TECHNICAL SPECIFICATION

CONTROL SYSTEM AND INSTRUMENTED PROTECTIVE FUNCTIONS FOR FIRED EQUIPMENT
- System for an automatically-started, forced draught, multi-burner furnace or boiler (S 24.030 or S 24.034)

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DESIGN AND ENGINEERING PRACTICE

USED BY

COMPANIES OF THE ROYAL DUTCH/SHELL GROUP

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1. INTRODUCTION

1.1 SCOPE

This DEP specifies requirements and gives recommendations for control systems and instrumented protective functions for an **automatically-started, dual-fuel fired, forced draught, multi-burner furnace/boiler without individual air shut-off dampers.** This DEP may also be used for a furnace firing one fuel only, i.e. if the furnace is fired on gas only, all fuel oil related instrumentation may be disregarded, and vice versa. This DEP shall not be used for single burner systems or natural draught furnaces/boilers.

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

Amended Per Circular 54/97

This DEP shall be used together with Standard Drawing S 24.030 (dual fuel) or S 24.034 (fuel gas).

This DEP is written for systems which use DCSs for control and monitoring and 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 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, 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 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

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 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
DCS	Distributed control system
IPF	Instrumented protective function
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 both gas and liquid fuel and for 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 minimum stop pressure controllers for both fuel oil and fuel gas, which guarantee a minimum burner load irrespective of the number of burners in operation. Similarly, maximum burner loads are limited by maximum stop pressure controllers.

NOTE: The fuel pressure control limiters do not provide absolute limits to burner loads; with fuel gas, fuel gas density variations exert an influence; in (steam-atomised) fuel oil burners, fuel oil temperature and atomising steam pressure likewise exert an influence.

In addition to the minimum stop fuel pressure controllers, the fuel control valves are provided with mechanical minimum stops. These are adjusted to correspond to minimum load with only one burner in operation, and act as a pre-set valve position for start-up of the first burner. In multi-burner installations this may result in excessively low valve lifts when starting up the first burner(s), in which case the mechanical stop should be limited to at least 5% valve lift (which gives higher loads at the first burner start-up), or the use of parallel control valves (low and high capacity, acting in split-range) should be considered.

Atomising steam for the fuel oil burners is controlled at a (constant) pressure differential relative 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 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 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 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 total fuel demand signal passes via the air/fuel ratio relay to adjust the set point 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 oil and fuel gas flows are added (the fuel gas flow being converted to a "fuel oil equivalent" flow, in terms of air requirement) in order to derive the total measured fuel flow. This fuel flow 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 set point. If the total fuel demand decreases, and the actual fuel flows do 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 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 total fuel demand signal to be sent to the fuel flow controller set point. If the total 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 transmit significant errors to the total fuel signal. For this reason, the fuel measurement is set to a hard zero when the TSOV of the fuel concerned is closed (deactivated).

If not all burners are in operation the air which is supplied to the burners not in operation should not be taken into account in the air/fuel ratio control. For this reason the measured fuel flow signal used for the air/fuel ratio control is multiplied by the ratio of the number of burners installed to the number of burners in operation.

If not all burners are in operation the oxygen measurement will not give proper information on the actual air/fuel ratio at the burner. Therefore the oxygen controller shall be switched automatically to manual if not all burners are in operation.

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.

In addition, there shall be individual waste gas TSOVs for each burner, which are closed when the relevant burner is tripped.

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

If the waste gas flow represents not more than 15% of the design heat input, it may be fed uncontrolled to the furnace provided that all relevant main burners are in operation.

3.4 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 oil and fuel gas burner TSOVs.

If a TSOV closing failure is detected on any main burner or any common header no burner can be started before the closing failure is corrected.

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 cycle 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 is 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. 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 or to support steaming out of oil guns). After 15 minutes the igniter is automatically stopped again.

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

Upon starting the first burner on gas, the header TSOV and burner TSOV open simultaneously and the vent valve closes. As the control valve is on its mechanical minimum stop, fuel flow to the first burner will be at minimum burner load.

Before start-up on oil the atomising steam differential pressure controller should be on automatic, maintaining a slight steam pressure on the burner. As the fuel header pressure increases, the atomising 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 burner TSOV closes to prevent an accumulation of unburnt fuel in the furnace.

It is not necessary to take the combustion air flow controller out of "cascade" control mode during furnace 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 set point 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 and the burner TSOV close, 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.

When the last oil burner is stopped, the fuel oil header TSOV is closed first, followed after 2 seconds by the burner TSOV to allow for depressurisation. This facilitates subsequent starting with low fuel and steam pressures.

In order to prevent severely substoichiometric firing with only a few burners in operation (assuming a failure of the A/F ratio system in DCS) the furnace can only be released from minimum firing if more than N/2 burners are in operation, where N is the total number of burners.

4. TECHNICAL DESCRIPTION

4.1 IMPLEMENTATION CONSIDERATIONS

Both minimum and maximum fuel gas pressure controllers for both fuels (PIC-1, PIC-2, PIC-3 and PIC-4) shall be locked in auto mode. The operator shall not be able to change the setpoint of the maximum pressure controllers (PIC-2 and PIC-4). The operator may be given limited control over the setpoint of the minimum pressure controllers (PIC-1 and PIC-3) 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, PIC-2, PIC-3 and PIC-4) shall be fast-acting (like compressor anti-surge controllers).

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

If the QRCA (oxygen controller) is forced to manual it shall retain its last output setting unless manually changed by the operator.

For furnaces with 3 or more burners equal percentage valves shall be used so that the performance of the (minimum stop) pressure controller is independent of the number of burners in operation.

The interfacing between the instrumented protective 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 in a total furnace trip initiator.

The Anti Reset Wind-Up (ARWU) to the fuel FRCs 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 neither fuel is on cascade, the TRC output shall be initialised to the total fuel flow.

If the combustion air is not on cascade, the oxygen QRC output 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 can be configured from Y10 to QRCA. This external feedback improves the response of the oxygen 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 feed back 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 minimise 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 initialisation techniques shall be configured.

4.2 LOCATIONS OF ALARMS, SWITCHES ETC.

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

Since oil firing requires the local presence of the operator (for checking atomisers, steaming out of oil guns, etc.), oil burners are 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 buttons are duplicated for dual fuel systems (on a local panel as well as in the control room).

For gas firing only, the above philosophy is reflected in Standard Drawing S 24.030.

If specified by the Principal the fuel gas start/stop buttons 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 FORMULAE

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 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:

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

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

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where:
P = Pressure, bar (abs)

T = Temperature, K

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

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.

Y4) Output = required (total) fuel flow - gas flow - waste gas flow [t/d SRF]
(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

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

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

M_{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.

Output = Fuel flow * 13.66 * [0.8+0.8 * 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.

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Output = M_{air} / (13.66 * 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 (see Note):

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

- For feed-forward from process flow through furnace:

Y12) $$\text{Output} = \frac{[\text{fuel flow}]}{[\text{process flow}]}$$

Y13) Output = [process flow] * [TRC output]

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

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

Y13) Output = [process flow] * {[TRC output] - k * [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.

Y18) $$\text{Output} = \text{Total fuel flow} * \frac{N_{\text{burners installed}}}{N_{\text{burners in operation}}}$$

(in which $N_{\text{burners in operation}} \geq 1$)

Y19) $$\text{Output} = \text{measured combustion air flow} * \frac{N_{\text{burners in operation}}}{N_{\text{burners installed}}}$$

(in which $N_{\text{burners in operation}} \geq 1$)

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 furnace.

If: i. the combustion air flow is not low; and

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

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

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

v. 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 via a signal to the DCS. 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 (under cascade).

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 purge is required.

4.4.2 Minimum stop module

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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 is present (where applicable) and

ii the air/fuel ratio is healthy; and

iii the module receives any “gas flame on” signal; and

iv the fuel gas pressure is not above “high-high”; and

v more than N/2 burners are in operation (in which N is the total number of installed burners); then

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

If, 30 seconds after a trip to minimum firing, the fuel gas pressure is not below twice the set pressure of the minimum stop, the module produces a “failure trip to minimum firing” signal to the fuel gas header module.

If:
i. the “not minimum firing” signal from the process is present (where applicable) and
ii the air/fuel ratio is not low; and
iii the module receives any “oil flame on” signal; and
iv the fuel oil pressure is not above “high-high”; and
v more than N/2 burners are in operation (in which N is the total number of installed burners); then

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

If, 30 seconds after a trip to minimum firing, the fuel oil pressure is not below twice the set pressure of the minimum stop, the module produces a “failure trip to minimum firing” signal to the fuel oil header module.

4.4.3 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 produce an "open igniter header" signal the igniter TSOV is open.

4.4.4 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. At the same time the output of the gas flow meter is incorporated in the firing and air/fuel ratio control.

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.

When the gas header TSOV is closed the output of the gas flow meter ceases to influence the furnace controls.

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 and any further ignition burner starts are inhibited.

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.

4.4.5 Fuel oil header module

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

If: i. the safe atmosphere module produces the safe atmosphere signal; and

ii. other process conditions (process trips) are healthy; and

iii. the atomising steam pressure is not low; and

iv. the stop oil firing switch is not activated; and

v. the "(NOT) failure to minimum stop" signal is healthy; and

vi. the fuel oil control valve is in the start position or any oil flame is on; then

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

If the oil header module receives at least one "open oil header" signal from the oil burner modules, the oil header is automatically opened. At the same time the output of the oil flow meter is incorporated in the firing and air/fuel ratio control.

If any one of the above conditions fails, the oil header TSOV closes and the "healthy for oil firing" signal disappears after 2 seconds to allow for depressurisation of the line. If all "open oil header" signals from the oil burner modules disappear the oil header TSOV closes also.

When the oil header TSOV is closed the output of the oil flow meter ceases to influence the furnace controls.

If the fuel oil header TSOV proximity switch (GBSA-05) does not indicate that the valve is closed within 15 seconds after initiating valve closure, an alarm is given and any further ignition burner starts are inhibited.

If, after all main oil 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 (see Note 1) and

ii. the module does not receive a "stop igniter" pulse from the gas or oil 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.

NOTE 1: The burner start is inhibited:

a) If any burner TSOV failed to close (up to 1 minute after recovery of the closing failure).

b) During 1 minute after each burner trip (or main burner start failure).

The module than produces the following signals:

a. open igniter header

b. open igniter TSOV

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

After the flame stabilisation timer has run out (after 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).

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 or an "oil flame 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.

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

ii. the gas burner stop button is not activated; and

iii. the main flame is detected 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 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.

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

If the gas burner TSOV proximity switch (GBSA-14-N4) does not indicate that the valve is closed within 15 seconds after initiating valve closure, an alarm is given and any further ignition burner starts are inhibited.

4.4.8 Oil burner modules

Each burner is equipped with its own oil burner module.

