.569|  0.000|-13.569|       |        |        |       |4P      |        |       |       |       |       |       |       |
4S      |D|UL|sw|1.0250|     |0.9558|12.115|15.722|  0.00|  5966.4|  5702.7|     0|  0.000|  0.000|  1.044| -6.433|     0.0|     0.0|-14.414|4S      |        |103.000|-15.000|  0.000|132.400|-12.100|  0.000|
5C      |S|UL|PB| 26.20|35.00|0.8825| 9.275|20.063| 83.24| 25634.7| 22623.8|     0|  0.000| -3.312|  6.035|-13.991|  2610.4|   109.4|-13.991|5C      |5S      | 69.200|-12.100|  0.200|103.000|  0.000|  0.000|
5P      |P|UL|PB| 26.20|35.00|0.8820| 5.101|22.736| 83.24|  9039.7|  7972.6|     0|  7.163|  0.000|  9.364|       |        |        |       |5P      |        |       |       |       |       |       |       |
5S      |S|UL|PB| 26.20|35.00|0.8838| 2.065|25.772| 83.24| 10386.7|  9179.3|     0|  0.000| -7.837| 11.094|-13.675|   473.1|   132.2|-13.675|5S      |        | 69.200|-25.300|  1.200|103.000|-12.100|  0.000|
AP      |E|UL|sw|1.0250|     |      |19.218| 0.023|  0.00|     0.0|     0.0|     0|-13.448|  0.000|-13.448|       |        |        |       |AP      |        |       |       |       |       |       |       |
FO_P_A  |W|UL|f1|0.9800|     |0.9800|10.806| 6.168| 15.00|   155.8|   152.7|     0|  4.269|  0.000|  4.358|       |        |        |       |FO_P_A  |        |       |       |       |       |       |       |
FO_P_F  |W|UL|f1|0.9800|     |0.9800|14.633|10.552| 15.00|   525.6|   515.1|     0| -0.305|  0.000|  0.180|       |        |        |       |FO_P_F  |        |       |       |       |       |       |       |
FO_S_A  |W|UL|f1|0.9800|     |0.9800|10.671| 6.303| 15.00|   155.8|   152.7|     0|  3.219|  0.000|  3.347|       |        |        |       |FO_S_A  |        |       |       |       |       |       |       |
FO_S_F  |W|UL|f1|0.9800|     |0.9800|14.448|10.738| 15.00|   525.6|   515.1|     0| -1.442|  0.000| -0.918|       |        |        |       |FO_S_F  |        |       |       |       |       |       |       |
FP      |D|UL|sw|1.0250|     |0.8954|12.001|15.836|  0.00|  4102.4|  3673.4|     0|  0.000|  0.000|  1.811|-11.158|     0.0|     0.0|-11.517|FP      |        |274.600|-15.000|  3.000|292.000|  0.000|  0.000|
SLOP_P  |P|UL|PB| 26.20|35.00|0.8820| 7.893|19.554| 64.97|  3232.5|  2850.9|     0|  4.489|  0.000|  6.619|       |        |        |       |SLOP_P  |        |       |       |       |       |       |       |
SLOP_S  |P|UL|PB| 26.20|35.00|0.8820| 7.886|19.560| 64.97|  3232.5|  2850.9|     0|  3.054|  0.000|  5.321|       |        |        |       |SLOP_S  |        |       |       |       |       |       |       |
POINT   | |  |  |      |     |      |      |      |      |        |   500.0|      |       |       |       |       |        |        |       |        |        |118.550|  0.000| 18.510|       |       |       |

DWT     181636   30911 LT Sdwt DRAFTMID  14.000  PB  184941.6 TOV  182186.0 GSV   163107 MT HYDROLOSS    6709 GRNDxs 158.561 LOWxs -10.915   Draftmarks
CARGO   163107  TPC      129.7 DRAFT AP  14.000                                            EXCHGLOSS    6086 GRNDys  -6.534 LOWys -23.440  Aft-P CANT_DO
BLLST    15052  MTC       2464 DRAFT FP  14.000                                            GRND FORCE -45874 LCB     12.393 LCG    12.856  Aft-S CANT_DO
BFO       1336  WETTED   18764 TRIM       0.000                                            DISPLCMENT 165036 TCB     -0.516 TCG    -1.640  Mid-P CANT_DO
OTHER      500  SEA_SG  1.0250 HEEL       2.000                                            MAX SHEAR   24591 VCB      7.290 VCG    10.978  Mid-S CANT_DO
NO SHEAR FORCE ALLOWABLE!      PROP IMM   4.497                                            MAX BEND  1128826 LOW_PT  -14.81 DEPTH  100.00  Fwd-P CANT_DO
NO BENDING MOMENT ALLOWABLE!   GM_corr    9.302                                            NO HULL MOI CURVE NO DOWNFLOOD POINTS!          Fwd-S CANT_DO
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Figure 10: Same as Figure 9 but with all cargo tanks sealed, PV low = -10m