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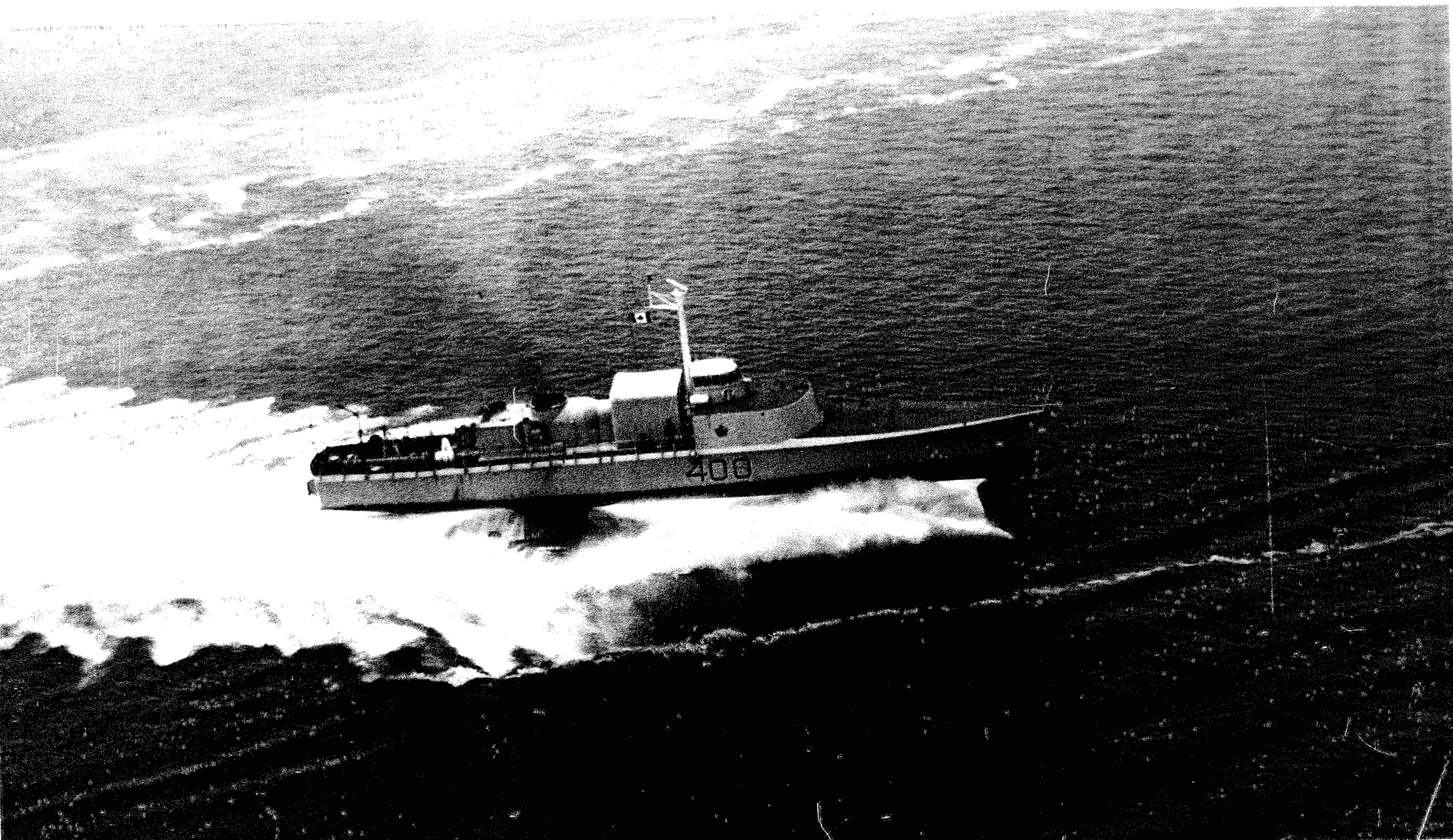
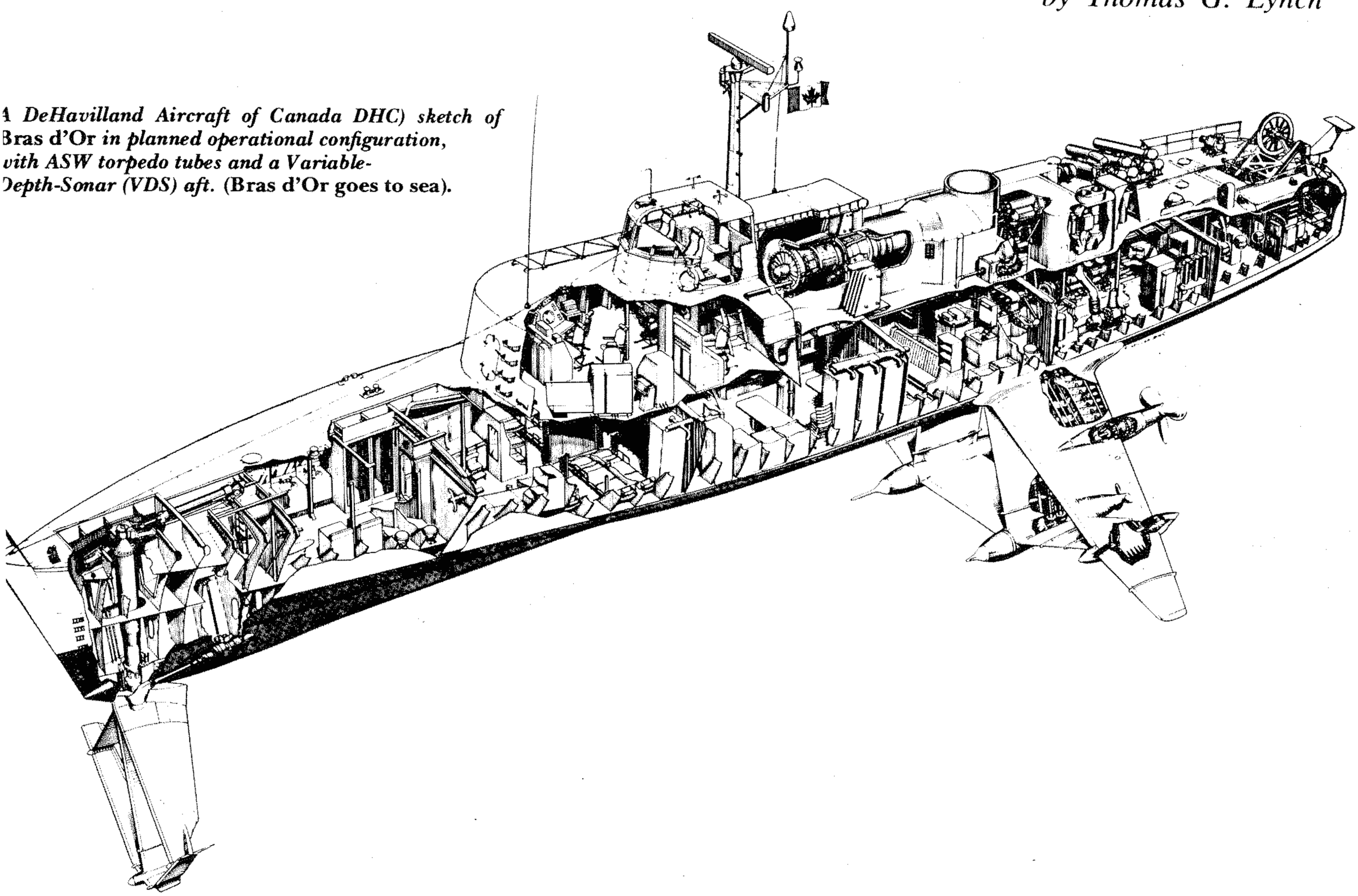



400

HMCS Bras d'Or

by Thomas G. Lynch

A DeHavilland Aircraft of Canada DHC) sketch of **Bras d'Or** *in planned operational configuration, with ASW torpedo tubes and a Variable-Depth-Sonar (VDS) aft.* **(Bras d'Or goes to sea).**



Ten Years in Retrospect

THERE IS TODAY A SMALL, graceful, light gray-colored hull that appears to perch atop two small houses on a flat barge, sitting forlornly on the Dartmouth side of Halifax Harbor. Her red anti-fouling paint has faded to a flamingo pink, as has her maple leaf insignia. Only her one-time pennant number stands out: "400." Here lies the remains of a bold experiment that has prompted worldwide notice of Canada's naval research capabilities. Indeed, she was one of a kind, flaunting her differences with her odd but graceful canard foil system, now hidden by the climatic shelters built about them in 1972. This is the end of a dream that almost came true.

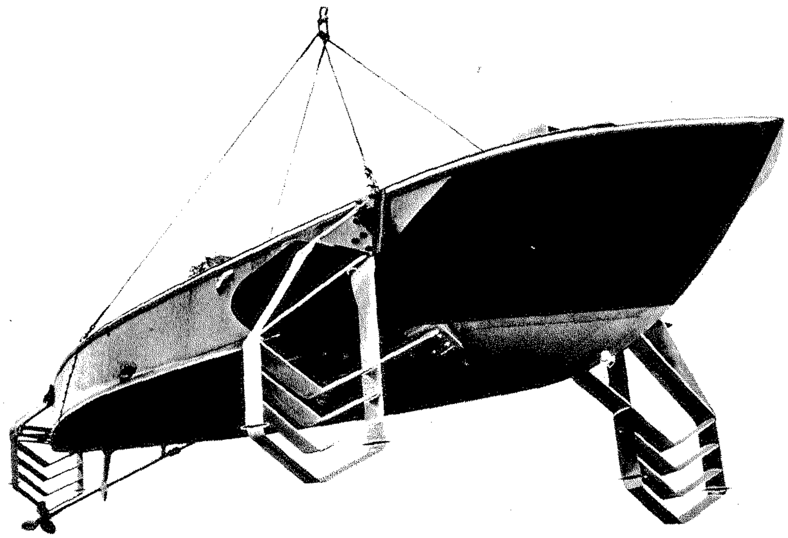
Origins

To trace the story of *Bras d'Or*, it is necessary to reach back into the now dim mists of the early 1950s. The Canadian Defence Research Establishment Atlantic (DREA) undertook a series of experiments to add to and improve the theories and evidence gained in the Baldwin-Bell experiments of nearly 35 years before. Small models were constructed and knowledge thus gleaned was used with larger, more ambitious craft. Finally, the research craft *Massawippi* was built, exhibiting the distinctive "ladder" of variable-altitude foils. This craft was followed by the larger experimental vessel *Baddeck* which had three equal size foils, two forward and one aft. Tests showed that the configuration would work, but in effect it asked ⅔rds of the system to be inefficient. Experience with these vessels led to the DREA Foil System concept, which, although based on the Bell-Baldwin theories, went far beyond. The final concept is discussed later in this text, but the big breakthrough was the elimination of 'pogo-ing' experienced in the original Bell-Baldwin experimental craft. Once the configuration was complete in theory, a ¼ scale set of canard configuration foils were fabricated and affixed to the experimental vehicle *Rx*, which shifted configuration to a 90%-10% load-bearing ratio.

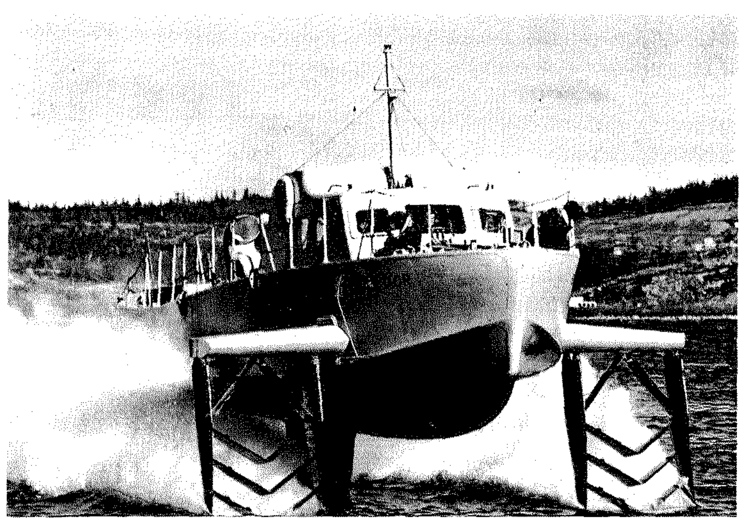
DREA issued a feasibility report in 1959, and it was decided to meet with British and United States officials that also were conducting hydrofoil research. A tripartite group was formed in January 1960 with regular meetings held to inform the partners of progress in each respective country. Meanwhile, back in Canada, bids had been set to tender for a design study. However, it was felt that the knowledge and expertise for this sort of project could be found only in the Canadian aerospace industry. Hence invitations to tender were extended only to A. V. Roe and DeHavilland Aircraft of Canada. When the bidding was closed, it was found that DeHavilland had won by default.

The design study was completed by DeHavilland in September, 1960 and duly submitted to the Defense Dept. Phase II study contracts were awarded to the same company in the fall of 1962, after DREA had evaluated the initial proposal. Early spring of 1963 saw the awarding of a construction contract to the same firm as prime contractor, to build a 'developmental,' 200-ton hydrofoil. Marine Industries Ltd. (MIL) of Sorel, Quebec province, was named as a major subcontractor and in fact the entire craft was constructed there from components.

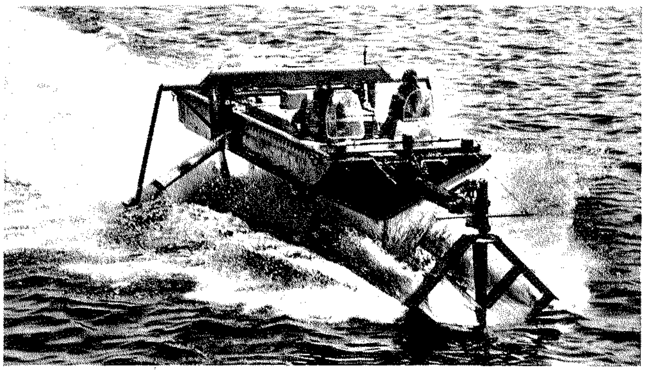
The entire hull and deck assemblies were fabricated



***The surface-piercing foil research craft* Massawippi. Defence Research Establishment Atlantic (DREA) photograph (P.O. Box 1012, Dartmouth, N.S.)**



The DREA research vessel* Baddeck, *seen here under her original name* Bras d'Or. DREA photograph. *Note the anti-ventilation fences on the foils, intended to minimize 'porpoising,' or failure of foil lift.



The small test vehicle **Rx. DREA photograph.** *This test platform incorporated a ¼-scale replica of the hydrofoil system planned for the much larger FHE-400.*

at MIL, using aluminum construction extensively. The hull and upper deck structures were assembled upside down, to utilize down-hand stroke welds to eliminate defects. The entire hull was fitted with bolt-on bearing races, in turn resting on bearing blocks. The scaffolding and supports were torn away and the hull rolled over in December, 1965, and then fitted out in the conventional upright position. The hull or components built in this manner never caused problems throughout the vessel's life-time.

The ship—named *Bras d'Or* officially when commissioned—rolled out of the shed at M.I.L. into the bright sunlight on June 21st, 1966. Final design and construction checks still were needed prior to turning her over to the R.C.N. However, tragedy was to strike first. November 5th, 1966 would witness the near completion of trials prior to delivery. Final components had been delivered and fitted, and a team of DeHavilland technicians were conducting pressure/start-up tests on the ST6 gas turbine at about 1500 hours. The turbine had been in operation some 18 minutes when at 1515, without warning, all hell broke loose. The engine room was engulfed in seconds with choking clouds of smoke that rapidly changed to fierce, forced-air-fed flames which burned severely one man and forced the crew to retreat out of the hull. The fire, growing by the moment, started to attack the aluminum bulkheads, stringers, frames and plates, burning its way through the deckhead and distorting major members overhead. The fire lasted 45 minutes and finally was subdued by MIL firemen together with firemen from the surrounding area.

Upon investigation and as brought out at the Board of Inquiry, it was established that the cause of the fire had been a malfunctioning relief valve that had, upon complete failure, sprayed hydraulic fluid over the hot exhaust stack of the ST6. The continued pumping of the turbine had provided a ready fuel supply for the fire. The fire damage retarded delivery until April, 1968 and cost the Canadian taxpayer a further $6 million (because the government underwrites its own projects.)

Bras d'Or at Sea

Bras d'Or finally arrived at Halifax, Nova Scotia, in July, 1968 and was commissioned the following day by the wife of the C.O. (then) Commander Constantine 'Tino' Cotaras. Immediately, the slave dock (especially constructed by Ferguson Industries, Pictou, N.S.) was flooded and *Bras d'Or* felt the salt water of the Atlantic for the first time. Hullborne trials were undertaken the following April, because the foilborne outboard transmissions were still undergoing extensive testing at Westinghouse. This period marked the beginning of a very frustrating time for the crew, for, like most 'one-ofs,' the vessel suffered from hundreds of malfunctions, defects and 'gremlins.' One of the most annoying and alarming was the infrequent sounding of the 'stack' fire alarm in the FT4 nacelle, eventually traced to sunlight triggering an inadequately-baffled fire sensor. Fittings jammed or stuck, sensors malfunctioned, oil leaks developed and all sorts of small things occurred to make life aboard 'interesting.'

