FACTORS AFFECTING THE SAFE AND EFFICIENT OPERATION OF BAGASSE/COAL FIRED WATERTUBE BOILERS

H VERBANCK, K MCINTYRE and Q ENGELBRECHT

John Thompson Boilers, PO Box 129, Bellville, 7535, South Africa
Email: info@johnthompson.co.za

Abstract

The paper covers various aspects relating to the operation and maintenance of bagasse/coal fired watertube boilers which, if properly implemented, will ensure that the boiler operates safely at optimal performance while maintenance and operating costs are minimised. The current philosophies on instrumentation and controls are discussed. This includes combustion and drum level control loops as well as interlocks and safety devices. Operating problems due to unbalanced steam line pressure drops are covered, and recommendations are given for the design of steam lines. The importance of training courses for operating and maintenance personnel is emphasised, including the day-to-day aspects of proper boiler operation. An overview of present and proposed legal requirements for operating, maintaining and repairing boilers in South Africa is also given.

Keywords: boilers, watertube boilers, boiler operation, training, legislation

Introduction

Boilers are key to the operation of any sugar mill. Over many years, John Thompson Boilers (JTB) has gained valuable knowledge of the problems experienced in the operation of bagasse/coal fired boilers. This paper touches on a number of these aspects and describes in detail instrument control philosophies and training. Recent developments in the Vessels Under Pressure (VUP) regulations – which will affect the sugar industry – are also discussed.

Control Philosophy

Combustion controls

The combustion controls of a typical coal and bagasse fired boiler are commonly set up to suit the combustion conditions associated with the predominant fuel. For both bagasse and coal firing systems, the master pressure controller gives an indication of the steam demand and signals the fuel feeders accordingly. With stoker fired boilers, this signal also controls the stoker speed. In the past, a significant number of dual-fuel boilers have been configured with coal as the predominant fuel. The reason for this is to run the boilers as efficiently as possible on coal to reduce the cost of the 'bought-in' fuel. With this configuration, the steam demand controls the forced draft fan damper, and the induced draft fan damper is controlled by the furnace pressure. Oxygen feedback trim is included in the forced draft control loop to make it more responsive when firing coal (Figure 1).

