Title
Scientific Bibliography on Human Powered Submarines, through 1997

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This scientific bibliography on human-powered submarines aims to list references containing some level of technical information. The references are listed in reverse chronological order.

1997

World Submarine Invitational 1997
Hardy, Kevin. Fish, Susan.
Sea Technology. v 38 n 6 June 1997. p 51-53
ABSTRACT: Human powered submarine racing has returned to the Atlantic waters off South Florida with the successful running of the World Submarine Invitational 97 (WSI 97). The proof-of-concept event held from May 2-4, 1997 was organized by the Florida Atlantic University's Dept. of Ocean Engineering (FAU-OE). The prototype event was limited to four invited entries in order to test and refine the format of a new open ocean race. In one event, teams launch and recover their own subs which are then moved to a starting buoy. After the go signal, the submarines accelerate out following a bottom guideline leading 500 ft. offshore to a turn buoy. The pilots steer around the outside of the buoy and return to the starting buoy where the timing clock is stopped.

New world speed record set by human-powered submarine.
International Underwater Systems Design, [London], vol. 19, no. 5, pp. 12-13; 1997
ABSTRACT: A streamlined submersible powered by a young Canadian ocean engineer streaked into the underwater spotlight in June, setting new world speed records in the 5th International Submarine Races and pushing back the frontiers of human-powered vehicle performance.

1996

4th International Human-Powered Submarine Races
Bland-Steven-A
IN: Oceans-Conference-Record-(IEEE).volume 1, 1996. p 265-271
Proceedings of the 1996 MTS/IEEE Oceans Conference. Fort Lauderdale, FL. Part 1 (of 3). IEEE, Piscataway, NJ, 1996
ABSTRACT: Describes the ISR'95, which was held in the David Taylor Model Basin at the Carderock facility in Bethesda, Maryland.

SubMaroon: A student experience in submarine design and racing
Ellis, Michael S. Ambrose, Billy D. Randall, Robert E.
IN: Oceans Conference Record (IEEE). v 1 1996. IEEE, Piscataway, NJ, USA, p 257-264.
Proceedings of the 1996 MTS/IEEE Oceans Conference. Part 1 (of 3). Fort Lauderdale, FL, USA.
ABSTRACT: The design, construction and performance of SubMaroon is described. SubMaroon is a two person human powered submarine that designed, constructed, and raced by ocean engineering students at Texas A&M University. It is a free flooded vessel with a life support for the divers provided by a standard SCUBA equipment. This was designed and built to be race in the 1996 World Submarine Invitational that took place in April of 1996. Video tape of the timed runs were used to analyzed the performance of the submarine for comparison with design expectations. Most repairs and adjustments were made underwater to minimized the removal of the submarine from the race basin.

Human-powered submarine races hosted by Scripps
Hardy, K
Sea Technology 37(6):45-48, June 1996
ABSTRACT: Describes the World Submarine Invitational '96 of April 1996 at the Offshore Model Basin in Escondido, California. Gives race results.

The Turtle dives again
Leary, J
American Heritage of Invention & Technology 11(4):19-26, 1996

ABSTRACT: Describes John Leary's building of a working replica of David Bushnell's Turtle, the first human-powered submarine.

Human-powered submarine races hosted by NSWC.
Burns, RE
Sea Technology 37(3):73-75, March 1996
ABSTRACT: Describes the International Submarine Race of Dec 1995 at the David Taylor towing basin of the Naval Surface Warfare Center. Gives race results and mentions contestants' range of vehicle lengths, diameters, weights, materials, etc.

The Human Powered Submarine Races.
Litowitz, L & J Hibberd
Ties, the Magazine of Design & Technology Education 0(0):11-13, January/February 1996.
ABSTRACT: Reviews experiences of Millersville State University's sub Hoagie II

1995
Human-powered submarine project to introduce students on marine engineering
Niemi, EE Jr.
IN: Investing in the Future. ASEE Annual Conference Proceedings, Volume 1, 1995. Anaheim, CA, June 25-28, 1995. American Society for Engineering Education, Washington, DC, p 421-424.
ABSTRACT: Students entering mechanical engineering programs often have as their main interest marine engineering, automotive engineering, or aeronautical engineering. This is often the case if geographical or financial considerations prohibit them from attending a school that offers an engineering program more specific to their taste. A way of introducing engineering students to these other program options is via a Capstone design project course. This paper presents one instance in which a Capstone design project was used to introduce mechanical engineering students to some aspects of marine engineering. The topic selected was the human-powered submarine project.

An efficient swimming machine
Triantafyllou, MS & Triantafyllou, GS
Scientific American 272(3):64-70, March 1995
ABSTRACT: Instinctive control of vortices lets fish swim the way they do. Fish have evolved swimming capabilities far superior in many ways to what has been achieved by nautical science and technology. Fish achieve extraordinary propulsion efficiencies, acceleration and maneuverability. A robotic tuna was developed consisting of aluminum links connected by hinges. Six motors, external to the robot, supplied the power to mimic the undulatory swimming of a real tuna. Separate systems of pulleys and tendons transfer torque from each motor, while isolating the motion of the links. Findings suggest that a properly designed flapping foil with high efficiency and high thrust could be a very attractive propulsor for ships, motor yachts and underwater vehicles. A free-swimming RoboTuna will next be developed.

Design of an underwater data acquisition system for measuring submarine performance.
Guy, BM III; Srinivasan, AK
IN: Proceedings of the Twenty-Seventh Southeastern Symposium on System Theory. Starkville, MS, 12-14 March 1995. Los Alamitos, CA: IEEE Comput. Soc. Press, 1995. pages 221-5.
ABSTRACT: The paper details the design of a data acquisition system for evaluating blade and shaft designs of a propulsion system for a human powered submarine. The objectives of the design were to sample and store data representing several analog signals and the time of measurement, and to display velocity and shaft rpm for the submarine operator in real-time. The sampled parameters are then used to calculate the submarine's performance in terms of velocity, thrust shaft torque and rpm. Several parameters are displayed in real-time to aid the submarine operator with training. System design restrictions including size, power requirements, heat dissipation, data integrity, and others had to be considered. Since the data acquisition system is a completely portable system, it is possible to incorporate the system into other applications.

