FlexSILon BCS

Protect Your Combustion Appliances against Hazards

By Karl-Heinz Kruse, BCS/BMS Application Manager at HIMA

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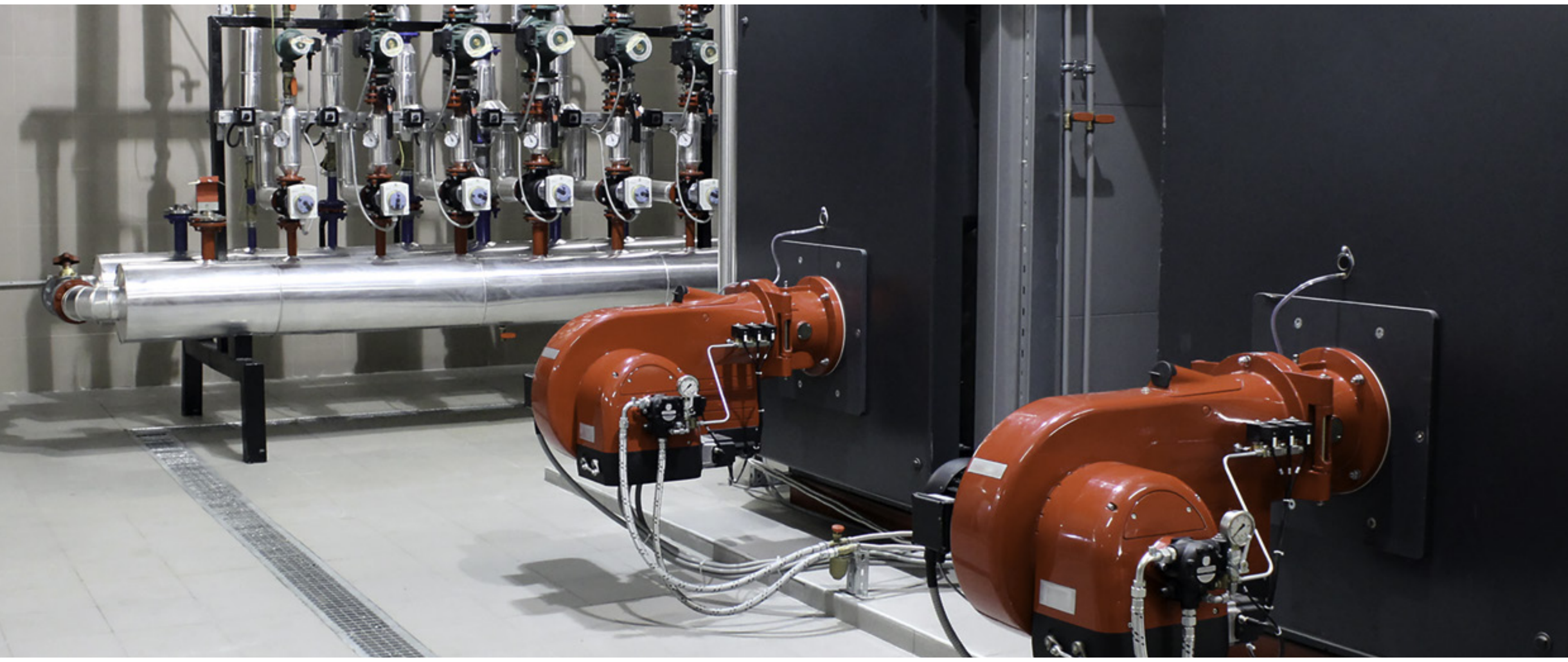
Combustion appliances, particularly burner applications, are consistently the focus of safety considerations. At the end of the 19th century, the hazard potential of burners and boilers was recognized; legislation was enacted, and organizations were founded. The main intent was, and is, avoiding accidents. Today, harmonizing activities of safety standards for burners and boilers are aligned globally. Major economic regions, including Europe, North America, China, are intending to establish equivalent safety standards. →



In general, combustion appliances, burners, and boilers are associated with a wide variety of hazards for people, plants, and the environment. Possible protective measures are described below. In the area of combustion technology, functional safety is frequently employed to safeguard against potential hazards. This involves different levels of protection. In this regard, qualified support in all phases of the safety lifecycle is also important.

