The Floating Factory: Dominant Designs and Technological Development of Twentieth-Century Whaling Factory Ships

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Introduction

When whaling began in Antarctic waters in 1904, it marked a new phase for the industry. Over a sixty-year period whaling expanded; experienced dramatic growth, crisis and technological transformation; and finally declined and disappeared. This life cycle offers economic and technological historians a fascinating range of themes which may shed light on more general issues. This article focuses on the so-called floating factory and the concept of "dominant design." There were always two "regimes" in the industry: shore-station and floating-factory whaling. While the former dominated the early modern industry, factory ships gradually achieved dominance by the mid-1920s and became the core of twentieth-century whaling. A typical pelagic whaling expedition consisted of one factory ship — really a combined tanker and factory — and about ten small catcher boats. The total number of men per expedition could be as high as 500. Catching was seasonal: a typical European (for many years primarily Norwegian or British) voyage would clear its home port in September/October and return in April. In the heyday of Antarctic whaling, a single factory ship would steam home from a season's activity in the Southern Ocean with oil and by-products processed from as many as 1000-2000 whales.'

These factory ships increased both in size and sophistication over the years, reflecting the development of the industry. There were also changes in overall design, especially relating to how to bring the heavy creatures on board and in handling them on deck before they were sent in small pieces for processing. Most of the technical aspects of this process are well known.' In the following essay I will analyze these changes within the context of "dominant design." This concept has been used mostly to study industries like automobiles and aircraft. Although naval architecture is a distinct field, it might be worthwhile to adopt the same analytic framework, for as Peter Quartermine recently argued, ships are "buildings on the sea."[3] The vessels examined in this article were no exception: they were factories on the sea, or floating factories.

In the late 1920s a new design emerged which became dominant and was never replaced in the period of active Antarctic whaling. I will argue that the concept of dominant design is useful in studying the development of the floating factory, and I will

The Northern Mariner/Le Marin du nord, VIII, No. 1 (January 1998), 21-37.

also shed some light on the theories and models that underpin it. I have three main questions: how did the dominant design develop? how can it be described and defined? and why did it dominate for such a long time?

The Concept of Dominant Design

While there is not an extensive body of literature on dominant design, there has been some interest in research on the topic, especially in the wake of William Abernathy and James Utterback's works in the 1970s.[4] Based on this literature, I will define the concept and relate it to similar ideas. I will also relate dominant design to innovation, or the process of technological change, and thus focus on the question of how and why a dominant design develops.

A dominant design may be defined as "a single architecture that establishes dominance in a product class" while meeting "the needs of most market segments for most producers."' Dominant design is thus an important stage, or what Abernathy and Utterback call "a milestone of change."[6] Yet there are several other concepts that partially overlap dominant design. One is Peter Gardiner's notion of "robust design."' Another is Devendra Sahal's "technological guidepost," which suggests that innovations "generally depend on bit-by-bit modifications of a design that remains unchanged in its essential aspects over extended periods of time. This basic design is in the nature of a guidepost charting the course of innovative activity."' Sahal also uses the phrase "invariant pattern of design." Then there are the well-known concepts which describe technology in much the same way, such as basic, dominant and radical technology; technological paradigm; and the like. Michael Hård has used the terms *vorbild* or "archetype," which he defines as "a product or process which has served as a pattern for later developments in an area of technology."[9] An obvious topic, then, is the relationship between a dominant design and a dominant technology — or more generally, between design and technology. Design relates to the physical appearance of a product or a process — the "architecture," as Abernathy put it. Technology, on the other hand, refers primarily to knowledge and skill: the abstract appearance of the product or process. Design is the implementation or configuration of technology and is chosen from among many alternatives. But a broad definition of technology might also include the physical product or process; thus, the development of a dominant design may be considered part of the broader processes of innovation and technological change.

A dominant design, in Utterback and Abernathy's terminology, marks the transition of an innovation from a "fluid" to a specific state and is a "key event" in this evolution.[10] The development is, of course, both dynamic and gradual. Gardiner, for example, uses the phrase "design trajectory," which he defines as a "dynamically evolving change in the state of the art at a succession of points in time."" The advance is also commonly viewed as part of a life cycle: from infancy to the establishment of a dominant design, maturity and finally exhaustion. Few authors, however, seem to believe this process to be linear, emphasizing instead discontinuities and non-technical factors to explain the emergence of dominant designs. Gardiner writes that the typical process leading to a robust design involves divergent stages with many new ideas and innovations, before eventually becoming convergent. This is followed by a phase of "stretched designs,"a new divergent process.[12] Philip Anderson and Michael Tushman have developed an evolutionary model of the relationship between technological change and dominant design." The cycle starts with a technical discontinuity in the form of a "breakthrough," which initiates an "era of ferment," a period of "intense technical variation and selection." Competition between designs occurs until a single dominant design emerges. A period of incremental technical progress then follows in which the dominant design is elaborated.14

The period of variation and selection leading to a dominant design raises the question of why one is eventually adopted. Does the dominant design represent the best available technology? According to Anderson and Tushman, the dominant design "lags behind the industry's technical frontier." They make the important point that:

> emergence of dominant designs, unlike technological discontinuities, is not a function of technological determinism; they do not appear because there is one best way to implement a product or process. Rival designs are often technologically superior on one or more key performance dimensions.15

Abernathy makes the same point:

> a dominant design is not typically the product of radical innovation. To the contrary, a design becomes dominant...when the weight of many innovations tilts the economic balance in favor of one design approach. Typically, the relevant design approach has already been in existence.

Commenting on the DC-3 and Model T, he concludes that "these designs were synthesized from individual technological innovations that had been introduced independently in prior products. The important economic effects of a dominant design afford a degree of enforced product standardization."16

There is another reason why state-of-the-art technology is not necessarily synonymous with dominant design. Several authors emphasize that the selection process must be explained in terms of non-technical factors. For example, Ji-Ren Lee and his associates stress that "innovations may become the dominant designs in their product classes for reasons that may have little to do with design."" Again, the dominant design does not necessarily represent the best technological solution. The most typical non-technological forces, generally speaking, are economic, organizational and socio-political, the last of which has gained increased attention from "social constructionists."'

