Expansion Board Set-Up Guide

Autoflame

AUTOFLAME®

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Important Notes

A knowledge of combustion related procedures and commissioning is essential before embarking work on any of the M.M./E.G.A. systems. This is for safety reasons and effective use of the M.M./ E.G.A. system. Hands on training is required. For details on schedules and fees relating to group training courses and individual instruction, please contact the Autoflame Engineering Ltd. offices at the address listed on the front.

Short Form - General Terms and Conditions

A full statement of our business terms and conditions are printed on the reverse of all invoices. A copy of these can be issued upon application, if requested in writing.

The System equipment and control concepts referred to in this Manual MUST be installed, commissioned and applied by personnel skilled in the various technical disciplines that are inherent to the Autoflame product range, i.e. combustion, electrical and control.

The sale of Autoflame's systems and equipment referred to in this Manual assume that the dealer, purchaser and installer has the necessary skills at his disposal. i.e. A high degree of combustion engineering experience, and a thorough understanding of the local electrical codes of practice concerning boilers, burners and their ancillary systems and equipment.

Autoflame's warranty from point of sale is two years on all electronic systems and components.
One year on all mechanical systems, components and sensors.

The warranty assumes that all equipment supplied will be used for the purpose that it was intended and in strict compliance with our technical recommendations. Autoflame's warranty and guarantee is limited strictly to product build quality, and design. Excluded absolutely are any claims arising from misapplication, incorrect installation and/or incorrect commissioning.

Contents

1 INTRODUCTION

1.1 Overview of Water Level Control

1.1.1 Water Level Control Philosophy

The Autoflame water level control focuses on safety and accuracy in controlling the water level in a steam boiler. The system has a typical level control accuracy of ± 2mm in still water. This accuracy is maintained during normal operation by Autoflame's patented "wave signature and turbulence management" software.

The system safety is guaranteed as the level measurement is managed by two identical capacitance probes both of which measure and control to the level switching points entered at the time of commissioning.

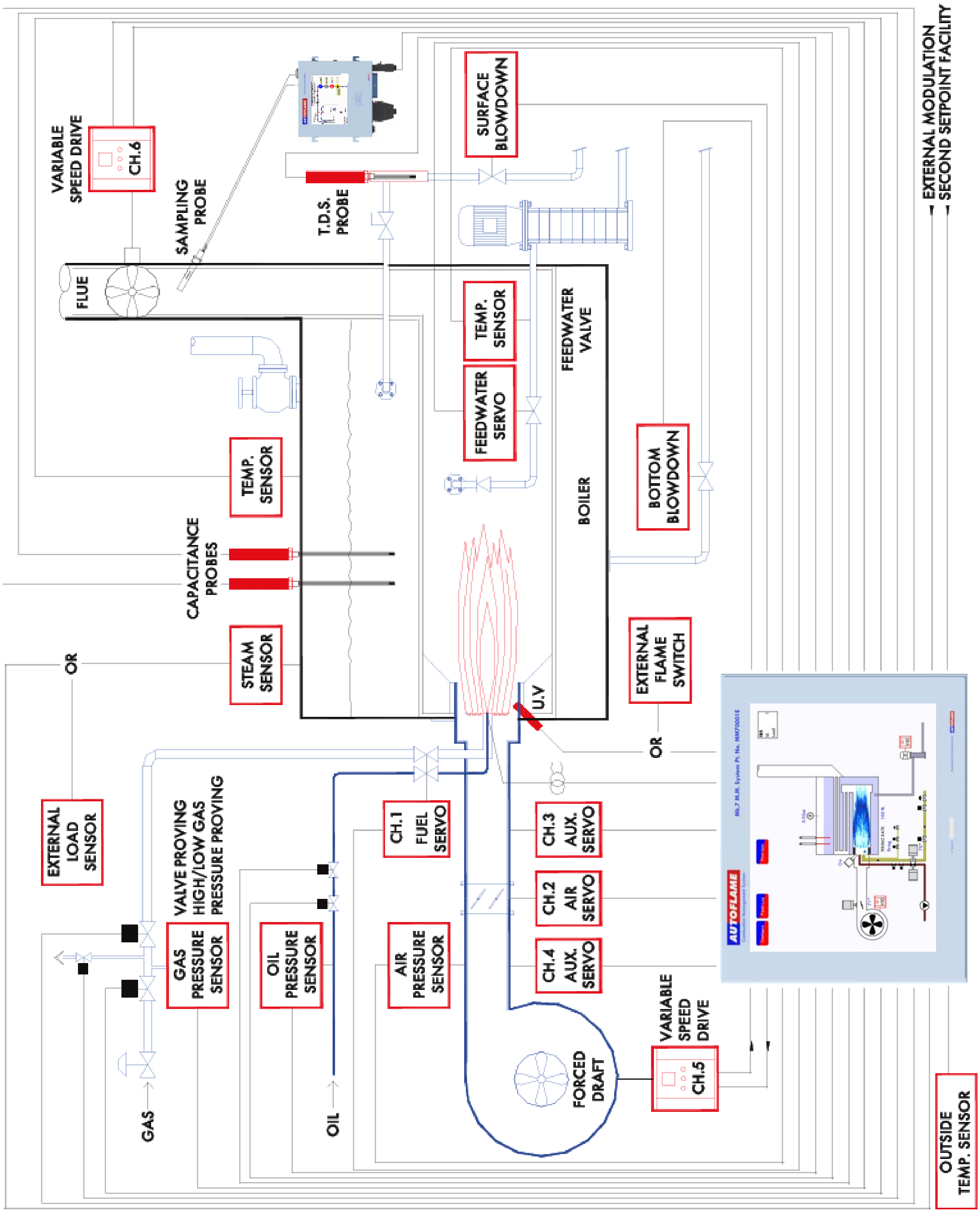
Both probes control typically "high level", "required level", "first low" and "second low". The actual water level readings taken from both the probes are constantly compared and checked against each other, as well the commissioned water levels. When controlling the required level this data stream is combined with a PI algorithm which controls either the two port feed water control valve or the variable speed drive to the feed water pump. Each probe is self-checked for electrical and mechanical integrity by hardware references and self-checking software routines. Each probe and its control electronics are compensated for ambient temperature variations and component drift, guaranteeing absolute safety of operation.