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

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

ii. the oil burner stop button is not activated; and

iii. the module receives an "igniter on" signal or a "gas flame on" signal; and

iv. the oil burner start button is activated; then

the oil burner module produces the following signals:

a. Open oil burner TSOV.

b. "Open oil header" to the fuel oil header module.

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

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

ii. the oil burner stop button is not activated; and

iii. the main flame is detected within the start timer setting; then

the module produces an "oil flame on" signal.

If any one of the above conditions fails the burner TSOV closes and the "open oil header" signal disappears. If no other oil burner modules produce an "open oil header" signal the oil header TSOV is closed.

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

If the oil burner TSOV proximity switch (GBSA-15-N5) does not indicate that the valve is closed within 15 seconds after initiating valve closure, an alarm is given and any further ignition burner starts are inhibited.

4.4.9 Main flame detection modules

The function of these modules is to provide an individual detector failure alarm and a "flame failure" signal to the burner modules. The main flame detection module produces a soft alarm if either of the two detectors does not detect a flame.

The main flame detection module produces a "flame detection failure" signal to the oil and gas burner modules if both detectors do not detect a flame.

The flame detectors shall not be equipped with Maintenance Override Switches.

4.4.10 Burner count module

The function of the burner count module is to provide a correction factor for the measured air flow, such that air which is supplied to burners which are not in operation is not included in the air/fuel ratio computation. In addition, it forces the QRCA (oxygen in flue gas) to manual if not all burners are in operation.

It further provides a signal "more than N/2 burners in operation" to the minimum stop module.

The module calculates the ratio of the total number of burners installed to the number of burners in operation.

To do this it makes use of the "oil flame on" and "gas flame on" signals of individual oil and gas burner modules (i.e. a burner is taken to be in operation if either the "oil flame on" signal or the "gas flame on" signal, or both signals, are healthy).

The output of the burner count module is sent to both the DCS and the PLC air/fuel calculations.

4.4.11 Burner TSOV tightness test module

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

Pressing this button will only result in opening of the header TSOV 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 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.

4.4.12 Waste gas firing module

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).

Two configurations are possible, dependent on the anticipated heat input of the waste gas:

4.4.12.1 Waste gas heat input not more than 15% of design

If the anticipated waste gas flow represents less than 15% of the total design heat input of the furnace, the waste gas to all burners is supplied via one common TSOV.

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 "all burners 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 if the furnace TSOV is closed).

The individual burners are equipped with manually operated valves. If short-term venting to atmosphere cannot be accepted (e.g. when burner guns are being cleaned), the manual valves shall be equipped with proximity switches which can be used to override the relevant flame detector signal (i.e. if the waste gas cock on a burner is detected closed, the waste gas TSOV is not tripped when this burner is taken out of operation).

4.4.12.2 Waste gas heat input more than 15% of design

If the anticipated waste gas flow represents more than 15% of the total design heat input of the furnace, the burners are equipped with individual waste gas TSOVs in addition to the common waste gas TSOV.

A. Common waste gas TSOV module

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 waste gas firing stop button is not activated; then

the module produces a "healthy for waste gas firing" signal to the individual waste gas burner modules.

If at least N/2 waste gas burner TSOVs are opened the common TSOV can be opened by activating the waste gas firing reset button.

If any of the conditions i to iii fail or if the "at least N/2 waste gas burner TSOVs open" signal disappears, the common TSOV closes again.

Usually the common waste gas TSOV to the furnace is operated in conjunction with a vent TSOV (i.e. the vent TSOV is automatically opened if the furnace TSOV is closed).

B. Burner waste gas TSOV module

If:
- i. the module receives a "healthy for waste gas firing" signal; and
- ii. the module receives a "main burner on" signal; and
- iii. the waste gas burner stop switch is not activated; then

the TSOV can be opened by activating the start waste gas burner reset button.

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).

The notes applicable to Table 1 are as follows:

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

2) It is assumed that if the (process I) trip to minimum firing fails to act, a process II trip is automatically initiated (e.g. if an outlet temperature remains too high for too long a period).

3) If the main flame detector cannot detect neighbouring flames the ignition flame detection is unclassified.

4) High fuel pressure only initiates a total trip in case of failure of trip to minimum firing.

5) Trip to minimum firing implemented as IPF class II, however, in case of failure of this trip, a total trip (implemented class III) will follow.

Table 1 Cause and effect diagram

Initiators		Actions 1)												
TAG	Service	Abort/ Inhibit start sequence	Header fuel oil TSOV close	Trip to minimum firing fuel oil	Header fuel gas TSOVs close	Vent fuel gas TSOV open	Trip to minimum firing fuel gas	Header igniter TSOV close	Main fuel gas burner TSOV close	Main fuel oil burner TSOV close	Ignition burner TSOV close	Switch QRC-1 (O2) manual	Switch oil flow meas. to zero	Switch gas flow meas. to zero
FZA-01-LL	Combustion air	-	III	0	III	II	0	0	0	0	0	-	-	-
FZA-02-L	Combustion air (for purging)	III	-	-	-	-	-	-	-	-	-	-	-	-
XZA-01-LL	Air/fuel ratio	-	-	II	-	-	II	-	-	-	-	-	-	-
PZA-01a-HH	Fuel gas	-	-	-	-	-	II	-	-	-	-	-	-	-
PZA-01b-H	Fuel gas	III	-	-	IV 4)	II 4)	0 4)	-	0 4)	-	-	-	-	-
PZA-03a-HH	Fuel oil	-	-	II	-	-	-	-	-	-	-	-	-	-
PZA-03b-H	Fuel oil	III	IV 4)	0 4)	-	-	-	-	-	0 4)	-	-	-	-
PZA-05-LL	Atomising steam	-	II	0	-	-	-	-	-	0	-	-	-	-
HZA-01/02	Manual trips	0	IV	0	IV	II	0	III	0	0	0	-	-	-
LZA-01HH	Fuel gas KO drum	-	-	-	III	II	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-06-S	Fuel oil control valve in start position	III	-	-	-	-	-	-	-	-	-	-	-	-
GBSA-05-C	Fuel oil header TSOV closed	III	-	-	-	-	-	-	-	-	-	-	-	-
Process I	General process trips 2)	-	-	II	-	-	II	-	-	-	-	-	-	-
Process II	General process trips	-	III	0	III	II	0	0	0	0	0	-	-	-
GBSA-14-C	Vent TSOV closed	-	-	-	-	-	-	-	-	-	-	-	-	-
XZA-11-n1	Ignition flame detection	III/- 3)	-	-	-	-	-	0	-	-	0	-	-	-
XZA-12-n2	Main flame detection	-	-	-	-	-	-	-	IV	IV	0	-	-	-
All XZA-12 to n2	All main flame detectors	-	0	0	I	II	0	-	-	-	-	-	-	-
GBSA-14-n4-C	Gas burner TSOV closed	III	-	-	-	-	-	-	-	-	-	-	-	-
GBSA-15-n5-C	Oil burner TSOV closed	III	-	-	-	-	-	-	-	-	-	-	-	-
> N/2 burners lit	Burner count	-	-	III 5)	-	-	III 5)	-	-	-	-	-	-	-
(Not) all burners lit		-	-	-	-	-	-	-	-	-	-	II	-	-
(Not) healthy for oil firing		-	-	-	-	-	-	-	-	-	-	-	II	-
(Not) healthy for gas firing		-	-	-	-	-	-	-	-	-	-	-	-	II

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.

Amended Per Circular 54/97

SHELL STANDARDS

Classification and implementation of Instrumented Protective Functions	DEP 32.80.10.10-Gen.

STANDARD DRAWINGS

Fuel-oil and fuel-gas system for an automatically started forced draught multi-burner furnace/boiler	S 24.030
Fuel gas system for an automatically started, forced draught, multi-burner furnace/boiler.	S 24.034

APPENDIX 1 Functional logic diagrams for a forced draught multi-burner furnace

**Amended Per
Circular 54/97**

Logics 30 Sheet 0

Furnace safeguarding logics for a forced draught, multi burner furnace.

References:

S24.030:
Fuel oil and fuel gas system for an automatically started, dual fuel fired, forced draught, multi burner heater or boiler.

S24.034:
Fuel gas system for an automatically started, gas fired, forced draught, multiburner heater or boiler (<16 burners).

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:

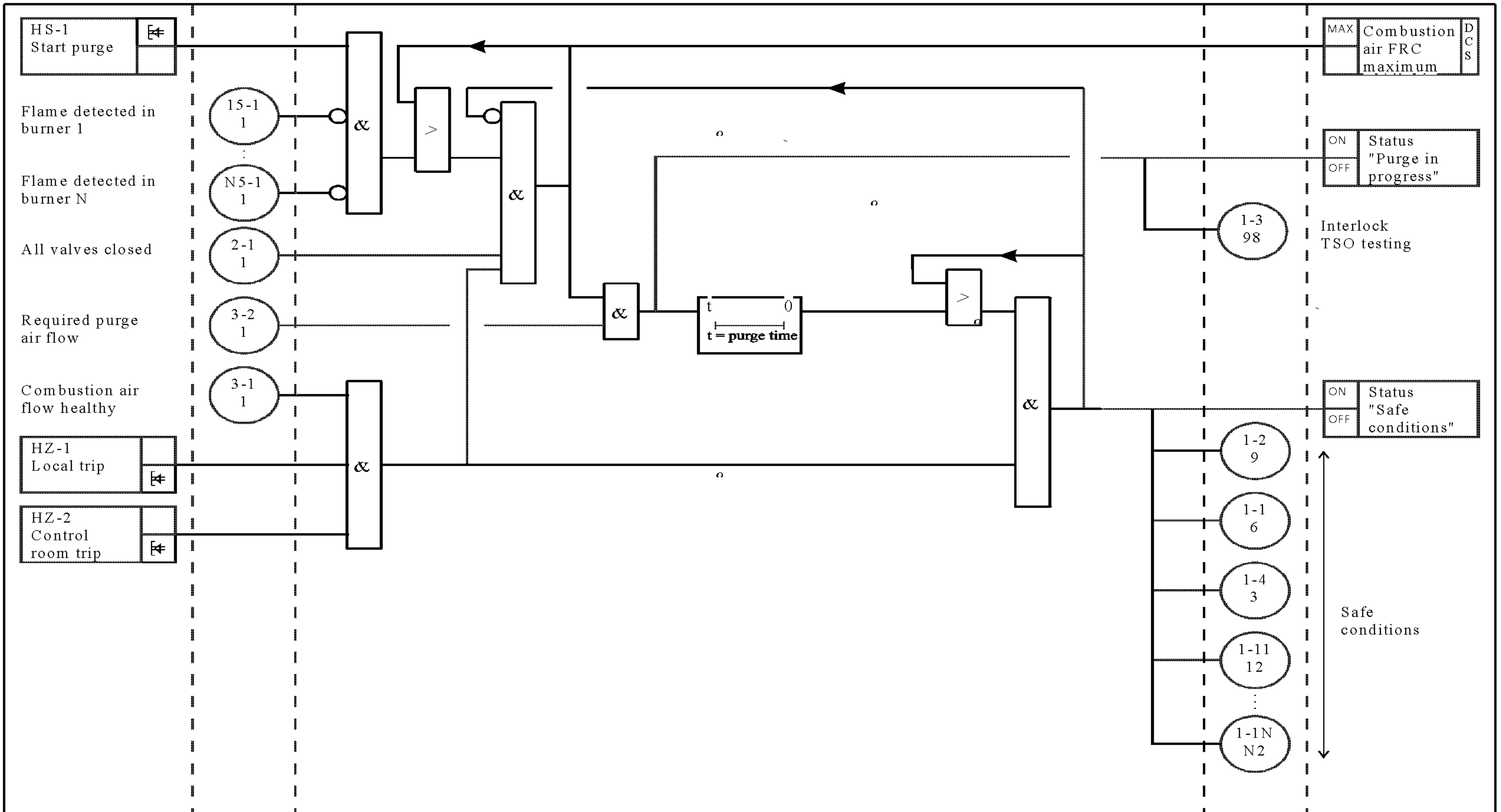
1. Safe atmosphere
2. General burner status
3. General trips
4. Minimum stop
5. Igniter header
6. Fuel gas header + vent
7. Gas firing trips
8. Fuel gas TSOV selection
9. Fuel oil header
10. Fuel oil firing trips