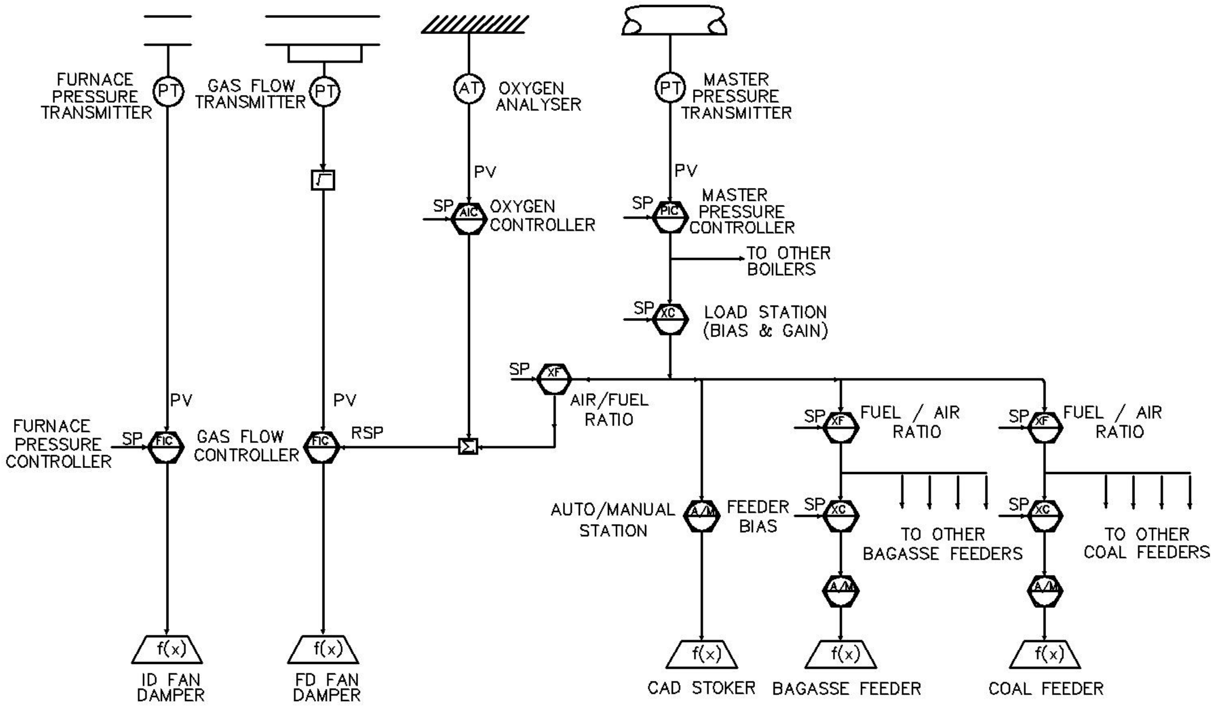

Figure 1. Combustion controls suitable for coal firing.

When set up for firing mainly bagasse, the controls are configured so that the steam demand regulates the induced fan control damper or speed, with the furnace pressure being controlled by the forced draft damper. With this setup oxygen trim is usually included in the fuel feeding control loop (Figure 2).

When configured as a predominantly coal fired boiler, the boiler operates optimally on coal. However, in practise, it has been found that this configuration leads to less stable furnace pressures when firing bagasse. This increases the extent of ‘puffing’, with its associated detrimental effects.

JTB recently commissioned a new bagasse/coal fired boiler where the customer insisted that the controls be configured as a mainly bagasse fired unit. Boiler performance is stable, and it has been operating efficiently when firing bagasse. This has led to a reduction in bagasse consumption, and resulted in less coal having to be burnt. The reduction in efficiency when burning coal was found to be very small.

It is therefore recommended that, unless coal firing efficiency is of utmost importance, for example when generating and exporting electric power, bagasse/coal fired boilers should be configured as predominantly bagasse fired. In addition, especially on larger boilers where more than one hot air duct supplies the undergrate air, two or more control dampers should be fitted to ensure even distribution of the combustion air across the width of the boiler. This results in more uniform combustion in the furnace and more even grate temperatures.

