(The section on the ExxonMobil's MANHATTAN Icebreaking Project was written by William O. Gray, Manager of the Arctic Project for Esso International with overall responsibility for design, construction, and technical studies of the Arctic (08 April 2008 W. O. Gray). For further consideration, please read, "Manhattan's Arctic Venture – A Semitechnical History" published by The Society of Naval Architects and Marine Engineers, 1981.)

ExxonMobil's MANHATTAN Icebreaking Project

William O. Gray April 8, 2008 Draft

The discovery of a major new oil field on Alaska's North Slope at Prudhoe Bay in the spring of 1968 signaled the start of a new era of oil transportation technology. While both tanker and pipeline transportation of crude oil were well known techniques, neither system had ever been exposed to the severe climatic conditions existing in the high Arctic. Accordingly both pipelining and tanker transportation specialists faced the Prudhoe Bay find as a new and exciting challenge to find which of these mature technologies would be superior for the movement of major amounts of crude oil south to refineries in America's "lower 48" on either its east or west coasts.

At that time 40 years ago it was generally accepted that for substantial crude oil movements, tanker transportation would generally provide major economic benefits compared to pipelines. As a "rule of thumb" unless the routes followed by the ships were more than three times as long as the distance for a pipeline, tankers would usually be cheaper. Furthermore tankers traditionally had two other "flexibility credits". First, tankers possess unlimited flexibility in choice of delivery points for the crude, and second, in the event of variable production rates from the oil field, varying numbers of tankers could be employed whereas pipelines generally have a fixed capacity for a given cost whether or not oil production reaches its designed output, or when production slows over time as happens with most oil fields. Finally virtually all these basic lessons in petroleum logistics had been learned in the deserts of the Middle East and in the hospitable lower latitudes North or South of the equator.

As the three oil companies who had discovered the Prudhoe Bay crude faced this novel logistics problem, two of them, ARCO and BP initially assumed the logical choice must be to build a pipeline over Alaska's Brooks Mountain range to deliver the crude to an "ice free" port in Valdez for tanker shipment south –an assumption also endorsed by many in the third company(now ExxonMobil), then Esso"s domestic affiliate Humble Oil and Refining. But because of the traditional tanker "flexibility credits", and the possibility to deliver crude direct to both US West and East Coasts, a small group in Humble persuaded their parent company, Standard Oil of New Jersey, to agree to spending $ 10-15 million to make a study of how to use "icebreaking tankers". Two questions had to be answered: first, what does an icebreaking tanker look like ? and second, how much will it cost ? (to deliver crude on an around the year basis). Without valid answers, or even speculation on answers available, Humble's ice breaking experiment was permitted to go ahead , but "only as a backup" to the cross Alaska pipeline if it failed to gain approval. In fact the pipe for this pipeline had already been ordered when what became the MANHATTAN project actually started.

Nonetheless, in summer/fall 1968 work progressed on several fronts in discussion with ice scientists and polar experts in the U.S., U. K., Canada and Finland. Preliminary designs of icebreaking tankers of nominally 200-300,000 DWT were commissioned from Canadian naval architects. We were able to witness tests in Lancaster Sound of the Northwest Passage of the novel “upward breaking” Axel Bow. While this radical new

concept seemed to offer a number of advantages at first, the test barge actually sank bow first when it met a multi-year ice flow it could not break. So much for that idea. It quickly became obvious that even with more traditional downward breaking bows there was no previous experience, voyages, or model tests simulating year round conditions with which to make credible predictions of how year round icebreaking tankers would look, cost or perform. Accordingly, it was decided it would be necessary to conduct a major experiment with a large ship in ice in order to answer the key questions about the icebreaking tanker proposal. This was the task given to Esso International, Jersey Standard’s marine technology experts, in the fall of 1968.

