

# 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 relevant 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 2004. 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](http://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

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 m<sup>3</sup> 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 m<sup>3</sup> 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 is 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.<sup>1</sup> 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 needs 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 that the equilibrium Live Bottom will now be 1.2

<sup>1</sup> 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.

<sup>2</sup> 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

meters above the top of the damage, Figure 6.<sup>2</sup> 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 intimately 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

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.

<sup>3</sup> 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.

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.<sup>3</sup>

## 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 spillage, such as the Coulombi Egg. In the case of the Coulombi Egg, a damaged wing cargo tank 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 m<sup>3</sup>, about 1500 m<sup>3</sup> 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 m<sup>3</sup>, a reduction of nearly 500 m<sup>3</sup> 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 m<sup>3</sup>. According to the NTSB, the actual spill was about 36,000 m<sup>3</sup>. 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 19,000 m<sup>3</sup>. In *The Tankship Tromedy* (Devaney, 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 about half 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.<sup>4</sup> 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 over half 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 in the flat calm that prevailed, so longitudinal stress is not an issue. 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, and the hull withstood the local hydrostatic pressures, she probably would have survived. Interestingly the spill would have been about 2,500 m<sup>3</sup> — 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

<sup>4</sup> 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.

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. And it can tell us nothing about local hydrostatic loadings which can be critical at high trim and list. We need to couple Mate with a finite element model. 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 program 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 masquerading as a Loading Instrument. As such, it is obvious it can be used a design tool. To facilitate 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”.

Similarly, 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 owner's 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 an 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](http://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 spent on preventing the casualty in the first place. Stronger, more maneuverable 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.

## References

- Devaney, J(2006), "The Tankship Tromedy", The Ctx Press.
- NTSB (1990), "Grounding of the U.S. Tankship Exxon Valdez on Bligh Reef, Prince William Sound, March 24, 1989", NTIS PB90916405.

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	OPT	PT	CGO	API	TEMP	SG	ULLAGE	INNAGE	%FULL	TOV	WEIGHT	Freevtr	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		
SL0P_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		
SL0P_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		
1F0_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		
1F0_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		
2F0_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		
2F0_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		
3F0_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		
3F0_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		
<b>DWT</b>	<b>441,536</b>		<b>25 below Sdwt</b>			<b>DRAFTMID</b>	<b>24.523</b>	<b>AL</b>	<b>1,004,316 TOV</b>	<b>992,626 GSV</b>	<b>135,116 MT</b>	<b>BLINDZONE</b>	<b>184</b>	<b>LOW PT</b>			<b>-24.64 DRAFT MARKS</b>		
<b>CARGO</b>	<b>429,131</b>	<b>TPC</b>		<b>230.2</b>		<b>DRAFT_AP</b>	<b>24.647</b>	<b>AM</b>	<b>946,704 TOV</b>	<b>933,886 GSV</b>	<b>129,156 MT</b>	<b>MAN_HT_ST</b>	<b>11.013</b>	<b>DEPTH</b>			<b>100.00 AFT S</b>	<b>24.648</b>	
<b>BLLST</b>	<b>0</b>	<b>MTC</b>		<b>5,951</b>		<b>DRAFT_FP</b>	<b>24.398</b>	<b>AH</b>	<b>1,188,830 TOV</b>	<b>1,170,700 GSV</b>	<b>164,858 MT</b>	<b>MAN_HT_PT</b>	<b>11.047</b>	<b>MIN_FLOOD</b>			<b>7.34 AFT P</b>	<b>24.626</b>	
<b>BFO</b>	<b>11,541</b>	<b>Wetted</b>		<b>37,305</b>		<b>TRIM aft-</b>	<b>-0.249</b>					<b>DISPLACMNT</b>	<b>509,459</b>	<b>AT</b>			<b>FR041 MID S</b>	<b>24.548</b>	
<b>OTHER</b>	<b>865</b>	<b>SEA SG</b>		<b>1.0250</b>		<b>HEEL stbd+</b>	<b>0.034</b>					<b>MAX SHEAR</b>	<b>-11,764</b>	<b>LCB</b>			<b>194.67 MID P</b>	<b>24.509</b>	
<b>MAX % Shear</b>				<b>-50.1% at FR066</b>		<b>Prop Imm</b>	<b>12.892</b>					<b>MAX MOM.</b>	<b>-864,867</b>	<b>TCB</b>			<b>-0.01 FWD S</b>	<b>24.419</b>	
<b>MAX % Moment</b>				<b>-79.3% at FR087</b>		<b>GM_corr</b>	<b>8.185</b>					<b>MAX HOG</b>	<b>-0.239</b>	<b>VCB</b>			<b>12.81 FWD P</b>	<b>24.399</b>	
<b>REDO</b>	<b>Parcels</b>			<b>Save Id</b>		<b>Print</b>		<b>Bend.</b>		<b>Stab.</b>		<b>Flood</b>		<b>Damage</b>		<b>Visual</b>	<b>Reg 25</b>	<b>Unused</b>	<b>Quit</b>

Figure 1: Typical departure full load, Normal Mode.