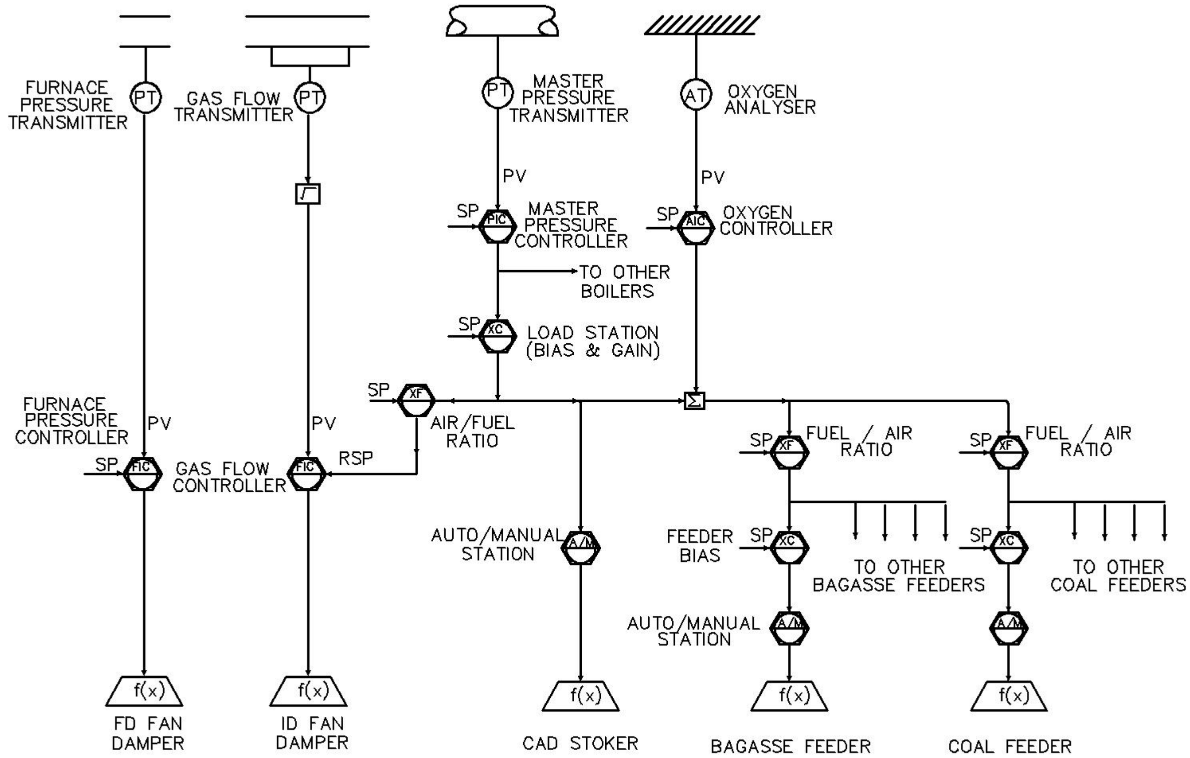

Figure 2. Combustion controls suitable for bagasse firing.

Drum level controls

Drum level trips are common in the sugar industry. The causes are typically poor operation, poorly configured drum level controls, poorly balanced steam lines or a combination of these and other factors. The JTB philosophy regarding drum level controls on watertube boilers in the sugar industry has changed slightly over the years (Figure 3).

Most three-element control strategies place too much emphasis on the drum level signal. The shrinking and swelling effect affects the drum level signal, and having too much bias from this signal tends to cause large upsets in the drum level during load swings. Controllers are sometimes configured with only a proportional band, excluding integral action, on the drum level controller. Using proportional band only in a three-element drum level control system can, depending on the amount of proportional band, result in the drum level control circuit reacting too quickly. Omitting the integration function in the drum level control loop results in the drum level having a permanent offset. The drum level control signal should act only as a trim facility to the remote set point of the feedwater valve controller. The steam flow signal should have the biggest effect on the remote set point of the feedwater valve controller. This will ensure a more stable water level, and compensate for load swings and line pressure changes that cause shrinking and swelling effects, and result in artificial drum levels. Properly set up drum level controls can make the use of mud drum blowdown valves as a method of drum level control a thing of the past. This would benefit the industry by reducing downtime and the dumping of very expensive chemicals. A large steam drum also has a beneficial effect on maintaining a stable water level (Moor, 1985).

JTB recently commissioned a new 125 t/h watertube boiler which, at the customer’s request, incorporates a large steam drum with modified internals to accommodate large drum level fluctuations. During the two-month commissioning period, after the three-element drum level control had been optimised using JTB’s latest control philosophy, no level trips occurred.

Even during very large load swings and mill stops, the water level remained in the range of +190 to –190 mm.

