THE ROYAL INSTITUTION OF NAVAL ARCHITECTS

No Stone Unturned – A comprehensive approach to the development and construction of a new class of High speed Ferry for Alaska

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SUMMARY

The paper discusses the initial concept and highlights key activities undertaken during the development of the 73m high speed catamaran vehicle ferry the "M/V Fairweather". Designed by BMT Nigel Gee and Associates (NGA), for the Alaska Marine Highways System (AMHS), and constructed by Derecktor Shipyard (DSY) the paper covers the owners / operators steps to the realisation that a high speed craft was required for the routes in question, the driving criteria that govern the concept for the design, the design approach and technical work completed by NGA in developing / producing the design and Derecktor Shipyard production development and techniques used to build and deliver the vessel to schedule.

NOMENCLATURE

LOA	Length Overall (m)
LBP	Length Between Perpendiculars (m)
LCG	Longitudinal Centre of Gravity (m)
VCG	Vertical Centre of Gravity (m)
HS	Significant Wave Height (m)
TP	Peak Wave Period (s)
LDR	Length Displacement Ratio ($L/\nabla^{1/3}$)
kPa	Kilopascals
kN	Kilonewtons
dB(A)	Decibels
MSI	Motion Sickness Index

1. INTRODUCTION

The 73m high-speed catamaran "M/V Fairweather" was designed by BMT Nigel Gee and Associates Ltd (NGA), a subsidiary of British Maritime Technology Ltd (BMT), and built by Derecktor Shipyard (DSY) in Connecticut. The vessel was the first IMO HSC Code vehicle ferry to be approved by the United States Coast Guard and classed by DNV in the US. Having successfully completed sea trials, and the delivery voyage from New York to Juneau Alaska the vessel went into service in June 2004.

The vessel was designed for and operated by the Alaska Marine Highways System (AMHS) and will be used on a number of routes in south-central and south-eastern Alaska serving the local community and tourists.

2. OWNERS DESIGN CONCEPTION

2.1 CONCEPT BACKGROUND

The Alaska Marine Highway System (AMHS) is in the early stages of a transportation improvement process as put forth by the Southeast Alaska Transportation Plan (ref. 1). The new system will utilise several new ferries in daily point to point service from homeports in Southeast Alaska and Prince William Sound. These new roundtrip routes range from 292 to 578 kilometres. The existing slower vessels in AMHS operate 24 hours a day on long range weekly schedules over thousands of kilometres stopping at multiple ports.

2.2 SPEED FOR REDUCED COST

The key to potential cost savings with a high-speed vessel of this type in the AMHS is to reduce crew costs, which total more than 70% of the operational costs of the current system. A typical AMHS vessel has a crew of 42 operating watches for 24 hours. A vessel that operates 12 hours or less, remaining within a single shift period, operates with a smaller crew providing significant savings.

In order to use day boats on these routes, AMHS must use vessels with double the speed of existing AMHS vessels. Even with currently high oil prices, studies show that savings in crew costs will clearly compensate for the increase in fuel and maintenance costs that come with speed if the vessel is properly utilised (ref. 2). A simplified comparison is shown in Figure 1.

High speed transport also offers major benefits to the customer in a more convenient service. AMHS is now providing substantially reduced travel times with convenient departure and arrival schedules. Customers have often shared their frustration with middle-of-the-night departures that unavoidably occur in a long-haul, multiple stop, system. A fast ferry operating for 12 hours avoids this frustration.

Juneau to Sitka, r.t.	16 knot vessel	32 knot vessel
Crew on board	42	10
Crew on duty	21	10
Underway hours	18	9.5
Workday hours	24	12
Crew berths/mess	Yes	No
Maintenance Ashore	By crew onboard	5
Fuel, gal. /day	4500	6500
Crew man-hours	378	180
Cost comparison*	$30,870	$20,800

* Assuming $65/hr and $1.40/gallon

Figure 1 - Daily Cost Comparison

2.3 AMHS STATUS QUO – THE EXISTING SYSTEM

AMHS consists of 900 men and women, ten vessels, 35 community terminals, and routes that cover over 5600 kilometres. Within the region of Southeast Alaska, AMHS uses eight vessels and calls at ports from Bellingham, Washington, to Skagway, Alaska, in year-round service. AMHS also crosses the Gulf of Alaska, and serves Prince William Sound, Kodiak, Kenai, and the Aleutian Islands. The system carries 100,000 vehicles and 350,000 persons per year. AMHS goes where roads do not, and provides basic transportation, not commuter service. AMHS is the highway for coastal Alaska. For a more information refer to the AMHS web site at www.dot.state.ak.us/amhs.

2.4 FAST FERRY ROUTES IN ALASKA

AMHS plans to acquire four high-speed ferries. The first vessel, the Fairweather, operates from Juneau and makes day runs to Sitka (489 km), Haines and Skagway (551 km). The second vessel, the Chenega, will operate starting in 2005 in Prince William Sound between Valdez, Whittier and Cordova (461 km). The third and fourth vessels will serve routes from Juneau to Petersburg (455 km) and from Ketchikan to Mitkoff Island (380 km). It is important to note that all of these routes are longer than a conventional speed ferry (operating at 16-18 knots) could accomplish in 12 hours or less, therefore requiring multiple crews, additional berthing, messing and other design or operational complications that come with 24 hour operations.

2.5 SEA CONDITIONS AND SEAKEEPING GOALS

Wind and wave climatology of Southeast Alaska and Prince William Sound was studied in depth by AMHS and The Glosten Associates (ref. 2 and 3). Joint probability wind speed and direction tables (monthly, seasonal and annual) and joint probability significant wave height and period tables for selected locations on routes of the proposed ferries were developed using hind cast methodologies. Significant wave height and peak period were estimated from synthesised hourly wind speed and direction data using a program developed by The Glosten Associates and a U.S. Army Corps of Engineers NARFET Program. Selected wave height results are illustrated in Figure 2. When this study was complete, the designers were presented with a simplified wave condition summary, 2 metres significant wave high with a peak period of 4 to 6 seconds. This condition is more severe than 99% of the conditions expected to be seen. The designer was required to meet motion sickness goals of 10% MSI in these conditions with the use of T-foils and no more than 15% MSI without.

2.6 GLACIAL ICE AND WOOD DEBRIS

Alaska is famous for its glaciers, and although the average winter water temperatures in Southeast Alaska and Prince William Sound are above freezing, glacial ice in the form of small icebergs and "bergy bits" do occur.

