The Z-Tech Concept

Peter Lim, PSA Marine (Pte) Ltd, Singapore

SYNOPSIS: As the leading provider of marine services in Asia operating in the world's busiest ports (Singapore and Hong Kong), PSA Marine has established a strong presence in Asia's maritime services industry. It has capabilities to handle a high volume and wide variety of jobs ranging from oil rigs and tankers to 5th generation container vessels and large ro-ros. To support its vision to become a more global corporation, PSA Marine has identified "design" as a critical success factor to propel its penetration into new markets. This paper introduces PSA Marine's experience in towage and pilotage services and explains what motivated the decision to invest in a new series of tug design, the way Robert Allan addressed this challenge, and describes the features of the new design.

INTRODUCTION TO PSA MARINE

Headquartered in the busiest port in the world, PSA Marine (PSAM) handles more than 120 000 vessels of all types annually. In Singapore, it is the largest towage operator, as well as the sole provider of pilotage services and also offers marine support to the offshore oil and gas industry worldwide.

A BRIEF HISTORY

PSAM grew with the development of the port of Singapore. As the shipping tonnage increased from 20.4million NRT in 1947 to 986.4 million NRT in 2003, PSAM began moved from steam engine tugs and twin-screw tugs for ship-handling in the early days to the Voith Schneidar tugs and the azimuthing stern drive(ASD) tugs in the harbour towage fleet today,.

ORIGIN OF Z-TECH – THE SINGAPORE EXPERIENCE

As the vessels calling in Singapore increase in both volume and size, PSAM is constantly seeking higher standards in ship-handling to keep ahead of the increasing sophistication and design of the vessels. Activities carried out include support for conventional dry cargo terminals, container terminals, shipyards, oil terminals, single buoy moorings (SBM) for the VLCCs as well as the handling of loaded VLCCs to the terminals. The 150 pilots and 30 z-pellar tugs in Singapore provide services to:

1. Tow barges
2. Coasters with low freeboard
3. Bunker barges and coaster tankers with very low freeboard
4. Car carriers (from coastal size to large ro-ro)
5. Conventional cargo vessels
6. Container vessels (from 2nd generation to 5th generation)
7. Bulk carriers
8. Tankers (from feeder to VLCC)
9. Oil rigs (from newly build jack ups to retrofitted FPSOs)
10. Others such as fishing vessel

With the variety of jobs handled daily, PSAM is always looking for the "ideal" tug design to improve the operational efficiency as well as the safety performance. When the need for improved equipment came up repeatedly during internal discussions, PSA Marine realised the potential to improve the functionality, usability and safety elements of its existing tug boat design. The gathering of feedback from the industry, from tug masters, pilots to tug operators both locally and internationally, further confirmed the need to renew the traditional tugboat design.

There was a split preference between the tractor style of tugs and the azimuthing stern drive (ASD) type. To achieve the best results from this revolutionary project, world-renowned naval architect, Robert Allan from Canada, was commissioned to design a tug incorporating the finest operational characteristics of both designs.

THE DEBATE – ASD AND TRACTORS

Robert Allan Ltd. was thus challenged by PSA Marine to create just such a unique "brand" of ship-handling tug for operations in Singapore and in their other ports of operation. The objective was to create a new and distinctive design that would truly represent a breakthrough in tug technology, but at the same time avoid any gimmicks that did not offer an improvement in performance and safety. The overall construction costs should also not be any higher than more conventional tugs of comparable power and size.

Robert Allan Ltd's senior staff spent several days in Singapore in early 2002, meeting with tug crews and PSA Marine's operations managers to gain a better understanding of the complete operation and their specific tug requirements. What emerged from that session was a clear understanding that some crews had a distinct preference for the tractor style of tug, while others favoured the ASD type. Since there clearly was no likelihood that either camp would change their minds, the objective was set to develop a single design that would incorporate the best features of both types. To do so required a clear understanding of how each tug type was operated and how it performed in the typical ship-handling operations. A good deal of time was therefore spent aboard both tug types observing how the crews worked these tugs within the busy port of Singapore.

Z-drive tractor tugs were generally favoured when working under large flares of container ships, especially when

inbound at speed. In this mode, the tractor tugs would typically approach the stern of the ship bow (drives) first, to avoid the skeg being impacted and pushed off by the propeller wash, then assume a running position alongside just ahead of the ships propellers on the aft quarter. The Masters would then position the (aft) working deck of the tug close under the flare so the deckhouse was as far as possible from the ship side, and in this attitude put up their towline from the aft deck, as illustrated in **Figure A.1**.

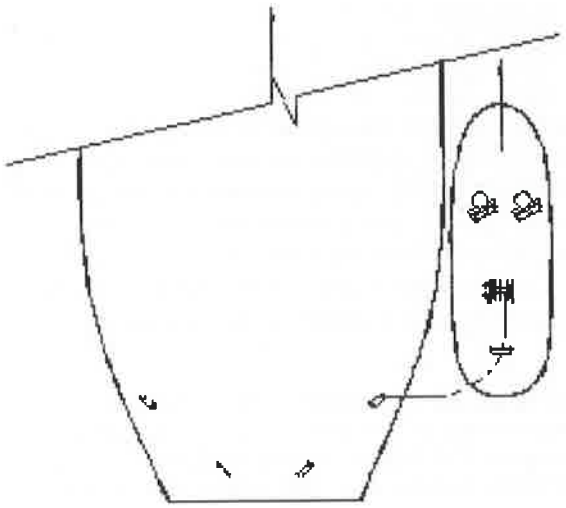

Figure A.1 – Z-tractor connecting up astern of a ship

The ASD tugs were favoured because of the overall layout and handling advantages, especially the obvious safety features with the working deck directly in front of the tug operator, with no need to look over his shoulder or turn around to see what the deck crews were doing. In addition, the ASD layout offers the distinct advantage in both construction and maintenance of fitting the drive units clear of the deckhouse where they can be installed later in the build process and withdrawn if necessary without any impact on the accommodation spaces.