By our method the probes control the required level by learning the wave signature and managing the turbulence within the boiler shell. This "wave signature management" takes into account the changes in burner firing rate and any variance in pressure in the boiler shell. Incorporated within the system hardware are all necessary electronic switching functions to control audible alarms, mute/reset and indication lights required to meet standard North American and European codes. Safety, accuracy and integrity are guaranteed.

<u>Movement Detection of Water</u>
When the burner is running it is expected that a wave turbulence signature of in excess of 20Hz / 1mm will always be present (due to vibration of thermal energy). Both probes are checked for this value. The default setting is 20Hz, a range of 0-100Hz is possible, if set to '0' this feature is turned off. This feature ensures that either probe cannot read a still water condition when the burner is running. This safety check ensures no static or stuck value can be accepted, thereby checking that the probes are in water.

<u>Swell Management</u>
When there is a sudden drop in boiler pressure an increase in water level will be observed. This is due to the expansion of the steam bubbles in the water causing the water level to increase. It follows that the water feed would then turn off or go to a low flow condition. The Autoflame system identifies this ambiguous condition by monitoring the sudden increase in burner firing rate to meet the load demand and increases the "required water level" by up to 50% of the distance between normal "required level" and "high water level". When normal conditions are reinstated and the boiler firing rate stabilises, the "required level" returns to the normal setting. This stops spurious shut downs due to 1st low being switched during these transient conditions. The Autoflame system knows what the firing rate and boiler pressure is at any one time and uses this information to identify the above condition. This feature is one of the main elements in the patent claim.

1.1.2 Water Level Schematic



1.2 Water Level Features

The Mk7 Expansion Board is used in conjunction with the Mk7 Micro-Modulation (M.M.) burner controller to report and control levels of water within industrial steam boilers. The intelligent water level control includes high water alarms, 1st low and 2nd low alarms. Alarm level reporting deals with the ability to determine whether the current water level in the boiler is above or below a predetermined level. These levels vary with each installation, and must therefore be programmed on site by a qualified commissioning engineer.

Intelligent Water Level Control
The feed water flow is managed by 3-element control, in response to the water level measured by the capacitance/frequency readings, boiler pressure and the burner's firing rate. The flow is controlled by a fully modulating feed water/VSD or by using an on/off signal from a feed water pump. The Autoflame 3-element level control has been granted a worldwide patent; being the only system that can combine firing rate, steam pressure and water level within one controller for the purpose of improving feed water control. Safety, accuracy and integrity are guaranteed.