Monitoring human powered submarine performance using a data acquisition system with a custom display ASIC.
Guy, BM III
IN: Proceedings of the IEEE Southeastcon '95 Conference. Raleigh, NC, Mar 26-29 1995. pp 413-416. 1995.
ABSTRACT: This paper details the design of a data acquisition system for evaluating blade and shaft designs for a propulsion system of a human powered submarine. The objectives of the design were to sample and store data representing several analog signals and the times of measurement and display velocity and shaft rpm for the submarine operator in real-time. These sampled parameters were then used to calculate the submarine's performance in terms of velocity, thrust, shaft torque and rotations per minute. Several parameters were displayed in real-time to aid the submarine operator with training. To accomplish this, a custom ASIC was designed using VLSI and VHDL techniques to perform binary to decimal conversion. System design restrictions included size, power requirements, heat dissipation, and data integrity. Since the data acquisition system developed is a completely portable system, it will be possible to incorporate the system into other applications.

1994
Sea Beaver: Design, Construction, and Performance of a Human-Powered Submersible.
Child, M.S.; Cangahuala, L.A.
Marine Technology and SNAME News, vol. 31, no. 3, pp. 231-237; 1994
ABSTRACT: This paper reports on the history of the Massachusetts Institute of Technology's entry in the 2nd International Human-Powered Submarine Race. The design of this entry was an evolution of the MIT design (named Icarus) from the first competition, held in 1989. Anticipating an increase in competitive entries, the new MIT entry (hereafter referred to as Sea Beaver) was designed to be more reliable and faster than Icarus. Sea Beaver was designed with a maximum diameter four inches smaller than Icarus. This change in cross section forced a change from a rotary to linear pedaling mechanism. The linear pedal motion was transferred to the drive shaft through an innovative arrangement of pulleys and one-way hub bearings. This arrangement allowed the pedals to remain independent from one another, opening up the possibility to experiment with different pedaling cadences. The propeller was designed for efficiency and to minimize the possibility of entanglement with lines along the course. The steering system was arranged to take up the least volume inside the hull as possible. In addition to taking advantage of experience gained in the design of Icarus, the MIT team also made significant advances in construction techniques. The hull, propellers, and nose cones were all fabricated from molds built by team members. Compared with the Icarus construction history, Sea Beaver was completed in less time, at less cost, with more spare parts available during the competition. For the design and construction of the propulsion system, the Sea Beaver team received the 1991 Medal of Engineering Excellence from Popular Science Magazine.

Submersible human powered research cycle (SHARC).
Klementovich, Joseph; Shaw, Bradley; Franklin, Eric
UNH Tech 797 report. Advisor: G. Sedor. University of New Hampshire.
Document No.: NHU-T-94-001; Project No.: E/A-10
Additional Report No.: UNHMP-AR-SG-94-6; 1994. 59 pages.
ABSTRACT: A team of undergraduates designed, built, and tested a training and test platform for evaluating and training prospective crew members for the International Human Powered Submarine races. The system measures the heart rate of a scuba diver who pedals it, the RPMs the diver achieves, and the air consumed. Data are sent to a personal computer for display, analysis, and recording. The system includes two modules: a classic rotary drive and a newly- developed linear drive; the design allows for variability in diver size and pedaling orientation. The system can be adapted to other underwater ergonomic research programs.

1993
Submarine Propelled by Underwater Divers
P. DoCarmo, J. Gittings, R. Kinter, T. O'Neil, J. Branscombe; and K. Saunders.
UNH Tech 797 report). Advisor: G. Sedor. University of New Hampshire
dditional Report No.: UNHMP-AR-SG-93-9. 57 pp., 1993

Computer-based propeller design series for human-powered submarines
Goudey, C.A.
Report. Massachusetts Institute of Technology Sea Grant Program., [Cambridge MA], 1993. 12 pages
Report NA86AA-D-SG089, A-2. Sea Grant MITSG-93-4
ABSTRACT: A design code called Propeller Lifting Line (PLL) is used to predict the performance of a series of propeller configurations suitable for human- powered submarine applications. Suitable ranges of speed, diameter, thrust, and RPM are used to yield results of use in the specification of non-ducted, single- component, 2-bladed propellers for two-person submarines at power levels less than 0.4 horsepower. The dimensional results are presented in tabular and graphic form to show the effect on efficiency of variations in input parameter. The dilemma of off-design operating conditions are discussed and the effects of variable RPM and variable pitch are shown over a range of speeds.

Design and fabrication of the Torpedo II human powered submarine
Benetti-Longhini, L et al
Human Power: the Technical Journal of the IHPVA 10(4):3-7, Fall 1993.
[entire issue on human powered submarines; available from International Human Powered Vehicle Association, PO Box 51255, Indianapolis, IN 46251, USA. Phone: 317/876-9478]
ABSTRACT: The design and fabrication of a human powered submersible present a number of interesting challenges. The vehicle must operate in the demanding ocean environment and still make maximum use of the amount of power available from a human. A human powered submarine must be built for both maximum reliability and efficiency. These design concepts were the goals of the team from Tennessee Technological University. The first priority of the project was the submarine be designed and built by students at the school. The second goal was to keep the vehicle as simple as possible. The last priority was to ensure that the safety of the occupants came before everything else. The team was rewarded for meeting its design goals by receiving awards for the best use of composite materials by an academic institution and the overall grand prize. This paper outlines the methods used by the students to design and build the Tennesseee Tech Torpedo II.

A human-powered submarine design process
DeRoos, B et al
Human Power: the Technical Journal of the IHPVA 10(4):9-14, Fall 1993.
[entire issue on human powered submarines; available from International Human Powered Vehicle Association, PO Box 51255, Indianapolis, IN 46251, USA. Phone: 317/876-9478]
ABSTRACT: Many of the design considerations for human powered submarines also apply to other types of underwater vehicles. A remotely operated vehicle (ROV) and an autonomous undersea vehicle (AUV) can each benefit from the research and development efforts that occur as a result of human powered submarine races. Optimization of the power transfer efficiency from the power source to the surrounding fluid is a key design consideration for underwater vehicles. For AUVs, which carry their power source on board in the form of batteries or fuel cells, increased efficiency can result in longer traverse distances, longer mission duration, or decreased vehicle size due to the ability to incorporate smaller power sources. For maximizing a human powered submarine's speed, the optimization of human power generation and transmission is vital. There are many factors that affect power transfer optimization including human factors, propeller design, and drive train desigh. The methods used in evaluating, integrating, and testing these factors are presented in this report.

