TECHNICAL SPECIFICATION

CONTROL SYSTEM AND INSTRUMENTED PROTECTIVE FUNCTIONS FOR FIRED EQUIPMENT

- System for a tangentially gas-fired CO boiler (S 24.036)

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1. INTRODUCTION

1.1 SCOPE

This DEP specifies requirements and gives recommendations for control systems and instrumented protective functions for a **tangentially gas-fired CO boiler.** This DEP shall not be used for any other equipment or firing configuration.

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

This DEP shall be used together with Standard Drawing S 24.036.

This DEP is written for systems which use DCS for control and monitoring and PLC and Solod 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 authorised by SIOP and SIEP, the distribution of this DEP is confined to companies forming part of or managed by the Royal Dutch/Shell Group, and to Contractors nominated by them (i.e. the distribution code is "C", as defined in DEP 00.00.05.05-Gen.).

This DEP is intended for use in oil refineries.

If national and/or local regulations exist in which some of the requirements may be more stringent than in this DEP 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 DEP 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 DEP 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, authorised to act for the Principal.

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

1.3.2 Specific definitions

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 DEP 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
CO	Carbon monoxide
DCS	Distributed control system
IPF	Instrumented protective function
MCR	Maximum continuous rating
PEFS	Process engineering flow scheme
PLC	Programmable logic controller
SRF	Standard refinery fuel
TSOV	Tight shut off valve

1.4 CROSS-REFERENCES

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

2. GENERAL

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

The Contractor shall prepare installation-specific narratives based on this DEP, 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 DEP, 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 fuel gas and combustion air.

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

Minimum fuel gas flow is ensured by a minimum stop pressure controller which guarantees a minimum burner load, irrespective of the number of burners in operation. Similarly, maximum burner load is limited by a maximum stop pressure controller.

Note: The fuel gas pressure control limiter does not provide absolute limits to burner load since this is also affected by variations in the density of the fuel gas.

In addition to the minimum stop fuel pressure controller, the fuel control valve is provided with a mechanical minimum stop. This is adjusted to correspond to minimum load with only one burner in operation, and acts as a pre-set valve position for start-up of the first burner.

The control system works as follows:

The heat input from the regenerator off-gas (sensible heat and heat of combustion) is calculated on the basis of the total air flow to the regenerator (including catalyst transport air), the CO content in the off-gas and the temperature of the off-gas to the boiler, and is converted into SRF equivalent values.
The SRF equivalent of the sensible heat in the off-gas is subtracted from the output signal of the master steam flow controller. The resultant signal, representing the total fuel demand (including CO), is then passed to the fuel gas flow controller via the air/fuel ratio control system.
The SRF equivalent (in terms of stoichiometric air requirement) of the CO is subtracted from the required fuel flow signal going to the fuel gas flow controller.
The SRF equivalent (in terms of stoichiometric air requirement) of the CO is added to the measured fuel gas flow before this signal is fed to the air/fuel ratio control scheme.

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, Y4). 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).

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 may 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:

- This measured fuel gas flow, including the SRF equivalent CO flow (in terms of air requirement), is multiplied by a factor (typically 0.9), and provides a minimum limit (via a high selector) to the total fuel demand signal to be sent to the combustion air flow controller setpoint. If the total fuel demand decreases, and the actual fuel flow does not react, this signal will limit the decrease in 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 gas 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 gas flow controller setpoint (after subtraction of the SRF equivalent (in terms of air required) CO flow)). 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 gas flow.

Since the system operates such that burners can only be operated above minimum stop conditions if all burners are in operation, the air/fuel ratio control does not need to be corrected for operation with less than the total number of burners in operation. The mechanical minimum stop on the combustion air damper (set at 35% flow) guarantees sufficient air for minimum stop operation.

3.3 START-UP

Each burner is equipped with individual start and stop switches for the ignition burner as well as for opening and closing the fuel gas burner TSOVs.

The system is equipped with an automatic purge sequence. Upon activation of the "purge start" the common air damper is opened fully for the period of the purge timer.

After the purge time has elapsed and if other conditions are healthy, ignition burners can be started by activating the ignition burner start buttons.

A new purge is only required in case of a combustion air failure. After any other trip a waiting time of 1 minute suffices.

After an ignition burner has successfully started, its main burner can be started up by activating the main burner start button. If the main burner is not started within 15 minutes, the ignition burner is stopped again.

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

Prior to start-up of the first burner, the fuel gas main and burner TSOVs are closed, the vent TSOV is open, and the fuel gas flow controller is automatically set to "manual" with zero output. The minimum stop pressure controller will sense the fuel gas supply pressure and drive the fuel control valves to the mechanical minimum stop setting (set for minimum load of one burner).

When the first main burner is started, the header TSOV opens, the vent TSOV closes and the main burner TSOV opens simultaneously. Fuel gas will flow to the burner at minimum load conditions.

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

If all burner TSOVs are closed the header TSOV is also closed.

It is not necessary to take the combustion air flow controller out of "cascade" control mode during boiler start-up because while the fuel flows are low the combustion air flow will be limited by the mechanical minimum stop on the air control damper. At minimum burner loads, the combustion air will remain at minimum stop until all burners are lit. When burner 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.

When the last gas burner is stopped, the header TSOVs close, the burner TSOV closes and the vent TSOV is opened.

NOTE: The vent TSOV only acts as a bleed, i.e. it only releases the pressure when header and burner TSOVs are closed.

The boiler can only be released from minimum firing if all burners are in operation.

At boiler loads below 35% MCR the individual flame detectors safeguard individual burners. Above 35% MCR, the boiler is considered as operating under 'fire ball' conditions. Under 'fire ball' conditions the loss of the "flame" signal of a single flame detector does not lead to a trip of the corresponding main burner. If 2 or more flame detectors fail to detect a flame the regenerator off-gas diverted to stack, the relevant fuel gas burners trip, and the remainder trip to minimum firing conditions.
Once the 'fire ball' conditions are reached, regenerator off-gas is allowed to be introduced into the combustion chamber. Upon loss of 'fire ball' conditions, the CO is diverted to atmosphere if not all flame detectors indicate flames present.

4. TECHNICAL DESCRIPTION.

4.1 IMPLEMENTATION CONSIDERATIONS.

Both minimum and maximum fuel gas pressure controllers (PIC-1 and PIC-2) shall be locked in auto mode. The operator shall not be able to change the setpoint of the maximum pressure controller (PIC-2). The operator may be given limited control over the setpoint of the minimum pressure controller (PIC-1) up to 2 times the minimum pressure. The latter flexibility is sometimes useful to prevent flame loss due to too low a pressure when manipulating burners.

The minimum and maximum pressure controllers (PIC-1 and PIC-2) shall be fast-acting (like compressor anti-surge controllers).

If the master controller TRC-1 and fuel gas flow controller FRC-1 are forced to manual with 0% output (minimum stop) the operator shall not be able to change their mode or output.

The fuel gas control valve shall have an equal percentage characteristic, and in this way the performance of the minimum stop pressure controller is independent of the number of burners in operation.

The interfacing between the PLC system and the DCS shall be hard-wired for those connections which are safety related (no serial link). This applies for example to the force to minimum stop. Although the latter is classified as IPF class II, a delay (related to the serial link) may ultimately activate a total furnace trip initiator.

The anti reset wind-up (ARWU) to the fuel gas FRC and the minimum and maximum pressure controllers is provided to ensure bumpless transfer when one controller overrides another.

ARWU protection shall also be implemented on the master temperature controller TRC-1 and the oxygen controller QRCA-1.

If the fuel gas FRC-1 is not on cascade, the master steam flow controller shall be initialised to the total fuel flow.
If the combustion air is not on cascade, the oxygen QRC shall be initialised to the (current) air/fuel ratio.

If the chosen DCS/controller algorithm supports the use of external feedback as ARWU protection then external feedback may be configured from Y10 to QRCA.
This external feedback improves the response of the oxygen QRCA during changes in load of the boiler.
The principle behind this external feedback is as follows:
If the load of the boiler is reduced and the air flow is reacting slower than the fuel flow (due to parallel lead/lag control configuration), the external feedback ensures a minimum overshoot. If there would be 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 minimise the overshoot during transients.

4.2 LOCATION OF ALARMS, SWITCHES, ETC.

The system is designed such that remote starting and stopping of burners is possible.

As starting and stopping from the main control room saves both capital expenditure (no local panel) and operating expenditure (starting/stopping of burners can be done by the panel man) start and stop buttons, alarms, etc. should be installed in the main control room.

Local panels shall be provided only if specified by the Principal (for example, if desired for uniformity with other equipment or if required by local regulations).

The standard scheme shown on S 24.036 reflects location of switches and alarms assuming remote starting and stopping of burners.

If a local start/stop is required, the indication lights of flame detectors and status indications shall be installed locally as well as in the control room.

4.3 CALCULATION FORMULAE

The following formulae shall be used:

Y1) Calculates regenerator off-gas flow to CO boiler.

$M_{off\text{-}gas}$ = 1.1 * Total air flow to regenerator * Opening of two-way slide valve to CO boiler (as a fraction of fully open)

(Total air flow to regenerator = Main air flow + Transport air flow)

Y2) Calculates SRF (Standard Refinery Fuel) equivalent of sensible heat in off-gas.

$$CO_{sensible\ heat} = \frac{M_{off\text{-}gas} * (T_{off\text{-}gas} - T_{stack}) * Cp_{off\text{-}gas}}{LHV_{SRF}} \qquad [tSRF / d]$$

where:

$T_{off\text{-}gas}$	=	Temperature of off-gas to boiler	
T_{stack}	=	Stack temperature	[200 °C]
$Cp_{off\text{-}gas}$	=	Specific heat off-gas	[1.16 kJ/kg°C]
LHV_{SRF}	=	Lower heating value SRF	[40 500 kJ/kg]

Y3) Calculates amount of CO in off-gas.

$$M_{CO} = Fr_{CO} * M_{off\text{-}gas} * \frac{MW_{CO}}{MW_{off\text{-}gas}} \qquad [tCO / d]$$

where:

Fr_{CO}	=	Volume fraction of CO in off-gas	
$MW_{off\text{-}gas}$	=	Molecular weight CO	[28]
$MW_{off\text{-}gas}$	=	Molecular weight off-gas	[32]

Y4) 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 or 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:

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

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

where:

P	=	Pressure, bar (abs)
T	=	Temperature, °C

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

The above formula assumes typical refinery fuel gases, i.e. mixtures of paraffinic hydrocarbons and hydrogen (with inerts less than 2%) and is only valid for MW > 5.
It further assumes the stoichiometric air requirement of SRF to be constant at

13.66 kg 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.

