Liquefied Natural Gas as Fuel in Passenger Vessels

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LIQUEFIED NATURAL GAS AS FUEL IN PASSENGER VESSELS

This briefing paper was prepared by WSDOT Ferries Division Vessel Engineering for purposes of providing technical background information on liquefied natural gas (LNG) to WSDOT executives, legislators and employees.

Introduction

Liquefied Natural Gas (LNG) definition: Natural gas (predominantly methane, CH_4) that has been cooled to -160 degrees Celsius at which point it is condensed into a colorless, odorless, non-corrosive and non-toxic liquid. In its liquefied form it occupies $1/640^{th}$ of its original volume which allows for ease of transportation and storage.

LNG as a fuel – In its gaseous state, LNG is the same fuel used to heat our homes and cook our meals. Use of natural gas in transportation has been steadily increasing for the last decade with LNG and CNG (compressed natural gas) being the dominant forms used for this purpose. LNG is fast becoming a transportation fuel for transit buses, short haul and long haul semi-trucks, and for ferries.

LNG as a Ferry Fuel

Using natural gas as a transportation fuel presents an opportunity to improve U.S. energy security, as compared with petroleum, which dominates the U.S. transportation sector. Natural gas is largely produced domestically, with imports accounting for only 10 percent of gas used. The bulk of the imports are from Canada with less than 3 percent coming from Mexico. These imports are mainly for convenience as the gas pipelines are originating from these areas.

LNG use as a marine fuel is both practical and cost effective and has been used in Norway for powering ferries for over a decade. Norway, which has the largest fleet of LNG fueled ships in the world, has been operating a number of LNG fueled ferries since 2000. At this time, there are at least eight gas powered vessels carrying passengers and autos as well as several more on order.

Although the capital cost of the gas engines and gas storage tanks is higher compared to conventional diesel equipment and fuel storage tanks, fuel cost savings can quickly pay back that capital investment.

LNG Benefits

Cost of LNG - LNG contains less energy per gallon than diesel fuel. Diesel equivalent gallons are commonly used to solve this problem. A diesel equivalent gallon is the quantity of LNG that contains the same energy as a gallon of diesel fuel. Because 1.67 gallons of LNG contain the same energy as 1 gallon of diesel fuel, 1.67 gallons of LNG are 1 diesel equivalent gallon.

The delivered price of LNG to the vessel by tank truck has been quoted as $0.75 per gallon. The current price of diesel fuel is around $3.34 per gallon. The per gallon savings is approximately 56 percent. Given these potential fuel cost savings, WSF is pursuing a retrofit of the Issaquah Class Ferries to burn LNG. The following tables outline the runs for the Issaquah Class boats and the monthly comparison of fuel burnt for diesel and LNG. The estimated cost of the initial retrofit is $14 million with an expected five percent learning curve reduction for each subsequent vessel. The cost to complete the retrofit of the six vessels is approximately $75 million.

Fuel Usage for Issaquah Class Ferries (6) Vessels

			MONTHLY	MONTHLY
			DIESEL	LNG
VESSEL	RUN	DESCRIPTION	GALLONS	GALLONS
ISSAQUAH	TRI	FAUNTLEROY-VASHON-SOUTHWORTH	56200	84300
CATHLAMET	MUK	MUKILTEO - CLINTON	45000	67500
KITSAP	BREM	SEATTLE BREMERTON	88252	132378
CHELAN	SID	ANACORTES - SIDNEY	54542	81813
SEALTH	SJ	ANACORTES - FRIDAY HARBOR	52905	79358
KITTITAS	MUK	MUKILTEO - CLINTON	45000	67500
		TOTAL	341899	512849