Safety-related programmable logic controllers from HIMA, TÜV-certified to SIL 3, are used as burner management and control systems in a variety of applications. To avoid errors when programming the systems, recurring combustion technology functions are summarized in function blocks for burner management (BMS, burner management system) and burner control (BCS, burner control system).

Potential Hazards

1. General

The greatest imminent danger in combustion appliances is the uncontrolled ignition of fuel-air mixtures in the combustion chamber and/or flue gas system. This dangerous event can be caused by various factors:

- Re-ignition of the burner without pre-purging
- Operating the burner without flame monitoring
- Leakages in the safety shutdown valves

The parts of the combustion appliances that have to be protected can be segregated as follows:

- Burner (gases, oils, dusts, and solids)
- Combustion chamber
- Heat exchanger (heater, superheater, air preheater, and economizer)
- Steam boiler

2. Burner

The hazard potential of the burner consists of flame loss and subsequent introduction of combustible and/or explosive fuel-air mixtures. These mixtures can ignite explosively at any point of the combustion appliance (e.g., combustion chamber, flue gas path, flue gas recirculation etc.). Ignition of these mixtures can be a considerable hazard for humans, the environment, and assets.

Moreover, an imbalance of fuel and combustion air quantities can lead to emissions of harmful exhaust gases that directly (e.g., CO, SO) or indirectly (e.g., NOx) endanger human lives and the environment. Additionally, CO emissions have an extremely high explosion potential.

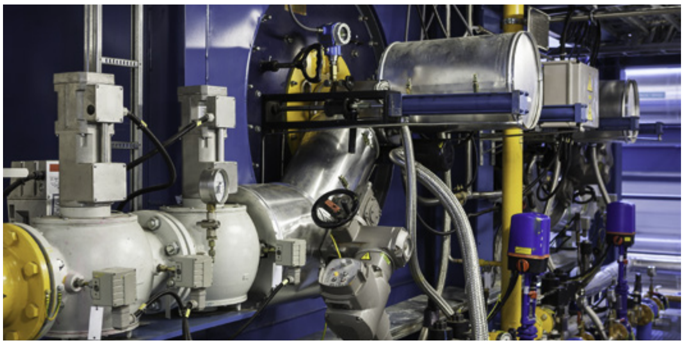


Fig. 1: Dual-fuel burner, multi-fuel burner design

Consequently, protective measures for combustion of fossil fuels are focused on maintaining the operational process variables that are responsible for the balancing of flame speed, flow rate of fuel, and combustion air. These speeds and flow rates must be in a predefined ratio.

Additional protective measures are included in the sequence function control of the start and stop sequences. Examples include the cycle of self-inertization and external inertization (pre-purging/post-purging) of the combustion chamber, the ignition sequence, the leak test of the safety shutdown valves, decommissioning, and the operating modes of the firing system.

3. Combustion chamber

The hazard potential of the combustion chamber consists of mechanical destruction through overheating, as well as through underpressure and overpressure. Often, the result is a total economic loss of the combustion appliances (furnace, steam generator, etc.). Escape of hot flue gases and/or flames can endanger human life.

Usually, the heater and superheater tubes or the upper and lower water drums are welded into the combustion chamber. Moreover, depending on the useful heating capacity, a large or minor fluctuation in pressure can destroy the walls of the combustion chamber.

As a result, protection measures for the combustion chamber are focused on maintaining the physical characteristics of the construction material used. The physical properties of the steels used influence the permissible temperature and pressure ranges of the combustion chamber.

4. Heat exchanger

The hazard potential of the heat exchanger consists of overheating of the tube bundles. Through overheating, the tubes expand impermissibly and the mechanical construction breaks or tears off. If there is excess pressure, this process can also result in the explosive destruction of the heat exchanger. Escaping hot media endangers human life and – depending on the medium – the environment as well. Often, defective heat exchangers in the combustion chamber also result in total economic loss of the combustion appliance (furnace, steam generator, etc.).

Consequently, protection measures for the heat exchanger are focused on maintaining the physical characteristics of the construction material used. The physical properties of the steels influence the permissible temperature ranges at the inlet and outlet of the heat exchanger.

Moreover, the heating medium is what keeps the heat exchanger from overheating. Therefore, the minimum flow rate of the heating medium must also be considered as safety protection of the heat exchanger.

