

# **PETRONAS TECHNICAL STANDARDS**

## **DESIGN AND ENGINEERING PRACTICE**

### **TECHNICAL SPECIFICATION**

#### **CONTROL SYSTEM AND INSTRUMENTED PROTECTIVE FUNCTIONS FOR FIRED EQUIPMENT - System for a Single Burner Furnace (S 24.024 and S 24.026)**

PTS 32.24.20.30

FEBRUARY 2011



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# PTS Circular 2011 - 11



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|------------|-------------------------------------------------------------------------------------------------------------------------------------|
| PTS No:    | 32.24.20.30                                                                                                                         |
| PTS Title: | Control System and Instrumented Protective Functions for Fired Equipment - System for A Single-Burner Furnace (S24.024 and S24.026) |

This revision of PTS **32.24.20.30 – Control System and Instrumented Protective Functions for Fired Equipment - System for A Single-Burner Furnace (S24.024 and S24.026) (February 2011)** has been updated to incorporate PETRONAS Lessons Learnt, Best Practice and new information issued by relevant industry code and standards. All updates in the document are highlighted in *italic* font.

The previous version of this PTS **32.24.20.30 (July 1997)** will be removed from PTS binder / e-repository from herein onwards.

## Document Approval

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## 1 INTRODUCTION

### 1.1 SCOPE

This PTS specifies requirements and gives recommendations for control systems and instrumented protective functions for a **dual fuel fired, forced draught, single burner furnace/boiler**. This PTS may also be used for single fuel fired equipment; if the heater is fired on gas only, all fuel oil related instrumentation may be disregarded, and vice versa. Similarly, this PTS may also be used for a natural draught furnace, in which case all relevant combustion air controls and trips may be disregarded.

This PTS shall not be used for multi-burner furnaces/boilers, unless specified by the Principal.

This PTS contains a control and IPF narrative and logic diagrams and refers to a standard specific process engineering flow scheme.

This PTS shall be used together with Standard Drawings S 24.024 (dual fuel) or S 24.026 (fuel gas).

This PTS is written for systems which use DCS for control and monitoring and Safety PLC or Solid State / magnetic core type Instrumented Protective Functions. Accordingly, more use has been made of inverted signals than would have been the case for relay type IPFs.

### 1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorized by PETRONAS, the distribution of this PTS is confined to companies forming part of PETRONAS Group, and to Contractors nominated by them.

This PTS is intended for use in oil refineries, chemical plants, gas plants, onshore and offshore exploration and production facilities, and supply/marketing installations.

If national and/or local regulations exist in which some of the requirements may be more stringent than in this PTS the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable as regards safety, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this PTS which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned with the object of obtaining agreement to follow this PTS as closely as possible.

### 1.3 DEFINITIONS AND ABBREVIATIONS

#### 1.3.1 General definitions

The **Contractor** is the party which carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project or operation of a facility. The Principal may undertake all or part of the duties of the Contractor.

The **Principal** is the party which initiates, and ultimately pays for, the project. The Principal will generally specify the technical requirements. The Principal may also include an agent or consultant, authorized to act for the Principal.

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

### 1.3.2 Specific definitions

|                                        |                                                                                                                                                                  |
|----------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Furnace                                | Includes both furnaces and boilers                                                                                                                               |
| Instrumented protective function (IPF) | A function comprising the Initiator function, Logic Solver function and Final Element function for the purpose of preventing or mitigating Hazardous Situations. |

NOTE: The term "safeguarding" is not widely used in this PTS because safeguarding relates not only to instrumented protective functions but also to protective equipment of a mechanical nature such as non-return valves, relief valves and bursting disks.

### 1.3.3 Abbreviations

|            |                                  |
|------------|----------------------------------|
| ARWU       | Anti Reset Wind-Up               |
| DCS        | Distributed Control System       |
| IPF        | Instrumented Protective Function |
| MW         | Molecular Weight                 |
| P&ID       | Piping & Instrumentation Diagram |
| PLC        | Programmable Logic Controller    |
| Safety PLC | TUV SIL Certified PLC            |
| SRF        | Standard Refinery Fuel           |
| TSOV       | Tight Shut off Valve             |

## 1.4 CROSS-REFERENCES

Where cross-references to other parts of this PTS are made, the referenced section number is shown in brackets. Other documents referenced by this PTS are listed in [\(5\)](#).

## **2 GENERAL**

This PTS shall be used as the basis for the control systems, IPFs, narratives, functional logic diagrams and P&ID for the installation for which it has been specified by the Principal.

The Contractor shall prepare installation-specific narratives based on this PTS, and shall add relevant tag numbers, set points, controller configurations, etc. The installation-specific narratives shall not contain general information which is not relevant to the specific installation.

Like this PTS, the narrative shall contain a functional description including operational aspects and a detailed technical description.

### 3 FUNCTIONAL (OPERATIONAL) DESCRIPTION

#### 3.1 LOAD CONTROL

Flow control is the lowest level of control function for both fuel gas and oil as well as combustion air.

Minimum combustion air flow is ensured by an (adjustable) mechanical minimum stop on the combustion air damper, while the maximum combustion air flow is limited by the capacity of the blower and air register resistance.

Minimum fuel flows are ensured by mechanical minimum stops on the fuel gas and fuel oil control valves.

Maximum burner load is limited by correct control valve sizing.

Note: This does not provide absolute limits to the burner loads because fuel gas density variations exert an influence. This problem can be solved by installing a maximum setpoint limiter on the fuel flow controller.

The furnace load controller (outlet temperature) acts on the fuel and combustion air flow controller set points via a "double-ratio cross-limiting" system. The basic principle is that both fuel and combustion air flows are controlled in parallel, with limits (maximum for fuel, minimum for air) to avoid sub-stoichiometric combustion.

