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HMCS BRAS D'OR - The Ship That Flew

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HMCS BRAS D’OR - The Ship That Flew

by Tom Bennett

[Webmaster’s note: CANDIB had the good fortune to enjoy a visit and presentation by Tom at one of its meetings. Tom had with him some photographs and other items of historical interest. This paper, along with an excerpt from the Retirees’ Corner from the 3 September, 1995 edition of the de Havilland publication “Plane Facts” was sent to CANDIB for use as seemed appropriate. Both the paper and the short article are posted here for visitors’ reading pleasure].

Introduction

HMCS Bras D'Or was a 200 ton hydrofoil ship designed for anti-submarine operations in the open ocean.

Why Build a Hydrofoil?

The Canadian Forces hydrofoil program was motivated by the need to develop the smallest and least costly vehicle that could operate with reliability and habitability in the open ocean in anti-submarine warfare. This called for an unusual ship. Submarine search requires slow quiet speeds. Submarine interception and attack requires short bursts of high speed, coupled with endurance and good maneuver ability.

The problem of increasing the speed of ships in rough water has challenged naval architects for several decades. In order to minimize surface wave resistance and the compounding effects of the rough water surface, the Canadian Defence Research Board sought to develop a method of keeping the bulky ships hull away from the waters surface in order to maximize speed potential.

Following experiments with several hydrofoil shapes, including radio-controlled models and small manned ships from 3-17 tons displacement and encouraged by postwar developments elsewhere in the lightweight propulsion systems and high strength materials so essential to the feasibility of larger hydrofoil ships, the Program entered into a comprehensive study of the potential usefulness of hydrofoils in ASW.

This study concluded that within the then predictable state-of-the-art hydrofoil systems, a hydrofoil of about 200 tons displacement with a surface-piercing foil system and a 50-60 knot speed capability would satisfy their requirements.

This proposal, based upon aircraft technology, was blessed by the British and US navies as complimenting their research/development programs. The British were developing a hovercraft and the Americans a fully submerged foil system hydrofoil with electronic height sensing.

Before deciding to embark on the actual design and construction of a prototype ASW hydrofoil system to examine the engineering premises and acquire data required for design purposes, a contract was let in March, 1961 to the De Havilland Aircraft of Canada, Ltd., for ship design studies which included an extensive model test program and an ambitious analog computer simulation of the foileborne behavior of the ship in regular and random seas.

When confidence in the feasibility of the proposed design had been reached, design study for the appropriate weapon system was made under contract let to Canadian Westinghouse Company in September, 1963.

References

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Tom Bennett’s Recollections

How the hydrofoil project came to De Havilland in 1960 was a mystery to me but I do recall that Dick Becker, my boss, suddenly became tight lipped and went off on some unexplained missions. Dick and I had worked together for many years. Our work on the Tracker Aircraft had resulted in the development of a good relationship with the air side of the Royal Canadian Navy.

Barry Davis, a hydrodynamicist, was interviewed and hired before Dick made me the third engineering person to share the secret of the hydrofoil project.

Of course none of us knew anything about hydrofoils. I was sent to the Naval Research Establishment in Dartmouth, Nova Scotia to design joints for foil elements of a 1/4 scale hydrofoil model. The RX (1/4 scale model) was designed as a test vehicle to evaluate different foil arrangements. After about 3 weeks I returned to D.H.C. Apparently the responsibility for the RX 1/4 scale foil system representative of the 200 ton hydrofoil had been contracted to D.H.C.

Back at D.H.C. I assisted Barry Davis by doing layouts of various foil arrangements. Barry was full of ideas and we studied many foil geometries with the Naval Research Establishment’s canard arrangement with 90% main foil and 10% bow foil weight distribution. The objective was to satisfy the requirements relating to stability, cavitation control and ventilation of the full ship size. These specifications were to be incorporated in the design of the R.X. model with minimal compromise.

The final arrangement had the following features:

main foil with centre and dihedral panels, parallel chords and identical geometry, tapered chord anhedral foils;

anhedral tips (length to be determined on R.X.) and struts; and

bow foil diamond shaped with a central ladder foil element.

Much consideration was given to foil intersections as these were critical to the performance of the full-size ship at high speeds.

The only compromise required on the R.X. was that the main foil struts had to be sloped outboard at the top in lieu of inboard for the full-size ship.