Y5) Calculates maximum allowable fuel flow

$$Output = \frac{\text{Measured air flow}}{0.9 \ * \ 13.66 \ (0.8 \ + \ 0.8 \ * \ QRC)} \qquad [tSRF / d]$$

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

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

Y6) Subtracts SRF equivalent of CO (in terms of air equivalent) from fuel demand.

$$Output = \text{Total fuel demand} - M_{CO} * \frac{SAR_{CO}}{SAR_{SRF}}$$

where:

SAR_{CO} = Stoichiometric air requirement of CO [2.47 kg air/kg CO]

SAR_{SRF} = Stoichiometric air requirement of SRF [13.66 kg air/kg SRF]

Y7) Adds SRF equivalent of CO (in terms of stoichiometric air requirement) to measured fuel gas flow ($M_{fuel\ SRF}$).

$$M_{total\ SRF} = M_{fuel\ SRF} + M_{CO} * \frac{SAR_{CO}}{SAR_{SRF}} \qquad [tSRF / d]$$

Y8) Sets a minimum limit for the combustion air flow.

Output = 0.9 * $M_{total\ SRF}$

Y9) Calculates the required air flow.

Air_{fuel} = Fuel flow * 13.66 * [0.8 + 0.8 * QRC]

The formula limits the air/fuel ratio between 0.8 and 1.6.

Y10) Calculates air/fuel ratio for low alarm and trip (to minimum firing).

$$Output = \frac{\text{Measured airflow}}{13.66 * M_{totalSRF}}$$

Alarm shall be set at a ratio of 1.0.

Trip to minimum firing shall be set at 0.8.

Y11) Total fuel demand = Total heat demand (from master) - $CO_{sensible\ heat}$ [tSRF/d]

Y12) Low selector to set a maximum to the signal to the fuel flow controller.

Y13) High selector to set a minimum to the air flow controller.

Y14) Calculates the adiabatic flame temperature. To ensure complete combustion of CO the adiabatic flame temperature should be 1000 °C or higher. Alarm to be set at 950 °C.

$$T_{adiabatic} = \frac{M_{fue\ SRF} * 40500 + M_{CO} * 10111 + M_{off\text{-}gas} * T_{off\text{-}gas} * Cp_{off\text{-}gas}}{(M_{fuel\ SRF} + M_{CO} + \text{Measured air flow}) * Cp_{flue}} \quad [°C]$$

where:

Cp_{flue} = 1.20 kJ/kg.°C

$CO_{off\text{-}gas}$ = 1.16 kJ/kg.°C

Y15) ARWU compensation block

external feedback = Total fuel SRF measured + $CO_{sensible\ heat}$

4.4 DESCRIPTION OF INSTRUMENTED PROTECTIVE FUNCTIONS

The IPFs are described by the functional logic diagrams (Appendix 1) and by the IPF narrative given below.

The functional logic diagrams are set up in a modular structure. This section follows the same structure but 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 boiler.

If: i. the combustion air blower is running; and

ii. the fuel gas header TSOVs and the individual main burner TSOVs are closed; and

iii. the two-way slide valve is in the "boiler bypass" position; and

iv. the local and panel trip switches are in the healthy position; and

v. no flame is detected (start condition only); and

vi. the "safe conditions" signal is not present; then

the purge sequence can be started by activating the "start purge" switch.

This initiates the full opening of the common air damper. As soon as sufficient air flow for the purging is available, the purge timer starts running.

If there are no disruptions of the above conditions and after the timer has run out, a purge ready indication is given and the combustion air damper is placed back under flow control.

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 boiler operation any one of the above conditions fails, the safe atmosphere signal disappears. Then a complete new purge is required.

4.4.2 General trips and CO back-flow protection.

This module contains a number of general trip initiators (low combustion air flow, low air/fuel ratio, low purge air flow and low boiler drum level) as well as the CO back-flow protection system.

The combustion air supply is equipped with a blower discharge damper which closes in case of a blower failure to prevent back-flow of CO-offgas into the combustion air intake.

In order to prevent formation of an explosive mixture upon re-opening the back-flow protection damper, purge steam is automatically introduced upon closing the damper.

The system operates as follows:

If the combustion air flow is healthy (FZA-02-LL) or the two-way slide valve is detected in the bypass position, the back-flow protection damper is open and the purge steam valve is closed.
If the two-way slide valve is not in by-pass position and the air flow becomes not-healthy, the back-flow protection damper closes and the steam valve opens and a “back-flow protection activated” alarm is given.
The damper only re-opens 2 minutes after the two-way slide valve has been detected in bypass position.

A latch circuit prevents the damper from reopening automatically upon a healthy FZA signal (this to prevent erratic behaviour which could lead to introduction of air into a hot, CO-filled fire box).

4.4.3 Minimum stop module

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

If: i. the air/fuel ratio is healthy; and

ii the module receives signals that all fuel gas burners are in operation; and

iii. the fuel gas pressure is not above high high; then

the fuel gas FRC can be taken into operation by activating the gas minimum firing reset in the control room.

4.4.4 Igniter header module

The function of this module is to monitor all the conditions required to open and close the igniter header TSOV and to control this valve.

The igniter header TSOV is fully governed by the igniter modules. As long as one of the igniter burner modules produces an "open igniter header" signal the igniter TSOV is open.

4.4.5 Fuel gas header and vent module

The function of this module is to monitor all the conditions required to open and close the fuel gas header and vent TSOVs and to control these valves.

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

If: i. the safe atmosphere module produces the "safe conditions" signal; and
ii. other process conditions (process trips) are healthy; and
iii there is no high level in the fuel gas KO drum; and
iv. the stop gas firing switch is not activated; and
v. the ‘(Not) failure to minimum stop’ signal is healthy; and
vi the fuel gas control valve is in the start position or any gas flame is on; then

the gas header module produces a "healthy for gas firing" signal for the gas burner modules.

If the gas header module receives at least one "open gas header" signal from the gas burner modules the pre-selected gas header is automatically opened and the vent TSOV is automatically closed.

If any one of the above conditions fails, the gas header TSOV closes, the vent TSOV opens and the "healthy for gas firing" signal disappears. If all "open gas header" signals from the gas burner modules disappear the gas header TSOV closes also.

If the vent TSOV proximity switch (GBSA-009) does not indicate that the valve is closed within 15 seconds after initiating valve closure, an alarm is given.

If the header TSOV proximity switch (GBSA-02/03) does not indicate that the valve is closed within 15 seconds after initiating valve closure, an alarm is given.

If, after all main gas burners are stopped, the control valve is not in its start position within 15 seconds, a "control valve not in start position" alarm is given.

4.4.6 Igniter modules

Each igniter is equipped with its own igniter module.

The function of these modules is to monitor all the conditions required to fire the individual igniters and to control the igniters.

If: i. the module does not receive a “burner start inhibit’ signal (any burner start is inhibited for 1 minute after any burner failure or if any fuel TSOV has failed to close); and

ii. the module does not receive a "stop igniter" pulse from the gas burner module; 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 stop button is not activated; then

the igniter can be started by activating the igniter start button.

The module then produces the following signals:

a. open igniter header

b. open igniter TSOV

c. ignition spark signal for a period of about 10 seconds.

After the flame stabilisation timer has run out (after about 15 seconds) the ignition flame shall be detected by the ionisation rod, and an "ignition flame present" signal is sent to the respective main burner module.

If the igniter start trial was unsuccessful, restart is inhibited for a period dictated by the igniter restart inhibit timer (about 30 seconds). This timer is installed to prevent damage to the ignition transformer.

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 main burner TSOV.

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

4.4.7 Gas burner modules

Each burner is equipped with its own gas burner module.

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

If: i. the gas burner module receives a "healthy for gas firing" signal and

ii. the gas burner stop button is not activated and

iii. the module receives an "igniter on" signal; and

iv. the gas burner start button is activated; then

the gas burner module produces the following signals:

a. Open gas burner TSOV.

b. "Open gas header" signal to the fuel gas header module.

c. After the start timer has run out (usually 5 seconds), stop the igniter.

d. "gas burner TSOV open" signal to burner count module.

If: i. the "healthy for gas firing" signal remains present; and

ii. the gas burner stop button is not activated or the "firing not on minimum stop" is present; and

iii. the module receives a "flame healthy" signal from the "fire ball and flame detection" module within the start timer setting; then the module produces a "gas flame on" signal.

If any one of the above conditions fails, the gas burner TSOV is closed, the signal to the burner count module drops off, and the "open gas header" signal disappears. If no other gas burner modules produce an "open gas header" signal the gas header TSOV is closed and the vent TSOV opened. Moreover, if no other main burners are in operation a complete new purge sequence is required.

The start inhibit timer inhibits the start of any ignition burner for 1 minute, after an unsuccessful start or after a stop of any burner.

If the burner TSOV proximity switch does not detect that the valve is closed within 15 seconds after initiating valve closure, an alarm is given.

Individual burners shall not be stopped if CO gas is lined up to the boiler. Therefore, the "stop gas burner" signal is overridden while CO gas is being burned in the boiler.

4.4.8 Flame detection and fire ball module

The function of these modules is to monitor the individual flame detector signals and to provide relevant trip signals.

The module receives the individual detector signals and the "steam production above 35% MCR" signal. It provides the following signals:

If: i. at least 3 flame detectors produce a flame-on signal; and

ii the steam production is above 35% MCR; then

the module produces a "fire ball conditions" signal, which is used to allow CO off-gas to be introduced.

