HOW TO DESTROY A BOILER

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We all know, or should know, the importance of good boiler plant operation and maintenance. Generally, if we do the rights things then all will be well. Most boiler house teams, most of the time will be doing their best to look after their plant, hoping that what they do is good enough. But how can they know?

I often find that turning problems or questions on their head can be a pathway to greater understanding. So instead of focusing on what we should do to look after our boilers, I want to ask the opposite question. What happens when we deliberately imagine how we can destroy our boilers? What would failure look like? What would the pathway to failure look like?

If we can understand how and why failures occur, then we should all be better able to prevent those failures.

Poor management, operation or maintenance of boiler plant and auxiliaries can result in catastrophic failure of boiler plant. Catastrophic failure is characterised by any, or all, of the following:

- Damage to plant and property
- Explosion causing catastrophic damage to plant, and buildings
- Injury or death to operators
- Injury or death to non-operators and/or members of the public

In the case of a boiler explosion, fortunately a rare event, it is usual for the burner to detach and travel away approximately on the axis of the boiler in one direction while the boiler shell travels approximately on the boiler axis in the other direction. The boiler shell may travel many metres, the burner could travel farther; other shrapnel may travel even farther. This prime event may cause other damage, e.g. fracture of fuel lines, further ignition of fuel, damage to building and other plant.

Avoidance of catastrophic failure should be achieved by proper and close attention to correct operating and maintenance practices.

In Table 1 below I have imagined and identified 12 scenarios that have the potential to cause catastrophic failure. And I allow for an unlucky and as yet unidentified 13th scenario.

Where events in the Table below do not immediately lead to a catastrophic event, they may still result in:

- Additional maintenance costs and outage time for :
    - acid cleaning
    - weld repairs
- Reduction in boiler rating capability; the Competent Person reducing the maximum allowable pressure or safe operating limits of the boiler
- Early removal from service following withdrawal of authorisation to operate by the Competent Person.

Boiler Managers and Operators are recommended to study the Table to reinforce the importance of correct operation and the possible consequences of incorrect operation

Table 1 - How to Destroy a Boiler

ID	Prime Event	Caused by	Leading To	Prevention/Mitigation
1	Uncontrolled ignition in furnace	Fuel leaking at burner when boiler is off. Incomplete post-firing purge Incomplete pre-firing purge.	Ignition of unburnt hydrocarbon during start up. Ignition of soot build up in furnace and tubes from incomplete combustion.	Strict adherence to correct operating routines particularly on starting or re-starting a boiler. Regular and correct maintenance Detection of irregular combustion during normal operating checks. Detection of irregular combustion at periodic boiler inspection by Competent Person.
2	Flame impingement	Incorrectly adjusted burner system directing flame directly on to furnace tube.	Furnace tube overheats and weakens. Weakened furnace tube distorted by boiler pressure to 'dome' then fail	Regular and correct maintenance Detection of irregular combustion during normal operating checks. Detection of irregular combustion at periodic boiler inspection by Competent Person.
3	Over-firing	Burner firing at above approved rate.	Reduction in boiler efficiency. Furnace tube overheats and weakens. Weakened furnace tube distorted by boiler pressure to form a dome then fail. Boiler tubes seeing higher than expected fire side temperatures. Boiler tubes weaken and fail.	Regular and correct maintenance Detection of irregular combustion during normal operating checks. Detection of irregular combustion at periodic boiler inspection by Competent Person.

ID	Prime Event	Caused by	Leading To	Prevention/Mitigation
4	Poor water treatment	Failure of water softening plant, insufficient salt/brine solution. Failure of Reverse Osmosis plant. Low condensate return. Water quality in hot well and in boiler not maintained to boiler manufacturers recommendations. Feed water too hard.	Insufficient Oxygen scavenge resulting in corrosion of shell and/or tubes. Scale formation on water side of boiler tubes and furnace tube. Areas of tube where scale has built up now lagged against heat transfer. Affected tubes overheat and fail. Furnace tube overheating and collapse leading to boiler explosion.	Strict adherence to correct operation of water treatment plant. Regular and correct maintenance of water treatment plant. Regular water quality checks by plant operators. Regular water quality checks by independent company. Periodic boiler inspection by Competent Person. Periodic NDT inspection by Competent Person. Acid cleaning if required by inspection.
5	Contaminated feed water	Contamination of feed water from interfaces between steam system and other site process systems, or elsewhere. Acidic condensate being returned and incorrectly treated. Copper contaminant in condensate Water quality in hot well and in boiler not maintained to boiler manufacturers recommendations.	Scale formation on water side of boiler tubes and furnace tube. Areas of tube where scale has built up now lagged against heat transfer. Copper pitting on tubes Affected tubes overheat and fail. Furnace tube overheats and collapses leading to boiler explosion. Insufficient Oxygen scavenge resulting in corrosion of shell and/or tubes.	Strict adherence to correct operation of water treatment plant. Regular and correct maintenance of water treatment plant. Regular water quality checks by plant operators. Regular water quality checks by independent company. Periodic boiler inspection by Competent Person. Acid cleaning if required by inspection.