In order to minimize stresses in the thin foil elements, piano hinged joints were adopted for both the R.X. and full-size ship.

Two interchangeable main foil length anhedral tips were manufactured. Foil sections used were Walchner C and NACA 16.50 and lenticular section struts. Thickness chord ratio was increased from 5% to 7% for R.X. for strength reasons since cavitation was not a problem at R.X. speeds.

Main and bow foil assemblies were mounted to R.X. via dynamometers to measure forces. These required a bridge structure over the top of the R.X. hull in order to mount the main foil.

The solid aluminum foil elements were subcontracted to Simpson Brothers Co. in Scarborough, ON. I will never forget the day when Dick Decker, Phil Halsey, Tom Mann (who had done most of the detail engineering) and I visited Simpsons to see the finished foils, which Simpsons had endeavored to assemble. On our arrival we were informed that the foils wouldn’t fit together. I almost fainted, knowing that this $40,000.00 project was the most expensive one I had had responsibility for. My anguish was eased when Tom Mann pointed out that the struts had been assembled incorrectly. My reputation was salvaged and we retired to enjoy a celebration lunch.

The foils were trial assembled at D.H.C. and I was sent to oversee their installation in Dartmouth. Much to my relief they went on without a hitch. I was back at D.H.C. awaiting initial trial results when Dick phoned to say that the longer anhedral tips were needed. These were shipped, fitted and the roll problem solved.

R.X. trials proceeded until the bow foil was lost, reportedly after running into a Russian freighter and sinking into the ooze of Halifax Harbor. By now the centre ladder element had been eliminated for R200 and we manufactured a new bow foil to the latest arrangement so the R.X. trials could continue.

Other test models for which I had responsibility were an 1/8 scale foil model and a 1/10 scale full ship model. The 1/8 foil model consisted of main and bow foils mounted to a representative portion of the hull. The centre main foil element was equipped with pressure sensing points with pipes running up the struts to the test equipment.

The 1/16 scale full ship model had to have the correct weight and balance of the full-size ship. I designed the hull with balsa wood core and fibre glass inner and outer skins, applying the techniques I had learned in England in the design of the Mosquito aircraft at De Havilland. The model was tested in the National Physical Laboratory tank in England.

It was built for displacement tests but became foilborne in spite of its simple flat bottom and circular top surface foil sections. The model proved useful in evaluating the need for fairings between the hull, foil and strut elements.

A company in Dayton, Ohio was contracted to construct a dynamic bow foil model. I was a member of the team who visited them to provide specifications. __________ was a small, remarkable company of experts who designed and built dynamic test models. While there we were shown a model of Apollo 11 about 20 feet high which was built of various materials chosen to represent mass and stiffness.

I secretly built a 1/25 scale model of the complete ship in my home workshop. It was radio controlled and, after Dick Becker was made aware of its existence, it was used in sea trials and gave us the first indication of a roll problem at slow foilborne speeds. This working model was displayed at the Canadian National Exhibition and, after many years, reappeared at the Museum of Science and Technology where it was refurbished and operated. (The story of its development, significance, disappearance, reappearance and final resting place was printed in the D.H.C. “Plane Facts” on 3 September, 1995.

After the basic foil geometry was established, I was given the task of preparing preliminary ship layouts. A number of gas turbines for foilborne power and diesels for displacement operation were considered. It was assumed that all of these engines would be…

[Webmaster Note: Page 6 of the source document is currently missing but efforts are being made to obtain a replacement].

S. Morita	(Saab)	Stress & Mechanical Design
M.J. Callow	(Martyn)	Powerplant and Systems (Ex Avro)
T.E. Bennett	(Tom)	Foil Design
A. Stonell	(Tony)	Simulation
W. Billings	(Bill)	Hull and Superstructure

When it was time to enlarge the team in order to complete the detail design, we were moved to the Avro plant at Malton, which De Havilland had acquired. At the time, Al Stenning, Rye Case and Tony Stonell had completed their tasks. The remaining team members became leaders of engineering groups which were augmented to a total of 140 members.

The team for which I had responsibility designed the foil structures. Two major changes in the original design required considerable change in the main and bow foils. These included moveable main foil anhedral tips and relocation of the bowfoil steering actuator. Moveable tips required completely separate assemblies incorporating solid tongues of 200 grade maraging steel which protruded into a socket in the main anhedral foil. The tips pivoted on the two large uniball bearings. The installation was tailored to provide the required range of travel within the original foil profiles. The hydraulic actuator and bell crank mechanism was located within the intersection pods.

