EEDI, A Case Study in Indirect Regulation of CO2 Pollution

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1 Three Different Definitions of Efficiency

Mankind's use of the atmosphere as a dumping ground for CO2 exhausted from the combustion of fossil fuels is a proto-typical case of an externality, using something without paying for the costs of that use. The atmosphere is a *public good*. It's not owned by anyone, and anyone can use it for free. As a result, CO2 concentrations in the atmosphere are 40% higher than the highest the planet has experienced in at least the last 650,000 years. If we do nothing, these already unprecedented CO2 levels will probably double by the end of the century.

The price for using the atmosphere to dump CO2 is zero. But the cost to society of this use is not zero, and may be monstrously large. Unfortunately, nobody knows what the cost is. One can make a plausible case that Nature can handle current and higher CO2 levels with reasonably mild, possibly even benign, changes. One can make an equally plausible argument that current and projected CO2 levels will result in truly cataclysmic effects. The truth probably lies somewhere in between.

Given this enormous range of uncertainty, we need insurance. Only the most imprudent would argue for doing nothing. The question is: what form should it take?

Economics tells us that there are two potentially *efficient* methods for regulating externalities:

1. An emissions tax based on the marginal cost to society of the pollutant.
2. Cap-and-trade with the mandated level of reduction set at the level at which the benefits of further reduction are less than the social cost of further reduction.

Here we are defining *efficient* to mean achieving any specified level of of CO2 emissions at minimum cost to society, or equivalently maximizing the level of reduction for a given societal cost. In this paper, I will refer to this kind of efficiency as *CO2 Efficiency*.

A more common definition of efficiency in shipping is ship *fuel efficiency* which for a given ship type and size and speed requirement, means achieving that speed at minimum fuel consumption.

In attempting to regulate CO2 emissions from ships, the IMO has come with yet another definition of the word, which I will call *EEDI efficiency*. To simplify considerably, EEDI efficiency is defined to be minimizing the ratio of installed power times Specific Fuel Consumption times carbon content of fuel over capacity times speed.

The third definition of efficiency is only very indirectly related to the first. Perhaps more surprisingly, the third definition is not consistent with the second definition. As we shall see, for a given ship type, size and speed, reducing installed power ***increases*** fuel consumption. The purpose of this paper is to explore the implications of the IMO's decision to attempt to regulate CO2 emissions using the third definition.

2 Energy Efficiency Design Index

2.1 The EEDI Formula

EEDI is an attempt to measure how much CO2 a ship emits per unit of transport provided. A formula producing an EEDI for each ship is developed. The current EEDI formula is outlined in MEPC.1/Circ.681, Interim Guidelines on the Method of the Calculation of the Energy Efficiency Design Index for New Ships, 2009-08-17, http://www.imo.org/environment/mainframe.asp?topic_id=681. Then an upper limit on EEDI is mandated for all newbuildings. In most variants, this upper limit drops through time.

The proposed EEDI definition is a typesetter's nightmare. It has to be one of the most complex formulas ever seriously proposed to be an actual part of legislation. Here it is, or at least as much as I can show.

$$\frac{\left(\prod_{j=1}^{M} f_j\right)\left(\sum_{i=1}^{nME} P_{ME(i)} C_{FME(i)} SFC_{ME(i)}\right) + \left(P_{AE} C_{FAE} SFC_{AE}\right) + \left(\left(\prod_{j=1}^{M} f_j \sum_{i=1}^{nPTI} P_{PTI(i)} - \sum_{i=1}^{neff} f_{eff(i)} P_{AEeff(i)}\right) C_{FAE} SFC_{AE}\right) - \left(\sum\right.}{f_i Capacity V_{ref} f_w}$$

The formula takes seven dense pages to explain. It is rife with correction factors, the lower case f's. The correction factors themselves are complex formulae. The formula gets more complicated on a monthly basis as more correction factors are proposed, with correction factors on correction factors. MEPC.1/Circ.681 correctly cautions that the formula may not apply to "diesel-electric propulsion, turbine propulsion or hybrid propulsion system".

Forgetting for the moment all the correction factors, the credits/debits for shaft generators/motors, the credits for "innovative energy efficient technology", and a number of arbitrarily chosen coefficients, the basic concept is a ratio test.

$$\frac{installed\_power \cdot SFC \cdot Fuel\_Carbon\_content}{Capacity \cdot Design\_speed}$$

This fraction purports to be "a measure of a ship's performance which reflects the emissions related to value to society. ... the value to society is determined by a simplified measure of transport utility giving the following conceptual definition:[1]

$$Index = \frac{Emission}{Transport\_Utility}$$

The next step is to determine the *required* EEDI for a ship. This is done by dividing the existing fleet by ship type. For each ship type, a *baseline* EEDI curve is derived. This curve is a function of ship capacity, which for most ship types is taken to be deadweight. The *baseline* EEDI's functions are derived by fitting an exponential curve through a scatter diagram of the EEDI's (essentially installed power) of the existing fleet and capacity. There is no theoretical foundation for this procedure.

Finally, we mandate that all ships built after 20xx will have EEDI's that are at least yy% below the baseline for that ship type. Present discussions envisage a series of downward steps in the required EEDI, for example, a 35% drop from the baseline by 2023. Unlike most mandated vehicle efficiency requirements such as CAFE, speed is not fixed. An automobile maker cannot meet his CAFE by testing his car at 40 mph rather than 55. But EEDI allows and encourages this.

2.2 CO2 Emissions are not linear in installed power

The first point to make is that the value to society of a ton-knot of transport capacity depends on the market. In the real world, the denominator in the EEDI formula is not constant for a particular ship. In the bulk markets, this value can change by a factor of ten in a matter of months. None of this is captured by the EEDI definition of transport utility. The practical impact of this error is that the ship is designed as if the market were always the same. There is no point in installing power to speed up in booms, nor is there any point in investing in slow-steaming enhancements. This also leads to the assumption that all ships will always operate at the same percent of installed power. Therefore, emissions are linearly related to installed power. This is simply not true.

In the real world, owners recognize that a ship makes most of its money in the often small fraction of its life when the market is in boom. The rest of the time, they are simply trying to survive until the next boom. In either case, the owner will operate at the speed which maximizes his profits for the current spot rate and bunker price. Speed at installed power is simply a constraint on this decision, an upper bound. ***In the real world given a properly designed ship, the owner will operate at installed power only during a boom.*** For example, at current bunker prices, a stabdard VLCC will not be operating at full power unless the spot rate is well above Worldscale 100.[2]

2.3 EEDI will INCREASE fuel consumption in non-boom conditions

Going back to the EEDI formula, the key number in the numerator is installed power. The EEDI formula pays lip service to fuel carbon content; but, since EEDI is only a design regulation, the actual fuel used has no impact on the index. Consider an owner contemplating a dual fuel (gas or oil) ship. Currently, EEDI assumes conservatively that the owner uses only oil. Therefore, ***there is no incentive to invest in the dual fuel capability.***[3]

[1] Longva et al, Determining a required energy efficiency design index level for new ships based on a cost-effectiveness criterion, Marit. Pol. Mgmt, March 2010, Vol 37, no2, 129-143.