Experimentation and Hybrid Designs

Eighteenth- and nineteenth-century Dutch, British and later American whalers used "factory ships" in the sense that right- and sperm whales were brought alongside and flensed. The blubber was hauled on board and dried out. Yet there are not many technological (or design) linkages between those vessels and the floating-factory ships of this century. Instead, the latter ships are linked to late nineteenth-century shore-station whaling during the "Svend Foyn" era. Foyn had solved the practical problems of catching finwhales by using small steam catcher boats and powerful explosive harpoons. He also designed shore stations with slipways, flensing platforms and processing plants for blubber, meat, bone and meal. These plants processed the whales more efficiently and completely than in traditional whaling, and the challenges of transferring these functions to a ship were quite substantial. The most obvious obstacle was space. Modern industrialized whaling needed not only a few trypots but an actual factory — a processing plant — with numerous large boilers and cookers.

The other important problem was how the whale should be brought on board. Flensing alongside had a long tradition. The blubber was stripped off in long pieces and lifted aboard. The same method was also used by the first generation of twentieth-century factory ships. The method was highly inefficient, however, compared to the slipway and the flensing platform at shore stations. The working environment at the stations was less dangerous; the work went faster; and much more of the whale was utilized. While the shore stations very early adopted the principle of "full utilization," most factory ships were only blubber-cookers.[19] Consequently, a large effort was put into finding a way to bring the whole whale onto the ship's flensing deck.

The development of the floating factory from the beginning of the Foyn era was in many ways typical, with gradual increases in size and technological complexity, but also significant basic innovations which set new standards. The first ships used as factories were sailing vessels. Foyn was one of the pioneers, sending expeditions to Spitsbergen in 1890 and Iceland in 1892.[20] A significant change, however, was connected with the whaling entrepreneur Chr. Christensen and his shipyard, Framnæs Mek. Verksted in Sandefjord, Norway. In 1903 the yard fitted cookers into the wooden steamer *Telegraf*. Later the same year it rebuilt an iron steamer and labelled the drawing "Kogeri No. 1" (Factory No. 1). It became the 1517-gross registered ton (grt) *Admiralen* and the prototype for the dominant design of the coming years.

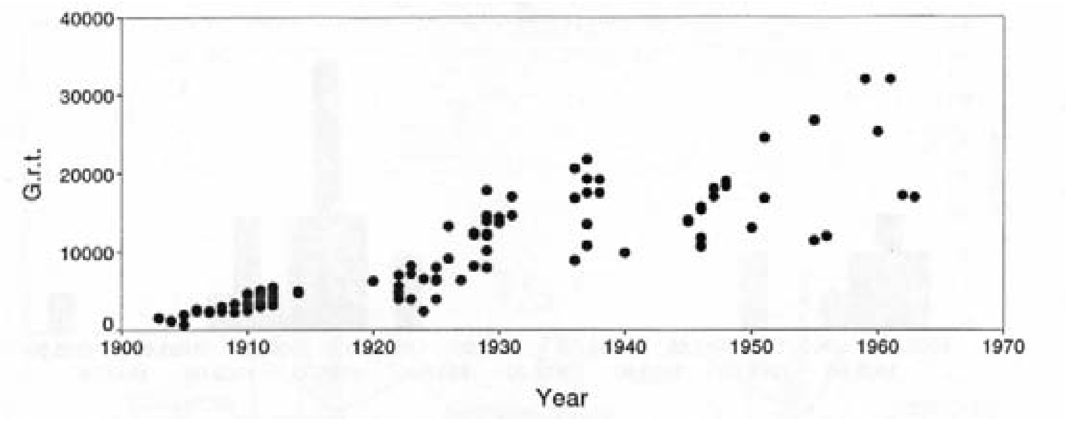
A significant feature of the factory ships up to 1928 was that they were not purpose built. Instead, they were converted, generally from passenger ships, liners or freighters. Most were also quite old at the time of conversion. *Admiralen* was built in England in 1869, and was thirty-four-years-old when it became a whaling factory ship. The average age at the time of conversion decreased somewhat, but stayed around twenty years throughout the 1920s. One exception was *Ronald*, built as a factory ship for Norwegian owners (Hektor A/S of Tønsberg) at the Duncan yard in Glasgow in 1920. It was the first purpose-built factory ship, and at 6249 grt, the largest floating factory thus far (figure 1). The equipment was modern and the vessel was a leap forward from earlier designs. But it was a mainstream rather than an innovative design.[21]

Although most vessels were old when they were rebuilt, they were always among the larger merchantmen, and size increased gradually over time. They also usually came from yards in Norway and Britain as rebuilt, modern ships. While the main machinery was often still in place, the superstructure was rebuilt to give room for the processing plant and storage facilities. Johan Tønnessen has noted that in the twenty years following *Admiralen's* launch as a whaler, technological development comprised mainly increases in size and the number of traditional cookers.[22] Although I would call the core of this process a design rather than a technological development, I believe his observation is correct. The changes were incremental. The gradual increase in size entailed fitting more and more pressure cookers into the available space, but there were no significant changes in the layout of the processing plant. The evaporator is another example of this gradual development. It was used on *Admiralen* to make fresh water, but had a limited capacity. It was gradually increased, making the factory ships more independent of fresh water supplies from ashore.23

Figure 1

Whaling factory ships, 1903-1963

Size and first year of operation



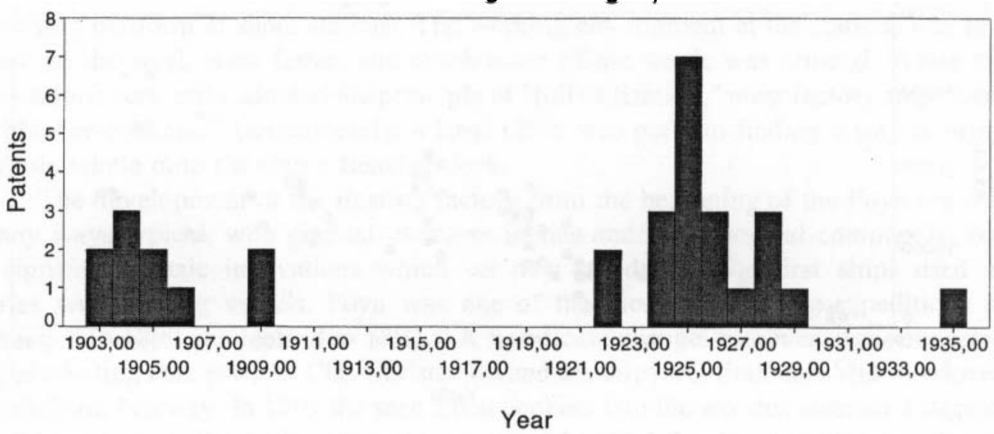
Source: Derived from a list generously provided by Dag Bakka, Jr.; on several lists published in A.O. Johnsen and J.N. Tønnessen, *Den moderne hvalfangst historie* (4 vols., Sandefjord/Oslo, 1959-1970), III, 590-591 and 623-626; and on Whalers Mutual Insurance Association, *Register of the Whaling Fleet,* various years.

