



Loads in circular frames due to hydrostatic pressure

Endorsed by
The Royal Aeronautical Society

ESDU DATA ITEMS

Data Items provide validated information in engineering design and analysis for use by, or under the supervision of, professionally qualified engineers. The data are founded on an evaluation of all the relevant information, both published and unpublished, and are invariably supported by original work of ESDU staff engineers or consultants. The whole process is subject to independent review for which crucial support is provided by industrial companies, government research laboratories, universities and others from around the world through the participation of some of their leading experts on ESDU Technical Committees. This process ensures that the results of much valuable work (theoretical, experimental and operational), which may not be widely available or in a readily usable form, can be communicated concisely and accurately to the engineering community.

We are constantly striving to develop new work and review data already issued. Any comments arising out of your use of our data, or any suggestions for new topics or information that might lead to improvements, will help us to provide a better service.

THE PREPARATION OF THIS DATA ITEM

The work on this particular Data Item was monitored and guided by the Aerospace Structures Committee. This Committee first met in 1940 and now has the following membership:

Chairman	
Mr K. Fitzsimons	— Westland Helicopters Ltd
Members	
Prof. P. Bartholomew	— QinetiQ, Farnborough
Dr R. Biswas	— BAE SYSTEMS, Luton
Mr A. Dickson	— BAE SYSTEMS, Warton
Mr S. Georgiou	— BAE SYSTEMS, Stanmore
Mr A. Missenden	— Cranfield Aerospace Ltd
Mr P.J. Mitchelmore	— Independent
Mr B. Popham	— Astrium Space Ltd
Mr M.S. Pressnell	— Independent
Prof. A. Rothwell	— Professor Emeritus, Delft University of Technology, The Netherlands
Mr J.H. van der Sloot	— Independent
Mr K. van Katwijk*	— European Space Agency, The Netherlands.

* Corresponding Member

The construction and subsequent development of the Data Item was undertaken by

Mr M.S. Pressnell.

The person with overall responsibility for the work in this subject area is Mr A.C. Quilter, Head of Strength Analysis Group.

LOADS IN CIRCULAR FRAMES DUE TO HYDROSTATIC PRESSURE

CONTENTS

	Page
1. INTRODUCTION	1
1.1 Notation	1
2. NOTES	3
3. THEORY AND APPLICATION	4
4. DERIVATION AND REFERENCE	5
4.1 Derivation	5
4.2 Reference	5
5. EXAMPLE	5

ESDU Copyright material. For current status contact ESDU.

Copyright © 2005 ESDU

LOADS IN CIRCULAR FRAMES DUE TO HYDROSTATIC PRESSURE

1. INTRODUCTION

This Data Item presents graphs which provide the internal loading distributions arising in circular frames supporting a hydrostatic internal pressure distribution.

Circular frames are commonly used in the construction of airframes such as pressurised fuselages, missile bodies, long-range fuel tanks and in other applications. Frames act to support and stabilise the semi-monocoque structure of which they form a part. They serve also in receiving local loadings and redistributing the forces into the skins of the structure. In particular, aircraft cylindrical tanks use circular frames to handle the effects of hydrostatic pressure, arising from accelerated flight or ground conditions. Similar loading actions can be found in certain ground installations and in non-aeronautical applications.



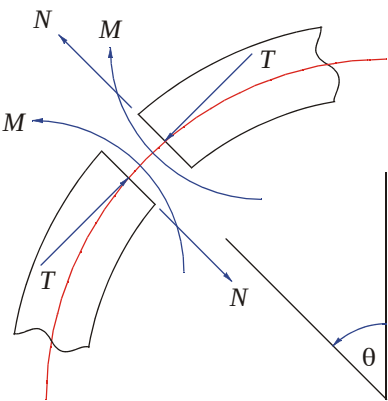
Photograph courtesy of Marshall Aerospace