[2] The Impact of Bunker Prices on VLCC Rates. An MBM which increases the owner's bunker costs (tax or cap-and-trade) will increase the full speed spot rate further.

[3] If EEDI assumes that the owner uses only gas, there is still no incentive to actually use gas, but there is a wasteful incentive for an owner to invest in a dual fuel capability he doesn't intend to use.

Since installed power goes at something more than the cube of design speed, a 35% reduction in installed power will result in something like a 10% reduction in design speed, and a much lower EEDI. The easy way to beat the EEDI rule is low design speed ships. ***At its core, EEDI is a mandatory reduction in installed power.***[4]

But it is not installed power that produces CO2, it is the amount of power that is actually used combined with the engine's fuel consumption at that power. ***For a given speed, fuel consumption is reduced by increasing installed power.*** Table 2.3 shows an actual example based on an 82,000 dwt bulkcarrier.[5]

Table 1: High powered vs Low powered Kamsarmax Bulk Carrier

	Low powered ship	High Powered ship
Main Engine	MAN 6S50 ME	MAN 6S60 MC
Installed power	10,680 KW @ 117 RPM	14,280 @ 105 RPM
Power at 14.5 kts	9,610 KW @ 113 RPM	9,050 @ 88 RPM
Full load speed	14.5 knots	14.5 knots
Consumption	38.4 TPD	35.0 TPD

The bigger engine allows two major fuel economies:

1. The engine can operate closer to the minimum Specific Fuel Consumption point which is about 70% of Installed Power. For a typical big low speed diesel, SFC at 70% power is about 5% lower than SFC at Max Continuous Rating.
2. The bigger engine can turn a larger propeller at lower RPM which improves propeller efficiency. The rule of thumb for calm water, new propellers is that propeller efficiency goes as diameter to the 0.25 power.[6] That's why the ship on the right requires less power at 14.5 knots than the ship on the left.

The low powered ship has a much "better" EEDI. It also has a 10% higher fuel consumption at the same speed. ***By mandating low installed power, the EEDI will increase CO2 emissions in non-boom conditions.*** An EEDI assumes that a low powered ship is a *fuel efficient* ship. In fact, low powered ships can be horribly *fuel inefficient*, while high power ships can be very *fuel efficient*.

In any event, the goal is not ship *fuel efficiency*, but CO2 emissions reduction efficiency, that is, reducing CO2 emissions in the least costly manner to society. These are two entirely different concepts. To help us keep these concepts separate, whenever I am using the word "efficiency" in the ship fuel sense, I will put it in italics.

2.4 EEDI has all sorts of strange biases

As mentioned above, the baseline required EEDI's are developed by breaking the fleet down by ship type and then doing power law regressions of EEDI (really installed power per size-knot) versus size of the existing fleet. The resulting correlation coefficients are all over the place reflecting the fact that there is no foundation for this ad hoc procedure. And it results in some weird biases. Akiyama and Taggi compared a series of standard ships and found that some quite normal ships were 15% better than the suggested Baseline EEDI (eg big containerships); others were 9% worse than the Baseline (e.g. VLCC's).[7] So a 15 knot VLCC which is perhaps the most efficient means of moving cargo ever invented will have to reduce installed power about 5% immediately. A 25 knot container ship has to do nothing.

[4] The EEDI formula also incorporates Specific Fuel Consumption (SFC). But since SFC is a relatively weak function of installed power and speed is a very strong function of installed power, the variation in SFC has almost no effect on EEDI. In many EEDI calculations, SFC is assumed to be constant.

[5] Source: NTUA Laboratory for Maritime Transport.

[6] The numbers in Table **??** are based on two unrealistic assumptions:

a both propellers in pristine condition,

b the ship is always in calm water.

In fact, the smaller, more heavily loaded propeller will suffer more cavitation damage and its surface smoothness will deteriorate faster than the bigger, more lightly loaded propeller. And that's in calm water. Throw in the added drag associated with anything above Sea State 3 and the efficiency of the smaller propeller will suffer much more than the bigger, even if the surface condition were the same. Couple the two factors together and the overall advantage of the big prop over a ship's life is far larger than Table 2.3 indicates.

[7] Akiyama and Taggi, Evaluation of EEDI Index, Tripartite Workshop on GHG Emissions, Beijing, 2010-06-03

Even within container ships, we find strange quirks. According to the EEDI formula, a narrow Panamax container ship has an EEDI or 17.99; a beamier, post-Panamax boxship will have an EEDI of 18.64.[8] But EEDI does not correctly credit the post-Panamax ship for the increase in practical container carrying capacity. IMarEST estimates that the post-Panamax ship will emit 382 g CO2/TEU-mile; the Panamax ship, with a 3.6% lower EEDI, generates 434 g/TEU-mile.

Such biases are but symptoms of EEDI's lack of theoretical foundation.

2.5 Allowable pollution proportional to past pollution

EEDI proposes the same percentage reduction in required EEDI over all ship types and sizes. Currently, IMO is discussing a 30% reduction by 2023. Under EEDI, the main way this will be accomplished is to build ships with lower speed capability. But because of bias in the baselines to meet the 30% requirement instead of building a 24 knot capable containership, the owner will have to build a 20 knot capable ship, a speed reduction of about 18%.[9] For a 14 knot bulk carrier, the required speed reduction is also 4 knots, a 30% reduction, ending up with a ship that can only do 10 knots in calm water. This ship will have a hard-time maintaining steerageway in any real weather.

Assuming totally incorrectly for the moment that EEDI equates to CO2 emissions, by basing the required cutback on historic levels rather than the cost of cutting back, EEDI give the big polluters a big break. As a rule, ship types that already have low EEDI's will find it more costly to cut back the same percentage than ship types that start out with much higher EEDI's. But ***EEDI simply ignores the cost to society of achieving a reduction.***

This bias against low EEDI ships shows up in another way. Under the power law regression. larger size ships face a tougher limit than smaller. Here EEDI creates an inducement for owners to move to smaller less *fuel efficient* ships.

2.6 EEDI's exemption of smaller ships

At the small size end, attempts to determine the EEDI of the existing fleet fall apart completely. Similar sized short-sea ships such as RO-RO's can have EEDI's that vary by a factor of five, reflecting the differing requirements of each ship's trade. Attempts to fit a curve to this scatter often end up with correlation coefficients less than 0.1. The same thing is true of other ship types at the small size end, if not quite so dramatically. As a result, all agree that a low end size limit is required below which the ships would be exempt from EEDI.[10] Some suggest that low end should be as high as 20,000 DWT.[11] Others suggestions range around 5,000 GRT. If the 5,000 GRT level is chosen, about 35% of all ship emissions would not be covered by EEDI. And we will quickly see a large number of 4,999 GRT ships. We could easily end up with two 4,999 GRT ships performing the function of one 10,000 GRT ship and at the same time putting significantly more CO2 into the air.