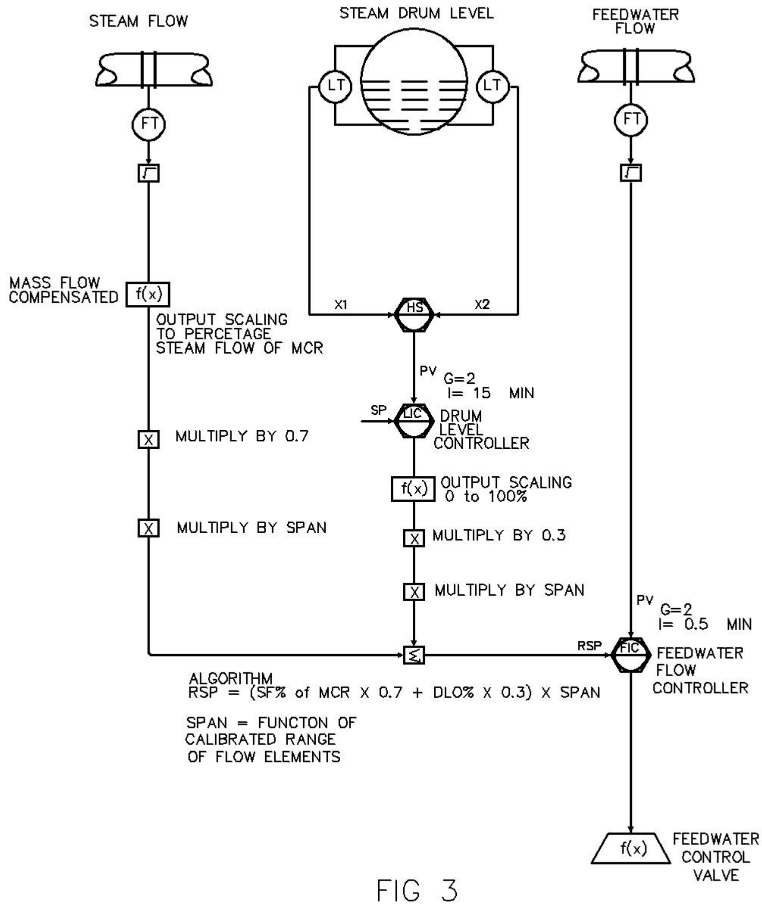

FIG 3

Figure 3. Three-element drum level control.

Interlocks and safety devices

In recent years, Programmable Logic Controller (PLC) and Distributed Control System (DCS) systems have become more entrenched in the industry. However, care must be taken that any boiler mountings or equipment that are being replaced to facilitate the use of PLC or DCS systems, must conform to the codes and regulations to which the boiler or equipment was originally designed and built.

As an example, water level gauge glasses are of utmost importance and cannot simply be replaced by equipment such as magnetic float indicators. This equipment can only be added to increase visibility or safety, but not to replace the absolute water level gauges.

A hard-wired system for safety shutdowns is essential, even where it is duplicated by PLC and/or DCS control systems. This will ensure redundancy on the safety shutdown system. Omitting hard-wired interlocks increases the risk of severe damage to the boiler that can be caused by errors in software programming of the control system. Furthermore, it is good practice to test all safety devices and interlocks at least once a week.

Steam Headers

The importance of having balanced steam lines/headers cannot be emphasised enough. To illustrate this, a hypothetical boiler and header configuration is shown in Figure 4. The steam lines are sized for a typical nominal steam velocity of 35 m/s, and assumes that each boiler is operating at 3100 kPa and at full capacity.

Using typical pipeline, valve and bend losses, the pipeline/header system would be similar to that in Figure 5. The scenario and calculations have been well documented (Goodall, 1980).

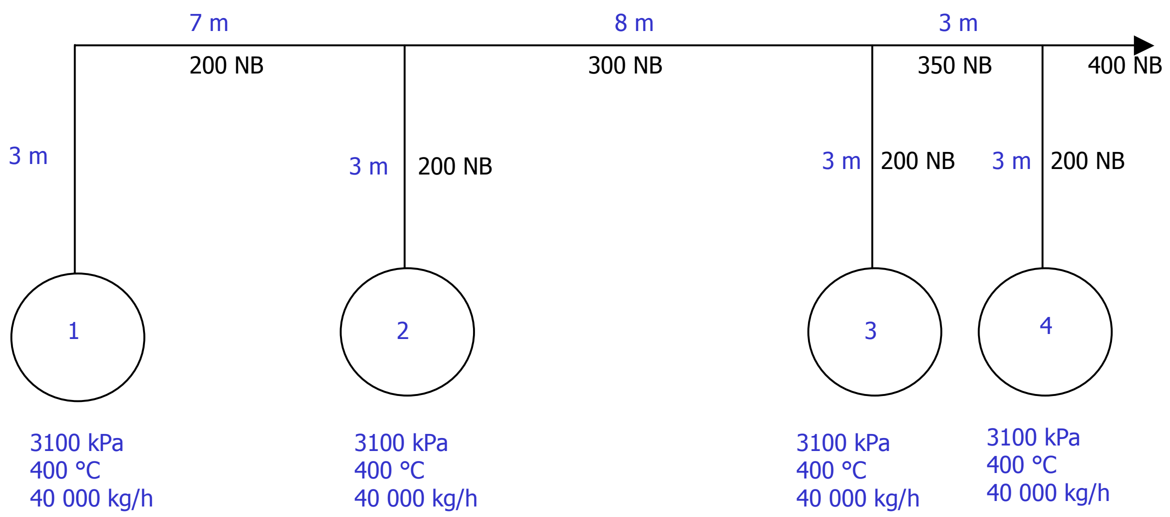

Figure 4. Boiler and header configuration.