5. Steam boiler

The main hazard associated with the steam boiler is mechanical destruction through overheating, as well as through underpressure and overpressure. Often, the result is a total economic loss of the combustion appliance (furnace, steam generator, etc.) and the adjacent plant sections.

Because the steam boiler is an energy accumulator (entropy of the water or steam), if there is a fault, the stored energy discharges explosively. The malfunction occurs when the steam boiler is operated outside of its physical parameters. A boiler explosion can cause considerable destruction within a radius of several hundred meters. In the worst case, the steam boiler is ripped out of the anchoring and flies through the plant without control.

Consequently, protection measures in the steam boiler area are focused on maintaining the physical characteristics of the construction material. The physical properties of the steels influence the permissible temperature and pressure ranges.

Moreover, the boiler water is used as energy transport medium, which also ensures the cooling of the steam boiler. Therefore, “minimum water level in a drum boiler” and “minimum flow in a water tube boiler” must also be considered as safety protection of the steam boiler.

In general, the steam boiler generates hot steam. To prevent saturated steam from entering the steam network, which would destroy steam consumers such as turbines, “maximum water level of a drum boiler” and “maximum flow in a water tube boiler” must also be considered as safety protection of the steam boiler.

The four protection levels

The risk analysis provides information concerning the degree of risk for a plant or a section of the plant. Various measures for reducing the risk are presented below:

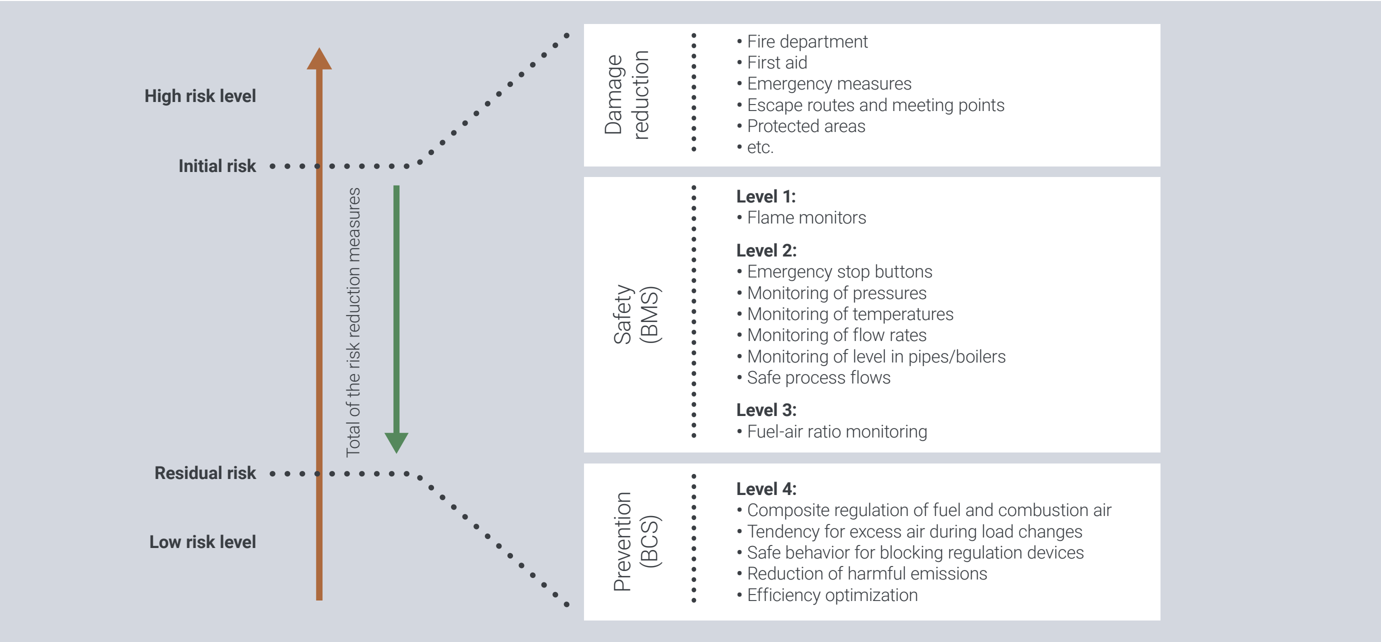


Fig. 2: Protection level model for firing technology

Based on the protection level model of the international safety standard for the process industry, IEC EN DIN 61511, the following protection levels have been defined in the solution concept for burner management and control systems from HIMA:

1st protection level (BMS):
- Flame monitors (e.g., in accordance with EN298, NFPA85 etc.)