Development of an interface system for the design of submersible internal arrangements and hull forms
Turco, K.T.
Report USNATSPR210. Naval Academy, Annapolis, MD. NTIS Order No.: ADA2708089XSP., 91 pp; 1993
ABSTRACT: This report presents the results of an investigation into the development of an interface system for the design of submersible internal arrangements and hull forms. The research and development were conducted as a Trident Scholar project at the United States Naval Academy. The design process was founded on what is being called concurrent design methodology. The development of the process involved the interfacing of commercially available geometric modeling and CAD tools with analytical parametric methods of marine vehicle drag analysis. The interfaced design tools were then employed to design a human powered submersible

in order to validate the efficiency of the particular concurrent design processes used in this project. The submersible vehicle's design requirement were established by the Biannual Human Powered Submarine Race committee. To provide a basis for relative performance comparisons, previously constructed and raced submersibles were remodeled using the system's CAD tools in order to be evaluated and compared to the new design generated by this project. The methods of design and analysis are detailed in this report. The report also contains a new program that was created to extract vehicle hull form characteristics from geometric data. The results of this project have shown probable reductions in vehicle drag over existing human powered submersibles.

The VICTORY human powered submarine
Scholl, R; Leibolt, E
Human Power: the Technical Journal of the IHPVA 10(4):15-16, Fall 1993.
[entire issue on human powered submarines; available from International Human Powered Vehicle Association, PO Box 51255, Indianapolis, IN 46251, USA. Phone: 317/876-9478]
ABSTRACT: The VICTORY human powered free-flooding submarine was designed by the students of Winston Churchill High School of Potomac, Maryland under the mentorship of the David Taylor Research Center Human Powered Submarine Club of Bethesda, Maryland. The design of this entry is based on the past experience with the TURTLE and TURTLE II submarines from previous races. This paper discusses hull design and construction, two-bladed propeller propulsion system, control surface design, life support system and safety devices, etc.

The Spirit of Annapolis: preparing for the human-powered submarine race
Davidson, WA
Human Power: the Technical Journal of the IHPVA 10(4):17-19, Fall 1993.
[entire issue on human powered submarines; available from International Human Powered Vehicle Association, PO Box 51255, Indianapolis, IN 46251, USA. Phone: 317/876-9478]
ABSTRACT: This paper discusses propulsion system design including propeller design and drive train. Experiments examined underwater human horsepower including optimal position of the human, optimum pedalling cadence, and maximum horsepower capability.

Cost effective fabrication of a graphite/epoxy submarine hull
Besterfield, GH; Paugh, WB
Human Power: the Technical Journal of the IHPVA 10(4):19-23, Fall 1993.
[entire issue on human powered submarines; available from International Human Powered Vehicle Association, PO Box 51255, Indianapolis, IN 46251, USA. Phone: 317/876-9478]
ABSTRACT: The fabrication of a cost effective graphite/epoxy submarine hull requires design consideration, prudent material selection, process preparation, and overall adherence to patience, teamwork, and dedication. The composite hull construction was based upon a male plug / female mold / male part technique. Utilizing industry standards and processes, Hercules (TM) AS4/3502 carbon composite lamina was layered within a female fiberglass mold and cured at an acceptable temperature cycle. After yielding symmetric male part halves, the halves were joined using stainless steel rivets and strengthened through inserted circular aluminum stiffeners. The weight of the hull was significantly less when compared to fiberglass, while far exceeding its strength. At an overall project cost of $6,000, the finished submarine hull represents a cost effective and lightweight structure that has the integrity to endure marine conditions and the capacity for superior performance.

H-P submarines: design parameters
Poole, PK
Human Power: the Technical Journal of the IHPVA 10(4):24-26, Fall 1993.
[entire issue on human powered submarines; available from International Human Powered Vehicle Association, PO Box 51255, Indianapolis, IN 46251, USA. Phone: 317/876-9478]
ABSTRACT: Design parameters are discussed including speed, power, physical size, and propeller efficiency. Includes Poole's Rules for human-powered submarine design

* If your calculated speed is 2.73 m/s (5 kt) or greater, you made a mistake
* Bow planes are a must
* Buoyancy, stay positive
* A bluff nose is good, pointy bad
* Control by articulating propeller alone is no control
* With high static stability you can ignore dynamic
* Laminar flow ends at the nose cone, don't coiunt on it anywhere else
* Propeller RPM > 120
* Nozzles/Ducts/Rings cannot improve the efficiency of high efficiency, unfoulded, unbroken propellers
* Keyways are better than shear pins

Human-pedaled subs compete in Fort Lauderdale
Pechter, A; Pechter, M
Sea Frontiers 39(6):50+, Nov-Dec, 1993.
ABSTRACT: Over 40 submarines powered by humans operating pedals participated in the third International Submarine Race in Fort Lauderdale, FL. Prizes were awarded for innovation, cost-effectiveness and speed.

"Impossible" mission has possible spin-off.
Merry, SL
Professional Engineering 6(8):6, Sept 1993
ABSTRACT: Work on a British-built human-powered submarine, which recently competed in the 3rd International Submarine Races in the US, could influence design of autonomous unmanned deep submergence vehicles. In the competition, each vehicle had to carry 2 crew, of whom only one could generate propulsive power. The other crew member is responsible for navigation, steering, and safety. The limited power source leads to a requirement for high overall efficiency and this relates directly to problems in the design of long distance autonomous underwater vehicles (AUV) such as Autosub. Autosub is a NERC funded community project to build an AUV for oceanographic data collection. The on-board battery power must propel the vehicle across the Atlantic and therefore high efficiency and a low resistance hull form are paramount. The design of Submission Impossible, the British entry into the International Submarine Races, is discussed.

Human subs get set for Florida's wet races.
Mundell, I
New Scientist 138(1871):19, May 1, 1993.
ABSTRACT: Human submarines of various designs are being readied for the third International Human-powered Submarine Races in Florida in Jun 1993. The submarines must carry two people, one to provide power and the other to steer and navigate. As the submarines let in water, the occupants use scuba gear to breathe air from an on-board supply. The criteria for winning include speed, maneuverability, innovative design and cost-effectiveness. Some designs from previous entries have been adopted by commercial marine engineers. The only entry from the UK in 1993 is called Submission Impossible.

1992
Composites make one 'hull' of a sub.
Advanced Materials & Processes 141(1):6, Jan 1992.
ABSTRACT:The Submarine Race team from Battelle, Columbus OH, built the Spirit of Columbus which won the Du Pont Co award for best use of composite materials. A two-person, human powered submarine, it runs 'wet', flooded with water with the crew wearing scuba gear. The polyvinyl-chloride foam-filled composite hull serves to keep the boat light yet able to withstand the boat's design. The designers decided to devise an innovative liner-thrust propulsion system based on how humans propel themselves through water.