12. Igniter burner 1
13. Fuel gas burner 1
14. Fuel oil burner 1
15. Flame detection burner 1

97. Burner count module
98. Burner TSO test
99. Status indications, alarms, switches

FURNACE SAFEGUARDING LOGICS		Logics 30 Sheet 0

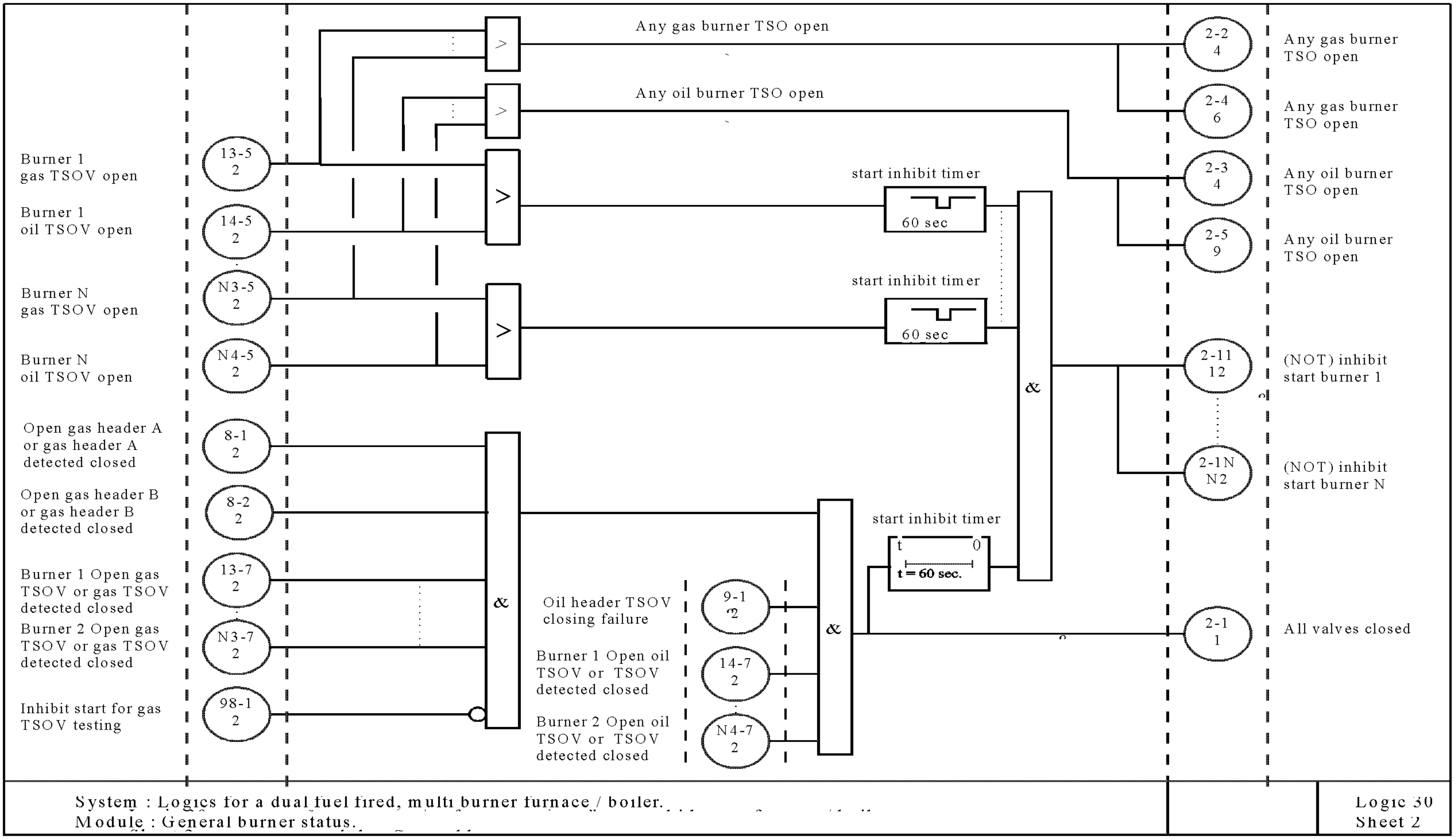
Logic 30 Sheet 1



System : Logics for a dual fuel fired, multi burner furnace / boiler.
Module : Safe atmosphere.

Logic 30
Sheet 1

Logic 30 Sheet 2



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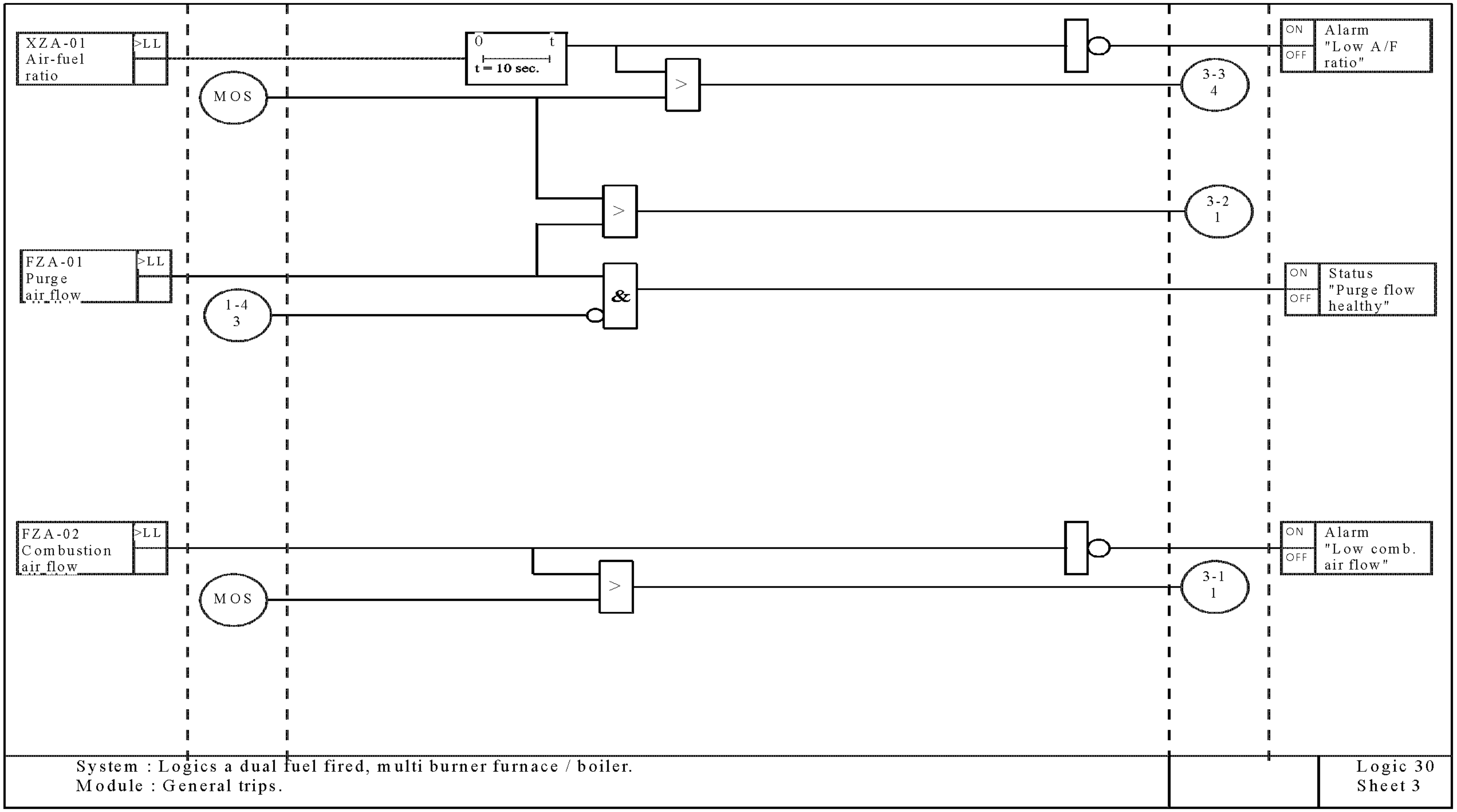