2.7 EEDI's Focuses Only on At Sea Fuel

The EEDI assumes the only way a ship produces CO2 is by burning fuel at sea. A ship produces CO2 emissions loading and discharging, by using tugs, when it is built, while it is being repaired, and when it is scrapped. By mandating low installed power and low lightweight, and hence more repair intensive and shorter-lived ships, EEDI will increase CO2 emissions associated with the latter three activities. Gratsos et al compared a Class minimum lightweight bulk carrier with a heavier, more robust ship of the same displacement. They found that the increase in Build/Repair/Scrap (BRS) CO2 emissions of the Class minimum ship outweighed the savings in fuel emissions associated with the higher

[8] Institute of Marine Engineering, Science and Technology,, Influence of Design Parameters on the Energy Efficiency Index for Tankers, Containerships, and LNG Carriers, MEPC 60/4/34, 15 January 2010.

[9] Norway, Additional elements to be considered when discussing the reduction rate, EE-WG 1/2/3, 2010-05-21.

[10] Currently, there are a number of other exemptions including diesel-electric ships because of the inability to agree on how to compute their EDDI. If such exemptions stand, we will see owners moving to the exempted technology, whether or not it makes any sense from a CO2 emissions standpoint.

[11] China, Technical consideration of the establishment of EEDI baselines, EE-WG 1/2/1.

deadweight.[12] This myopia will become increasingly costly as we move to systems that shift the CO2 emissions off the ship: fuel cells, batteries, and the like.

More fundamentally, when you mandate slower speed ships, you are mandating more ships. There is a trade-off between the operating CO2 and the BRS CO2. EEDI ignores one side of this trade-off.[13]

EEDI notwithstanding, it should be obvious that at-sea fuel is just one part of the problem. Geared and self-unloading bulk carriers consume slightly more at-sea fuel than their gearless counterparts. Yet in many trades their replacement by gearless ships will require wasting large amounts of resources on shore-side facilities which will create their own set of emissions. LNG fueled ships produced roughly 25% less C02 at sea than oil fueled; but EEDI ignores the fact that about 10% of the gas input to an LNG plant is burned in the liquification process.

2.8 EEDI assumes a cost abatement curve that goes from 0 to ∞ at the mandated level

An EEDI offers no incentive for doing any better than the mandated level no matter how low the costs are. EEDI, like any mandated limit, implicitly assumes the cost of violating the EEDI is infinite and the benefit of doing better than the EEDI is zero. Both assumptions are as wrong as wrong can be.

Even if ship *fuel efficiency* were the goal, ***which it is not***,

and even if EEDI correctly measured ship *fuel efficiency*, ***which it does not***,

we had better pick the resource efficient EEDI level for each ship or we are going to waste a lot of society's resources.

In fact, EEDI makes no attempt to pick a cost efficient EEDI for each ship. It simply mandates the same percentage reduction for all ships from artificially constructed baselines.

2.9 EEDI is based on unrealistic and misleading sea trials data

Assuming away all the above problems, the EEDI still doesn't have anything to do with actual emissions at sea. It is just another newbuilding rule which will be checked by sea trial results, after which the EEDI is a number on a certificate. Sea trials are an artificial environment: most importantly, calm weather and the hull and propeller in pristine condition.[14] In such conditions, it pays the yards to go with a thin bladed, highly loaded propeller. Not only will this propeller be slightly more efficient during sea trials than a higher blade area ratio, more lightly loaded prop, but it is lighter and cheaper to build as well.

Unfortunately, the performance of highly loaded propellers quickly falls apart due to cavitation damage.[15] Combine this with the additional load associated with hull fouling and bad weather, and the propeller efficiency falls off a cliff. In really bad weather, you end up with a ship that is burning fuel and going nowhere.

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[12] Gratsos et all, Life Cycle CO2 Emissions of Bulk Carriers: A Comparaative Study

[13] More ships produces more CO2/GHG emissions in a number of other ways ignored by EEDI. Here are just two examples:

1. If we double the size of the fleet, we will be flying twice as many crews around the world.
2. If we double the size of the tanker fleet, we will double the amount of cargo lost to the atmosphere by tank breathing. Currently, tankers put at least two orders of magnitude more cargo hydrocarbons into the atmosphere than they spill. These light hydrocarbons are powerful GHG's, about 25 times as powerful as CO2.

[14] Other unrealistic features of the trials include

1. The sea trials are run at an almost never used *design* waterline rather than the full-load, *scantling* waterline.
2. The engine Specific Fuel Consumption (SFC) is based os shop trials using a water brake, rather than on-board with the actual propeller.
3. The nameplate SFC is based on a fuel Net Calorific Value that does not exist in the real world.
4. The assumed ambient conditions (air and water temperature) are highly optimistic.

[15] Highly loaded propellers cavitate much more than lightly loaded. Cavitation occurs when the reduction of pressure on the lifting side of the blade results in the water boiling in the form of bubbles. When these bubbles collapse, the energy released creates little pits on the surface of the blade. These pits not only ruin the propeller's efficiency but they also become sources for more cavitation.

2.10 EEDI does not 'incentivize' slow-steaming

Life is just a series of short-runs. In the short-run, with the fleet fixed, just about the only means of reducing CO2 emissions is slow-steaming. Unlike a bunkers tax or cap-and-trade, EEDI does nothing to induce slow-steaming, as IMO itself admits: "[EEDI's] environmental effect is limited because it only applies to new ships and because it only incentivizes design improvements and not improvements in operations."[16] In fact, it's worse than this. In any market except a boom, the owner with an artificially low installed power will be operating farther away from the minimum SFC point and producing more CO2 emissions than a ship with more power. The only time EEDI will actually reduce at sea CO2 emissions is during a boom, which is precisely the time shipping should emit more CO2 relative to shoreside activities.

As far as CTX can determine, despite its importance, there has been no real study of how much EEDI will reduce CO2 emissions. Such a study would need to consider the following factors:

1. The impact of EEDI on ***at sea*** emissions in any period will depend critically on whether or not the market for that section (e.g. tankers) is in boom or not:
   (a) If not, EEDI will increase at sea emissions by at least 10% by forcing owners to operate at a higher percentage of MCR with a smaller propeller.
   (b) If that market is in boom, EEDI will probably decrease ***at sea*** emissions during that period, since owners will not be able to steam as fast as they would have without EEDI.[17] This effect will be at least partially balanced by more ships at sea and by the fact that those ships will be at least 5% less fuel efficient due to the smaller prop. The rule of thumb for tankers is that the market is in boom 1 year in 5, and in that year, the market is in real boom less than half the year.