Relocation of the bow foil steering actuator was required to meet steering stiffness criteria. The original design consisted of a scissor arrangement located at the top of the bow foil mount shaft which travelled back and forward with bow foil trim.

The new arrangement located the hydraulic actuator at the bottom of the hull with the piston rod protruding through the hull. This was connected to the bow foil via a floating link with uniball ends to permit bow foil trim.

As the foil design progressed, each detail part was measured, and an engineering order was issued for the material requirement. Republic Steel of Akron, Ohio, supplied the maraging steel made to size for each part.

Drawings were produced for fittings requiring forging. These were all hand forged by Ladish Co. from 200 KSI (pounds per square inch) maraging steel. Ladish was also contracted to supply the fully machined bow foil dihedral elements and the foilborne propeller components.

Pheonics Metal Spinning Co. supplied the formed skin components for the complex intersection pods. Pheonics and Ladish, located in Milwaukee, proved to be remarkable companies. They were a pleasure to work with. Mr. Brown, the 80 year old C.E.O. of Ladish gave me a personal tour of the huge plant on his golf cart. He seemed to know every employee.

The bow foil was mounted on a 12’ long, 17" diameter hollow shaft machined from a 32,000 lb solid steel forging. The bottom end of the shaft was tapered to mate with the bore at the top end of the bow foil. This bow foil fitting was made from an 8,000 lb hand forged billet of maraging steel. A 2-1/4" bolt with an extension to the top of the mount shaft secured the bow foil.

The lower bow foil mount bearing presented a major challenge. It had to provide for bow foil steering, fore and aft trim, shaft deflections and very high loads in all directions. Teflon-coated fabric bonded to the centre bobbin was selected as a low friction surface material. Large surface areas were required to carry the dynamic design loads. The centre uniball bobbin had a 17" internal diameter and had 2 radil spherical surfaces around a common centre with area tailored to carry the loads. Three major components comprised the bearing; the centre uniball bobbin and the upper and lower housing made from large aluminum forgings. These components were bolted together to form a subassembly with an integral tongue for multiple bolt attachment to the hull. A flexible rubber boot sealed the bow foil to the hull.

De Havilland did not have the capacity to manufacture all the foil elements on schedule. After competitive bidding, a contract was awarded to North American Aviation, which is located adjacent to Los Angeles Airport. This contract required that all materials be supplied by De Havilland.

As a member of the liaison team, I made many visits to Los Angeles. North American Aviation had just completed the design and manufacture of the XB70 supersonic bomber. On one occasion, we were privileged to be flown to Edwards Air Force Base to view this new plane.

As part of their proposal, North American Aviation had produced exploded view drawings of each foil element which illustrated every part in accurate isometric detail. This demonstrated their complete understanding of the drawings. North American Aviation was contracted to manufacture the bow foil (Ladish provided machined dihedral elements to N.A.A.), main anhedral foils, anhedral tips and the main foil right hand strut. They carried out a pre-assembly of the bow foil and mount shaft and trial fitted the anhedreal tips to the main anhedral foil, complete with linkage mechanism and mock up actuator.

Barry Davis adn I had the responsibility of signing for the units at North American Aviation after receiving the De Havilland inspection reports. Our understanding was that both signatures were required for acceptance. Barry was not sure that the tips were acceptable and we agreed that, because of Barry's tight schedule, he would sign and that my signature would be withheld until a final decision was made. North American acted on Barry's signature and shipped the units to Sorel, Quebec, where the ship was being assembled.

It was my unenviable task to inform Harry Beffort (ex Avro), our feisty productions manager, that the tips would have to go to D.H.C. Downsview for rework. Harry was visibly angry and rewarded me by calling me a "screwball and a junior screwball at that". I guess he had second thoughts about the situation because later that evening, at one of our social gatherings, he patted me on the back and said, "How are you doing Tom?" Ultimately, in my opinion, the tips turned into a success story. The technology developed had the potential for future applications (Anhedral Tip Story) ref. Peter Tomblin.