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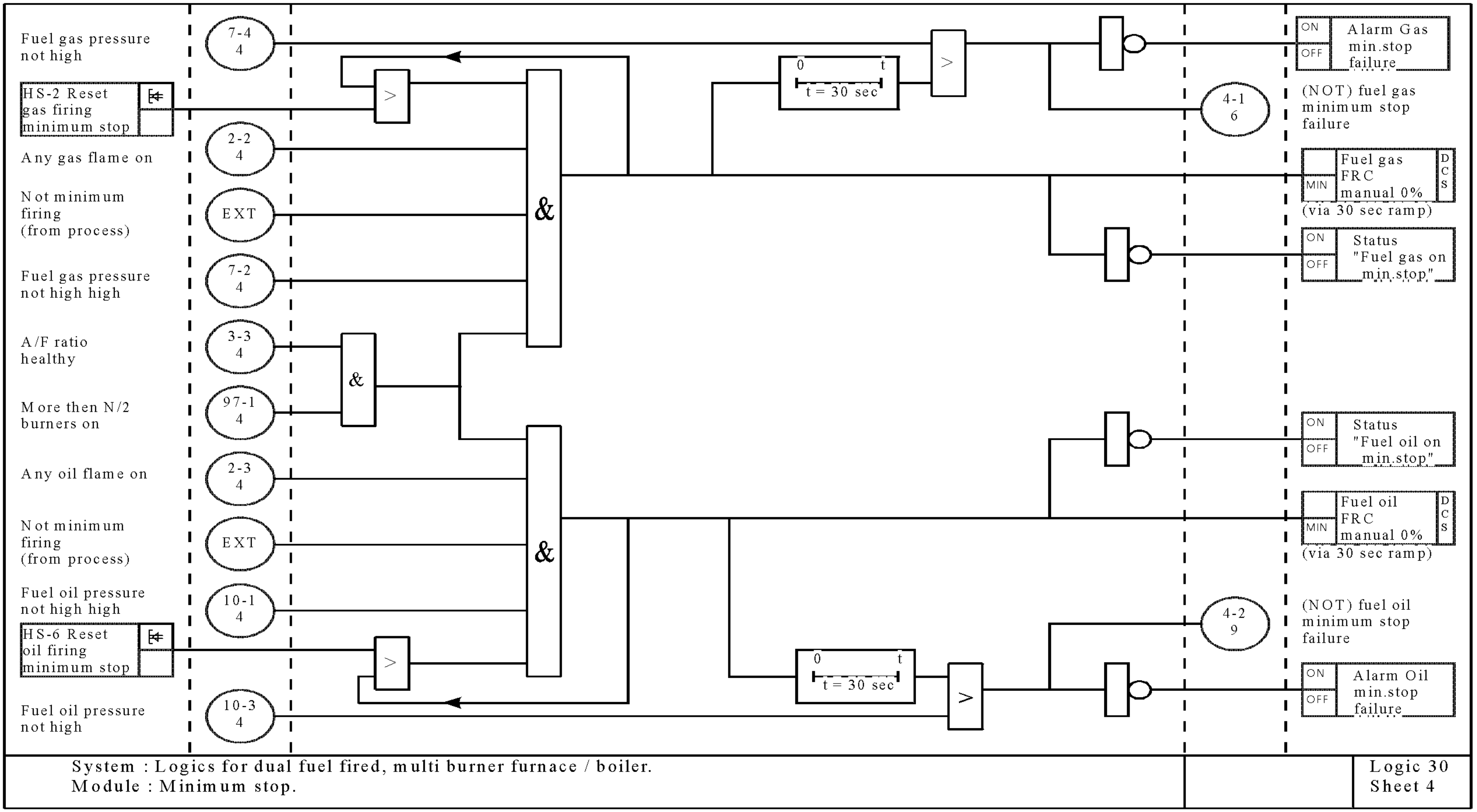
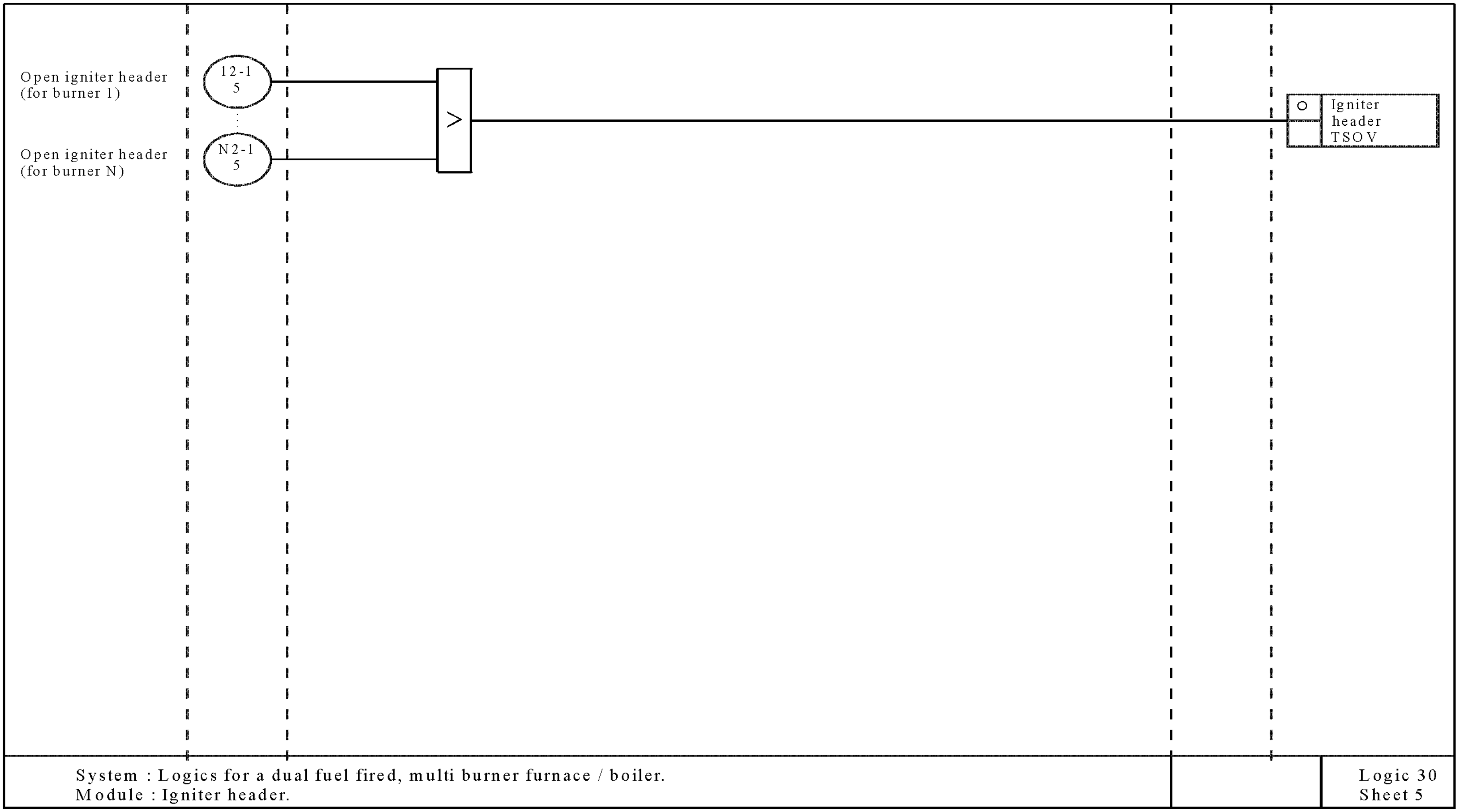
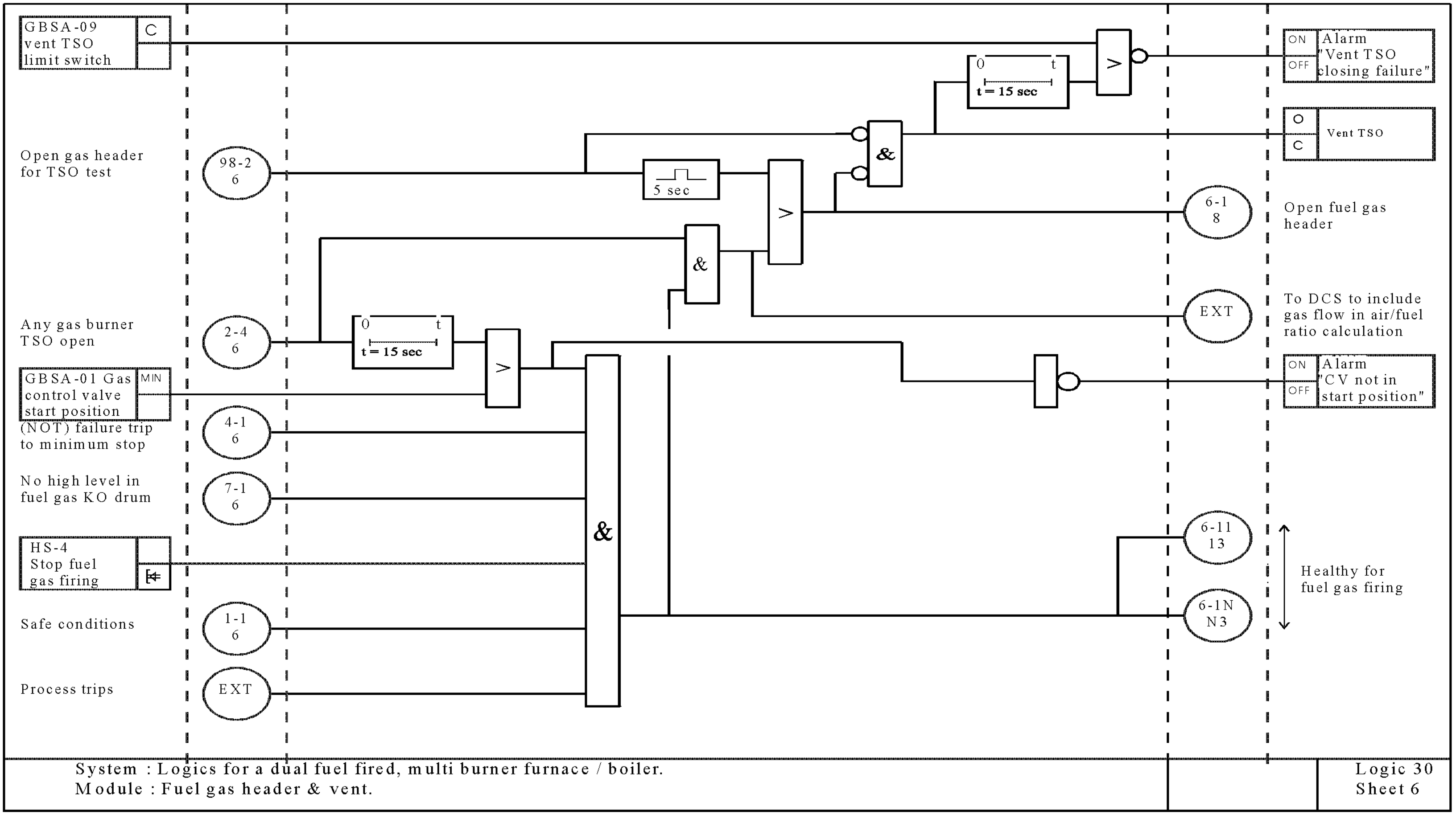