Fuel Savings for Issaquah Class Vessels with LNG

			MONTHLY	MONTHLY	MONTHLY	PERCENT	ANNUAL
			DIESEL	LNG	SAVINGS	SAVINGS	SAVINGS
VESSEL	RUN	DESCRIPTION	COST	COST			
ISSAQUAH	TRI	FAUNTLEROY-VASHON-SOUTHWORTH	$187,708	$63,225	$105,712	56.32%	$1,268,546
CATHLAMET	MUK	MUKILTEO - CLINTON	$150,300	$50,625	$84,645	56.32%	$1,015,740
KITSAP	BREM	SEATTLE BREMERTON	$294,762	$99,284	$166,002	56.32%	$1,992,024
CHELAN	SID	ANACORTES - SIDNEY	$182,170	$61,360	$102,594	56.32%	$1,231,122
SEALTH	SJ	ANACORTES - FRIDAY HARBOR	$176,703	$59,518	$99,514	56.32%	$1,194,172
KITTITAS	MUK	MUKILTEO - CLINTON	$150,300	$50,625	$84,645	56.32%	$1,015,740
							$7,717,344

NOTES:	HEATING VALUE OF MARINE DIESEL	18300	BTU/LB	LHV
	HEATING VALUE OF LNG	20908	BTU/LB	LHV
	DENSITY OF MARINE DIESEL	52.95	LB/FT3	
	DENSITY OF LNG (-169 DEG C)	27.7	LB/FT3	
	DIESEL FUEL PRICE DELIVERED: per gallon	$3.34		
	LNG PRICE DELIVERED : per gallon	$0.75		
	PERCENT FUEL SAVINGS	56.32%		

At today's pricing, the payback for the retrofit of six vessels is approximately seven years with a 28-30 year life left on each of the vessels. In addition, the conversion to LNG results in a 20 percent reduction in the use of marine diesel fuel for the whole ferry system. We believe the price quoted per gallon of LNG is high, so we are expecting a better return as the number of boats burning LNG increases to six.

Emissions – LNG engines are clean burning, the fuel requires no pre-heating, no separators and less filtration than conventional diesel bunkers. In general the emissions reductions from a Tier 2 diesel propulsion engine to a pure LNG propulsion engine are predicted as:

NO_x – At least 90% reduction

PM – Approximately 100% reduction

SO_x – Approximately 100% reduction

CO_2 – Approximately 20% reduction (LNG from a Land Fill Reclamation Site – 90% reduction)

MONTHLY EMISSION SAVINGS						
CARBON DIOXIDE			PARTICULATE	NOX		
DIESEL	LNG	REDUCTION	SAVINGS	DIESEL	LNG	REDUCTION
MT	MT	MT	MT	MT	MT	MT
566	333	233	0.395	6.710	0.744	5.966
453	267	186	0.316	5.373	0.596	4.777
888	523	365	0.620	10.537	1.169	9.368
549	323	226	0.383	6.512	0.722	5.790
532	313	219	0.371	6.317	0.701	5.616
453	267	186	0.316	5.373	0.596	4.777
		1416	2.400			36.294

With ever more stringent emission regulations in the future, WSF will be required to meet Tier IV emission criteria by 2014 on any new vessels built and for any vessels that will undergo an engine overhaul if Tier IV kits are available. The use of LNG as a fuel meets Tier IV requirements with no additional after treatment of the exhaust gases.

LNG Operational Challenges

Availability - Natural gas is a widely available fuel across North America. LNG is in limited use in Washington State today, but if a large enough market existed in the Puget Sound area, a gas supplier may build a local liquefaction plant. Currently two liquefaction facilities exist on the Washington/Oregon border and another in British Columbia, Canada. All potential ferry fuel would have to be trucked to the vessel much like 70 percent of the diesel fuel is today. Presently, two commercial shipping entities - Fortis and Teekay Shipping - are developing a plan to supply LNG into Puget Sound by truck and barge. Puget Sound Energy already has a fleet of trucks that deliver LNG to their Peak Shaving Plant in Gig Harbor.

