Expert Report

Dipl.-Ing. Jochen Loos
Dipl.-Wirtschaftsing. (FH), Dipl.-Informationswirt (FH)
Markus Tuffner, Bosch Industriekessel GmbH

BOSCH
Invented for life

History of the development of water level control in steam- and hot water boilers

Introduction
Before the introduction of quickly controllable boiler firing and automated limiting devices, steam boiler systems with a set fixed minimum water level were operated manually from the heater. The water level was established by means of a sight glass outside the boiler and the water feed was switched on or off manually. If there was failure of the water feed, the fuel supply was also prevented, usually manually as well. With solid fuel firing, the rust from the fuel also had to be released.

This procedure was automated with the introduction of water level regulating devices. With systems with oil or gas firing, these devices operated directly on the fuel supply. If there was a failure of the water level regulating device, which generally functioned on the basis of a float with magnetic force transmission, the fuel supply was automatically stopped. These devices were generally installed outside the boiler in special immersion containers.

Due to the increasing automation of steam boiler systems and the drive towards operation without constant supervision, the development of sophisticated water level regulating and limiting devices was driven forward at the beginning of the, 70s and was implemented on the principle of conductivity.

Since the initial use of the first conductivity controlled devices was not satisfactory, particularly with regard to safety against insulation faults, more proven concepts working on the float principle were combined with these new conductivity controlled devices.

With the improvement in insulation capacity and in electrical switching through the use of two-channel systems, this combination with mechanical units was abandoned and it became possible to operate without daily tests. Tests by experts had to be made every half year. At the end of the, 70s, through a process of systematic ongoing development, the absolute, self-monitoring water limiting device was developed on the basis of electrodes and this was brought into use as standard. These devices no longer require daily tests, nor do they need to be tested by experts after half a year. The precondition for this is however that the devices are located internally within the boiler.

Operational characteristics of the various units

The following designs are known and used so far:

- Mechanical float-type water level limiters with transmission of the signal by magnetically actuated switch contacts:
  a) units with manual checking arrangement
  b) units with electro-mechanical checking arrangement
- Conductivity-based water level limiting system:
  a) simple arrangements with automatic checks at specific intervals
  b) two-channel arrangements
  c) self-monitoring arrangements.

Float-type water level limiter

The float-type water level limiters use the buoyancy of a float, to which is attached a small rod holding a magnet. The magnet is held in a guide sleeve on whose outside electromagnetic locking switches are applied. As the magnet passes the electro-magnetic locking switches, the electromagnetic locking switch is thrown by magnetic force into its closed or open setting, resulting in an electric switching action which can be used for shutting off the firing system or for triggering alarms. This arrangement can be checked at predetermined intervals generally daily by means of an ordinary magnet, at which time, also by magnetic force, the float is forced below the actual water level to simulate a water shortage. The magnet of the float must then switch over the electromagnetic locking switch, which must lead to the safety shutdown of the firing system and the boiler installation.

So that this process can also be remotely controlled, electromagnets were used instead of the ordinary magnets.

These units were initially installed externally in special accommodating vessels, the connection between the external float bodies and the boiler drum involving electrically protected valves with limit switches. In the case of the external arrangement, daily checking and cleaning of the immersion sleeve was also necessary, for the reliable prevention of water-simulating sludge deposits.

Figure 1: Float-type water level limiter – checking the safety circuit and daily blow-through cleaning are obligatory

Figure 2: simple electrode – mandatory daily test through blowing in nitrogen.

Simple probe arrangements with daily checks
Because of their low degree of safety, particularly as regards insulation monitoring, simple probe water failure safeguards using the conductivity principle require a daily obligatory check. This consists of injecting nitrogen into the protective probe sleeve: the injected nitrogen lowers the water volume in the protective sleeve and the probe loses contact with the water. When the water level has been lowered to below the probe tip, the boiler installation is forced to switch off, or a signal is emitted which indicates that the equipment is functioning correctly.

Two-channel probe water level monitors
With the idea in mind that two devices do not generally fail at exactly the same moment, two-channel devices were designed. With these devices the probe insulation was already simultaneously monitored, but the electrical switching arrangement was not supervised. The operation of these devices now as then has to be checked regularly for several times yearly by the authorized inspector of a technical inspection authority by lowering the water level and recording the switch-off point.