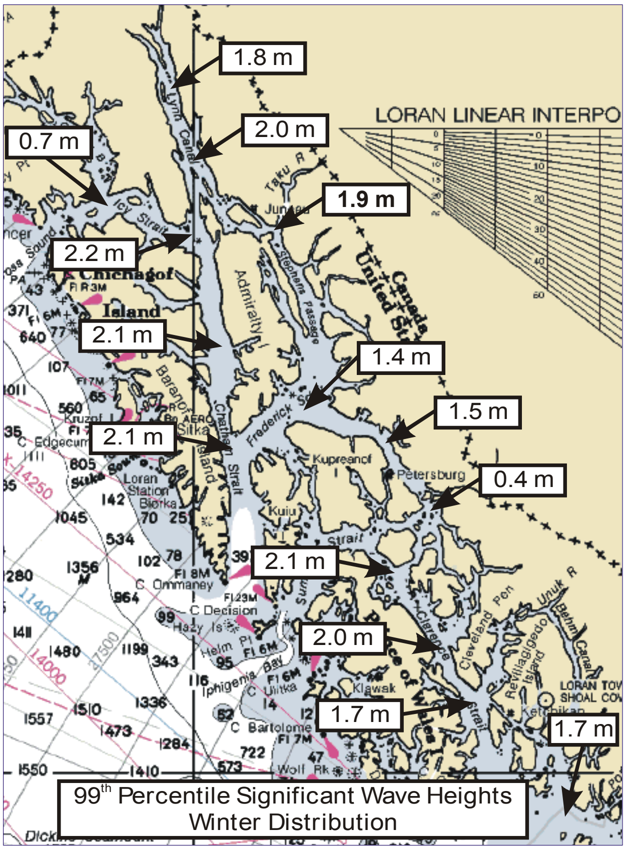

Figure 2

Larger icebergs occur in regions of Prince William Sound which will require slow downs based on reported sightings and known areas of concentration. Existing AMHS vessels have operated in these areas for many years and monitoring locations of ice is standard procedure. Logs and floating wood debris also occur.

As a long term defence against damage from debris, and clearly knowing the weight impacts, AMHS required scantlings to exceed class society requirements by 100% for stem bars, 50% for selected forward shell plate and by 25% in forward side frames.

2.7 ICE AND SNOW

The HSC Code Annex 5 defines zones of operation where ice accretion must be considered in the vessel design. The Prince William Sound and Southeast Alaska routes are outside these established zones, however, through experience with the existing fleet, freezing rain and spray conditions are known to occur. Therefore, to increase safety and reduce delays due to the weather, AMHS stipulated that the vessel be designed applying annex 5 of the HSC. Additionally, the vessel was to be designed to accommodate snow loads for Cordova, Alaska, which corresponds to a ground snow load of 4788 Pascals (100 pounds per square foot). Due to this all external decks were to be designed with camber / sheer to shed snow.

2.8 PAYLOAD

The vessel payload at full load includes 250 passengers with luggage, 12 bicycles, 6 kayaks and a total vehicle weight of 122,727 kilograms (270,000 pounds). Pickup trucks, campers, and sport utility vehicles dominate the Alaska vehicle population. The automobile equivalent unit (AEQ) definition for this project is noticeably larger and heavier than notional vehicles used in design of ferries for urban commuter traffic or European vehicles. Each AEQ is defined as 6.1 metres long, 3 metres wide, and weighing 2727 kilograms. In contrast, a typical lower-48 U.S. or European AEQ is less than 5 meters by 2.6 meters and only 1250 kilograms. The FVF is capable of transporting tractor/trailer units and most heavy vehicles meeting the State of Alaska highway standards up to axle loads of 10,909 kilograms.

2.9 CLASSIFICATION AND REGULATION

Early in the project AMHS chose to have these ships built in accordance with the IMO HSC Code and to have the vessel classified by Det Norske Veritas. The design is also required to meet all applicable requirements of the USCG, applicable Alaska State regulations, and the Americans with Disabilities Act. US Federal Highway Administration funds most of this project, so the builder is required to meet applicable federal rules including Buy American, Ship US, Fly US, Disadvantaged Business subcontract Goals, Equal Employment Opportunity regulations and applicable wage rate regulations. These regulations required the builder and the AMHS onsite team to spend substantial effort in compliance and administration.

2.10 MANNING

Reducing manning levels is critical to the success of this vessel and early in the project AMHS identified a goal of 9 crew during a normal 12-hour day operation. These crewing positions were as follows: Master, 2 Deck Officers, 2 Engineers, 2 Seamen, and 2 Passenger Services Workers.

With approval from USCG, however, the minimum manning level was increased to 10 as this is the minimum number of persons required to operate the vessels evacuation systems, not the number of persons required on watch.

2.11 SHORE SIDE INTERFACE

The home port is equipped with new stern loading facilities as shown in Figure 3. Vehicles will load via the stern at the home port and offload using the forward side door at the destination port, reversing the procedure for the return trip. To maximise the use of the new high speed ferries within the existing system, the new vessels were required to operate in the full range of tides (up to 6.7m) using the existing terminals. The key interface issue is maintaining similar freeboards to the existing fleet of monohulls.

Figure 3

3. DESIGN REQUIREMENTS – CHALLENGES AND SOLUTIONS

3.1 GENERAL ARRANGEMENT

Given the owners design conception / requirements, the vessel was designed with the following characteristics.

LOA	71.25m
LBP	64.20m
Breadth moulded	18.00m
Depth moulded	5.50m
Design draught	2.59m
Crew	10
Passengers	250
Cars / Pick-ups	35
Trucks	8

DNV Classification:- ✠1A1 HSLC, R3, Passenger, Car Ferry A, EO.

Passengers enjoy a mixture of comfortable reclining and dining table seats in the interior main deck, the forward observation lounge and amidships snack bar. Further seating is provided in the exterior solariums at the rear of the ferry. There are also dedicated areas for working and playing video games.

The vehicle deck configuration was driven by the specified loading of cars, trailers, recreational vehicles and trucks giving the requirement for 245 car/truck lane metres. See the general arrangement Figure 21.

3.2 WEIGHT

To minimise through life running costs AMHS put significant emphasis on vessel weight and its control, setting significant liquidated damages for vessel weight at $100.00 per pound for the first 25,000 pounds deficit with non-acceptance of the completed vessel above this.

To ensure the vessel met the target weight, a stringent weight management programme was set up. This evolved from estimated weights, through calculated weights to "as weighed" weights.

Figures 4 through 6 show the record of weight, LCG and VCG tracking through the project. The target figures being those set by the weight review prior to the model test programme in February 2002.

The margin shown includes the contract modification margin and a service life margin. Both of which had to be accounted for in the contract weight.

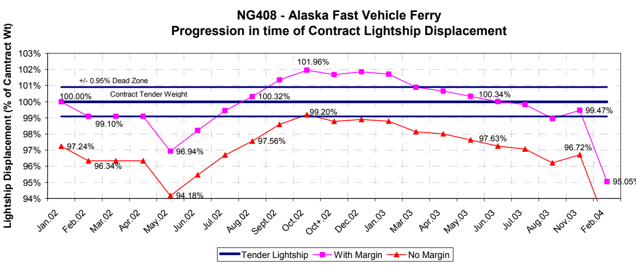

Figure 4

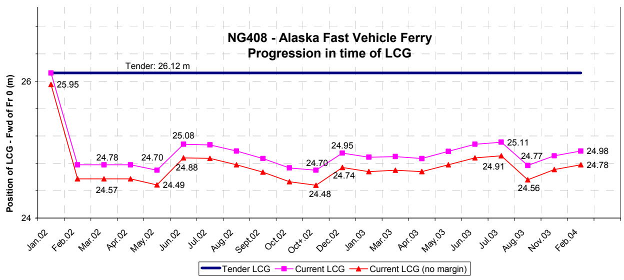

Figure 5

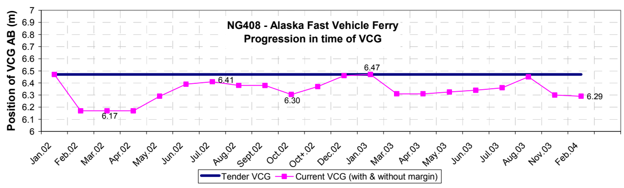

Figure 6

Part way through the project a contract displacement dead zone was established to eliminate unavoidable lightship survey measurement error that may result in substantial penalties for either party and was set at +/- 0.95% of the contract lightship.

