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## OPERATION HABBAKUK:

## A WORLD WAR II VESSEL PROTOTYPE\*

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## INTRODUCTION

The location, recording and sampling of the remains of the World War II vessel prototype known as *Habbakuk* represents the first phase of a three-phase project. In spite of the fascinating history and historical value of this proposed secret weapon -- an indestructible ship of ice -- the importance of the *Habbakuk* site *per se* does not differ from that of other sites in terms of the overall project. Therefore, my discussion focusses on the scientific, technological and historical significance of the Allied wartime project, with only a cursory glance at the project framework.

Three lakes, known to contain historical remains, were selected. These are located in three National Parks: Patricia Lake, Jasper; Lake Minnewanka, Banff and Waterton Lake, Waterton. The decision to concentrate on historic remains was predicated upon several factors. Salient among these is the observation that such sites are more easily recognized and, therefore, more vulnerable to vandalism and the predations of souvenir-hunters. Also, the availability of background information provides controls on the archaeological data gathered and the project will contribute to information about the effects of long-term submergence in fresh water and at high altitudes. In addition to providing a record of extant remains, this study will permit the assessment of extensive and intensive public use. Much of the knowledge gained about the chemical and mechanical effects of inundation will prove useful when extrapolating into other areas of archaeological study such as prehistoric sites and cultural resources on bottomland lease areas which may be threatened by offshore natural resource exploration and exploitation. Another purpose of the project is to create viable cultural resource management programmes for the conservation and interpretation of submerged heritage remains.

Little serious study has been carried out in Canada in any of these areas.<sup>1</sup> A research programme encompassing some of these

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goals has just been designed in the USA which utilizes reservoir studies recently completed.<sup>2</sup> Taken in conjunction with the American work, this Canadian research can make major contributions to archaeological knowledge.

The decision to initiate the project at Patricia Lake was based on a number of facts: it is the least visited of the three lakes and the wreck is very deeply submerged, leading to the expectation of better preservation of the remains. As it is the only lake containing a single site, it provides an opportunity to detect and solve logistical problems.

#### HISTORICAL BACKGROUND AND THE MODEL

During the Second World War, U-Boats operated successfully in the Mid-Atlantic, an area beyond the attacking capability of air patrols from both Europe and North America. This area became known as 'U-Boat Alley.' To close the gap and protect convoys, a means of landing and refueling aircraft was needed. Conventional aircraft carriers were vulnerable to torpedoes, their decks were too short for bombers and they could not be used in high seas.

In 1942, Geoffrey Nathaniel Pyke, an eccentric British genius, was attached to Lord Louis Mountbatten's Combined Operations Headquarters. He made a proposal which fired the imaginations of Mountbatten and Prime Minister Winston Churchill. The resistance of icebergs to destruction was well documented from attempts by international ice patrols to blast them apart after the sinking of the *Titanic* in 1912.<sup>3</sup>

Pyke became obsessed with the idea of breaking off huge sheets of ice from the Arctic icecap and towing them to the war zone for service as floating aerodromes. He believed that

Ice was to be the new strategic material that would win the war.<sup>4</sup>

On 4 December 1942, Churchill dictated a 'Most Secret' memo detailing how these ice airfields should be constructed. He admitted and demonstrated an absence of knowledge about the physical properties of ice and observed that the concept was only possible if the materials and labour in the form of seawater and low temperatures were provided by nature.<sup>5</sup> His scheme was simplistic and flaws were plentiful. For example, the British Admiralty pointed out that at least a fifty-foot freeboard was necessary for a flight deck in mid-ocean swells. Therefore, a simple ice flow would be out of the question. Since a solid iceberg maintains 90% of its bulk beneath the water's surface, a vessel with a fifty-foot freeboard would have a draft of almost 500 feet. This would be very difficult to move. Therefore, the idea began to change to the construction of an ice vessel of conventional form with bulkheads and other compartments. Unfortunately, this would mean a corresponding loss of the 'indestructible' quality that had led to the initial suggestion of using icebergs. These would also require continual refrigeration and an insulating skin, which would add to costs in materials

and manpower. The proposed dimensions were 2000 feet long by 300 feet at the beam and 200 feet gross depth with the necessary 50-foot freeboard. For refrigeration and movement, twenty electric motors would be supplied from a turbo-electric generating plant. A minimum speed of 7 knots was required to ensure that the vessel was controllable.