If: i. the "fire ball conditions" signal is healthy; or

ii. all fuel gas burners are in operation; then

the module produces a "fire ball or all burners in operation" signal, which is used as a requirement to continue to operate on CO off-gas.

If: i. the "fire ball conditions" signal is healthy; or

ii. an individual flame detector produces a "flame on" signal; then

the module produces a "flame healthy" signal to the relevant individual gas burner.

4.4.9 CO off-gas firing module

The function of this module is to monitor all conditions required to operate on CO gas and to release operation of the two-way slide valve.

If: i the module receives the "fire ball conditions or all burners in operation" signal; and

ii. the "Stop CO firing" button is not activated; and

iii. the external trip conditions are healthy; and

iv. the fuel gas header is open; and

v. the module receives the "fire ball conditions" signal; then

the CO firing can be reset by activating the "Start CO firing" button.
This activates the solenoid of the two-way slide valve and releases operation of this valve via HIC-01.

If any one of the conditions i to iv is effective, the two-way slide is tripped to the bypass position and locks HIC-1 in manual, zero output.
If the slide valve is not in the by-pass position within 120 seconds, a "slide valve closing failure" alarm is given.

4.4.10 Burner TSOV tightness test module

To allow the tightness of the individual burner gas TSOVs to be tested during shutdown only the gas header TSOV can be opened for a short period by pressing HS-9.

Pressing of this button will result in opening of the header TSOV only **if:**

i. all gas burner TSOVs are confirmed closed; and

ii. neither the "purge ready" signal nor the "purge in progress" signal is present.

If these conditions are effective and HS-9 is activated, the header TSOV is opened for about 5 seconds. The vent is closed at the same time and is kept closed during the test. During the whole testing period starting is interlocked via the "inhibit start" signal to the safe atmosphere module.

After the testing period has expired (normally about 5 minutes) the vent is opened and the "inhibit start" signal disappears.

4.5 IPF CLASSIFICATION AND CAUSE AND EFFECT DIAGRAM

The IPFs described in (4.4) have been classified and implemented in accordance with DEP 32.80.10.10-Gen. The classification results are indicated in the cause and effect diagram (Table 1).

Table 1 Cause and effect diagram

Initiators		Actions 1)									
TAG	Service	Abort/ Inhibit start sequence	Header fuel gas TSOVs close	Vent fuel gas TSOV open	Two-way slide valve in by-pass mode	Trip to mininum firing fuel gas	Header igniter TSOV close	Main fuel gas burner TSOV close	Igniter burner TSOV close	CO backflow protection damper close	purge steam valve open
FZA-01-LL	Combustion air	-	III	II	III	0	0	0	0	III 6)	III 6)
FZA-02-L	Combustion air (for purging)	III	-	-	-	-	-	-	-	-	-
XZA-01-LL	Air/fuel ratio	-	-	-	-	II	-	-	-	-	-
PZA-01a-HH	Fuel gas		-	-	-	II	-	-	-	-	-
PZA-01b-H	Fuel gas	III	IV 5)	II 5)	III 5)	0 5)	0 5)	0 5)	0 5)	-	-
HZA-01/02	Manual trips	0	III	II	III	0	III	0	0	-	-
LZA-01-HH	Fuel gas KO drum	-	III	II	III	0	II	0	0	-	-
GBSA-01-S	Fuel gas control valve in start position	III	-	-	-	-	-	-	-	-	-
GBSA-02/03-C	Fuel gas header TSOVs closed	III	-	-	-	-	-	-	-	-	-
GBSA-04 By-pass	Slide valve in by-pass position	III	-	-	-	-	-	-	-	III 6)	III 6)
LZA-02-LL	Boiler drum level	-	IV	II	III	0	0	0	0	-	-
GBSA-14-C	Vent TSOV closed	-	-	-	-	-	-	-	-	-	-
XZA-11/21/31/41	Ignition flame detection	III/- 2)	-	-	-	-	0	-	0	-	-
XZA-12/22/32/42	Main flame detection	-	-	-	-	-	-	IV	0	-	-
3 off XZA-12/22/32/42	At least 3 main flame detectors 3)	II	-	-	III	-	-	-	-	-	-
FZA-xx-LL	Steam flow >35% MCR 3)	II	-	-	III	-	-	-	-	-	-
4 off XZA-12/22/32/42	All main flame detectors	-	I	II	III 4)	III 4)	-	-	-	-	-
GBSA-14-n4-C	Gas burner TSOV closed	III	-	-	-	-	-	-	-	-	-

NOTES:

1) - = No action
   0 = Unclassified, but serves purpose in sequence control
   II = IPF class II
   III = IPF class III
   IV = IPF class IV

2) In case the main flame detector cannot detect neighbouring/opposing flames the ignition flame detection is unclassified.
3) Combination of 3 flame detectors and FZA-xx forms "fire ball condition".
4) Only in case 'fire ball" conditions are not healthy.
5) High fuel gas pressure only initiates a total trip in case of failure of trip to minimum firing.
6) CO back-flow protection is only activated in case of low air flow AND slide valve is detected in bypass position (GBSA-04).

5. REFERENCES

In this DEP, 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.

DEPs

Classification and implementation of instrumented protective functions	DEP 32.80.10.10-Gen.

STANDARD DRAWINGS

Combustion control and safeguarding scheme for a tangentially gas-fired CO boiler	S 24.036

APPENDIX 1 Functional logic diagrams for a tangentially gas-fired CO boiler

Amended Per Circular 57/97

Logic 36 Sheet 0

Furnace safeguarding logics for S 24.036

Logics for a tangentially, gas fired, CO boiler.

Reference:
S 24.036, Standard drawing for a system for an automatically started, tangentially, gas fired, CO boiler.

Sheets:

1. Safe atmosphere
2. Burner & Valve status.
3. General trips & CO back flow protection.
4. Minimum stop
5. Igniter header
6. Fuel gas header + vent
7. Gas firing trips
8. Fuel gas TSOV selection
9. Fire ball & flame detection
10. CO off-gas firing

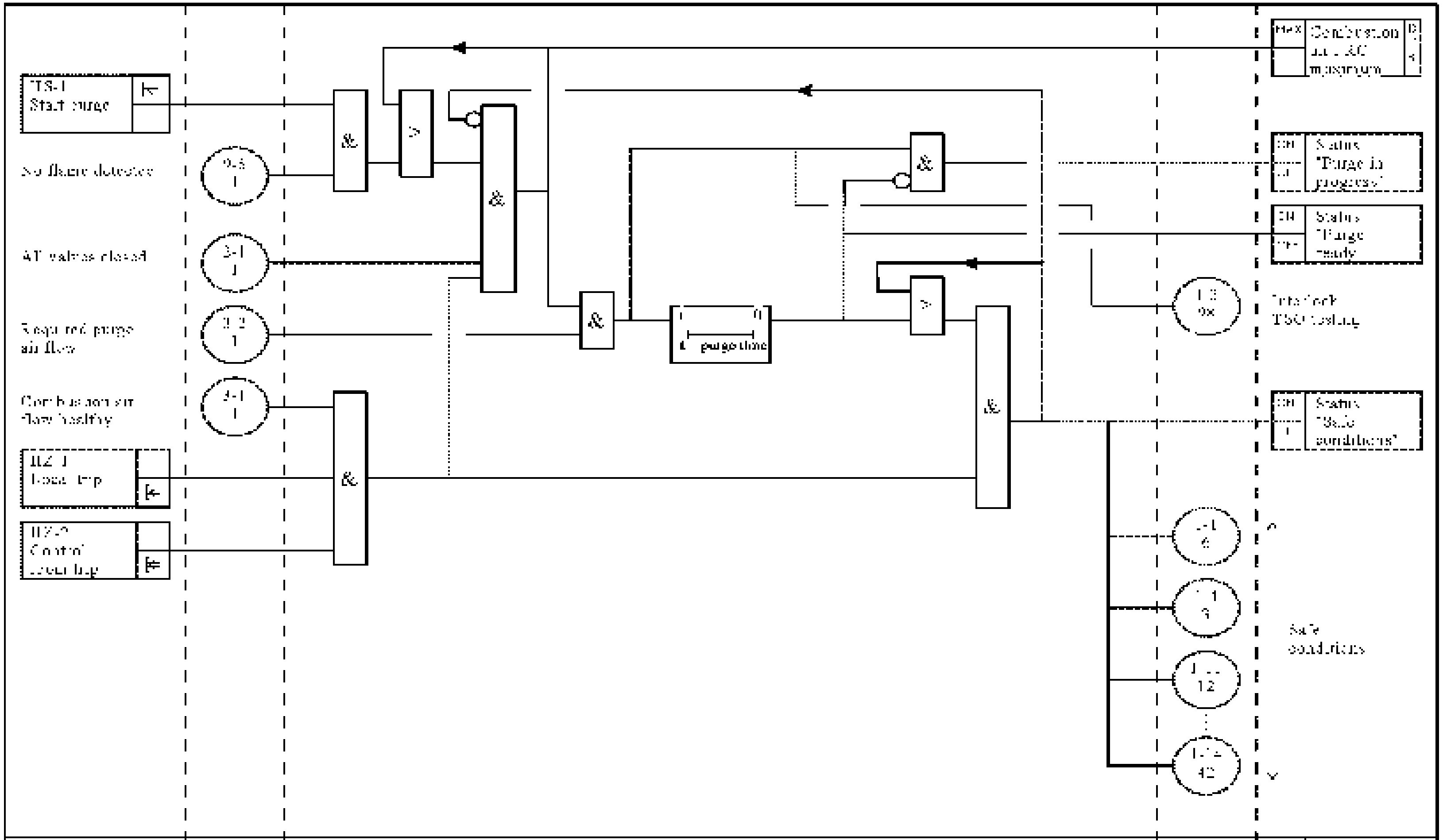
12. Igniter burner 1
13. Fuel gas burner 1

