5.3 Piping

The failure modes for pipe sections can be described as either blockage, leak, or break. The frequency of blockage will normally be very dependent on the flow type, particularly freezing or solidification of substances or to crystallisation from solution, due to heat tracing failure or especially cold weather conditions are a cause. Only in extreme cases will corrosion be a cause of blockage. Mechanical damage, as a result of crashes, or explosions, can pinch or bend pipes sufficiently to prevent flow. Otherwise, the main causes are deposits, crud, or foreign bodies, especially at low points in a pipe section, and with still standing flows and freezing of liquids.

Leak or break of a pipe can be caused by many things

- Corrosion or erosion
- Crashing vehicles, cranes
- Overstressing, when pipework is also used as structural support (especially during construction or rigging)
- Damage occurring during installation (this can remain hidden for a long time)
- Expansion stresses, especially if flexible joints are jammed
- Movement in structures or foundations
- Underground pipes may be inadvertently excavated
- Explosion or overpressure, both internally and externally
- Overtemperature due to process runaway or to fire, causing weakening of pipe walls
- Vibration causing fatigue
- For very high temperature pipe work, creep.
- Fire

Failure rates for all these causes are impossible to give - they depend far too much on circumstances. The more generally applicable causes can be estimated as a general average. API failure data have been used as a basis, supplemented by data from direct experience, and from other literature sources. Causes such as crashes, explosions and overpressure bursts, which lead to secondary failures in pipes, have been excluded from the data. The interpretation of data is further complicated by the fact that the term "leak" is not generally well defined.

A leak here is defined as a small crack or pinhole in the range 0.01 mm^2 to 10 mm^2. A large leak is in the range 10 mm^2 to 1000 mm^2. Anything above this is regarded as a break.

Data for small pipes, from 1/2" to 2", and for medium size pipes for general service, in ranges 2" go 6" and pressures up to 30 atm. are described. for larger and higher pressure piping, the fracture mechanics methods described in the section or pressure vessels can perhaps be used.

Failure Mode	Failure Rate
Blockage	depends on system
Small leak	0.001 per 10^6 hr. m = 10^{-9} per hr. m.
Large leak	0.0001 per 106 hr. m. = $1*10^{-10}$ per hr. m.
Break	0.00003 per 10^6 hr. m. = $3*10^{-11}$ per hr. m.

Plus rates for secondary failures e.g. catastrophic corrosion, overpressuring.

Table 5.7 Failure rates for pipes in 2"-6" class up to 30 atm.

Failure Mode	Failure Rate
Blockage	depends on system
Small leak	0.001 per 10^6 hr. m.
Break	0.00003 per 10^6 hr. m.
Plus failure rates due to secondary failures	

Table 5.8 Failure rates for pipes in 1/2" to 2" class.

5.4 Flanges

The most important failure modes for flanges are leak or breakdown.
The causes may be many

- The flange can be too loose due to the fact that screws or bolts are not tightened, or because heating, overpressuring, vibration, mechanical loads have lengthened bolts or opened the flange .
- Overstressing of bolts can cause breakage. Pipe expansion which has not been allowed for, or jammed hangers, can bow pipes and cause opening of flanges
- Sometimes too few bolts will be fitted or some will be left untightened, during installation or maintenance, as a result of error. The remainder may be overstressed.
- Corrosion products in the flange opening itself can force flanges apart.
- Corrosion or aging can weaken packings.

- Corrosion under a packing, particularly if the packing is scored, can lead to a leakage route around the packing.
- Foreign bodies, mishandling, dirt, or burrs on the flanges can cause damage to seals under installation.
- Bolts can break through overstressing, fatigue or corrosion.
- Sometimes flanges are simply unbolted in error by maintenance staff while the system is under pressure, or remains undrained.
- Flanges can fail as the result of other failures. For example packings can be blown out by overpressure (unless recessed) or be destroyed by fire.

Table 5.9 gives failure rates for failure modes which do not involve human errors or are not the result of secondary failures.

Failure Mode	Failure Rate
Small leak +) (0.1-10 mm^2 hole)	0.4 per 10^6 hrs.
Packing blown out, or partially destroyed, or flange opens several mm (not recessed flanges)	0.03 per 10^6 hrs.
Flange breaks open +)	0.01 per 10^6 hrs.

+) for high pressure piping designed to high standards, and with no temperature cycling, the valves may be divided by 10.

Table 5.9 Failure rates for flanges in 2-6" piping.

Small leaks of corrosive liquors such as hot, salt laden water under pressure, can corrode or erode paths over flange faces, so that a large leak is formed in the course of a few hours.

5.5 Pipe Welds

Welds represent one of the weakest points in piping, due to the problems of weld inclusions, material differences, pits and holes, and of unavoidable structural changes to material under the heat of welding. It is probable that many of the failures in piping described earlier in fact occur at welds. Nevertheless, more accurate results are obtained if failure rates specifically for welds are added to the overall failure rates for pipes, at least in the cases where there are many welds. Failure modes concern leakage and breakage. WASH 1400 data, which concerns high pressure, moderately high

temperature steam and water service, is reflected in table 5.10.

Failure Mode	Failure Rate
Leakage (less than 10% of weld area)	0.03 per 10^6 hr.
Breakage	0.003 per 10^6 hr.

Table 5.10 Weld failure rates for larger pipe sizes (1 1/2" to 24")

Risk Analysis for Process Plant, Pipelines and Transport

J.R. TAYLOR
Taylor Associates Aps
Glumsø
Denmark

Taylor & Francis
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

© 1994 Taylor & Francis

ISBN 0 419 19090 2

Apart from any fair dealing for the purposes of research or private study, or criticism or review, as permitted under the UK Copyright Designs and Patents Act, 1988, this publication may not be reproduced, stored, or transmitted, in any form or by any means, without the prior permission in writing of the publishers, or in the case of reprographic reproduction only in accordance with the terms of the licences issued by the Copyright Licensing Agency in the UK, or in accordance with the terms of licences issued by the appropriate Reproduction Rights Organization outside the UK. Enquiries concerning reproduction outside the terms stated here should be sent to the publishers at the London address printed on this page.

The publisher makes no representation, express or implied, with regard to the accuracy of the information contained in this book and cannot accept any legal responsibility or liability for any errors or omissions that may be made.

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

Library of Congress Cataloging-in-Publication data available

∞

Printed and bound by Antony Rowe Ltd, Eastbourne