Self-monitoring probe water level monitors
These limiting devices generally have a complex sensor with an electric switching arrangement which continuously monitors the probe for insulation short-circuit, as well as continuously checking the correct operation of the safety function of the electrical switching arrangement as such at intervals of approx. 15 – 20 seconds. With these arrangements the daily check of the equipment is dispensed with, as are the regular inspections by the inspection authority. These Installations are as a rule checked for correct operation by the boiler manufacturer‘s aftersales service simply by pressing test buttons provided for that purpose.

Figure 3: Two-channel probe water level monitor – the operation of the system must be checked regularly by the boiler inspection authority

Figure 4: Self monitoring probe water level monitor – no maintenance, no functional test required

Figure 5: Probe system in the protective sleeve – insulation distance between probes and protective sleeve is permanently guaranteed

The safety probe as a low-water limiter is inclined sloping towards the centre; contact with the protective sleeve is impossible

Summary

The use of float-type water level limiters has been largely replaced by today‘s electronic sensor units.

The increasing operation of steam boiler installations without constant supervision meant that the limited reliability of float-type devices – arising from its mechanical weaknesses as well as the need for conscientious daily checks was no longer acceptable.

Particularly with increasing age of float-type water level limiters, the failure risk of these devices grows constantly and impercep- tibly greater.

This is caused by a weakening of the magnetic force of the emitter as well as of the switch-over magnet in the magnetic locking switch.

The shortcomings found in these mechanical water level limiters led in the early seventies to the development of the electronic sensor water level monitors.

With all sensor-based devices, the prevention of a short circuit between probe and surrounding boiler body was the primary concern during development and testing.

Due to the operational principle of conductivity, a fault in the insulation of the probe, i.e. the electrical separation between probe terminal and mass, can simulate water and dangerous conditions may arise if switch-off does not take place when a genuine water failure occurs.

The development of an insulation monitoring system made it possible to cope reliably with faults concerning only the insulation.

Preventing the probe from coming into contact with the protective sleeve was with the first probe versions attempted by means of plastic centring cross-pieces. This was not successful, however, since the formation of deposits on the plastic cross-piece may create a conducting path, again leading to an electrical connection between mass and probe.

In the case of the systems described in Section 4, Self-monitoring probe‘, the fitting of any plastic centring cross-pieces is therefore rejected. Instead, by limiting probe bar length to approx. 600 mm and by inclining the probes towards the centre or enlarging the protective sleeve, a space between sleeve and probe is created whose length makes contact of the probe bars with the sleeve impossible, provided that the system is correctly installed and subsequently checked. Over a 30-year period, 30 000 boiler installations were equipped with this system and no water failure damage or other irregularity occurred during this time.

The safety of a large number of old plants which were originally equipped with either float-type water level controllers or with controllers of the two-channel type, was also considerably

Enhanced through the installation of self-monitoring probes. Water failure damage is as a rule today only still known in old installations which use the float principle.

An exception are of course electrical interventions in the form of inserting bridges etc.; these are, however, possible with all safety systems, regardless of the emitter principle in question, and these must be strictly forbidden by appropriate instruction of the operating and maintenance personnel, this also applies to gross negligence regarding the required water quality. Massive ingress of grease / oil or hardness affect the function of the probe. Any such ingress can be reliably detected and contaminated water can be drained in time before entering the boiler.

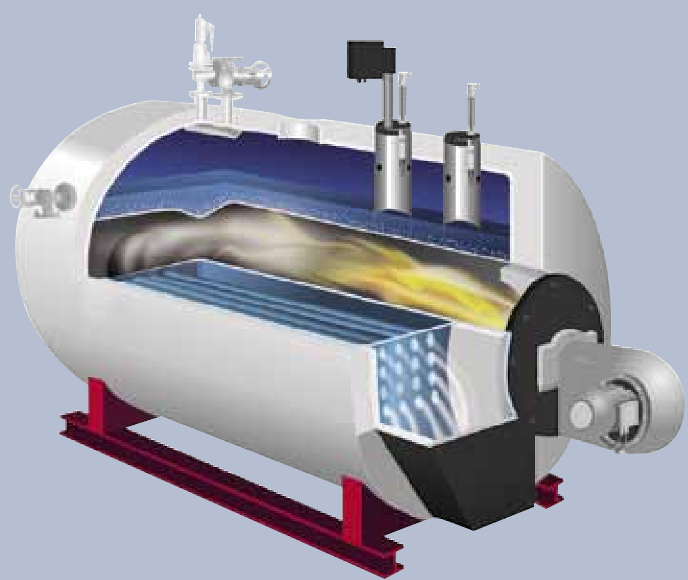
Although experience has shown that the self-monitoring systems offer the greatest degree of safety, there are additional circuits for specially anxious users; these continuously monitor the electrically conducting path between protective sleeve and low water probe, and when the maximum permissible conductivity in this path is exceeded also switch off towards the safe side.