Due to the poor stern geometry of many ASD tug designs, they are unable to run astern at a reasonable speed, and frequently lack directional stability going astern. Well-designed ASD tugs can perform the same function as described above for the Z-Tractor, but the genre suffers due to the many tugs of this type which are not designed to perform well running astern. Figure A.2 illustrates how a properly designed ASD tug would execute the exact same manoeuvre as a tractor tug, when connecting to the stern of a moving ship

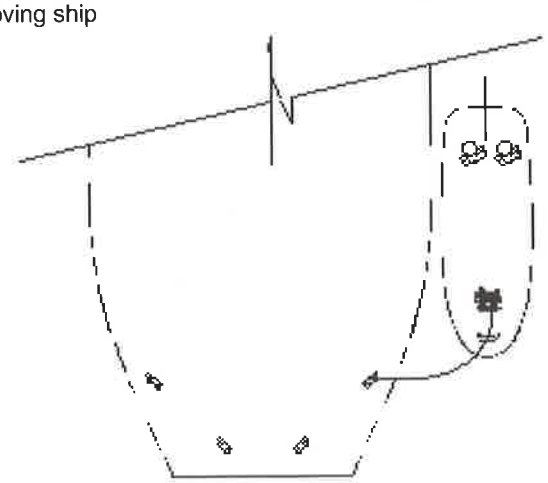

Figure A.2 A well-designed ASD tug connects astern of a ship exactly as would a Z-Tractor. Correct stern lines are critical to this operation

Another major disadvantage of some ASD designs is the strong sheer of the fore deck, which is also the primary working deck. If significant bow height is required in the tug for whatever reason, then in some cases the foredeck area can be unsafe if too steeply sloped. In many ASD designs, as illustrated in **Figure A.3**, the house is pushed well forward in order to accommodate an aft winch, which may be seldom used, but which is essential if the tug is to be suited for any towing outside of harbour. This creates a crowded and potentially unsafe forward working area, particularly if the hawser winch also incorporates anchor chain wildcats. It also puts the wheelhouse very close to the side of a ship, and at risk of damage, especially if working under flares.

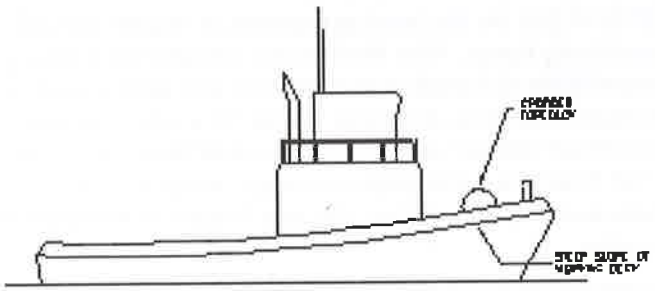

Figure A.3 Many ASD tug designs result in crowded and steeply sloped fore decks, the prime working area

Z-TECH WAS BORN

After a brief brainstorming session, senior designers from Robert Allan Ltd proposed that the different operational advantages of both tug types could be incorporated in one modified style of ASD tug, using the style of deep escort skeg developed by RAL for use on previous series of tug designs. Although in previous cases this large skeg was added solely to enhance indirect steering forces, in this instance it would also fulfil the objective of enabling steady operation in ASD tractor mode. The ***Z-Tech*** concept was born, complete with a new trademark name proposed by the architects. By simply altering the sheer line of a typical RAL-style ASD hull design, (which is generally considered to be quite unique, plagiarists aside), as illustrated in **Figure A.4**, and then pulling the deckhouse as far *aft* as possible, the new design concept at once offered the following advantages:

- The forward deck (over the skeg) has a low, flat sheer, creating a spacious, relatively flat and safe working deck, without any obstructive anchor chains etc.
- The aft deck (over the Z-drives) is reduced in size to provide just sufficient space to install or withdraw the Z-drive units. A small anchor winch is fitted on this deck, for one or two anchors (or none!) as required.
- For "sea-going" operations, the ***Z-Tech*** tug works astern in tractor mode, so the shape of this part of the hull is more rounded in plan than would typically be seen in any ASD design. (**Figure A.5**) However even with relatively flat transoms, RAL designed tugs have proven in practice to be virtually identical in performance ahead and astern, so there is no appreciable loss of BP or speed in this direction of operation. The increased flare and freeboard at the "aft" end is simply to ensure a drier operation when towing in this direction
- Only one winch is required for both harbour and coastal towing operations. When towing long distances, the tug will simply tow in tractor mode going "astern".(**Figure A.6**) In practise this is most likely to be a double-drum winch, with one drum carrying a synthetic hawser, and the other

fitted with steel wire rope.

- The low sheer forward, coupled with the aft bias of the deckhouse and wheelhouse enable the ***Z-Tech*** design to work under large overhanging ship flares (**Figure A.7**)
- A single control station (**Figure A.8**) serves both harbour ship-handling duties, (facing forward over the working deck), and transiting voyages, (facing "astern").

