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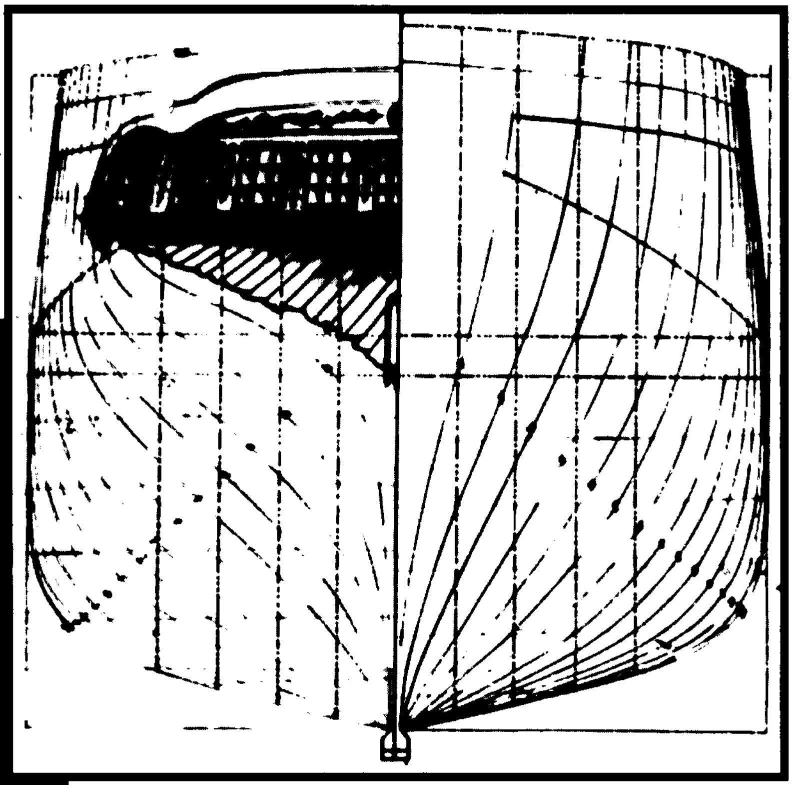

A HISTORY OF SHIPBUILDING AND NAVAL ARCHITECTURE IN CANADA

Garth Wilson

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Contents

Abstract

Ships and shipbuilding arrived in Canada along with the first Europeans and represented some of the most striking and sophisticated examples of western technology and culture. This study will examine the building and design of ships in Canada from the establishment of royal government in New France to the final decade of the twentieth century. Given the scope of this subject, what follows cannot hope, and is not intended, to be all-inclusive. Instead, this study is limited to the following objectives: to place Canadian shipbuilding and naval architecture within the broader western tradition from which they evolved; to explore the connection between science and shipbuilding; and, finally, to examine the historical context and consequences of the building and design of ships in Canada. In serving these objectives, this study focuses on large-scale shipbuilding, that is, the construction of large vessels used in important international trades or in support of significant national interests. However, the exclusion of small ship and boat construction should not be construed as a denial of the important, ubiquitous role of small craft and coastal vessels in Canadian maritime history. Rather, a more focused study of large vessel building simply offers the best and most coherent means of guaging the various social and economic implications of shipbuilding, and examining the relationship between science and the technology of ship construction.

Résumé

Les navires et la construction des navires ont fait leur apparition au Canada en même temps que les premiers Européens, figurant parmi les principales manifestations de la culture et de la technologie occidentales. La présente étude examine la construction et la conception des navires au Canada depuis l'établissement du gouvernement royal à Québec jusqu'à la dernière décennie du vingtième siècle. Puisqu'il s'agit d'un sujet très vaste, le présent ouvrage ne saurait être exhaustif. Il porte plutôt sur des objectifs précis : situer la construction des navires et l'architecture navale au Canada par rapport aux grandes traditions occidentales; explorer le lien entre la science et la construction des navires; enfin, examiner le contexte historique et les conséquences de la conception et de la construction des navires au Canada. Compte tenu de ces objectifs, la présente étude se penche sur la construction des navires à grande échelle, c'est-à-dire sur la construction des navires de fort tonnage destinés au grand commerce international ou à la défense d'intérêts nationaux importants. L'exclusion des petits bateaux et navires ne devrait pas être interprétée comme un reniement de l'importance et du rôle omniprésent des petits navires côtiers dans l'histoire maritime du Canada. Ce choix de la construction des navires de fort tonnage offre simplement la meilleure façon d'évaluer de façon cohérente les diverses répercussions sociales et économiques de la construction des navires et d'examiner le lien entre la science et la technologie en ce qui concerne la construction des navires.

Foreword

When Canada has been an important participant in maritime affairs, as in the nineteenth century and at times in the twentieth, the vessels used have overwhelmingly been Canadian-built. Yet if there is a neglected topic in Canadian maritime history it is shipbuilding. This makes Garth Wilson's *A History of Shipbuilding and Naval Architecture in Canada* especially significant. Its importance rests in its synthesis of a wide variety of sources. Before we can begin to fill the lacunae in our knowledge about shipbuilding, we need to understand the state of the art and the context in which relevant unanswered questions can be posed. Synthesis is an art, and Garth Wilson deserves our gratitude for doing it so well.

But this volume is only in part about shipbuilding. It also deals with an equally-neglected subject, naval architecture. In particular, it examines the way ideas are transported and the manner in which science has come to infuse the design of ships. These are important concepts, on the cutting edge of historical inquiry in the late-twentieth century. Garth Wilson covers these complex topics fully yet in a readable style that makes the book an enjoyable experience.

A History of Shipbuilding and Naval Architecture in Canada is a book that both the layperson and the specialist will find useful in their own ways. In summarizing the state of our knowledge it clears the decks for further research. In this sense it is far more important than its unprepossessing title might suggest.

Lewis R. Fischer
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Avant-propos

À l'époque où le Canada joua un rôle de premier plan dans le domaine maritime, comme ce fut le cas au dix-neuvième siècle et, pendant un certain temps, au vingtième siècle, la grande majorité des navires étaient construits au Canada. Or, s'il y a un aspect de l'histoire maritime canadienne qui a été fort négligé, c'est bien celui de la construction navale. C'est cette lacune qui rend le livre de Garth Wilson *A History of Shipbuilding and Naval Architecture in Canada* particulièrement intéressant. L'importance de cet ouvrage réside dans la synthèse que nous fait l'auteur de renseignements tirés d'une multitude de sources. Avant que nous puissions combler les lacunes dans notre connaissance de la construction navale, nous devons comprendre les technologies actuelles et le contexte dans lequel soulever les questions qui leur sont pertinentes. La synthèse est un art dans lequel Garth Wilson est passé maître et, à ce titre, il mérite notre admiration.

Mais la construction navale n'est qu'un des sujets abordés dans ce livre. L'auteur y traite également d'un autre sujet tout aussi méconnu, à savoir l'architecture navale. En particulier, il examine la concrétisation des idées et l'importance croissante accordée aux principes scientifiques dans la conception des navires. Il s'agit là d'importants concepts, dont l'étude représente le nec plus ultra en recherche historique au seuil du vingt-et-unième siècle. Garth Wilson explore ces sujets à fond, tout en utilisant un style clair et precis qui rend la lecture de ce livre très agréable.

A History of Shipbuilding and Naval Architecture in Canada est un livre qui plaira à la fois au profane et au spécialiste, pour des raisons différentes. En résumant l'état actuel de nos connaissances, nous ouvrons la voie à des recherches plus approfondies. En ce sens, l'utilité de cet ouvrage pourrait être de loin supérieure à ce que ne laisse supposer son modeste titre.

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Introduction

Canada is endowed with a great abundance of coastline, rivers and large, navigable lakes. It was by water that Europeans first came to North America and it was by water, guided by the indigenous people, that Europeans first explored the interior of the continent and later settled and exploited it. The most impressive and lasting legacy of this historical fact is reflected in the waterfront location of Canada's principal urban centres. Exploration, trade and settlement required vessels of various sizes, shapes and complexity. Initially, the largest of these were built in Europe and imported along with the crews that sailed them. Small craft, though sometimes imported, were usually built from scratch, blending old-world traditions and technology with indigenous ideas and materials. Transportation by water was the most efficient (and for almost two hundred years the fastest) means of moving people and goods. Thus, the construction and repair of water craft soon became a functional imperative for the new colonists, and expertise in this technology was appropriately valued. As political, economic and social conditions evolved, the practise of building and designing ships took root on our shores.

This study will examine the building and design of ships in Canada from the establishment of royal government in New France to the final decade of the twentieth century. Given the scope of this subject, what follows cannot hope, and is not intended, to be all-inclusive. Instead, this study is limited to the following objectives: to place Canadian shipbuilding and naval architecture within the broader western tradition from which they evolved; to explore the connection between science and shipbuilding; and, finally, to examine the historical context and consequences of the building and design of ships in Canada. In serving these objectives, this study will focus on large-scale shipbuilding, that is, the construction of large vessels used in important international trades or in support of significant national interests.[1] However, the exclusion of small ship and boat construction should not be construed as a denial of the important, ubiquitous role of small craft and coastal vessels in Canadian maritime history. Rather, a more focused study of large vessel building simply offers the best and most coherent means of guaging the various social and economic implications of shipbuilding, and examining the relationship between science and the technology of ship construction.

1. The distinction made here follows the reasoning presented in a formative study of nineteenth-century shipbuilding in Canada: Richard Rice, "Shipbuilding in British America, 1787–1890," (University of Liverpool, unpublished Ph.D. dissertation, 1977), pp. 4–6.

Ships and shipbuilding arrived in Canada along with the first Europeans and represented some of the most striking and sophisticated examples of western technology and culture. The newcomers used imported tools, followed imported techniques and, more to the point, embraced an imported perception of the world. By the end of the seventeenth century, this perception had been largely reoriented toward the peculiar, analytical, atomizing mentality known as "the scientific view."[2] This is not to suggest, however, that shipbuilding in the seventeenth century was even remotely scientific. At that time, shipbuilding was more heavily informed by centuries of inherited practice than by abstract theory or mathematical analysis. It was at best a blend of art (or more precisely, craft) and some very rudimentary geometry. Today, that blend of art and science survives, though with a distinct emphasis on science. Indeed, the employment of science as an analytical tool in the design and building of ships led ultimately to the modern discipline of naval architecture.[3]

This raises an important distinction applied in the present work to shipbuilding and naval architecture. Shipbuilding is here understood primarily to concern the materials, tools and techniques employed in the construction of ships. Naval architecture, on the other hand, refers to the theory and science applied to ship design. In attempting to relate practice to theory, it is essential that to explore the technology and the science of the subject. In contemporary terms, this technology involves the "application as well as the knowledge of the technique and the tool,"[4] and science "the endeavour to include all (relevant) natural phenomena within a pattern."[5] A further distinction, this time between naval architecture — the design of the ship as a complete entity — and marine

2. W.J. Eccles, *Canadian Society During the French Regime* (Montreal: Harvest House, 1968), pp. 54–55. The point is also made, more generally but with broader cultural implications by Northrop Frye. See Northrop Frye, *Divisions on a Ground: Essays in Canadian Culture* (Toronto: Anansi, 1982), pp. 168–170.
3. In his book, *Engineering and the Mind's Eye* (Cambridge, Mass: MIT Press, 1992), Eugene S. Ferguson makes a compelling argument for the recognition and appreciation of the "art" inherent in engineering design.
4. John W. Abrams, "Technology in Perspective," *Basic Issues in the Philosophy of Science* (New York: Science History Publications, 1976), p. 201.
5. *Ibid.*, p. 199, (parentheses mine). For a concise summary of how the term "science" has evolved in English usage, see Edwin T. Layton Jr., "American Ideologies of Science and Engineering," *Technology and Culture*, vol. 17, no. 4 (October, 1976), p. 689.

engineering — the design and installation of a ship's machinery — will also be observed.[6]

The present narrative commences in the late seventeenth century and traces the gradual rise and evolution of science as applied to the construction of ships. In this respect, the Canadian story largely echoes, though sometimes faintly, the practices and trends initiated abroad. Yet, the effort to relate the evolution of science in ship design to the history of shipbuilding in Canada sets this account apart from other works on the subject. Another distinguishing feature of this work is the structural requirement that it serve as an historical assessment for the purposes of collection development at the National Museum of Science and Technology. As a result, this study must explore the following prescribed sub-themes: "Canadian Context," "Finding New Ways," "How Things Work" and, finally, "People, Science and Technology."[7]

Organized chronologically into three chapters, this study begins with an examination of shipbuilding in New France, a period covering roughly one hundred years characterized by ship construction largely directed and supported by the state. The second chapter will address the nineteenth century, a "golden age" when shipbuilding briefly constituted a prominent economic activity. The third chapter will review the twentieth century, an era marked by the building of a national merchant fleet in steel, a dramatic expansion of production fostered by the demands of World War II, and the industry's decline in recent times. Each chapter addresses the following subjects, under separate headings: the historical background in overview ("Canadian Context"); the broad economic, social and political implications of shipbuilding ("People, Science and Technology"); and, finally, the salient features of ship construction and design with emphasis on the extent to which science, contextually defined, actively informed these processes ("How Things Work" and "Finding New Ways").

Aside from its chronological convenience, this division of chapters also reflects, by and large, the boundaries observed by existing scholarship in the field. Another of its advantages is to invite the application of a thematic structure in which shipbuilding under the French regime can be viewed as a craft-cum-state enterprise, nineteenth-century construction as a manufactory, and twentieth century-production as a full-fledged industry. Admittedly, this approach, derived from Marxist historiography, is flawed by a tendency to simplification. However, considering that this effort is intended as a survey, it may be well-served by such a socio-economic construct. For the most part, this study will also draw heavily on the corpus of secondary sources, using primary material in a mostly illustrative manner. The intention here is not to add to or revise areas already the subject of attention by specialists, but rather to synthesize so as — to borrow the words of one historian — "to adjudicate the extant body of research and to bring its disparate and dispersed elements into fruitful juxtaposition."[8] Where this effort deviates from the established realm, and where it hopes to make some small, original contribution, is in its attempt to relate the history of shipbuilding in Canada to the history of science.

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6. Harry Benford and J.C. Mathes, *Your Future in Naval Architecture* (New York: Richards Rosen Press, 1968), pp. 19–20.
7. With respect to "Canadian Context," references to Canada and the special circumstances of Canadian history will pervade the study. One defining element of this work is its primary concern with a particular, historically defined geo-political construct: a place called Canada upon which various political arrangements have been imposed and within which various social and economic relations have developed. Regarding the theme of "Finding New Ways," it should be conceded from the outset that shipbuilding and naval architecture in Canada have been primarily imported and adaptive (though nonetheless important) activities. Innovation, in so far as it has occurred, has usually arisen within areas of strictly limited influence. Still, as dialect is to language, it is often these small variations which provide the defining element while adaptation itself may sometimes be called a "New Way." However, in those cases where significant Canadian innovation is identified, it will be given all due attention. "How things Work," will find expression in both the practical and theoretical aspects of this subject. The focus here is on what is essentially a type of complex machine, the ship, which, while always retaining certain basic characteristics, has had many applications and has been subject to substantial conceptual and structural changes. Last, but not least, the theme "People, Science and Technology" requires that the technological and scientific legacy of ship construction be appropriately integrated with the history of Canadian society. Shipbuilding often involves large numbers of people as well as substantial material, financial and intellectual resources, all of which are subject to various degrees of political direction or intervention. In this respect, it is impossible to appreciate the importance of this topic without recognizing its broader, social, economic and political implications. In the absence of such recognition, the history of shipbuilding becomes little more than a register of people, places and ships.
8. Dale Miquelon, *New France 1701–1744*, **The Canadian Centenary Series**, no. 4. (Toronto: McClelland and Stewart, 1987), p. xiii.

Chapter 1

Shipbuilding in New France: An Overview

While French settlement in North America dates to the first decade of the seventeenth century, the history of shipbuilding in New France really began with the imposition of royal government in 1663. This new regime was a response to disappointment with the fur trade monopoly charter, and a reflection of the mercantile policies the government of Louis XIV.[9] In France, the most ardent advocate of these policies was Jean Baptiste Colbert. In matters maritime, Colbert's inspiration derived from a studied understanding of the most economically successful colonial powers of his time, England and the Dutch Republic, and from the well-known historical precedents of Spain, Portugal and Venice.[10] The power of these states had been firmly based on maritime enterprise, and each had fostered a substantial merchant fleet sustained by a notable shipbuilding capacity. Likewise, ships were an essential element in Colbert's plan to increase French control of global resources and markets.

The potential of the timber-rich colony of New France as shipbuilding centre had been identified as early as 1630 by Samuel de Champlain, though shipbuilding before 1663 was little more than an incidental activity.[11] Prior to the establishment of royal government in the colony, boats and small ships had been built or assembled to serve the basic transportation needs of the fur trade and of the few colonists who had settled there. This construction was restricted to vessels required for river and coastal traffic, and figured primarily as an extension of indigenous maritime trade and transportation.[12] Under the new colonial regime, the policy was to make shipbuilding a serious, independent concern in New France. Rather than a mere response to necessity, shipbuilding would contribute to the growth and diversification of the colonial economy. The ultimate goal was to develop a capacity to build ocean-going ships, and such large-scale construction is precisely the focus of the present study. Shipbuilding of this magnitude served the French Crown's objectives as a productive enterprise in its own right, as a logical means of capitalizing on the colony's rich timber resources and as an instrument in the export of locally-produced goods. Thus, in his *mémoire* of March 1665 to Jean Talon, the first Intendent of New France, Louis XIV wrote:

> *Par tous les rapports qui ont esté faits du Canada, il est constant qu'il s'y trouve une très grande quantité de bois propre à toute sorte d'usages, et mesme à la construction de toutes les parties d'un vaisseau, et qu'il y a des arbres de la grosseur et de la hauteur nécessaires pour master. Et comme c'est un trésor qu'il faut soigneusement conserver pour avec le temps dresser quelques ateliers pour y bastir des navires pour le Roy, il sera bon, lorsqu'il se deffrichera quelque terre, d'empescher l'abbattis du bois qui sera de la plus belle venue, et que l'on pourra employer à l'effet susd. Cependant led Sr. Talon rendra un service au Roy qui luy sera bien agréable, et contribuera en mesme temps à l'establissement du commerce dans la colonie, s'il peut disposer les habitans les plus accommodez à entreprendre quel-ques bastimens pour eux; à quoy mesme ils trouveront d'autant plus de facilité, si l'on vient à ouvrir les mines de cuivre, de plomb et de fer, que l'on a vérifié estre très abondantes par les divers essais qui ont esté faits.*[13]

This view of shipbuilding as a potentially valuable economic stimulus — as well as a means of keeping specie within the developing merchantilist system —

9. The concept of mercantilism, particularly as applied to France and New France in the seventeenth and eighteenth centuries is highly problematic. For an examination of this term and its usefulness, see J.F. Bosher, "What was mercantilism in the age of New France?" *Festschrift for J.-C. Dubé...* (Ottawa, forthcoming), pp. 423-4. For a broader context for this discussion, see D.C. Colman, *Revisions in Mercantilism* (London: Methuen & Co., 1969).
10. Etienne Taillemitte, "Colbert et la marine," *Un nouveau Colbert* (Paris: Sedes, 1985), p. 217. M. Taillemitte makes reference to Colbert's "Mémoire sur le commerce: premier conseil de commerce tenu par le roy, dimanche 3 aoust 1664,". See Pierre Clément, ed., *Lettres, instructions et mémoires de Colbert* (Paris: 1861-1882), II, pt. 1, pp. CCLXIII-CCLXXI.
11. Eugene Rouillard, "Les origines de la construction des navires au Canada," *Recherches Historiques*, vol. 43 (1937), p. 133.
12. James S. Pritchard, "Ships, Men and Commerce: A Study of Maritime Activity in New France," (University of Toronto, unpublished Ph.D. dissertation, 1971), pp. 7-9. Réal Brisson, *Les 100 premières années de la charpenterie navale à Québec: 1663-1763* (Québec: Institut québecois de recherche sur la culture, 1983), pp. 24-25. For a study of an important indigenous maritime culture, see Charles A. Martijn ed., *Les Micmacs et la mer* (Montréal: Recherches amérindiennes au Québec, 1986).
13. *Rapport de l'archiviste de la province de Québec*, (1930-1931), p. 19.

echoed Colbert's aspirations for the mother country. His interest in maritime affairs began when he assumed office in 1661. In 1663, while the new administration was being established in Québec, Colbert firmly expressed to the King his concern regarding the very poor state of France's fleet.[14] However, it was not until he was appointed Minister of Marine in 1669 that his influence became absolute. Colbert's naval policy was as impressive as it was multifaceted. It involved the development and organization of infrastructure, such as bases and dockyards; successful control and management of materials and provisions for the fleet; a census of available manpower and, last but not least, a vigorous and intense program of ship construction.[15] Such was Colbert's ultimate success that by 1688 the French navy had grown to the point where it was larger than that of England and the United Provinces combined.[16] This extraordinary effort in building the French fleet and developing the nation's shipbuilding capacity had an overtly military impact, through the expansion of the navy, as well as an economic impact "*car le mouvement entraînerait la création de manufactures, de voies de communication et contribuerait ainsi à vivifier certaines régions encore peu industrialisées.*"[17] It was the pursuit of just such a favourable conjunction of military and economic benefits that inspired the establishment of a dockyard in New France.

Nevertheless, the expansion of French maritime influence faced serious international competition. In the 1660s, European shipping and shipbuilding were dominated by the merchants of the United Provinces. Not only were the Dutch Europe's preeminent shipbuilders for much of the seventeenth century, but they also controlled the Baltic trade in the essential raw materials of ship construction: wood, pitch and tar. Indeed, Dutch dominance in international trade extended even to the French West Indies which relied on Dutch merchants for most of their supplies (a market Colbert and Talon hoped to secure for New France). In light of these circumstances, the rapid expansion of French naval power and overseas trade required massive state subsidy and investment. And while this was true for France proper, for the new administration in Québec, the challenge was further complicated by a myriad of other factors: the distracting appeal of the fur trade, the chronic shortage and high cost of skilled labour and vital materials, a serious lack of basic infrastructure, and the limited navigation season on the St. Lawrence.

In spite of these many obstacles, Jean Talon's early efforts to foster shipbuilding in New France bore some, albeit meagre, fruit. Skilled labour was essential to the project and metropolitan shipwrights were therefore granted contracts, renewed on lucrative terms, to come and work in the colony. The first four of these craftsmen were sent in 1663, ahead of Talon himself, to oversee the building of numerous small vessels then urgently required for the war against the Iroquois.[18] Soon after the Intendant's arrival, a shipyard was established on the south arm of the St. Charles River, close to the Hôtel Dieu. In addition to the few ships and various smaller vessels assembled or repaired there, the new yard served as a training ground for the first generation of *Canadien* shipwrights. Their apprenticeship was to last a period of four years, after which time it was hoped that these new colonial craftsmen would sustain and promote their trade and, in turn, disseminate their skills.[19] At the same time, Talon actively promoted various ancillary activities, notably the cutting of timber, the cultivation of hemp, the production of tar and the mining of iron — products that were also valued for their export potential.

The first ship built at the new yard in Québec was a 120-ton vessel ordered in 1666 by Talon himself, acting as a private businessman. The Intendent was evidently hoping to profit from the establishment of a colonial carrying trade, with the immediate objective of conveying food stuffs to the French West Indies. While some of Talon's entrepreneurial activity did provoke complaints, such investment on the part of a government official was not then perceived as an open conflict of interest; though it does, perhaps, demonstrate Talon's faith in the enterprise. In 1667 Talon also ordered the construction of a barque, *La Sainte Barbe*, this time on behalf of the Crown. This ship, however, was not intended for ocean service. One year later another 120-ton vessel was built for the merchant Charles Aubert de la Chesnaye. Apparently satisfied, Chesnaye ordered a 300-ton ship from the yard in 1668/69, the aptly named *L'Espérance de Québec*.[20] Though these four vessels and various small craft represent the sum of the shipyard's output during Talon's first term, Colbert was sufficiently impressed, or at least encouraged, to continue the support for shipbuilding and related activities in New France. Thus, when Talon returned to the colony in 1670, he was able to bring with him another six shipwrights under royal contract and later sought, unsuccessfully, to enlist a further twelve. Then, in 1671,

14. Clément, ed., *Lettres, instructions...* (Paris: 1861-1882), II, pt. 1, pp. 50-51.
15. Geoffrey Symcox, "The Navy of Louis XIV," *The Reign of Louis XIV: Essays in Celebration of Andrew Losskey* (London: Humanities Press International 1990), pp. 131-135.
16. *Ibid.*, p. 138. Taillemitte, "Colbert et la marine", pp. 218-219.
17. *Ibid.*, p. 225.
18. Brisson, *Les 100 premières années*, p. 25.
19. *Ibid.*, pp. 21-30.
20. *Ibid.*, p. 26. Brisson provides a very useful complete inventory of ships built in New France of all sizes as well as an inventory of repairs: pp. 216-243, 261-267. See also, Rouillard, "Les origines de la construction des navires," pp. 133-135, and Pierre-Georges Roy, "Le premier navire construit a Québec," *Bulletin des recherches historiques*, vol. 2 (1896), p. 312.

Talon received a grant from the crown of 40 000 *livres* specifically to finance ship construction. He also gained indirect support in the form of 10 000 *livres* to promote the mining of iron (metal fastenings and components were an expensive, requisite import for the shipyard), as well as 600 *livres* in support of tar production.[21] Talon's final term as Intendant ended in 1672, and in that same year his efforts to encourage the construction of oceangoing ships culminated in the launching of a royal "galoitte" of 450 tons.[22]

The construction of a 450-ton ship in what was then a small town perched on the edge of the European orbit is certainly a remarkable achievement. Yet judged against France's mercantile objectives, Talon's shipbuilding program was at best a partial success. A capacity for large-scale ship construction had been established and the first generation of Canadian shipwrights had been trained. However, what work they found after Talon's departure was confined to repairs or building smaller vessels — bateaux, barques and chaloupes — required for service within the colony.[23] Such small-scale construction undoubtedly constituted an important aspect of the economy of the small but growing colony, and the failure of Talon's program substantially to satisfy the larger policy objectives should not detract from this contribution. Yet, as part of the expansion of France's commercial network, Québec-built hulls made only the most nominal contribution.

Following Talon's final departure, large-scale shipbuilding in New France effectively ceased for the remainder of the seventeenth century. Against a backdrop of continuous European colonial rivalry and warfare, the energy and resources of the French colonial administration concentrated on western expansion, and the specific objective of dominating the fur trade. Nevertheless, one notable event in the annals of Canadian shipbuilding did occur during this period: the construction of the first merchantman on the Great Lakes in 1679. The ship, named the *Griffon*, was a galliot, after the Dutch fashion, and was estimated to have been about 65 feet in length.[24] The famous Robert Cavelier, Sieur de la Salle, ordered its construction with the intention of facilitating the transportation of furs from the Western frontier to the St. Lawrence. Though its career was short-lived, the *Griffon* inaugurated shipbuilding on the Great Lakes and thereby established what would later become a unique shipping tradition.

The construction of oceangoing ships in New France only resumed at the end of the first decade of the eighteenth century. Ironically, the incentive for this revival arose from the serious economic isolation which afflicted the colony following the outbreak of the War of the Spanish Succession (Queen Anne's War) in 1702.[25] In the course of this conflict, which once again saw France and England at war, the military and financial resources of the French Crown were very seriously strained. Shipping between France and New France was reduced by almost fifty percent.[26] Yet out of these difficult circumstances, privateering and intercolonial trade — more specifically the provisioning of Placentia and the French West Indies — emerged as profitable, though risky, opportunities. Thus, large-scale shipbuilding in Québec began anew, albeit gradually and not without some serious difficulties.[27] Construction during this period was dominated by the initiative and investments of a single Québec merchant and Captain of the Port of Québec, M. Louis Prat. In 1704 M. Prat ordered a fifty ton brigantine, *Le Joybert*; in 1709 he had the 130 ton frigate, *Le Pontchartrain*, built; then, in 1710, another brigantine of ninety tons was commissioned; and, finally, Prat, in partnership with two other merchants, had the 350 ton frigate *St-Jérome* built in 1712.[28]

Although the War of the Spanish Succession concluded with Acadia, Newfoundland and the Hudson Bay ceded to the English under the terms of the Treaty of Utrecht (1713), shipbuilding continued in the various private yards around Québec. In the ensuing peace, agricultural production recovered and, following the example set by Prat and his partners, interest in the provisioning trade grew. Between 1714 and 1717 no less than nine vessels of 100 tons or more were built. Then, in 1719, the French government's decision to build the fortified port-city of Louisburg on Ile Royale (Cape Breton Island) provided what was to

21. W.J. Eccles, *Canada Under Louis XIV 1663-1701* (Toronto: McClelland and Stewart, 1964), p. 52.
22. Deep sea merchant vessels averaged about 200 tons by the end of the seventeenth century, with the largest being between 500 and 700 tons. G.P.B. Naish, "Ships and Shipbuilding," *A History of Technology*, vol. III (London: Oxford University Press, 1957), p. 496. With respect to tonnage measurement during the French regime, the French "ton (*tonneau*) was equivalent to 2 000 *livres* or 956 kgs." Blaise Ollivier, *18th Century Shipbuilding: Remarks on the Navies of the English and the Dutch from Observations made at their Dockyards in 1737*, David H. Roberts, ed. and trans. (Rotherfield: Jean Boudriot Publications, 1992), p. 4. Calculation of tonnage is a vexing issue in maritime history. In 1737, the French master shipwright Blaise Ollivier registered these observations as part of his study of English shipbuilding practices: "Very few English shipwrights calculate the tonnage of a ship from its displacement, as do all our shipwrights today in France." Ollivier, *18th Century Shipbuilding*, p. 169.
23. Brisson, *Les 100 premières années*, pp. 30-31.
24. C.H.J. Snider, *Tarry Breeks and Velvet Garters* (Toronto: Ryerson Press, 1958), p. 14. A first-hand account of the building of the *Griffon* can be found in: Father Louis Hennepin, *A New Discovery of a Vast Country in America*, 2 vols. (London: M. Bentley, J. Tonson, H. Bontwick, T. Goodwin & Son. Manship, 1698.) Reprint: R.G. Thwaites, ed. (Chicago: A.C. McClurg & Co., 1903); George R. Fox, "Was This La Salles's Griffin (sic)," *The Beaver* (Winter, 1955-6), pp. 37-41.
25. For a thorough analysis of the economic impact of this war on New France, see Pritchard, "Ships, Men and Commerce," pp. 252-304.
26. Miquelon, *New France*, p. 72.
27. Pritchard, "Ships Men and Commerce," pp. 281-283.
28. Brisson, *Les 100 premières années*, pp. 224-225.

become the single most important market for Québec merchants interested in the inter-colonial trade. In the thirty years following Utrecht, the merchants of New France enjoyed unprecedented success carrying food stuffs, especially wheat, and lumber to the Gulf of St. Lawrence, the Caribbean and even, on occasion, over to France itself. Nevertheless, this trade remained fragile, subject as it was to the vicissitudes of fluctuating harvests, a limited navigation season, obstructive regulations, and competition from metropolitan and New England merchants.[29]

With the appointment of Gilles Hocquart as Intendent in 1731, shipbuilding in New France gained its most committed and experienced advocate. Prior to his posting in Canada, Hocquart had worked for fifteen years as a commissary at the ports of Toulon and Rochefort, where he gained a wide range of experience in the operation and administration of naval dockyards. Recognizing the fledgling industry's need for further government aid, Intendent Hocquart obtained and administered a royal bounty on ship construction in New France. In effect from 1732 to 1739, the bounty provided a subsidy of 2.5 percent of the cost of any ship built in Québec.[30] Intended to offset the higher costs of labour and imported materials, the bounty reflected the hope that large-scale shipbuilding would serve as an effective catalyst for the further development of commerce and colonial trade.[31] Ultimately, however, the viability of merchant shipbuilding on private accounts in New France was dependant upon the availability of exports and markets, and while there was some notable improvement during Hocquart's tenure, many problems remained.

In terms of tonnage, scale and sophistication, the most important and impressive period of shipbuilding in Québec began in 1739 with the rebirth of the Royal Dockyard. This revival resulted from a combination of factors: the effective advocacy of Intendent Hocquart, a resurgence of mercantilist policies on the part of the Crown, the further development of important secondary industries, such as Les Forges du Saint-Maurice, and, not least, France's continued need for ships, particularly with the prospect of war once again looming on the horizon.[32] To oversee the new yard on the St. Charles River, the Crown enlisted the services of René Nicolas Levasseur, a very able 33-year old *sous-constructeur* from a distinguished family of French shipwrights and engineers.[33] Under Levasseur's supervision, and with state support still forthcoming, the reborn Royal Dockyard became an enterprise of the first order, organized according to the metropolitan model. The basic infrastructure and supply of materials were expanded and a work force assembled.[34] While this new facility was from the outset intended primarily to produce ships for the French navy, it too was conceived in — or at least partially justified by — the hope that it might also serve as a nursery for skilled labour — ever in short supply — and as a stimulant to colonial industry.

The immediate result, however, was rather different. As the new dockyard geared up it began draining private yards of workmen and essential materials. Conscious of this trend, Hocquart undertook remedial measures, including maintaining a wage differential in favour of the private yards and occasionally requisitioning labour from the Royal Dockyard to work on private projects.[35] In the five years between the revival of the dockyard and the outbreak of King George's War in 1744, conditions for shipbuilding in New France remained favourable enough that no less than twelve vessels of more than eighty tons were built in private yards, several of which were for metropolitan merchants. In 1742 Levasseur launched his first ship: a large merchantman (flute) of 500 tons called the *Canada*.[36] By this time the approach of war in Europe had intensified the King's need for warships. To this end, the old launching ways of the yard on the St. Charles River were found wanting. Thus, in 1746, in a atmosphere of growing urgency and at a cost of some 165 000 *livres*, a second Royal Dockyard was opened along the St. Lawrence River in front of rue Champlain, at a spot called the Cul-de-Sac.[37] This expansion of capacity, though in appearance a vote of confidence, actually eroded private, large-scale ship construction in the colony. Skilled tradesmen and scarce supplies of materials were now concentrated to meet the imperative of building large and complex fighting ships. Once more, the compelling logic of the colony's "military ethos" reigned supreme and the economy reverted unequivocally to a command structure.[38]

From 1746 until the fall of Québec, shipbuilding in the colony was almost exclusively state-sponsored naval construction. Among the ships launched were: a 700-ton flute, various corvettes and frigates carrying

29. Pritchard, "Ships, Men and Commerce," pp. 344-386.
30. Miquelon, *New France*, p. 212.
31. In view of what is known about the true differentials in cost, this modest subsidy was unlikely to make much of a difference. See Alice Jean Lunn, *Dévelopement économique de la nouvelle France 1713-1760* (Montréal: Les Presses de l'Université de Montréal, 1986), p. 164, footnote 25.
32. Jacques Mathieu, *La construction navale royale à Québec 1739-1759* (Québec: La société historique de Québec, 1971), pp. 9-13.
33. *Ibid.*, pp. 13-14.
34. *Ibid.*
35. Donald J. Horton, "Gilles Hocquart, Intendant of New France 1729-1748," (McGill University, unpublished Ph.D. dissertation, 1974), pp. 210-211; Mathieu, *La construction navale royale à Québec*, pp. 78-79.
36. Brisson, *Les 100 premières années*, p. 238.
37. Horton, "Gilles Hocquart," p. 211; and Lunn, *Dévelopement économique*, p. 173.
38. W.J. Eccles, "The Social, Economic and Political Significance of the Military Establishment in New France," *Essays on New France* (Toronto: Oxford University Press, 1987), pp. 110. Miquelon, *New France*, p. 219.

between ten and thirty guns, two sixty-gun ships and one seventy-two-gun ship of 800 tons, the largest vessel launched in Canada during the French regime.[39] Under the circumstances, this was indeed a remarkable effort. Nevertheless, problems with the procurement of quality wood, along with the increasing pressures and demands of the Seven Years' War (1756–1763) eventually undermined this last, most dramatic episode of shipbuilding in New France.[40] Hence, when the city and its dockyards fell to the invading British forces in 1759, there remained on the stocks of the Cul-de-Sac yard the unfinished hull of the frigate *Québec*; a fitting symbol of both a colony and a colonial enterprise whose development had been too often plagued by war.

Shipbuilding and Society in New France:

In 1672, at the end of Talon's final term as Intendent, the entire colony of New France had a population of little more than 6 000 permanent inhabitants. Nevertheless, in the government shipyard at Québec, then a town of less than 1 000 people, a vessel of 450 tons, large even by metropolitan standards, was under construction. Though this achievement might well have been viewed in official circles as a symbol of hope and an indication of the seriousness of the Crown's commitment to the colony, to others it must also have appeared as something of an aberration; and, in truth, it was more the latter than the former. The shipyard had been established by Talon as a direct extension of Colbert's project to extend France's maritime power and ultimately bolster its political and commercial might. Yet, whereas in France there was sufficient skilled labour, capital and material resources for Colbert's efforts to gain real momentum, in New France these elements were either lacking or non-existent. Wood was usually available in good quantity, if not always in sufficient quality, but everything else, including labour, had to be purchased at a very high price which consistently offset any comparative advantage that easy access to timber might have bestowed. In spite of continued population growth and gradual economic diversification, the building of large ships in New France remained encumbered by these circumstances. This was true even during the 1730s, the heyday of shipbuilding and export commerce in the colony. A comparison of the costs involved in building a "flute" (a type of merchant ship of Dutch origin), in Rochefort and Québec in 1732, shows that the metropolitan-built vessel cost 9 282 *livres* less, or 61 196 compared to 70 478 *livres*. These savings were found entirely in labour costs.[41]

While the initial establishment of the dockyard under Talon can be explained as a product of a particular approach to political economy, the recurrent appeal of the idea in official circles after 1672 is more difficult to understand.[42] One possible explanation was the persistent need for French administrators to find ways to fuel economic growth in the colony. On the face of it, shipbuilding was a multifaceted, labour-intensive enterprise which produced something of value for both the commercial and military sectors of the state. By advocating further government support for large-ship construction, colonial officials could appeal to the King's desire for both wealth and power when seeking an increase in royal grants to the colony. The same arguments might, of course, also serve more selfish and corrupt motives. Another interpretation might cite the constant insecurity of the French Government regarding timber resources for naval shipbuilding.[43] In this context, New France was repeatedly identified as a source of unrealized potential. Here, too, there was ultimate disappointment, although the combination of timber, tarriff and shipbuilding was, in the nineteenth century, to prove particularly dynamic. Indeed, the linkages associated with the staple approach at least suggest that the French Crown's aspirations were not without validity.[44] Be that as it may, large-scale shipbuilding in New France was ultimately the product of circumstances and government policies driven more by military concerns than by commercial considerations.

Shipbuilding on a more modest level was another matter. Given the pattern of trade and settlement in New France, the need for small ships and boats was a constant feature of the colony. Such construction existed before Talon, and Talon's support of shipbuilding and the resulting apprenticeship of Canadian shipwrights in the government shipyard, no doubt contributed to the ability of the colony to provide for these growing local needs. As an engine of economic growth, however, large-scale shipbuilding was much less viable in New France. Ironically, the most notable phase in private large-ship construction in New France began in a context of economic isolation and upheaval during the war of the Spanish Succession. With established trading patterns and traditional profits seriously weakened, colonial-based shipping and privateering took on greater appeal. In the thirty years of peace that followed the Treaty of Utrecht, shipbuilding in New France slowly developed in conjunction with a nascent, fragile export trade in food stuffs and timber. In 1732, shipbuilding received a

39. The exact chronology of construction varies among the secondary sources. See Brisson, *Les 100 premières années*, pp. 239-243; and Miquelon, *New France*, p. 218.
40. Lunn, *Dévelopement économique*, pp. 169–176.
41. Lunn, *Dévelopement économique*, p. 164, footnote 25.
42. Joseph-Noel Fauteux, *Essai sur L'Industrie au Canada*, vol. 1 (Québec: A. Proulx, 1927), pp. 238–241.
43. Bamford, *Forests and French Sea Power*, 1600–1789 (Toronto: University of Toronto Press, 1956), pp. 10–29.
44. See Chapter Two.

further government boost in the form of new Crown subsidies administered by an Intendent, Gilles Hocquart, who was very familiar with the particular dynamics of government-run maritime enterprise. Encouraged by this growth in ship construction and driven by a renewed commercial and military rivalry in Europe, the French Government thus elected to re-establish the Québec shipyard in 1739. By this same action, however, the tenuous vitality of large-scale private shipbuilding was eventually undermined. When war came a few years later, private construction was among the first casualties, as available resources were concentrated in the enormous effort required to build large warships.

While it is arguable that, even without the restablishment of the Royal Dockyard in 1739, the onset of war would ultimately have undermined private shipbuilding, the irony remains. This irony also serves to reinforce the impression that large-scale shipbuilding in New France was a rather tenuous enterprise overly dependent on direct state subsidy. Viewed from this perspective, the Royal Dockyards established at Québec in the 1740s should really be seen as further extensions of the mercantile policies that had originally fostered large-scale shipbuilding in the colony; and, more overtly, as reflections of the military-colonial rivalry that characterized the century. If Québec's Royal Dockyards are understood as simply large military establishments, rather like a fortress, then the economic impact of shipbuilding in New France may be considered essentially similar to that of other major military investments. As W.J. Eccles noted:

> *Mirabeau remarked that the primary industry of Prussia was war. The same could as aptly be said of New France. If it were possible to have an accurate accounting — unfortunately, it is not — it likely would be found that the military establishment ran the fur trade a close second as the economic mainstay of the colony. But it was not only the economy that was affected by this establishment. The whole fabric of Canadian society was imbued with the military ethos.*[45]

As with other large military projects, the Royal Dockyards of New France benefited society most immediately simply by drawing a large quantity of government funds into the colony. Admittedly, this type of government involvement served largely to distort market-driven economic growth, but it was nonetheless well-received. Both financial and social benefits accrued through the importation of skilled labour. The various *engagés* shipwrights and related master craftsmen, like so much contract labour in New France, were bought at a high price, or, put more bluntly "bribed with handsome salaries and a prepaid return passage."[46] In social terms, their residence in the colony, and that of the apprentices they trained, also contributed to the development of urban society and culture. And if they worked for the King, as so many did in the last decades of the French regime, that too brought additional economic as well as social advantages to the individual concerned; the latter being all the more significant in a society with a relatively simple social structure.[47] On the other hand, the eventual displacement of private ship construction by the activities of the Royal Dockyards also reduced to wage-labourers some Canadian shipwrights who might otherwise have become private shipbuilding entrepeneurs, resulting in a diminishment of local capital and social standing.

With respect to labour and workplace organization, shipbuilding in New France was among the very earliest large-scale manufacturing activities. Furthermore, shipbuilding was one of the few, and, if one excludes masons, probably the first, trade that was practiced in Canada by a structured assemblage of workers.[48] The very scale of the activity ensured that it would come to be a prominent, defining aspect of the colonial community (at the height of the Seven Year's War, as many as 1 000 workers were required to keep the naval shipyards of New France going).[49] Moreover, within the shipyard, one finds what are among Canada's earliest examples of both a management hierarchy and a complex division of labour, skilled and unskilled; characteristics that were most pronounced in the Royal Dockyards, particularly as organized by Levasseur after 1739.[50] Indeed, the first recorded strike in Canadian history occurred in 1741 at the royal shipyard in Québec when ships' carpenters sent from Rochefort refused to continue work after local Canadian shipwrights were laid off because of inclement weather.[51] Yet, this event reflected distinctions between metropolitan *engagés* and colonials, rather than the modern industrial dichotomy of management and labour. Clearly, the simple existence of an organized division of labour within the workplace, even a large state enterprise like an eighteenth century dockyard, does not indicate that shipbuilding constituted an industrial activity in the modern sense. With the exception of the very few naval *maîtres constructeurs*, shipwrights in New France were still essentially engaged in a handicraft, as were the various other tradesmen (caulkers, riggers, etc.) employed in shipbuilding. Beyond the walls of the Royal Dockyards, which might be said to consititute a state-run "manufactory," shipbuilding in

45. Eccles, "The Social, Economic and Political Significance of the Military Establishment in New France," p. 110.

46. Peter N. Moogk, "The Craftsmen of New France," (University of Toronto, unpublished Ph.D. dissertation, 1973), p. 76.
47. *Ibid.*, p. 266.
48. *Ibid.*, p. 302.
49. Mathieu, *La construction navale*, p. 60.
50. *Ibid.*, p. 56.
51. Moogk, "The Craftsmen of New France," pp. 313-314.

eighteenth-century Québec was still primarily a family-based craft.[52] As Peter Moogk has noted, shipwrights in New France lacked a working-class identity and "at best...were drawn together in a few areas by a vague craft particularism. The loyalty of most was limited to their own family and in-laws."[53] Indeed, the extent to which familiar bonds influenced social relations in the shipyard has been reinforced by the research of Brisson, who estimates that some six families accounted for fifty percent of all full-time, career shipwrights in the colony.[54]

Shipbuilding was also almost certainly the first productive enterprise in the colony (excluding fortification construction) which involved a community of individuals developing and exchanging their ideas through the medium of the engineering drawing: the ship's draught. The impact of this intellectual phenomenon, so important as a facilitator of technological ideas and a basis for future scientific design, is difficult to measure quantitatively, but was, nevertheless, a significant first step in the transformation of Canadian craftsmen into modern engineers. This point deserves emphasis. In the seventeenth and eighteenth centuries, ships were among the very largest and the most complex of machines, and warships were easily the most sophisticated of all vessels. The introduction of the technology and social relations associated with naval shipbuilding thus constitutes a very significant transplantation of European secular culture to North America. More specifically, with the establishment of the Royal Dockyard in 1739 and the appointment of M. Levasseur to oversee its operation, the intellectual, social and administrative reforms that were professionalising the naval constructor's trade in the metropolitan shipyards of France were, however modestly, introduced and fostered in Canada.

Ship Design and Construction in the 17th and 18th Centuries: The European Origins of Naval Architecture in Canada

> *"The English Shipwrights claim that the French know no more than they; and I believe that that is true, and yet in England as in France a distinction is made between the work of a skilful Builder and that of a mediocre one. We have inherited from the Builders who went before us a certain number of draughts of ships whose good qualities and faults are known to us from long experience. A skilful shipwright knows how to take up from these what is good, and correct that which is bad..."*
>
> *Blaise Ollivier, "Remarks" 1737*[55]

The ideas, technology and techniques which accompanied the establishment of the naval dockyard in Québec were French in nuance, but, in essence, belonged to a greater northern European tradition. By the second half of the seventeenth century, this tradition had achieved a level of sophistication whereby accumulated skill and experience exceeded scientific understanding. Thus this period is characterized by a marked intensification of explanatory and theoretical work in naval architecture, much of which was, in fact, conceived of, or fostered, in France.[56] The origins and early development of shipbuilding in Canada coincided with this era and ultimately became a prominent aspect of the European society that was transplanted on the shores of the St. Lawrence by the *ancien regime*. Accordingly, to understand the guiding principles and practices of ship design and construction in New France, one must examine contemporary developments in Europe.

The first shipwrights sent to Canada from France in the 1660s brought with them ideas, techniques and experience that were a quintessential part of European technology and culture. Through the training of *Canadien* apprentices, the knowledge and skills required to design and build large ships were disseminated among the colonial population and subsequently enhanced through the periodic arrival of metropolitan craftsmen. The most important new infusion in European shipbuilding standards and practices in New France came with the reestablishment of the royal dockyard in 1739 under the direction of an able French *sous-constructeur*, René Nicolas Levasseur; an initative supported by an Intendent, Gilles Hocquart, who was himself very well-versed in maritime matters. As a naval shipbuilder, M. Levasseur was the product of an administrative and educational system that, since Colbert's time, had become arguably the best in Europe. Still, theoretical speculation and technical rivalry in ship construction among the leading maritime powers of Europe remained intense throughout the late seventeenth and eighteenth centuries, and it was in this evolving context that naval architecture, complete with nascent scientific aspirations, arrived and was fostered in Canada.

52. See Rice, *Shipbuilding in British America*, pp. 168–196.
53. Moogk, "The Craftsmen of New France," p. 315; An intriguing Marxist perspective of labour and government policy in New France can be found in L.R. MacDonald, "France and New France: The Internal Contradictions," *Canadian Historical Review*, vol. LII, no. 2 (June, 1971), pp. 121–143.
54. Brisson, "Shipbuilding in New France", *Horizon Canada*, vol. 9, no. 108 (1987), p. 2589; for a detailed analysis, see also *Les 100 premières années*, pp. 167–190.
55. Ollivier, *18th Century Shipbuilding*, p. 143.
56. W.F. Stoot, "Some Aspects of Naval Architecture in the Eighteenth Century," *Transactions of the Royal Institution of Naval Architects*, vol. 101 (1959), p. 32; Geoffrey Dyson, "The Development of Instruction in Naval Architecture in 19th Century England," (Canterbury: University of Kent, unpublished M.A. thesis, 1978), pp. 5–7.