The control system works as follows:

The output signal of the furnace outlet temperature (load) control can be adapted with signals from the furnace inlet temperature and/or the process coil flow in order to add a feed-forward control signal. The resultant signal, which represents the fuel demand, is then passed to the fuel flow controller.

Atomising steam for the fuel oil burner is controlled at a (constant) pressure differential to the burner fuel oil pressure. The furnace load controller (outlet temperature) acts on the fuel and combustion air flow controller set points via a "double-ratio cross-limiting" system. The principle applied is that both fuel and combustion air flows are controlled in parallel, with limits (maximum for fuel, minimum for air) to avoid sub-stoichiometric combustion.

The control system works as follows:

The output signal of the furnace outlet temperature (load) control can be adapted with signals from the furnace inlet temperature, and/or the process coil flow, in order to add a feed-forward control signal. The resultant signal, which represents the total fuel demand, is then passed to the fuel flow controllers as follows:

- the set point of the fuel gas flow controller is the total fuel demand minus the (measured) fuel oil flow.
- the set point of the fuel oil flow controller is the total fuel demand, minus the (measured) fuel gas flow.

Note It is a part of the design philosophy that only ONE fuel is on cascade load control at any time; the other fuel may be either out of operation or on local set point control, operator adjustable)

Depending on the variation in the MW of the fuel gas, the fuel gas flow measurement shall be corrected for changes in gas density (see Section 4.3, Y3). This density compensation compensates for errors in flow measurement and for changes in stoichiometric air requirement.

As the compensated signal also gives a reasonably accurate representation of heat input this signal is also used as input to the fuel flow controller. In this way the fuel gas flow controller indicates a flow in Standard Refinery Fuel (SRF). An additional indication of actual mass flow should be provided for mass balance purposes.

### 3.2 AIR/FUEL RATIO CONTROL

In parallel to adjusting the fuel flow, the fuel demand signal passes via the air/fuel ratio relay to adjust the setpoint of the combustion air flow controller. The required air/fuel ratio can either be manually set by the panel operator, or automatically set by a closed-loop stack oxygen controller. Limits should be set to the range over which the air/fuel ratio can be adjusted, in order to prevent settings that correspond to sub-stoichiometric combustion.

In addition to the basic parallel control system described above, limits are imposed on the adjustment of the set points of fuel and combustion air, as follows:

- The measured fuel gas flow is being converted to a "fuel equivalent" flow, in terms of air requirement, in order to derive a standardised fuel flow. This fuel flow is multiplied by a factor (typically 90%), and provides a minimum limit (via a high selector) to the fuel demand signal to be sent to the combustion air flow controller setpoint. If the fuel demand decreases, and the actual fuel flow does not react, this signal will limit the decrease to the combustion air flow to prevent sub-stoichiometric combustion. The control system changes from a "parallel" control system to a "fuel-leading" system (fuel decrease leads air decrease) after the high selector has limited the decrease in combustion air flow.

A similar system applies to the fuel flow as follows:

- The measured combustion air flow passes through a "minimum air/fuel ratio" relay (with a setting typically 10% lower than the normal air/fuel ratio, and the signal provides a maximum limit (via a low selector) to the fuel demand signal to be sent to the fuel flow controller setpoint. If the fuel demand increases, and the actual combustion air flow does not follow, this signal will limit the increase in fuel flow demand. The control system changes from a "parallel" control system to an "air leading" system (air increase leads fuel increase) after the low selector has limited the increase in fuel flow.

When only one fuel is in operation small zero errors in the flow transmitter of the fuel not in service can give significant errors to the total fuel signal. For this reason, the fuel measurement is set to a "fixed" zero when the related fuel TSOV is closed (deactivated).

### 3.3 WASTE GAS FIRING

If the waste gas flow represents more than 15% of the design heat input of the furnace, it shall be taken into account in the load and air/fuel ratio control. I.e. the waste gas flow shall be measured and subtracted from the total fuel demand, before it is fed to the fuel flow controllers. Similarly, the measured waste gas flow shall be added to the fuel flow, which is then used in the air/fuel ratio control scheme.

A fixed heating value and stoichiometric air requirement may be used for the waste gas.

If the waste gas flow represents less than 15% of the design heat input, it may be fed uncontrolled to the furnace, provided the main burner is in operation.

### 3.4 START-UP AND OPERATIONAL ASPECTS

The system is equipped with an automatic purge sequence, asking for a "long" or a "short" purge, depending on the cause of the trip preceding the purge. Each purge is automatically started, provided the combustion airflow and other start permissive are (or have become) healthy. A "long" purge is required if the trip was initiated via the low airflow trip or via the manual trip switches. Duration of this purge is sufficient to replace 5 times the firebox volume at minimum airflow. All other trips require a "short" (5 min) purge.

NOTE: The purge sequence does not include an automatic opening of the combustion air damper.

After the purge time has elapsed and if other conditions are healthy, the burner can be started.

Prior to start-up, the fuel TSOVs are closed, and the fuel flow controllers are automatically set to "manual" with zero output. This will drive the fuel control valves to the mechanical minimum stop setting.

Upon activating the igniter start button the igniter is started. An indefinite number of igniter start trials can be made without purging the furnace.

If the ignition flame is detected, the main burner can be started by activating the main burner start button. If the main burner is not started within 15 minutes, the igniter is stopped again. Although it is possible to start up with fuel oil, start up should be on fuel gas since ignition is easier and timer settings, etc. can be better defined.

Five seconds after starting the main burner, the igniter is automatically stopped. Thereafter the igniter can be restarted at any time (e.g. for testing purposes). After 15 minutes the igniter is automatically stopped again.