Three of us in InterEsso had been involved 6 years before with the design, and sea trials of a twin screw tanker from Bethlehem Steel in Quincy Mass, USA. When delivered in January 1962, MANHATTAN, at 106,000 DWT and 43,000 HP, was for a short while the largest ship in the world, and in the fall of 1968 she was still one of the strongest and most powerful ships in the world, and fortunately she was available for charter to become our test vehicle. We thought of her as a gigantic model test candidate because despite everything we subsequently did to convert her in to an experimental ice breaking test vessel, it was impossible to make her, or any existing merchant ship, into a fully Arctic capable vessel or prototype.

At the same time we asked two dozen shipyards world wide to bid on handling this conversion. By December 1968 only Sun Shipbuilding and Drydock in Chester Pennsylvania offered to undertake this work, but not on a fixed price because we still didn’t know what we needed to do to convert MANHATTAN for ice breaking tests.

It was at that stage that Wartsila Helsinki Shipyard came to see us saying that although they didn’t want to help us they were going to help us because after having built two thirds of the world’s ice breakers, they were worried that without their expertise icebreaking would get a bad name for their best product line, so we had to pay them. We agreed, paid them a good fee, and in the end it was the best thing we did. What had originally been billed as a $ 10-15 million experiment eventually ended 21 months later having cost $ 58 million (with BP & ARCO each contributing $ 2million to “get a seat” on MNAHATTAN). The conversion alone lasting eight months had cost $ 28 million as MANHATTAN sailed for the Arctic in late August. 1969.

The full story of MANHATTAN's conversion, results from it's two voyages north, ice model tests in a new facility in a Helsinki bomb shelter, an icebreaking tanker preliminary design and the economics of tankers compared to pipelines was told in a 1981 paper to The Society of Naval Architects and Marine Engineers "Manhattan's Arctic Venture-A Semitechnical History" by this author and Capt Ralph Maybourn, BP's senior representative on MANHATTAN's 1969 Arctic voyage. Excerpts from that paper and some of its pictures, charts and tables help describe the key points in the project.

In a period of only 4-5 weeks during the Christmas-New Years holidays of 1969-70 with the Wartsila "knowhow" to guide us, virtually all the major conversion features involving ice going structural and machinery design criteria were reached. Only the proposed icebreaking bow shape had been decided prior to this intensive period. With these decisions reached, steel and other materials and equipment could be ordered by early January 1969 just as MANHATTAN arrived in Chester ready to be rebuilt.

When we saw the magnitude of the work to be done, it was obvious that Sun Shipbuilding alone couldn't possibly handle the job and still be finished in the 6-7 months hoped for to complete conversion. As the massive steel additions would require three times the labor available in Chester, Sun suggested that we cut the ship into various pieces and move them to other shipyards as subcontractors before returning them too Chester for reassembly in Sun's drydock, which itself had to be enlarged to lift the the fully converted ship whose lightship weight was increased by nearly 10,000 tons from its original value of 30,500 tons.

A schematic of the converted MANHATTAN is shown in figure 1, which also shows the main sections into which the ship was cut and two totally new sections

- Front of new bow built in Bath Maine, brought to Chester in an old tanker
- New ice breaking bow built in Sun's new drydock section built in Chester
- Forward tanks with bow bulges and ice belt installed at Newport News, Va
- Fwd cargo tanks & bridge to which Alabama added internal struts and ice belt
- Aft half of ship with engine & boiler rooms which had a new inner double skin added, stayed at Sun where internal struts and ice belt were added, and major machinery modifications were needed to propellers, shafts, gears, and cooling systems.

Figures 4-7, 10 and 23 show some of these pieces, and figs 23-26show both sections, the "MANHATTAN fleet" fig 24 and the sequence of reassembly of the finished conversion fig 25.

Table 1 shows changes in principle dimensions (longer, wider and deeper), estimated added steel, and principal conversion features needed to make the ship ice worthy even as a test vessel.

In order for Sun to devote its entire production labor force to our job, we paid them to stop work on two newbuildings and other yard customers who were more than happy to have Jersey Standard reimburse them for a few months delay. All in all this was a project which NY Times journalist William D. Smith in his excellent book “Northwest Passage” described as “the most intensive shipbuilding operation in the United States since WW II”.