One important factor which limited the operation of the floating-factories was the problem of getting the whales on board. Again, this was solved by trial and error and creativity, which led to a number of patents clustered in the years between 1905 — when the first "modern" floating-factory ships were used at Spitsbergen and the Antarctic — and the mid-1920s, when the pelagic expansion really started (figure 2). Although some vessels tried to use winches and nets to lift the whales onto the deck, most inventive efforts were expended on constructing a slipway from the sea to the deck, following the concept of the shore station. The first practical attempt was made at Spitsbergen in 1911 on board *Ambra,* but the major efforts were made in the 1920s.

Lancing (7990 grt), belonging to the Norwegian company A/S Globus (Melsom and Melsom of Larvik) was a breakthrough technologically when it steamed south to the whaling grounds in 1925. The stern slipway, invented and patented in 1922 by Petter Smile, proved successful and was soon licensed and adopted by many others. When he died in 1933, eighteen ships had slipways based on his patent.[24] But Sørlle was not alone. The owners of A/S Globus, especially H.G. Melsom, were active in rebuilding *Lancing.* In addition to the inventor and the capitalists, there were also the naval architects, such as Olaf Arnesen and Chr. Fred. Christensen, who for many years had been involved in rebuilding factory ships. Arnesen, as a former inspector of the Norwegian classification society, Det Norske Veritas, had supervised the refit of *Admiralen* in Sandefjord. He had also inspected the work of *Ambra* at Middle Docks, South Shields, in 1911 when it got the rudimentary slipway. The partners had two companies: Arnesen, Christensen and Smith Ltd. of Newcastle, and Arnesen, Christensen and Co. A/S of Oslo.25

Figure 2

Patents relating hauling up devices



Source: B.L. Basberg, *Patenter og teknologiskendring i Norge, 1840-1980. En metodediskusjon om patentdata anvendt som teknologi-indikator* (Bergen, 1984), chapter 5.2.

Christensen in 1931 delivered a paper to British shipbuilders at which he gave his version of the construction of *Lancing's* slipway:

> The Author was called in as technical expert to co-operate with Captain H.G. Melsom in the conversion of this vessel. The proposal was partly to cut out the stem as far as possible above the rudder quadrant and fit an extended hinged grating, as it was absolutely necessary to get the whale on board. After discussing this proposal, we agreed that it would not be a satisfactory arrangement. The Author had Mr. Davidsen's idea in mind and decided to propose making drastic alternations, namely, to arrange a straight slipway, cut away about 11 feet of rudder stock, and stern-frame post, cut down the rudder, add a sunk quarter portion to the hull to provide additional space between deck and slipway surface and the slipway side for steering compartment. This provided a permanent slipway down to the water-line. Drawings and models were prepared in Antwerp and after some days' discussion in London, we had Lloyd's

approval. This revolutionary design proved successful, and has been the base upon which all others have been designed.26

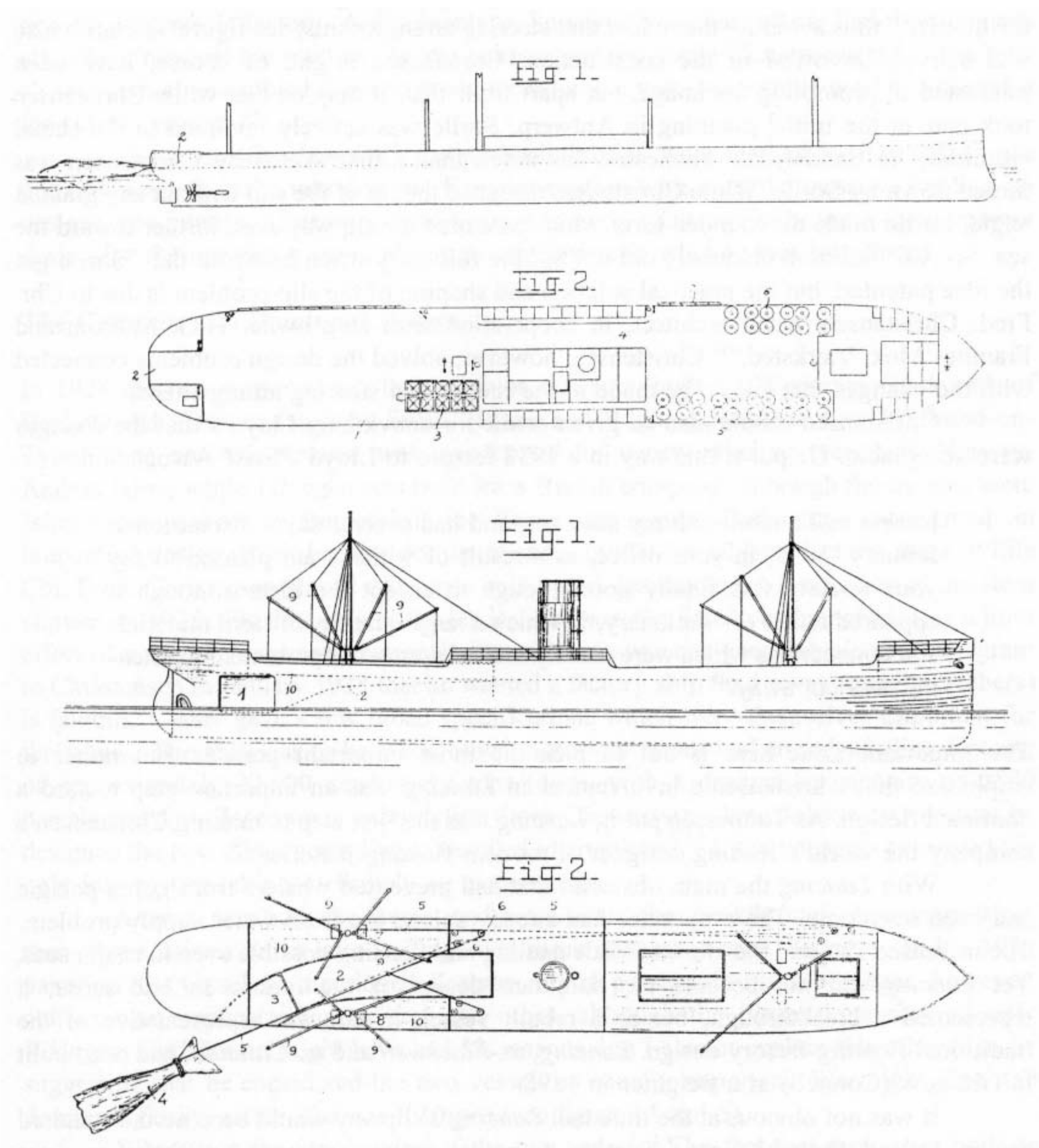


Figure 3: The Hauling-Up Problem. Nokard Davidsen's patent from 1905 (top) illustrates one of many suggestions that were never put into practice. Petter Sørlle's 1922 patent (below) was the model for the stern slipway which became pa rt of the dominant design of the late 1920s.