My first trip to Sorel was like going to the end of the world, after my frequent California trips. Dick Decker and I flew to Montreal, where we were met by Larry, the driver, who was hired to shuttle personnel between Dorval and Sorel, a 40 mile trip. Larry's fast, exciting, driving on that cold, rainy, windy day kept us on the edge of our seats. Our adrenaline and anxiety was not relieved by our short stop for a beer en-route. In Sorel, we parked in front of a 'prehistoric' multi-storied wooden building called Hotel Sorel. My dingy room was above the Marine Cabaret, which was in full swing. The music and loud voices were augmented by the hissing of steam heating pipes and the banging of the radiators. Street brawls erupted when the bar closed. To add to my discomfort, the individual in the adjoining room locked my entrance to our shared bathroom.

It wasn't long before our group moved into the new hotel "Auberge de la Rive" owned and operated by Pierre Cardin, the one time Minister of Defence under John Diefenbaker. The D.H.C. group formed a cohesive team which worked hard and played hard.

The task of assembling the bow foil and installing the main foil elements began. The four main foil elements were attached to the hull with 64 x 1-1/2" diameter Inconel 718 bolts. Marine Industries Limited employees had the task of torquing the bolts using a heavy torque multiplier with long arms while standing on scaffolding approximately 20' in the air. One evening a group of us was watching the operation when there was a thundering crash. To our horror the torque multiplier and arms fell and landed on the centre foil. Fortunately, the only damage consisted of a few fence studs broken off. The bolts were fitted with pre load indicating (P.L.I.) washers to ensure correct pre tension. The washers consisted of four rings. The centre ring was designed to crush and become tight when the correct pre load is reached. We estimated that 8,000 in pounds had been applied but the ring remained loose. Because we suspected that the washers were faulty, I was sent back to De Havilland to have the washer assembly checked. The Olson Tineous machine confirmed that the washers were good. It became obvious that the nuts had seized up on the bolts so that the bolts were winding up like torsion bars. I was concerned that we may have a serious problem, since D.H.C. had specified the material for the custom made bolts. I discussed the problem with the supplier, who suggested that we apply Molykote G on the threads. Their suggestion was relayed to the shipyard. Shortly after I received a call to say that the bolts were torquing up perfectly at about 2,000 lb.

Up until this point no serious engineering mistakes had occurred. I had been meticulous in checking the drawings and felt that my attention to detail had paid off. However, a potentially serious problem happened on the day we torqued up the bow foil bolt. The tapered bore of the 8 ton bow foil was mated to the 17" diameter mount shaft. A highly specialized 2-1/4" diameter bolt with a 12' extension, designed to reach to the top of the mount shaft, secured the bow foil in place. The installation drawing called for 40,000 lb torque. Marine Industries Limited (M.I.L.) had made a massive turret with 4 arms and equipped with a torque indicator. Four M.I.L. yard workers were stationed at the arms, on the narrow foredeck some 30' above the floor, and began their circular walk. When I noticed that the torque was not increasing, I asked the foreman to stop their efforts and returned to the office to phone D.H.C. stress office and request a check on the torque value. In my absence, the bolt had been rotated 4 more times with no torque increase and I knew we were in trouble. The return call from D.H.C. confirmed that the torque value was correct. Within a few hours, Larry provided another hair-raising ride to Dorval so that I could return to D.H.C. and personally pester the stress office person to recheck the torque figure. I knew that my concern had been valid when he came into my office and said that he needed to sit down. An extra zero had been added to the calculations, so the torque should have been 4,000 inch pounds, not 40,000. After removing the bolt, we found that had been stretched 5/16". A new bolt was made, the bow foil threads were checked and the bow foil was successfully secured.

While I was back at Downsview in July 1966, the ship was rolled out. Because the outboard transmissions and the anhedral tips were not installed, it looked rather stark.

News of the tragic fire in the engine room which damaged the hull reached me on November 5, 1966 while I was back working in Toronto. There was a great deal of uncertainty regarding the future of the project at that time. The project continued. When the damage was evaluated, I was made a member of Bill Billing's engineering team on hull repair. When I returned to Sorel after the repairs were completed, I faced a new challenge. The foreman in charge of foil and transmission had left the company and Bob Prout decided that I should be his replacement.

The skilled tool and die personnel were apprehensive of my ability to be a foreman, but we developed a good rapport and worked dilligently toward a common goal. An excellent job had been done to align the foilborne and displacement transmissions. Because we had no way to check the alignment of the displacement propeller hub to the gearbox, I designed a special tool for the job which was made back in Downsview. The alignment proved to be inaccurate so tapered rigns were made and installed to correct the problem. After many hours of operation Henry Sorensen, the representative of General Electric Company, congratulated us on the overall successful alignment. (another hurdle overcome).