2nd protection level (BMS):
- Emergency stop buttons in the plant and control rooms
- Limit value monitoring of pressures
- Limit value monitoring of temperatures
- Limit value monitoring of flow rates
- Limit value monitoring of level in pipes/boilers
- Safe start, stop, and operating sequences

3rd protection level (BMS):
- Fuel-air ratio monitoring and shutdown

4th protection level (BCS):
- Stabilization of process points mentioned in protection levels 2 and 3

1. Burner management (BMS)

For protection levels 2 and 3 described above, the following safety-relevant function groups have been defined:

1. FB for pre- and post-purging of the fire box and the flue gas paths
2. FB for gas ignition burner (class 1, 2, and 3 igniter)
3. FB for gas main burner
4. FB for gas main burner with direct ignition (class 3 special igniter)
5. FB for oil main burner with pressure atomization of the fuel oil
6. FB for oil main burner with steam atomization of the fuel oil
7. FB for fuel-air ratio monitoring and shutdown

By means of the function blocks listed above, customized BMS application programs can be developed for process furnaces and steam generators. The interconnection of various function blocks for gas burners and oil burners is presented schematically below:

The function blocks were subjected to a four-phase test procedure by TÜV Süd:

1. Test of the safety specification and FMEDA
2. Test of the programming (implementation of the safety specification)
3. Full function test on accepted test and simulation systems (HIQuad X, HIMax and HIMatrix F)
4. Test and acceptance of burner management systems (BMS) in real plants

The test and the results have been recorded and documented by TÜV Süd in a certificate of conformity and in test reports (EN and U.S. test reports). Implementation in protective circuits and safety circuits has been confirmed.

After two years of implementation of the function blocks in test projects and in a wide variety of combustion appliances, HIMA officially released the BMS function block library in June 2010.

2. Burner control (BCS)

The following critical function groups have been defined for protection level 4:

1. FB for pressure and temperature correction of operating flow rates
2. FB for linearization and adaptation
3. FB for ramps and attenuation
4. FB for controller module for the compound control of fuel and air flow
5. FB for controller module for motor control valves

The function blocks have been subjected to the following function block tests by TÜV Süd as part of the BMS function block tests:

1. Test of specifications
2. Test of programming (implementation of the specification)
3. Function test on accepted test and simulation systems (HIMax and HIMatrix F)
4. Test and acceptance of burner control systems (BCS) in real plants

The test and the results have been recorded and documented by TÜV Süd in a test report.

After six years of implementation of the function blocks in test projects and in a wide variety of combustion appliances, HIMA officially released the BCS function block library in June 2014.

3. Stabilization of process points (protection level 4, BCS)

Process points for which a safety function was defined in the hazard analysis (phase 2) or in the definition of the hazard avoidance measure (phase 3), or for which a safety function was defined in the applicable safety device standard (e.g., device standard EN 298 or ANSI/ISA TR 84.00.05), can be stabilized in their predefined safe operation ranges by process control measures. This stabilization of the process points leads to an increase in plant availability (lower trouble shooting costs and higher productivity). Thanks to the safe burner management and control systems from HIMA, the valuation of the process point stabilization (critical control) can be viewed from a safety engineering perspective as a prevention measure to reduce avoidable plant shutdowns.