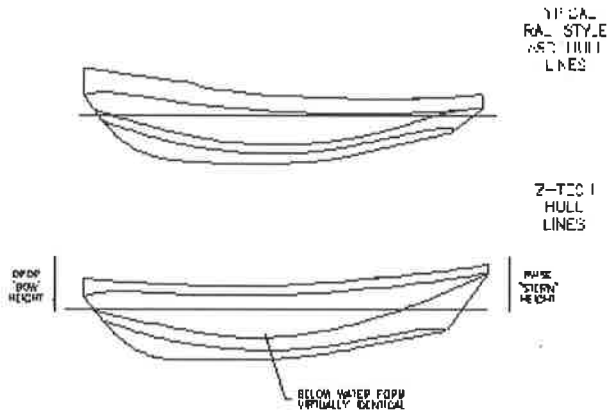

Figure A.4 Modified Sheer Line Defines the Z-Tech Concept

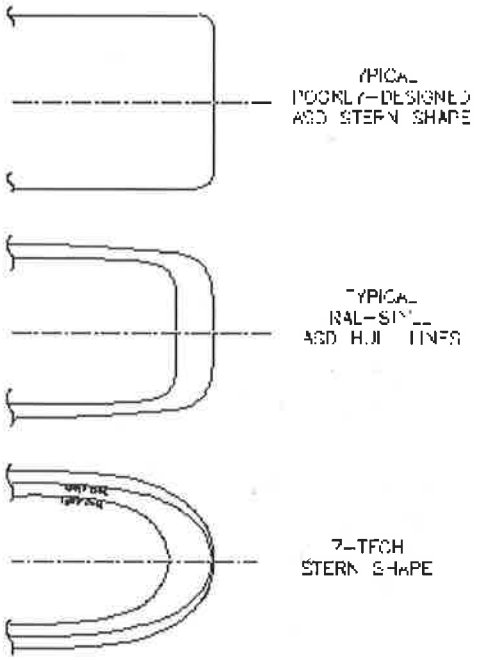

Figure A.5 A well-rounded stern with high freeboard characterises the Z-Tech "sea-going" stern

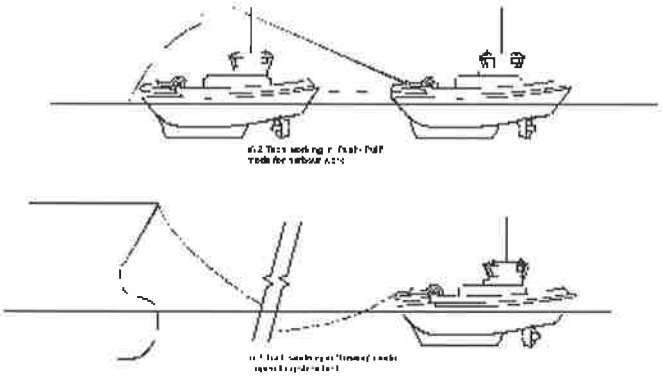

Figure A.6 A single winch serves all ship-handling and towing duties

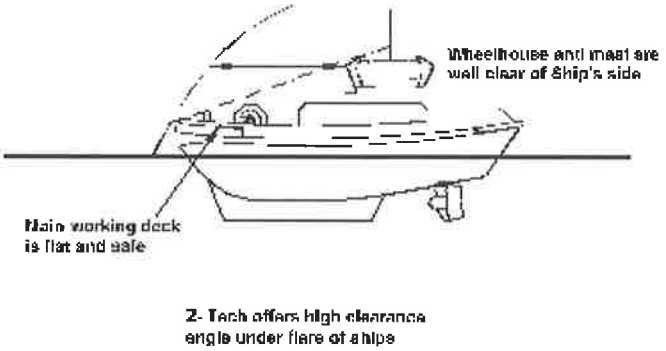

Figure A.7 Aft-ward disposition of the deckhouse and wheelhouse enables the Z-Tech to get well under ship's flares

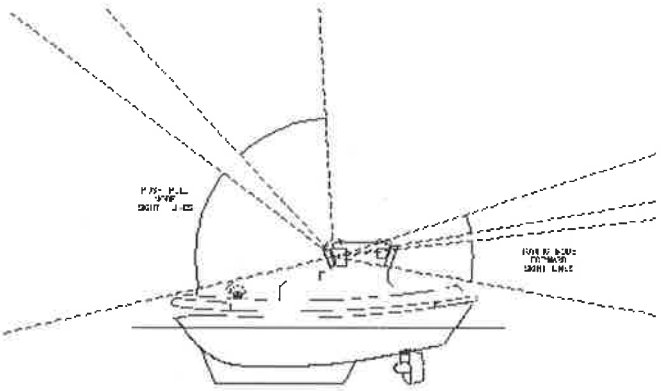

Figure A.8 A Single Control Station serves both fore and aft-facing operations, with excellent visibility in both directions

CONTRACT DESIGN EVOLUTION:

Once this basic concept was developed, the task of actually designing the first of Class commenced. After some deliberation, PSA Marine set the following basic objectives for the design:

- Bollard Pull approx.60 tonnes
- GRT ideally under 300
- Max. Length about 28m, or as appropriate to the GRT
- Beam to suit power and stability requirements
- Crew up to 7 persons, in 3 single and 2 double cabins
- Ability to work as both a harbour and coastal towing vessel

Preferences were also stated for a particular model of medium speed main engine.

