Combustion Optimization gained through innovative Control- and Safety Shut-Off Valve Technology

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ABSTRACT

The Safety Shut-Off Valve is a key element for reliable protection against hazardous explosion associated with fuel firing. Furthermore it is playing an important role with regard to proper burner operation. This paper delivers a technical analyzes and a comparison of the different codes and standards for this type of equipment. As a conclusion this paper also contains recommendations for a state of the art technology with regard to reliable and long life tightness performance.

Additionally this paper describes in detail the innovative hybrid technology of a Combined Safety Shut-Off and Control Valve (SSO&CV). Finally this paper summarizes the significant benefits for plant operation due to this new technology.

CONTENT

1. INTRODUCTION

Today modern power generating plants have to meet high demands with regard to load change flexibility as well as emission limits getting more stringent and restricted. Additional aspects of this particular new scenario is meeting maximum degree of operational freedom in combusting various types of fuels or dealing with fuel switching. According to the general regulations proper plant operation has to be secured by a safe and reliable isolation of the hazardous fuel flow.

The current scenario of extending the boundaries for fuel management at modern power generating plants consequently requests for advanced and innovative solutions on the technology sector of quick shut-off devices and flow control valves.

2. BACKGROUND

Modern steam generators are operated with several and different types of fuel. For example coal fired units are fueled with Hard Coal or Bituminous Coal as main fuel. But for boiler startup and support fire during part load these plants are additionally fired with Heavy Fuel Oil (HFO) or/and Light Diesel Oil (LDO).

Steam generators which are connected to steel mills have to manage even more type of fuels. These plants are additionally fueled with Blast Furnace Gas (BFG) or Coke Oven Gas (COG).

Fig. 1
Burner Level with four types of fuel on a Power Boiler at a Steel Mill in China

"Explosion and fire are inherent hazards associated with fuel-fired heating equipment, such as boilers, ovens, dryers, and furnaces, especially during startup and shutdown. The leading causes of fires and explosions are lack of proper controls and safety devices, lack of adequate maintenance, improperly trained operators, failure to test controls and safety devices, and complacency on the part of the operator due to long periods of trouble-free operation.

While there are many safety devices required by codes and standards to ensure the safe operation of fuel-fired heating equipment, the **safety shut-off valve (SSOV) serves as a key safety control device to prevent the flow of gas or oil into the combustion chamber** when the equipment is shutdown or an abnormal condition occurs." *(Reference 1)*

The proper selection and design of the appropriate and correct safety shut-off valve (SSOV) is an important element to prevent the plant from hazardous explosion and consequently is vital to protect people's life and capital goods from serious losses.

Fig. 2
Sign for Explosion Risk Area

3. COMPARISON OF GUIDELINES, RULES, CODES, STANDARDS AND LAWS

Looking from a global perspective there is no internationally accepted common standard for fuel shut-off devices or Burner Trip Valves. Historically there are the following two main standards and codes relevant for combustion processes:

- Based on American Rules: **NFPA – Rules**
  NFPA = National Fire Protection Association

- Based on European Standards: **EN – Standards**
  EN = European Norms

Power plants installations in India are influenced by both of the a.m. groups of rules and standards. Indian plant operators can contribute with sustainably more safety and operating flexibility, if the equipment is selected and build according to the best choice of both a.m. standards. The following content delivers a technical analyses and comparison of both groups of standards and concludes with clear recommendations.

4. OIL FIRED BURNER INSTALLATIONS

Modern oil burners are fueled with Heavy Fuel Oil (HFO) or Light Diesel Oil (LDO). For achieving a good combustion behavior the HFO is atomized with steam and the LDO is atomized with air. For installations infront of the oil fired burner we therefore have to split into the following media lines:

- Fuel Oil Line (HFO or LDO)
- Atomizing Line (Steam or Air)

Please see Figure 3 for a typical arrangement in front of an oil fired burner.