Due to possible calibration errors during the weighing of equipment and structure, a 2% margin was maintained on all weighed weights. This is believed to account for the 4 % drop at final lightship.

Through tight weight control, attention to lightweight construction through the use of specifically designed aluminium extrusions and equipment purchased, the final vessel weight was significantly below the contractual requirement as shown below. All results gave more confidence of success for vessel performance on trials.

	Contract Requirement	Actual Achieved
Weight	100%	95.5%
LCG	24.78m	24.98m

3.3 SERVICE SPEED / MAX SPEED / SEAKEEPING / WASH

3.3.1 Calm Water Resistance

The graph shown in Figure 7 compares curves of predicted results to model testing and vessel performance on sea trials. The graph compares 4 sets of data

1. Model test results recorded at the model test displacement.
2. Predicted results calculated prior to the model test at the model test displacement.
3. Predicted Trials results at the trials displacement.
4. Actual trials results.

The owner's requirement specified 36.5 knots at 100% MCR and 35 knots at not more than 90% MCR, all at full load displacement, including margins for growth.

The model test results show a 2.5% improvement in vessel performance over the calculated prediction value at the contract speed.

The sea trials results are a little more difficult to interpret due to the characteristics of the trials area.

Having to run the trials in Long Island Sound, vessel performance was hindered by shallow water effects. To obtain a depth Froude number below 0.7 the water depth would need to be in excess of 74m. The deepest water in the Sound, however, is only 36m. At this depth the vessel would be operating close to its critical Froude depth making contract speed more difficult to achieve.

It was deemed that the best approach in the given conditions was to run in shallow water, approximately 12m, running the vessel at a super critical Froude depth of 1.73. This would reduce the detrimental effect on residuary resistance as much as possible, however, there would be additional resistance due to an increase in skin friction as a result of vessel sinkage. This additional resistance is not very well documented for high speed craft and would therefore be difficult to account for.

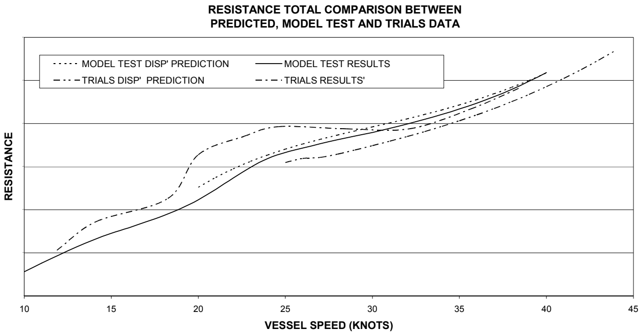

Figure 7

The graph shows a distinct hump between 20 and 25 knots close to the critical Froude depth. At the higher speed range, however, above 32 knots the curve shows good correlation with regards to the shape but is offset by 4.5 % due to the additional drag in the shallow water.

Even in the arduous conditions of the Sound the results obtained during trials showed that at 100% MCR the vessel achieved 38.0 knots, 1.5 knots over the contract requirement. It was also shown that the vessel speed achieved at 90% MCR was 36.7 knots, also 1.5 knots over the contract requirement.

The vessel achieved all contract requirements with regards to speed and fuel consumption despite the adverse conditions.

In terms of performance the waters of Alaska are considered to be infinitely deep and AMHS has confirmed that the vessel is performing significantly better than in the shallow water of Long Island Sound. As such AMHS have requested that the vessel documentation for the operating speed be increased to 38 knots.

3.2.2 Seakeeping and MSI

Extensive sea keeping and manoeuvring model tests were conducted by MARINTEK (Norway) in their ocean basin using a self propelled, 1:16.5 scale model. See Figure 8.

The sea states to be considered for the seakeeping analysis were

HS=1.2m, TP=4.0s
HS=2.0m, TP =6.0s.

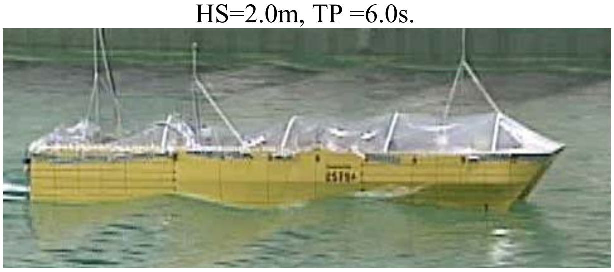

Figure 8

represented by a JONSWAP spectrum, with a standard peak enhancement factor of 3.3.

Exposed for a 2 hour duration, the Owners requirement was for a maximum Motion Sickness Index (MSI being the percentage of passengers expected to get seasick, computed using the ISO 2631-1.method) of 10% for the 4 and 5 second periods and 15% for the 6 second period sea state.

Initially the vessel was designed with active stern interceptors and bow T-foil systems. Successful model tests show that the 15% MSI requirement was achieved with the active interceptors alone, see Figure 9. As a result the first vessel was designed for, but not with the foundations saving weight and equipment costs.

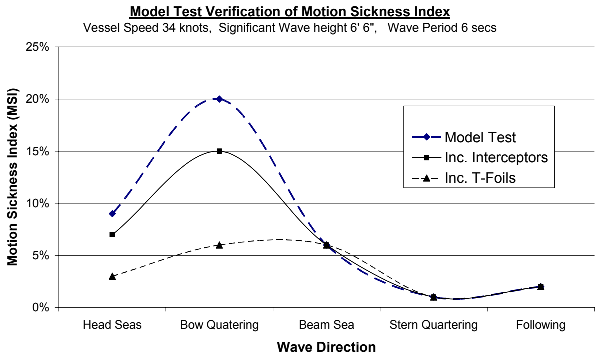

Figure 9

3.2.3 Course Keeping

Course keeping characteristics were tested for all main headings in the specified sea states. See section 3.2.2.

Given the historical wave data analysis for the route (see section 2.5), the majority of the time the expected sea state would be below the HS=1.2m, TP=4.0s specified.

In head, bow-quartering, beam and following seas the vessel showed excellent course keeping characteristics.

As with all catamarans, in general, stern quartering seas are the most problematic with regards to directional control. Consequently, with the greater wave height and longer wave period, the low frequency of encounter induced slight yawing angles being a maximum of 3.7 deg RMS at 33 knots.

No critical conditions such as broaching, excessive roll or loss of directional control arose. In the lower wave condition which is considered to be the higher wave spectrum for the route, the vessel showed no problems whatsoever in stern quartering sea.

3.2.4 Slamming

Due to the low cross deck height driven by the existing shore side facilities in Alaska cross deck slamming was examined in the specified sea states.