In 1663, while France was establishing a new administration in Canada, the famous English writer and naval administrator, Samuel Pepys, began receiving instruction on the basic tenets of ship design from Mr. Anthony Deane.[57] These lessons were later developed into one of the most important works in the history of shipbuilding: *Anthony Deane's Doctrine of Naval Architecture*. While this was not the first treatise on the subject written in England, Anthony Deane went on to achieve a high reputation as a naval constructor and his life's work is very well-documented, thanks in no small part to his long-standing association with Mr. Pepys. However, the *Doctrine* is exceptional in that it provides the first "complete plan of an English ship," and, moreover, presents the first written account of a reliable mathematical formula for the calculation of a ship's displacement.[58] As a result of this formula, Deane has been called the first "scientific" naval architect. Certainly this claim is subject to serious argument, although Deane did manage to formalize a crucial element in basic ship hydrostatics and was also clearly interested in the application of mathematics to ship design.[59] Thus he writes at the beginning of his *Doctrine*:

> *Before I proceed unto the several lines in a ship's body, I do think it not amiss, for the sake of those who may be desirous, to learn. what is intended for instruction, namely to show them the full art of measuring all sorts of figures and shapes, both superficial and solid, together with the art of gauging, and the rule static, as well by geometry as by arithmetic, which being attained unto, I conceive those who intend to build ships may be the more apt to proceed without difficulty.*[60]

Whether or not Anthony Deane is, or ought to be, considered the first successfully to apply such "science" to ship design, he was undeniably in the vanguard of what was then an international trend. The construction of ships, particularly fighting ships, was increasingly being subjected to intellectual scrutiny by governments and individuals anxious to bring reason and rules to bear on this important and very expensive activity. And in a century commonly associated with the scientific revolution, the century of Descartes and Newton, it is hardly surprising that the intellectual climate should exert an influence on the building of what was then humanity's largest and most complex machine: the ship.

There were two important, related factors involved in this trend. The first, alluded to above, was intellectual fashion. To speak of the scientific revolution is certainly to speak of a frustratingly vague phenomenon, but even so there is every reason to believe that a business as important to the state as that of building ships would be influenced by the same impulse which gave rise to the Royal Society of London (1662) and the French Royal Academy of Sciences (1666). The second factor was the desire for greater predictability in naval construction, particularly in the face of strident competition, fuelled by commercial rivalry and war. Not only were warships among the most sophisticated machines of the seventeenth century, but they were also among the most expensive. The largest French ships in Colbert's navy required 100 000 cubic feet of oak — equal to several thousand trees — 300 000 pounds of iron and between 130 000 and 140 000 days of labour.[61] It is, therefore, not surprising that governments might invest a high level of pride and expectation, along with the requisite capital, in the building of these powerful and impressive extensions of state power. The failure of large warships to perform was therefore not only a financial, but also a political liability. The best known example of such a failure is the Swedish ship *Vasa* of 1628, a well-preserved naval miscalculation (overseen by imported Dutch expertise) now, ironically enough, celebrated within its own large museum.[62] A similar force compelled improvements in navigational science and technology and there is understandably a strong correlation between advances in this area and those societies most concerned with ships and shipping. Here, too, predictability — in this case getting from A to B quickly and safely — was paramount and laws embodied by mathematical calculation ultimately proved to be its foremost servant.

Jean Baptiste Colbert — who in France epitomized the new class of rationalist administrator — was certainly among those who actively sought a wider margin of control and predictability in prosecuting naval policy. Thus, when Colbert set about to rebuild the French Navy in the last half of the seventeenth century, he expressed a great and persistent interest

57. Anthony Deane (Sir), *Deane's Doctrine of Naval Architecture, 1670* (London: Conway Maritime Press, 1981), p. 21.
58. *Ibid.*
59. Westcott Abell (Sir), *The Shipwright's Trade* (London: Conway Maritime Press, 1981), p. 56. Brian Lavery, in his introduction to the Conway edition of *Deane's Doctrine*, disputes the extent of this claim, while still acknowledging the importance of Deane's work. See: Anthony Deane, *Deane's Doctrine*, pp. 21-30. W.F. Stoot gives overwhelming preference to the work of Pierre Bouguer (1698-1758) calling his *Traité du Navire*, "the greatest work ever published on naval architecture"; W.F. Stoot, "Some Aspects of Naval Architecture in the Eighteenth Century," p. 32 and W.F. Stoot, "Ideas and Personalities in the Development of Naval Architecture," *Transactions of the Royal Institution of Naval Architects* vol. 101 (1959), pp. 217-218. Daniel Harris makes a similar claim for Chapman in his book; Daniel Harris, *F.H. Chapman: The First Naval Architect and his Work* (Annapolis: Naval Institute Press, 1989).
60. Deane, *Deane's Doctrine*, p. 34.
61. Paul W. Bamford, *Forests and French Sea Power*, p. 11.
62. Lars Ake Kvarning, "The Royal Ship *Vasa* — Key to a Lost World," *Five Hundred Years of Nautical Science, 1400-1900* (Greenwich: National Maritime Museum, 1981), pp. 193-203; Lars Ake Kvarning, "The Vasa Museum," *VIIth International Congress of Maritime Museums, Proceedings 1990* (Stockholm: National Maritime Museums, 1990), pp. 62-71.

in foreign practices and in the discovery of a scientific approach to naval construction.[63] For much of the century, France had relied heavily on ships purchased abroad or built in France by imported, principally Dutch, shipwrights.[64] Shipbuilding was also among the most cosmopolitan of trades with skilled shipwrights of one nation frequently finding work in the shipyards of another. While this certainly did not eliminate suspicion and prosecution, particularly in times of political tension, it did promote a fluid exchange of ideas.[65]

An early indication that Colbert may have known of the formula, which Anthony Deane described in his famous manuscript, is found in a letter of March 20, 1669 to M. de Croissy, the French Ambassador in London. In it Colbert writes:

> *Je seray bien ayse de voir le mémoire que vous avey fait concernant la marine d'Angleterre, laquelle je vous prie de bien pénétrer, afin que nous puissions profiter de leur grande expérience en cette nature de guerre.*
>
> *Surtout, je seray bien ayse de scavoir, s'il possible, comment ils mesurent la capacité de leur vaisseaux....*[66]

While "*capacité*" here may not necessarily mean displacement, it is at least possible given Colbert's intense interest in the subject.[67] A few months later, Colbert wrote to Colbert de Terron, Intendant at Rochefort, about building according to "la, form à l'angloise"[68] and early in 1670 he instructed Sieur Hubac Fils, a well-connected young French shipwright then in the Netherlands studying Dutch techniques, to proceed to England "pour connoistre aussy la manière de bastir, et si le gabarit y est différent de celuy de Hollande."[69] Once M. Hubac was in England, Colbert was more specific in his demands, as is evident in his letter of April 11, 1670:

> *Outre les remarques générales que vous avez faites sur les constructions, il faut, s'il se peut que vous en fassiez de particulières sur les proportions, estant essentiel de scavoir combien un vaisseau de cent pièces de canon a de pieds de quille, et de l'etrave à l'étambot, sa profonder, les hauteurs etre les deux ponts et sa largeur, afin de faire un jour une bonne application de toutes ces connoissances... .*[70]

A reliable formula for the calculation of displacement was particularly important to seventeenth century naval construction simply because it provided a means for ascertaining with some certainty the flotation waterline for multi-deck fighting ships. Contemporary naval tactics, with the new emphasis on the line of battle formation, favoured the production of large ships which could bear a maximum weight and number of cannon broadside. It was therefore essential that the lowest deck, which often bore the greatest concentration of cannon, be placed high enough above the load waterline to insure that the gun ports could remain operative in most sea conditions. An accurate calculation of displacement in advance of construction would accordingly improve the shipwright's ability to predict this all important aspect of naval design.[71]

That such a system was, in fact, of immediate interest to Colbert, is perhaps most explicitly stated in a letter written to M. Arnoul Fils, Intendant de Marine at Toulon, in 1678:

> *Mon intention est donc de travailler à faire une théorie sur le sujet de la construction des vaisseaux, c'est-a-dire d'establir des mesures et des proportions si justes de tous les membres et de toutes les parties d'un vaissseau de chacun des cinq rangs que le Roy a ordonnés, que l'on fust assuré que, en bastissant un vaisseau sur les mesures et les proportions qui auroient esté determineés, ce vaisseau seroit bon et fin de voile, que ses batteries seroient bien establies...et qu'il ne fust jamais nécessaire ni de la doubler, ni de se donner de la peine et de la difficulté pour trouver sa véritable assiette.*[72]

By 1680, this "*intention*" to discover a theory, takes on the tone of an imperative as Colbert informs the Lieutenant Général des Armées Navales,

63. James Pritchard, "From Shipwright to Naval Constructor: The Professionalization of 18th-Century French Naval Shipbuilders," *Technology and Culture*, vol. 28, no. 1 (January, 1987), pp. 5–6. Pritchard cites Clément, ed., *Lettres, instructions...*, III, pt. 1, pp. 125–6 and p. 177, though these are but a few instances in which Colbert's concern is expressed in official correspondence. See also W.F. Stoot, "Ideas and Personalities in the Development of Naval Architecture," pp. 215–216.
64. Symcox, "The Navy of Louis XIV", p. 132. Martine Acerra, "Les constructeurs de la marine (XVII^e^–XVIII^e^ siècle)," *Revue Historique* (Avril–Juin 1985), p. 284.
65. Ollivier, *18th Century Shipbuilding*, p. 25; Brian Lavery, "Introduction," *The Line of Battle: the Sailing Warship 1650–1840*, Robert Gardiner, ed. (London: Conway Maritime Press, 1992), p. 9.
66. Clément, ed., *Lettres, instructions...*, III, pt. 1, p. 110.
67. By 1666 Pepys was making reference to Deane's "secret" so the idea could very well have been circulating in official channels by 1669. Still, Colbert might well be interested here in the more mundane matter of tonnage measure, though such information would seem less likely to require the efforts of the ambassador. It is perhaps also worth recalling in this context that in the following century, the French method of measuring tonnage was based on the calculation of displacement. Ollivier, *18th Century Shipbuilding*, p. 169.
68. Clément, ed., *Lettres, instructions...*, III, pt 1, p. 132.
69. *Ibid.*, p. 211.
70. *Ibid.*, p. 234.
71. Deane, *Deane's Doctrine*, p. 25.
72. Clément, ed., *Lettres, instructions...*, III, pt. 1, p. 126.

M. Duquesne, that the Crown's search for a "*théorie des constructions (est) à présent la plus importante affaire de la marine.*"[73]

Notwithstanding the great interest and efforts of influential French ministers like Colbert and, in the next century, Jean-Frédéric de Maurepas, the calculation of displacement represented, by and large, the full extent to which science, in this case geometry, would influence European naval architecture for much of the next one hundred years. And while it is true that in this period the French navy developed dramatically both quantitatively and qualitatively, it would be wrong to associate the great esteem in which French shipbuilding was held during the eighteenth century (particularly by the British Admiralty) with any particular success on the part of Colbert or his successors in discovering a comprehensive "*théorie des constructions*". Certainly, important theoretical treatises were published during the *ancien regime*, most notably Pierre Bouguer's *Traité de Navire* of 1746 and Leonard Euler's prize-winning *Scientia Navalis Tractatus de Connstruendis et Dirigendis Navibus*. French espionage in foreign dockyards also continued apace. Yet notwithstanding the very important work of Bouguer, Euler and, later, Fredrik Henrik af Chapman, a coherent scientific basis for ship design remained elusive.[74] The best that could be said for the efforts of the late-seventeenth and eighteenth centuries, is that there developed a more refined understanding of the essential problems of ship design, while at the same time, training and construction practices were standardized and regulated.[75] In this regard, the French were particularly successful and thus were able to apply these improvements to their activities in New France.

If the role of mathematical calculation in the development of new designs remained limited, the same is not so for the language and medium in which the naval shipwright presented and documented his work. By the end of the seventeenth century, it had become common practice for naval shipbuilders to describe their ideas by means of technical drawings. This practice had its beginnings during the Elizabethan era of naval expansion with the work of the Englishman Matthew Baker. His drawings from about 1586 rank among the very earliest attempts in northern Europe to relate information on ship design through this medium.[76] However, as already noted, Anthony Deane is credited as having provided in his *Doctrine* the first complete architectural drawing of an English ship. In France, the early development of line drawings is more obscure owing to the destruction of much of the naval archives. Sieur Dassié's *L'Architecture navale* from 1677 offers the first published evidence of this practice in France, though in 1669 one reads of M. Hubac sending Dutch draughts to Colbert, and so there can be little doubt of their earlier acceptance and utility.[77] Unlike the merely informative illustrations found in volumes like *L'Album Colbert*, however, lines drawings served an essential, technical function in the construction of ships.[78] Accordingly, they soon became an important feature of French naval construction and were therefore also used and produced in Canada, notably by Levasseur as well as his Canadian assistant, Sieur Cressé.[79]

Ships' draughts, or lines drawings, are essentially a two-dimensional means of defining the shape of a complex three-dimensional object. Thus, they show the hull from three views: profile (view parallel to the keel), planview (fish or bird's eye view) and bodyplan (view from directly in front and/or behind the hull). The latter is the most important of the three, wherein the shape of the hull is defined through a series of lateral slices representing the frames, or ribs, of the vessel. These frame shapes were originally drawn using a series of tangent arcs, confined by established dimensions, at the sheer (frame tops), maximum breadth (in vessels with "tumblehome" — a brandy glass form — this would be greater than the sheer) and floorline (the transition point between the bottom of the hull and the sides). Sheer, maximum width and floor lines would be shown in the planview. By the end of the seventeenth century lines plans would display a greater number of such longitudinal slices, known as waterlines, which would facilitate the process of fairing (making regular and smooth) the shape as drawn on paper.[80] The profile view would show the curve or rake of stem and stern, the alignment of the frames, the placement of wales and gunports, as well as the arrangement of decks and other internal elements. In the nineteenth century, the

73. *Ibid.*, p. 177.
74. Chapman was himself an admirer of Bouguer and Euler; Daniel Harris, *F.H. Chapman*, pp. 12–13 and p. 227. Harris's treatment of Chapman's life and work offers a useful context for any discussion of the ascendence of science in ship construction. See also Pritchard, "The Professionalization," pp. 6–9. Regarding naval espionage, perhaps the best published contemporary account is found in Blaise Ollivier's "Remarks" of 1737. See Ollivier, *18th Century Shipbuilding*.
75. For a good technical review of theory and experiment in eighteenth century naval architecture, see W.F. Stoot, "Some Aspects of Naval Architecture in the Eighteenth Century," pp. 31–46; for more biographical details, see W.F. Stoot, "Ideas and Personalities in the Development of Naval Architecture," pp. 215–223.
76. Howard Chapelle, *The Search for Speed Under Sail* (London: Conway Maritime Press, 1983), p. 15. Abell, *The Shipwright's Trade*, pp. 36–40.
77. Jean-Claude Lemineur, "Commentaire général sur l'album de Colbert," *L'Orient arsenal XVII^e–XVIII^e Siècles* (Lorient: Service historique de la marine, 1983), p. 16. Sr. Dassié, *L'Architecture navale, contenant la manière de construire les navires, galères et chaloupes et la definition de plusieurs autres espèces de vaisseau* (Paris: 1677).
78. Jean-Claude Lemineur, "Commentaire général, pp. 13–25, Michel Vergé-Franceschi and Eric Rieth, eds. *Voiles et Voilier Au Temps de Louis XIV* (Paris: Du May, 1992), pp. 87–116.
79. Lunn, *Dévelopement économique*, pp. 168–169.
80. Deane, *Deane's Doctrine*, p. 26.

profile would also be used to show buttock lines, or longitudinal slices perpendicular to the frames. Early practice required that only every third or fourth frame shape in the bodyplan be drawn, starting with the midpoint or maximum width and working to either end. From these scaled-down shapes, full-scale moulds or frame patterns would be built.

At the shipyard these mould frames would be erected along the laid keel, connected with battens running from stem to stern and thereby provide a basis for the formation of all the remaining frames. Problems in consistent definition of the stem and stern shapes using this assembly system lead to a greater number of mould frames being drawn and set up at the extreme ends.[81] In general, the fairer the shape presented on the plan, the closer the proximity of the design to the built form. As an intermediate step, the drawn design would often be translated into a model both as a means of displaying the design to those unfamiliar with the language of the draught, and as a further control on the design and general arrangement.[82]

Ship draughts were produced on parchment or paper, with the latter surface dominant by the end of the seventeenth century. By 1678 there was even special grid paper available to facilitate the calculation of displacement.[83] A Swedish treatise on naval architecture from 1691 provides an image of the instruments used in drawing lines plans. Aside from the expected compass, pen and pencils, there are two special battens shown for drawing curves, one strung like a bow and the other regulated by three long screw adjustments.[84] The problem of drawing the difficult shapes characteristic of ships lines was also solved by way of sets of precut wooden templates, usually made of thin veneer. Another solution was thin splines held in place with special weights called "ducks". Mistakes in lead pencil were removed using fresh bread or if the offending line was drawn in pen, then it would be scraped away and the area repaired by polishing with a metal or ivory "smoother". Another important tool was the scale, but since there were no reliable means of standardizing calibration it became common practice to include a scale as part of the plan.[85]

In addition to providing a convenient, reliable means for documenting and conveying information about hull form and structural arrangement, the regular use of draughts in ship construction marked an important stage in the development of the shipbuilding trade. By resorting to a standardized visual format for projecting and refining ideas about ship form, the shipwright took a major step towards the realm and status of the naval architect. As has been noted "probably the greatest single difference between a craftsman and an engineer is that the craftsman nearly always designs 'in the material'.[86] In this respect, the evolution of the practice of draughting the lines of a ship constitutes the development of a professional language: in this case, the language of naval architecture, complete with "established alphabet, rules of grammar and composition, abbreviations, accepted conventions and idioms."[87] Though "non-verbal" in nature, the regular use of this language had an impact that was both social and intellectual.[88] Professionally, it lead to a distinction between those in the shipbuilding trade with sufficient training to communicate in this language and those whose skills were confined to the physical execution of the craft.[89] Of course, the two need not be mutually exclusive and, indeed, the majority of wooden merchant ships were designed principally by way of models until the end of the nineteenth century. But in a complex, expensive, state-run enterprise like a naval dockyard, the constant demand for superior designs and bureaucratic control, lead naturally to the growth of a community of individuals with an ability to develop and exchange their ideas in a medium that was at once more flexible and sophisticated. Accordingly, these individuals assumed a superior social and professional status.

The intellectual impact of this development was also significant. Generally speaking, the language of the lines plan not only serves to convey thoughts, it also facilitates thinking. The increasing recourse to draughts which occurred in the naval dockyards of Europe in the seventeenth century was thus much more than a bureaucratic convenience; it was in a very real sense an expansion of intellectual boundaries distinct from, though related to, scientific thought. As Eugene Ferguson has noted: "all our technology has a significant intellectual component that is both nonscientific and nonliterary."[90] For those who were able to master this particular form of visual language, it is fair to assume that they might enjoy some competitive advantage among their peers. More specifically, however, the use of lines plan was also an important prerequisite for the one scientific element in the seventeenth and eighteenth century ship design:

81. Chapelle, *The Search for Speed*, p. 18. The explanation of both the process and the basic tools used in drafting ships' lines is largely derived from Chapelle's discussion of the subject found in Chapter 1 of this volume.
82. Naish, "Ships and Shipbuilding," pp. 490–492.
83. Deane, *Deane's Doctrine*, p. 25.
84. Åke Classon Rålamb, *Skeps Byggerij eller Adelig Öfnings Tionde Tom* (Stockholm: Sjohistoriska Museum, 1943), Tavla A., a.
85. Chapelle, *The Search for Speed*, pp. 20–21.
86. Robert M. Vogel, "Draughting the Steam Engine," *Railroad History*, vol. 152 (Spring, 1985), p. 17.
87. *Ibid.*, p. 18.
88. A very useful and concise exploration of the concept of the drawn image as a non-verbal medium of intellectual expression can be found in Eugene S. Ferguson, "The Mind's Eye: Nonverbal Thought in Technology," *Science*, vol. 197 (August, 1977), pp. 827–836. These ideas are expanded further in his book *Engineering and the Mind's Eye*.
89. Vogel, "Draughting the Steam Engine," p. 17.
90. Ferguson, "The Mind's Eye", p. 827.

the calculation of displacement. In short, the effective and widespread use of geometry to calculate volume and displacement required, a priori, a two-dimensional depiction of hull form. Once established as common practice, this visual expression of the shipwright's ideas paved the way for other scientific concepts to influence the design process.[91]

At this point, it seems appropriate to say something about the high reputation of French naval architecture in the late seventeenth and eighteenth century. Unfortunately, this is a subject of debate which usually generates more heat than light. While the superior quality of French naval design has been widely accepted by historians, the truth is more difficult to measure.[92] Not only are the comments of the British naval officers — the source of much of this reputation — suspiciously self-serving (a variation of blame the instrument, not the player), but the fact remains that no objective technical criteria for comparison have yet been established or applied.[93] The performance of any sailing ship depends on too many inter-related variables, human and technological, to permit the uncritical acceptance of all contemporary accounts. Still, it is true that as early as the Third Dutch War (1672–1678), French warships began attracting the attention and admiration of other nations, particularly England.[94] This trend continued during the next century, notwithstanding a quantitative decline in French naval construction around 1700, and culminated in the development of a successful new series of sixty-four, seventy-four and eighty gun, two-deck ships.[95]

In this context, James Pritchard has argued convincingly that the apparent success of warship design in France was not the result of an explicitly more scientific approach to shipbuilding, but rather was principally due to social and administrative developments: social, in so far as the status of the master shipwright in France was elevated by the government to a point where it became a respectable calling — a "profession" — for any gentleman of society to follow; and administrative in that effective measures were taken to formalize and improve educational requirements, thereby establishing the basis of a professional association.[96] Not surprisingly, this tradition began with Colbert, who, in his quest for better ships, founded the "conseils de construction" consisting of both naval officers and shipwrights. These councils were assembled to consider various design issues and, as Pritchard notes, "it had to be here that noble officers became aware that their social inferiors were doing something quite different from ordinary master craftsmen."[97] Just what it was they were doing that was different, is best reflected in the use of naval draughts for ship design, as discussed above. Indeed, providing formal instruction to shipwrights in drawing lines plans was one of the specific responsibilities given to the Marquis de Langeron when appointed Inspector of Naval Construction in 1684.[98] By 1737, Blaiser Olliver could report that it was standard practice for French shipwrights to calculate tonnage from displacement, a fact which further suggests the well-established use of drawings.[99] The 1730s also saw Henri-Louis Duhamel du Monceau engaged in a major examination of French shipbuilding practice on the initiative of the Secretary of State for the Navy, Jean-Frédéric de Maurepas. Monceau's efforts led to significant educational reforms that included augmented mathematical training for naval constructors; ultimately, however, theory remained subjugated to the rule of experience.[100]

Thus, the French tradition of naval architecture in the eighteenth century — of which the chief of the Québec dockyard, M. Levasseur was a product — was characterized by well-educated individuals who tempered theory with best practice, and this, more than any abstract "*théorie des constructions*", may account for whatever superior qualities French warships displayed. At any rate, the evidence suggests that the development of the "profession" of naval architecture — with its own language, regulated practice and educational requirements — was more advanced in eighteenth-century France than

91. This point is the central thesis of an unpublished paper presented at the 1992 SHOT Meeting in Uppsala Sweden: David McGee, "Deane's Doctrine: Design, Drawing and the Birth of a Scientific Naval Architecture." The author is indebted to Dr. McGee for making the manuscript of this paper available.

92. Pritchard, "The Professionalization," pp. 1–4, offers a good summary of the arguments. See also, Dyson, "The Development of Instruction in Naval Architecture," pp. 7–9.

93. Garth Wilson, "The Great Lakes Historic Ships Research Project: An Innovative Approach to the Documentation and Analysis of Historic Hull Design," *International Journal of Maritime History*, vol. 1, no. 2 (December, 1989), p. 200. The system described in this article could perhaps serve as a starting point for such an investigation.

94. Deane, *Deane's Doctrine*, p. 13.

95. Brian Lavery, "The Ship of the Line," *The Line of Battle: The Sailing Warship 1650–1840* (London: Conway Maritime Press, 1992), p. 18; Alexander McKee, "The Influence of British Naval Strategy on Ship Design: 1400–1850," *A History of Seafaring Based on Underwater Archaeology*, George Bass, ed. (New York: Walker and Company, 1972), p. 234.

96. Pritchard, "The Professionalization," pp. 1–25.

97. *Ibid.*, p. 13.

98. *Ibid.*, p. 8.

99. Ollivier, *18th Century Shipbuilding*, p. 169.

100. *Ibid.*, pp. 15–16; Acerra, "Les constructeurs de la marine," p. 289. The philosopher, Marquis de Condorcet described Duhamel's investigations into shipbuilding as follows: "everywhere he seeks to establish clearly what is the best practice; to reduce it to definite rules distinguishing it from routine; and even to bottom it on principles of physics, though eschewing any reliance on theories that had no firmer foundation than hypothesis," quoted in Charles C. Gillispie, *Science and Polity in France at the End of the Old Regime* (Princeton: Princeton University Press, 1980), p. 338.

elsewhere, as was also the related sphere of engineering.[101] Whatever the immediate impact of this on the design of particular vessels, it is fair to conclude that the professionalization of naval constructors in France served to promote the regulation of practice and standards, and thereby ensured a greater degree of consistency and predictability.[102] These are certainly qualities that French shipowners, particularly the Crown investing large sums in warships, would appreciate, and they are also qualities that would support the effective operation of a large naval dockyard in a distant colony like New France.

Wooden Ship Construction:

The dramatic expansion of the French fleet at the end of the seventeenth century coincided with the end of an era of growth and development in large wooden sailing ship construction. Throughout the seventeenth century, European governments had encouraged the building of ever larger and more powerful fighting ships and, as noted above, it was largely these military concerns that fueled developments. The emphasis on the number of guns carried made "line ahead" battle formation the dominant offensive tactic. The line ahead arrangement brought to bear each vessel's full broadside complement of cannon and thereby reinforced the role of the large warship (henceforth, "ship of the line") as essentially a sailing gun-platform.[103] This trend confronted the shipwright with a formidable task in which an effective balance was sought between the conflicting values of firepower and stability on the one hand, and speed and manoeuvrability on the other.[104] Achieving this balance remained a constant design challenge to the naval constructor but the reliance on wood as the principal building material set limits on the size and general arrangement of the ship's structure. As a result, by 1700, the principle components and procedures for building large wooden sailing ships, military or merhant, were firmly established. These remained, in essence, unchanged for much of the next two-hundred years, although styles evolved, iron and steel became increasingly prominent in rigging and secondary scantlings, and production techniques generally became more mechanized.

For purposes of simplicity, the process of building a large wooden sailing vessel may be divided into five distinct stages: laying the keel, framing, planking, launching and fitting out.[105] All but the last of these stages was carried out on the ways, or in a dock. The building site was invariably situated along the water's edge so that when complete, the hull could be set afloat with minimal effort and stress to the structure. Construction began with the keel blocks being set and aligned to serve as an elevated foundation for the hull while under construction. If the ship was built on ways, rather than in a drydock, the keel blocks were arranged at a slight incline of about 3/8 inch per foot to facilitate the launch.

The keel is the ship's spine and principal member. It is therefore the first component to be assembled. Often constructed of elm, the keel was built in sections scarfed (joined at an angle rather than butt-on) together. The stark horizontal line of the keel was broken at either end by stem and sternposts, made of similar material and firmly scarfed in place. Often, the stem itself was an assemblage of several timbers. To the sternpost was added the transom and, once in place, both stem and stern were carefully aligned with the keel and shored firmly in place.

The frames determined the shape of the vessel and gave it much of its strength. Each frame was formed from a number of timbers (usually oak) assembled according to a pattern derived from the bodyplan on the ship's draught or lifted and scaled-up from a model. Assembly began with the floors, so named because these timbers ran across and were fastened to, the keel. Initially only every second floor was set down. To the extremities of each were attached long ribbands (rib-bands) of fir, a temporary measure devised simply to allow the shipwright to check that the longitudinal shape defined by the floors was fair. This done, the remaining floor timbers were put in place and the keelson, a sort of secondary, internal keel, set on top. Keelson, floors and keel were then fastened together by means of large iron bolts. The floors served as the foundation for the rest of the frame which was made from a double layer of curved timbers called futtocks, fastened together with treenails

101. Acerra, "Les constructeurs de la marine," pp. 293–294; Frederick B. Artz, *The Development of Technical Education in France, 1500–1850* (Cambridge: The Society for the History of Technology and M.I.T. Press, 1966), pp. 109–111.
102. Here it is worth noting that "professional" is not necessarily synonomous with "superior" a point that is well-argued by Susan Cannon in her analysis of science and culture in the nineteenth century. Indeed, the values of professionalization must always be examined within a defined cultural context. Susan Faye Cannon, *Science in Culture: the Early Victorian Period* (New York: Dawson and Science History Publications, 1978), pp. 137-166.
103. Lavery, "The Ship of the Line," *The Line of Battle*, pp. 11–25.
104. Robert Gardiner, "Design and Construction," *The Ship of the Line: The Sailing Warship 1650–1840* (London: Conway Maritime Press, 1992), pp. 116-125.
105. The process of building large wooden sailing ships is well-covered in the corpus of maritime history literature. For the layperson, illustrations offer the best means of understanding the various steps. Unfortunately, production costs and time precluded the inclusion of such images here. An exceptionally well-illustrated volume dealing specifically with this subject is: Basil Greenhill, *The Evolution of the Wooden Ship* (London: B.T. Batsford, 1988). One very concise account relating specifically to warships of the late-seventeenth and early-eighteenth century is A.P. McGowan, "The Basic Structure of the Wooden Warship," *Five Hundred Years of Nautical Science, 1400–1900* (Greenwich: National Maritime Museum, 1981), pp. 168–180. The generic description of construction provided here is largely derived from this latter source.

(tightly fitting doles, wedged at the ends and then cut flush). The futtocks, numbered on each frame according to their order of placement, were cut and assembled so that the end joints of the one layer were fully overlapped by the second. The futtocks concluded at each frames maximum breadth, at which point the frames where bound by another temporary ribband, again to check for fairness. Once this was done, the frames were temporarily cross-paled, that is joined from one side to the other, while awaiting the placement of the deckbeams. The frames were then concluded with the addition of toptimbers. The deckbeams were heavy squared timbers, scarfed as length required.[106] They were fastened in place with various knees carved, for strength, from naturally occuring crooks or, alternatively, made of iron. The beams themselves served to support the decks and brace the frames. The number and spacing required depended on the vessel's size and service, though warships usually had a beam below every gunport. The beams were also supported by deck pillars erected over the keel. In the eighteenth century, the structure of larger ships was given further strength by the addition of a heavy internal framing made up of large timbers called riders. These were set over the ceiling planking, in a somewhat irregular pattern, but by the end of the century, the Englishman Sir Robert Seppings, Surveyor of the Navy, had devised a very effective, consistent system of internal framing using diagonal riders which gave new life to older warships and further extended the size and strength of new ones. These timbers were later replaced by metal strappings.[107]

Ships were planked on both the outside and inside of the frames. The planking was applied parallel to the keel and fastened to the frame with bolts and treenails. The exterior planking was naturally the most important and it usually consisted of long timbers (length depended on available supplies), twelve inches wide and between one and one-half and eight inches thick, depending on its location. Again, oak was the preferred wood and steam was used to facilitate bending when necessary. The outside planking was thickest at the main wale, a band extending the entire length of the hull from the turn of the bilge to the bottom of the main gunports. The planking was first applied here, working down to the keel, and from the keel working up to the wale. The planking under the floors was about four inches thick, increasing dramatically at the main wale and then decreasing gradually to the sheer. The planking was always arranged carefully to ensure that the butt joints on any given strake (single continuous series of planks) were sandwiched by three or four unbroken lengths of plank above and below. The internal or ceiling planking was usually about four inches thick with heavier pieces being used to plank over the butt-joints of the floors and futtocks and to support the clamps that held the deckbeams. The decks themselves were made of four-inch planking laid across the main deckbeams, with further support provided by smaller cross timbers called ledges and ceiling planking. Once the planking was in place, the next step was to caulk the seams between the external planks. This was done using rolled lengths of oakum saturated with pine tar and driven into the seams using a series of special tools called caulking irons. The caulking was applied in layers using irons with different edges for each layer. After the final layer, the seam would be capped with pitch. This lengthy, labour-intensive process served both to seal the hull and, wedge-like, to tighten the structure along its entire length. After the caulking was done, the hull would be painted or, if paint was unavailable or too expensive, tar, oil and whitewash could serve as substitutes.[108] Such coatings were essential for the preservation of the wood, a chronic concern of shipwrights and owners in this era. Varnish or oil would also be used on the vessels upper-works.

After the hull had been planked and painted it could be launched. In the seventeenth and eighteenth centuries, most of the internal components, accommodations and decorations were in fact completed before the ship left the ways.[109] Launching in a drydock simply involved shoring up the vessel and slowly letting the water flood the dock and float the hull off the keel blocks. Launching on the ways was more difficult. Here the ship had to be jacked up off the keel blocks, using wedges, and then set down on a specially-built cradle. Once the hull was securely seated, the cradle was released from its moorings and allowed to slide down the smooth, well-greased slipways, into the water.

In the fitting out stage, the primary task was to assemble the masts and rigging.[110] On fore- and aft-rigged vessels which used a simpler arrangement of spars than that found on square-riggers, the masts were often set in place before the launch. However, on square-rigged ships all this was done after the hull was afloat. By definition a standard full-rigged ship carried three masts and was square-rigged on all but the mizzen, the mast positioned furthest aft, though the upper sections of the mizzen were also rigged to carry square sails. The masts of such ships were complex assemblages, made of numerous component parts, size being determined by an established formula based on hull dimensions. On large ships masts were usually composed of three main stages. First, the lower mast was set into its step in the hull, supported at each deck by heavy timbers called partners which ran perpendicular to, and rested on,

106. McGowan, "The Basic Structure," pp. 169–170.

107. Gardiner, "Design and Construction," *The Line of Battle*, p. 122.

108. Chapelle, *The Search for Speed*, pp. 14–15.

109. Gardiner, "Design and Construction," *The Line of Battle*, p. 124.

110. What follows is a thumbnail sketch of an enormously complex subject. A very thorough and well-illustrated discussion can be found in: James Lees, *The Masting and Rigging of English Ships of War 1625–1860* (London: Conway Maritime Press, 1979).

the deck beams. This was the largest of the three stages and it was fashioned with a gentle taper along its length, from heel (bottom) to head. Since single straight logs (usually pine) of sufficient size were increasingly difficult to find, lower masts were often constructed of various timbers, elaborately cut and scarfed together, then heavily reinforced, top to bottom, with a multitude of rope woolding or metal bands. At the top of the lower mast was a cap, below which, at a prescribed distance, were the "hounds", strong timbers providing support to the network of horizontal members (trestletrees), upon which a platform called the "top" was erected. The top served as an excellent lookout or, in war, a sniper's station. Here was found the base for the heel of the topmast (the second stage) which was seated directly in front of the lowermast and held firm by the cap of the latter. The topgallent mast (the final stage) was similarly seated and fastened above and in front of the topmast. Both topmast and topgallent were often made of a single pole. Still, they were fashioned with great skill and were usually fitted with internal pulleys. This basic pattern of overlapping spars of diminishing size was repeated, with slight variations, on the other masts of the vessel, including the bowsprit jib-boom arrangement which was in essence a mast, set at an extreme angle.[111]

The main sails of a square-rigged ship were carried on long spars called yards. The yards were attached perpendicular to the masts by means of a complex, flexible collar arrangement known as a parrel. One important exception on the rig of seventeenth-century ships was the main sail of the mizzen mast. Originally, the mizzen carried a lateen sail, a Mediterranean rig of Arab origin, prized for its superior windward performance. The sail was triangular in shape and carried on a long yard, usually made of two overlapping spars, and held at an angle to the mast. This sail, positioned aft, made the full-rigged ship better able to sail into the wind and thus improved its manoeuvrability. In the eighteenth century these qualities were further improved on by replacing the lateen with a gaff sail, another, more easily handled type of fore-and-aft-rig. Another innovation which occurred around the same time was the addition of other fore-and-aft sails called stay sails because they were rigged along the stays (see below). This was most significant at the bow, where the stays running between the bowsprit, jib boom and foremast began to carry an array of triangular fore sails. Like the gaff-rig on the lower mizzen, these sails improved manoeuvrablity and windward performance.

By themselves, the masts lacked sufficient strength to withstand the enormous pressure that the wind exerted on the sails. Essential strength and stiffening was therefore provided by an elaborate arrangement of lines commonly referred to as standing rigging. Rope, made from hemp of various braids and thicknesses, was originally the primary material used in standing rigging. In the nineteenth century, however, iron chain, linked rods and wire eventually replaced rope in this capacity.[112] The main lines in the standing rigging which ran fore and aft were the stays; those which ran transversely were the shrouds. Stiffness was an essential quality of the standing rigging, and to maintain it various arrangements of tackle were used. The most important and prominent example was the so called "chains," the tension point of the lower shrouds. Here, iron strapping secured a shelf (chain wale) extending from the side of the hull at about the sheer. Each strap anchored a deadeye, a thick, hardwood disc pierced with three holes that functioned like a pulley block. At the end of each shroud was a similar disc. These complementary pairs of deadeyes were then joined by a rope (lanyard) which looped back and forth between the deadeyes, providing the purchase required to keep the shrouds perfectly rigid. A similar arrangement was employed at the base of the topmasts and topgallents.

To manipulate the multitude of sails carried on a large full-rigged ship, a complex — to the layman almost incomprehensible — network of mannila ropes, pulley blocks and tackles was employed. The collective term for this network is running rigging. Control power aboard sailing ships was provided by the crew, and the running rigging served to facilitate or multiply the effort available from the muscle of the men. In order to move large spars and control the tremendous energy captured by the sails, the ship's complement relied on the simple, but effective amplifying capacity of blocks and pulleys. In the seventeenth century, a 74-gun ship of the line would require as many as 1 000 blocks of various types and sizes, together with miles of cordage in different widths and strengths.[113] Marine blocks and pulleys comprised an assembly of carefully-crafted, static and dynamic elements. They had to be strong and reliable in a challenging and changing environment. Blockmakers required specialized skills and training, even though the tools they used were common to other forms of fine joinery.[114] So great was the demand for these essential, ubiquitous components of shipbuilding that, by 1808, blockmaking in Britain became one of the very first items to undergo mechanized mass production.[115]

111. Karl Heinz Marquardt, "Rigs and Rigging," *The Line of Battle: The Sailing Warship 1650-1840* (London: Conway Maritime Press, 1992), pp. 132–133.

112. Basil Greenhill, "The Iron and Steel Sailing Ship," *Sail's Last Century* (London: Conway Maritime Press, 1993), pp. 79–80.

113. Carolyn C. Cooper, "The Portsmouth System of Manufacture," *Technology and Culture*, vol. 25, no. 2 (April, 1984), p. 183. For a good visual summary of blocks, see William Baker et al. *The Lore of Sail* (Gothenburg: Nordbok, 1982), pp. 172–177.

114. Cooper, "The Portsmouth System," p. 185, fig. 2.

115. *Ibid.*, pp. 182–225. Carolyn Cooper provides a thorough and very interesting examination of this development.

Aboard ship, blocks and pulleys were used in appropriate combinations — the greater the weight or force to be controlled, the more purchase required — that bore different names. To hoist and control yards, "jears" and "braces" were used. Sails were managed with arrangements called halyards (for raising), downhaulers (for lowering), and sheets (for trimming). Most of the ships sails were set, shortened and furled directly by hand by teams of men working from the yards. The sails themselves were made of strips of linen or canvas sewn together and framed with cord (boltropes) and cringles. Reefing bands were also sewn across their width, and leech and buntlines attached to their sides and bottom, respectively, to facilitate their use. Other elements of the running rigging included various tackles for lifting and moving cargo and armaments. For the heaviest jobs, like hoisting anchor, a large, centrally located capstan (a rudimentary machine using the winding principle) was used. Capstans, which were also operated by teams of men, were an essential built-in component of all large vessels.

The Tools of Wooden Shipbuilding:

Just as the essential components and procedures for large wooden ship construction had been firmly established by the end of the seventeenth century, so were the basic tools used by the shipwright.[116] A shipwright building lumber schooners in Vancouver in the early twentieth century would have little trouble recognizing the tools used in Levasseur's Royal Dockyard.[117] Wood was, of course, the essential common denominator and the tools used by the shipwright largely concerned the cutting, shaping and smoothing of this raw material. Indeed, with a few notable exceptions, the shipwright's tools differ very little from those of the carpenters' trade. Ownership of tools was mixed. A master would almost certainly have a variety of his own tools, both for his personal use and for the use of his apprentices.[118] In a naval dockyard, like that at Québec, a more defined division of labour or hierarchy of craftsmen and skills would be enforced. Trade specialists would tend to have their own tools, while all yards would keep a selection of basic shipbuilding tools for general use. More complex, heavy equipment and specialized tools would also be available at the larger shipyards.

Wood was often sawn into timber at a mill, powered by wind, water or, in the nineteenth century, steam, before being brought to the shipyard. Still, logs would also be squared or cut into deals, planks and boards alongside the slipways. Most shipyards had sawpits or an equivalent above-ground platform on tall saw horses.[119] Whether above or below ground, approximately two metres clearance was required. The timber to be cut rested on a series of beams. A long rip saw with a handle at either end was then used to cut the timber. One man, usually an experienced sawyer, worked guiding the blade from above while another man, often an apprentice, pushed and pulled the saw from below.[120] Smaller hand saws were also used though much of the irregular cutting was done with axe and adze. The shipwright used a variety of axes, characteristically large and with long blades. The ship carpenter's adze was longer and flatter than usual, and was employed with great skill to shape and smooth the timbers. Simple hand planes were also used to smooth or finish the rough work. Draw shaves up to 45 centimetres in length were also used for trimming masts and spars, while other fine work was done with large chisels. For drilling holes, simple shell blade and twist augers of various diameters were used. An important variant was the chest auger, which allowed the craftsman to exert his full weight on the blade. For driving treenails, spikes, bolts and rivets, a variety of hammers and wooden mallets were used. One such specialized tool was the ship maul, a long-handled hammer with a tapered pin on one side of the head.

Another specialized hammer was the caulking mallet, used exclusively for driving caulking irons. This mallet had a long, relatively narrow head fashioned from exceptionally hard species of wood and reinforced at the ends with heavy iron collars. The caulking mallet stands apart from similar tools in that its head is drilled through on either side of the handle. The exact reason for this feature is unclear, though evidence suggests it results from a desire to soften the mallet's sound when striking.[121] As noted above, caulking was performed using a sequence of special chisel irons, each bearing a variety of blades and tips. These were soaked in linseed oil, carried in a wooden oil box, to prevent them from sticking in the seams. Other items used in caulking included a pitch ladle for filling the seams and scrapers for removing the dry excess.

116. A very useful survey of the tools of the shipwright's trade can be found in: R.A. Salaman, "Tools of the Shipwright 1650-1925," *Folk Life*, vol. 5 (1967), pp. 19-51. The particulars regarding the tools included here are derived from this article.

117. In his study of ships' carpenters in New France, Réal Brisson, drawing heavily from notary records and other primary sources, lists seven tools (excluding those used in caulking) as being basic to the trade: La "Scie de travers" (hand saw), La Cognée (short-handled axe), L'Herminette (adze), La "plaine" (draw shave), La Tarière (augur), La "Bisaigue" (a type of chisel), and Le Maillet (wood mallet); Brisson, *Les 100 premières années*, pp. 130-139.

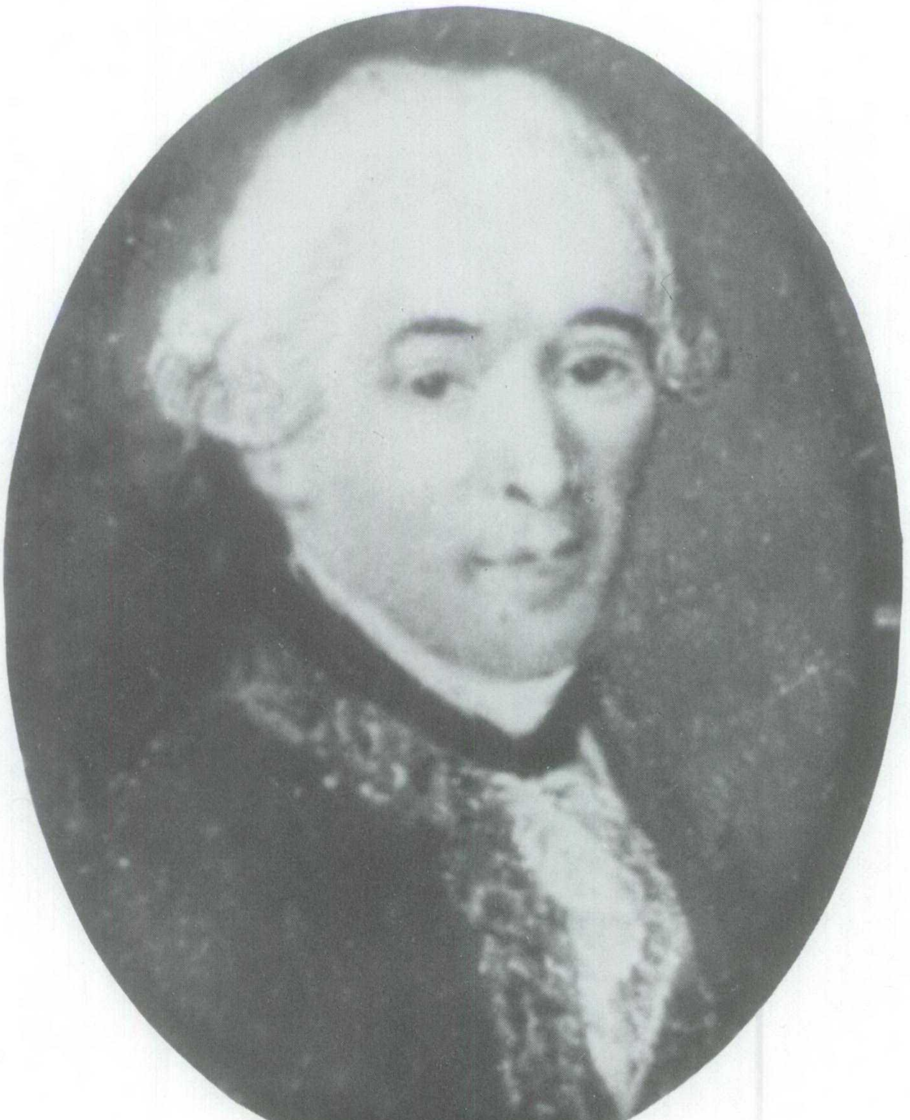
118. *Ibid.*, p. 145.; Richard Unger, *Dutch Shipbuilding Before 1800* (Assen/Amsterdam: Van Gorcum, 1978), p. 61.

119. The manuscript edition of Anthony Deane's Doctrine in the Pepysian Library, Magdalene College Cambridge, includes an image of a shipyard of 1675 in which an above-ground sawing platform is prominent in the foreground (Pepys 2910). Cited in Salaman, "Tools of the Shipwright," plate 3.

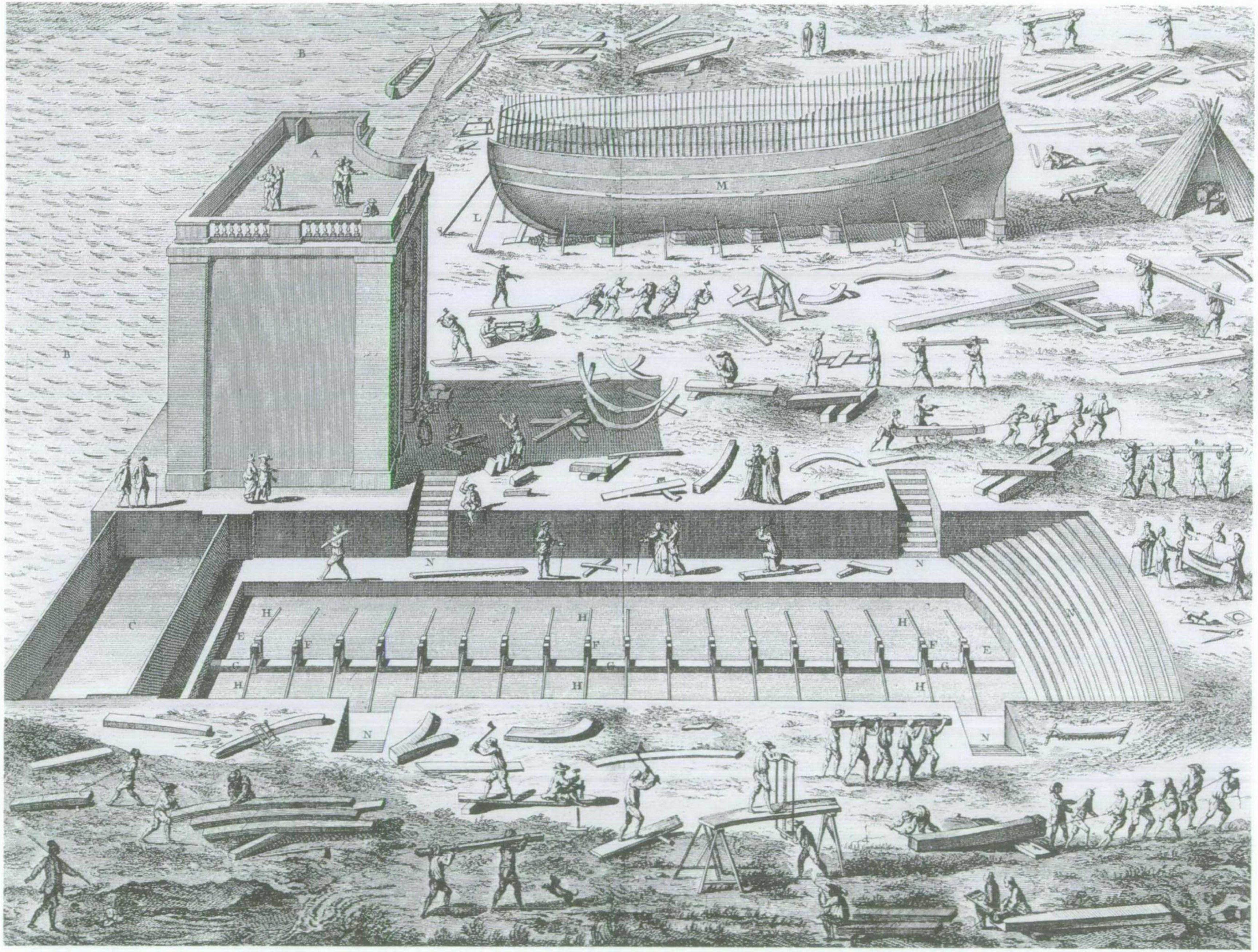
120. Greenhill, *The Evolution of the Wooden Ship*, p. 98. Greenhill cites a case in England in the 1860s where women and girls were used to fill the undesirable role of "pit boy."