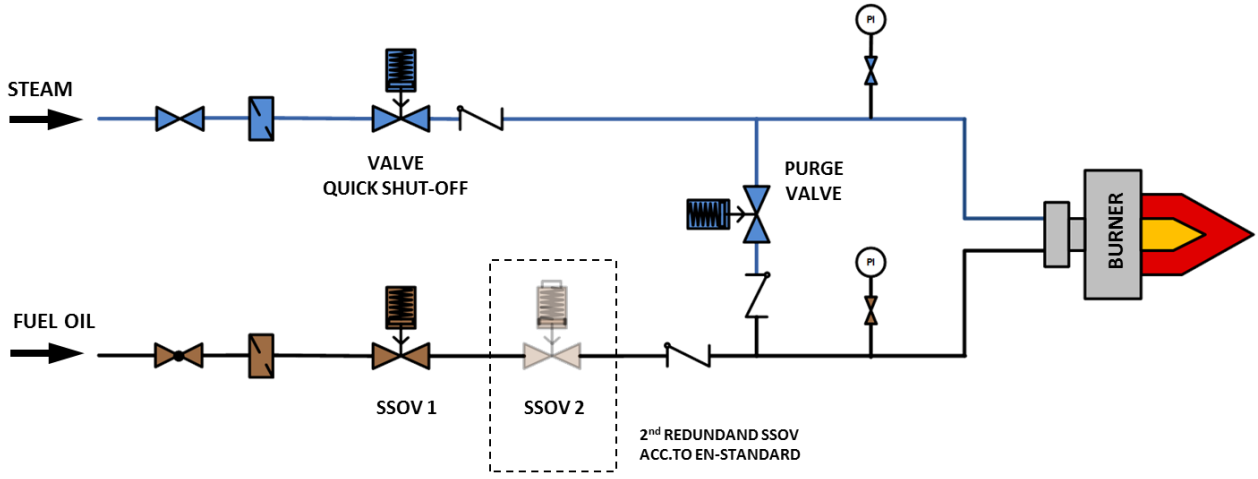

Fig. 3

P&I of Safety Shut-Off Valve Arrangement in front of Oil Fired Burner

For the further detailed technical analyses we will concentrate on applications with HFO and Atomizing Steam. These rules are likewise the same for LDO and Atomizing Air installations. Comparing the two different sectors of standards – NFPA and EN – please see the results and main differences as described below.

4.1 NFPA – Rules for Oil Fired Burners

Fuel Oil Line

According to NFPA 85 it is necessary to install two automatic spring-closing automatic shut-off valves in the oil line to the burner. Mostly it is interpreted in such a way that one spring-closing shut-off valve is installed on a central position within the fuel oil feed line. The second spring-closing automatic shut-off valve is installed as a Burner Trip Valve in front of each individual burner. Whereas according to the European EN-Standards there is a redundant arrangement of two Burner Trip Valves in front of each individual burner.

But NFPA 85 requests additional features and criteria for the Safety Shut-Off Valves as listed below (2):

- The Safety Shut-Off Valve shall be a fast closing valve that automatically shuts off the gaseous or liquid fuel supply in response to a normal, emergency, or safety shutdown signal
- For fuel oil applications, valve leakage shall be Class IV as defined by ANSI/FCI 70-2, Control Valve Seat Leakage
- The Safety Shut-Off Valve should be installed as close as possible to the burner

Compared to the NFPA codes the EN-Standards define more precisely for parameters and clear data regarding qualification of Safety Shut-Off Valves in front of the burner. Please also see Chapter 4.2

Atomizing Steam

There are two valves installed on the atomizing steam line. One steam valve for the main steam shut-off on each individual burner. The second steam valve is operated as a change-over valve (purge valve) and is set to open mode when purging of the oil lance is requested. For installations in Indian these steam valves have to meet the general requirements according the Indian Boiler Regulation (IBR 1950).
The IBR 1950 is a high standard for steam valves and generally secures a safe a reliable operation with regard to the risk potential of steam as fluid inside a valve.

Additional attention has to be paid regarding the inner tightness – seat tightness - of such a steam valve. Because a leaking steam valve can tremendously impact the boiler operation and can cause a lot of operational costs due to steam losses.
The special qualification and the key design criteria for a steam valve to meet highest tightness class and reliability is not content of this paper but can be explained in detail by the author on individual request.

4.2 EN – STANDARDS FOR OIL BURNERS

According to the EN-standards the basic layout and arrangement of the combustion system on an oil fired boiler has to meet the criteria according to EN 12952-8. This EN-Standard is more precisely with regard to technical features and design criteria compared to NFPA 85. Compared to NFPA 85 there are the following main differences:

- According to EN 12952-8 it is mandatory to install two Burner Trip Valves as a redundant setup in the fuel oil supply line in front of each individual burner
- The Burner Trip Valves have to meet requirements according to EN 23553-1

According to this particular equipment standard EN 23553-1 the Safety Shut-Off Valve has to meet the following fundamental criteria – please see Table 1.