The model had two slamming panels installed forward in the wet deck and the slamming analysis counted occurrences of force measurements (pressures) above a certain threshold set at 100kPa (kN/m^2).

This threshold is low with regard to structural integrity, but set due to passenger comfort levels with regards to slamming noise.

From the results, the number of slamming occurrences during the given registration time was converted to occurrences per hour.

In the HS=1.2m, TP=4.0s waves at 34 knots, there were 2 occurrences equating to 16 slams in a 1 hour period. In the HS=2.0m, TP =6.0s there were 3 occurrences at 32 knots in the head seas and 6 in the bow quartering sea.

There were no other occurrences for all other speeds and headings and throughout the tests there were no occurrences of water jet ventilation.

3.2.5 Manoeuvring

Using the same self propelled model a full set of manoeuvring trials, as listed in Figure 10 were conducted.

	Vessel Speed (Knots)							
	4.5	6	8	12	20	25	30	35
10/10 zigzag		●		●		●		●
Turning circles (5 Deg Nozzle)			●					
Turning circles (10 Deg Nozzle)	●		●	●	●		●	
Turning circles (15 Deg Nozzle)	●			●	●	●	●	
Turning circles (20 Deg Nozzle)	●		●	●	●	●	●	
Turning circles (30 Deg Nozzle)	●		●	●	●	●	●	
Reversed spirals various deg / sec			●	●	●	●	●	

Figure 10

Note. Rate of turn for reverse spirals ranged from 0.25deg/sec to 1.23 deg / sec.

To compensate for the higher model viscous resistance compared to the full size vessel, and subsequent higher power output on the model water jets leading to better steering capabilities, the manoeuvring tests were undertaken with a friction fan installed. The function of the fan is to generate a forward thrust, which equals the difference in relative viscous resistance between the model and the full-scale ship to make the relative steering capabilities equal for the model and the ship.

The results from the analysis and observations during testing indicated excellent manoeuvrability for the vessel. For example, the results for the 10/10 zigzag test show that the first overshoot angle never exceeds 10 degrees. The spiral tests conducted through the speed range, only gave the slightest sign of instability at 30 knots. This was indicated by small hysteresis loop showing a maintained yaw rate of 1.2 deg/sec for a reversed nozzle angle of 1 degree. This is not unusual for a high speed water jet propelled catamaran.

The turning circle tests show that the vessels tactical diameter for an entry speed of 30 knots with a nozzle angle of 30 degrees was 5.2 times the vessel length. Sea trials results were slightly better than expected with a tactical diameter of 4.2 times for an entry speed of 32 knots.

3.2.6 Wash Predictions and Actual Results

AMHS had concerns regarding environmental impact from wash generated by new additions to the fleet. AMHS spent time looking at existing vessel wash in the region and charted where they expected the Fairweather to be on a speed vs. wash basis. Although wash was not detailed as a contractual requirement, through NGA's extensive experience designing low wash ferries they were able to predict the likely wash generated by their latest design.

During the model test programme MARINTEK ran wash measurements enabling NGA to make comparisons to the predictions, which were then verified on trials.

At a speed of 32 knots the model test results gave a wash height of 700mm compared to a prediction of 660mm. On trials the actual results gave a wash height of 590mm giving a 10.6% improvement on the initial prediction.

3.3 FINITE ELEMENT ANALYSIS & FATIGUE

3.3.1 Finite Element Analysis

NGA commissioned CETEC Ltd to complete a global FEA of the hull with the purpose of weight optimisation for the structural design as calculated and drawn in-house.

Having generated the model, including detailed frame, engine bed and extruded structure, (see Figures 11 and 12) CETEC were able to confirm that the global structure was very efficient in its design and no further optimisation could be done. The analysis highlighted the high stress points were as predicted in the tunnel haunch at the transom and in the ship side planking just aft amidships, however, the level of stresses were within the allowable design limits.

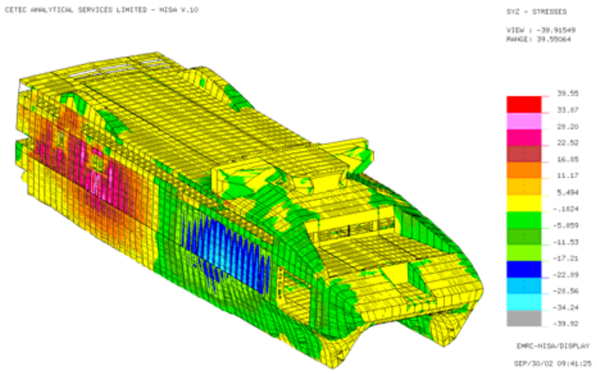

Figure 11

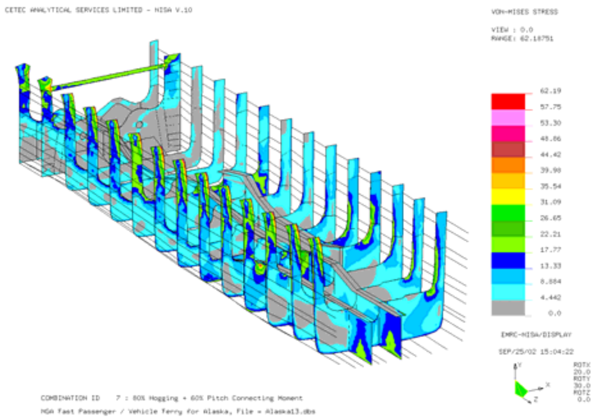

Figure 12

3.3.2 Fatigue

A comprehensive analysis of the hull fatigue strength was required by AMHS to demonstrate 25 years service life. Standard classification society structural rules generally approve up to a 20 year service life so a full analysis was required to demonstrate that the scantlings specified would meet the requirements.

For the calculation to be completed, NGA in conjunction with MARINTEK ran hydrodynamic calculations using wave spectrum data supplied by AMHS for the specific routes. This was done to determine the global loads and encounter frequency for the fatigue analysis. The vessel response data was then supplied to CETEC for calculation using defined DNV fatigue criteria for scantling determination.

Over the calculated 25 year prediction, the highest fatigue damage factor (1 being equal to 25 years) was 0.908 for the hull bottom longitudinals at amidships. This gives an estimated fatigue life in the order of 27 to 28 years based on the AMHS operating profile. The next highest fatigue damage factor was for the hull frames above tank tops at amidships giving 0.1860 far in excess of the 25 year requirement.

3.4 NOISE AND VIBRATION

Noise requirements for the vessel were, in general, set not to exceed those specified by HSC and DNV requirements. There were, however, a few additional requirements which needed further, consideration. These were the HVAC noise set at 55 dB(A) and noise on the external aft solarium deck set at 82 dB(A). Additionally, the noise at 1000 ft from the vessel was set at 60 dB(A).

The vibration criteria for structures is defined by DNV rules and those for normally occupied spaces above the vehicle deck was limited to a maximum allowable vibration of 4 mm/sec in maximum repetitive magnitude in the frequency range of 1 to 100 Hz in accordance with revisions to ISO 6954.

3.4.1 Noise

To ensure compliance, noise and vibration consultants, J&A Enterprises Inc. were contracted to model the vessel and its mechanical installations/outfit to predict/confirm that the noise and vibration requirements would be met.

