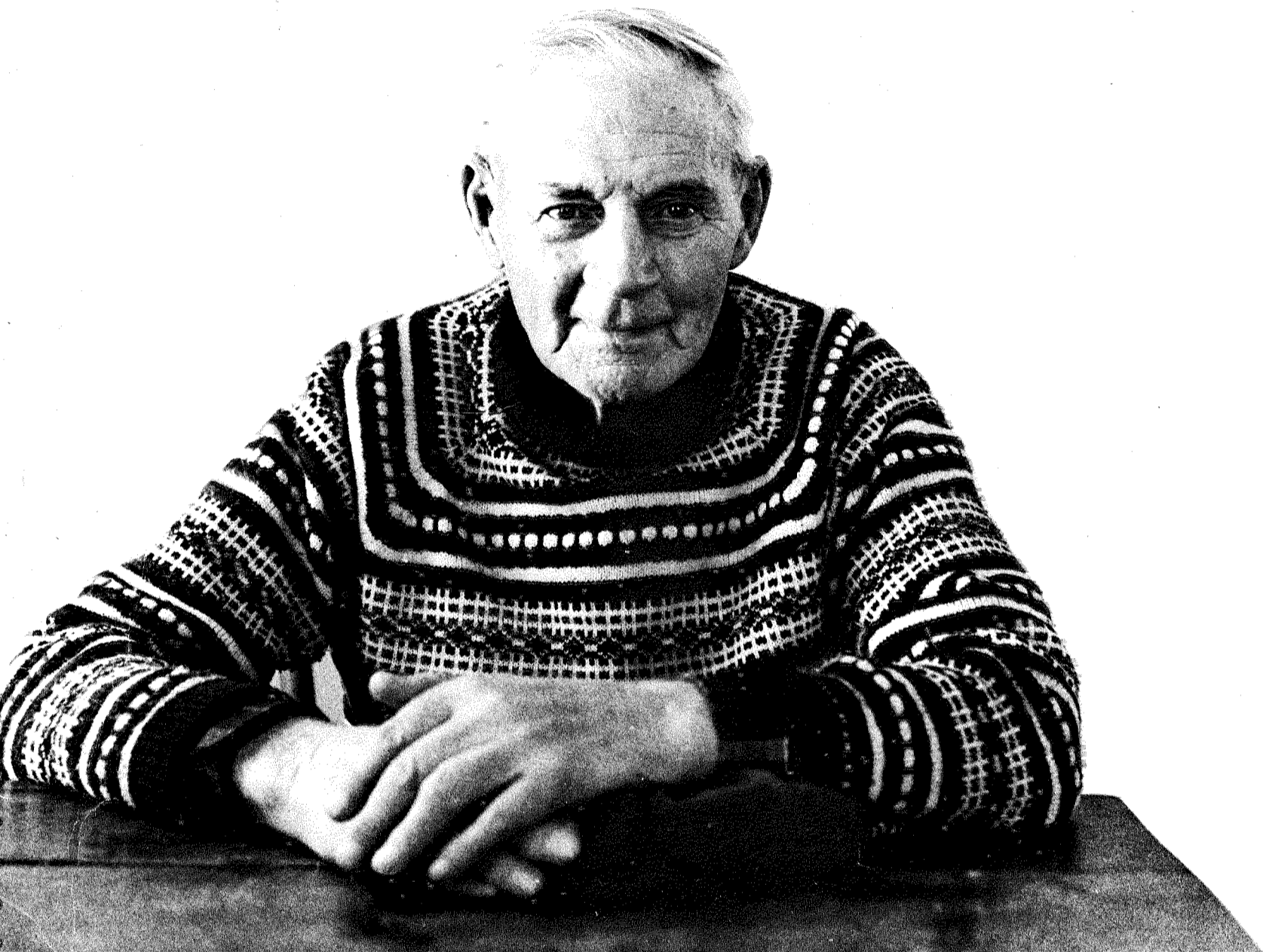


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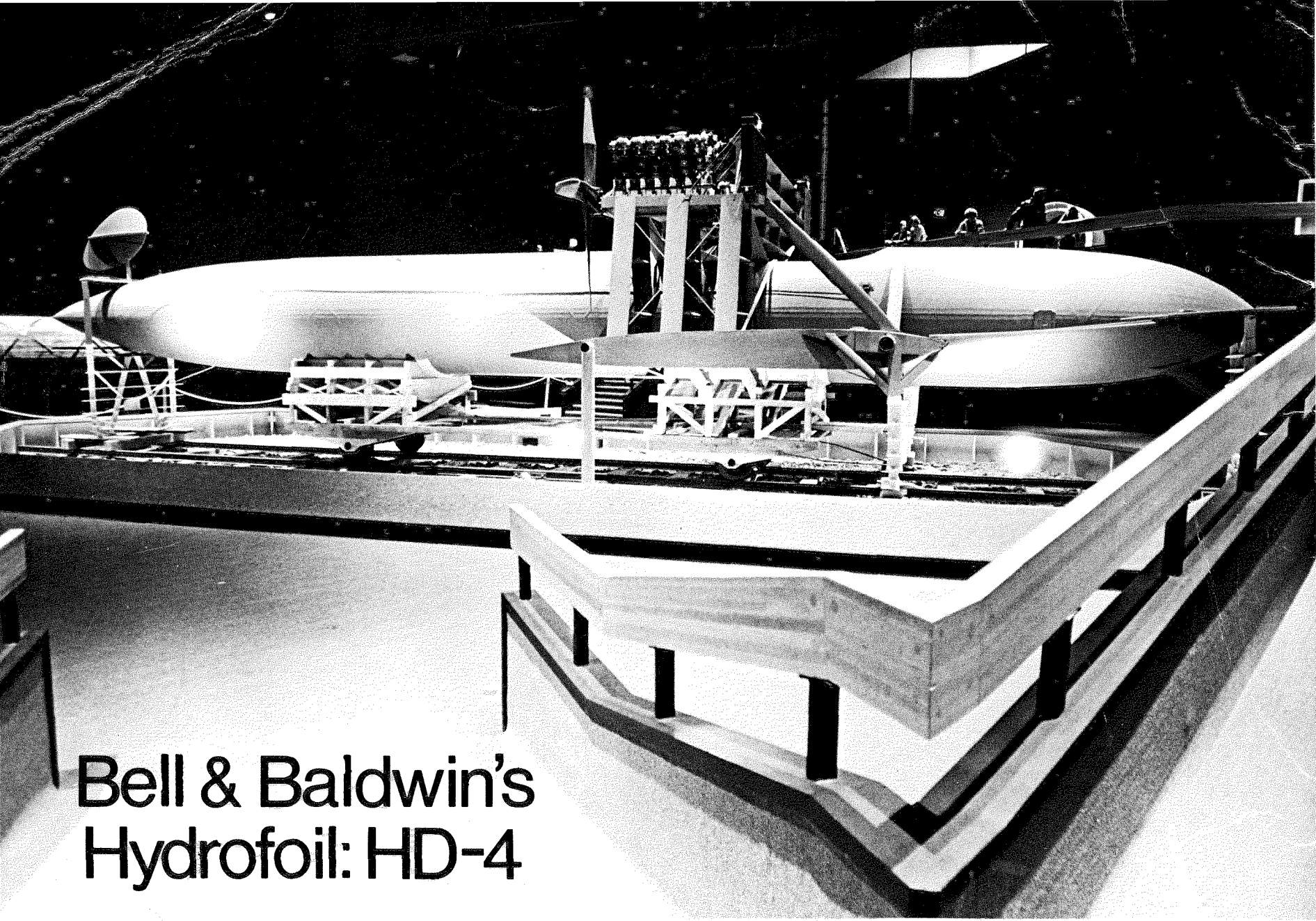
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Bell and Baldwin's Hydrofoil: the HD-4