The project was grudgingly approved by the British Admiralty early in 1943 and the Canadian Government was approached to undertake the feasibility research, costs and the construction of the vessels. The National Research Council, under Dr C.J. Mackenzie, undertook the building and testing of a model. In his war diaries Mackenzie calls it, at the outset

... another of those mad wild schemes [that started] with a couple of crazy men in England. 6

Pyke called the proposed vessel *Habbakuk*, a misspelling of the Old Testament book of the prophet Habakkuk which says

... regard and wonder marvellously: for I will work a work in your days which ye will not believe, though it be told you. (Habakkuk 1:5)

By the end of January, Mackenzie seemed to have warmed to the project and had instigated research into the properties of ice at the Universities of Manitoba, Saskatchewan and Alberta, and ice testing was undertaken at Banff and Lake Louise and in Montreal, New York and London. Although most of the designing took place in Ottawa, Patricia Lake was chosen for the building of the model, to test ice and refrigeration units for *Habbakuk*. It was not as cold as Lake Louise, but it offered a source of labour, conscientious objectors' camp of Mennonites and Doukhobors, good rail connections and secrecy. Since the area had already been sequestered for training ski paratroopers, extra military and governmental activity would not be readily discerned.

Early in February plans were being drawn up for the model (Figure 1). Although lake ice was used in the model, where an actual vessel would be concerned, Mackenzie noted that

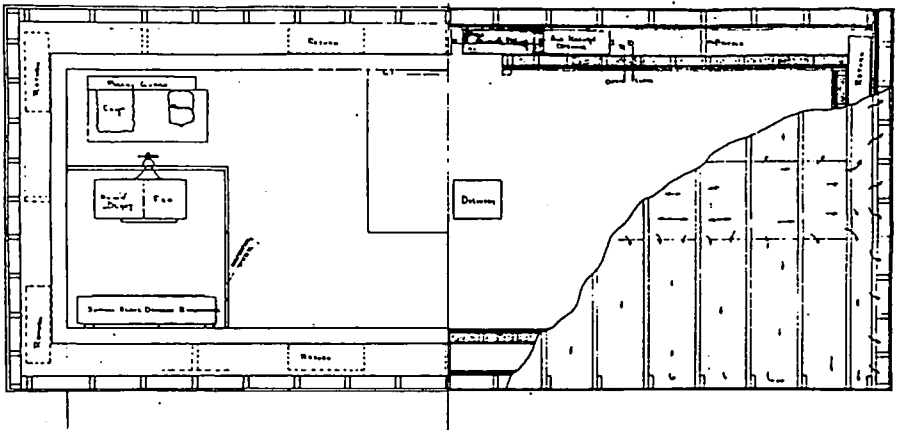
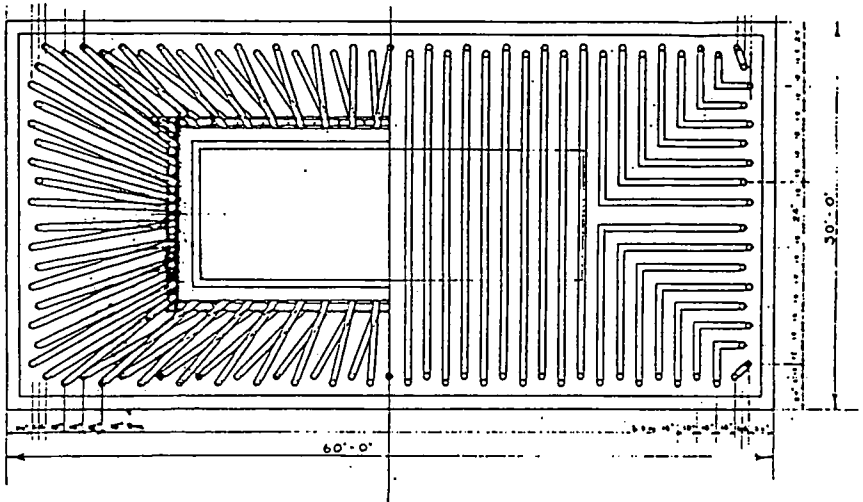
At the present time I am being led to believe that the use of material cut from lakes is completely out of the question but we must manufacture the material either in place or in blocks. I think the welding would present no difficulty were it not for the coefficient of expansion and I think some form of porous macro reinforcement is absolutely essential.<sup>7</sup>