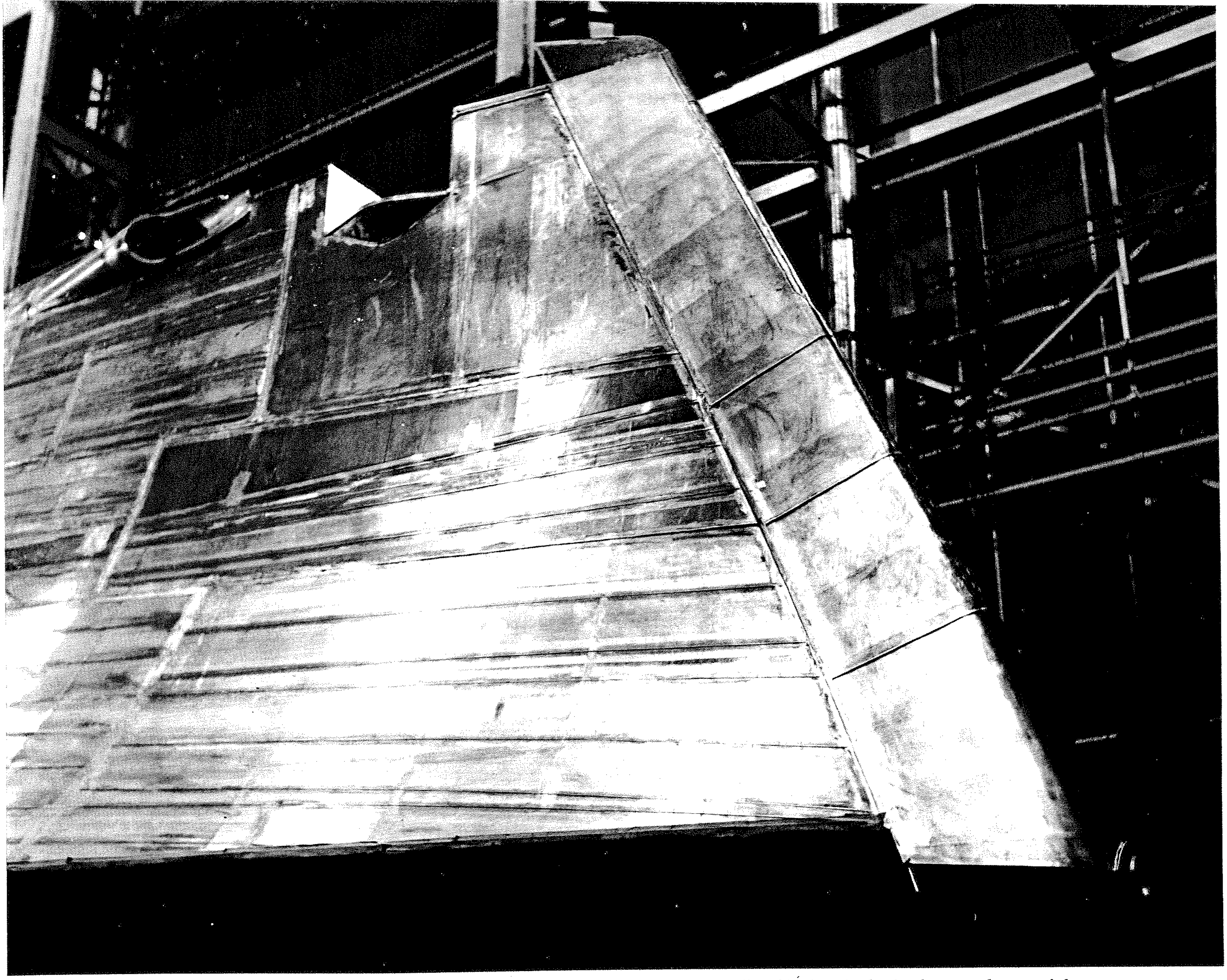
The outboard transmissions arrived in April, 1969 and *Bras d'Or* was docked on her barge to have these fitted. Minor repairs were carried out, but progress appeared in May, when near-foilborne take-offs were practiced just outside the harbor. However, 'Tino' Cotaras, who had nursed her through her teething problems, would not be aboard to see her really 'fly.' In July, Captain Gordon L. Edwards took command of what was to be the most exciting segment of *Bras d'Or*'s ill-starred life.

Foilborne trials were accelerated and, in the latter part of July, *Bras d'Or* exceeded her designed top speed. She hit 63 knots as excited DREA, RCN and press personnel watched aboard the escorting destroyer. However, this elation turned to disappointment in September when several cracks were found in the main foil section. The foil was removed and the damage attributed to a faultily-installed end plug, which had allowed salt water to enter the foil, causing stress cracking and corrosion problems. (This is explained more fully later in the text.)

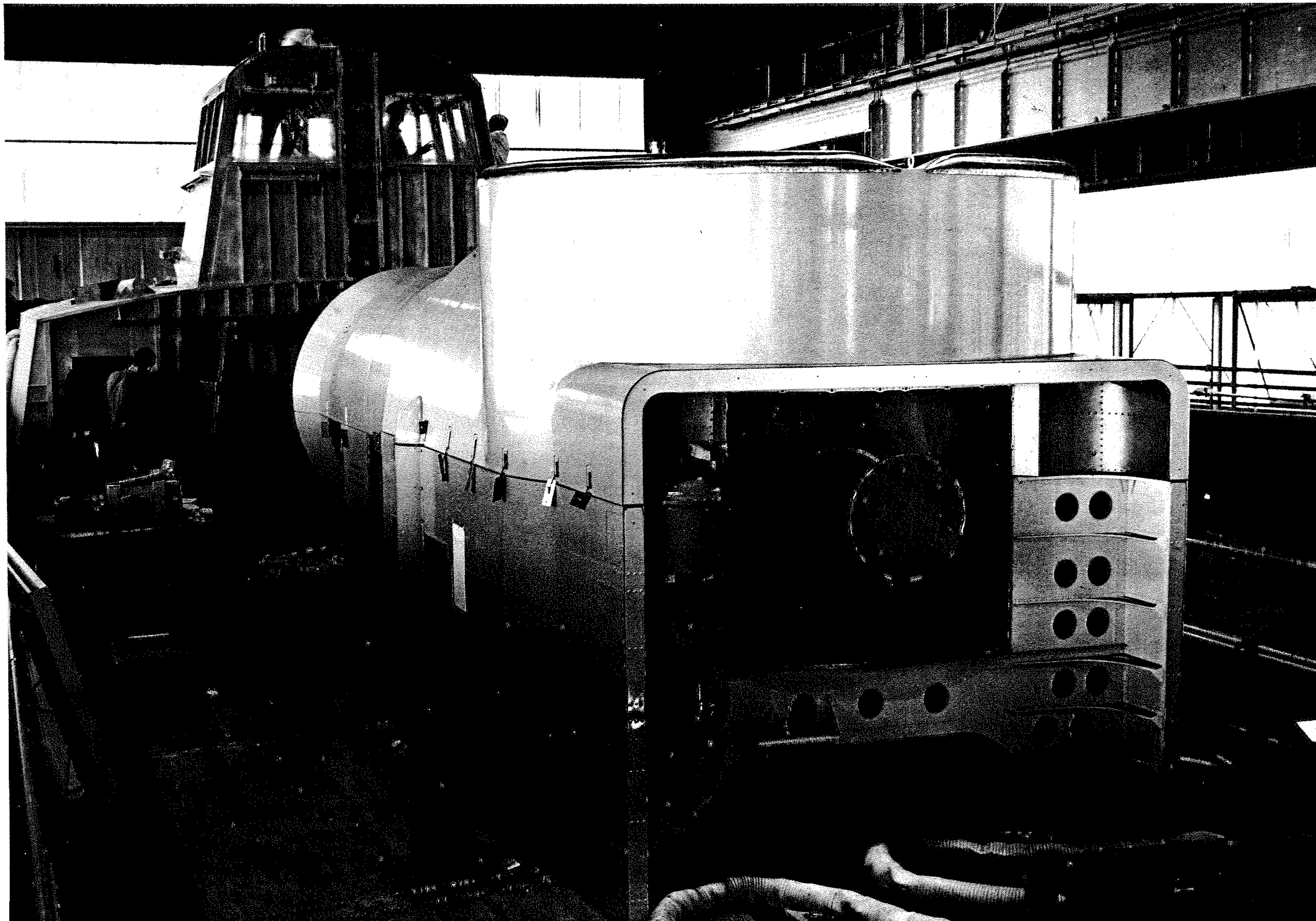
Bras d'Or was confined to hull-borne testing until a new foil section could be fabricated. The new section was finally delivered in late December 1970. However, the period spent waiting had not been wasted. In late October, 1970, hullborne rough water trials had been undertaken in Sea States four and five (6 ft.-8 ft. waves). The foil system vindicated the theory that the system would act as a huge damper in hull-borne mode, the hydrofoil having a better sea-keeping motion than the accompanying *Restigouche* class destroyer. At 12 knots, head-on into the seas with 25 kt. winds, only small amounts of salt water found their way aft to the bridge. Complications arose during the testing, some 40 miles off the Nova Scotia coastline. An emergency hydraulics shut-down was necessary for some twelve minutes and the craft assumed a slight list, caused by erratic movement of fuel oil. The list was judged not to be dangerous and the hydraulic problem, the failure of the AP12 hydraulic pump at the auxiliary gearbox, was overcome by using the GT85 emergency turbine. *Bras d'Or* reached Halifax in 6 hours without incident.

Further rough-weather testing was undertaken on February 8, 9, 10th, 1971, although it was not planned that way! Although fairly calm in harbor, it was found

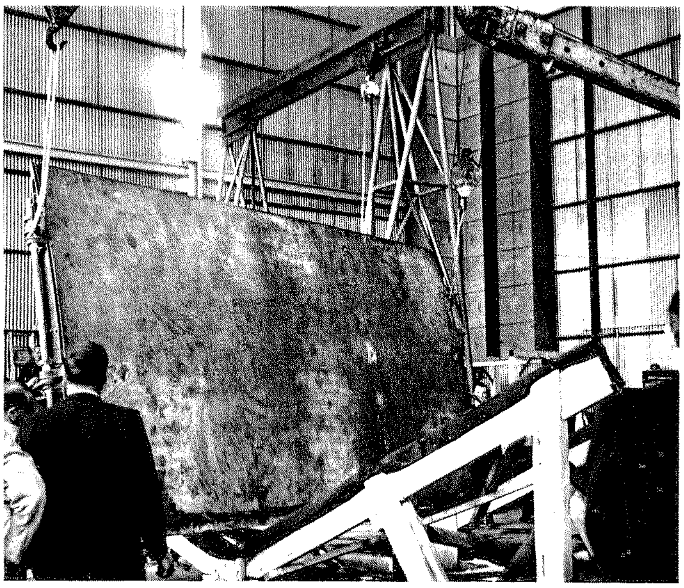
An interior view of the hull—this was a section of the ship that was burned through in the Nov. 1966 fire. The plates and ribs are fabricated from Alcan D54s aluminum. The aluminum was still as shiny as seen here when the author visited the ship in 1979. **Author's photograph, copyright.**



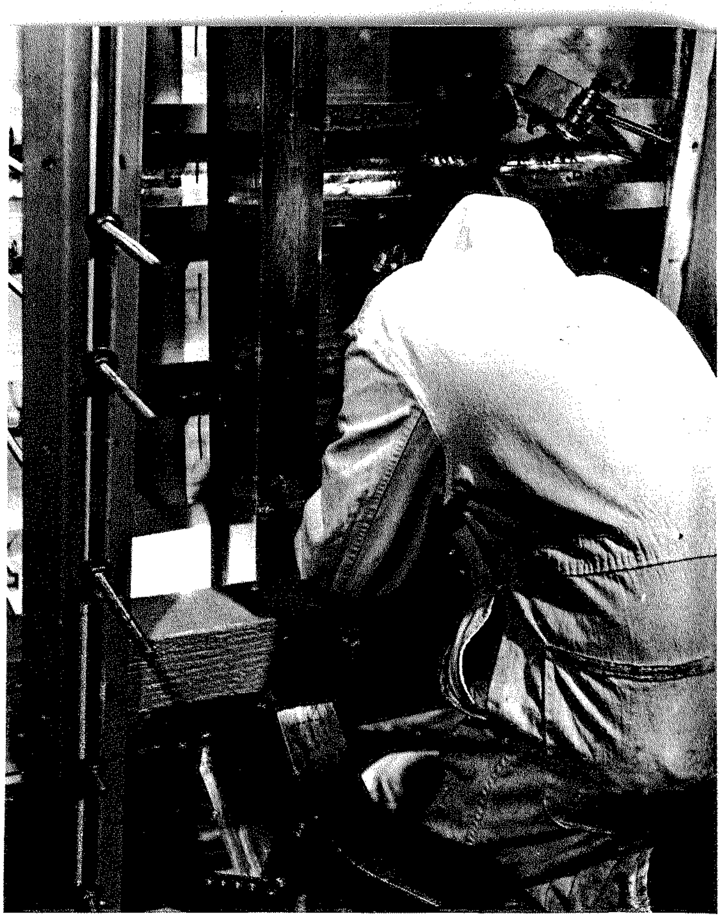
The forepeak of **Bras d'Or** *prior to the roll-over. The steering piston gland shows well in this view.* **Author's photograph, copyright.**



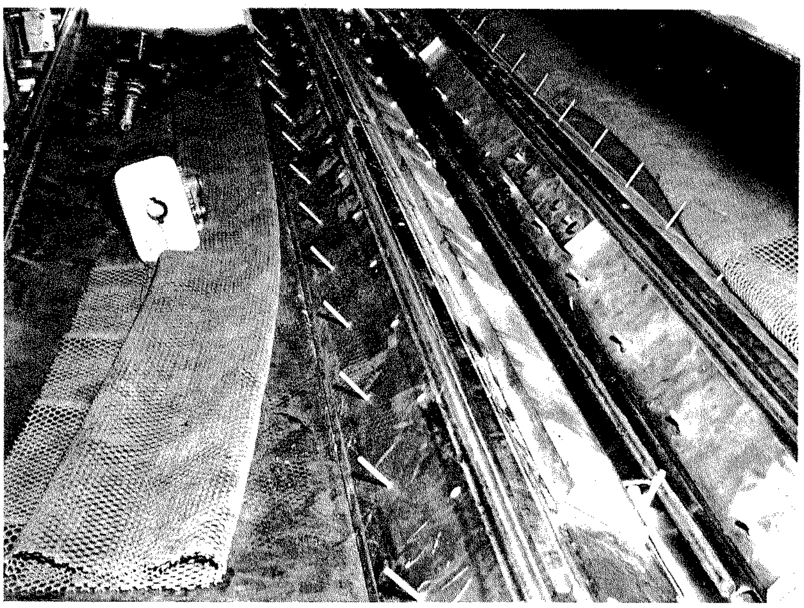
Bras d'Or *in assembly at MIL, Sorel, April 1966. The Pratt & Whitney FT-4A-2 engine is in its module, resting in position on the main deck, in this view. The intake shroud and baffles have not yet been fitted, hence the gap between the bridge in the background and the engine.* **Author's photograph, copyright.**



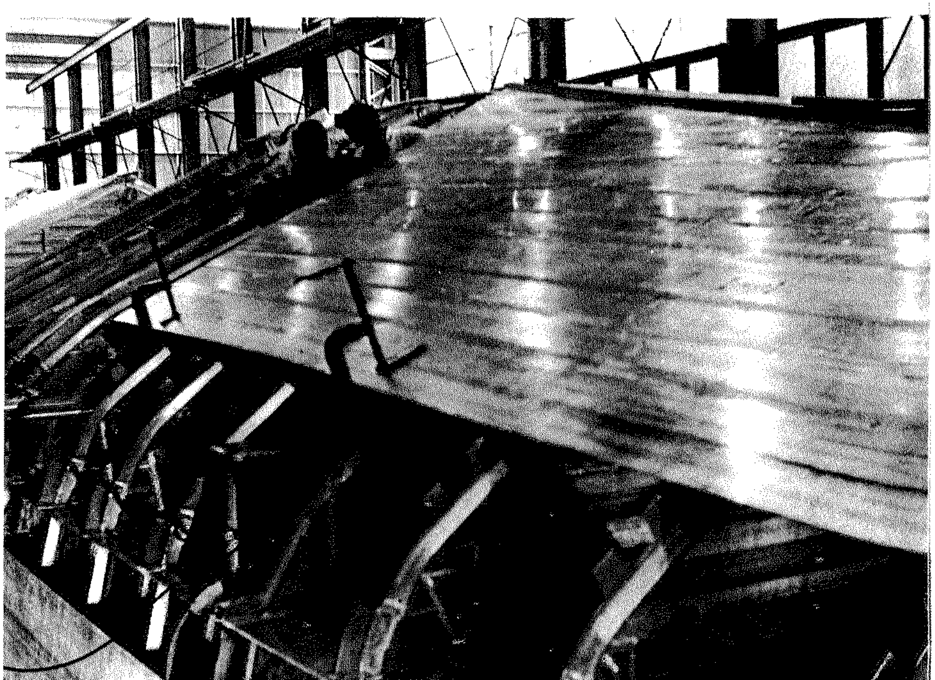
The main center foil is handled during the neoprene coating process. Author's photograph, copyright.



