

Appendix 3 Partial Proof Testing Example

This appendix contains an illustrative example of how to consider partial proof testing within the PFD calculation.

Taking the equations:

$$PFD_{AV} = \frac{\lambda_D \times T_i}{2} \quad \text{Where:} \quad \begin{array}{l} \lambda_D - \text{Failure Rate (Dangerous)} \\ T_i - \text{Proof Test Interval} \end{array}$$

[Equations taken from BS EN 61508-6:2001 B2.2.1 and assuming mean time to repair is small relative to the proof test interval. Note that these equations have been simplified for the purposes of demonstration of particular issues.]

These equations are suitable for low demand modes of operation only, i.e. where demand frequency ≤ 1 per year and $\leq 2 \times$ proof test frequency – BS EN 61508:-4:2001 3.5.12.

The PFD_{AV} can be calculated for each component of the system (e.g. S – Sensor, LS – Logic Solver and FE – Final Element) and then summed together.

$$PFD_{AV} = \frac{\lambda_{D(S)} \times T_{i(S)}}{2} + \frac{\lambda_{D(LS)} \times T_{i(LS)}}{2} + \frac{\lambda_{D(FE)} \times T_{i(FE)}}{2}$$

[This approach is only valid for small values of PFD]

This approach can also be used to further break down a component into failure modes (for example where partial stroke testing is used).

For example if the final element is a valve required to close to achieve the safety function and the failure modes were as follows (note – these figures and failure modes are illustrative only and should not be used)

Failure Mode	Failure Rate (per year)	Detected by partial stroke testing?
Solenoid fails to vent	0.005	Yes
Valve sticks open	0.004	Yes
Valve doesn't fully close or passes	0.001	No
Other unknown failures	0.006	No
TOTAL	0.016	

If we assume that the plant is only shut down every 4 years, without partial stroke testing then the PFD for this valve would be:

$$PFD_{AV(Valve)} = \frac{\lambda_D \times T_i}{2} = \frac{0.016 \times 4}{2} = 0.032$$

However, with partial stroke proof testing every 3 months (0.25 years):

$$\begin{aligned} PFD_{AV(Valve)} &= \frac{\lambda_{D(PST)} \times T_{i(PST)}}{2} + \frac{\lambda_{D(NT)} \times T_{i(NT)}}{2} \\ &= \frac{(0.005 + 0.004) \times 0.25}{2} + \frac{(0.001 + 0.006) \times 4}{2} \\ &= 0.001125 + 0.014 \\ &= 0.015 \end{aligned}$$

The PFD_{AV} of the valve is more than halved with the partial stroke proof testing in this example.

Note that this partial valve test is assumed to be a proof test not a diagnostic test, since it doesn't detect and action failures found within the specified mean time to repair (which has been assumed to be very small in this case).

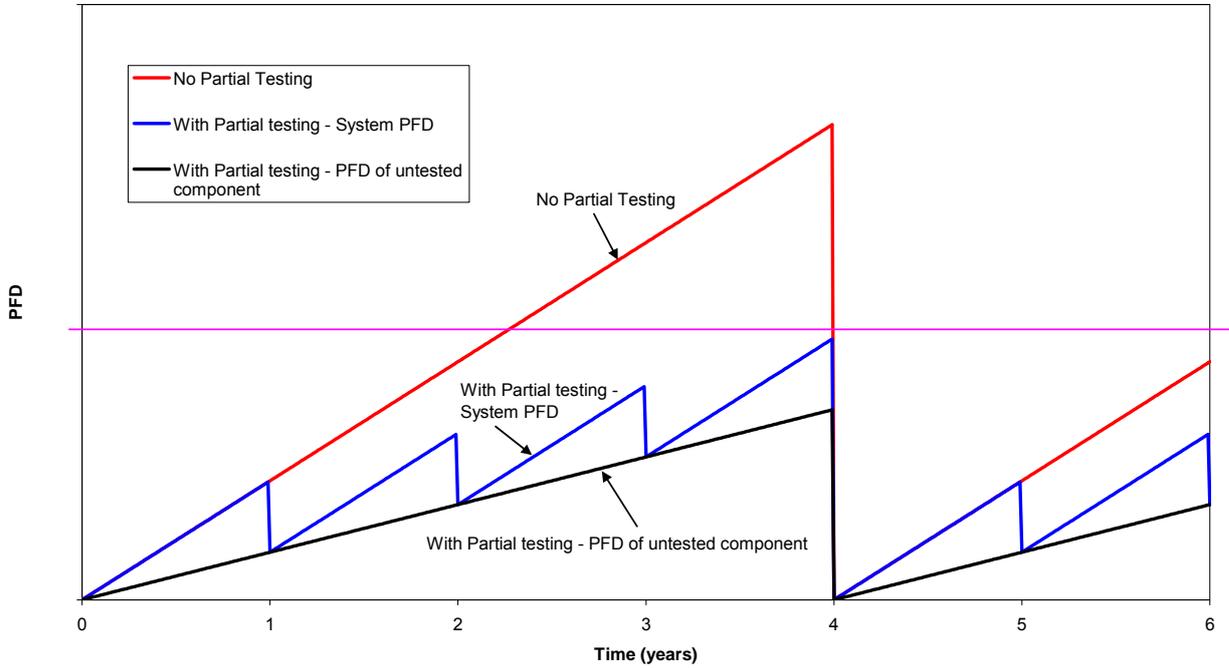
In the above equation, note that the first term on the right hand side refers to failures of the system that are detected during partial stroke testing and the second term refers to the remaining failures that are only tested every 4 years at shutdown. Therefore, even if we did the partial stroke testing almost constantly (e.g. every hour = 0.0001 years), such that the first term became almost zero, the minimum PFD_{AV} value would be 0.014.

This shows the effect of partial testing, i.e. it doesn't matter if you test part of the system very well, the failure rate will eventually be dominated by the parts of the system that are not tested.

This can also be show graphically (see below):

- Note on the graph the PFD is shown as varies over time (note – this is PFD not PFD_{AV}).
- The red line represents the scenario where no partial testing is done. Only a full test is done every 4 years.
- The blue line represents the PFD of the system with partial testing. Note that the PFD of the untested part of the system (black line) increases until 4 years when a full test is carried out. By the end of the 4 years, the PFD is dominated by the untested part of the system.
- The purple line represents the required performance.

How PFD changes over time with Partial Testing



Note that in a low demand system, the object is to discover dangerous failures through proof testing before they are discovered by a real demand. For this reason, the demand frequency should be considerably lower than the proof testing frequency. With partial proof testing the demand frequency should be considerably lower than the worst case proof test frequency (i.e. considerably lower than once per 4 years proof test in the above example). Typically, the following rule of thumb should be satisfied:

$$D T_i \ll 1$$

Where D is the demand rate and T_i is the proof test interval.