The two capacitance probes control up to six operational levels including:
- High high level
- High level
- Pre-high level
- Control point or pump on/off levels
- Pre-1st low level
- 1st low level
- 2nd low level
- End of probe level

The capacitance readings are constantly checked between both of the probes, the commissioned value and an internal hardware reference capacitor (to account for long term drift and temperature variations).

Both probes have a self-checking feature for mechanical and electrical integrity. The commissioned levels by the capacitance probes have an accuracy of ± 2mm repeatability.

The patented movement detection of water feature ensures that no static value can be accepted, i.e. the probes are in turbulent water.

The swell management feature prevents intermittent shutdowns from the 1st low being switching due to increases in steam requirements. The Autoflame Micro-Modulation (M.M.) module knows the firing rate and boiler pressure, and accommodates for this transient condition by increasing the 'control point' level.

The commissioning procedure for water level control, with a Mk7 M.M. unit and Mk7 Expansion Board, is extremely time-efficient and can be performed at operating pressure.

It is ideal to maintain an amount of water in the boiler appropriate to the amount of steam being generated. Should the water level drop below this ideal level by an excessive amount, it is necessary to stop the burner firing. If there is insufficient water in the boiler damage may occur to its structure.

In extreme cases there is the potential for the boiler to explode. The water level control herein is designed to maintain a satisfactory level of water in the boiler, whilst controlling and reporting low water level conditions.

These are the main water levels:

- High Water:

A high water level, although not dangerous is undesirable as water may infiltrate the steam header. If the boiler water level goes above this point the burner may or may not continue to run depending on the system configuration. If a high water level condition is detected high water audible and visual indicators are activated to notify the user. The audible indicator may be muted by means of the mute/reset push button.

- Pre High

A pre high level, is a pre warning before the water level reaches the high level. A visible alarm is shown. The alarm will reset once the water level is below the commissioned value.

- Control Point:

Ideal water level regulation point. There are no audible or visual indicators active.

- Pre Low

A pre low level, is a pre warning before the water level reaches 1st low. An audible and visual alarm is indicated. The alarm can be muted via the mute/reset button. The burner will not turn off; alarms will be reset once the water level is above the commissioned value.

- 1st Low:

A 1st low water level is a point below the control point at which the burner will turn off. If the water level falls below this point 1st low audible and visual indicators are activated. The audible indicator may be muted by means of the mute/reset push button. If the water level is restored above this point the burner will start automatically and all indicators will also be reset.

- 2nd Low:

A 2nd low water level is a point below 1st low at which the burner will remain off. If the water level falls below this point 2nd low audible and visual indicators are activated. The audible indicator may be muted by means of the mute/reset push button. Even if the water level is restored above this point the burner will remain off. Operator intervention is required to manually reset the system and can only be performed once the level is above the 2nd low point. The 2nd low reset condition is non-volatile - if the system is powered down the reset condition will remain when power is reapplied. In this scenario the operator reset will still be necessary.

- End of probe:

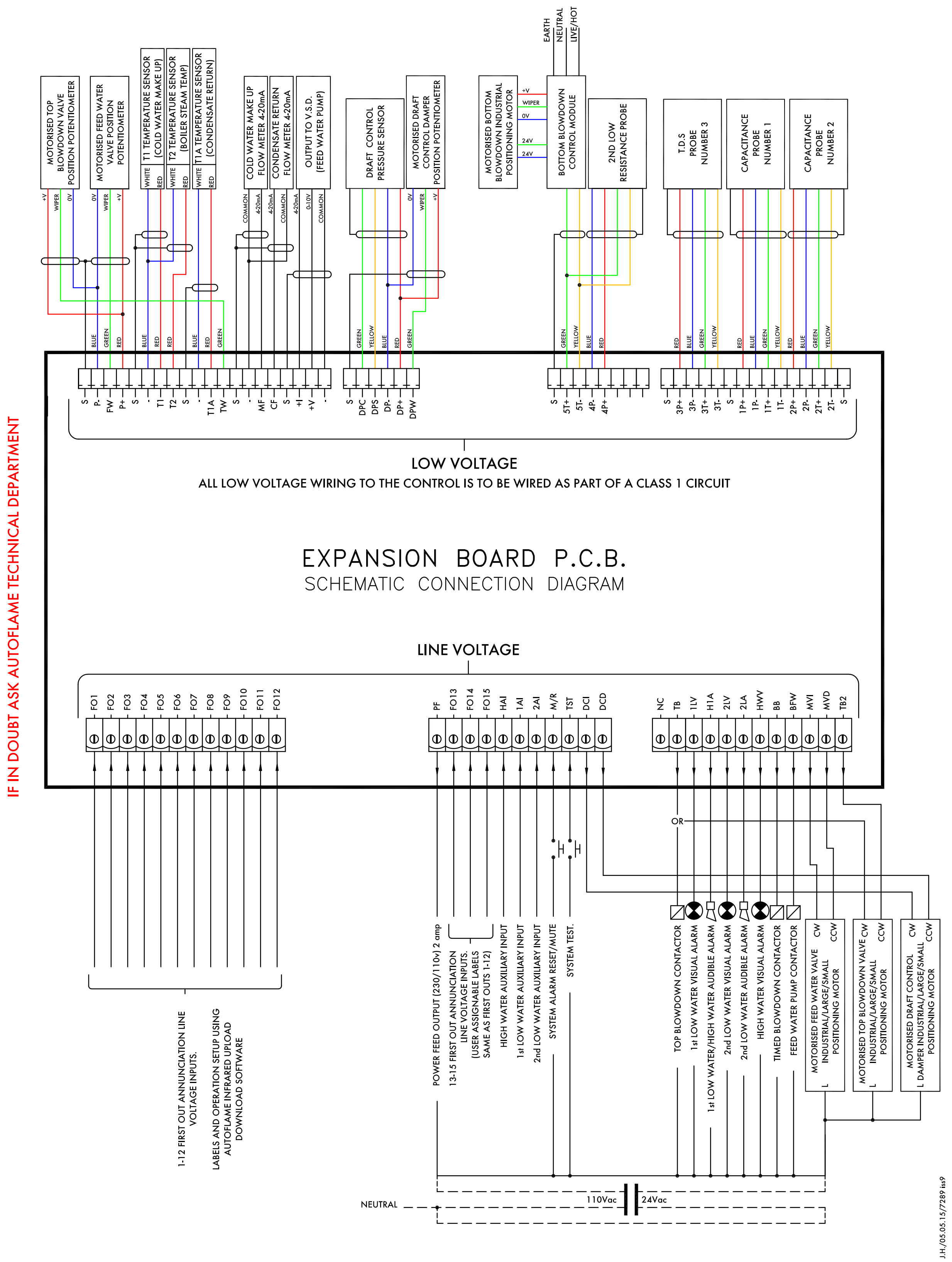
The end of probe level is used to identify the point below which the probe cannot obtain a valid water level, it has no operational use.

