



Kinney Lectures

A publication of United States Friends of World Maritime
University

and

World Maritime University

United States Friends of World Maritime University

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World Maritime University

proudly present the publication of the Kinney Lectures

in honor of

Admiral Sheldon Kinney

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In Memoriam



Rear Admiral Sheldon H. Kinney, United States Navy, Retired
Naval Officer, Commandant of Midshipmen, College President, and Maritime Educator

Rear Admiral (Ret.) Sheldon Hoard Kinney died December 11, 2004 at age 86 following a brave fight with cancer. His 38-year naval career included distinguished combat service in three wars, and took him from Signalman to command of 125 ships and 65,000 officers and crew of the Cruiser-Destroyer Force of the Pacific Fleet. He served as the Navy's Chief of Education & Training, as Commandant of Midshipmen at the U.S. Naval Academy, as President of the New York State Maritime College at Ft. Schuyler, and as Rector (President) of the International Maritime Organization's World Maritime University at Malmö, Sweden.

Tribute to a Great Mariner and Educator



Karl Laubstein

President Emeritus

World Maritime University (1996-2008)

Since its establishment in 2004, the annual “Sheldon Kinney Lecture” has become a highlight in the academic calendar of the World Maritime University (WMU). The lecture was conceived as a lasting tribute to Admiral Sheldon Kinney (1918-2004), a distinguished personality of the international maritime community who played a major role in the establishment and further development of the World Maritime University.

Admiral Kinney had a long and illustrious career in the United States Navy, and he received various commendations and honors for his outstanding service and personal bravery during World War II. Following his retirement from the US Navy, Admiral Kinney became actively involved in the field of Maritime Education & Training (MET), first as Commandant of Midshipmen at the US Naval Academy at Annapolis and then as President of the New York State Maritime College at Fort Schuyler, New York. During his time as President of the Maritime College at Fort Schuyler, Admiral Kinney also served as Special Advisor to Dr. C.P. Srivastava, the then Secretary-General of the International Maritime Organization (IMO), who conceived and spearheaded the project to establish the World Maritime University.

Dr. Srivastava, in a later study on the creation of WMU, has paid full praise to Admiral Kinney for his invaluable contribution to the creation of WMU in terms of both his advice on the academic program of the new University and his important role in securing the necessary international support for this project. Then, a little more than a year after WMU had been inaugurated in July 1983, the University faced a sudden crisis in 1985 with the unexpected resignation of its first Rector. Admiral Kinney immediately responded to the urgent request from the IMO Secretary-General to become Rector of WMU on a temporary basis until a long-term replacement had been found for this position. As WMU’s Rector in 1985 Admiral Kinney organized the inaugural graduation ceremony of the University modeled on the format of leading maritime academies in the USA. This ceremony has not been changed until this day. In 1984 Admiral Kinney established and became the founding Chairman of US Friends

of WMU, Inc., a Washington-based non-profit organization of American supporters of the World Maritime University. Over the years, the US Friends have provided different kinds of invaluable assistance to WMU such as the following:

- financial assistance for special purposes such as the cost of consultants, the binding of student theses, the purchase of WMU minivans, and the travel and subsistence of invited experts (such as the speakers at the Sheldon Kinney lectures)
- facilitating the award of student fellowships to WMU from American sponsors such as Mobil Oil and the American Bureau of Shipping (ABS)
- providing academic staff assistance through the provision of visiting professors and the facilitation of fully funded ongoing staff secondments from the US Coast Guard
- facilitating regular contact with senior officials from the US Government such as the US Coast Guard and the Maritime Administration (MARAD)
- assisting WMU in being accepted by the US Department of Veterans' Affairs (DVA) as an educational institution at which US veterans can study with DVA funding

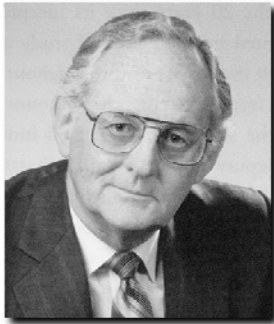
As Admiral Kinney had played such an important role in the development of the World Maritime University, I was of course delighted when members of the Board of the US Friends of WMU approached me in late 2003 with the proposal to establish a special annual lecture at WMU in honor of this remarkable man. The annual "Sheldon Kinney Lecture" is a public lecture on a significant topic in maritime transportation which is held in conjunction with the annual meeting of the University's international Board of Governors. The speakers are internationally renowned experts in different areas of maritime transportation whose appearance is funded by a small endowment from the US Friends and by WMU. The inaugural Sheldon Kinney Lecture was held at WMU in Malmö, Sweden on 9 June 2004. It was presented by Mr. William O'Neil of Canada, long-time Chancellor of WMU and Secretary-General of the International Maritime Organization.

Shortly after the inaugural Sheldon Kinney Lecture in June 2004, Admiral Kinney passed away after a heroic last battle with cancer. WMU subsequently established the Sheldon Kinney Doctoral Fellowship at WMU, tenable to outstanding WMU graduates in its M.Sc. program. The first recipient of this fellowship was Michael Manual of Ghana, who graduated with a Ph.D. in Maritime Administration in October 2009. As the fellowship is funded entirely from the University's earnings from research and consultancy projects by its staff, this is a special tribute by the academic staff of WMU to Admiral Kinney.

During my 12-year-tenure as President and CEO of the World Maritime University (1996-2008) I had the good fortune and pleasure of getting to know Admiral Kinney personally. I will

long remember him as a very kind and unassuming person who always made you feel welcome and comfortable when you met him. He was deeply committed to the ideals and values which are fundamental to the service of the World Maritime University to the global maritime community. Thus, the Sheldon Kinney Lecture is a fitting tribute to a great mariner and educator who played such a significant role in the history of the World Maritime University.

Foreword



Mr. William A. O'Neil

Chancellor Emeritus

Ex-Secretary-General, International Maritime Organization

9 June 2005

I am delighted and honored to deliver this inaugural Sheldon Kinney Lecture. I congratulate the US Friends of WMU on their initiative in establishing this very special annual event which ensures that Sheldon's contribution to the international maritime community lives on. I was privileged to know and work with Sheldon Kinney when he was appointed as the second Rector of WMU in 1985, when I was the Chairman of the IMO Council. Sheldon brought to WMU strong leadership and a proven commitment to maritime education having served for some 10 years as President of the State University of New York Maritime College. I thought that I should speak today about the WMU and the important contribution which the University makes to the maritime world and which, I am sure, it will continue to make in the years to come.

As a specialized agency of the United Nations, a vital part of the work of the International Maritime Organization is to help less developed countries around the world to establish and improve their ability to participate effectively in global seaborne trade, in full compliance with the globally applicable safety, security and environmental instruments established by the IMO.

In the days when the term "globalization" had yet to be invented, a major factor limiting the effective global implementation of the IMO instruments was an enduring and acute paucity of top-level maritime expertise in developing countries. Back in the 70s and 80s, nearly all developing countries with a coastline had trained maritime technical personnel drawn from the sea-going professions – notably Master Mariners and Chief Engineers, who were employed in their national maritime administrations as examiners, surveyors, managers and as teachers and trainers. But they had not received the benefit of post-graduate education in contemporary maritime policy developments nor professional training in the skills of teaching or designing study programmes. In this situation, most developing countries were simply unable to build a modern maritime infrastructure, which was so vital for their economic

development and their foreign trade. This gap between the developed and developing economies increased as the shipping industry became increasingly sophisticated and technologically advanced.

The IMO, supported by the United Nations Development Programme (UNDP), had tried in the early 1980s to fill this gap by recruiting specialists from developed countries and making their services available to developing countries on short-term missions. This technical cooperation initiative was, however, of limited benefit. The specialists did their best to assist developing countries within the limited time available to them. But there was no lasting benefit. Moreover, there was a high cost: UNDP's "expert" programme cost approximately US\$ 2.5 million per annum.