98. Burner TSO test
99. Status indications, alarms, switches

FURNACE SAFEGUARDING LOGICS

Logics 36
Sheet 0

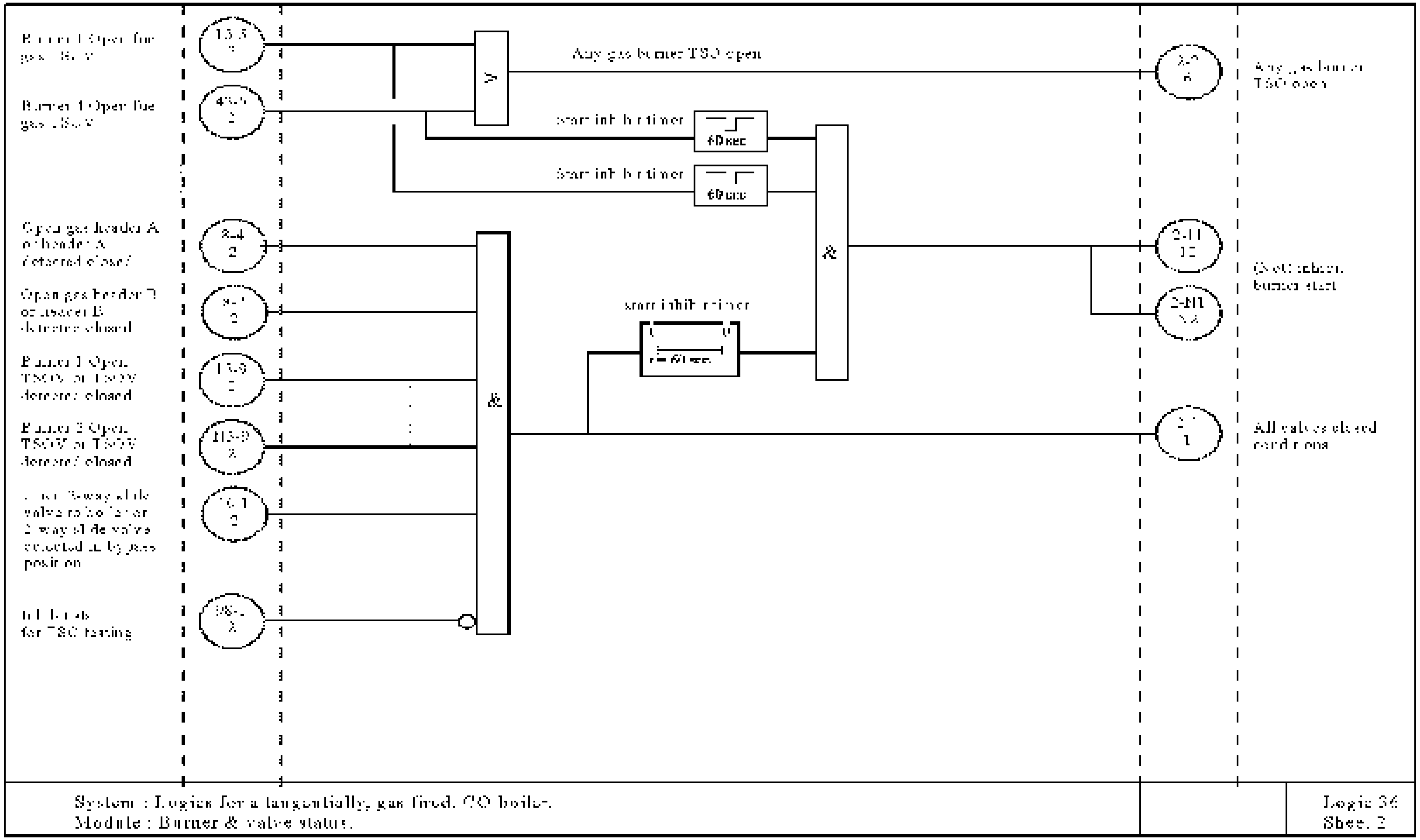
Logic 36 Sheet 1



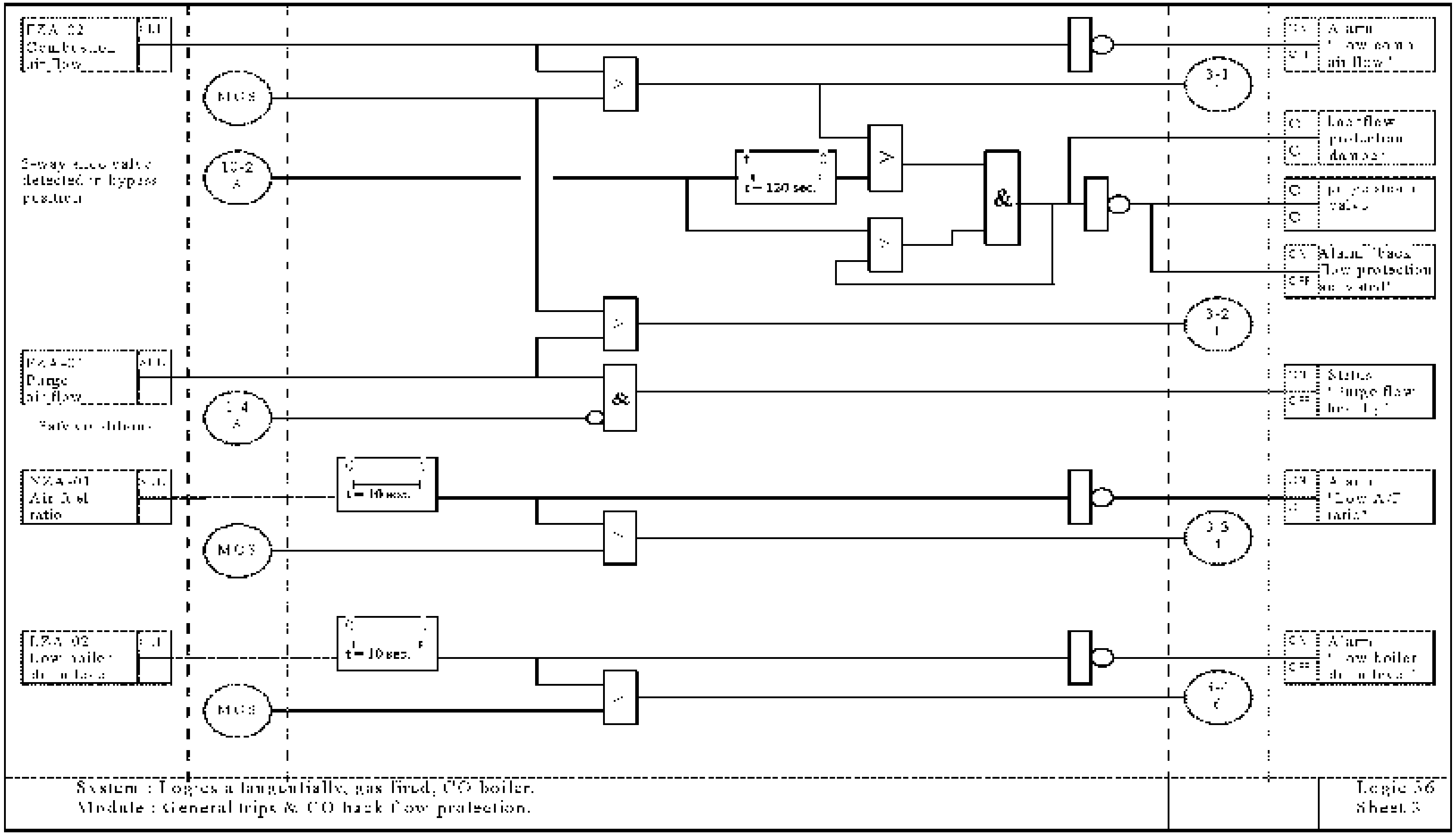
System : Logics for a tangentially, gas fired, CO boiler.
Module : Safe atmosphere