He soon received both a confirmation of and a solution to this problem. Dr Herman Mark of the Brooklyn Polytechnical Institute had been experimenting with various ways of reinforcing ice. He had hit upon a 4-10% mixture of wood pulp in the ice which substantially increased its strength and resistance to bullets and explosions.<sup>8</sup> He named this substance pykrete for

FIGURE 1

(Top) Plan view of model showing ductwork connecting to the refrigeration chamber (left) and ductwork running beneath the chamber (right in cut-away).

(Bottom) Plan view of model showing interior of refrigeration chamber (left) and the interior of the double walling and flooring (right in cut-away)



Pyke. In addition to its great strength, it was light, buoyant and resisted melting but could be turned on a lathe, hammered and sawed. Although it solved many problems, it did mean that nature could not be relied on solely and that material costs and manpower would be greatly increased.

In the meantime work progressed on the model under the auspices of Dr C. Niven. Although the model was ostensibly under construction between 1 February and 31 March 1943, in fact work did not begin until the middle of February. Most of the delay was caused by the late arrival of materials and the interval was spent experimenting with various means of bonding ice blocks. Electricity was brought in by means of lines to a small generating station at the prestigious Jasper Park Lodge and an area was cleared on the frozen surface of the lake, the wooden flooring laid and wall framing erected (Plate 1). Pitch caulking took place from 15-21 February, followed by asphalt covering for the floor and walls (22-27 February) while tinsmiths worked on the ducts. The first layer of ice was laid on the flooring between 1-6 March, but piping problems began to appear. A brine coolant had originally been chosen; however, many joints arrived damaged and leaked badly, leading to the decision to use cold air instead. About this time Mackenzie began to express doubts as to the project's viability. Also, the weight of the ice and insulation rising to eight feet up the walls was causing the floor to bow upward. By 13 March the floor piping was completed and sealed with pitch. The ducts had been packed round with sand and then covered over with crushed ice and water. By 20 March, the wall piping was in place as was the second 27-inch thick layer of ice. The structure was cut loose from the surface ice of the lake, partly to test how it floated and partly to relieve the weight strain on the floor. It sank to the level of the surface of the ice flooring inside and remained stable. In the following week the third layer of ice was installed and a channel cut in it for a longitudinal duct to run beneath the refrigeration chamber. By 10 April the machinery was in place and functioning. A roof was built over the model to protect the machinery and open surface insulation from the elements. This gave it the appearance of a 'boathouse' (Plate 2).

Niven's post-project synopsis describes the model as follows:

The overall dimensions ... were 60'x30'x19 1/2'. The casing was made of two sheets of shiplap on the floor and sides. The floor was covered with a mixture of asphalt or pitch and either charcoal or vermiculite to a depth of ten inches and covered with one thickness of half-inch insul board ... The walls were insulated with ten inches also of the asphalt mixture which was poured around the 3"x6" studs forming the frame of the wall. The asphalt mixture was held in place by insul board ... The top of the material was covered to about the depth of a foot with shavings and sisal craft blankets were spread on top. In the centre of the material