Against this background, my distinguished and far-sighted predecessor, Dr Srivastava concluded that a far more cost-effective approach would be to build national competencies by delivering a programme of post-graduate study in contemporary maritime safety policy and governance at the middle and senior management levels for the maritime administrations and institutions of developing countries. As Chairman of the IMO Council, I was pleased to provide Dr. Srivastava with all the support that I could muster from the IMO membership. When the World Maritime University opened its doors to students in 1983, it marked the inauguration of the most ambitious and exciting of all IMO's technical assistance projects. As I have indicated, our vision was that the WMU graduates would return to their national Administrations, fully conversant and confident in securing the implementation of the IMO's policies, its conventions and its operational guidelines.

Were we realistic? In fact the results have surpassed all our expectations. In the 20 years since its inception, many hundreds of students who have benefited from a period of study at WMU have made their mark in their own administrations. By the end of this year, over 2,000 WMU graduates will have returned to their home countries to take up a wide variety of pivotal positions in the public sector as government ministers, deputy ministers and ambassadors with shipping and/or maritime portfolios.

Others have pursued career paths that have led to senior positions in shipping companies, regional maritime organizations and national port and harbour authorities. Some have become educators and senior surveyors. Many have returned to IMO as part of their national delegations. Collectively, they form a unique cadre of highly trained maritime experts continuing to pass on the skills and values they absorbed during their time at WMU and thereby widening still further the influence of this unique institution. But just as important,

they have forged bonds and established a network that has spread throughout the shipping world. So, the creation of WMU has proved to be a “smart business decision”. The University has become an integral and indispensable component in the global supply chain by facilitating world trade and contributing to IMO’s mission of “Safer Shipping: Cleaner Oceans”.

Some 20 years later, our world of today is very different from that of 1983 when WMU was established. The global geo-political landscape has changed beyond recognition: the liberalization of trade, of services and of financial markets has created a truly global market place. International seaborne trade in 1983 was some 3.3 billion tons; some 20 years later, driven by world growth including the emerging and transition economies, it has more than doubled to 6.7 billion tons. Correspondingly, in 1985, the total world fleet was some 674 million dwt: a decade later it had grown to almost 900 million dwt. The tectonic shifts in manufacturing and production to Asia and China in particular are radically changing global distribution patterns.

In 1983, environmental consciousness was barely on the political radar. Today, the public is increasingly intolerant of oil spills. There is an increasing determination to limit the emission of greenhouse gases from international marine bunker fuel. A further major concern today is the introduction of invasive species through ship ballast water carrying viable organisms from one body of water to another. The intergovernmental framework regulating maritime safety and the environment in 1983 was also very different from that of today. The emphasis placed by developing countries in sustaining national shipping lines through cargo reservation or public ownership has given way to privatization and disengagement by governments from the economic management of shipping activities. Similar privatization policies have been adopted in relation to ports and to port management.

In OECD countries, the political importance of shipping and of national “flag” carriers has given way to robust, arms-length economic policies: no subsidies; no tax concessions. But at the same time, the growing political emphasis on the marine environment, brought into sharp focus recently in Europe and the European Union in particular by two major oil spills, has put maritime safety and environmental standards high on the political agenda. All this is to show that the general global context in which the WMU was established has evidently changed radically over the last 20 years. However, the focus of the University’s capacity-building role remains: the developing countries and their maritime administrations in particular do not have the resources and range of competencies required for effective maritime governance. In conclusion: we can see a change in the dynamics of the world around us. But the role of the

WMU is as relevant today as it was two decades ago. The new, younger generation of maritime professionals in maritime administrations graduating from WMU, return to their home well able to rise to the challenges which they will meet in their own countries.

I should recall, in closing, that WMU would not and could not exist without the support of its donors and friends. So I would again wish to commend the US Friends for their support and for launching the Sheldon Kinney lectures. Thank you.

The 50th Anniversary of Container Shipping



Captain Richard T. Soper (retired)

American Bureau of Shipping

"Father of the Modern Containership"

31 May 2006

The 2006 Sheldon Kinney Lecture by Captain Richard Soper of the USA, was delivered by Jerry Malia, President of the US Friends of WMU Inc., as Captain Soper's health prevented him from traveling to Sweden.

Introduction

It is an honor and a privilege to be invited to address this distinguished gathering. Especially for me as I first met the late Admiral Kinney when this fine University was in its conceptual stage and I was invited to support this objective and to help bring it to a reality. I am grateful for all those years we worked together.

The 50th anniversary of container shipping is a subject of great interest to me, as I was fortunate enough to spend a major part of my professional life working for Malcom McLean's Sea-Land, and at a time when many people felt it was just an "idea" that would never amount to anything. Hindsight solves many controversies and I wonder how many interested observers ever realized the significance of what was about to happen; nothing short of one of the most influential events in the history of the transportation industry. In retrospect, I am not at all sure I realized the magnitude of what was about to happen and I would ask your indulgence in some of my memories and experiences. I prefer not to use the first person singular but that is difficult in that many of my experiences are both personal and vivid. It doesn't seem possible that all of this happened almost 50 years ago. In my comments I will try to trace key events in the evolution of Container Shipping. It is a vast subject and ultimately will generate its own literary history. While personal viewpoints may differ, most of what transpired is historical and much will often be written in the decades ahead. To suggest a little of the atmosphere in those days I will just recall a few memories.

Without question the dominant influence was the founder of this "new" system and the Chairman of Sea-Land Service. A truly remarkable man for whom I worked, and believe me, was in awe of; quiet, modest and introspective, and radiating practical common sense. Like

many important innovations, once there is a semblance of success it's interesting to note how many "pioneers" or "creators" surface. Although Sea-Land (Malcom McLean) is usually acknowledged as the "Pioneer", long before the historic events of 50 years ago various forms of small steel containers were in use, including the popular 10footer "Milvans" of World War II vintage. Used only sporadically, they still embraced the basic container concept. The idea that the "big Box" could be used economically and efficiently on a massive scale was really the province of a once disparaged "Trucker" from North Carolina. His own words in familiar modesty say a lot about his identity with the development. The idea that revolutionized cargo handling the world over, and forever changed the nature of shipping, came to him one day back in 1937 at an American Export Lines pier in Hoboken, New Jersey: "I had driven my trailer truck up from Fayetteville, North Carolina with a load of cotton bales that were to go on an "American Export" ship tied up at the dock. For one reason or another I had to wait most of the day to deliver the bales, and as I sat there, I watched all those people muscling each crate and bundle off the trucks and into the slings that would lift them into the hold of the ship. On board the ship every sling would have to be unloaded by the stevedores and its contents put in the proper place in the hold. What a waste of time and money!

Suddenly the thought occurred to me: "Wouldn't it be great if my trailer could simply be lifted up and placed in the ship without its contents being touched? If you want to know, that's when the seed was planted..."

The idea that there could be a better, practical way to load and discharge cargo never occurred to me. There had been almost no advances or technical improvements in the time-honored methods of "break-bulk" shipping in the liner trades. I had plenty of opportunities to be unhappy with the way we did things. I had sailed for the very same fine old traditional company, the American Export Lines where Malcom McLean got his idea about a more economical and efficient system. By coincidence one of my former ships the "Exanthia" is pictured berthed at the exact same pier where some nine years earlier, McLean waited all day with his truckload of cotton bales. The not very clear picture of "Exanthia" with its traditional "forest" of booms tells its own story.

The crude map (definitely NOT to be used for navigation) gives some indication of the multiplicity of port calls on our Western Mediterranean run. Rigging and unrigging all those booms, sometimes twice in a day, did not make for a simple job for the Chief Officer and his crew.

When I joined Sea-Land and became Manager of Vessel Operations I had no idea how important the next decades would be. The old conventional systems were about to be changed thanks to a man, usually considered by the old line "Shipping People" as an interloper. Sadly, many of the nay-sayers, and they were legion in those days, ultimately fell by the wayside, or much too late realized that "the Trucker's" ideas were not only going to work but would presage a unique milestone in transportation history. Dramatic proof that what most people do not like is "change".

Brief reminiscences of Malcom McLean: In those early days, having only recently joined Sea-Land, one Sunday afternoon I looked up from my desk to see a tall man standing in the doorway. Dressed like most of the dockworkers, I assumed he was a stevedore looking for someone and asked if I could help him. "You probably can, he said, my name's Malcom McLean"; so much for my introduction to my new boss! Several hours later I remember being quite exhausted by his seemingly endless stream of complex questions. "I just want to learn something about my boats", he said, and I soon trying to help with that, albeit being somewhat unnerved.