1.1 Notation

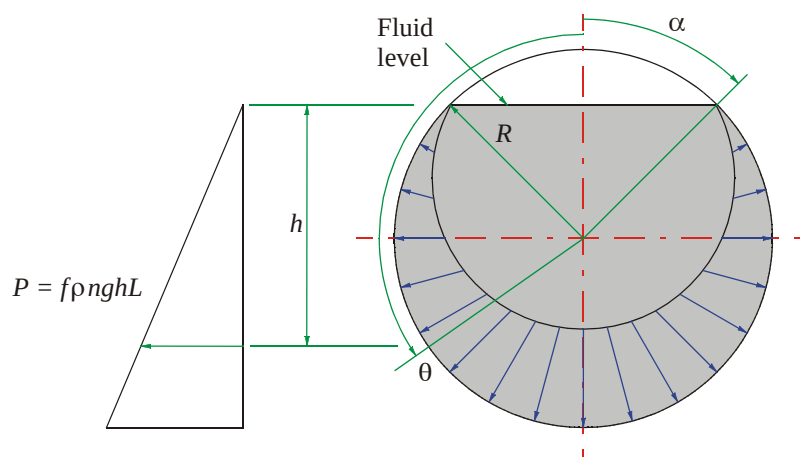
Both SI and British units are quoted but any coherent system of units may be used. The notation and sign convention used in this Data Item, see Sketch 1.1, are identical to those used in the Struct 03.06 series of Data Sheets.

f	$= \left(\frac{R_o}{R} \right)^2$; tank volume correction factor		
g	acceleration due to gravity	m/s ²	in/s ²
h	depth at reference section below fluid surface	m	in
L	distance over which frame collects hydrostatic pressure (usually frame pitch)	m	in

M	bending moment in frame, positive if it produces tension on inside	N m	lbf in
N	shear force in frame, positive when acting outwards on clockwise side of reference section	N	lbf
n	inertia factor ($n = 1$ corresponds to steady level flight)		
P	hydrostatic loading on frame, positive outwards	N/m	lbf/in
R	radius of frame measured to centroid of frame section	m	in
R_o	radius of frame measured to skin	m	in
T	direct load in frame, positive when tensile	N	lbf
α	angular position of fluid level, measured from top of frame	deg	deg
θ	angular position on frame, positive when measured anticlockwise from top of frame	deg	deg
ρ	density of fluid in tank	kg/m ³	lb/in ³



Sketch 1.1 Positive internal forces and bending moments acting at reference section in frame located by angle θ



Sketch 1.2 Hydrostatic pressure loading acting on frame

2. NOTES

Figures 1 to 4 provide the direct force, shear force and moments in circular frames arising from hydrostatic pressure. Figures 1a, 1b and 1c present curves of $T/f\rho gLR^2$, $N/f\rho gLR^2$ and $M/f\rho gLR^3$ versus θ respectively for the tank-half-full condition ($\alpha = 90^\circ$) and for $\alpha = 75^\circ$. Figures 2 to 4 consist, respectively, of curves of $T/f\rho gLR^2$, $N/f\rho gLR^2$ and $M/f\rho gLR^3$ versus θ for values of α from 0 to 165° .

The data are plotted for half the frame over the arc $0^\circ \leq \theta \leq 180^\circ$. The loads are symmetrical over the full 360° but note that the convention for shear force, N , is antisymmetric in nature.

The capability of frames to redistribute load depends upon the stiffness of a particular frame relative to the shell and to the adjacent frames. Flexible frames can dissipate load to neighbouring frames quite rapidly. However, in the case of hydrostatic pressure loading, a number of adjacent frames receive similar loads simultaneously. This implies that, if the frames are of similar stiffness, the deformations in each frame will be similar. That is to say, each frame is obliged to handle its own applied loads, as if its stiffness was much enhanced, and for this reason the frames are treated as acting alone in this analysis.

This Data Item does not resolve the complex matter of exactly how the hydrostatic pressure reaches the frame; there is undoubtedly an interaction between the function of the stringers in flexure and the skins in hoop tension with shear diffusion. Where the stringers are relatively stiff they may be treated as the principal load-spreading mechanism, an assumption that is applied here. In the particular case of tanks constructed with corrugated skins, possibly without separate stringers, these assumptions are fully justified. The assumptions adopted may be expected to lead to conservative estimates of the bending moments and loads acting in the frame.

This may be contrasted to the behaviour of a thin cylindrical shell structure, loaded by a uniform internal pressure, where the frames play a much less significant role and the skins furnish the main support to the loading through circumferential (hoop) stress. An isostatic pressure within a cylindrical tank, also loaded with hydrostatic pressure, falls in this category.

Attention is drawn to other potentially important cases for fuel tanks. For example, when a lateral acceleration occurs in combination with a normal acceleration, the fuel level will slope. As a result, the locations of the maximum loads will move around the circumference of the frame. Also, axial acceleration