Regulatory - Since no LNG fueled passenger vessels have yet been built in the United States (other than small retrofit pilot projects), the United States Coast Guard (USCG) does not have an established path for regulatory review. As the USCG is WSF's primary regulator, early engagement with them to discuss an approach to gaining their approval of an LNG ferry is essential. The basic design for the Issaquah Class boat has been approved by the Coast Guard and we are presently working on the Safety and Security Plan with consultant, Det Norske Veritas (DNV), and the local USCG district. The Safety and Security Plan will include Navigation, Risk Assessment and Operational procedures.

DNV has been the classification body that has been involved in developing international standards along with Lloyd's Register for the use of LNG in passenger vessels. These rules are largely based on a well established safe design practice of the International Maritime Organization (IMO) International Gas Carrier (IGC) Code.

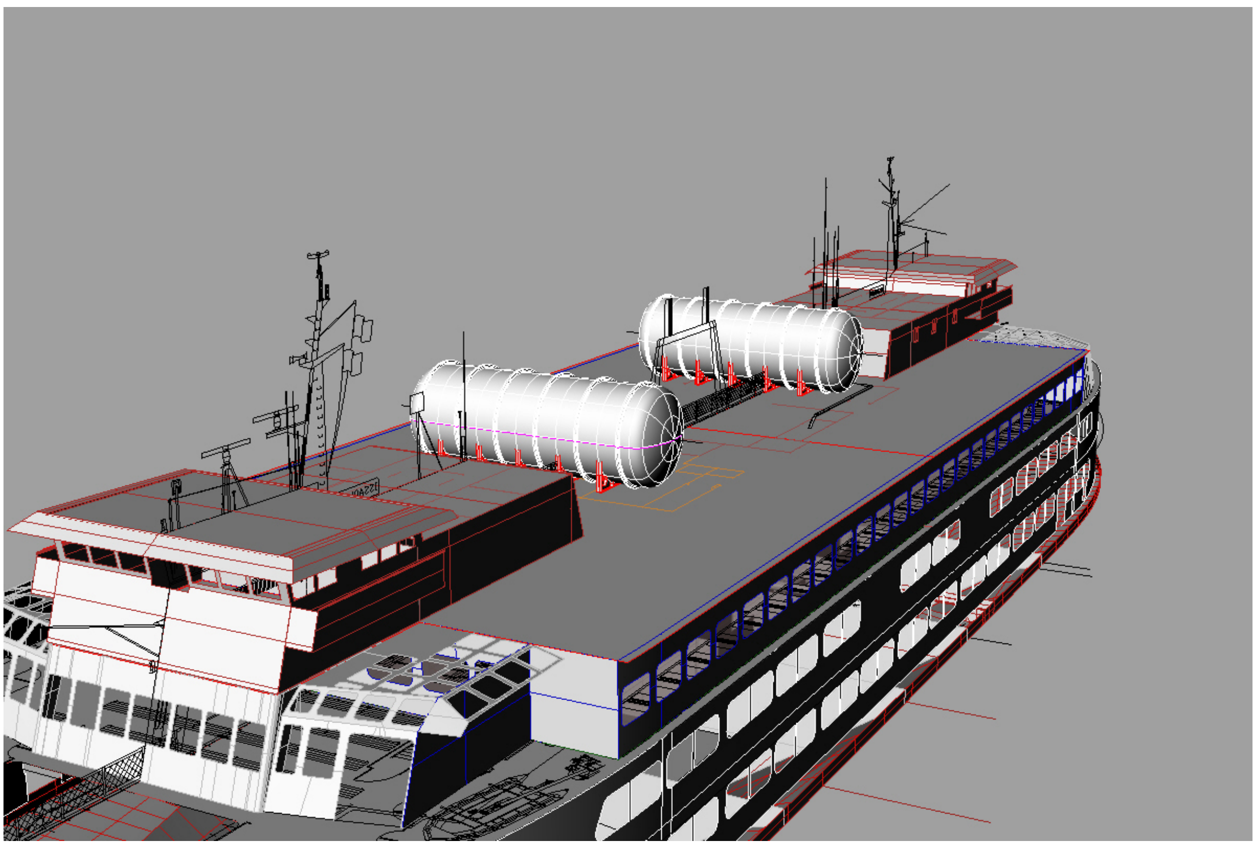
DNV has more experience than any other classification society in classifying ferries since they were the first to create these rules and have applied them to a number of vessels and vessel types, most notably the Norwegian passenger / auto vessels.