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	OPT	PT	CGO	API	TEMP	SC	ULLAGE	INNAGE	XFULL	TOV	WEIGHT	ICS nn	HBL n	Ull n	Tank UL	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														
1P	C	UL	AL	33.40	85.0				98.00																				
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														
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_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														
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														
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_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														
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														
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														
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														
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_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														
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														
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_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														
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														
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														
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														
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_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														
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			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														
2B_P	H	UL	sw	1.025	0.00				0.00			0	-27.00	0.000	-26.997														
2B_S	H	UL	sw	1.025	0.00				0.00			0	-25.65	0.000	-25.654														
3B_P	H	UL	sw	1.025	0.00				0.00			0	-26.81	0.000	-26.810														
3B_S	H	UL	sw	1.025	0.00				0.00			0	-25.28	0.000	-25.281														
4B_P	H	UL	sw	1.025	0.00				0.00			0	-26.44	0.000	-26.438														
4B_S	H	UL	sw	1.025	0.00				0.00			0	-24.91	0.000	-24.908														
5B_P	H	UL	sw	1.025	0.00				0.00			0	-25.54	0.000	-25.535														
5B_S	H	UL	sw	1.025	0.00				0.00			0	-24.54	0.000	-24.536														
AP	H	UL	sw	1.025	0.00				0.00			0	-10.39	0.000	-10.389														
FP	H	UL	sw	1.025	0.00				0.00			0	-26.15	0.000	-26.151														
1F0_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														
1F0_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														
2F0_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														
2F0_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														
3F0_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														
3F0_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														
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														
F0_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														
F0_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														
DD_SET_S	U	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														
DD_SRV_S	U	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														

DWT	452,066	10,505 above Sdvt	DRAFT MID	24.989	AL	137,818.8 TOV	136,219.9 GSV	116,827 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	29,508	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. limm	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		

REDO	Parcels	Save Id	Print	Bend.	Stab.	Flood	Hotspot	Section	Unused	Unused	Quit
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Figure 2: Damage to 1B\_P up to 13 m. 1P grouped with 1B\_P. Crew does nothing.