Bill Smith, who later joined us in Exxon, was my bunkmate during MANHATTAN’s voyage to Prudhoe Bay and Point Barrow, and ice testing in Sept/Oct 1969. Smith and a number of other journalists, US politicians, Canadian Parlimentarians

joined the ship’s 45 crew members, and perhaps 15-20 ice scientists and naval architects/marine engineers to make a total compliment of 126 souls who were stuffed into cots in every available empty space. Fortunately MANHATTAN had enough room to handle and feed this crowd. Extra life rafts were fitted to meet safety regulations, and the ship’s two helicopters were busy at the stern heliport needed to exchange all the people who managed to fly out and visit us.

Since the fabled Northwest passage is virtually totally surrounded by parts of Canada, and only Canadian ice breakers and crews then had experience there, it was clear at the outset that we would be very dependent on their assistance. While the U. S. Government officially believed this waterway to be an international strait, and therefore refused to ask permission to sail there, the U. S. Coast Guard participated with us fully and we in Exxon asked the Canadian Government for permission to do our tests and to have their assistance. This they did in abundance, providing the, at that time nearly new ice breaker JOHN A. MCDONALD, and later we were joined by their LOUIS ST LAURENT on her shakedown Arctic cruise. And Capt Tom Pullen RCN (ret), a descendant of several Arctic mariner ancestors was an admirable senior Canadian representative aboard MANHATTAN.

In the final analysis the Canadian icebreakers and personnel were the main “shepherds” for our test ship, which, as expected all along, often got stuck in her icebreaking progress and because of limited astern power(which in non- ice going vessels is usually about 20-30 % of ahead power) had to be cut out

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Two smaller American “WIND” class icebreakers of WW II vintage were with us, mostly in fact for “flag waving” purposes, a role which they carried out to perfection although this was hardly the case at first. When one of these ships had to leave MANHATTAN’s ice experiments because of machinery failure and limp home, and this fact showed up on the front page of many US newspapers the fact that Americans had to be bailed out by Canadians in this high profile project gave the US Government a real “black eye”. Fortunately the Coast Guard Commandant, who was with us aboard MANHATTAN just then, was able to fly back to Washington, put together a proposal and get Congressional approval and funding for two brand new polar ice breakers all before MANHATTAN left the Arctic. Thus came a few years later USCG’s POLAR STAR and POLAR SEA.

Of course the press with us made much of MANHATTAN's failures, like being unable to make a west bound passage through McClure Strait(which to this date in 2008 has still not been done) and her inadequate backing power, a nuisance but of no real consequence in our ice tests. For this first 1969 trip, several weeks of ice breaking tests in Parry Channel were carried out very successfully in Sept/Oct. Again, however, as the experts, both from Finland and Canada had predicted , as had even some of us Arctic neophytes, the biggest problem was that we had too much very easy one year ice and only a little harder multiyear ice. Also there was no wind driven ice pressure to lock us in as inevitably can occur in the winter and spring. So it was obvious that another voyage

would be needed in spring 1970 to get data in harsher winter conditions for which preparations soon started. What had clearly been learned in the 1969 voyage were several basic Arctic ice breaking truths:

- A large mass moving at decent speed (our "model") could break very tough multi-year ice and ridges, but she would need real backing power to prevent getting stuck, an absolute "must" if un-escorted tankers were to suceed.
- Maneuverability in ice is very difficult for a "parallel body" merchant ship shape even with bow bulges
- Geared steam turbine machinery with new propellers and shafts could withstand the severe shocks which broken ice floes going through the propellers often caused.
- In near "open" water conditions, growlers and bergy bits were able to cause major structural damage in non-reinforced parts of the ship's hull
- Success of ice breaking tankers would be very much in the hands of a ship's crew, even with reconnaissance by aircraft and side looking radar, to find preferable routes though the ice.

