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THE INFLUENCE OF GOVERNMENT REGULATIONS ON VESSEL EFFICIENCY

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INTRODUCTION:

At present there is a very worthy trend both to be and to be seen to be "green". Conferences are awash with solutions to improve the fuel efficiency of industry at all levels, and firms compete to promote their own brand of energy-saving or emissions-reducing devices. In the marine field every week there is some pronouncement about concepts for new energy-efficient powering system designs, often involving diesel-electric, fuel cell, LNG or CNG systems or hybrid derivatives of all the above. The author's company has been involved in a number of projects which have broken new ground in this regard, including the design of the world's first hybrid-powered tugboat, and a Short-Sea shipping Ro-Ro ferry for the US eastern seaboard, powered by clean-burning CNG. Although in both these cases the solutions are technically elegant, and they result in a significant reduction in both fuel consumption and emissions, these savings come at a significant premium in direct capital cost. The savings in real terms make an economic payback difficult over the life of the project, unless one factors in the impact of government regulations, subsidies or tax incentives in one form or another which deliberately tilt the playing field in favour of the new technologies. There is nothing wrong with that policy, but in the absence of such a dictum, these new systems simply cannot compete economically with the simple direct diesel machinery installations that they may ultimately replace, and so the question becomes "who pays" for the implementation costs? That is not to say that these projects and many others like them lack merit, as both achieve the end objective of reduced emissions and reduced fuel consumption, and are leading examples in the marine field of emerging technologies that will ultimately become more cost-competitive. Whether the overall carbon footprint of these projects is truly a benefit to the planet or not, remains to be seen. The total cost of producing and regularly replacing and disposing of the large number of batteries in a hybrid power system for instance is rarely addressed as an element in the life-cycle cost of those systems. Nor is the cost of using grid-based power to re-charge the batteries overnight. It is essential therefore when looking at aspects of energy efficiency, to step back and look at the largest possible picture. What are the basic design factors which really could make a significant difference in the efficiency of marine transportation systems? Can we make significant improvements in vessel energy efficiency without the cost and complexity of the type of innovative power systems being proposed today? Can we make a real impact just by designing smarter? I know we can.

One major barrier to such obvious and simple options however is the basic regulatory regime under which many sectors of the marine world operate. There are regulations that govern the construction, outfitting, operation and manning of vessels of all types that have artificial and often nonsensical limits imposed at varying "hurdles" of ship length, volume and power. Most often these regulations are not well-integrated, and almost never are these regulatory boundaries set in a way which relates to the optimal efficiency of the vessel operations.

This paper examines a very small sample of some of these regulations, from Canada in particular, which interfere directly with the ability to make wise design choices for maximum energy efficiency, and hence which ultimately adversely affect the cost of transportation in our waters, and add to the emissions polluting the atmosphere. Significant reductions in fuel consumption, emissions and overall transportation costs could be achieved simply by changing obsolete or illogical regulations, without having to invest in very expensive new technologies.

HISTORICAL BACKGROUND:

One does not have to go too far back in history to see that a couple of generations ago ships were moving more slowly and the installed power per Deadweight (DWT) tonne of cargo was appreciably lower than it is today. Certainly it is true that modern diesel engines are far more efficient than their predecessors, but this has resulted in a tendency to simply install more power, rather than taking advantage of those advances in terms of fuel savings. We move the same cargoes faster, rather than cheaper.

Figure 1 below illustrates trends over time in general terms for ship capacity (DWT), Power, and length. Clearly the trend over the past 50 years has been consistently to larger and more powerful ships, all consuming more energy. This data, is taken from the very well-documented archives of the East Asiatic Company which ceased operations in the mid-1980's, but the trend has certainly continued, and even accelerated in the past decade.