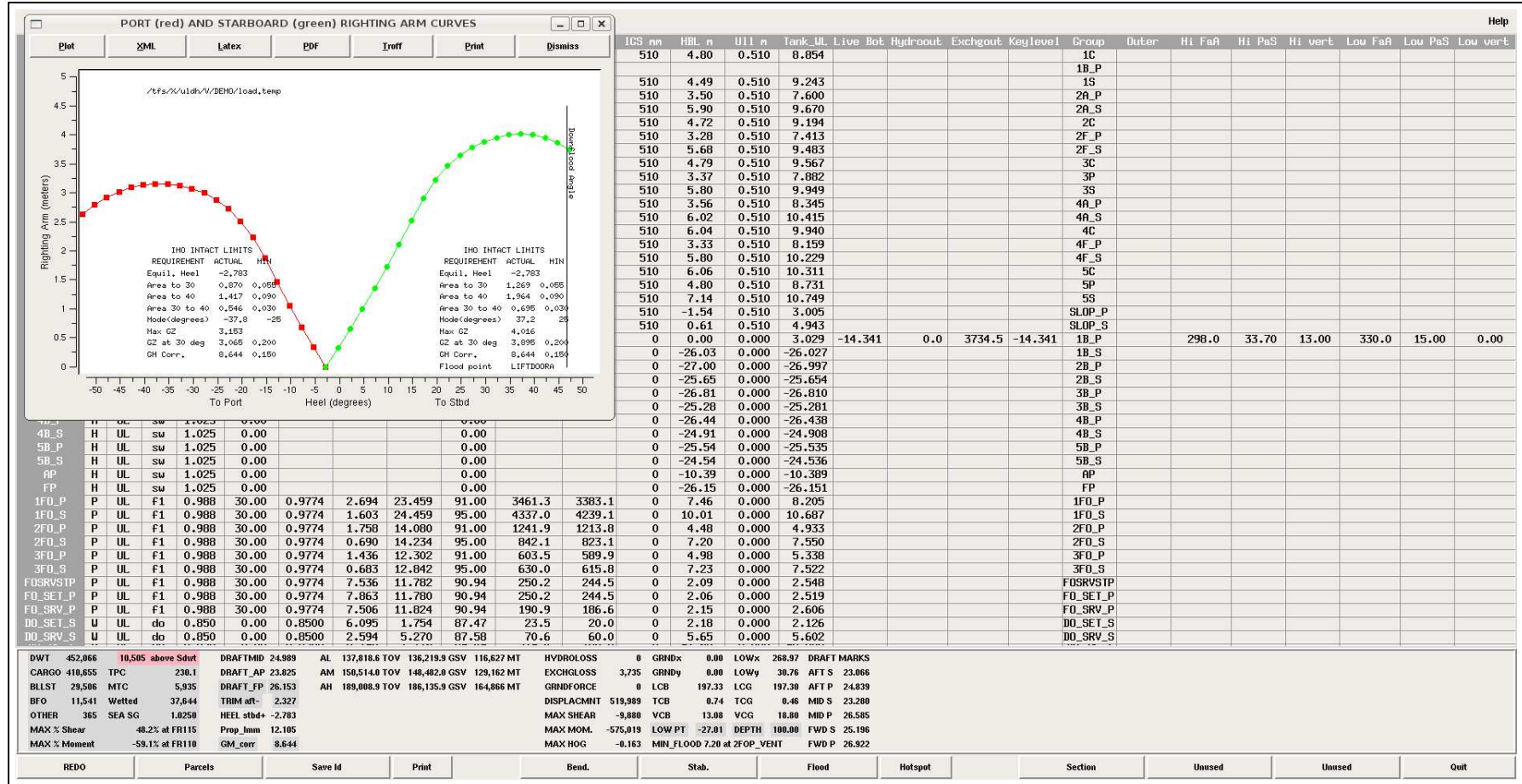


Figure 3: Damaged Righting arms.

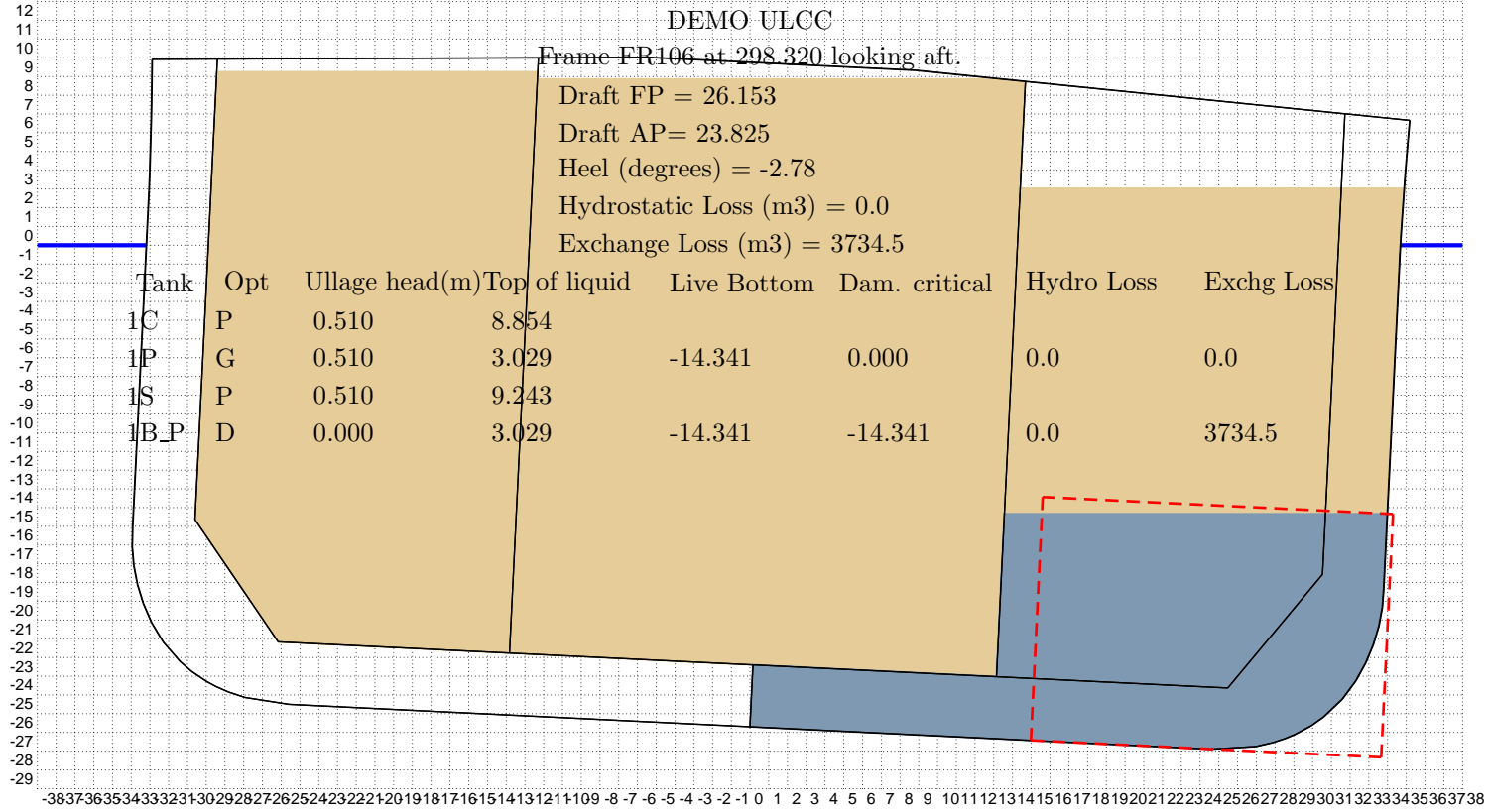


Figure 4: Transverse section in way of damage.