121. Salaman, "Tools of the Shipwright," p. 38.

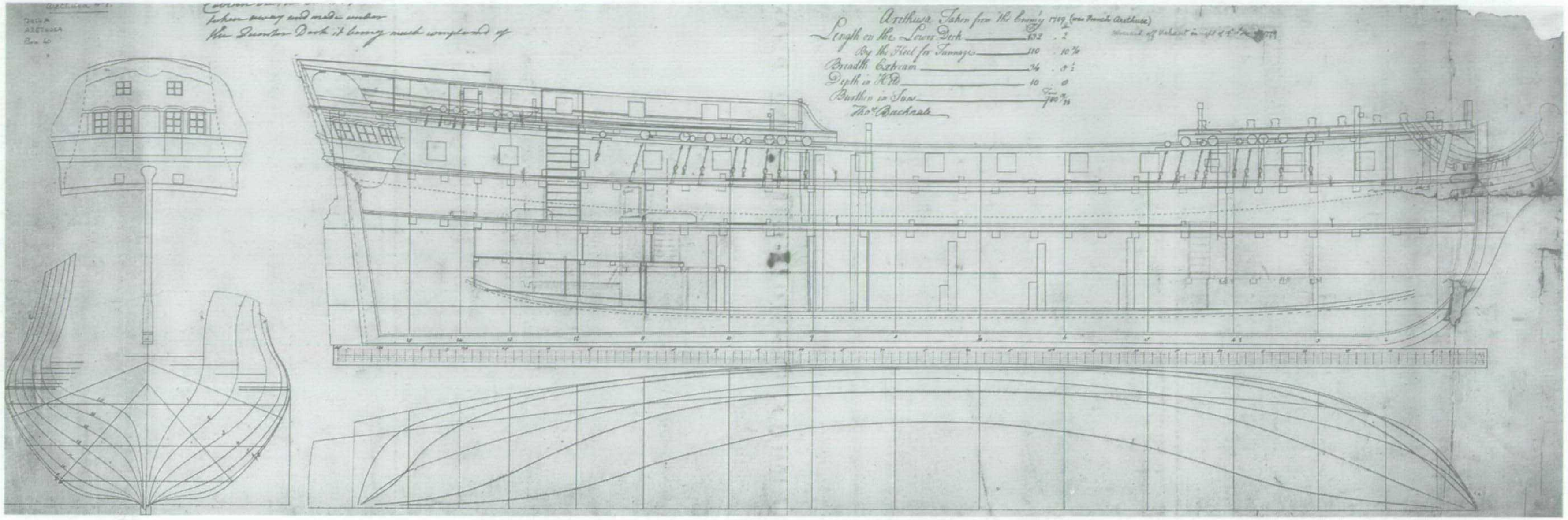
Rigging and sailmaking also required specialized tools which, generally speaking, remained remarkably constant in basic design and appearance from the seventeenth through to the twentieth century. For splicing rope, a tapered wooden rod called a fid was used. These were often fashioned from *lignum vitae.* For metal wire, the equivalent tool was a steel rod called a marlinespike. Where rigging required protection from rubbing, it would be very tightly wound with spun-yarn using a special mallet-shaped tool with a grooved head known as a server, or serving mallet. Wherever rope required hard twisting, a heaver or turning fid was employed to give extra leverage. Heavers resembled wooden tool handles with a half-moon carved out on one side of a flat, squared head. As for sailmaking, the principle tools all related to sewing. A horn or leather cone filled with tallow was commonly used to hold a supply of large needles. To drive these needles through layers of thick sailcloth, a sail-maker's palm was required. This was basically a heavily reinforced leather strap designed to fit snuggly around the hand and thumb. It increased the pushing-power of the craftsman's hand and protected from injury. Finally, a variety of hooks and picks for holding and working material were also standard equipment in the essential business of turning fabric into sails.



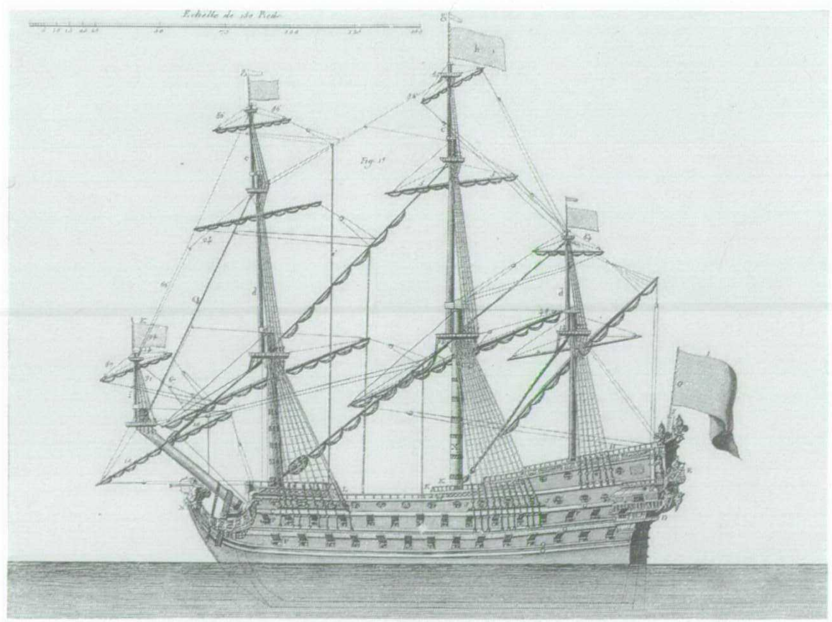
Portrait of René Nicolas Levasseur, the young naval sous-constructeur *sent by the French Crown in 1739 to develop and oversee the new naval dockyard at Québec. (Courtesy of the* Archives nationales du Québec à Québec*).*



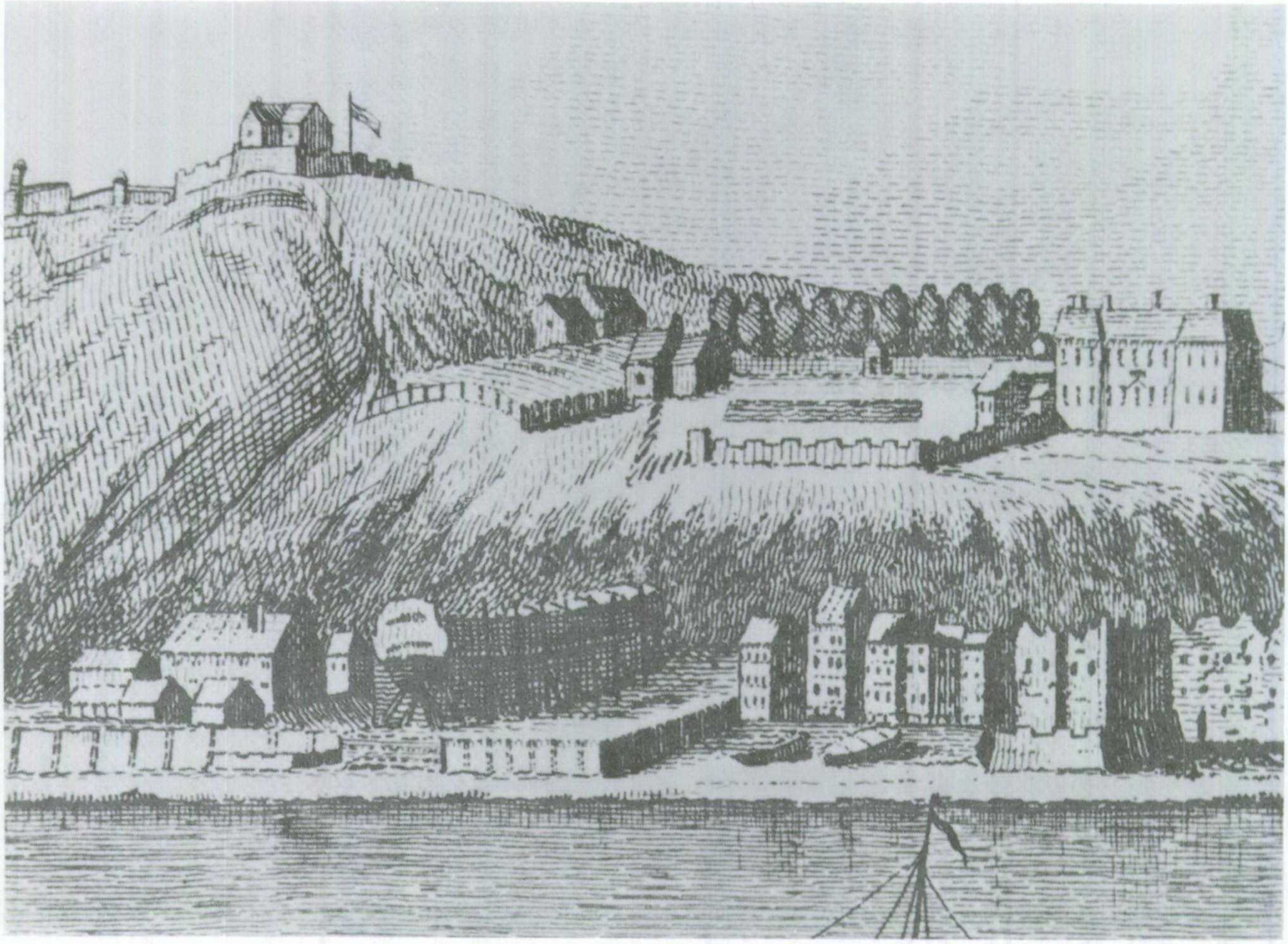
An 18th Century French Shipyard (L'Encyclopedie Diderot, *National Library of Canada*).



An 18th Century lines plan of the French 36-gun frigate Aréthuse. *The* Aréthuse *was at Louisbourg during the seige of 1758. It escaped the seige only to be captured by the British in 1759. (Courtesy of the National Maritime Museum, London, Ships Plans Collection, Foreign Warships, no. 2414A).*



*An 18th Century French Ship (*L'Encyclopedie Diderot, *National Library of Canada).*



Detail from a view of Québec City, by Hervy Smyth (1759) showing the frigate Québec *on the stocks. (Courtesy of Réal Brisson,* Les 100 premières années de la charpenterie navale à Québec: 1663–1763. Québec: Institut québécoise de recherche sur la culture, *1983 p 117.)*

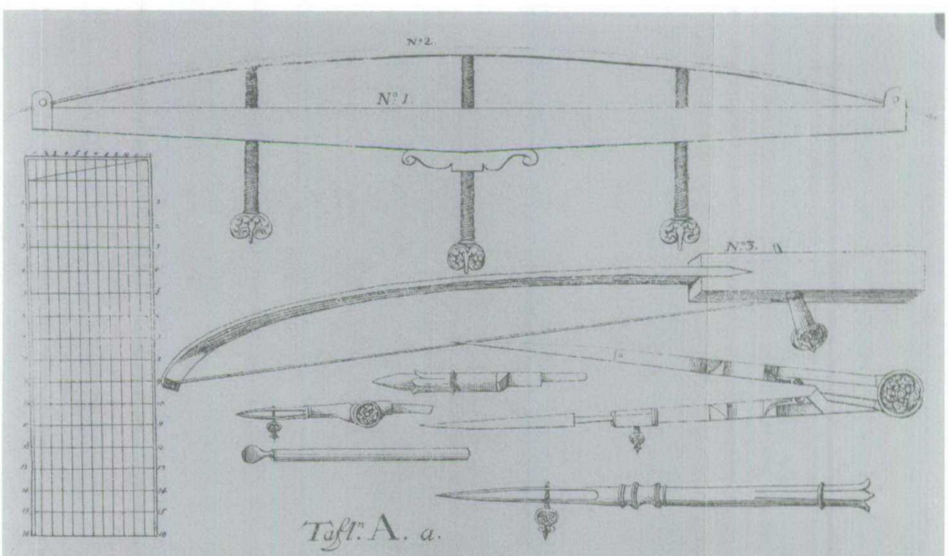


Illustration of instruments for drawing ships lines from the Swedish treatise Skeps Bygerij eller Aldelig Öfnings Tionde Tom *by Åke Classon Rålamb (1691).*

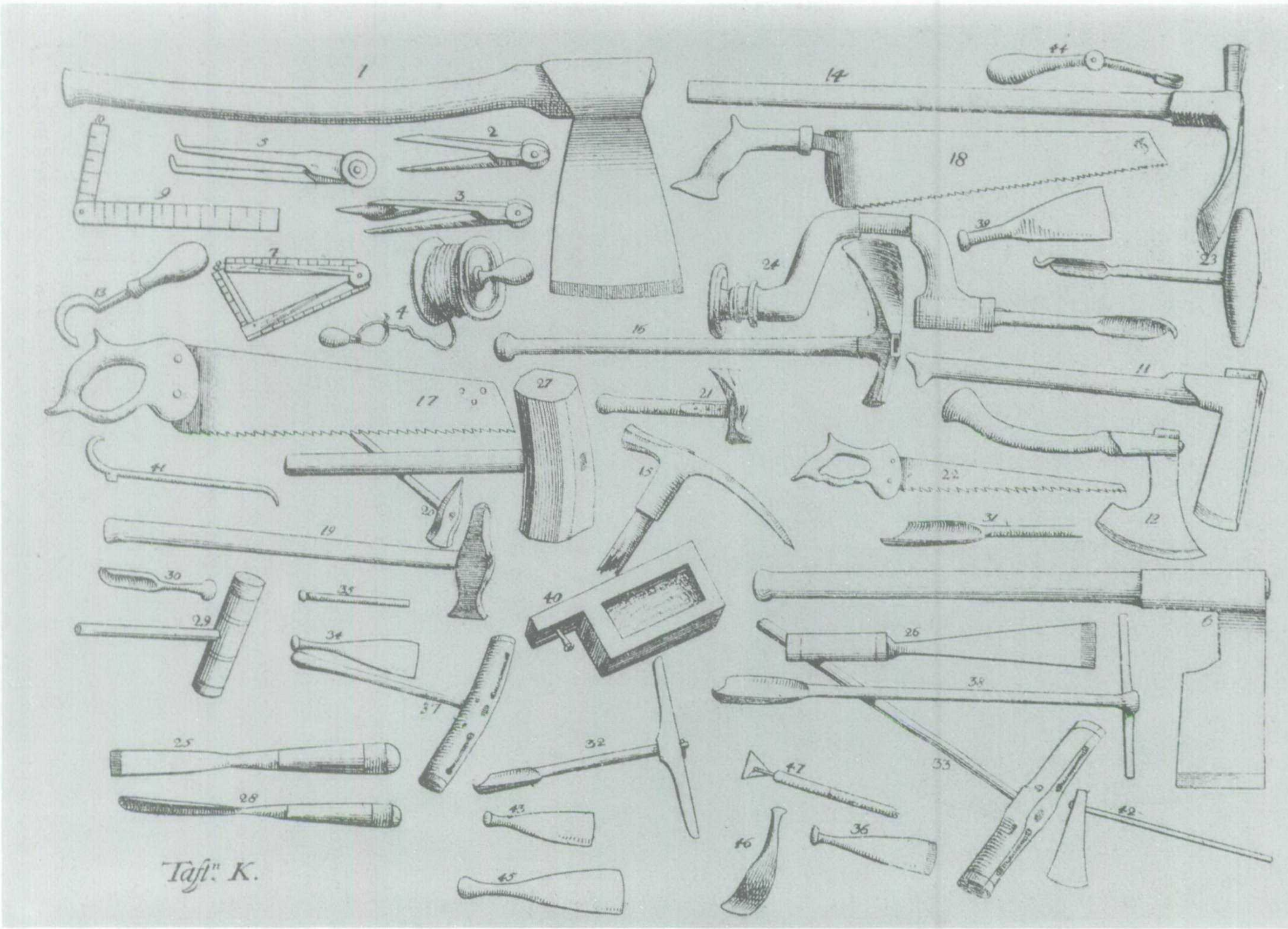


Illustration of shipbuilding tools from the Swedish Treatise Skeps Bygerij eller Aldelig Öfnings Tionde Tom *by Åke Classon Rålamb (1691).*

1) English axe
2) Compass
3) Compass (with marker)
4) Plumb line
5) Calliper compass
6) Dutch axe
7) Folding rule
8) (not shown)
9) Dutch rule
10) (not shown)
11) Swedish axe
12) Broad axe
13) Scribe
14) Adze
15) Adze (side view)
16) Adze
17) English hand saw
18) Dutch/Swedish saw
19) Heavy hammer
20) Hammer
21) Claw hammer
22) Compass saw
23) English screw auger
24) Chest auger
25) Chisel
26) Chisel
27) Maul
28) Chisel
29) Mallet
30) Hand auger, reamer?
31) Auger bit
32) Swedish auger
33) English caulking mallet
34/35/36) Caulking irons
37) Swedish caulking iron
38) English auger for treenails
39) Caulking iron
40) Oil box for caulking irons
41) Oakum hook
42) Horsing iron
43/45/46) Caulking irons
44) Folding scribe
47) Scraper

Chapter 2

Shipbuilding in 19th Century Canada: An Overview

The nineteenth century is often called the "golden age" of Canadian shipbuilding, and with reason — irrespective of the mythical overtones. After little more than fifty years, the underdeveloped, sparsely-populated colonies of British North America became renowned producers and exporters of wooden sailing tonnage. This occurred in close conjunction with the effective harvesting and export of Canadian timber, a staple which would ultimately have an important impact on the country's social and economic development. For the first half of the century shipbuilding was the preeminent manufacturing activity in British North America. Although the last third of the century was a period of general decline in this trade, Canadian-built hulls remained prominent in international shipping. Technologically, the nineteenth century was also a period of dramatic improvement and innovation in ship design and construction, giving rise to mechanically-powered vessels as well as the last and largest generation of merchant sailing ships. These technological changes, driven by developments in Great Britain, ultimately eroded the comparative advantage that access to, and the export of, large quantities of timber bestowed on Canadian shipbuilding. At the end of the century, shipbuilding in Canada had been reduced to a marginal enterprise, despite the dramatic expansion of the nation's industrial capacity.

Britain's supremacy in North America at the conclusion of the Seven Years War initially offered little hope for a major renewal of large-scale shipbuilding in the St. Lawrence valley. The skills and experience developed over a century of French rule remained largely intact, though the opportunity for expansion was initially quite limited. Ships continued to be built along the St. Lawrence, but as a new addition to a larger, more developed empire, Québec's shipbuilding capacity and potential paled in comparison with the circumstances, resources and output of the thirteen American colonies.[122] Along the Eastern Seaboard shipbuilding had successfully developed as a thriving element of the British colonial economy. Blessed with a large, settled population, healthy exports and ready access to essential materials, colonial American shipwrights were in a much better position to exploit the comparative advantage of abundant timber supplies. Serving as both economic catalyst and agent, colonial, American-built ships became an important factor in a robust Atlantic triangular trade. By the start of the American Revolution, fully "one third of the British-owned merchant fleet was composed of colonial built vessels."[123] Yet, all this would change dramatically within a generation. In the wake of the American War of Independence, circumstances altered the context and prospects of shipbuilding along the St. Lawrence and in the region now defined as Canada's maritime provinces.

The violent political separation of the thirteen southern colonies from the less developed possessions of Nova Scotia and Québec elevated the St. Lawrence to the status of Britain's principal North American entrepôt and commercial highway, just as Halifax would become the most important British naval base in the western Atlantic. The revolution also led to a large influx of new colonists, whose numbers and civic culture gave impetus to the settlement of what remained of British North America, a jurisdiction then occupied by scarcely more than 100 000 people.[124] All told, some 40 000 Loyalists travelled north from the new republic to receive land grants under a program of resettlement and support established by the British Government. About three-quarters of this number ended up in Nova Scotia, the core of which would form the colony of New Brunswick in 1784.[125] Another group of Loyalists settled along the shores of the St. Lawrence and Lake Ontario, some of them shipbuilders.[126]

These new arrivals brought the immediate benefits of expanded settlement and latent economic potential, reinforced by the fact that the former colonies to the south were now denied full access to Britain's Atlantic trading network. Yet in the short term, the British North American economy remained dependent upon fishing, agriculture and the fur trade. The fall of the French regime in the St. Lawrence had been little more than a change of management. While it might be argued that Britain's domination of Québec enhanced the colony's mercantile opportunities, the fact remained that the commercial focus of the colony, the fur trade,

122. David T. Ruddel, *Québec City:1765–1832* (Ottawa: Canadian Museum of Civilization, 1987), pp. 122–123.

123. James A. Henretta, *The Evolution of American Society, 1700–1815: An Interdisciplinary Analysis* (Toronto: D.C. Heath and Co., 1973), p. 79.

124. Richard Pomfret, *The Economic Development of Canada* (Toronto: Methuen, 1981), p. 17. For 1770 the following figures are cited: Québec 72 500; Nova Scotia 21 000; and Newfoundland 11 500.

125. J.M. Bumsted, *The Peoples of Canada: A Pre-Confederation History* (Toronto: Oxford University Press, 1992), p. 166.

126. Eileen Reid Marcil, "Shipbuilding at Quebec, 1763–1893: The Square Rigger Trade," (Laval University, unpublished Ph.D. dissertation, 1987), p. 13.

was by nature inimical toward settlement.[127] On the other hand, settlement was certainly not discouraged by the organized harvesting of timber: trees had to be cut if land was to be cultivated and logging was a labour-intensive, largely seasonal, activity.[128] More importantly, at the beginning of the nineteenth century, Britain's traditional supply of essential shipbuilding material from the Baltic was cut off by Napoleon, generating conditions that led British North America to add timber to its short list of major exports.

The growth of the timber trade was the single most important element in the development of nineteenth-century British North American shipbuilding. At the same time, however, other activities, most notably the fishery and the West Indies trade, also fostered a demand for tonnage, though the ships built in these trades were usually of the smaller variety, notably schooners and brigantines.[129] Large-scale shipbuilding, however, developed and concentrated in the principal centres of timber export: Québec and the Loyalist city of St. John, New Brunswick, both situated on the tidal reaches of important river systems. According to the staple model of W.A. Mackintosh and Harold Innis, shipbuilding qualifies as both a backward linkage — the production and export of timber provided an effective basis and comparative advantage for the construction of ships — and a forward linkage — ships were required to export the timber to Britain — of the British North American timber trade.[130] As one scholar has noted,

> *shipbuilding was in many respects an ideal processing industry. It relied primarily on the rich timber resources that British North America had in abundance. It did not require excessive capital outlay for physical plant or materials, and its products could either be sold abroad or employed at home; the "carrying-trade" was a major contributor to any mercantile economy.*[131]

While shipbuilding developed out of the timber trade, timber exports thrived on preferential duties. By 1809, the closure of ports on the eastern Baltic crucial to British naval supply sparked a crisis that brought about the doubling of duties on continental timber in an effort to encourage colonial production.[132] By 1813, a further 25 percent increase was applied and remained in effect until 1821. In that year came the first of a series of partial reductions in these duties leading to their elimination in 1851 and final removal in 1860.[133] The impact of the preferential tariffs is evident in the fact that, before 1840, timber from Canada sold in England at thirty shillings to two pounds per load lower than the equivalent Baltic product, though the former generally cost about ten shillings per load more to cut and ship to market.[134] Such was the success of these duties in stimulating the British North American timber industry that "in every year from 1816 to 1846 Canadian timber accounted for at least 60 percent of all British imports of unsawn timber and in most years for over 75 percent."[135] Much of the additional real cost of Canadian timber owed to freight rates, although "reductions corresponded fairly closely both in timing and in amount with the reductions in the duties, presumably a reflection, in part at least, of the anxiety of shipowners to keep their ships employed."[136] Evidence indicates that Baltic producers were willing to pay the additional freight rates to ship their products into England through colonial ports (that is, across the Atlantic and back) in order surreptitiously to avoid these duties.[137]

In his examination of nineteenth-century shipbuilding in British North America, Richard Rice identified four primary means by which the timber trade promoted the construction of colonial tonnage:

1) the creation of a high volume of trade between Great Britain and its North American colonies;

2) the provision of large quantities of low cost shipbuilding timber;

127. For a concise account of the commercial culture — or lack thereof — in New France, see James Pritchard, "Commerce in New France," *Canadian Business History: Selected Studies, 1497-1971* (Toronto: McClelland and Stewart, 1972), pp. 27-43.
128. The promotion of land clearance and settlement as a direct by-product of timber production was also a factor in the establishment of preferential duties; Arthur R. M. Lower, *Great Britain's Woodyard: British America and the Timber Trade, 1763-1867* (Montréal: McGill-Queen's University Press, 1973), p. 55.
129. The influence of the fisheries on shipbuilding is particularly evident in the fact that from 1776 until about 1830, shipbuilding output in Newfoundland was greater than, or comparable with, that of the other colonies of British America. Rice, "Shipbuilding in British America," p. 11; see also Eric W. Sager and Lewis R. Fischer, *Shipping and Shipbuilding in Atlantic Canada, 1820-1914* (Ottawa: Canadian Historical Association, 1986), pp 4-7.
130. Eric W. Sager and Gerald Panting, "Staple Economies and the Rise and Decline of the Shipping Industry in Atlantic Canada, 1820-1914," *Change and Adaptation in Maritime History: The North Atlantic Fleets in the Nineteenth Century* (St. John's: Memorial University of Newfoundland, 1985), p. 5.
131. Bumsted, *The Peoples of Canada*, p. 213.
132. Lower, *Great Britain's Woodyard*, pp. 54-55.
133. *Ibid.*, Chapter 8, Lower here provides a very concise account and explanation of the rise and fall of these preferential duties. Another very useful article is J. Potter, "The British Timber Duties, 1815-1860," *Economica*, vol. XXII (London: The London School of Economics and Political Science, 1955), pp. 122-136.
134. Potter, "British Timber Duties," p. 125.
135. *Ibid.*, p. 124.
136. *Ibid.*, p. 126.
137. *Ibid.*, pp. 131-132.

3) the concentration of export activity in locations also well-suited to shipbuilding, and;

4) the promotion and integration of related businesses.[138]

Of these four, Rice placed greatest importance on the last, arguing that such related businesses were "the agencies of the economic factors.... In form they were certainly not new, but what was unprecedented was their brute number and pervasiveness. Every stage in the trade was characterized by a more or less large number of capitalistic enterprises."[139] Rice's point is well-taken, yet all four factors were closely connected. Indeed, in recognizing the generation of export trade and the provision of abundant shipbuilding material as important components in the relationship between the timber trade and shipbuilding, Rice simply acknowledges the linkages defined in classic staple theory. Fueled by a growing demand for wood in England, the export of timber from British North America expanded from some 98 900 tons in 1808 to over a million tons by 1847.[140] To carry this freight, "up to a fifth or more of all British registered tonnage was engaged."[141] This increase in trade required the construction of new ships. Return voyages carried a variety of processed or manufactured goods and, most importantly, provided a relatively inexpensive means of transport for the growing numbers of emigrants.[142] In meeting the demand of British shipowners, the shipbuilders of Québec and the Atlantic colonies could also capitalize on the comparative advantages of timber prices, market access, duty-free imports of vital materials and the benefit of a guaranteed cargo en route to the largest shipping market in the world. The close relationship between shipbuilding and this lucrative export staple had the further benefit of encouraging British North American shipwrights to specialize in vessels of a size and quality so well-suited to the carriage of timber that they became the preferred product among shipowners with an interest in this trade.[143] In fact, these same shipowners were often outspoken defenders of the timber duties.[144]

Reference to the size and quality of the ships built for the timber trade invites a short reflection on the nature of British North American shipbuilding.[145] The carriage of bulk goods like timber called for very large, capacious hulls capable of trans-Atlantic passage. Notwithstanding the fame of a ship like the *Marco Polo*, British North American vessels were usually designed with speed as a secondary consideration, though it has been argued that they were faster sailers than equivalent European-built merchantmen.[146] Yet the same softwood construction which might have added to their speed, also contributed to the inferior classification of British North American-built vessels, although in some cases they may have suffered from longstanding and self-serving prejudice regarding the overall quality of colonial

138. Rice, "Shipbuilding in British America," pp. 55-56. Another noteworthy factor, suggested by Prof. L.R. Fischer in private correspondence with the author was the transfer and accumulation of capital, though this might also qualify as part of number four in the list presented here.

139. *Ibid.*, p. 62.

140. *Ibid.*, p. 56, footnote 1. Rice takes his figures from records of the London Customs House, cited as Customs 36/5/58, G.B. Parl Papers, XVII, 178; 1847, LX, 134; and 1854, LXV, 364.

141. *Ibid.*, p. 57.

142. Pomfret, *The Economic Development of Canada*, p. 25.

143. R.S. Craig, "British shipping and British North American shipbuilding in the early 19th century, with special reference to Prince Edward Island," *The South-West and the Sea* (Exeter: University of Exeter, 1968), pp. 26-27. The building of vessels with the specific intention of transporting timber took its most extreme form in the building of two huge (by contemporary standards) raft-ships, the *Columbus* of 1824 (3 690 tons) and the *Baron of Renfrew* of 1825 (5 294 tons). See Eileen Reid Marcil, "Ship-rigged Rafts and the Export of Québec Timber," *American Neptune*, vol. 48, no. 2 (Spring, 1988), pp. 77-86; F. W. Wallace, *Wooden Ships and Iron Men*, pp. 14-17 and pp. 324-327.

144. Lower, *Great Britain's Woodyard*, p. 99. The actual political power of the British "shipping interest" in this period has, however, been seriously questioned by Sarah Palmer in her book *Politics, Shipping and the Repeal of the Navigation Laws* (Manchester: Manchester University Press, 1990), especially pp. 21-39.

145. Regarding size, the problem of tonnage measurement in the nineteenth century stems not from the obscurity of the measurement formula, but from the existence of three distinct usages: Old Measure (1773-1835), New Measure (1836-1854) and Moorsom (1855-on). In his thesis on British North American shipbuilding, Richard Rice addresses this problem directly. After explaining the difference in calculations, Rice observes that, "we are thus confronted in the series of shipbuilding data with figures which, in the strict sense, are not comparable over the entire period, but only within periods in which the same tonnage measure was utilized... . On a less rigourous basis, however, it is clear that the three measures were sufficiently similar to allow us to rely on the long series for indication of the general magnitudes in output, provided we recall that New Measure tended to overstate and Moorsom understate British American tonnages compared with the Old Rule." Rice, "Shipbuilding in British America," pp. 22-26.

146. For the story of the *Marco Polo*, the classic text is Frederick William Wallace, *Wooden Ships and Iron Men*, Canadiana Reprint Series, no. 56 (Belleville: Mika, 1976), pp. 44-53. A more technical analysis can be found in David R. MacGregor, *Merchant Sailing Ships 1850-1875* (Annapolis: Naval Institute Press, 1984), p. 47. The argument regarding the superior sailing qualities of British North American ships is found in Craig, "British shipping and British North American shipbuilding," pp. 26-27.

construction.[147] The effective life span of "colonial-builts" was usually limited to Lloyds A1 for seven years, although timber, the staple cargo of so many British North American ships in the first half of the century, was among the less dangerous and demanding of cargos.[148] The comfort and safety of the emigrants who often made the return voyage to North America in these hulls was entirely another matter. Some ships, particularly in the early era of the timber trade, were built and rigged to a minimal degree of finish before being loaded with wood and sent to England. Once across the Atlantic, owners could draw upon English labour and materials to provide whatever additions, refinements or finishing touches were deemed necessary or desirable. But with the posting of Lloyds officials in British North America starting in 1852, standards of construction rose steadily.[149]

In rig, the form most favoured for the long-distance, high-value trades was the true ship, a vessel with three masts, each equipped with a sequence of square sails. While ships of well over 1 000 tons were built, particularly in the later years, the average was around 500 tons. Barques — vessels with three or more masts square-rigged on all but the mizzen — were built to a similar size but were more common.[150] Timber export, though the driving force in the rise of British North Americian shipbuilding, was by no means the only trade for which vessels were built. As part of the general increase in economic activity engendered by increasing trade and settlement in the first half of the nineteenth century, shipbuilders, particularly in the maritimes, also answered a demand for brigs (two-masted vessels, square-rigged on both masts) and brigantines (two-masted vessels, square-rigged on the foremast only) of less than 500 tons to be employed in various other services.

A multitude of smaller, usually fore-and-aft rigged, vessels for fishing and local trades were also produced. However, shipbuilding on this scale was, as Rice noted, "tied directly to local economic and social relations,... tended to be subordinate to community functions and customs, and (was) thus comparatively insulated from wider market and technological forces."[151] Because this study aims to cultivate an understanding of Canadian shipbuilding in that context of wider market and technological forces, and because the importance of small-scale ship construction beyond a local or regional level is so much more difficult to assess, smaller vessels (for the nineteeth century vessels of 150 tons or less) have been deliberately excluded. Yet it must also be conceded that such production probably constituted from 33 to 40 percent of all vessels built in this era.[152] In the nineteenth century, small-scale shipbuilding clearly represented a very significant part of total production, though its relative value to the shipbuilding economy was probably less than the unit figures suggest. Moreover, the vitality of this sector was largely independent of the timber trade and the various trends associated with that staple export.[153]

With the growing ascendency of laissez-faire economic policy in Britain during the first half of the nineteenth century, the timber duties were slowly removed, beginning in earnest around 1840. Although this loss of preference was gradual and offset in the short term by declining freight rates, the long-term impact on shipbuilding in Québec and the maritimes was aggravated by the repeal of the Navigation Acts in 1849. Nevertheless, shipbuilding in British North America had by this time gained sufficient strength and momentum, despite a number of slumps, it was able successfully to exploit three subsequent episodes of heightened demand before entering a final decline in the 1870s. The first major expansion outside of the timber trade came with the rush to the Californian and Australian gold fields in 1848 and 1851 respectively. Both events required large vessels suited to long sea voyages and capable of fast passages. The demand that resulted from these events diverted existing tonnage and generated a need for more. The emphasis on speed in this instance encouraged the construction of some of the finest British North American vessels.[154] A further surge in demand for tonnage came with the outbreak of the Crimean War in 1854. Fear in Britain that Baltic timber supplies would be interrupted by Russian naval activity put a premium on Canadian timber which, in turn, further stimulated the market for tonnage. Perhaps more importantly, the war effort itself stimulated a substantial increase in the demand for merchant ships. However, the impact of the war was short-lived. The Baltic remained open, steamships gained preference among military planners for transport and supply and American builders became increasingly active in supplying British markets. The deflationary pressure of excess capacity therefore began to take its toll, reducing output for the remainder of the decade and cutting production by almost 50 percent in 1858.[155]

147. Craig, "British shipping and British North American shipbuilding," pp. 26-27; a good discussion of this issue, with specific British opinions cited, can be found in Eric Sager and Gerald Panting, *Maritime Capital: The Shipping Industry in Atlantic Canada 1820-1914* (Montreal & Kingston: McGill-Queen's, University Press, 1990), pp. 62-68. Any quantitative discussion of quality demands reference to registration and classification records. For a discussion of this issue, sympathetic to the grievances of colonial builders, see Eileen Reid Marcil, "Shipbuilding at Quebec," pp. 236-245.

148. Rice, "Shipbuilding in British America," p. 41.

149. Sager and Panting, *Maritime Capital*, pp. 67-68.

150. Rice, "Shipbuilding in British America," p. 96.

151. *Ibid.*, p. 5.

152. Eric W. Sager and Lewis R. Fischer, "Atlantic Canada and the Age of Sail Revisited," *Perspectives on Canadian Economic History* (Toronto: Copp Clark Pitman Ltd., 1987), p. 99.

153. *Ibid.*

154. Wallace, *Wooden Ships and Iron Men*, pp. 42-78.

155. Rice, "Shipbuilding in British America," pp. 82-83 and 87.

The shipyards in the United States were also a factor in the last great expansive period for British North American builders, though the influence was felt by virtue of their relative decline. The strength of American wooden sailing ship industries began to wane in the mid 1850s and the subsequent diversion of manpower and resources caused by the Civil War greatly accelerated the competitive decline of American shipbuilders in British shipping markets.[156] At the same time, the internal preoccupations of the United States created new opportunities for British North American merchants and shipowners, which generated new demand for British American tonnage. This new demand helped to offset the overall rate of decline in the 1870s.[157]

A particularly important market for Canadian shipowners of the day was the expanding trade in American commodity exports in the aftermath of the Civil War.[158] Yet, in the years of transition from colony to dominion, technological change — including improvements in the quality and durability of British American hulls[159] — as well as greater competition from abroad, led to an overall decrease in the construction of Canadian ocean-going tonnage. The colonial timber trade, no longer supported by preferential duties, had lost much of its influence as a stimulant for new ship construction. Indeed, in the last quarter of the century, iron and steel became the preferred materials for the hulls and rigging of large sailing ships, while the important trans-Atlantic trades were increasingly propelled by steam. Britain, with its well-developed industrial infrastructure became the international leader in both these technologies, while Canada remained primarily an exporter and shipper of raw materials and agricultural products. Although there was still demand for wooden sailing tonnage, particularly in the carriage of American staples, the market for such vessels became increasingly marginal towards the end of the century, and as it went, so went Canada's place as a shipbuilding nation.

19th Century Steamship Construction in Canada:

Technological change was clearly an important factor in the declining vitality of British North American shipbuilding. As new technologies, materials and industrial techniques developed over the course of the nineteenth century, the comparative advantage in ship construction passed from timber-rich British North America to the more industrialized United Kingdom, as well as to Europe and United States. Nevertheless, British North America was also influenced and engaged by these developments, particularly the use of steam power. In fact, British North Americans were quick to explore the advantages of steam power for inland navigation, a fact which is understandable given the importance of water transportation to Canada's early development. Thus, while steam-powered vessels ultimately constituted only a small percentage of British North American shipbuilding production in the nineteenth century, the new blend of technologies played a noteworthy part in the early industrial development and settlement of the British North American colonies.

Steam navigation in Canada began in Montréal in 1809 with the the steamship *Accommodation* built by the brewing magnate, John Molson. The immediate inspiration for this vessel had come directly from the pioneering efforts of Robert Fulton on the Hudson River in 1807. However, unlike Fulton's ship, the *Clermont*, which was powered by an English-built, Boulton & Watt engine, both the hull and the machinery of the *Accommodation* were manufactured in Canada.[160] *Accommodation* was, therefore, the first completely North American-built steamship. The vessel was intended for passenger and light freight service between Montréal and Québec, and although it was less than a complete technological success (its engine was rather weak and its boiler needed replacement after only one season), it served to demonstrate the utility and appeal of steam-powered vessels to British North American entrepeneurs.

Economically speaking, what distinguished the building of steamships from the building of sailing vessels was their respective financial requirements. Building wooden sailing vessels demanded relatively little capital outlay and, as Rice has noted, in this line of the business "the shipbuilder had little interest in promoting industrialization."[161] With steamships, however, the opposite was generally true. In an article which directly addresses the economics of early steamship construction in England, Sarah Palmer notes that:

> *for probably the majority of companies and individuals concerned with the business of steam shipping in its earliest days, the most significant*

156. Jeffrey J. Safford, "The Decline of the American Merchant Marine, 1850-1914: An Historiographic Appraisal" *Change and Adaptation in Maritime History: The North Atlantic Fleets in the Nineteenth Century* (St. John's: Memorial University of Newfoundland, 1985), p. 79.
157. Rice, "Shipbuilding in British America," p. 85; also, Lewis R. Fischer, "Historical Background of Atlantic Shipping 1820-1914," *The Niobe Papers*, vol. 4 (Naval Officers' Association of Canada, 1992), p. 13.
158. Keith Matthews, "The Canadian Deep Sea Merchant Marine and The American Export Trade, 1850-1890," *Volumes not Values: Canadian Sailing Ships and World Trades* (St. John's: Memorial University of Newfoundland, 1979), pp. 195-244.
159. Sager and Panting, *Maritime Capital*, p. 65.
160. Larry McNally, "Montreal Engine Foundries and Their Contribution to Central Canadian Technical Development." (Carleton University: unpublished M.A. thesis, 1991), pp. 17-22. It is interesting to note that some of the larger castings for this pioneering vessel may have been provided by the Forges du St. Maurice, a facility whose early development related to the demand for iron in the Québec shipyards under the French regime.
161. Rice, "Shipbuilding in British America," pp. 69-70.

characteristics of such enterprise were the risks attached and the severe financial consequences of failure. Both were a result of the high capital costs involved.[162]

And what was true for England was equally, if not more, applicable to the colonies. The exceptionally high financial costs were almost all related to the machinery of the vessel and "the risks attached" lent a dynamic to the business of building and operating steamships that was absent from the construction of sailing ships. High capital costs and risks, combined with the attraction of new economic opportunities, also generated stiff competition and, on any given route, the trend was always towards collusion, merger and monopoly.[163] The primary market for steamships was the passenger and package trade, and the primary selling point was speed, followed by comfort, both physical and psychological (safety). Indeed, owners were always at pains to reassure their customers that the price of speed was not danger. However, as pointed out in a 1839 British Parliamentary inquiry into the safety of steamship operation, the "competition in speed was so great as to supersede every consideration of safety, economy and prudence."[164] Again, the costs, speed and risks associated with steamships largely resulted from the machinery involved. In this respect, owners — and indirectly, the builders — naturally developed an interest in engine and boiler manufacture. Indeed, in British North America, the connection between steamship construction and early industrialization was particularly strong.

From a technical perspective, steamship building during the first half of the nineteenth century, in Canada as elsewhere, involved two distinct areas of enterprise which contain the roots of the modern distinction between naval architecture and marine engineering. The first concerned the shipwright who provided the hull and superstructure, and the second, the forge operater/engine builder, who produced the machinery. Steamships could be, and were built almost anywhere a slipway could be erected and appropriate materials and labour assembled. Aside from some additional reinforcement of the hull and alterations to the superstructure, early steamships were built using the same techniques and tools as sailing ships. They were often also built to be sailed, if circumstances required. On the other hand, engine construction was a specialized, labour-intensive activity concentrated in only a few urban centres. As a rule, investors would have a hull constructed and order the engine to be built and delivered to the shipyard. With the notable exception of *Accommodation*, for the first two decades of the nineteenth century, British North American steamships had their hulls built in the colonies but were powered by imported, usually British, engines. Eventually, however, local production developed in response to the growing demand. In British North America the focus of this development was Montréal, starting with the Eagle Foundry in 1819.[165] A port city of growing economic influence, Montréal was well situated to serve as a gateway to both the Atlantic and the expanding Canadian interior; the development of steam navigation, in turn, greatly facilitated that role. Other foundries of various sizes were established over the course of the next thirty years, both in Montréal and elsewhere in British North America. Almost invariably, the markets they served were dominated by the demand for marine engines.[166] In short, the early growth of heavy industry in British North America was inextricably related to the demand for steam-powered ships. While it is true that the railways ultimately drained much of the vitality out of the inland steamship business, it is equally true that steamship engine production provided much of the infrastructure and skills required by the various industrial activities associated with Canadian railway construction and westward expansion.[167]

Great Lakes Shipping and Shipbuilding in the 19th Century[168]*:*

The end of naval construction at the Québec dockyard in the 1750s did not bring an immediate end to French shipbuilding at the head of the St. Lawrence. The smaller warships required for service on the Great Lakes could be, and were, built on a more ad hoc basis. The flurry of shipbuilding activity on the Great Lakes during the Seven Years War (eighteen vessels

162. Sarah Palmer, "Experience, Experiment and Economics: Factors in the Construction of Early Merchant Steamships," *Ships and Shipbuilding in the North Atlantic Region: Proceedings of the Conference of the Atlantic Canada Shipping Project, 1977* (St. John's: Memorial University of Newfoundland, 1977), p. 234.

163. *Ibid.*, p. 235. Palmer refers specifically to England, but the same is true of Canada. For a study of early developments along the St. Lawrence, see George H. Wilson, "The Application of Steam to St. Lawrence Valley Navigation," (McGill University: unpublished M.A. Thesis, 1961). For a brief overview of the subject, see Victoria Baker, "Steam Navigation on the St. Lawrence River," *From Sail to Steam: Ships and Shipbuilding in the Regions of Quebec and Montreal* (Saint-Lambert: Le musée Marsil de Saint-Lambert, 1982), unpaginated.

164. *Ibid.*, p. 236. Palmer quotes "Accidents", *British Parliamentary Papers* (1839), XLVII, p. 117.

165. Walter Lewis, "The Ward brothers, George Brush and Montreal's Eagle Foundry," *FreshWater*, vol. 4 (1989), pp. 29–33. Larry McNally, "Montreal Engine Foundries," pp. 24–27.

166. McNally provides a thorough review of early Canadian engine foundries in "Montreal Engine Foundries," pp. 24–46 and 105–111.

167. *Ibid.*, pp. 87–88. As McNally points out, the contribution of the Montreal foundries to the railway industry did not, however, include locomotive construction.

168. Much of this section was originally written by the author as part of the *Great Lakes Historic Ship Research Project* (1987–1989) at the Marine Museum of the Great Lakes at Kingston, and was subsequently published in article form; see Garth Wilson, "The Evolution of the Great Lakes Ship," *FreshWater* Vol. 5, No. 2 (1990), pp. 4–15.

were built by both sides from 1754 to 1759) arose from a limited tradition of small-ship construction which began with the French westward expansion of the previous century. Most of the vessels were less than 100 tons and were fore-and-aft rigged, though there was also a small number of naval brigs built, the largest being the *Iroquoise*, launched at Point au Baril in 1759.[169]

Nevertheless, in the fifty years between the fall of New France and the War of 1812, the typical Great Lakes vessel was small (usually under 100 feet in length), of shallow draft and fitted with a fore-and-aft rig. The choice of a shallow draft was necessitated by the limited depths of the harbours and estuaries around the Lakes while the fore-and-aft rig offered the best windward performance with a minimum amount of manpower. The report of 1788 by the Deputy Surveyor General, Mr. John Collins, to Lord Dorchester, provides some insight into early perceptions of Great Lakes navigation and the context of the tradition that arose there:

> *Vessels sailing on these waters being seldom for any length of time out of sight of land; the navigation must be considered chiefly as pilotage to which the use of good natural charts is essential, and therefore much wanted. Gales of wind or squalls rise suddenly upon the lakes, and from the confined state of the waters, or want of sea room (as it is called), vessels may in some degree be considered as upon a lee shore, and this seems to point out the necessity for their being built on such a construction as will best enable them to work to windward. Schooners should perhaps have the preference as being rather safer than sloops. They should be from eighty to one hundred tons burthen on Lake Ontario and fifteen tons burthen on Lakes Erie and Huron; but if not intended to communicate between these two lakes they may then be the same size as on Lake Ontario, and if this system is approved there can be no necessity to deviate from it, unless an enemy should build vessels of greater magnitude of force, but as the intent of bringing such forward, at least the building of them, can never remain a secret there may be always time to counteract such a design by preparing to meet them on equal terms at least. It does not seem advisable, nor do I know any reason to continue the practice of building vessels flat-bottomed or to have very little draft of water; they are always unsafe, and many of the accidents which have happened on the lakes have perhaps occurred, in some degree, owing to that construction. On the contrary, if they are built on proper principles for burthen as well as sailing they are safer.*[170]

Among the few vessels from this period for which lines plans exist is one from 1802 "of 90 tons proposed to be built at Kingston on Lake Ontario."[171] The plans for this relatively small (length of keel: 53 feet), two-masted vessel were drawn up in Québec, and while it seems doubtful that it was ever built, this design might well be considered as a response to Mr. Collin's report. This is strongly suggested by the draft of the vessel which, at ten feet, is considerable for a ship of this size.[172]

During the era of the Provincial Marine (c. 1765–1813), ship construction on the Lakes was frequently conducted with an eye to the necessity of quick conversion to fighting form, albeit with limited success.[173] The largest vessels of the Provincial Marine, like the 22-gun corvette *Royal George*, built in Kingston in 1808, were purely naval designs, the products of increasing military tension between England and America. When the war on the Lakes started, it intensified the introduction of techniques and expertise from Europe and the Eastern Seaboard of North America. Ship types and designs were imported wholesale into the region, with some adaptation to accommodate local conditions and available materials. The military demand for ships on the Great Lakes reached its apex in 1814 with the building of first-rate ships-of-the-line by both the British and the Americans. Large even by oceanic standards, these vessels were the remarkable product of an inland naval arms race. In the broader scheme of Great Lakes ship design, however, they were aberrations. Indeed, the ships built during the War of 1812 represent a marked deviation from the style and type of vessel which, after the Inland Navigation Act of 1788, was evolving in response to increased settlement and commerce around the Lakes. With the adoption of the Rush-Bagot Agreement, military construction on the Lakes was largely eliminated. Still, the naval building program during the War of 1812 did have a lasting, if indirect, impact on Great Lakes shipbuilding by bringing into the region a pool of skilled labour. The remnants of the work force assembled in the course of the war provided the basis for the significant expansion in private, commercial shipbuilding which followed the cessation of hostilities.