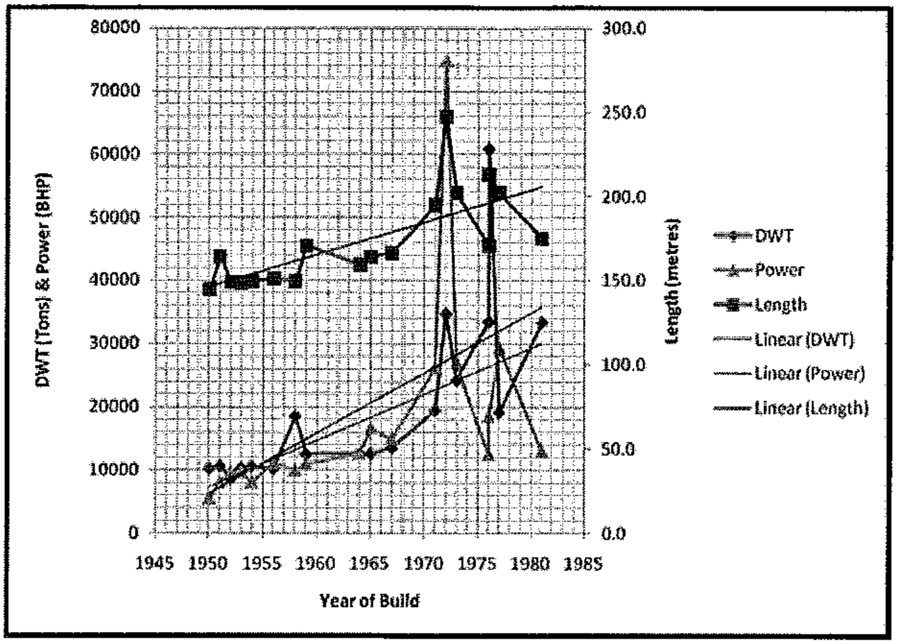


Figure 1 – Trends in Ship Size and Power over the Period 1950-1982

Figure 2 illustrates the Power/DWT ratio as well as other indices of capacity and operational efficiency for a sample of bulk and general cargo vessels over the same period. The general trend to higher powers and higher speeds is obvious, although it is noteworthy that the Power per "Knot-Tonne", the energy required to move cargo, remains fairly constant. There are obviously some swings in the trends due to specific samples, but overall we see that cargo capacity per vessel size continues to grow, generally meaning fuller ships which require more power for the same speed, and the power per tonne trends upward, reflecting higher transit speeds.

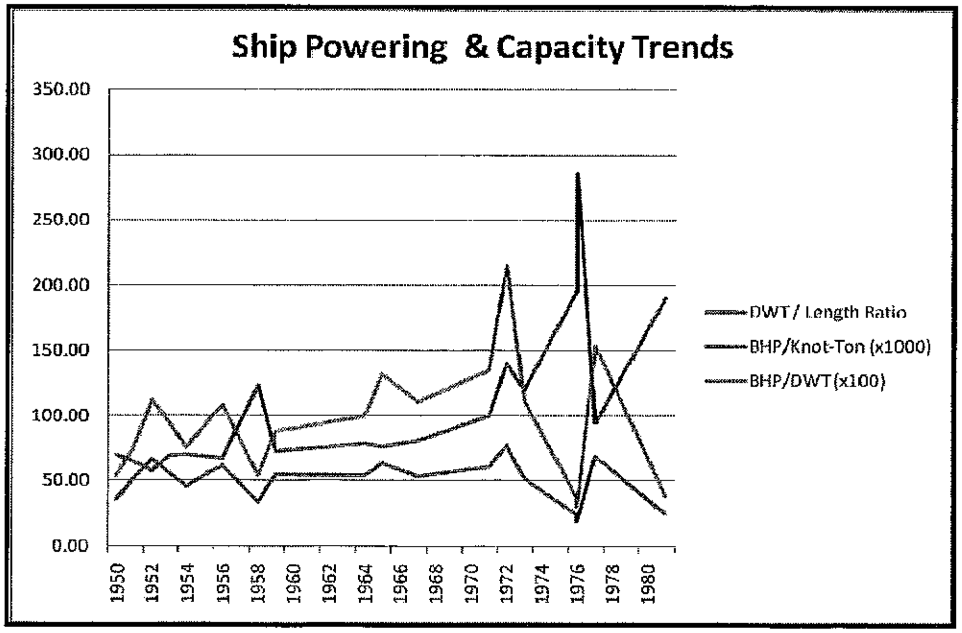


Figure 2 – Trends in Vessel Operating Efficiencies

In local waters, one simply has to take a walk on any local fishing wharf and see how the graceful lines of the old wooden seiners have been supplanted by the boxy shapes of the latest generation of vessels (See Figure 3) engaged in the same fishery. Certainly the latter hold more volume, but why have the new hulls become so blatantly inefficient? One does not have to be a trained naval architect to recognize that one hull form will be more easily driven through the water than another. The answer, unfortunately, generally lies in the regulations under which these boats are licensed and operate.

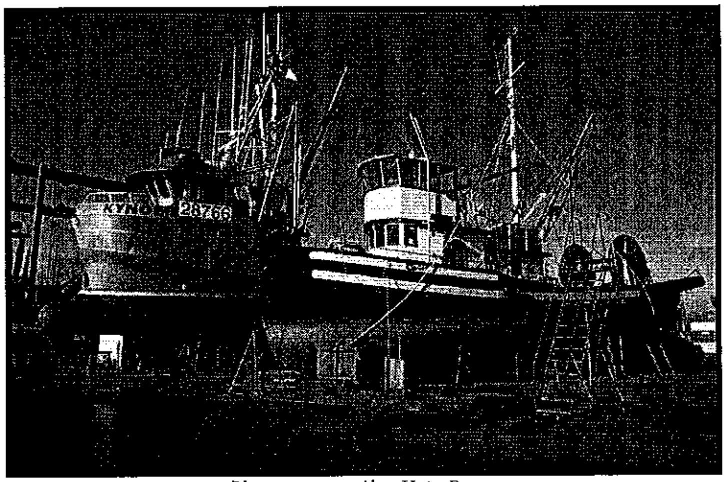


Photo courtesy Alan Haig-Brown

Figure 3 – Contrast in Hull Forms over the Generations

Designers of my Grandfather's generation were not so constrained by regulation, and by habit and training designed for the lowest possible resistance of their vessels. Speed was accomplished more by the design of a longer, leaner vessel than by throwing more power at the problem. The contrast in the typical wakes that these vessels leave behind (Figures 4 and 5) is a testament to the fact that energy consumption was close to optimum in the older designs. (Regrettably the lovely old vessel in Figure 4 was not doing so well in terms of emissions!!)