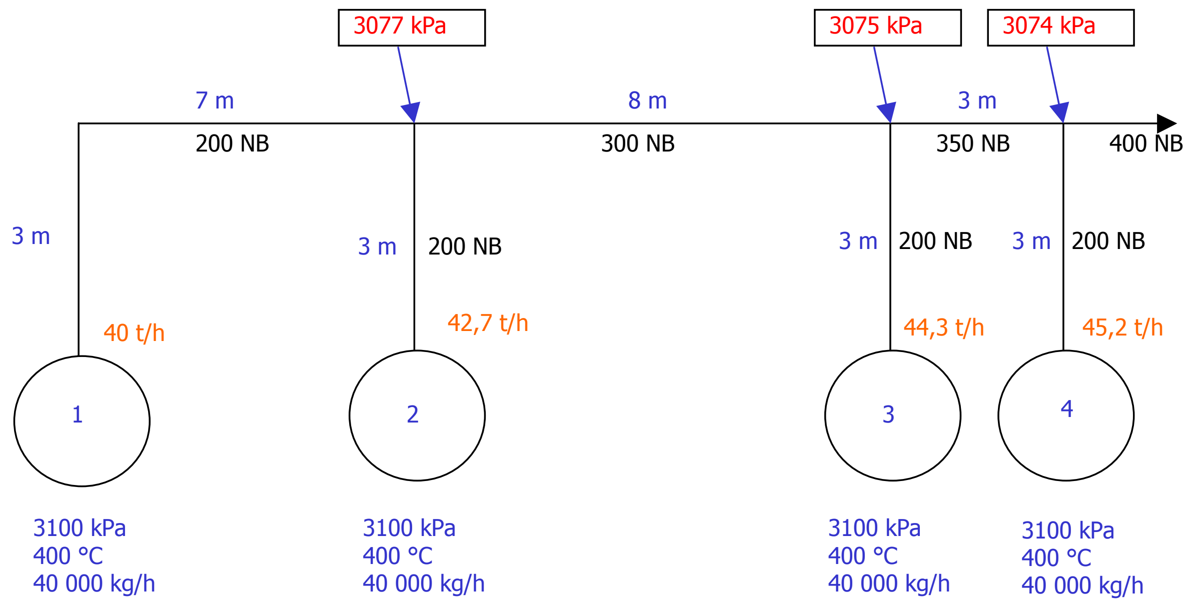

Figure 5. Steam flow and pressure distribution.

Although theoretical, the example shows clearly that, with this pipeline configuration, even under steady loads, boiler 4 is forced to operate at about 13% above its capacity, whereas boiler 1 is running at its design capacity. Assuming that it does not trip during load swings, this configuration can have an extremely adverse effect on boiler 4. This example illustrates how unbalanced steam lines can have a major effect on boiler load and, as a result, also on boiler water level controls.

The steam pipeline/header system shown in Figure 6 has pipelines run in such a way that pressure drops between boilers and final steam take-off point are balanced, thus avoiding this problem.