With this Statement of Requirements, RAL set about to see what this new Z-tech tug might look like. After developing a basic general arrangement and lines plan, with basic dimensions of 28m x 10m x 4.75m, it quickly became evident that it would be next to impossible to achieve the 300 GRT and still have a safe and well-designed tug. The beam required to accommodate Z-drive units large enough to develop 60 tonnes BP was at least 10.5m and to achieve the

standard of stability desired by the designers for best performance, a minimum beam of 11.00m was required. To accommodate the preferred medium speed engines, which had a rather tall profile, also demanded a hull depth no less than 5m. In efforts to reduce GRT, the overall length was also reduced. It was put to PSA at this stage in the design evolution that constraining the tug to 300 GRT was not going to result in the highest possible performance as befitted the overall design objective. Therefore after a detailed review of the implications, PSA Marine agreed to drop the 300 GRT requirement.

Quickly the final dimensions of the new tug settled out at 27.4 x 11.5 x 5.0 metres.

Once more decisions were made with respect to a large double-drum main towing winch as well as other design-driving equipment, the working deck became more constrained, and a number of further modifications were introduced. After much deliberation, a decision was made to go with the initially prescribed high speed main engines, with CAT 3516 HD engines, rated 2500bhp at 1,600 rev/min being selected for installation. The end result was the contract design level General Arrangement as shown in **Figure A.9**.

PRODUCTION DESIGN AND ENGINEERING:

After tendering the design to a number of qualified shipbuilders, PSA Marine selected Cheoy Lee Shipyards of Hong Kong to build the first ***Z-Tech*** tugs. A contract for two vessels was placed in December, 2002. Robert Allan Ltd was tasked not only with completing the design for Class approval by Lloyd's Register of Shipping (LRS), but also with producing the complete production engineering package for construction of the tugs. For this purpose, the very capable software package "*ShipConstructor*", developed by Albacore Research Ltd. of Victoria, BC, Canada, was used for both all steel part definitions, and for all piping components. Figures A.10 through A.14 illustrate the full 3-D steel product model, examples of individual frame components, the full 3-D engine room piping model, the 2-D piping arrangements developed, and finally the individual piping spool pieces defined in