Finally we needed the ice model basin which Wartsila was building for us in Helsinki using the "high salinity ice" technology developed by the Soviets. We could explore different hull shapes, powering requirements, and behavior in breaking ridges. At the same time, based on the 1969 data from MANHATTAN, and with Wartsila's guidance on hull structural criteria especially from wind-driven ice pressure which MANHATTAN finally experienced early in her spring 1970 voyage, we started preliminary design for twin or triple screw ice breaking tankers of 300,000 DWT. These studies involved Newport News Shipbuilding and steam turbine, boiler and gear experts.

In April of 1970 MANHATTAN went north again headed for Lancaster Sound at the east end of the Northwest Passage. When she got there, neither the test ship or assisting escorts could get very far into the fabled waterway which was plugged solid with winter ice, She experienced real pressure which quickly validated the Wartsila design criteria, and then headed back to Pond Inlet between Bylot and Baffin Islands where her icebreaking testing continued, mostly in new one year ice of about 6-7 ft or two meters. As anticipated and shown in figure 35 the power required for a given thickness of level ice to be broken based on the 1970 tests was about 20-25 % greater than from the 1969 tests with more rotten ice .

With data from these two sets of tests, the model basin results, and using one-year ice thickness estimates from Canadian and Finnish sources shown on figure 31 for both the Northwest Passage, and Beaufort Sea, Bering Strait and Chukchi Sea, it was possible to make time and speed estimates for voyages both East and West from Prudhoe Bay to US “lower 48” at different times of the year as shown in figures 32, 33 and 34. The main points these estimates show is that:

- The time needed for a voyage south from Prudhoe Bay would be at least

  twice as long in the hardest time of the year (late spring) as that at the easiest time (late summer early fall)
- Accordingly, there would be a need for large amounts of oil storage at both ends of the trip since the oil fields would want to produce at steady rate and the greater amounts of crude arriving at the southern end in summer/fall would would be arriving at a “low demand” time of the year.
- Combining the design characteristics for adequate structural reliability and power, speed in level ice, ramming, and in open water we were able to estimate the capital and operating cost for the icebreaking tankers. To get a feel for the difference between the main design features of large open water tankers and our proposed 300,000DWT icebreaking tanker , and also the world’s largest ice breakers then, table V shows main features for each and characteristics and size comparisons are in figures 41. Figure 42 is a schematic of our ice breaking tanker and has main features identified

Using data from these estimates it was possible to make a very rough comparison of the relative economics for a fleet of icebreaking tankers in comparison to the trans Alaska pipeline solution which had already been agreed upon before our ice tanker trials had been completed. Some rough figures from that time (1970 $) follow:

One 300,000 DWT IceBrk Tkr Cost $ 105 M (vs $ 18-20 M for “water” 250,000 DWT)

To move 1.5 MBD	To East Coast (DelBay)	To West Coast (PugetSound)
Ave delivery/ship	60 mbd	100 mbd
No. of ships	25	15
Capital Invest, for ships	$ 2.5 B	$ 1.6 B

By comparison, the first capital investment number I recall hearing for the pipeline was about $ 3-500 million, but by the time it opened the figures fom various sources said about $ 3- 7 Billion. Of course none of this proves the case either way, as the marine numbers above don’t include the cost of a terminal at Prudhoe Bay or storage, and the pipeline numbers don’t count the 20-30 ships built to haul crude from Valdez to the west coast, or via Panama to U.S. Gulf or east coast. In any case, in 1970 our marine case generally projected a lower delivered cost than the pipeline, but as already stated, icebreaking tankers were always regarded as a “backup” in case the pipeline wasn’t improved.

To complete this brief recount of our MANHATTAN experiment, here are Exxon statements from a press release of Oct 21, 1970:

“The use of icebreaking tankers to transport crude oil from Alaska’s North Slope to U. S. markets is commercially feasible, Humble Oil and Refining said today, but pipeline transportation appears to have an economic edge at present. The company has decided to suspend its icebreaking tanker studies while concentrating on pipeline

alternatives. Humble said Arctic Tanker development work could be resumed on short notice if economic factors changed or other circumstances warrant.”

It went on to say

“ The two Arctic voyages of the S. S, MANHATTAN were highly successful in providing valuable data for our studies concerning the various transportation alternatives for moving Alaskan Crude to U. S. Refineries. We know now that icebreaking tanker transportation is a workable alternative, and this gives us much greater flexibility in meeting future transportation needs”.