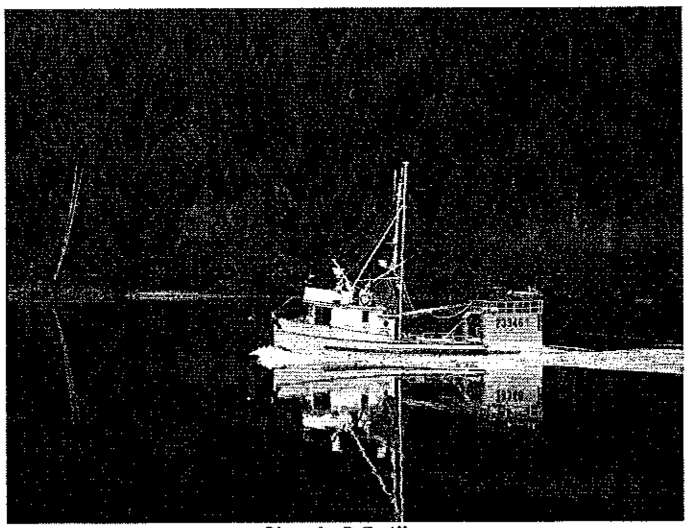


Photo by R.G. Allan

Figure 4 – Low Wake Impact of a Classical West Coast Seiner

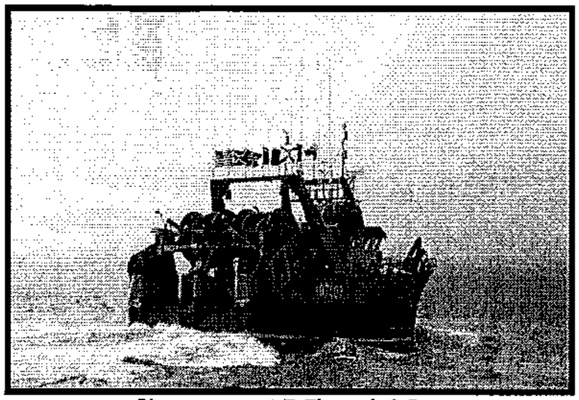


Photo courtesy A.F. Theriault & Sons

Figure 5 – Wake from a modern East Coast dragger with short, very full hull form

So let's have a closer look at some of the regulations that most impact the Canadian commercial workboat industry, and their influence on overall energy efficiency of the boats in question.

THE COASTAL TOWING INDUSTRY:

In BC, nearly all coastal transportation of commercial goods is undertaken by tug and barge. There are no "ships" engaged in port-to-port transportation with the exception of a very few small cargo vessels moving people and goods on the west coast of Vancouver Island, and of course the BC Ferry fleet. Otherwise, everything from logs to gravel to newsprint to mixed general cargo and containerized goods moves up and down the BC coast on generally crude, rectangular barges, towed by tugboats.

Coastal tugboats are designed as platforms to transmit power for duties other than moving themselves, as generally they will not earn revenue when running on their own. Typically the power required is determined by the tow they must manage, and the required service speed. But tugs ARE affected seriously by regulations, particularly those that affect their Gross Tonnage (GT)...a measure of the internal volume of the boat itself, and nothing to do with its weight or capacity directly. The following are some of those current breakpoints:

- 5 GT - vessel must be registered as a tug with Transport Canada. Note that this is an extremely tiny boat, in the range of 6-7 metres, so virtually every vessel engaged in towing in this country is subject to extensive regulations, a distinct contrast to our US neighbours where most tugs are unregulated except for stability requirements
- 15 GT - this used to be a major breakpoint for BC tugs, above which a vessel became subject to Transport Canada inspection, and a number of other standards applied. Before a change to the manner in which GT was measured (which changed about a decade ago), it was possible to manipulate GT by installing artificially deep structural members and similar design "fiddles". Keeping length low had a major influence on GT, and so a whole generation of these tugs were built (Figure 6) and continue to operate, carrying around redundant steel simply to beat what is now an obsolete rule. The same archaic system of

GT measurement however still exists in the USA today, the only jurisdiction in the world that still does so, although their breakpoints are quite different to those in Canada, and relate primarily to crew licensing requirements. Accordingly, by manipulating the tonnage frames and tonnage openings a designer can create quite a large tug which can be built to tow deep sea, and still not require a licensed Master! (Is this a wise regulation??) A great deal of energy is wasted through compliance with this outdated regulation, namely:

- Energy to make the redundant steel
- Energy to fabricate the wasted steel
- Energy wasted in hauling the redundant steel around for the life of the ship
- Energy wasted to maintain the redundant structure

and in essence it creates a potentially unsafe operating environment for the entire crew. A simple change in Licensing (in the US) to specific duties and to voyages rather than to GT limits would eliminate this wasteful practice.