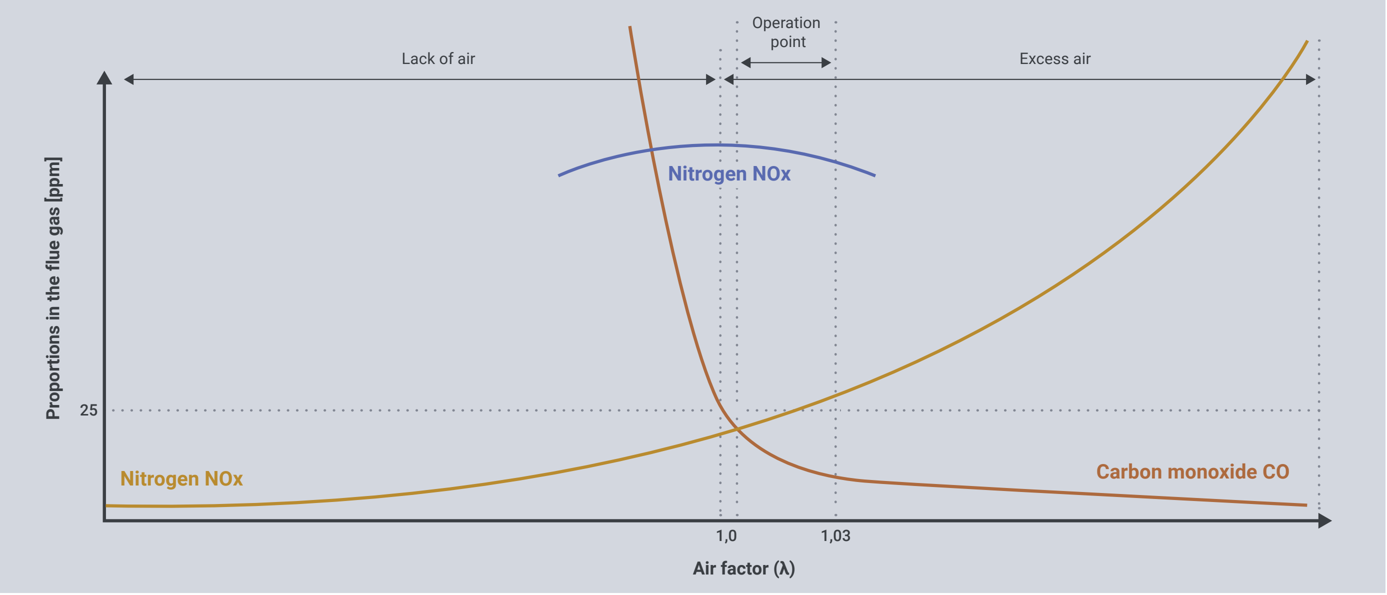


Fig. 3: Schematic relationships of efficiency, emissions and λ lambda

In addition to the potential hazards cited above, the environment must also be considered, and protective measures should be taken. The hazard potential due to emissions of pollutants also increases very quickly and dramatically. Classification in accordance with the requirements of the international safety standard (SIL) would certainly be possible.

The critical control functions in combustion technology that could be classified as mentioned above are the following:
1. Fuel-air ratio
2. O_2 proportion in the flue gas after combustion
3. Air factor (λ)
4. Heat output
5. Boiler drum level
6. Heating medium flow
7. Boiler pressure

Combustion appliances that are not optimally adjusted harm the environment, and they can also significantly drive up operating costs. Therefore, for economic reasons, the combustion system must be operated in the most environmentally friendly operation range.

4. Smart Safety Solutions for Small Gas Burner Configurations

A wide range of different single fuel burner configurations can be managed with a pre-programmed SIL 3 Combustion Safeguard CSG system (flame guard system), which has undergone a type approval according to the European, US and Canadian burner standards. By using an LCD parameter panel, it is possible to adjust the pre-programmed CSG to almost all accepted instrumentations of gas burners.

HIMatrix CSG is a pre-configured and inexpensive safety controller for burner control and safeguarding. The CSG was developed for use as flame guard system. The non-programmable CSG can be parameterized via an LCD monitor, DCS, SCADA or other supervisory systems that operate as MODBUS TCP master. Therefore, the CSG is ready for use and can simply be implemented in the control circuitry, which reduces the design and installation costs.

There are five different CSG components available. Each component is adjusted to a dedicated burner type:
- Single fuel burner, with gas igniter lance (HIMatrix F30 platform)
- Dual fuel burner, with gas igniter lance (HIMatrix F30 + F3 DIO 20/8 platform)
- Dual fuel burner, with gas igniter lance and combustion control based on fuel and air damper feedbacks (HIMatrix F30 + F3 DIO 20/8 + F3 AIO 8/4 platform)
- Dual fuel burner, with gas igniter lance and combustion control based on fuel and air flow feedbacks including lead controller and O_2/air factor correction (HIMatrix F35 + F3 DIO 20/8 + F3 AIO 8/4 platform)

The technical design reduces operation and maintenance costs. HIMatrix CSG supports more than 65,000 configurations of instrumentations and is compatible with 99% of burner management applications. The CSG can be used with industrial standard instrumentation (ON/OFF, 4-20mA).