Source: A.O. Johnsen, *Norwegian Patents Relating to Whaling and the Whaling Industry* (Oslo, 1947), 57 and 59.

It is interesting that Christensen did not mention Sørlle in his paper. Yet there is no doubt that the slipway was based on his 1922 patent, rather than on the older 1905 patent of Nokard Davidsen (a slipway, in Christensen's words, "swung from center of deck out into the quarter," thus avoiding the rudder and steering arrangements; see figure 3). Sørlle also was actively involved in the construction. Christensen might, of course, have been interested in promoting his image, but apart from that, it may be that while Christensen took part in the initial planning in Antwerp, Sørlle was actively involved in the actual rebuilding in Sandefjord. Tønnessen has noted that a first sketch by Christensen was turned down by Sørlle. While Christensen designed the tip of the slip without any gradual angle, Sørlle made the rounded form which extended the slipway even further toward the sea. So A.O. Johnsen obviously did not tell the full story when he wrote that "Sørlle got the idea patented, but the practical solution and shaping of the slip-problem is due to Chr. Fred. Christensen, naval architect, in cooperation with ship owner H.G. Melsom and Framnes Mek. Værksted."" Christensen, however, solved the design problems connected with the changes that had to be made to the rudder and steering arrangements.

Christensen should also be given credit for convincing Lloyd's that the changes were acceptable. He put it this way in a 1938 lecture to Lloyd's Staff Association:

> 1 came to London with my sketches, and had several days' discussion in January, 1925, in your office, as a result of which I am pleased to say your Society was finally good enough to accept the idea, although it appeared rather revolutionary, in which a large quantity of stern materials and connections which were usually looked upon as important strengthening was cut away.[28]

The important issue here is not to pick the most important persons, but rather to emphasize that Christensen's involvement in *Lancing* was an important step toward a dominant design. As Tønnessen put it, *Lancing* was the first step to making Christensen's company the world's leading designer of modern floating factories.[29]

With *Lancing* the main obstacles that had prevented whalers from going pelagic had been overcome. The evaporator had already solved the fresh water supply problem. The increased size and the slipway made hauling and flensing possible even in rough seas. Yet *Lancing* did not become the dominant design of the future. In one sense, it represented a breakthrough, but as a rebuilt vessel, it still was representative of the traditional floating-factory design. *Lancing, ex-Flackwell* and *ex-Calanda,* had been built in Glasgow (Connell) as a freighter in 1898.

It was not obvious at the time that *Lancing's* slipway would become the standard design. Indeed, the path from invention, to patent, to innovation and diffusion was not linear. In the years between Sørlle's patent in 1922 and the end of the decade, the number of patents peaked (figure 2). Several ideas were also tried several years after *Lancing's* successful introduction.[30] Actually, a majority of the patents proposed solutions to the hauling problem other than the stern slipway. We may call these "hybrid solutions," still representing divergent designs. There were designs where whales were taken through a gate in the vessel's side into a flensing dock, and also slipways alongside as an oversized gangway. The British *Southern Empress* tried to winch whales alongside the ship as late as 1928/1929. Christensen was responsible for the design of the bow slipway in *C.A. Larsen* in 1926. This design illustrates the problem of non-complementarity, so typical during transitions. *C.A. Larsen* was a converted tanker, a ship type with many advantages as a floating whale factory. A disadvantage, however, was that tankers had their engines aft, which blocked the way for the stern slipway of the Sørlle/Christensen type. The bow slipway, which resembled those on modern car ferries, was successfully used in Antarctica for several seasons.31

The years after *Lancing's* design breakthrough were marked by ferment, to use one of the words in the introduction. Experimentation with several alternative hauling-up designs was intense. After only three years, however, what was to become the dominant design for the remaining years of large-scale Antarctic whaling was introduced.

The Creation of a Dominant Design

In 1928 the two purpose-built factory ships, *Kosmos* (built by Workman Clark Ltd. of Belfast) and *Vikingen* (built by Swan, Hunter and Wigham Richardson of Wallsend-on-Tyne) were ordered. *Kosmos* was constructed for a new whaling tycoon in Norway, Anders Jahre, while *Vikingen* was built for a British company, although the owners were Jahre's competitors in Sandefjord, the Rasmussen group. Both ships represented an innovative design which became dominant and a model for all later factory ships. While Chr. Fred. Christensen played a key role in the work leading to the innovation of the stern slipway in 1925, this time he was the leader. *Kosmos,* the first to be launched, was a joint effort of a visionary entrepreneur/capitalist and a creative designer. Jahre's short telegram to Christensen in January 1928 that he wanted a factory ship (and seven to eight catchers) is famous.[32] Jahre gave a few broad specifications which were themselves important for the future. The ship was to be a combined motor- or steam-tanker and whaling factory, of approximately 22,000 deadweight tons (dwt), with a production capacity of 2500 barrels per day. Based upon information from Christensen, Arne Johnsen wrote that he designed the two ships "according to detailed instructions."[33] If the telegram conveyed the only information, this is definitely an exaggeration.

Kosmos was both the largest and represented the breakthrough. It is interesting, then, that Christensen in later writings was more concerned with *Vikingen.* In his 1931 paper on this vessel, he mentioned *Kosmos* only in passing. In his 1938 paper, however, neither was emphasized more than the other, although the illustrations showed only *Vikingen.* Christensen might have had his reasons, but I cannot explain this other than by suggesting that he considered the two vessels as equally important. We might label the dominant design as the *Kosmos-Vikingen* (see figures 4 and 5).