169. For a list of vessels built on the Great Lakes during the French regime, see George Cuthbertson, *Freshwater* (Toronto: MacMillan, 1931), pp. 275–276. Cuthbertson's narrative is, unfortunately, infected by an overt anglo-royalist tone. See also C.H.J. Snider, *Tarry Breeks and Velvet Garter*.

170. Alexander Fraser, ed., *Third Report of the Bureau of Archives for the Province of Ontario* (Toronto: Kings Printer, 1906), p. 363.

171. National Archives of Canada, RG 8M-76703, NMC 18023.

172. *Ibid.*

173. W.A.B. Douglas, "Anatomy of Naval Incompetence: The Provincial Marine in Defence of Upper Canada before 1813," *Ontario History*, vol. 71, no. 1 (1979), p. 10.

The nineteenth century was a period of dramatic demographic and economic development in the Great Lakes region. On the Lakes as elsewhere, this was a century of revolutionary change in shipbuilding. As the population increased and the natural resources of the Great Lakes basin were developed, the shipbuilding industry responded accordingly with growth in vessel size, improvements in technology and a substantial increase in working tonnage. While most sailing vessels built in the Great Lakes region were small by comparison to their ocean-going contemporaries (although a small amount of ocean-going tonnage was also built on the Lakes), their trade activities were crucial to the economic growth of central Canada, and hence to the confederation of colonies which formed in 1867. Moreover, this region's shipping tradition, along with the industrial capacity which subsequently developed along the Great Lakes-St. Lawrence corridor, provided the basis for a full-fledged Canadian shipbuilding industry in the twentieth century.

Most of the opportunities in shipping on the Lakes during the nineteenth century involved the movement of bulk cargo.[174] Initially, commercial activity on the Upper Lakes was largely focused on the fur trade, and to a lesser extent on supplying the needs of the small trading posts and forts of what was then the northwestern frontier. For the most part, this trade was conducted in canoes or by a small number of sailing vessels.[175] On Lake Ontario, however, settlement was more advanced and the extent of the trade in the first decade proportionally greater; by 1810, about 26 privately-operated sailing vessels were engaged in the Lake Ontario trade.[176] Following the War of 1812, trade and commerce in the Great Lakes basin was spurred on by a dramatic increase in emigration. The development of steam navigation in the 1820s and 1830s accelerated the movement of settlers west by providing regular, reliable transportation while the opening of the Erie and Welland Canals in the 1820s greatly facilitated the export of grain and flour, the most important products of the new western settlements.[177] By 1835, 543 815 bushels of wheat were being exported from the Lakes region.[178] Sixteen years later, the figure had climbed to 12 193 202 bushels, a clear indication of demographic and economic growth during these early decades.[179] The eastward flow of grain continued to intensify throughout the century and remains an important component of Lakes trade to this day.

Another prominent bulk cargo in the Lakes trade during the nineteenth century was timber. The clearing of forests was an inherent part of the settlement of the Great Lakes basin. The mixed hardwood and coniferous forests harvested from the Lakes region also met the demands of the ever-increasing North American population and of the booming lumber trade with England via Québec. As discussed earlier, colonial timber (timber shipped from a colonial port) was given preferential treatment in England and the demand for this commodity, though subject to the usual market vicissitudes, was sufficient to ensure the industry's prosperity through much of the nineteenth century.[180] Timber, particularly oak and pine, was carried to the eastern end of Lake Ontario where it was assembled into huge rafts and guided down the St. Lawrence to Québec City. On the American side, the largest market was in Chicago, with Oswego, Buffalo and Toledo also serving as important entrepôts. The demand for timber from the northwestern Great Lakes states continued to grow throughout the century and peaked around 1889.[181]

Ore and coal were also among the most important bulk commodities carried on the Lakes during the nineteenth century. Even though this trade was dominated by the Americans, its impact on shipbuilding technology was felt on both sides of the Great Lakes. The discovery and exploitation of vast deposits of iron ore in the northwestern U.S. Great Lakes region had a tremendous impact on the Lakes trade in the second half of the century. The opening of the Sault Ste. Marie Canal in 1855 and the outbreak of the Civil War with the consequent increase in demand for iron and steel, added great impetus to the shipment of ore. From this remote region, iron ore was carried south and east to the ports and steel mills

174. The classic survey of this subject is found in J.B. Mansfield, *History of the Great Lakes*, vol. 1 (Chicago: J.H. Beers, 1899), reprinted in 1972 by Freshwater Press: Cleveland, Ohio.

175. Ian Stuart, "Early Transportation on the Upper Lakes," *FreshWater*, vol. 2, no. 2 (Kingston: Marine Museum of the Great Lakes, 1987), pp. 16–19.

176. Emily Cain, "Building the Lord Nelson," *Inland Seas*, vol. 41, no. 2 (Vermilion: Great Lakes Historical Society, 1985), p. 122. Mrs. Cain derives this number from William W. Campbell, *The Life and Writings of De Witt Clinton* (New York, 1849), p. 77. See also Emily Cain, "Customs Collection — and Dutiable Goods Lake Ontario Ports, 1801–1812," *FreshWater*, vol. 2, no. 2 (1987), pp. 22–27.

177. Thomas McIlwraith, "Logistical Geography of the Great Lakes Grain Trade, 1820–1850," (University of Wisconsin, unpublished Ph.D. dissertation, 1973).

178. United States Treasury Department, *Communication from the secretary of the Treasury, transmitting, in compliance with a resolution of the Senate the report of Israel D. Andrews on the trade and commerce of British North American colonies and upon the trade of the Great Lakes and rivers* (Washington: Treasury Department, 1854), p. 51.

179. *Ibid.* For a more complete discussion of the American grain trade on the Great Lakes see Thomas D. Odle, "The American Grain Trade of the Great Lakes 1825–1873," *Inland Seas*, vol. 7, no.4 through vol. 9, no. 4 (1951–1953).

180. Douglas McCalla, "Forest Products and Upper Canadian Development 1815–46", *Canadian Historical Review*, vol. 68, no. 2 (1987), pp. 159–98.

181. Randall E. Rohe, "The Upper Great Lakes Lumber Era", *Inland Seas*, vol. 40, no. 1 (1984), pp. 16–29. See also Richard Palmer, "Oswego: Lumber Trade Capital of the U.S.," *Inland Seas*, vol. 40, no. 1 (1984), pp. 30–38.

along the south shore of Lake Erie. Out of these same ports came cargos of coal mined in Pennsylvania. In the second half of the nineteenth century, coal was quickly becoming the primary source of fuel for home heating and for transportation and industry. The greatest coal market for Lakes carriers came from expanding western U.S. cities like Chicago; vessels carrying grain, timber or iron ore from the West could return with shipments of coal. Like grain, the bulk shipment of iron ore and coal continues to be an important source of employment for Lakes ships up to the present day.[182]

The movement of these bulk goods (and others of lesser importance such as copper, salt and pig iron) had a significant and lasting impact on the design, size and types of vessels built on both sides of the Great Lakes. Indeed, the movement of these goods helped to define the special character of the Great Lakes commercial carrier. In transporting high-volume, low-value bulk goods, carrying capacity became the most valued characteristic in hull design. This economic fact tended to determine the general shape of the hull, encouraging a tendency to very full forms. Another, equally important, factor in determining the type of ships built on the Great Lakes was the network of canals. In conjunction with the St. Lawrence system, the opening of the Welland Canal in 1829, and its subsequent upgrades, provided an all-Canadian route from the upper Lakes to the sea. In 1855, the completion of the canal at Sault Ste. Marie provided access to the largest of the Great Lakes. The construction of these canals obviously did much to promote shipping and shipbuilding on the Great Lakes. In design terms, the size of the canals was a crucial determinant of the dimensions of Great Lakes ships. As lock size increased, so did the average hull size. Yet as size increased — and again, size was valued in the bulk trades — the trend toward barge-like hulls grew: long, blunt, narrow and flat.

In contrast to the bulk trades, the transport of passenger and package freight, also an ongoing concern of Great Lakes shipowners, was dominated by steamboats. Steamships first appeared on the Lakes in 1817. While relatively few in number, these vessels were structurally larger and much more elaborate than their sailing contemporaries. Often built for service within a single lake or region, steamboats were initially less influenced (restricted) by canal development. This fact, combined with the pressing demand for speed in the passenger trade, led to hull forms distinguished by their length and extremely fine (sharp) lines. By the middle of the century, however, Great Lakes passenger steamships had lost much of their market to the railways and were therefore confined to more marginal service. At the same time, the increasing use of the screw propeller fostered the development of steam-powered bulk carriers capable of transiting the canals. Once the technology became more affordable and reliable (propellers required a different type and arrangement of machinery that placed new demands on the shipbuilder), propeller-driven ships became more competitive and common in the bulk trades, leading to what would eventually be recognized as the unmistakable form of the classic laker.

182. For a good quantitative analysis of the Great Lakes bulk trades in the latter part of the century, see Samuel H. Williamson, "The Growth of the Great Lakes as a Major Transportation Resource, 1870–1911," *Research in Economic History*, Paul Uselding, ed. (Greenwich, Conn.: Ai Jai Press, 1977), pp. 173–248. See also Jerome K. Laurent "Trade, Transport and Technology: the American Great Lakes, 1866–1910," *The Journal of Transport History*, 3d series, vol. 4, no. 1 (1983), pp. 1–24.

Shipbuilding and Society in 19th Century Canada

Even the briefest survey of nineteenth-century Canadian history will invariably contain some mention of shipbuilding. Reflections of this activity emerge in a wide variety of contemporary documents and cultural artifacts. However vague and romanticized these traces may be, the impression is undeniably one of an enterprise of substantial magnitude. Shipbuilding was also preeminently an economic activity. Unfortunately, the quantitative indicators for accurately measuring the economic impact of this sector — beginning, but not ending, with the question of tonnage — are problematic.[183] Perhaps the best overall quantitative account of the magnitude of British North American shipbuilding is the estimates provided by Richard Rice. Using the British market as a context, Rice notes that British North American ship construction climbed from 8 percent of all British tonnage built at the beginning of the century (the decade from 1797 to 1806), or 48 000 tons out of a total of about 788 000 tons, to a high of 43 percent in the decade from 1847 to 1856, or about 1 343 000 tons out of a total of 3 148 000 tons of production.[184] In the following decade (1857 to 1866), the market share for British North American builders fell by 8 percent, but production increased to an all-time, ten-year high of 1 558 500 tons. By the end of the century (1887–1896), the Canadian share of the British market had dwindled

183. The problems of measuring production are thoroughly examined in Rice, "Shipbuilding in British America," pp. 13–35. The figures presented here should thus be read in the context defined by Rice, as cited in footnote 145.

184. Rice begins his decade-by-decade breakdown in 1787, hence the rather unorthodox ten-year periods.

to a mere 4 percent, or about 243 000 tons. Total production for the 100-year period beginning in 1796 was estimated at about 6 950 000 tons.[185]

While these figures provide a general impression of the importance of British North American shipbuilding to the growth of the British merchant fleet, the economic contribution of shipbuilding to nineteenth century Canada remains obscure. To convert the tonnage production to a gross dollar amount — and approximations are all that can be hoped for — an average of $35.00 dollars per ton offers some measure of the monetary value of this activity.[186] To view this against the product of the entire British North American economy during the best years of tonnage output, a very rough indication can be derived by taking the mean annual production of the peak period, 1857 to 1866 (155 850 tons), and comparing the gross value of that production against the estimated GNP for the year 1860: $5 450 750.00 worth of shipping out of $319 000 000.00 GNP or approximately 1.7 percent.[187] Still, such gross estimates do little to indicate the net economic contribution of shipbuilding throughout the century. Harold Innis, combining his staple approach with an evident fascination for the role of technology in history,[188] has done much to promote the idea that shipbuilding was a "linchpin" of nineteenth century Canadian economic development.[189] This assertion has been seriously challenged, however, first by Peter McClelland — who took direct aim at this notion in his study of the New Brunswick economy — and latter, though less emphatically, by members of the Atlantic Canada Shipping Project.[190]

McClelland's study was confined to New Brunswick. However, in view of New Brunswick's preeminence in British North American shipbuilding by tonnage measure, this provincial study is instructive.[191] As noted earlier, the construction of wooden sailing ships was not intrinsically a capital-intensive activity, and not a focus of large-scale investment.[192] Reviewing shipyard sales and "calculat[ing] to give a strong upward bias," McClelland has noted that the percentage of gross regional product related to shipbuilding was only 3.3 percent and likely improved total gross regional product by only 1 percent, allowing that shipbuilding was 30 percent more profitable than other sectors of the economy.[193] Hence, McClelland argues, "it is difficult to conclude from a comparative statistics case that shipbuilding was a central stimulus to the economic growth of New Brunswick between 1835–1880."[194] More recent scholarship, reviewing the entire Atlantic region (excluding Québec), has generally supported McClelland's conclusions though not his more contentious argument that shipping and shipbuilding constrained regional economic growth.[195] Along the St. Lawrence valley, where the colonial economy grew more diversified as the century progressed, it is hard to imagine that ship construction would have any greater influence than McClelland's calculation for New Brunswick.[196]

In spite of McClelland's comparative statistics, it remains difficult to discount the importance of shipbuilding in the development of the British North American economy. An appropriate analogy might be a catalyst in a chemical formula; its measurable content may be small, but its influence greatly facilitates the outcome. In more emphatic terms, one can argue that McClelland's thesis does not place enough weight on the historic variables, primarily the absence of documents and data, along with the dynamics of social and family relations which can often obscure or otherwise influence strict quantitative measure. After all, quantitative analysis is subject to its own species of romanticism: economic positivism and its underlying assumptions. Even so, the questions surrounding the socio-economic impact of shipbuilding remain. In very general terms, it is safe

185. Here it is worth remembering that Rice is concerned exclusively with large-scale shipbuilding. Moreover, these figures do not include construction on the Great Lakes. Rice does provide some general figures for construction in Ontario on a decade-by-decade basis, though only from 1856 to 1895, amounting to a total of 191 800. The peak period was 1866–75, in which 75 000 tons of shipping were built. These figures are derived from *Journals of the Canadas* and the *Canadian Sessional Papers*.

186. This is a rough average, in post-Confederation Canadian dollars, based on British market prices. It is derived from an informal discussion of the matter with Prof. Lewis Fischer of Memorial University and from the figures provided in Sager and Panting, *Maritime Capital*, pp. 65–70.

187. The figure for GNP is from O.J. Firestone, "Development of Canada's Economy 1850–1900" *National Bureau of Economic Research studies in Income and Wealth 24: Trends in the American Economy in the Nineteenth Century* (Princeton: Princeton University Press, 1960), p. 225, cited in Pomfret, *The Economic Development of Canada*, 2d ed., p. 153.

188. Melville Watkins, "The Staple Theory of Economic Growth," *Perspectives on Canadian Economic Development* (Toronto: Oxford University Press, 1991), p. 80.

189. C.R. Fay and H.A. Innis, "The Maritime Provinces," *The Cambridge History of the British Empire* (New York: Macmillan, 1930), vol. VI, p. 663. Traces of this are evident in very recent general works, such as Bumsted, *The Peoples of Canada*, p. 213. The term "linchpin" used by Innis is interpreted by Peter Dean McClelland as meaning "central to" or "a key determinant of," see P. D. McClelland, "The New Brunswick Economy in the Nineteenth Century," (Harvard University, unpublished Ph.D. dissertation, 1966), p. 232.

190. McClelland, "The New Brunswick Economy"; Sager and Fischer, "Atlantic Canada and the Age of Sail Revisited," pp. 110–115.

191. Rice, "Shipbuilding in British America," Table 2, 1.

192. Sager and Panting, *Maritime Capital*, p. 184. In relative terms, urban shipyards tended to be more captial-intensive than those in rural locations.

193. McClelland, "The New Brunswick Economy," p. 231.

194. *Ibid.*

195. Sager and Fischer, *Atlantic Canada and the Age of Sail Revisited*, pp. 110–111.

196. Unfortunately, the systematic analysis provided for the Atlantic Provinces by the Atlantic Canada Shipping Project and the Maritime History Group has not been extended to Québec.

to conclude that its impact was more keenly felt in the first than in the last half of the century. This activity's relative influence was undoubtedly greater in the formative stages of economic development. Certainly, the production figures indicate that the most dramatic rise in output occurred during the early period, suggesting that this was when shipbuilding's impact was keenest. The logic of the various linkages associated with the rise of the timber trade, as well as the limited population and economic diversity of the region in the first half of the century, also reinforce this suggestion. Similarly, the impact of shipbuilding was probably greater on the local economy of the major building centres of Québec City and St. John than at the colonial level. In so far as these centres were vital in the development of their regions, shipbuilding's contribution to their economic strength should not be understated. Ultimately, these general assertions remain mere impressions since the data required to test them either does not exist or has yet to be thoroughly analyzed. During the latter half of the century the data clearly improves, though the pattern for British North American shipbuilding after 1875 follows a general decline in both relative and absolute terms.

Despite this decline, significant shipbuilding capacity persisted in the Atlantic colonies during the latter half of the nineteenth century, largely as a result of an intensive and profitable period of large-vessel ownership in the region (notably from 1865 to 1878). An international glut in merchant tonnage following the rapid expansion of the early 1850s and 60s, meant that British North American-built ships were much more likely, by force of market circumstance, to remain under local ownership. When in the 1860s freight rates began their rise to record levels and circumstances in the United States generated new and expanding opportunities for shippers, the conditions were ideal for a remarkable (and unique) period of successful and profitable interaction between shipbuilders and shipowners in Canada. For a time, the new federation became, by tonnage, the third largest shipping nation in the world, a fact often noted in the secondary literature.[197] This, however, proved to be the last hurrah for Canadian ocean shipping and shipbuilding in the nineteenth century. Though this distinction clearly resulted from a fortunate convergence of circumstances (inexpensive, available tonnage, expanding American exports and high freight rates), its memory remains a prominent part of the regional mythology and historical consciousness of Atlantic Canada.[198]

Steamship construction was a minor component of the shipbuilding sector and played a less direct role in the development of the economy of British North America than the square-rigger trade. What was important was not so much the extent of steamship construction in British America (the number of ships built and sold or the quantity of trade carried), but the industrial activity it encouraged, and the communications it facilitated. Steamship building was clearly a significant factor behind the introduction of heavy industry in British North America, though perhaps more decisively in the Canadas than in the Atlantic colonies. Unfortunately for the shipbuilders of Québec and the Maritimes, the nature and location of early Canadian industrialization would never give rise to an iron-and steel-shipbuilding industry on a scale that could compete with British capacity. Moreover, as the era of the wooden merchant sailing ship waned, so did much of the influence and importance of Canada's traditional shipbuilding centres. In the second half of the century, with industrialization underway along the St. Lawrence-Lake Ontario corridor, the focus of the British North American economy shifted to the West, along with much of the demographic and political weight.

The rough concurrence of industrial development in central Canada and the decline of Atlantic-based wooden ship construction raises the question of shipbuilding's role in the development of industrial culture and social relations in Canada. The number of men regularly employed in nineteenth century shipbuilding in British North America is difficult to measure. Rice suggests a very rough average, based on a census report for 1851-52, of 180 per yard in the larger centres.[199] Obviously, this number varied according to the size of the operation and the time of year, since shipbuilding was subject to seasonal as well as market cycles. For example, between 1841 and 1842 the number of men recorded as employed in shipbuilding in Québec City dropped from 2 860 to

197. Lewis Fischer, "Historical Background of Atlantic Shipping 1820-1914," *The Niobe Papers*, vol. 4 (Naval Officers' Association of Canada, 1992), pp. 12-13. See also Matthews, "The Canadian Deep Sea Merchant Marine."

198. The greatest reflection of this impact on historical consciousness is the written legacy of Frederick William Wallace. The persistant resonance of this memory in current historical and political discourse is addressed in Fischer, "Historical Background," pp. 11-18. For McClelland's analysis of this episode in New Brunswick, see "The New Brunswick Economy," pp. 200-209. Interestingly, McClelland concedes in this instance that if "net receipts from shipowning compare(d) favourably with those that would have been available in the next best alternatives (...) then shipbuilding may have indirectly contributed to New Brunswick growth, insofar as it contributed to these developments," p. 207.

199. Rice, "Shipbuilding in British America," p 179. In Québec, some ten years earlier, the average among 13 yards was 144; see Ruddel, *Québec City*, p. 135.

1 640.[200] Moreover, much of the work in any given yard was organized and calculated on a day-by-day, project-by-project basis. Peter McClelland, in his study, argued that shipbuilding employed no more than 2.3 percent of the New Brunswick work-force, though it should be noted that the census figures are less than transparent.[201] However, he also notes that "the actual earnings of shipyard workers were (by provincial standards) relatively high."[202] Beyond the slipways, shipbuilding obviously involved, encouraged and sustained a larger percentage of British North American society. This would include the families of those working in the yards and also those who produced or sold materials essential to ship construction. The paucity of evidence makes it difficult to determine the precise extent of this impact, though McClelland again downplays the economic importance of the supply linkages in New Brunswick.[203] On the other hand, a contemporary account from Québec City suggests that, in 1841, the employees of the shipyards (some 2 860 men) directly supported an additional 4 000 to 5 000 people at a time when the City's total population numbered about 32 000.[204]

A large urban shipyard would generally divide labour along established trades: shipwrights, smiths, caulkers, riggers, rope and block makers, and general labourers. Clerks and apprentices were also a fixture of established urban yards. The main structures included the slipway(s), floating docks and gridirons (for repairs), moulding lofts, a forge, a business office and the proprietor's house.[205] The heavier equipment essential to production, the forge tools, steambox, heavy saws (sometimes including steam-powered mills) as well as a variety of blocks, tackles, drags and other general items, constituted the basic infrastructure of the shipyard. All of this was within the purview of the owner, while hand tools, particularly those associated with the specialty trades, were owned by the tradesmen. This division of control over infrastructure and tools underlines the British North American shipyard's identity as an intermediate stage between craft and industry. As the century progressed, the various trades organized increasingly into unions which represented the collective interests of these trades to employers, a process which intensified after 1840.[206] While various strikes are recorded, their lack of success in a context where labour was generally in short supply, strongly suggests that these nascent trade unions had little influence in the workplace, though they may have served to reinforce existing hierarchies within the shipyards.

Labour relations and the labour process are a major focus of Rice's thesis on British North American shipbuilding. He argues that the large colonial shipyard was, and always remained, a "manufactory," distinct from both the handicraft which preceded it and the full-scale industry which eventually followed.[207] The distinction is based on the nature and organization of labour within the yard. Hence,

> *with manufacturing, the various work activities centred upon the crafts are decomposed and reorganised thus introducing a division of labour and fragmentation of tasks, even though the craft remains the foundation of the work. In this process, various kinds of work, based upon the old crafts but now reorganised, become interdependent, and from this there arises the collective worker to whom the individual worker becomes subordinated.*[208]

In many ways, the labour process associated with shipbuilding in nineteenth century British North America was little more than an intensification of the system which characterized the royal shipyards of New France. Infrastructure — the number and size of slipways and outbuildings — was more elaborate, and steam power was a notable addition that supported various shipyard functions. Still, this was largely a difference of degree and the methods, tools and materials of wooden shipbuilding remained essentially the same in the nineteenth as in the eighteenth century. For Rice, however, the most important point is that British North American shipbuilding never became an industry. This distinction is significant in two respects. First, it prevents shipbuilding from being inappropriately included in, and confused with, the early history of industrialization in Canada (the demand for marine steam engines being the only notable link between shipbuilding and industrialization). Second, it clarifies the decline of British North American shipbuilding in the face of British industrial competition and the resulting paucity of Canadian scientific and engineering efforts in this field, about which more will be said later. In other words, by recognizing that British North American shipbuilding never became an industry in the true sense of the word, its failure in the face of competition from industrial shipyards in Britain can be more readily understood. At the same time, any expectation that shipbuilding might have helped foster an industrial culture or full-fledged industrial social relations in Canada ought to be tempered by a recognition

200. *Le Canadien* (12/iv/1841 and 6/iv/1842); *Quebec Mercury* (10/iv/1841 and 4/iv/1842).
201. McClelland, "The New Brunswick Economy," p. 181.
202. *Ibid.*
203. *Ibid.*, p. 196.
204. *Le Canadien* (6/iv/1842). For population growth and area breakdown see Ruddel, *Québec City*, table 2, p. 253.
205. For a good account of nineteenth century British American shipyard facilities, see Marcil, "Shipbuilding at Québec," pp. 181-220.
206. Rice, "Shipbuilding in British America," pp. 186–187.
207. *Ibid.*, pp. 168–169. For a more precise elaboration and discussion of these three stages, see Christian Palloix, "The Labour Process: from Fordism to neo-Fordism," *CSE Pamphlet No. 1: The Labour Process and Class Strategies* (London: stage 1, 1978), pp. 51–54.
208. Palloix, *The Labour Process*, p. 52.

of these limits. As will be shown, the evolution of science in naval architecture was closely tied to the development of industrial shipbuilding. Still, the scientific theories and innovations associated with advances in ship design did circulate, as ideas do, through developing avenues of communication: the print media, higher education and professional associations in Canada. This impact, however, was indirect and is difficult to trace. For aspiring Canadian naval architects at the close of the century, England had become the preeminent source of educational expertise and professional opportunity.

Ship Design and Construction in 19th Century Canada: The Advancement of Science in Naval Architecture

> *"The want of an Institution which should have for its exclusive object the improvement of ships and all that specially appertains to them has long been felt by many professional men."*
>
> *E.J. Reed*
> *Introductory Address to the Inaugural Meeting of the Institution of Naval Architects, January 16, 1860.*[209]

It has become commonplace to associate the nineteenth century with dramatic scientific, technological and industrial development. The substance of this association is a lengthy catalogue of invention, adaptation and innovation. These constitute essential components of what the Whig tradition defines as progress. This Whig view has since been subjected to vigourous reassessment, but the accomplishments remain self-evident. As Asa Briggs put it,

> *the cult of progress was very generally accepted by the mid-Victorians, and the defence of it was put forward by different people at different levels....*
>
> *The simplest defence was a statement of the obvious. Scientific and technical advance in England was visible, it could be measured in figures and summed up in "facts"....*
>
> *The industrial progress which these facts witnessed was indisputable, and it continued to depend on that same inter-relationship of business initiative and technical invention which had made possible the industrial revolution of the eighteenth century. New technical advance stimulated further "improvements," and between the age of Watt and Arkwright and the mid-Victorian epoch there had been many far-reaching discoveries....*[210]

Moreover, in a political equation which linked "progress" to national and imperial power, prominent Victorians, individually and through various institutions, argued for more and greater direct government support for scientific and technological endeavour. There was, in short, much activity and much talk, and in the British realm, this was rarely more serious or intense than when it concerned ships and sea-power.[211]

Strong colonial bonds, improvements in communications (including more frequent and reliable shipping) and a general increase in literacy, did much to ensure that all the relevant activity and talk that originated in England made its way to Canada. Here, the importance of Victorian scientific and technological developments has been widely reinforced by the legacy of Harold Innis.[212] Even in more general, cultural terms, the technological aspects of Canada's history have been identified and celebrated as uniquely important to the formation of the Canadian identity; technology was the principal means by which Canadians addressed a vast and often hostile environment.[213] As a result, the Victorian concept of progress through science and technology still resonates in Canadian historical consciousness, specifically as it pertains to the nineteenth century Canadian experience.

Against this background, it is interesting to note that the advancement of science in naval architecture during the nineteenth century was almost imperceptible for the first seventy-five years. This was true in the United Kingdom. Not surprisingly, reference to science in the design of ships in Canada was even further retarded. The advancement of science in naval architecture in Great Britain coincides chronologically with the decline of British North American shipbuilding. An examination of the reasons for this offers insight into both the nature of nineteenth century shipbuilding and naval architecture, and, more generally, into the relationship of science to the

209. E.J. Reed, "Introductory Address," *Transactions of the Institution of Naval Architects*, 1 (1860), p. xvi.

210. Asa Briggs, *The Age of Improvement* (London: Longman, 1959), pp. 394–395. For a lengthy discussion of the Victorian view of progress and social change, see Peter J. Bowler, *The Invention of Progress: The Victorians and the Past* (Oxford: Basil Blackwell, 1989).

211. Briggs, *The Age of Improvement*, p. 399; Dyson, "The Development of Instruction in Naval Architecture," p. 60.

212. Kenneth Buckley, "The Role of Staple Industries in Canada's Economic Development," *The Journal of Economic History*, vol. XVIII, no. 1 (1958), p. 440. Buckley's concern is with the validity of Innis's staple theory as a theory of economic development and it is in examining this point that he notes the importance of technology, with "special attention to techniques of transportation and communication," in Innis's historical interpretation.

213. A good example of this is found in Northrop Frye's *Divisions on a Ground*, p. 17.

various "improvements" for which the century is so well known.

As noted above, the tools, techniques and technology of wooden shipbuilding in the nineteenth century remained substantially the same as those employed in the late seventeenth and eighteenth centuries.[214] Some innovations and efficiencies were introduced in the construction process, particularly to accomodate the new and larger hull shapes, but the essential stages and aspects of wooden-ship construction remained unchanged. Most of the shipyards which arose in Québec and the Maritimes during the nineteenth century were established by emigrant shipwrights and entrepreneurs, many of whom maintained or later established strong connections with Britain through their involvement in the British shipping market.[215] In basic design and structure, Canadian ships were essentially identical to their British-built equivalents. One notable area of difference concerned materials. As already noted, softwoods were increasingly common in Canadian shipbuilding so as the century progressed and the desired quantity of available hardwood diminished while prices increased accordingly. Iron also became much more prevalent in rigging, strapping, knees and small components, though its use for such purposes also dates back to the previous century. A more dramatic departure came with the construction of composite ships: vessels with metal frames and wooden planking. This type of construction was seriously discussed in Canada, but never fully pursued.[216]

Even though the practice of wooden shipbuilding remained largely unchanged in the nineteenth century, some notable advances were made in sailing ship design. These improvements were most evident in the matter of speed under sail during the so-called clipper-ship era, roughly from 1845 to 55. The main impetus for this sudden concentration on speed was the demand for quick transport to the gold fields of California and Australia. These trades offered rates of return sufficient to allow builders to develop designs which exchanged greater speed for reduced carrying capacity. Here, the focus of attention was hull form. British North American builders were also influenced by, and involved in, this trend. Aside from the above-mentioned *Marco Polo*, the well-known clipper-ship designers, Laughlin and Donald McKay, also had British North American connections. Generally speaking, however, British North American design was influenced more by the prosaic circumstances of the trans-Atlantic bulk trades than by the dynamics of long-distance clipper service.

In response to the demand for faster sailing ships, builders drew largely upon established traditions. Of the three distinct types of extreme clippers, only one was an independent departure from established forms.[217] Some of the theoretical bases for the superiority of the clipper bow had, in fact, been established in the late 1830s through experimental model testing undertaken by John Russel (of *Great Eastern* fame); this work was later rewarded by the Royal Society of Edinburgh. Russel also shed light on the importance of hull length in ship speed.[218] Notwithstanding Russel's efforts and the published ideas of other prominent designer-builders such as the famous American John W. Griffiths, the development of fast sailing ships was still much less the product of science than of craft and emperical experimentation. Even so — and this point deserves emphasis — new knowledge was obtained from these efforts.[219]

The use of lines plans as a primary design tool, though common among naval constructors, was not universally adopted by private builders until the end of the nineteenth century. The reasons relate to the cost and complexity of construction, rather than quality of the product. In private shipyards, particularly those whose production was tied to a specific market — as many British North American yards were — the relationship between innovation and capital risk was generally much less intense than in naval establishments. Furthermore, in commercial shipbuilding, accountability was more direct and less entangled in bureaucracy.[220] As a result, for most private shipyards,

214. See above, "Ship Design and Construction in the 17th and 18th Centuries: the European Origins of Naval Architecture in Canada."

215. As a case study, see Richard Rice, "The Wrights of Saint John: A Study of Shipbuilding and Shipowning in the Maritimes, 1839-1855," *Canadian Business History: Selected Studies, 1497-1971* (Toronto: McClelland and Stewart, 1972), pp. 317-337; see also, Rice, "Shipbuilding in British America," p. 193.

216. "Select Committee appointed to inquire into the General Condition of the Building of Merchant Vessels," *Journals of the House of Commons of the Dominion of Canada* (Nov. 6, 1867 to May 22, 1868), vol. 1, appendix 11. See also, Rice, "Shipbuilding in British America," p. 88. In the U.K., composite construction was "never of great account in terms of tonnage built... and became irrelevant after 1870." David M. Williams and Jonathan Hutchings, "Shipowners and Iron Sailing Ships: The First Twenty Years, 1838-1857," *Research in Maritime History No. 3: People of the Northern Seas*, L.R. Fischer and Walter Minchinton eds. (St. John's: International Maritime Economic History Association, 1992), pp. 115-116.

217. Chapelle, *The Search for Speed under Sail*, p. 322.

218. Dyson, "The Development of Instruction in Naval Architecture," pp. 32-33. In light of Russel's work in the 1830s the claims made for and against the place of the *Scottish Maid* (1839) as the "first" clipper form, suggest an underlying "chicken and egg" type argument: what role did established tradition have on Russel's model experiments and what influence did Russel's ideas have on empirical experimentation and innovation? See Boyd Cable, "The World's First Clipper," *Mariner's Mirror*, vol. 29 (1943), pp. 61-91; David R. MacGregor, *Fast Sailing Ships* (Annapolis: Naval Institute Press, 1988), pp. 99-105.

219. John W. Griffiths, *Treatise on Marine and Naval Architecture* (New York: 1850). For a discussion and scientific reflection on the results of these efforts, see Chapter 8 of Chapelle, *The Search for Speed*, pp. 398-436.

220. David R. MacGregor, *Merchant Sailing Ships 1850-1875* (Annapolis: Naval Institute Press, 1984), p. 113.

the favoured alternative to the lines plan was a three-dimensional equivalent: the half-model. Half-models were essentially carved, scale representations of a design idea. The term itself refers to the fact that only half the hull was represented; since ships are symmetrical, nothing more was required. Half-models were carved either from solid blocks of softwood or, more commonly, from a laminated block made up of even layers of wood held tightly together with long dowels. As instruments of design, half-models served two important functions. First, they provided a three-dimensional scale illustration of the designer's intentions, something a prospective owner could inspect and appreciate. Secondly, and more importantly, the half-model served as a pattern from which full-size moulds of the ship's frames could be derived.[221] The manner in which the lines were lifted from the carved and completed half-model depended on the model type. In the most popular version, the laminated model, the dowels could be removed from the finished block and each layer would then function as a waterline along which scaled-up measurements for each frame station could be easily taken.

In comparing the relative virtues of half-model and lines plans in nineteenth century, wooden sailing-ship design, Howard Chapelle has noted that,

> *except that the model gave a better illustration of the shape of the hull than a lines plan, it produced some difficulties at times. The model could not be quickly and roughly made; it had to be accurate and fair to be an effective design tool. Used alone, there was some awkwardness in taking precise measurements from the model for the displacement calculations. As has been stated, the model and drawing were used by the trained builder. Sometimes the preliminary design was by model, with drawings made from it for the final design; sometimes the lines were first drawn and then checked by model. But use of the model as the mode of preliminary design was the most approved method....*
>
> *A shipbuilder-designer had little time to thoroughly study hull form by means of a lines drawing alone. The supervision of the yard took up most of his time and energy.... Hence, any shortcut in design was attractive, and the model was a superb tool for preliminary hull design.*[222]

Here, it is worth reiterating that there was no inalienable connection between the use of lines plans and the construction of superior ships. Admittedly, the suggestion of such a connection is reinforced by the fact that, when shipwrights engaged in published debates on matters pertaining to ship design, the lines plan was the natural means by which to disseminate any innovation in hull form. In this fact one again finds a good example of the way in which technical drawings served to facilitate theoretical exchange and speculation; in some cases, improvements were indeed acheived through this exchange. Nevertheless, the use of this medium to express an idea did not necessarily amount to an inherently more scientific approach. When ship design did finally become more scientific late in the century, however, lines plans were to prove an essential design medium. Thus, while lines plans became common, standardized tools for naval constructors from the eighteenth century on, and used with increasing frequency by nineteenth century shipbuilders, particularly those with a theoretical bent or those engaged in the more capital-intensive steamship business, their value, in the absence of a more scientific naval architecture, remained mostly educational, bureaucratic and, perhaps, psychological. All of these factors might have indirectly helped constructors build better ships, but did not necessarily lead directly to that end.

The introduction of steam power also fostered new hull designs. Steamships were initially built as sailing hulls equipped with an auxillary steam engine. As steam engines became more reliable and powerful, the hull design of steamships became more specialized, with particular consideration given to speed, or more precisely, hydrodynamic efficiency. The result, beginning in the 1830s was the evolution of a true steamship with a limited number of rigged spars to provide auxillary or emergency sail power. In North America, this trend was most apparent in the construction of passenger and package-freight steamships for coastal or Great Lakes service. Such vessels often relied on large, low-pressure engines — preferred for their safety and simplicity — driving side-mounted paddle wheels. To maximize the speed produced by these engines, shipbuilders developed hull forms characterized by high length-to-beam ratios and shallow draft. In his *Treatise on Marine and Naval Architecture* of 1850, the American theorist, John Griffiths, emphasized the special nature of steamship hull form:

> *There is no analogy existing between the proportions of length, breadth or depth of steamboats, as compared with sailing vessels,... . The reason is obvious to the thinking man — they are required for great speed, which is only attainable by having great length and a sufficiency of breadth to secure the stability of equilibrium, and no more depth that the grand object at which we aim (viz. speed) requires.*[223]

221. For a description of the process, see *Half Hull Modeling*, pp. 4–14, and Basil Greenhill, *Merchant Schooners*, vol. 1 (London: Percival Marshall & Co., 1951), pp. 30–39.

222. Chapelle, *The Search for Speed Under Sail*, p. 284.

223. John W. Griffiths, *Treatise on Marine and Naval Architecture* (New York: 1850), p. 323.

While this long, narrow shape brought speed, its match with a heavy, centrally-placed engine often required elaborate truss-and-arch supports to prevent sagging of the hull structure. To increase carrying capacity, large longitudinal sponsons, extending the width of the paddlewheels, were usually mounted on the hull high enough above the waterline to prevent them from taking on water in heavy seas. The result was a new style of ship, the development of which clearly required some design innovation. Indeed, the records of shipbuilder Robert Gilkison, who lived and worked on the Niagara peninsula in the 1830s, contain some of the earliest examples of a private Canadian shipbuilder using lines plans to develop new designs. Gilkison had come to Canada specifically to build steamships for Lake Ontario; his plans and writings reflect something of the challenges facing a formally educated shipbuilder (Gilkison had been trained in England) in designing this new type of vessel.[224] With the development of compound engines, metal hulls and propellors in the second half of the century, the special shape of the paddlewheel steamship was eventually replaced by less extreme, more versatile hull forms. At the same time, shipyards producing steam-powered, metal-hulled vessels demonstrated a notable trend toward a greater integration of production, with engines, boilers and hull all built at one facility.[225]

The 1840s and 50s also witnessed some very important and well-publicized milestones in ocean-going steam navigation: Nova Scotia-born Samuel Cunard's inauguration of the first regularly scheduled, trans-Atlantic passenger/mail service (1840), and the launch of Brunel's *Great Britain* (1843) and *Great Eastern* (1858), the former the first iron-hulled, propellor-driven ship, the latter a monumental engineering achievement that introduced a number of important technical innovations in naval architecture and marine engineering.[226] In the rich historical traditions surrounding Brunel and these vessels, the notion of a causal link between science and the progress of shipbuilding is most strongly reinforced. Yet these "great" vessels were essentially the products of inspired empirical practice, and although they were sufficiently innovative to provide important points of reference for future builders, neither were the product of scientific naval architecture in the modern sense. Hence, the deficit between experience and understanding remained.

By 1860, this deficit was felt widely enough among concerned individuals in Great Britain to initiate the formation of the Institution of Naval Architects.[227] Even allowing for the usual rhetoric of self-justification at such events, the published proceedings of the initial meeting provide a good impression of the relationship between science and shipbuilding as it then existed. Driven by a consensus of national peril caused by increasing competition for naval supremacy, and conscious of the inconsistencies and inertia which still plagued ship design, much hope was invested in a remedy based on science.[228] Exactly what science entailed and how it could serve was less clear and hardly a point of common agreement. For many in the shipbuilding business, theory, independent of experience, was still viewed with great suspicion. Accordingly, science meant something like experience well-interpreted and widely-shared.[229] For others, however, science in naval architecture clearly demanded the establishment of a reliable set of rules or laws governing the various factors and phenomena which influenced a ship's stability and performance in the conduct of its intended function. These rules had to be universally applicable to the problems they concerned. Speaking to the opening session of the Institution "on the present state of the mathematical theory of naval architecture," Joseph Woolley noted that:

> *it must, unfortunately, be conceded that the mathematical theory of that science [naval architecture] is in a very imperfect state, and that some of the most important and interesting problems have hitherto eluded the grasp of the geometer and physicist. One of the chief benefits to be looked for from the Institution of Naval Architects, which we are inaugurating to-day, is a more systematic inquiry into the laws of nature on which the motions of a vessel at sea depend than has hiterto been attempted — an inquiry that shall furnish to the mathematician satisfactory data on which he*

224. Robert Gilkison, *Diary*: April 24, 1838–Dec. 23, 1839 (Ottawa: National Archives of Canada), MG24 I-25, vol. 2. Copies of Gilkison's lines plans can be found at the Niagara Historical Society and Museum, Niagara-on-the-Lake, Ontario. Another, earlier and more famous example is that of the *Royal William* of 1831, built in Québec by James Goudie who, like Gilkison, had been apprenticed in the U.K.

225. Anthony Slaven, "The Shipbuilding Industry," *The Dynamics of Victorian Business* (London: George Allen & Unwin, 1980), pp. 122–123. As with all aspects of industrial shipbuilding, this integration of engine and hull fabrication was a later development in Canada.

226. Interestingly enough, William Froude, an outstanding figure in the history of scientific naval architecture, was closely associated with Brunel and, more specifically, investigated the pronounced rolling of the *Great Eastern*. Ewan Corlett, "Iron, Steel and Steam," *Five Hundred Years of Nautical Science 1400–1900* (Greenwich: National Maritime Museum, 1981), p. 289.

227. This was, however, not the first time that British interests had attempted to establish an institution dedicated to furthering knowledge of shipbuilding science in England. For a survey of these various endeavours, see Dyson, "The Development of Instruction in Naval Architecture." See also K.C. Barnaby, *The Institution of Naval Architects 1860–1960* (London: Allen and Unwin, 1960), pp. 7–13.

228. Vice-Admiral Charles Yorke, Earl of Hardwicke, "Introductory Address," *Transactions of the Institution of Naval Architects*, 1 (1860), pp. 8–9.

229. *Ibid.*, p. 8.

may found his calculations. The great and hitherto insurmountable difficulty has been the discovery of these laws.[230]

The laws which interested theoretically-minded naval architects principally concerned four areas of enquiry. These are identified by Woolley as displacement, stablility, fluid resistance and centres of effort.[231] As already noted, displacement was the first aspect of ship design to be successfully tackled through geometry and mathematical calculation; while questions remained in this area, it was probably the best understood piece of the puzzle. At the same time, questions regarding horizontal and vertical centres of effort pertained mostly to sailing ships. Although these questions were still important in 1860, and would remain the subject of interest among yacht designers, sail power had already fallen into decline.[232] After 1860, the focus of scientific activity in naval architecture was primarily stability and fluid resistance, and improvements in these areas were the most keenly felt.[233] Interestingly enough, only a year after the Institution foundation, William Froude, a leading figure in the history of scientific naval architecture, presented his first ground-breaking work on ship motion, a question closely tied to dynamic stability.[234] Over the course of the next twenty years, Froude, followed by his son, would go on to lay the foundations of modern ship-hydrodynamics, a principal concern of which is fluid resistance.[235]

If the issue of fluid resistance held the key to designing faster or more efficient ships, stability was the key to building safer ships. Moreover, the absence of stability was more readily detected and usually of greater immediate concern to mariners (and, depending on the size and nature of the investment, shipowners) than resistance. Even in the high-value, low-volume trades, vessels which gained speed (or firepower) at the cost of stablitity would unlikely be of any service to their builders or owners. In Britain, ship stablitity ultimately served as a kind of final threshold, the crossing of which marked the beginning of a complete commitment to science among the shipbuilding establishment.

This is most evident in the development of British warship design, particularly in the controversy surrounding the 1870 sinking of the experimental turret-ship H.M.S. *Captain*. This tragic espisode which cost the lives of 473 men including the ship's controversial inventor-designer, Capt. Cowper Coles, has been carefully examined by David McGee. McGee's thesis is primarily concerned with the social process of design, and how, in the case of the *Captain*, an absence of effective policy combined with political disputes in a climate of growing national urgency undermined the ship's proper conception and construction.[236] From the outset, Capt. Coles' ideas for a turret ship had met outspoken opposition from Edward Reed, the Admiralty's Chief Constructor, a founding member of the Institution and, most importantly in the present discussion, a leading advocate of "naval science" or theoretical naval architecture. However, Reed's party was overruled and the *Captain* was built — incorrectly as it turned out — and sailed despite serious concerns about its stablility. Although McGee makes it clear that this failure was a product of misdirected process rather than a final contest between "amateur" and "professional" naval architects as some would claim, the Court Martial which resulted from the disaster publicly elevated mathematical theory in naval architecture to a status where it became the arbiter of right and wrong in questions of innovative warship design. As McGee put it, "the sinking [of the *Captain*] brought the naval scientists a swift and total victory."[237]

While this and other developments[238] lead to a significant change in the intellectual basis for ship design and construction in Great Britain, their impact on Canadian shipbuilding practice was much delayed and diffuse. The most significant reason for this lies in the all-important relationship between the advancement of science in naval architecture and the industrialization of shipbuilding. As A.R. Hall noted in a paper reviewing the historical evolution of scientific

230. Joseph Woolley, "On the Present State of the Mathematical Theory of Naval Architecture," *Transactions of the Institution of Naval Architects*, 1 (1860), p. 10. For a commentary on this paper within the context of the foundation of the Institution see also Barnaby, *The Institution of Naval Architects*, p. 13.

231. *Ibid.*, pp. 12–36.

232. It is noteworthy that in the inaugural address to the newly-formed Institute, Sir John Somerset Pakington does not fail to mention the schooner *America* when citing reasons for Britons to be vigilant in ship design and construction. Sir John Somerset Pakington, "Inaugural Address," *Transactions of the Institution of Naval Architects*, 1 (1860), pp. 3–4.

233. In reviewing the history of naval architecture for the Fourteenth Dickinson Memorial Lecture to the Necomen Society, A.R. Hall reinforces the central importance of stability and fluid resistance in the search for a more scientific approach to shipbuilding. See A. R. Hall, "Architectura Navalis," *The Newcomen Society: Transactions*, vol. 51 (1979–80), pp. 157–166. Also, Hall begins his paper by noting the frustration expressed by John Scott Russell — famous for his collaboration with I.K. Brunel — over the lack of science in shipbuilding.

234. Corlett, "Iron, Steel and Steam," p. 289.

235. *Ibid.*, p. 290; see also Capt. A.D. Duckworth, ed., *The Papers of William Froude* (London: The Institution of Naval Architects, 1955), pp. xi–xxi.

236. David McGee, "Floating Bodies, Naval Science: Science, Design and the *Captain* Controversy, 1860–1870," (University of Toronto, unpublished Ph.D. dissertation, 1994), p. 10. The author is grateful to Dr. McGee for sharing his insights and advice. See also Barnaby, *The Institution of Naval Architects*, pp. 69–70.

237. McGee, "Floating Bodies," p. 7.

238. A good overview of the salient contributions to the development of theoretical naval architecture in Great Britain after 1860 can be gleaned from Barnaby, *The Institution of Naval Architects*.

naval architecture, "it was not the case that rational shipbuilding made the iron steamship possible: quite the contrary, it was the iron steamship that made rational shipbuilding possible."[239] Setting aside the rather problematic use of the term "rational," the point is that, in the decades after 1870 as industrial shipbuilding developed and shipyard capitalization and infrustructure increased accordingly, science, with its facility for risk reduction and predicatable innovation, became a necessary component of the ship design process.[240] Furthermore, Hall's argument also serves as a salient example of how science often followed, explained and clarified the various technical improvements of the nineteeth century rather than caused them. At the same time, the science of naval architecture that developed in association with the efforts of the Institution and the demands of shipyard industrialization was not, in essence, the science of the laboratory. Instead, it embodied a type of "engineering science" related to but distinct from the more abstract form. This significant distinction, carefully defined by Edwin Layton, is manifest in both the conceptual approach and the final product:

> *Engineering science often differs from basic science in important particulars. Engineering sciences often drop the fundamental ontology of natural philosophy, though on practical rather than metaphysical grounds. ...Engineering theory and experiment came to differ from those of physics because it was concerned with man-made devices rather than directly with nature. Thus, engineering theory often deals with idealizations of machines, beams, heat engines, or similar devices. And the results of engineering science are often statements about such devices rather than statements about nature. The experimental study of engineering involves the use of models, testing machines, towing tanks, wind tunnels, and the like. ...By its very nature, therefore, engineering science is less abstracted and idealized; it is much closer to the "real" world of engineering. Thus, engineering science often differs from basic science in both style and substance. Generalizations about "science" based on one will not necessarily apply to the other.*[241]

Industrial shipbuilding not only necessitated a scientific approach to naval architecture, as Hall suggests, but served to define its essential character to the extent that industry is primarily concerned with the design and production of material things. Similarly, the chronological connection between the ascendence of industrial shipbuilding in Great Britain and the decline of Canadian shipbuilding must be viewed as causal.