Figure 1.2.i Capacitance Probe

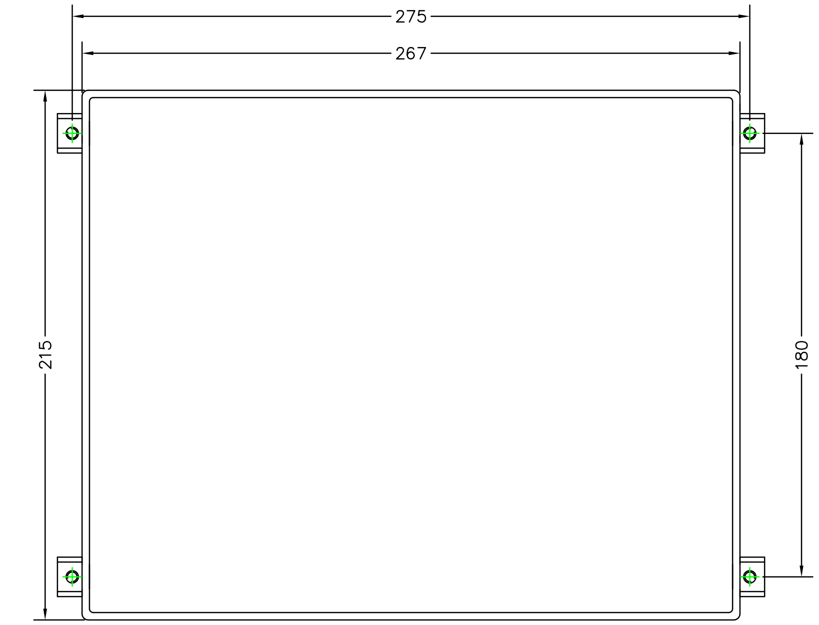
2 SET-UP

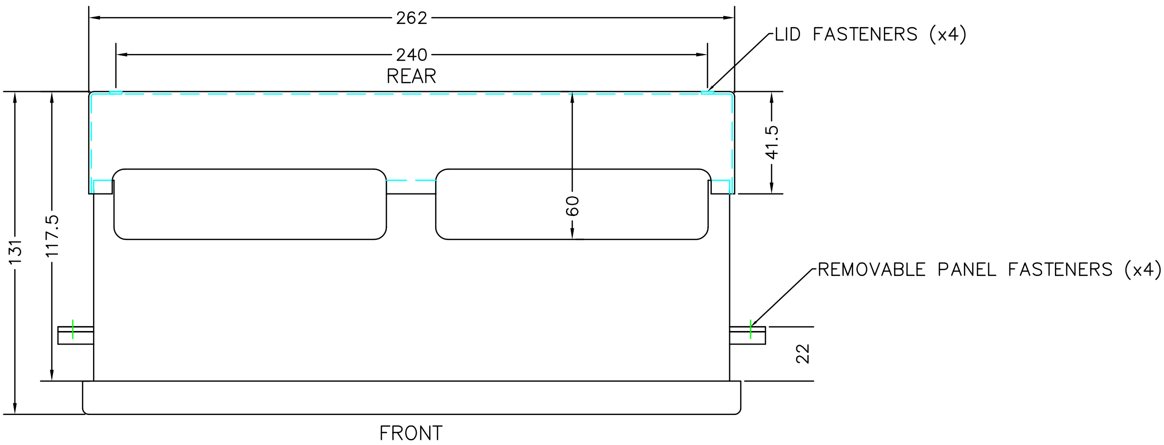
2.1 Expansion Board Wiring and Dimensions

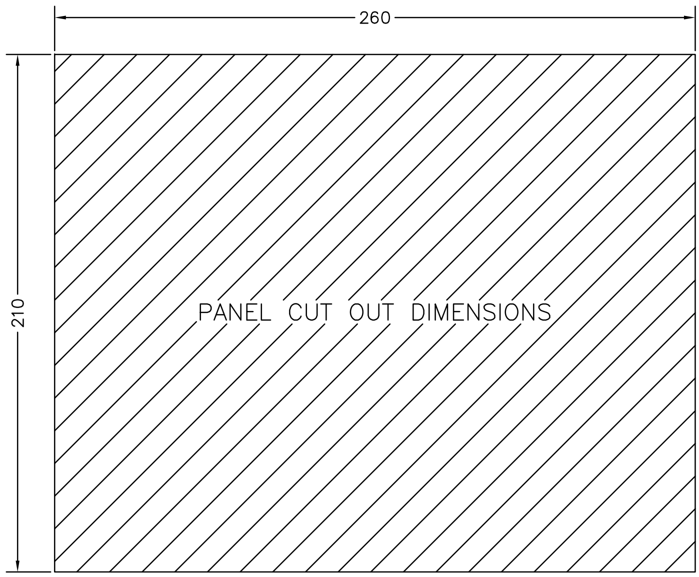
2.1.1 Wiring Diagram



2.1.2 Dimensions







2.1.3 Terminals Description

Note that all the "-" & P- terminals on the low voltage connection strip are common to each other, All of the circuitry associated with this terminal strip (analogue inputs and outputs) is isolated from earth potential (i.e. floating). If a VSD is used that has isolated input signal circuitry, link one of the "-" terminals to an S terminal (e.g. between P- and the adjacent S terminal to its left). If using a VSD and the VSD signal input circuitry is earthed, do NOT install a link.