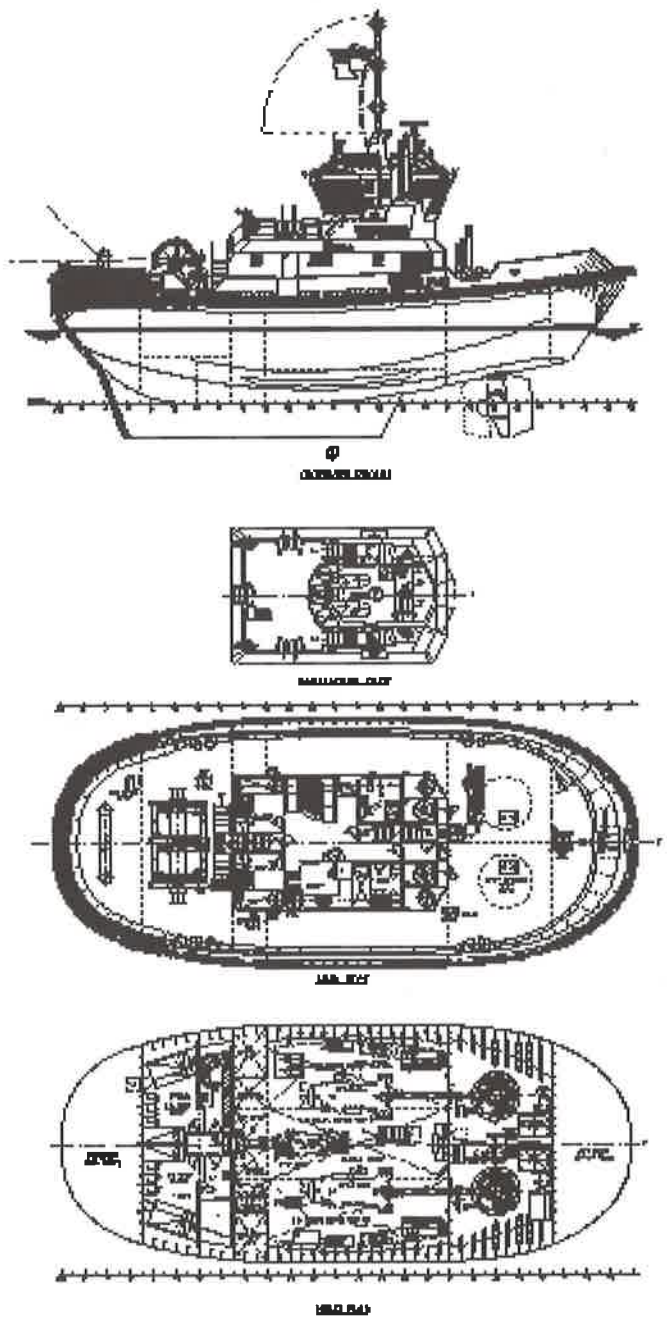

Figure A.9 Contract Design Stage General Arrangement

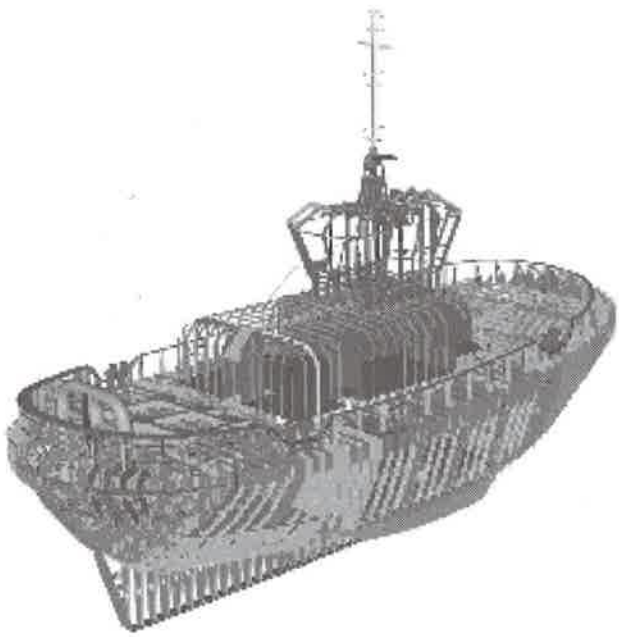

Figure A.10 3-D Steel Product Model for Z-Tech Hull

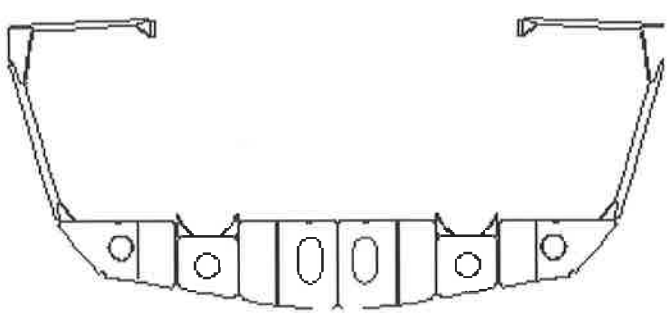

Figure A.11 Typical Steel Frame, defined for NC Cutting

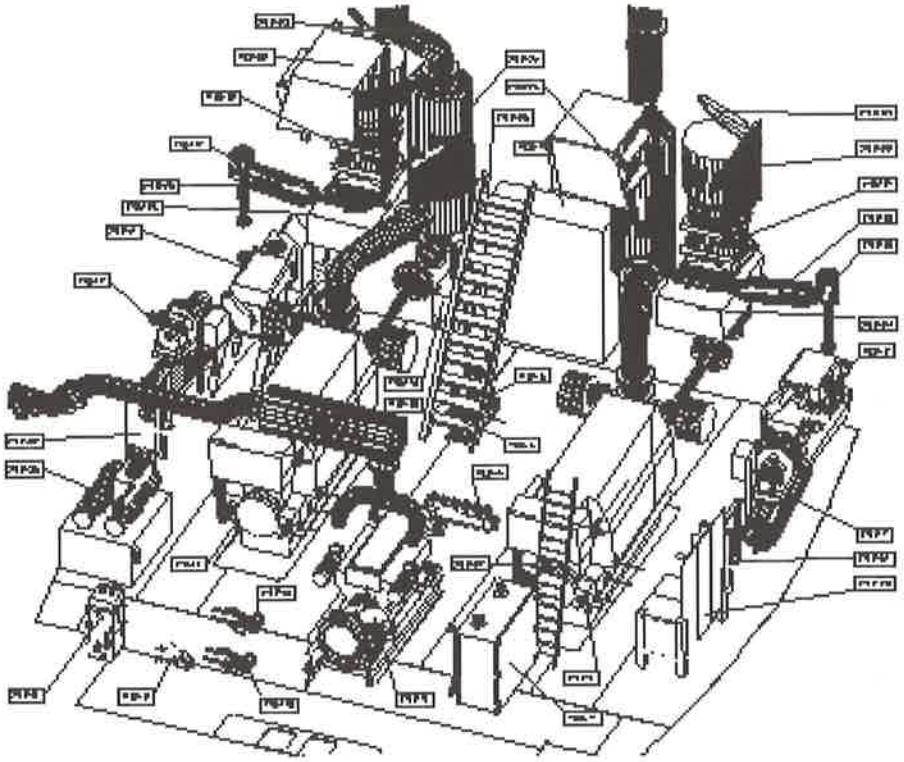

Figure A.12 3-D Engine Room Equipment and Piping Model

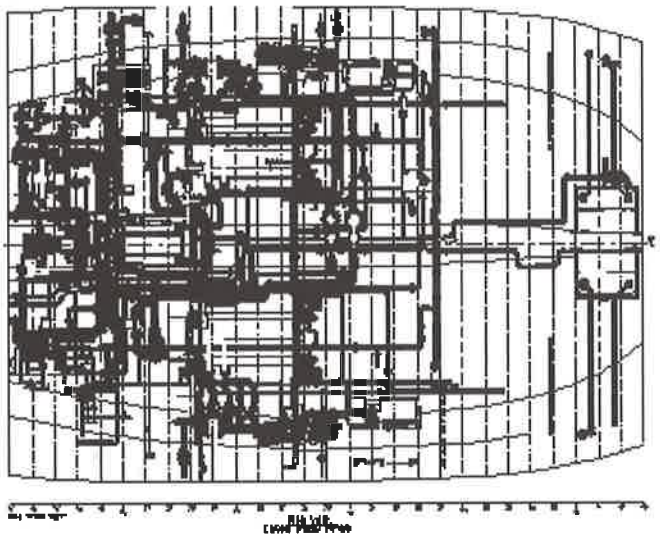

Figure A.13 2-D Piping Arrangement, from Product Model

ShipConstructor for this vessel. The use of this software enabled highly accurate steel weight and CG calculations, plus a complete bill of materials to be developed for the steel and all piping systems. By all accounts from the shipyard, all the steel components went together very well, with no fit-up problems at all.