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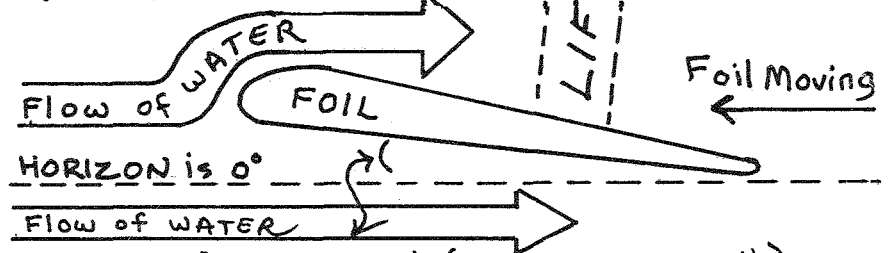
Bell & Baldwin's Hydrofoil: HD-4

Above is a full-size model of the HD-4, constructed and now on display at the Alexander Graham Bell National Historic Park in Baddeck. While the cigar-shaped craft itself is impressive, the important elements are the hydrofoils. The hydrofoils are the ladder-like sections under the craft (seen best in this photo under the stern--left). Once moving through water, the HD-4 would rise up out of the water and ride on these foils. The foils in water lifted the body of the HD-4 in the same way the wings of an airplane lift the airplane as it moves through the air.

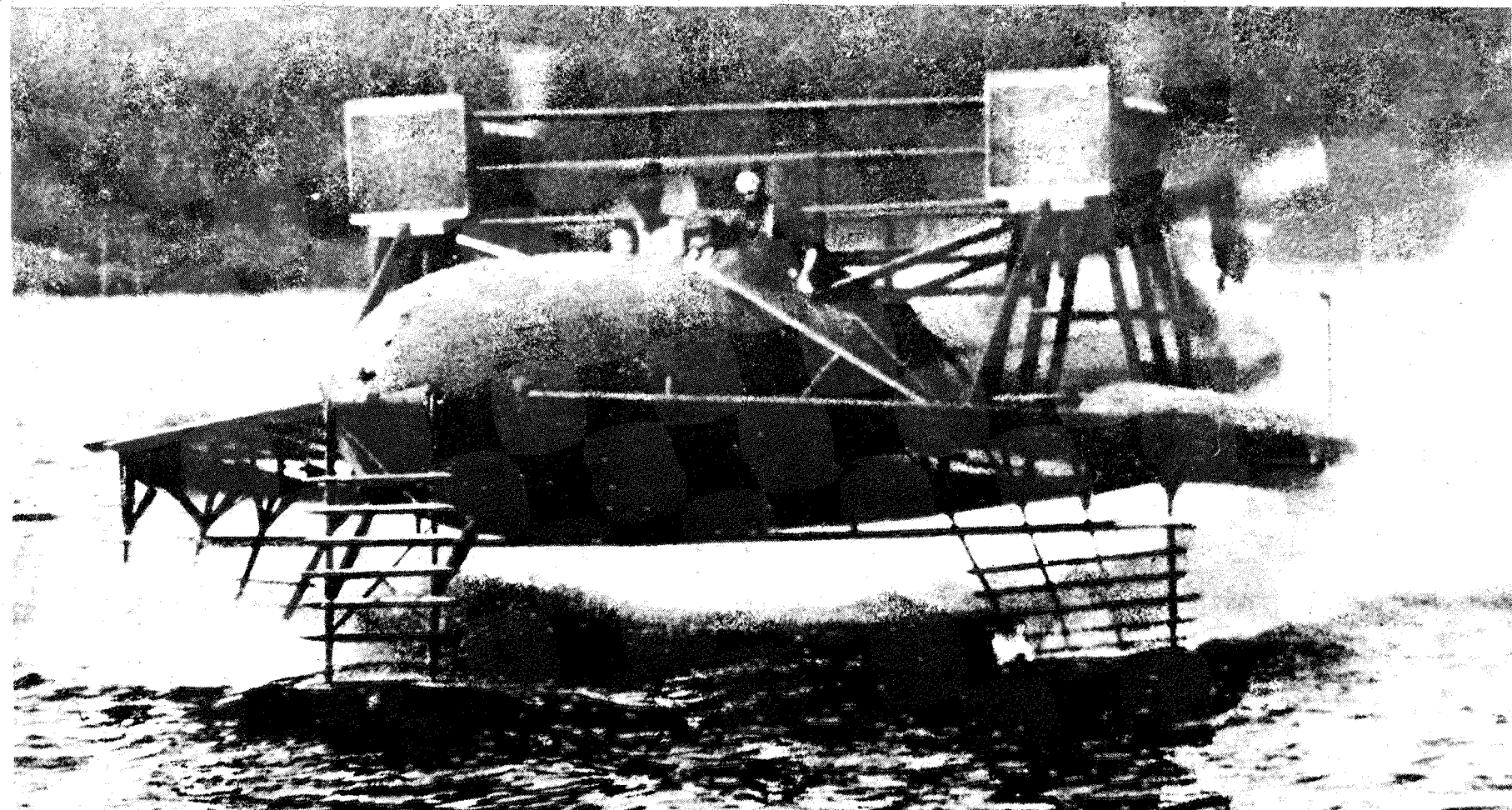
Elizabeth Quance, historian, Parks Canada: Bell first became interested in hydrofoils in 1906. At that time he was thinking mainly in terms of a boat which he could use as a hull for a tetrahedral aircraft. He was actively engaged in experiments with tetrahedral kites at that time. And that summer, Casey Baldwin, who was a friend of J. A. D. MacCurdy's, and who had just graduated from the University of Toronto in mechanical engineering, came down to Baddeck at MacCurdy's invitation and stayed with the Bells. Baldwin was very interested in the Bells' experiments and among other things they discussed the possibility of using hydrofoils on boat hulls.