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	OPT	PT	CGO	API	TEMP	SC	ULLAGE	INNAGE	XFULL	TOV	WEIGHT	ICS nn	HBL n	U11 n	Tank_UL	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	0.304	32.719	98.00	40316.4	35164.9	510	2.77	0.510	7.276															
1P	C	UL	AL	33.40	85.0				98.00																					
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															
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_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															
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															
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_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															
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															
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															
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															
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_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															
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															
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_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															
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															
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															
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															
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_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															
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				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															
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_S	H	UL	sw	1.025	0.00				0.00			0	-26.99	0.000	-26.991															
3B_P	H	UL	sw	1.025	0.00				0.00			0	-30.11	0.000	-30.107															
3B_S	H	UL	sw	1.025	0.00				0.00			0	-26.19	0.000	-26.189															
4B_P	H	UL	sw	1.025	0.00				0.00			0	-29.31	0.000	-29.306															
4B_S	H	UL	sw	1.025	0.00				0.00			0	-25.39	0.000	-25.388															
5B_P	H	UL	sw	1.025	0.00				0.00			0	-27.21	0.000	-27.206															
5B_S	H	UL	sw	1.025	0.00				0.00			0	-24.59	0.000	-24.587															
AP	H	UL	sw	1.025	0.00				0.00			0	-9.92	0.000	-9.919															
FP	H	UL	sw	1.025	0.00				0.00			0	-28.23	0.000	-28.232															
1F0_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															
1F0_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															
2F0_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															
2F0_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															
3F0_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															
3F0_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															
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															
F0_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															
F0_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															
DD_SET_S	U	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															
DD_SRV_S	U	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															
DD_TK_S	U	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															
CD_STR_P	H	UL	sw	1.025	0.00				0.00			0	-1.40	0.000	-1.399															
DWT	468,597		27,036 > Sdwt			DRAFTMD	25.898	AL	137,818.6	tov	136,214.4	gsw	116,823	mt	HYDROLOSS	0	GRNDx	0.00	LOWx	268.97	DRAFT MARKS									
CARGO	410,637	TPC	231.3			DRAFT_AP	23.180	AM	150,514.0	tov	148,476.0	gsw	129,156	mt	EXCHGLOSS	0	GRNDy	0.00	LOWy	30.76	AFT S	21.409								
BLLST	46,054	MTC	5,966			DRAFT_FP	28.216	AH	189,008.9	tov	186,126.5	gsw	164,858	mt	GRNDFORCE	0	LCB	199.79	LCG	199.73	AFT P	25.822								
BFO	11,541	Wetted	38,189			TRIM aft-	5.036								DISPLACMNT	536,520	TCB	1.85	TCG	1.22	MID S	21.314								
OTHER	365	SEA SG	1,0250			HEEL stbd+	-7.146								MAX SHEAR	-8,899	VCB	13.59	VCG	18.62	MID P	29.839								
MAX % Shear			52.6%	at FR115		Prop_Lmm	11.435								MAX MOM.	-590,681	LOW PT	-30.50	DEPTH	100.00	FWD S	25.780								
MAX % Moment			-68.8%	at FR108		GM_corr	9.484								MAX HOG	-0.158	MIN_FLOOD	3.87	at 1B_P_VENT		FWD P	30.402								

Figure 5: Damaged per Figure 2 but 2B\_P ballasted.