McLean had a brilliant financial mind and dealt with large numbers, almost always on the back of a used envelope. I did my best to keep up but constantly fell behind. Later I was advised: "My way is quicker, I just drop zeros." For those of us fortunate enough to work for and with him, we soon learned that when he called he inevitably opened any discussion with: "Lemme ask you a question..."; time to reach for the aspirin bottle, or do some immediate homework. He had an insatiable curiosity about everything and applied his native common sense and quick intelligence to everything connected with the entire operation. I know he was intrigued with suddenly becoming a major ship-owner. He worked long hours and showed by personal example, a solid work ethic; definitely a "hands-on" man. I have always believed that a dominant reason for that company's success was a sort of built-in challenge and unrest. For most of us Sea and Land meant just that, and there were many trying times when we felt: "Yes, and never the twain shall meet". The trucking side usually thought of the maritime sector as the "boat-drivers", but this built-in competition brought out the best in both facets of transportation; perhaps begrudgingly, but we both learned a lot from each other. Maybe not always cheerfully, though.

Not everything was wonderful. Viewed from today's perspective of electronic systems we tend to forget those early rather primitive days. Many humorous things happened (though not seen that way at the time). What was known as "Trailer Control" was little more than a

magnetic board supporting individual magnetic blocks showing the container number. These were neatly, and laboriously arranged in columns of destinations or shipboard assignment. All went well until the night that an overly zealous cleaning lady gave the board a swipe and just like that some 4,000 containers had no location identity.

In another “Dark moment” we were experimenting with a new, more powerful power source for maintaining refrigerated loads in the terminal. That we did not succeed was evident when suddenly we blew all the power for the city of Elizabeth, New Jersey. But gradually far more sophisticated methods evolved and systems began to mesh properly. Youth doesn’t always have a lot of tolerance for the “older generation”. I am sure they would not believe how primitive things were. Remembering those days it is clear that none of those innovations happened by “magic”. There were many dark and discouraging days.

I have always believed that whatever success we had was due to Mr. McLean’s fundamental philosophy that “there must be a better way to do something” and most emphatically, “never say it can’t be done”. This will all sound a bit quixotic, but it was the real world we lived in day after day of very long hours. Best of all it was a fantastic environment in which to learn and to accept challenges. Exciting days full of adventures, enough to fill a very large book.

Fifty years of container shipping and now (and I will understand if you say “thankfully”) let’s take a quick look at the 50 years we are recognizing. There are so many obvious visible signs of Containerization: the seemingly endless lines of double stacked rail cars moving through the countryside – the vast container terminals in virtually every major seaport in the world – the numerous arrivals and departures of containerships from the huge “Post-Panamax” ships to the small feeder-ships that are found on every waterway in the world. On the autobahns, autostradas, motorways, interstate highways and local roads, no one can be unaware of the physical presence of container transportation. The magnitude of the economic impact is no doubt, less apparent.

75-85 million-\$ large, fast containerships

100-150 million-\$ modern container terminals

6 million-\$ terminal gantry cranes

Literally billions of dollars in containers, road equipment and cargo.

The often-cited “capital-intensive” description of the whole system seems inadequate, today. The total investment, always climbing, is estimated to be in the \$700 billion range.

The more subtle economic aspect of containerization relates to its profound impact on domestic and international trade. Simply put, the cost of shipping goods in containers, in real dollars, is dramatically less than with the break-bulk methods it replaced. This is because of:

- Lower labor costs;
- Better utilization of equipment, hence lower capital costs;
- Reduction of pilferage;
- Less cargo damage, staining, tainting, contamination, crushing, sweat damage, damage from multiple handling, and hence lower insurance costs;
- Simpler documentation;

and the list of economies goes on. This all has resulted in lower transportation costs. The elimination of multiple handling, and faster loading and discharge has dramatically reduced the door-to-door transit time. The importance of all this on the movement of perishable foodstuffs is obvious. The advent of hermetically sealed, climate and atmosphere controlled, refrigerated or heated containers, resulting in extended shelf life, more healthy, less bruised products, has created new markets for fruits and vegetables. The effect of faster shipments and lower transport costs has made it possible to produce and ship goods to markets that would not otherwise be feasible. Literally, it has created new markets and expanded existing ones. Faster and more reliable delivery times have resulted in JIT (just-in-time) logistics and reduced inventory costs. The beneficiaries of lower costs are the manufacturers, shippers and distributors – and more importantly, the consumers, the general public.

Let's consider the principal elements that make it all work. We'll take a condensed look at:

- The Past – How it all began
- The Intervening Years – Gradual acceptance
- The Future

Speaking of the future reminds me of Yogi Berra, the colorful American baseball player, who is purported to have said many things that he didn't. One of the things he "Didn't" say was: "The Future ain't what it used to be".

Containerships

At Sea-Land the very first ship employed was a T-2 Tanker, the “IDEAL X”, fitted with a spar deck, a system used successfully in World War II. On April 26, 1956 a little more than 50 years ago, she made her inaugural voyage carrying 33-ft. containers. Confirming what looked very promising, the company began converting 6 Maritime class C-2 cargo vessels, formerly operated by Waterman Steamship.

A cellular system was installed in each hold and with sponsors added to the hull, 2 traveling gantry cranes were fitted on each ship. Over the next several years the greatest “Cut and Paste” program ever imagined took shape. It should be mentioned that among Malcom’s many talents was an uncanny ability to obtain financing in the most favorable way. For a few years the U.S. Gov’t, was anxious to diminish the huge post-war tonnage surplus, with a system we called “The Box-top” program. (For many years cereal companies had a sales incentive program whereby you could send in a box-top from a purchase and get a replacement at no cost.) Similarly, we were permitted to turn in antiquated, essentially useless old tonnage (nondescript to say the least) in exchange for C4 class vessels – especially suitable for our needs because of size and engine-aft configuration. A matching fleet of new cellularized mid-bodies was constructed using several shipyards. The bow and stern sections were cut free of the original cargo sections and the new mid-bodies inserted. It sounds simple, but it was **not**. These were precedent-setting methods and required the highest level of understanding and technical analysis of the U.S. Coast Guard in Washington. Looking back to these hectic times – the introduction of the entire system could have been delayed indefinitely had it not been for the willingness of the Coast Guard and the American Bureau of Shipping to give us a fair hearing.

Among my own responsibilities at the time was the re-registering of what comprised a “new/old” fleet, and I admit that I wasn’t always certain which bow was now married to which stern. Over decades the C-4 fleet formed the nucleus of a relatively inexpensive and efficient fleet – preceding the ultimate construction of a fleet of “state-of-the-art” ships. Time is so often the critical factor in the success of any program. Regardless of all the time and effort expended we were very lucky we were able to complete what was an unprecedented, unique program, quickly and at low cost.

Meanwhile, other American liner companies, which in one form or another had reluctantly embraced the container mode, began their own fleet revisions but with a much more conservative and modest approach. (“Tradition” peering over shoulders?) Similar developments were taking place in Europe. Cellular containerships were converted general

cargo ships of very modest size. Sea-Land's early containerships carried only 226 35-foot containers. Matson, Grace Lines and others early containerships were of similar size and capacity. Between 1957 and 1962, the container capacity of new and converted ships increased steadily, so that by 1962 a typical new containership might have a 1,000 to 1,200 TEU capacity. The first containerships were geared vessels, with each ship having 1 or 2 shipboard gantry cranes. By 1962, the trend reversed and was definitely in the direction of gearless containerships. The early containerships rarely stacked containers higher than 2 or 3 on deck. By the mid-60s, however, container stacks had reached 4 or 5 on deck. The era of the 70's and 80's saw containership sizes, including length, beam, depth, draft and capacity all increase steadily to Panamax size. By the mid-1980's the largest containerships were Panamax vessels, on the order of 4,400 TEU, with beams of 32.2 meters, lengths of 275 to 290 meters and drafts on the order of 10 meters.