   In either case, EEDI will increase B/R/S emissions since EEDI will result in more, slower ships.
   To do the reduction estimate correctly, you must postulate a fleet with and without EEDI, and then run each fleet through a ship's lifetime of market cycles. This has never been done.
2. The study would also have to take into account the improvement that would have taken place without EEDI.[18] According to DNV, as a result of recent massive increases in bunker price, there are over 500 million tons per year of CO2 reductions which have negative abatement costs. See Section 4. These improvements will take place without any regulation whatsoever.

CTX strongly suspects that, if such a study had been done, it would conclude that the net effect of EEDI on CO2 in the air is in the noise, while at the same time wasting precious resources on too many, too slow ships.

2.11 Suspicions confirmed at least for VLCC's

Since the above section was written, CTX undertook just such a study for Very Large Crude Carriers (VLCC).[19] This study concluded:

> Our figures indicate that, under reasonable assumptions, ***the imposition of EEDI will result in slight increase in VLCC operational CO2 emissions***, while imposing a heavy burden on society in market cost and safety. Even under an unrealistically optimistic set of assumptions, the Phase 2 CO2 reduction is less than 3%.
>
> Why is EEDI is so ineffective in reducing VLCC CO2 emissions?
>
> The answer is two fold:
>
> 1. EEDI does not limit CO2 emissions. EEDI limits installed power. But at current and expected bunker prices, a non-EEDI VLCC owner/term charterer uses all his installed power only in a full boom, or about 10% of

[16] Second IMO GHG Study, 2009, MEPC 59/24/Add 1, 2009-04-09.

[17] At $400 per ton bunkers, a VLCC owner will not operate at full speed unless the market is over Worldscale 100. See The Impact of Bunker Price on VLCC Spot Rates.

[18] The study ideally would also compare EEDI with market based measures such as a carbon tax or cap and trade with respect both to amount of emissions reduction and cost.

[19] The Impact of EEDI on VLCC Design and CO2 Emissions

the ship's life. So for the great bulk of her life, a non-EEDI ship uses little or no more power than an EEDI compliant ship

2. In limiting installed power, EEDI induces owners to use smaller bore, higher RPM engines which means that the EEDI-compliant VLCC will consume more fuel than the non-EEDI ship when the market is not in boom, which is most of the time.

....

There is good reason to believe that the same analyzes applied to smaller tankers and bulk carriers will arrive at very similar conclusions. With the demise of the conference system, the same thing is true of containerships, with the important caveat that liner owners will be limited to a discrete set of slow steaming speeds if they wish to main schedule frequency. Certainly, such analyzes should be performed before a final decision is made on EEDI.

CTX urges anybody truly interested in shipborne CO2 emissions to take a look at this study and reach your own conclusions.

2.12 EEDI cannot be fixed with more correction factors

The EEDI concept violates just about every principle of efficient regulation. A basic principle of efficient regulation is ***regulate directly***. If you are attempting to reduce CO2 emissions, do so in as direct a manner as possible. Indirect regulation is almost automatically inefficient. As we have seen, EEDI certainly falls into that category. It cannot be fixed with still more correction factors.

But there is worse to come. The proposed EEDI is extremely dangerous in terms of safety and oil pollution.

3 The Dangers of EEDI

3.1 Reduced Main Engine Power

The EEDI is not only an indirect and wasteful way of achieving a particular reduction of CO2 emissions, it is a major step in exactly the wrong direction as far as safety and oil spillage go. Ships already are badly under-powered, despite the fact that the engines are very aggressively rated. The result is that the over-rated engines are being pushed hard, and the fleet is experiencing frequent main engine failure. CTX estimates that the tanker fleet over 10,000 deadweight is currently experiencing at least 10 complete losses of power every day.[20] Anecdotal evidence points to a much higher number.

Most losses of power result in no damage and go unreported. But not all. Table 2 is a list of the biggest oil spills that resulted from main engine or generator failures.

Phase 3 EEDI will require VLCC owners to cut installed power by half.[21] Low powered ships have poor maneuverability, and poor ability to get off lee shores. Table 3 is a list of major casualties in which poor maneuverability was a major factor. Pushing installed power down with an EEDI is the worst thing we can do from an engine reliability and reserve power point of view.

Simple prudence dictates that the impact of drastically reducing installed power on heavy weather performance and maneuverability should be studied by a properly equipped seakeeping program prior to imposition of EEDI. This has never been done.

3.2 Limiting Generator Power

The same thing is true with respect to generator power, the term starting with P_{AE} in the formula. In theory, today's ships are designed so that under normal operating conditions they need only run one generator on-line. Most big ships have three generators, so there should be plenty of redundancy. In fact, Class rules combine an extremely unrealistic view of electric loads, with an optimistic assumption of generator output. As a result, ships normally need to have at least two generators on line, and even then blackouts are frequent.

[20] Devanney, The Case for Twin Screw, CTX, 2006.
[21] Devanney, The Impact of EEDI on VLCC Design and CO2 Emissions, CTX, 2010.

Table 4 list the casualties in the CTX CDB where we have been able to determine that under-sized generators were a causal factor. We can be confident this is the tip of the iceberg. In our 1999 VLCC newbuilding program, both ABS and LR approved a 980 KW generator. We found we needed 1260 KW to ensure that in nearly all normal operations, only one generator would have to be on-line. We opted for the 1260 KW machine, and ended up with ***lower*** generator fuel consumption, because we needed only one generator on line, and that generator was operating close to the min SFC point most of the time. With an EEDI, a prudent owner would no longer have this option.

3.3 Effectively Outlawing Twin Screw

By far, the single most effective measure to improve engine room reliability and low speed maneuverability is twin screw. Twin screw, properly implemented, offers an 1000-fold decrease in full loss of power incidents and at the same time a drastic improvement in low speed maneuverability. The list of deadly and/or high volume spillage casualties that probably would have been avoided if the ship(s) had been twin screw is a long one. Table 5 is a list of all such casualties in the CTX database involving known dead or a spill greater than 1000 m3, These casualties killed 250 people and spilled 1.2 million cubic meters of oil. But while twin screw ships can be *fuel efficient* — SSPA claims up to a 9% fuel consumption improvement relative to a twin screw ship for VLCC's — the optimal twin screw ship is a higher speed ship than a single screw ship due both to the increase in initial investment and the improved *fuel efficiency*. A more *fuel efficient*, far, far safer twin screw ship will have a higher EEDI than an equivalent single screw ship. ***Mandating an EEDI will effectively outlaw twin screw.***

3.4 Limiting lightweight

EEDI will also have a pernicious effect on structural strength. For most ship types, the *Capacity* term in the EEDI denominator is deadweight. By reducing lightweight, that is by reducing structural steel, a designer can increase deadweight without increasing displacement or reducing trial speed and thereby generate a lower EEDI. But once again we are dealing with a fleet in which structural margins have been pared to nothing, a fleet in which fatigue cracking is endemic, a fleet with very low corrosion margins.[22] Prudent owners recognize this and spec more steel than Class requires. A Class minimum VLCC will have a lightweight of 39,000 to 40,000 tons. Many owners add 3,000 or more tons to this to obtain a ship that they believe is reasonably robust.[23] With an EEDI, this will no longer be an option.