Thus, in Canada, where true industrial shipyards were established only after the turn of the century, the demand for scientific naval architecture was very limited. In the absence of full-fledged industrial ship design and construction, evidence of the evolving science of naval architecture in late-nineteenth century Canada can only be found obliquely in vague and diffuse form: namely in the rise of academic engineering and physics in Canadian universities after 1870.[242] In university and through various apprenticeships, Canadian students might well have been introduced to some of the basic principles and equations relevant to and arising from ship design. In Great Britain, where scientific shipbuilding ultimately flourished, the first university chair in naval architecture was founded, by endowment, at Glasgow in 1883.[243] In Canada, a comparable academic commitment to naval architecture would not arise until the last

239. Hall, "Architectura Navalis," p. 170. See also Corlett, "Iron, Steel and Steam."

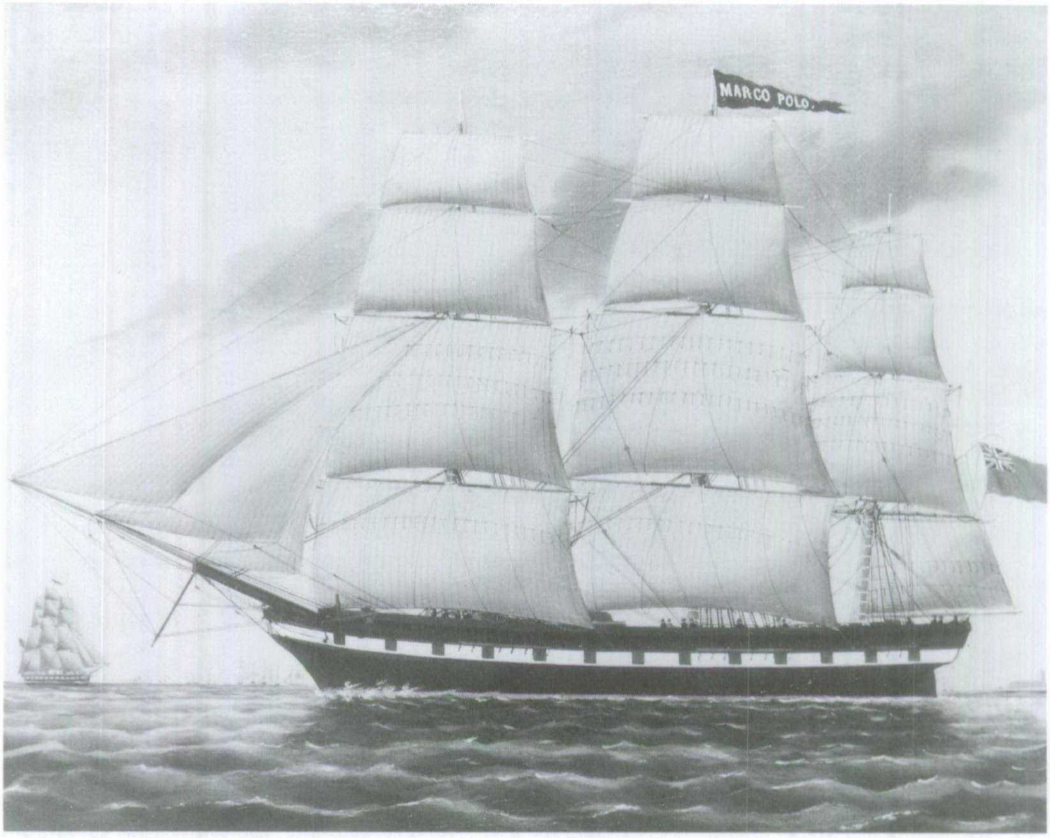
240. The matter of what constitutes "rational" shipbuilding, and the implications the use of this term has for the design and construction of wooden ships, requires careful reflection. Modern naval architecture still contains a creative element, though today that creativity is much more strictly prescribed by established scientific principles. Therefore, if by "rational" Hall is understood to mean ship design and construction based on such principles rather than craft tradition, his assertion makes sense. However, it is evident from the context that Hall's main concern is to subvert the perception that science drove improvements in shipbuilding and, to this end, the phrase is also repeated here.

241. Layton, "American Ideologies," p. 695;. see also Layton's earlier article "Mirror-Image Twins: The Communities of Science and Technology in 19th-Century America," *Technology and Culture*, Vol. 12, No. 4 (October, 1971), pp. 562–580. For a discussion of this distinction in the context of relationship between science and technology, see John M. Staudenmaier, *Technology's Storytellers* (Cambridge: MIT Press, 1985), pp. 103–120.

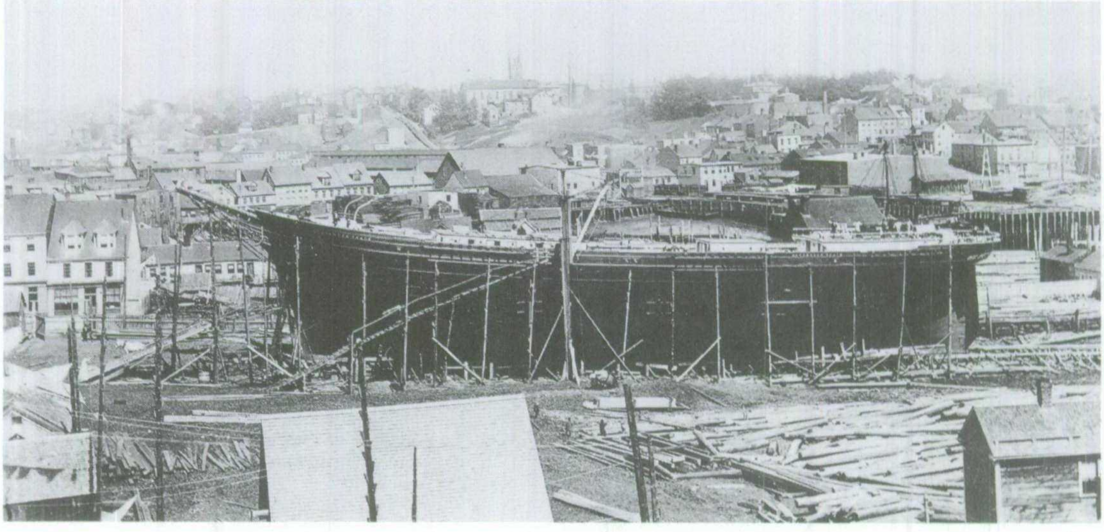
242. Robin S. Harris, *A History of Higher Education in Canada 1663–1960* (Toronto: University of Toronto Press, 1976); Yves Gingras *Physics and the Rise of Scientific Research in Canada* (Montreal & Kingston: McGill-Queen's University Press, 1991). Central to Gingras' thesis is the argument that the study of physics "as a discrete entity" at Canadian universities was brought about by the growth of academic engineering, itself a product of industrial expansion in Canada. In the 1868 calendar for University College, Toronto, statics, dynamics and hydrostatics appear as course material under mathematics and natural philosophy (physics), as well civil engineering. *The Calendar of University College, Toronto* (Toronto: Henry Rowsell, 1869), p. 22 and 18.

243 J.W. Doerffer, "Impact of the Application of Iron and Steel as Structural Material Upon the Development of Science and Technology in Shipbuilding in the XIX Century," *Five Hundred Years of Nautical Science 1400–1900* (Greenwich: National Maritime Museum, 1981), p. 324.

quarter of the twentieth century. Though steel shipbuilding and scientific design began in Canada before the outbreak of World War I, the industry long remained dependant on expertise educated abroad. Indeed, it was only after World War II that the kind of industrial and political forces which had been instrumental in the ascendency of English shipbuilding in the late 1800s finally evolved sufficiently in Canada to inspire the establishment of an academic program in naval architecture.

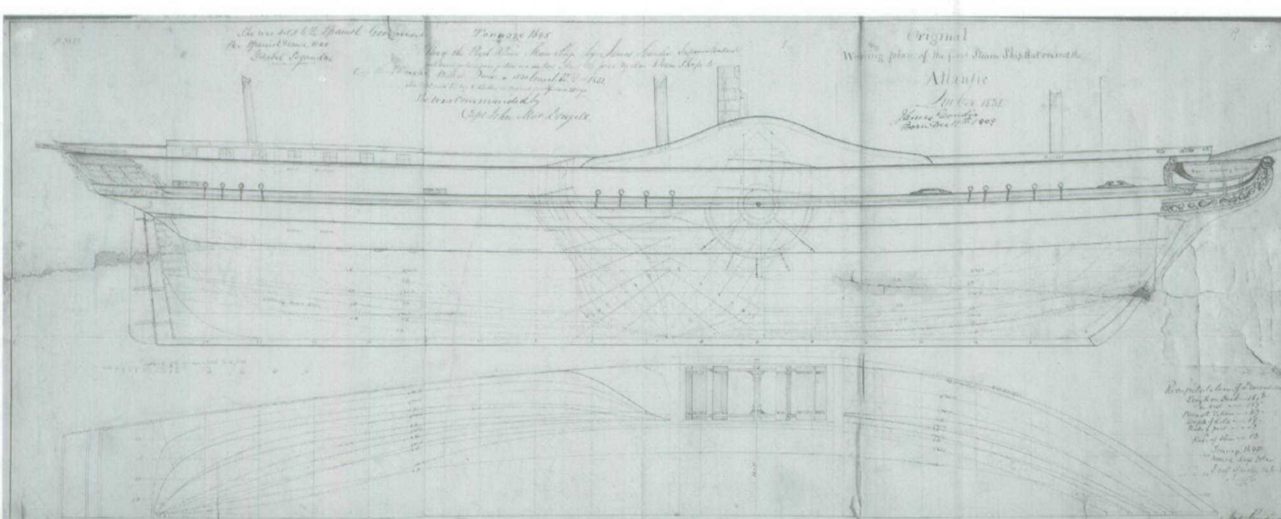


Portrait of the ship Marco Polo *(Courtesy of the Yarmouth County Museum Archives).*

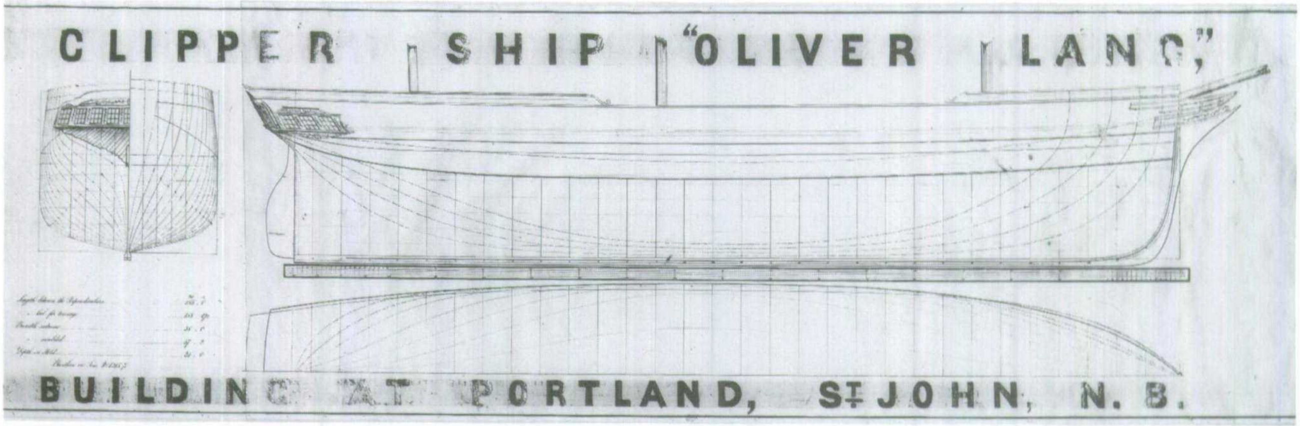


The ship Alexander Yeats *on the Stocks, Portland N.B. (Courtesy of the New Brunswick Museum, neg. no. 54.83).*

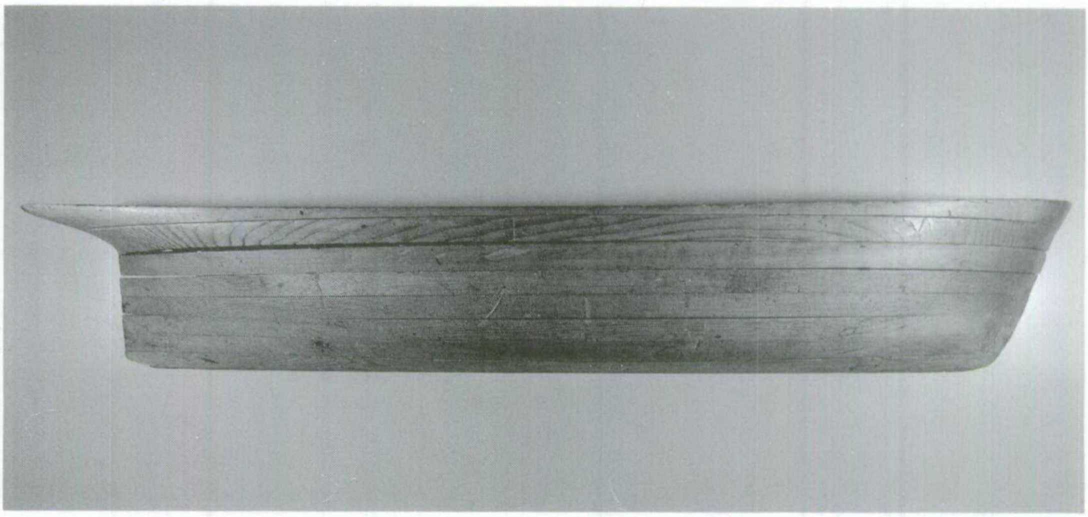
Timber Ships at Quebec, 1872 (Courtesy of the Notman Photographic Archives, McCord Museum of Canadian History, neg. no. 76319-I).



The extra cost and complexity of early steamship construction encouraged builders to develop their designs on paper, using the established format of the lines plan. Here is the lines plan for the famous Canadian steamship Royal William. *Designed in Quebec in 1831 by James Goudie (who had apprenticed in the U.K.). Unprofitable in its intended service between Quebec and the maritimes, it sailed to England in 1833 and thereby made the first transatlantic crossing primarily under steampower. (Courtesy of the Chicago Historical Society).*



Lines drawing for the ship Oliver Lang *built in St. John, N.B., 1853 (Courtesy of the New Brunswick Museum).*



A typical 19th Century shipbuilder's half-model (Collection of the National Museum of Science and Technology).

Edward J. Reed (1866), a founding member of the Institution of Naval Architects and a leading advocate of scientific naval architecture in Victorian England. (Courtesy of the Illustrated London News Picture Library*).*

Chapter 3

Shipbuilding in 20th Century Canada: An Overview

The transformation of Canada after 1870 was based primarily on continental growth and industrial expansion. To describe the changes since Confederation as dramatic is to indulge in both understatement and cliché. The story of this expansion has been discussed at length elsewhere and will not be retraced by this study in any detail, except where such details relate directly to the history of the Canadian shipbuilding industry. However, a few salient themes are essential to the context and deserve mention at the outset.[244]

In the 100 years following Confederation, the geographic expanse of Canada grew tenfold. Most significant to the present discussion was the expansion of coastline and access to the Pacific Ocean which resulted from the addition of British Columbia in 1871. An even larger coastal area was added with the adoption of the vast territory of the high Arctic in 1870 (Rupert's Land) and 1880 (the Arctic Islands), a jurisdiction which would later exercise an important influence on Canadian shipbuilding and naval architecture. The addition of Newfoundland and Labrador to Confederation in 1949 extended Canada's coastal expanse further. While the benefits of this expansion were many, the assumption of political responsibility for a coastline extending some 243 797 kilometres (the longest in the world) would require the dedication of significant resources and, more importantly, would provide business for Canadian shipbuilders and an enduring argument for their advocates.[245]

Along with the geographic expansion, Canada also experienced tremendous demographic growth. In 1870, the population of Canada stood at about 3.5 million; by 1914, at 7.8 million, it had more than doubled. Between 1939 and 1991, the population more than doubled again, growing from 11.2 to 27.2 million. This great expansion in population growth was fuelled in large measure by immigration, the single most intense period of which was from 1900 to 1914 and was closely associated with the development of the wheat-growing economy of the Canadian Prairies. This influx continued to be dominated by citizens of the United Kingdom and the United States, but also involved a substantial number of Eastern Europeans whose presence and regional concentration began to give the land the beginnings of the multi-culturalism that would later comprise a prominent demographic feature of Canada. Indeed, after a downturn in immigration caused by the Depression and Second World War II, Canada began to receive immigrants from a wide variety of European countries and, in recent decades, less-developed nations. Early settlement was promoted (both literally and figuratively) and facilitated by the building of national transportation and communication networks, most notably the transcontinental railway system. The development of the Canadian West early in the century shifted the focus of domestic economic activity inland, away from the established nineteenth century centres of shipbuilding. This both confirmed the decline of the Atlantic shipyards and stimulated maritime activity along the Great Lakes and St. Lawrence River. While immigration drove population growth in the twentieth century, the balance between rural and urban inhabitants shifted decidedly in favour of the latter after 1921. The chief causes of this were economic. In the twentieth century, Canadian industry expanded in size and diversity, with growth being most heavily concentrated in the large towns and cities of central Canada. There labour was most readily available and markets most accessible. Industrial growth, in turn, spawned the need for services and infrastructure, and the opportunities thus created attracted — and continue to attract — both immigration and emigration to our urban centres.

Canadian industrialization was fostered by protectionist measures undertaken by the federal government beginning in the late 1870s under the Conservative rubric of "The National Policy." Still, the capital required for this growth came largely from foreign, particularly British, investment. World War I distorted this pattern of growth and, among other things, inspired a rapid expansion of shipbuilding capacity. The war also intensified an already apparent shift in Canadian economic orientation from trans-Atlantic to continental. This was particularly evident in the development of the automotive manufacturing sector in the 1920s.[246] Corporate concentration also became more pronounced. World War II confirmed and amplified this shift while also providing a context for dramatic industrial expansion in Canada that was particularly apparent in the shipbuilding sector. After the war, with Europe rebuilding, Canadian industrial growth generally continued, based on access to U.S. markets, a rising

244. For a recent synthesis of this period, see J.M. Bumsted, *The Peoples of Canada: A Post-Confederation History* (Toronto: Oxford University Press, 1992).

245. Thomas E. Appleton, *Usque ad Mare* (Ottawa: Department of Transport, 1968), pp. 45-89.

246. Donald F. Davis, "Dependent Motorization: Canada and the Automobile to the 1930s," *Journal of Canadian Studies*, vol. 21, no. 3 (Fall, 1986), pp. 106-132.

standard of living (then among the highest in the world) and a corresponding increase in levels of consumption. Like manufacturing, the resource economy also grew and diversified, and exports of raw or semi-processed materials remained the defining element of Canada's export economy. Expansion in the resource sector — beginning with wheat — echoed the expansion and growth of the western provinces but was by no means confined to that region. Mining, fishing, and forestry (especially pulp and paper) were all growth areas in the economies of Central and Eastern Canada after World War II. The trans-shipment of western produce together with manufacturing and resource extraction along the Great Lakes and St. Lawrence River was an important basis for the development of a Canadian-built, merchant fleet. Government involvement in the economy also increased substantially in all sectors after World War II, most notably in health, social-welfare, communications and education. The Cold War, and Canada's involvement in the NATO alliance, also influenced public policy and justified government involvement in strategic industries, including shipbuilding. The adoption of Keynesian economic ideas further reinforced the post-war trend of public investment. With respect to scientific research and education, the expansion of the National Research Council along with the dramatic increase in the number and size of Canadian universities after 1945 made it possible for more and more Canadians to participate in the scientific basis of industry and technology. However, in the last quarter of this century, the Canadian economy has proven less buoyant and its latent structural weaknesses — particularly in the industrial sector — have grown more apparent.

From a global perspective, the development of industrial shipbuilding in the final quarter of the nineteenth century was closely tied to improvements and efficiencies in iron and steel production.[247] This was nowhere more evident than in the United Kingdom, where the regions in which metal shipbuilding flourished — most notably the Clyde and the Northeast of England — tended to be areas with an established industrial engineering and metallurgical capacity.[248] Accordingly, the traditional centres of British (wooden) ship construction — most notably the Thames and the Southwest — fell into a decline which, to some extent, mirrored the fate suffered by Canadian builders.[249] In Canada, however, the iron and steel industry was late in developing, having benefited very little from the growth of the railways which, until the end of the century, ran on imported rails. Only in the late 1890s, with market demand growing and new government tariffs and subsidies in place, did iron and steel production increase dramatically.[250] While this evolution shares a rough chronological correlation to early efforts at industrial shipbuilding in Canada, it is difficult to identify any immediate cause-and-effect link between these industries for reasons that will be discussed later. For example, a rolling mill capable of producing steel plate for shipbuilding began operating in Canada only in 1920.[251] Nevertheless, it can be argued in very general terms that the expansion of Canada's economy at the turn of the century — the growth of industry and manufacturing, the continuing expansion of the railways and a general increase in exports centred on prairie wheat — provided a context wherein large-scale metal shipbuilding could be seriously considered and tried. The truth of this argument is suggested by the fact that the origins of industrial shipbuilding in Canada, however tentative, were found in the most industrialized parts of the country (Ontario and Québec), and were closely linked to the main transcontinental arteries of communication and trade.

The first large, steel ship built in Canada was the S.S. *Manitoba*, launched in 1889 at Owen Sound, Ontario for the Canadian Pacific Railway. At 2 616 gross tons, this propeller-driven vessel was designed to serve as a passenger and package-freight carrier between the C.P. terminals at Owen Sound and Port Arthur.[252] Very little is known about the cost of building the *Manitoba*, or the exact reasons for awarding the contract to Polson Iron Works, a company with no previous experience in building ships of this size or quality. Furthermore, no large-scale shipbuilding facility existed in Owen

247. Simon P. Ville, *Transport and the Development of the European Economy, 1750–1918* (New York: St. Martin's Press, 1990), pp. 48–49 and 51–52.

248. See Alastair Reid, "The Division of Labour in the British Shipbuilding Industry 1880-1920," (Cambridge University, unpublished Ph.D. dissertation, 1980), pp. 11-14; Simon Ville, "Introduction: Regional Fluctuations in United Kingdom Shipbuilding in the Nineteenth Century," *Research in Maritime History No. 4 — Shipbuilding in the United Kingdom in the Nineteenth Century: A Regional Approach* (St. John's: International Maritime Economic History Association/Trustees of the National Museums and Galleries on Merseyside, 1993), pp. xi-xii.

249. For a detailed discussion of this decline see Sarah Palmer, "Shipbuilding in Southeast England 1800-1913" and David J. Starkey, "The Shipbuilding Industry of Southwest England, 1790-1913" both in *Research in Maritime History No. 4 — Shipbuilding in the United Kingdom in the Nineteenth Century: A Regional Approach* (St. John's: International Maritime Economic History Association/Trustees of the National Museums and Galleries on Merseyside, 1993). Palmer is exclusively interested in commercial tonnage.

250. Craig Heron, *Working in Steel: The Early Years in Canada, 1883–1935* (Toronto: McClelland and Stewart, 1988), pp. 13–24. Pomfret, *The Economic Development of Canada* (2d ed.), pp. 180-181. Heron gives much less credit than Pomfret to the role of government subsidy in the early development of the industry. In a discussion paper examining the role of tariffs in the expansion of the Canadian iron industry, Kris Inwood argues in favour of an effectual role for tariffs: "Transportation, Tariffs and the Canadian Iron Industry" — Discussion Paper No. 89-3, Dept. of Economics, University of Guelph.

251. Heron, *Working in Steel*, p. 26.

252. The dimensions of the S.S. *Manitoba* were 303 × 38 × 15 ft. The vessel remained in service until 1950.

Sound when the contract was tendered; the yard had to be erected along with the vessel itself. And yet the *Manitoba* proved to be, in many respects, a model of its type and time. It would appear that Polson's was speculating hopefully on an expansion of their established business success in building boilers, engines and steam yachts. Unfortunately, the *Manitoba* proved to be an anomaly, albeit a distinguished one, and steel shipbuilding in Canada languished, remaining more a hopeful idea than a reality until the first decade of the century.[253] For those in need of steel ships, Great Britain remained the primary source, and British yards continued to enjoy delivery of their product into Canada duty-free.

The absence of metal shipbuilding in Canada was not lost on interested observers of the marine trades at the end of the nineteenth century. In a speech to the Maritime Board of Trade, recorded in October of 1898 in the journal *The Railway and Shipping World*, Mr. J. M. Carmichael, cited as "evidence of small enterprise on the part of Provincial shipowners," the fact that the transition from sail to steam, and from wood to iron and steel, had been so readily accepted as the defeat of their business.[254] Mr. Carmichael stressed the need to pursue and foster Canadian shipping in order to provide a basis for industrial shipbuilding, noting that "the more quickly our people get back into the carrying trade, no matter where they get their ships for the first few years, the more quickly will large ship-yards be established here."[255] Convinced that the necessary skills and labour still existed in the Maritimes, a sentiment reflected among those responding to the speech, and that the necessary metal angles and plates could be imported at minor additional expense (an idea supported with several references to the shipyards of Belfast), Carmichael was adamant about the need to protect this latent capacity through the removal of import taxes on a variety of other materials — "forgings, castings, brassware, canvas" — essential to modern metal shipbuilding. The aim was "to make the materials composing ships at any rate as [duty] free as the ships themselves."[256]

Many of these issues were reiterated in the same journal three years later, most notably by Mr. W.E. Redway, the naval architect of the Polson Iron Works in Toronto. Focusing specifically on the question of relative costs, Redway stressed that in materials, the main difference between Canadian and British-built steel ships related less to the hull than to the myriad of internal parts, noting that a modern ship "contains within herself probably a greater diversity of manufactured materials than any other structure."[257] When the duty on such imported items was combined with that applied to large casting and machinery, Redway cited a differential in costs of 25 to 35 percent in favour of the British builder. Here the finger was pointed directly at the system of protective tariffs on manufactured items:

> *however desirable it may be that Canadian makers of these goods should be protected to the extent of this preference during the earlier stages of manufacture, and until an increased demand will justify its discontinuance, that does not make it any easier in the meanwhile for the shipbuilder who has to compete with those who can obtain the same articles at 25% less cost. It is true that a Customs tariff of 25% on machinery and 10% on the hull is levied on new ships purchased abroad and registered in Canada which, apparently, is so much in favor of the Canadian builder, but this is purely a negative concession, and is really operative only as to ships purchased in the U.S., because British ships registered in Britain or Newfoundland are not subject to the tariff, and, consequently, are brought in freely, clear of duty.*[258]

In labour costs, Redway reported a further disadvantage for Canadian builders of between 12.5 and 15 percent. Still, Redway was more sanguine than Carmichael about the state of the internal market for shipping (perhaps reflecting the contrasting reality of their respective regions) noting that "many steamers

253. Michael B. Moir, "Franklin Bates Polson," *The Dictionary of Canadian Biography*, vol. XIII (Toronto: University of Toronto Press, 1993), pp. 841–842.

254. "Iron Shipbuilding in the Maritime Provinces" *The Railway and Shipping World*, (October 1898), p. 217. (This journal, retitled in 1906 as *The Railway and Marine World* and again in 1912 as *Canadian Railway and Marine World* will henceforth be referred to simply as *RMW*. As of January 1937, however, the journal further broadened its mandate and became *Canadian Transportation*, hereafter, *CT* (see bibliography). J. M. Carmichael was the son of James William Carmichael, the prominent shipowner, businessman and politician from New Glasgow, N.S. Among other things, the Carmichaels "pioneered the construction of steel steamers in Nova Scotia...(the)...largest being the 485 ton Mulgrave,... built in 1893 for Carmichael's firm." L. Anders Sandberg, "James William Carmichael," *The Dictionary of Canadian Biography*, vol. XIII (Toronto: University of Toronto Press, 1994), p. 170.

255. "Iron Shipbuilding in the Maritime Provinces," p. 217.

256. *Ibid.*, p. 218. Parenthesis mine. Here it is worth remembering that New Glasgow, Carmichael's home town, was also a centre of early Nova Scotia iron and steel production: Heron, *Working in Steel*, p. 16.

257. W.E. Redway, "Steel Shipbuilding in Canada," *RMW* (April 1901), pp. 122.

258. *Ibid.*, p. 123. It is interesting to note that James William Carmichael opposed measures to restrict the Canadian practice of registering ships in Britain which Redway here criticizes; Sandberg, "James William Carmichael," p. 170. The detrimental effects of allowing British tonnage to enter Canada duty-free is echoed again on the West Coast by the Victoria Board of Trade as late as 1912; see "Shipbuilding in British Columbia," *RMW* (November 1912), p. 586.

have been brought into Canada during the past 10 years from Britain sufficient in number and importance to have permanently established steel shipbuilding had conditions been favourable for building them here."[259] To establish those conditions, Redway called for intervention and investment by the federal government. Describing iron and steel production as the sine qua non of all industrial growth, Redway argued (while no doubt thinking of the English Northeast and the American Great Lakes trade) that the shipbuilding and metallurgical industries were mutually supportive enterprises: ships had to be built to carry iron-ore and coal to steel plants which, in turn, would supply the demands of industry and, hence, the shipyards.

Despite Redway's concerns, 1901 marked an important year in the history of industrial shipbuilding in Canada. In this year, The Collingwood Shipyard and Drydock Co., on Georgian Bay, launched the first in a long line of steel ships: the 340-foot, 3 330 ton passenger and package-freight vessel, S.S. *Huronic*, designed by Collingwood manager Hugh Calderwood for the Northern Navigation Co.[260] Shipbuilding first began in Collingwood in the late 1850s, and a drydock was subesquently built there in 1883. However, it was only through major refinancing — supported by the one-time Collingwood resident Alexander McDougall, famous as the designer of the whaleback freighter, coupled with federal government drydock subsidies, that an industrial steel shipbuilding facility was established at the turn of the century.[261] The *Huronic*, like the *Manitoba*, was an attractive, high-quality and well-appointed ship; it suggested the need, or desire, to establish capacity and credentials. Unlike Polson's Owen Sound yard, Collingwood survived and surpassed the launch of the *Huronic*. In the years before the outbreak of war, a succession of steam-powered steel vessels of various types were built at Collingwood, including: a sister ship to the *Huronic*, the S.S. *Hamonic* (1908), a navigational-aids tender, two dredgers for the Department of Marine and Fisheries and various bulk carriers for the expanding Lakes trade, three of which, the S.S. *Emperor* (1911), the S.S. *James Carruthers* (1913) and the S.S. *J.H.G. Hagarty* (1914) were over 500 feet long. In 1915, Collingwood Shipyards also earned the distinction of building the first Canadian tanker, the 258-foot S.S. *Royalite* which served in the Atlantic during both World Wars.[262] The wide variety of tonnage produced by Collingwood in its first decades of operation reflects an important feature of industrial shipbuilding: the development of increasingly specialized ship types.[263] Such specialization was, moreover, promoted and amplified by concurrent developments in marine engineering.

Although the early development of steel shipbuilding in Canada is closely related to the expansion of trade (particularly wheat exports) and industrialization, politics also played an important role, specifically the Naval Services Act of 1910. The Naval Services Act arose out of increasing tension among the great European powers and a desire, on the part of Britain, to strengthen its security by co-ordinating its empire's manpower and resources. Canada was then the senior member of the British colonial realm, and shared vital Atlantic connections with Britain. Because seapower was the basis of British imperial might, the escalating naval-arms race with Germany lead Britain to request contributions from the colonies toward establishing a unified imperial fleet. Anxious to balance the imperial sentiments in English Canada against the *Canadien* nationalist position in Québec, the government of Wilfrid Laurier elected to build a small fleet of four cruisers and six destroyers to be manned and maintained by Canadians. This was the substance of the Act by which the Canadian Navy was born.[264] After some deliberation, the Liberal government also decided that the new ships should be built in Canada, notwithstanding the severe limitations of existing Canadian shipyards.[265] In an earlier, related government bill that also addressed the growing concerns of imperial security as well as Canadian industrial interests, the government proposed a new Drydock Subsidies Act to further encourage the development of

259. Redway, "Steel Shipbuilding."

260. In August of 1901, *RMW* featured two articles by individuals closely associated with the new Collingwood shipyard, Mr. T. Long (a director of the Northern Navigation Co.) and Capt. Alexander McDougall in which arguments, similar to Redway's were made for government support and protection of steel shipbuilding in Canada. As part of his address, Mr. Long noted that the new *Huronic* would have to go to American yards for repairs, since the only Canadian drydock on the lakes was too small to receive this vessel: pp. 248-249.

261. Skip Gillham, *The Ships of Collingwood* (St. Catharines: Riverbank Traders, 1992), p. 2. "Ontario and the Great Lakes," *RMW*, (September 1901), pp. 283-284. "Collingwood Shipbuilding History," *Canadian Transportation*, — henceforth, *CT* — (October 1949), p. 580; Patrick Brophy, "Collingwood Shipyards: a hundred years of craftsmanship, innovation and integrity," *Canadian Shipping and Marine Engineering* — henceforth, *CSME* — (May 1983), pp. 32-42.

262. Gillham, *The Ships of Collingwood*, p. 29.

263. Sidney Pollard and Paul Robertson, *The Shipbuilding Industry: 1870-1914* (Cambridge: Harvard University Press, 1979), pp. 18-24.

264. For a more detailed discussion of the politics and context of the Naval Services Act, see: Nigel D. Brodeur, "L.P. Brodeur and the Origins of the Royal Canadian Navy," *The RCN in Retrospect, 1910-1968* (Vancouver: University of British Columbia Press, 1982), pp. 13-32. The best, all-round account of the historical context within which the Canadian Navy was born is provided in Michael Hadley and Roger Sarty, *Tin-Pots and Pirate Ships: Canadian Naval Forces and German Sea Raiders 1880-1918* (Montreal & Kingston: McGill-Queen's, 1991), Part One: pp. 3-78.

265. J.H.W. Knox, "An Engineer's Outline of RCN History: Part 1," *RCN in Retrospect: 1910-1968* (Vancouver: University of British Columbia Press, 1982), pp. 96-97.

large modern facilities for shipbuilding and ship-repair.[266] Even though the Naval Services Act was never implemented, its intentions and implied future prospects were sufficient to encourage Vickers Ltd., then among the world's largest armaments manufacturers, to establish a branch shipyard in Montréal. The decision to locate in Montréal appears tied to a variety of interests beyond the two federal bills already mentioned: a desire to dampen French-Canadian resistance to the Naval Act with the promise of jobs while also pleasing the local constituency interests of the then Minister of Marine, Louis Philippe Brodeur; generous concessions on the lease of the land (a 33 acre riverside sight in Maisonneuve); Montréal's importance as an industrial port; and, finally, the city's secure strategic location.[267] Formally incorporated in 1911, with a construction budget of $2.5 million and capital of twice that amount, Canadian Vickers Ltd. was by far the largest and most sophisticated shipyard in Canada.[268] The completed facility contained five berths with a capacity to receive ships of up to 1 000 feet long and 25 000 gross tons, including a large, enclosed berth for year-round work and a floating drydock, the *Duke of Connaught*, then among the largest in the world.[269] To operate the new facility, Vickers also imported most of the required technical and architectural skills, including Horace German, about whom more later. Although the promise of naval construction was shelved with the change of government after the 1911 election, the first contract for Canadian Vickers Ltd. nevertheless came from the Crown. The ship, appropriately enough, was a large icebreaker, the *J.D. Hazen*, a project valued at just under a million dollars when the contract was issued in 1914. Moreover, the design of this vessel was Canadian, provided by Mr. C. F. Duguid, a naval architect working for the Ministry of Marine.[270]

The development of Collingwood Shipyards, Canadian Vickers and various other drydock facilities throughout Canada during the years immediately preceding World War I provided the somewhat belated basis for industrial shipbuilding in Canada. Still, these were modest beginnings and the rapid expansion of production capacity required by the war effort dramatically altered the aspirations, expectations and scope of this nascent Canadian industry. Between 1914 and 1918, over 9 million gross tons of British shipping were sunk (some 3 149 vessels). The rate of loss accelerated as the war progressed to a high of 1.4 million gross tons in the second quarter of 1917.[271] In response to this crisis, the Imperial Munitions Board (IMB) decided to build 87 ships in Canada, including 39 steel steamships. To the members of IMB, the fact that Canada was not an established centre of naval shipbuilding, but had the basis of a shipbuilding industry, made it an appealing potential source of new tonnage. The ships ordered by IMB ranged in size from 1 800 to 8 800 deadweight tons (dwts).[272] Interestingly enough, most of the steel vessels ordered were contracted to a West Coast fabrication company with no pre-war shipbuilding experience: J. Coughlan & Sons of Vancouver.

Prior to World War I, shipbuilding on Canada's West Coast was a very limited activity serving almost exclusively local coastal operations. From 1873 until 1891, shipyards in the region produced an average of six vessels a year, all weighing in under 100 tons.[273] The ocean-going shipping vital to British Columbia's

266. Graham D. Taylor, "A Merchant of Death in the Peaceable Kingdom: Canadian Vickers, 1911-1927" in P. Baskerville (ed.), *Canadian Papers in Business History*, vol. 1 (Victoria, B.C. 1989), p. 218; "Dry Dock Construction in Canada," *RMW*, (June 1908), p. 449; the view of dry dock construction as an important stimulant to shipbuilding is more explicitly stated in the article "Proposed Dry Dock Construction," *RMW*, (October 1910), p. 881. The list of incorporators in the newly formed Dominion Dry Dock Co., provided in this piece, suggests something of the interests involved: Sir. Thos. G. Shaughnessy, President C.P.R., Hugh A. Allan, Allan line; G.D. Davie, Quebec (Davie Shipbuilding), Lord Pirrie, Chairman Harland and Wolff, Belfast et al.

267. Taylor, "A Merchant of Death in the Peaceable Kingdom," p. 218.

268. *Ibid.*, p. 219.

269. *Ibid.*; "The Floating Dry Dock for Montreal," *RMW* (September 1912), p. 482; "The Floating Dry Dock for Montreal," *RMW* (October 1912), pp. 524-525; "Largest Floating Dry Docks in the World," *RMW* (November 1912), p. 578.

270. "Icebreaking Steamship for the St. Lawrence River," *RMW* (May 1914), p. 238; "Icebreaking Steamship for the St. Lawrence River," *RMW* (May 1916), pp. 202-203; "Launching of Icebreaking Steamship, *J.D. Hazen*," *RMW* (June 1916), pp. 245-246. At the post-launch luncheon, the then Prime Minister Robert Borden, drew upon the oft-repeated, hopeful rhetoric of Canadian shipbuilding interests, sighting the historic roots of the industry in Canada and the economic and strategic benefits of developing the industry.

271. W.H. Mitchell and L.A. Sawyer, *British Standard Ships of World War I* (Liverpool: Sea Breezes, 1968), p. ix.

272. Tonnage measurement evolved in the twentieth century in response to increasing regulation and specialization in shipping. In modern parlance, a ton consists of 100 cubic feet or 2.83 cubic metres. Ships are defined in terms of registered, gross, net and deadweight tons. Registered tonnage is that listed in the vessels certificate of registry; gross tonnage refers to the volume of all enclosed spaces within the ship; net tonnage indicates the volume of all cargo spaces; and deadweight tonnage refers to the total mass of all supplies, fuel and cargo that a ship is designed to carry. D.A. Taylor, *Dictionary of Marine Technology* (Toronto: Butterworths, 1989).

273. Canadian Sessional Papers cited in Rice, "Shipbuilding in British America," p. 11. For an account of shipyards in B.C. before World War I, see *A History of Shipbuilding in British Columbia* (Vancouver: Marine Retirees Association, 1977), pp. 4-7; and (more obliquely), G. W. Taylor, *Shipyards of British Columbia* (Victoria: Morriss, 1986), pp. 15-30.

development before the completion of the C.P.R. was built entirely abroad. Notwithstanding the Royal Navy's interest in a Pacific station and the subsequent construction of a naval drydock at Esquimalt, local ship-repair facilities remained limited right up to 1914, with much of the available business going to larger American yards.[274] Local iron foundries, like the Albion Iron Works and Victoria Machinery Depot, both in Victoria, provided a range of cast and machined parts for shipbuilding and repair. But the scale of their operations was limited by the nature of coastal shipping. The December 1913 purchase of the Bullens yard in Esquimalt by the Clyde shipbuilder, Alfred Yarrows, greatly expanded this potential.[275] Yarrows, like the management of Vickers, was attracted to Canada by the prospect of naval construction.[276] When war came, however, the contracts of the IMB were not the only stimulus to B.C. shipbuilding. By 1915, with vessels being requisitioned to meet wartime priorities, the government and business elite of British Columbia had become deeply concerned about the paucity of merchant shipping to carry their exports, particularly lumber. In response to this, the provincial legislature passed the British Columbia Shipping Act which provided for loans and direct subsidy to encourage shipbuilding and shipping in the province.[277] These measures and further fiscal action by Ottawa prompted two British Columbia shipyards, Wallace Shipbuilding in Vancouver, and Cameron-Genoa in Victoria, to begin construction of a dozen (six per yard) five-masted, wooden-hulled auxiliary schooners of 2 500 dwts. for the lumber trade. Wallace subsequently received IMB orders for three dry-cargo ships of 4 600 dwts., all with names prefixed by the word "war." The first of these, *War Dog* was launched in May 1917 and received the distinction of being the first Canadian-built, steel steamship constructed for ocean service. The largest IMB orders called for ten 8 800 dwts. steel steamships from J. Coughlan & Sons, all but the first of which would also have names bearing the "War" prefix. Like the series built at Wallace Shipyards, this new construction actually began by order of a neutral country (Norway) before the IMB interceded.[278] On launching, the first of this series, the S.S. *Alaska* became the largest ship ever built in Canada. All of these vessels were built to a standard British design, which greatly simplified the production requirements of the newly-formed industrial yards.[279] Although obtaining parts and materials sometimes posed problems, the quality of the work proved entirely satisfactory.

The internal demand for tonnage experienced in B.C. was also felt elsewhere in the country.[280] In 1916, the dominion government initiated a "customs drawback" to further encourage Canadian shipbuilding while permitting construction for neutral countries also experiencing trouble obtaining merchant ships in the face of British war priorities.[281] By the close of 1916, steel shipbuilding facilities existed, however marginally, in at least eight Canadian cities: New Glasgow, Lauzon, Montréal, Kingston, Toronto, Collingwood, Port Arthur and Vancouver.[282] With the arrival of IMB orders for steel freighters, contracts were issued to: Canadian Vickers (six of 7 200 dwts.), Port Arthur (one of 4 300 dwts. and six of 3 500 dwts.), Polson's Iron Works in Toronto (eight of 3 500 dwts.), Collingwood (two of 2 900 dwts.), and Nova Scotia Steel and Coal in New Glasgow (one of 2 400 dwts. and one of 1 800 dwts.). Other smaller yards also initiated large steel shipbuilding through IMB contracts, including: Midland Shipbuilders, Midland, Ontario (three of 3 500 dwts.); British American Shipbuilding, Welland, Ontario (three of 3 500 dwts.); and Canadian Allis Chalmers of Bridgeburg, Ontario (four of 3 500 dwts.). The German threat to shipping in 1917 also generated the need for additional patrol vessels. To meet this requirement, the IMB requested the construction of 60 armed, steel-hulled steam trawlers, 12 of which

274. Taylor, *Shipyards of British Columbia*, pp. 17–19.

275. In 1913, Bullens built the first steel steamship in B.C. for the C.P.R.: the 1 777 gross ton coastal steamer S.S. *Princess Maquinna*. For information on Yarrows and other prominent personalities in B.C. shipbuilding, see Taylor, *Shipyards of British Columbia*, pp. 170–205.

276. Taylor, *Shipyards of British Columbia*, pp. 66–68. During World War I, Yarrows was largely occupied with naval repair work; see "Shipbuilding and Repairing at Esquimalt," *RMW* (February 1918), p. 86.

277. David R. Conn, "The War Orders: B.C. Shipbuilding 1915–1920," *Canadian West*, no. 8 (Summer, 1987), pp. 83–84; "Proposed Provincial Aid for British Columbia Shipbuilding" *RMW* (June 1916), p. 77; "Aid for Shipbuilding in British Columbia" *RMW*, (June 1916), p. 254; "Shipbuilding in British Columbia," *RMW* (July 1916), p. 301; "British Columbia Legislation to Encourage Shipbuilding," *RMW* (December 1916), p. 508.

278. "Steel Steamships for Norway," *RMW* (January 1917), p. 39. The acceptance by Canadian yards of orders from third-party neutrals "aroused considerable adverse criticism," from British shipping interests then also searching for new tonnage. The Canadian response betrays a distinct resentment at this belated attention: "Great Britain and Shipbuilding in Canada," *RMW* (February 1917), p. 81 and "Hawking Canadian Shipbuilding Contracts," *RMW* (January 1917), p. 34.

279. For details regarding these ships and a full list of vessels built under IMB orders, see Mitchell and Sawyer, *British Standard Ships of World War I*, (part six).

280. Kenneth S. Mackenzie, "C.C. Ballantyne and the Canadian Government Merchant Marine, 1917–1921," *The Northern Mariner*, vol. II, no. 1 (January 1992), pp. 2–3.

281. "Customs Drawback for Shipbuilding in Canada," *RMW* (December 1916), p. 507. For further national context, see "Steel Shipbuilding and a Mercantile Marine for Canada," *RMW* (June 1916), p. 248 and "The Minister of Marine on Canadian Shipbuilding," *RMW* (December 1916), p. 509.

282. "The Minister of Marine on Canadian Shipbuilding," *RMW* (December 1916), p. 509. The Davie shipyard at Lauzon, Québec was not mentioned by the Minister since it was occupied with other business and did not then have any IMB contracts. It did, however, have facilities for steel-ship construction and had received a contract in 1915 to build the steel ferry *Canora* for B.C. coastal service.

were to be assigned to the Canadian Navy. These 12 ships thus constituted the first naval vessels built in Canada for the Canadian Navy. Like the IMB merchant ships, the trawlers were a series built to a specific British design: the "castle class." Contracts for these modest (136 registered tons) vessels were let to both the larger, better-equipped yards including Canadian Vickers, Collingwood, Polson, Port Arthur, Kingston Shipbuilding, Davie Lauzon, as well as smaller facilities like Thor Iron Works, Toronto; the federal government shipyard at Sorel, Québec; and Tidewater Shipbuilding at Trois Rivières.[283]

The construction of 60 steel trawlers in the course of only a year and a half was a notable achievement on the part of Canadian shipbuilders, but the construction of large, deepsea merchant ships ultimately had the greatest impact on the industry. The sudden expansion of capacity created by the conditions of war prompted serious consideration of how Canadian shipbuilding could be sustained in the post-war period. A *Canadian Railway and Marine World* editorial of March 1918, accompanying a paper by Alexander Johnston, Deputy Minister of Marine and Fisheries, clearly establishes the context:

> *Considerable doubt is at times expressed as to whether shipbuilding is to become a permanent industry in the Dominion, or whether, when the governments cease placing orders on the present basis, the majority of plants which have been got together to cope with the emergency, will be closed and the staffs dissipated. In the situation, as it exists today, there is no room for the pessimist. The opportunity for which Canadian shipbuilders have been waiting is here, and it remains for them to make the most of it. There is no doubt that for several years to come the shipbuilding yards of the whole world will be fully occupied in replacing lost tonnage of all descriptions as well as in keeping pace with the ordinary requirements of water transportation. Under existing conditions, there is ample opportunity for shipbuildiing and allied trades to, at least, lay the foundations for a large and permanent shipbuilding trade on both oceans as well as on inland waters.*[284]

In the accompanying paper, Johnston cites the limitations of Canadian steel plants in producing the required plates and frames as a principal concern. However, after noting that "it would be difficult to exaggerate the importance of shipbuilding as a national undertaking to a country...like Canada," he hints at the likely prospect of future government involvement:

> *possibly with the aid of one or another of the methods already adopted by some other governments for encouraging the growth of a merchant marine, it is not unreasonable to suppose that Canadian shipbuilding might be put on a firm, enduring and profitable footing.*[285]

That prospect had begun to take shape as early as January 1918, when C.C. Ballantyne, Minister of Marine, announced the government's intention to place orders for a fleet of government-owned merchant ships as soon as Canadian yards completed their IMB contracts.[286] By April 1918, four vessels had been ordered, ranging in size from 3 750 to 8 100 dwts.; as of October, 25 vessels, for a total of 146 300 dwts., were under construction for the Canadian government.[287] In late November 1918, the first of these new vessels, the S.S. *Canadian Voyageur* (all of these ships were given names prefixed by "Canadian") was launched and, at the same time, the government's plans for the operation of these vessels were revealed. As part of the formation of Canadian National Railways, the Canadian Government Merchant Marine (CGMM) was meant to serve as the sea-link to a government-owned, international transportation network. It was somewhat like a public version of Canadian Pacific.[288] Beyond the very real value of keeping the shipyards busy and thereby sustaining employment, these new ships were viewed as a means of insuring that Canadian exports came to market during the post-war reconstruction period. Collectively, albeit less explicitly, they were an expression of Canadian autonomy and national maturity. Government orders continued throughout 1919, as did plans for a new rolling mill in Sydney, Nova Scotia; to meet the needs of the CGMM building program a further boost to shipbuilding in the maritime provinces came with the development of a new steel shipbuilding yard in

283. IMB also ordered smaller wooden drifters. Daniel G. Harris, "Canadian Warship Construction, 1917-19: The Great Lakes and Upper St. Lawrence River Areas," *Mariner's Mirror*, vol. 75, no. 2 (May 1989), pp. 149-158.

284. "The Shipbuilding Situation and Outlook in Canada," *RMW* (March 1918), p. 119.

285. *Ibid.*

286. "The Dominion Government's Shipbuilding Programme," *Canadian Railway and Marine World* (February 1918), pp. 83.