ALL TERMINALS MARKED "S" ARE CONNECTED TO MAINS EARTH TERMINAL 66 ON THE MK7 M.M. AND ARE ONLY FOR CONNECTION TO CABLE SCREENS

Terminal Block 1

P- Top Blowdown and Feed water valve position potentiometer

FW Feed water valve position potentiometer

P+ Top Blowdown and Feed water valve position potentiometer

\- Cold water make up and boiler steam temperature sensor

T1 Cold water make up temperature sensor

T2 Boiler steam temperature sensor

\- Condensate return temperature sensor

T1A Condensate return temperature sensor

TW Top Blowdown valve position potentiometer

\- Cold water make up and condensate return flow meter

MF Cold water make up flow meter

CF Condensate return flow meter

I+ Feed water VSD output

V+ Feed water VSD output

\- Feed water VSD output

Terminal Block 2

DPC Connections solely dedicated to the Autoflame draft pressure sensor

DPS Connections solely dedicated to the Autoflame draft pressure sensor

DP- Draft pressure sensor & motorised draft control damper voltage –ve

DP+ Draft pressure sensor & motorised draft control damper voltage +ve

DPW Motorised draft control damper potentiometer wiper

Terminal Block 3

5T+ Bottom blowdown control module & 2nd low resistance probe data

5T- Bottom blowdown control module & 2nd low resistance probe data connection

4P- Connections solely dedicated to the Autoflame 2nd low probe

4P+ Connections solely dedicated to the Autoflame 2nd low probe

Terminal Block 4

3P+ Connections solely dedicated to the Autoflame T.D.S. probe

3P- Connections solely dedicated to the Autoflame T.D.S. probe

3T+ Connections solely dedicated to the Autoflame T.D.S. probe

3T- Connections solely dedicated to the Autoflame T.D.S. probe

1P+ Connections solely dedicated to the Autoflame control probe 1

1P- Connections solely dedicated to the Autoflame control probe 1

1T+ Connections solely dedicated to the Autoflame control probe 1

1T- Connections solely dedicated to the Autoflame control probe 1

2P+ Connections solely dedicated to the Autoflame control probe 2

2P- Connections solely dedicated to the Autoflame control probe 2

2T+ Connections solely dedicated to the Autoflame control probe 2

2T- Connections solely dedicated to the Autoflame control probe 2

Terminal Block 5

FO1 First Out annunciation input 1

FO2 First Out annunciation input 2

FO3 First Out annunciation input 3

FO4 First Out annunciation input 4

FO5 First Out annunciation input 5

FO6 First Out annunciation input 6

FO7 First Out annunciation input 7

FO8 First Out annunciation input 8

FO9 First Out annunciation input 9

F10 First Out annunciation input 10

F11 First Out annunciation input 11

F12 First Out annunciation input 12

Terminal Block 6

PF	Power Feed
FO13	First Out annunciation input 13
FO14	First Out annunciation input 14
FO15	First Out annunciation input 15
HAI	High water auxiliary input (Only available with Autoflame Water Level Control)
1AI	1st low auxiliary input (Only available with Autoflame Water Level Control)
2AI	2nd low auxiliary input (Only available with Autoflame Water Level Control)
M/R	System alarm reset/mute
TST	System test
DCI	Motorised draft control damper positioning motor – increase (output switched neutral)
DCD	Motorised draft control damper positioning motor – decrease (output switched neutral)

Terminal Block 7

NC	No connection
TB	Top Blowdown Contactor/ Motorised top blowdown valve positioning motor – increase
1LV	1st Low visual alarm
H1A	1st Low/ High water audible alarm
2LV	2nd Low visual alarm
2LA	2nd Low audible alarm
HWV	High water visual alarm
BB	Time blowdown contactor
BFW	Feed water pump contactor
MVI	Motorised feed water valve positioning motor – increase (output switched neutral)
MVD	Motorised feed water valve positioning motor – decrease (output switched neutral)
TB2	Motorised top blowdown valve positioning motor – decrease

2.1.4 Electrical Specification

Classifications

Outputs:	110/230 V	All outputs with the exception of PF are switched neutrals
MVD	1.5A	
MVI	1.5A	
BFW	250mA	Must be connected through contactor
BB	250mA	Must be connected through contactor
HWV	100mA	(alarm indicator)
2LA	100mA	(alarm indicator)
2LV	100mA	(alarm indicator)
H1A	100mA	(alarm indicator)
1LV	100mA	(alarm indicator)
TB	500mA	Must be connected through contactor when used with a solenoid valve
TB2	500mA	
DCI	500mA	
DCD	500mA	
PF	Maximum 2A	(load currents for above terminals)

Note MVD MVI only one output switched at a time.
Max number of alarm indicators on at any time is 3 (1LV, 2LA, 2LV)
Use 4-core screened cable to connect capacitance probes.