If you have the boat hull, there are a number of different conformations of hydrofoil that you can attach to them. The ones Bell and Baldwin used were generally rows of hydrofoils arranged in steps (like a ladder). And as the boat moves through the water the lifting action on the hydrofoils is similar to the lifting action on an airplane wing: it is produced by the stream of water moving over the surfaces. And as the speed of the boat increases, the lift generated by the hydrofoils in-

THE FOIL MOVES THROUGH WATER. THE FLOW OF WATER CREATES AN AREA OF LOW PRESSURE ABOVE FOIL, AND THE FOIL RISES.



creases, so that the hull is actually lifted out of the water and the boat just rides on the foils. You can see this quite clearly in pictures of the HD-4, the hull of the HD-4 is entirely out of the water and the boat is riding on these foils. The foils remain in the water but as the boat moves the lift generated on the foils is proportional to the speed at which the boat is moving, among other things, so as the boat is moving some of the uppermost foils will themselves rise out of the water. So the boat is then riding on the lower foils--and the resistance is thereby reduced.



The original HD-4--weight over 10,000 pounds--underway and riding only on its foils.
(Photograph by Gilbert Grosvenor)

Ms. Quance continues:

Their original idea was to design an aircraft that would take off from the water. At that point the Aerial Experimental Association had already built three aircraft. First, Bell had built a giant kite--Cygnet I--with which they had experimented in December of 1907, and it had flown carrying a man, Thomas Selfridge. But then the kite came down into the water and because neither Selfridge nor the men in the tow-boat realized how close to the water it was, they didn't cut the towing line and the kite was destroyed. Bell had agreed that each member of the association should have a chance to design a plane. So after the kite was destroyed, they had moved the headquarters of the association to Hammondsport, N. Y., and built three planes there: the Red Wing and the White Wing and the June Bug, which won the Scientific American Trophy. And at that point Bell had gone back to Baddeck for the summer. And he asked Casey Baldwin to come back to Baddeck to work with him, because Bell was still very anxious to design a tetrahedral airplane. Those which the A.E.A. built in Hammondsport were bi-plane, a more conventional type of plane--and Bell was very anxious to put his ideas concerning a tetrahedral type of plane into a powered form. So they decided to work on the possibility of building an aircraft that would take off from the water and which would have a boat hull--and to facilitate take-off they wanted to design a hydrofoil boat. The idea would be that the boat would start off with aerial propellers and it would rise up on its hydrofoils and then it would take off from the water. They did some ex-

periments in 1908 and 1909. They built hydrofoil crafts but the projected tetrahedral airplane was never completed.

Experiments were still continuing in the spring of 1910--at which time the Bells decided to go on a world tour. Casey Baldwin and his wife accompanied them. And in the spring of 1911, after having travelled around the world, they were in Italy--and they went to see Forlanini's experiments on Lake Maggiore. You see, a lot of other people who were interested in aviation were also interested in hydrofoils. Bell and Baldwin rode on Forlanini's experimental craft and came back very enthusiastic about the idea--and they were now thinking of designing hydrofoil boats, not just designing an amphibious airplane.

HD stands for Hydrodrome. This was a parallel with the term aerodrome which Bell used to refer to aircraft. And HD-4 stands for the fourth in the series. When they built the HD-4, what they wanted was a craft that could be used as a sub-chaser--they had that in mind. They hoped either the British or American navy would purchase it. In its trials for the British Admiralty, the HD-4 set a world speed record for watercraft--and this is the period to which the full-size model has been constructed.

Arnold Roos, historian, Parks Canada: After the early experiments, Bell reduced his work with hydrofoils when Canada declared war, because he was a U. S. citizen and the U. S. was still neutral. Experi-

mentation never really stopped but it was greatly reduced. He did carry out some model experiments. HD-1 and -2 are basically the same with modification. HD-3 attained a speed of 50 m.p.h.--that's going fairly quickly. In 1917 when the U. S. declared war, he decided to go ahead with hydrofoil development. Casey talked about joining the navy. Bell talked him out of it. He told him he could do his war bit by producing a craft that could be used as a naval platform, as a gun platform. And Baldwin agreed. And from that point on all the design and construction was Baldwin's. Bell had a lot of input. But Bell never agreed with the HD-4 as the most viable entity for his concern. He always thought a hydroplane was not as susceptible to disablement as a hydrofoil. If you put obstructions in the way, the foils can be wiped out, as they found out with the HD-4 when they did the record run September 9th, 1919. They went across the bay here and they hit something and the main wood hydrofoil was carried away. They still did the record run, without the main hydrofoil--70.86 m.p.h. with a damaged HD-4--but they also learned that it was vulnerable. At another time they picked up seaweed and found that their speed was reduced by something like 20 m.p.h.--just seaweed on the foils themselves. So Bell always felt they should have gone to a hydroplane boat--an ordinary speedboat is a hydroplane--it planes across the top of the water--it uses the bottom surface of a foil, basically. Baldwin felt, on the other hand, that a hydroplane is only good in relatively smooth water; whereas with the hydrofoil, all that's below the water and on top of the water is the foils which just cut right through it. And the main body is above the waves.

(If the hydrofoils are really the whole story here, why did the craft have this peculiar cigar-like shape?) Well, it's based on the zeppelin. That's the whole concept. Because they looked upon this as the zeppelin of the ocean. The airship of



Dr. Bell and Casey Baldwin side by side in the cockpit of the HD-4.

the ocean. See, Bell said to Baldwin, why don't you produce a design that would also be good for progression through water? And Baldwin felt its time in the water was a necessary evil. He wanted it out of the water as quickly as possible, after which it becomes basically an airship. And you want the shape that is most aerodynamically sound. And at that time the shape was most aerodynamically sound was the zeppelin, more or less bullet-shaped. It offers least wind resistance--he wasn't too concerned with water resistance--he intended for the foils to lift it quickly up out of the water--so he was concerned with wind resistance.

So in 1917 they decided to go ahead and build the thing. They built a 17-foot model first of all, basically on Bell's insistence that you should always try something out with models. It was never powered; it was pulled behind a boat. They found out it worked very well and, I think, in December of 1917 they decided to go ahead with construction. In the next 3 or 4 months they completely constructed the HD-4. They did 54 m.p.h. in that season with Renault engines and they wrote a report. With the report, Bell did some politicking