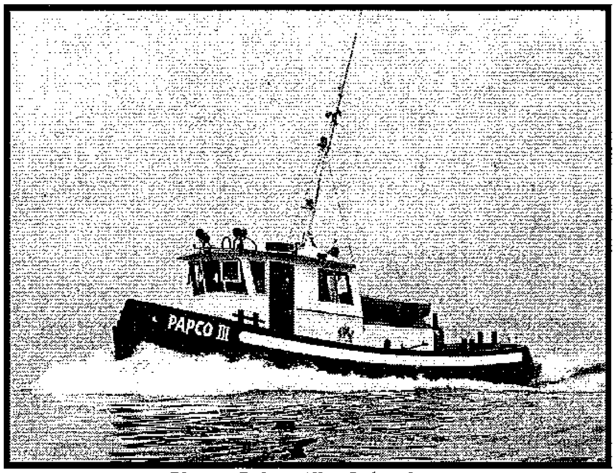


Photo – Robert Allan Ltd archives

Figure 6 – Typical <15 GT Tug, ca. 1965

- 150 GT - at this size a tug is subject to annual inspections by Transport Canada, rather than quadrennial inspections. Shipyards advise that these dockings and associated work cost at least in the order of $30-$40,000, so there is a serious incentive to stay below that size limit, which represents a tug about 24 metres in length. A whole series of tugs of this Class (Figure 7) were built in the 1970's. Their configuration was also significantly impacted by a new set of Hull Construction Regulations introduced in 1972 which prevented placing the accommodation below the main deck level, amongst many other changes. The nature of the new rules forced the development of tugboats with the fully raised forecastle configuration illustrated in Figure 7, and in order to maintain safe stability characteristics, the boats had to get wider to support the larger topsides structures. These tugs are contrasted with the longer, leaner vessel illustrated in

Figure 8, a style of tug typical of those built barely a decade before, and which have the reputation as the best towing tugs on the coast. The 1972 regulations effectively prevented this style of tug from ever being built again, in spite of their excellent safety record and proven performance efficiency.

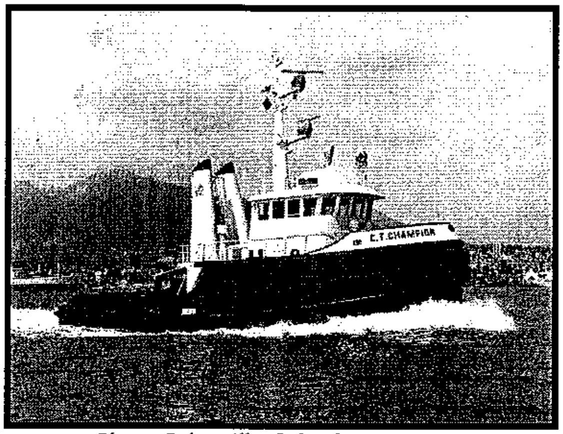


Photo – Robert Allan Ltd archives

Figure 7 – Typical 149 GT West Coast Tug; 23.5 metres

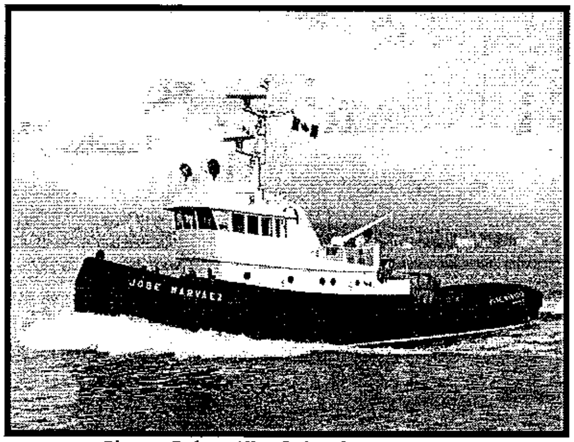


Photo – Robert Allan Ltd archives

Figure 8 – 26.5 metre Coastal Tug Built before 1972 Regulations

- 500 GT - above this limit a number of major Canadian and international regulations related primarily to fire safety and equipment requirements come into effect, all of which can have significant impact on vessel cost. This creates a strong incentive to stay below this size (volume) limit, which represents a typical tugboat about 34-35 metres in length. For a vessel engaged in long distance coastal towing along the North American west coast for example, that is simply too short a boat to be efficient or even to be totally safe, and yet there is a strong financial incentive to stay under that size. Historically the best performing tugs in that service have been over 40 metres in length, and accordingly well over 500 GT.