	SSOV acc. to EN 23553-1
Fuel Type	HFO / LDO
Operating Pressure	up to 50 barg
Secured Closing Time	less than 1 second
Tightness Class	Class A no visible leakage (better than ANSI Class VI)
Test Cycles	up to max. 200,000 load cycles
Approval	Approved with Type Test Certificate

Table 1
Performance Criteria for SSOVs on Oil Fired Burners

The EN-type of Burner Trip Valve for oil fired applications also has to prove long life and reliable tightness performance thru a Type Test Approval.

Type Test Approval: The Type Test Approval is an examination process where the valve has to perform up to 200,000 load cycles under maximum operating conditions (pressure and temperature). During these

load cycles as well as after completing the load cycling process the following key safety parameters are monitored, checked and recorded:

- Closing time less than 1 second
- Tightness class A – no visible leakage (better than ANSI class VI)

This Type Approval Tests is executed, monitored and verified by a Notified Body (third party like TÜV, Bureau Vertias, or others). Such valves which successfully passed this test procedure are granted and labelled with a Type Test Certificate acc. to EN 23553. The manufacturer then holds the Type Test Certificate for this particular valve type for 5 years.

Fig. 4

SSOV Skid Solution on a

1,000 MW Coal Fired Unit in Germany

Combined Safety Shut-Off and Control Valve

The operators of most of the European oil fired boilers prefer to install SSOV as a globe type valve which is **additionally equipped with regulation cone on the valve plug**. This regulation cone is

integrated to the valve plug and ensures a certain flow characteristic which is very beneficial for the entire oil system on the burner and the boiler operation in general:

- Soft Burner Start – smooth and continuous opening of fuel oil flow to the burner lance.
  Elimination of immediate oil flushing to the burner lance which then causes failures with regard to problematic burner ignition and consequently forced interruption of boiler start-up.
- No Pressure Hammer – smooth and soft continuous closing of fuel flow prevents the entire pipe system from pressure hammer. Most of the Fuel Oil Feed Lines in modern European power boilers are not equipped with pressure accumulators. Consequently the prevention of pressure hammers leads to a significant reduction in overall investment costs of a plant as well as a remarkable reduction regarding the maintenance cost.
- More Flexibility for Tuning the Combustion - the combined Safety Shut-Off and Control Valve installed per each single burner offers a wide range in flexibility for tuning the fire ball even on an individual burner level.

For More details please also see Chapter 6.

4.3 CONCLUSIONS AND RECOMMENDATIONS FOR OIL BURNER INSTALLATIONS

India is neither bounded to NFPA codes nor to the EN-Standards. India is in a unique position and has the chance to select the best options out of both codes to secure maximum safety level for the operation of their power plants. For **Oil Fired Burner Installations in India** it is therefore strongly recommended to take the best solutions out of both standards as described below:

- **Atomizing Steam Valves**
  The Atomizing Steam Valves have to be selected according to IBR 1950 to ensure maximum safety with regard to the risk exposure by the fluid steam.
  Make sure that you decide for a valve brand with a high quality seat/plug arrangement which ensures a long life tightness performance.
  Decide for the best operation performance of the entire fuel oil system by choosing the cone to be integral part of the plug on a globe type of SSOV – Combined Safety Shut-Off and Control Valve.
  Please also see details described in Chapter 4.2 and in Chapter 6
- **Burner Trip Valves**
  For safe and reliable isolation of fuel oil flow use SSOVs according to EN 23553-1. This quality grade will ensure to have a tested and proven state of the art long-term tightness performance. SSOVs according to EN 23553-1 have passed the Type Test Approval.