From the analysis a number of issues were raised on both accounts as follows:-

1. With regards to noise, it was established that achieving the low vehicle deck fan noise (80dB(A) at 20 air changes per hour with all engines running) was going to be difficult. Early on in the design J&A were able to recommend general changes to the ducting, fans and use of silencers.

Trials showed that these noise levels were slightly exceeded only in the close proximity of the fans. A very simple remedy of installing a baffle plate some distance from the inlet damper was used as the solution.

2. Suggestions on louvre arrangement/selection were made with further recommendations on the use of limited noise treatment solutions and silencers, giving the best possible solution without resulting in significant weight penalty were followed and post trials with some minor balancing of the air flow acceptable interior noise requirements were achieved.

3. The other area of concern was achieving the 82dB(A) for the exterior solarium deck noise. Given the thrust of the jets at full speed, and the resulting noise generated by the flow of water, it would have been impossible to meet the criteria in this area. The only possible solution in this instance would have been to enclose the solarium behind Perspex screens. It was agreed, however, that this would take away the enjoyment of being outside on the solarium deck so this slightly elevated noise level was accepted.

On trials, noise measurements ranged from 85 dB(A) to 88 dB(A) right by the aft rail.

3.4.2 Vibration

Having J&A Enterprises involved early in the project ensured that the natural frequencies of structure did not coincide with propulsion system blade rate and machinery excitation frequencies. Any possible issues that arose with regards to structural vibration ensured that NGA could review and incorporate a minimal amount of additional structure at the design stage to eliminate any possible sources of vibration.

As an example, the analysis of the preliminary bearing foundation design at Frame 8 indicated that the foundation was adequately rigid to avoid resonance in the transverse and vertical directions at the primary excitation frequencies of shaft rate and 2 x shaft rates. However, the preliminary structure was calculated to have an axial vibration mode within this range.

This was corrected by stiffening the bearing foundation with larger longitudinal brackets between frames 7 – 8. See Figure 13.

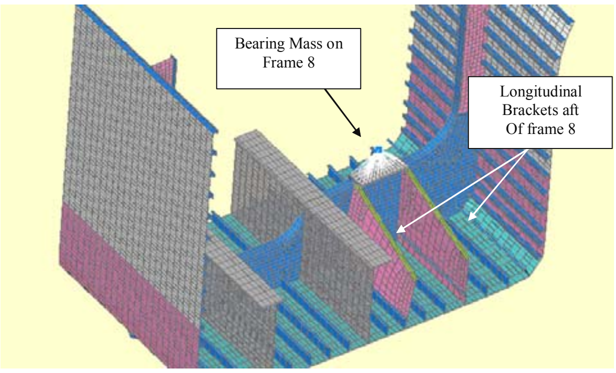

Figure 13

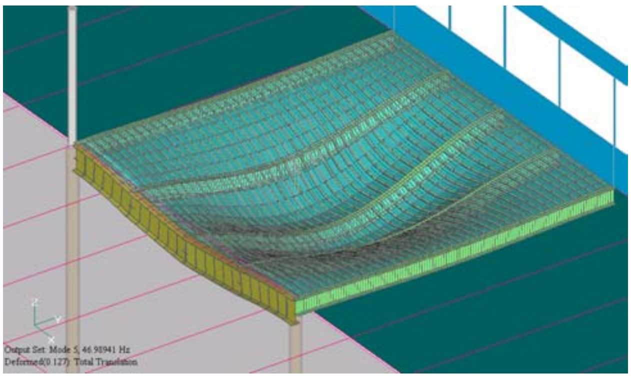

Figure 14

Mode Shape of Beam/Plate Mode Passenger Saloon Deck Outboard deck, 46.5Hz

Another area of concern was the large deck panels making up the passenger deck sole. As the interior outfit stiffness contribution and passenger loads were difficult to model this was seen as a potential problem area requiring careful attention during trials. (See Figure 14)

This and other areas of concern highlighted by the analysis was tested at the dockside and / or during sea trials. These tests confirmed that no areas of initial concern required additional stiffening.

3.5 CFD GAS STACK FLOW

The owner's requirements requested consideration be given to the flow of stack gases during normal operation and at a reasonable range of speed, heading and wind direction. The purpose of the analysis was to avoid:-

1) re-introduction of exhaust gases into any ventilation or combustion air intakes

2) exhaust gases sweeping down onto decks normally occupied by passenger or crew (e.g. solarium deck).

To satisfy these requirements CFD Norway conducted a CFD analysis considering various apparent wind speeds and headings. These ranged from 0 knots to 75 knots and at headings between ahead and astern in 30 degree intervals. Figure 15 is an example of the calculation supplied.

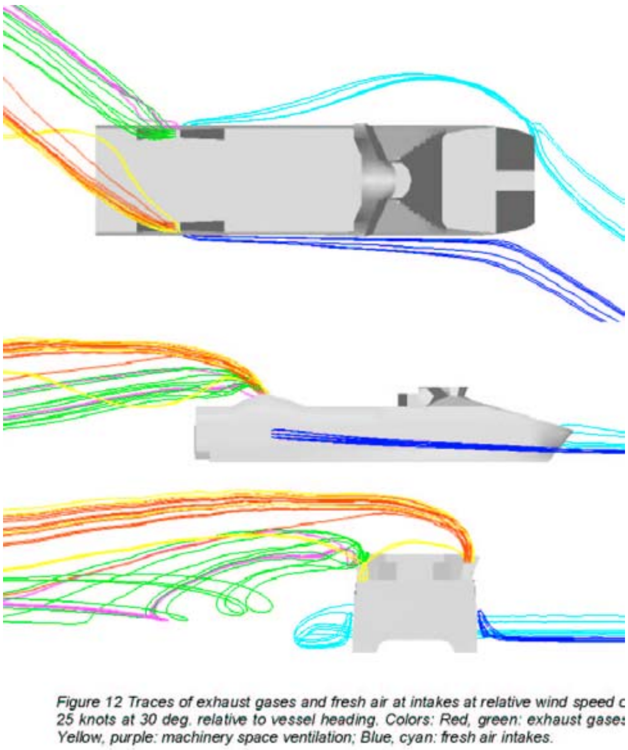

Figure 15

The extensive calculations generally show a smooth air flow over the vessel with minimal exhaust gas being re-ingested or showing vortexes into the solarium deck. It was only at the very highest apparent wind speeds between the angles of 60 to 120 degrees where there was evidence of gases at the engine room air intakes, re-introducing exhaust gases to the combustion air intakes. At these angles, however, the true wind speed would be extreme for the operation and therefore unlikely to be a problem.

In the final design the aft air handling units moved to vessel centreline and in service underway the ingestion of exhaust gases has not been observed. AMHS have, however, had to shut down one of the air inlets in calm conditions when slow speed manoeuvring.

3.6 CFD STATION KEEPING.

Using the same computer model, calculations were also performed to verify the station keeping capabilities of the vessel.

Combining trust data supplied by Kamewa, the bow thrusters were sized to meet the station keeping requirements in 28 knots of wind from any direction.