During this period from 1960 to 1985, while the fastest ships were increasing in size, there were and still are considerable numbers of new containerships built in the 2,000 and 3,000 TEU capacities. The widely accepted advantage of large containerships is capital cost economy of scale. However, there are several other strong reasons to opt for such vessels. Most containerships carry ballast for stability. Larger ships require less or no ballast. (Note that the freight rate on ballast water is not very attractive.) There is also more flexibility in stowage locations on larger ships.

With a concept still pretty much in an embryonic form, but gaining universal acceptance, brand new tonnage from the keel up became the norm, and with it the brief era of the "Cut and Paste" process was becoming a memory.

It became clear to containership operators during this period of growth, that there was a need also for "pick-up and delivery service"; in other words, feederships. The first purpose-built container feedership was the ADDA, put into service in 1965 in Hamburg. These feederships also proved useful in the short sea trades. The feederships are generally in the 200 to 800 TEU size. However, vessels older and larger than this also act as feederships from time to time.

It was obvious that large "Line-Haul" ships did not have to service every port, in fact couldn't. With regard to speed, the early converted containerships were all of the 16 to 17 knot class.

By the 60's average speeds had increased to 19 knots with some vessels, somewhat faster. By the 1970's and 1980's, however, the faster of the containerships were in the 23-24 knot

range, whereas the vast bulk of the containerships were still operating at less than 20 knots. During the late 1980's there was a surge in power and speed so that the newer containerships were all in excess of 23 knots and usually 24 to 25 knots. The exception to all this was the Sea-Land SL-7 program of the early 1970s, when eight 33- knot containerships, the fastest merchant ships ever built except for the SS United States, entered into service.

During the 1990's, we saw a departure from the adherence to the requirements that ships need to be able to pass through the Panama Canal. Consequently, the first of the post-Panamax vessels appeared. In the last ten years hundreds of vessels of the post-Panamax size have been constructed and/or ordered. The "Regina Maersk" is typical of the largest.

These 25-knot vessels have beams of 42.8 meters and lengths of 318.2 meters. To obtain maximum utilization of the deck, containers on the Panamax vessels are stowed 12 or at most 13 across, whereas, the more recent post-Panamax ships are stowed 17 containers athwart ships. This increase in width of ship has resulted in the requirement that many terminals serving these vessels have had to construct new cranes with extended boom capacity. The increased beam also has resulted in an inherent increase in the stability of these containerships. The result has been that the cells and stacks below are deeper and the height of stacks on deck are higher.

Container securing systems were and are primitive, operationally costly and delay vessel turnaround. There is no reason why there should be so many deck-stowed containers going overboard. Reducing stack height is not the answer; better securing systems is.... Virtually all of the new or large containerships are gearless, whereas the smaller feeder ships and intermediate sizes are often outfitted with revolving cranes, rather than the shipboard gantries that were so prevalent in the early days of containerization.

In the early 1960's, there were a number of projects, principally in Europe, where insulated containers were used in conjunction with centralized cooling plants in the ship to permit the carriage of refrigerated cargo. This concept, while successful, did not gain widespread acceptance.

The early containerships often had electrical capacity and electrical outlets to accommodate containers with what were really simple highway non-marine refrigeration units. The number of containers that could be carried was somewhat modest, in the order of 50 to 100. However, in more recent years the demand for refrigerated cargo space on ships has increased steadily, such that it is not unusual to find containerships with 300 to 400 reefer-

container capacity. We can expect to see a steady increase in containership size, dimensions and speed. However, the rate of increase may be somewhat shallower and not as accelerated as in previous years. This is principally due to the challenges being presented by port and channel depths, traditional container crane outreach problems, air draft clearances, etc., as well as the economic impact of larger ships on total logistics and infrastructures. We live in a world of superlatives (real or imagined). There are frequent claims that these super “Line-Haul” vessels can be much larger. It is not beyond the capability of world shipbuilding facilities and knowledge to construct “Giant” ships. The reality of it is that they must be able to safely use our world ports, and do so with great operational and financial excellence. “Bigger is not necessarily better.” The allure of “Economy of Scale” must be challenged objectively.

Containers

Just as with the ships that carry the containers, the box itself has gone through many mutations:

- McLean 33 (“Ideal-X”)
- Pan-Atlantic S/S (McLean) 35
- Grace Line 17.5 (In tandem = 35)
- Matson S/S 23
- Union Carbide 30

In the U.S. the initial controlling factor was, and is, the highway standards of the Interstate Commerce Commission (ICC). Many parts of the U.S. permit “tandem” trailers, hence the hoped-for versatility of the doubled smaller units, i.e. Grace, Matson, etc. As the container shipping process was proliferated and improved many adjustments and changes occurred. The fundamental concept required increasing the efficiency of land transport (Truck and Rail) in all countries. By the time the container concept was practically universal, world standards had simplified the variety of sizes (and shapes), and the ISO Standards, with a few variations, became the now traditional 20 and 40 footer. However, nothing remains static or the same, and today, and certainly in the near future, we will see the gradual acceptance of more economical sizes, driven by ever higher gross freight revenues.

The U.S. vehicle interstate highway regulations increased widths to 102 inches, to make them compatible with European road widths of 2.5 meters and their so-called “pallet wide” containers. U.S. trailer lengths grew with the regulations, in the early 1980’s to 45 feet, by the

late 1980's, 48 feet and 53 feet. Major trans-Pacific carriers introduced 48 footers in their U.S. to Far East Service in 1997.

What will the future bring?

Obviously, the container standards were intended to promote efficiency and interchange in transportation rather than hinder it. The ISO standards were recommendations, not regulations. Understandably, developing countries regularly oppose any expansion of the current standards for fear that their massive and hard-earned investments in ports and infrastructure will become jeopardized. This is an extremely complicated issue for obvious reasons. I recall endless meetings about how to economically and efficiently design ships and land systems that could accommodate a multitude of larger containers. Beyond that most unlikely eventuality the industry will be sorely tested to find a practical solution.

When one considers the enormity of the financial impact on just not “falling behind” we realize we are all facing a daunting challenge. It is likely the future will see highway regulations permitting increasing sizes, primarily in length and height, and possibly axle loads; ISO and domestic standard sizes also increasing; and designers and operators developing new and ingenious ways to introduce and, in some ways, integrate the new larger sizes into the existing systems.

To say that this will require worldwide cooperation and consideration is an understatement, but where competition and investment in the “future” is concerned, few things remain static. A world about “**knowing where they are**”; what a very long way we have come from our original old manual magnetic boards to the modern miracle of almost instant electronic communications. There is always the temptation to think: “Oh that potential was **always** there”; potential yes, reality no. The advances in modern equipment and documentation control have been astonishing; a quantum advance and I am sure we are not through with improvements yet.

Terminals

Container terminals are of course an essential element in containerization. We have come a long way in the last 50 years. The first container terminals were little more than a quay and an open marshaling area, sometimes not even paved. The early yards were chassis systems rather than stacked storage. Ships were self-sustaining. Matson and Pace co-pioneered the purpose-built shore container cranes. The appearance of straddle cranes and stacked yards soon followed.

Facilities improved through the 60's with the addition of container and reefer maintenance facilities, more sophisticated gate procedures and systems, fencing, high intensity lighting, reefer outlets, consolidation (stripping and stuffing) sheds, etc., together with improved road and rail infrastructures. The terminal became a very expensive capital cost center. Ownership and operation varied between user-operators, public terminal companies and port authorities. In fairness to shipping interests that could not, or would not, adopt the "new container shipping" system 50 years ago, it is well to remember that a critical sector of the whole process involved the need for unobstructed acreage. A visit to Manhattan's North River's all but abandoned piers is mute testimony to why some prestigious old shipping lines never made the transition. I'm sure the need for space was equally, or more critical, in Europe and Asia.

Over the years most inland truck, rail and barge terminal facilities have kept pace thus far, physically, with the increases in size and capacities of ships. The world's major ocean port facilities are constrained by topographical characteristics and by local and national regulations. The looming, perhaps threatening shadow of ever larger, wider, longer, and deeper ships must be a subject for concern: channel depths, crane outreach, quay lengths etc. Although the system is still quite a young phenomenon, we are all conscious of the need to evaluate expansion with care, and one hopes, worldwide cooperation.