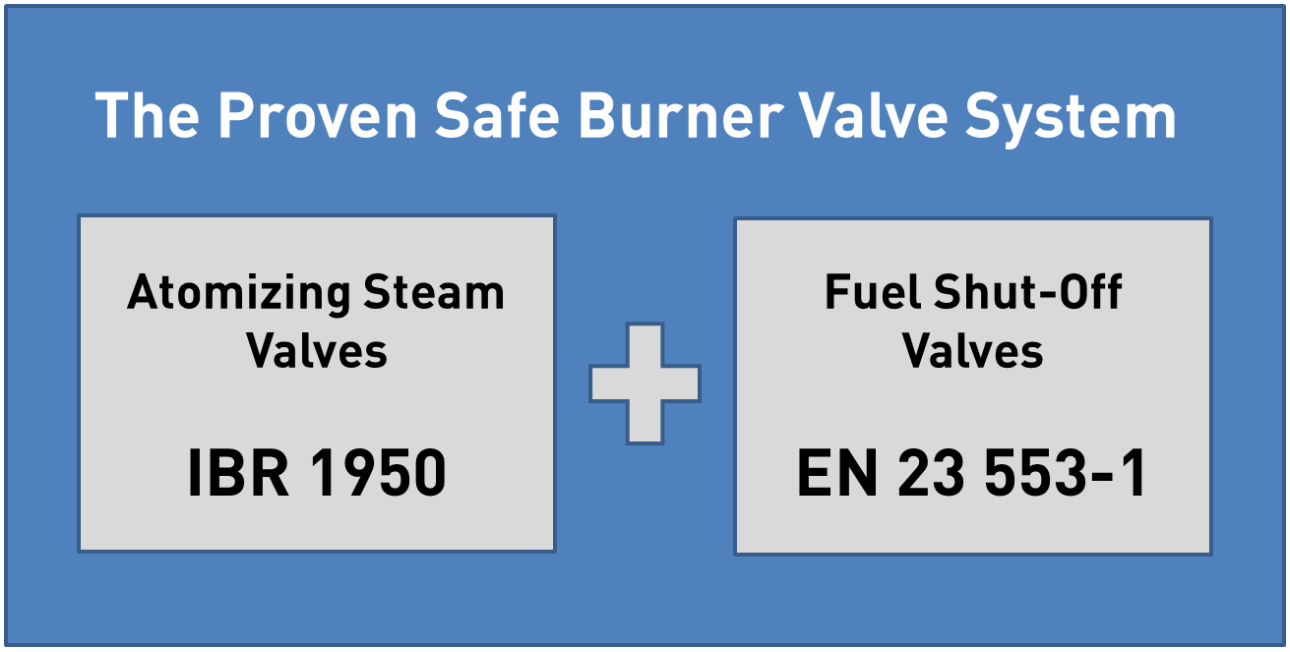

Fig. 5

Preferred Combination of Standards for Burner Valves in India

Fig. 6

3 D Engineering of SSOV Skid Solution for NTPC 660 MW PP

Fig. 7

Assembled and Tested SSOV Skid Solution for NTPC 660 MW Power Plant

5. GAS FIRED BURNER INSTALLATIONS

For Burner Trip Valves installed in front of gas fired burners there is a wide range of overlap between NFPA and EN. Please see Figure. 8 for a typical P&I at a gas fired burner.

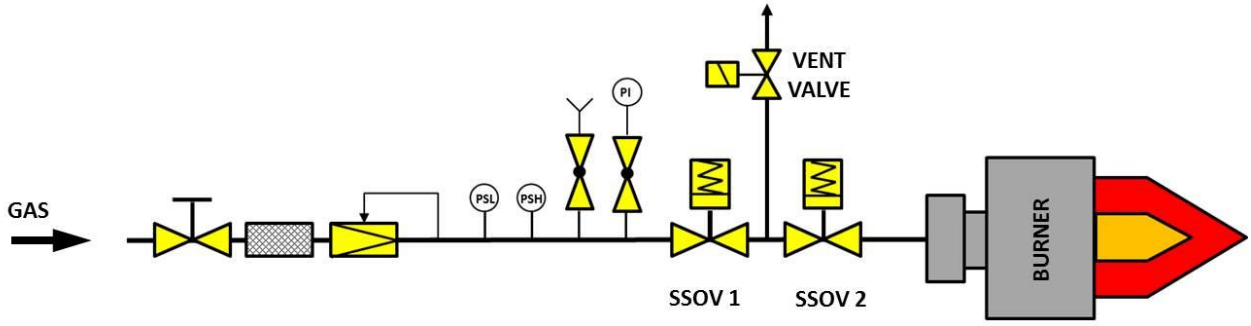

Fig. 8

P&I of Safety Shut-Off Valve Arrangement infront of Gas Burner

According both NFPA and EN it is mandatory to install two Safety Shut-Off Valves (SSOVs) including a vent valve – Double Block and Bleed arrangement. The main differences between NFPA and EN are as follows:

5.1 NFPA – RULES FOR GAS BURNERS

According to NFPA 85 there is a fixed relation between the size of vent line and the size of the main fuel line. E.g. for a 6" main fuel line to the burner the size of the vent line has to be 2 ½ ". The NFPA requests some criteria for the Safety Shut-Off Valves. These criteria are generally the same as for SSOVs installed on oil fired burners. For these details please also refer to Chapter. 4.1

But once again, the EN-Standards define more precisely parameters and clear data regarding the qualification of Safety Shut-Off Valves in front of the burner.