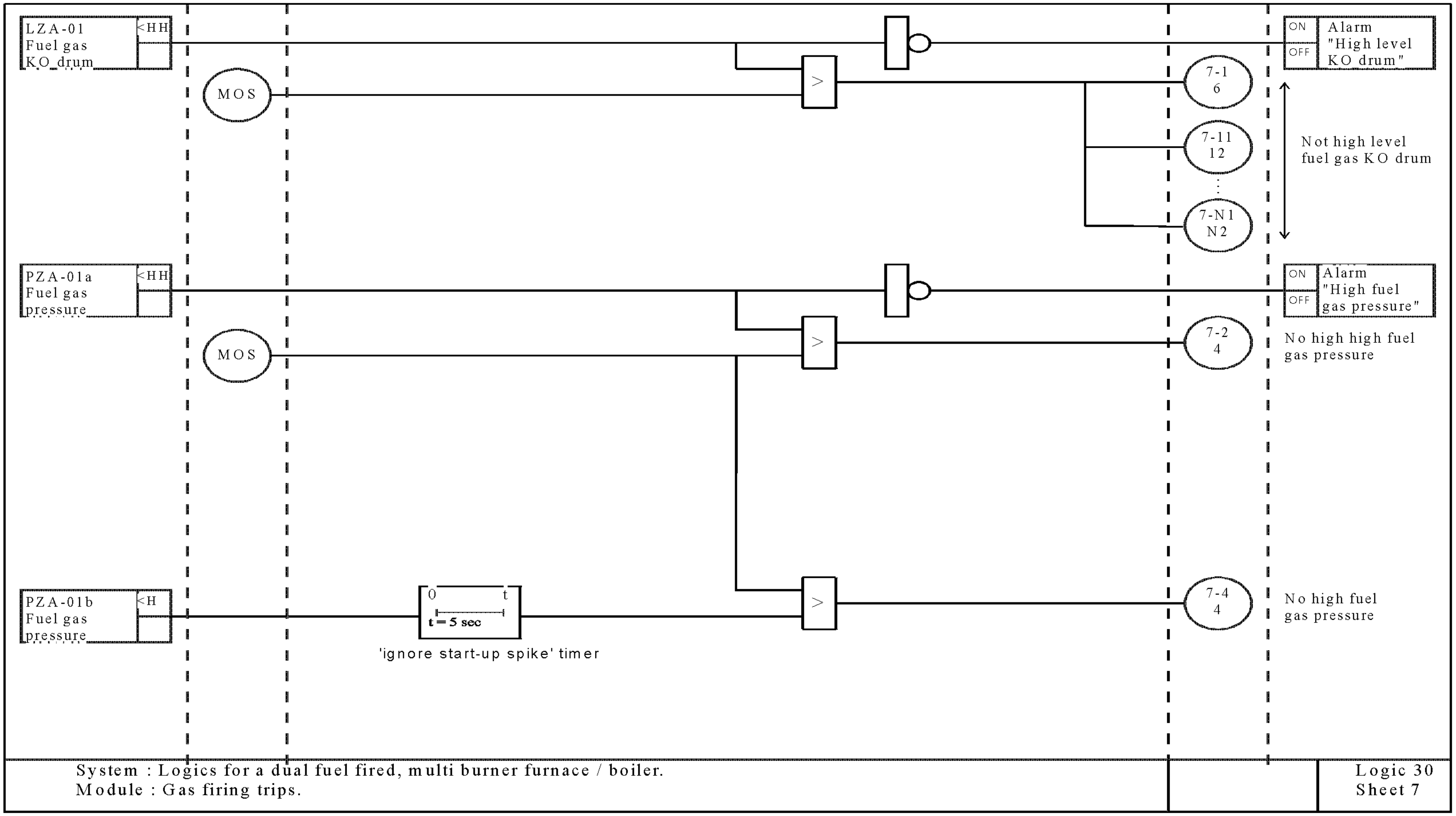
Logic 30 Sheet 5



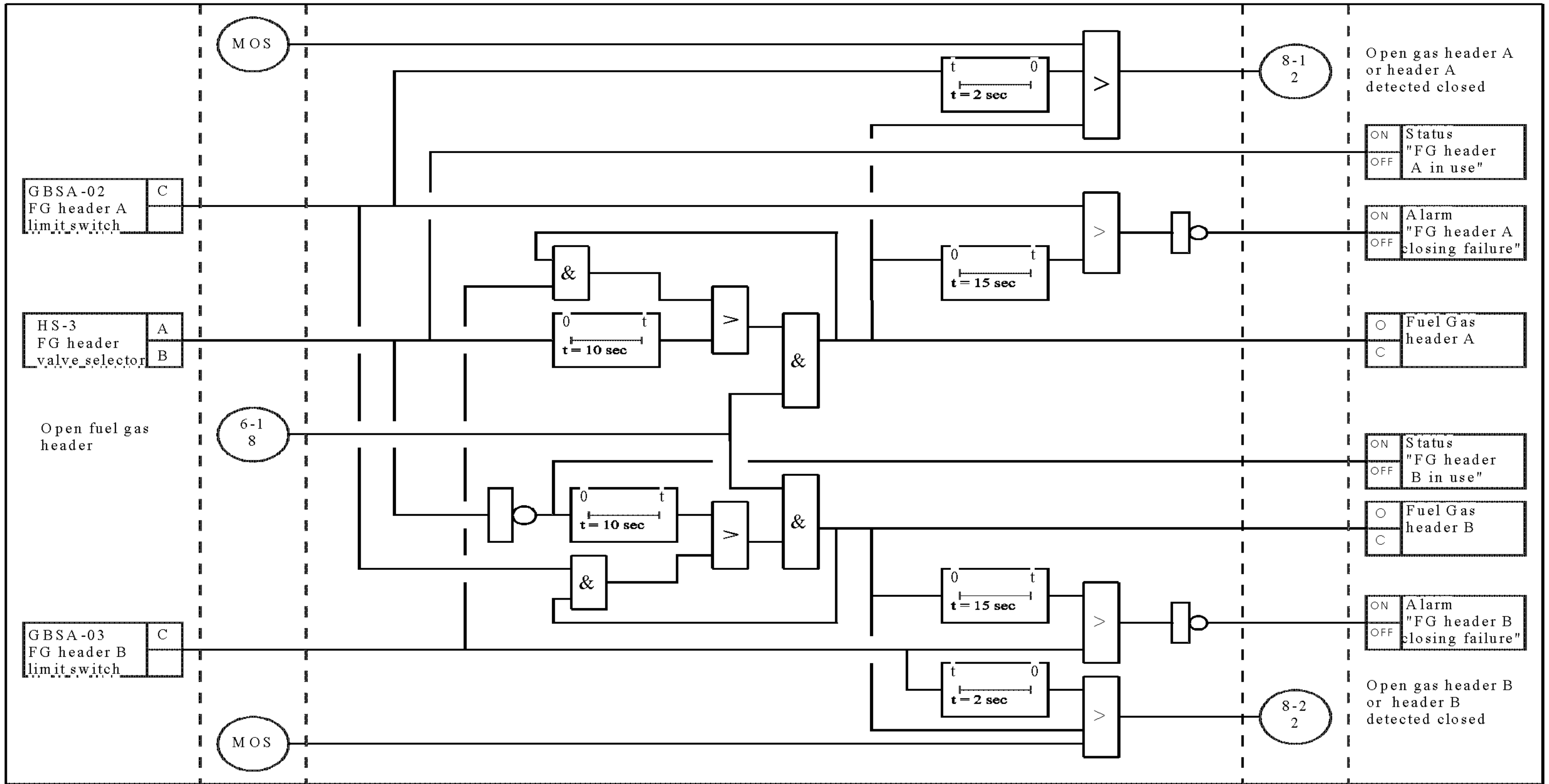
Logic 30 Sheet 6



Logic 30 Sheet 7



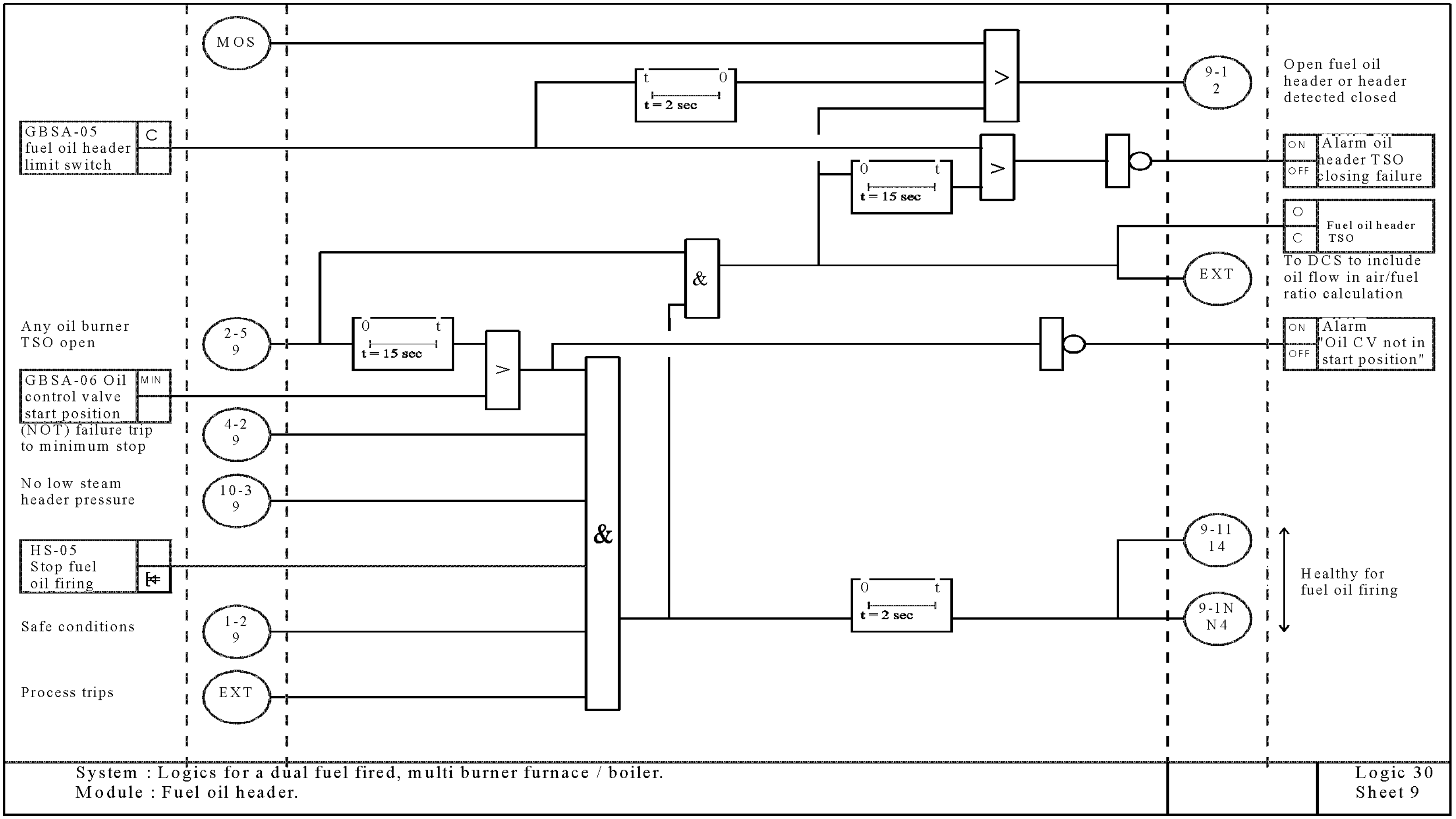
Logic 30 Sheet 8



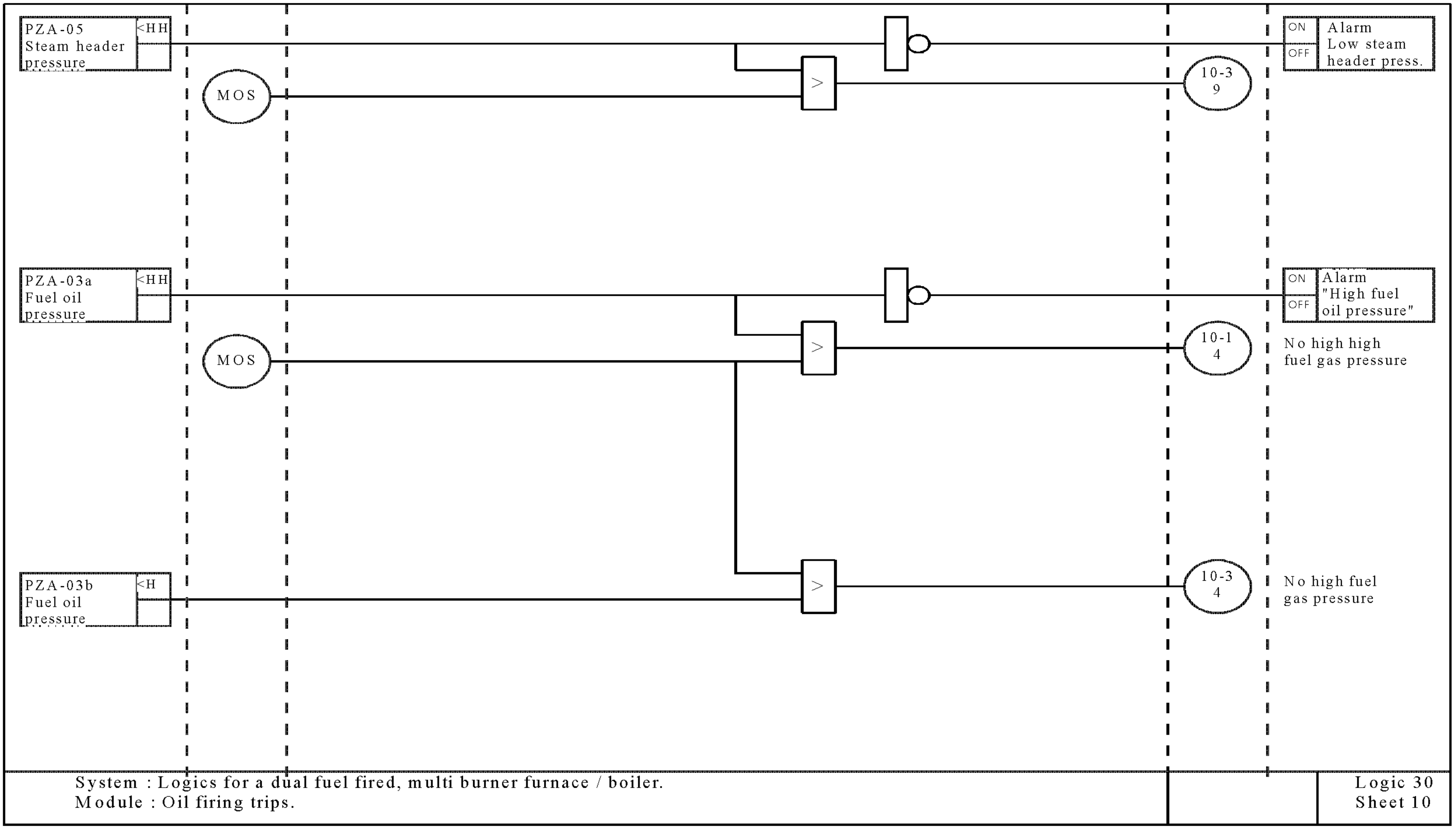
System : Logics for a dual fuel fired, multi burner furnace / boiler.
Module : Fuel gas header valve selection.