1991
"USF Enterprise" simplicity makes a reliable and cost effective submarine.
Bowers, AL; Besterfield, GH

IN: MTS '91. An Ocean Cooperative: Industry, Government, and Academia. 1991. Washington DC: Marine Technology Society. pp 682-688
ABSTRACT: The USF Enterprise a.k.a. Two Dive Crew, the University of South Florida Mechanical Engineering Department's entry in the 2nd International Submarine Races at Riviera Beach, Florida, was designed and fabricated with simplicity as the primary goal. The USF Enterprise , although simplistic in design, had many innovative features in the propulsion and navigation systems. The conversion system from human power to rotary mechanical power utilized a bicycle-style crank with one set of meshing bevel gears in a 1:2 gear ratio. With only one set of gears and only three oil impregnated bushings, the power conversion system was very efficient and reliable. One unique aspect of the propulsion system was the ability of the propulsor to adjust the blade pitch "on-the-fly" (i.e., the propulsor could simply move a lever to any position while submersed and underway, thereby allowing the blade to take more or less of a "bite" out of the water). The navigation system incorporated rudders mounted aft of the propeller and dive planes situated near the bow. The unique aspect of the dive planes was the ability to control the submarine's pitch and roll characteristics using a joystick.

A computer-based propeller design series for human-powered submarines
Goudey, C.A.
IN: MTS '91. An Ocean Cooperative: Industry, Government, and Academia. Proceedings. 1991. Washington DC: Marine Technology Society. pp. 525-531
ABSTRACT: A design code called Propeller Lifting Line (PLL) is used to predict the performance of a series of propeller configurations suitable for human- powered submarine applications. Suitable ranges of speed, diameter, thrust, and RPM are used to yield results of use in the specification of non-ducted, single- component, 2-bladed propellers for two-person submarines at power levels less than 0.4 horsepower. The dimensional results are presented in tabular and graphic form to show the effect on efficiency of variations in input parameter. The dilemma of off-design operating conditions are discussed and the effects of variable RPM and variable pitch are shown over a range of speeds. | A design code called Propeller Lifting Line is used to predict the performance of a series of propeller configurations suitable for human-powered submarine applications. Suitable ranges of speed, diameter, thrust, and RPM are used to yield results of use in the specification of non-ducted, single-component, 2- bladed propellers for two-person submarines at power levels less than 0.4 horsepower. The dimensional results are presented in tabular and graphic form to show the effect on efficiency of variations in input parameter. The dilemma of off-design operating conditions are discussed and the effects of variable RPM and variable pitch are shown over a range of speeds.

Design overview of the human powered submarine Subasaurus
Allen, B.G.; Catalano, R.A.
IN: MTS '91. An Ocean Cooperative: Industry, Government, and Academia. Proceedings. 1991. Washington DC: Marine Technology Society. pp. 392-397
ABSTRACT: Design factors considered are hull shape, power delivery to the water, human power plant, overall vehicle control, and safety considerations.

Lessons and wisdom from the human powered submarine races
Hardy, K.
IN: MTS '91. An Ocean Cooperative: Industry, Government, and Academia. Proceedings. 1991. Washington DC: Marine Technology Society. pp. 865-868
ABSTRACT The submarines have returned to their home ports. The fiberglass dust has settled. The cockpits have dried out. The shouts on the beach are now drowned by memories instead of surf. Looking beyond the races was elemental to the Scripps team plan. SubDUDE will now be retired to the Scripps Aquarium-Museum as an educational display. This paper discusses the development path followed, the choices made and why, parallel options that lost out, and what promising designs and materials were left unused. Key areas of potential improvement to the non- propeller machine are considered. Lessons in technical team building, goal setting and technology spin-offs are examined.

"Submission Impossible": A trans-Atlantic human-powered submarine.

Ratley, RW; Tollerfield, PG; Merry, SL
IN: MTS '91. An Ocean Cooperative: Industry, Government, and Academia. Proceedings. 1991. Washington DC: Marine Technology Society. pp 667-673
ABSTRACT: Submission Impossible , the British entry into the 2nd International Submarien Races which took place in June 1991 at Riviera Beach, Florida, was designed and built by a group of students enrolled for Southampton University's Master of Engineering (MEng) course. Design projects incorporate a feasibility study and a full detailed design.

The physiological aspects of underwater work.
Stoate, NM; Merry, SL
IN: MTS '91: An Ocean Cooperative: Industry, Government, and Academia. Proceedings of the Marine Technology Society. Washington DC: Marine Technology Society, 1991. pp 858-864
ABSTRACT: The first International Submarine Races were held in Riviera Beach, Florida, in June 1989. The competition was for small, free-flooding submersibles operating at 7 metres depth in the ocean, propelled solely by human power. To minimize hydrodynamic drag, the majority of vehicles were torpedo shaped, with minimal frontal area and enclosed volume. This restricted the posture of the human propulsor (lying face up) or prone (face down). Submarine designers had to select the position for optimum power output. The Faculty of Engineering and Applied Science at the University of Southampton, UK, designed a submarine for the 2nd International Submarine Races in 1991. To define the most efficient posture for the propulsor, an undergraduate projectwas conducted by two senior students from the Dep. of Mechanical Engineering, to design and build an underwater ergometer for comparative measurements of underwater workrate by human subjects in the prone and supine positions. This paper describes the ergometer construction and experimental procedure selected for the tests and presents the results of pilot studies on the propulsor of the Southampton Submarine.

Performance of a human powered submarine the Aggie Ray.
Manlove, T.L.; Longridge, J.K.; Randall, R.E.
IN: MTS '91. An Ocean Cooperative: Industry, Government, and Academia. Proceedings. 1991. Washington DC: Marine Technology Society. pp 509-515
ABSTRACT: This paper describes the design concepts, construction techniques, and experience gained in building and racing a human powered submarine. Texas A&M University Ocean Engineering students designed and built the Aggie Ray , a free flooding submarine 11.2 ft long, 4 ft wide, and 2.5 ft high. The unique flat elliptical hull shape permits two divers to lie side-by-side in the prone position, allowing visual communication among the crew. One diver propels the submarine using a standard bicycle crank mechanism, while the second diver pilots the submarine with a rudder and two dive planes. Primary and emergency air supplies are provided. The submarine is constructed of wood and consists of a plywood internal framework and a cedar veneer skin. Ducted counter-rotating propellers power the vessel at an estimated top speed of 3.5 kt. In addition to speed considerations, safety systems and cost effectiveness also governed the design.