4.0 VESSEL BUILD

Derecktor Shipyards is at the forefront of aluminium construction in the high speed craft industry in the United States. With building operations at three yards on the East Coast, in Florida, New York and Connecticut with new construction taking place at all three locations. The extensive development of the facilities in Connecticut has promoted this as the centre for major new constructions, offering a 93,000m^2 facility with over 11,000m^2 of heated draft free fabrication space.

4.1 CONSTRUCTION

Commercial construction contracts typically have very short duration periods with one-off designs having to be prepared and the vessel built and tested in short order. This project was no different, so to reduce risk to the project a large amount of the naval architecture and conceptual design had been completed prior to the bid submission. Following the award of the contract and design verification, the construction strategy was initiated.

4.2 CONSTRUCTION STRATEGY

The construction strategy was to build as much as possible in sub-assemblies and then assemble in units prior to final erection. The result was a reduction in time working in enclosed spaces with poor light and ventilation, improving worker safety as work on stage equipment was minimized. The vessels hull and superstructure were sub-divided into 20 pieces, each with specific designation that was used for parts identification, weight control and time keeping. The following diagram (Figure 16) indicates the breakout of the parts for the hulls.

The unit breaks were designed to take advantage of obvious structural boundaries, such as bulkhead and tank tops. Other items to consider were the shipyard's crane lift capacity and positioning once the units were fabricated. Derecktor owns the largest travel lift in the Northern Hemisphere (600 tonnes), so very large fabrications can be assembled on the ground and then lifted into position – for example, the wet deck which is approximately 64m long and weighs 82 tonnes was handled by this method inside the covered erection building.

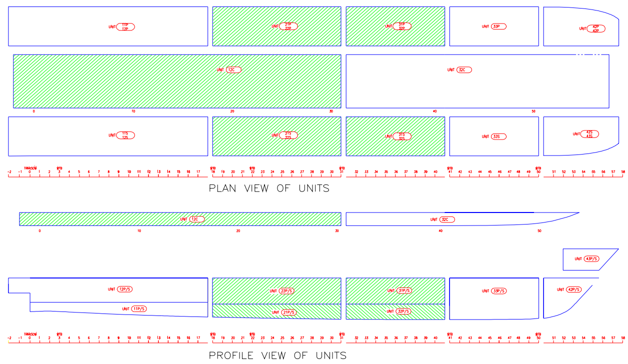

Figure 16 – Unit break down lay out

All the units were jigged upside down (see Figure 17) to take advantage of the tank top flats so better light, ventilation and access were available to the workers - yielding better quality in construction.


Figure 17 – Unit 31S under construction

4.3 USCG / HSC / DNV

This was the first vessel for which the U.S. Coast Guard had actually completed HSC approval for an entire project and the first new construction project for DNV in the United States since the high speed passenger catamarans built by Pequot River Shipyard in 1998.

Most vessels built in the United States are inspected and given certification to sail by the USCG using a combination of class and Codes of Federal Registration, chapter 46 requirements. In 1999 the USCG completed the development of NVIC 6-99 which is a document reviewing the HSC code requirements and defines the USCG interpretations of the HSC. Subsequently, the USCG now accept that if the HSC rules are applied in their entirety, they would issue certification for the vessel. For this to be effective, however, a class society must review and approve the plans. The USCG do, however, maintain responsibility for the review of plans concerning vessel and passenger safety.

Prior to commencing the project, AMHS, NGA, DSY, DNV and USCG reviewed the plan submission process ensuring that everyone was involved, giving their input and minimising the number of times plans were re-issued to various parties prior to final class / flag approval.

Plan submission was made directly to DNV in Oslo, Norway from NGA. The approved plans were then electronically submitted directly to the USCG with any comment letters. The use of the electronic submittal was a great time, paper and cost saver giving a very rapid approval process on a time/cost sensitive project.

Being DNV's first new construction of a vessel of this type in the Unites States they pulled from their world wide resources to complete the project. This included support for local surveyors from Canada and Norway as well as structural surveyors from Australia being more familiar with light weight aluminium construction. This added additional support and depth to the US team ensuring a rigorous, yet rapid, review and approval process.

As there have been no vessels previously certificated in the US to the HSC code to draw experience from, great attention was paid to the detailing of the plans, particularly with regards to the structural fire protection. Every detail had to be drawn and approved prior to application. Following the application a very rigorous inspection programme of work ensured the application was installed as detailed.

4.4 WEIGHT CONTROL

As discussed in section 3.2, weight penalties on the project were extremely severe - $100/lb. Having set the baseline weight as part of the bid submission weight was monitored throughout the project. A rigorous weight control program was prepared and followed throughout construction.

This weight program included of the following:

1. As part of the purchase order, engineering had to approve the item from a weight aspect. If an item deviated from the weight specified in the weight schedule, then a value engineering exercise was initiated.

2. Purchase orders had the weight specified on them and weight penalties were agreed with the vendor in case the received weight deviated from the contract.
3. All material received at the yard passed through a weigh station and the weight compared to the purchase order.

4. Each structural unit was weighed on completion and any missing structure accounted for prior to being cross checked and up dated in the weight estimate.

5. Monthly weight estimates were provided to the customer as part of the contract. The weight estimate included the gross weight of the vessel, the percentage of all parts weighted, the centre of gravity, longitudinally, vertically and transversely.

The net result being that the builder was able to keep a very accurate track of the weights and centres, such that the actual weight and centre came within 0.5% and 0.1m respectively of the predicted.

4.5 VALUE ENGINEERING

Through the construction of every vessel, especially first of class, there is always an opportunity to integrate, modify, apply new technology, and revise arrangements.

To control these changes, the shipyard and client used a contractual system where the yard would give the customer, at no cost, a rough order of magnitude, within 20%, of the cost associated with any proposed change. If the client was interested, they would pay the yard to develop a fixed cost for that change. Through this method the shipyard brought to the client a number of ideas that were integrated into the construction, post contract. Some of these items included:

1. The first complete use of vinyl on the exterior surfaces of a vessel instead of paint. The benefits to customer being large weight savings and long term savings on maintenance.

2. Derecktor developed and received approval on new arrangements for Structural Fire Protection, reducing the thickness of the material required, saving weight significantly.

3. Halogen free wire: contract specifications called for the use of conventionally insulated cable. The extensive use of halogen free cable was again a very large weight saving.

4. Use of FM200 rather than CO_2. With the use of Halon banned as a fire retarding agent, CO_2 has been the only single system that is approved for fire extinguishing in engine rooms. Recently UCSG has approved FM200 as a non life threatening alternative. The comparison between weight and size of each system was made and accepted by AMHS as a design improvement.

4.6 ENCUMBRANCES

The construction financing of the vessel for the State of Alaska was provided by the Federal Government. With that came contractual requirements that are not encountered in private contracts.

Some of these items included:

1 Buy America – This required that all steel used in the vessel be of U.S. origin with an allowance of \$35,000 worth being exempt from this. However, even in an aluminium vessel there is a remarkable amount of steel and everything counts – even the steel springs inside fluorescent lights were required to have a statement for the source of origin.

2 Jones Act – As this vessel operates on port to port domestic U.S. routes it is required to comply with the Jones Act. All hull components are therefore required to be manufactured in the domestic United States.