Status: Over the past two years, WSF has been working internally on the Issaquah Class conversion as well as with Glosten Associates on the feasibility of converting the 144 Car Ferry design to burn LNG. The basic design of the Issaquah Class and the 144 has been approved by the USCG Marine Safety Center in Washington. The USCG has agreed that the modification or retrofit of the Issaquah Class ferries to LNG does not constitute a major conversion requiring a complete upgrade of all systems to the latest standards.

LNG Design Challenges

LOCATION OF THE LNG STORAGE TANKS

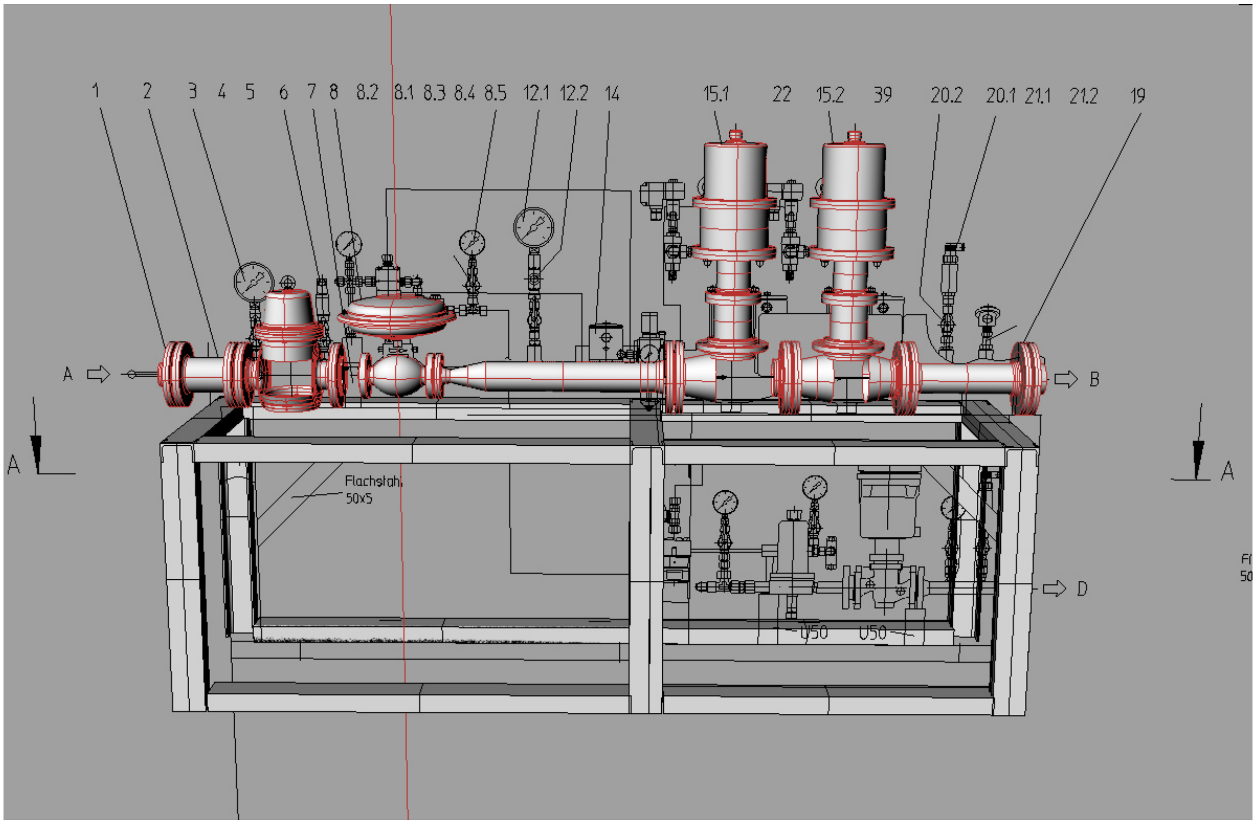
The location of the storage tanks is difficult because of the nature of the tanks. The LNG is maintained under pressure at -160 deg C in an insulated tank that is a body of revolution which must be B/5 feet, which equates to 15.7 feet from the side of the vessel. The present design locates the tanks up on the sun deck to provide the B/5 clearance as well as provide a safe position for any escaping vapor to dissipate naturally away from the vessel and passengers. LNG is about half the density of diesel fuel, but has about 10 percent more heating value per pound. The result is we need about 165 percent more volume of LNG for the equivalent volume of diesel fuel.