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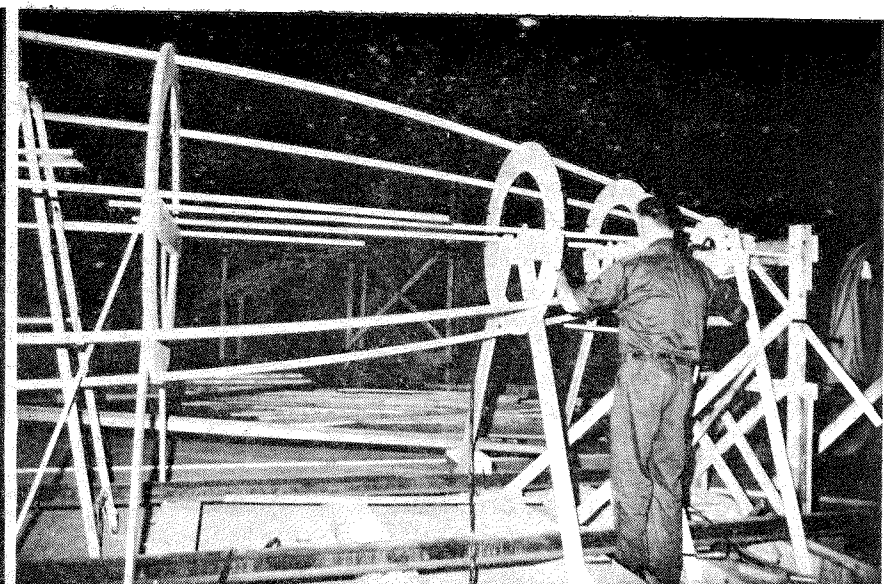
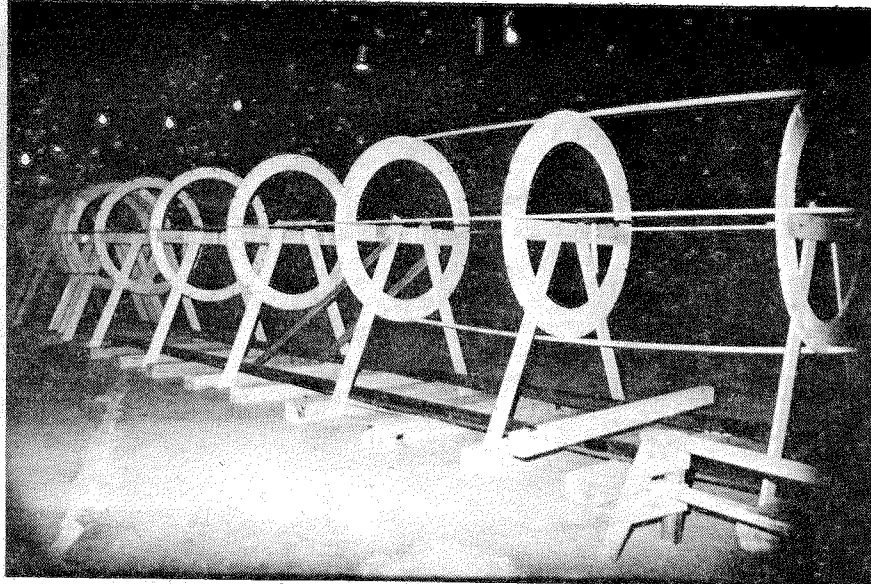
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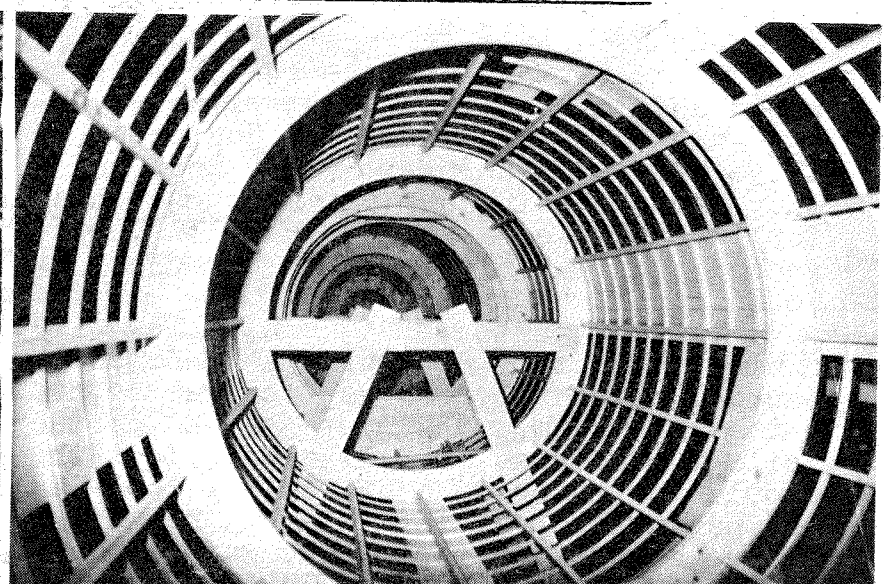
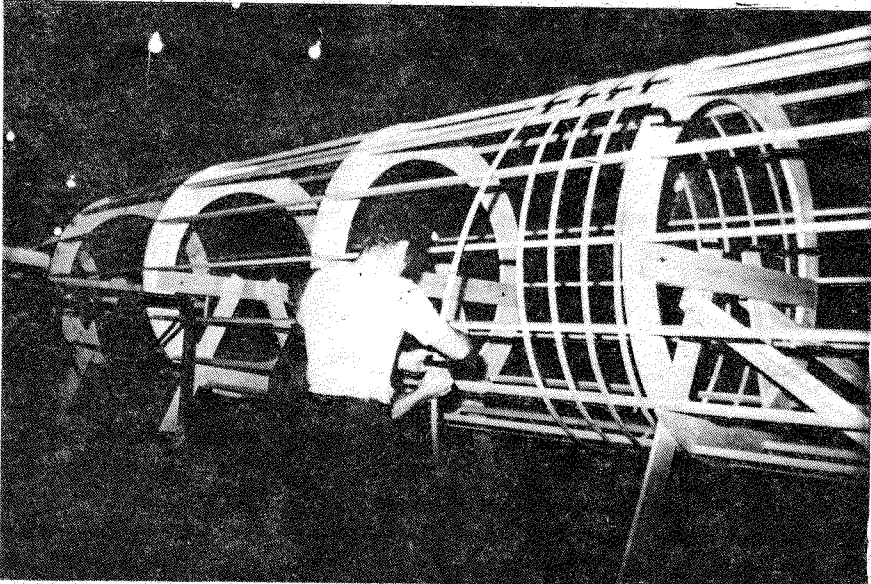
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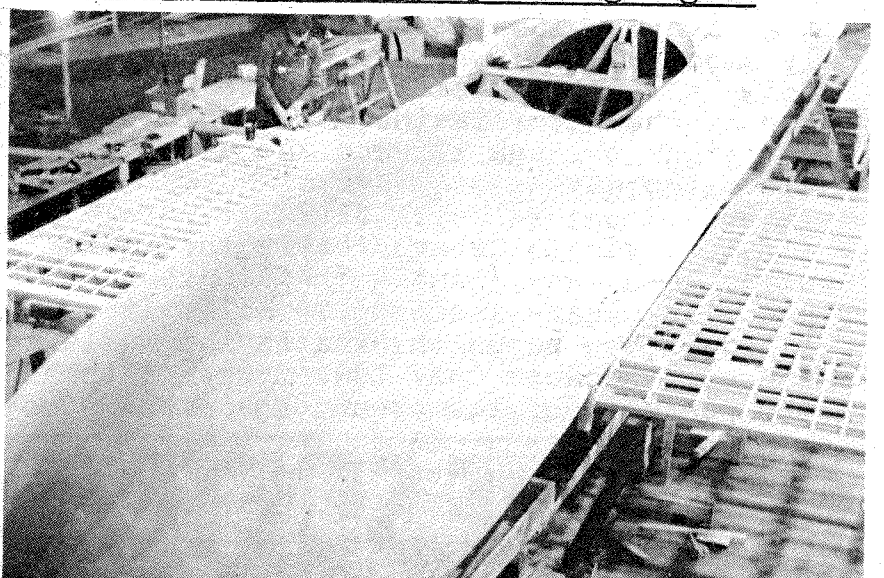
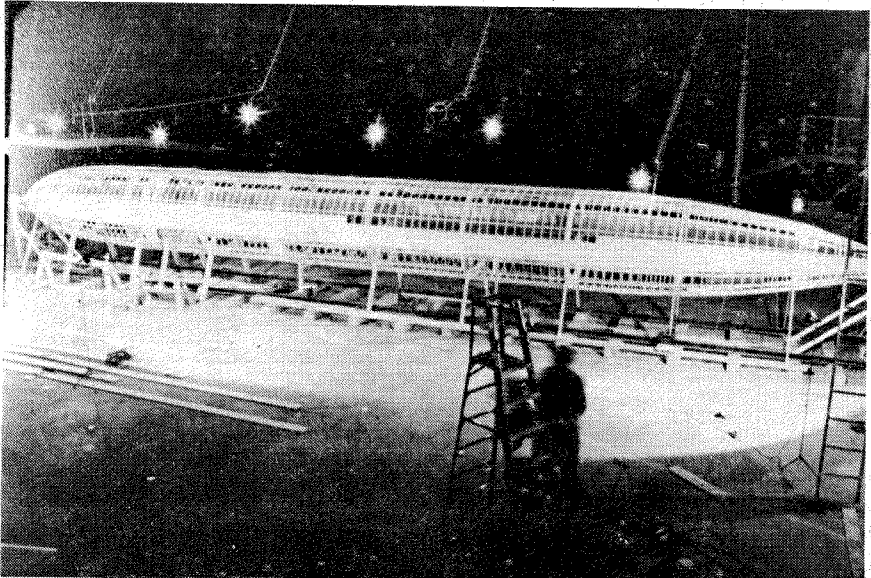