A very positive factor in the evolution of modern terminals has been crane cycle times. Primitive, dockside revolving cranes moved 5 to 10 containers per hour. The first shipboard cranes in the late 50's did 15 to 20 moves per hour. The dockside cranes of the 60's increased this to 25 to 30 moves per hour. Today, cycle times in excess of 45 moves per hour are regularly achieved in some terminals. Thinking of crane cycle time, and indeed everything else relative to the time a ship is in port, I recall long ago Malcom McLean asking me about a sailing delay and commenting: "The only time a ship makes any money is when it is at sea."

Rail Service

The importance of supporting rail service is exponentially greater where it is a factor in large continental land masses. In the U.S. the railroads can be credited with pioneering efforts in Intermodal transportation. However, it is also true that the railroads were among the last to climb aboard the container bandwagon (A mixed metaphor?). Probably in part due to their early heavy commitment in TOFC (Trailer on flat car) COFC (Container on flat car) that didn't really marry with the international intermodal scene until double-stacked container cars and container unit trains came into vogue in the 1980's and 1990's. Just as topography has

influenced the optimum size and capacity of the ships, it has equally, if not more so, become a dominant challenge for improved rail technology. Some basic concerns include:

- Line capacity
- Siding lengths
- Tunnel clearances
- Lateral clearances (especially on curves), and
- Rail wheel loads

It is not likely that we will see growth in lateral or vertical clearances on the rails either in Europe or North America. What we will see in North America is consolidation and mergers. Europe has great opportunities for improved efficiency through rail coordination and mergers. Asia, Africa and South America are starting to develop their full potential for container-rail. Despite the inherent problems, rail systems, especially over great distances, will continue to be a vital segment in the total system.

Summary

We have considered some of the history of the Container revolution. 50 years is not such a long time in the overall spectrum of technological development. It is clear that we are not yet a fully mature industry.

There are plenty of opportunities for improvement. The future should provide many chances to improve profitability safety, efficiency, transit time, reduce costs, reduce damages, and overall, improve customer service and hopefully provide a decent living for everyone. The container facet of the transportation industry has one thing in great abundance, problems and challenges, and is largely dependent on international cooperation. May I suggest some challenges we all face.

- Find ways for standardization to improve transportation and not stifle technological advancement.
- Decrease door-to-door delivery time.
- Eliminate shipboard deck stowed losses.
- Improve crane handling cycle time.
- Reduce terminal throughput costs.
- Improve container securing systems to make them less costly and more reliable.
- Decrease vessel turnaround time.
- Increase rail in-transit speeds.
- Develop shallower-draft large ships.

- Address the looming rail capacity constraints.
- Provide environmentally friendly, deeper draft port facilities.
- Improve the climate inside the box.
- Eliminate box damage.
- Develop improved and less costly methods for stripping and stuffing containers.
- Reduce dwell time for containers in terminals.
- Increase vessel sea speeds.
- Extend container life.
- Reduce container manufacturing costs.
- Improve container utilization rates.

Conclusion

I have tried to address a vast subject celebrating one of the most influential advances in the science of transportation. One of the most interesting aspects of this universally adopted system is its global or international scope. We will see countless advances and improvements. An intriguing aspect of these challenges is the broad scope of opportunities for young transportation professionals. In a system dependent on intricate interrelated services the future will put heavy demands on: naval architects, shipbuilders, land transportation sciences, port development and management, international shipping economics, transportation education and environmental sciences.

Here in a unique university, young men and women are enhancing their knowledge and experience to become outstanding professionals. They are doing so in a truly international environment. They will play major roles in providing the world with ever better facilities and services for people all over the world. I have great confidence in what the World Maritime University can and will achieve.

Design Challenges for the next Generation of Large Ships



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Abstract

The size of ships has increased over time to accommodate the demand of increased world trade. The economies of scale, facilitated by advanced technology in ship design and ship production, have seen the size of ships of various types grow enormously. The technical challenges of designing these larger ships are unique to the type of ship and cargo carried. It is often the port infrastructure and trading routes that limit size.

Ships are basically self-propelled vessels whose fundamental purpose has not changed over the years, yet ship designs have changed due to technological improvements in materials, propulsion, and engineering analysis. New technologies have provided more advanced analytical capabilities, automation and improved propulsion engines to enable the growth in ship size.

Introduction

Seventy percent of the earth is covered by water and over seventy percent of world trade is carried by ships on its surface. Ships are highly complex and specialized, and as world trade increases, their size has expanded to accommodate the need for increased cargo transport capacity. What are some of the challenges involved in designing the next generation of large ships? Are there limits to the size of ships that can be designed and built? What governs these limits, and what are some of the technical challenges in designing such ships?

Cruise Ships

Ships such as cruise ships, tankers, bulk carriers, containerships and liquefied natural gas (LNG) carriers have grown significantly in size, as have cruise ships, during the last 73 years. The success of mega-cruise ships is a major achievement for cruise lines, shipbuilders, and

designers alike. With cruise ships, the increase in size is primarily driven by economies of scale. In 1969, the largest cruise ship was the Queen Elizabeth II which was 70,000 gross tons in size and carried 2,900 crew and passengers. In 2009, the biggest cruise ship is the Oasis of the Seas. It is 220,000 gross tons, more than three times the gross tonnage of the Queen Elisabeth II, and can carry more than 6,000 crew and passengers. When compared to an aircraft carrier, large cruise ships are about the same length and beam as the largest aircraft carrier, and carry about the same number of people.

One of the key challenges in designing cruise ships as they become larger and carry more people is that of ship survivability in the event of grounding, collision, flooding or fire. With so many people aboard, escape and evacuation in the event of abandoning ship becomes more problematic. This important topic is being addressed by the IMO Maritime Safety Committee.

Oil Tankers

Historically oil tankers have been the largest commercial ships, both in size and deadweight tonnage. Tankers are essentially box girder type structures with a high degree of structural redundancy. Oil tankers built today have a double hull in which the cargo tanks are enclosed by an outer hull, except at the deck.

The size of oil tankers has grown significantly in the last fifty years. There are a number of advantages to be gained from building larger ships. Crew costs do not rise in proportion to the size of the ship. Other personnel costs, such as shore management, also depend mainly on the number of ships involved rather than their size.

Further, fuel costs tend to decrease with larger size. A 60,000 dwt ship might need about 16,000 horsepower to operate at 15 knots. A tanker of 260,000 dwt might require 42,500 horsepower. The larger tanker uses 2.7 times more energy but can carry more than 4.3 times as much cargo as the smaller one.

In practice, a number of factors help to prevent tanker sizes from growing indefinitely. There is a limit to the number of shipyards capable of building them and the number of ports capable of receiving them. Also many of the world's most important shipping routes are unable to handle very large ships. The Panama Canal is limited to ships with breadths of 32.2 meters or less until 2014, when expansion of the Canal will be completed to handle ships with breadths up to 49 meters. The Suez Canal is limited to fully loaded ships of 200,000 dwt and 18.9 meters draft. The Malacca Strait, between Malaysia and Indonesia, is too shallow for loaded tankers greater than 260,000 dwt.

Different tanker sizes are used for different routes, because of distance and port access constraints. Some of the categories of oil tankers based on size are the Aframax, Suezmax tankers, the largest of which are the very large (VLCC) and ultra large (ULCC) crude carriers. Most VLCC sizes are generally about 300,000 dwt and carry 2 million barrels of oil. The largest double hull ULCCs are 442,000 dwt and carry 3 million barrels of oil.

The biggest change in tanker designs occurred as a result of some significant maritime accidents causing major oil pollution in the seas. The requirement that tankers trading to United States ports have double hulls came about as a result of the Exxon Valdez oil spill disaster in Prince William Sound, Alaska which resulted in the U.S. passing the Oil Pollution Act of 1990. This was later followed by the International MARPOL Regulation 13F, requiring tankers trading to ports worldwide to be built with double hulls.

It is perhaps not well known that the MARPOL regulation also allows for two alternative designs to double hulls; the Mid-Deck tanker design and the Coulombi Egg design. Both the Mid-Deck design and the Coulombi Egg design are rather innovative approaches to mitigating oil spills in case of collisions or groundings. However, neither of these designs have ever been built as they are not considered to be equivalent to double hulls under the Oil Pollution Act of 1990, and therefore cannot trade in U.S. waters.