5.2 EN – STANDARDS FOR GAS BURNERS

According to EN 12952-8 there is no fixed relation between size of vent line and size of main fuel line as it is known from NFPA. EN 12952-8 only requests for a vent line of minimum ND 20 mm (¾ “)

But on the other hand EN 12952-8 requests to install Safety Shut-Off Valves (SSOVs) – Burner Trip Valves – according to the following equipment standard

- EN 161 for operating pressure up to 5 barg
- EN 16678 for pressure from 5 barg up to 63 barg

Both a.m. EN-Standards for Burner Trip Valves requests for very stringent criteria to be fulfilled with regard to important technical as well as quality parameters. Please see Table 2 below

	SSOV acc. to EN 161	**SSOV acc. to EN 16678**
Fuel Type	Fuel Gas	Fuel Gas
Operating Pressure	up to 5 barg	5 barg up to 63 barg
Secured Closing Time	less than 1 second	less than 1 second
Tightness Class	Class A no visible leakage (better than ANSI Class VI)	Class A no visible leakage (better than ANSI Class VI)
Test Cycles	up to max. 200,000 load cycles	up to max. 200,000 load cycles
Approval	Approved with Type Test Certificate	Approved with Type Test Certificate

Table 2

Comparison of EN-Standards for Gas SSOVs

Such Burner Trip Valve for gas fired applications acc. to the EN-standards also has to prove long life and reliable tightness performance thru a **Type Test Approval**. The Type Test Approval Process is described in Chapter 4.2

5.3 CONCLUSIONS AND RECOMMENDATIONS FOR GAS BURNER INSTALLATIONS

For **Gas Fueled Burner Installations in India** it is strongly recommended to install Safety Shut-Off Devices (Burner Trip Valves) according to EN 161 for following reasons and benefits:

- Secured, reliable and continuous higher operational safety. Such valves have passed a tough Type Test Examination Process and have proved their long term proper tightness performance accordingly.
- No extra costs are incurred for such a type tested valve.
  Even costs saving can be expected on maintenance side because such valves are engineered with a robust design and are particular sized for long service life.
  Additional costs savings also have to be considered because no unplanned boiler outage needs to be faced due to the proven performance of the SSOV.

If required the Safety Shut-Off Valve also can meet additional performance level according to Fire Safe Regulations or even SIL Requirements (SIL = Safety Integrity Level). As an additional aspect of safety with regard to emissions such a SSOV for gas application can also meet the requirements according ISO 15848 – formerly known as TA-Luft / German Clean Air Act.
For gas applications in India it is even sometimes required to follow DVGW = German Technical and Scientific Association for Gas and Water. This DVGW Association also defines standards with regard to safe operation of shut-off valves for gas applications.

The above mentioned additional features are not part of this paper but can be explained by the author on individual request.

It is also recommended to install the SSOVs for gas applications as a combined Safety Shut-Off and Control Valve – because this is saving investment costs and offers more operational flexibility. For technical details please also see Chapter 4.2 and Chapter 6

Fig. 9

SSOV Installation on a Gas Fired Boiler in Germany

6. TWO IN ONE - COMBINED SAFETY SHUT-OFF AND CONTROL VALVE (SSO&CV)

"Why to accept less, if you can get more better and advanced performance for the same price?"

For a proper burner operation it is vital to selectively control and adjust the fuel flow. In the past it was common practice to install a flow control valve in the header of the oil supply system. To achieve a certain degree of freedom for a better combustion adjustment it was also common practice to install a fuel oil control valve per single burner elevation. Please also see Figure 10. This type of installation is also known as Burner Level Control.