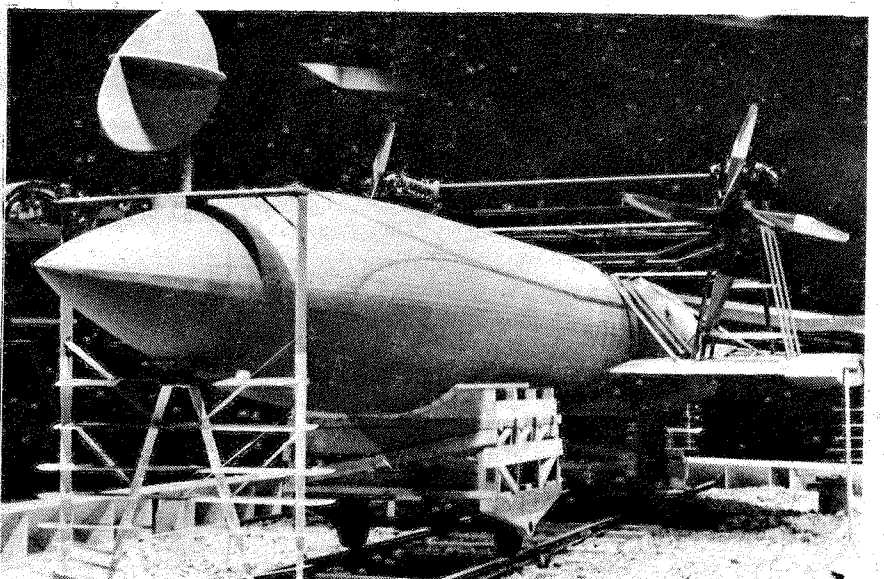
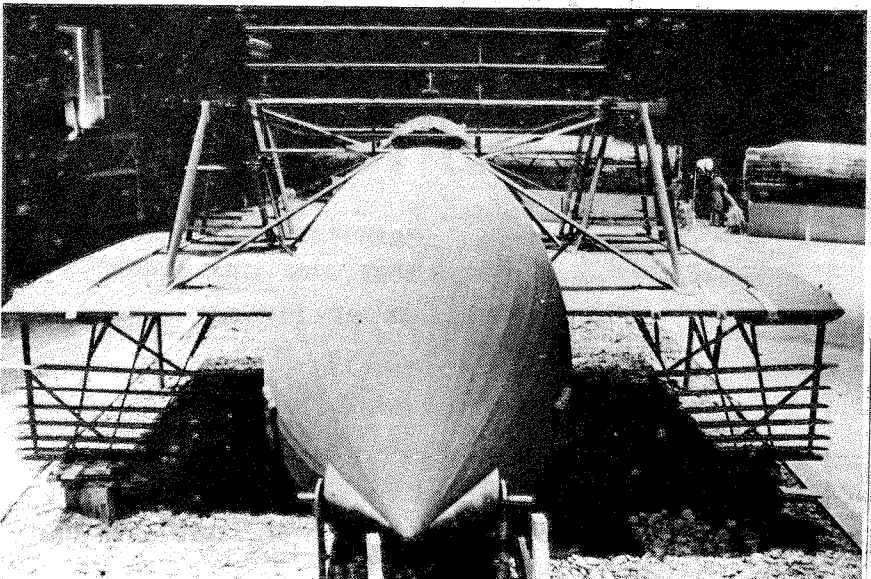
Main hull frames lined up and the first longitudinal ribs in place.



Spiral ribbing being placed on craft; interior view with outer planking begun.



Exterior view of main hull with planking underway; once planked, hull covered in canvas; note the cockpit opening and sponsons at sides under construction.



View from front with foils in place beneath sponsons; finished view from the rear, showing the rudder foil set, the air rudder and propeller.

← Some Steps in Building the New HD-4

in Washington and through friends they got Liberty engines. They put the engines on and they added one extra air foil up top--above the cockpit, the air foils that go between the engine beds--that's called the Phillip's Blind--they added one more foil to that. And there are absolutely no pictures for that period between the receipt of the Liberty engines and the record-breaking run. You see, they didn't expect to break the speed record. Because as soon as they put the Liberty engines on, they encountered a lot of trouble. They couldn't get even up to the 54 m.p.h. they attained with Renault engines. They talked about changing the bottom foil--did change it eventually--but on September 9th, 1919, they hit something and carried away the main foil. The water was extremely smooth and they decided to do the run in any case because they were having good success that morning on the 1/4-mile course. They did the mile course and did 70.86 m.p.h.--broke the world speed record. Shortly after that they lowered the engine beds--and that's where you get all the pictures taken.