What were the innovations of the two vessels? The fact that they were built as floating factories was the first, although they have to share this distinction with *Ronald.* The average age of vessels converted in the late 1920s was still about twenty years, which made the launch of *Kosmos* and *Vikingen* especially dramatic.[34] Size was the second. The 17,801-grt *Kosmos* and the 14,526-grt *Vikingen* were the largest whaling ships thus far, although the latter was not much bigger than several rebuilt factory ships of the late 1920s.[35] It thus seems correct to describe the increase in size as gradual.

A third major innovation had to do with the layout. While most earlier factory ships were former passenger liners or freighters, the concept for *Kosmos* was, as Jahre ordered, based on tanker designs. There were already a few rebuilt tankers in the whaling fleet. Since they had their engines astern and not amidships as in most merchantmen, the naval architects did not know how to build a stern slipway. It became too steep, and the funnel also blocked the way. With the exception of *C.A. Larsen,* which we have seen had a bow slipway, the other rebuilt tankers had no slipways at all, although some builders experimented with hybrid designs. Christensen made a design breakthrough with *Kosmos* and *Vikingen.* The slipway was curved so not to interfere with the engine, and he added twin funnels. Tønnessen was obviously correct to observe that when this problem was solved, tankers were the most useful ships to convert to whaling factories.36

The new factory ships were really modern tankers with an extra factory deck on top. They not only were very efficient but also could easily be converted to tankers if the market for whale oil collapsed. That scenario was obviously in the back of Jahre's mind. As Christensen put it, "the new ships are so built as to be transferable to ordinary tanker trade, or utilized for other trades, whilst the converted old ships would more or less be of scrap value."[37] A Lloyd's representative expressed the same view: "Vikingen is classed to carry `Petroleum in bulk,' and the pipe lines have been designed so that the vessel could enter this trade without any alternations, after the oil tanks had been cleaned."38

Figure 4 **(Part A)**

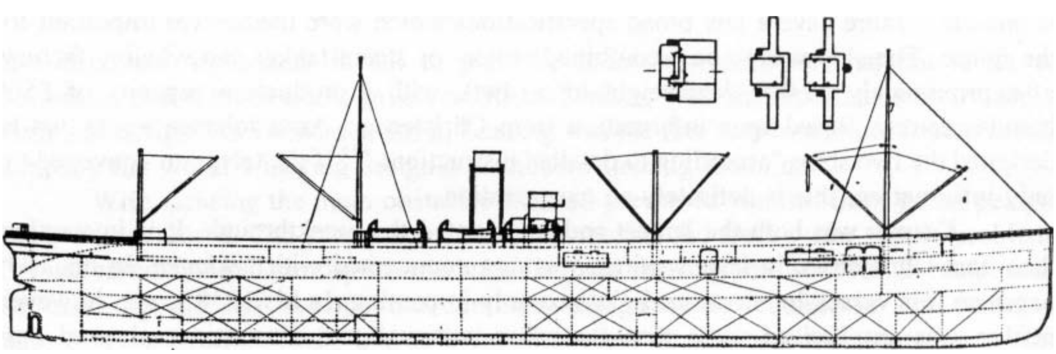


Figure 4 (Part B)

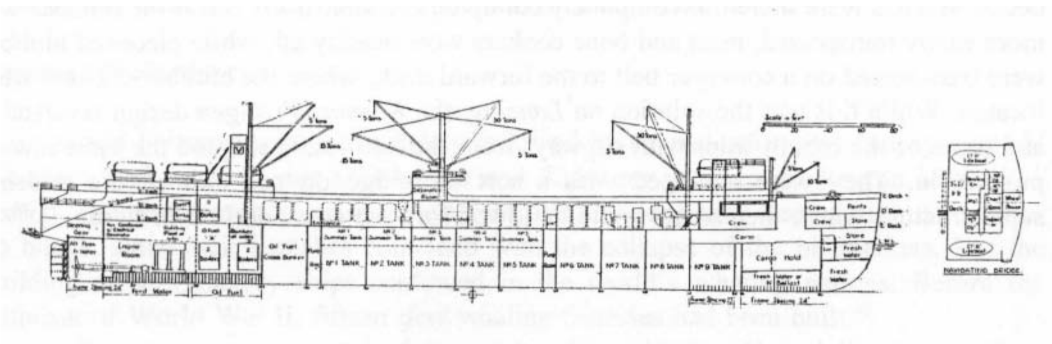


Figure 4: The Converted Cargo Ship versus the Dominant Design. The 13,797-grt *Hektoria* (top, ex-White Star Line *Medic)* was built in 1899 by Harland and Wolff in Belfast, and converted to whaling factory ship in 1929. The 14,526-grt *Vikingen* (below) was built as a floating factory in 1929 at Swan, Hunter and Wigham Richardson in Wallsend-on-Tyne. The drawings are of approximately the same scale: Hektoria was 550 feet, while *Vikingen* was 493 feet.

Source: Chr. Fred. Christensen, "Notes on Whaling and its Development," *Lloyd's Register Staff Association, Special Lecture* (London, 1938).

The stern engine caused a problem, but it also facilitated a new and better layout of the superstructure. Christensen's design was widely adopted. He moved the bridge as far forward as possible. Amidships he placed two wing houses with a bridge across, where the main winch and several smaller winches and cranes were located. The gate divided the top deck in two. Astern was the blubber deck, where the whale was flensed into long strips and dropped into holes leading to the blubber cutters and further into the blubber cookers on the factory 'tween deck, just below. In front of the midship gate was the meat deck, where meat and bone were cut and sent into pressure- and Hartmann-cookers. This was a significant improvement over former designs in which cookers often were located on the upper deck, which meant that the blubber and meat had to be lifted before being lowered into cookers. It also meant a more efficient handling of the whale: the carcass (meat and bone) could be towed in one piece to the forward deck before it was cut up. The traditional production "line" was from fore to aft (the whale was usually flensed alongside on the port forward side). The earliest factories utilized only blubber, and the cookers were installed in the forward rooms. Later, when meat and bone were also processed, the carcass was taken alongside and lifted onto the after deck. The slipway changed operations somewhat, but the blubber was still processed on the forward deck in the mid-1920s. The whale was brought up on the after deck and flensed. Because of the bridge and funnel amidship, there was no easy connection between the forward and after decks. Whales were therefore completely cut up on the after deck. Since the blubber was more easily transported, meat and bone cookers were usually aft, while pieces of blubber were transported on a conveyer belt to the forward deck, where the blubber cookers were located. While this was the solution on *Lancing,* the *Kosmos-Vikingen* design reversed it and some of the rebuilt ships with slipways from the late 1920s adopted the same line of production. They were equipped with a sort of bridge on one side of the midship superstructure where the carcass could be towed forward (see *Solglimt* in figure 5).39