3 Disadvantaged Business Enterprise – A goal of 6% of the sub-contracted work is to be given to certified minority businesses.

4 Cargo Preference – On Chenega, the follow-on vessel to the Fairweather, the buy America clause changed to requiring all material or vendors coming into the United States travel on American carriers. Federal projects are full of clauses and it is very important for Contracts Management to be aware and current on all aspects of the contract.

Additional to the above, the contract with AMHS called for an “open book” policy for all communication that took place between the Builder and Class. Rather than this being a negative, it had the result that every one worked within the concept of a “team” and was beneficial to the project.

4.7 FACILITY

Fundamental to the success in securing and completing the project was the lease of the Connecticut site in 2001. Converting 93,000m^2 of a 223,000m^2 steel mill enabled Derecktors to build a new facility tailored to the business and future growth of the shipyard. (See Figure 18)

The \$12 ½ million project funded by Derecktors and the State of Connecticut, has been invested to renovate 40,500m^2 of land, renovate the existing building (183m * 28m), fabricate a new erection hall (92m * 46m * 28m) and install bulk heading and piers for the travel lift.

Figure 18 Production facilities in Connecticut.

4.8 LAUNCHING

As this was a new facility, an analysis of the best way to launch the ferry was conducted. Since repair and refit work is a big part of the business plan, the investment in the launching equipment and method used needed to apply to both new construction and maintenance service.

The analysis reviewed various types of equipment such as floating cranes, slipways, a travel lift, a Synchrolift, a combination of each and dry-docks. The travel lift was deemed to be the most cost effective method to haul and launch service vessels in the future and was therefore the obvious selection. Once this decision was made, a lifting cradle had to be designed and built as the slings alone would damage the vessel. The first vessel was rolled out and launched in less than two hours. After trials, as part of the contract, the vessel was hauled out using the lifting cradle and travel lift to inspect the hull and waterjets. (See Figure 19)

Figure 19

4.9 CONSTRUCTION VALIDATION

Through construction a great deal of emphasis was applied to inspection, testing and trials. This was to the benefit of the project, as it is easier to make adjustments to the vessel prior to delivery.

4.9.1 USCG and DNV

The vessel, as stated earlier, was designed and built under survey. As part of that, Derecktor contracted DNV through NVIC 1099, (a document giving the class authority to sign off plans as approved by a Professional Engineers) to review and inspect the vessel’s construction for the USCG. The USCG, at their discretion, attended a minimum of 10% of inspections.

This system worked very well. Being the first full HSC vessel built in the United States, the USCG did attend most inspections and tests. Also, as the state of Alaska is dependent on the marine highway, AMHS have a very sophisticated engineering and project management staff. AMHS policy was to ensure that a team of AMHS marine engineers was present for onsite inspection of all the structure and systems from the beginning of construction through to delivery of the vessel.

For all inspections, the following parties attended: DSY, AMHS, USCG, and DNV. The scheduling of inspections was therefore important.

4.9.2 Inspection/Test/Trials – Seven Step Program

Over the whole program there were 480 test memorandums written, reviewed and approved prior to each test being initiated. The validation of construction was broken down into a seven step program as follows:

Step 1: Shop Inspection
This represented factory inspection, during which a class required shop test would be scheduled. Factory visits were made to MTU – the main engine manufacturer, Northern Lights – the generator manufacturer, the switch board manufacturer, the integrated machinery and controls manufacturer, etc.

Step 2: Construction Inspection
This was broken down to structural, mechanical installation, electrical installation, joinery installation and paint application.

Prior to any plate being cut, the thickness was checked using an ultra sound machine. In a number of circumstances, this picked up that the plate was below mill tolerance and further structural calculations had to be performed to ensure that the plate thickness was sufficient for the location it was intended to be used. In certain instances the plate had to be set aside and other plate used.

With regards to structure, over 250 x-rays were taken of butt joints. 15 selected areas of the engine room fillet welds were inspected using dye penetrate and 1% of the remaining hull. Ultra sound was also used to confirm laminate thickness on the water jet inlet ducts.

Mechanically, lasers were used for alignment along with calibrated hydraulic torque wrenches for making up the equipment.

Other inspections were in principle based on ensuring that the equipment, cable, bulkheads etc. were clean, fit for work and installed to good shipbuilding practice.

Step 3: Operation And Performance Testing
All equipment was started and run up to the full rating of the equipment. Various measurements were taken such as flow rate, pressure, amps etc ensuring the required performance.

Step 4: Dock Trials
Repeat of step 3, starting the equipment remotely if designed to do so.

Step 5: Builder Sea Trials
The builders sea trials were conducted over a two days. Traditional trials such as, speed, turning and stopping trials were conducted on day one. These trials were all run with no dead weight or ballast on board. Day two started with a four hour endurance run followed by wake and motion trials confirming contractual requirements.

Step 6: Acceptance sea trial
Repeat of Step 5, but at full load displacement.

Step 7: Special Trials such as the Failure Mode and Effects Analysis, wash measurements and an evacuation trial.

Supplementary to the prescribed vessel trials all the prime and auxiliary equipment was monitored and structure loading recorded through a hull monitoring (HMON) instrumentation package.

4.10 INTEGRATED LOGISTIC SUPPORT

In addition to the vessel construction, Derecktor provided the HSC manuals and trained three initial crew members such that they were HSC certified and qualified to operate the vessel. Subsequent training has been conducted by newly trained AMHS staff.

4.10.1 Manuals

The generation of the ships HSC manuals was a joint development between the Shipyard and AMHS. AMHS reviewed the outline, the first draft and the final submission to ensure that the product was in a format that would support their long term training needs. At each stage, the manuals were delivered as hard copies and electronic format so they could be reviewed through the entire AMHS network and by selected consultants.

The HSC manuals included in the delivery were:

1. Maintenance and Service Manual
2. Route Operating Manual (produced by outside vendor and AHMS)
3. Training Manual
4. Craft Operating Manual

Once reviewed and accepted by the USCG and DNV, electronic copies of the manuals were loaded to the server on the vessel in addition to providing hardcopy manuals on the bridge.

4.10.2 Training

As discussed above, familiarisation training was conducted for designated personnel both on the vessel and at the factories of major equipment suppliers. In addition to training the ships crew, Derecktor also provided the delivery crew with USCG approved training. The benefit to this exercise was that Derecktor and the USCG were assured that the delivery crew was familiar with operating the vessel and its safety equipment prior to departure. As this is a multiple vessel program, DSY elected to become certified as an approved training centre for this and future delivery crew requirements.

4.11 WARRANTY

The warranty term of the contract extends for 18 months. In additional to the extended time frame, the location – approximately 4000 miles from the shipyard and in an isolated area with limited resources – means that redundancy in the ships systems had to be planned for. The vessels service was designed such that the vessel would be able to operate on only three engines. The water jets were over sized to ensure that cavitation would not occur when operating on three jets. The expectation was that the vessel would have to operate for a number of days on three engines if for example, wood debris was sucked up into a jet that could not be back flushed. This has happened three times during the first season of operation.

5.0 CONCLUSIONS

The project has been a great success for AMHS, Derecktors Shipyard and BMT NGA.