Logic 36
Sheet 1

Logic 36 Sheet 2



Logic 36 Sheet 3



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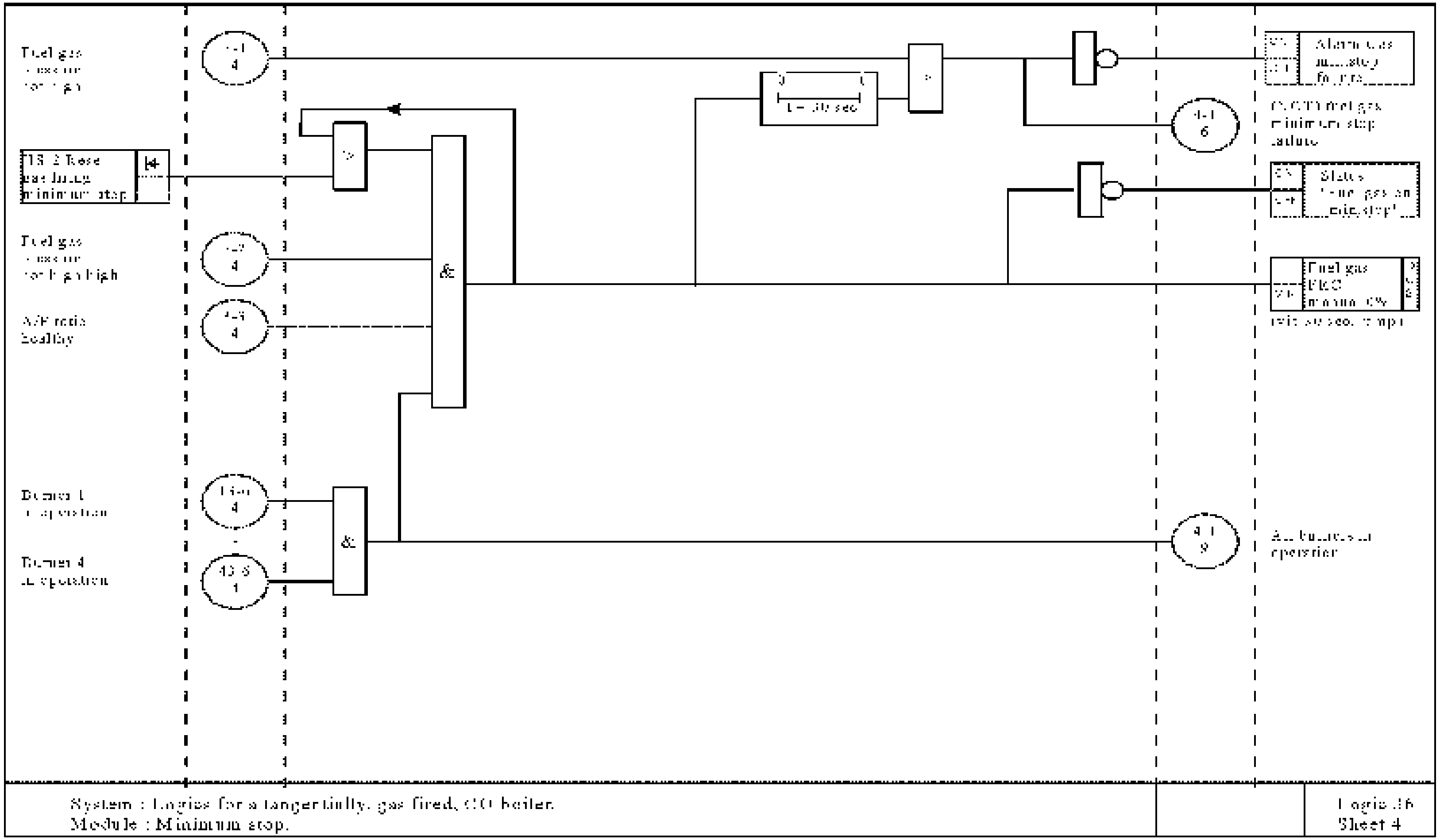
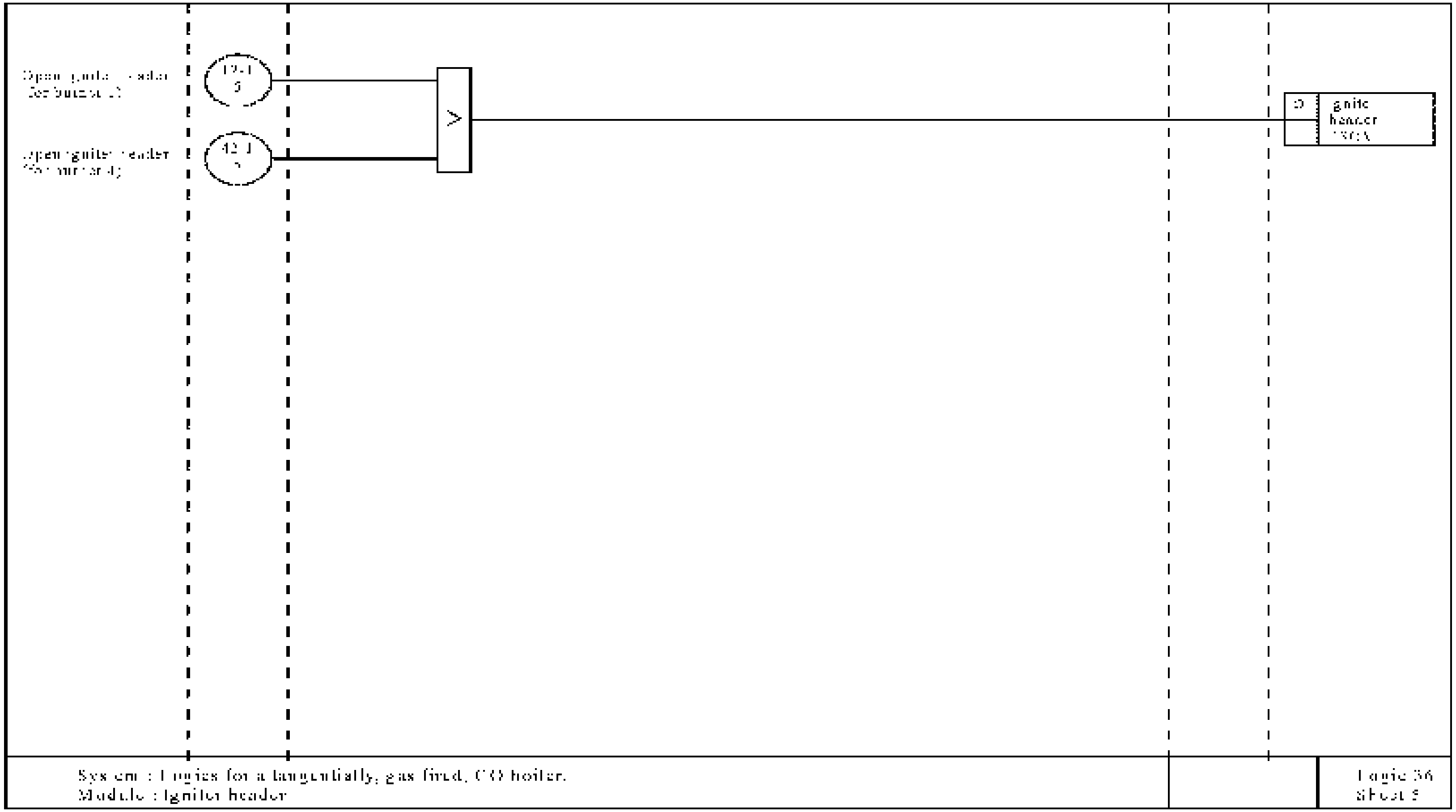


Logic 36 Sheet 5



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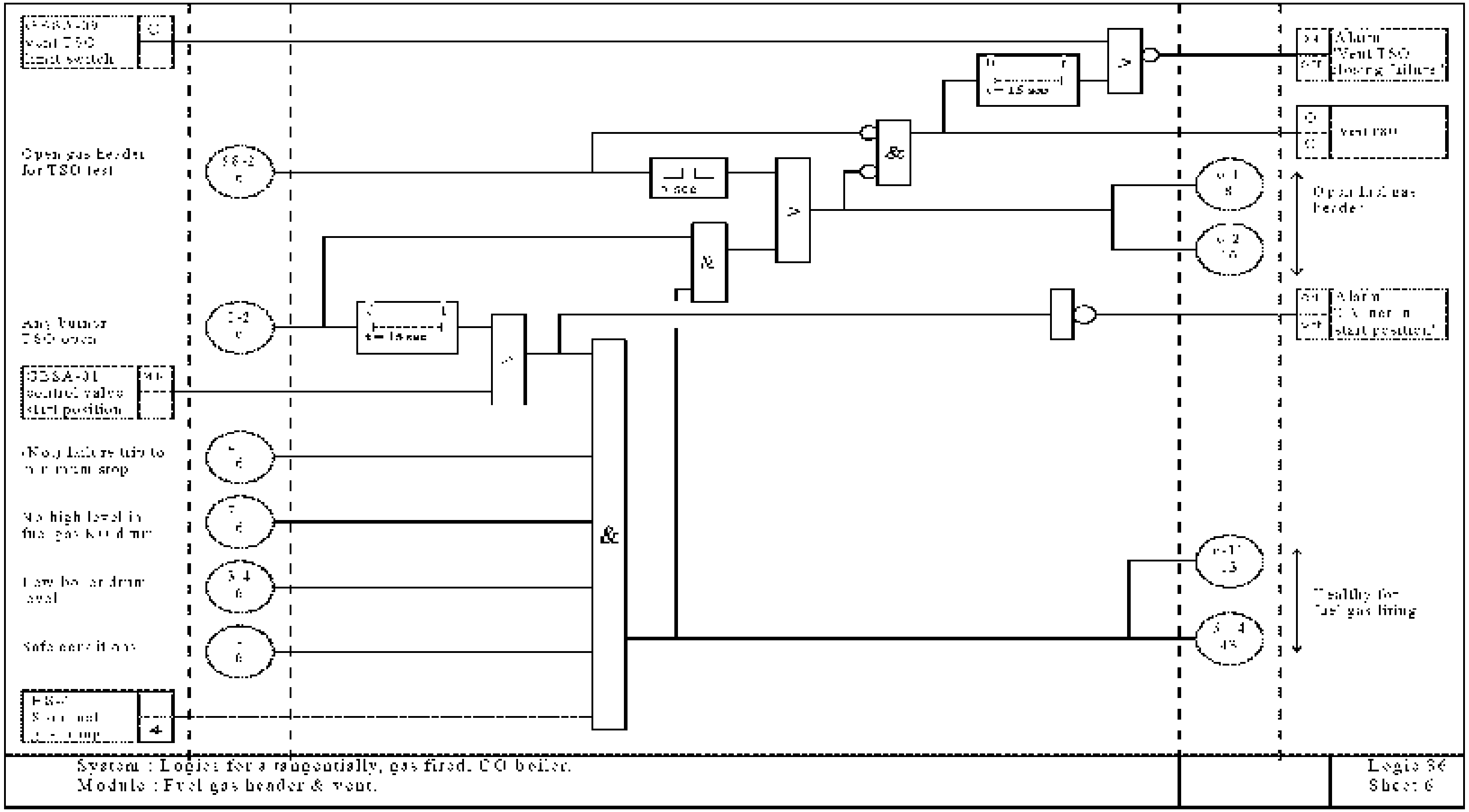