The Spirit of Columbus: An innovative approach to submarine propulsion.
DeRoos, B.G.; Alten, A.A.; Scott, K.B.; Guza, D.E.; Wilson, G.R.; Stulen, F.B.
IN: MTS '91. An Ocean Cooperative: Industry, Government, and Academia. Proceedings. 1991. Washington DC: Marine Technology Society. pp 516-524
ABSTRACT: In October 1990, Battelle machinists, designers, technicians, and engineers formed a team to respond to the call for entrants for the Second International Human Powered Submarine Race. Within eight months, the team designed, built, and tested the Spirit of Columbus . This human powered submarine, embodies the spirit of Christopher Columbus, who pursued the unknown; the spirit of Columbus, Ohio, a center for technology advancement; and the spirit of innovation, which led the team to develop a unique articulated linear-thrust engine.

The SUB-HUMAN II project: The redesign and modifications to a human powered submarine.
Hardiman, J.E.
IN: MTS '91. An Ocean Cooperative: Industry, Government, and Academia. Proceedings. 1991. Washington DC: Marine Technology Society. pp 674-681

ABSTRACT: This paper will document the design and engineering decisions made during the successful reconstruction of the original SUB-HUMAN vehicle for the 2nd International Submarine Races. The author will discuss the history of the vehicle, original design concepts, operational problems, and what caused the poor performance of the original vehicle. The design process and decision making of the reconstruction will be addressed by discussing the major vehicle design requirements (hydrostatics, hydrodynamics, structures, propulsion, control systems, life support, and race requirements) and why particular configurations were selected and other designs rejected.

F.A.-U BOAT: If you don't succeed the first time ...
Coulson, R.
IN: Oceans '91: Ocean Technologies and Opportunities in the Pacific for the 90's. Volume 3. Piscataway, NJ: IEEE, 1991. pp 1605-1608.
ABSTRACT: The hull, power train, and control surfaces for the Florida Atlantic University entry in the Second International Human Powered Submarine Races are described. Also outlined are factors relating to the air supply, deadman's switch, and launch and recovery.

Maximum performance with minimum power.
Haselton, FR.; Brown, Duncan.
IN: Oceans '91: Ocean Technologies and Opportunities in the Pacific for the 90's. Volume 3. Piscataway, NJ: IEEE, 1991. pp 1609-1612.
ABSTRACT: In order to maximize performance for any submersible vehicle it is necessary to decide upon which performance characteristics are dominant. This is particularly important when designing a human powered submarine. It is also important to consider external constraints imposed by, for instance, launch and recovery limitations. A realistic mission profile will determine the power budgets allocated to transit as well as maneuvering requirements. The authors address all of the relevant technologies which bear upon the solution and prioritize design considerations.

Overview of the 1991 Second International Human-Powered Submarine Race.
Dunn, S E.
IN: Oceans '91: Ocean Technologies and Opportunities in the Pacific for the 90's. Volume 3. Piscataway, NJ: IEEE, 1991. pp 1598-1600.
ABSTRACT: The Second International Human-Powered Submarine Race was held in Riviera Beach, Florida, in June 1991. A program involving 36 competing teams from the United States, Canada, Great Britain, and Germany was convened to test the imagination and engineering capabilities of the competitors in a contest of speed, maneuverability, cost effectiveness, teamwork, and reliability. An overview of the competition is presented.

West Virginia University 1991 submarine race entry design.
Loth, JL.
IN: Oceans '91: Ocean Technologies and Opportunities in the Pacific for the 90's. Volume 3. Piscataway, NJ: IEEE, 1991. pp 1601-1604.
ABSTRACT: A description is presented of West Virginia University's conventional streamlined 36-in diameter hull for a human-powered submarine. In order to simplify the layout of the mold, the geometry described by the equation for an axisymmetric version of NASA 0024 airfoil was chosen. The hull was constructed by applying three layers of fiberglass cloth on a male foam mold. Afterwards four stringers and two bulkheads made of 3/4-inch plywood were added. Floatation was controlled by two 6-inch-diameter by 12-in-long floodable and movable PVC cylinders. The dive planes are 6-inch-long chord NASA 0009 airfoils.

'Spirit of Columbus' garners composite award at sub races.
Design News 47(25): 34, Dec 16, 1991.
ABSTRACT: Battelle Memorial Institute's Spirit of Columbus won the 1991 International Submarine Race by exhibiting the best use of composites of all the human-powered submarines entered. Du Pont sponsored the $2,000 award.

Sub racers pedal to victory.
Herzog, C.
Sea Frontiers 37(6):13, Dec, 1991.
ABSTRACT: The International Submarine Races aim to attract more students into ocean engineering and oceanography. The overall winner in this year's human-powered sub race was won by Benthos Inc., while Florida Atlantic University had the fastest model.

A propeller design process for human-powered marine vehicles
Poole, PK
Human power: the technical journal of the IHPVA 9(1), Spring 1991.

Technology Race under the Waves
Popular Science, July 1991
ABSTRACT: A look at some of the machines that were heading for the 1991 International Submarine Races, Ft. Lauderdale, Fl.

Get it right - simulate the solution; from the supersonic AFT to a human-powered submarine, computers take the guesswork out of design.
Machlis, S
Design News 47(13): 70+, July 8, 1991.

Human-powered submarines. The second generation
Merry, SL
Sea Technology 32(9): 35-45, Sept 1991
ABSTRACT: The 2nd International Submarine Races held in June 1991 witnessed a significant overall improvement in speed of submarines since the first competition in June 1989. A top speed of 4.7 knots was achieved in the time trials by F.A.U-Boat (Florida Atlantic University). Four other submarines also clearly exceeded the previous winning speed of 2.76 knots. Four of the submarine hulls were based on laminar flow shapes, but the majority of teams chose simple bodies of revolution formed by rotating an efficient wing section about the hull center line, or an even simpler cylinder with rounded ends for ease of fabrication. More exotic construction materials were in evidence for the first time this year with a carbon fiber composite hull and a filament-wound Kevlar hull. Although traditional rotary propellers remained the most popular choice for the human-powered submarines, some novel concepts for propulsion were also in evidence, including an articulate linear thrust engine drive and a paddlewheel propulsion system with a radially extended linear impeller. There was a significant increase in the use of shrouds this year, which were simple protective rings surrounding the propeller to prevent blade damage. The percentage of Kort nozzles, which are hydrodynamically shaped shrouds designed to improve propeller efficiency, also increased significantly.
1990
Propulsion of human powered submarines
Merry, SL
IN: MTS '90: Science and Technology for a New Oceans Decade. Volume 2, Proceedings of the Marine Technology Society. Washington DC: Marine Technology Society, 1990. pp 495-500
ABSTRACT: A demanding task for competitors is to design an efficient propulsion system to operate at low power, rotational speed and advance velocity. Most propellers were designed from fundamental lifting line or blade element theories. This paper describes the technical details and innovations of human powered submarine systems including oscillating fin mechanisms and compares the design philosophies applied to the solution of this unique problem.