This system is not used in Germany, however, because of the results and sophistication achieved with probe installation as described above.

In other countries, extremely simple probe arrangements without any safety standard are sometimes still being used.

In these installations, constant checking of the water level sight glass is necessary, since no automatic switch-off takes place in the case of a fault.

Figure 6: Sectional view of a modern three-pass steam boiler with integrated probe system inside protective sleeve.



System comparison of the designs used			
1. Float-type water level limiters		**2. Probe with nitrogen test**	
Advantages	Disadvantages	Advantages	Disadvantages
Easy adjustment of the switching point	Sensitive to corrosion	Checking for contact of probe with protective sleeve, i.e. Short-circuit	Checking generally takes place only at 24-hour intervals, so that no safety is provided for this very long period, since the probe is generally of a simple design, and also the electrical switching section is not self-monitoring.
No length limitation of the distance between level to be monitored and position of the operating head	Safety function lessens after a lengthy period of operation due to decrease in magnetic force	No simple possibility of manipulating switching points because of fixed installation	The injection of nitrogen requires stricter safety measure when running the boiler for inspection and flushing – danger of suffocation!
Minimal electrical equipment for evaluating the switch signal	Moving parts in the magnetic locking switch may prevent necessary switching actions through difficult movement	Long-term supervision of the boiler water quality and safety shutdown in the case of non conducting deposits on the probe or in the case of oil ingress	Moving parts for nitrogen feed, such as solenoid valves etc.
Very low cost	Switching reliability depends on rate of level descent		High nitrogen consumption in the case of test intervals shorter than 24 h
	Switching reliability depends on the ambient temperature		Necessity of monitoring sufficient nitrogen reserve for carrying out the test.
	Easy to interfere with by unauthorized persons by changing the position of the magnetic locking switches		
	Daily check required to detect possible irregularities		
	In the case of external installation, immersion container must be flushed daily		
	Experience has shown that the normally used test methods do not exclude water failure occurrence shortly after the test		
	Water failure damage in the case of slow water level drop through lack of additional forces, as occur if float magnet moves quickly.		

System comparison of the designs used			
3. Probe water level monitors of two-channel design		**4. Self monitoring probe water level limiting arrangements**	
Advantages	Disadvantages	Advantages	Disadvantages
No moving parts	The electrical section is not self-monitoring, so that if both channels fail water shortages can occur unnoticed	No moving parts	Higher initial cost
No simple possibility of manipulating switching points because of fixed installation	Higher water level in the boiler can generally only be achieved by shortening the probe bar	No possibility of manipulating switching points because of fixed installation	Higher water level in the boiler can generally only be achieved by shortening the probe bar.
Long-term supervision of the boiler water quality and safety shutdown in the case of non-conducting deposits on the probe or in the case of oil ingress		Long-term supervision of the boiler water quality and safety shutdown in the case of deposits on the probe or in the case of oil ingress	
Low cost		Periodic self-testing of the electrical switching section at intervals of 15 – 20 seconds	
		The insulator of the probe as well as the electric switching section can be unequivocally function tested with one separate test button each	
		Safety in the case of wire fracture or short circuit of the probe supply cable	

Production facilities:
Factory 1 Gunzenhausen
Bosch Industriekessel GmbH
Nürnberger Straße 73
91710 Gunzenhausen
Germany

Factory 2 Schlungenhof
Bosch Industriekessel GmbH
Ansbacher Straße 44
91710 Gunzenhausen
Germany

Factory 3 Bischofshofen
Bosch Industriekessel Austria GmbH
Haldenweg 7
5500 Bischofshofen
Austria

www.bosch-industrial.com