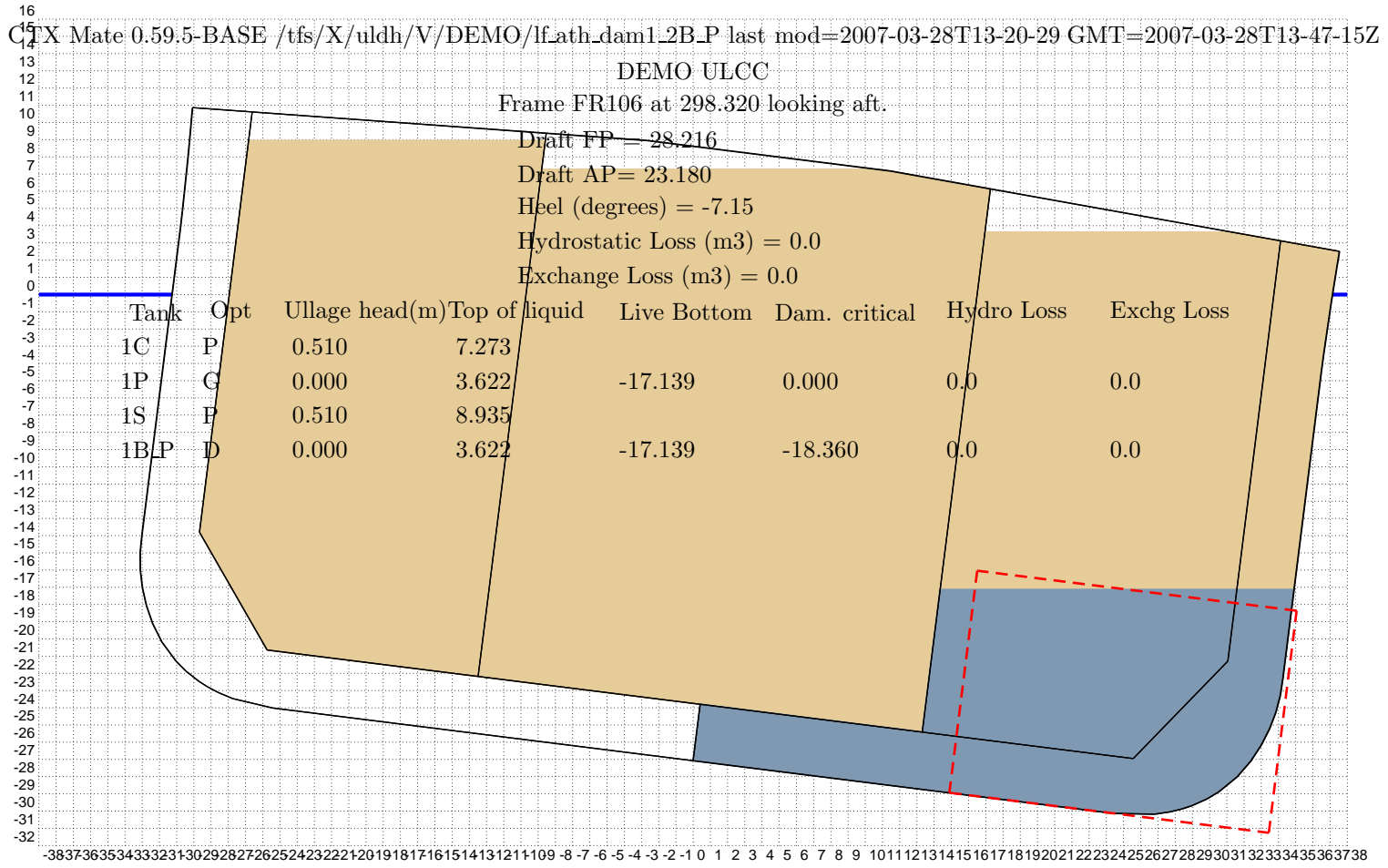


Figure 6: Section in way of damage with 2B\_P ballasted.