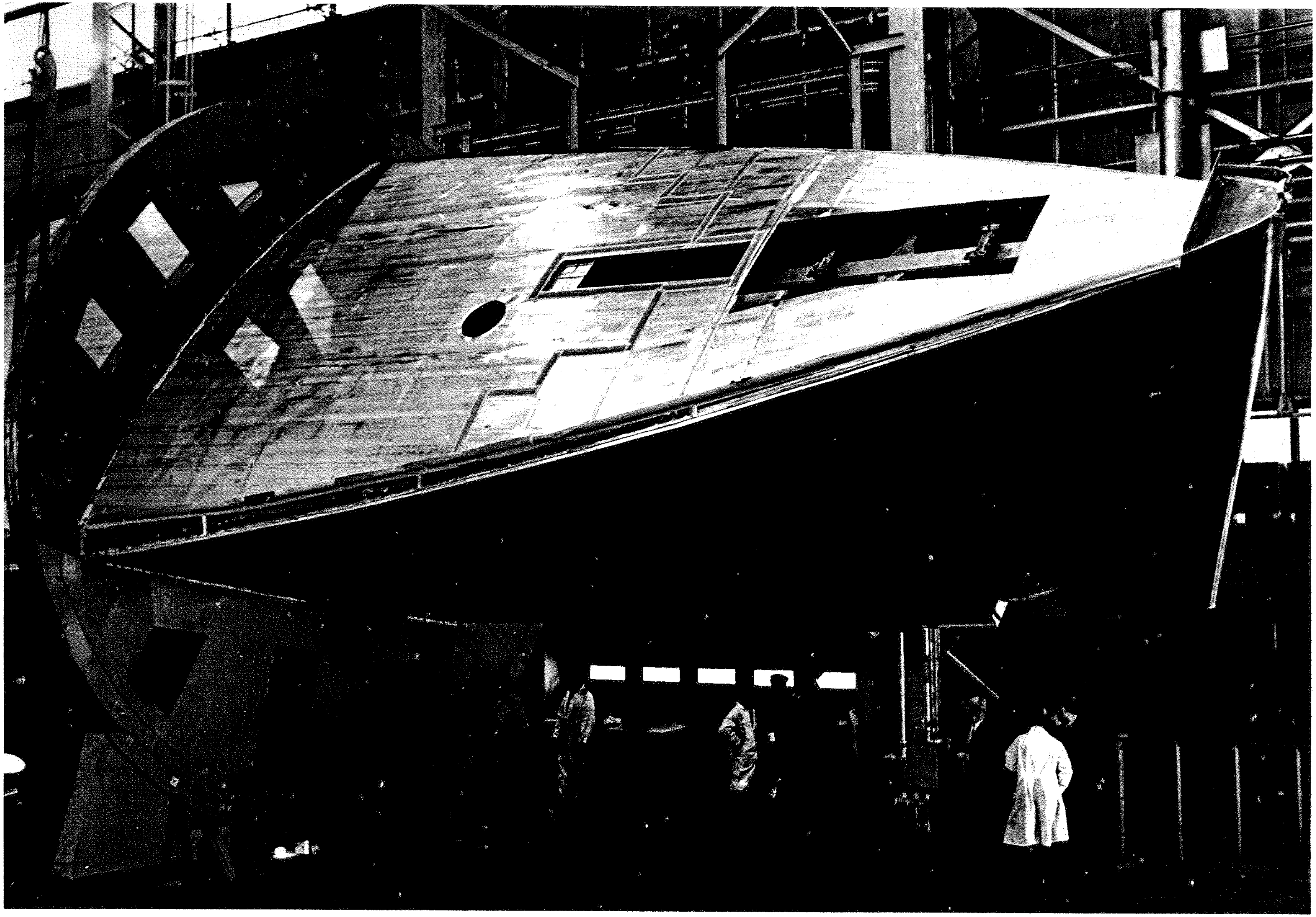
Aluminum plates being shaped to the ship's ribs. The novel system of turnbolts seen here was used because the hull was stressed. This was exacting work that had to be done in correct sequence, for otherwise the plate would buckle rather than bend. Author's photograph, copyright.



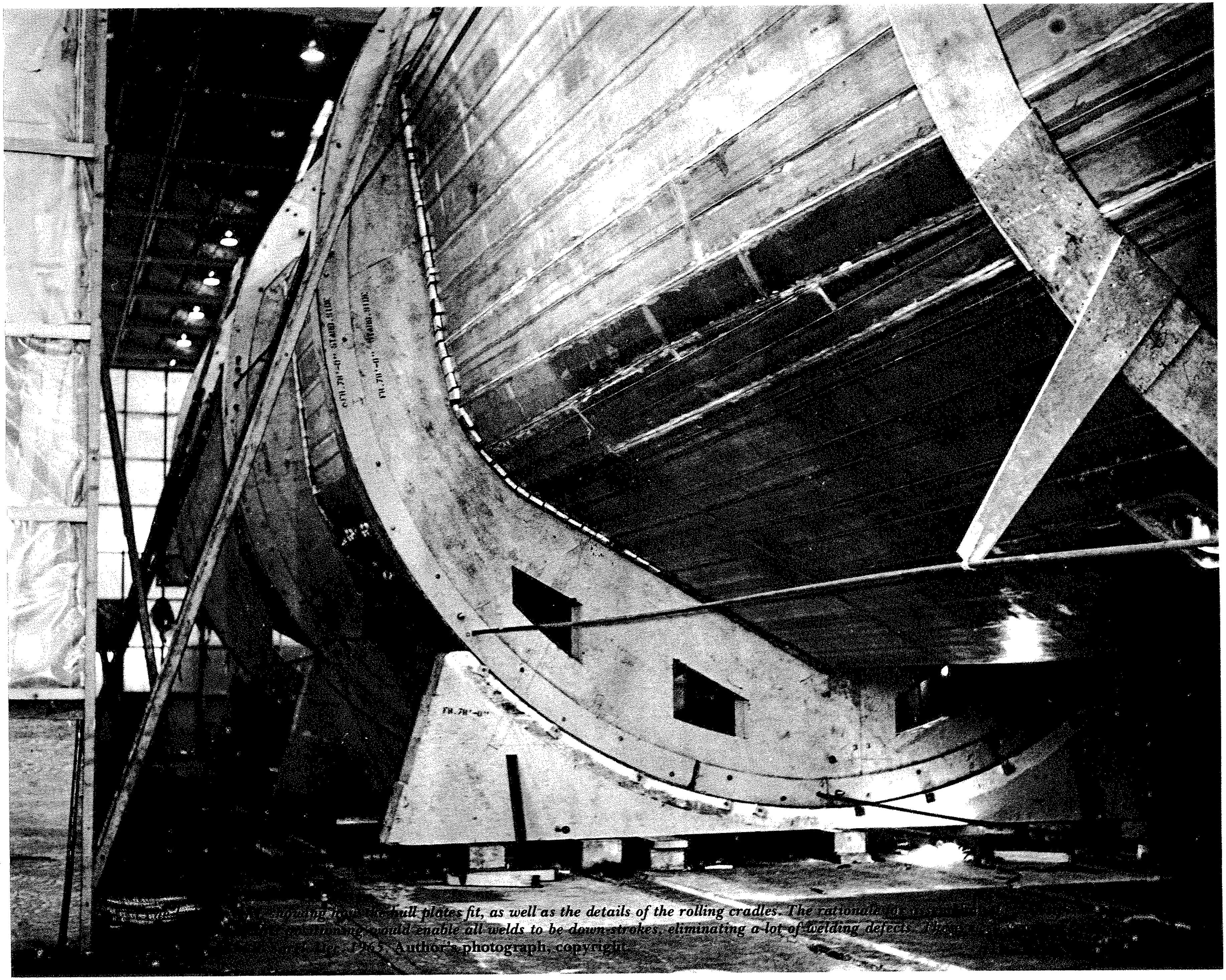
Above—*A main foil section, showing the rubber net mats in place. These mats held the sprayed neoprene in place until dry*. Author's photograph, copyright.



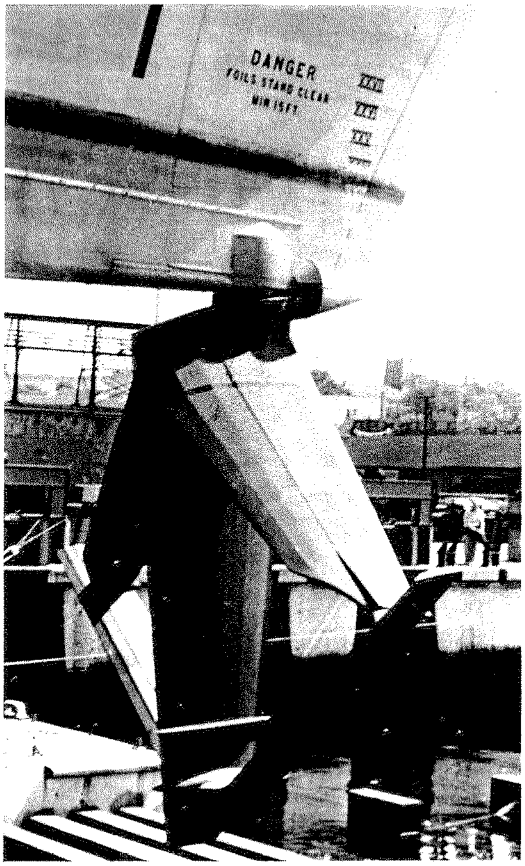
Right—*Construction methods. Here the skin is being mated to the frames, stringers, and ribs. The hull was pre-stressed, necessitating precision of the skin plates*. Author's photograph, copyright.

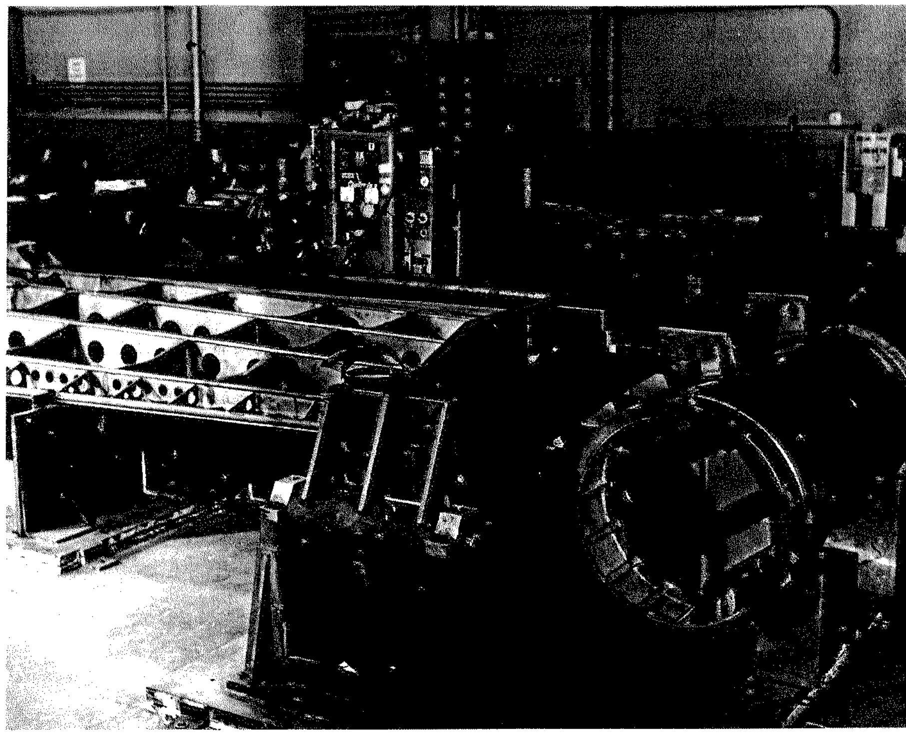


The roll-over nearly complete, with the steering compartment visible. The plank to retain the bearing shaft will be removed when the ship settles upright. MIL, Sorel, Dec. 1965. **Author's photograph, copyright.**

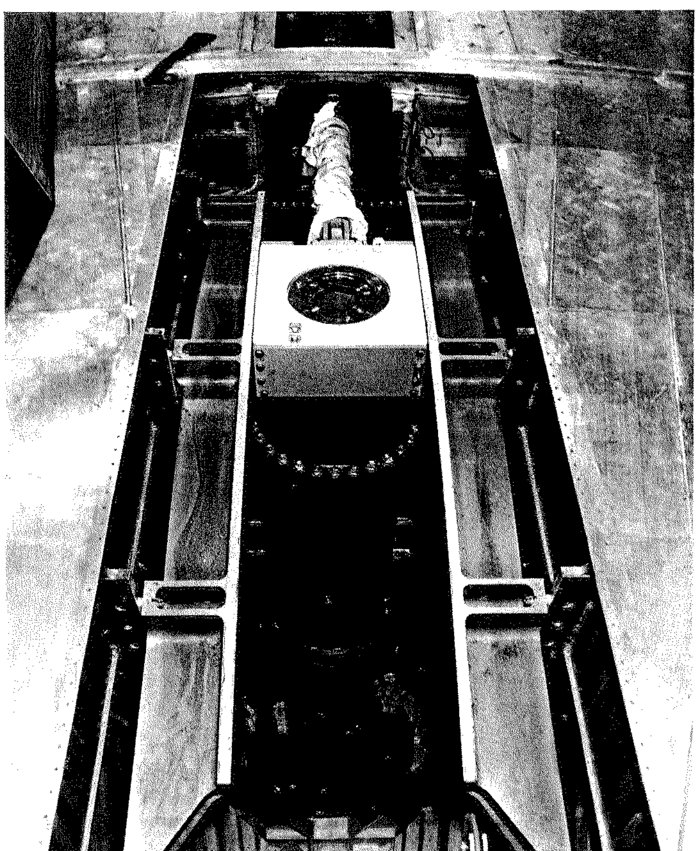


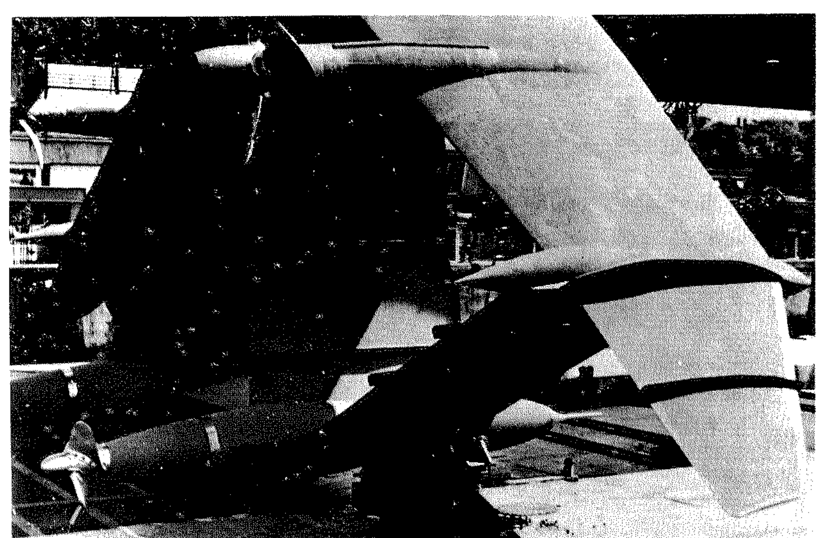
[illegible] showing how the hull plates fit, as well as the details of the rolling cradles. The rationale [illegible] positioning would enable all welds to be down-strokes, eliminating a lot of welding defects. [illegible] 1965. Author's photograph, copyright.