Location of (2) 100 cubic meter LNG Tanks on an Issaquah Class Vessel (45,000 gallons)

GAS REGULATING UNIT (GRU)

The vaporization of the LNG will be accomplished at the tank with two heat exchangers built into each tank as a unit. The heat exchangers will be incorporated into the LNG storage system all mounted on a skid supplied by the vendor. The gas from each tank will be cross connected to be able to supply gas to either engine room, but in general, one tank will supply each engine room. As the gas line enters the vessel casing, the line will transition to a double walled pipe that will run to each engine room. In the engine room, the line will be attached to a container hung from the overhead that contains the Gas Regulating Unit (GRU) which has to be within 8 meters (25 feet) of the engine. The GRU is not a double-walled unit and must be housed within a secondary barrier that is ventilated at a rate of 30 air changes per hour. The line leaves the GRU at a double wall flange connection on the boundary of the enclosure and is run to the engine.

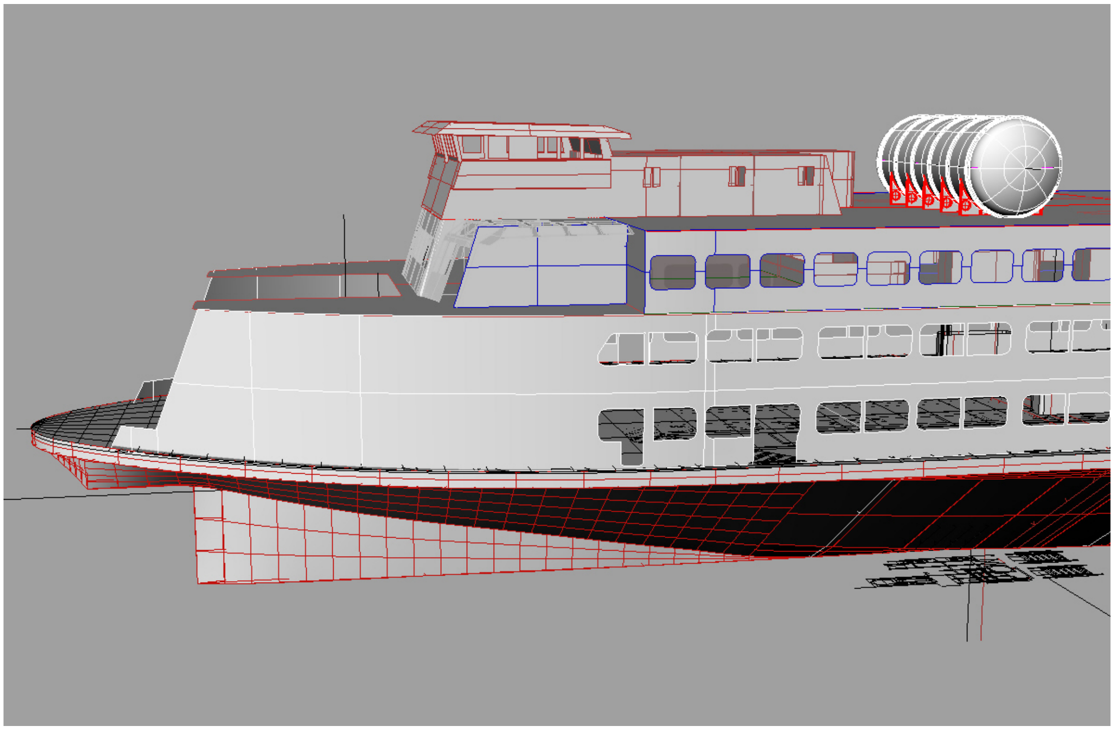


Gas Regulating Unit: (GRU)