Before start-up on oil the atomizing steam differential pressure controller should be on automatic, maintaining a slight steam pressure on the burner. As the fuel header pressure increases, the atomizing steam pressure will increase to maintain the correct steam/oil differential pressure, aiding a smooth light-off.

If a prompt light-off is not detected the TSOV closes to prevent an accumulation of unburnt fuel in the furnace.

Following the burner light-off (at minimum stop) the fuel flow controller can be commissioned, to increase burner load, and proceed to cascade load control, as required.

It is not necessary to take the combustion air flow controller out of "cascade" control mode during furnace start-up because the combustion air damper is provided with a minimum stop.

Once the load is increased, the setpoint of the combustion air flow controller will increase automatically to take up the load, and increase the combustion air flow above the minimum stop.

## 4 TECHNICAL DESCRIPTION

### 4.1 IMPLEMENTATION CONSIDERATIONS

If the fuel gas flow controller FRC-1 or fuel oil flow controller FRC-3 is forced to manual with 0% output (minimum stop) by the PLC the operator shall not be able to change mode and output.

Anti-reset wind-up (ARWU) protection shall be implemented on the master temperature controller TRC-1 and the O<sub>2</sub> controller QRCA-1.

The actual form of the ARWU protection to be implemented will depend on the choice of DCS vendor and the type of controller algorithm used.

If neither fuel is on cascade, the TRC output shall be initialized to the total fuel flow.

If the combustion air is not on cascade, the oxygen QRC output shall be initialized to the (current) air/fuel ratio.

If the chosen DCS / Controller algorithm supports the use of external feedback as ARWU protection then external feedback can be configured from Y10 to QRCA. This external feedback improves the response of the O<sub>2</sub> QRCA during changes in load of the furnace. The principle behind this external feedback is as follows:

If the load of the furnace is reduced and the air flow is reacting more slowly than the fuel flow (due to parallel lead / lag control configuration), the external feedback ensures a minimum overshoot. If there were no external feedback, the QRCA would react to the excess air and further reduce the air, thereby resulting in an overshoot when approaching the final steady state value.

If the control scheme is implemented in a DCS which does not support external feedback (i.e. only ARWU used) the QRCA should be tuned to slow response to minimize the overshoot during transients.

The control scheme is not designed to operate with both fuel flow controllers in cascade mode, due to possible interaction between the two loops. Therefore, when switching over between cascade and automatic modes, both flow controllers should be placed in automatic mode. However, it is recognized that this alone does not ensure a bumpless transfer and therefore the appropriate initialization techniques shall be configured.

For furnaces with a common stack, the low air/fuel ratio trip is considered to be SIL class 1, which implies that in these cases the low A/F ratio trip shall be implemented in the PLC, with dedicated trip transmitters. For furnaces having their own stack, a too low A/F ratio is expected to lead to little or no damage, for which reason the low A/F ratio trip can be implemented as SIL a" (i.e. in DCS) in these cases.

### 4.2 LOCATIONS OF ALARMS, SWITCHES, ETC.

The system is designed such that remote starting and stopping of the gas burner is possible.

Since oil firing requires local presence of the operator (for checking atomizers, steaming out of oil guns, etc.), the oil burner is started and stopped locally.

To enable the operator to start/stop fuel gas from the control room, and to start/stop fuel oil locally, the igniter start/stop button is duplicated (on a local panel as well as in the control room).

The above philosophy is reflected in Standard Drawings S 24.024 & S 24.026.

If specified by the Principal the fuel gas start/stop button shall be located on the local panel (reasons for this may be to standardize with other furnaces or to comply with local regulations). In this case status indications shall be installed on the local panel as well as in the DCS.

#### 4.3 CALCULATION FORMULAS

The following computing formulae shall be used:

- Y1) If the fuel oil TSOV is closed, the oil flow signal to the total fuel flow summer is zero (Y5, Y6).

NOTE: The measured value is still fed to the fuel oil FRC, so that the operator is informed about possible measurement offsets prior to introducing oil.

- Y2) If the fuel gas TSOV is closed, the gas flow signal to the total fuel flow summer is zero (Y4, Y6).

NOTE: The measured value is still fed to the fuel oil FRC, so that the operator is informed about possible measurement offsets prior to introducing gas.

- Y3) Corrects fuel gas flow measurement for fuel gas density, and (optionally) for pressure and temperature at the transmitter, and converts it into an equivalent flow in SRF. The actual formula to be used depends on the type of flow meter (vortex orifice type) as well as the type of density meter (line density or Molecular Weight).

In setting up the actual formulae, the following equations shall be used:

$$M_{\text{air stoichiometric}} = 14.77 \left( 1 + \frac{2.68}{MW} \right) * M_{\text{fuel gas}} \quad [\text{t / d}]$$

$$\text{Fuel gas density} = 12.03 \left( \frac{MW * PT}{T} \right)$$

where:

P = Pressure, bar (abs)

T = Temperature, °C

$$M_{\text{fuel SRF}} = \frac{M_{\text{air stoichiometric}}}{13.66} \quad [\text{tSRF / d}]$$

The above formula assumes typical refinery fuel gases, i.e. mixtures of paraffinic hydrocarbons and hydrogen (inert less than 2%) and is only valid for MW > 5.

It further assumes the stoichiometric air requirement of SRF to be constant at 13.66kg air/kg SRF.

If the anticipated Molecular Weight (MW) variations are less than ±20% of the average molecular weight, a fixed (average) value for MW may be used.