Logic 30
Sheet 8

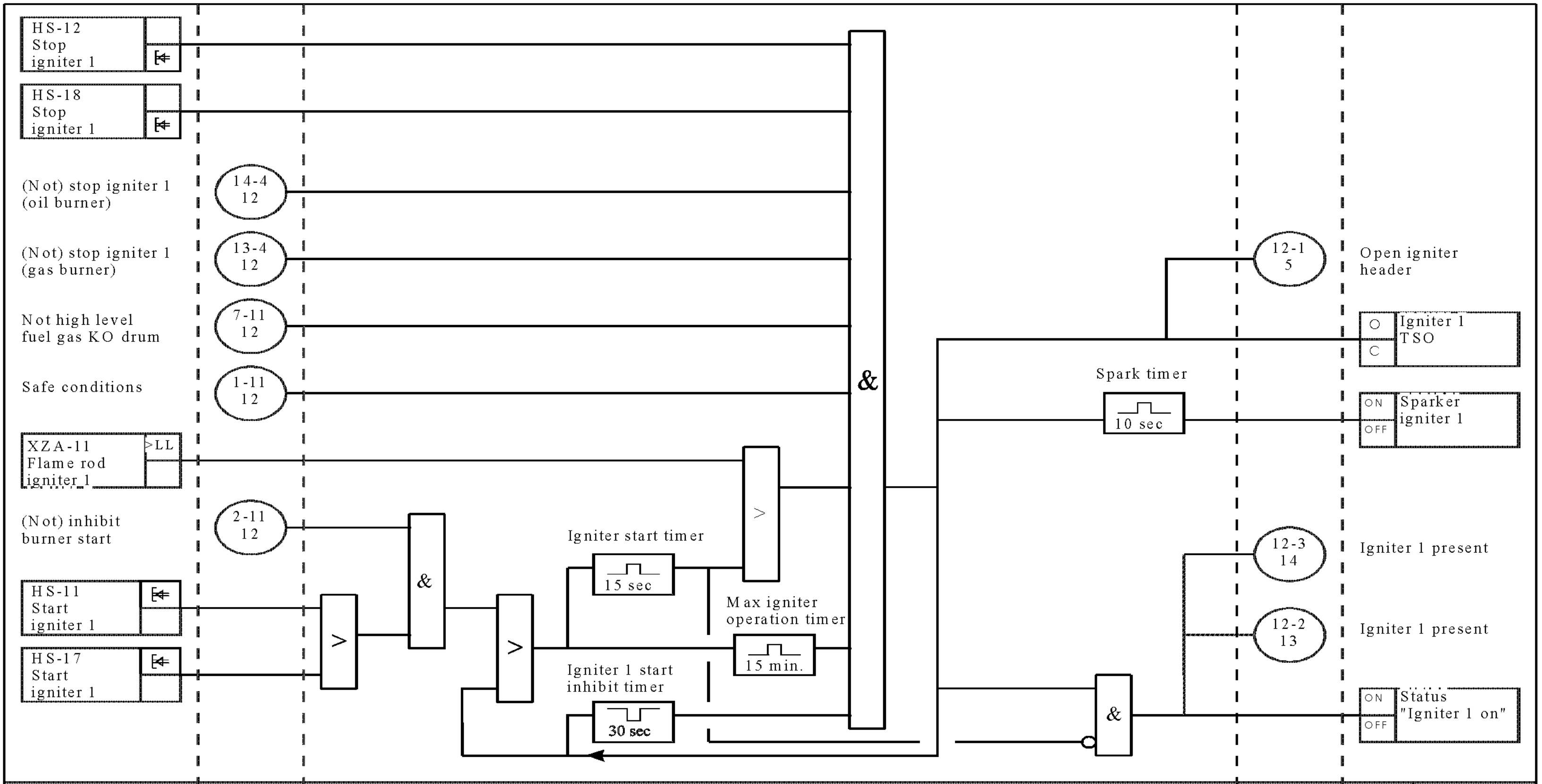
Logic 30 Sheet 9



Logic 30 Sheet 10



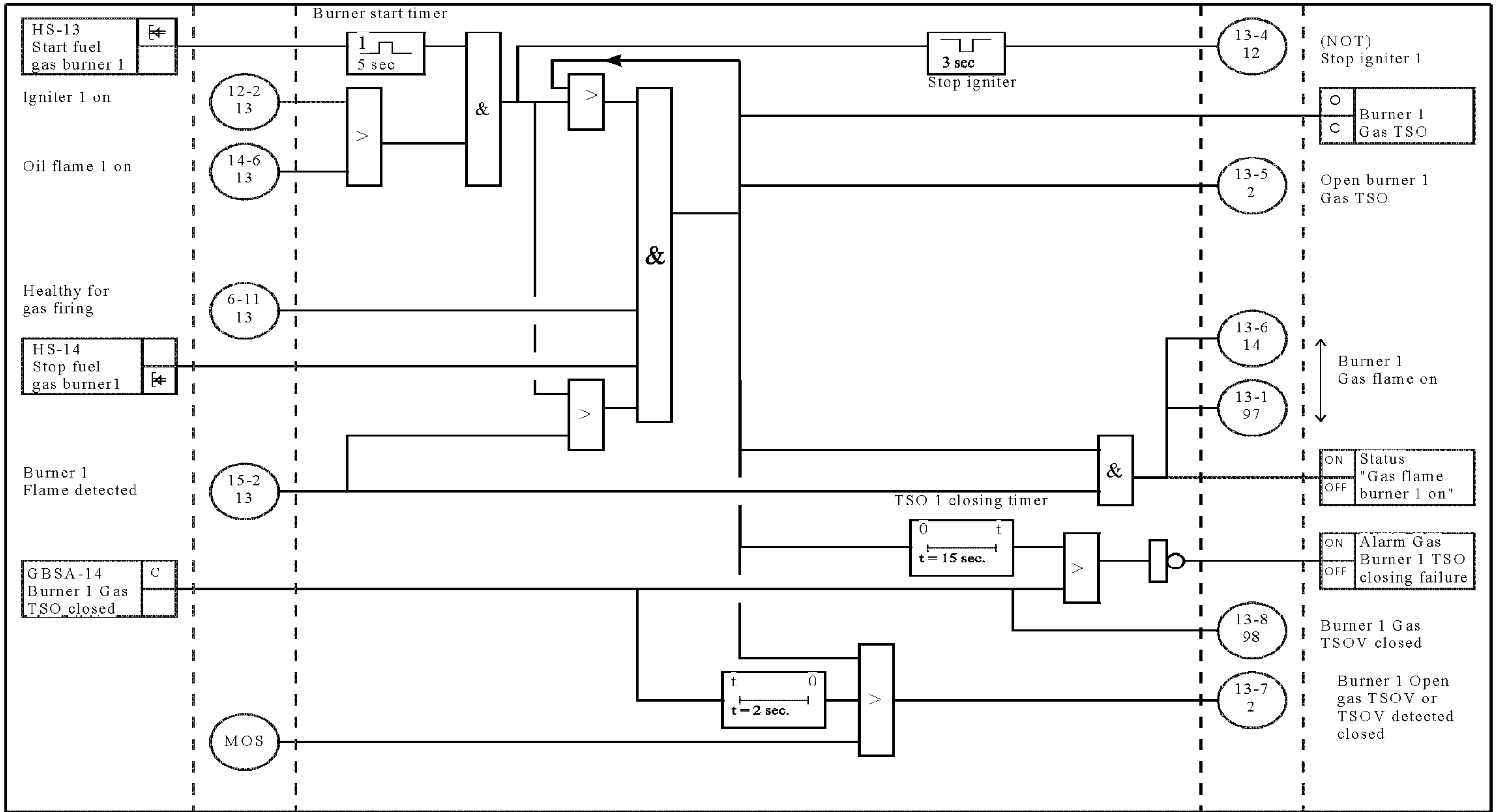
Logic 30 Sheet 12



System : Logics for a dual fuel fired, multi burner furnace / boiler.