While most in the media at the time wrongly concluded this was an oil major “sugar-coating” a failed experiment that had “cost them a bundle”, the real story was as Ralph Maybourn and I stated in our SNAME paper:

“ The entire project team had no doubt whatsoever that it would be feasible to build and to operate successfully a fleet of large icebreaking tankers either through the Northwest passage or through the Bering Strait from Prudhoe Bay on a year-round basis.The point was specifically made, however that this judgement as to feasibility could not extend to operations very far out into the Beaufort Sea within the polar gyral. It was judged that continual operation in multi-year polar ice was at least an order of magnitude more difficult than was foreseen for the routes studied in the MANHATTAN project.”

To complete this tale of Exxon’s MANHATTAN icebreaking experiment 38 years ago three other subjects should be addressed, First is a breakdown of the cost of the project(in 1969-70 $’s)

Design and consulting studies	$ 3 M
Conversion	$ 28 M
Un-conversion (leave ship in converted state)	$ 10M
Charter hire & Operating Expense	$ 15M
Miscellaneous	$ 2M
Total	$ 58 Million

Second is how and where would icebreaking tankers have been built if that solution had been selected. Because the U. S. Jones Act requires ships in domestic trades (U. S. origin and destination for cargo) to be built in the United States, that is where we would have to have them built. But we had decided because of the poor efficiency of large American shipyards then (and still now), we would have built a totally new shipyard and have it run by European or possibly Asian management. In the economic comparison on page 6 the cost of $ 105million for the icebreaker compared to $ 18-20 M for slightly smaller conventional VLCC, the values are in terms of known prices we were getting then in European or Japanese yards. The same 250-270,000 DWT "water" tankers

were being offered by US yards then for over $ 50 million—a very stiff penalty which we could not accept.

Third and last, is what we felt then, and now, were the lessons learned from our MANHATTAN ice breaking experiment. I would list the following:

- Most important was the conclusion supported by all who participated that it is technically and economically feasible to use non-escorted large ice breaking merchant ships for the routes we explored, and most likely also for the Northern sea route above Russia.
- Our project team felt that the relative efficiency of icebreaking(i.e. power, size, speed in level ice) had been improved perhaps 20 %, possibly because of the shape of MANHATTAN's bow(curved vs 25-30 deg straight slope) and bow bulges to reduce friction from broken ice on parallel body.
- These two developments, together with Wartsila's ice model basin capability, certainly acted like a challenge or incentive to the marine world to innovate in Arctic worthy vessels, and our Canadian friends said our work had been the catalyst for creation of Canada's Arctic Waters Protection Act which came out in the early 1970's .
- While we had been unable to fit Wartsila's "mixed flow air" device (the "Bubbler') to MANHATTAN, we witnessed its successful trial on their icebreaking RoRo FINCARRIER in the Baltic in spring 1970. This successful little ship was also I believe the first unescorted ice merchant ship in the Baltic and had twin cpntrollable pitch propellers,CPP, another ice breaking first
- Later developments, like reamers on icebreaking offshore supply craft in Canadian McKensie Delta and I think in Sweden.
- Very smooth and hard underbody coatings in more 1980's(?) icebreakers
- Double acting azipod installations pioneered about 1992 by KvaernerMasa with LUNNI and UKKU, and later in recent newbuildings for both Baltic and Arctic service by Aker Arctic Technology.

I have the impression that compared to the state of ice breaking technology prior to MANHATTAN we are now approaching at least 50 % improvement. But these comparisons are best made by those active now in the field. For this author I believe my experience with Exxon's Arctic experiment was clearly a highlight in my career. It was a privilege to have the chance to visit a beautiful, if at times cold, part of the world, and to do so in the company of many delightful and stimulating people, As I tell people “if you have the chance to go icebreaking, TAKE IT !!! It is not always fast, but it surely is fascinating”

ExMbMh.doc Figure and Table numbers refer to my 1981 SNAME paper
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