- Y4) Output = required (total) fuel flow - gas flow - waste gas flow [t/dSRF]  
(see Note 1)

Y5) Output = required (total) fuel flow - oil flow - waste gas flow [t/d SRF]  
(see Note 1)

Y6) Output = gas flow + oil flow + waste gas flow [t/d SRF]  
(see Note 1)

NOTE 1: Waste gas flow shall only be incorporated in calculations if the heat input by waste gas represents more than 15% of the total design heat input.

Y7) Sets a minimum limit for the combustion air flow.  
Output = 0.9 \* Total fuel flow

Y8) Calculates a maximum allowable fuel flow

$$\text{Output} = M_{\text{air}} / (0.9 * 13.66 * [0.8 + 0.8 * \text{QRC}]) ;$$

in which: QRC = Output of oxygen controller [signal 0-1]

$M_{\text{air}}$  = Measured air flow [t/d]

The formula limits the air/fuel ratio between 0.8 and 1.6 (times 0.9).

Y9) Calculates the required air flow.

$$\text{Output} = \text{Fuel flow} * 13.66 * [0.8 + 0.8 * \text{QRC}]$$

In which the fuel flow is the master signal or (0.9 \* total fuel flow), whichever is higher. The formula limits the air/fuel ratio between 0.8 and 1.6.

Y10) Calculates air/fuel ratio for low alarm and trip.

$$\text{Output} = M_{\text{air}} / (13.66 * \text{Total fuel flow}) ;$$

Alarm shall be set at a ratio of 1.0.

Trip to minimum firing shall be set at 0.8.

The total fuel flow shall be given a minimum value to avoid "division by zero", which can give spurious alarms when the furnace is out of operation.

Calculation blocks for (optional) feed-forward:

NOTE: Anti-reset wind up of TRC is always required.

- For feed-forward from process flow through furnace:

$$\text{Y12) Output} = \frac{\text{Fuel flow}}{\text{process flow}}$$

$$\text{Y13) Output} = [\text{process flow}] * [\text{TRC output}]$$

- For feed-forward from process flow and furnace inlet temperature:

$$\text{Y12) Output} = \frac{\text{Fuel flow}}{\text{process flow}} + K * [\text{inlet temperature}]$$

$$\text{Y13) Output} = [\text{process flow}] * \{[\text{TRC output}] - k * [\text{inlet temperature}]\}$$

$$\text{where } k = \frac{\text{specific heat process fluid}}{\text{fuel LHV} * \text{furnace efficiency}}$$

Y16) Low selector to set a maximum to the signal to the fuel flow controllers.

Y17) High selector to set a minimum to the signal to the air flow controller.

#### 4.4 DESCRIPTION OF INSTRUMENTED PROTECTIVE FUNCTIONS

The instrumented protective functions are described by the functional logic diagrams ([Appendix 1](#)) and by the IPF narrative as given below. An IPF review shall be carried out to ensure all safety related instrumentation meets the required IPF classification.

The functional logic diagrams are set up in a modular structure. This section follows the same structure. However, it only describes the main modules. Assisting modules such as the "general trips" module are not described separately. Their functionality is described in the modules where they are relevant.

##### 4.4.1 Safe atmosphere module

The function of this module is to continuously check for, and if necessary re-establish by purging, a safe atmosphere for firing the furnace.

- If:**
- i. the combustion airflow is not low; and
  - ii. the local and panel trip switches are in the healthy position; and
  - iii. both main fuel gas TSOVs and the fuel oil TSOV are detected closed (start condition only); and
  - iv. no flame is detected (start condition only); then

the purge sequence is automatically started.

This initiates the maximum purge timer to start running.

This maximum purge timer is set to give a minimum of 5 complete air changes of the firebox (assuming a minimum combustion airflow of at least 25 %).

If there are no disruptions of the above conditions and after the maximum purge timer has run out, a "safe conditions" indication is given.

- If:**
- i. the purge is completed; and
  - ii. the combustion air flow is not low; and
  - iii. the local and panel trip switches are in the healthy positions,

a safe atmosphere signal is given to the header modules and to the igniter modules.

If during normal furnace operation any one of the above conditions fails, the safe atmosphere signal disappears. Then a complete new maximum purge is required.

As long as above safe conditions signal remains healthy, no "full purge" cycle is required. However, after **any** total trip of the furnace (shown in the functional logics by the closing signal to the header TSO valves), the "safe conditions" signal disappears and a 'short' purge cycle of 5 min is automatically started via the 'minimum purge timer' timer.

Similar to the maximum purge, the minimum purge is only started if no flames are detected and all header and burner TSO valves are detected closed.

If there are no disruptions of the above conditions and after the purge timer has run out, a "safe conditions" indication is given.

During purging a "purge in progress" indication is given.

NOTE: In none of the purge cycles is the airflow changed from its original value.

#### 4.4.2 Minimum Stop Module

The purpose of this module is to control the set and release of the fuel minimum stops.

- If:**
- i. the "not minimum firing" signal from the process (e.g. high temperature trip to minimum firing) is present (where applicable); and
  - ii. the air/fuel ratio is healthy; and
  - iii. the module receives a "gas flame on" signal; then the fuel gas flow controller can be taken into operation by activating the gas minimum firing reset in the control room.
- If:**
- i. the "not minimum firing" signal from the process (e.g. high temperature trip to minimum firing) is present (where applicable); and
  - ii. the air/fuel ratio is healthy; and
  - iii. the module receives a "oil flame on" signal; then

the fuel oil flow controller can be taken into operation by activating the oil minimum firing reset in the control room.

NB. For furnaces with a common stack, the low air/fuel ratio trip is considered to be SIL class 1, which implies that in these cases the low A/F ratio trip shall be implemented in the PLC, with dedicated trip transmitters.

#### 4.4.3 Igniter Module

The function of this module is to monitor all the conditions required to fire and to control the igniter.