Module : Igniter 1.

Logic 30
Sheet 12

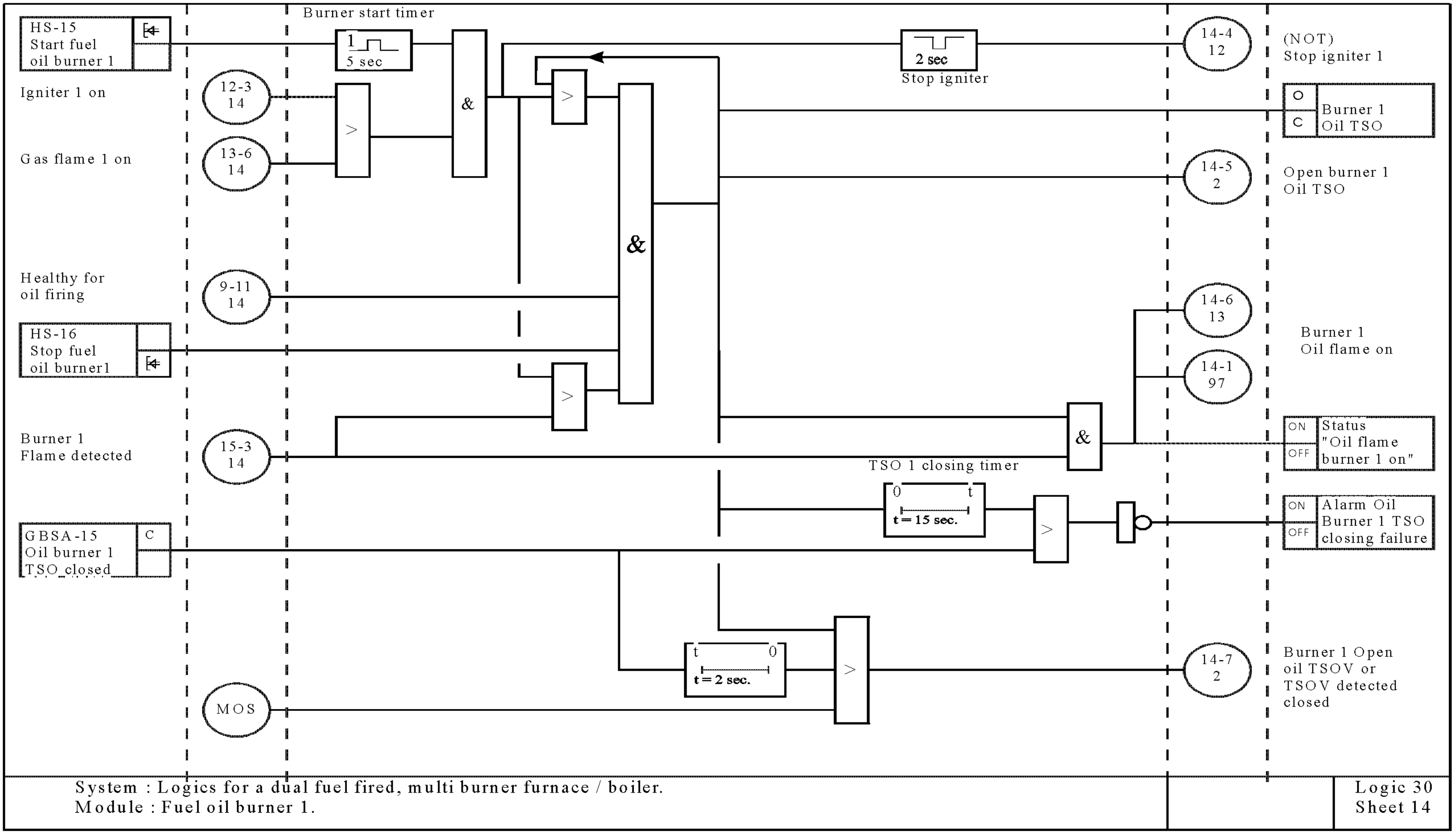
Logic 30 Sheet 13



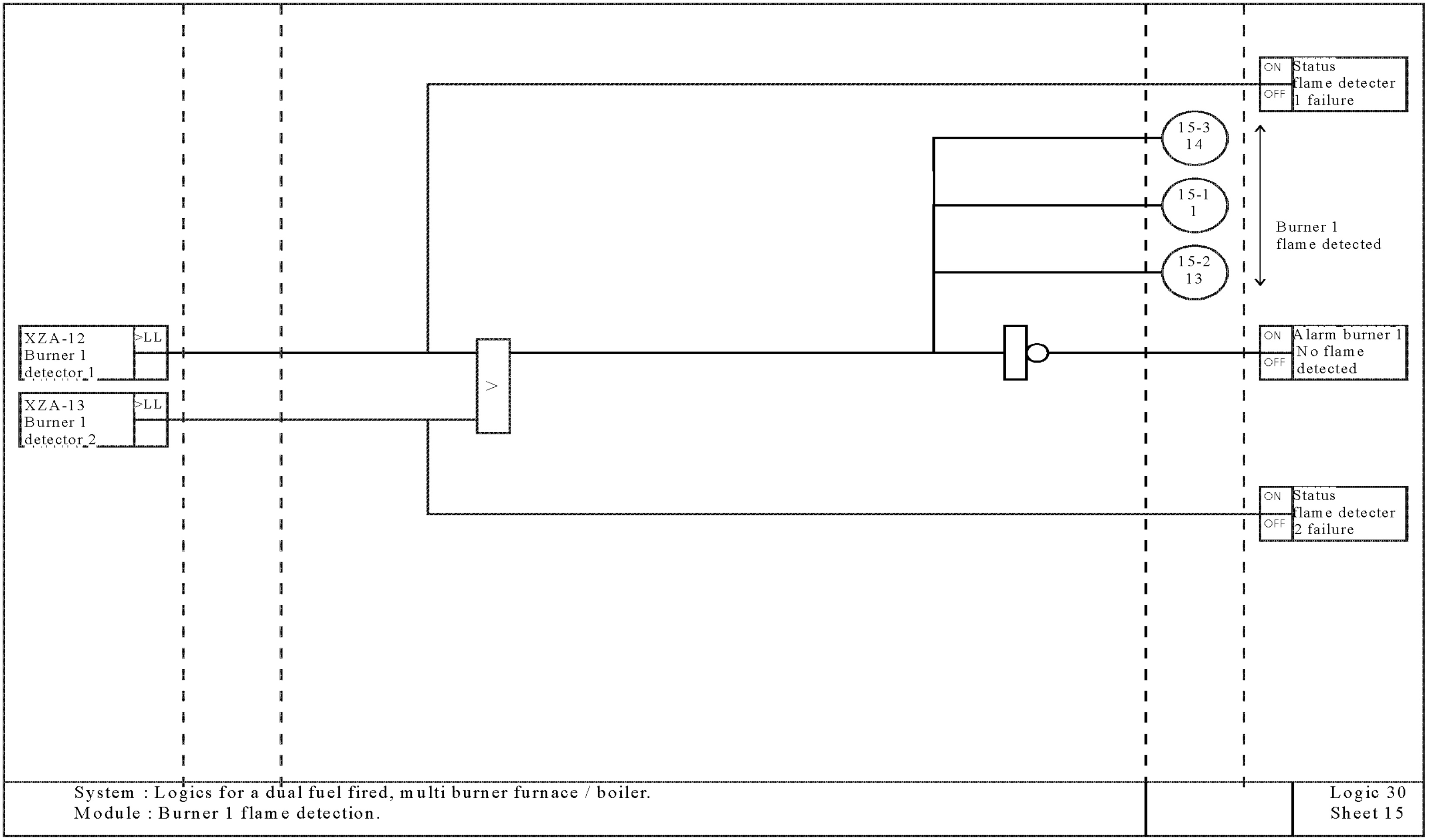
System : Logics for a dual fuel fired, multi burner furnace / boiler.
Module : Fuel gas burner 1.