Have double hulls been effective? The effectiveness of double hulls to mitigate oil spills from damages due to collision or grounding depends largely on the energy of impact. A double hull tanker rammed by a barge sustained a 30 meter by 1 meter gash in its outer hull, with no oil spilled because the inner hull was undamaged. This was clearly a low energy collision.

A case of a double tanker involved in a high energy collision where oil was spilled occurred in 2001 when the 33,000 dwt double hull tanker "BALTIC CARRIER" collided with a small bulk carrier "TERN" in the international waters of the Baltic Sea. The accident resulted in about, 2,700 tons of heavy fuel oil being spilled.

In the case of low energy grounding or collision, where only the outer shell is penetrated, double hull designs have clearly proven themselves over any other alternative. From a structural design perspective, one of the concerns with larger tankers is not the overall strength of the ship, but rather the strength of structural details.

Critical structural details are usually located in way of corners or intersections at connections of structural members. These are areas of high stress concentration and are subject to cyclic loading and flexing from the ships motion in a seaway, which can result in the development of fatigue cracks. Although small cracks are a concern for any ship, they are of particular concern for oil tankers because of pollution risks. To ensure good design of structural details, a sophisticated finite element structural and fatigue analyses of critical connections are often carried out during the design of the ship.

As double hull tankers become older, greater importance must be attached to maintenance and concern for corrosion. Compared with single hull tankers, double hull tankers with their double sides have 2 to 3 more steel surfaces exposed to salt water in the ballast tanks. Although the ballast tanks are required to be coated, it is important that the coatings be well maintained to be effective. Also the insulating effect of the air cap produced by the ballast tanks acts like a thermos bottle that causes oil to stay at elevated temperatures for a much longer period at sea. Since corrosion tends to accelerate at higher temperatures, about double the corrosion rate for each 10°C increase in temperature, double hull tankers are subjected to a more corrosive environment than single hull tankers. Many of the larger double hull tankers are now more than 12 years old and have performed satisfactorily without major problems. No matter how well a ship is designed, its service life depends on a number of factors such as quality of construction, how well the ship is operated and most importantly how well it is maintained, especially against the ageing effects of corrosion.

Bulk Carriers

Bulk carriers are a more complex box girder structure than a tanker because of the large deck openings needed for loading and discharging dry bulk cargoes. The lower portion of a bulk carrier consists of double bottom and hopper tanks which are used for ballast water. The upper portion consists of the upper wing ballast tanks. Both upper and lower portions are connected by side frames.

While tanker designs have been most affected by concerns for safety of the environment and prevention of oil pollution, the design of dry bulk carrying ships had been influenced by concerns for the safety of the crew. This was evident by the large number of losses of bulk carriers and their crews in the early 1990s due to structural failure, especially in the side shell plating in the forward hold. Why were bulk carriers susceptible to side shell failures, especially when carrying heavy iron ore?

Bulk carriers often carry heavy dense cargoes such as iron ore, and highly corrosive cargoes such as coal, nitrates and fertilizers. These cargoes tend to collect between the side frames, requiring jack-hammers to be used to free the cargo during unloading. Bulldozers are also used in the hold.

The vertical side frames stiffen the side of the ship, which are connected to the topside ballast tanks and the lower hopper tank. The lower part of the side frame and its end bracket can become detached from the side shell and lower hopper tank. This can be caused by corrosion and fatigue, as well as by damage during unloading from discharging grabs or other unloading equipment making contact with the ship's structure.

If a sufficient number of the side frames become weakened, then the frames are no longer able to support the side shell plating and the shell plating becomes detached. What is clearly visible is that the side shell plating and side frames are lost between the upper and lower hopper tanks. The corrugated transverse bulkhead is undamaged. The shell plating is lost on both the port and starboard sides of the ship. This damage occurred in No. 1 Hold which is more susceptible to damage than other holds because of the greater dynamic forces in the fore body of the ship from wave action. Also the shape of this hold changes, so there is greater risk of contact damage by grabs and unloading equipment.

Why, then, do many bulk carriers suffer damage to the side shell frames and plating? Unlike a tanker with double sides, bulk carriers have single side frames which are more flexible than double sides. When fully loaded with heavy iron ore, because of its heavy density, the level of the ore at the side shell is only to the top of the lower hopper for the ship to be down to her marks. This causes the bottom to deflect downward, causing the side frames to deform inboard. The external action of sea pressure and waves causes further deformation and stresses in the frames. In addition, if there is ballast water in the upper wing tanks, there is further bending and compressive forces on the frames. These loads on the side frames, plus their exposure to possible contact damage from unloading equipment, result in the side frames being the weakest link in the strength of bulk carriers and therefore subject to possible failure.

To increase the structural safety of new and existing bulk carriers, IMO adopted new SOLAS regulations and IACS (International Association of Classification Societies) developed new structural requirements containing specific safety requirements for bulk carriers. These include strengthened side frames, hatch covers and transverse bulkheads. For new bulk

carriers, IACS has additional requirements to fit a closed foc'sle on the freeboard deck to provide protection to foredeck fittings and the forward hatch way.

Because many bulk carrier losses have been due to flooding of the forward cargo hold due to side shell failure, IMO had further proposed amendments to the SOLAS Convention to require bulk carriers to have double side skins, similar to that required for tankers.

In bulk carriers, the purpose of double hulls is to strengthen the side structure and to protect the side frame and shell plating structure from corrosion and mechanical damage. There has been much debate in the industry as to whether double sides improve safety when compared to single side bulk carriers. This debate has been very similar to that in the 1990s when the Regulatory requirements to mandate double hull tankers was promulgated. In the end, the industry's objections to mandating double hulls for bulk carriers prevailed at IMO, as the new amendment to SOLAS requires that double hulls are only to be considered as an optional alternative for all new bulk carriers of 150 meters in length and greater. The double hull alternative became effective for ships built on or after July 1 2006.

Some of the benefits of a double hull over a single hull bulk carrier are:

1. A double hull eliminates exposure of side frames to mechanical damage and corrosion since there is a smooth inner skin.
2. The smooth inner skin provides for better quality surface preparation for coatings. Also there is less coating surface area since a smooth inner skin has less surface area than side frames and plating.
3. A double hull provides a much stiffer side structure and improves the fatigue resistance of the side structure. Also it provides for greater protection against collision damages.
4. A double hull improves the speed of cargo discharge because the smooth sides facilitate ease in cargo discharge.

It is apparent that as bulk carriers grow in size, there are benefits to having a double hull. A double hull requires a slight increase in steel weight, about 2% to 3%, and also in cost. Also with a double hull, the depth of a double hull tanker is about 0.5 m higher than the depth of a single hull bulk carrier for the same cargo capacity. As with other ship types, bulk carriers are also undergoing economies of scale in ship size. The largest are the Capesize bulk carriers which are about 185,000 dwt. However for the specialized trade of carrying ore from South America to Asia and Europe, there are ore carriers that are 300,000 dwt in size. There are also ultra large ore carriers being designed that are 450 m in length and 600 dwt in size.

Container Ships

Container ships have recently experienced a significant growth in size. From a structural design perspective, container ships are more complex than tankers and bulk carriers. Because of their requirement to operate at higher speeds, container ships are less of a box girder structure because of their streamlined hull form. They are essentially an open deck ship with very wide deck openings to facilitate the loading and unloading of containers.

Driven by a continual expansion in Asian trade, particularly China, container demand and container ship fleets are forecast to expand further. With the greater growth in container trade, world container port demand is forecast to double by 2012, and triple for South East Asia. The world wide container fleet is fairly new as 70% of the current fleet capacity is less than 10 years old.

Container ships are volume limited ships since the maximum cargo capacity is limited by volume rather than weight. Cargo capacity is measured in TEU's which is the number of 20ft equivalent container boxes that can be carried aboard ship. Container ship capacities continue to grow in size with the average capacity having tripled since 1970. Twenty years ago, 4,500 TEU containerships were the largest ships built. Today, ships three times that capacity are being built. These Super Post-Panamax containerships are highly cost effective as the unit cost of carrying containers is much less for these bigger ships. For example, the operating costs per year of a container slot on a 10,000 TEU ship is 64% of those on a 4,000 TEU ship. Nonetheless, the largest ships built to date are of 13,000 TEU to 15,000 TEU in size. Further, the 18,000 TEU Malaccamax, a conceptual design only, is based on the maximum ship size that can trade through the Malacca Straits.