- If:**
- i. the module does not receive a "burner start inhibit signal"; and
  - ii. the igniter stop button is not activated; and
  - iii. there is no high level in the fuel gas KO drum; and
  - iv. the safe atmosphere module produces a "safe conditions" signal; and
  - v. the igniter start button is activated; then

the igniter module produces the following signals:

- i. open igniter TSOV
- ii. ignition spark signal for a period of 10 seconds.

After the flame stabilization timer has run out (after 15 seconds) the ignition flame shall be detected by the ionization rod or pilot flame detector and an "ignition flame present" signal is send to the oil and gas burner modules.

If the igniter start trial was unsuccessful, restart is inhibited for a period dictated by the igniter restart inhibit timer (about 30 seconds).

An indefinite number of restarts of the igniter can be attempted without a new purge cycle being required. It is assumed that the capacity of the igniter is sufficiently low to ensure that the overall gas/air mixture is below the lower explosion limit.

After the igniter has been successfully started, it will run for a maximum period of 15 minutes. It will be automatically stopped by the main burner module 5 seconds after opening of the oil or gas burner TSOV.

After the main burner has started the igniter can be re-started at any time (for testing purposes). After 15 minutes the igniter is stopped again.

#### **4.4.4 Gas Burner Module**

The function of this module is to monitor all the conditions required to open and close the gas burner TSOVs and to control their actions.

There are two parallel TSOVs to allow tightness testing during operation. By means of a selector which, either gas header A or gas header B can be selected to be in operation.

- If:**
- i. the module receives a "safe conditions" signal; and
  - ii. the other process conditions are healthy (process trips); and
  - iii. there is no high level in the fuel gas KO drum; and
  - iv. the "stop gas firing" button is not activated; and
  - v. the ignition burner is on, or the oil burner is on; and
  - vi. the "start gas firing" button is activated; then

the module produces the following signals:

- a. Open preselected gas burner TSOV. At the same time the output of the gas flowmeter is incorporated in the firing and air/fuel ratio control.
- b. After the trial for ignition timer has run out (5 seconds after the burner TSOV has opened) the module gives a "stop igniter" pulse.

The start timer is set at 5 s. This timer setting shall not be confused with the so-called maximum allowable Trial For Ignition Time. The reason is that in practice all systems should be able to achieve a reliable start-up within 5 s – longer times would only reduce the safety level, and shorter times reduce the robustness of the start system.

- If:**
- i. either condition i or iv fail; or
  - ii. the main flame is not detected within 5 seconds; then

the gas burner TSOV closes, and a new purge cycle is required (only if the oil TSOV is not open).

If the gas burner TSOV is open and the main flame is detected the gas burner module produces a "gas burner on" signal.

The main flame is detected by means of two flame detectors of which at least one has to detect a flame.

#### 4.4.5 Oil Burner Module

The function of this module is to monitor all the conditions required to open and close the oil burner TSOV and to control its action.

- If:**
- i. the module receives a "safe conditions" signal; and
  - ii. the other process conditions are healthy (process trips); and
  - iii. the atomising steam pressure is not low; and
  - iv. the "stop oil firing" button is not activated; and
  - v. the ignition burner is on, or the gas burner is on; and
  - vi. the "start oil firing" button is activated; then

the module produces the following signals:

- a. Open the oil burner TSOV. At the same time the output of the oil flow meter is incorporated in the firing and air/fuel ratio control.
- b. After the trial for ignition timer has run out (5 seconds after the burner TSOV has opened) the module gives a "stop igniter" pulse.

- If:**
- i. either condition i or iv fail; or
  - ii. the main flame is not detected within 5 seconds; then

the oil burner TSOV closes, and a new purge cycle is required (only if the gas TSOV is not open). ~~and a next start (of the ignition burner) is inhibited for one minute. If the TSOV failed to close, restart of the igniter remains inhibited until the failure is recovered (or overridden).~~

If the oil burner TSOV is open and the main flame is detected the oil burner module produces a "oil burner on" signal.

The main flame is detected by means of two flame detectors of which at least one has to detect a flame.

#### 4.4.6 Waste gas firing module (optional)

The function of the waste gas firing module is to monitor all conditions required to open and close the waste gas TSOV(s) and to control this (these) valve(s).

- If:**
- i. the module receives a "furnace NOT on minimum stop" signal; and
  - ii. there is no high level in the waste gas KO drum (if applicable); and
  - iii. the module receives an "main burner in operation" signal; and
  - iv. the waste gas firing stop button is not activated; then

the waste gas TSOV to the furnace can be opened by activating the waste gas reset button. Usually the waste gas TSOV to the furnace is operated in conjunction with a vent TSOV (i.e. the vent TSOV is automatically opened in case the furnace TSOV is closed).

Once the TSOV is opened, the waste gas flow signal is accounted for in the air/fuel ratio control system (only if the anticipated waste gas flow represents more than 15% of the total design heat input of the furnace).

#### 4.5 SIL CLASSIFICATION AND CAUSE AND EFFECT DIAGRAM

The possible hazardous situations as may occur in and around the fired equipment have been assessed, and the results thereof are given in the table below, thereby defining the initiators that (may) detect such hazardous situation. The safeguarding system as described in this PTS is in line with the SIL levels as shown in this table.

A full SIL classification exercise should be carried out on the actual fired heater design to confirm that the required SIL classes of all the safeguarding loops are in line with the heater configuration and take into account site specifics (e.g. common fuel gas KO vessels, proximity to other plant, special environmental requirements).