A propeller design process for human-powered submersibles
Poole, PK
IN: MTS '90: Science and Technology for a New Oceans Decade. Volume 2, Proceedings of the Marine Technology Society. Washington DC: Marine Technology Society, 1990. pp 501-506

ABSTRACT: A propeller design process for human-powered submersibles is presented. The process described is based on simple momentum theory with modifications to account for the energy lost in rotational motion which is prevalent in low speed propellers typical of those in human-powered propulsion. The process gives designers a complete mechanism to generate relatively high efficiency propellers specifically suited for their submersible while allowing for a variety of design options.

The First International Human Powered Submarine Races: a review of hull forms and power transmissions
Osse, J
IN: MTS '90: Science and Technology for a New Oceans Decade. Volume 2, Proceedings of the Marine Technology Society. Washington DC: Marine Technology Society, 1990. pp 507-512
ABSTRACT: A review of hydrodynamic shapes and principal dimensions of the various hulls that competed is presented. Following this is a discussion of the various power transmission and propulsion systems used and lessons learned from the viewpoint of a designer/builder/competitor.

Icarus: MIT's human-powered submarine.
Goudey, Clifford A.; Coney, William B.
Paper presented at a meeting of the New England section of the Society of Naval Architects and Marine Engineers, November 30, 1990. Page(s): 21
Document No.: MIT-R-90-002; Project No.: RTS-4; Additional Report No.: MITSG 90-8
ABSTRACT: In June 1989, the H.A. Perry Foundation sponsored a race among human-powered submarines. The rules were simple: design a two-person, wet sub in which one person provides the means of propulsion and one person pilots, both breathing with scuba. The prescribed course was three laps around a one-third kilometer course. In addition to speed, judging criteria included innovation and cost effectiveness. The competition attracted 19 entries. This paper describes Icarus, MIT's entry into this unusual competition, which was designed and built by students. The hull form, propulsion system, and control surface geometry are described. Several unusual features are also explained, including the articulated tail, the automatic buoyancy control system, and the slender propeller blades made of carbon fiber; numerical techniques used in the propeller design are also covered.

1989
Overview of the human-powered submersible races.
Merry, SL
IN: OCEANS '89:The Global Ocean. Volume 3: Navigation, Remote Sensing, Underwater Vehicles Exploration. Piscataway, NJ: IEEE, 1989. pp 708-709
ABSTRACT: A unique competition for human-powered submarines took place in June, 1989. This paper outlines the philosophies of the organizers in staging the event, the rules of the competition and the judging criteria. Some of the design innovations inspired by the contest are described. The main objective of this competition was to foster advances in the hydrodynamics, propulsion, and life-support systems of subsea vehicles. It is concluded that this objective has been achieved.

Overview of the human-powered submersible races.
Merry, SL.
IN: Oceans '89. Part 6: Human-Powered Submersibles - A Record of the First Annual International Submarine Races. Seattle, WA, Sept 18-21 1989. Piscataway, NJ: IEEE, 1989. p 1-2.
ABSTRACT: A competition for human-powered submarines took place in West Palm Beach, Florida, June 1989. Originally envisaged as a student design competition, the event was intended to inspire students from a variety of engineering disciplines to explore the broad area of underwater technology through a project that was both fulfilling and enjoyable. The race organizers placed a heavy emphasis on safety and competitors were required to comply with stringent safety guidelines. Although each vehicle carried a crew of two persons, only one was permitted to supply propulsive power, the second crew member being restricted to duties such as navigation, steering, and safety. The author outlines the philosophies of the organizers in staging the event, the rules of the competition, and the judging criteria. Some of the design innovations inspired by the contest are described.

Application of aeronautical engineering techniques to the design of control surfaces for human powered submarines.
Drinkard, TD
IN: Oceans '89: The Global Ocean. Part 6: Human-Powered Submersibles - A Record of the First Annual International Submarine Races. 1989. Piscataway, NJ: IEEE. pp 53-58.
ABSTRACT: The author discusses and evaluates various design features of the control surfaces of Subversion, the submarine that set the speed record in the First Annual International Human-Powered Submarine Races. He believes that this design was the fastest because a superior job of systems integration was done. The control system was fully optimized in regard to the limited amount of information available. As much elasticity as possible was left in the design to compensate for unknown factors. Control surface performance could have been improved slightly by testing different configurations and even more by sacrificing interchangeability and using more specialized surfaces.

Application of the KISS principle in the design of a human-powered submarine.
Sedor, G.
IN: Oceans '89. Part 6: Human-Powered Submersibles - A Record of the First Annual International Submarine Races. Seattle, WA, Sept 18-21 1989. Piscataway, NJ: IEEE, 1989. p 43-46.
ABSTRACT: A version of the KISS principle--keep it safe and simple--is applied to the design of SPUDS (submarine propelled by underwater divers), the University of New Hampshire's entry in the First International Submarine Races for human-powered submarines. The principle is used to develop system design criteria and in making design decisions. The result is a safe, reliable, rugged, and seaworthy vehicle which meets all major design requirements.

Basics of design and construction of a human powered submarine.
Lockert, CR.
IN: Oceans '89. Part 6: Human-Powered Submersibles - A Record of the First Annual International Submarine Races. Seattle, WA, Sept 18-21 1989. Piscataway, NJ: IEEE, 1989. p 47-52.
ABSTRACT: The author describes the systematic approach used by him for the design and construction of the human-powered submarine Sea Panther. The order in which various items were examined was based on the author's knowledge, research, and experience. Utilizing a design spiral as an outline, the basic components and features of the Sea Panther as well as some test results and construction techniques are presented. Ship design basics, test results, and suggestions of previous HPV (human-powered vehicle) designers are examined, followed by the design decisions made for the Sea Panther and the rationale for those decisions.