BUNKERING SYSTEM

The bunkering system is a challenge as the vessels are tied up at night with the bow end on to the pier. The result is there is no access to the side of the vessel. The Issaquah class vessels are presently fueled by truck overnight, during the out of service time. We have met with the LNG suppliers and they currently use a dedicated trailer that carries 10,000 gallons of LNG. We plan to continue to use trucks to bunker the vessel during the overnight tie-up with the switch to LNG. The hose connection would be attached at the ramp just inside the curtain plate to a manifold. The manifold would contain the necessary valving for transfer of LNG to the tank. One LNG supplier informs us that a pump will be required to transfer the LNG from the pickle fork up to the tank on the sun deck. The pressure in the storage tank is controlled by the addition of LNG as a condensate to cool the tank which will reduce pressure. The condensate line is off the fill line at the tank.

The truck will normally have a pump to transfer the LNG, but if the trailer is not fitted with a pump, a mobile bunkering unit could be used to transfer the LNG from the trailer to the storage tanks. A vapor return line is attached to the fill tank and the trailer to equalize the pressure between the two tanks reducing the pumping head to the height and velocity head of the fluid. The piping for the bunkering system is a double walled pipe and qualified for cryogenic use with the space between the inner and outer pipe held at a vacuum providing excellent insulation.



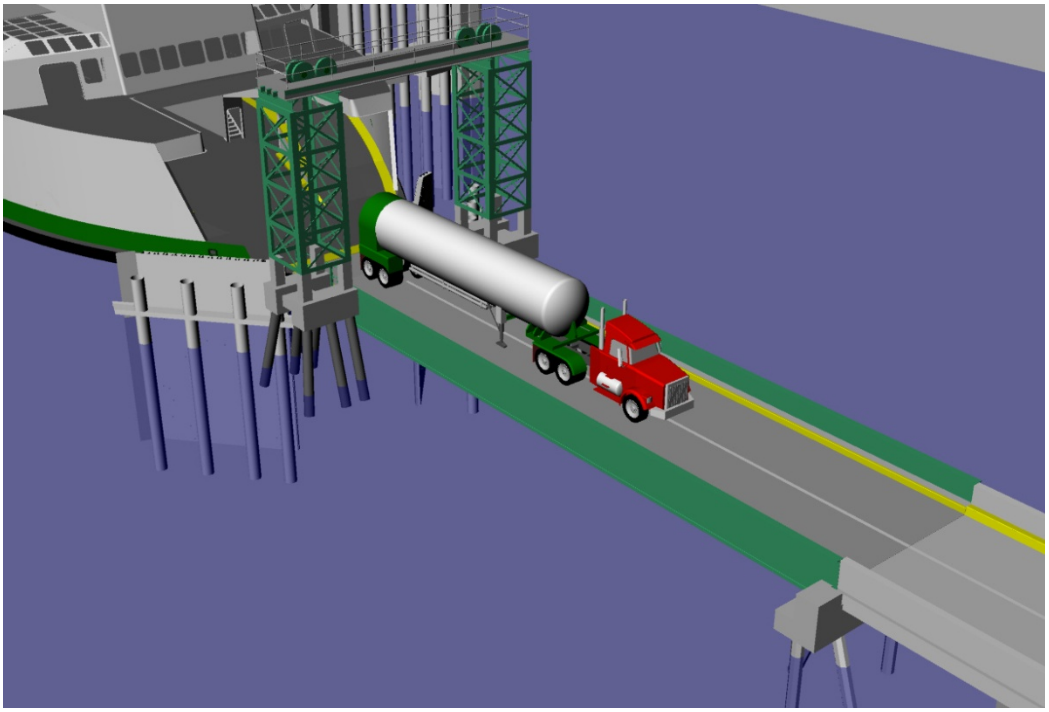
Position of LNG Tanks in Relation to the Car Deck