Small LCD HMI for comfortable handling:
- Operation overview of the burner
- Indication of the start and stop sequences
- Setting of the safety and process parameters
- Setting of the instrumentation configuration
- Definition of the customer password
- Analysis of diagnostics
- First-up alarming
- Indication of the burner operation time
- Settings of damper feedback, O_2, air factor and flow curves

Functionalities:
- Timer for combustion chamber and flue gas system purging
- Start, operation, and stop sequence of igniter
- Start, operation, and stop sequence of main burner
- Safety interlock (BPS, BMS)
- Flame sensoring via compact flame scanner (dry contact)
- Tightness test of the safety shut-off valves
- Monitoring of the fuel-air ratio and safety shutdown
- Combustion control (control valves and/or motor dampers)
- O_2-/λ- control

Data and facts:
- Standard industrial instrumentation (binary = 0/24VDC, analogue = 4-20mA)
- Flexibility that supports a wide range of different burner configurations
- Very short shutdown times thanks to the comprehensive diagnostics
- Comfortable process adjustment by an LCD parameter panel
- Connection with supervisory systems via MODBUS TCP
- Tightness test of the safety shut-off valves according to EN 1643/EN 13611
- Fuel-air ratio monitoring and shutdown according to EN 12067-2
- Integrated density correction of the flow by pressure and temperature measurement
- Calculative SIL 3 evidence of the safety interlocks
- Cross feedback combustion control based on control damper feedbacks
- Cross feedback combustion control based on fuel and air flow measurements
- Combustion control including lead controller, O_2 and air factor correction

5. Safety-related and programmable logic controllers

The following programmable safety controllers from HIMA are implemented in many projects as burner management and control systems:

1. HIQuad X (BMS) system family

- TÜV-certified for applications up to SIL 3
- Can be used as burner management system
- Single-channel and dual-channel hardware design is possible
- Mix of single-channel and dual-channel hardware design is possible
- Modular 19” technology
- SILworX development software

2. HIMatrix system family (BCS/BMS)

- TÜV-certified for applications up to SIL 3
- Can be used as burner management and control system
- Single-channel hardware design is possible
- Compact modules for central sections and RIOs
- DIN rail installation
- SILworX development software

3. HIMax system family (BCS/BMS)

- TÜV-certified for applications up to SIL 3
- Can be used as burner management and control system
- Single-, dual- and multi-channel hardware design is possible
- Mix of single-channel and multi-channel hardware design is possible
- Baseplate system with plug-in modules
- SILworX development software

6. Safety programming

To avoid errors while developing the user program, international standards (e.g., IEC EN DIN 61508, IEC EN DIN 61511, EN DIN 50156, EN 746, ANSI/ISA TR 84.00.05, CSA B149.3) require pretested function macros for constantly recurring automation tasks.

HIMA has summarized functionalities that recur in combustion technology in special function blocks (FB) to implement the error avoidance measures described above.

Functional Safety in Combustion Technology

Services in the safety lifecycle areas (safety lifecycle)

From the planning perspective, to safeguard against the described potential hazards, quality management systems are required and implemented for project management. The use of functional safety (FS) in accordance with international safety standards (e.g., IEC EN DIN 61508, IEC EN DIN 61511, EN DIN 50156 [VDE0116], EN DIN 746) is well accepted.

Functional safety describes process flows that are adjusted to the development of safety-relevant products and/or safety-critical production plants.

The project workflows are divided into special steps (phases):

1. Concept phase
2. Hazard analysis phase and assessment
3. Definition of hazard avoidance measures (specification phase, SIF)
4. Design and construction phase
5. Assembling and installation phase
6. Integration phase (hardware and software)
7. Definition phase for maintenance and test intervals
8. Modifications in the operating phase

Moreover, functional safety requires the execution of verification and auditing activities during each of the project phases listed above. Each project phase must be completed by a validation procedure. Functional safety likewise requires preparation of legible and complete documentation. The quality of the participating managers, project planners and programmers is also defined.

Within the framework of its Safety Lifecycle Services, HIMA can support the customer in all phases of the project. Specialists and experts in the areas of functional safety and firing technology are available.