FINAL SPECIFICATIONS:

The final selection of machinery and outfitting components was made in concert with the shipyard, and is reflected in the Outline Specification attached as an Annex to this paper.

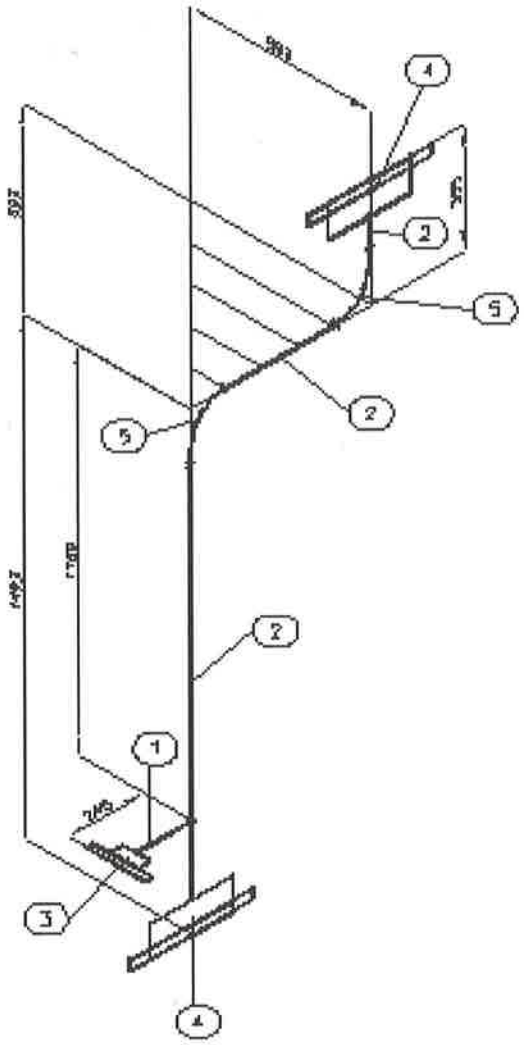

Figure A.14 Individual Piping Spool piece

UNIQUE DESIGN FEATURES:

Some specific and noteworthy design features of the ***Z-Tech*** design, apart from the operational advantages previously described, are the following:

SHAFTLINE CONFIGURATION

The shaft line is designed to minimise the number of bearings and associated pedestal structure, and to eliminate the use of universal joints, thus simplifying the overall alignment, eliminating the service life issue and maintenance costs related to U-joints, and eliminating the potential for future bearing induced bending stresses and vibration in the shafting. The system also saves the initial cost of the bearings and pedestals, and the often considerable cost of effectively aligning shafting with multiple bearings.

The system as designed (**Figure A.15**) incorporates the following elements, from engine output aft:

- Elastic Coupling -Vulkan "VULASTIC" type L-4310 for torsional vibration control
- flywheel housing- mounted bearing to provide the support for the forward end of the line shaft and to isolate the shafting loads from the crankshaft
- Flexible Plate Coupling – Flenders ARS-6ND to accommodate the expected movement of the main engine on the vibration isolators. This coupling is torsionally and radially rigid, but can readily accommodate axial and angular misalignment
- hollow steel intermediate shaft to reduce the shaft weight and thus increase the allowable span between bearings
- Self-aligning Bulkhead bearing/seal. The bulkhead provides excellent radial support with little additional structure compared to pedestal bearings, and eliminates the need for a separate seal – again saving initial cost and ongoing maintenance costs.
- "Elastic Shaft": Flenders Model ARS-6 DHD. This shaft consists of a pair of the flexible plate couplings (the same as used at the engine end) separated by a short "floating" shaft. This arrangement tolerates very high misalignments in all 3 axes, and in combination with the misalignment coupling at the engine end of the hollow shaft, allows the engine and z-drive to move relative to each other without creating any vibration and without overstressing the bearings in the engine or in the z-drive.

NOISE CONTROL FEATURES

Noise and vibration control on smaller, high-powered tugs is of increasing importance. Recognising this fact at the outset of the Z-Tech project, the following features were incorporated into the design:

- main engine resilient mounting (coupled with the shaft coupling system described above)
- auxiliary engine resilient mounting
- high attenuation silencer systems:
- main engines: EM model SRU
- Auxiliary engines: duplexed silencer systems, comprising:
- Cowl TS-40 type, plus
- EM model SRUE
- resiliently mounted exhaust systems

