5.6 Pressure Vessels

There is an enormous number of potential causes of pressure vessel failure, and of these, only a few can be evaluated in terms of a generic failure rate. For example, airplane crash is a potential cause of tank failure, but it depends more on tank size, distance to airports, and air traffic rate, than on the tank itself.

A list of more common causes of pressure vessel failure is:

- Design errors, including underdimensioning, specification of inadequate materials, specification of wrong welding procedures, overloading of supports and designs in which there are weak points or stress raisers.
- Some pressure vessels require cooling, and multiwall or wound vessel require drains in the walls to protect against leakage - These present special problems.
- Overload, due to too high pressure or temperature, as a result of equipment failures, operation or administrative errors or fire.
- Material faults, welding faults, and faults due to errors in heat treatment.
- Corrosion (especially stress corrosion)
  Corrosion can attack both internally and externally. A frequent cause is improper water treatment, or contamination of water supplies. Stainless steel is especially vulnerable to chloride contamination. For vessels holding liquids other than water high water concentrations are often a problem (e. g. in liquid ammonia).
- Ageing (creep or fatigue)
- Excessive vibration (can cause fatigue or direct overload, usually at flange or weld attachment to vessels.
- Foundation collapse

- Frost heave
- Earthquakes
- Crashes (aircraft, ground vehicles, cranes, missiles from explosions.
- Internal explosions and runaway reactions.
- Structural overload of vessels due to external stresses, especially pipe expansion or contraction.
- Liquid expansion when a vessel is completely full of liquid, and is also shut off.

Some failures are the result of several causes combined.

Of these causes, overload, crash, explosion and vibration are properties of the application and not of the pressure vessel. They must be separated out in any treatment of statistical data. In risk analysis, risk from these causes should be assessed separately.

Similar arguments might also be applied to corrosion, since this depends on the environment in which tanks operate. So far, however, this has not been the normal practice in risk analysis, because of the difficulty of obtaining data.

Failure probabilities will be very dependent on the frequency with which pressure tests and inspections are carried out on tanks. Many of the direct causes of failure are small cracks or pits, which develop over a longer period until a critical size is reached. Non destructive testing, using ultrasonic or X-ray or gamma-ray photography can reveal many such flaws, as can surface inspection in some cases, For some applications pressure vessels are inspected regularly, every two or four years (especially transport vessels).

There have been several thorough studies of pressure vessel failure rate data. Phillips and Warwick (PHI 68) studied pressure vessels built to very high standards, and in a following study (SMI 74) the number of "tank years" was brought up to 105402. These studies showed probability for catastrophic failure of pressure vessels of $4.4 * 10^{-5}$ per year. Of these, catastrophic failures were such a small part that a failure rate for catastrophic damage of $3 * 10^{-6}$ could be given. In all, the study covered 1,700,000 tank years. Table 5.10 shows the distribution of errors.

Boesbeck (1975) undertook an evaluation of these and other data, to find a probability of catastrophic failure which is somewhere between 10^{-5} and 10^{-6}. These studies lead to the results in table 5.11.

A. M. Thomas of Rolls Royce Ltd. has, in a series of articles, used the available data for tanks together with data from pressure vessel testing, to build up a model for pressure vessel reliability. This uses a theory of fracture mechanics which is not universally accepted, but which seems to give a reasonably good correlation with the available data.

Failure Mode	Failure Rate
Catastrophic failure	$3 * 10^{-6}$ per annum $2.5 * 10^{-4}$ per 10^6 hr.
Small leak or small break	$3 * 10^{-5}$ per annum $2.5 * 10^{-3}$ per 10^6 hr.

Table 5.11 Failure rates for pressure vessels.

The theory is based on the conditions which are necessary for a built in flow to reach a critical size. The constants in the theory are adjusted to fit data from 700 well studied tank failures.

Risk Analysis for Process Plant, Pipelines and Transport

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Taylor & Francis Group
LONDON AND NEW YORK

Published by Taylor & Francis
2 Park Square, Milton Park, Abingdon, Oxon, OX14 4RN

First edition 1994

Transferred to Digital Printing 2005

ISBN 0 419 19090 2

A catalogue record for this book is available from the British Library

Library of Congress Cataloging-in-Publication data available

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Printed and bound by Antony Rowe Ltd, Eastbourne

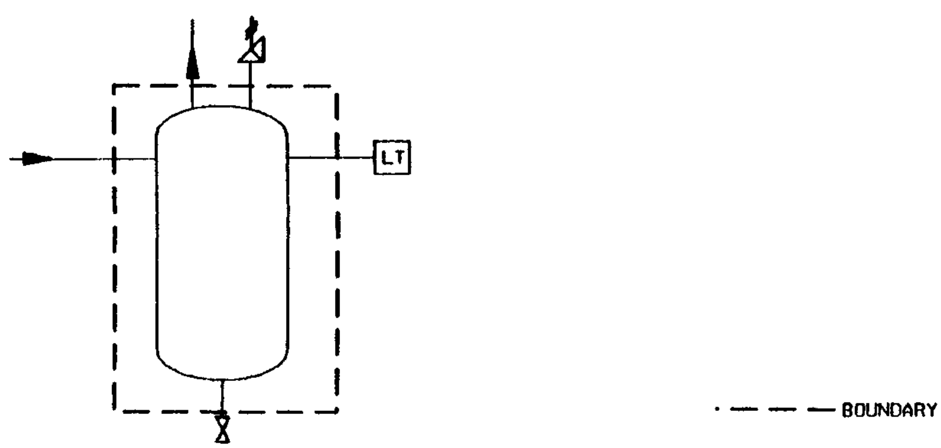
DATA ON SELECTED PROCESS SYSTEMS AND EQUIPMENT

Taxonomy No. 3.6.2.1	**Equipment Description** VESSELS-PRESSURIZED-METALLIC
Operating Mode	**Process Severity** UNKNOWN