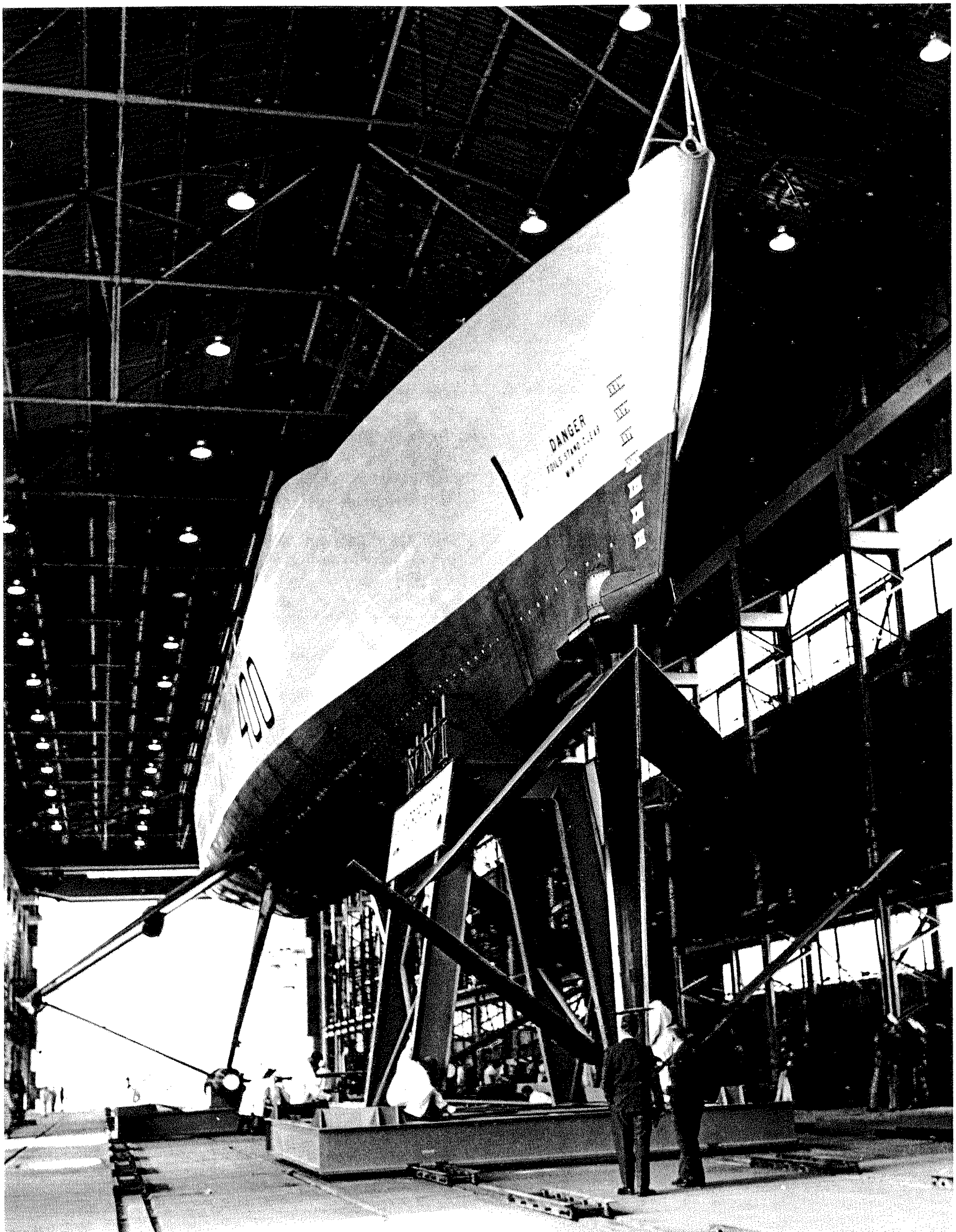




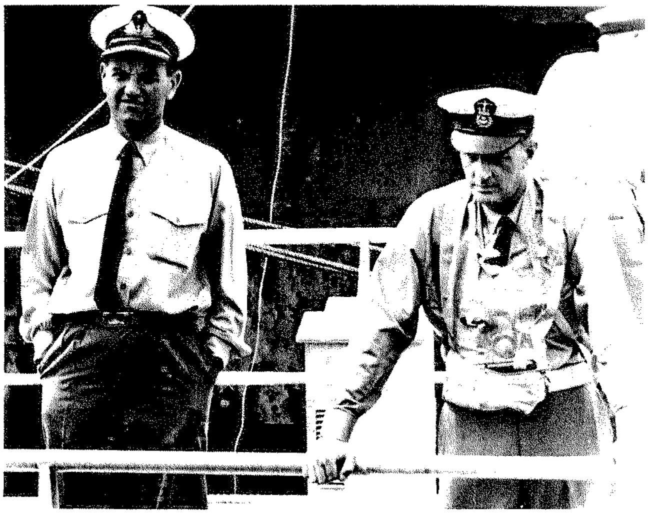
Top left—*Detail of the bow foil unit. Photographed in 1969 when the hullborne transmissions were being installed. Less than 10% of the ship's weight was carried by this foil array.* DeHavilland (DHC) photograph, copyright. Top right—*The foilborne transmission pod, mounted on the vertical strut. The first maraging steel plates are being fitted. Over 70% of the steel in these plates was ground away until the plate fit in every way. Needless to say, expense was tremendous! The pin bushings will locate to the outboard foil. Temporary brackets welded to the jig were used to support the pod, aiding in alignment but not used for mounting.* Author's photograph, copyright. Lower left—*The forward foil top bearing and post. The hydraulic piston attached to the post alters the angle of attack of the foil (the trim). Trim was limited to 5° aft and 15° forward trim. Also shown is the steering jack that could turn the foil a total of 30°, stop to stop. This is hidden below the trim position.* Author's photograph, copyright. Below—*Detail of the main foils, 1969.* DeHavilland (DHC) photograph. *The foilborne transmissions have been installed by this time. The foil between the high speed (foilborne) propeller gearing fairings is the one that leaked. Note the 'fences' on the delayed-cavitation sections, intended to control ventilation and loss of lift. The anhedral tips show well here.*







Roll out of Bras d'Or *at Marine Industries Ltd., Sorel, 21 April 1966. Note the fairing forward of the bow foil shaft, meant to reduce strain during hullborne/foilborne transition.* Author's photograph, copyright.



***Commander C. 'Tino' Cotaras, first commanding officer of* Bras d'Or, *watches preparations for getting underway. Chief Petty Officer Barry Howles supervises. CPO Howles was the co-helmsman of FHE-400 through the 1968–69 trials.* Author's photograph, copyright.**

that 10 - 15 foot seas were running outside. It was decided to proceed 40nm to the test site, though the weather persisted all the way. A 48-hour exercise had been planned and some 28 persons were aboard. Captain Edwards noted that during the first part of the trip out, the waves were very steep and short in interval. Further, green water was being shipped over the superstructure. Within six hours it was noted that water was entering the inlet air trunk for the GT85 turbine, but after starting the engine, it was found that no serious damage was done by the water. Other minor defects developed, mostly in the sensors, shorted by water working inside the insulating 'boots.' A crack developed on the port inlet manifold of the diesel, but did not impair the engines' running. Several minor oil leaks developed, but oil consumption for the 48 hour period remained well below normal expectations, at 17 gallons.

Two companion ships had accompanied *Bras d'Or*: HMCS *Fraser* and *Saguenay*. From the very first these 2,263-ton destroyers experienced acute ship movement and those decks open to the weather were declared "off limits" most of the time. *Fraser* signalled *Bras d'Or* on the 8th:

> Weather conditions were considered most unpleasant; heavy seas and 10-15 foot swells, wind gusting to 60 knots, ship spraying overall, with upper deck out-of-bounds most of the time. *Bras d'Or* appeared to possess enviable seakeeping qualities. She was remarkably stable, with a noticeable absence of roll and pitch and apparently no lack of maneuverability. The almost complete absence of spray over the foc's'le and bridge was very impressive. Of some 250 people onboard *Fraser*, 15-20% were seasick during this period.

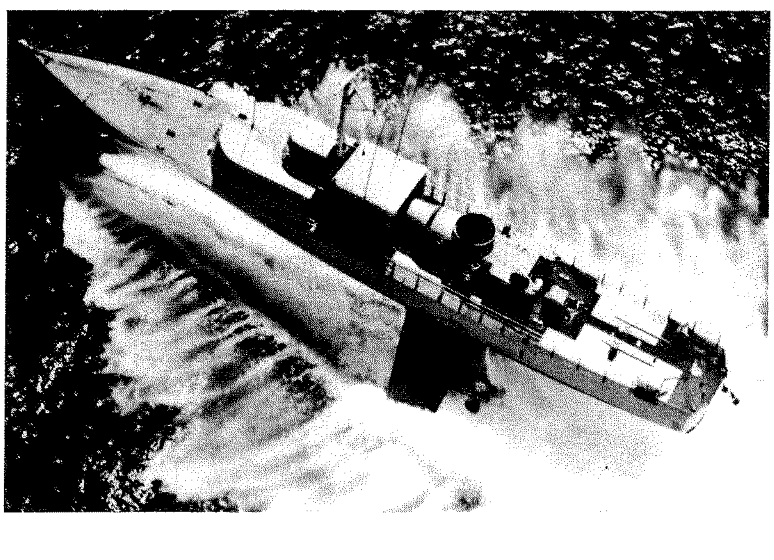
Indeed, *Bras d'Or* was stable . . . although she was in hullborne mode, she was faring better than the destroyers. *Fraser* signalled she had "revs" on for 6-8 knots, while *Bras d'Or* had indicated "revs" for 4-5 knots. Indeed, for the entire 48 hour period, the hydrofoil steamed in continuous figure-eights to maintain station on the destroyers! The last 20 hours were in visibility of less than two cables.

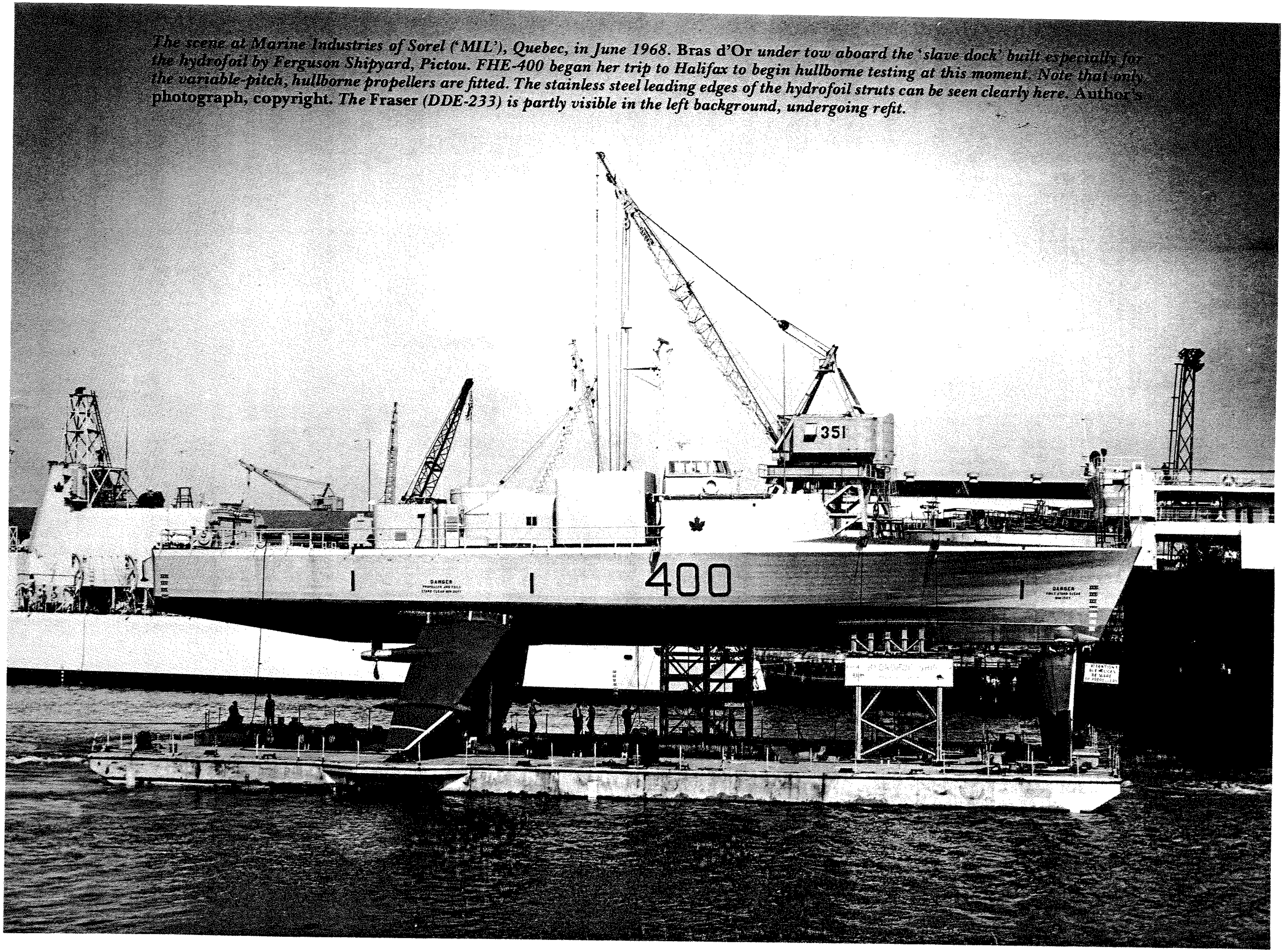
During the last few hours of the storm on the 10th, as the seas abated to Sea State Five, all systems were flashed up and the final hour spent foilborne. *Saguenay*, still laboring in the heavy seas and after watching the hydrofoil for some time, sent the following:

> Performance of your ship in seas 3 feet with swells to 10 feet was impressive. You looked more comfortable at 40 knots than *Saguenay* at 18. Maximum sensible speed in DDHs in these conditions, without straining the ship would be about 22 knots. Your motion appeared smooth, both in pitch and roll. You seemed to be borne entirely by foils, although the forward foil did come clear of the water on occasion.

The next and what proved to be the last major seaborne trial took place in June 1971. Since reliability had improved considerably in the months since February, it was decided that more 48 hour runs were necessary. Plans for a longer run were thought out while *Bras d'Or* underwent annual refit in February, where all foils and systems were thoroughly checked. Undocking on April 6th, *Bras d'Or* achieved what must be considered a breakthrough in reliability, with nine trips in a month without a defect. Hence, in May, 1971, support for the hydrofoil in foreign ports was looked into, with plans finally jelling in June.

***Overhead view of* Bras d'Or *running foilborne during Summer, 1970. The hullborne propellers show well here, just above the water. The FT-4 exhaust funnel and the ST-6A exhaust outlet appear on the FT-4 housing and to the left of the gear housing.* Author's photograph, copyright.**





The scene at Marine Industries of Sorel ('MIL'), Quebec, in June 1968. Bras d'Or *under tow aboard the 'slave dock' built especially for the hydrofoil by Ferguson Shipyard, Pictou. FHE-400 began her trip to Halifax to begin hullborne testing at this moment. Note that only the variable-pitch, hullborne propellers are fitted. The stainless steel leading edges of the hydrofoil struts can be seen clearly here.* Author's photograph, copyright. *The* Fraser *(DDE-233) is partly visible in the left background, undergoing refit.*

Bras d'Or, clear of the slave dock, is towed astern in preparation for first hullborne trials in July 1968. **Author's photograph, copyright.**
She was limited to the hull mode until mid-1969 because the foilborne transmission was undergoing further testing at Western Gear.

Bras d'Or, *clear of the slave dock, is towed astern in preparation for first hullborne trials in July 1968.* **Author's photograph, copyright.** *She was limited to the hull mode until mid-1969 because the foilborne transmission was undergoing further testing at Western Gear.*

Bras d'Or *comes about for a photographer aboard a helicopter. The anhedral foil tips proved their worth, smoothing turns and indeed tightening them. However, they added $1M to the cost and were criticized by experts and press alike.* **Author's photograph, copyright.**

June 15th: *Bras d'Or* slipped her moorings and proceeded to sea with AOR *Preserver* and four destroyers. A limited amount of fleet work was conducted with these other units, but it was found that it was nearly impossible to keep station with these ships when steaming at more than 12 knots unless the foilborne mode was used. Clearly, hydrofoils would have to work semi-detached from conventional units! A one hour replenishment exercise proved successful, using the jack-stay transfer/fuel hose loop method, with solids being transferred by line and with JP5 pumped aboard through a 2½ inch hose. The stay had been secured to a new tripod welded to the quarterdeck in the last refit. This event, concluded on the 16th, was the first at-sea replenishment of any hydrofoil.

Half way to Bermuda, *Bras d'Or* broke away from the escorting ships and made a three hour foilborne run to assure arrival off Bermuda on time. The last day the weather worsened, with a 10-12 foot head-seas and visibility of one mile. No problems were encountered and Bermuda was spotted by radar on time. A foilborne entry was made through the Narrows, but the tricky part of South Channel was made in hullborne mode. Foilborne, again, she entered harbor, putting on an exhibition before several thousand people at Murray's Anchorage and with foilborne passage of Dundonald Channel and Two Rocks, at 40 knots, then landing with a flourish in front of the Princess Hotel. The hydrofoil was berthed at a standard barge at Flagpole Jetty. The only defect to be corrected was a fractured lube line, which had delayed her at sea by half an hour.

While in Bermuda, the GT85 turbine was run continuously for four days, providing on-board power. Several thousand people visited aboard that Sunday and questions were thick and furious in number. Sunday evening was taken up by a reception for dignitaries and Monday provided a chance to take the Governor and others of his party to sea for a brief demonstration. Returning, the hydrofoil refuelled at Port Royal, from a standard fuel barge, with 12,000 gallons being accepted in 20 minutes.

Leaving Bermuda that Tuesday, foilborne, *Bras d'Or* proceeded for three hours at 45 knots, encountering USS *Diamond Head*, which was given a royal 'run-around.' The first of several defects came to light on this leg, a rocker arm in cylinder #5 of the diesel engine fractured and luckily it was isolated or *Bras d'Or* would have arrived in Norfolk 16 hours too early!

A foilborne entry was made up the 20 mile Norfolk channel and the ship was berthed port side to a barge courteously supplied by the Port Authority. External power was supplied and the crew was grateful that the ST6 would not be required, since its noise was a little much at night. The next day, five twenty minute briefings were held, followed by 45 minute demonstrations for USN and foreign officers. The following day, three further briefings were carried out, followed by extensive tours. A scheduled demonstration for 1300 was cancelled, when the ST6 cut out twice and shut-down with high turbine inlet temperatures. This was eventually gotten around by resetting the cut-out switch to its emergency 1900 degree F. position, from its 1730 degree F. normal setting. Temperatures, when restarted, stabilized at 1850 degrees F., the hydraulics were loaded, the diesel started and the ST6 shut down. It was decided not to use it again except in emergency. *Bras d'Or* proceeded to sea, Halifax-bound, that afternoon.

On the route back, it was hoped that *Bras d'Or* would be able to intercept the NATO Squadron, but this proved impossible with the defects and position of the ship in relation to the conventional units.

At 22:45 on June 28th, the diesel again lost power and it was discovered that an entire bank of cylinders had been lost through a fracture of a driveshaft of the injector unit for that side. It couldn't be repaired, so the entire bank was disconnected and the ship proceeded foilborne. She arrived off Chebucto Head at 0400 on the 29th, went dead in the water until 0900, her scheduled arrival time. She arrived back in Halifax to the cheers of all ships in harbor and a band of the Royal Canadian Regiment.