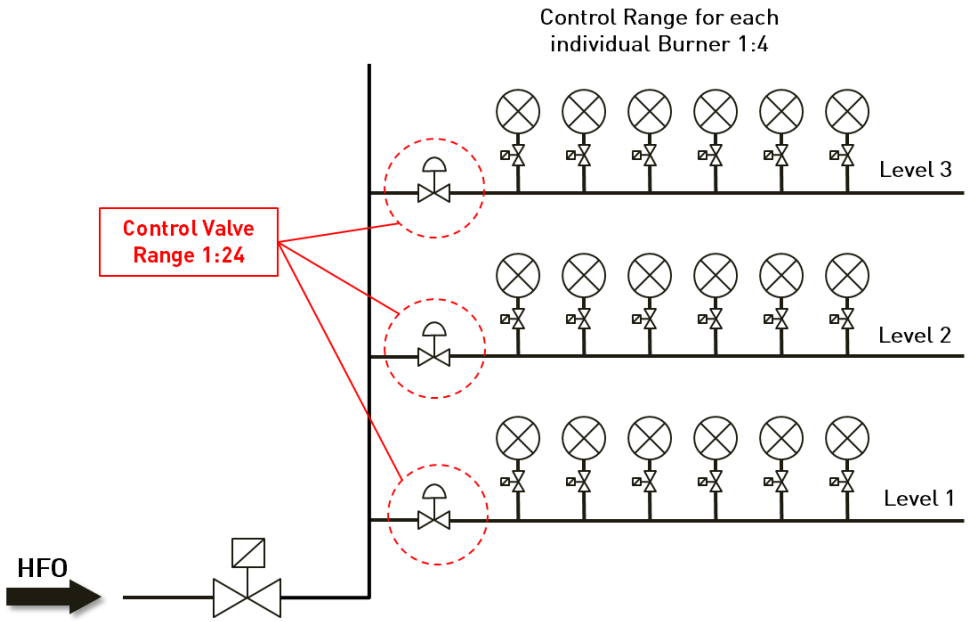

Fig. 10

Burner Arrangement with Burner Level Control Valve

For this type of Burner Level Control installation such a particular flow control valve has to meet extreme high demands and has to cover a wide control range.

For example:

- There is a boiler with 6 burners per each elevation.
- Each burner is designed for a flow range of 1:4.
- As a result for such an application the Burner Level Control Valve has to cover a total control range of 1:24

Control valves for such a wide control range are mostly very expensive and they are also very critical in operation with regard to achieving the required accuracy and proper flow regulation. But on the other hand if this particular and important Burner Level Control Valve is not performing the exact and reliable regulation service then the boiler operator will immediately face problems like:

- Not correct conditions and severe mistakes with regard to burner ignition
- The targeted operation of the boiler or the exact and stable tuning to part load is no longer secured

The innovative technology of a Hybrid Valve:

To avoid this high potential for combustion operation problems it is meanwhile state of the art technology and common practice for most of the plants in Europe to install a dedicated flow control valve individually per single burner. Please also see Figure 11. To save costs and installation space this flow control function is integrated into an advanced Safety Shut-Off Valve. Nowadays modern power boilers in Europe are equipped with Combined Safety Shut-Off and Control Valves in front of each burner.

According to the input data of the previous mentioned example this would mean that such a dedicated single control valve only has to cover a control range of 1:4 instead of 1:24.
A control valve with a small control range of 1:4 ensures a very quick, precise and reliable positioning and therefore a prime performance for each individual burner.