So my problem (in preparing diagrams for construction of an HD-4) was to dig up all the photographs, go through Bell's Home Notes, take a look at the as-found drawings of the original artifacts--and try to get out some sort of picture of what it actually was. I worked along with the engineer, who did the same thing--Alex Barber--we sat down together and came up with what one cannot get from as-found drawings, etc.--what was uncertain--and the design was brought out.

The whole interior was no problem--it's really cross-bracing and frames and bulkheads--you can see that on the original artifacts. The difficult area was the instrumentation and the engine systems that had to go into the cockpit, had to be con-

trolled from the cockpit. You can trace the wires going into the cockpit to certain points--but after that you have to go to witness marks that are on the cockpit to figure out what instrumentation was there. Engineers knew what kind of systems had to be controlled from the cockpit--a certain amount of photos show some instrumentation--like a voltage regulator. So the design, while not exact, is as close as we can come.

But so many parts of the original artifact are missing. We have about 110 photos of the HD-4--over half of which are moving so they don't give that much detail. Some close-up pictures do give enough detail so that scale can be done--like for the foil sets--very little was left of the original foil set-ups, but enough so that we could check against the photos. There are diagrams but they are basically rough sketches in a notebook that Baldwin left behind. The foils were made to swing back and forth, so you can change your angle of incidence, that is your angle of attack to the water. They wanted to find out the best angle that would give them the greatest speed. So they started at 8 degrees positive and slowly moved back and found that they'd get their best speed at 1 1/2 degrees positive. The water line is 0. You go to 1 1/2 positive from that. That's the set of the record run. That is, you raise the leading edge of the foil just 1 1/2 degrees from 0. 1 1/2 degrees above waterline. Every foil is set at the same angle to the horizon, and it's the foils moving through the water that gave the lift. Also, the HD-4 itself ran at about 1 1/2 degrees positive. Therefore if you set your foils at 1 1/2 degrees positive and then increase your flying angle--your foils would really be attacking the water at 3 degrees positive. That's the set we've built to, the set of the record run.

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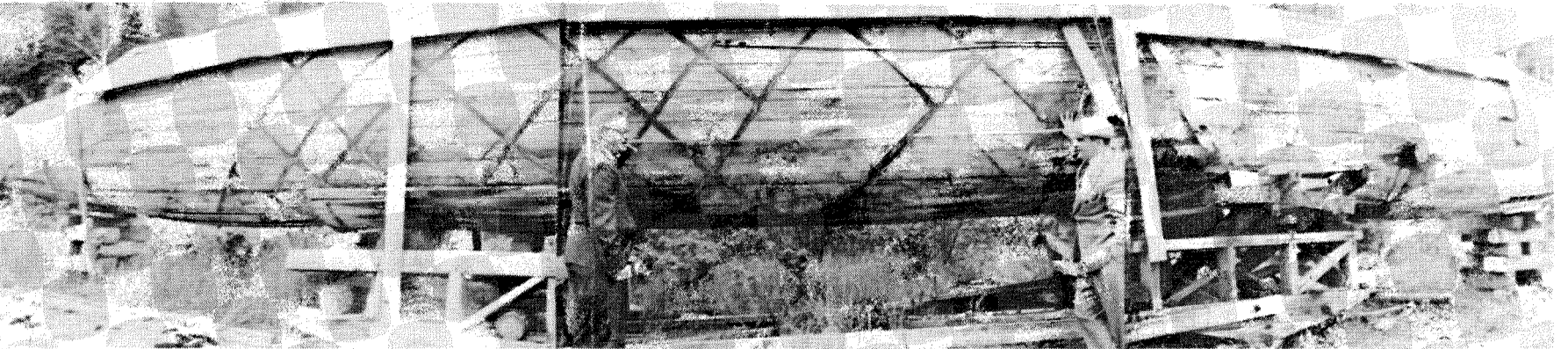
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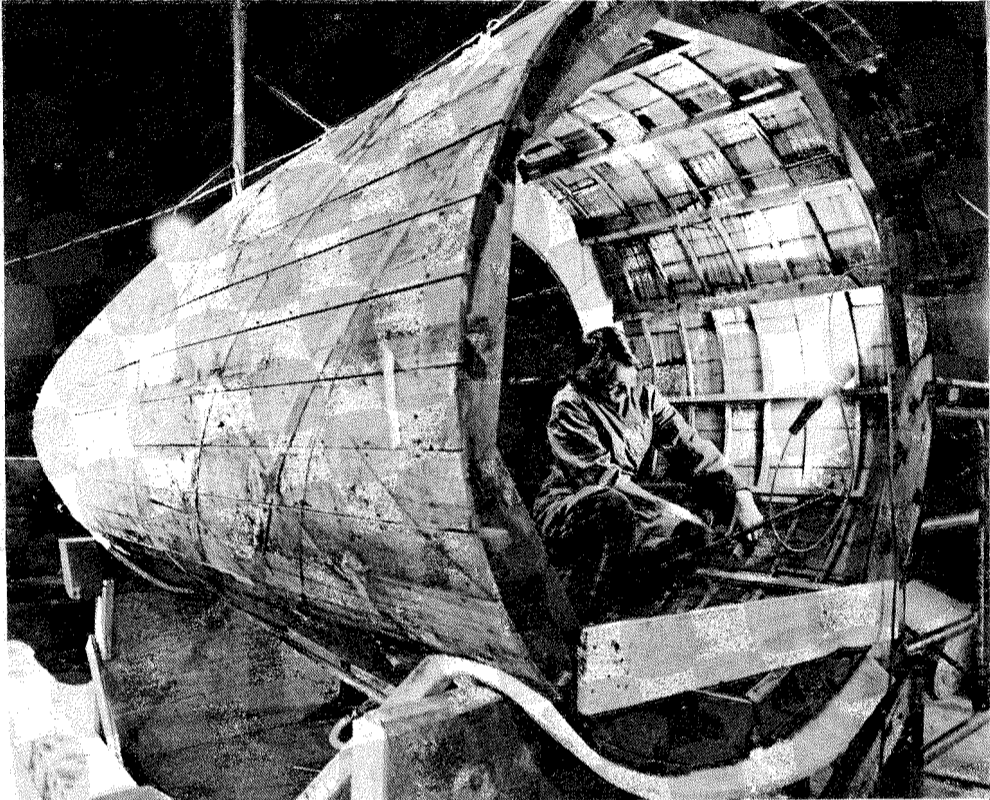
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The Remains of the Original HD-4