Growing from a highly detailed set of owners requirements, this project has called, not only upon the design and construction skills required for success, but upon many skills and areas of expertise and technical consultancy available in the marine industry today.

Having a dedicated team, maintaining consistency through the life of the project, ensured that the vessel met all of the initial requirements set by AMHS, with enhancements that naturally develop with design definition.

Meeting all contractual requirements, and having been successfully delivered, the vessel now serves the local communities and visiting tourists within the State of Alaska.

Figure 20 – The M/VFairweather in service

6.0 ACKNOWLEDGEMENTS

The success of this project is due to a number of reasons, and benefited greatly from the efforts of the team members from AMHS and The Glosten Associates who reviewed the work being completed, adding their own feedback from personal experience and expertise, for the efforts of both the USCG and DNV approval team and team of surveyors for their efforts in the design / build review process, and all the companies that provided their areas of speciality such as MARINTEK (Norwegian Maritime Technology Research Institute), J.&A. Enterprises, Inc and CETEC Ltd.

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8.0 AUTHORS BIOGRAPHY

Jago Lawless graduated from the Southampton Institute with an honours degree in Naval Architecture specialising in Yacht & Powercraft Design. Since graduating Jago has worked as a designer of yachts for Ed Dubois Naval Architects, before joining FBM Babcock Marine as a Naval Architect, being promoted to Senior Naval Architect and qualifying for Chartered Engineer Status in 2001. Jago then joined BMT Nigel Gee and Associates Ltd in 2002 as the Project Manager for the AMHS contract.

John Bonafoux graduated from Southampton College of Higher Education in 1983 with a Diploma in Yacht and Boat Design and CEI Part II examinations qualifying for Chartered Engineer status, entered the high speed ship and boat building industry and held a number of posts with builders Vosper Hovermarine Ltd, and Watercraft Ltd specialising in the design of high speed workboats, pilot boats, Police launches and ferries. In 1986 he was a joint founding Director of BMT Nigel Gee and Associates Ltd and has overall responsibility for the technical content of all design and drawing information leaving the Company.

Gary Smith has been the Naval Architect for the Alaska Marine Highway System since May of 1998. He is responsible for acquisition of new vessels and issues of naval architectural concern with the existing fleet. Prior to this he worked ten years for the U.S. Navy Naval Sea Systems Command as Project Engineer, Trials Manager and Acquisition Manager for the construction of the

Harpers Ferry Class (LSD 49-52) of Landing Ship Dock vessels built at Avondale Shipyards in New Orleans. Previous employment was for U.S. Navy contractors in the Washington, DC area. Mr. Smith graduated from the Massachusetts Institute of Technology in 1978 with a degree in Naval Architecture and Marine Engineering, and is a member of the Society of Naval Architects and Marine Engineers (SNAME).

Gavin Higgins has been the Chief Operating Officer of Derecktor Holdings since October 2000 and has been the General Manager of Robert E. Derecktor, Inc. since 1997. Previously, he was the Chief Engineer at Robert E. Derecktor, Inc. from 1988-1997. Gavin has a degree in Naval Architecture from Southampton College in Southampton, England. He is a Chartered Engineer in the U.K. and a Member of the Royal Institute of Naval Architects. In the U.S., he is a Member of SNAME, the Society of Naval Architects and Marine Engineers.

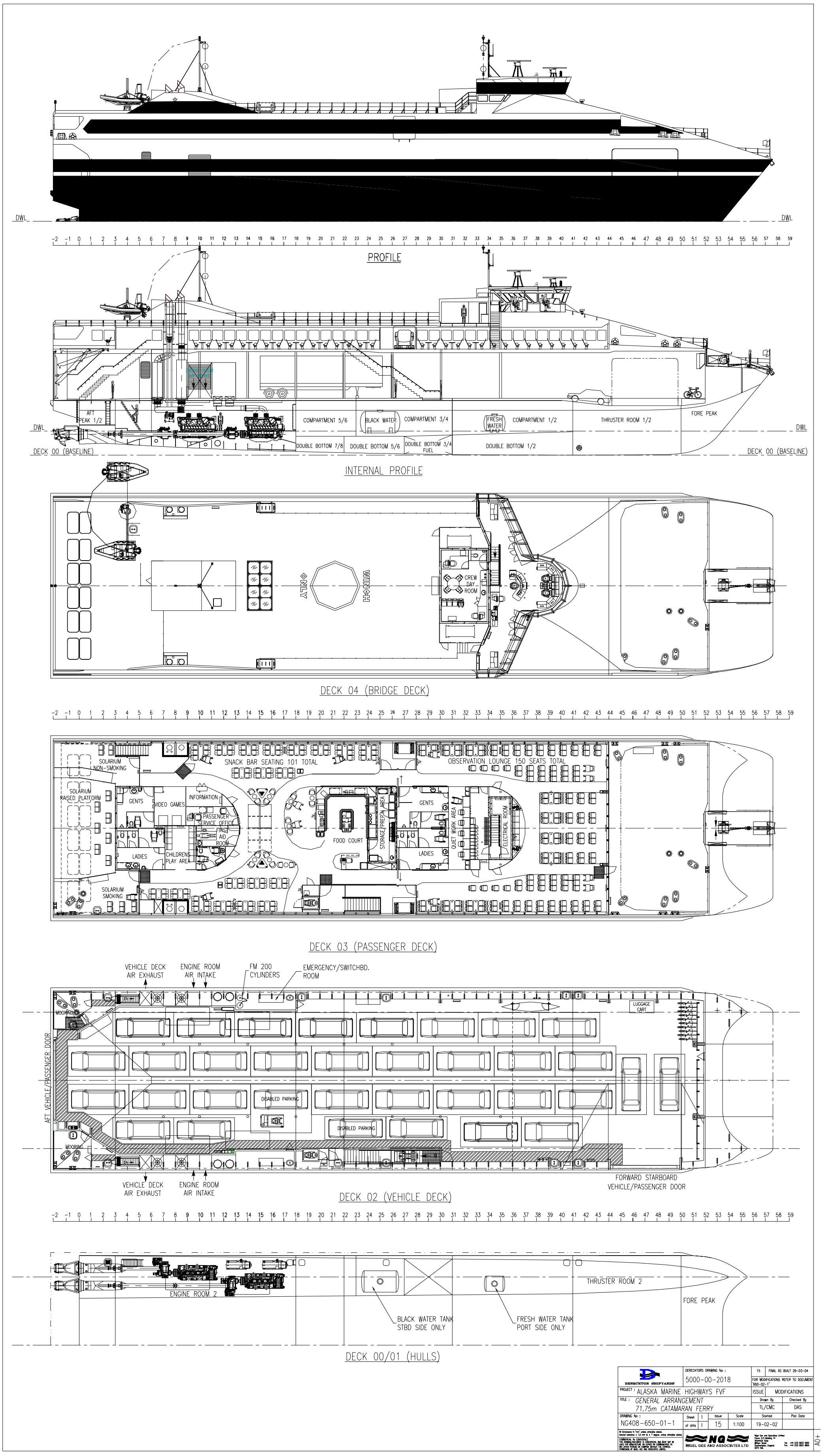

Figure 21 – M/V Fairweather General Arrangement.