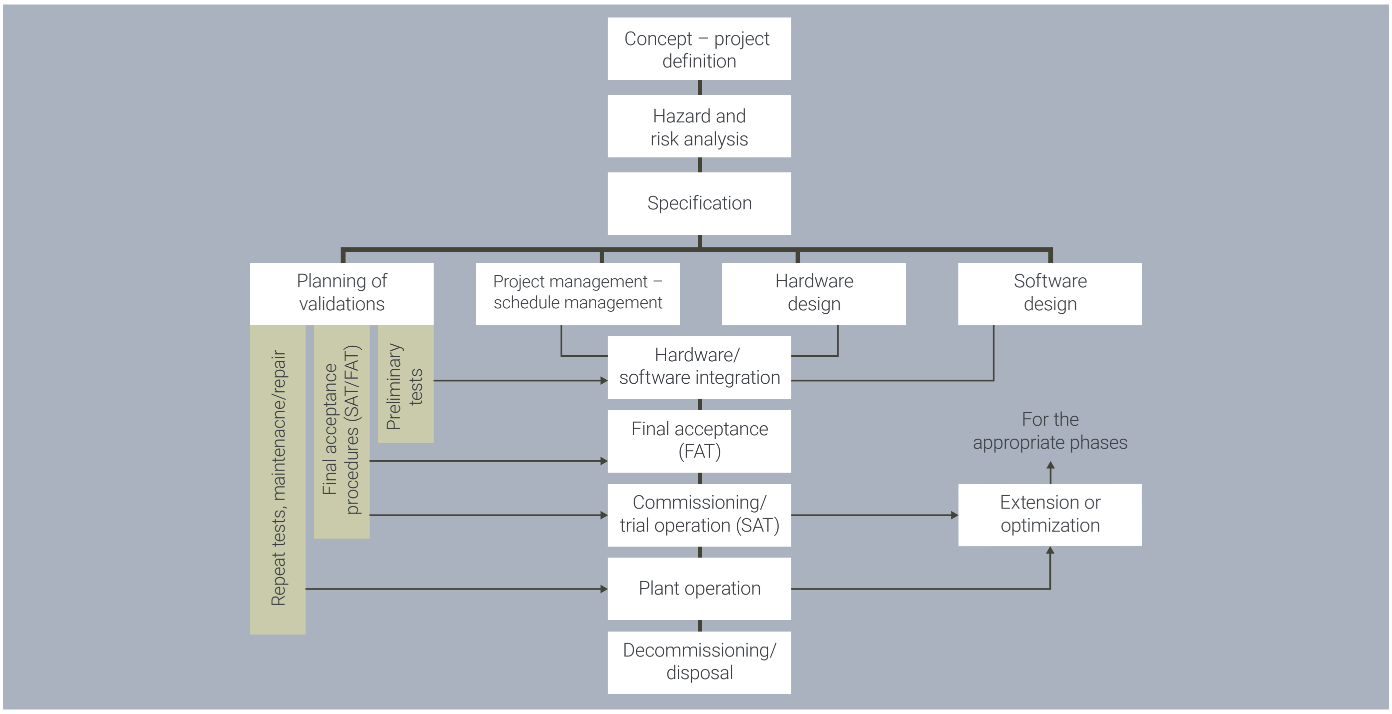


Fig. 4: Safety CV based on international safety standards

Management Summary

Analysis and research of optimal and safe operation of combustion appliances are driven forward on a constant basis. Current technology and new technological developments are influenced by these findings.

To successfully execute a project over the medium or long term, the customer must be supported as early as the task definition phase. As part of its Lifecycle Services, HIMA offers the customer a variety of services in the areas of functional safety and combustion technology.

As a developer and manufacturer of programmable safety controllers, HIMA makes systems with high availability and reliability available to its customers (system families Planar4 SIL 4/PLe, HIQuad X SIL 3/PLe, HIMax SIL 3/PLe, HIMatrix SIL 3/PLe and CSG). These systems are state of the art and ensure protection for people, the environment, and assets. Complex, application-specific functionalities are implemented through coordinated interaction of system hardware and the application program.

Solutions include small SIL 3 flame guard systems (CSG), boiler control systems that include burner and boiler safety interlocks, and control algorithms for critical process point control with the highest availability in hardware and software design.

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