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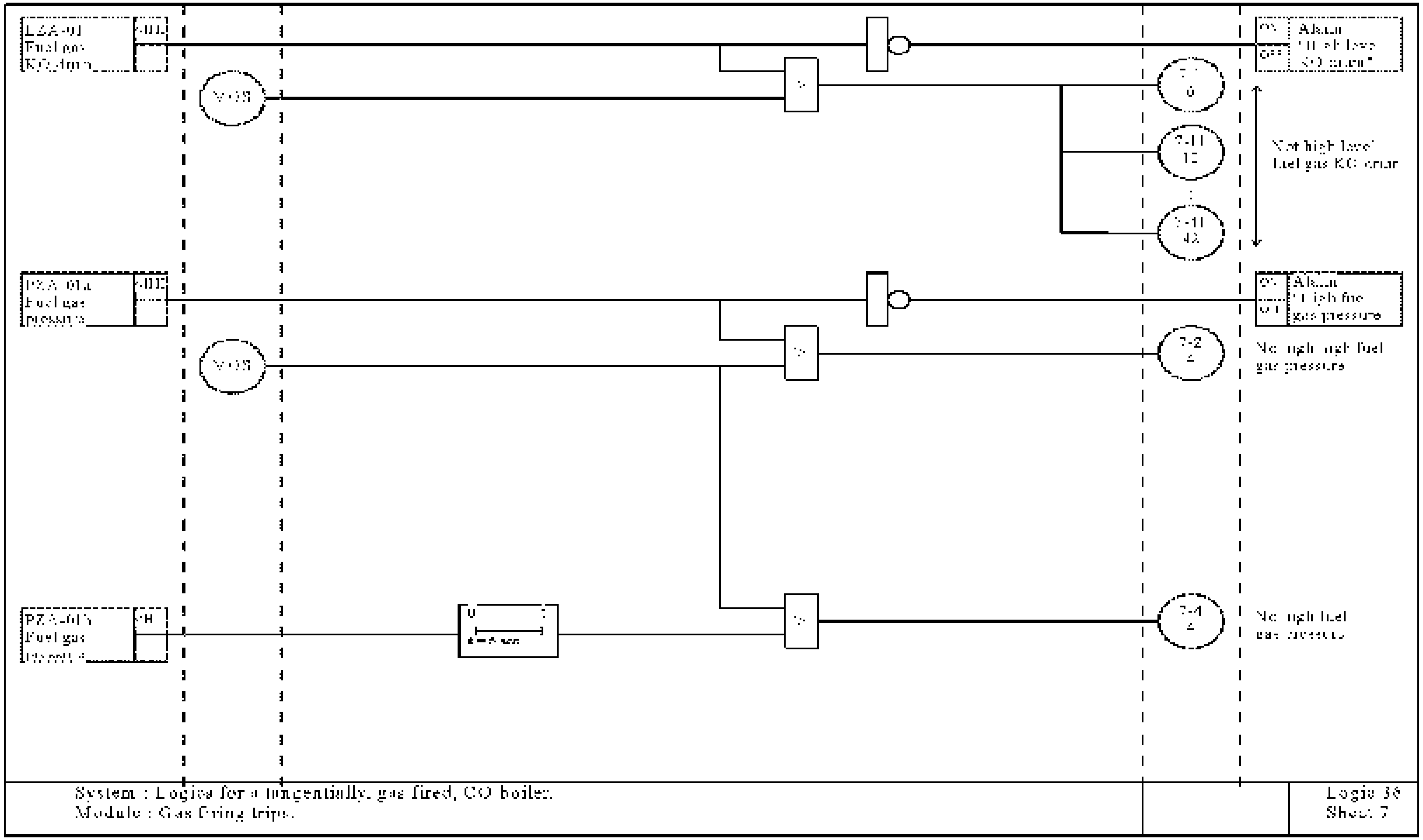
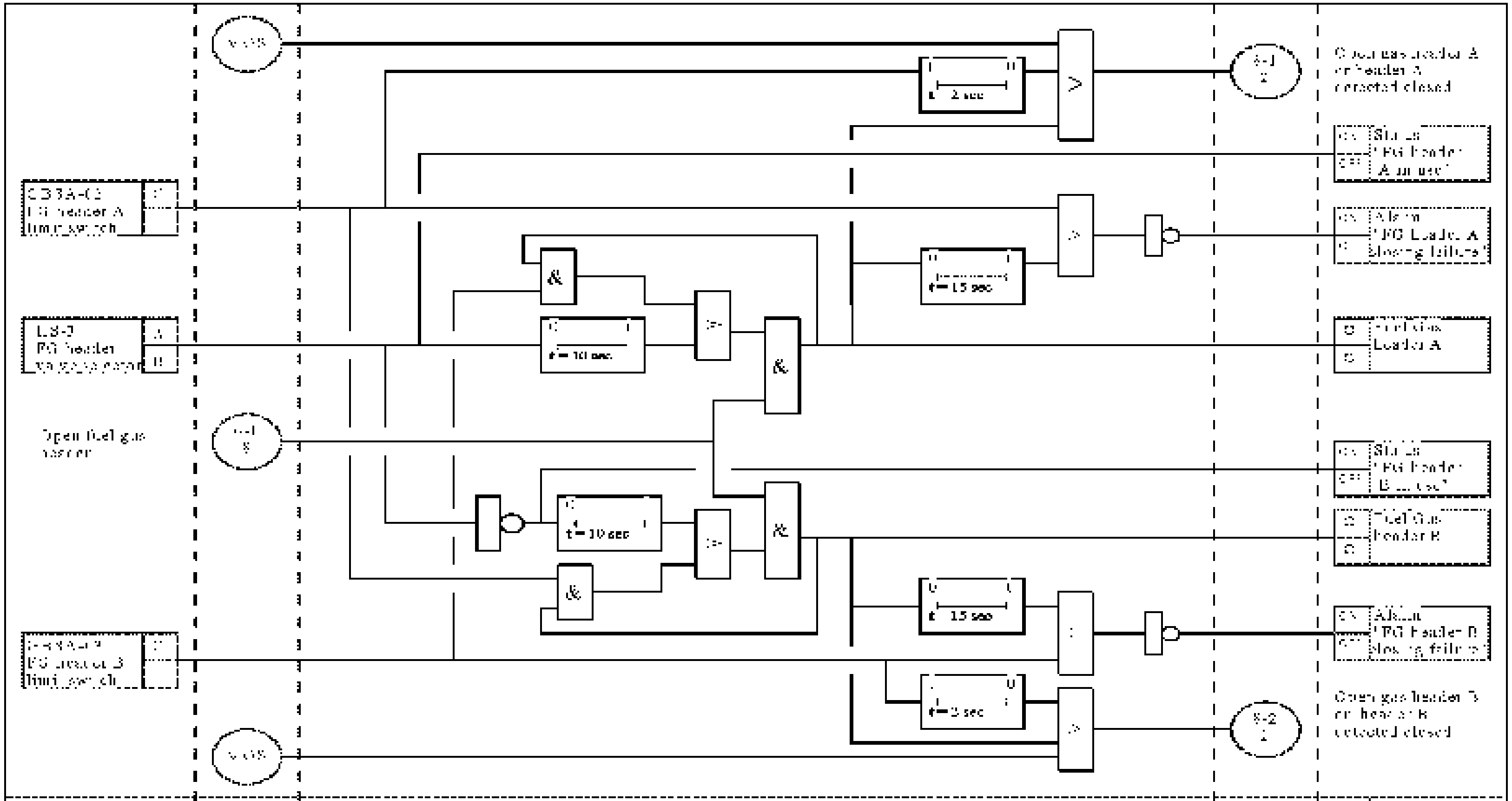


