BOOK REVIEW[1]

Handbook of Acrylics for Submersibles, Hyperbaric Chambers and Aquaria

By Jerry D. Stachiw
Best Publishing Co., 2003
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This unique book is a "must have" for anyone designing and building pressure resistant underwater structures or instruments, as well as anyone designing with acrylic as a structural material. While the focus of this book is on acrylic structures under pressure, this highly visual 1066 page book, with over 500 graphs, drawings, and photographs, provides a wealth of information about the design of pressure tolerant structures in general, from submarines to aquaria. Engineers, designers, manufacturers, fabricators, operators, and inspectors of acrylic windows will find this book an essential reference.

This is a deeply practical, nuts and bolts volume filled with both detailed information and over forty years engineering wisdom and insight into the problem of building stuff that works. For example, with a basis in theoretical principles, the author researched, designed, and then reduced to practice the acrylic hulls for the submersibles NEMO and Johnson Sea Links 1&2, the first acrylic hull submarines. Dr. Stachiw has also made important contributions investigating the use of structural ceramics for high pressure applications (see his website at www.hydroports.com), and also remains active in the field of pressure vessels for human occupancy (ASME PVHO).

The book was a team effort, with a wonderful historical introduction, "The quest for panoramic vision underwater," written by Dr. Joan Stachiw. Dr. Jerry Stachiw has a refreshingly unabashed, direct style and does not hesitate to offer clearly stated design guidelines and criteria. For example: "The crack-free, cyclic fatigue life of acrylic windows and pressure hulls in manned diving systems is considered to be adequate if it exceeds 1000 pressure cycles of 4-hour duration at design pressure and temperature." The book is well organized with a detailed table of contents and an extensive index, allowing the reader to easily drill down into this large reference and find needed specific information. The book also includes numerous references and bibliographic citations in association with most sections.

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In his references Stachiw generously includes the significant works of others that have contributed to acrylic research and its structural use. Examples include Auguste Piccard's work with conical viewports in some of the first deep submersibles. He also refers to the significant but little known works of von Mises, whose graphs for cylindrical pressure hulls have been and are still used but seldom credited, possibly because they were developed prior to WW1 for submarine hulls.

Among his accomplishments, Stachiw completed the impossible dream of the early pioneer in deep submergence, Auguste Piccard. At the end of his brilliant career, Piccard fantasized about a submersible with a transparent hull made up of 12 spherical segments to provide a panoramic view of the undersea. This would permit better research than could be done with the limited vistas from the small viewports that he had developed. After artist Bruce Beasely demonstrated to the acrylic manufacturers how to cast very thick, large pieces of acrylic without flaws in 1969, Stachiw upgraded the 12 piece Nemo hulls into 2 hemispheres for the two Johnson Sea Links, thus establishing the standard of spherical pressure hull fabrication used currently by virtually all acrylic deep submersibles. Until such time as there is a major technical breakthrough in transparent structural materials, this handbook will be the bible for the designing, fabricating and maintenance of acrylic pressure vessels and structures for human use.

The book focuses on several aspects of acrylic window usage. The main topics covered in the book are the design, fabrication, quality assurance, installation, service inspection, and maintenance of pressure resistant windows in service. Major attention is devoted to design procedure. Simple guidelines are presented that facilitate the conversion of previously published test data into maximum working pressures by application of conversion factors. For non-standard window configurations, a set of design stresses for service in different ambient temperatures is suggested.

An interesting feature of the section on the design of different window configurations is the figures depicting the mechanism and propagation of fracture under over-pressurization or pressure cycling, and the locations on the window where cracks generated by different loading conditions originate. Distinction is made between critical and non-critical crack locations and magnitudes.

Although traditionally acrylic components of aquaria do not fall into the category of pressure resistant windows, their design is very challenging, particularly for submerged tunnels and domes. Aquaria have come a long way from being simple flat windows set in concrete. Underwater observation chambers accessible by tunnels fabricated from plane and thermoformed acrylic plates now complement the sheer expanse of acrylic walls. Guidelines for the design, fabrication, and installation of acrylic panels are presented. A specification for procurement of acrylic castings concludes this very informative section.

An interesting feature of the section on fabrication is the presentation of techniques for the detection of residual stresses, the result of incomplete annealing. The included tables

cover the whole gamut of thermal treatments available for reduction of residual stresses introduced into the acrylic component by the casting and machining procedures.

Of great help to the operator of any vessel equipped with acrylic windows is the description of environmental conditions that cause acrylic to deteriorate. Particularly useful is an extensive listing of chemical compounds whose contact with the acrylic may be detrimental to the optical and structural performance of the windows. The effect of submersion in water and weathering on the deterioration of acrylic is also noted and their effect quantified.

One of the features of a pressure vessel for human occupancy that generally is not covered in, other publications is the techniques for the illumination of the hyperbaric chamber's interior for the benefit of occupants undergoing treatment. Designs of lights for illumination of the interior through acrylic light pipes or windows are shown and their salient features discussed.

No book on acrylic would be complete without a description of bonding processes. What makes the description of bonding procedures in this book unusual is that it addresses not only procedures for achieving good bonds but also how to repair bad ones.

The Section on optical performance of acrylic serves as a good introduction to optical effects one can expect from different window configurations. Particular emphasis is given to the optical effects generated by spherical sector windows.

The book concludes with a very informative description of the ANSI ASME/ PVHO-1 Safety Standard covering acrylic components of pressure vessels. In the discussion one is introduced to the origins of the Standard as well as its objectives and the major technical areas it addresses. Since the author was one of the co-authors of the Standard, his opinions expressed in this Section provide a valuable insight into some of the fundamental concepts, such as design life, service life, minimum safety margin, and others promulgated by the Standard.

It was hard in this short review to present an account that does real justice to die contents and presentation of this large volume. Between the covers of this book the author attempted to cover all facets of acrylic material, procurement, design, fabrication, installation, testing, and in service inspection. In this endeavor he was quite successful, presenting the reader with both the empirical design criteria and the test data from which they were derived.

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