For completeness sake the relevant Cause & Effect diagram is given in table I.

| <b>Hazardous situation</b>                                  | <b>Demand</b>                      | <b>Health &amp; Safety</b>           | <b>Economics</b> | <b>Environment</b> | <b>SIL</b> |
|-------------------------------------------------------------|------------------------------------|--------------------------------------|------------------|--------------------|------------|
| Flame detector trip                                         | D2                                 | S4/mitigation -1                     | 4                | 1                  | 2          |
| Low fuel pressure trip (in systems with flame detection)    | D2                                 | 0                                    | 0                | 0                  | -          |
| Low fuel pressure trip (in systems without flame detection) | D2                                 | S4/mitigation -1                     | 4                | 1                  | 2          |
| Atomising steam Delta P trips (with flame detection)        | D1                                 | 0                                    | 0                | 0                  | -          |
| Atomising steam Delta P trips (without flame detection)     | D1 <sup>1</sup>                    | S4/mitigation -1                     | 4                | 1                  | 1          |
| Low air flow trip                                           | D1 <sup>2</sup>                    | S4/mitigation -1                     | 4                | 1                  | 1          |
| FD fan motor trip (in systems with low air flow trip)       | D1 <sup>2</sup>                    | 0                                    | 0                | 0                  | -          |
| FD fan motor trip (in systems without low air flow trip)    | D1 <sup>2</sup>                    | S4/mitigation -1                     | 4                | 1                  | 1          |
| Low air/fuel ratio trip                                     | D1 <sup>3</sup><br>D1 <sup>3</sup> | S0<br>S4/mitigation -1               | 3<br>4           | 0<br>1             | a2<br>1    |
| High fuel pressure trip                                     | D2 <sup>4</sup><br>D2 <sup>4</sup> | S0<br>S4/mitigation -1               | 3<br>4           | 0<br>1             | a2<br>1    |
| High level fuel gas KO drum level trip                      | D2 <sup>5</sup><br>D1 <sup>5</sup> | S4/mitigation -1<br>S4/mitigation -1 | 4<br>4           | 0<br>0             | 0<br>1     |
| Control valve in minimum stop position during start-up      | D1 <sup>6</sup>                    | S4                                   | 4                | 1                  | 1          |
| Fuel gas ESD valves closed detection prior to start         | D1 <sup>6</sup>                    | S4                                   | 4                | 1                  | 1          |
| Low purge air flow (during automatic purge sequence)        | D1 <sup>6</sup>                    | S4                                   | 4                | 1                  | 1          |

- <sup>1</sup> Too low atomising steam differential pressure results in less than 10 % of the cases in flame failure. If flame detection is installed this has no serious HSE consequence.
- <sup>2</sup> Too low an airflow results in less than 10 % of the cases to major damage. A failing FD fan is generally detected by a low air flow trip and has therefore no HSE consequence if a low air flow trip is installed.
- <sup>3</sup> For furnaces connected to a common stack, a too low A/F ratio in one furnace could lead to an explosion in a flue duct or stack, leading to serious damage – in less than 10 % of the cases (S4/ mitigation -1). For furnaces with own stack, a too low A/F is expected to lead to little damage. I.e. only for furnaces with common stack a low A/F ratio is classified as SIL1.
- <sup>4</sup> Too high fuel gas pressure is expected to result in over firing, after burning or a minor explosion, leading to minor damage. On some burners, too high fuel gas pressure leads to flame blow off and - if not safeguarded with flame detectors - to an explosion with major damage.
- <sup>5</sup> Too high level in the high KO drum level in most cases leads to minor damage, but in less than 10 % of cases the damage will be extensive.
- <sup>6</sup> Failures of start-up checks, such as control valve position check, ESD valves closed checks and purge air flow check result in less than 10 % of the cases in major damage.

**Table 1 Cause and Effect Diagram**

| Initiators       |                                 | Actions                      |                      |                     |                        |                    |
|------------------|---------------------------------|------------------------------|----------------------|---------------------|------------------------|--------------------|
| TAG              | Service                         | Abort/Inhibit start sequence | Fuel gas TSOVs close | Fuel oil TSOV close | Trip to minimum firing | Igniter TSOV close |
| FZA-01-LL        | Combustion air                  | x                            | x                    | x                   | x                      | x                  |
| XZA-01-LL        | Air/fuel ratio                  | -                            | -                    | -                   | x                      | -                  |
| XZA-11           | Flame detection ignition burner | x                            | -                    | -                   | -                      | 0                  |
| XZA-13/14        | Flame detection main burner     | -                            | x                    | x                   | x                      | -                  |
| HZA-01/02        | Manual trips                    | x                            | x                    | x                   | x                      | x                  |
| GBSA-02/03       | Fuel gas TSOVs closed           | x                            | -                    | -                   | -                      | -                  |
| GBSA-01          | Fuel oil TSOV closed            | x                            | -                    | -                   | -                      | -                  |
| LZA-01-HH        | Fuel gas KO drum                | -                            | x                    | -                   | x                      | x                  |
| PZA-01-HH        | Fuel Gas                        | -                            | -                    | -                   | x                      | -                  |
| PZA-02-HH        | Fuel Oil                        | -                            | -                    | -                   | x                      | -                  |
| PZA-05-LL        | Atomising steam                 | -                            | x                    | x                   | x                      | x                  |
| Process trips I  | General                         | -                            | -                    | -                   | x                      | -                  |
| Process trips II | General                         | -                            | x                    | x                   | x                      | x                  |

## 5 SYSTEM BACKGROUND AND DEVIATIONS FROM INTERNATIONAL STANDARDS

### 5.1 GENERAL

The system as described in this PTS has been reviewed against the following standards:

- NFPA 85
- EN 746-2

The main deviations are given in this Section, including the reasoning behind these deviations and the applied alternatives (where needed).