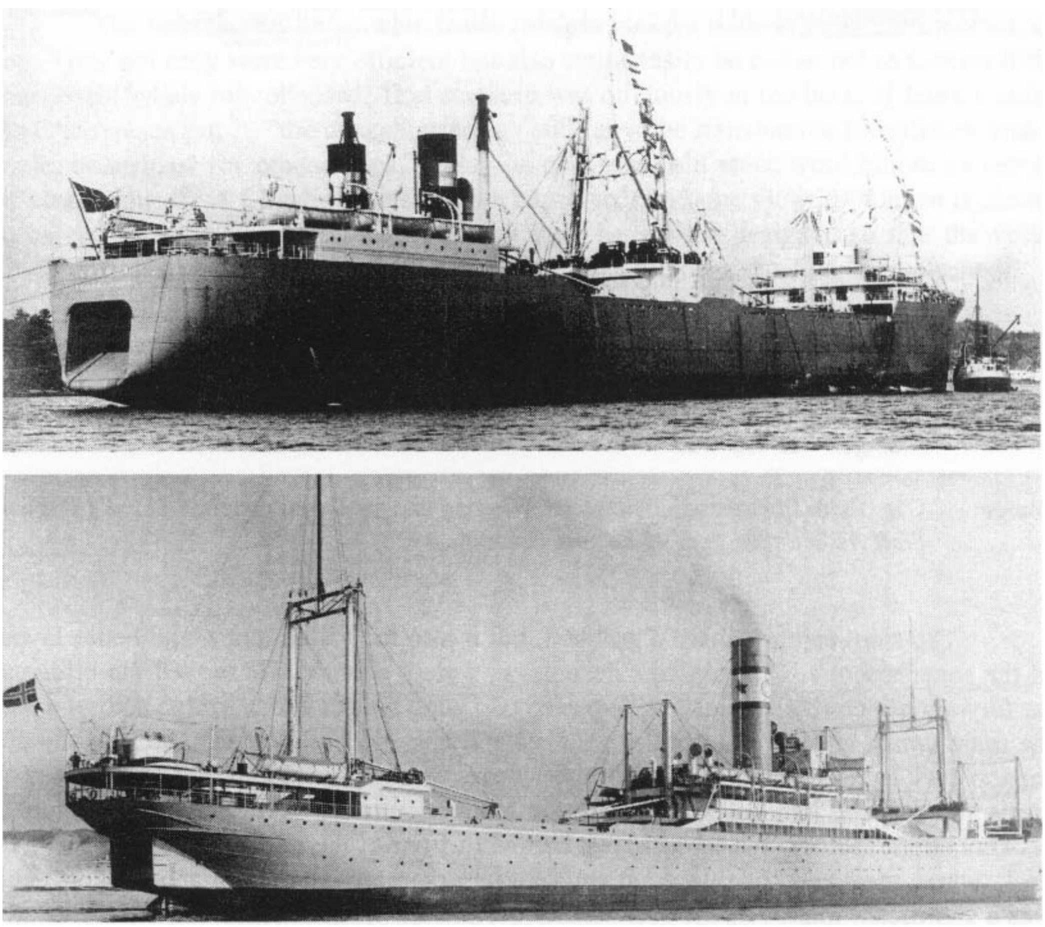


Figure 5: The Converted Passenger Ship versus the Dominant Design. The 12,246-grt *Solglimt* (top), ex-Svenska Amerika Linien's *Stockholm,* was built in 1900 at Blohm and Voss in Hamburg, and converted to a whaling factory ship in 1929. The 17,801-grt *Kosmos* (below) was built as a floating factory in 1929 at Workman Clark Ltd. in Belfast.

Source: Corn Chr. Christensen's Whaling Museum, Sandefjord.

How did *Kosmos* and *Vikingen* look below deck? As with their size, the lower parts were not revolutionary but were extensions of the designs of the 1920s. The factory decks were filled with what were then well-adopted and traditionally-designed cookers. *Kosmos* and *Vikingen* were newer on the outside than on the inside.

Gradual Perfection

Kosmos and *Vikingen* were immediately followed by several other new factory ships of the same design. *Sir James Clark Ross* and *Tafelberg* were ready for the 1930/1931 season. The next season, three more left the yards, although they went straight to the lay-up buoys, since their launches coincided with the collapse of the oil markets. But the building of new factory ships continued in the world's whaling nations. Before the outbreak of World War II, fifteen new whaling factories had been built.[40]

The new ships to a certain extent replaced the old ones. Especially after the "lay-up-season," closer cooperation between whaling companies led to the scrapping of many older and smaller factory ships.[41] The old ones did not, however, completely disappear. As in so many industries, old and new technology existed together, and the traditional floating factories sometimes even attracted large investments. All of them got stem slipways. New processing machinery was installed and layouts modified. Some were lengthened. A few of the rebuilt factory ships which entered whaling in the late 1920s actually remained successful until 1960.

World War II represented another era of transformation for whaling. The modem factory ships were among the largest merchantmen. They had both large oil capacities and room for commodious deckloads (for airplanes, for example). Consequently, British and Norwegian factory ships were allocated to Allied convoys.[42] But they paid a heavy toll: of more than twenty British and Norwegian factory ships that operated in the last prewar seasons, only four Norwegian vessels survived the conflict.

Planning to rebuild the whaling fleet shows that there were no new dominant designs after 1945. Instead, plans were based on the pre-1939 concept of a "modified" tanker. Actually, this concept even dominated planning during the war. One reason had to do with the fact that no one knew how long the war was going to last. The Ministry of War Transport needed tankers, not whalers. Consequently, whaling advocates tried to convince the Ministry to construct a "series" of tankers which at a later stage could easily be converted into floating-factories. From 1943 planning took place in a joint British-Norwegian committee of representatives from the Whaling Section of the UK Chamber of Shipping and the Norwegian Shipping and Trade Mission. The minutes of the inaugural meeting in June 1943 show that the firm of Arnesen and Christensen was still active:

> It was reported that Mr. Hjersing of Messrs. Arnesen, Christensen and Smith, Newcastle, had been working on a specification for a ship which would be suitable for war service and at the same time be rapidly convertible into a floating factory after the war. Provisionally his specification was for a tanker of length about 550 ft. max. (i.e. not too big for the floating dock in Oslo) breadth about 78 ft. (suitable for dry docks in the U.K. and Norway), loaded draught 35 ft. max. and a speed

> of 15 knots. The various features necessary to enable rapid conversion into a floating factory would of course be included.43

The proposal was soon modified: two months later the committee was planning to convert six existing British tankers of the Empire Opal class and to build three new factory ships of the *Sir James Clark Ross* type. The result was that keels were laid in late 1944 at Furness Shipbuilding Co. in Haverton Hill on Tees for one Norwegian and one British ship. Both the 13,830-grt *Norhval* and the 14,418-grt *Southern Venturer* were built as factory ships. No tankers were converted.