The D.H.C. team in Sorel expanded to approximately 120 personnel which contributed to the local economy. We became a very dedicated, focused group which enjoyed interaction with our Quebec comrades.

As the ship neared completion, the army was called in to dismantle the building in which we had worked. During the operation, a soldier fell through the roof, landing on top of the bridge structure which only hurt his dignity. Had he missed the ship it would have been another story.

The foilborne transmission was still in work at General Electric, so the ship was to be transferred to Halifax on a barge without it. A decision was made to fill the four 35' long downshaft housings with oil. On the day before the ship was to be moved to the floating slave dock, Dave Kendrich and I were walking past the starboard main foils when a jet of oil came out of the bilge outlet onto the anhedral foil. Apparently, a missing plug allowed the oil to flow into the bilge. This severely damaged the paint finish. Marine Industry personnel worked all night to repair the damage and by morning it was back to normal.

The ship was transferred to the floating slave dock without a hitch. That night we had a big celebration. We awakened the next morning in time to see Bras d'Or start its journey to Halifax propelled by a large tug. We said our farewells to our many colleagues and friends and looked forward to some well-deserved rest before heading off to Halifax. On July 23, 1968 Bras d'Or was towed on the slave dock from the Naval Dockyard to the Halifax Shipyard for launching. She entered the massive floating dock which was raised to support the slave dock. The slave dock valves were opened to allow it to sink with the floating dock. Bras d'Or floated for the first time.

While the foilborne transmission continued to be tested at General Electric, I went back to Downsview during which time the displacement trials began. The foilborne transmission was delivered to the shipyard the last week of December 1968. I returned to Halifax and a group of us worked over New Years to install it.

After this installation, I returned to Downsview and anxiously awaited news of the first foilborne run.

A problem of oil flow at the hull side crown spline couplings was solved by adding baffles to deflect the flow around the coupling.

In April I received the long-awaited news of the first foilborne run. My total faith in the ship was confirmed. After receiving positive reports of the 63 knot run in July I was elated.

In the fall of 1969, I returned to Halifax to resume my position as a permanent member of the team. As problems developed in the foils and the transmissions, I continued to wear two hats as engineer and foreman.

The problem of greatest concern was unexplained cracking of the foils. Every time the ship was hauled, an engineer examined the complete foil system in order to detect cracks and document their location. In my opinion, all of the cracks were associated with welds, perhaps caused by the fact that the foil elements were not stress relieved. This process had been eliminated because of the fear that it would result in unacceptable distortion. (If the top speed of future ships is reduced, permitting thicker foil sections, a simple stress-relieved core with a moulded urethane surface could be developed to provide a perfect profile.) This moulding process was developed for the FHE 400 anhedral tips and was highly successful. (ref. Peter Tomblin).

Repair of the cracks was a lengthy process. First they had to be detected, then neoprene coating removed. The crack was ground out, rewelded and the coating replaced. Each time the ship was taken out of the water, wood frame and plastic sheds were built around the bow and main foils. The sheds were often subjected to storms. On one occasion the bow foil shed collapsed shortly after the workers were advised to leave.

Cracks in the main foil element necessitated its removal. After reevaluation, it was decided to manufacture a new one. A dummy foil was made and fitted so that displacement trials could continue.

About a year later, the new centre foil was fitted and I went to sea for the first time. On the way out of the harbour, I watched our progress on the television monitors. I left the monitors for a brief time while I walked forward in the ship. When I returned I saw, by the monitors, that we were foilborne. I had not detected any sensation of the take-off.

During my second trip, I recall the sensations experienced during the following and head sea trials. Climbing the back side of long following sea swells and gliding down the forward side as we overtook them at a relative speed of 10 knots was exhilarating. However, the shock of hitting the head sea swells at a relative speed of 80 knots was very alarming.

Prior to the second run, we had replaced a ring of bolts which attached the inboard portion of the foilborne downshaft to the outboard via face splines. We found that, although the original bolts lasted many hours of operation, their replacements lasted only 1-1/2 hours. It was concluded that the problem with the bolts was caused by bending, which was due to the deflection of the face spline couplings. Spacers were made and fitted and no further failures occurred.

