Summary

After more than a century of developments, the tanker industry has become an indispensable link in today's society. With the emergence of a global economy, especially the oil trade evolved into one of the largest industries in the world, which has influenced the design of tank vessels and liquid bulk terminals tremendously (Huber 2001).

Besides the carriage of oil and oil products, tank vessel design has been adapted over the years to meet the demands of other specific liquid bulk cargoes. This development has basically led to two types of oil tankers: the crude tanker and the product or chemical tanker [Huber, 2001].

The trade of liquid bio-fuels is relatively new in the liquid bulk industry, but in search of a more sustainable future these energy sources are seriously considered for replacing current energy sources [Marchetti et al, 2008]. Currently promising types of liquid bio-fuels include bio-diesel and bio-ethanol, both these types exist in a variety of grades and blends [Taylor, 2008].

This report focuses primarily on the basic design of product and chemical tankers and the equipment installed on such tank vessels designed for loading and discharging liquid bulk cargo. Secondly, basic characteristics of liquid bulk terminals and the interface between product tankers and these terminals will be investigated. Furthermore, the implications that the handling of liquid bio-fuels impose on the design and regulations of tank vessels and terminals will be discussed. This literature study concludes with suggestions for future research possibilities regarding the interface between tank vessels and terminals and the handling of liquid bio-fuels.

Tank vessel design and classification

Catastrophic oil spillage incidents involving tankers in the past have led to implementation of severe safety and ship design regulations, e.g. the legislation requiring larger sized tank vessels to be designed with a double hull construction [Huber, 2001] [Skea, 1992].

Regulating agencies, together with other stakeholders in the tanker industry such as classification societies, are also responsible for the implementation of a tank vessel classification system. The most commonly used classification system (Flexible Market scale, see table 1) is based on the size of a vessel, which can be expressed in a so called "deadweight tonnage" (DWT) [Evangelista, 2002]. The deadweight tonnage of a vessel is defined as the amount of cargo, fuel, water and stores a vessel can carry when fully loaded [Huber, 2001].

The product tanker category shown in table 1 can be further subdivided into product/chemical tankers (up to 40.000 dwt) and product/oil tankers (up to 60.000 dwt). Finally the International Maritime Organization (IMO) has three classification levels regarding product/chemical tankers: IMO ship type 1, 2 and 3 [IMO, 1998]. IMO ship type 1 tankers are intended for transporting chemicals presenting the greatest overall hazard, whereas chemicals suitable for IMO ship type 3 tankers present the smallest threat.

Table 1: Flexible Market scale vessel classification system [Evangelista, 2002].

Flexible Market Scale	
Product Tanker	10,000 – 60,000 dwt
Panamax	60,000 – 80,000 dwt
Aframax	80,000 – 120,000 dwt
Suezmax	120,000 - 200,000 dwt
VLCC	200,000 – 315,000 dwt
ULCC	320,000 – 550,000 dwt

Loading and discharge equipment onboard tank vessels

In order to load and discharge liquid bulk vessels, dedicated cargo handling equipment such as cargo piping and pumps are required onboard. Cargo piping systems, which are always present on decks of tank vessels and in some occasions also installed on the tank bottoms, enable the flow of liquid bulk to and from the vessel's cargo tanks [Huber, 2001]. The driving force behind the cargo flow during discharge operations is generated by cargo pumps that can either be installed on the ship's deck or in a dedicated pump room located near the engine room of the vessel [Huber, 2001].

Other generally installed equipment onboard tank vessels such as tank venting systems and tank cleaning systems concern the safety inside the vessel's cargo holds and prevention of cargo contamination.

Liquid bulk terminals

Liquid bulk terminals serve as a distribution hub for connection to and from the hinterland, which can be accomplished by transport modes such as barges, trains, trucks and pipelines. Operations and activities performed by liquid bulk terminals include: loading/discharging or transshipment of tank vessels, storage of liquid bulk products and filtration, blending and processing of products [Ministry of VROM, 2005].

Essential facilities and pieces of equipment installed at liquid bulk terminals to accommodate the various terminal activities consist of: storage tanks, loading pumps, tank vessel berths equipped with jetties, pipelines, manifolds and hoses, tank cleaning and waste water processing facilities [Ministry of VROM, 2005].