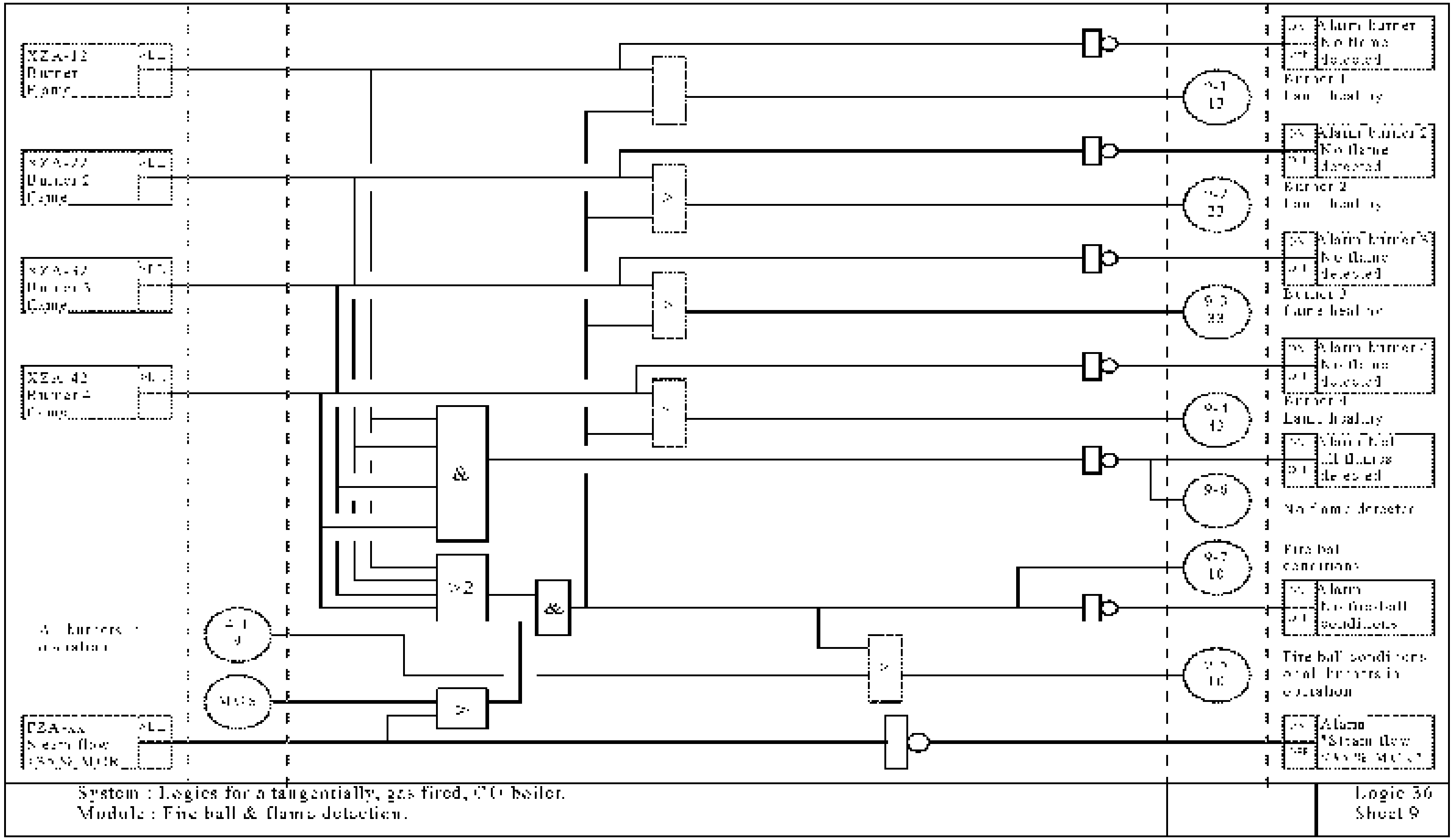
Logic 36 Sheet 8



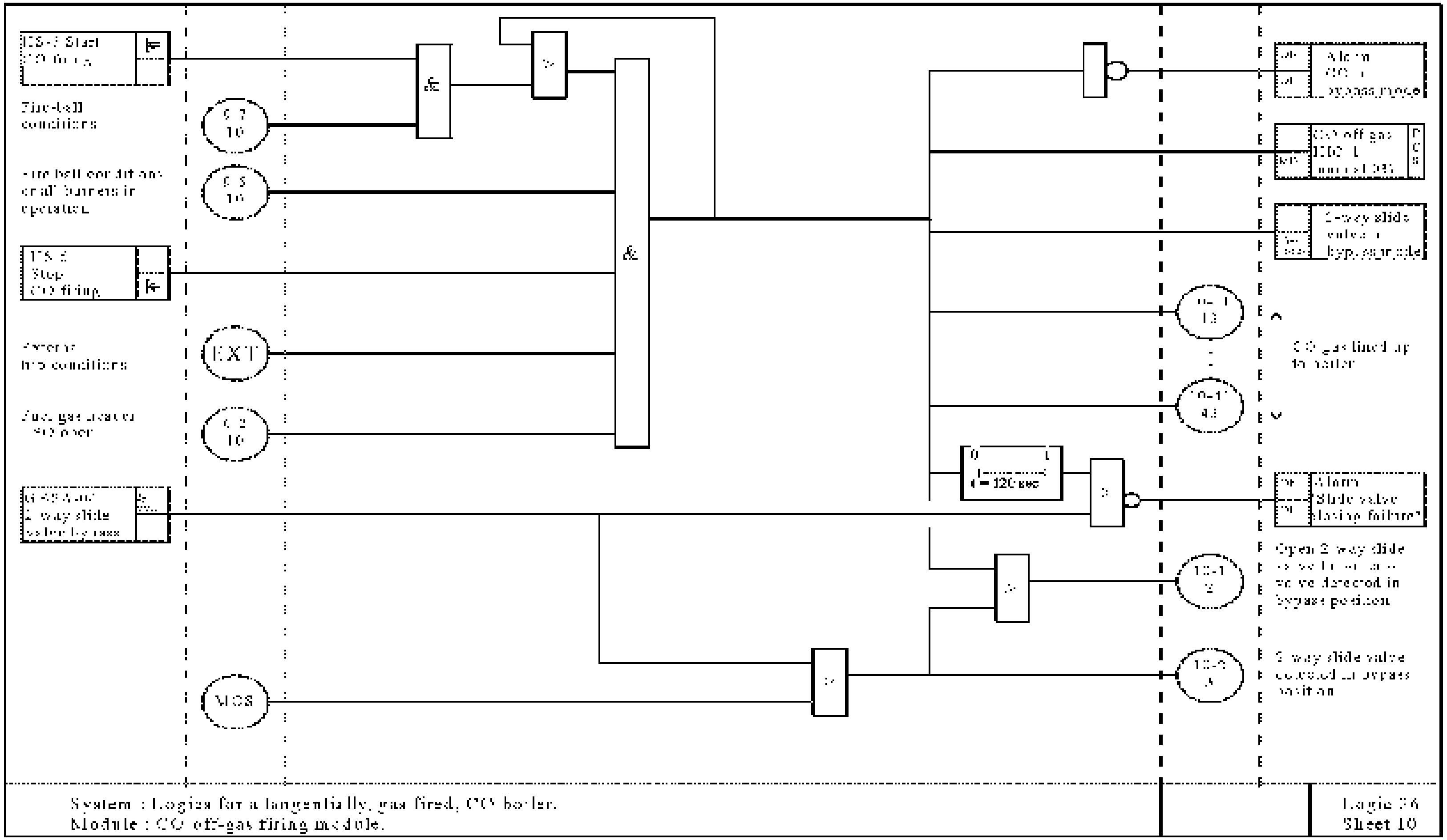
System : Logics for a tangentially, gas fired, CO boiler.
Module : Fuel gas header valve selection.