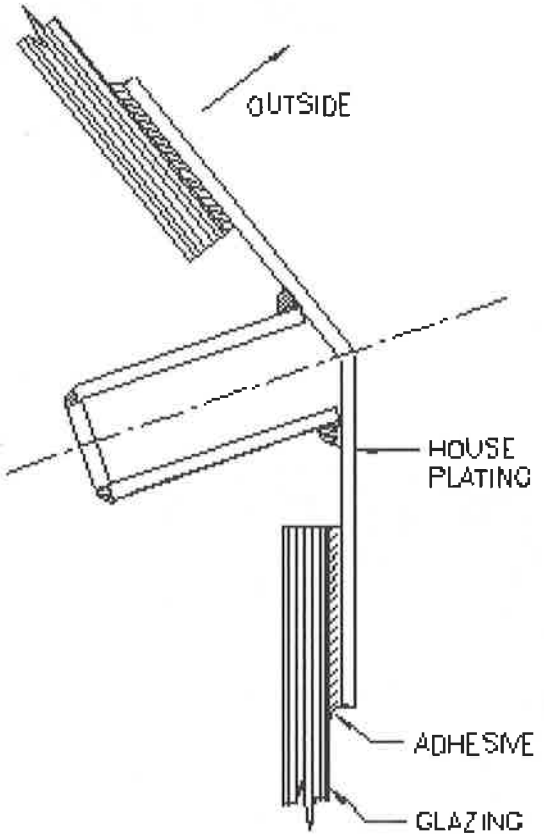

Figure A.16 Detail of Bonded Windows

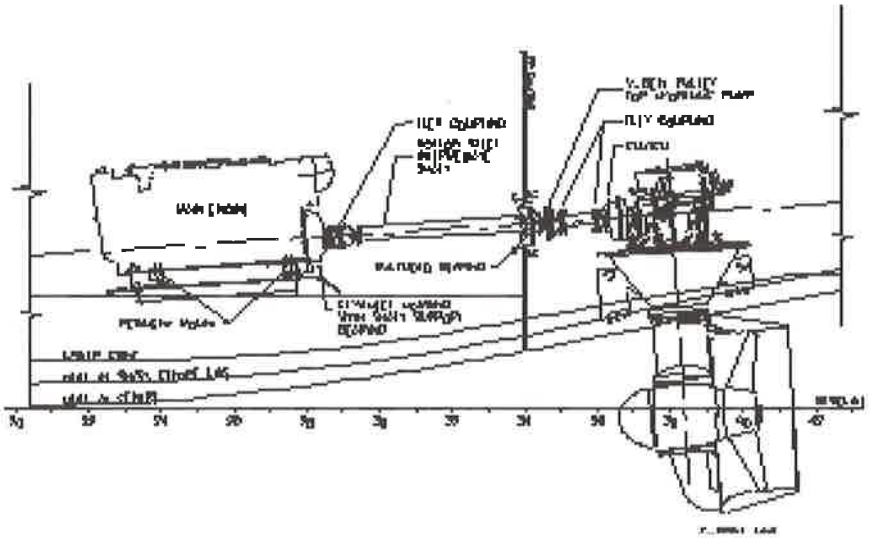

Figure A.15 The final shaftline assembly, high-lighting use of hollow shafting and flexible couplings.

BONDED WINDOWS:

Although not a first among RAL tug designs, the use of adhesive bonding of glass to steel is still a fairly unique application of this technology, widespread in the fast ferry industry, but as yet little used elsewhere in the marine world. By eliminating the complete window frames, the amount of "wood" between windows can be absolutely minimised, and obviously then the arcs of vision are maximised.

"ESCORT SKEG"

The escort skeg performs a number of critical functions in the ***Z-Tech*** design. It enables the tug to work in the Z-drive tractor mode, much as a more conventional Z-tractor tug would do. When the ***Z-Tech*** works as a "pusher" or ASD tug, the skeg provides much enhanced astern directional stability, without impeding regular ahead performance in any way. In keeping with the original design development, the skeg also enables the ***Z-Tech*** design to offer a much enhanced indirect towing capability.

Z-TECH PERFORMANCE:

At the time of writing this paper, the first of the Z-Tech tugs was still about one month away from trials. It is anticipated that trials results will be circulated as an addendum at the ITS Convention.

ALTERNATE Z-TECH CONFIGURATIONS:

Although the first of this new class of advanced ship-handling tug, the ***Z-Tech 2800*** has been designed for multiple series construction, the trademarked general design concept is by no means limited to this size of tug, nor to the specific crew and deck layout. **Figures A.17** & **A.18** illustrate respectively a ***Z-Tech 2800***, 28m, 60-tonne "dayboat" arrangement with a much reduced size of deckhouse, and a ***Z-Tech 3000***, 30m version, with up to 75-tonne BP capability.

A complete family of ***Z-Tech*** concept designs, from 24m to 32m metres is currently under development, and are expected to be ready for construction in the very near future.

DISCUSSION – DAY ONE, PAPER No. 3

Mike Allen
Peter, thank you very much for that clear guide through your search for the Holy Grail of the tug world. I trust that they will give you many years of successful service. Do we have some questions, please?

Bob Alario, Offshore Marine Service Association
Peter, of the modifications that you have developed in this hybrid tug, which are the ones that you feel will require perfection or more work as you go into the next series? Which modifications did you find did not produce perhaps as revolutionary a result as you might have hoped and that you're going to have to do some work to perfect?

Peter Lim
On the Z-Tech, you mean? Are you referring to Z-Tech?

Bob Alario
In the designs that are forthcoming, which things might you change, that you have incorporated in the first series, because they haven't worked out as well as you had hoped?

Peter Lim
Yes, the first series was powered up to 60 tonnes. We think that in Singapore this could be a bit of overkill, so we are trying to bring the power down a little. We are also looking at the main engines. The first Z-Tech series was equipped with Caterpillar 3516 high-speed engines. This has raised some concern for our engineers because of the impression that high-speed engines do suffer much more wear and tear, especially for our kind of operation in PSA in Singapore. Not so if you are operating in a quieter port. So main engines. Then coupling to a different type of main engine, whether the Schottel propellers would be the right fit. So that also would be a question, which is going to be raised, something that is going to be discussed. And finding the right bollard pull will be something, which we really have to determine soon. In fact, there is another batch of Z-Tech being built. We are talking for the batch after the next. So those are the questions that we are grappling with now.