In designing large container ships there are a number of factors that affect the ship design: length, breadth, depth, draft, speed, container capacity and location of the deck house and engine room. Although there is no length limit restriction in major terminals, a 9,000 TEU container ship is typically 325 meters in length. A 400 meter length is considered to be the limit for a 14,000 TEU container ship. A practical length limit is also governed by the size of the shipyard building dock.

The maximum ship breadth is a function of the container crane outreach. For a 9,000 TEU container ship with a breadth of 46.0 meters, the required outreach is about 48 meter. In anticipation of even larger ships, many terminals have already installed cranes with an outreach nearly 60 meters to accommodate the 12,000 TEU and larger ships. Ship depth depends on the number of tiers of containers stowed in the cargo hold. Typically, the

maximum number of tiers is 9 or 10, which is a function of the strength of the containers as well as the weight of cargo contained in the containers, since the bottom container must support those above it.

Ship draft is limited to the depth of water at the berth and the approaching channels; the typical ship draft being 14.5m since water depth is 15m to 16m at most terminals. Due to trade requirements, container ships operate at 25 knots. For a 9,000 TEU ship, a 12-cylinder diesel engine provides the necessary power, whereas for a 12,000 or 14,000 TEU ship, a 14-cylinder engine would be required. For ships larger than 14,000 TEU then two engines with a twin screw would be necessary.

The container capacity is determined by how many containers can be carried in the holds and on deck. The number of containers is governed by intact and damage stability requirements, and also by forward visibility requirements from the ship's bridge which limits how high containers can be stacked on deck.

Another design issue is the location of the deck house and engine room. Considerations such as forward visibility, length of shafting system, and hatch corner distortion, are factors affecting the location of the deck house and engine room, and whether there is a single deck house or two deck houses. For container ships up to 10,000 TEU, the deck house and engine room are located aft of amidships. For larger container ships up to 14,000 TEU, a single deck house will be located nearer amidships. Larger container ships of 13,000 TEU or greater will usually be designed with two deck houses; the navigating bridge deck house located forward of amidships and the after house located above the engine room aft of amidships.

An 8,000 TEU container ship design with the deck house aft typically carries 9 tiers of containers in the cargo hold and a maximum of 8 tiers on deck, with 17 rows across the deck. Some of the unique technical design challenges for container ships are:

- Bow flare impact loads
- Stern slamming loads
- Hull and deck house vibration
- Large deck opening distortion and consequent high stress concentrations at the corners of deck openings
- Parametric roll

Because of the desire to carry as many containers on deck as possible, and to travel at speeds of 25 knots, the shape of container ship hulls below the waterline are designed for

speed, with a narrow bow and stern and a full midship section. Above the waterline, they are designed to maximize on-deck stowage capacity by extending the wide main deck as far forward and aft as possible. This creates a large bow flare and a large overhanging stern. As a result, in rough seas and high waves, the bow and stern are subject to large impact forces. As the ship gets larger, the flare and overhanging stern also becomes larger and therefore more susceptible to bigger impact forces. These forces can also cause structural vibration. The structural design must therefore adequately address these higher forces.

Containerships can be susceptible to structural vibration due to excitation forces from the waves, the main engine and propeller forces acting on the surface of the overhanging stern. Deck houses are also very slender and high, and therefore structurally flexible. The wheelhouse and bridge wings are thus susceptible to vibration if not properly designed. Finite element vibration analyses are usually carried out at the design stage to predict the vibration characteristics of the hull and deckhouse structure to ensure that vibration is not a problem.

When a ship encounters waves at an oblique angle it is subjected to twisting as it traverses through the waves. This twisting or torsion response is due to the alternating forces acting laterally on the ship's sides from the passing waves.

Because of the large deck openings in container ships, the torsion responses tend to be very large, causing significant twist and warping deformation at the main deck and the top of the hatch coaming. As ships become larger, this distortion also increases in response.

The large distortions of the main deck openings cause high stresses at the corners of the opening. To reduce the high stresses at the corners, they are designed with a radial curvature to reduce the stress concentration. The large distortion also presents a challenge to design an adequate on-deck container securing lashing system.

One very interesting and serious phenomenon that has occurred in large container ships at sea is parametric roll resonance. Parametric roll causes unexpected large roll motions in head or following seas, which can be problematic with on-deck containers. This is highly unusual as one would expect only pitching motion to occur in such seas.

There are several key reasons that cause parametric roll in large containerships:

1. With a large bow flare and overhanging stern, as a wave passes the water plane area changes. The water plane becomes larger when the wave trough is amidships, and becomes smaller when the wave crest is amidships.

2. GM is larger in a wave trough and smaller in a wave crest since GM is a function of the water plane area.
3. Stability is improved with a larger GM as there is a larger restoring force due to the larger righting arm.
4. The above factors result in a larger restoring force when a wave trough is amidships, and a smaller force when a wave crest is amidships.

For parametric roll to occur, several conditions must be met:

1. Wave heights must be fairly large.
2. Wave length must be nearly equal to the ship's length.
3. The wave encounter period must be about one half the ship's roll period.

With the above three conditions taking place, the parametric roll is likely to occur. The restoring force reaches a maximum when the ship is at maximum roll which occurs when the wave crest is at the bow and stern (trough amidships). The restoring force becomes less than maximum when the ship is upright during the roll motion and the wave crest is amidships. The restoring force again reaches maximum just as the ship rolls to the other side, and reaches a maximum angle when the wave crest is at the bow and stern. As this rolling motion continues, the restoring force acts in resonance with the maximum roll angle causing parametric roll to occur.

Fortunately, parametric roll rarely occurs. However, in 1998, the 4,500 TEU Post-Panamax containership APL China was in the North Pacific Ocean in Force 11 to 12 wave conditions and encountered significant wave heights of 12 to 14 meters. To reduce roll, the Master reduced speed and headed the ship into the seas, which is normal ship handling practice in bad weather. During this time, the ship took on especially severe rolls, to angles of 35 to 40 degrees. As a result the ship lost a third of its deck containers overboard, and many of those that remained on board were severely damaged.

The risk of parametric roll is not limited to only large containerships, but to any large ship with a large bow flare and overhanging stern. These include car carriers and passenger ships. What can be done to prevent parametric roll? From a design perspective very little, unless the hull shape is changed to a fuller form ship, like a tanker or bulk carrier, which is an impractical solution. Anti-roll fins will help to a limited degree, and operationally, the Master can change speed and or heading so as to change the wave encounter period to minimize the chance of resonance occurring.

Liquefied Natural Gas Ships

Another big growth area, both in world trade and ship size, is the transportation of natural gas. The demand for natural gas is driving a significant increase in the size of liquefied natural gas (LNG) ships. LNG fleet capacity is projected to grow by nearly 75 percent in the next four years, with the number of ships projected to increase by 100.

The rapidly changing LNG environment alters the worldwide shipping trading patterns from regional to global, creates demands for larger ships thus requiring a close review of the shipboard LNG containment systems, and generates the need for LNG terminals to handle the processing and discharging of the gas.

From 1975 to about 2004, nearly 30 years, there was very little growth in the size of LNG carriers which ranged from 120,000m³ to 148,000m³ cargo capacity. Beginning in 2005, the designs for the next generation of LNG ships have jumped to the 200,000m³ to 250,000m³ range, a significant step-change in size. By taking advantage of the economies of scale, increasing the size of an LNG carrier from 145,000m³ to 200,000m³ or more can reduce transportation costs by as much as 15 percent.