Because of these GT limits, which typically translate into length restrictions, tugs in all trades in Canadian waters have generally tended over the past 30 years to become short and wide, and as a consequence are not as efficient when towing as the previous generation of longer boats. This is largely a function of the impact that waves have on the shorter boats, whereas longer boats will push through seas more easily. Smaller boats are also simply more susceptible to weather and sea-states, and unfortunately operators tend to use these small but powerful tugs in conditions more exposed than is often prudent. The risk to the tug, its crew and the tow increase significantly. Given the choice of a longer boat for the same power, it is hard to imagine a scenario where operators would not prefer the larger, more seakindly tug. Towing speeds would be more easily retained in worse weather conditions, and fuel would be saved due to the better seakeeping and towing performance. For the same power the total voyage time, hence fuel burn, would be reduced.

Barges, fortunately, are not governed by many regulations in Canada, and generally their dimensions are determined mostly by the limitations of berths on length and breadth (or draft), the need for good stability in what are generally mostly deck cargo barges (hence wider barges than are suited to low resistance), and of course cost of construction, where length is generally perceived to be the most expensive dimension in terms of construction cost. However here too there are opportunities for Owners to consider geometry carefully when building new tonnage. The proportions of a barge, the bow form, and the skeg geometry each can have a dramatic influence on the towed resistance of a barge. The power required to tow at a specific speed can easily be reduced by as much as 30% or more by careful design. For example, consider a typical 5,000 tonne deck cargo barge; a longer barge with a spoon bow will cost somewhat more to build than a simple square ended scow, but the difference in steelweight between barge A and B, as shown in Table 1 below, would be only about 250 tonnes, representing a cost delta of less than $250,000 at today's new construction prices. However, if a towing speed of say 7.5 – 8 knots is achieved on the shorter barge with an 1800 HP tugboat, the longer, narrower barge would require only about 1400 bhp to achieve the same speed, consuming approximately 85 litres less PER HOUR! At $0.80/litre the fuel savings is $68/hour. The capital cost premium would be paid off in 36 months, assuming towing at 100 hours per month, and in that time more than 300,000 litres less fuel would have been burned for the same cargo throughput!

Table 1 - Comparison of Barge Particulars

	A - Scow Form	*B - Better Form*	
DWT	5000	5000	*tonnes*
Length	83.60	97.50	*metres*
Beam	20.90	19.50	*metres*
Depth	5.25	6.00	*metres*
Draft	4.00	4.00	*metres*
Cb	0.89	0.85	
L/B	4.00	5.00	
Steelweight	1130	1380	*tonnes*

Figure 9 illustrates graphically how the resistance characteristics of barges can be influenced by form and proportions, which translates directly into fuel savings in service, and yet many new barges continue to be constructed without taking advantage of the body of science readily available through qualified design firms to enable the accurate prediction of better performance.

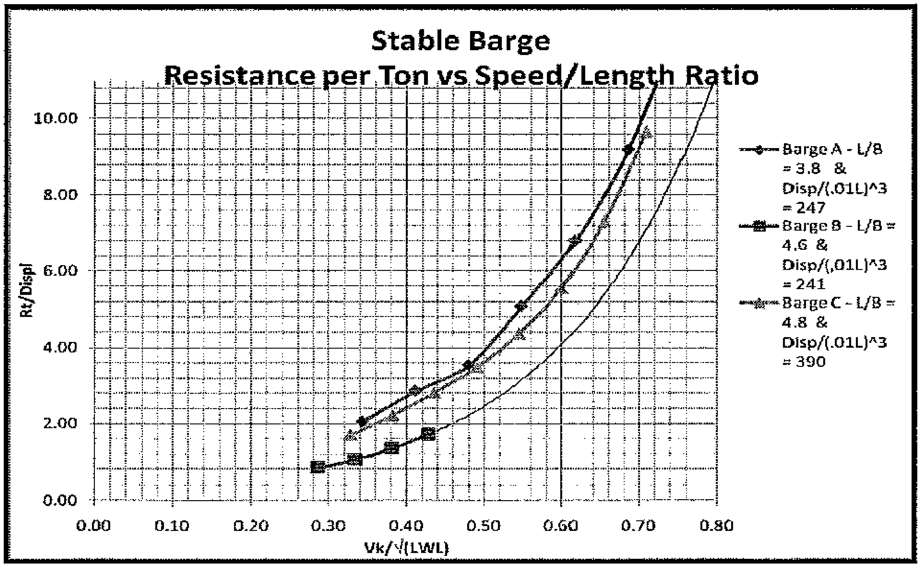


Figure 10 – Resistance Characteristics for Barges of Varying Proportions

The best (or depending on one's perspective, the worst) example of how regulations affect the towing industry is in the use of Articulated Tug-Barge (ATB) systems. There is no question that the use of a tug with multiple barges in a "swap and drop" type of shipping scenario can be a very economical and efficient way to move low value bulk cargoes [1]. However there is currently a proliferation of ATB systems, particularly in the US, which are engaged primarily in the oil cargo trade and which are used solely to take advantage of the differences in rules for manning of tugboats vs. those for "ships". Very seldom is the "drop and swap" scenario exercised; these tugs are generally dedicated to one barge. The ATB (Figure 11) carries the same volume of product, on the same voyages, as would a small tanker. However the rules for manning on tugs require only a crew of about five (5) persons to make these coastal voyages. A self-propelled ship (tanker) of the same capacity would require a crew of about 11 persons, hence the operating costs would be very much higher, but there is no rational reason whatsoever for the tanker to have a larger crew.