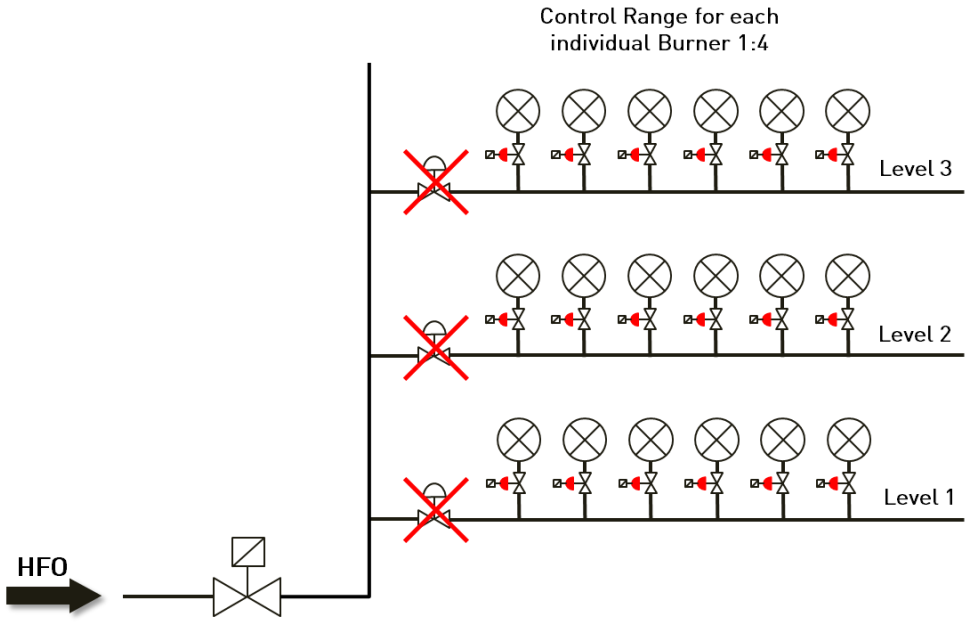

Fig. 11
Burner Arrangement with
Combined Safety Shut-Off & Control Valve

6.1 DETAILS AND DESIGN FEATURES OF COMBINED SSO&CV

The Combined Safety Shut-Off and Control Valve (SSOV/CV) basically contain the same main design elements as a regular globe type SSOV. To ensure a proper control function the SSO&CV additional is equipped with a regulating cone attached to the normal valve plug and a positioner installed at the valve actuator. Please also see Figure 12.

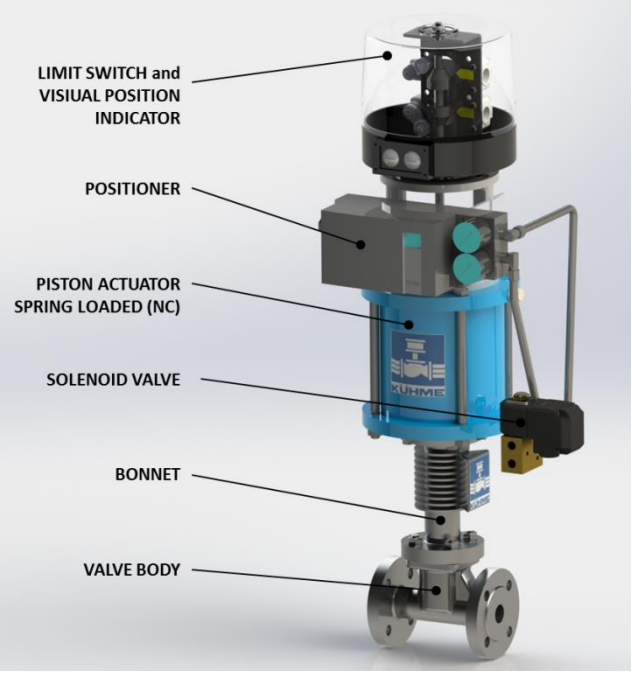

Fig. 12
Combined Safety Shut-Off & Control Valve

The size and the shape of the regulating cone for the SSO&CV valve is individually calculated according to the operation data. Depending on the operation condition the regulating element can be of linear or parabolic type as well as it can be a perforated plug.
A conventional control valve can not be used for the operation mode like a SSOV&CV. Because the conventional control valve mostly will not meet the tightness performance criteria like it is mandatory for a Burner Trip Valve.

The required reliable long life tightness on the SSOV&CV is generated due to the proper design of the seat and plug combination. This particular seat and plug combination is based on the proven experience of the SSOV according to EN-Standard. Therefore the SSOV&CV valve also successfully passed the Type Test Approvals. Please also refer to Chapter 4.2