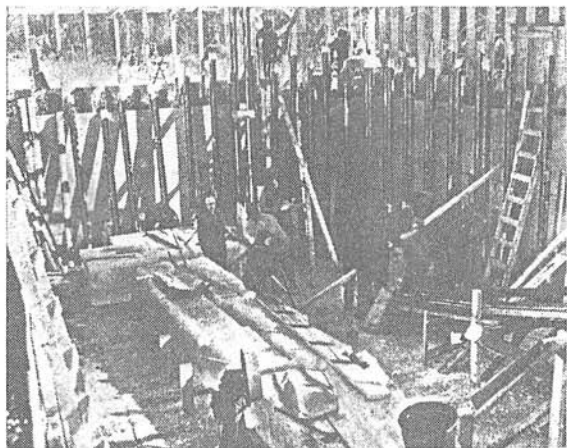


PLATE 1

Base of the model with air pipes up the walls.

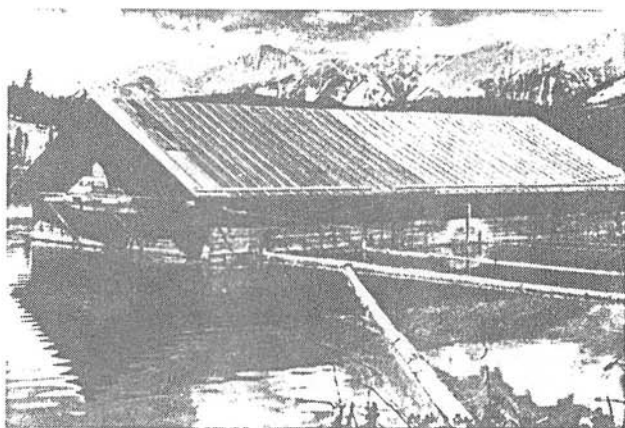


PLATE 2

The 'Boathouse' roof.

there was a machinery chamber, the internal dimensions of which were 30'x10'x10'; there were three fan chambers in this 6 1/4'x6 1/4'x7'. These chambers as well as the walls of the cabin were insulated between the four-inch studs with vermiculite and two thicknesses of half-inch insul board. The floor was insulated with two thicknesses of half-inch insul board ...<sup>9</sup> (Plate 3)

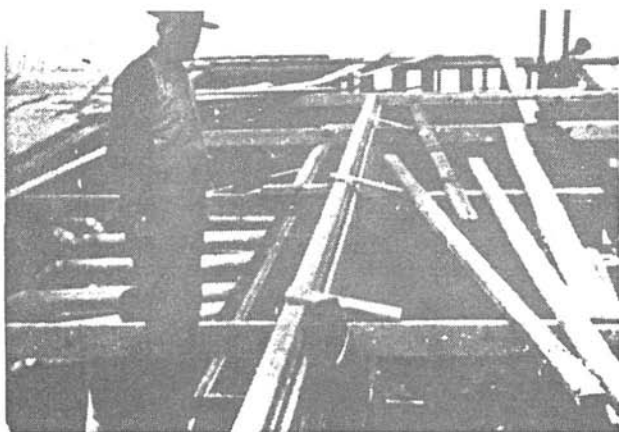


PLATE 3

Refrigeration unit (right) and piping (left).

While the width and depth of the model fit a 1/10 scale of the measurements suggested by the British Admiralty, the length is substantially shorter (60' versus 200' for a 1:10 ratio). There is no explanation for this choice in any of the documentation.

With regard to the air circulation and the construction of the refrigeration cabin, Niven notes:

The machines discharged into a common duct under the machinery cabin; this duct was in connection with the outer of the air spaces in the floor and walls of the machinery cabin.



From this outer air space the six inch galvanized iron stove pipe ducts started travelling down the wall 18 inches from the surface of the material [ice] (measured centre to centre of duct), then across the floor 15 inches from the surface of the material, then up the other wall 12 inches from the surface of the material and finally back to the inner of the air spaces surrounding the cabin.<sup>10</sup>

This system of refrigeration is based on a system devised by Dr W.H. Cook of the NRC who oversaw its modification for *Habbakuk*. The original scheme was a means of turning the entire hull of a vessel into a refrigeration unit for the transoceanic shipping of fresh food by ribbing the inside of the hull with piping for brine coolant. The solution was electrically recooled when it circulated through longitudinal spines along the top and bottom of the hull. The close similarity of the *Habbakuk* design to this 'jacket' system may be seen in its plans although cold air replaced the brine.