In the late 1940s and 1950s a number of new factory ships, flying not only the flags of the two major whaling nations, Norway and Great Britain, but also of several other countries, were launched. The ships were only slightly larger, with two exceptions: the identical Soviet-built *Sovietskaya Ukraina* and *Sovietskaya Rossia* from 1959 and 1961. At 32,024 grt, they were in effect dinosaurs without futures. Indeed, most newly-built factories after World War II were between 15,000 and 20,000 grt, a range which the *Kosmos-Vikingen design* had established as an "optimal" floating-factory size.

The post-World War II factory ships were still built as tankers with an extra factory deck. Actually, several factory ships were used as regular tankers in the late 1950s and 1960s when regulations, quotas and declining markets created an excess capacity of floating-factories. Indeed, *Kosmos V* and *Juan Peron* went straight from the shipyard into the tanker trades without ever visiting the Antarctic whaling grounds. A few, especially Japanese and Soviet factories, were also converted from tankers in this period.44

What about developments in processing technology? The core product of twentieth-century whaling was oil. The efficiency of processing may be measured by the number of barrels of oil produced per whale.[45] By this measure, the efficiency of processing increased in the 1920s and 1930s before levelling off after 1945. Yet in one area of processing there was a significant change after the war. Even when ships grew larger, the manufacturing of by-products, especially meat and bone meal, was an on-going problem because of lack of space. At shore stations, on the other hand, there was an abundance of space, and by-products were always a speciality.[46] The focus on by-products may be measured by bags of meal per barrel of oil or value of the by-products as a percentage of total production. By such measures shore stations were far ahead of the floating factories in every season up to the 1960s. Only in the very last years of Antarctic whaling did the floating factories really specialize in by-products.[47] More equipment and processing machinery were installed in the already crammed ships, which came to resemble highly sophisticated chemical plants. But it would be incorrect to call this change a discontinuity or an alteration in the dominant design. It was more of a gradual path towards technical perfection in response to the increased difficulties of the business. Several technological innovations were obviously introduced, but they were all subordinated to the general concepts of the *Kosmos-Vikingen* dominant design.

Conclusions

The development of the twentieth-century whaling factory ship may be summarized briefly. The first converted ships of the pioneer era of Antarctic whaling established a dominant design for almost twenty years. There were significant changes in size and the number of cookers, but these shifts were gradual and the overall design concept was not altered. The successful stern slipway introduced on *Lancing* in 1925 was a major innovation. It represented a discontinuity a new direction. The following five years may be labelled an era of ferment, a period of intense competition between several solutions to the hauling problem and between types of vessels. Three years after *Lancing's* whaling debut, *Kosmos* and *Vikingen* were built and became the dominant design. The years from about 1930 to the end of large-scale commercial whaling in the Antarctic was once more a period of gradual, incremental change in size and processing machinery.

The development thus seems to fit well into the model described by Anderson and Tushman. It is also possible to describe the "creation" of the dominant design as a converging process: several of the elements in the *Kosmos-Vikingen* design had been introduced previously, the most important of which were the stern slipway and the tanker concept. A ship had also been built as a floating factory before, although the typical path had been to convert older vessels. Finally, the dominant design was going to have a very long life, a characteristic also found in other industries. But there were also aspects which did not fit the models so nicely, such as the fact that the dominant design did not represent state-of-the-art technology or design. *Kosmos* and *Vikingen* were obviously based on known technological and design elements. Yet they also featured a distinct new layout which made the dominant design state-of-the-art at the same time. As well, the era of ferment seems to have continued for a few years after the introduction of the dominant design. There was no immediate halt in conversions of older vessels. Patents and practical solutions for alternative hauling-up devices also flourished for a few years. The dominant design seems to have emerged in the middle of the era of ferment, not at its end.

NOTES

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1. The catches, of course, varied substantially from one season or expedition to another. Species and sizes also varied, so the number of barrels of oil rather than the number of whales was used to compare catches. The late 1920s, late 1930s and mid-1950s were peak periods of Antarctic whaling.

2. The standard reference work is still A.O. Johnsen and J.N. Tønnessen, *Den moderne hvalfangst historie* (4 vols., Sandefjord/Oslo, 1959-1970). There is also a one-volume edition: *The History of Modern Whaling* (London, 1982). In the following I refer to the longer version.

3. P. Quartermine, *Building on the Sea. Form and Meaning in Modern Ship Architecture* (London, 1996).

4. W.J. Abernathy and J.M. Utterback, "Patterns of Industrial Innovation," *Technology Review,* LXXX, No. 7 (June-July 1978); and Abernathy, *The Productivity Dilemma: Roadblock to Innovation in the Automobile Industry* (Baltimore, 1978).

5. Abernathy, *Productivity Dilemma,* 56.

6. Abernathy and Utterback, "Patterns," 46.

7. J.P. Gardiner, "Robust and Lean Designs with State-of-the-Art Automotive and Aircraft Examples," in C. Freeman (ed.), *Design, Innovation and Long Cycles in Economic Development* (London, 1986), 143, discusses explicitly the degree to which his model overlaps Abernathy and Utterback's dominant design concept.

8. D. Sahal, *Patterns of Technological Innova* (Reading, MA, 1981), 33; and Sahal, "Technological Guideposts and Innovation Avenues," *Research Policy,* XIV (1985), 71.

9. M. Hard, *Machines are Frozen Spirits: The Scientification of Refrigeration and Brewing in the 19th Century-- A Weberian Interpretation* (Frankfurt, 1994), 55, sees archetype as very similar to a basic invention or innovation.

10. J-R. Lee, *et al.,* "Planning for Dominance: A Strategic Perspective on the Emergence of a Dominant Design," *R&D Management,* XXV, No. 1 (1995), 4. See also K.B. Clark, "The Interaction of Design Hierarchies and Market Concepts in Technological Evolution," *ResearchPolicy,XIV (1* 985), 235 ff.