Back in the early 80's, when I was inspecting tankers for potential purchase, my first question was always: what's her light weight? My second question was: how much power does she have? If the answer to both those questions was "more than normal", then I knew it was likely I was dealing with a good ship. If the answer to both those questions was "less than normal", I wouldn't even bother to inspect. If EEDI had been around in the 1980's, I would have had very little to do.

3.5 Market Based Measures render EEDI superfluous and counter-productive

The one thing we can be sure of is that EEDI will get rid of the good owners. EEDI will either

a. force the good owners out of the industry, or
b. force the good owners to build under-powered, Class minimum ships.

Any owner who builds such a ship is a bad owner. The whole EEDI concept is not just flawed. It is dangerous nonsense. It cannot be fixed by yet another correction factor.

The tragedy is that, if we adopt a market based emissions reduction program, then design constraints such as EEDI are both unnecessary and counter-productive. Once we have internalized the cost to society of emitting CO2 by imposing a bunkers tax (or an equivalently priced cap-and-trade), our job is to sit back and let the market go to work.[24]

[22] Tromedy, Section, 4.6, Chapter 5,

[23] In our 1999 VLCC newbuilding program, we speced a ship with a lightweight of 48,150 tons. Amoco came up with a very similar lightweight for the Ocean Guardian. These ships were not over-built. They were simply solid, safe structures.

[24] See companion document Efficient, Safe Reduction of CO2 Emissions from Ships

Mandatory design features that happen to be efficient will have no effect since the shipowners will adopt them automatically. Any inefficient design features won't be adopted which is exactly what we want.

In particular, forcing shipowners to install less power than they otherwise would is about as counter-productive as you can get. It will increase fuel consumption at whatever speeds they actually operate at while at the same time reducing already unsafe power plant reliability.

4 Why EEDI?

If EEDI has all the crippling problems and drawbacks, we have claimed, why is the IMO even considering EEDI? The answer is that the IMO feels under great pressure to do ***something*** about CO2 emissions. And EEDI has one overwhelming procedural advantage over the safe, CO2 efficient alternatives.

Both a carbon tax and a cap-and-trade will require a whole new IMO Convention in part to handle the funds generated. EEDI, on the other hand, despite its importance and its critical safety implications, procedurally is merely an admendment to an annex of MARPOL. As such it can be adopted by a handful of people (the MEPC) behind close doors and deemed accepted without a vote. The new convention process will probably take around 7 years. The adopt and deemed accepted admendment process takes less than a year.

The tragedy is there is no need to hurry.

1. Ocean transportation is by far the least carbon intensive mode of transportation If ocean transportation were to further reduce CO2 emissions in a costly manner before the other modes did likewise, then the shift to the other modes could actually increase worldwide CO2 emissions.
2. Thanks to the rise in fuel prices over the last 30 years, ocean transportation has already reduced its carbon intensity by at least 25% and in some sectors (big tankers) by over 75% over the last three decades.
3. And there is a lot more to come. In the last five years, BFO prices have increased about \$300 per ton BFO. This has increased the owner's cost of a ton of CO2 emissions by about \$100, and engendered a massive increase in slow-steaming. For tankers see Devanney, The Effect of Bunker Prices on VLCC Rates. For containerships see Cariou, The impact of speed reduction on liner shipping CO2 emissions. However, the post-2005 bunker price rise has happened so recently that we cannot expect to start seeing the long-run effects on ship design for a few more years.

   This lag shows up in *negative abatement costs.* The combination of the massive increase in bunkers prices over the last few years together with shipping's sensitivity to bunker prices has resulted in around 600 million tons per year of CO2 reductions with negative abatement costs.[25] ***These reductions will occur over the next 20 years even if we do nothing***.[26]

In short, we have time.

- There is no need to hurridly implement ineffective, unsafe measures such as EEDI.
- We have time to decide on tax vs cap-and-trade.
- We have time to bring a tax or cap-and-trade convention into force.
- Five or so years down the road, we should have a better idea of the social cost of CO2 pollution, and with the convention in place, we can impose a tax (permit price) based on that cost.

Finally, even if we were in a hurry, this would not be an argument in favor of EEDI. Quite the contrary. EEDI applies only to newbuildings. The first phase a 10% reduction in EEDI (not to be confused with a reduction in CO2 emissions which will be much smaller), will apply only to ships delivered between 2013 and 2017. Phase 2, a 25% reduction in EEDI, will apply to ships delivered between 2018 and 2022. Phase 3, a 35% reduction in EEDI, will apply to ship delivered in 2023 and later.

A tax/cap-and-trade which came into force in, say, 2017 would immediately apply to every ship afloat. At that point, a 10% reduction in EEDI would apply to only a very small proportion of the trading fleet.

[25] DNV, Pathways to Low Carbon Shipping, June 2010.

[26] For a more complete discusion of this issue, see CO2 Emissions from Ships: the Case for Taking our Time.

A Ship Efficiency Credit Trading

A.1 Trading in EEDI credits

In recognition of the fact that EEDI is strictly a design constraint, there are serious proposals to extend all of EEDI's problems to the ship's operating life. One of these is called Ship Efficiency Credit Trading or SECT. Under SECT, an operating ship's EEDI would be periodically tested. If a ship fails to meet the required EEDI over a period, the owner would have to purchase EEDI credits from an owner whose ship exceeds the requirement, based on the difference between the actual and the required times the miles traveled in the period. An owner whose ship has an actual EEDI lower than required would earn credits based on the difference between required and actual times the distance the ship travelled.

The fundamental problem with SECT is reducing EEDI is not the goal. The goal is reducing CO2 emissions efficiently. EEDI is an indirect, wasteful, and unsafe means of reducing CO2 emissions. This in itself is a priori ground for rejecting SECT and other proposals based on EEDI. But on top of all of EEDI's problems, SECT generates it own set of problems.

A.2 Perverse Incentives for Low EEDI ships

SECT extends EEDI's CO2 inefficiency to the short-run. In the short run, the only effective means of reducing CO2 emissions is slow-steaming. While SECT will induce a shift toward more use of low EEDI ships and less use of high EEDI ships, which shift might or might not reduce CO2 emissions, SECT incentivizes additional miles, that is, less slow steaming, from low EEDI ships. And it could be even worse than this. What SECT does is set up a system in which it could pay a low EEDI ship to steam around in circles to build up credits. So here's a system that is supposed to reduce CO2 emissions which ends up with a large number of low powered ships steaming around in circles at a high SFC, pouring out CO2.