287. "Cargo Steamship Building for Dominion Government," *RMW* (May 1918), p. 226; "Steel Cargo Building for Dominion Government," *RMW* (November 1918), p. 511. For details on the ships being built, see "Cargo Steamship Building for Dominion Government," *RMW* (April 1918), pp. 166-167; "Cargo Steamship Building for Dominion Government," *RMW*, p. 405; "Steel Cargo Steamships Building for Dominion Government," *RMW*, pp. 457-458.

288. "Steel Cargo Building for Dominion Governments," *RMW* (December 1918), p. 562; Mackenzie, "C.C. Ballantyne and the Canadian Government Merchant Marine," pp. 4-5. For the terms by which Canadian National Railways would operate the vessels, see "National Railways to Operate Government Boats," *Harbour and Shipping* (July 1919), p. 297.

Halifax.[289] When the last of the contracts was let in April of 1920, 63 ships, totalling 379 297 dwts., had been built at cost of $72 818 073.00, or about $192.00 per ton.[290]

The history of the CGMM has been covered elsewhere and, although it has yet to receive the attention it deserves, the purpose of this survey limits further examination of the subject. However, it is important to note that the CGMM, after some success in the 1920s, did not survive the global economic downturn of the 1930s. As of June 1936, the fleet had been sold and Canadian National steamship service was henceforth confined to coastal and West Indies routes.[291] More important to the present discussion is that the Canadian government's attempt at operating a merchant fleet did nothing, after 1920, to generate more Canadian shipbuilding. Certainly, ship-repair facilities received more business than they might otherwise have done, but as an ongoing source of contracts for new tonnage, the CGMM was a disappointment. The problem was simply that Canadian shipbuilding remained as much as 30 percent more expensive, in both the cost of materials and labour, than the British equivalent.[292] This was no surprise to informed commentators. As one West Coast writer put it early in 1919:

> *How long will the shipbuilding industry live? The question is one which is being discussed far and wide, and the answers to it are almost as numerous as the experts who discuss it. The industry on this continent is a child of war, and it is generally recognized that on the scale created by the war's necessities, it cannot long survive. During the war, the only factor was speed. Cost was a secondary consideration. Now, cost is a factor and in time it will become the dominant factor. When it does, the yards that cannot meet competition will disappear. When governments buy ships, they may put a premium on the homemade article, but when private capital is invested, it will buy in the cheapest market.* [293]

When the last of the CGMM contracts had been let, the industry and its advocates began clamouring for further government support, specifically bonuses to the tune of "$10.00 per load displacement ton and $10.00 per indicated horsepower on steel ships built in Canada and completed after April 1920."[294] Even the popular press took up the cause, repeating the familiar litany of issues and obstacles while appealling to post-war pride for more support to foster and sustain this newly expanded industry.[295]

Nevertheless, subsidy of the order required to maintain wartime capacity was not forthcoming and the industry languished. At Canadian Vickers, then the best-equipped of Canada's shipyards, income from construction work fell by 50 percent in 1920; in the following year, total net income declined by more than 75 percent.[296] At Collingwood, the largest of the Great Lakes facilities, the yard managed to build only one ship a year throughout the 1920s, though in this it faired better than most.[297] Nevertheless, as an appeal to Parliament by Canadian shipbuilders in 1925 noted, 47 ships had been ordered by Canadian shipowners from foreign yards in 1922 alone, 27 of them for the strictly internal, Great Lakes-St. Lawrence trade.[298] By 1929, some 411 foreign-built ships worth $97 million had been purchased by Canadian owners.[299] The problems noted in the 1925 appeal — and repeated regularly until 1939 — echo those cited before the war: Canadian shipping interests continued to purchase and import British-built ships duty-free; Canadian shipyard wages were generally 50 percent higher than wages in Great Britain, while parts and steel plate (no longer available in Canada since the failure of the Sydney mill) were also more expensive. Added to these well-worn issues were more recent expectations and concerns related to wartime expansion: a great investment had been made in Canadian shipbuilding and ship-repair facilities; Canada's growing export economy required more and larger ships; just to maintain adequate repair facilities, equipment and labour for the increased shipping

289. For discussion of the new steel mill, see "Steel Cargo Building for Dominion Government," *RMW* (December 1918), p. 563; for the new Halifax shipyard see "Steel Shipbuilding Plant for Halifax, N.S.," *RMW* (July 1918), p. 312. The granting of building contracts to the new Halifax yard and, similarly, on the West Coast, to Prince Rupert, contradicted the government's many assertions that the CGMM building program was not intended to foster new facilities.
290. "Orders for Steel Cargo Steamships for Canadian Government Merchant Marine," *RMW* (December 1920), p. 681.
291. See Mackenzie, "C.C. Ballantyne and the Canadian Government Merchant Marine, 1917-1921," pp. 1-13; Donald MacKay, *The People's Railway: A History of Canadian National* (Vancouver: Douglas and McIntyre, 1992).
292. Percentile taken from "Canadian Ship Building and Ship Repairing Industry and Its Relation to Unemployment," *RMW* (October 1930), p. 679.
293. "What of the Shipbuilding Industry?" *British Columbia Shipping Gazette and Foreign Trade Review* (January 1919), p. 15.
294. "Shipbuilders Petition Dominion Government for Bonuses," *RMW* (February 1920), p. 95.
295. For example, Garnault Agassiz, "The Case for a Shipbuilding Subsidy," *The Canadian Illustrated Monthly*, vol. V, no. 3 (May 1920), pp. 11-28. (This magazine was published by Canada Steamship Lines.)
296. Taylor, "A Merchant of Death in the Peaceable Kingdom" p. 224.
297. By 1927, Collingwood Shipyards operated facilities at Kingston and Port Arthur. See "Consolidation of Great Lakes Shipbuilding Companies," *RMW* (January 1927), p. 26.
298. "Canadian Shipbuilders Ask for Protection for Their Industry," *RMW* (February 1925), p. 88.
299. "Canadian Ship Building and Ship Repairing Industry and Its Relation to Unemployment," *RMW* (October 1930), p. 679.

trade, Canadian yards required building contracts; skilled labour was draining to American yards, while Canadian duties on equipment and repairs purchased abroad amounted to only half the duty applied by Americans to the same goods and services.[300] Three years later, with no action taken, the appeal was again repeated with the added information that some $72 million worth of ships had been purchased abroad between 1922 and the 1927 for use in Canada.[301]

In a more positive vein, the 1920s also brought the construction of a massive new drydock facility at Esquimalt. The dock, which took five years to complete, was subsidized by Ottawa with the interests of Imperial defense very much in mind: at a length of 1 175 feet, the new drydock was the second largest in the world, sufficient to accommodate the next generation of battleships.[302] During this same decade, the famous "Great White Fleet" of passenger ships was formed by Canada Steamship Lines. Used for holiday cruises between Lake Ontario and the Saguenay, three of the largest and most elaborate of this fleet were built at Davie Lauzon: the S.S. *St. Lawrence* (1927), the S.S. *Tadoussac* and the S.S. *Québec* (1928), all of which were over 300 feet in length.[303] In Montréal, the 1920s also saw the establishment of what would become Canada's best-known firm of naval architects: Lambert and German, later Milne, Gilmore and German and, most recently, German and Milne.[304] Walter Lambert, the founder, had originally come from Britain in the service of the IMB, while Horace German had come to Montréal to work at Canadian Vickers in 1913. Harold Milne joined the firm in 1936, when Walter Lambert resigned. After World War II, another naval architect from Canadian Vickers, James Gilmore, joined the company. That such a firm should arise at a time of diminishing construction contracts indicates that most Canadian steel shipyards, born of war, were mere assembly sites, building established designs. In this respect, they differed from the British yards — upon which model Vickers was originally conceived — which were able to design and build to order. This distinction would become evident during World War II.[305] An independent Canadian firm of naval architects could make itself available to any yard that found itself in need of architectural advice or design services for repair or construction work.

With the onset of the Great Depression, the prospects for Canadian shipbuilders worsened, and yards operating between the wars survived largely on the basis of ship-repair and miscellaneous structural fabrication. As noted in yet another industry appeal to the federal government in 1934, "except for repair work, shipyards throughout Canada have been practically idle for a number of years."[306] While the government remained generally unresponsive to the Canadian shipbuilders' repeated arguments for support, the outbreak of World War II initiated a scale and intensity of construction against which even the expansion of 1917 paled. The context for this is well known and need not be pursued here. In addition to making very real quantitative gains in both unit and tonnage measure, Canadian yards also made distinct qualitative advances by building a variety of naval vessels, including tribal-class destroyers, frigates, corvettes, mine-sweepers, large repair and maintenance ships, fast patrol boats and landing craft.[307] However, as in World War I, these ships (with the exception of six 3 600 dwts. tankers of Canadian conception) were built to established designs and, as such, Canadian shipyards were again engaged in what was essentially assembly shipbuilding. All tolled, between 1939 and 1945, 21 Canadian shipyards produced 383 warships and 395 merchant ships.[308] By region, the greatest number were built on the Pacific Coast, followed by the St. Lawrence, the Great Lakes and, lastly, the Maritimes. However, among the various types of vessels ordered, the most sophisticated — the four, tribal-class destroyers — were all built in Halifax. The largest class of ships ordered was a series of 361 dry-cargo/tanker/supply

300. *Ibid.*, pp. 87–89.
301. "Canadian Ship Building and Ship Repairing Industries Handicaps," *RMW* (April 1928), p. 238.
302. Taylor, *Shipyards of British Columbia*, pp. 72–73. In the 1920s, after much delay a floating drydock was also established in Vancouver; see "A Drydock for Vancouver?" *Harbour & Shipping*, vol. 5, no. 3 (January 1923), pp. 87–89; "Floating Drydock for Vancouver," *Harbour & Shipping*, vol. 5, no. 6 (April 1923), pp. 207–209.
303. Edgar A. Collard, *Passage to the Sea: The Story of Canada Steamship Lines* (Toronto: Doubleday, 1991), pp. 130–183.
304. See Maurice Smith, "German & Milne: Its Role in the History of Ship Design in Canada," *FreshWater*, Vol. 9, No. 1, pp. 9–23.
305. "Shipbuilding in Canada During the Second World War," *Journal of Naval Engineering*, vol. 1 (1947), p. 10.
306. "Protection Asked to Save Canadian Shipbuilding Industry," *RMW* (April 1934), p. 179. See also, W. Harold Milne, "Diminishing Shipbuilding Trend in Canada," *CT* (December 1949), p. 697.
307. For a review of Canadian naval construction, see "Shipbuilding in Canada during the Second World War," *Journal of Naval Engineering*, vol. 1, no. 3 (1947), pp. 6–10. Brief histories of the various Canadian naval vessels can be found in Ken Macpherson & John Burgess, *The Ships of Canada's Naval Forces* (Toronto: Collins, 1981), pp. 29–159. For a technical overview of World War II Canadian warship construction, see J.H.W. Knox, "An Engineers Outline of RCN History," pp. 103–115.
308. Clarence Wallace, "Presidential Address," *Canadian Shipbuilding and Ship Repairing Association: Annual Report* (Ottawa, 1947), p. 10. The actual numbers tend to vary from source to source, depending on the dates applied (end of hostilities or delivery of ship) and whether or not a ship is considered merchant or naval. Hereafter, annual reports of the Canadian Shipbuilding and Ship Repairing Association will be cited as *CSSRA Annual Report*. In 1987, the CSSRA broadened its mandate and changed its name to the Canadian Marine Industries Association (CMIA).

ships of 10 000 dwts., better known by their prefix nomanclenture as "Fort" and "Park" ships.[309] The "Park" series also included a smaller class of merchant ships of 4 700 dwts. and the Canadian-designed 3 600 dwts. tankers. A further 35 "B" and "C" type, 1 250 dwt. coasters of British design were built at the end of the war, most of which ended up in civilian Canadian service.[310] That the output of Canadian shipyards in World War II "was probably the most remarkable even of the three great naval powers"[311] and, more generally, an extraordinary example of rapid industrial expansion, is readily apparent in a few statistics. For example, in September of 1939, Canadian shipyards employed only 2 430 men; by September of 1943, that number had reached a wartime high of 52 912. The total value of all new construction (wood and steel) in 1939 was $2 343 759 compared to $334 471 576 in 1943.[312] If the expectations and sense of self-worth among Canadian shipbuilders had been established by the formative experience of 1917 to 1920, the scale and importance of their World War II production completely exploded the context in which their industry functioned and was perceived; by 1945, Canada ranked fourth among shipbuilding nations. One important reflection of this new stature was the 1944 foundation of the Canadian Shipbuilders and Ship Repair Association, the mandate of which was "the preservation, maintenance and development of the shipbuilding and ship-repairing industries in Canada and particularly the prevention of avoidable unemployment of personnel associated with such industries during the post-war era."[313]

As was the case after World War I, the end of hostilities in 1945 cast the future of Canadian shipbuilding into question. Just as the expansion of production to meet war orders had been most pronounced in Canada, so Canadian builders suffered the reversion to peacetime market conditions. In 1947, Canadian yards continued to enjoy a position of relative strength in the post-war period of reconstruction, with some 75 percent of new contracts coming from abroad. Still, total employment dropped by almost one-third and the industry experienced some problems in acquiring the necessary steel.[314] By 1950, foreign contracts had dwindled to only 15 percent of all orders. At this time, British shipyards enjoyed a cost advantage of about 25 percent over Canadian builders, a problem heightened by devaluation of the Pound Sterling. Meanwhile, employment in shipbuilding dropped another 50 percent from 1947 levels to about 8 242 jobs. Aside from economic issues, both industry and government had become concerned with the strategic role of shipbuilding, specifically, the need to sustain capacity to meet any new national emergency. In reviewing the prospects for the future, R.J.R. Nelson, President of the *CSSRA* observed that

> *the serious problem facing the shipbuilders today is where they can get orders for new ships and repair work to maintain not only an overall nucleus as a bulwark of our national defence, set at approximately 7 000 by the Canadian Maritime Commission, but a nucleus in each of the four strategic shipbuilding areas in Canada-the Pacific Coast, the Great Lakes, the St. Lawrence and the Atlantic Coast.*[315]

Aside from insisting on a "nucleus" of shipbuilding capacity, perhaps the most significant corollary to the strategic considerations reflected in the recommendations of Canadian Maritime Commission (established in 1947) was the foundation of the Canadian Naval Shipbuilding Programme. Canada's role in convoy escort and the experience gained by the Royal Canadian Navy in anti-submarine warfare (ASW) during World War II, gave rise to a call for a new generation of

309. The 10 000 dwts. vessels were essentially riveted versions of the American "Victory" ship. For a good survey of the administrative and technical aspects of Canadian merchant shipbuilding during World War II, see John Robson, "Merchant Shipbuilding in Canada," *Transactions of the Royal Institution of Naval Architects*, vol. 88 (1946), pp. 280-294.

310. A thorough, detailed listing of merchant/supply ships built or converted by Canadian shipyards can be found in W.H. Mitchell, and L.A. Sawyer, *The Oceans, the Forts, and the Parks: Merchant Shipbuilding for British Account in North America during World War II* (Liverpool: Sea Breezes, 1966).

311. P.R. Elliot, *Allied Escort Ships of World War II* (Annapolis: Naval Institute Press, 1977), p. 23. The point refers less to the total output than to the expansion itself. This same point is made in "Review of Shipbuilding Activity," *CT* (September 1945), p. 531, and also in Robson, "Merchant Shipbuilding in Canada," p. 289.

312. Employment figures are from the Dominion Bureau of Statistics listed in Table 8 of the *CSSRA Annual Report* for 1947 and refer only to the workforce of the 17 member associations. The value of production figures covers a wider range of shipbuilding activity and is taken from "Survey of Canadian Shipbuilding Industry," *CT* (August 1945), p. 459.

313. From the objectives printed on the front page of the *CSSRA Annual Report*, 1947. See also, *CSSRA Newsletter*, no. 6, series II. Interestingly, after 1950, the specific concern for employment was dropped. For a useful review of scholarship (and the lack thereof) on post-war Canadian shipping and shipbuilding, see Michael A. Hennessy, "Postwar Ocean Shipping and Shipbuilding in Canada: An Agenda for Research," *The Northern Mariner*, vol. 1, no. 3 (July 1991), pp. 25-33.

314. Wallace, "Presidential Address," *CSSRA Annual Report* (1947), pp. 7-8.

315. R.J.R. Nelson, "Presidential Address," *CSSRA Annual Report* (1950), p. 6. See also *CSSRA Newsletter*, no. 9, series II.

Canadain-made ASW ships.[316] This program originated late in 1948 and aimed to sustain and develop the expertise gained during the wars, and to help maintain the industrial capacity of Canada's shipyards. The Korean conflict (1950–1955) and the Cold War gave this initiative even greater urgency and importance.[317] Modern warship design entails the conversion of a set of prescribed requirements into a form which best serves the desired ends. Since modern warships are a highly complex and sophisticated combination of hull form, accommodation, propulsion, control, command and fighting systems, their design necessarily involves the successful resolution of conflicting demands and is often quite protracted.[318] To undertake the design of a "made-in-Canada" ASW ship required the development of a Canadian naval design office, originally known as the Naval Central Drawing Office, but later renamed the Naval Ship Design Agency. Much of the expertise required to staff this new facility was, however, recruited from Britain, including its chief designer, Constructor Captain Roland Baker.[319] The primary result of this initiative was the design and development of a unique new type of destroyer escort (DDE), the "St. Laurent" class. Appropriately enough, the lead yard was Canadian Vickers; after almost forty years, the most advanced and integrated shipyard in Canada finally served as the cradle of a true, "made-in-Canada" Navy. The salient architectural features of the "St. Laurent" design were: a hull form (366 LOA × 42 × 13 feet) designed for high speed in heavy weather with inherent stablity sufficient for "avoidance of any capsizing moment as a result of damage"[320]; a smooth, low-profile, light-weight aluminum superstructure with a minimum of obstructions on deck to reduce spray and icing; and airtight, filtered workspaces and accommodation to provide for operations amid nuclear fallout.[321] In addition to its unique design features, the "St. Laurent" class led to an important, Canadian innovation in ship prefabrication: unit construction. In essence, this technique allowed for these ships to be built in small sections and then transported to an assembly yard. The idea was clearly inspired by the experience of World War II, since it "would make possible the rapid building of many ships to meet an emergency."[322] Unit construction, or large-scale, sectional prefabrication, has proven to be a highly economical concept since adapted, in various forms, by shipyards around the world. For Canadian builders, the fact that these ships were of all-welded construction was also significant in that they provided a context for developing infrastructure, equipment and skills; 20 ships of this basic type were eventually ordered and strategic considerations required that the contracts — and the technology they entailed — be distributed among yards in three of the four shipbuilding regions.

Another important result of Canada's post-war commitment to naval design and construction was the Canadian Navy's hydrofoil program.[323] Hydrofoil research in Canada dates back to 1911 when Alexander Graham Bell and F.W. Baldwin began their now famous experiments with the concept of foil-borne boats in the Bras d'Or lakes of Nova Scotia. During World War II, the National Research Council experimented with small hydrofoil craft for naval, smoke-laying applications.[324] Then, beginning in the late forties, the Defense Research Board began a serious examination of the technology for use in larger applications, specifically ASW. Research in the 1950s was conducted in cooperation with the Royal Navy, then interested in applying hydrofoil technology to fast, coastal-patrol boats. Owing to the absence of suitable, lightweight engines, it appeared that a hydrofoil large enough and powerful enough to operate in the North Atlantic was unfeasible. Nevertheless, the RCN remained an active partner in the sea-trials of the R-103, a scaled-down, 17-ton prototype of a coastal patrol hydrofoil for the British navy. Serious stability problems associated with the original foil design of the R-103 lead to further research in foil structure and arrangement. As a result, the Canadian team discovered that by reversing the traditional foil arrangement, which placed the large lift foil forward and the steering foil aft, it might be possible to build an ocean-going ASW hydrofoil. This new "canard" or "Canadian" foil arrangment provided the basis for the design of the FHE 400 *Bras d'Or*, a 150 foot-long, 200-ton ship capable of 60 knots and

316. For a review of the circumstances leading up to and influencing the construction of the "St. Laurent" class destroyer escorts see Mathwin S. Davis, "The 'St. Laurent' Decision: Genesis of a Canadian Fleet," *RCN in Transititon 1910–1985* (Vancouver: University of British Columbia Press, 1988), pp. 187–208.
317. *Ibid.*, p. 203.
318. Regarding the "St. Laurent" project see "Problems and Progress of the Canadian Naval Shipbuilding Programme," *CT* (August 1956), pp. 470–471.
319. J.H.W. Knox, "An Engineer's Outline of RCN History: Part II," *The RCN in Retrospect 1910–1968* (Vancouver: The University of British Columbia Press), pp. 317–319.
320. Knox, "An Engineer's Outline of RCN History, Part II," p. 319
321. *Ibid.*, pp. 119–121. For further details on the "St. Laurent," class see "Escort Vessel Construction Under Way," *CT* (August 1951), pp. 474–475; "Escort Vessel Keel Laid at Halifax," *CT* (November 1951), pp. 639–640; "Revolutionary Shipbuilding Method," *CT* (March 1952), pp 155–156; "Anti-Submarine Escort Launched at Montreal," *CT* (January 1952), pp 41–42; "First of the Sub-Killers," *Canadian Shipping* (November 1955), pp 28–38.
322. "Revolutionary Shipbuilding Method," *CT* (March 1952), pp. 155–158.
323. The best overview of this subject is M.C. Eames, "A Review of Hydrofoil Development in Canada," *First International Hydrofoil Society Conference* (London:International Hydrofoil Society, 1982).
324. John W. Milman, "The Canadian Hydrofoil Programme," *Transactions of the Royal Institution of Naval Architects*, vol. 108 (1966), pp. 97–112.

operation in sea-state five.[325] The prototype was designed and built by the De Havilland Aircraft Company of Canada and assembled at the M.I.L. shipyard in Sorel, Québec. The project proved to be an outstanding example of design innovation involving an unprecedented application of aeronautical analysis to ship stability and hull forms.[326] The vessel also required innovative aluminum welding and construction techniques.[327] Before being shelved in 1971 — the victim of a combination of defense policy, accident, faulty materials and cost over-runs — the HMCS *Bras d'Or* was subjected to extensive sea trials. These trials clearly demonstrated the viability of the design and operational systems.[328] The culmination of thirty years of research and development, the FHE 400 established Canada as a world leader in hydrofoil technology.

The post-war Canadian naval construction program did much to encourage the shipbuilding and ship-repair community. Between 1950 and 1954, the number of people employed in the industry increased to an average of 13 500, due in good measure to the new naval and government orders.[329] And while Canadian yards continued to receive some international contracts, the "differential in the capital cost of vessels built in Canada and foreign yards," meant that the industry's future hopes remained focused on government contracts and changes to coastal shipping policy.[330] The industry's longstanding concerns on the latter issue were clearly presented in a brief by the CSSRA to the Royal Commission on the Coasting Trade set up in 1955. The matter was given even greater urgency owing to the prospect of ocean shipping having unprecedented access to the Great Lakes trade by virtue of the new St. Lawrence Seaway, then under construction.[331] The old complaint of free access by U.K. vessesls under the British Commonwealth Merchant Shipping Agreement of 1931 was the principal focus. However, the CSSRA also capitalized on growing Canadian nationalist sentiment by noting that "just as the concept of 'British subject' has changed, so has the concept of 'British Ship' changed."[332] Against the CSSRA's influence and the strategic value of their work stood as always the many corporate interests and producers who were best served by a free market in shipping and the lowest possible freight rates. When the Royal Commission finally issued its report in May of 1958, some two and a half years after its inception, it chose to equivocate, stating that if the government deemed it necessary to sustain Canadian shipyards at a level beyond that supported by the market, it should do so through "direct subsidization."[333]

The extension of the "St. Laurent" destroyer escort program, an expanded public investment in icebreakers and other vessels, along with new orders for larger lake ships, insured that the 1950s were good years for the industry, despite the trend toward general decline after the peak in 1953. By the end of the decade, with the Seaway open and the Canadian coastal trade still unrestricted, shipbuilding prospects were greatly diminished and the industry outlook was a cause of "serious concern."[334] In May of 1961, however, the government acted on the the recommendation of the Royal Commission by establishing a new subsidy of 40 percent on commercial vessels (excluding fishing vessels) while offering a 99 percent drawback on duty applied to materials essential to ship construction and repair. The subsidy inspired considerable domestic construction and, for a time, brought a good measure of stablity to the industry. The demand for new "maximum Seaway size" bulk carriers and the development of new trade focused on the lower St. Lawrence further supported the industry. Indeed, between 1958 and 1986, an average of one new "maximum Seaway size" laker was built each year in Canada, and this market inspired a steady stream of design innovation.[335] The government subsidy payments totalled $136 million between 1961 and 1965.[336] However, in 1966, the subsidy

325. Eames, "A Review of Hydrofoil Development," p. 4. For a discussion of technical problems encountered in the development stage see J.H.W. Knox, "Trials and tribulations of a hydrofoil," *CSME* (April 1970), pp. 33-36.

326. Author's interview with M.C. Eames, Senior Scientist (ret.) Defense Research Establishment Atlantic, December 1989.

327. Andre Rochon, "Shipyard Approach to the Hull Construction of the FHE 400 Hydrofoil Ship," *Paper Presented to the CSSRA Technical Section-Annual Meeting*, (1967); Capt. R.G. Monteith RCN and R. W. Becker, "Developments of the Canadian Antisubmarine Hydrofoil Ship," (Paper Presented to the Canadian Congress of Engineers, Montréal, 1967), pp. 7-9.

328. M.C. Eames and T.G. Drummond, "HMCS Bras d'Or — Sea Trials and Future Prospects," *Transactions of the Royal Institute of Naval Architects*, vol. 114 (1972).

329. T.R. McLagen, "Presidential Address," *CSSRA Annual Report* (1954-55), p. 5.

330. *Ibid.*, p. 6.

331. "Royal Commission on Coasting Trade," *CT* (August 1955), pp. 462-463. For a shipbuilder's perspective on the economics of the seaway, see Sydney A. Vincent, "Economics of Future European-Great Lakes Freighter Service," *CT* (September 1956), pp. 527-532. For a general history of the St. Lawrence Seaway, see Jacques Lesstrang, *Seaway: The Untold Story of North America's Fourth Seacoast* (Seattle: Superior, 1976).

332. "Royal Commission on Coasting Trade," p. 462. Of interest in this regard is Michael Hennessy's observation that "throughout this era the old imperial connection played a larger role than generally acknowledged in undercutting Canadian efforts to protect the shipping and shipbuilding industries. The UK roundly criticised virtually every protective measure adopted by Canada and threatened to challenge many under the GATT regime." "Post-War Ocean Shipping," p. 29.

333. "Recommends Against Canadian Monopoly," *CT* (July 1958), pp. 62-63. The article also provides a small sample of reaction from the press.

334. Harold Husband, "Presidential Address," *CSSRA Annual Report* (1959/60), p. 6.

335. Gary S. Dewar, "Canadian Bulk Construction: Seaway and Subsidies," *Inland Seas*, vol. 43, no. 2 (1987), pp. 103-119; Henry Walsh, "The Crisis in Canadain Shipbuilding," *Seaway Review* (January-March 1986), p. 139.

336. J.W. Hudson, "Presidential Address," *CSSRA Annual Report* (1964/65), p. 6.

was reviewed and reduced to 25 percent with further staged reductions scheduled toward a target of 17 percent in 1973. The government had clearly determined that subsidies were not a long-term solution. Yet, as the subsidy was withdrawn the industry began a precipitous decline: production output fell from $122 620 000 in 1966 to $76 149 000 in 1970. Employment levels that had remained relatively stable at about 12 500 between 1962 and 1967 fell to 7 100 in 1970.[337] The number of member shipyards in the CSSRA also dropped from 15 to 12, with the most notable loss being Canadian Vicker's withdrawal from shipbuilding in favour of repair work and general industrial fabrication at the close of 1969. (Vicker's last ship, like its first, was an icebreaker, the C.C.G.S. *Norman McLeod Rogers*).[338]

In 1969 the government, through the Canadian Transport Commission, established yet another committee to examine the coastal trade, while the Department of Transport called for a study on the prospects of a Canadian flag merchant marine. At the same time, the Department of Industry commissioned a specific study of shipbuilding and ship-repair in Canada, funded in part by the CSSRA.[339] This latter study, the so-called Robertson Committee Report (named after its chairman, Cmdre. O.C.S. Robertson), gave rise to the last great flourish of Canadian shipbuilding under the so-called STAP subsidy (Shipbuilding Temporary Assistance Program).[340] The program, set in place for 18 months, functioned as follows:

> *a shipyard will receive support up to 17% of the audited costs of a ship under 40 000 dwt built for a foreign buyer. If a ship is more than 40 000 dwt, the support will amount to 14% of audited costs. The rate of this temporary assistance will decline by 1/2% per quarter after Sept. 30 next year.*[341]

However, the success of this initiative was largely dependent on external factors, most notably a dramatic surge in international demand for tonnage, and the corresponding prospect of premiums for early delivery. The subsidy itself, though, was insufficient to offset the higher costs of Canadian-built ships, particularly in British Columbia where both labour and materials were more expensive than elsewhere in Canada.[342] Still, the STAP subsidy had the desired effect; throughout 1971 and 1972, Canadian yards received a remarkable number of new international orders, including a contract from the Greek company Vardinoyannis at Davie Lauzon for three 80 000 dwts. tankers.[343] These vessels, the so called "Kriti" ships after the series' prefix, were the largest ships ever built in Canada.[344] The success of the STAP initative eventually extended the subsidy until 1975, with the rate of subsidy reinstated to a standard 17 percent for any vessel over 500 dwts.[345] On the Pacific Coast, one very notable event amid much industry anxiety was the 1974 launch of an innovative new ship type: the self-propelled/self-loading/self-dumping barge, *Haida Monarch*. Designed by the Vancouver naval architectural firm of Talbot Jackson & Associates, and built by Burrard Yarrows, this ship was the logical culmination of a self-dumping barge technology developed in B.C. specifically to serve the forest industry.[346]

Aside from the wave of international orders, another major focus of interest and discussion among Canadian shipbuilders in the early 1970s was ice navigation. Following the opening of the Seaway, winter shipping increased as much as 800 percent, thereby placing enormous demands on the government fleet of icebreakers.[347] The issue of sovereignty in the Arctic had also grown more urgent since World War II, with the Cold War bringing a new strategic value to control, access and communications. Resource exploration and development in the region, particularly in the energy sector, added greatly to this trend. A

337. Louis Rochette, "Presidential Address," *CSSRA Annual Report* (1970/71), p. 7.
338. *CSSRA Annual Report* (1971/72); "Hopes high as yard's image and role change," *CSME* (December 1969), pp. 48-50. Other large shipyards, like Davie Lauzon, had been branching out into fabrication as part of their efforts to achieve greater stability; "Davie Shipbuilding Enters Industrial Field," *CT* (July 1954), pp. 431-432.
339. J. Eric Harrington, "Presidential Address," *CSSRA Annual Report* (1969/70), pp. 4-16; "What Happened to the Gusto?" *CSME* (July 1970), p. 3; "The Robertson Committee Report on Shipbuilding," *CSME* (July 1970), pp. 11-20; "More reaction on that Report," *CSME* (August 1970), p. 26.
340. Louis Rochette, "Presidential Address," *CSSRA Annual Report* (1970/71), pp. 7-9.
341. "Glad tidings A.D. 1970," *CSME* (December 1970), p. 5.
342. *Ibid.* Labour rates were cited as 30 percent higher, while materials, owing to freight charges, were estimated to be a further 5 percent higher.
343. Peter Cale, "Breakthrough into the export market," *CSME* (April 1971), pp. 13-17; "Bull's-eye — the jackpot" *CSME* (June 1971), p. 3; "Yards Explode that Big Myth," *CSME* (October 1974), pp. 24-25.
344. "Kriti series puts Davie among the heavyweights," *CSME* (September 1973), pp. 17-20.
345. For an industry perspective on the impact of this subsidy and the vibrant international market, see the following articles in *CSME*: "That Old STAP Magic," (April 1973), p. 4; "The Turning of the Tide," (October 1973), p. 11; "STAP: the key to the future" (coast-to-coast shipyard survey), (January 1974), pp. 11-26.
346. "A year of special achievements for Burrard/Yarrows," *CSME* (January 1975), pp. 18-19; "*Haida Monarch*: Quiet Splash causes big stir on the west coast," *CSME* (Feb. 1975), pp. 24-25. For information on earlier developments, see "Burrard builds log dumping barges," *CT* (July 1957), p. 73.
347. Ballinger, "Canada's Marine Requirements in the Seventies," *CSME* (December 1972), p. 77. A total of sixteen icebreakers were "built or converted" for the Canadian Coast Guard between 1970 and 1988: David G. Parkes, "Marine Training and Research in Canada," *A Half Century of Maritime Technology 1943-1993* (Jersey City: Society of Naval Architects and Marine Engineers, 1993), p. 164.

notable result of this growing interest in Canada's north was the design and construction of the C.C.G.S. *Louis S. St. Laurent*. Launched in 1969, the 13 500-ton ship was then the world's largest non-nuclear icebreaker.[348] Nevertheless, with a steam turbo-electric power plant generating 24 000 shp., the *Louis S. St. Laurent* fell far short of the necessary requirements for year-round, Arctic operation. The much publicized transit of the Northwest Passage in 1969 by the modified, ice-breaking supertanker S.S. *Manhattan* — aimed at testing the possibility of transporting oil from Alaska to the American East Coast — further intensified the debate over sovereignty.[349] In response, the Canadian government began a protracted policy review and, after 1974, directed technical research towards the design and construction of an icebreaker capable of year-round operation. In conjunction with this, government support was also given to the design and construction of one of the world's most advanced, ice-capable merchant ships, the 28 360 dwt. M.V. *Arctic*. Built at Port Weller in 1977; this vessel has "operated at a continuous 8kts in ice nearly 1m thick...(and)...has pioneered the use of advanced ice navigation systems."[350] Oil and gas exploration in Canada's Beaufort Sea also lead to private-sector development of innovative icebreaking supply ships such as the M.V. *Miscaroo* built in Vancouver in 1983.[351] By 1985, following a very controversial transit of the Northwest Passage by the American icebreaker *Polar Sea*, a decision was finally made to proceed with the construction of a "Polar-8" icebreaker (a ship capable of breaking eight feet of ice at a constant speed of three knots).[352] Unfortunately, the project, slated for construction on the West Coast on a projected budget of $320 million, fell victim to government budgetary cutbacks and was subsequently cancelled in 1990.[353]

In 1975, the government established a long-term plan of subsidies at a reduced rate of 14 percent. The 3 percent cut from the previous STAP rate was then converted into an incentive grant for modernization and productivity gain. Financial support of export sales was also provided through the government's Export Development Corporation. Another significant initative in 1975 was the long-awaited, much-desired change in the terms of the British Commonwealth Shipping Agreement: after 1980, Canadian coastal shipping would finally be reserved for Canadian ships.[354] Under this regime, and with increasing activity in offshore energy development, the Canadian shipbuilding industry continued to show production and productivity gains through the end of the decade. Nonetheless, as of July 1, 1980, the government susidy was reduced to 9 percent with a cap of $75 million applied for three consecutive fiscal years beginning in 1979/80. These changes, along with a glut of tonnage on the world market, finally placed the industry at a "critical cross-road in its history," notwithstanding the very jaded nature of that expression among industry professionals.[355] Figures for total production (construction and repairs) fell dramatically after 1982, from $949 146 000.00 to $585 965 000.00.[356] Employment in the major Canadian shipyards for the same period decreased from 11 947 to 7 795.[357] Production figures improved again around 1985 due almost entirely to a surge in government orders as part of a Special Capital Recovery Program, but the trend was still one of decline. In subsequent years, shipyards became almost entirely dependent on government contracts for new orders, notably the "Tribal Class Updates," the promised "Polar-8 Icebreaker" and the "City Class" frigate program.[358] This trend is readily apparent in the production statistics: between 1976 and 1983, commercial orders made up 90 percent of shipyard business compared to only 45 percent in 1985; by 1990, that figure had shrunk to only 5 percent.[359]

The closing of Collingwood Shipyards in 1986 signaled a symbolic end to Canada's attempts to sustain

348. "Triple-screw icebreaker in service," *CSME* (August 1969), pp. 50-52.

349. A very good impression of the discussion can be derived from the following articles in *CSME*: "Presence in the Arctic" (March 1970), p. 7; Gordon German, "Polar Icebreakers: key to the Arctic's future"(April 1970), pp. 20-24; Stephen Duncan, "The Ministry of Transport's Involvement in the Arctic: Interview with Don Jamieson, Minister" (August 1970), pp. 7-11; Gordon German, "Bulk shipping and icebreaker support in the Arctic" (January 1971), pp. 21-24; "Polar Icebreakers" (July 1971), pp. 7-9; Peter Cale, "Why the government is stalling on polar icebreakers" (November 1972), pp. 5-7; William White & Andrew McArthur, "The Arctic challenge and Davie — The Arctic challenge and St. John" (March 1978), pp. 32-35.

350. Capt. L.W. Brigham "Service, Support and Industry Vessels," *The Shipping Revolution: The Modern Merchant Ship* (London: Conway Maritime Press, 1992), p. 156; "M.V. Arctic: first of how many?" *CSME* (July 1978), pp. 25-29.

351. J.Y. Clarke, "Canadian Ship Construction," *A Half Century of Maritime Technology 1943-1993* (Jersey City: Society of Naval Architects and Marine Engineers, 1993), p. 203.

352. Commander L.W. Brigham, "A World Class Icebreaker: the Canadian Polar-8," *Proceedings of the United States Naval Institute* (March 1986), pp. 150-152.

353. G.E. Mortimore, "Shipyard report: West Coast" *CSME* (Jan./Feb. 1987), p. 4. In spite of the cancellation of the Polar project, Canada continued to develop innovative icebreakers, notably the C.C.G.S. *Henry Larsen*, an Arctic Ice Class 4 vessel of 2 478 dwts.; see Clarke, "Canadian Ship Construction," pp. 204-205.

354. Alastair Gillespie, "Ottawa's New Deal for the Yards," *CSME*, pp. 43-44. J.H. Regnaud, "President's Address," *CSSRA Annual Report* (1974/75), pp. 6-9.

355. Henry Walsh, "Looking Back and Looking Ahead," *CSSRA Annual Report* (1980), pp. 5-7.

356. *CSSRA Annal Statistical Report* (1986), p. 28.

357. *Ibid.*, p. 35.

358. *Ibid.*, p. 4.

359. *Industry Profile 1990-91: Shipbuilding and Ship Repair* (Ottawa: Industry Science and Technology Canada, 1991), p. 2.

a modern, internationally-competitive shipbuilding industry through vigorous public subsidy. While industry officials and analysts might cite political myopia, specific program faults and a lack of consistency or rationale in the government's approach to shipbuilding, the fact remains that the Canadian decline in the late 1980s echoed that of established shipyards throughout the industrialized west.[360] In this respect, the most recent downturn in Canadian shipbuilding serves as a window on a much wider contemporary phenomenon: the economic restructuring associated with western de-industrialization. As one scholar of this trend has noted:

> *In the progression from birth to senescence, industries experience different forces which compel the relocation of production. ... After enduring a long phase of maturity, the contemporary shipbuilding industry is confronted with the pressures imposed by this progression: it is devoid of significant technical innovation, subject to an intense cost price squeeze, and fails to prosper signally because of a glaring mismatch between the supply of shipbuilding capacity and the demand for the shipping needed to sustain it. The industry has succumbed to the dictates of technical advance which have left it exposed to the kind of cost competition that requires summary plant excision some places at the same time as new capacity is being brought on stream elsewhere. In keeping with both its protracted evolution and latter-day convolutions in location, the shipbuilding industry offers itself as a quintessential candidate for scrutiny. It serves, in short, as a touchstone for global industrial trends, setting off the problems of industrial heartlands against those arising in the parts of the earth which have only just taken up the banner of industrialization.*[361]

As with the shipping trades, the building of ocean-going ships in Canada has always existed within a larger, international context. Long before other manufacturing activities, shipbuilding was subjected to international market forces and global trends. The story of the Canadian shipbuilding industry at the end of the twentieth century should be judged and understood against this global backdrop. However much the Canadian government may have viewed the industry as a national concern, and whatever the net national benefit of this particular industrial enterprise, the course of its development has been largely determined by forces operating outside our national boundaries.

360. Walsh, "The Crisis in Canadian Shipbuilding," p. 137. For a very recent critique of Canadian governemnt shipbuilding policy, see Peter T. Haydon, "The Canadian Government's Role in Shipbuilding Past, Present and Future," *SNAME Transactions*, Vol. 101 (1993), pp. 53-62.

361. Daniel Todd, *Industrial Dislocation: The case of global shipbuilding* (London: Routledge, 1991), p. i (preface).

Shipbuilding and Society in 20th Century Canada

Though periodically driven to prominence by the winds of national urgency, shipbuilding in Canada was a marginal and tenuous industrial activity for most of this century. The imperial ties with Britain, a world leader in ship design and construction through much of this period, delayed the development of a Canadian shipbuilding industry and displaced much of the opportunity for growth that arose from the dominion's expanding export trade. The active elements of this retardation and displacement include a full range of factors: the cost of materials, the absence of sufficient infrastructure, the productivity and price of labour, and market control and regulation all favoured British builders. Internally, federal government efforts to protect Canadian manufacturers through tariff policies undermined early attempts at industrial ship construction, since a good part of the cost of a completed vessel went towards imported manufactured items. Those same items could, however, enter Canada duty-free if they arrived as components of British built tonnage. In addition, the Canadian government was unable and unwilling (or both) to restrict coastal shipping exclusively to ships built and registered in Canada. Aside from the constant pressure of imperial politics, Canadian shippers understandably wanted the best ships at the cheapest freight rates available and, as a group, they certainly formed a more compelling lobby.[362] Finally, the labour market in Canada insured that the wages of skilled Canadian tradesmen remained consistently higher — between 25 and 35 percent in the case of shipbuilding — than British levels.

Thus, the eventual development of industrial shipbuilding in Canada was largely the consequence of war and the expectation of war. Still, some notable steel ships were built in Canada prior to World War I. In part, this was possible by virtue of special owner-builder relations. Such was the case for the *Huronic*, and also for the ships ordered by the Department of Marine and Fisheries. Government investment in drydock facilities further contributed to the early development and sustenance of the industry, in that repair work provided, and still provides, an essential economic nucleus for construction capacity and potential. The dynamics and nature of the Great Lakes trades presented additional opportunities and stimulants, though limited in scope. Above all, however, it was the naval arms race that made the difference in the decade leading up to 1914. The threat of war, and the Laurier government's particular response to it, made Canada home to an important branch of the British munitions giant Armstrong Vickers Ltd., giving rise to what was then one of the world's most sophisticated shipbuilding facilities. On the Pacific coast,

362. Hennessy, "Postwar Ocean Shipping and Shipbuilding in Canada," p. 29.

Alfred Yarrows' purchase of the Bullens yard in Esquimalt was similarly motivated.

When war finally did come, it did far more than anyone could have predicted to imbue Canada with industrial shipyard facilities, coast-to-coast. As one commentator aptly noted in 1919, the Canadian shipbuilding industry was "a child of war."[363] Indeed, it was only as a result of the shortage of tonnage caused by the war that large-scale industrial shipbuilding took root in British Columbia, and on the Pacific Coast the long-term, regional impact of the industry was enhanced by the simple fact that B.C. hitherto had only a very limited manufacturing capacity. The scale of shipbuilding in Canada after 1917 also inspired the concept of a Canadian Government Merchant Marine (CGMM), although this initiative ultimately served only to defer the inevitable while further increasing industry expectations. This psychological element (the assumptions and expectations) in the dramatic development of industrial shipbuilding in Canada, though difficult to define precisely, must be taken into account for a full understanding of the industry's subsequent history. Simply put, by the end of World War I, Canada found itself building ships for England, the very thing that so long had served as a symbol of British industrial strength and imperial dominion.[364] Combined with the much-discussed heightening of national identity and pride that Canadians gained through their experience of the war, it is easier to comprehend both the rhetoric and the reality of the CGMM.[365] This raises an important point. Throughout the century, both before and after the CGMM, Canadian shipbuilders argued that the creation of a national merchant navy was crucial to the survival of their industry. Although their reasoning was coherent — Canadian builders could not be expected to compete in the international market given wage and price differentials, hence the value of a home-based market for ships — the argument is not entirely self-evident today. As Sager and Panting noted in the postscript to their study of the shipping industry in Atlantic Canada, "the history of world shipping in the twentieth century shows that there is no necessary connection between growth in shipowning and a domestic capacity to build ships."[366] Still, the connection between shipowning and shipbuilding capacity, particularly in Britian, was a compelling paradigm that retained some relevance right up until the 1950s.[367]

The return of peacetime market conditions, followed by the Great Depression, might well have entirely erased such industry hopes and expectations. Within twenty years, however, the world was once again at war and Canada was again building ships and expanding capacity at a remarkable and unprecedented rate. This expansion was clearly not without problems; but by the end of the conflict the accomplishment was evident to everyone concerned.[368] Here, due credit is owed to Canadian shipyards for their part in maintaining the all-important World War II Atlantic lifeline, even though recent Canadian scholarship on the Battle of Atlantic has shown that organization and logistics were ultimately as great a problem as capacity.[369] Be that as it may, the vast expansion in shipbuilding during World War II did lead to the formation of The Canadian Shipbuilding and Ship Repair Association in 1944. This national organization, made up of representatives of the country's largest shipyards, became the most prominent and outspoken lobby for the shipbuilding industry in the post-war period. Even a brief review of its annual reports demonstrates the importance of the war experience on the industry's sense of identity and purpose.[370]

Indeed, the salient aspects of the Canadian shipbuilding industry after 1945 were mostly related to war, real or anticipated, and the strategic importance of shipping in a wartime context. Because of this, and because the industry had accomplished its greatest achievements under the strict command economy of wartime, Canadian shipbuilders developed a very close bond with government; in turn, the federal government displayed a much greater willingness to participate in all aspects of the nation's social and economic development after 1945. The most obvious example of the close, post-war bond between state and shipyard is the "St. Laurent" — class destroyer escort program, by which Canadian shipbuilders gained both lucrative contracts and valuable improvements in plant infrastructure and technologies. At the same time, the decision to develop a designed-and-built-in-Canada Navy broadened the industry's horizons considerably and was subsequently the source of much building and repair work in the Cold War era. Another, closely-related component was the "strategic nucleus" policy of the Canadian Maritime Commission, a

363. "What of the Shipbuilding Industry," p. 15. (See footnote 293).

364. "Canadian Shipbuilders Ask for Protection for Their Industry," *RMW* (February 1925), p. 89.

365. Mackenzie, "C.C. Ballantyne and the Canadian Government Merchant Marine, 1917-1921", pp. 1-13. On the various cultural manifestations of Canadian nationalism, see Bumstead, *The Peoples of Canada: A Post-Confederation History*, pp. 223-235.

366. Sager and Panting, *Maritime Capital*, p. 204. In support of this argument, the authors cite S.G. Sturmey, *British Shipping and World Competition* (London: Athlone Press, 1962), p. 9.

367. K.E.A de Silva, *An Economic Analysis of the Shipbuilding Industry Assistance Program* (Ottawa: Economic Council of Canada, Discussion Paper No. 351, 1988), pp 9-10.

368. Some of the problems are discussed in "Training Canada's New Shipyard Workers," *CT* (September 1943), pp. 495-497; see also "Shipbuilding in Canada during the Second World War," pp. 6-10, and Robson, "Merchant Shipbuilding in Canada," pp. 281-285.

369. Marc Milner, "The Battle of the Atlantic," *The Journal of Strategic Studies*, vol. 13, no. 1 (March 1990), pp. 45-66.

370. On the influence of the CSSRA see de Silva, "An Economic Analysis," pp. 61-96.

concept that served as reassurance and a launching pad for industry advocates. Lastly, Canada's assertion of sovereignty over the Arctic in response to the region's growing strategic and economic value generated work and fostered national design expertise in a very advanced area of shipbuilding and naval architecture: icebreakers. In seeking to understand the role of shipbuilding in Canadian society during the twentieth century, the primary claim, however general, is that shipbuilding was one means by which Canada expressed its evolving political independence and national identity.