On-going studies on site and in other research centres demonstrated the impracticality of the project and Mackenzie recommended its end in May.<sup>11</sup> By June, Churchill had been informed -- much to his displeasure -- that the refrigeration machinery had been removed and the model was left floating while scientists monitored its longevity.<sup>12</sup> It lasted well through the heat of the summer before subsiding into the lake.

The cost of building one full-sized *Habbakuk* was estimated at £17 million<sup>13</sup> (approximately \$70 million), less than half the cost of a conventional carrier of comparable size.<sup>14</sup> In all, the model and the valuable concomitant research and testing cost only \$150,000.<sup>15</sup> A letter to C.D. Howe, Minister of Munitions and Supply, dated 16 April 1943 notes that the Canadian War Committee had approved construction of a full-scale vessel and had authorized an initial expenditure of \$1 million to this end.<sup>16</sup> However, less than a month later came Mackenzie's decision against continuing the project.

Other factors contributing to the premature obsolescence of *Habbakuk* took the form of technological developments, such as the construction of better long-range aircraft and the invention of centimetric radar as well as the establishment of airbases in Iceland. The combination of these elements successfully closed 'U-Boat Alley.' When the venue of the war shifted to the Pacific, Churchill 'cajoled and bullied' the USA into continuing the research,<sup>17</sup> but the plan was subsequently pronounced to be not cost effective and *Habbakuk* died.

An overall assessment of Operation *Habbakuk* may be summarized as follows: the project succeeded, but the operation failed. The building of the model and all of the related research, experiments and testing demonstrated that the concept was sound and could prove successful. However, the operational goal of putting a flotilla of such vessels into military service was impractical in terms of time and costs; these conclusions coincidentally occurred about the time when other

circumstances obviated the need for such craft.

#### ARCHAEOLOGICAL REMAINS

The remains of the model were located lying on an East-West diagonal on a steep sideslope about fifteen metres offshore on the South side of Patricia Lake (Section 20, Township 45, Range 1 West of the sixth Meridian). The depth of the shallowest corner (the southwest) is 26 metres and the deepest corner (the northeast) is 43 metres. Because of the altitude of the lake (approximately 4000'), about 20 feet must be added to depths to allow for the correct calculation of safe decompression times. This factor put extreme limits on the amount of bottom time permitted. Therefore, dives had to be carefully planned to maximize efficient use of available work time. A datum line was run west to east along the north side of the vessel. This is a weighted rope marked in one-metre intervals. This facilitates key measurements and permits the mapping of specific features by triangulation of the location from two-metre marks on the datum. A grid system works best when either excavating a site where layers may be drawn as they are 'peeled' away or for mapping sites reduced to a single plane. However, in the case of *Habbakuk*, where three-dimensional remains are present, recording is the only purpose of the project and time severely limits extensive drawing so that a datum line is most effective. As many measurements, drawings and photographs as practicable were made. The overall position of the site was surveyed by transit from a nearby benchmark to buoys secured on three corners of the vessel.

The outstanding features of the site are the incredible jumble of piping from the ductwork and the great quantity of asphalt which lies scattered in slabs or still clinging to the walls. While the former was unexpected only in quantity, the latter came as a complete surprise. Although documentation has explained the occurrence, there are no archival photographs recording its presence and there is no indication of the tonnage (Plate 4).

What was believed to be tarpaper but which has been identified as the remains of tarred insul board was recovered from both the interior and the exterior of the refrigeration chamber. Fragments of electrical wiring and metal hardware were also noted but there was no evidence for the vermiculite. Since more than two train carloads of this substance were delivered,<sup>18</sup> it is expected that remnants will be present. Analyses do not show that it was mixed into the asphalt.