Project SQUID - A lesson in design simplicity.
Nuckols, ML.
IN: Oceans '89. Part 6: Human-Powered Submersibles - A Record of the First Annual International Submarine Races. Seattle, WA, Sept 18-21 1989. Piscataway, NJ: IEEE, 1989. p 38-42.
ABSTRACT: The US Naval Academy's entry in the First Annual International Submarine Races in Riviera Beach, Florida during June 1989, SQUID (submerged quick intervention device), was designed and fabricated with simplicity as the primary emphasis. An essential requirement was to have a vehicle with sufficient reliability that could be counted on to start the race and maneuver the course to the finish line. The SQUID won the Best Overall Performance prize by achieving the highest total score in speed, cost effectiveness, and innovation of all eighteen entries. Not only did the SQUID design show proven reliability in the competition by not logging a single mechanical failure in the 3-day event, but minimal design failures were noted during all prior vehicle testing beginning in mid-March. The authors highlight some of the more significant features of the SQUID design in the areas of structural design, power conversion, man-machine interface, control, and innovation in complying with the rules of the race. These features, along with others, are listed categorically in accompanying charts.

Design of a human powered wet submersible for competition.
Skidmore, JE.

IN: Oceans '89. Part 3: Navigation; Remote Sensing; Underwater Vehicles/Exploration. Seattle, WA, Sept 18-21 1989. Piscataway, NJ:IEEE, 1989. p 720-727.
ABSTRACT: A description is presented of the design and construction of the Lockheed Advanced Marine System (AMS) entry in the First Annual International Human Powered Submarine Race. AMS's competitive strategy and resources are discussed. Design decisions on the sub's layout and hull and on the propulsion, ballast, control and life-support systems are explained. Construction methods and materials selection are discussed.

Design of a human powered wet submersible for competition.
Skidmore, JE.
IN: Oceans '89. Part 6: Human-Powered Submersibles - A Record of the First Annual International Submarine Races. Seattle, WA, Sept 18-21 1989. Piscataway, NJ: IEEE, 1989. p 30-37.
ABSTRACT: The authors describe the design and construction of the Lockheed Advanced Marine System (AMS) entry in the Submarine Race. AMS' competitive strategy and resources are discussed. Design decisions on the sub's layout and hull, and on the propulsion, ballast, control, and life support systems are explained. Construction methods and material selection are discussed. The sub's hull was designed for small size, to minimize projected frontal area, wetted skin area, surface and bottom effects, and entrained water. 3-D CADAM (computer-aided design and manufacturing) was an invaluable tool in packaging the sub efficiently, and in producing reliable layouts. Direct drive fin propulsion was chosen because of its innovative approach. Propulsion testing was conducted in the AMS tow basin using test sleds, minimizing the impact of propulsion development on sub construction. An innovative variable ballast system using an evacuated tank was designed to compensate for buoyancy gain due to life-support consumption.

'Fautilus' twenty feet under the sea.
Rae, GJS.
IN: Oceans '89. Part 3: Navigation; Remote Sensing; Underwater Vehicles/Exploration. Seattle, WA, Sept 18-21 1989. Piscataway, NJ: IEEE, 1989. p 715-719.
ABSTRACT: A description is presented of Florida Atlantic University's entry in the First Annual International Human Powered Submarine Race. Design procedure and construction techniques are discussed. Body configuration, control surface configuration, and internal configuration are outlined. Frame and hull construction are also described. Factors relating to air supply, general buoyancy, buoyancy control, initial testing, and the drive train are examined.

'FAUtilus' twenty feet under the sea.
Rae, GJS.
IN: Oceans '89. Part 6: Human-Powered Submersibles - A Record of the First Annual International Submarine Races. Seattle, WA, Sept 18-21 1989. Piscataway, NJ: IEEE, 1989. p 16-25.
ABSTRACT: The Florida Atlantic University human-powered submersible project (FAUtilus) is described. The following issues are discussed: body configuration, powering methods, frame and hull construction, air supply, buoyancy control, and safety systems. Initial testing is described.

Icarus: Design and testing of a human-powered submersible.
Goudey, CA.
IN: Oceans '89. Part 6: Human-Powered Submersibles - A Record of the First Annual International Submarine Races. Seattle, WA, Sept 18-21 1989. Piscataway, NJ: IEEE, 1989. p 26-29.
ABSTRACT: When the HA Perry Foundation announced a competition for human-powered submarines, a group of students at MIT formed to meet the challenge. The authors describe the submarine that evolved, covering the design of the more important subsystems in detail as well as some of the thought processes and analyses involved. A safe, fast, and maneuverable human-powered submarine was the result. Attention is given to the hull design, the propulsion system, control, and human factors and safety. The authors also report on the performance of the MIT submarine on occasions other than the Florida competition.

Low drag technology applied to human powered vehicles.

Osse, J.
IN: Oceans '89. Part 6: Human-Powered Submersibles - A Record of the First Annual International Submarine Races. Seattle, WA, Sept 18-21 1989. Piscataway, NJ: IEEE, 1989. p 7-11.
ABSTRACT: The author presents a review of the major drag reduction techniques and their applicability to HPVs (human-powered vehicles). The drag reduction methods can be categorized into passive and active techniques; active techniques use an external power source for direct manipulation of the vehicle boundary layer. While active techniques offer several advantages, the additional complexity is of questionable value to human-powered submersibles. Drag reduction through choice of body shape was found to be substantial when compared to turbulent flow bodies. Results of a previous study to optimize this body shaping are presented and discussed as relating to HPVs. It is shown that robust designs are to be used with strong favorable pressure gradients that will maintain laminar flow over the vehicle forebody. This is due to the high levels of ambient turbulence where HPVs are likely to operate, a significant amount of maneuvering, and inaccuracies inherent in the likely construction techniques. The Applied Physics Laboratory at the University of Washington entered a laminar flow body into the First Annual International Submarine Races. The vehicle was 16 feet long and 32 inches in diameter and was constructed of wood and fiberglass.

Low cost provision for human powered submersible construction.
Leibolt, EA.
IN: Oceans '89. Part 6: Human-Powered Submersibles - A Record of the First Annual International Submarine Races. Seattle, WA, Sept 18-21 1989. Piscataway, NJ: IEEE, 1989. p 59-62.
ABSTRACT: A submarine design club was formed at David Taylor Research Center (DTRC) to design and build a two-man wet submersible to compete in the First International Submarine Races held by the HA Perry Foundation. This club had no public funding and hence relied on private membership fees of the employees of DTRC. This necessitated that a low-budget design be developed that required only the skills of an amateur boat builder. The design was developed using a Macintosh SE personal computer to save design time and develop a easy access database. The construction methods are based on the use of simple construction materials and typical home mechanic tools. The on-board equipment consists of standard sport diving equipment and simple bicycle parts. Numerous special features, needed to conform to the race committee rules, were designed using simple hardware and used parts. Descriptions are given of the design and construction of the hull, the power unit, the propeller, the control surface, the buoyancy control, and the air supply. Safety features are also discussed.