Beyond the defects mentioned above, there were defective valves, fouled fuel lines and shorted turbine ignitors (the cause of the ST6 overheating in Norfolk). It was also noted that a distinct 'clunking' sound came from the bow foil and this was traced to excessive wearing of the bow foil upper bearing liners, which would need replacing at next refit.

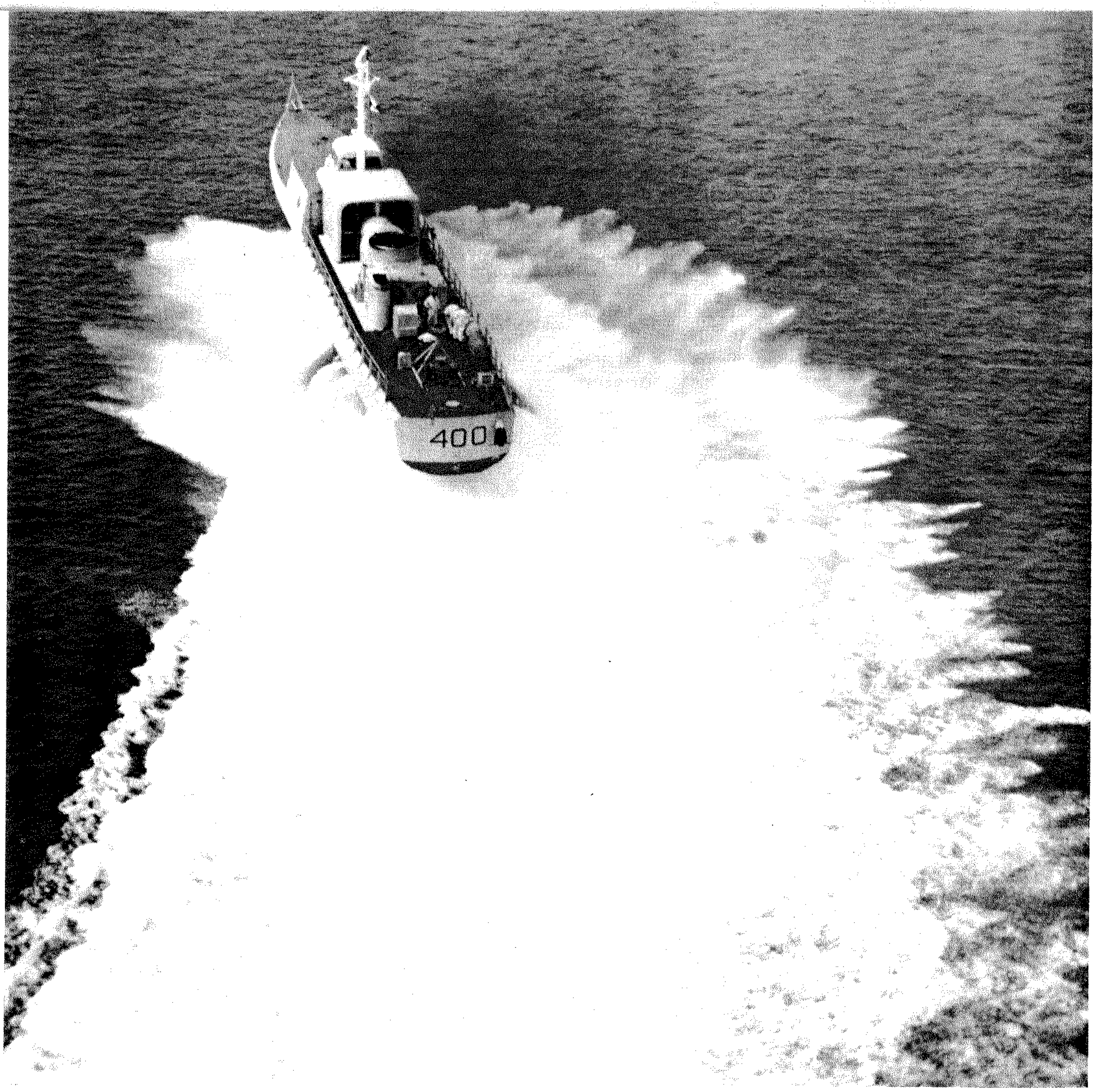
Bras d'Or was positioned on her slave dock and the water pumped out of the ballast tanks of the former, while engine parts were ordered from the U.K. A sea-water leak into the hydrofoil's port foilborne propulsion pod had been noted previously, and the cause was soon apparent as she came clear of the water . . . it could be seen that water was running *out* of the middle main foil element! Also, an improperly-sealed door on the pod was leaking and several cracks were noted in the struts and one intersection pod, as well as an inches-long crack in the main high speed foil. Further inspection with penetrative dyes showed a long crack in the lower surface of this foil and the inches-long crack revealed itself to be in excess of *six* feet long, running athwartships. These cracks were considered to be the result of high residual stresses existing from manufacture, plus the ever-present stress-corrosion cracking of the first unit to fail. However, this unit was adjudged to be repairable, by using peening, welding and heat-treating to relieve stresses. *Bras d'Or* would be laid up for six weeks while the repairs were carried out.

Decision to Lay Up

Meanwhile, politicians in Ottawa were plainly worried. Criticism from the media, the Opposition party and from within had weakened the resolve of the Liberal government to continue with this 'developmental' craft. Besides . . . it was a Conservative project. The great harping about the waste of $53 millions had taken its effect, and now the chance had come to lay her up indefinitely. With the utter shambles that the Defence White Paper had caused in defense priorities, the ASW role that the hydrofoil was intended to meet was shuffled to the bottom of the list. Uncertainty

Bras d'Or *during a demonstration run in Hampton Roads, 24 June 1971.* **Official USN Photograph USN K-90232, taken by PH2 Thomas L. Lawson USN. Bras d'Or'***s foil and power system differs substantially from the submerged foil, water jet system employed by the current U.S.* **Pegasus** *(PHM-1) class design.*

Bras d'Or *underway in Hampton Roads, Virginia, on 24 June 1971.* **Official USN Photograph USN K-90230, taken by PH2 Thomas L. Lawson USN.** *This was* **Bras d'Or'***s only visit to a United States port.*



Bras d'Or *leaves a wide swath of white water behind during Hampton Roads demonstrations on 24 June 1971.* **Official USN Photograph USN K-90228, taken by PH2 Thomas L. Lawson USN.** *Note the pennant number on the fantail.*

Bras d'Or *at sea foilborne during 8 to 10 February 1971. Note the surface chop and large amounts of spray, with very little on the upper deck and superstructure. 50-knot speeds were maintained in state 5 seas for the first time.* **Canadian Forces Photograph, negative SW70-1984.**

as to *Bras d'Or*'s future was resolved on November 2nd, 1971. The Minister of Defence rose in the House of Commons and calmly announced that *Bras d'Or* would be laid up for a period of five years, while roles it could possibly play were studied. But members of DREA and the Navy were not fooled . . . FHE-400 was dead . . . and with it the hydrofoil ASW program.

Bras d'Or was hauled up into the storage area of the Syncro-Shed and stored there for two years, as an interim measure. However, the space was needed and from the amount of gear that was being removed, it was plain that she had sailed for the last time. Accordingly, she was removed and placed aboard her slave dock and weather-tight shelters were erected over the bow foils, the main foils (with the anhedral tips removed) and the FT4 main engine structure. She was then shifted to the farthest corner of Dockyard to the south and quietly forgotten. In 1978, the government tried to dispose of her, but such a protest was mounted that the 'retirement' period was extended. In 1980, with renovation of Dockyard underway, she was transferred across to the Dartmouth side of the harbor and left, a reminder of what might have been if the government had persevered with the project.

The ship has been offered to museums, but with a $1 million price tag for a suitable accommodation there, understandably, have been few takers. Commodore Edwards and a few others battle on, trying to save the *Bras d'Or* from the same fate as the Avro Arrow . . . summary scrapping. However, her days are numbered, since her extension will soon run out and the dockyard needs all the space it can lay its hands on, while the ten year-long renovation of the facility takes place.

Discussion with officials at DREA shows that they are still understandably irate over the cancellation of the project, even after ten years. They consider the media criticism in Canada of the supposed $53 million cost to be misleading. In fact, a good listening ear yielded the following-rounded figures of where the $52.7 million went:

DRB Programme—small and ¼ scale models and tests (1953–70)	$ 3 million
Fighting Equipment (separate program, should not be included)	10 million
Loss in fire—insured by government	7 million
Bras d'Or—actual costs	29 million
Slave dock	1 million
Trials, logistics, shore facilities	3 million
TOTAL	$53 million

(the .3 million dollars being accounted for by the slave dock, which cost less than $1 million to build.)

Description of the Ship

These subsequent sections will provide more detail on the systems and sub-systems that made up the *Bras d'Or*.

Bras d'Or was a 200 ton, surface-piercing hydrofoil ship designed primarily for ASW in the open Atlantic. She was capable of 60+ knots and indeed was never pushed to her design limits. She was capable of maintaining 40-to-50 knot speeds in seaways up to and including Sea State 5 (ten foot vertical seas).

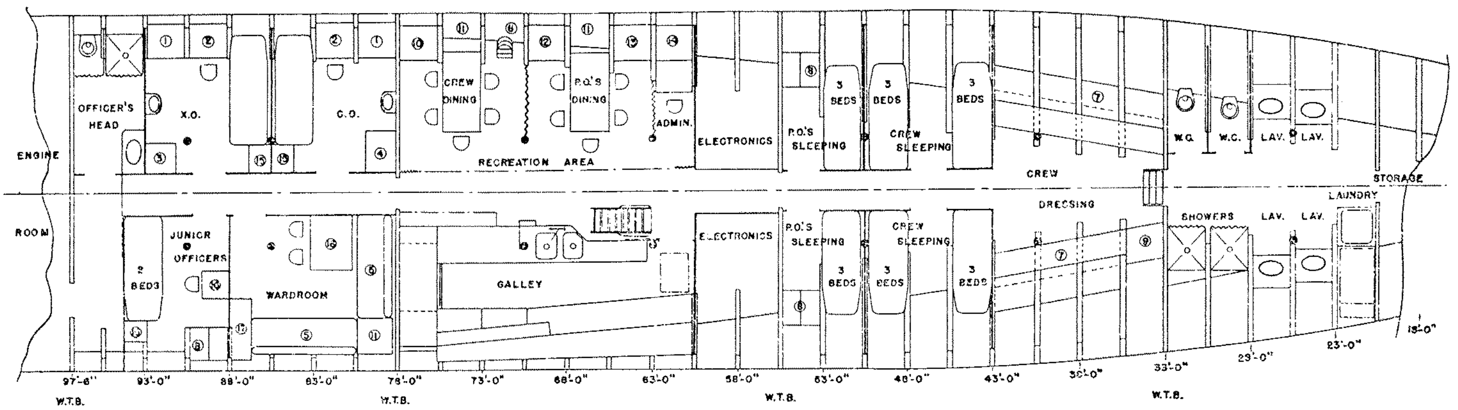
General Arrangement: With the bow foil carrying only 10% of the hull weight, the center of gravity was situated well aft, as was all major machinery. Hull shape was determined by the need for a low hullborne resistance and wave impact loads. It was slender displacement-type in configuration, with extremely fine lines forward and high deadrise. The clean design of the upper deck and superstructure forward helped to reduce air and spray resistance, a significant factor at maximum speeds, where wind velocities may reach hurricane force.

Hull Structure: The all-welded aluminum alloy (Alcan D54s) was essentially longitudinally framed, but some departures from normal practice were dictated by the importance of minimizing weight and concentrated loads when foilborne. Skin panels were prefabricated from extruded sections, butted together by machine welding under controlled conditions to form comparatively large plates with integral stringers (typically 8 x 10 ft.). This longitudinally-stiffened shell and similarly prefabricated deck were welded to the outside of the traverse web frames and bulkheads without notching. The aluminum alloy plate and extrusions were used throughout the hull and superstructure, except for the foil attachments, which were forged aluminum 7075 (T73). Skin thicknesses varied from .25 in. on the hull, to as little as .093 in. on the deck.

Internal Layout: The internal deck layout can be seen by referring to diagrams A & B. These arrangements are based on a normal crew of 20 officers and men working in two watches. The crew accommodation was thought to be properly sound insulated at the time of construction and was roomy by warship standards of the day. Actual trials proved the officers' quarters to be near-uninhabitable when the FT4 and/or secondary machinery was in operation. Earplugs proved to be necessary. The heating was another sore point, since the only heat source was via the ST6A turbine heat exchanger. This was deemed too inflexible and in cases, insufficient, as was the air conditioning. Individual climate control was recommended, but was never implemented. The following description gives, in effect, a tour of the internal layout.

Starting forward is the narrow steering compartment, a half-deck down from the crews' head deck, containing the bow foil steering and rake adjusting machinery. Abaft this and up the half-deck are the washing basins, showers and toilet facilities. Next aft and down three steps is the crew accommodations for 4 petty officers and 12 ratings abaft that. A small electronics bay separates the sleeping quarters on the starboard side from the dining-recreational area. The galley is semi-detached on the starboard side as well, containing micro-wave ovens, fridges, etc., for either pre-packed airline-type meals or the preparation of conventional meals when conditions allowed. However, conventional meals did throw a strain on the one cook in the crew with the staggered watch hours. Abaft of this, on the starboard side, is one double-berth cabin and the wardroom with spare berth-settees. Port side are