Max Newman, Panama Canal Authority
Peter, what is the main difference or the difference in bollard pull between the 5500 and the 6000 Z-Tech design?

Peter Lim
Yes, there would be a difference.

Rob Allan, Robert Allan Limited
Actually, Peter, there was a bit of an error in that slide, because the designations that we've applied, Max, 5500, 6000, and 7500 actually apply to the bollard pull, so those are designed as a 55 tonne, a 60 tonne and a 75 tonne boat.

Max Newman
Thank you

Greg Castleman, Rolls Royce Commercial Marine
Can you comment a little bit on the sea trial performance and particularly, we're interested in what kind of escort performance you might have achieved. Did you actually do the indirect mode pulls and how did that work out, compared to predictions?

Peter Lim
I'll leave the escort performance to Robert again, but the trials – yes, I was on board. Robert and I were on board. Ken Lo was on board. We spent eight hours on the tug doing the sea trials and it was a good feeling, a really good feeling, honestly. I have managed all those tugs you saw on the screen, and I seriously testify that this is the best feeling I've had – on the Z-Tech, and when the bollard pull was done, I was there on the wall. I saw how the metre went up much faster than when we did last year's bollard pull test. So it was a good feeling; the vibes are good, and I am positive that this tug will work well in Singapore. The tug masters in Singapore have all been trained and are quite disappointed actually that the first batch didn't come down to Singapore. So you've got to work fast, Robert [Allan]!

Robert Underhill, Jayco Mooring & Rigging
Peter, I had the pleasure of being in Port Hedlund last Wednesday, and the training master took the three appointed masters out on the tug for a training run, and I was able to go on board. It was interesting to see their response to the facilities that the tug offered them. After a couple of hours, they were really taking to it, and impressed with the manoeuvrability and the visual aspect of their position. It seems to be excellent, and they have taken to it very well.

Peter Lim
Thank you – I'm glad. I told you it was a good feeling we had. Positive throughout the sea trials. And it was so quiet, that we in fact had a meeting during the sea trials where we hopefully will conclude the deal.

Mike Allen
Peter, I see in your paper that you have accommodation for a maximum of seven. How many crew do you anticipate you will be operating with?

Peter Lim
In Singapore, we would – that's why Robert is scratching his head – we would prefer a ten-man, crew aboard, because we want the flexibility of taking a boat out of Singapore. You see, I am in charge of 54 tugboats now. We are expanding; 30 in Singapore and 24 operate outside of Singapore. I need the flexibility of moving them in and out. We had day boats in the past, in the old Authority days. Almost all of them have been phased out, except a couple of the V-tugs, the Voith Schneider tugs. Those are still the day boats, which we operate with our local crew, our Singaporean crew.

Andy Crawford, Serco Denholm Ltd
Can you tell me what experience you have had so far with coastal towing, and how it's performed in those conditions? On the Z-Tech, how has it performed in coastal towing, in the astern mode?

Peter Lim
Like I said, the first batch of tugs did not come down to Singapore and really, I have not had that experience. Shortly reaction is coming in from Australia and already has been good. Is there anything you want to elaborate? We have had sea trials and unfortunately for us, fortunately for the Australians, the tugs were delivered directly to Australia, in Port Hedlund. Maybe, Robert, you want to elaborate a bit on the escort performance?

Evert van Tellingen, Redwise Maritime Services
I'm quite happy to inform you that we were responsible for the delivery of the tug to Darwin and our master reported that she had excellent sea-going capabilities, very easy to handle, under the stern or the bow of the vessel, in short, a very fine voyage. He enjoyed it and he's looking for the second one.

Peter Lim
Yes, thank you. I told you it was the combination of Robert Allan and his staff spent many hours with us and all the feedback gathered from the pilots and the tug masters was put into this design. We are positive, I'm sure, that it will work in Singapore. It works, in our experience and if it does work in Singapore, I'm sure that there are ports in the other parts of the world that could also find this tug useful. Maybe you could allow Robert to elaborate a bit on the escort performance of the tug.

Robert Allan
I guess there are a couple of questions here that I'd like to address, and the first one was Bob Alario's question about what might we do differently the next time around. Precious little, quite honestly. We were very pleased with the overall performance of the boat. There are aspects of the astern visibility that I would want to work on a little bit, to try and improve that, but it certainly was not bad at all. There are exhaust pipes and things that simply have to be there, but we're going to work on that a little bit.

Probably work on the console configuration a bit, to enhance the astern going visibility and ergonomics a little. Other than that, the whole layout of the boat worked out pretty much as we had hoped and we're very pleased. And also very pleased with the work that Ken Lo and his people at Cheoy Lee did on building this boat in China. A first-class job, Ken.

Greg, your question about escort performance – there haven't been any full-scale trials yet to my knowledge, anyway. Certainly, the trials that we performed in China and Hong Kong about three weeks ago were more or less conventional performance trials but the hull form is really no different from that of many ASD tugs that we've designed, using the same escort skeg. The tug was not primarily designed as an escort tug, but certainly is capable of that. It has the freeboard and the stability to handle that. So, we're predicting that we'll be seeing indirect forces 35-40 per cent above bollard pull, in that order. But that wasn't a primary objective.