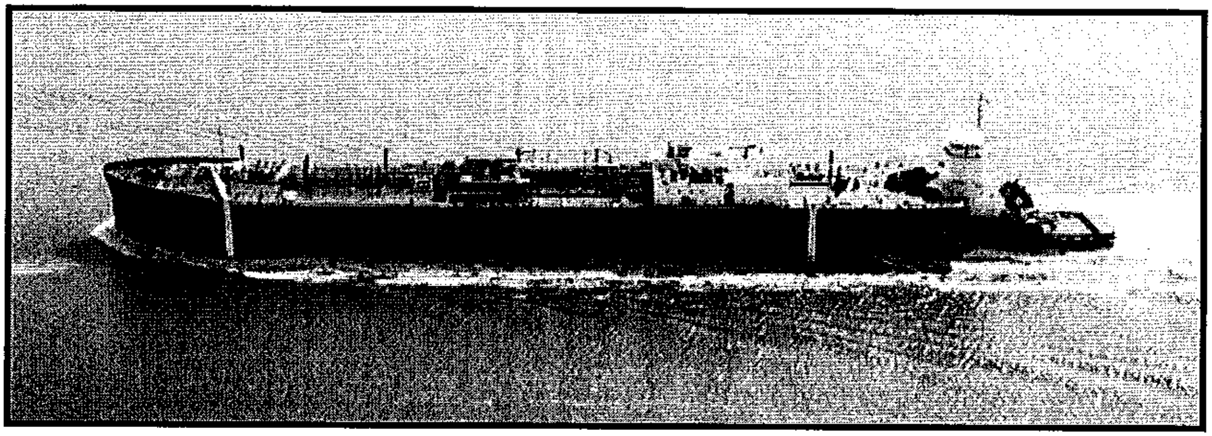


Figure 11 – Typical Articulated Tug-Barge Combination

The end result is that the ATB operates with an efficiency at least 15-20% lower than that of a proper monohull ship. The losses are associated with the turbulence in the notch interface between the tug and the barge, and in the lower propeller efficiency of the tug, due to the smaller propeller diameters possible on the latter. A simple change to the manning regulations to relate to the service and the voyage would eliminate this inequity and enable the far more efficient use of small tankers in this coastal trade, at a very significant cost and energy savings.

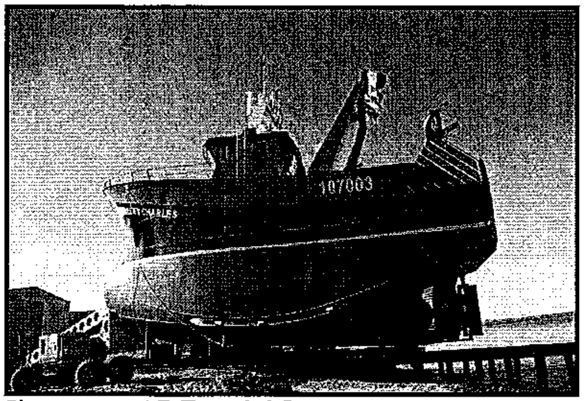
THE FISHING INDUSTRY:

This industry in Canada is perhaps the best (worst??) example of how regulations have made a complete mess of the efficiency of operations. In this country, fishing vessel regulations at many levels are tied simply to length, and not to the more obvious operational and economic criteria of fish-hold capacity.

Note the following:

- Small Fishing Vessel regulations apply to "...vessels from 0 to 150 Gross Tons, not exceeding 24.4 metres used in Commercial Fishing"• More onerous "Large" Fishing Vessel regulations apply to vessels over 24.4 metres, although these regulations are under revision and will be more uniform in their application than at present
- There is a major regulatory breakpoint for specific fishing vessel limits on the east coast, particularly in Newfoundland, at 20 metres (65 ft.) length. Similar regulations used to apply in local and Alaskan waters (there is a whole fleet of "Alaskan Limit" Seiners, at 58 feet length)
- A vessel license is tied to the length of the boat, and not to capacity, so when a new boat is built it cannot be any longer than the boat it is replacing (a truly ludicrous situation).

The consequence of this situation is that new boats entering the fishery are getting wider and higher, and generally less seaworthy. Figures 12 and 13 illustrate some recent examples of how box-like these vessels have become. Several vessels of this type have been involved in fatal accidents.