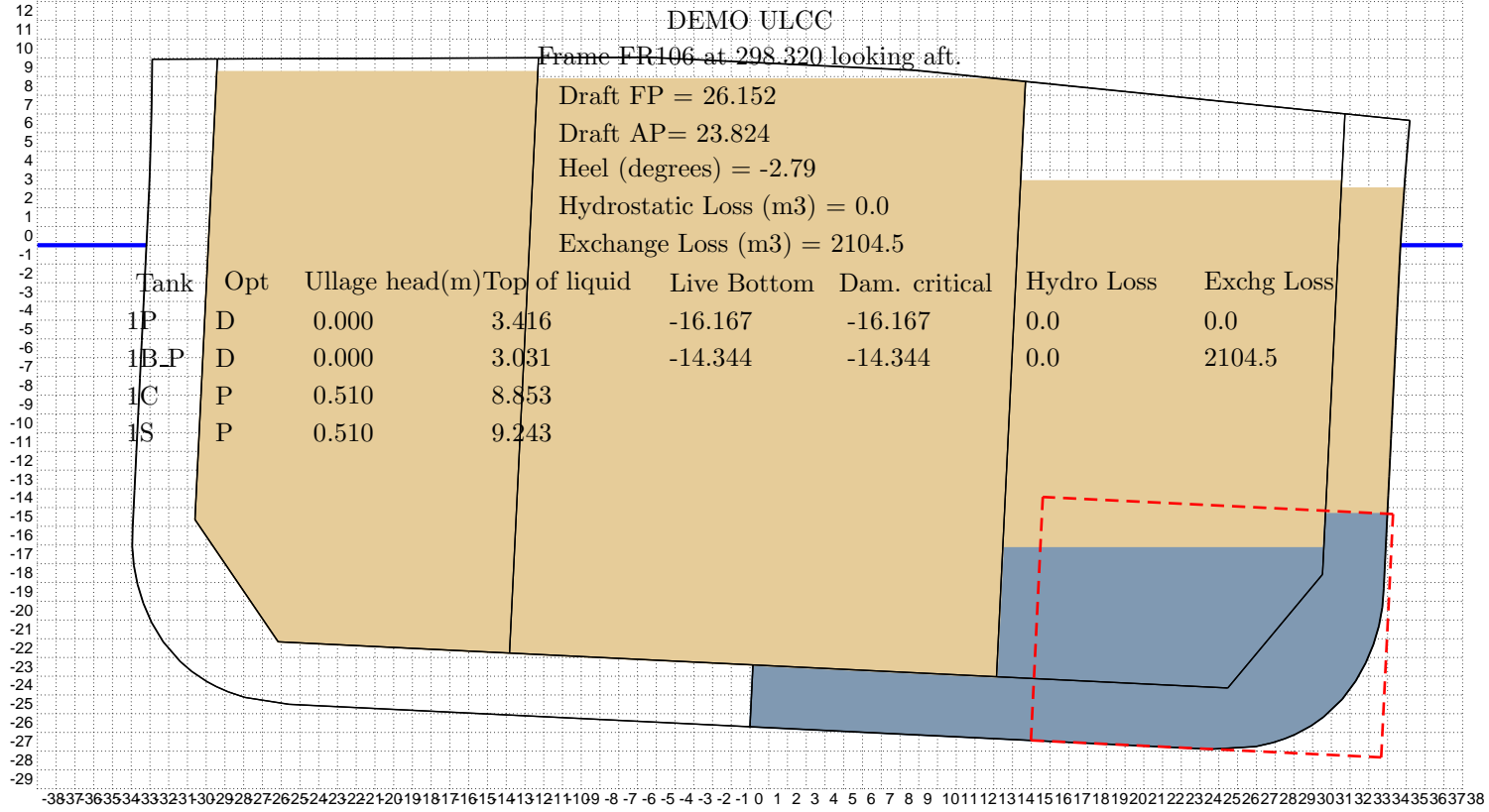


Figure 7: Example of Outside In Flow, damage in 1P double side up 11 m

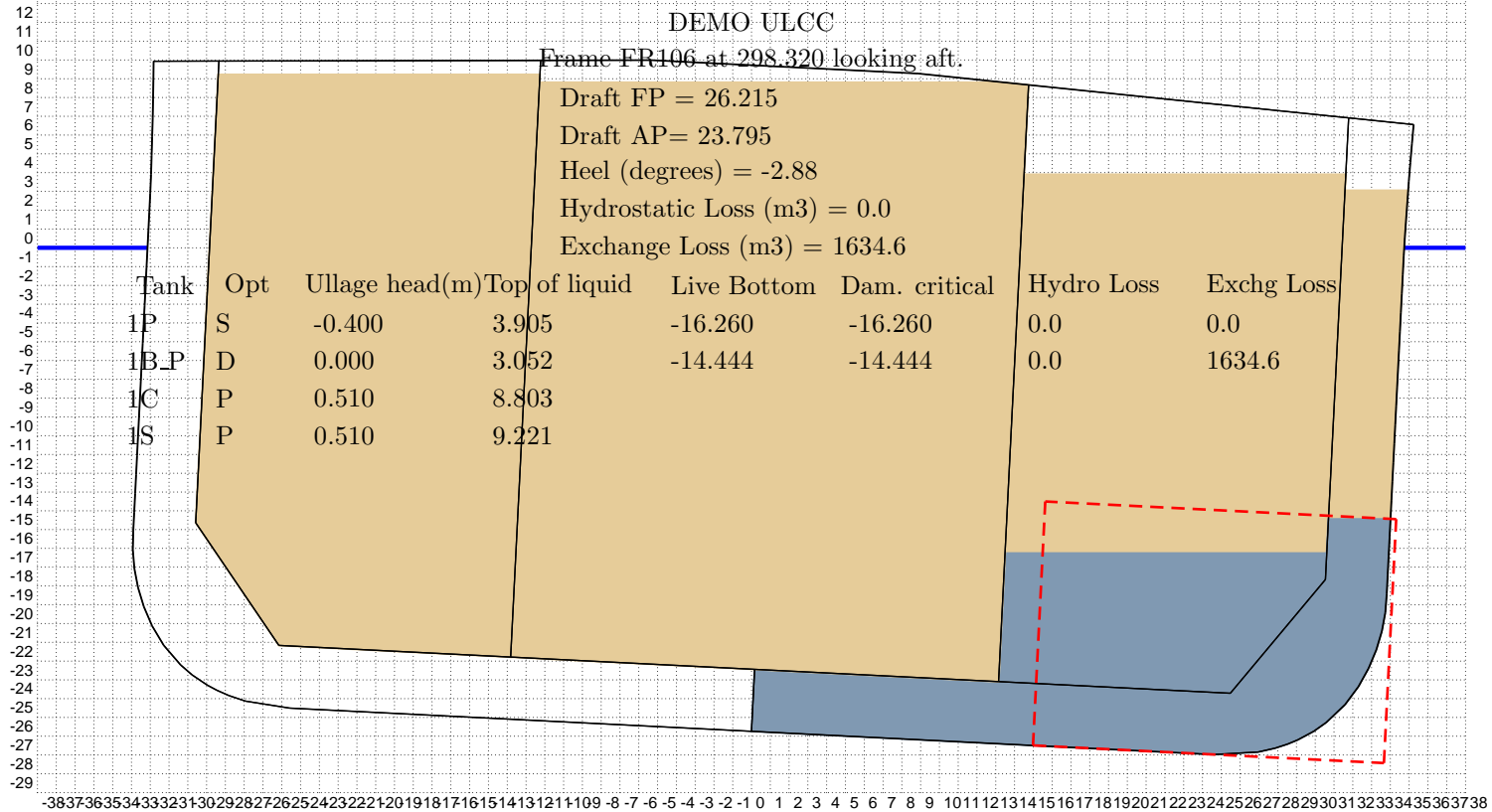


Figure 8: Same as Figure 7 except 1P is pulled down to -0.4m H2O

CTX MATE 0.71.0-BASE. Ship is CTX\_VALDEZ. Load pattern is lf\_ntsb\_oi\_lw\_fp. Last modified at 2007-08-02T11-47-37  
 USING API/SG .01/.0001, F/C .1/.01, VCF\_4, 0\_INN/WEDGE, NO ALLOWABLES, STRANDED! SHIP IS NOT AFLOAT!  
 ntsb but capture in FP, outside in  
 ntsb damage in center tanks pretty optimistic

TANK	COG	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 0.8820	13.135 16.203	83.24	14825.2	13142.7	0	0.000	0.000	2.176 -13.414	3182.2	472.7 -13.414	1C	FP	236.100 -12.100	1.000 274.500	0.000	0.000													
2C	D UL PB	26.20 35.00 0.8820	13.135 16.203	83.24	19301.2	17121.2	0	0.000	0.000	2.176 -13.414	966.6	689.0 -13.414	2C	2S	186.500 -12.100	1.000 236.100	0.000	0.000													
3C	D UL PB	26.20 35.00 0.8820	13.459 15.879	83.24	20630.1	18674.6	0	0.000	0.000	1.852 -11.416	9918.5	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 0.8979	11.943 16.546	83.24	5101.0	4580.0	0	0.000	0.000	1.873 -11.549	2279.7	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	-13.569	0.000 -13.569				2P																		
2S	D UL sw	1.0250		11.524 16.345	0.00	10431.4	9585.0	0	0.000	0.000	1.667 -10.277	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	D UL PB	26.20 35.00 0.8820	11.233 16.604	83.24	11726.3	10617.1	0	0.000	0.000	1.926 -11.876	4085.0	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 0.8820	13.135 16.203	83.24	11440.6	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	-13.569	0.000 -13.569				4P																		