STATUS

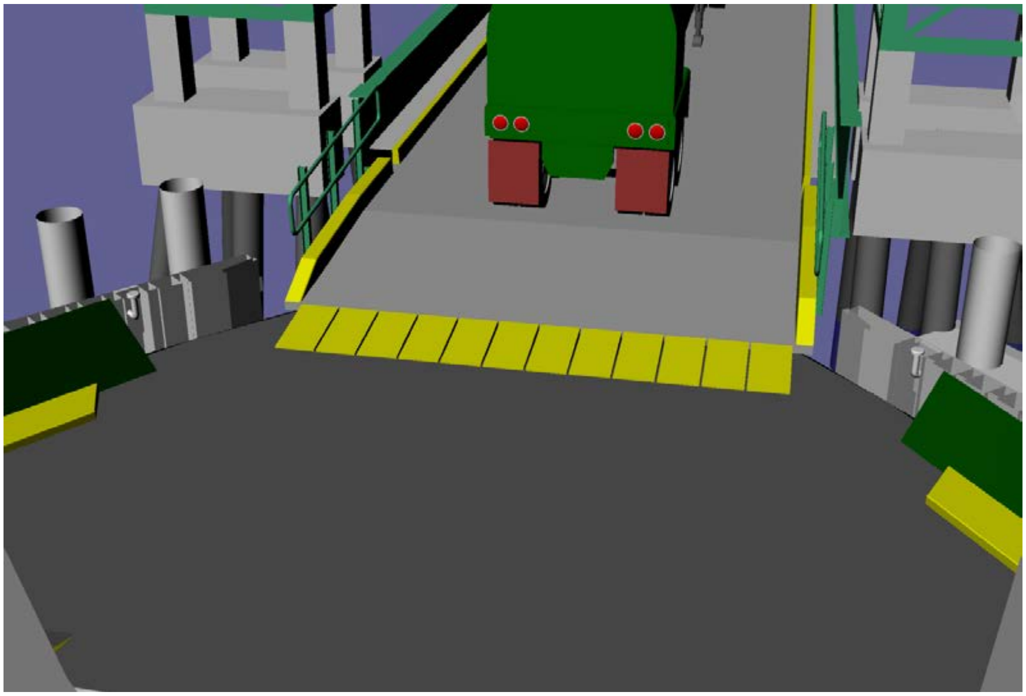
WSF has developed and issued a request for proposal (RFP) for the retrofit of all six Issaquah Class ferries. The RFP due date is March 4, 2013. The package includes the supply of all the equipment, engineering and installation of the LNG tanks, gas supply system, bunkering system and natural gas engines for all six vessels. The RFP requires the contractor to purchase and install all the required equipment and get all the required approvals to allow the vessel to obtain a COI for operation with LNG as a fuel.

Both “gas only” and “pilot injected” engines are acceptable per Addendum 3. The gas only engine utilizes a spark plug to ignite the gas and air mixture. The pilot injected engine also known as a dual fuel engine, uses a small injection of diesel fuel, about 1-1.5 percent of the normal fuel injection to ignite the remainder of the gas and air mixture. The dual fuel engine can run on either a pilot ignition mainly gas fuel or it can switch back to diesel fuel and operate as a standard diesel engine.

A second RFP has been awarded to DNV for the Safety and Security aspect of the use of LNG as a fuel. DNV has begun to put together the Safety and Security Plan, the Risk Assessment and the Operational Manual. DNV hopes to complete the work by spring 2013.



LNG Trailer & Cab Parked on Transfer Span



Trailer Positioned at the end of the Transfer Span