A.3 No incentives to use Low Carbon Fuel

Nor is there any incentive to actually use a low carbon content fuel. Instead there is an incentive to claim at survey time you will use a low carbon fuel.

A.4 Implementation Issues

Then there is a number of implementation issues:

Biased Baselines The promoters of SECT talks confidently about how each type of ship would have to cut back evenly from the baseline, creating "an equitable and straightforward approach".[27] But the baseline regressions have correlation coefficients in the 0.6 to low 0.7 range, which generates all kinds of weird biases. A standard 15 kt VLCC is +9% above the baseline; a standard 25 kt big containership is -15% below the baseline.[28] Nothing equitable here; and far more importantly, nothing CO2 efficient here.

Limited Lifetime Credits SECT proposes to limit the lifetime of credits. This creates an administrative nightmare. Under this proposal, there will be a multitude of prices in the credit trading market(s). Every change in market price will create all sorts of arbitrage possibilities. What's the point? What's wrong with an owner hanging onto her credits if she thinks they are going to be more valuable in the future? The answer is that the SECT promoters know they have a problem with credit availability (see below) and they incorrectly think this will ameliorate it. But what it surely does is that it makes the credits less valuable and therefore there is less incentive to earn credits.

Periodically Determining EEDI Under SECT, the flag state/class determine the ship's EEDI. But the owners choose and hire both flag and class. If an owner cant get the EEDI he wants from one flag/class combo, he will keep changing combos until he

[27] Ship Efficiency Credit Trading with Efficiency Standards, May 2010, page 2-4

[28] Akiyama and Taggi, Evaluation of EEDI Index, Tripartite Workshop on GHG Emissions, Beijing, 2010-06-03

find the flag/class that will come up the right EEDI. At the sea trials, there is some self-enforcement because the owner and yard have conflicting goals. At the periodic checks, no such conflict exists. Everybody will be on the same page.

Determining Vessel Activity SECT needs to know the miles the ship has travelled, and suggests that this be taken from the ship's log. With AIS there may be some chance of enforcing this. Otherwise, it is a pipe dream. More importantly, using miles steamed rather than some measure much closer to the real function of a ship sets up the steaming in circles scenario. Certainly, it incentivizes extra miles per period (read less slow steaming, read more CO2 in the air) from any ship whose EEDI is below the required level.

A.5 USA experience with ABT programs

The SECT promoters make much of USA experience in ABT (Averaging, banking and trading) programs. In particular they point to the improvement in US outboard motors. This example is misleading in several instructive ways.

1. Unlike SECT, the outboard program had nothing to do with actual operation. ***It was strictly a newbuilding requirement tested at the factory.*** There was no need to measure "activity". This is also true for all the other examples offered by the promoters.[29] The true ship counterpart would be shipyards trading newbuilding EEDI's.
2. The requirement was imposed on the manufacturer's overall output, not on each single unit. Among other things, this meant the program had to deal with only a handful of outboard producers rather than thousands of ship owners.
3. Almost all the reduction in USA outboard pollution was from switching from 2 stroke to 4 stroke, and from carburetted to fuel injected motors which would have happened anyway. This switch was driven by fuel/lube prices and complaints about two-stroke noise and putting lube oil in the water.
4. The standards were set well above what these technologies could achieve. This is the only way they could guarantee having enough credits around. In other words, the standards were not a real limit. This in turn meant the current value of the credits was near zero.
5. There was little or no trading in the credits.[30] The manufacturers aren't stupid. They held on to their low value credits as insurance againt tighter future standards and the value of the credits sky-rocketing.

A.6 No way of assuring sufficient credits

A final, crippling problem with SECT is: how do you guarantee that there will be enough credits available for the ships that don't comply? The assumption is that for every ship that needs a credit there will be a ship that produces a credit. But the system has no means of assuring that.[31] And if you do come up short in any period, the price of the EEDI credits will sky-rocket; and we will see low EEDI ships steaming around in circles in order to generate credits.

The answer to the question is: ***the only way you can guarantee that there are sufficient credits is to set the standards very leniently***. This was the case with respect to USA outboards. The promoters are very much aware of this. That's why they exempt very old ships.[32] That why they set the operating EEDI higher than the newbuilding EEDI.[33] In other words, regulation that is no regulation. This makes it easy to generate credits, which means the current value of the credits are low, which means credit holders don't sell them, anticipating the credits will be much more valuable in the future.

So they impose an ad hoc limit on credit life. And then they top the whole mess off with a fine,[34] implicitly admitting that without the fine, they don't have a system. At this point, we are way, way down the rabbit hole.

[29] Ship Efficiency Credit Trading with Efficiency Standards, May 2010, page 4-6.
[30] ibid, 4-7
[31] In a static, deterministic world you can argue that eventually you will reach a long-run equilibrium EEDI credit price. In the real world, this is a zero probability event.
[32] ibid, page 5-1.
[33] ibid, page 6-4.
[34] ibid, page 6-4.

This is what happens when you build a house of cards (SECT) on a foundation of quicksand (EEDI).

B Vessel Efficiency System

Another EEDI-based proposal is Vessel Efficiency System (VES). Like SECT, VES would periodically measure a ship's EEDI. If the EEDI is worse than the EEDI required for that ship, the ship would be fined an amount proportional ratio of the ship's measured EEDI to the required times the fuel consumed in the period. Administratively, VES requires both the periodic determination of a ship's EEDI and validation of each ship's fuel consumption.

VES shares three of SECT's specific problems

1. Dependence on the owner chosen and hired flag and class to determine the EEDI.
2. Despite being called an operating measure, there is no incentive to use a low carbon content fuel. There is an incentive to claim at survey time you will use a low carbon fuel at survey time.
3. Despite being called an operating measure, there is no incentive to slow-steam. But at least we wont have ship's steaming around in circles to earn EEDI credits.

On the plus side relative to SECT, there is no need to maintain a market in anything. VES is not a market based measure by any reasonable definition. Nor does VES need to determine the ship's "activity".

On the negative side, VES offers no incentive for doing better than the required EEDI, and, like the true market based measures, tax and cap-and-trade, it does need to validate the ship's fuel consumption. To put it another way, if we can do VES, we can do a tax with less administrative cost.

But the fundamental problem with VES, like SECT, is reducing EEDI is not the goal. The goal is reducing CO2 emissions efficiently. EEDI is an ineffective, wasteful, and unsafe means of reducing CO2 emissions. This in itself is a priori ground for rejecting VES.