4S	D UL sw	1.0250		11.142 16.695	0.00	6342.0	5703.9	0	0.000	0.000	2.017 -12.432	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 0.8820	13.041 16.297	83.24	20794.3	18355.2	0	0.000	0.000	2.269 -13.991	9270.9	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 0.8820	10.941 16.896	83.24	6448.0	5705.7	0	0.000	0.000	2.218 -13.675	2591.7	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	-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_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_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_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																			
FP	D UL sw	1.0250		1.0250 12.106	15.731	0.00	4075.4	3669.3	0	0.000	0.000	1.706 -10.517	0.0	26.8 -10.517	FP		274.600 -15.000	4.000 292.000	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	153268	59279	LT Sdwt	DRAFTMID	14.000	PB	38696.8	TOV	38120.2	GSV	34129	MT	HYDROLOSS	32295	GRNDxs	162.897	LOWxs	-10.915	Draftmarks												
CARGO	139496	TPC	129.7	DRAFT AP	14.000								EXCHGLOSS	7274	GRNDys	-5.320	LOWys	-23.440	Aft-P	CANT_DO											
BLLST	11936	MTC	2464	DRAFT FP	14.000								GRND FORCE	-17506	LCB	12.393	LCG	13.013	Aft-S	CANT_DO											
BFO	1336	WETTED	18764	TRIM	0.000								DISPLCMENT	165036	TCB	-0.516	TCG	-0.866	Mid-P	CANT_DO											
OTHER	500	SEA_SG	1.0250	HEEL	2.000								MAX SHEAR	10677	VCB	7.290	VCG	9.765	Mid-S	CANT_DO											
NO SHEAR FORCE ALLOWABLE!				PROP IMM	4.497								MAX BEND	465671	LOW_PT	-14.81	DEPTH	100.00	Fwd-P	CANT_DO											
NO BENDING MOMENT ALLOWABLE!				GM_corr	10.486								NO HULL MOI CURVE NO DOWNFLOOD POINTS!						Fwd-S	CANT_DO											

Figure 9: Approximate reconstruction of Exxon Valdez damage. All tanks vented.