EN 746-2 specifically states that the preventative measures as specified should not be considered as the only possible solution. Any other solution leading to the same risk reduction is permissible if an equivalent level of safety is achieved.

The system described in this PTS is considered to have an equivalent level of safety as that of EN 746-2 (and for that matter also of NFPA 85), and is therefore considered to be in line with EN 746-2.

This Section does not relieve the Contractor of its obligations as described in (1.2).

### 5.2 LINE UP OF TSO VALVES AND USE OF DOUBLE BLOCK AND BLEED VALVES.

Both NFPA 85 and EN 746-2 specify two TSO valves in series. Both codes require an automatic vent valve between the two TSO valves and an automatic leak test (of the TSO valves).

For the system as specified in this PTS the following considerations have been taken into account:

- It is based on appropriate SIL.
- The fuel gases as applied in the petrochemical industry are often of a fouling nature, which occasionally leads to TSO valve closing failures. Application of two-valves-in-series often is not a proper solution in view of the possible common mode failure (both valves fouling up).
- Refinery fired equipment often operates for a number of years in succession. Therefore facilities are incorporated to allow on-line testing of TSO valves, at a frequency as set by the SIL or RCM analysis in the event of dominant age related failures (fouling).
- The system is geared towards minimum nuisance during operation and start-up, as any such nuisance (e.g. trips, start-up delays, etc.) intrinsically has a negative impact on safety.
- For environmental reasons, the number of vents must be minimized, thereby minimizing the chance of unintentional venting to atmosphere (due to passing vent valves).

The system as specified in this PTS applies two TSO valves in parallel (for fuel gas) and single individual burner TSO valves (with a manual block valve upstream thereof).

The above setup allows on-line testing (and if required repair) of the TSO valves.

Since implementation of the TSO valves (number and test frequency) is done in line with their SIL class, the system as specified in this PTS **does not** include automatic leak test systems. Experience has shown that such systems often lead to nuisance (typically caused by instrument failures) during start-up – thereby reducing the safety level.

Notwithstanding the above, the system as specified in this PTS **does** include a check of the closed position of the main burner TSO valves prior to purging and main burner ignition.

Small leakage rates (below 1 % of valve rating) are not considered harmful, since the mixture of fuel and air exiting the burner will still be well below LEL.

### 5.3 LOW FUEL PRESSURE TRIP

Most codes prescribe the application of a low fuel pressure trip (PZA-LL).

However, when applying the SIL approach, one can consider that the effect of a failure on demand of this low-pressure trip is – in safety terms – nothing. That is to say, if the PZA-LL fails to see the pressure dropping below its threshold, the flame may extinguish, which will be detected by the flame detector(s), which will initiate the TSO valve(s) to close.

It is considered that the application of the low-pressure trip dates from the times when reliable, fail-safe flame detectors were not used or were not available. On refinery applications, where large turn down on individual fuels is often required, low pressure trips often lead to nuisance.

It is for the above reasons that the system as specified in this PTS does not include the low fuel pressure trip.

### 5.4 PURGING REQUIREMENTS

NFPA 85 requires a minimum purge flow of 70 % for single burner systems. For multiple burner systems NFPA 85 indicates that airflow rate should not be increased after a trip. Background of this requirement is that a sudden increase in airflow into a hot fuel rich environment could cause an explosion

Since the latter is just as valid for single burner installations, the system as specified in this PTS no longer automatically increases the air to maximum during the purge cycle.

Moreover, in the system as specified in this PTS, the minimum airflow during purging (being minimum 25 % of the design airflow) is equal to the minimum airflow during normal operation.

Both NFPA 85 and EN 746-2 do **not** distinguish between the causes of a trip, and assume that prior to each purge, the firebox could be filled with 100 % hydrocarbons. This results in the requirement that each purge shall be long enough to give a minimum of 5 complete air changes of the firebox volume or 5 min, whichever is the longer.

The system as specified in this PTS distinguishes **two** purge 'cycles':

- The maximum purge cycle, as is required after a combustion air related trip, e.g. a low airflow trip as well as after a manually initiated emergency trip. This requires a full purge cycle, which implies purging at a minimum flow rate of 25 % of the design airflow rate, and with a purge time which gives a minimum of 5 complete air changes of the firebox volume or 5 min, whichever is the longer. This full purge cycle is automatically initiated as soon as the airflow (and other start permissive) are healthy. The five air changes are based on the assumption that the firebox could be filled with 100 % hydrocarbons.
- The minimum purge cycle, which is required after any other (non combustion air related) firing trip. This purge cycle starts immediately after the shut-off of the fuel supply, and implies purging at a minimum flow rate of 25 % of the design airflow rate, and with a purge time of 5 min.

The reasoning here is that if the airflow has remained at 25 % at least of design, the firebox is filled with at most 40 % hydrocarbons (assuming the most extreme condition of a fuel input of 100 % and an air input of 25 %).

Since prolonged purging generally has serious consequences on a Unit re-start, the purge time under these circumstances has been limited to 5 min.

NFPA 85 requires an immediate start of the burner at the end of the purge cycle, whereby the end of the purge cycle could be interpreted as the moment when the purge timer expires.

Provided there is no interruption of the combustion air supply, it can be argued that the purge cycle only ends at the moment when the first burner is started.

This PTS applies the latter interpretation

## 5.5 IGNITION BURNER REQUIREMENTS

This PTS is based on the use of an ignition burner with a capacity of about 0.5 % to 3 % of that of the main burner. This amount, mixed with the (forced) combustion air through the main burner (with a minimum flow of 25 % of design), will always be below the flammability limit. It is for this reason that the system as specified in this PTS allows multiple **ignition** burner starts without the need for a new purge cycle.