Table 2: Biggest Main Engine/Generator Failure Spills

Based on CTX Casualty Database as of 2010-05-15T13:54:53

DATE	SHIP	Dead	Kilo-liters	Brief Description
19930105	braer	0	99600	pipes on deck hit vents, sw in BFO, no power, grnded Shetland
19830107	assimi	0	60200	ER fire, Gulf of Oman, cause uncertain, spreads to tanks, sinks
19750110	british ambassador	0	56000	sw inlet leaked N Pacific, vlv failed ER flooded, sank under tow
19831209	pericles gc	0	54100	ER fire east of Doha, sank
19710227	wafra	0	47000	SW circ pump fracture, ER flooded, drifted aground SA, sunk
19760204	st peter	0	44300	'elec fire in ER' off West Coast of Columbia, sank
19770527	caribbean sea	0	35200	ER flooded South of El Salvador, sank, cause unknown
19720611	trader	0	34000	Engine room flooded E Med, sank, prob machinery but need info
19650523	heimvard	10	32000	hit Muroran jetty 'at speed', explosion, 18 killed, total loss
19821126	haralabos	0	31900	ER fire, Red Sea, cause unknown, beached, cgo transhipped, CTL
19671024	giorgio fassio	0	25000	Engine room flooded cause unknown, sank off SW Africa
19720331	giuseppe giulietti	0	25000	ER flooded off C St Vincent, no power, sank
19940313	bc shipbroker	42	23500	BC Shipbroker black out, no rudder, coll Bosporus, massive exp
19700114	albacruz	0	23000	main sw piping failed, er flooded, sank loaded in N Atlantic
19740723	theodoros v	9	23000	Engine room explosion loaded off Dakar, 9 killed, sank, no cause?
19701007	anastasia j l	0	22000	ER flooded, sank fully loaded NE Azores
19680426	assimi iii	5	20000	ER fire south of Singapore, sank, nil info on initial cause
19680508	andron	0	20000	ER pipe failed, ER flooded, sank off SW Africa
19700131	gezina brovig	0	18800	piston thru crank case NW PR, broke SW main, ER flooded sank
19600627	george macdonald	0	17000	loaded, massive condenser leak, ER flooded, sank
19611001	hess mariner	0	17000	Main prop. generator overspeed, holed condenser, ER flooded, sank
20020814	golden gate	0	15200	entering Karachi, maybe mach, maybe conn, volume hi?
19680307	general colocotronis	0	6000	machinery failure cause unknown, grounded off Eleuthera
20061020	front vanguard	0	6000	blackout Suez, grnded, Anna PC avoiding grnded, spilled 5000T
19761227	olympic games	0	5880	engine failure, Delaware R, 39 ft draft, grounded
19700804	ampuria	0	3700	Burn out of main generator. Stranded WC India, ER flooded,
19770415	universe defiance	9	3000	Boiler room fire off West Africa, 9 killed, scuttled
20001128	westchester	0	2100	crankcase explosion in Miss.River, grounded, 1S holed, big spill
19850928	grand eagle	0	1640	ship lost power, grounded near Marcus Hook
20041208	selendang ayu	6	1300	cracked cyl liner, bad rings, no restart, drifted ashore, 6 dead
20010114	amorgos	0	1100	mn eng failure, stranded Taiwan, broke up, no deaths, 1000t spill

Table 3: Casualties in which poor maneuverability a factor
Based on CTX Casualty Database as of 2010-05-15T15:31:28

DATE	SHIP	Dead	Kilo-liters	Code	Brief Description
19921203	aegean sea	0	87000	WS	could not turn ship in bad weather, grounded, fire, OBO
20030727	tasman spirit	0	35200	MA	chan?pilot?mach?, guess ship too deep for Karachi channel
19680303	ocean eagle	0	13200	DS	slowed for pilot, lost control, grounded in hvy swell
20041214	al samidoon	0	10600	G_	hit Suez bank avoiding dredge, probable pilot error, holed
20061020	anna pc	0	6000	DS	blackout Suez, grnded, Anna PC avoiding grnded, spilled 5000T
19710118	arizona standard	0	3240	MA	collision SF Bay, wrong frequencies, poor steerage, VTS useless
19660616	alva cape	37	2066	DS	coll w Tex Mass, AC went astern, lost steerage, bow swung to port
19970702	diamond grace	0	1550	WS	had to slow down in Tokyo Bay, lost steerage, grounded
19950710	iron baron	0	500	GS	grounded picking up pilot, nil low spd maneuverability, scuttled
20040119	rocknes	18	240	Vu	rockdump ship, nil stability,maneuverability, grounded, 18 killed
20030705	zeus	0	0.080	MA	wake unmoored Nita M on Neches, flange busted, small spill.
19870331	hyundai new worl	0	0.000	G_	grounding leaving Pt da Madeira, sank, poor maneuverability?
20010806	eagle charlotte	0	0.000	MA	unmoored by outbound eagle charlotte wake, hose parted, spill
20061006	giant step	10	0.000	WS	lee shore in gale, dragged anchor, windless/mn eng failures
19750105	lake illawarra	12	0.000	DS	Lake Illawarra hit Tasman Bridge. 7 crew, 5 motorists killed
19790225	mobil vigilant	0	0.000	CN	coll w Marine Duval Neches R., bank effect, slo spd dop gt 5m
19961214	bright field	0	0.000	Ca	lost power, then steerage, downbound Miss, hit Riverwalk, 62 hurt
20020911	sea mariner	0	0.000	DS	took shallow route, slowed for traffic, lost steerage, grounded
20061024	ocean victory	0	0.000	GS	part-discharge, left port late, pushed down on jetty by BF10 wind
20070608	pasha bulker	0	0.000	MA	slow to weigh anchor in gale, nil manueverability, stranded,
20071103	axel spirit	0	0.000	CA	Master fails to properly respond to current, hits Ambrose Light
20071220	overseas meridia	0	0.000	WS	lost steering S end of Suez, grounded, holed, no spill
20080624	minerva xanthe	0	0.000	MA	ran aground holding for traffic, nil low spd maneuverability

Table 4: Casualties in which under-sized generators a factor
Based on CTX Casualty Database as of 2010-05-17T08:34:00

DATE	SHIP	Dead	Kilo-liters	Code	Brief Description
19941008	seal island	3	238	MO	leak from temporary strainer repair, huge ER fire HOVIC
20020415	polar endeavour	0	0	MB	loss of power in 'fully redundant/independent' twin screw ship
20020621	genmar constanti	0	0	MB	black out, Mississippi, collided with moored USN ships
20030720	chilbar	0	0	MB	1 gen failed, other not big enough, blackout
20030813	jo oak	0	0	MB	not enough gen power to run bow thruster, crew blamed
20031029	cygnus voyager	0	0	MB	6 min loss of power, generator over-load, off El Segundo
20080907	moldanger	0	0	MB	Blackout due to loss of 1 of 3 generators on line
20081218	panagia lady	0	0	MB	black out, outbound Arthur Kill, no damage
20081226	overseas long be	0	0	MB	lost gen switching fuel off California, black out