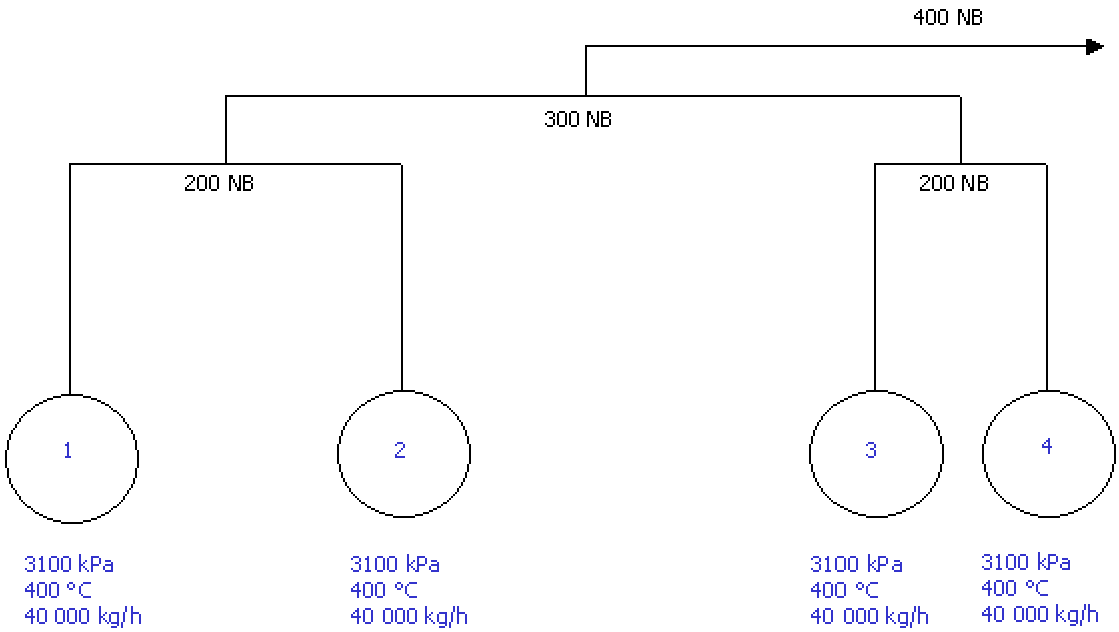

Figure 6. Typical balanced steam header system.

The Importance of Training

The boiler is the heart of every sugar mill, and loss of steam either in tonnage or pressure is a major problem in the efficient operation of the enterprise. Annual inspections during the offcrop highlight deficiencies in the physical and control aspects of the steam generation plant. These deficiencies can be addressed by upgrading the equipment or selective maintenance. It is essential to apply the same philosophy to the most important resource at the boiler, the operator. Technological changes through the use of PLC or DCS demand a higher level of operator skill.

When applying advanced technology, the basics are often forgotten. Boiler operation is not a comfortable occupation, and there are increasing numbers of failures caused by over-reliance on digital systems and neglecting the basics. It is therefore important that boiler operators and maintenance personnel know the dynamics of boiler operation and the consequences of their actions. Training during the offcrop gives such staff the opportunity to learn from previous mistakes without incurring the cost penalties of repeating them.

One example is the rapid start-up and shutdown of boilers. This is the most critical period in the boiler cycle and the point where mechanical and metallurgical stresses are at their highest.

The most common result of starting up too rapidly is ruptured superheater tubing leading to further ruptures due to steam or water erosion. Had the superheater drain valves been properly maintained and operated, the resulting outage and repair costs could perhaps have been avoided.

Because of the resulting water loss, the panic reaction of an untrained operator would be to flood the boiler with water – usually cold. This can result in acute metallurgical damage to the drums, and often the tubes are pulled out. An understanding of the consequences of such an action would help prevent a recurrence of the situation.

It is a legal requirement that any welding to be done on pressure parts has to be approved by an Authorised Inspection Authority (AIA). This is not merely bureaucratic meddling. Unauthorised welding can result at best in unnecessary minor damage and at worst to major cracking and ruptures. Likewise, the grinding out and welding of cracks may bring the boiler back on line, but the cracking is invariably an advance warning of a more severe problem that will manifest later in a larger and more disastrous form.

Although much money is invested in the upgrade of electrical and mechanical systems, the most important element is the human one. Operators need to be trained to recognise the signals exhibited by faulty equipment, and must be given clear and informative instruction on what action to take.

Overview of Present and Proposed Legislation Pertaining to Boiler Operation

At present, the VUP regulations of the Health and Safety Act govern the operation, inspection and maintenance of boilers in South Africa. This applies to all vessels under pressure, except those operating in the mining sector, in which case they fall under the Mines Act. Unfortunately, both sets of regulations are quite different with respect to inspection and responsibilities. However, in the sugar industry it is only the VUP regulation which is of concern. The VUP legislation is the responsibility of the Department of Labour (DoL), formerly familiar in the form of the Inspector of Machinery.

As defined in the VUP, a ‘vessel’ means a housing designed and manufactured to contain fluids under a design pressure equal to or greater than 50 kPa or containing any dangerous substances, and includes fired heaters.

A ‘steam generator’ (boiler) means any apparatus to convert continuously any liquid into steam vapour at a pressure higher than that due to the atmosphere, and where the heat is derived from a source other than steam or the ambient temperature of the atmosphere. It includes any superheater or economiser, which is integral or separately fired.