Although very much a creature of the state, twentieth century shipbuilding was clearly an economic concern also. The construction of large steel hulls that characterized the technological development of shipbuilding after 1900 demanded a much higher level of capital investment and a much more rational organization of plant facilities and labour than had existed before. In this respect, the development of shipbuilding followed the general pattern of industrialization in all sectors, though its formation was closely tied to the British model. Canadian shipbuilders always took pains to note the quantity of materials and manufactured goods required to build an average ship. Like so much else, however, this consumption must be seen in the context of other industries. Using total domestic product as point of reference, and beginning with the first two post-World War I years when the Canadian government was vigorously building a national merchant fleet, new tonnage production amounted to approximately $73 million of a total net domestic income (NDI) of $8.5 billion. This represents .86 percent of NDI.[371] While these figures are not precise, this .86 percent of NDI represents the apex of relative production value for the century. For example, in 1938, with production once again growing in anticipation of the coming war, total production was valued at $11 million out of a total GNP of $5.25 billion.[372] However, in 1943, at the height of the wartime shipbuilding program, total new ship construction (wood and steel), remarkable though it was, constituted only .03 percent of Canadian GNP. A glance at the industry high points for the following two decades (1953 and 1967) shows the percentage of GNP represented by the industry for these years to be .007 and .002, respectively.[373] In short, the economic value of shipbuilding relative to GNP consistently decreased after 1920. An external historical comparision covering the years from 1884 to 1914, a period in which Britain absolutely dominated world shipbuilding production, reveals that this industry constituted 1.25 percent of Great Britain's gross domestic product.[374] Another perspective, this time from the Canadian transportation sector, can be gathered from figures for combined locomotive, railway car and rail production in Canada. In 1957, a year of exceptionaly high production in all three areas, the total value of these related activities equalled .69 percent of GNP.[375]

Employment in the shipbuilding industry generally followed step with production. In 1920, approximately 23 000 men were employed in the industry. That figure shrank by a factor of ten in the 1930s only to reach an unmatched high of approximately 52 912 in 1943.[376] After the war, employment fell steeply, only to recover again at a post-war high of 22 571 in 1953, representing about $72 732 056 in wages.[377] A downswing followed, with an average industry workforce over the next three decades of approximately 12 000.[378] In organizational terms, Canadian shipyard labour adapted to the industrialization of the workplace through unionization. As they did, they experienced a gradual loss of trade-specific identity and, in later years, a decline in overall numbers due to plant modernization and automation. As the century progressed, the trades profile of the shipyard came to mirror more closely that of other large industrial plants. At the same time, the high demand for Canadian skilled labour kept shipyard wages consistently above those paid by Britain and most other major world producers. Unlike other industries, market cycles, so often driven by global factors and government intervention, and the tenuous nature of the industry, greatly dampened the power of the shipyard unions. In stark contrast to the British situation, work-stoppages were relatively few and short-lived. Efforts to increase productivity focused on improvements in work force organization and the modernization of plant facilities; but these were too small to have little real effect on the long-term prospects of the industry.[379]

In assessing the national economic impact of shipbuilding, regional factors also deserve consideration. Clearly, in some areas of the country, the industry was of greater relative importance than in others. This is particularly true for the yards of the Maritimes and, more recently, the St. Lawrence, where the closing of any large industrial plant tends to have a greater

371. NDI here replaces GNP. See F.H. Leacy, *Historical Statistics of Canada*, 2d ed. (Ottawa: Minister of Supply and Services, 1983), Series F153-165. The value of production given represents the value of CGMM ships ordered between April 1918 and April 1920. CGMM orders constituted the overwhelming majority of ships built in this period.

372. "Survey of Canadian Shipbuilding industry," *CT* (August 1945), p. 459; Leacy, *Historical Statistics of Canada*, Series F1-13.

373. "Shipbuilding Industry Activity Reviewed," *CT* (May 1957), p. 89; Schedule no. 2, *CSSRA Annual Report* (1969–1970); Leacy, *Historical Statistics of Canada*, Series F1-13.

374. Pollard and Robertson, *The British Shipbuilding Industry*, p. 6.

375. M.C. Urquhart, ed. *Historical Statistics of Canada* (Toronto: Macmillian, 1965), Series Q196-252, pp. 480–481.

376. Table 8, *CSSRA Annual Report* (1947).

377. "Shipbuilding Industry Activity Reviewed," *CT* (May 1957), p. 89.

378. *CSSRA Annual Report* (1975), p. 91; Table 8, *CSSRA Annual Report* (1983). The figure is somewhat higher if non-CSSRA members are included.

379. For figures showing changes in labour and material intensities from 1961–84, see Table 2-16 in de Silva, *An Economic Analysis*, p. 37. On the matter of productivity see also de Silva, p. 13 and Table 2-23, p. 44.

real and psychological impact.[380] Such considerations invariably influenced the political response to the industry's needs.[381] Aside from its prominent role as a consumer of ships, the government's primary instrument of support for the shipbuilding industry was subsidy. While more work remains to be done in this area, a brief survey of the evidence suggests that the net value of subsidy was limited and the relative success of any given subsidy program was largely determined by external factors. These included the subsidy programs of competing nations and, above all, the global demand for tonnage. Subsidy served the industry as a kind of government-administered painkiller; it temporarily relieved the discomfort, but ultimately did little to slow the course of the disorder. In this case, the disorder (the lack of competitive advantage) was also evident to a greater or lesser extent in other Western shipbuilding nations and, indeed, in other sectors of the Canadian economy. That the Canadian shipbuilding industry should suffer sooner and more acutely from this problem simply underlines the fact that its growth and persistence in this century owes more to political circumstance and will than to any inherent economic advantage.[382]

With respect to the scientific and technological contribution of shipbuilding, the industry's impact on Canada has been largely incidental, though not insignificant. Certainly, Canadian naval architects and shipbuilders can take pride in their success in those areas where circumstances presented an opportunity, or a need, for invention and innovation; most notably this relates to ice-capable ships, hydrofoils, anti-submarine vessels and Seaway-size bulk carriers. Moreover, in many of these efforts, the National Research Council proved to be an important partner to the shipbuilding industry through its hydrodynamics laboratory, a fact which further strengthened the industry's association with the state. Canadian naval architects have historically also been at the forefront of ship-design computerization. Unfortunately, the opportunities within Canada to apply and develop new ideas have grown increasingly limited in the past few decades. In this respect, it is certainly ironic that the development of Canadian university programs in naval architecture occured only in the past sixteen years. At long last, Canada has the facilities to train its own ship designers but little capacity to employ them. This is a crucial deficit. In the twentieth century, the translation of scientific and technological ideas into social and economic benefit has been, and continues to be, largely a function of industrial control.

Ship Design and Construction in 20th Century Canada: The Merger of Science with Industry

> *"The efficiency of a ship does not vary as the Builder, but rather according to its design and specifications. ... The design and construction supervision of new tonnage is essentially the function of the Naval Architect... . The Naval Architect's services eliminate wasteful duplication of effort and enables strictly competitive prices to be obtained... ."*
>
> *Lambert and German, Naval Architects, 1932*[383]

Around 1900, directed science became an established component of Western technological innovation and industrial development. In the nineteenth century, scientific research and the development of new technologies generally existed within seperate orbits that occasionally intersected. These intersections increased as the century progressed, but the regular employment of academic science in industry and the establishment of corporate research laboratories was largely a twentieth century development.[384] In this context, Britain, whence Canada derived its early models, lagged behind Germany and the United States. This lag partly reflected the English tradition of "amateur" scientists and empirical engineering, a characteristic also associated with British industrial stagnation.[385] While the historical dynamics of science in the service of industry are too complex to be addressed in detail here, the fact remains — as David Noble has argued — that the ascendency of modern, corporate, capitalist economies (Canada included) cannot be properly understood in isolation from the merging of science with industry.[386] Accordingly, the evolution of British shipbuilding between 1870 and 1914 offers an interesting and very early case study of science — the engineering science of naval architecture — directed by an industrial alliance of state and corporate inter-

380. C.S.M. Shepard, *An Inquiry into the Canadian Shipbuilding Industry: The Facilities, Subsidies and Future* (Halifax: Canadian Marine Transportation Centre, 1983), p. 70.
381. Haydon, "The Canadian Government's Role in Shipbuilding," p. 54.
382. The best single economic review of the Canadian shipbuilding industry after World War II, and one which is highly critical of the subsidy program, is de Silva, *An Economic Analysis*. De Silva is particulary critical of the lack of rationale, which further suggests that political will and psycological factors like national prestige were the operative factors.
383. Lambert and German, Naval Architects, *Floating Equipment* (Montreal, 1932), p. 26.
384. See Ian Inkster, *Science and Technology in History* (New Brunswick: Rutgers University Press, 1991), pp. 110-116; David F. Noble, *America by Design: Science Technology and the Rise of Corporate Capitalism* (Toronto: Oxford University Press, 1977), pp. 110-117.
385. For an interesting discussion of the question of "professionalization" in science, see Susan Fay Cannon, *Science in Culture* (New York: Dawson, 1978), pp. 137-166. For a good, concise review of the arguments concerning Britain's relative economic decline at the end of the nineteenth century, see Pollard and Robertson, *The British Shipbuilding Industry*, pp. 1-8.
386. Noble, *America by Design*.

ests. Furthermore, the issue is of contextual and immediate relevance to the Canadian experience because industrial shipbuilding in Canada was born in the shadow of British domination and because, for most of this century, naval architecture in Canada was practiced by immigrants from Great Britain or, alternatively, by Canadians trained there.

After 1870, the systemiatic use of scientific methodology by naval architects in the design of new ships was increasingly encouraged by the British shipbuilding industry. In the case of British industrial shipbuilding, however, the model was not so much one of a single company using laboratory science to further its corporate goals as, for example, in turn-of-the-century America where "science was the handmaiden of corporate interests" for certain dominant companies such as General Electric and Du Pont — though isolated examples may exist.[387] For British shipbuilding, it was more a coalition of public and private interests fostering the intellectual base of an enterprise perceived as absolutely essential to national strength and economic advantage. Similarly, the focus was less on developing and protecting patents in an effort to control market share, than on the broader issue of retaining national dominance over international shipping and seaways. The collective national interest in British shipbuilding involved an exceptional alignment of the main pillars of late-Victorian society: the mercantile interests that required ships to import raw materials and export manufactured goods, an imperial political culture (of which Canada was a central part) sustained by trade links and naval power, and, above all, the Admiralty's persistent demand for bigger and better warships. One might also add to this list the travelling public, whose concern lay with safer and faster passenger ships. For all of these interests, the primary arbiter of good practice and scientific questions became the Institution of Naval Architects.

Founded in 1860, the Institution had three explicit objectives which defined its future role:

> *First, the bringing together of those results of experience which so many shipbuilders, marine engineers, naval officers, yachtsmen, and others are acquiring, quite independently of each other... and which, though almost valueless while unconnected, will doubtless tend much to improve our navies when brought together in the Transactions of the Institution. Secondly, the carrying out by the collective agency of the Institution of such experimental and other inquiries as may be deemed essential to the promotion of the science and art of shipbuilding but are of too great magnitude for private persons to undertake individually. Thirdly, the examination of new inventions, and the investigation of those professional questions which often arise and are left undecided because no public body to which professional reference can be made now exists.*[388]

As already noted, the Institution provided an important forum for the ascendancy of mathematical theory in shipbuilding and, among other things, served an important supporting role in the breakthrough experimental research by William Froude. More to the point, however, these developments occured in close conjunction with the ascent of industrial shipbuilding in Great Britain. It would, be a gross, deterministic exaggeration to assert that the engineering science practiced in Great Britain was "the key" to the subsequent success and global dominance of the British shipbuilding industry; too many other factors, whether social, economic, technological or political, entered the equation.[389] Nevertheless, the British industry triumphed in an overwhelming manner (between 1892 and 1914 British-built tonnage constituted, on average, 64 percent of world production)[390] in the decades immediately following the Institution's establishment, and this fact suggests a stronger connection than previously acknowledged.

Sidney Pollard's and Paul Robertson's formative study of *The British Shipbuilding Industry 1870–1914* argues explicitly against the notion that science supported the success of British shipbuilding. However, they fully acknowledge the extensive British contribution to the advancement of naval architecture after 1860, but stress the reluctance of British shipbuilders to pursue academic research in this area:

> *In short, British shipbuilders did not believe that the benefits to be gained from increased research and education justified their expense. Most progress consisted of many small changes produced by men of little or moderate education. Great improvements, based on a solid knowledge of scientific theory, were few, and the attitude of the builders was: why should we equip laboratories and hire scientists to produce some basic breakthrough that may never come? Furthermore they had little faith in the ability of scientists to contribute anything of much value, because scientists did not know how to build ships, and it was felt that only people who had passed through a proper apprenticeship in the yards and ships were likely to know enough*

387. Noble, *America by Design*, p. 114. See also David A. Hounshell and John Kenly Smith, Jr., *Science and Corporate Strategy: Du Pont R&D, 1902–1980* (Cambridge: Cambridge University Press, 1988), esp. pp. 593–601.

388. Reed, "Introductory Address" *Transactions of the Institution of Naval Architects*, 1 (1860), p. xviii.

389. Pollard and Robertson, *The British Shipbuilding Industry*, pp. 1–8.

390. F. Geary and W. Johnson, "Shipbuilding in Belfast, 1861–1986," *Irish Economic and Social History* (1989), p. 42. The figure cited comes from *Lloyd's Register of Shipping*.

of the problems involved in shipbuilding to be able to arrive at satisfactory solutions.[391]

This line of argument, while internally coherent, is flawed by its portrayal of science in relation to industrial development, particularly in this context. The reference to men of "little or moderate education" and to "laboratories" betrays a perception of (or at least an emphasis upon) the professional scientist derived from the nineteenth century German model which rather anachronistically favours pure or academic, over applied, science. The problems inherent in such a perception have been effectively demonstrated by Susan Faye Cannon.[392] More recently, Ian Inkster, analysing "scientific enterprise" prior to 1914, has reinforced Cannon's ideas:

> *the traditional stress upon universities and research programmes has given rise to theories which relate industrialisation to innovative institutions (e.g., Germany or Japan) and deindustrialisation to retardative institutions (e.g., Britain or France). Our broad treatment of the scientific enterprise of major nations suggests that a somewhat more complex series of linkages was involved. ...Historians overly-concerned with the origins of "professionalisation" in science or with "research and development" may mistakenly equate such processes with the economic role of the scientific enterprise. ...A nation such as Britain, with its wide "audience" for science, might actually seem to be falling behind in science if "progress" in science is measured in terms of such criteria. But in terms of the creation of new, abstract knowledge, in terms of the diffusion of information through the social system and in terms of the sustenance of routine "ordinary inventiveness" throughout the industrial system, Britain may well have been significantly ahead of most nations at this time.*[393]

Inkster here raises, although does not fully answer, the difficult question of what constitutes an appropriate critera for judging the effective social desemination of scientific knowledge. Paul Robertson, in his study of technical education among British shipbuilders and marine engineers from 1863 to 1914, documents both the apparent weakness of the British system of technical training relative to Germany and the U.S., as well as the concerns expressed by contemporary observers.[394] However, he also documents the very evident economic success of the British industry despite these apparent deficiencies. How best to explain this? While on the surface this might appear to negate the influence of theoretical training, a more probable reading of the evidence suggests that the educational system then in place was sufficient, both quantitatively and qualitatively, to serve effectively the evolving needs of British industry. Robertson suggests as much when, reflecting on British success, he notes "that the Germans, especially, with their extensive system of schooling for all grades of workman, may have overinvested in education at this [lower grade apprenticeship] level."[395] Robertson then admits that evidence also shows that, notwithstanding the relative size of British programs for higher-level education, British naval architects "were as competent and inventive as their better-educated competitors abroad." This statement again begs the question of how one defines "better educated."[396]

From the founding of the Institution to the outbreak of World War I, shipbuilding, as Robertson notes, still relied on large numbers of tradesmen for whom practical experience was at least as important as formal class-room education.[397] In the pyramid of production, however, the number of theoretically-trained naval architects required to provide successful new designs (these individuals being the primary concern of this study), while dynamic over time, was probably less than the contemporary rhetoric of concern would suggest. And, as that demand increased toward 1914, so did the facilities and the overall receptivity towards formal scientific training in Great Britain. In more general terms, the "economic role of the scientific enterprise" in industrial shipbuilding during this period was most evident by increasing the predictability of innovation and improvement. Through the judicious application of mathematical principles concerning displacement, stability and resistance, new designs could be effectively tested and measured in advance, and their relative technical and economic benefits determined. It is worth repeating that what makes one ship decidedly better than another depends largely on the vessel's intended function and operational conditions. Moreover, one of the salient aspects of industrial shipbuilding developement was the production of more specialized vessels.[398] The introduction of new materials, techniques, machinery and weapons systems all necessitated design innovation which, in turn, had to be tested and refined. In this way scientific naval architecture, understood as a form of "engineering science" based on "theory and experiment... concerned with man-made devices" and producing "statements about such devices rather than

391. Pollard and Robertson, *The British Shipbuilding Industry*, p. 148.
392. Cannon, *Science in Culture*, Chapter 5.
393. Inkster, *Science and Technology in History*, pp. 128–130.
394. Paul L. Robertson, "Technical Education in the British Shipbuilding and Marine Engineering Industries, 1863–1914," *The Economic History Review*, Second Series, Vol. 27, No. 2 (May 1974), pp. 223-235.
395. *Ibid.*, p. 234.
396. *Ibid.*
397. *Ibid.*
398. Pollard and Robertson, *The British Shipbuilding Industry*, p. 18.

statements about nature"[399] was undoubtedly an essential element in the development of Britain's shipbuilding industry.

By thus allowing science to play a more active and substantive role in the early development of British industrial shipbuilding, the interpretive value of Noble's thesis becomes evident: scientific naval architecture was an important instrument in the early economic sucess of the British industry and was ultimately, if not uniformly, recognized as such by those who ran it. In the imperial culture of the late-nineteenth and early-twentieth century, British merchants, shipowners and shipbuilders, together with the Royal Navy, clearly had a collective, if not corporate, interest in the advancement of naval architecture in Britain. Their participation in the origins and subsequent development of the Institution of Naval Architects reflected this interest. The Institution was the creature of this common interest, a kind of combined corporate laboratory, library and lecture hall. As a forum for the diffusion and exchange of ideas and information, and as an association that encouraged the education and application of engineering science in shipbuilding, the Institution also served in the formative years to define professional standards.[400] Industrial shipyards required the applied science of naval architecture to serve the evolving demands of an expanding, largely British-controlled shipping market. Thus, the generation of naval architects trained after 1860 became on-site engineering scientists in the expanding industrial shipyards of Great Britain. Their laboratories were the design offices of these yards wherein the specific needs of their clients, whether power, economy, carrying capacity, safety or some combination of the above, were resolved through the design process. Success was measured by an ability to meet these demands in the most economical manner possible. Accordingly, naval architects became servants of both the technology and the economics of shipping. In David Noble's words,

> *the technical and capitalist aspects of the engineer's (naval architect's) work were reverse sides of the same coin, modern technology. As such, they were rarely if ever distinguishable: technical demands defined the capitalist possibilities only insofar as capitalist demands defined the technical possibilities.*[401]

What emerges from this is a paradigm in which the naval architect, as scientist-engineer, became an integral part of the development of his industry and, by extension, of the economy within which it functioned. For turn-of-the-century Britain, shipbuilding represented an economic keystone. It figures as a prominent, early example of how science developed as a component of modern industry. Still, the exact extent to which scientific naval architecture contributed, along with other factors, to the industry's remarkable success remains unclear. However, the very strong British builder-owner linkages of the inter-war period, indentified and examined by Anthony Slaven, offer an important clue to what may have been the operative element of this influence: specialization.[402] By cultivating a strong relationship with a specific client or client group, British shipyards could increase the comparative advantage of their product by concentrating design effort and expertise. Such concentration, through specialization, encouraged a highly advantageous refinement of skills and solutions; the links thus forged undoubtedly had a significant influence on the dynamics of the marketplace both nationally and internationally.[403]

Modern Naval Architecture in Canada:

In Canada, the market for steel steamships in the first half of the century was overwhelmingly dominated by the British industry and the underlying British technology. With little industrial shipbuilding taking place in Canada before World War I, the demand for scientific naval architecture was limited. The same applied to educational opportunities in the field, a situation that persisted throughout much of the century, although the United States increasingly served as an alternative source of expertise and training.[404] When Vickers established its new shipyard in Montreal in 1911, the company imported the naval architects it required for the effective operation of the facility. Similarly, during World War I, Canadian shipbuilding, though remarkable, was predominantly an assembly operation, using established British designs and imported supervisory expertise. The practice of importing naval architects remained a defining characteristic of the Canadian shipbuilding industry, and although increased government involvement after 1945 gave the

399. Layton, "American Ideologies," p. 695.
400. Barnaby, *The Institution of Naval Architects*, pp. 570-571.
401. Noble, *America by Design*, p. 34. (parenthesis mine)

402. Anthony Slaven, "British Shipbuilders: Market Trends and Order Book Patterns Between the Wars," *The Journal of Transport History*, vol. 3, no. 2 (September 1982), especially p. 54 and pp. 56-59.

403. As Slaven points out, however, in the buyer's market of the interwar years these same linkages restricted the extent to which British yards exploited the advancing technologies of the motorship and the tanker: Slaven, "British Shipbuilders," pp. 43-46. This suggests that although specialization may have sharpened skills and expertise during the period of British shipbuilding dominance, in later years it may also have served to retard British innovation in new and expanding markets.

404. S.A. Alpay, *A Study to Identify the Requirement for Academic Naval Architecture and Marine Engineering Within Canada's Marine Industries* (Ottawa: Aerospace, Marine and Rail Branch, Department of Industry, Trade and Commerce, 1968), xi. MIT established the first American degree program in Naval Architecture (Course XIII) in 1893, the same year in which the Society of Naval Architects and Marine Engineers was founded. The Webb Institute of Naval Architecture in New York opened in 1894.

industry a greater national bent, the result was still very much a variation on an Anglo-American theme.[405]

One such imported expert was Walter Lambert, who came to Canada during World War I to work for the Imperial Munitions Board. In 1922, Lambert established a private naval architecture and engineering firm in Montréal. Six years later, Lambert was joined by a former employee of Vickers, Horace German; together, these men established what was to be the single most important and successful Canadian firm of naval architects.[406] In 1932, the firm published a volume entitled *Floating Equipment* to promote their services. The volume is essentially a retrospective catalogue of their work, but includes a concise explanation of the role of the naval architect:

> *The efficiency of a ship does not vary as the Builder, but rather according to its design and specifications. The practice of inviting several shipbuilders to bid on a special type of vessel, giving them only a few essential particulars, is purposeless as a means of obtaining an accurate measure of comparative values. ...The design and construction supervision of new tonnage is essentially the function of the Naval Architect... . The Naval Architect's services eliminate wasteful duplication of effort and enables strictly competitive prices to be obtained on the basis of common tender data. ... It is the Naval Architect's business to keep abreast with marine development. Failure in knowing, and inability to analyse correctly such developments, results in a degree of obsolecscence occurring before the life of the equipment is terminated by physical deterioration... .*[407]

This firm, which was later known as Milne, Gilmore and German, and, finally, German and Milne, enjoyed one of its most productive periods in the late 1940s.[408] German and Milne developed a strong reputation in the area of ice-breaking hulls, its most celebrated single design being the diesel-electric, quadruple-screw ferry *Abegweit*, launched in 1947.[409] Intended to provide year-round service between Prince Edward Island and the mainland, the ship was the largest and most powerful ferry of its time. It was also an early Canadian example of diesel-electric propulsion and all-welded ship construction (German and Milne were leading proponents of welded ships world-wide).[410] The *Abegweit* was only one in a series of ice-breaking and ice-capable vessels designed by this firm. The list includes the Canadian Coast Guard Ships *John A. Macdonald* (1960), *John Cabot* (1965) and *Louis S. St. Laurent* (1969). Indeed, together with the naval architects employed by various federal government agencies, the staff at German and Milne (including Horace's two sons, William and Gordon) became key players, and outspoken advocates, in the development of a unique Canadian tradition in icebreaker design.[411]

Another noteworthy Canadian firm of naval architects was the Montréal-based Camat Transportation Consultants Inc. Founded in 1968 by Norman Laskey, Pierre Boisseau and John Blake, most of Camat's work was conducted for foreign companies, often on speculation. Notable Camat designs include: the Very Large Crude Carrier *King Alexander the Great*, an innovative series of mini (5 000 dwts.) bulk carriers, and the world's first multi-purpose ore/bulk/oil carrier. Camat, which eventually established offices in London and Tokyo, also engaged in specific hull form and systems research. Its best known Canadian design was the M.V. *Arctic*, the highly sophisticated ice-breaking bulk carrier already mentioned.[412]

Canadian research in the science of naval architecture was also encouraged by the efforts of the hydrodynamics lab of the National Research Council (NRC). Although the NRC was founded in 1916, roughly at the same time as Canada's remarkable wartime expansion in shipbuilding, the first hydrodynamics laboratory dates to 1930–31.[413] Built at the John Street site in Ottawa, the lab's principal component was, naturally, a towing tank. This facility, originally intended primarily for the testing of aircraft floats, ultimately proved to be too small for larger applications. In the early 1940s, again in the midst of war, a new 450-foot long facility was built on the Montréal Road Campus.[414] The resulting NRC towing tank and hydrodynamics lab, complete with model-making facility, ultimately provided Canadian scientists

405. *Ibid.*, p. 5.

406. "Mainly About Marine People Throughout Canada," *RMW* (June 1929), p. 399. In the announcement of this new partnership, it is noted that the firm "will act in association with A.T. Wall and Co., Liverpool, England."

407. Lambert and German, Naval Architects, *Floating Equipment* (Montreal, 1932), p. 26.

408. Smith, "German & Milne: Its Role in the History of Ship Design in Canada," p. 17. The archival records of German & Milne are preserved at the Marine Museum of the Great Lakes at Kingston, Ontario.

409. "Diesel-powered, Quadruple-screw Ferry Abegweit," *CT* (August 1947), pp. 465–474. For a British perspective on the work of Milne, Gilmore and German, including the Abegweit, see A.C. Hardy, "Review of Some Canadian Ship Designs," *CT* (April 1951), pp. 219–221.

410. Conversation with Gordon German, formally of German and Milne.

411. E.C.B. Corlett, and G.R. Snaith, "Some Aspects of Icebreaker Design," *Transactions of the Royal Institution of Naval Architects*, vol. 106, no. 4 (October 1964), pp. 389–413. For examples of this advocacy, see J. Gordon German, "Polar Icebreakers: keys to the Arctic's future," *CSME* (April 1970), pp. 20–24; J. Gordon German, "Bulk shipping and icebreaker support in the Arctic," *CSME* (January 1971), pp. 21–23.

412. Joseph Gough, "Innovative ship designing," *CSME* (August 1971), pp. 43–45.

413. W.E. Knowles Middleton, *Mechanical Engineering at the National Research Council of Canada 1929–1951* (Waterloo: Wilfrid Laurier University Press, 1984), p. 32.

414. *Ibid.*, pp. 81–85.

with the means to participate in a full range of hull-form and marine sytems research. This increase in support for shipbuilding research and development was clearly a product of the same set of values and concerns that drove the government procurement program. In particular, the lab developed a high level of expertise in the design of icebreakers and ice-capable ships.[415] In 1984, the hydrodynamics lab was transferred to a new, state-of-the-art facility in St. John's, Newfoundland. The new "Institute for Marine Dynamics," (IMD) provides a full range naval architecture and ocean engineering services for Canadian and, increasingly, foreign clients. The salient features of this facility are its ice tank, at 90 metres, the world's largest, a 200-metre long, wave-making towing tank, and a "Stardent" mini-supercomputer used in a full range of computational hydrodynamics.[416] Since 1945, the aerodynamics lab at the NRC has also been engaged in testing ship superstructures. This work, conducted with models in a wind tunnel, has been especially valuable in improving exhaust-stack and helicopter-deck design. Since helicopters have become essential components in both ASW and ice-breaking service, the location and aerodynamic features of landing pads and the effective dispersal of ship-engine exhaust are important issues in the effective operation of these vessels.

In the educational sector, Canadians interested in naval architecture remained unable to pursue advanced studies in Canada until 1978.[417] In that year, the Technical University of Nova Scotia (TUNS) began offering a limited number of post-graduate courses in naval architecture. The first, full-time professor of naval architecture at TUNS was hired in 1983, and the program granted its first Master's degree in 1984. The first Ph.D. degree was awarded three years later. The program currently consists of two full-time and one part-time faculty members guiding twenty graduate students. In 1989, the Centre for Marine Vessel Design and Research (CMVDR) was established, with a directed emphasis on small craft hydrodynamics and engineering. In connection with its academic program and research centre, TUNS also maintains a 30-metre, fully-automated, wave-making towing tank. While TUNS plans to expand the naval architecture program to include undergradute course work, the only accredited undergraduate naval architecture program currently in Canada is offerred by Memorial University of Newfoundland, in St. John's.[418] Introduced in 1980, the MUN program in Naval Architectural Engineering is very broadly based, reflecting an expanded definition of the field now described as Ocean Engineering. MUN offers a wide range of courses in structural, mechanical and hull design as well as technical electives in areas such as propulsion efficiency, vibration analysis, ship production management, and ocean engineering and design. As of the 1993/94 academic year, the MUN program employed four full-time and one half-time professors teaching an enrolment of 25 students. On the West Coast, the University of British Columbia offers a naval architecture "option" as part of its degree program in mechanical engineering. Directed graduate studies are also available. Like that at TUNS, this program dates to 1978. During the 1980s, at the height of the Beaufort Sea energy exploration project, approximately 15 to 20 students a year graduated under the U.B.C. option program. To facilitate research, U.B.C. has a 30-meter, wave-making towing tank as well as a manoeuvering basin.[419]

The Design Process:

To appreciate more fully the role of the naval architect in modern industrial shipbuilding, it is necessary to examine the modern design process. Throughout the century, ships generally became larger and more complex while new materials and parallel developments in marine engineering resolved problems and created new challenges. Allowing for a trend towards more sophisticated and specialized designs, as well as a general evolution towards more sophisticated techniques, basic ship design can best be understood as involving five principal steps:[420]

1) operations analysis,
2) ship characteristics and basic design,
3) preliminary design,
4) contract specifications design, and
5) detailed working plans.

Operations analysis entails a definition of the function or trade that the desired ship will serve. In most cases, the owner provides this information, although

415. For an example of this research see S.T. Mathews, "Investigation into Icebreaking," *CSME* (April 1957), pp. 41.

416. National Research Council, Institute for Marine Dyanmics Booklet, *Marine research environments that are second only to nature*; National Reseach Council, Institute for Marine Dynamics *Annual Reports, 1990/1991* and *1991/92*.

417. The need for university-level training in naval architecture and marine engineering in Canada was the subject of a special study commissioned in 1967 by the federal Department of Industry, Trade and Commerce. See Alpay, *A Study to Identify the Requirement for Academic Naval Architecture and Marine Engineering*; see also Parkes,"Marine Training and Research in Canada," pp. 163-164.

418. MUN also has a formal arrangement with the University of New Brunswick whereby, on completion of a core programme at UNB, students transfer to MUN to follow dedicated courses in naval architecture. A similar arrangement also exists with the University of Prince Edward Island. *Ibid.*, p. 163.

419. The author wishes to thank Prof. C.C. Hsiung at TUNS, Prof. Haddara of MUN, and Prof. H. Vaughan at UBC for providing information on their respective programmes.

420. Benford and Mathes, *Your Future in Naval Architecture*, p. 64. This section is largely derived from the explanation provided in Chapter 5.

shipyards have sometimes engaged in speculative building for which the yard would identify the kind of ship required. From an engineering perspective, the function helps establish the problem(s) to be addressed. The "ship characteristics and basic design stage" requires identifying all operational parameters based on function (for example, if the ship to be built was a laker, then the size of the canals it must transit would set limits on its dimensions) and establishing fundamental ship particulars such as size, speed, capacity, accomodation, etc. At this point, the architect suggests materials, form, machinery and provides, as appropriate, a basic technical and cost analysis of any competitive options. Some tentative drawings would also be produced to facilitate the discussion. Any and all competitive values (for example, speed vs. capacity) are addressed and resolved at this stage. Once this is complete to the owners' satisfaction, the naval architect can proceed with the preliminary design. Perhaps the most important aspect of this phase of the process is the design of the hull form, since the shape of the ship will profoundly influence performance, stability and economy. Once a form has been chosen and lines drawn, careful calculations and, when appropriate, tank tests, are conducted to insure the basic compatibility of the shape with the selected propulsion system. A set of general arrangement drawings are also produced to show the relative location and shape of the various ship sections, compartments and major components. At the same time, the basic structure and scantlings are defined. With these elements set down on paper (or entered in the computer) the naval architect can calculate weight displacement and stability. Special attention must be given to determining how the vessel will respond to different sea and wind conditions. Theoretical considerations supported by mathematical calculations play an important role in improving predictability, especially in the case of radical designs. Manoeuvrability is also important, particularly for specialized, high-performance vessels such as warships and icebreakers, or for ships required to navigate in confined or otherwise difficult circumstances. In this regard, modern developments in marine engineering, most notably the bow thruster and "kort" nozzel, have simplified the task of the naval architect.[421]

The final two steps, though less creative and much more time-consuming, are essential to the efficiency and economy of the construction process. "Contract specifications design" requires the careful refinement of all previous design work and the production of a detailed list of vessel specifications. These describe the expected quality and performance of the design and its principal components, thereby providing the basis for accurate time and cost calculations by shipyard management. After the specifications have been reviewed and accepted, the final step is to produce detailed working plans wherein every structural element, system, component and fixture is drawn to scale and carefully defined. These drawings provide assembly instructions for the various tradesmen and labourers in the shipyard and are the starting point for construction of the ship.

In performing these tasks, this century's naval architects have largely relied on refined versions of the drawing instruments used in the eighteenth and nineteenth centuries. The use of lines plans in the design process accelerated dramatically with the introduction of steel and steam in shipbuilding, together with the demand for better equipment. The materials and the technology of everything from pens to scales and various measuring rules improved while drawing surfaces with better resistance to humidity fluctuation were also introduced. Some of the more characteristic tools of the naval architect are ships curves as well as long battens, or splines, used in conjunction with small weights, called "ducks" or "whales," all used to define the complex shapes of ship design. The greater application of mathematical principles to industrial ship design also required more sophisticated measuring and calculating instruments. The planimeter and integrator for measuring area, and varieties of slide rules for calculations, became common tools of the trade for much of the century. Logarithmic tables were equally indispensable. Mechanical calculators were also employed until the late 1960s when electronic scientific calculators were introduced. While many of these items were used in other areas of applied science, some ship-design tools were more particular to established maritime traditions.

One example is the plating model, a kind of half-model for metal-ship construction. Like its predecessor, the plating model faithfully represents the ship's form; rather than using it to determine frame shapes, however, the surface is marked to scale, with all the different shapes and sizes of required hull plates. Plating models provide an effective three-dimensional tool for planning and organizing the metal plates required to form the vessel's outer shell. Even more important to the design process are the full-form models used in experimental towing tanks. As previously noted, the concept of the towing tank dates back to the eighteenth century. However, it was the research of William Froude in the 1860s and 1870s which finally provided a sound theoretical basis for using scale models effectively to test hull resistance.[422] The first privately-owned towing tank was the

421. Such mechanical solutions to performance issues tend to errode the traditional distinction between naval architecture and marine engineering. See Smith, "German & Milne: Its Role in the History of Ship Design in Canada," p. 17.

422. The essential discovery was what is known as Froude's Law of Comparison: "the wave or **residuary resistances** of geometrically similar ships are in the ratio of their displacements when their speeds are in the ratio of the square roots of their lengths." Taylor, *Dictionary of Marine Technology*, p. 79. See also, Duckworth, ed., *The Papers of William Froude*, p. xvi.

Denny Tank, built in 1882 by the Scottish shipbuilder William Denny and now preserved as a part of the Scottish Maritime Museum. While towing tanks differ in size, depth, structure and machinery, the basic concept is simple: a model hull, carefully fashioned after the lines of the proposed vessel and equipped with sensitive measuring instruments (usually a dynamometer) is attached to a rail-mounted carriage which is propelled down the length of a tank at a prescibed speed. The models are very carefully constructed in wax, wood or plastic, and precisely ballasted to reproduce accurately the movement of the proposed vessel. In most modern towing facilities, wave-making equipment is installed at one end of the tank to produce wave effects against which the hydrodynamic performance of the hull can be measured.[423] In an ice tank, like that featured at the NRC Institute for Marine Dynamics, ice is formed from a combination of water, detergents and polypropylene glycol to accurately reproduce, in scale, the characteristics of the various ice types encountered in northern waters. In this way the ice-breaking capacity of different hull forms can also be studied. A more modern variant of this type of model experiment involves running trials on self-propelled, true-form models in a large basin. These tanks are usually square in shape and are also commonly equipped with wave-making machinery. Such tests are conducted to provide important information on the manoeuvrability of a proposed design in different sea conditions. Finally, models representing the form of the above-water hull surface and superstructure are also used in wind tunnels to examine the pattern of air flow around the vessel at various wind speeds and angles.

As with so many other industries, of computer technology applications in shipbuilding and naval architecture have profoundly influenced both process and product. The use of computers in ship design and construction dates to the 1950s. Initially, computers were cumbersome and used primarily to facilitate the execution of long, complex calculations. However, the Canadian firm of German and Milne was quick to adopt this new technology; in 1958, it began to produce specialized in-house programs to perform arduous ship-design calculations. Run on computers available at McGill University, these programs could execute in only three days mathematical tasks that would normally take a person up to one month. These early efforts proved successful enough to prompt German and Milne to establish a subsidiary company in the mid-1960s called "Procom," specifically to sell computer calculation services for naval architecture applications.[424] More recently, the development of computer-aided design (CAD) software and compact, desktop hardware, has fundamentally altered the ship-design process.[425] In naval architecture, modern CAD systems allow a full integration of the drawing board and specialized scientific computer. Mathematical calculations involving complex equations and theories are now reduced to function keys, allowing for fast and economical investigations of even minor design alterations. Modern CAD graphics allow the naval architect electronically to sculpt the hull form in simulated three dimensions and to isolate and magnify selected elements. New designs, in preliminary or final form, can be quickly and easily produced as lines drawings or isometric views using computer plotters. The same information can also be electronically transferred to computer-operated machinery capable of translating the CAD image directly into material form. Increasingly, computers are also being used by naval architects to replicate laboratory experiments. Although such applications have yet to render tank-testing facilities obsolete (these too have benefited from computerization), it has refined the problems pursued in the laboratory. Among the best naval architecture CAD programs available today is "Fast Yacht/Fast Ship." Originally intended for use in competitive yacht design, "Fast Yacht/Fast Ship" was co-developed by a Canadian naval architect, Steve Killing. Today, "Fast Yacht/Fast Ship" is used for didactic as well as design purposes by major shipbuilders, design firms and schools, including: the United States Navy, the Webb Institute of Naval Architecture, MIT, Royal Schelde (Netherlands), and the Universita di Genova (Italy). In Canada, "Fast Yacht/Fast Ship" is also used by the Marine Dynamics Laboratory of the NRC, the Department of National Defence (Canada), and the Vancouver office of Kvaerner Masa Marine.[426]

20th Century Ship Construction:

The transition from wood to steel as the primary material in ship construction increased the scale, cost and complexity of modern ships. The assembly process was also much more complicated — increasingly so as the century progressed — with the traditional stages of laying the keel, erecting the frames, setting the cross-beams, and planking significantly altered to address the characteristics of heavy, complex steel structures and specialized forms. In addition, the considerable capital investment associated with the construction of large modern ships greatly

423. Leo Walter, "Scale models in ship research," *CSME* (May 1957), pp. 36–48.

424. Conversation with Gordon German, formally of German and Milne.

425. In 1973, William German, of the firm of German and Milne, argued publicly for the establishment of a centralized "Numerical Control" computer system to be used on a time-sharing basis by shipyards across Canada. In the late 1980s, a more advanced version of the kind of system he described as costing approximately $800 thousand would be available, in a desktop form, at about one-sixteenth the price. William German, "Canada *can* build cheaper ships," *CSME* (February 1973), pp. 22–25 (carried over to p. 30).

426. For a very recent review of ship design and shipbuilding software, including "Fast Ship" see "Computing," *Shipbuilding World and Shipbuilder* (May 1994), pp. 16–24.

encourages careful planning and organization to maximize construction economy and work force efficiency. This systemization is well reflected in the trend towards prefabrication, whereby the form and structure of the ship is designed and then abstracted into component parts, each of which is independently constructed and then transferred to the launch ways for assembly.

Still, the influence of tradition did not entirely vanish with the application of industrial organization and techniques. In the first half of the twentieth century, vestiges of the past persisted at least in the initial stages of production. For example, the frames were first drawn out in the moulding loft; the keel blocks were carefully placed and aligned along the ways (albeit in a heavily reinforced berth); a plate-and-girder keel structure was the first element laid down, and the alignment of the whole carefully controlled by a tradesman called a "shipwright." Thereafter, the implications of steel construction became more evident. The ascendency of steel hulls and mechanical propulsion promoted a general tendency toward vessels designed with distinctly rectangular midsections and increasingly long stretches of parallel body. The reasons for this were primarily economic: a rectangular shape offered the most complementary mixture of maximum carrying capacity, structural rigidity and simplicty of construction. The hydrodynamic performance of the hull developed primarily through the design of the bow and stern form. In very simple terms, the early stages of metal ship construction comprised the assembly of a strong, steel box attached to more complex bow and stern shapes.[427]

When the keel structure was set, the bottom of the "box" was assembled with floors (transverse girders) and bottom shell plates, stiffened internally with longitudinal girders.[428] Internal plating was then laid over this framework creating a double bottom. The vertical frame sections were then attached to the floors and, using battons and cables, the resulting structure was thoroughly aligned and faired. This work was conducted by the yard's shipwrights. Once this process was complete, the deckbeams could be fastened on top of the frames, thus completing the skeleton of the box. Next came the transverse bulkheads and other major structural elements like stem and stern frames. As the work progressed, scaffolding was erected alongside the hull to provide easy access to the evolving structure at all levels. This was particularly important in the application of the hull plating. The metal plates were fastened to the hull in a series of longitudinal strips beginning amidships, about half-way up the side, and working to either end. The actual sequence of plate application was determined by the method of fastening. If riveted, then the plates were applied in alternating lines, or strakes, with the complete series of "inner" strakes (those closest to the frames) set down first, followed by the second, or "outer" series fastened atop and between the first. The plating sequence was carefully planned to ensure that the strake at the turn of the bilge (where the side meets the bottom) is among the "outer series." Riveted plates also required caulking by indenting the overlapping plate with a caulking tool. However, in the case of welded plates, the sequence must be "from amidships to the ends and from half height upwards and...downwards to the bilge simultaneously, otherwise serious distortion may result."[429]

Beyond the basic hull structure itself, various large scantling girders and foundations were required to reinforce and secure the propulsion system and its related elements. In addition, modern ships also contain a complicated matrix of bulkheads, tanks, machinery, pipes, wires and accommodation spaces, all of which must be built and installed in proper sequence. Much of the fitting out and finishing work, however, was performed after the launch. The preparation for the launch was an inversion of the practice established centuries earlier: the sliding ways were raised under the hull with wedges; once in place, the vessel was secured by a trigger mechanism. Because of the trend toward flat-bottom hull forms in modern ships, only a rudimentary cradle, made up of strategically located poppets at bow and stern, was required. Activation of the trigger, usually following a formal christening ceremony, sent the hull sliding down the ways into the water, its progress controlled by a series of carefully arranged drag chains. On the Great Lakes, the common practice was to side launch ships. Either way, the launch of a large ship is a dramatic, finely balanced undertaking, requiring careful consideration and calculation of all the forces involved. A poorly-executed launch could be a very dangerous and destructive thing.[430]

The quantity of materials involved in the construction of a modern steel ship is indeed impressive. For example, even a very modest cargo ship of only 15 000 dwts. (some tankers today measure 1 500 000 dwts!) contains approximately 5 000 tons of steel (sufficient for about 10 000 automobiles),

427. For a good, if somewhat dated, technical review of the development of merchant ship design, reflecting the trend towards rectangluar midsections see: J.M. Murry, "Merchant Ships, 1860–1960," *Transactions of the Royal Institution of Naval Architects*, vol. 102 (1960), pp. 663–709.

428. The generic assembly process described here largely derives from the very concise description provided in J. Anthony Hind, *Ships and Shipbuilding* (Temple Press, 1959), pp. 32–37. Other well-illustrated examples can be found in Edward V. Lewis and Robert O'Brien, *Ships* (Time Life Books, 1968), pp. 15–29; and for a specifically Canadian, Great Lakes perspective, see Donald Page, "The Construction of the S.S. *Mathewston* in 1922," *FreshWater*, vol. 8, no. 1 & 2 (1993), pp. 3–63.

429. Hind, *Ships and Shipbuilding* (Temple Press, 1959), p. 34.

430. For more details regarding launching, see Hind, *Ships and Shipbuilding*, pp. 38–45; Page, "The Construction of the S.S. Mathewston in 1922," pp. 52–55; Robert Woodcock, *Side Launch* (Toronto: Summerhill, 1983).

enough paint to cover 200 houses, 20 miles of electrical cable and some 10 miles of piping.[431] To bring these together with a large work force made up of a variety of trades required an extensive and well-organized facility. In the first half of this century, industrial shipyards in Canada varied greatly in the size and sophistication of their industrial plants, with Vickers in Montréal representing the best facility. Aside from the launch ways and/or drydock, easily accessible storage areas for materials were essential. While the waterfront location of the shipyard would allow some delivery by water, rail lines to and from these storage areas were typical. Large enclosed shop areas for the fabrication of frames and fashioning of steel plates (the principal structural components) were also required; further arrangements had to be made for the carriage of materials between storage and shop, and between shop and launch ways. The principal features of this system would be lifting machinery, heavy derricks and, wherever feasible, large cranes. Indeed, cranes became increasingly important with the move toward prefabrication. Ancillary shop facilities were also provided for forges, casting, pipe fitting, anglemaking and carpentry. As with the design process, the industrialization of the shipyard meant that many of the tools techniques and trades involved were common to other types of heavy industry, and mirrored general developments in power, automation and efficiency. A list of shipyard trades from 1920 notes thirty separate occupations, among which only five standout as particular to the shipyard: patternmakers, shipwrights, caulkers (wood and steel) and riggers.[432]

Prior to World War II, the principal fastening technique for shipbuilding was riveting. The use of rivets required that each structural member and plate be prepared in advance of assembly, a labour-intensive process which, like the act of riveting itself, required planning, organization and effective teamwork. The production of ship's plates from steel sheets required tools and machinery for punching, shearing, planing, drilling, rolling, flanging and scarfing.[433] While this equipment was largely generic to heavy industrial production, the organization of plate preparation and prefabrication was strictly governed by the ship assembly plan. After World War II, welding became much more common. Today, it completely prevails in shipbuilding. Welding is much less labour-intensive than riveting, and hence had great inherent appeal. In addition, welding allowed for a lighter-weight of steel to be used, where desirable, while eliminating the structural overlap required by riveting.[434] However, effective, reliable welding demands greater quality control; unlike its riveted equivalent, the welded seam is more susceptible to dangerous rupture.[435] Regulatory bureaus were initially reluctant to accept the wholesale use of welding in shipbuilding, a fact which served to delay the transition in technology. Once accepted, however, welding altered both the assembly process and, consequently, the organization of the shipyard itself.[436]

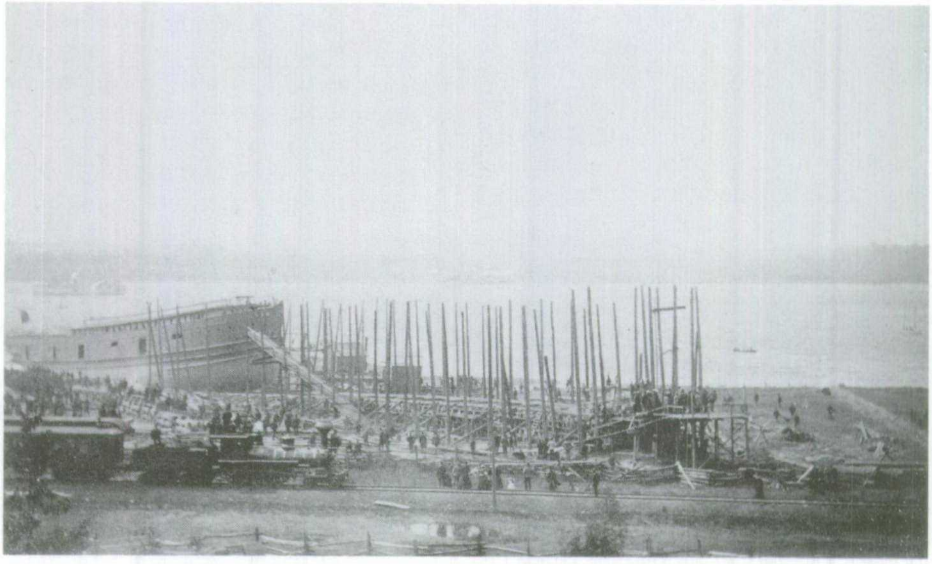
Welding, and particularly the adoption of automatic welding machines, greatly increased prefabrication. As one author put it, "the maximum amount of welding applied to ship construction implies prefabrication and vice versa."[437] Welding and prefabrication technology required ever larger enclosed construction areas, serviced by mammoth cranes capable of moving very heavy sections from their construction site to the shipyard assembly berths.[438] As already noted, Canada developed a unit construction process as part of the "St. Laurent" class destroyer escort program in the early 1950s. The logical extension of this practice is evident in the unit block construction of Canadian ships like the Marine Atlantic ferry M.V. *Cariboo* built at Davie between 1984 and 1986, and, more recently (1993), the new B.C. Super Ferries. These latter vessels, M.V. *Spirit of British Columbia* and M.V. *Spirit of Vancouver Island*, were built in three separate sections at three different West Coast yards.[439] Prefabrication has also been facilitated by significant improvements in plant automation, enhanced further through standardization of design.