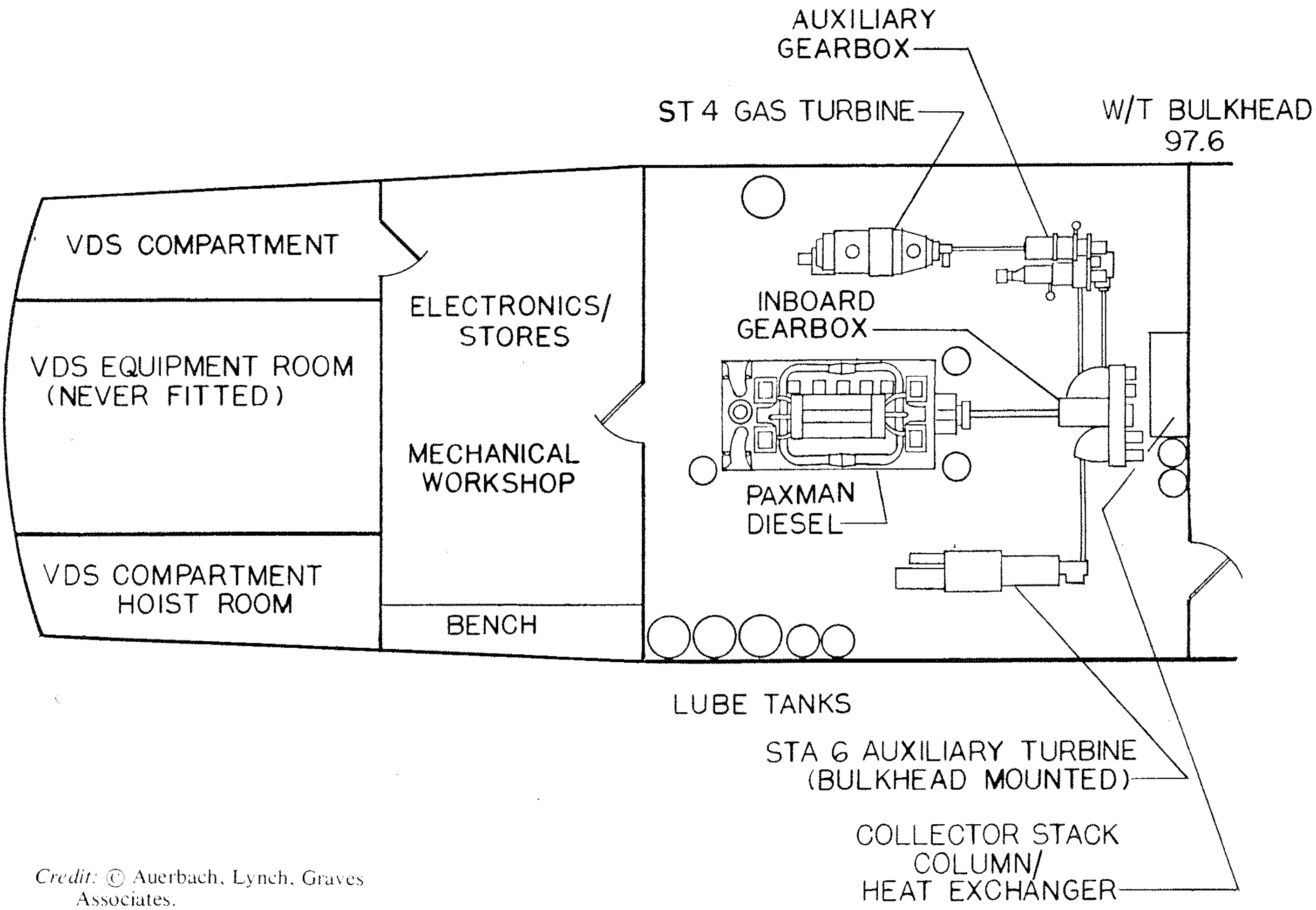
DIAGRAM A
Internal Layout Forward



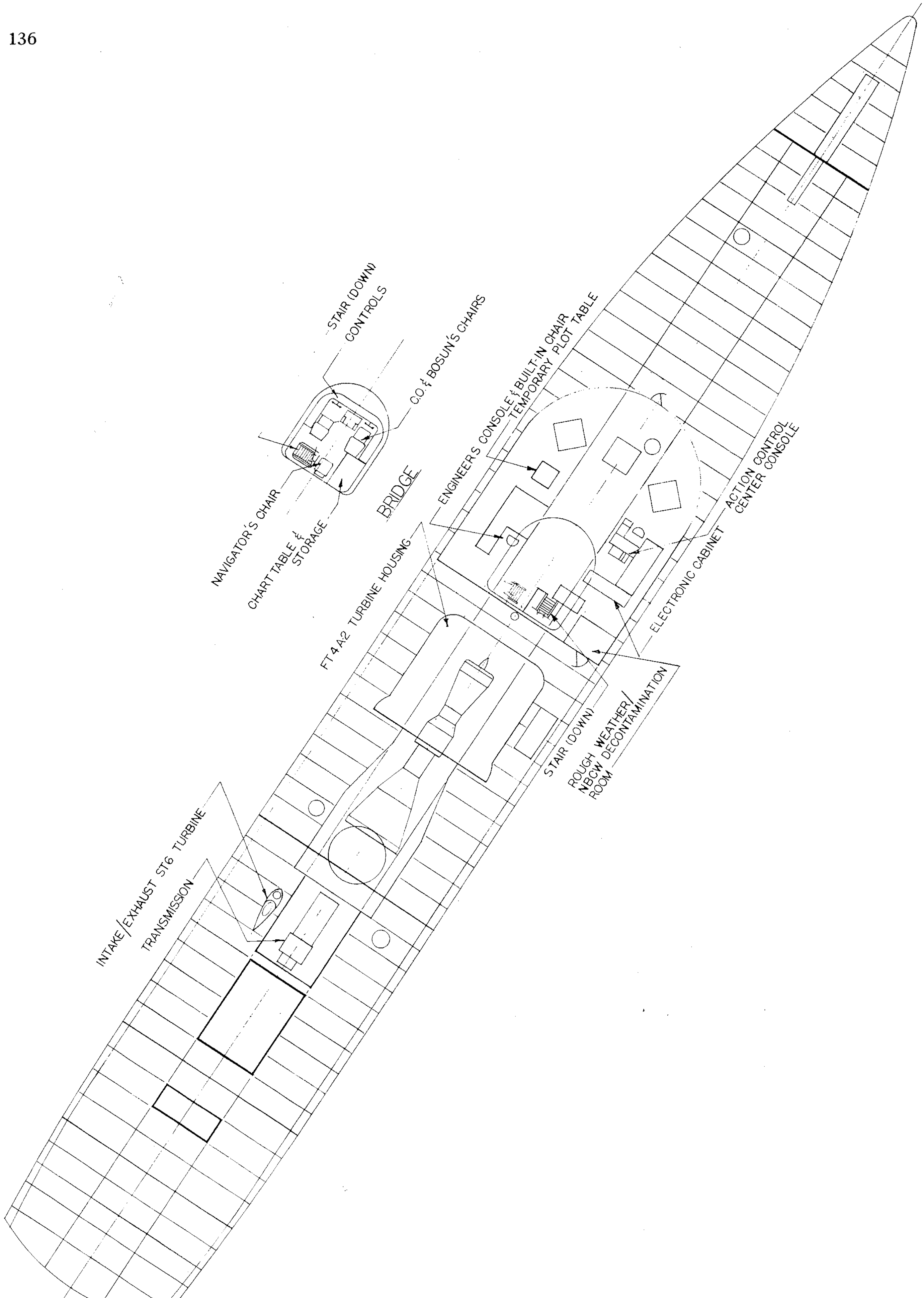
1	WARDROBE	9	LONG HANGING WARDROBE
2	DESK	10	DIVING GEAR STOWAGE
3	SAFE	11	UNALLOCATED STOWAGE
4	SIDEBOARD	12	ENTERTAINMENT STOWAGE
5	SETTEE (2-BEDS)	13	N.B.C., F.F., D.C. STOWAGE
6	CHAIR STOWAGE	14	ADMIN. & FIRST AID STOWAGE
7	2 TIER LOCKERS	15	BOOK STOWAGE
8	DOUBLE WARDROBE	16	FOLDING TABLE
		17	SIDEBOARD & ICE MACHINE

Credit: © Auerbach, Lynch, Graves Associates.

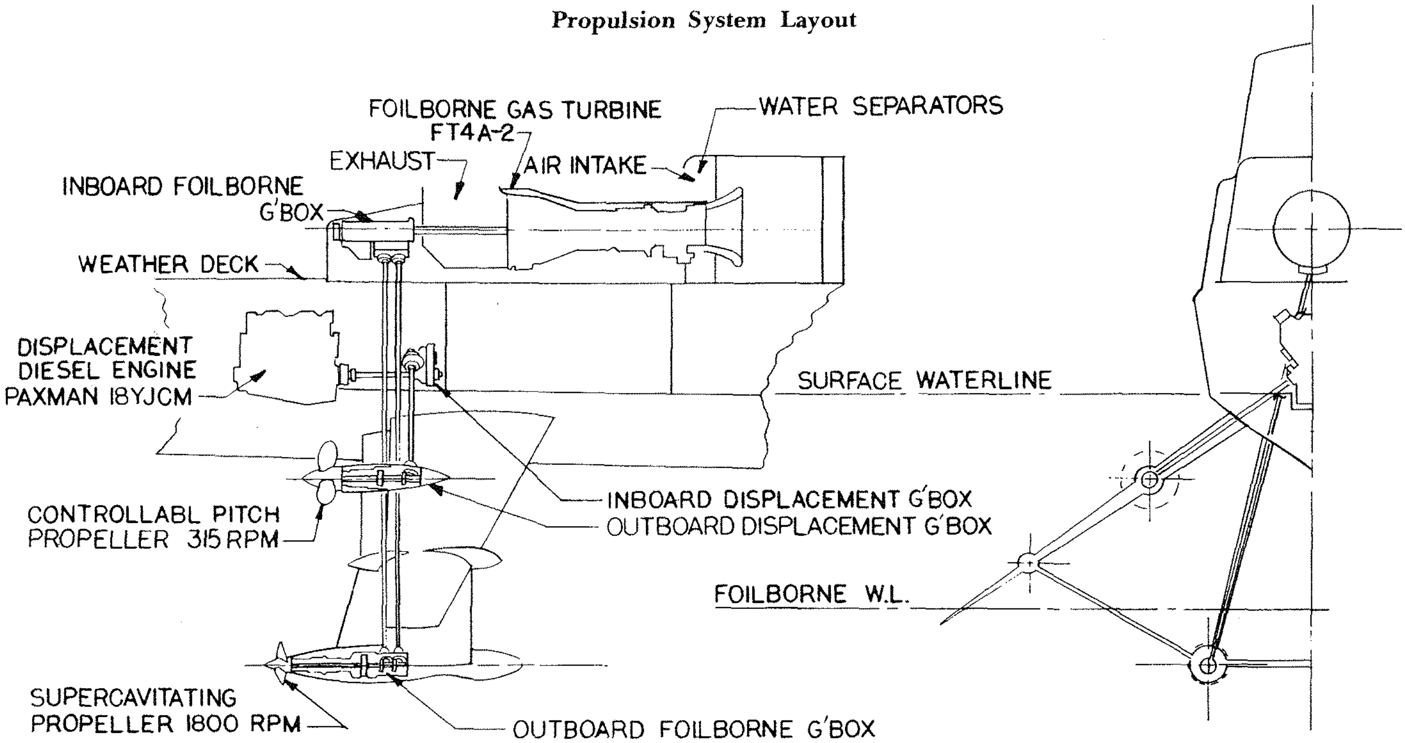
DIAGRAM B
Internal Layout Aft



Credit: © Auerbach, Lynch, Graves Associates.


STAIR (DOWN)
CONTROLS
C.O. & BOSUN'S CHAIRS
NAVIGATOR'S CHAIR
CHART TABLE & STORAGE
BRIDGE
ENGINEERS CONSOLE & BUILT-IN CHAIR
TEMPORARY PLOT TABLE
ACTION CONTROL CENTER CONSOLE
ELECTRONIC CABINET
FT 4 A2 TURBINE HOUSING
STAIR (DOWN)
ROUGH WEATHER/ NBCW DECONTAMINATION ROOM
INTAKE/EXHAUST ST6 TURBINE
TRANSMISSION

Propulsion System Layout



two single berth cabins, one each for the Captain and Executive Officer, with the officers' heads hard against the engineroom bulkhead, same side.

The main machinery space is next and bears a detailed look as to layout. Centrally-located *was* the Paxman 16YJCM high speed diesel (since removed), which was coupled to the inboard displacement gearbox. To the port side, facing forward, is the ST6A-53 gas turbine, connected to the auxiliary gearbox to port of the displacement gearbox. The auxiliary gearbox is driven via clutches and allows displacement drive from the ST6 or the diesel. The gearbox also allows the turbine to be used in tandem with the diesel in hullborne mode or used as emergency propulsion. To the starboard side of the diesel and slightly ahead is the GTCP-85-295 gas turbine. This is mounted to the deckhead, well above the floodline and provided a secondary electrical source and hydraulic power, fire-fighting pressure and bleed-air to turn the FT-4 main turbine. This unit too could be used as emergency propulsion in the hullborne mode.

Aft of the machinery space is the electronics bay and workshop, with the VDS well space, operators' space and hoist machinery space occupying the stern. Nothing was ever fitted in any of these three spaces, although a lightweight VDS of the quality of the AN/SQS-507 H.S. was intended.

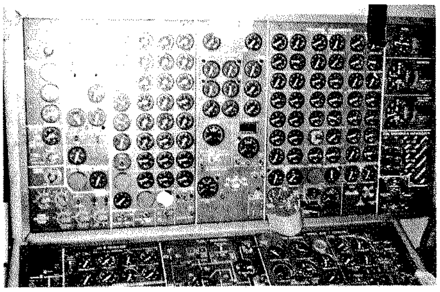
From here, one would walk back to the recreational space and up a set of stairs, emerging in the Engineer's station area and hence, forward into the operations room proper. Here were to be the components of the Attack Center, most of which were never fitted. However, large amounts of the primary-task electronics were installed, such as radar plot, radio communications, etc. Back in the corridor, a further flight of stairs led up into the small bridge. Looking more like the cockpit of a small plane, dual wheels and seats were found, surrounded by segmented armor glass windows affording an excellent view for the Captain and Petty Officer helmsman. Behind them is a small jump seat and fold-down desk for the navigator.

Down to the Attack Center and exiting aft on the staboard side through two watertight doors, (the space in between is set up as a NBCW decontamination room) we find ourselves on the quarterdeck, next to the FT4 engine nacelle. Inside, there are the air intakes and water separators, sucking air through the reverse-flow nacelle. The water separators were a first of kind item, using baffles and traps to create sudden changes in air pressure that precipitated ambient humidity and other moisture on the plates, which was then collected in channels and drained away. Intruding into the nacelle, of course, is the FT4 intake.

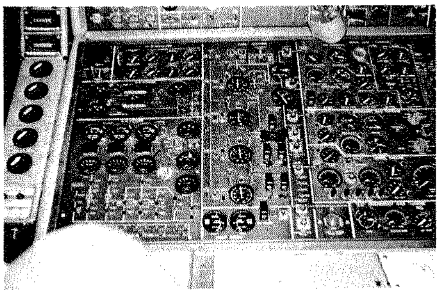
Bras d'Or was the first Canadian vessel to use a gas turbine as a main propulsion unit. The Pratt & Whitney FT4A-2 gas turbine was mounted on the main deck for major reasons. It permits removal of the unit in case of failure or maintenance, simplifies air and exhaust ducting and minimizes transfer of heat and noise to the accommodation areas. With the nacelle lined with acoustic dampening material, the noise levels in the operations room and bridge were acceptable, although it had the unfortunate tendency to redirect sound downwards into the officers' accommodation areas.

Hydrofoil System Structure: The unusually large hull clearance and high top speed caused limit load stresses in excess of 100,000 PSI in the foils, presenting very difficult structural design and fabrication problems for DeHavilland. However, a new (at the time) steel alloy, 18% maraging steel, appeared to meet the need and steel of this sort was used in plates

Bras d'Or's *bridge layout*. DREA photo.

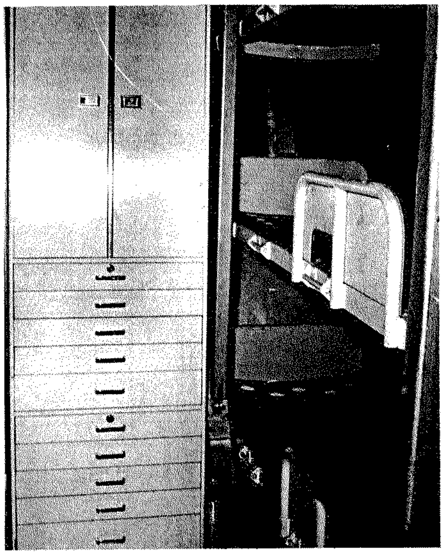


The engineer's operating console (top portion). The engine room is unmanned while the vessel is foilborne. Author's photograph, copyright.

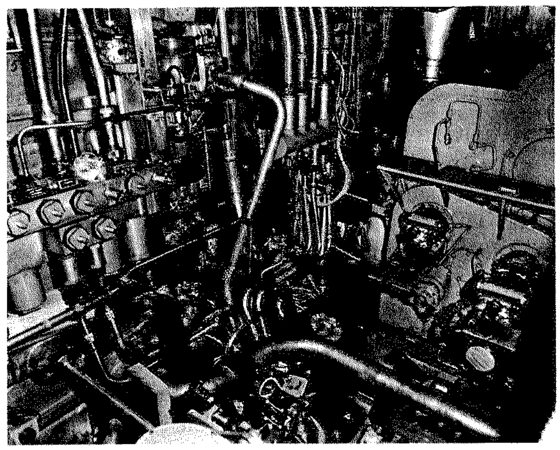


The lower portion of the engineer's console. Author's photograph, copyright.

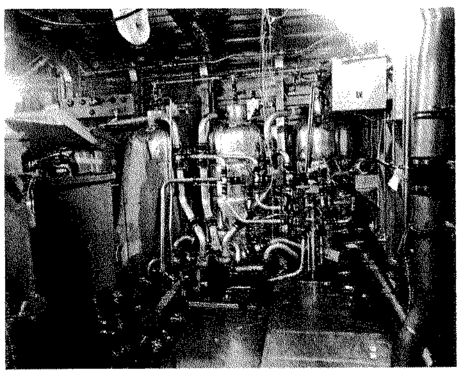
The galley section of the ship's mess, as seen on 21 March 1979. Microwave oven and grill are seen here; the proximity of the refrigerators under heating equipment resulted in their operating continuously! Author's photograph, copyright.



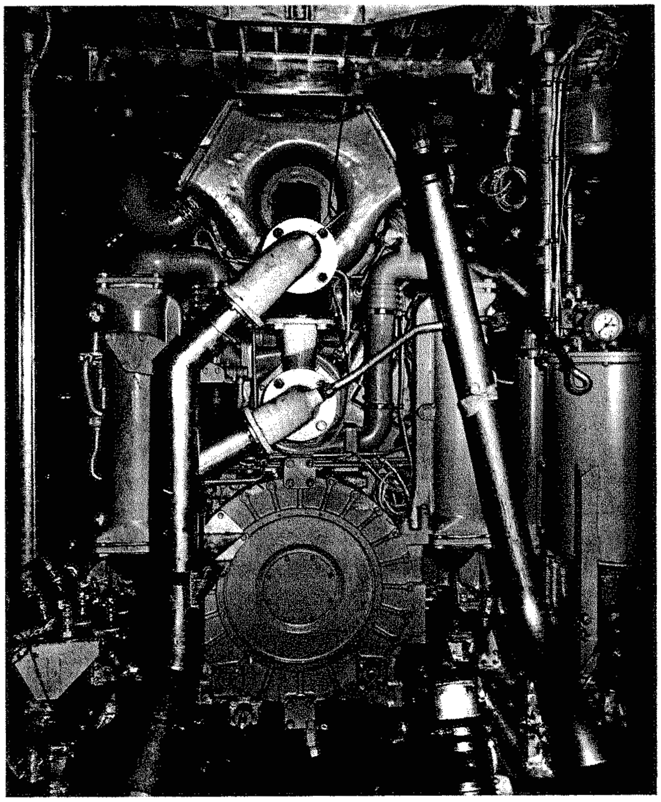
One of the Petty Officers' compartments. Crew fatigue proved to be far less than expected, although turbine noise and temperature control were problems. Author's photograph, copyright.