The actual interface between tank vessels and liquid bulk terminals can either be accomplished by installing a flexible hose between the tanker's and terminal's manifolds or by a mechanically operated loading arm, which can automatically connect to the cargo manifold of a tank vessel [FMC Technologies, 2005].

Cargo characteristics and handling specifications of liquid bio-fuels

In 1973 the International Maritime Organization (IMO) adopted the International Convention for the Prevention of Pollution from Ships (MARPOL), which covers marine environment pollution by oil, chemicals, harmful substances in packaged form, sewage and garbage [IMO, 2009]. In this convention a subdivision is made between crude oil and oil products (referred to as Annex 1 products) and general noxious liquid substances (referred to as Annex 2 products) [IMO, 1998].

Liquid bio-fuels, defined as liquid fuels that have been made according to a refinement process of a variety of biomass materials, are classified as Annex 2 products under current MARPOL regulations [IMO, 1998]. Within this MARPOL Annex 2 convention, products are further divided into three pollution categories (X, Y, Z) according to the threat they present to the environment. Bio-diesel grades are currently classified in pollution category Y, whereas bio-ethanol is classified in the less threatening Z category [IMO, 1998].

Conclusions and recommendations regarding the carriage and handling of liquid bio-fuels

[MEPC, 2004 $_2$] Following current regulations, different grades of biodiesel are required to be carried with IMO ship type 2 carriers, which belong to the product/chemical tanker category as mentioned before. Bio-ethanol on the other hand can be carried in vessels without IMO ship type certification, so besides product/chemical tankers also product/oil tankers are suitable.

The most suitable loading/discharge equipment installed on tank vessels basically depends on factors such as the magnitude of the liquid bio-fuel trade and how many different grades need to be transported per voyage. In case of smaller batch sizes in combination with the carriage of a variety of different grades requires a multiple segregated cargo handling configuration. So called “deepwell pumps”, which are deck mounted cargo pumps placed at each cargo hold individually, prove to be an ideal solution to provide the required cargo segregation [Marflex, 2009].

If, on the other hand, the liquid bio-fuel trade scales up to meet the future energy demands, larger product tankers (up to 60.000 DWT) will be required, which generally have fewer but larger segregated cargo tanks. To ensure acceptable ship turn around times, the discharge capacity of these vessels should also scale up, which leads to the use of centrifugal type main cargo pumps located in a pump room. These pumps can deliver better discharge performances but do require more complex tank bottom piping [Huber, 2001].

The basic characteristics of a liquid bio-fuel handling terminal resemble the characteristics required for a multiple product/ chemical handling terminal. Again the magnitude of the liquid bio-fuel trade is a deciding factor in considerations regarding the storage tank sizes and jetty characteristics.

As for the size of the storage tanks, IMO Ship type 2 vessels are allowed to carry up to 3000 cbm of cargo inside a single tank [IMO, 1998]. Assume that such chemical tankers carry multiple grades of bio-diesel or even a range of entirely different products and the conclusion can be made that storage tanks in the size order of 5000 cbm are suitable [Vopak, 2009]. But if the batch sizes of liquid bio-fuels increase, for example if larger product/oil tankers (up to 5000 cbm per tank) are used and less different grades are carried, the capacity of storage tanks at the receiving terminals should increase significantly.

Future research recommendations, regarding the pollution elimination and cost reductions of tank vessels, include the developments of more efficient tank stripping and cleaning systems and longer lasting tank coatings. Because society demands cleaner and safer tank vessels, stronger regulations are implemented that demand higher performances of the specific stripping and cleaning equipment [IMO, 2009].

Additional research goals, regarding the interface between tank vessels and terminals and the handling of liquid bio-fuels, that can be suggested for the near future include the further automation and implementation of marine loading arms and the quick coupling connectors connected to them. Furthermore in order to reduce CO2 emissions during loading and discharge operations, future research could focus on the use of shore supplied electrical power (AMP) instead of using the vessel's own diesel generators to power the cargo pumps [Siuru, 2008].

Finally because new types of bio-fuels and bio-fuel blends are not yet regulated according to the MARPOL Annex II Convention, there is still an ongoing debate regarding the handling requirements of these substances [Strode, 2008]. The development of updated regulations that include these substances requires additional research, which can be successful if the technical committees of the regulating agencies can cooperate with the manufacturer of the substance and the liquid bulk product shipping companies.