Liquefied natural gas exhibits characteristics that are beneficial to shipping natural gas by ship. Cooling natural gas (methane gas) to a very cold temperature of -160°C at normal pressure results in the boiling or condensation of the gas into liquid form, which is LNG. The specific gravity of LNG is about one-half of water so it is a relatively light weight liquid. The most important characteristic, especially for transportation of natural gas, is that in liquid form LNG takes up about 1/600th the volume of gaseous natural gas. LNG is transported by sea in double hull tankers with specialized insulated tanks. The gas is kept in liquid form by self-refrigeration, a process in which the LNG is kept at its boiling point so that any heat into the system is countered by energy lost from LNG vapors. This boil-off of the vapor is vented out of the cargo tanks and either re-liquefied or used to power the ship. LNG ships are distinguished by the type of tank containment system employed. The challenge is to ensure that the containment system can sustain the fluid loading and also provides proper thermal insulation. The three major LNG containment systems are the membrane, independent spherical tank, and independent prismatic tank. The number of tanks in a ship is usually four or five, depending on the ship size.

In the membrane tank system, the tanks consist of the inner skin of the double hull with its inner surface covered by an insulation system. The LNG is carried within the inner hull, and it

is separated from the inner hull steel by a double membrane insulation system. The membrane tanks are an integral part of the double hull structure. The spherical and prismatic tanks are independent tanks and are self-supporting. Both spherical and prismatic tanks are constructed outside the hull, and then placed inside the double hull. A majority of the LNG ships currently being built, including the larger 200,000 and proposed 250,000m³ designs, will use the membrane containment system. The membrane tank systems are cheaper to build and operate than the independent tank systems. There are basically two types of membrane containment systems used. One type is called the Mark III system which consists of reinforced foam as the insulation material.

The surface or membrane of the tank exposed to the LNG consists of a matrix of stainless steel corrugated panels. The other type of membrane system is the GTT No 96 system, which is somewhat similar to the Mark III, except that plywood boxes filled with Perlite material serve as insulation, and the membrane material is a thin INVAR steel material. More recently, a CS-1 hybrid membrane containment system has been used which consists of reinforced foam as the insulation material, together with a membrane of INVAR steel.

In a membrane tank system, the forces from the liquid cargo are transferred through the insulation system to the hull structure. The independent spherical tank is a large aluminum sphere the outer surface of which is covered by insulation. The sphere is supported at the equator by a cylindrical skirt that is, in turn, supported at the base by the hull structure. In the spherical tank of LNG carriers there is considerable void space in the hull, and a large wind area due to the large spheres exposed above deck. With larger a ship size, the void space and wind area also increase proportionately which creates a disadvantage for the spherical tank system.

The independent prismatic tank is a stiffened prismatic tank constructed to conform to the shape of the ship's inner hull. The tank's outer surface is covered by insulation and then placed inside the ship. In both the spherical and prismatic self-supporting tanks, the forces from the liquid cargo are absorbed directly by the independent tank structure.

A key technical design challenge for the next generation of large LNG carriers is the design of the membrane type tank and containment system to withstand the higher LNG sloshing forces when the ship is in a seaway. The independent spherical tank (because of its shape) and the prismatic tank (because of the internal structure) are not subject to large sloshing impact pressures. The previous generation of LNG carriers was designed to carry LNG in loaded tanks which were 80% or more filled. Today's designs are being developed for all

filling levels. This partial filling allows for a more flexible trading pattern, as well as an ability to load and unload at offshore terminals.

The high pressures due to liquid sloshing loads when partially filled may damage the load bearing insulation system and inner hull structures unless properly designed. At high filling levels a standing wave can develop in a moving tank. At filling levels of less than 30%, progressive waves can develop. The hull structure and pump tower in the tank must also be designed for such sloshing pressures.

To analyze the sloshing pressures, deflections and stresses on the membrane tank and containment system, Computational Fluid Dynamics (CFD) software can be applied to simulate the liquid motions in the tanks. The application of CFD together with scale model tank sloshing tests can be used to design and analyze the strength of the insulation system and the hull structure supporting the insulation.

A proposed 250,000m³ membrane tank carrier currently being designed will have five tanks rather than four, because with five tanks the tank lengths will be shorter, which reduces the magnitude of the sloshing pressures.

Because of the criticality of sloshing pressures, there have been some new novel design concepts for membrane tank designs. The Pyramid-Prism shaped tank reduces the free surface area, thus reducing high impact sloshing loads. This type of membrane tank design is being proposed for a 235,000m³ LNG carrier having four tanks.

As an alternative to the spherical tank containment system, there is a proposed design which is a cylindrical tank with spherical dished ends. The benefit of this design is that it minimizes the void spaces in the hull when compared to the spherical tank design. Having void spaces can be costly in the operation of an LNG carrier. For example, for a spherical tank LNG carrier, the Suez Canal transit fee, which is based on Net Tonnage, can be \$100,000 higher than the same size membrane tank LNG. This could amount to an additional \$1 million annually for LNG ships regularly transiting the Suez Canal.

Most LNG carriers have a design speed of between 19 and 21 knots. The new generation of large ships will be designed to operate within this same speed range. This will require an increase in propulsion horsepower. Although existing carriers have used gas boil-off to run steam turbine plants, the new generation of large ships will be powered either by:

1. Diesel engines with an on-board re-liquefaction plant that will return cargo boil off to the tanks.
2. Dual fuel diesel engines that have recently been developed which burn both natural gas and fuel oil.
3. The dual fuel diesel engines can be used to drive the propeller shaft directly, or to power generators for electric motors which drive the propeller shaft.
4. Gas turbines.

Some benefits of dual fuel power plants are lower fuel consumption and lower emissions.

Summary

There are a number of driving forces affecting ship designs and size: the economies of scale are a major driver of increasing ship size to improve transportation efficiency. Technical limitations do not restrict the building of even larger ships. Often the port infrastructure and trading routes limit size.

Ships are basically self-propelled vessels whose fundamental purpose has not changed over the years, yet ship designs have changed due to improvements in technology in materials, propulsion, and engineering analysis. New technologies have provided more advanced analytical capabilities, automation, and improved propulsion engines to enable the growth in ship size.

Accidents unfortunately continue to happen. Lessons learned from major marine disasters have resulted in changes in the design as well as the operation of ships. This has been particularly true for tankers and bulk carriers.

Finally, size matters when designing the next generation of ships. However, the over-riding driving force for the next generation of large ships is that they be designed, built, and operated with safety in mind... of the crew and passengers, of the ship structure, and of the marine environment.

Navigating Through a Sea of Change



Admiral Robert E. Kramek (retired)
US Coast Guard

3 June 2008

Navigating through a Sea of Change-Strengthening the Environmental and Safety Regime

The oceans not only encompass over 70% of the world's surface but, at present, account for over 90% of the transportation system for world commerce. Challenges brought on by issues of safety, the maritime environment, and climate change, impact significantly on the Maritime Industry. These challenges go to the heart of the Maritime Transportation System.

"The people who design, manage and operate the system; the technology associated with the system; vessels; marine vehicles and facilities; and regulatory bodies..." these elements are the system.

Today I will discuss the Maritime Environmental Regime; It has many elements. I will present this from a global or macro perspective as too often we focus narrowly on only one aspect of the regime; all aspects are interrelated and accordingly should be considered as a system.

I will, in the spirit of this conference, and with respect to the students at WMU, place considerable emphasis on the maritime environment. What are the influencing factors? What weaknesses exist? And how can we as people, the "human factor" so to speak, account for these influences and deal with them? You will be presented with what I have called the "Marine Environmental Design Spiral" and the potential impact on cost, quality, and design of marine vehicles, vessels and facilities.

Some operational and management considerations will be discussed and most important a suggested solution to the management of these complex issues will be recommended. It is note-worthy that **you** are at the center/apex of potential solutions here, as you study at the World Maritime University as part of the International Maritime Organization.

So as we get started I want to share with you, that in my fifty years of learning and working and teaching in the Marine Industry, never have changes developed with such an accelerating pace; size, speed, complexity, capacity seem to know no rational bounds, and the impact on the mariners who operate the system is significant. The Sea is an unforgiving environment and must be respected; we do not take this into account often enough. Also I want to complement all of Europe, especially the northern European nations, for taking the strong lead in just about all issues associated with maritime environmental protection and the potential impact of climate change; based on my personal observations you are way ahead of Asia and the Americas. However, it will take all nations of the world to properly manage what needs to be done; one country, continent or state cannot do it alone, and unilateral action will not be successful. We need to stand tall and look to the International Maritime Organization for leadership and direction. We are in need of international, global solutions and it is appropriate to discuss this here today at the World Maritime University.