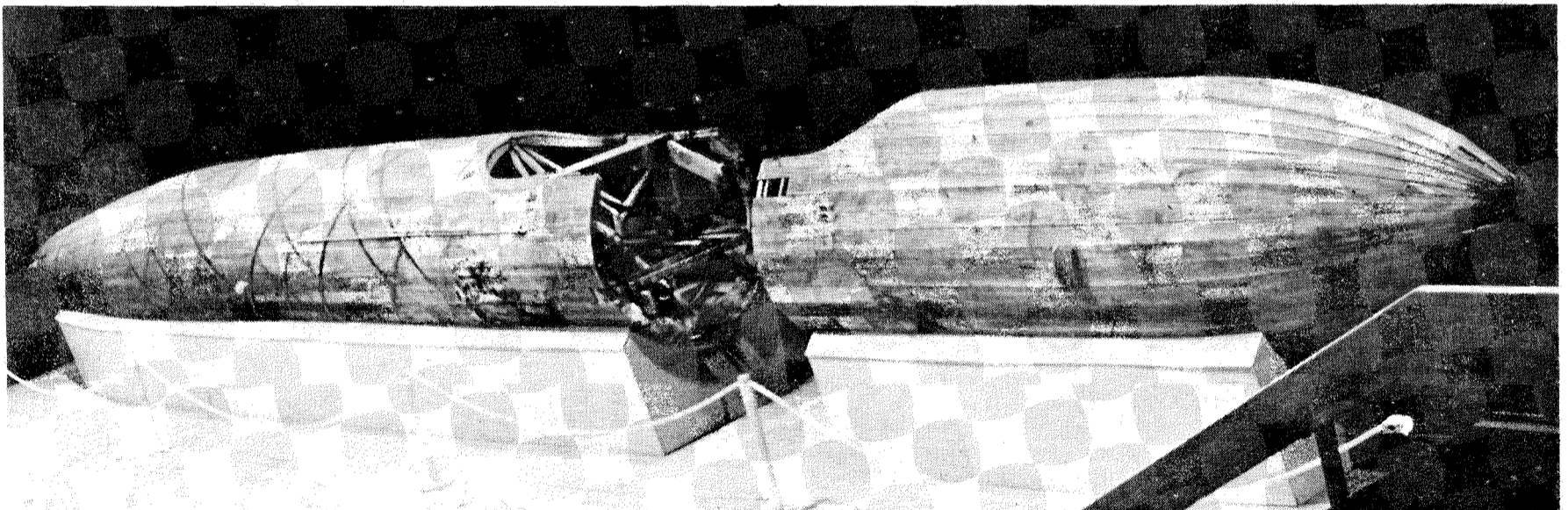


The hull of the HD-4 prepared for the move from the beach to the A. G. Bell Museum.

The work of conservation on the remains of the original HD-4 (carried out principally by Susan Mahoney and Kryisia Spirydowicz of Parks Canada), was intended to stabilize what was left of the craft, rather than make it look new again. Bell and Baldwin had no intention of conserving the HD-4. It was really just a full-scale model, and once thoroughly tested they were through with it. It was beached at Beinn Bhreagh in 1921 and was not moved to the museum grounds until 1956. In the meantime, children had played in it, birds had nested in it, and people had ripped off pieces to build bonfires. The work of stabilizing the HD-4 included structural repairs where really necessary, cleaning it and painting it with a colourless protective resin, injecting glue into parts that were extremely soft, and taking out the nails, inserting dowels and nailing again through the original holes. The conserved hull of the HD-4 is displayed in Hydrofoil Hall in such a way as to take advantage of the fact that someone had cut the original into sections; it is displayed in a way that permits the public to walk between the sections and see the



interior of the craft. The photos here include the HD-4 prepared for moving in 1956, conservation work underway and the display.



Our thanks to the staff and guides of the Alexander Graham Bell National Historic Park serving in the summer of 1978, for their generous assistance in preparing this article. They supplied nearly all the photographs used here. The back cover and centre photo above are by Owen Fitzgerald. And thanks to Ray Martheleur, Sydney, for special photographic lab work.

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Dr. Melville Grosvenor, Beinn Bhreagh:

When I rode on her, it was the summer of 1920. I was up here on vacation from the naval academy and I was 20 that summer. But I saw her develop from the beginning--all the little models. She was number 4. There were 3 other hydrodromes before her. And before that there was "Dhonnas Beag" and "Jumping Jack." "Jumping Jack"--they would jump out of the water, the models, jump and dive, jump and dive--but he wasn't able to get it so it was steady. That was where he developed the reefing, which means he put the ladderlike foils on an angle, so there would be continuous lift. Before that, it'd be like steps in a ladder and as soon as one foil came out (of the water) she'd either jump or dive. But when he had it reefed, as they called it, tilted, there was never a break in the lift of these foils. You'll see in the pictures how they are tilted so that these foils or planes always overlapped (some portion of a plane was always in the water) and that got rid of the jumping jack effect. You see, the HD-4 didn't come just overnight. They had years of towing experiments. Then all the knowledge gained, Casey and he put it into the HD-4--and that was a success from the beginning.

Believe it or not, Grampy could not be inveigled to ride on his HD-4, not for anything. He wouldn't think of riding on it. I thought he was a great sissy because he wouldn't ride in it. I was disappointed in my grandfather. Until, just recently. I'm now a year older than he was when he died--and I can well understand why he wouldn't want to get out there and hang onto those struts and be thrown around. He couldn't do it, physically. My grandmother was 10 years younger. She tried to get him to ride it. But he wouldn't do it. But my grandmother did. She went for a ride with Casey Baldwin and came back to the dock, and the pictures tell the story right in the museum. There's one of him standing on the end of the dock with papers in his hand, his cap on, hunched down, watching the HD-4 out on the lake. Well, my grandmother was steering it at that time and he knew that and he was worried sick. Then she came around and Casey took over and she landed at the dock. And he came to her and he embraced her. He thought she'd been to the moon or something. And there's a picture of that.

She wrote him this letter, from the Home Notes, 1919, Armistice Day: "We roared out on the lake past Baddeck in a great circle, around Bone Island and Spectacle Island." Now, that's a very narrow passage between Bone Island and the shore--and I couldn't believe that they went through there but that's where they went, right around Spectacle Island--then out into the lake. "She rose so slowly that I had no sensation of rising. She went steady as a rock and kept on an even keel. She is so stiff and solid--impossible to feel the least tiny sen-



sation of fear. When the engines were slowed, there was no jerkiness or feeling of coming down hard. From Spectacle Island I steered the boat almost to the wharf. The really remarkable thing to me was the feeling of perfect confidence she inspired. MGB" (Mabel)

That was 1919, really the first summer they were testing it. She was trying to build up his confidence, but she couldn't do it. I went out the next year. And today, I can see why he'd be cautious. I'm 76 today and he was about 73 then. (But do you think if the HD-4 were put on the water today, do you think you'd go for a ride?) Hell, yes. Greatest thrill I ever had. So level. We went out toward Spectacle Island, went out in the lake--then they started making these sharp turns to see what she'd do. Would she keel over or skid or anything--and she was steady as a rock. She did heel just the slightest bit, but the centrifugal force was terrific--you'd have to hold on because she'd make a tight turn. Then there was quite a sea running out here--south wind--you wouldn't feel it at all, maybe a little vibration. (And noise?) Oh, terrific roar. Two big Liberty engines up in the air, right at my ear. It was absolutely thrilling, going express train speed--because 70 m.p.h. is damned fast when you're on the land in a vehicle--but we were exposed to the wind and everything.