The centuries-old trade of the loftsman was first rationalized by application of "optical marking," a process that entailed the photographic enlargement of very precise drawings of scantlings and plates for use in the production of full-scale patterns.[440] A further improvement saw assembly-line techniques applied to plate preparation and cutting using mechanical conveyers and automated cutting torches. Finally, just as computers were applied to the design of ships (CAD), the same advanced technology has been applied to the construction process through com-

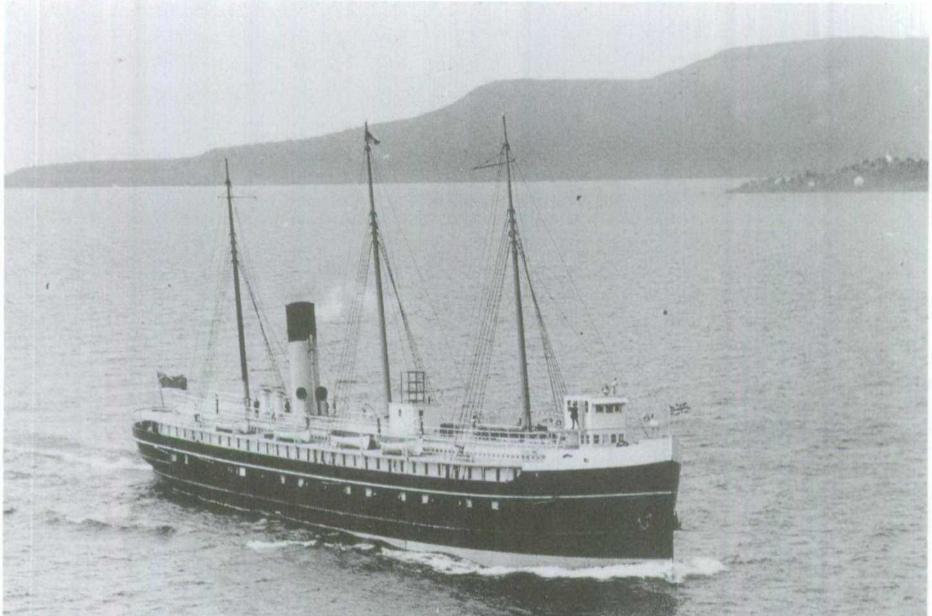
431. "What One New 15 000 ton Cargo Vessel Can Mean!" (*CSSRA Newsletter*, no.1 (January 1961).
432. Agassiz, "The Case for a Shipbuilding Subsidy," p. 14.
433. F.G. Fassett Jr., ed., *The Shipbuilding Business in the United States of America*, vol. 1 (New York: The Society of Naval Architects and Marine Engineers, 1948), p. 49.
434. Hind, *Ships and Shipbuilding*, p. 35.
435. A.J. Sims, "Warships, 1860–1960," *Transactions of the Royal Institution of Naval Architects*, vol. 102 (1960), p. 656.
436. A good breakdown of the basic capital equipment requirements of an industrial shipyard can be found in Table 2-15 of de Silva, *An Economic Anaylsis*, p. 36.
437. Hind, *Ships and Shipbuilding*, p. 35.
438. The Canadian climate made the covered construction space especially important. For a portrait of a growing Canadian shipyard, Davie Shipbuilding Ltd. of Lauzon, Québec, and a description of its facilities circa 1958, see "Building Ships For Over 75 Years," *CT* (October 1958), pp. 68–69. Davie was by then, and remains today, the largest shipyard in Canada. See also, "Prefab at Collingwood," *CT* (April 1960), p. 56.
439. See Clarke, "Canadian Ship Construction," p. 204; "Integrated Ferry Constructors Ltd. Delivers ***Spirit of British Columbia*** — On Time and Within Budget," *Harbour and Shipping* (April 1993), pp. 31–53.
440. E.W. Brown, *Ships* (London: Wheaton, 1968), p. 22.

puter-aided manufacture (CAM). In the best-equipped shipyards, advanced computer programs govern a growing number of operations on a much larger scale.[441] Standardization, prefabrication and computerization have combined to create an industry that, notwithstanding the immense scale of its unit output, today bears many of the salient attributes of mass production.

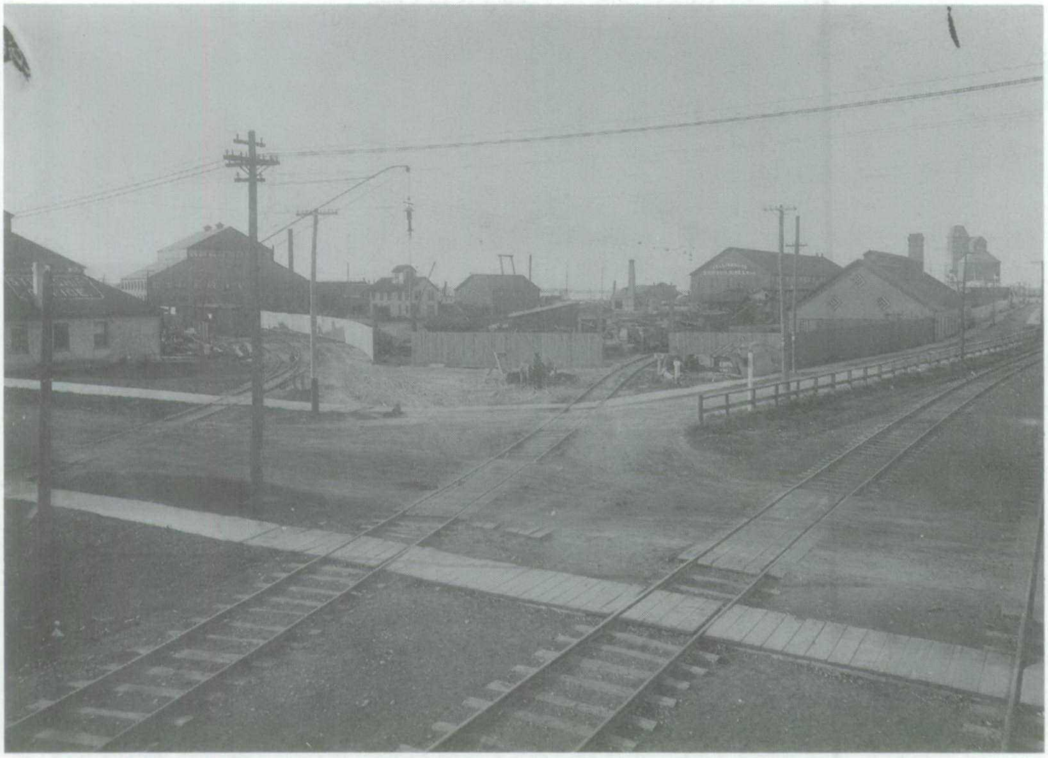
441. Hee Seok Bang, "The Modern Shipbuilding Industry," *The Shipping Revolution: The Modern Merchant Ship* (London: Conway Maritime Press, 1992), p. 190.



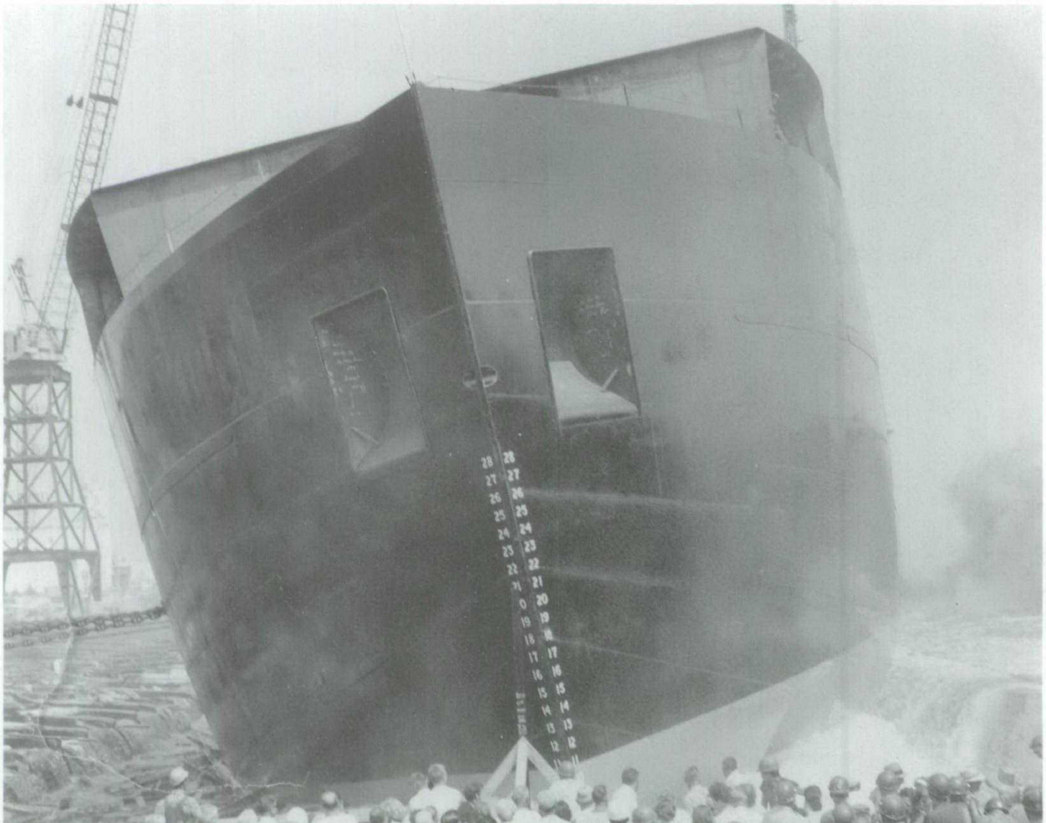
The launch of the S.S. Manitoba *(Canada's first steel-hulled ship) at Polson Iron Works Owen Sound yard in 1889. (Courtesy of the Archives of Ontario, Toronto, no. ACC 9814 S15976).*



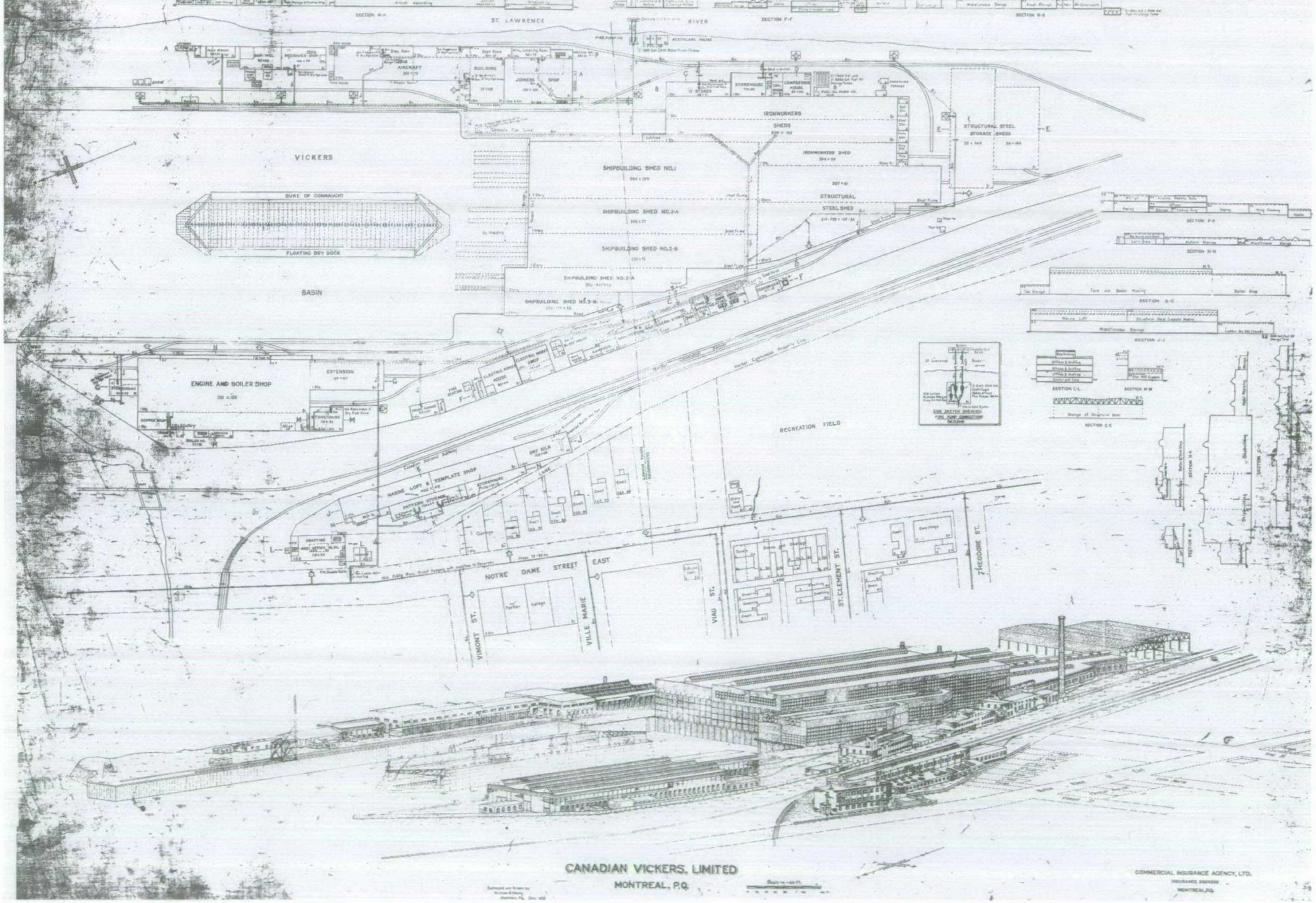
The Canadian Pacific Steamship, S.S. Manitoba. *(Courtesy of the Archives of Ontario, Toronto, no. R6 1/E.13 — Book 5,16).*



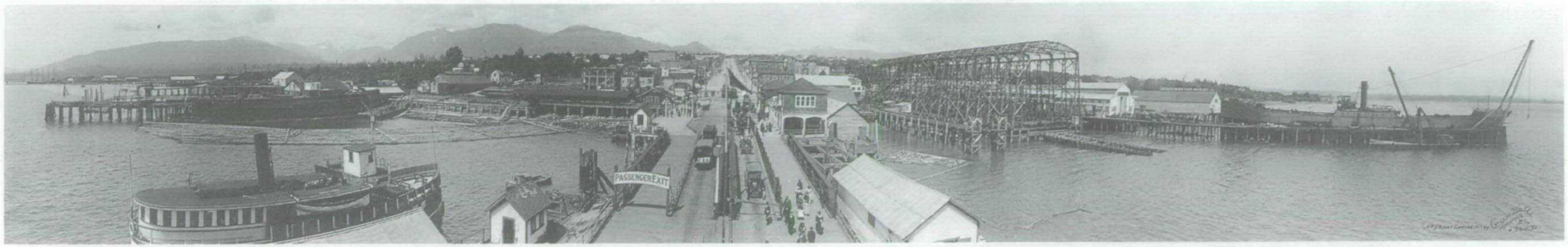
View of Collingwood Shipbuilding Co. cica. 1910 (Courtesy of The Collingwood Museum Collection)



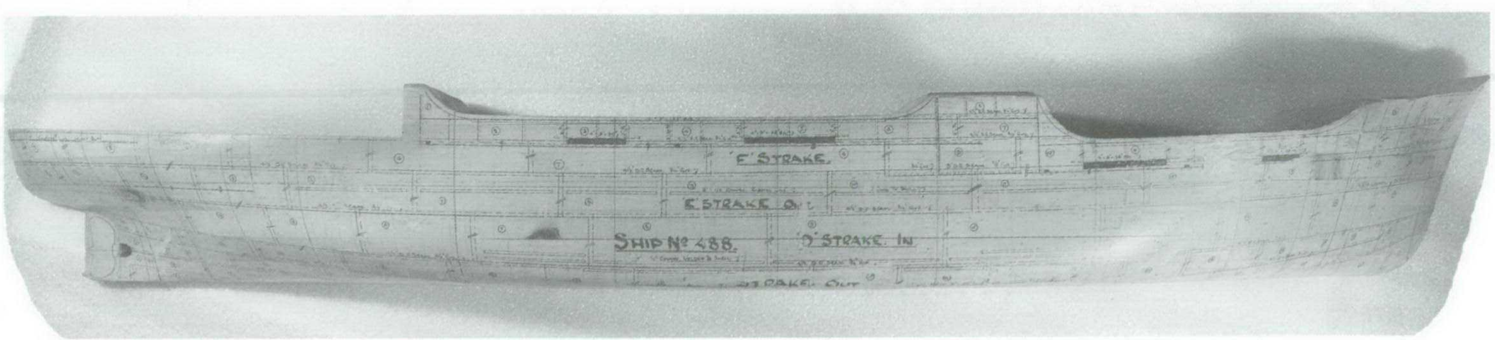
The self-unloading, Great Lakes bulk carrier Tarantau *being side-launched at Collingwood in 1964. (Courtesy of The Collingwood Museum Collection).*



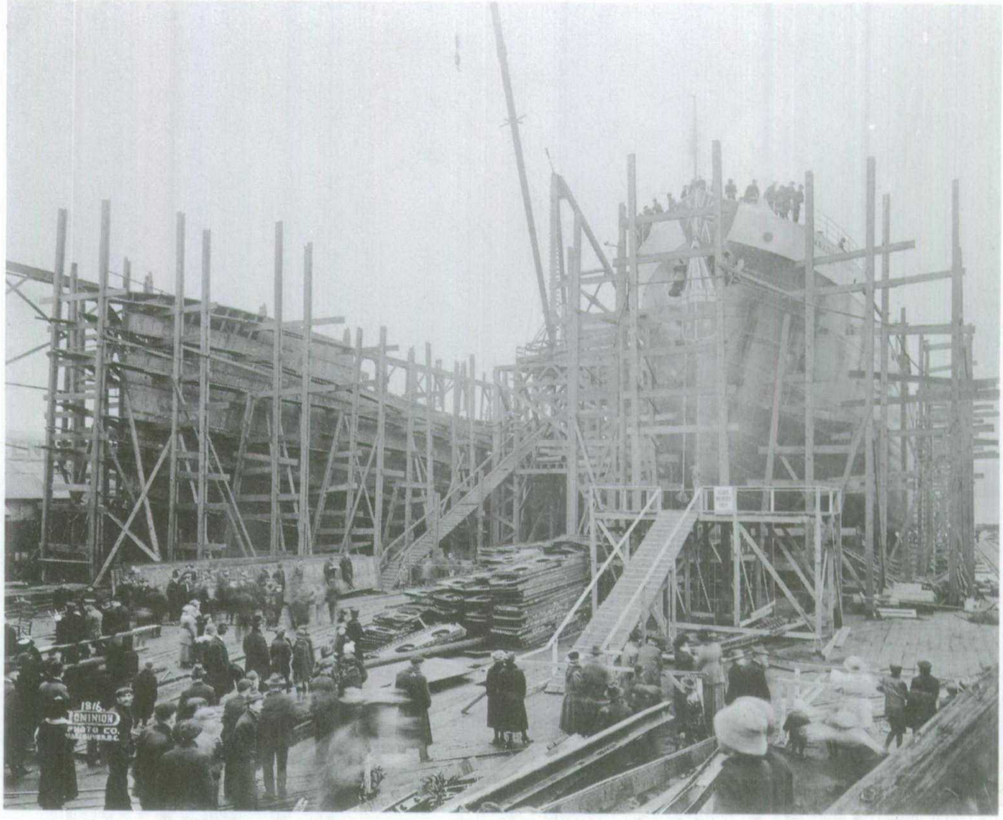
A site plan and isometric view of the Canadian Vickers Shipyard in 1933, including the floating drydock Duke of Connaught. (Collection of the National Museum of Science and Technology).



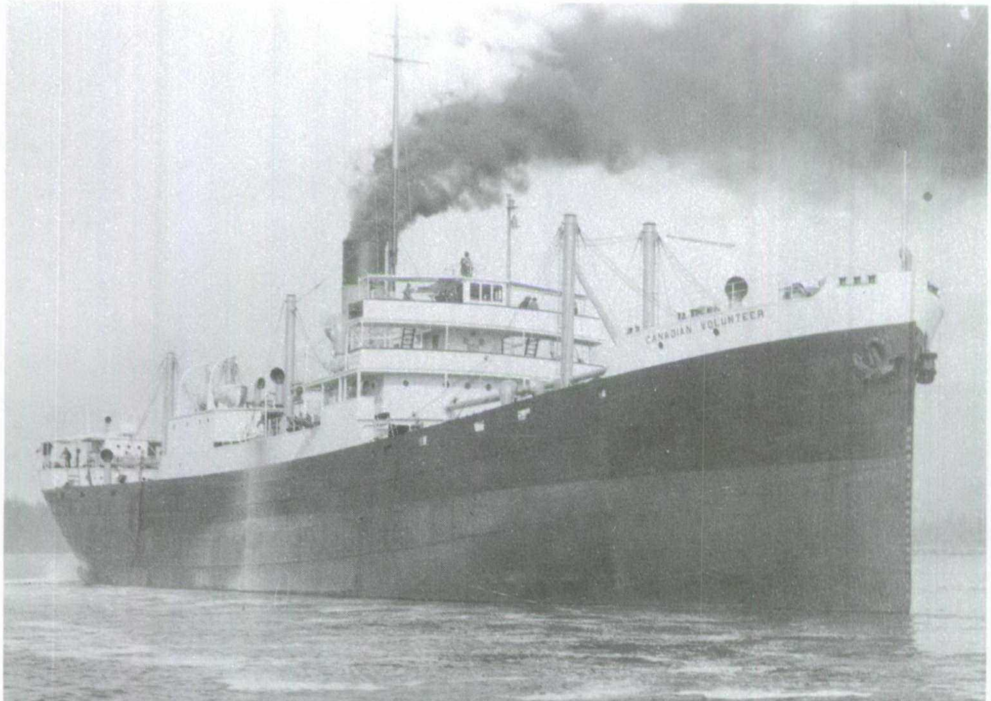
An 1917 panorama image of North Vancouver shipyards showing wooden auxiliary schooners on the left and War Dog, the first Canadian-built, ocean-going, steel steamship on the right. (Courtesy of the North Vancouver Museum and Archives)



A typical 20th Century shipbuilder's plating model (Collection of the National Museum of Science and Technology).

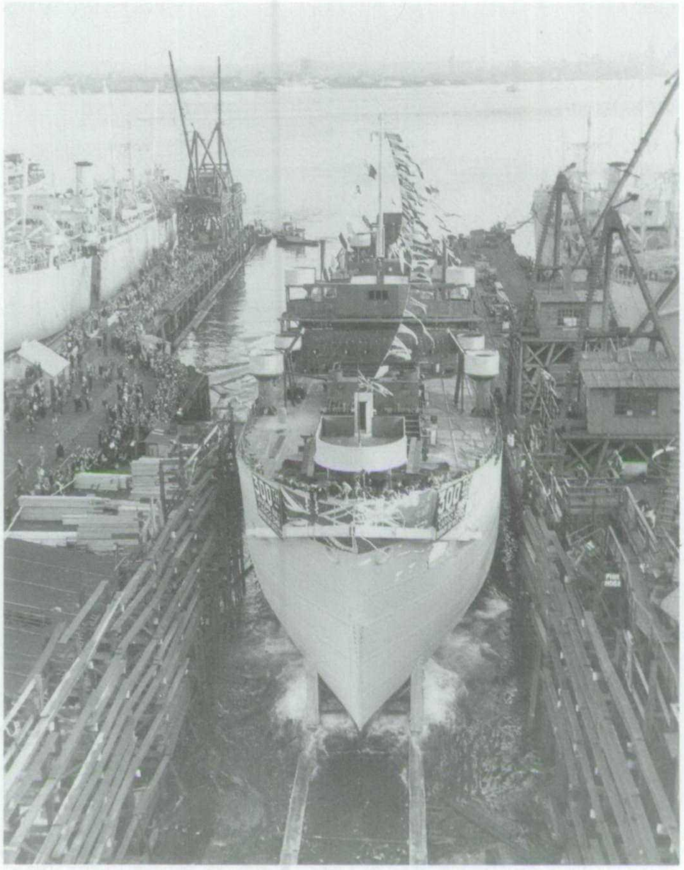


Building ships for the Canadian Government Merchant Marine. The 8,100 ton Canadian Volunteer *(right) on launch day, April 5th, 1919. (Courtesy of the North Vancouver Museum and Archives).*

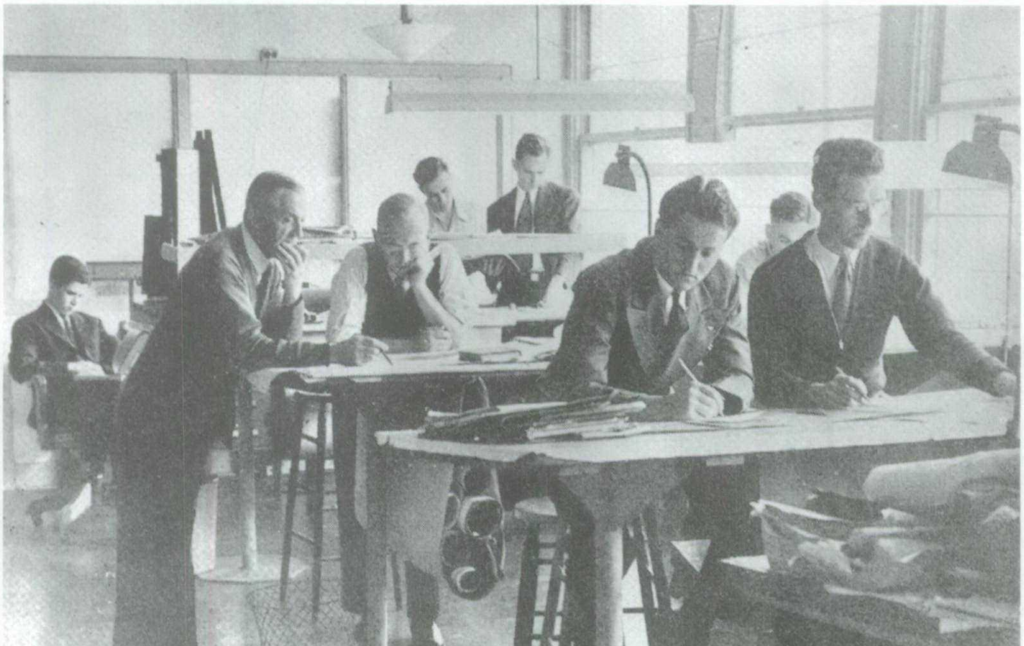


The Canadian Volunteer *underway. (Courtesy of the North Vancouver Museum and Archives).*

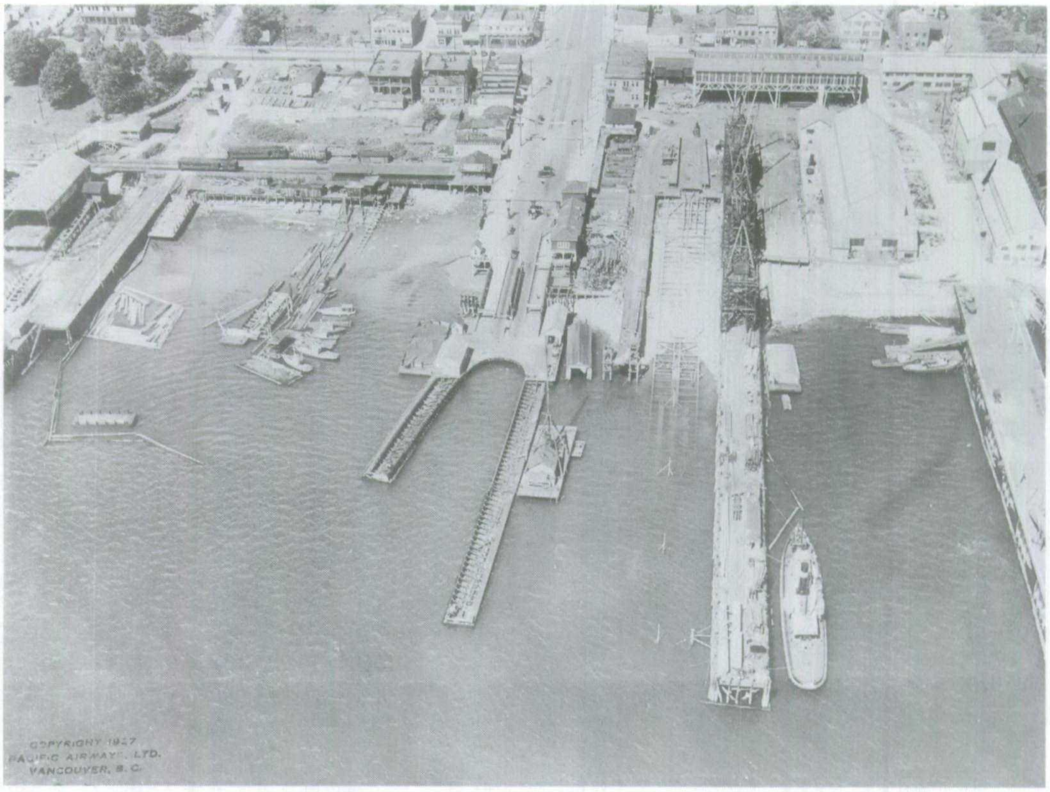
Horace H. German, a founding member of the Canadian firm of naval architects, German and Milne. Horace's two sons, William and Gordon also joined the company and later became prominent members of the Canadian shipbuilding industry. (from Floating Equipment*).*



World War Two production: the Westend Park *sliding down the ways in North Vancouver, 1944. (Courtesy of the North Vancouver Museum and Archives).*



The Burrard Shipyard drawing office, 1943 (from the Wallace Shipbuilder*, Courtesy of the North Vancouver Museum and Archives).*

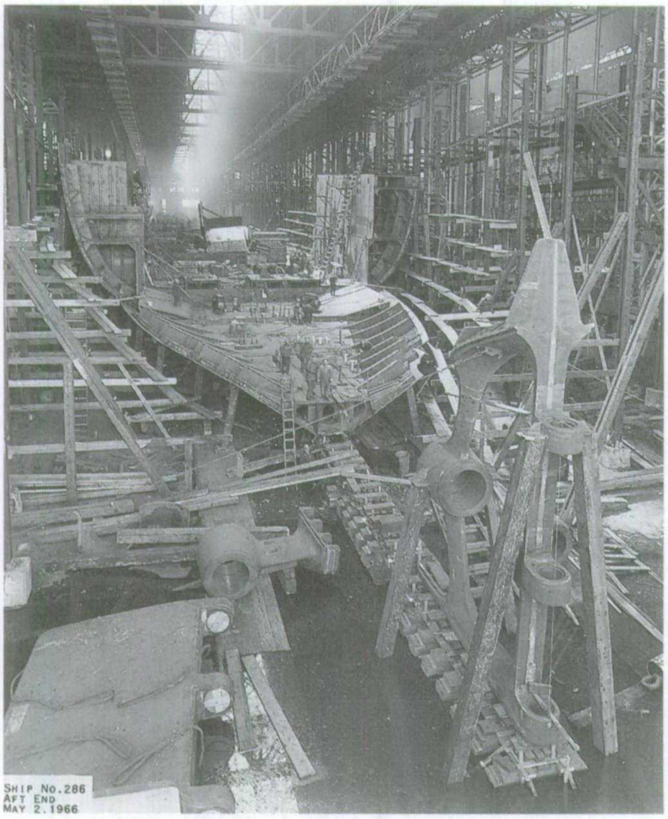


Two aerial views of North Vancouver waterfront 1926 and 1948, showing the dramatic expansion of shipbuilding activity that resulted from the demands of wartime production. (Courtesy of North Vancouver Museum and Archives)

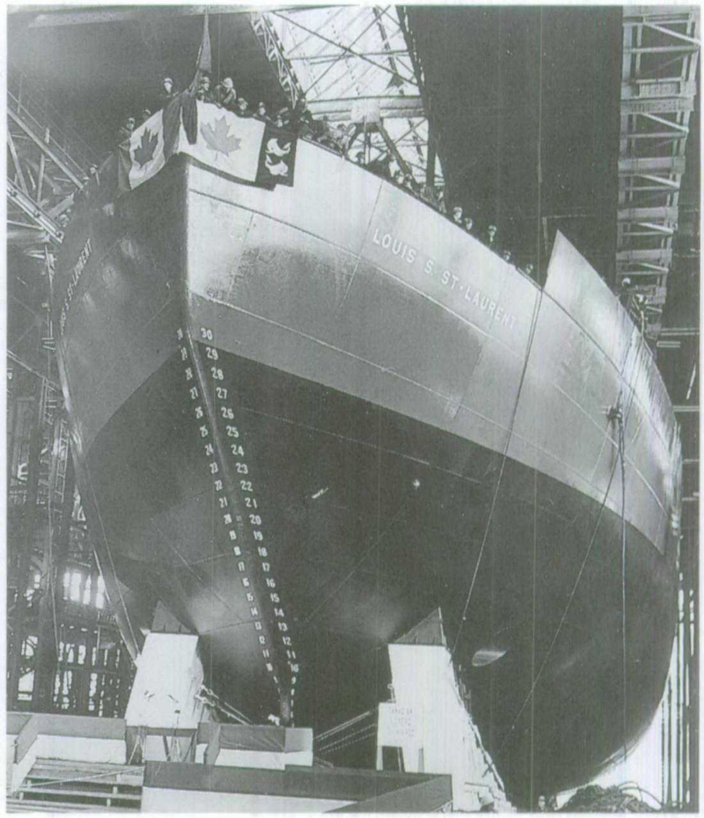
The celebrated Canadian ice-breaking ferry designed by Milne, Gilmore and German, the quadruple screw M.V. Abegweit *(from* Floating Equipment*).*

H.M.C.S. St. Laurent, *the lead ship of the first class of naval vessels to be both designed and built in Canada. (Courtesy of the Department of National Defence).*

The FHE-400 naval hydrofoil, foilborne. (Courtesy of de Havilland Canada).



The C.C.G.S. Louis S. St. Laurent *under construction at Canadian Vickers, Montreal (Courtesy of the Canadian Coast Guard).*

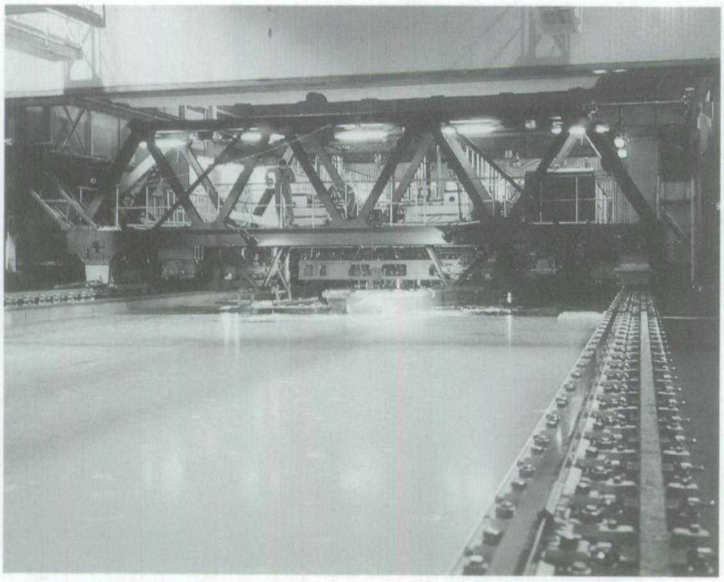


The launch of the C.C.G.S. Louis S. St. Laurent *at Canadian Vickers, Montreal (Courtesy of the Canadian Coast Guard).*

The C.C.G.S. Louis S. St. Laurent *escorting the modified American supertanker* Manhattan *through the Northwest Passage, 1969. (Courtesy of the Canadian Coast Guard).*

One of the world's most advanced, ice-capable merchant ships, the M.V. Arctic, *designed by Camat Transportation of Montréal and built by Port Weller Shipyard in 1977. (Courtesy of the Canarctic Shipping Company).*

Great Lakes/Ocean service, self-unloading bulk carrier M.V. Atlantic Superior, *built at Collingwood in 1982 (Courtesy of the Marine Museum of the Great Lakes at Kingston, neg. no. 983.18.409).*



Towing-tank model of Canadian Coast Guard R-Class icebreaker hull (1:8th scale) being tested in the world's largest ice-tank at the National Research Council's Institute for Marine Dynamics, St. John's, Nfld. (Courtesy of the National Research Council, IMD).

The joining of superstructure and hull during construction of the B.C. Ferry Corporation's new S-Class Ferry, M.V. Spirit of British Columbia *(Courtesy of Avcom International Ltd.).*

B.C. Ferry Corporation's S-Class Ferry M.V. Spirit of British Columbia, *commissioned in 1993. (Courtesy of Avcom International Ltd.).*

Conclusion

The Canadian Context

The history of shipbuilding in Canada has been primarily a story of subsidy and special circumstances, most notably war. In the fledgling colony of New France, the building of ocean-going ships was introduced and supported by the state as part of a larger policy aimed at developing French colonial trade. The persistent struggle for continental domination between France and Britain amplified, focused and defined this initiative such that shipbuilding in New France ultimately became a state-controlled, military enterprise. In the first half of the nineteenth century, large-scale shipbuilding in British North America rose to world prominence under the protection of British preferential tariffs on lumber. As these were removed toward mid-century, special circumstances (two gold rushes and two wars), sustained the demand for new tonnage before a shift in the scale, substance and structure of shipbuilding eventually rendered Canadian yards obsolete. Notwithstanding the industrial expansion that characterized the Canadian economy at the end of the nineteenth century, shipbuilding remained a marginal activity, completely overshadowed by Britain's global dominance in this area. It recovered only as the threat of war and, ultimately, World War I, created the exceptional conditions necessary to establish and develop a substantial industrial shipbuilding capacity in this country. For Canadian shipbuilding, World War I was indeed a formative experience that generated a new set of expectations and effectively married the concept of political autonomy with the idea of a made-in-Canada merchant fleet. The CGMM building program was the consummation of this marriage. Yet the resurgence of British capacity in the twenties and the worldwide economic calamity of the thirties led to a serious decline in Canada's nascent shipbuilding industry. This decay might have proven irreversible had not the outbreak of World War II renewed and amplified the circumstances of 1917. In terms of gross economic value and total employment, the 1940s were the Canadian shipbuilding industry's best years. More importantly, the experience of World War II lent new strength to the arguments linking national autonomy with shipbuilding capacity; in the latter half of this century, Canadian shipyards benefitted from vigorous government-directed building programs (naval and civilian) and a string of subsidies. International market forces sometimes served to strengthen the effect of these subsidies, but by the late 1980s dramatic reductions in government expenditures combined with global overcapacity in shipbuilding led to a serious contraction of the Canadian industry. In the 1990–91 federal government industry profile on shipbuilding in Canada, the industry was described somewhat euphemistically as "radically restructuring and reducing its productive capacity to meet the new market circumstances."[442]

Shipbuilding and Canadian Society

That shipbuilding in Canada was historically so often and so much the recipient of state support and protection clearly suggests that, although tenuous at times, governments recognized its inherent value or potential benefit. Certainly this was true in the case of the *ancien régime*. In the twentieth century, social, economic and political arguments all figured prominently in the industry's calls for the expansion and/or extension of government subsidy. In the nineteenth century, shipbuilding was a less direct object of state support, though the capacity that developed in conjunction with the tariffs on timber was vital both to the growing British North American economy and to the general expansion of British Imperial trade. Moreover, in every era, war or the threat of war invariably served to reinforce the importance of shipbuilding capacity to the welfare of the state.

In general terms, there can be little doubt that large-scale shipbuilding represented a significant socio-economic activity: it was a labour-intensive employer of skilled tradesmen, a consumer of great quantities of raw and processed materials and, last but not least, a producer of large, constructed, value-added items. Of course, shipbuilding was not always lucrative or viable, though there was often more to the equation than pure economics. In pre-Confederation Canada, pre-industrial entreprise of this sort and scale was rare; shipbuilding assumed an importance that exceeded its quantifiable measure. In the twentieth century, when the relative stature of shipbuilding in Canada diminished, the industry was transformed through war into a salient expression of national sovereignty. From a labour history perspective, shipbuilding in Canada also offers an interesting, panoramic view of an enterprise evolving from craft, to manufactory, to full-fledged industry, with the accompanying implications on capitalization and workforce organization.

When assessing the social, economic and political impact of shipbuilding and naval architecture, it is also important to account for the often dynamic role of human psychology and imagination. Admittedly, this

442. "Industry Profile 1990–1991," p. 5.

dimension has received only scant mention in this study precisely because it is often so difficult to document. Nevertheless, notable hints of its influence certainly deserve consideration. For example, in New France, the existence of the Royal Dockyard reinforced the European identity of the colony, providing a kind of secular, technological equivalent to the presence of the Church; in the popular historiography of the Maritimes, nineteenth-century shipbuilding is a touchstone of lost greatness, with its awkward mixture of pride and disappointment; finally, in the twentieth century, the role of Canadian shipyards in serving and sustaining Britain through two world wars — the urgent provision of proverbial coals to Newcastle — ought to be viewed as part of the larger development of Canadian national autonomy and identity, itself a psychological phenomenon with broad political ramifications.

Ships have also long enjoyed a vivid, romantic association with people, places and things. Aside from being an essential means to a variety of quantifiable human ends, such as trade, war, exploration, communication and travel, ships are also a common element in poignant social transitions such as exploration, emigration, deportation and homecomings. It is no surprise that ships and seafaring figure so prominently in the Western mytho-poetic tradition: Homer's *Odyssey*, the Biblical story of Noah, the Norse Sagas and the Irish *Imrama* are among the more obvious examples. Perhaps the most common and vivid reflection of the psychological dimension of shipbuilding is the time-honoured launching ceremony. This small drama, performed by dignitaries before an assembled crowd, is the technological equivalent of a baptism involving speeches, presentations, a benediction and a climatic christening to mark the new vessel's introduction to the sea. Above and beyond their quantifiable value, ships have traditionally been imbued with a certain grandeur both shipbuilders and the communities in which they worked often enjoyed something of this status.

In addition to these various associations, shipbuilding in Canada has also provided a forum for the scientific and technological imagination. In Canada, as elsewhere, ships are among the most impressive examples of human creative endeavour. In the most obvious respect, this owes simply to their size and sophistication; ships, merchant or naval, consist of a complex matrix of inter-related technologies. They are essentially very large machines: elaborate, man-made systems governed by direct human input and serving a variety of functions essential to society. Unfortunately, science and engineering are commonly presented and perceived in a manner that accentuates their aura of rational objectivity and diminishes their dynamic creative element. Yet, as with artistic expression, to understand science and technology fully as social and cultural activities requires a proper recognition of their roots in the human imagination. As Jacob Bronowski noted,

> *all created works, in science and in art, are extensions of our experience into new realms. All of them must conform both to the universal experience of mankind and to the private experience of each man. The work of science or art moves us profoundly, in mind and in emotion, when it matches our experience and at the same time points beyond it. This is the meaning of truth that art and science share; and it is more important than the differences in factual content which divide them.*[443]

The Technology and Science of Shipbuilding

In Canada, the technology of shipbuilding was almost entirely imported, although some local adaptations in materials and style occurred. The skills and tools required to build ships were transplanted at various times from France, Britain and the United States, and often followed similar lines of development. For wooden sailing vessels, this technology remained remarkably static from the late-seventeenth through to the end of the nineteenth century. The most notable transitions occurred with the introduction of mechanical power (a subject that will be the focus of a separate study) followed by the use of iron and steel in hull construction. In the twentieth century, a marked global trend emerged toward specialization in ship types and forms and, indeed, most of the notable Canadian innovations arose during this century in areas specifically relevant to our geo-political context.

Yet to note this is not at all to disparage Canadian shipbuilding technology. From the late seventeenth century on, European and American ocean-going ships reflected a remarkably international set of techniques, tools and skills. Technological ideas and innovations in shipbuilding were widely dispersed and as open to scrutiny as the wharves of the various ports to which merchant vessels regularly carried their goods. Similarly, warships were subject to capture, and naval dockyards commonly infiltrated by foreign agents. In the era of steam and steel, the early domination of British technology encouraged a good deal of standardization worldwide. For the centuries relevant to this study, the national distinctions in shipbuilding technology were often less apparent than the similarities, and the exchange of information was characteristically dynamic. Changes in tools and techniques also influenced the required capitalization and division of labour. Here, too, developments in Canada mirrored those elsewhere. In technological

443. Jacob Bronowski, *The Visionary Eye: Essays in the Arts, Literature, and Science* (Cambridge: MIT Press, 1978), p. 32.

terms, the development of Canadian shipbuilding parallels that of most Western, maritime nations and must be viewed as part of that greater whole.

The same applies to the evolving use of science in naval architecture. The introduction and cultivation of shipbuilding in New France at the end of the seventeenth century coincided with the vigorous pursuit of a theoretical basis for ship design, an effort indicative of the intellectual spirit of the age. In this regard, it is worth remembering that the establishment of the Royal Dockyard in Québec and the elevated concern for a more systematic naval architecture were separate manifestations of the same French government policy. Moreover, of the major European powers, the French also made the most concerted effort to develop the intellectual component of ship design; by the eighteenth century, there was a widespread belief in the inherent superiority of French naval architecture. In reality, French superiority was evident more in the organizations, educational and administrative, that fostered conceptual innovation than in the actual concepts. Nevertheless, the Royal Dockyards of New France became, by extension, an outpost of the organization and the ideas inherent in this new "scientific" attitude towards naval architecture.

During the nineteenth century, the practice of naval architecture in Canada was driven much less by theoretical concerns than by the prescriptions and dynamics of the marketplace. The demand for sailing tonnage to carry low-value, high volume goods provided little opportunity or cause for dramatically innovative design. This is not to say that improvements were not made. But these changes were relatively minor and generally evolved slowly from accumulated experience rather than dedicated theoretical analysis. Two notable exceptions were in the building of clipper ships for fast passage to the gold fields of California and Australia and, more importantly, the construction of steamships. However, British North American builders were relatively minor participants in both these areas. By the end of the century, the trend toward large, propeller-driven, steel-hulled steamships greatly reduced the competitive advantage formerly enjoyed by Canadian shipyards, and necessitated a naval architecture more firmly rooted in the modern methods and measures of science.

Great Britain subsequently became the preeminent world producer of steel steamships and a leader in the scientific practice of naval architecture. Colonial status and connections reinforced Canada's subordinate place in this area of industrial engineering and engendered a heavy reliance on Britain for much of the Dominion's shipping. Although World War I greatly accelerated the establishment of shipbuilding as an industry in Canada, this production was based almost entirely on imported (usually British) design expertise. The situation remained largely unchanged until after World War II, when a political commitment to a made-in-Canada navy and to sovereignty in the high Arctic combined with a general expansion of the North American economy to provide the basis for a sustained, government program of subsidy and construction. Government support for the shipbuilding industry was an essential first step towards developing a capacity for ship design. The same political and economic factors that inspired subsidies, ultimately gave direction and focus to the study of naval architecture in Canada. This trend was facilitated and strengthened through the agency of the National Research Council which provided much of the necessary leadership and research facilities. Only in the last quarter of this century did naval architecture finally find a place in the Canadian academy as an independent discipline.

In tracing the evolution of naval architecture in Canada from 1663 to the present, two notable patterns emerge. The first concerns the evolution of science in the international context of ship design. The pursuit of theory in the seventeenth and eighteenth centuries (inspired by the French tradition) was later tempered by a more pragmatic focus on the ship as machine in the nineteenth century (sustained by the British tradition) which, in turn, through industrialization, led to the establishment of naval architecture as a form of engineering science. During the period of the French regime, shipbuilding, particularly naval construction, provided an important early focus for scientific enquiry and engineering practice, science being understood as a "systematic knowledge, including that associated with a craft."[444] Although the real dividends from these efforts proved minimal, the approach and organization in the practice of naval architecture changed perceptibly. In the first half of the nineteenth century, ship design followed a less overtly theoretical path, with innovation arising largely from the empirical and mechanical traditions of the United Kingdom. In the latter half of the century, however, the demand for larger, metal-hulled steamships, together with dramatic innovation in naval ordinance, required that ships be built in accordance with industrial practices. This necessitated a more rigorous analytical approach to naval architecture sponsored and facilitated by such organizations as the Institution of Naval Architects and, in the U.S., the Society of Naval Architects and Marine Engineers. The twentieth century has been largely a continuation and expansion of this development, although leadership, at least in mercantile shipbuilding, has now shifted globally from West to East. And while naval architecture is firmly established in the university, and therefore subject to increasingly sophisticated analytical practice, its focus on "man-made devices rather than nature" identifies it clearly with what has been described as engineering science.[445]

444. Layton, "American Ideologies," p. 689.

445. *Ibid.*, p. 695.

The second pattern relates specifically to the Canadian experience of this evolution. By virtue of geography and colonial association, the practice of naval architecture in Canada has been dominated by imported ideas and experts. Only in the last half of the twentieth century did Canada become a centre of expertise, and then only in a few specific areas, these principally being ice-breaking ships, anti-submarine vessels (including open-ocean hydrofoil technology) and Seaway-size Great Lakes bulk carriers. And yet, from the earliest days, the demand for ocean-going ships in Canada presented a context which forced conceptual energies to focus on the problems of designing these large and complex machines. This intellectual effort constitutes a very real social dynamic, the importance of which should rightly be gauged according to the relative stature of shipbuilding as a productive enterprise in early Canadian society. By this measure, the design of ships in Canada in the centuries before Confederation was certainly among the most important and prominent expressions of the scientific and technological imagination in all its various forms.[446]

After Confederation, Canadian shipbuilding lost much of its importance in this regard, and was largely overshadowed by engineering and industrial production in other sectors. However, the twentieth century's two world wars brought shipbuilding a renewed prominence and ultimately heightened the demand for design skills. In the second half of the century, as shipbuilding became an important expression of political autonomy, naval architecture in Canada gradually assumed an identifiable national character as well as a place in the academy. Unfortunately, these national gains have not been matched by a corresponding expansion in professional opportunity. In fact, with the Canadian shipbuilding industry now suffering severely from the combined effects of contracting government funding and international competition, the future of naval architecture in Canada stands in question — even as the nation's reliance on shipping, and by extension the science and technology of ships, continues to grow.

446. It is commonplace in art historical scholarship to identify and define forms of artistic expression and to interpret their cultural and social significance. Similarly, scientific and technological expression must also be understood as important reflections of culture and the human creative impulse, an argument which forms the basis of Bronowski's book of essays, *The Visionary Eye*. In practice, this similarity is perhaps most vividly apparent in the process of engineering design; see Ferguson, *Engineering and the Mind's Eye*, p. 23.

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