Table 5: Fatal or big spill casualties in which twin screw might have helped

Based on CTX Casualty Database as of 2010-05-15T16:21:20

DATE	SHIP	Dead	Kilo-liters	Brief Description
19600627	george macdonal	0	17000	loaded, massive condenser leak, ER flooded, sank
19611001	hess mariner	0	17000	Main prop. generator overspeed, holed condenser, ER flooded, sank
19640918	trentbank	1	0	Fogo hit overtaking Trentbank whose unreliable strng gear failed
19660616	alva cape	37	2066	coll w Tex Mass, AC went astern, lost steerage, bow swung to port
19671024	giorgio fassio	0	25000	Engine room flooded cause unknown, sank off SW Africa
19680303	ocean eagle	0	13200	slowed for pilot, lost control, grounded in hvy swell
19680307	general colocot	0	6000	machinery failure cause unknown, grounded off Eleuthera
19680426	assimi iii	5	20000	ER fire south of Singapore, sank, nil info on initial cause
19680508	andron	0	20000	ER pipe failed, ER flooded, sank off SW Africa
19700114	albacruz	0	23000	main sw piping failed, er flooded, sank loaded in N Atlantic
19700131	gezina brovig	0	18800	piston thru crank case NW PR, broke SW main, ER flooded sank
19700701	agip ancona	6	0	Lost steering, Bosporous. Killed 6 people on shore.
19700804	ampuria	0	3700	Burn out of main generator. Stranded WC India, ER flooded,
19701007	anastasia j l	0	22000	ER flooded, sank fully loaded NE Azores
19710227	wafra	0	47000	SW circ pump fracture, ER flooded, drifted aground SA, sunk
19720331	giuseppe giulie	0	25000	ER flooded off C St Vincent, no power, sank
19720611	trader	0	34000	Engine room flooded E Med, sank, prob machinery but need info
19730602	sea witch	16	5000	rammed NY harbor by Sea Witch whose steering gear failed
19740723	theodoros v	9	23000	Engine room explosion loaded off Dakar, 9 killed, sank, no cause?
19740926	transhuron	0	4000	A/C nipple failed, water on swbd, no power, grounded SW India
19750105	lake illawarra	12	0	Lake Illawarra hit Tasman Bridge. 7 crew, 5 motorists killed
19750110	british ambassa	0	56000	sw inlet leaked N Pacific, vlv failed ER flooded, sank under tow
19750131	e m queeny	24	42200	hit by E M Queeny, Marcus Hook, no IG, no twin screw, pilot error
19760124	olympic bravery	4	842	'series of engine failures', VLCC drifted aground on Ushant
19760204	st peter	0	44300	'elec fire in ER' off West Coast of Columbia, sank
19760218	scorpio	0	34900	lost steering, grounded Gulf of Campeche, CTL
19760724	diego silang	0	6200	Vysotsk crossed in front, went astern, turned into Braz Faith
19761227	olympic games	0	5880	engine failure, Delaware R, 39 ft draft, grounded
19770327	anson	0	2330	steering gear failure Orinoco, grounded
19770415	universe defian	9	3000	Boiler room fire off West Africa, 9 killed, scuttled
19770527	caribbean sea	0	35200	ER flooded South of El Salvador, sank, cause unknown
19780316	amoco cadiz	0	267000	steering gear failure, grounded Britanny, broke up
19790302	messiniaki fron	0	14100	grounding Crete, radar on wrong scale, no visuals
19791213	energy determin	1	0	explosion in slop tank Hormuz, inerting not in use, sank
19801012	julia wilson	1	0	fuel line break, ER fire, one dead, towed to Las Palmas
19810505	humilitas	4	0	engine room fire off Naples, 4 killed, no cause info
19811121	globe assimi	0	17000	grounded bad storm lving Klaipeda, broke up, slow to leave
19820820	corinthian	0	1470	engine room fire off Fujairah, flooded, sunk, no other info
19821126	haralabos	0	31900	ER fire, Red Sea, cause unknown, beached, cgo transhipped, CTL
19841020	uss roanoke	0	1400	'steering failure', grounded outside Pearl Harbor, 1400m3? spill
19850928	grand eagle	0	1640	ship lost power, grounded near Marcus Hook
19861118	kowloon bridge	0	2000	bad crack on deck, temp repairs, loses anchor, loses steering,
19870623	fuyoh maru	6	20	collision w Vitoria in Seine 'damage to helm'
19891229	aragon	0	29400	lost power, big spill under tow near Madiera?, conflicting info
19900629	chenki	0	9600	lost steering Suez Canal, grounded, holed, towed to Suez
19900819	silver energy	0	3800	rudder, machinery damage, grounded, No 1 holed, spill
19920920	briolette	1	0	LO leak, fire in engine room, 1 killed, towed to Subic
19921203	aegean sea	0	87000	could not turn ship in bad weather, grounded, fire, OBO
19930105	braer	0	99600	pipes on deck hit vents, sw in BFO, no power, grnded Shetland
19931005	sks horizon	1	0	hyd ? pump leak, ER fire, 1 killed, 6 hurt
19940313	bc shipbroker	42	23500	BC Shipbroker black out, no rudder, coll Bosporus, massive exp
19950104	you xiu	27	0	waited too long, lost power, hit breakwater in storm, 27 killed
19950104	paris	27	0	waited too long, unable to heave anchor, hit breakwater, 27 dead
19970702	diamond grace	0	1550	had to slow down in Tokyo Bay, lost steerage, grounded
20000228	bear g	1	0	ER? explosion, 130 mi ESE Kingston, 1? dead/4 hurt, nil info
20001003	natuna sea	0	8230	grounded off Singapore, prob nav???
20001128	westchester	0	2100	crankcase explosion in Miss.River, grounded, 1S holed, big spill
20010114	amorgos	0	1100	mn eng failure, stranded Taiwan, broke up, no deaths, 1000t spill
20010329	baltic carrier	0	2900	steering failure Baltic, collision with Tern, 6m plus penetration
20030727	tasman spirit	0	35200	chan?pilot?mach?, guess ship too deep for Karachi channel
20041208	selendang ayu	6	1300	cracked cyl liner, bad rings, no restart, drifted ashore, 6 dead
20041214	al samidoon	0	10600	hit Suez bank avoiding dredge, probable pilot error, holed
20060227	grigoroussa i	0	1300	steering gear failure Suez, hit west bank, strange fire
20061006	giant step	10	0	lee shore in gale, dragged anchor, windless/mn eng failures
20061020	front vanguard	0	6000	blackout Suez, grnded, Anna PC avoiding grnded, spilled 5000T