Logic 36
Sheet 8

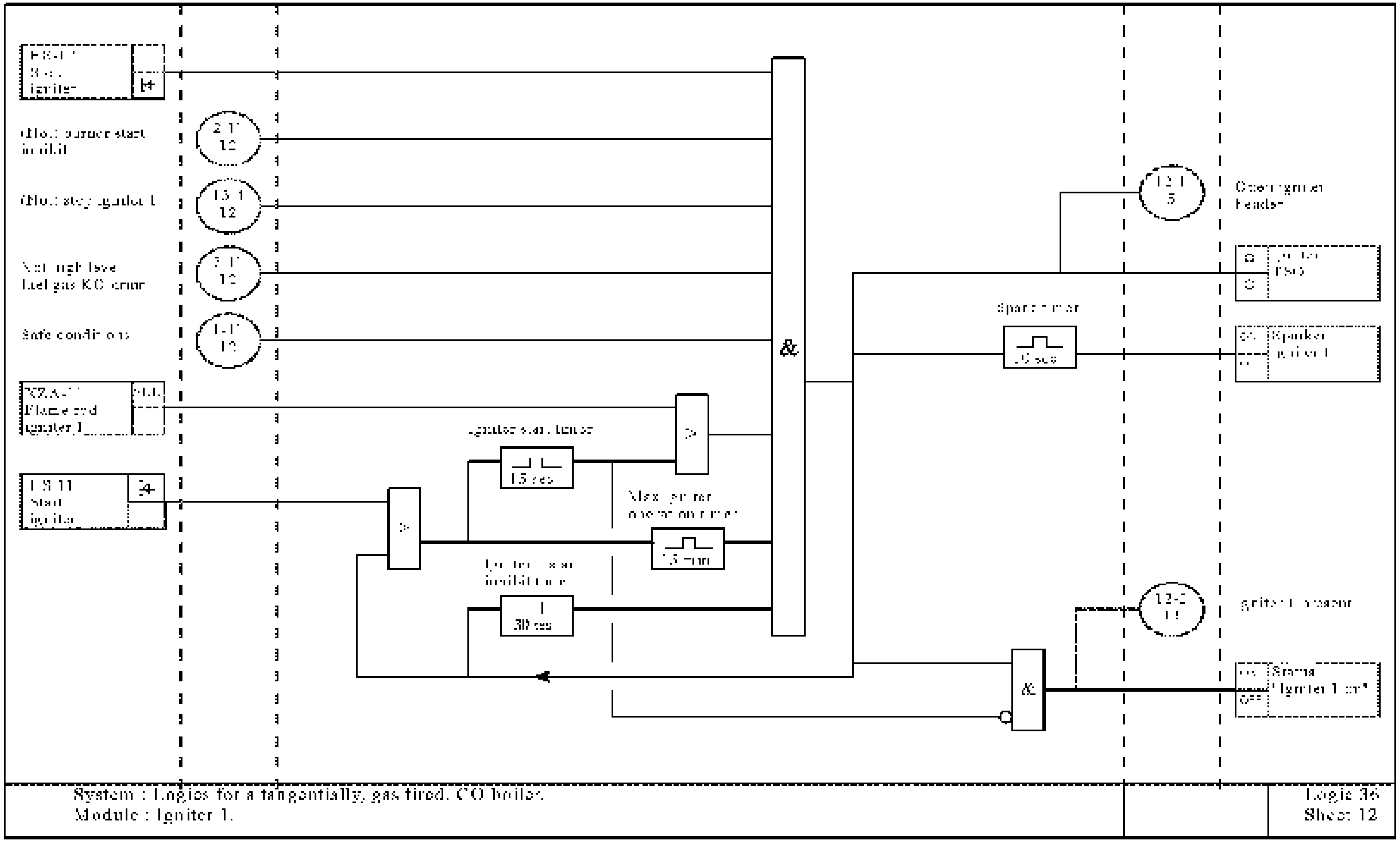
Logic 36 Sheet 9



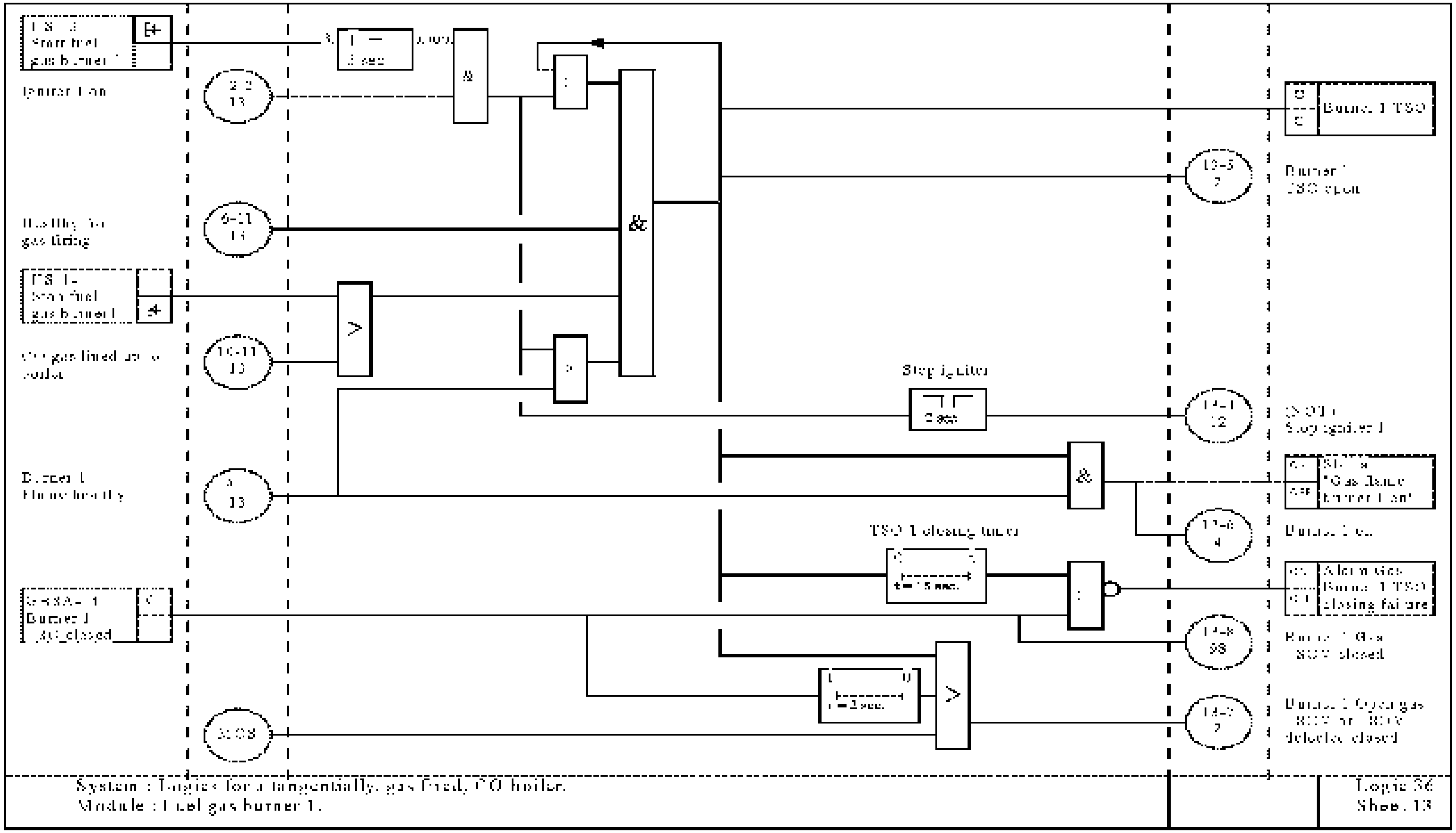
Logic 36 Sheet 10



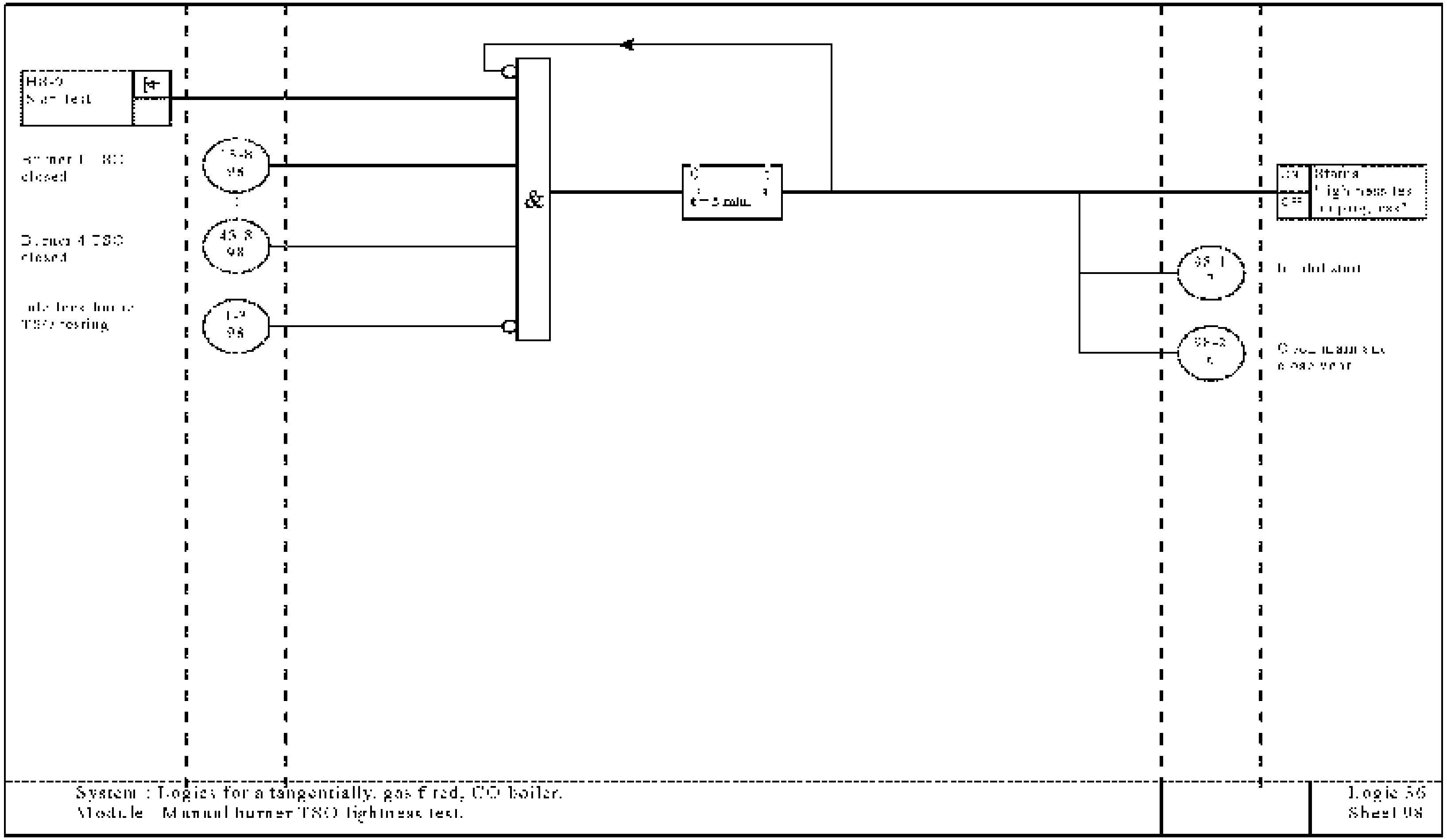
Logic 36 Sheet 12



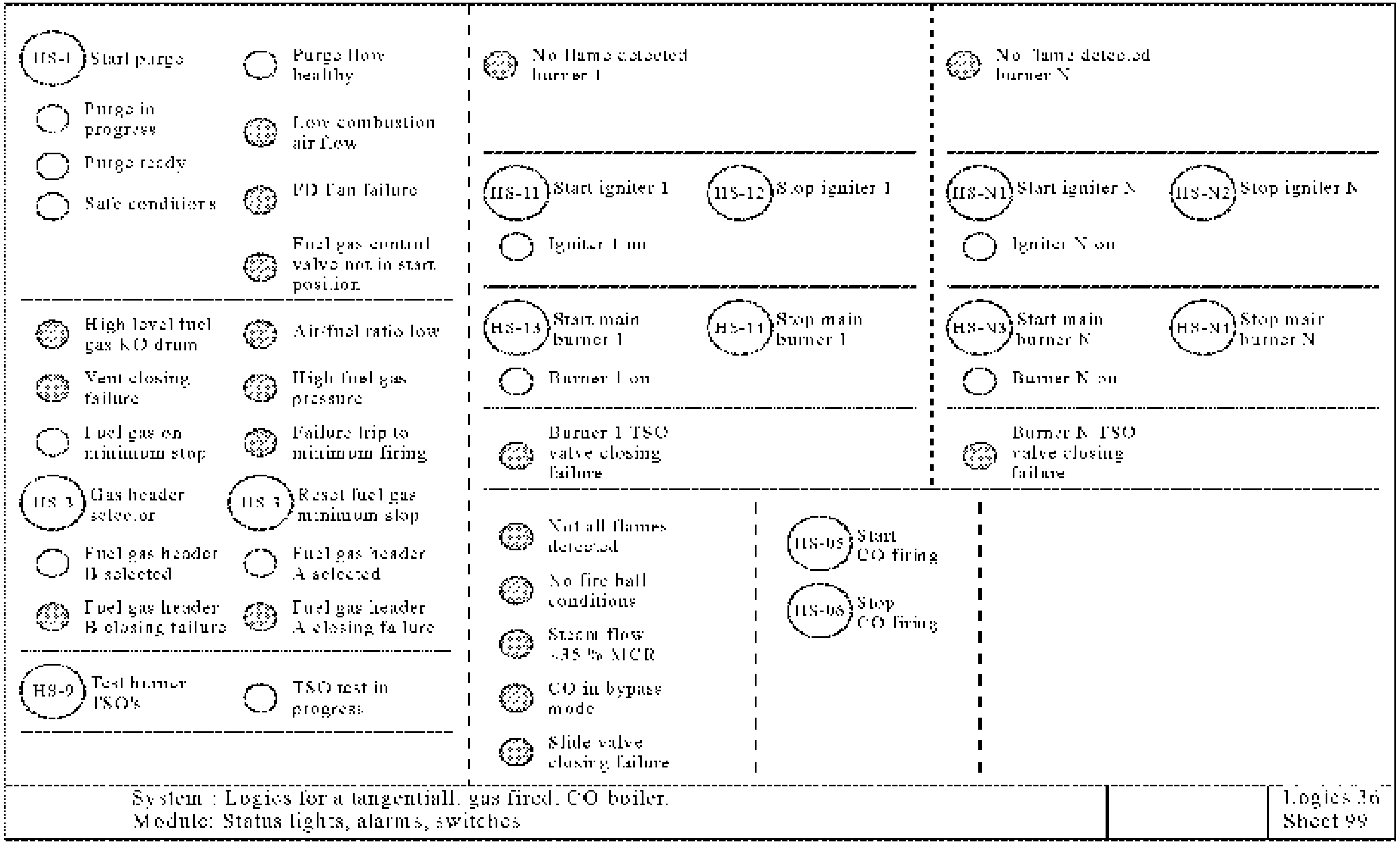
Logic 36 Sheet 13



Logic 36 Sheet 98



Logic 36 Sheet 99



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