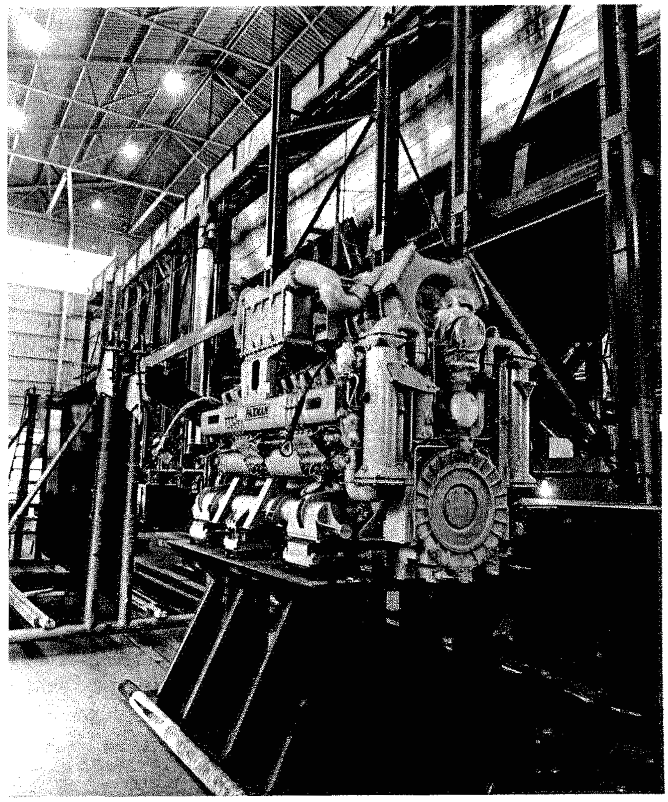
Engine room, starboard side, showing the pneumatic system. The ST-6A-53 turbine appears at bottom right. The installation is incomplete, as evidenced by loose wiring and the package of cigarettes lying on deck. Author's photograph, copyright.



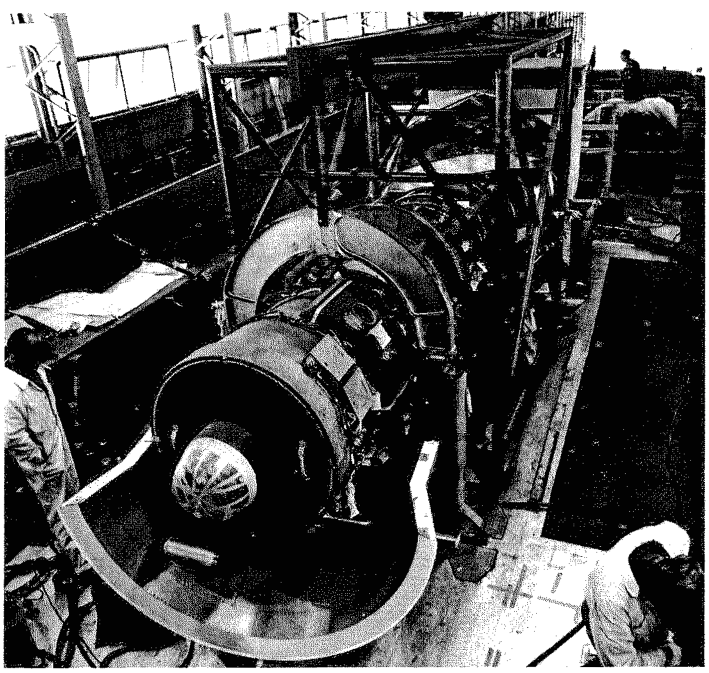
Lube tanks on the port side, seen from the starboard side of the ship. Author's photograph, copyright.



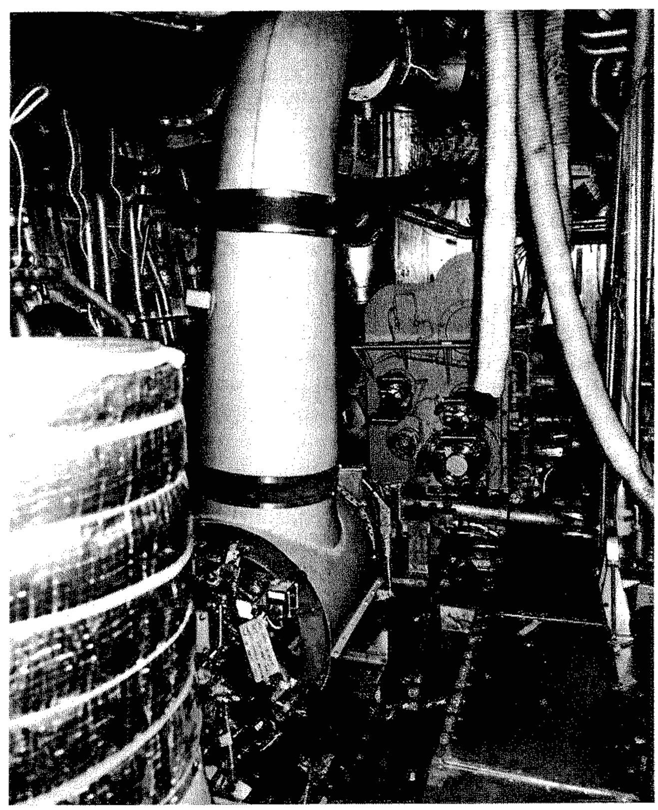
The Davey Paxman 16YJCM diesel. This diesel proved fairly reliable, though when defects became apparent parts became hard to find and expensive. **Author's photograph, copyright.**



Paxman diesel engine before its installation. Note that the FHE-400 hull behind has been rolled over, right side up, and is set in framing ready for foil system to be installed. **Author's photograph, copyright.**



The FT-4A-2 engine fitted to its modular skid. The engine's intake venturi is being altered. **Author's photograph, copyright.**



The ST-6A auxiliary gas turbine, fitted to starboard of the Paxman diesel, facing forward. The 2-speed auxiliary gearbox can be seen behind this unit. The large white pipe is a heat exchanger. **Author's photograph, copyright.**

and forgings of the foils. This was terribly expensive, but the high tensile strength of 250,000 PSI was the deciding factor. Major advantages of using this material were that only low temperature heat treatment without quencing was involved, with only small dimensional changes after treatment. This, then, would allow building large foil structures and surfaces without sacrificing strength. However, the problems of using maraging steel in a marine environment were not fully appreciated at the time, leading to problems in later years. All foil surfaces were treated to a coat of neoprene about .55 in. thick. Accessible areas inside were treated with a zinc 'sacrificial' coating and on flat surfaces a neoprene matting was secured to control movement of minor seepage. The idea was sound, but the massive leaks that developed overwhelmed the zinc coat and attacked the steel itself. Faults resulted from improperly sealed access panels, which in turn caused cracks in the structural panels through stress-corrosion cracking and hydrogen embrittlement. Combined with the stresses of usage, this caused the major damage to the two main foil elements in 1969 and 1971. However, in neither case were these cracks considered to be grounds for abandoning scheduled tests. Indeed, several high speed runs were conducted on the cracked foil in 1969 *before* the cracks were discovered and even with the element entirely filled with water!

The leading edges were replaceable, being external to the coating and were made of stainless steel, except those of the main anhedral foils, which were plastic.

The main foil used delayed-cavitation sections with 'fences' to prevent uncontrolled ventilation and 'porpoising' as experienced in the Bell-Baldwin and later DREA experiments. As can be seen from the photos, the foils are of the surface-piercing type and non-retractable. Although this did increase hullborne draft to 23 ft. 6 in., it did give *Bras d'Or* the stability in rough water, in hullborne mode, of a vessel the size of the average destroyer, without the tophamper and attendant roll and pitch. The entire foil arrangement is at odds with systems adopted by U.S. and European navies. The canard arrangement does away with excessive overhang, as seen in the U.S.S. *Plainview* (AGEH-1). The main foil arrangement carries 90% of the ship's weight, which meant a center of balance further aft than other comparable hydrofoil craft. This was a decided advantage in the North Atlantic, open-sea conditions that this ship was intended for and this set *Bras d'Or* apart in the military aspect of design.

A central, fully submerged, horizontal foil makes this a heavily damped and efficient unit and is supported by two nearly vertical struts. Outboard of these are intersecting dihedral and anhedral foil elements. The latter extend beyond the intersection and these anhedral tips are incidence-controlled in the manner of conventional ship stabilizing fins. These were also an add-on item to the original design and posed a myriad of problems, accommodating the actuators and in design of the tip pivot arrangements. In their own right they added over $1 million to the cost of FHE-400 and their necessity on a developmental vessel is still debated. Indeed, concessions to the military on this largely research-oriented vessel pushed the cost way beyond original estimates and eventually the cancellation of the program.

The stability augmentation system was primarily fitted to meet a requirement introduced late in the design for extended cruising at low foilborne speeds. In practice, tip incidence control was used at all speeds to improve maneuverability. The tips were gyro-controlled, but could be manually offset by a lever at the command position to allow co-ordinated or part-co-ordinated turns.

The horizontal and dihedral foils are pin-jointed and each forged end-fitting of the anhedral foils and struts are bolted to the hull foundation by 16 bolts. The pods at the foot of the struts accommodate the outboard gearboxes of the foilborne transmission and are faired to smooth pressure distribution and prevent cavitation.

Bow Foil: The bow foil is steerable and acts as a rudder for both foilborne and hullborne modes. Rake is adjustable, a total of 20 degrees, enabling the best angle of attack to be selected for either mode of travel under prevailing load and sea conditions. Basically of diamond form, it has a vertical strut and short, horizontal bridge-piece of delayed-cavitation section at the lower apex. The dihedral foils are pin-jointed to the bridge-piece and to the anhedral foils at the outboard intersections, but the upper ends of the anhedral foils are bolted rigidly to the strut. The mounting shaft pivots at a spherical bearing in the forefoot and the upper bearing traverses through an arc, fore and aft, to provide a rake angle adjustment of −15 degrees to +5 degrees, combined with a steering angle range of ±15 degrees (restricted to ±5 when in foilborne mode.) The steering actuator is located at the lower end of the bow foil shaft to avoid torsional oscillations and a yaw-rate gyro provides damping to smooth the steering. Steering is automatically controlled from the ship's compass to maintain a constant heading, optionally.

Transmission: Returning to the main deck, aft of the FT4 housing, but within the compartment is the General Electric dual output transmission, which directs the FT4's power 90 degrees downward, through the vertical struts. Difficulties were encountered in design here as well. The very necessary thinness of these struts to prevent cavitation made transmission of power to the pods difficult. Apart from lack of internal space, the struts deflect appreciably under load, considerably complicating downshaft and bearing support design. Downshaft diameter was reduced by employing dual shafts geared up 1:2. The pod-mounted gearboxes then provided a 4:1 down-ratio to the foilborne propellers, giving a net 2:1 reduction from the engine. The fixed-pitch, three-bladed, supercavitating propellers are 48 in. in diameter and were jointly developed by DeHavilland and the Ship Division of the National Physical Laboratory in England. They are allowed to windmill for displacement operation by means of overrunning clutches.

Pressure lubrication was provided to the three hullborne gearboxes and associated shafting to all, using hydraulically-driven pressure and scavenge pumps. The oil is pre-heated before operation and cooled by sea-water heat exchangers when in operation. Continuous wet-down to one system when the other is in operation is provided. The pre-heat came about through the discovery in 1968 that the lubricant was too cold when it reached the foilborne gearboxes.

Connecting the inboard foilborne gearbox to the outboard foilborne gearboxes are two long driveshafts. Early in the initial foilborne trials, a systematic vibration was noted in the transition period between displacement and foilborne modes. This was eventually traced to torsional twisting of these long shafts and a method of slower start-up procedure was developed that obviated this vibration.

Similarly, the displacement propellers are driven by two much shorter shafts from the inboard displacement gearbox and the Paxman diesel. The displacement pods are mounted on the main anhedral foils and the two, three-bladed, controllable-pitch propellers are 84 inches in diameter. These were built by KMW, Sweden and are feathered when foilborne to minimize wave impact loads.

Auxiliary Systems: The ship's electrical and hydraulic supply systems are provided through the auxiliary gear-box in the machinery space. For normal hullborne operation this is driven from the diesel engine and when foilborne, from the ST6A-53 gas turbine, continuously rated at 390 shp at 2,100 RPM. The gearbox drives three 60 KVA generators for the main 115/200 volt, three-phase, 400 Hz. electrical supply, six hydraulic pumps for the 3,000 PSI main hydraulic system and a sea-water pump.

A common fuel is used by all three turbines and the diesel, with JP-5 being the normal fuel used, but high distillate marine diesel is also satisfactory. The fuel is stored in four compartments below the lower deck and comprehensive inter-tank transfer arrangements exist. However, it was found that baffling within and between tanks was inadequate.

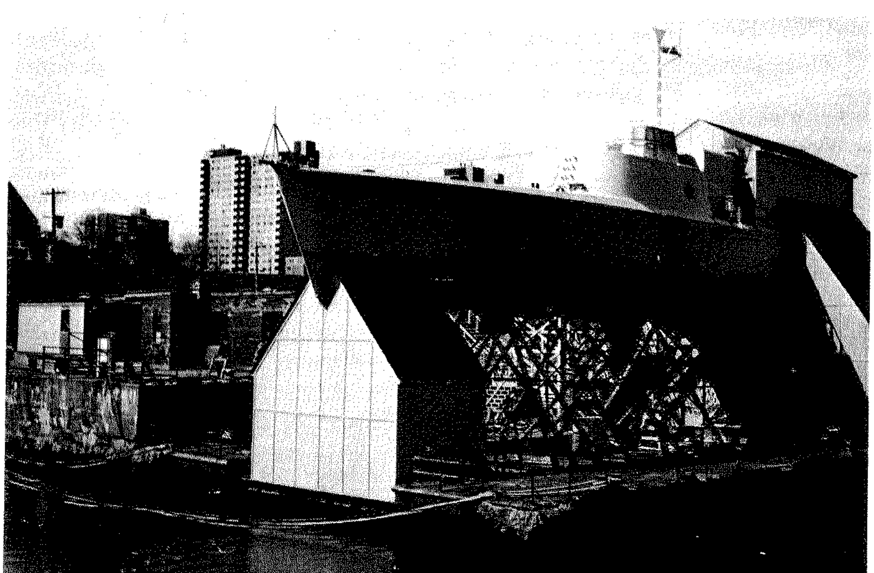
The main hydraulic system uses four continuous-duty pumps and four peak-duty pumps to provide 90 and 75 U.S. gallons per minute, respectively, to various hydraulic services. These include bow foil steering and rake adjustment, incidence control of the anhedral tips, anchor windlass, powered bollard, air compressors for the ship's pneumatic system and pumps for the transmission lubrication system. Pneumatic services are supplied through reducing valves from high pressure reservoirs for main turbine starting, diesel engine prime and air starting, hullborne transmission clutches, propeller automatic pitch-control and other miscellaneous duties. Salt water is distributed from a salt water sea chest filled through inlets on the hull and lower foil structure, to various heat exchangers, the main fire main and domestic services and to the distillation unit for fresh water supply.

This primarily finishes the detailed description of *Bras d'Or* and her sub-systems. Although greater technical detail could be injected, it was thought that the graphs, drawings, and photographs would describe *Bras d'Or* in a satisfactory detail.

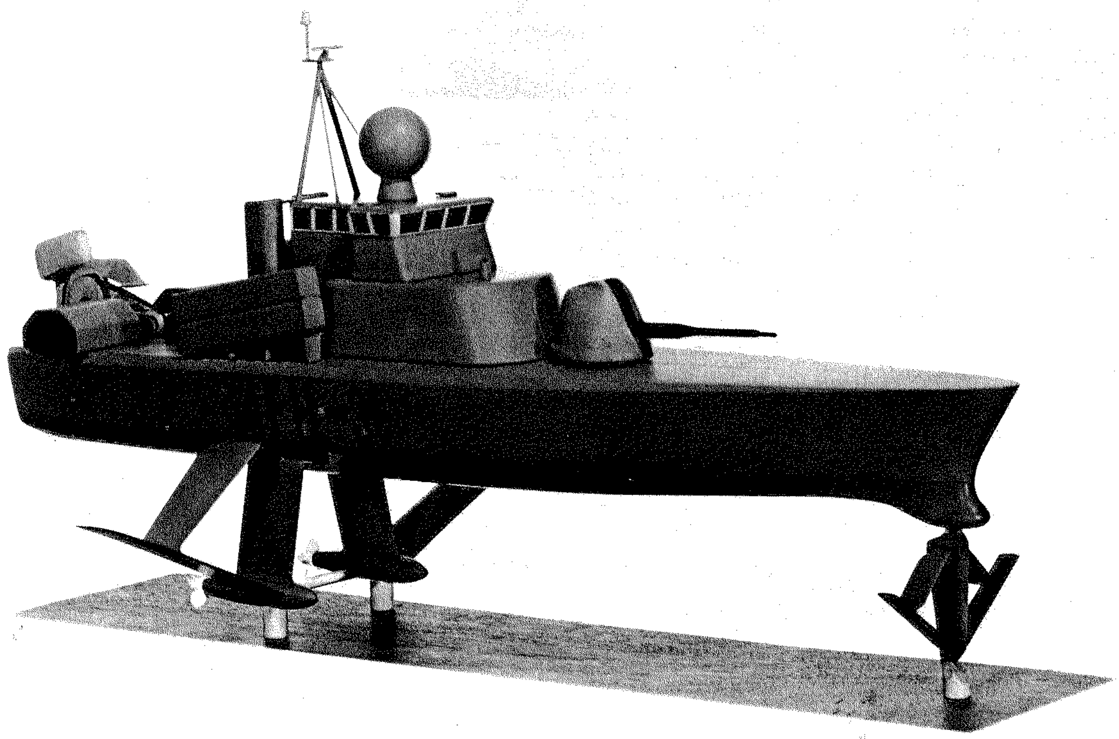
Conclusion

Although *Bras d'Or* is officially, if not physically, gone, the money spent was not wasted. Canada received more than equal repayment from the research results, many of which were incorporated in the DDH-280 class and to a lesser extent on the new Canadian Patrol Frigate.