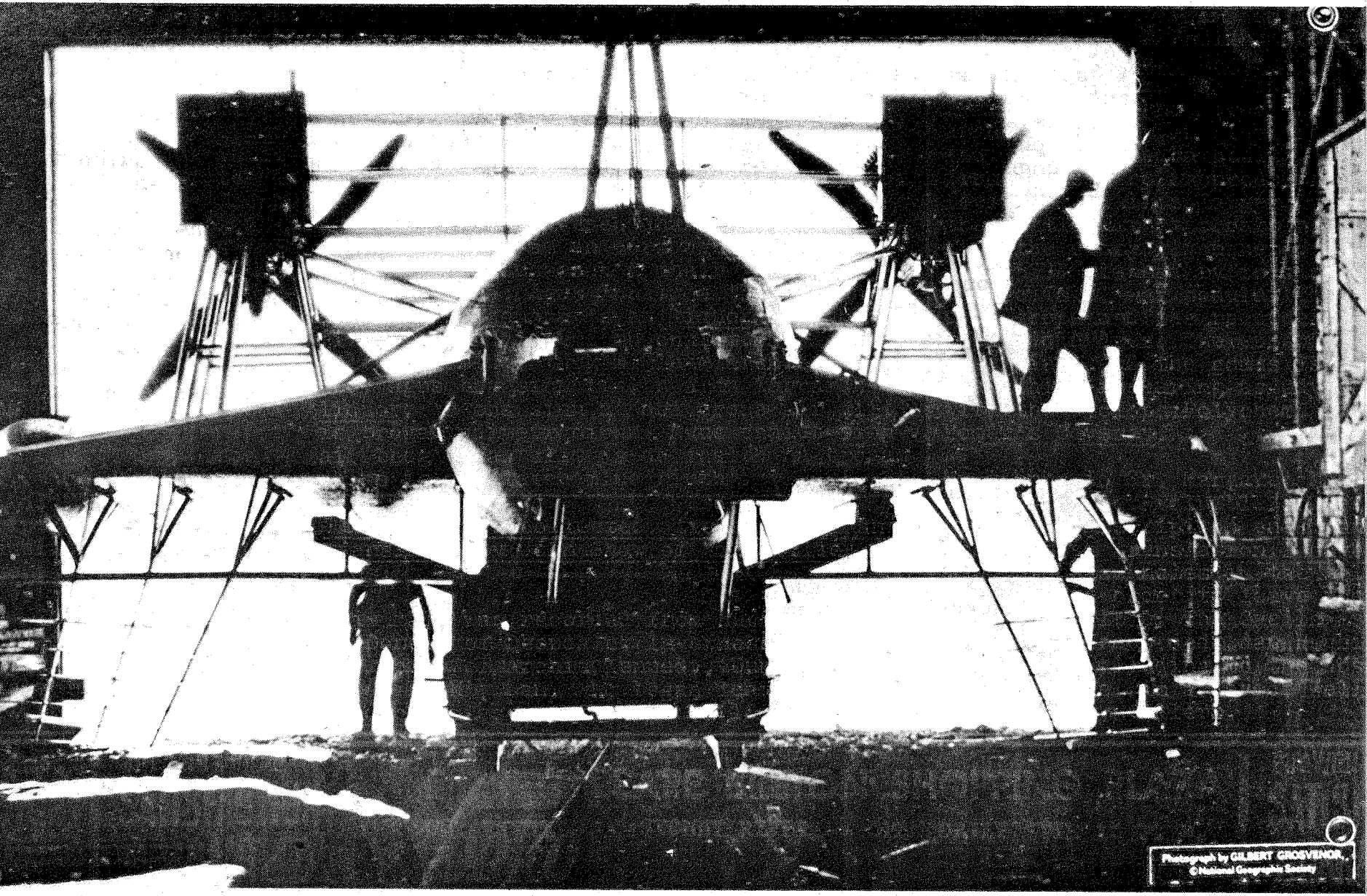
That same time, the navy sent up a four-man team made up of a rear admiral, and a captain and two commanders, to inspect and test this HD-4 as a possible submarine

chaser. They put it through every kind of a test. First was whether they could pick up the sound under the water. They had a hydrophone in the water on the end of the dock--and they couldn't pick it up. See, they only had the 2 or 3 bottom foils in the water and they were very small. They couldn't pick up the sound of the engines because they were up in the air. They figured if she was going full speed a submarine couldn't pick her up from underwater. Then they tested her stopping dead and going suddenly full speed--and the length of time it would take for her to rise and get going. It was terrific. She'd get up on her foils and just take off as soon as she got her hull above the water. Then they'd stop her. And all the time they'd be listening under the water, whether a submarine could hear her approaches. And they had a submarine out here, Canadian submarine and several destroyers--in deep water in the lake--and they were trying to pick up the submarine on the hydrophone, and they did--but they couldn't pick up the HD-4. As I remember, they proved they could sneak up on a submarine without being heard. She could stop and start without being heard. Then they tried loading her down with pig lead and she picked it right up. And that impressed them. But mainly they were impressed by the fact that they couldn't pick her up under water.

Well this board went back to Washington and gave a very glowing account. We know

they did because they were very enthusiastic. And my grandfather was so pleased, he thought they'd get some backing. 10,000 was what he thought he needed to carry on this work. Up to now he'd done it at his own expense; he'd sell his telephone stock to pay for it. I mean, he couldn't support that laboratory of 30 men and more indefinitely on his income from the dividends of his stock. So he'd sell and he'd keep selling to pay for his experiments. So he tried to get government money.

Well, he never heard a word from them till the day he died. He never heard a word of even thanks for all the trouble, although he put them up here in the house for a week or so. Casey would be down in Washington, trying to find out from the navy department, what do they think of it, what's the report. Just recently friends located this report and the way it came to me is that it had gone up through everybody, all favourable. Went right to the top--C.N.O.--Chief of Naval Operations. This is what's been told me; I haven't seen it with my own eyes so I can only tell you what I've heard. He wrote, "An old man's toy. An airplane that won't fly. And it's worthless." Put his initials on it and sent it back. Well, the underlings wouldn't touch it from then on. Just that one admiral stopped it. Amazing. And grandfather died disappointed, because he never knew. It was a shame.



Photograph by GILBERT GROSVENOR.
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