Logic 30
Sheet 13

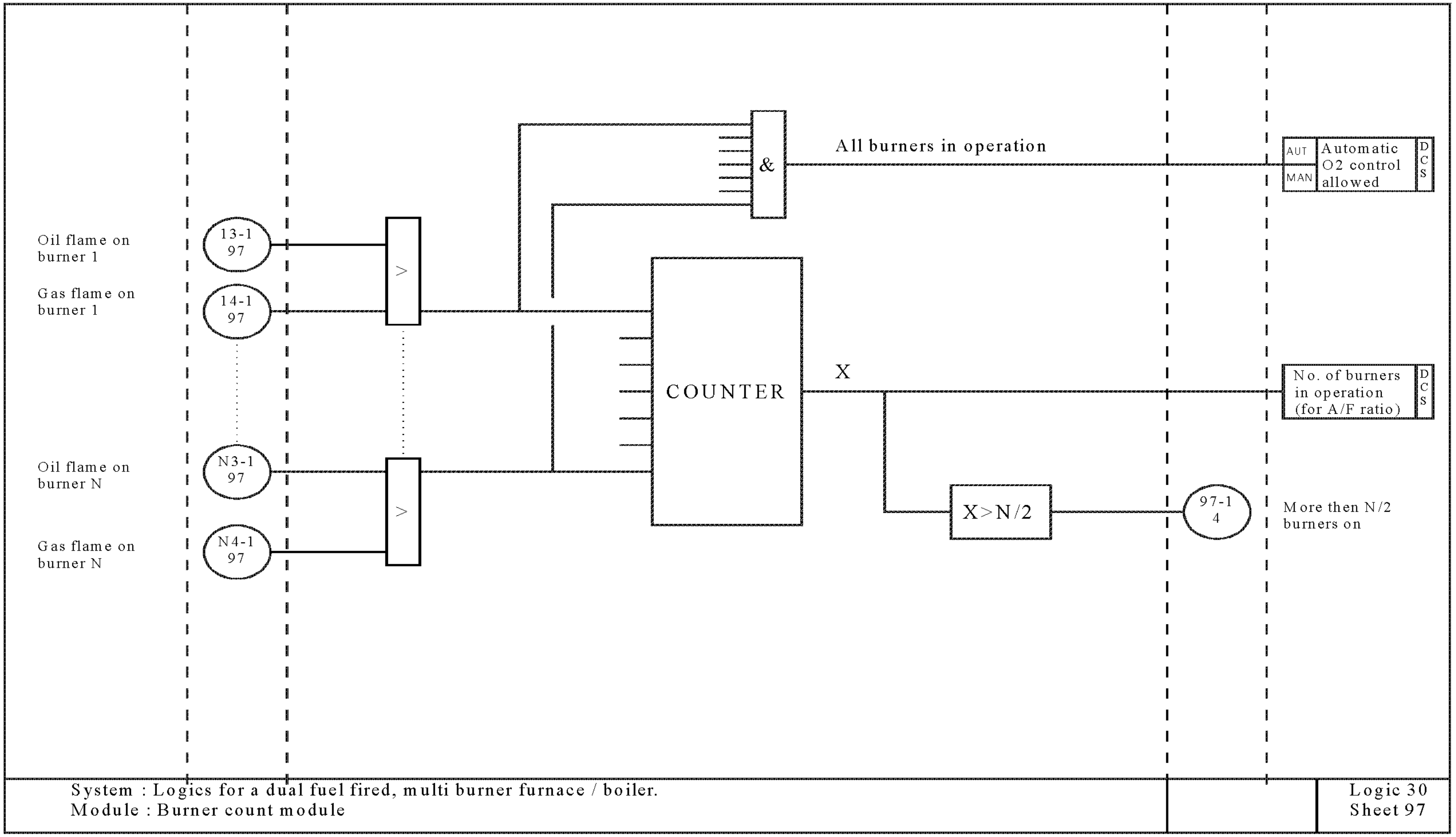
Logic 30 Sheet 14



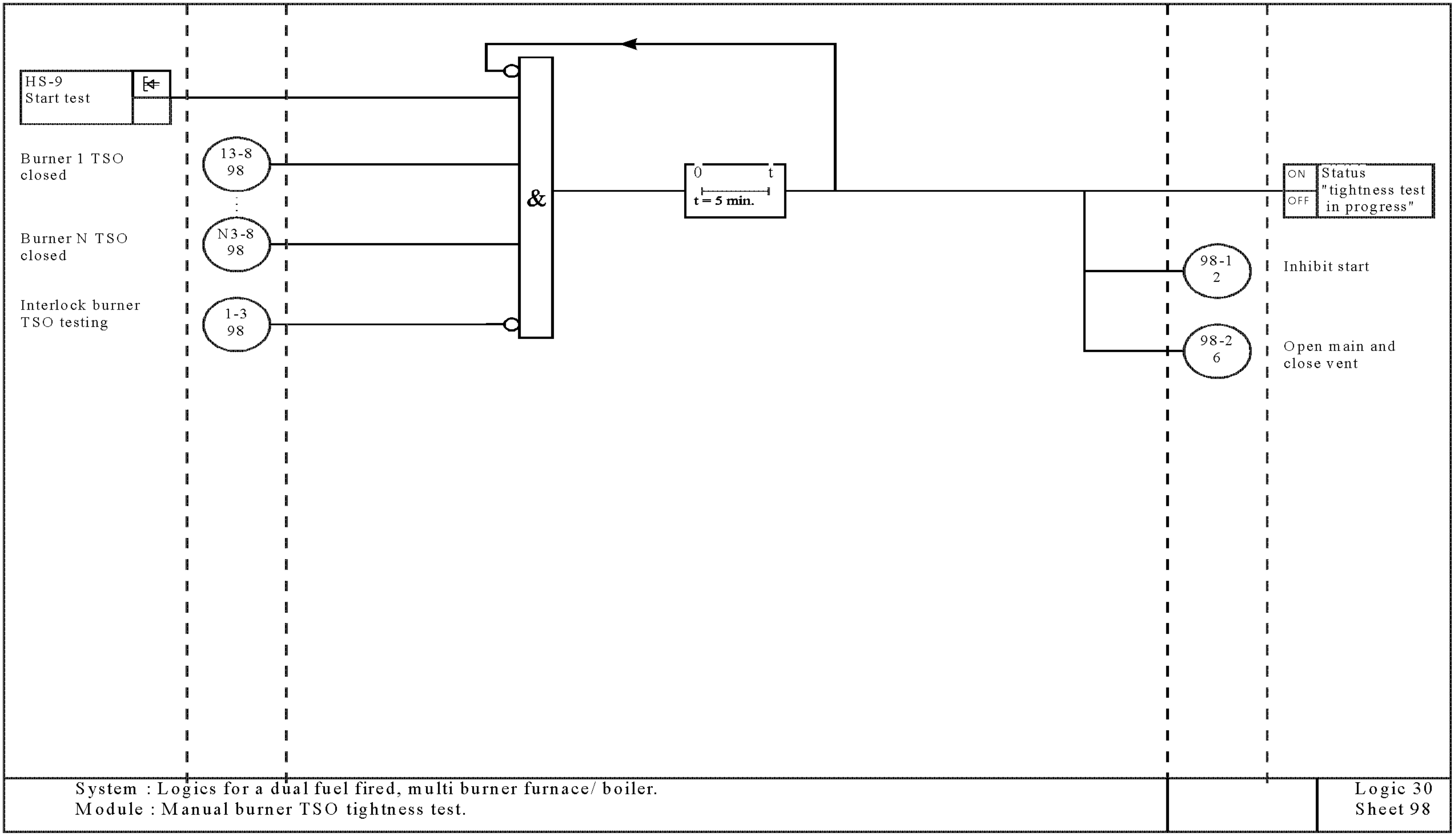
Logic 30 Sheet 26



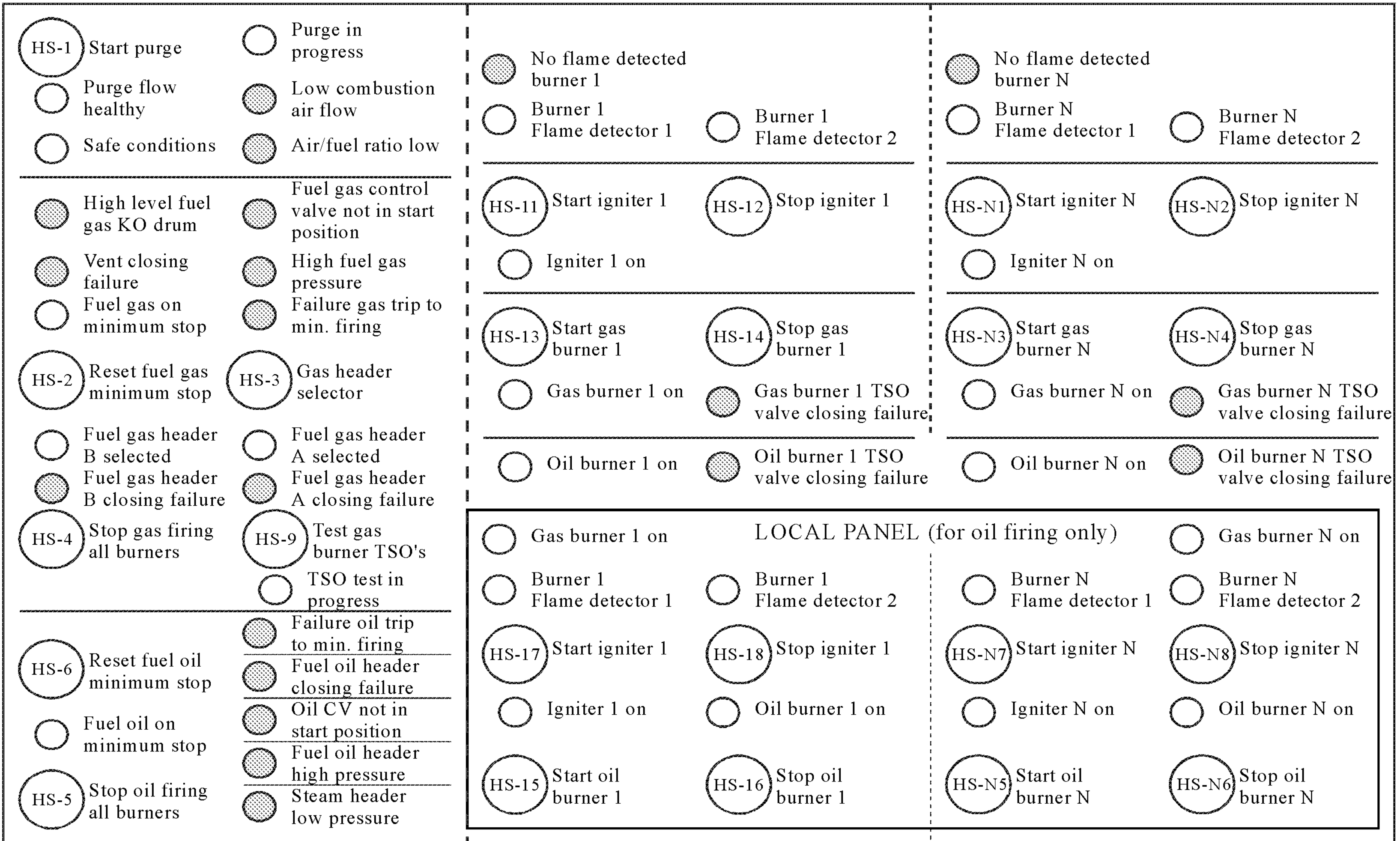
Logic 30 Sheet 97



Logic 30 Sheet 98



Logic 30 Sheet 99



System : Logics for a dual fuel fired, multi burner furnace Module: Status lights, alarms, switches		Logics 30 Sheet 99

Last page of this DEP