11. J.P. Gardiner, "Design Trajectories for Airplanes and Automobiles during the Past Fifty Years," in Freeman (ed.), *Design,* 122.

12. Gardiner, "Robust," 143-144.

13. P. Anderson and M.L. Tushman, "Technological Discontinuities and Dominant Designs: A Cyclical Model of Technological Change," *Administrative Science Quarterly,* XXXV (1990), 604 ff.

14. For a review and critical discussion of the Anderson and Tushman positions, see O. Uusitalo, *A RevolutionaryDominant Design. The Float Glass Innovation in the Flat Glass Industry* (Helsinki, 1995).

15. Anderson and Tushman, "Technological Discontinuities," 616.

16. Abernathy, *Productivity Dilemma,* 50 and 75.

17. Lee, *et al,* "Planning," 3.

18. See, for example, R. Henderson, "Of Life Cycles Real and Imaginary: The Unexpected Long Old Age of Optical Lithography," *ResearchPolicy,* XXIV (1995), 631 ff. A similar focus is found in M. Hard and A. Knie, "The Ruler of the Game: The Defining Power of the Standard Automobile," in K.H. Sørensen (ed.), *The Car and its Environment. The Past, Present and Future of the Motorcarin Europe* (2 vols., Trondheim, 1994), II, 137 ff.

19. A few factory ships also specialized in the narrow niche of carcass *(skrott)* factories, working close to the shore stations at South Georgia in their first years of operation. At that time the shore stations utilized the blubber only, but that habit soon changed. Shore-station versus factory-ship strategies regarding the utilization of whales are analysed in B.L. Basberg, "Survival against All Odds? Shore Station Whaling at South Georgia in the Pelagic Era, 1925-1960," in B.L. Basberg, J.E. Ringstad and E. Wexelsen (eds.), *Whaling and History. Perspectives on the Evolution of the Industry* (Sandefjord, 1993).

20. Johnsen and Tønnessen, *Den moderne hvalfangst historie,* I, 363 ff.

21. *Ronald* is a curious example of "the disadvantage of being first." Still operational in 1951, it was the only Antarctic floating factory still without a stern slipway.

22. Johnsen and Tønnessen, *Den moderne hvalfangst historie,* III, 58.

23. Fresh water was a crucial factor in the steam cooking of whales to make oil. In early Antarctic whaling, factory ships were moored or anchored in sheltered waters close to shore, and specially-designed small water boats shuttled between the mother ship and the closest river mouth. This system obviously limited the operation and flexibility of floating factories, and the introduction and increased capacity of evaporators was a factor that paved the way for real pelagic whaling operations.

24. Johnsen and Tønnessen, *Den moderne hvalfangst historie,* III, 289.

25. *Ibid.,* III, 287 and 584.

26. Chr. Fred. Christensen, "The Whaling Factory Ship `Vikingen' with some Notes on Whaling,"

North East Coast Institution of Engineers and Shipbuilders *Proceedings* (1931), 4.

27. A.O. Johnsen, *Norwegian Patents Relating to Whaling and the Whaling Industry. A Statistical and Historical Analysis* (Oslo, 1957), 60. See p. 197 for information on Christensen's patents. While Christensen had no patents on slipways, he did have a number from 1933 onward relating to other aspects of floating whaling factories.

28. Chr. Fred. Christensen, "Notes on Whaling and its Development," *Lloyd's Register Staff Association, Special Lecture* (London, 1938).

29. Johnsen and Tønnessen, *Den moderne hval-fangst historie, III,* 289.

30. Johnsen, *Norwegian Patents.* For a detailed discussion of these patents and their relation to innovative activity, see B.L. Basberg, *Patenter og teknologisk endring i Norge, 1840-1980. En metodediskusjon om patentdata anvendt som teknologi-indikator* (Bergen, 1984), chapter 5.2.

31. Christensen, "Notes," 2, mentioned that the bow slip also had the advantage "that the risk of getting the whale or the wires entangled in the propellers is non-existent."

32. Johnsen and Tønnessen, *Den moderne hval-fangst historie,* III, 362. It has not been possible to find the original telegram.

33. Johnsen, *Norwegian Patents,* 91.

34. In 1929, when *Kosmos* and *Vikingen* were built, seven vessels were re-built; their average age was twenty-one years.

35. Size is a more important variable than age. *New Sevilla,* for example, was thirty-years-old when rebuilt in 1930. At 13,801 grt - the largest ship ever converted to a floating factory - it was bigger than several of the newly-built ships in the next decade.

36. Johnsen and Tønnessen, *Den moderne hval-fangst historie,* III, 346.

37. Christensen, "Whaling Factory Ship," 28.

38. *Ibid.,* 27.

39. A detailed account of the layout of several generations of floating factories is found in M. Holden, "De flytende kokeriers utvikling fra *Admiralen* til *Thorshavet,"* in H.S.I. Bogen, *Aktie-selskabet "Omen," 1903-1953* (Sandefjord, 1953), 72 ff.

40. Johnsen and Tønnessen, *Den moderne hval-fangst historie,* III, 590.

41. B.L. Basberg, "Technological Transformation in the Norwegian Whaling Industry in the Interwar Period," *Scandinavian Economic History Review,* XXXIII, No. 2 (1985).

42. It was not without opposition from the whal-ing community; see B.L. Basberg, "`Whaling or Shipping:' Conflicts over the Use of the Norwegian Whaling Fleet during World War II," *International Journal of Maritime History,* III, No. 1 (1991).

43. Norway, National Archives, Nortraship Archives, Mossige file, 78, 18.02/16c, "Minutes of Inaugural Meeting of the Joint Committee held at the Offices of the Chamber of Shipping, Bury Court," 29 June 1943.

44. The fourth largest factory ship ever, the 25,376-grt *Juri Dolgorukij,* was among them. Another was the infamous Onassis-owned *Olympic Challenger.*

45. For a discussion on the measurement of productivity in twentieth-century whaling, see B.L. Basberg, "Productivity in the 20th Century Antarc-tic Pelagic and Shore Station Whaling. Growth and Stagnation in Two Technological Regimes," *TOH-serien,* No. 4 (1995).

46. A detailed discussion on by-products and shore station whaling is found in Basberg, Ringstad and Wexelsen (eds.), *Whaling and History.*

47. The Japanese factory ships were exceptional in that they specialized in meat production for final consumption from the beginning of their Antarctic operations.