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6	Low-water level	No water available from hot well. Failure of water control system. Failure of water level detection system Feed pump failure. Feed injection valve failure.	Water level in boiler shell drops. Top row(s) of boiler tubes exposed. Exposed boiler tube(s) overheat. Overheated boiler tube(s) fail. White smoke/steam seen in boiler exhaust.	Strict adherence to correct operating routines. Regular and correct maintenance of plant and systems. Regular checks of visual boiler water level indicators (Gauge Glasses). Normal boiler controls detect the low water level and stop boiler firing. Alarm out via BG01 panel.
7	Blowdown systems defect	Irregular bottom blowdown. Automatic TDS control not working correctly.	Sludge build up and scale formation on water side of boiler tubes and furnace tube. Areas of tube where sludge/scale has built up now lagged against heat transfer. Affected tubes overheat and fail. Furnace tube overheat and collapse leading to boiler explosion.	Strict adherence to correct operation of boiler. Regular and correct maintenance of boiler plant and systems. Regular water quality checks by plant operators. Regular water quality checks by independent company. Periodic boiler inspection by Competent Person. Acid cleaning if required by inspection.

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8	Incorrect warm-up	Boiler brought to working conditions more quickly than boiler manufacturer's recommendations.	Boiler shell and tubes will expand with temperature. Boiler tubes will see furnace gas and exhaust temperatures and could be brought up to full temperature and expansion very quickly. The shell plating is much thicker than the tubes, the boiler shell will only see water/steam temperatures and will expand slowly. If boiler tubes expand too quickly then the Tube Plates will tend to bow at each end, placing very high stresses across the tube plate to shell weld. Over time cracks will develop in the shell to tube plate welds. Expansion of steel is approx. 0.012mm/m/^{o}C.	Strict adherence to correct operation of boiler, particularly on starting or re-starting a boiler. Regular and correct maintenance of boiler plant and systems. Periodic boiler inspection by Competent Person. Periodic NDT inspection by Competent Person.
9	Incorrect shut-down	Taking boiler from operating conditions to cold too quickly. This is the reverse of Improper warm up.	Boiler tubes may lose temperature and shrink more quickly than the shell. Tube plates bow inwards, placing very high stresses across the tube plate to shell weld. Over time cracks will develop in the shell to tube plate welds.	Strict adherence to correct operation of boiler, particularly on boiler shut-down. Regular and correct maintenance of boiler plant and systems. Periodic boiler inspection by Competent Person. Periodic NDT inspection by Competent Person.

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10	Pulling a vacuum in the boiler	On shut down allowing the boiler to cool down with the crown valve and boiler vent valve shut.	Boiler components, shell or tubes, distorted by vacuum stresses, leading to initiation of cracks in welds.	Strict adherence to correct operation of boiler, particularly on boiler shut-down. Regular and correct maintenance of boiler plant and systems. Periodic boiler inspection by Competent Person. Periodic NDT inspection by Competent Person.
11	Boiler not correctly preserved when not in service.	Boiler water retained in shell: Boiler water quality not correctly maintained.	Boiler water retained in shell: Initiation of corrosion at any air-water interface Pitting of shell leading to reduction in shell strength/ability to withstand hoop stresses. Boiler water freezes in cold weather causing mechanical damage to shell/tubes.	Use appropriate Boiler Lay-Up procedure for boiler out of service, e.g.: • <3 days – Water at working level (W). Water level maintained, any water added to be correct quality, especially Oxygen scavenge. • <2 months – Water wedged (WW). Water dosing maintained to ensure Oxygen scavenge reserve and the pH value at correct levels. Protect against water freezing in winter. • >2 months – Empty open and de-humidified (EO+D) Maintain humidity at <30% or maintain Oxygen <0.5%. Periodic boiler inspection by Competent Person . Periodic NDT inspection by Competent Person .
		Boiler shell empty of water: Moisture allowed to collect on shell and tube surfaces.	Boiler shell empty of water: Initiation of corrosion. Pitting of shell leading to reduction in shell strength/ability to withstand operating stresses. Corrosion, pitting or general, on tubes leading to reduction in tube strength/ability to withstand operating stresses	

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12	Impact damage to tubes	Damage to tubes caused during maintenance activities.	Even a small ‘dink’ could be the initiation site for cracking and failure.	Regular and correct maintenance of boiler plant and systems. Care taken not to cause any damage to tubes during inspection and maintenance activities. periodic boiler inspection by Competent Person. Periodic NDT inspection by Competent Person.
13	Other?			