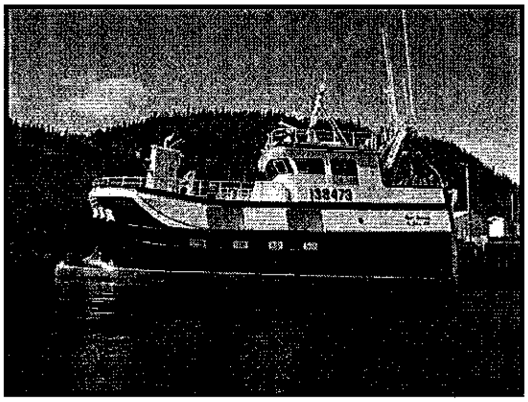


Photo courtesy A.F. Theriault & Sons

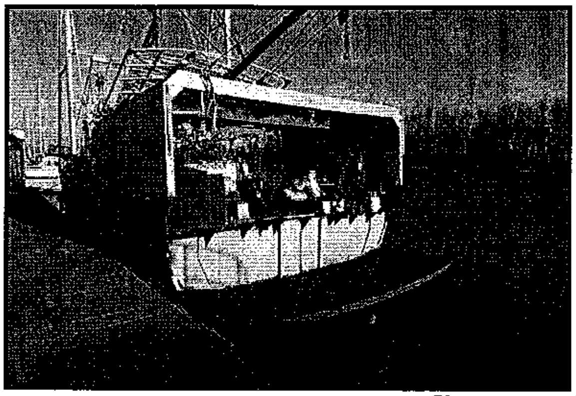
Figures 12 and 13 – "Small" Canadian Fishing Vessels built to Maximum Capacity but under 20 metre Length Limit

Under the present Canadian regulations, the vast majority of "small" fishing vessels are not even required to have basic stability data to verify if the vessels can safely carry their catch. This anomaly has resulted in many deaths in the industry over the past several years. Fortunately action is now slowly being taken to rectify this situation, but only because the industry itself and the actions of WorkSafe BC have forced this action. Why smaller vessels, generally more susceptible to the influence of wind and waves and more easily overloaded should have been exempt from these basic safety regulations is a mystery, undoubtedly rooted in some political decision not to "penalize" the smaller fisherman.

The need to stay under these artificial length restrictions has led some Owners to actually build fishing vessels with "bolt-on" bows or similar stern surgeries, as illustrated in Figures 14 and 15. This ridiculous practice, while probably not condoned by DFO, is actually recognized and implicitly accepted in the DFO regulations [2]; i.e.:

> *"Where bows are modified to include a forward bulkhead, airtight or not, this bow is to be included in the overall length. In order to be excluded from a vessel's overall length, bow modifications must meet the definition of a deck extension as defined above...."* (which goes on to define the allowable use of openings and gratings over normally closed structures)

The lengths to which people will go to circumvent the regulations are clearly indicated in the surgery being inflicted on the bow of the boat in Figure 15. Such actions really ought to be illegal!



Photos courtesy Alan Haig-Brown

Figure 14 – Stern Modifications to meet License Length Limits
Figure 15 – Bow Modifications to meet License Length Limits

Canada is regrettably not alone in such nonsense. One only has to look at some of the new fishing vessels being built in Scotland to recognize that there are also regulations afoot there to force the design and construction of monstrosities such as that illustrated in Figure 16. These regulations force designers and Owners into short, beamy, and often top-heavy boats, with attendant efficiency losses and safety risks.

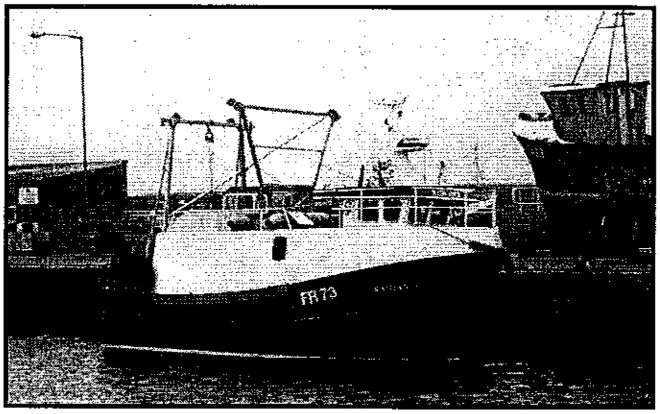


Figure 16 – Scottish Fishing Vessel built under Licensing Constraints
(*One assumes no-one would voluntarily build a boat this ugly!*)

A great deal of research [3] was performed in BC in the late "80's" and early "90's" related to improving the efficiency of "typical" west coast fishing vessel hull forms through the application of bulbous bows. Figures 3, 12 and 13 illustrate the types of appendages that were tested and built, and indeed many of these did improve the efficiency of the generally short and wide hulls to which they were fitted. But no one seemed to challenge the reasoning behind why these boats were so very boxy in shape to begin with! The money spent on designing these bulbs would have been far better spent simply analyzing the merits of "leaner" hull forms. Fisheries and Oceans Canada appear to have recognized this problem in a recent review of Fishing Vessel Safety [4], but have not acted on it; i.e.:

"Fishing Vessel Replacement Policy

The literature review ... and a number of the agencies identified ..., have drawn particular attention to the role of fisheries management in establishing fishing vessel size restrictions. ***The Fishing Vessel Replacement Policy has many in the industry holding the view that fishing vessels are fundamentally too small to travel long distances offshore and still maintain operational safety.*** *(my emphasis). Some of the problems highlighted are:*

- *Inadequate accommodation space for crew comfort and safety;*
- *Insufficient deck space for crew safety;*
- *Incapable of safely loading and transporting product from areas fished;*
- *Inadequate size to weather adverse sea conditions;*
- *Incapable of carrying bulk harvesting gear;*
- *Incapable of accommodating bulky stability technology; and*
- *Insufficient fuel capacities for long distance harvesting*

On the other hand, there is a recognized need to balance fleet capacity to the available resource. Larger vessels can and must fish more and would undoubtedly exert pressure for increased access to fish resources. Also, those who trade up to more mobile vessels would pressure for access to areas not previously fished by them and to the possible detriment to the viability of enterprises currently fishing those areas. As stated by the National Research Council Marine Board, "over-capitalization would lead to more marginal operators who find it economically difficult to adequately maintain and equip their vessels to improved safety in a hostile environment." Indeed, the SAR database identifies mechanical failure as the most common reason for increases in SAR incidents. Clearly, vessel size is not the sole determinant of fishing vessel safety. While elimination of vessel replacement guidelines and size restrictions would likely compromise vessel safety, flexibility in these guidelines may seek to address both the safety and overcapacity issues. Reviewing and accessing the vessel replacement guidelines will pose a great challenge for all stakeholders.

The claim above that larger vessels "*can and must fish more*" should be challenged: if "larger" means greater hold capacity, then there is some truth to the statement. However, if larger simply means longer for the same hold capacity, then the argument fails. The vessel would be more efficient, faster, safer, and less expensive to operate, and would not necessarily need to "fish more".

Finally, builders readily acknowledge that it is more difficult and more expensive to build these length-constrained designs than it is to build a larger and more spacious boat where there is reasonable room in which to fit all the equipment. There can actually be cost savings in building a larger hull. Certainly maintenance is easier, and crew comfort is enhanced, resulting in less crew fatigue.

Very clearly this is in an industry in need of a drastic overhaul of its Regulatory framework, in full recognition of the collective and conflicting impact of the myriad regulations to which it is subject.

MANNING REGULATIONS:

For most marine industries in Canada, regulations impacting on the number and qualifications of crew are related to either length, Gross Tonnage, or installed power. In reality however the skill sets required are much more related to the location of voyage and the type of service (barge towing, ship-handling, fishing, etc.) than they are to the size or power of the vessel. Some regulations, more logically, are also categorized by voyage limits. The following are but a few examples of some of these regulations which lack logic:

- Fishing Vessel needs an engineer if power > 750 kW
- Vessel Master certification break points at 15, 60, 100 and 300 GT

SUMMARY:

This paper illustrates, at a deliberately high level, that regulations can have serious and frequently deleterious consequences on energy efficiency if not thought through rationally. Even where there may have been historically good reason to impose a limit on vessel length or Gross Tonnage, when we all are challenged to look at ways and means to reduce our individual and collective carbon footprint, we cannot afford to simply continue to accept outdated regulations because they have some "inertia" in the regulatory system. The objective of this paper has not been simply to slang the Government (as tempting as that often is!), but to illustrate how with some care and foresight we can influence the overall energy consumption of marine transportation very significantly, simply through good design, and without requiring very complex or expensive technological solutions. Undoubtedly there are applications, and harbour towage is an excellent example, where the solution to lower emissions is driven by the need to tailor power available "on line" to the actual wide range of power demand, and hull size and form has very little influence. But anywhere cargo is being moved, hull form becomes a critically important consideration, and Rules and Regulations should NOT constrain the Naval Architect from developing the most efficient ship design possible.

The following are suggested as overriding guidelines in this regard:

- Regulations must focus on the safe performance of the type of service provided in the intended area of operation, and encourage efficient hull design, rather than setting artificial boundaries on vessel size
- No regulation should be based on vessel length as a cut-off criterion: length is the single most valuable parameter in terms of reducing energy consumption
- Crew licensing must also relate to the service and to the intended voyages, and not necessarily to vessel size or power
- Fishing Vessel licenses must be regulated by cargo capacity – nothing else

Owners and their consulting Naval Architects should be unfettered in their ability to develop the safest and most energy efficient designs possible in order to cope with the challenges facing the marine industry at every level. Artificial regulatory hurdles and barriers at arbitrary limits of length and size serve no useful purpose whatsoever towards this objective.

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