The remains are in excellent condition, a fact borne out by electronmicroscopic examination of wood samples. Although the roof is missing, all four walls are present. Three are intact and one of these is still upright. The fourth has become disjointed and is strewn down the sideslope as far as divers could safely be permitted to descent.

The refrigeration chamber is intact although it has been dislodged from its central position and lacks its internal hardware (Plate 5). Its double-walling with airspaces and traps proved enigmatic at first. However, study of the various

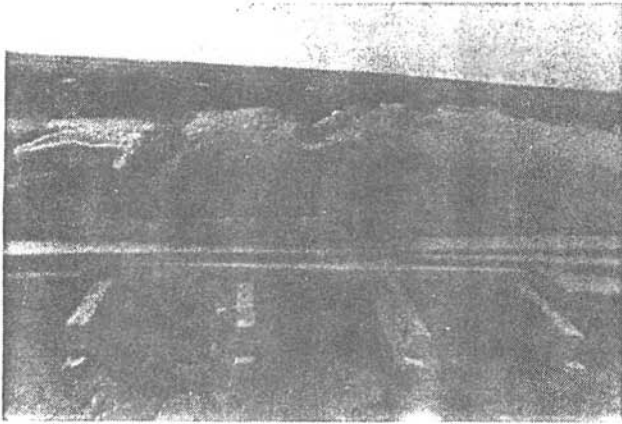


PLATE 4

Billow of asphalt insulation between floor and collapsed south wall (looking north).



PLATE 5

North-east corner of the refrigeration chamber (looking south-west).

openings in the walls produced the correct interpretation before substantiating documents were located. As there had been only three fans and three sets of cooling equipment, five large holes cut into the floor were puzzling. A personal letter between researchers provided the solution, revealing them to be manholes to monitor and repair the duct-work.<sup>19</sup>

In accordance with Parks Canada policy and the research design of the overall project, only minimal wood and asphalt samples were collected for testing. Analyses were carried out by Drs E. Wang and B. Bains, Department of Agricultural Engineering, University of Alberta (wood) and Drs R. Roche and G. Ritchie, Department of Chemistry, University of Calgary (asphalt). The good state of preservation, excluding some vandalism in the form of initial carving, can be attributed to the depth and cold water temperature as well as the recent nature of the site, although these same factors also work against the researcher.

#### CONCLUSION

It is interesting to note that now, as in the past, the subject of *Habbakuk* has the ability to inflame the imagination. A demonstration of the human tendency to dramatize the glamorous over the mundane is the pandemonium which broke out when a security leak was suspected about the time the construction of the model was completed. An episode of the cartoon strip 'Superman' contained references to iceberg ships. Copies of these were sent to the National Research Council by the Head of Civil Engineering at the University of Manitoba with the advice 'that they be taken seriously, in part.'<sup>20</sup>

From the point of view of the overall project, the data thus far obtained have been most gratifying. The experience accrued from this phase has provided both the means to streamline future phases and some useful information about the chemical and mechanical effects of inundation in fresh water and at high altitudes. These results will be used in conjunction with findings from the other two phases in order to provide a time frame for the changes. These data will also provide the means by which sites may be monitored, over time, for degradation or deterioration due to human and natural impacts. Such information is invaluable in determining the best form for management and public educational programming to take.

The *Habbakuk* project succeeded in reaching its professed goals in that it demonstrated the possibility of building a vessel of reinforced ice which would be theoretically unsinkable. The fact that the operation never reached fruition does not detract from this. The information gained through research into macro-reinforced ice was used by North Rankin Nickel Mines in 1957 researching the possibility of building pit supports and a pier of pykrete on the western shore of Hudson Bay.<sup>21</sup> Problems were encountered in obtaining sufficient information which had been declassified and the governments of both Canada and Britain refused to open many files. Documents cited as still unavailable by Robertson<sup>21</sup> were

declassified upon request for this archaeological project. Recently, some Arctic oil drilling rig specialists have agreed to explore the possibility of using it in building the ice islands which cushion rigs from winter sea ice.

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Plates 1-3 Courtesy of National Research Council of Canada