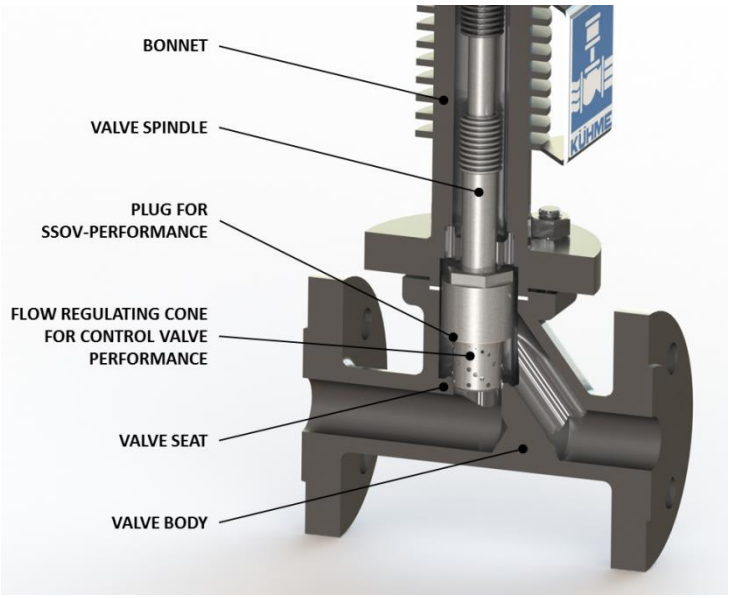

Fig. 13
Valve Trim Details of
Combined Safety Shut-Off & Control Valve

6.2 ADVANTAGES AND RECOMMENDATIONS FOR MODERN POWER BOILERS IN INDIA WITH REGARD TO FUEL FLOW CONTROL

The fuel oil supply arrangement in front of the burner containing a **Combined Safety Shut-Off and Control Valve (SSO&CV)** according to EN-Standards generates significant advantages for the boiler operator as described below

- Optimum SSOV features: The emergency shut off is secured in less than 1 second and there is the guarantee for reliable long life tightness (type tested valve that passed up to 200,000 load cycles)
- Exact, fast and repeatable adjustment of fuel flow individually for each burner
- Less number of valves installed on the boiler: Because the expensive, complex and sensitive Burner Level Control Valves are deleted and no longer needed. The Safety Shut-Off Valve which is anyhow installed in front of each burner contains also the selective flow control function.
- Less maintenance and consequently remarkable cost savings: Because the Burner Level Control Valves are deleted.
- **More operational safety** with regard to the boiler operation: Because each burner is equipped with a single flow control function.
  With the old set-up using a central flow control valve or alternatively burner level control valves there is a big potential of entire boiler failure. Because if such a central and predominant control valve will fail then the entire burner level cannot be controlled properly with regard to combustion parameters.
- **More flexibility with regard to boiler operation**: The individual control valve function means that each burner can be adjusted and triggered according to the particular operation requirements. For example on a single burner elevation the burners located in the corner area can be operated with a bigger flame impact than the burners in the central. In total this feature offers a significant control option for selective adjustment of fire ball position and entire combustion behavior.
- **More easy and reliable ignition and start-up process of the boiler**: With a conventional valve there is always a rapid flushing of fuel oil to the burner lance. This can cause problems for the oil flame to start properly in given time frame. Consequently the automatic flame monitoring system detects a failure and there is a forced interruption of start-up sequence. The time consuming purging has to be done and the start-up sequence has to be rebooted again.
  Because of the integrated control characteristic on the SSO&CV there is a smooth opening and consequently a **Soft Burner Start**.
- No Pressure Hammer: Smooth and soft continuous closing of fuel flow prevents the entire pipe system from pressure hammering. In Europe on most of the modern boilers there are no pressure accumulators installed in the Fuel Oil Feed Lines.
  Consequently the **Prevention of Pressure Hammers** leads to a significant reduction in overall investment costs of a plant as well as a remarkable reduction regarding the maintenance cost.
- **More Flexibility with regard to Fuel Switching**: If there is a fuel switch after years of plant operation then it is required to tune the combustion parameters with regard to flow capacity. The SSOC&CV combination makes it very easy to adjust the valve performance to the new demands. By

simply reprogramming the positioner the valve will get a new characteristic. Because of the bolted connection of the plug it is even possible to replace the regulating cone very quick and comfortable.

7. SUMMARY AND OUTLOOK REGARDING THE TECHNOLOGY TREND OF SAFETY SHUT-OFF VALVES

If it comes to the topic of health and safety for people working in a power plant there is definitely no room for compromise.
This paper shows in detail the significant advantages with regard to the reliable and long life tightness performance of a SSOV which is approved according to EN-Standard. The Type Test Approval acc. to EN-Standards ensures that the SSOV meets the tough demands requested by modern power plant operation in India.

The Combined Safety Shut-Off and Control Valve is the innovative instrument for a very flexible and selective operation within the fuel oil supply system for Indian power plants. This type of special valve is the state of the art technology to achieve maximum performance at each burner.

There are trends in India for bigger power generating units as well as to extend the flexibility of power plant operation with regard to load changes, fuel switching, etc. The advanced valve technology as described above supports power plant operators to meet nowadays demand for a significant increase in plant performance.

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