After many hours of operation, grinding noises were reported to be emanating from the bow foil foundation bearing during trimming of the bow foil. This could only be caused by damage to the bonded woven teflon bearing surface. The bearing was removed and returned to the manufacturer for reapplication of the teflon. The bearing would have required further study for future similar applications.

After the Bermuda trip, the ship was hauled for foil inspection. At that time, John Oliver informed me that he had found what appeared to be a large crack in the centre foil leading edge. We cut the neoprene coating on the underside of the leading edge and released a seepage of water; a sure sign of a crack.

When the crack was ground out, it was found to extend almost two thirds of the foil span. Only two small bridges of uncracked weld remained along the crack. The intensity of the locked in weld stresses was exhibited when a loud bang was heard as one of the bridge welds cracked through while I was standing beside the foil. This was repeated shortly after when the other bridge cracked.

Once again the dummy centre foil was fitted. Before the repairs were completed, the contract was cancelled. Consequently, the ship that sits forlornly on the banks of the St. Lawrence River at the site of the Bernier Museum has the ugly dummy foil as one of its components.

Frank Williams and I were the last De Havilland employees to leave Bras d’Or. We had the responsibility of “mothballing” the ship and subsequently carrying out two annual inspections of the ship and boxed transmission. This was the last official contact I had with Bras d’Or, a project that dominated the most challenging and exciting twelve years of my forty-five year career to aircraft design.

In 1990 my wife and I travelled to Halifax to renew my friendship with some of my former colleagues. With the help of Barry Davis, our congenial host, we arranged to meet for dinner. Barry Davis, Mike Eames, John Oliver, Ralfe Lynas and Martyn Callow joined us. Some of their spouses accompanied them. We were overwhelmed by the emotional reminiscing which took place at that meeting. The Bras d'Or development obviously impacted significantly on their respective careers too.

After our reunion, we returned to Ontario via L'Islet-Sur-Mer.

At the Bernier Museum, we saw the forlorn F.H.E. 400. We were distressed to see that the anhedral tips were sinking into the sand on the banks of the St. Lawrence. There was very little information about the development of the Bras d'Or. Does Canada really undervalue its achievements?

Conclusions

The ship was designed and built by a dedicated and enthusiastic group of people. It was a good thing that none of us had any previous experience with hydrofoils or we would have been intimidated by the complexity of the project. We developed complete faith in the successful outcome which enabled us to overcome the challenges we faced.

The hydrodynamic design of the foils, intersection pods and foilborne propellers was superb and were completely devoid of cavitation damage.

The scope of the project was not appreciated by the public. The media reported the cost as the most significant aspect of the project. In my opinion, the cost was in keeping with the demands of the development. My engineering contact at North American Aviation who built many of the foil components compared Bras d'Or as the marine equivalent of the supersonic XB70 that North American had recently completed.

The major problem with Bras d'Or was undoubtedly cracking of the foil material. All cracks discovered were associated with welds of the 250 K.S.I. (kips per square inch) grade maraging steel. No cracks were found in the parent material or the 200 K.S.I. grade maraging steel forging.

The value of the anhedral tip development where uretheane was moulded on the inaccurage welded assemblies did not seem to be fully appreciated. I believe it was highly successful and could have been applied to future hydrofoils whereby a relatively simple stress-relieved metal core with a moulded surface could be developed. A small reduction in the 60 knot top speed requirement would have permitted a thicker foil section. A very accurate 6% thickness chord ratio foil profile may be better than a 5% T/C less accurate foil.

I had the pleasure of working with several excellent subcontractors. Republic Steel of Akron, Ohio produced all the maraging steel. Ladish of Milwaukee, Wisconsin produced all the maraging steel forgings, machined the bow foil dihedral elements and manufactured the beautiful foilborne propeller components. Phoenix Metal Spinning, also of Milwaukee, produced all the spun maraging steel components for the intersection pods. General Electric produced the foilborne and displacement transmissions. North American Aviation manufactured the bow foil (except for the dihedral foils), the main anhedral foils and tips and the right hand main strut. (It should be noted that unbalanced welds in the design of the anhedral tips contributed to the problems we experienced with the anhedral tip profile).

Bras d'Or met her performance requirements. All the development problems would have been resolved if a second ship had been contracted.

The recent Turbot incidents off the east coast could have made good use of ships like the Bras d'Or.