Optimum thrust generation for minimum drag bodies.
Haselton, T.
IN: Oceans '89. Part 6: Human-Powered Submersibles - A Record of the First Annual International Submarine Races. Seattle, WA, Sept 18-21 1989. Piscataway, NJ: IEEE, 1989. p 12-15.
ABSTRACT: The propulsion and drag reduction aspects of low-power human-powered submersibles are examined. It is noted that human-powered submersibles require that the designer use all those techniques that optimize speed and control within the constraints of the rules. Propulsion efficiency and low drag are prerequisites. The field of options quickly narrows to include only thrust devices offering the highest efficiencies at very low power levels. This implies large-diameter propellers with many optimally shaped blades. Additionally, the ability of the propulsor to generate control forces as well as forward thrust eliminates the need for drag-producing control surfaces. A body shape consistent with containing two people and having minimum drag points directly to laminar flow designs.

Sub-Human: A 'garage-built' approach to a competitive human-powered submarine.
Keane, M
IN: Oceans '89. Part 6: Human-Powered Submersibles - A Record of the First Annual International Submarine Races. Seattle, WA, Sept 18-21 1989. Piscataway, NJ: IEEE, 1989. p 3-6.
ABSTRACT: The design and building of a human-powered submarine (called Sub-Human) to be raced in the First Annual International Submarine Races held in West Palm Beach, Florida, in June 1989 are described. Some of the overriding factors influencing the design included a very minimal budget, and that much of the fabrication be done in the family garage by the group members themselves. Throughout the design process the

TLAR (that looks about right) method was used extensively due to the limited amount of time available for research, detail designing, and testing. Descriptions are given of the hull, the propulsion, the propellers, the control system, and the life support. In the race itself the submarine did not perform well.

Self-propelled underwater designed submarine (SPUDS).
Conners, Daniel; Pope, William; Perron, Lorrie; et al.

Additional Report No.: UNHMP-AR-SG-89-8.
ABSTRACT: SPUDS is an acronym for Self Propelled Underwater Designed Submarine. The challenge of SPUDS was to design and build a two-person, human- powered submersible which could be used to compete in the First International Submarine Race in West Palm Beach, Florida on June 23, 1989. The race is intended to provide incentive to improve the efficiency of hydrodynamics, propulsion and life support systems for small underwater vehicles. The rules of this competition restrict the vehicle's power system to human power, thus focusing attention on maximizing the vehicle's design and life support system. The design and construction of such a vehicle are described here; in addition to providing complete information on the development and propulsion of the sub, the report also covers the consideration given to the training and safety of the two-man crew.

A method for the design of a class of optimum marine propulsors.
Coney, William B.
Document No.: MIT-Y-89-001; Project No.: RO-35. Massachusetts Institute of Technology, 1989. 187 pages
Additional Report No.: MITSG 91-6TH
ABSTRACT Ships are usually driven by screw propellers that produce thrust through the production of lift on their rotating blades. This thesis describes procedures for the computer-aided design of a class of propulsion devices typified by the screw propeller, a propeller operating behind a nonaxisymmetric stator and ducted propellers. The novel design of a propeller for a human- powered submarine is also presented.

Human-powered submersibles: Generating "new technologies".
Merry, S.
Sea Technology, vol. 30, no. 12, pp. 25-30. 1989
ABSTRACT: The competition produced few totally innovative concepts; more commonly, designers demonstrated innovative applications of existing, albeit unfamiliar, technology. In addition, the competition indicated which new technologies may be economically feasible in a commercial environment.

"Wet" wonders amaze at first annual international submarine races.
Arnold, R.J.
Sea Technology, vol. 30, no. 8, pp. 65-68. 1989
ABSTRACT: Successful completion of the first annual international human-powered submarine races on Sunday, June 25th, 1989 in Riviera Beach, Florida, marked the culmination of a dynamic learning experience that brought together ocean engineering industry leader and young engineering students from across the U.S. The original plan for the competition focused on the challenge of designing, building, and racing a two-person human-powered wet (flooded) submarine over a 1 kilometer course, 7 meters deep. For the purpose of this event, a submarine was defined as "a marine vehicle which operates entirely beneath the surface of the water." The competition was co-organized and sponsored by the H.A. Perry Foundation and Florida Atlantic University Department of Ocean Engineering.

Sub humans sink to new heights; the 1st International Submarine Races.
Earle, SA
Oceanus 32(4):86+, Winter, 1989.

1988
The state of the art; current human power research touches everything from helicopters to submarines.
Martin, S

Bicycling 29(10):76+, Dec, 1988.

Human power generation in an underwater environment
Merry, SL et al
IN: Oceans '88: A Partnership of Marine Interests. Proceedings of the Marine Technology Society. Washington DC: Marine Technology Society, 1988. pp 1315-1320.
ABSTRACT: A pilot study of scuba divers pedaling an underwater bicycle/ergometer is described. The ergometer design and experimental procedure used for tests on fourteen male and female subjects in the age group 22-46 is presented. The average useful power output for subjects who are regular bicyclists or who participate in a regular exercise program was 0.12 horsepower at the optimum cadence of fifty rpm. Non-bicyclists and less fit subjects tended towards a lower cadence for maximum performance. These results and the test subjects' reactions to the tests, are discussed in relation to the design and safety of a human-powered submersible.

RELATED
Manned Submersibles
Busby, R Frank
1976, Office of the Oceanographer of the Navy
ABSTRACT: Kevin Hardy sez "You know this book, you know submersibles."

Handbook of Ocean and Underwater Engineering
Myers, John J., Editor, Carl H. Holm, Raymond F. McAllister
1969, McGraw-Hill Book Company, New York, NY
ABSTRACT: Kevin Hardy sez "A unique and valuable asset to any ocean engineer. Section 6, Underwater Power Sources, discusses human power systems."

Fiberglass Boats, Construction and Maintenance
Cobb, Boughton, Jr.
1965, Yachting Publishing Co., New York, NY
ABSTRACT: Kevin Hardy sez "A fabulous book describing numerous types of fiberglass hull fabrication techniques, mechanical attachments, repairs, and more."

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Compiled by Peter Brueggeman, Scripps Institution of Oceanography Library