It has been known for some time that the VUP regulations have serious shortcomings and the recent spate of fatal accidents has spurred the government, in the guise of the DoL, to review the regulations. The aim is to reduce the potential for accidents by imposing stricter control of manufacture, installation, inspection and repair. As a third world economy, South Africa has to accept that first world standards, while desirable, are not always practical. A technical review committee consisting of technical representatives from the major users, inspection bodies, manufacturers and the DoL, has been charged with redrawing the legislation. After a study was made of other similar regulations, notably in Australia, New Zealand, the United States of America and Europe, it was decided to follow the format of the European Pressure Equipment Directive (PED). This is a highly comprehensive and complicated piece of legislation that is interconnected with many other standards and codes.

The proposals are to present two documents, the first being the VUP regulations that will define what has to be done. The second document will be an Annexure that will detail how to conform to the regulations, and will supply detailed documentary tools. It is the intention of the proposals to allocate accountability, while as far as possible not overburdening users or AIAs with additional financial constraints.

The regulations propose an annual inspection of steam generators (boilers) by the existing competent persons. Statutory testing for other pressure vessels will remain at three yearly intervals.

Pressure vessels will fall into four categories, with the category being defined by:

- The type of equipment, namely vessel, steam generator, piping, safety and pressure accessories, all as defined under the PED regulations.
- The state of the contained fluid (gaseous or liquid).
- Whether the fluid is classed as dangerous or non-dangerous according to the provisions of SABS 028.

Boilers fall into the highest category by definition, but a Hazard and Operability review (HAZOP) by the mills will be required on all pressure vessels.

The duties of users include:

- Ensuring that the equipment is maintained and operated within its design and operating parameters.
- Identifying the information on the specific characteristics relating to pressure, chemical composition of the fluids and hazardous situations.
- Ensuring that the equipment has a valid certificate of repair or modification, issued by the repairer or modifier and verified by the inspection authority, stating that the equipment has been modified in accordance with the approved Health and Safety Act standard.
- Ensuring that all other relevant certificates are received.
- Ensuring that the certification and notifications pursuant to the use of steam generators are complied with.

A requirement will be that the design and/or *modification* of a vessel under pressure or steam generator must be reviewed by a Professional Engineer or a Professional Technologist registered with the Engineering Council of South Africa (ECSA). He/she will then be accountable for any design inadequacies.

Where a modification to a pressure part is carried out by a mill the responsibilities of the manufacturer are transferred to the user, i.e. the user becomes the manufacturer.

The responsibilities of the manufacturer include:

- Ensuring that the equipment is safe and without risk to health when used properly.
- Ensuring the correct categorisation of equipment.
- Ensuring that interventions by the inspection authority are in accordance with those stated in the Annexure.
- Issuing a certificate of compliance with the regulations (in the case of imports, this becomes the importer’s responsibility).
- Ensuring that all welding/permanent joining of pressure components is approved by an AIA.
- Ensuring that all pressure vessels are fitted with at least one locked pressure safety device as defined in the respective design standard

Internal and external boiler inspections will become an annual requirement, with a witnessed hydraulic test every 36 months. The power and petrochemical industries that have implemented an approved Risk Based Inspection (RBI) programme may be given an extension to 72 months.

Inspection authorities are given increased scope of responsibilities, and their involvement in overseeing repairs and modifications is increased. The insistence on the use of registered Professional Engineers/Technologists with relevant experience is the most dramatic change.

Conclusions

Proper control philosophies and control systems are crucial to the safety of operation and availability of boiler plant.

In multiple boiler installations, having pressure drop balanced steam lines is often an overlooked requirement for ensuring that the drum level controls work adequately.

Ongoing training is very important to ensure availability and safe operation of boiler plant. This includes monitoring any changes in legislation that pertains to boiler plant operation.

REFERENCES

Moor B St C (1985). A reliable high efficiency sugar mill boiler. *Proc S Afr Sug Technol Ass* 59: 118-125.

Goodall PM (1980). *The Efficient Use of Steam*. IPC Science and Technology Press. 59 pp.

BIBLIOGRAPHY

Pressure Equipment Directive (PED 97/23/EC).

Vessels Under Pressure Regulations (1996).