The design intent is that the ignition burner is automatically switched off 5 s after the fuel supply to the main burner has been opened. It should therefore be regarded as a Class 3 ignitor according to the NFPA 85 definition.

## 6 REFERENCES

In this PTS, reference is made to the following publications:

NOTE: Unless specifically designated by date, the latest edition of each publication shall be used, together with any amendments/supplements/revisions thereto.

### **PETRONAS STANDARDS**

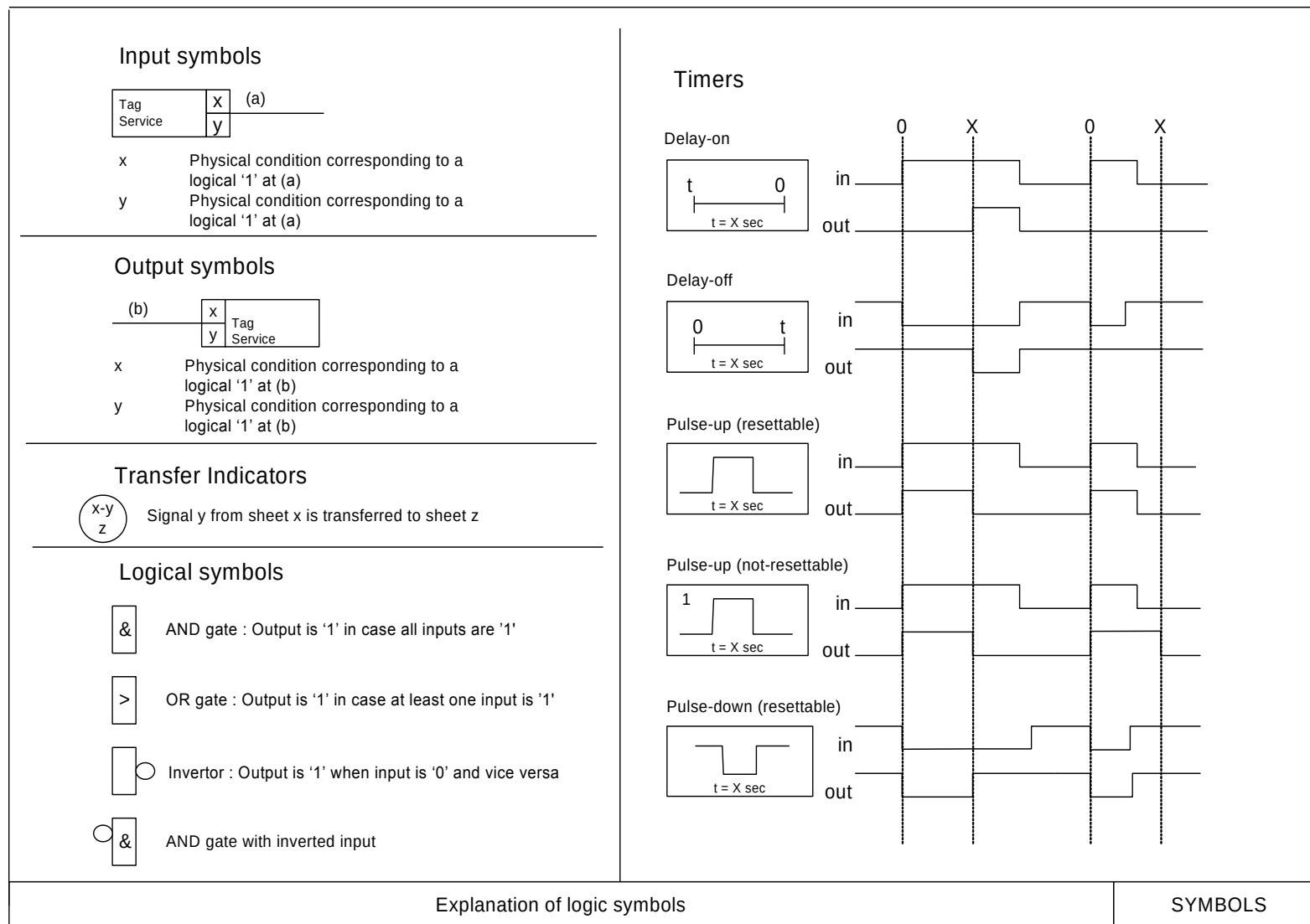
|                                                                        |                 |
|------------------------------------------------------------------------|-----------------|
| Classification and implementation of Instrumented Protective Functions | PTS 32.80.10.10 |
|------------------------------------------------------------------------|-----------------|

### **STANDARD DRAWING**

|                                                                                     |          |
|-------------------------------------------------------------------------------------|----------|
| Control and safeguarding system for a dual fuel fired, single burner furnace/boiler | S 24.024 |
|-------------------------------------------------------------------------------------|----------|

|                                                                              |          |
|------------------------------------------------------------------------------|----------|
| Control and safeguarding system for a gas fired single burner furnace/boiler | S 24.026 |
|------------------------------------------------------------------------------|----------|

## APPENDIX 1 FUNCTIONAL LOGIC DIAGRAMS FOR A SINGLE BURNER FURNACE.



## Furnace safeguarding logics for single burner furnace

### References:

S24.024:  
Fuel oil and fuel gas system for a single burner heater or boiler

S24.026:  
Fuel gas system for a single burner heater or boiler

### Note:

When these logics are used for a single fuel system, e.g. gas only, the relevant fuel oil signals must be disregarded / deleted where applicable.

### Sheets:

1. Safe atmosphere
3. General trips
4. Minimum stop
8. Fuel gas TSOV selection
12. Igniter
13. Fuel gas burner
14. Fuel oil burner
15. Flame detection
99. Status indications, alarms, switches