CTX MATE 0.71.0-BASE. Ship is CTX\_VALDEZ. Load pattern is lf\_ntsb\_oi\_lw\_fp.s. Last modified at 2007-08-02T12-44-29  
 USING API/SG .01/0.0001, F/C .1/.01, VCF\_4, 0\_INN/WEDGE, NO ALLOWABLES, STRANDED! SHIP IS NOT AFLOAT!  
 ntsb but capture in FP, outside in, all cargo tanks sealed  
 ntsb damage in center tanks pretty optimistic

TANK	OPT	CGO	API	TEMP	SG	ULLAGE	INNAGE	%FULL	VOLUME	WEIGHT	IGS_mm	HBL_m	Ull_h	mTANK_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	0.8820	9.329	20.009	83.24	18342.6	16244.9	0	0.000	-3.349	5.981	-13.414	0.0	137.5	-13.414	1C	FP	236.100	-12.100	1.000	274.500	0.000	0.000	
2C	S	UL	PB	26.20	35.00	0.8820	9.343	19.995	83.24	23827.8	21113.5	0	0.000	-3.336	5.967	-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	0.8820	9.548	19.790	83.24	25723.0	23166.3	0	0.000	-3.445	5.763	-11.416	4825.5	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	8.322	20.168	83.24	6360.8	5691.1	0	0.000	-3.190	5.495	-11.549	1019.9	567.3	-11.549	1S		236.100	-24.500	3.300	274.500	-12.100	0.000	
2P	E	UL	sw	1.0250			128.065	-0.196	0.00	0.0	0.0	0	-13.569	0.000	-13.569					2P								
2S	D	UL	sw	1.0250			11.0250	12.142	15.727	0.00	10030.6	9584.9	0	0.000	0.000	1.049	-6.463	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	0.8820	8.023	19.814	83.24	14006.1	12627.8	0	0.000	-2.836	5.136	-11.876	1805.2	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	0.8820	9.343	19.995	83.24	14123.7	12514.9	0	0.000	-3.336	5.967	-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			128.033	-0.196	0.00	0.0	0.0	0	-13.569	0.000	-13.569					4P								
4S	D	UL	sw	1.0250			11.0250	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	0.8820	9.276	20.062	83.24	25634.4	22624.0	0	0.000	-3.312	6.035	-13.991	4430.8	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	0.8820	7.591	20.246	83.24	7934.3	7016.6	0	0.000	-2.961	5.568	-13.675	1105.4	132.2	-13.675	5S		69.200	-25.300	1.200	103.000	-12.100	0.000	
AP	E	UL	sw	1.0250			119.218	0.023	0.00	0.0	0.0	0	-13.448	0.000	-13.448					AP								
FO_P_A	W	UL	fl	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	fl	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	fl	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	fl	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			11.0250	12.106	15.731	0.00	4075.4	3669.3	0	0.000	0.000	1.706	-10.517	0.0	26.8	-10.517	FP		274.600	-15.000	4.000	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	175920	36627	LT Sdwt	DRAFT	MID	14.000	PB	38696.8	TOV	38120.2	GSV	34129	MT	HYDROLOSS	13187	GRNDzs	162.373	LOWxs	-10.915	Draftmarks								
CARGO	157252	TPC	129.7	DRAFT	AP	14.000															EXCHGLOSS	6250	GRNDys	-4.691	LOWys	-23.440	Aft-P	CANT_DO
BLLST	16833	MTC	2464	DRAFT	FP	14.000															GRND FORCE	-40159	LCB	12.393	LCG	13.556	Aft-S	CANT_DO
BFO	1336	WETTED	18764	TRIM		0.000															DISPLCMENT	165036	TCE	-0.516	TCG	-1.166	Mid-P	CANT_DO
OTHER	500	SEA_SG	1.0250	HEEL		2.000															MAX SHEAR	21937	VCE	7.290	VCG	10.649	Mid-S	CANT_DO
NO SHEAR FORCE ALLOWABLE!				PROP IMM		4.497															MAX BEND	1053230	LOW_PT	-14.81	DEPTH	100.00	Fwd-P	CANT_DO
NO BENDING MOMENT ALLOWABLE!				GM_corr		9.613															NO HULL MOI CURVE NO DOWNFLOOD POINTS!						Fwd-S	CANT_DO

Figure 10: Same as Figure 9 but with all cargo tanks sealed, PV low = -10m