Population	**Samples**	**Aggregated time in service (10^6 hrs)**		**No. of Demands**	
		Calendar time	**Operating time**		

Failure mode	**Failures (per 10^6 hrs)**			**Failures (per 10^3 demands)**		
	Lower	**Mean**	**Upper**	**Lower**	**Mean**	**Upper**
CATASTROPHIC	0.000142	0.0109	0.0424			
a. Leakage >1/4"						
b. Leakage 0 - 1/4"						
c. Rupture						
d. Plugging						
DEGRADED	0.000951	0.0636	0.247			
a. Restricted Flow						
INCIPIENT						
a. Wall Thinning						
b. Embrittlement						
c. Cracked or Flawed						
d. Erratic Flow						

Equipment Boundary



Data Reference No. (Table 5.1): 10

TABLE 5.1
Resources Used for Data Tables

Data Reference No.		Data Resource Title	Chapter 4 Resource No.
1.		Development of an Improved Liquefied Natural Gas Plant Failure Rate Data Base.	4.3-2
2.		Pressure Vessel Reliability.	4.4-1
3.		Some Data on the Reliability of Pressure Equipment in the Chemical Plant Environment.	4.4-3
4.		Some Data on the Reliability of Instruments in the Chemical Plant Environment	4.4-4
5.		Failure and Maintenance Data Analysis at a Petrochemical Plant.	4.4-5
6.		Hazardous Waste Tank Failure.	4.5-1
7.		Reliability Data Book for Components in Swedish Nuclear Power Plants.	4.6-6
8.*		SAIC Proprietary Data Set containing data from:	4.6-10
	8.1	The In-Plant Reliability Data Base for Nuclear Power Plant Components.	4.6-11
	8.2	IEEE Standard 500-1984.	4.6-12
	8.3	Generic Data Base for Data and Models Chapter of the National Reliability Evaluation Program Guide (NREP).	4.6-13
	8.4	Offshore Reliability Data Handbook (OREDA).	4.6-14
	8.5	RADC Non-Electronic Reliability Notebook.	4.6-15
	8.6	Reliability Prediction of Electronic Equipment (Military Handbook 217E).	4.6-16
	8.7	Data Summaries of Licensee Event Reports at U.S. Commercial Nuclear Power Plants (Various Components).	4.7-8
	8.8	Reliability of Emergency Diesel Generators at U.S. Nuclear Power Plants.	4.7-14
	8.9	Big Rock Point Probabilistic Risk Assessment.	4.8-1
	8.10	Indian Point Units 2 and 3 Probabilistic Risk Assessment.	4.8-3
	8.11	Interim Reliability Evaluation Program: Analysis of the Millstone Point 1 Nuclear Power Plant Assessment.	4.8-5
	8.12	Oconee-3 PRA: A Probabilistic Risk Assessment of Oconee Unit 3.	4.8-6
	8.13	Yankee Nuclear Power Station Probabilistic Safety Study.	4.8-7
	8.14	Zion Probabilistic Safety Study.	4.8-8
	8.15	Reactor Safety Study: An Assessment of Accident Risk in U.S. Commercial Nuclear Power Plants (WASH-1400).	4.8-9
9.		An Analysis of Reportable Incidents for Natural Gas Transmission and Gathering Lines—1970 through June 1984.	4.7-19
10.		Pressure Vessel Failure Statistics and Probabilities.	4.7-21

*Note: SAIC has selected some data from resources 8.1 through 8.15 to construct its proprietary data files for use in performing PRAs. Relevant data from these files was used to construct the CCPS Generic Failure Rate Data Base. Accordingly, all usable data points contained in the resources used by SAIC may not be in the Data Tables in this book.

NON-PROCESS EQUIPMENT DATA SOURCES

TITLE: Pressure Vessel Failure Statistics and Probabilities	
SPONSOR/AUTHOR: J. R. Engel, AEC Advisory Committee on Reactor Safeguards	**NO.:** 4.7-21
INDUSTRY: Nuclear	**TIME FRAME:** Through 1971
TYPE: Journal Article	**FREQUENCY OF UPDATE:** None

NUMBER AND TYPE OF RECORDS: 4 tables containing failure data for vessels

DATA BOUNDARY: Primarily concerned with boiler failures

DATA ACCESS:

Contact: Nuclear Safety, Vol. 15, No. 4, July - August 1974

DESCRIPTION:

This report summarizes data on non-nuclear pressure vessel failures in order to develop data which could be applied to the nuclear power industry. Tables 3 through 6 present summaries of vessel failures and failure rates.

GUIDELINES FOR

PROCESS EQUIPMENT RELIABILITY DATA

WITH DATA TABLES

CENTER FOR CHEMICAL PROCESS SAFETY
of the
American Institute of Chemical Engineers
345 East 47th Street, New York, New York 10017

Library of Congress Cataloging-in-Publication Data

Guidelines for process equipment reliability data
with data tables

Bibliography: p
Includes index.
1. Chemical plants—Equipment and supplies—Reliability. I. American Institute of Chemical Engineers. Center for Chemical Process Safety.
TP155.5.G78 1989 660.2'83 88-36039
ISBN 0-8169-0422-7

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