Firstly, it showed in Canadian shipyards that construction of such a vessel made the digital computer a necessity in shipyard design offices. Next, the lightweight Automated Action Control Centre (ACC) that was designed for *Bras d'Or*, but never fitted, found a home in the DDH-280 class, saving millions in acquiring foreign equipment or having to develop such a system from scratch. The turbine technology acquired was applied to the design of the DDH-280 class and indeed to this day, MARCOM enjoys the longest turbine life expectancy in NATO, through the use of water-separators and filters first used aboard the FHE. Micro-miniature circuitry proved to be possible within Canadian industry and indeed, provided the footing for the fledgling industry. However, the biggest 'spin-off' was exchange of knowledge. The free ex-



***At an interim resting place,* Bras d'Or *aloft on the slave dock at the farthest extremity of the South Dockyard, Halifax, on 29 March 1979. The huts and hull are climate-controlled. The vessel since has been moved across the harbor to Dartmouth as the main dockyard is rebuilt.* Author's photograph, copyright.**



This model displays what a future production ship derived from the **Bras d'Or** *experience might look like.* **DREA photograph.** *This ship type represents one of three possible alternatives to fill multi-role naval needs after the new class patrol frigates are undertaken during the 1980s. A VDS sonar is carried at the stern, missile launcher canisters are sited alongside the superstructure, and a 3-inch gun is mounted forward. The athwartships containers aft of the inclined missile canisters probably are ASW torpedo tubes, and it is possible that the slightly bulbous bow forefoot incorporates a small sonar array for hullborne use.*

change of information through the tripartite commission provided Canada with information from the U.S. and Great Britain that we would never have been made privy to under other circumstances. Lastly, we acquired the knowledge of how to build a 200 ton hydrofoil that could operate in open North Atlantic conditions. Indeed, the hydrofoil design isn't as dead as one would think in this country. With the new Canadian frigate (CPF) costing 330 million current dollars in 1988, another craft that could fulfill a limited role, thus freeing most costly units for National Defence, is a distinct possibility. It is one of three possibilities considered as a 'follow-on' to the CPF Program. The proposed design is compared to *Bras d'Or* in the tables, as are proposed armaments. As can be seen, major deficiencies in FHE-400's design are corrected, without sacrificing sea-keeping or survivability. Diagrams 1 and 2 show the factors that determine the proposed craft.

Summary

With the increasing demand of higher and higher technological training for naval personnel, it seems the day of the 200+ crew count are fast fading. Indeed, in most major navies of the world, the shortages of seagoing, trained sailors are creating a crisis, with too few available to man the ships. *Bras d'Or* demonstrated that an alternative is available to MARCOM, if the necessary planning and knowledge acquired are applied to a practical design. With a group of 30 for a crew, the hydrofoil would be capable of providing a rapid-response ASW patrol vessel for North American waters in time of war, a patrol vessel within the 200 mile economic control zone and, working with conventional units, a distant picket/attack craft, used in conjunction with Sea King helicopters and Aurora aircraft. They would patrol, hullborne, using their superior speed to dash to the site of a reported detection and/or sighting.

While discussing *Bras d'Or* with officials of DREA, it was suggested that such a craft could still be built for between 18-24 million 1979 dollars, plus weapons. Taking into consideration the costs of the CPF Program and the demise of 16 steam-driven frigates by the mid-1990s, Canada will have some hard and weighty decisions to make within the next few years.

Meanwhile, a painful reminder of a bungled dream sleeps quietly in a forgotten corner of the Dockyard, hovering on the brink of extinction. Will Canadians provide a lasting monument to this unique vessel? . . . Or will we see the following in the future: "*Bras d'Or* for Sale—Cheap"?

PROPOSED WEAPONS FIT FOR HYDROFOIL
PROPOSED DESIGN

weapon	*minimum*	*compromise*	*maximum*
Missiles	2	4	6
Torpedoes	6	8-10	12
3 in. gun ammo	300	400	500

Proposed armament and equipment would be as follows:
- 1 Blowpipe (Short) Stabilized launcher (36 rnds.)
- 1 3-in. automatic mount (probably Oto-Melara 76mm./62 Compact)
- — Mk. 46 torpedoes
- 4 either Harpoon or MM 38 missiles, two launchers per side
- M-22 Fire control system
- 1—AN/SQS-507 H.S. towed VDS
- FHE-TAC Data system

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COMPARATIVE TABLE OF LEADING PARTICULARS

Bras d'Or vs New Design

	Bras d'Or	*New General Purpose Design*
Normal Foilborne Weight (lb.)	475,000	425,000
Overall Length	150.75 ft.	125 ft.
Foil-base Length	90 ft.	79 ft.
Overall main foil span	66 ft	64 ft.
Hull breadth	21.5 ft	25 ft.
Hull depth	15.58 ft.	14.5 ft.
Hullborne draft	23.5 ft.	20.5 ft
Hull clearance at 50 knots	8 ft.	6.5 ft.
Speed (in knots)		
Max. foilborne speed;		
calm water	60	50
sea state 5	50	45
Hullborne speed—max.		
(one engine)	13.75	25
design cruise	12	12
Engines		
Foilborne	1 G.T.	2 G.T.
Total S.H.P. (continuous)	22,000	10,000
Hull borne	1 Diesel	———
Total S.H.P. (continuous)	2,000	———
Accommodation		
Normal	20	24
Maximum	25	31
Radar Fitted;	Phillips 8GR-300/4	not known
Navigation;	Decca Mk. 23 Gyro	not known
Communication;	2-SSB HF transceivers	not known
	1-UHF transceiver	not known

SPECIFICATIONS AND WEIGHTS OF FHE-400

Bras d'Or

Normal foilborne weight: 475,000 lb.

Dimensions:
- Overall length: 150 ft. 9 in.
- Foil base length: 90 ft.
- Overall main foil span: 66 ft.
- Hull breadth: 21 ft. 6 in.
- Overall height: 47 ft.
- Hull depth: 15 ft. 7 in.
- Hullborne draft: 23 ft. 7 in.
- Foilborne draft at 60 kt.: 7 ft. 6 in.
- Static freeboard: 8 ft. aft; 11 ft. fwd.
- Hull clearance at 60 kt.: 10 ft. 6 in.
- Crash test deceleration: 40 to 6 kt. in 600 ft.

Speed: maximum foilborne speed: 63 kt. plus (*Bras d'Or* was never tested to limits)
rough weather: 50 kt.
design hullborne speed: 12 kt.
speed where foils become effective: 22 kts., calm water.

Engines:
Foilborne; Pratt and Whitney FT4A-2 gas turbine
22,000 shp-continuous
30,000 maximum
Hullborne; Paxman 16YJCM 16 cylinder high speed diesel.
2,000 bhp-continuous
2,400 bhp-maximum
Auxiliary; United Aircraft ST6A-53 gas turbine
390 shp-continuous
500 shp-maximum
Emergency; AiResearch GTCP-85-295 gas turbine
190 shp-continuous

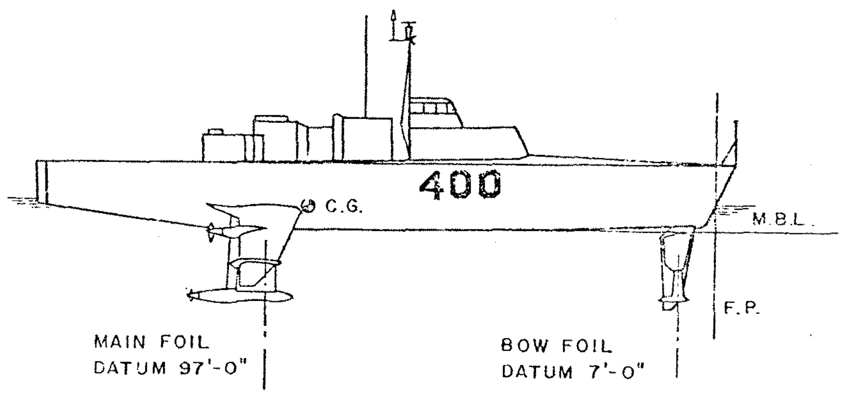
Propellers:
Foilborne; two fixed pitch, supercavitating
Hullborne; two KMW feathering, reversible pitch
Dia. 48 in., max. rpm; 2,000
Dia. 84 in. max. rpm: 315

Accommodation:	*Normal*	*Max.**
Petty Officers	4	6
Officers	4	7
Other ranks	12	12

* On one trip, overnight in 1971, there were 31 personnel aboard, but this was an exception.

Weight Breakdown:	*Weight in lb.*	*Percentage of 475,000 lb.*
Hull structure	73,100	15.4
Foil structure	88,300	18.6
Propulsion	77,800	16.4
Systems & outfit	58,200	12.2
Basic weight	297,400	62.6
Fuel & payload	177,600	37.4
All-up weight	475,000	100.0

TABLE 1— ***The trials instrumentation package used magnetic tape, oscillograph, film and video-tape recording. The first two systems had signal patching facilities to allow data channels to be selected and switched to suit trial requirements. Table one lists pertinent data on the main instrument sensors relevant to the craft, together with the location of foil and C.G. references.***



X – LONG POS'N AFT OF F.P. – FT
Y – LAT. POS'N FROM ℄ (+ TO STBD) – FT
Z – VERT POS'N ABOVE M.B.L. – FT

C.G. POS'N	X	Y	Z
10 %	88.0	0	4.4
12 %	86.2	0	4.4

SENSOR	LOCATION X	LOCATION Y	LOCATION Z	RANGE	REQUIRED ACCURACY
VERT ACCEL – BOW	10.5	0	12.3	± 5 G	0.05 G
VERT ACCEL – STERN	130.5	0	7.4	± 2 G	0.05 G
VERT ACCEL – C.G.	93.3	+ 2.7	5.8	± 2 G	0.05 G
LAT ACCEL – OPS RM	64.4	– 0.3	20.6	± 2 G	0.025 G
LAT ACCEL – C.G.	93.3	+ 2.7	5.8	± 2 G	0.025 G
ROLL ANGLE	93.3	+ 2.7	5.8	± 15°	0.50°
PITCH ANGLE	93.3	+ 2.7	5.8	± 10°	0.50°
HULLBORNE SPEED	TOWED KNOTMETER			0 – 15 KT	0.25 KT
FOILBORNE SPEED	FOILBORNE POD			0 – 80 KT	1.0 KT
HULLBORNE TORQUE	INBOARD GEARBOX			0 – 40,000 FT LB	2,000 FT LB
FOILBORNE TORQUE	OUTBOARD GEARBOX			0 – 40,000 FT LB	2,000 FT LB
DIESEL R P M	AT ENGINE			0 – 1,600 R P M	20 R P M
F T 4 FREE TURB R P M	AT ENGINE			0 – 4,000 R P M	20 R P M

TABLE 2—***Shows hullborne motions in sea state 5 and 6. Maximum roll recorded was 6.3 degrees in head sea state 6. As can be seen, the foils acted as massive dampers which resulted in smooth hullborne motions in both pitch and roll, with a notable lack of slamming in any sea. Experienced officers consistently under-estimated sea conditions and sea approach angles while below decks.***

Hullborne Motions in Sea State 5 and 6

	SEA STATE	5	5	5	5	5	6
	DIRECTION TO SEA	Head	Bow	Beam	Quart	Foll	Head
	MEAN SPEED (K)	12·5	12·75	12·5	12·4	12·4	8
STANDARD DEVIATIONS	ACCELERATIONS (g)						
	Vert. Bow	0·11	0·11	0·07	0·08	0·09	0·18
	Vert. Stern	0·07	0·07	0·05	0·04	0·04	0·14
	Vert. C.G.	—	—	—	—	—	0·10
	Lat. Ops. Rm.	0·05	0·05	0·05	0·06	0·06	—
	Lat. C.G.	0·02	0·02	0·02	0·03	0·03	0·04
	ATTITUDES (°)						
	Pitch	1·4	1·1	1·5	1·2	1·4	—
	Roll	0·9	1·0	1·8	1·3	1·1	1·5
MAXIMA	ACCELERATIONS (g)						
	Vert. Bow	0·33	0·33	0·21	0·22	0·26	0·65
	Vert. Stern	0·22	0·18	0·13	0·11	0·11	0·45
	Vert. C.G.	—	—	—	—	—	0·30
	Lat. Ops. Rm.	0·13	0·14	0·15	0·15	0·14	—
	Lat. C.G.	0·07	0·07	0·06	0·07	0·08	0·12
	ATTITUDES (°)						
	Pitch	3·5	3·0	3·8	3·2	3·9	—
	Roll	2·5	2·8	4·4	3·7	3·4	6·3
MINIMA	ACCELERATIONS (g)						
	Vert. Bow	−0·36	−0·36	−0·22	−0·26	−0·26	−0·50
	Vert. Stern	−0·22	−0·20	−0·15	−0·15	−0·13	−0·40
	Vert. C.G.	—	—	—	—	—	−0·28
	Lat. Ops. Rm.	−0·16	−0·14	−0·16	−0·18	−0·17	—
	Lat. C.G.	−0·05	−0·07	−0·06	−0·07	−0·08	−0·11
	ATTITUDES (°)						
	Pitch	−3·7	−2·8	−3·7	−3·1	−3·4	—
	Roll	−2·3	−2·8	−4·6	−3·1	−3·0	−5·0

TABLE 3—***Foilborne trials proved the smoothest take-off was to delay take-off by raking the bow foil to −9 degrees. Thus take-off was delayed until 26 knots over 22 knots was reached, the bow foil raked to 0 degrees and the ship trimmed up at about 6 degrees in angle, before the bow foil ventilated. The ship then trimmed up at about 1 degree until fully foilborne. The following values were obtained in Sea State 5 with various sea directions.***

Foilborne Motions in Sea State 5

	DIRECTION TO SEA	Head	Bow	Beam	Quart	Foll	Head	Foll	Head	Foll
	MEAN SPEED (K)	38·0	37·5	39·3	39·3	39·3	34·2	34·2	42·3	44·9
STANDARD DEVIATIONS	ACCELERATIONS (g)									
	Vert. Bow	0·18	0·21	0·17	0·16	0·16	0·19	0·12	0·23	0·18
	Vert. Stern	0·18	0·22	0·13	0·14	0·11	0·17	0·08	0·22	0·15
	Lat. Ops. Rm.	0·07	0·07	0·08	0·08	0·08	0·07	0·06	0·09	0·11
	Lat. C.G.	0·04	0·04	0·05	0·05	0·04	0·03	0·03	0·04	0·04
	ATTITUDES (°)									
	Pitch	0·7	0·9	1·1	1·6	1·5	0·8	1·3	0·7	1·2
	Roll	1·2	1·1	2·1	1·7	1·7	1·2	1·7	1·3	1·5
MAXIMA	ACCELERATIONS (g)									
	Vert. Bow	0·58	0·75	0·46	0·46	0·54	0·65	0·34	0·71	0·52
	Vert. Stern	0·49	0·71	0·40	0·34	0·34	0·58	0·21	0·68	0·42
	Lat. Ops. Rm.	0·22	0·22	0·28	0·25	0·24	0·19	0·19	0·28	0·32
	Lat. C.G.	0·11	0·12	0·16	0·11	0·11	0·08	0·09	0·10	0·12
	ATTITUDES (°)									
	Pitch	2·4	3·5	3·3	5·4	5·1	2·1	3·7	2·3	4·0
	Roll	4·8	4·1	6·1	4·1	5·1	3·3	4·5	5·5	4·3
MINIMA	ACCELERATIONS (g)									
	Vert. Bow	−0·54	−0·58	−0·50	−0·62	−0·66	−0·52	−0·40	−0·71	−0·58
	Vert. Stern	−0·52	−0·59	−0·40	−0·34	−0·34	−0·47	−0·26	−0·68	−0·47
	Lat. Ops. Rm.	−0·20	−0·21	−0·22	−0·20	−0·24	−0·20	−0·18	−0·30	−0·31
	Lat. C.G.	−0·11	−0·09	−0·15	−0·12	−0·11	−0·07	−0·09	−0·10	−0·12
	ATTITUDES (°)									
	Pitch	−2·4	−2·3	−2·8	−3·5	−4·2	−2·4	−3·5	−1·9	−3·3
	Roll	−6·8	−5·8	−5·8	−5·5	−4·8	−3·6	−5·2	−3·9	−5·0

About the Author:

Mr. Lynch was born into a multi-generation naval family in Great Britain and Canada, and served with the R.C.N./Maritime Command from 1967–1969. Leaving the Navy after Unification, he went into the Canadian Coast Guard for a further year in 1970, before "swallowing the anchor."

However, his interest in nautical matters has sharpened since Service time with the publication of several articles: "The Last Corvette," *W.I.*; "Abrams XM-1 . . . Tank of the Future?" *Scale Models*; "Savior of Ceylon" and "The Cougar AVGP" both in *War Monthly*; "Maritime Command—An Assessment," *Canadian Defence Quarterly*; "Happy Haida," *Model Boats*; "Haida, 1943–1962"—A Unit History, Maritime Naval Historical Society. His first book is *Canada's Flowers*—Canada's Corvettes, 1939–45—IGC; reprint, Nimbus Books. Research into a reference book on Maritime Command is on-going, with publication in 1983.

Mr. Lynch resides in Halifax, N.S., the place of his birth, as near the Navy as possible. As well as writing, he serves as unofficial photographer for the Maritime Museum and has acted as consultant on Canadian naval subjects for local television, as well as the National Film Board of Canada. He is 32 years of age.