Main Voltage Signal Inputs

At 120V Current Loading Approximately 0.6mA
At 230V Current Loading Approximately 1.15mA

Refer to Mk7 M.M. Electrical Specifications in Mk7 Manual Vol 1: M.M. Installation and Commissioning Guide for other general ratings.

The Autoflame water level PCB has one main fuse located next to the PF Terminal. It is a 2A (T) Fuse.

When upgrading or replacing an existing older version water level board to the current expansion board, you can use the existing water level software or the latest expansion board software.

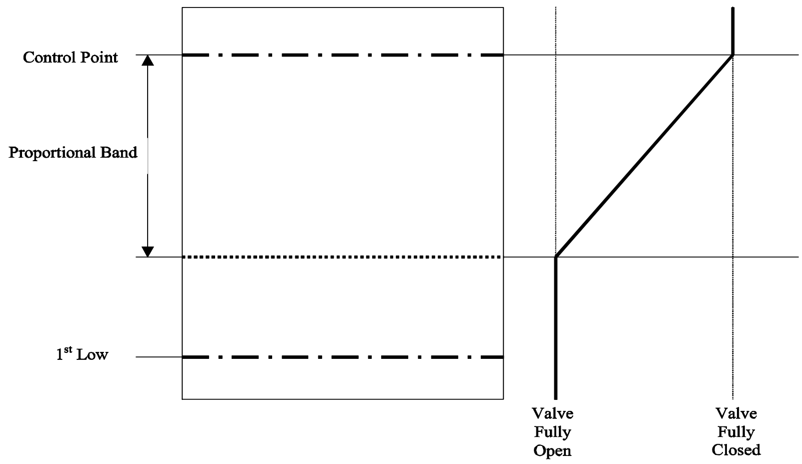
Note: If you use the existing water level software, you will not get the new additional features of the expansion board. Please contact Autoflame Technical Support.

2.2 Options

The expansion options can be changed by going to the Commission screen, entering the password and pressing on Expansion Options. These expansion options will need to be configured before commissioning the water level probes.

To go into the additional water level set-ups, set M.M. parameter 109 to 1.

Exp. Option	Factory Setting	Value	Description
1.1	**Disabled**		**Control Type:** Configures the boiler feedwater type.
		Modulating Standard	Boiler feedwater is fitted with a motorised valve or variable speed drive capable of adjusting the feed water flow rate. This technique uses PID contrrol to position the feed water valve to match demand.
		On/ Off	Boiler feedwater has no variable flow adjustment and only provides on/off pump control through hyster Using this configuration requires "pump on" and pump off" levels to be set during commissioning. Wher operating, the feedwater pump will continue to remain ON until the "pump off" point is reached.
		Modulating High High	As modulating standard with additional 'High High' Water position. Boiler feedwater output turns OFF when water level reaches High High water position. Boiler feedwater turns ON when water level falls tc the operating level position.
		Modulating Pre-alarms	As modulating standard with two additional pre-alarms. These include a 1st low pre-alarm and a high water pre-alarm. If the water level reaches the pre-alarm levels then the burner will continue to fire. A pulsed audible alarm will become active. The operator can mute this alarm by pressing the water level button in the Mk6 mode screen. The visual alarm will still be displayed until the fault condition has cleared when the water level reaches the operating level.
		Disabled	This option disables Autoflame water level control.
2.1	**Modulating Ball Valve**		**Feedwater control element:** Required for display purposes.
		Modulating Ball Valve	Autoflame motorised ball valve
		VSD	AC Variable Speed Drive
		General	On/Off control Valve
3.1	**50%**		**Proportional Band:** When using PID, the controller output is proportional to the error between the current water level and the required operating level. This setup represents a percentage of the total ban between 1st low and the control point used to proportion the output.
		5% - 100%	



Exp. Option	Factory Setting	Value	Description
4.1	**20**		**Integral Time:** This is used to set a period of time 'n' for integral action. At these intervals a percentage (See Integral Factor) of the present offset from the control point variable is added or subtracted to the present proportional value. If configured as OFF no integral action is performed. This only applies for modulating control.
		0	OFF
		1 - 100	Seconds

Exp. Option	Factory Setting	Value	Description
4.2	0.10	 1 - 50	**Integral Factor:** This expansion option is used to set the percentage of the present offset from the cont point variable to be added or subtracted from the present proportional value. This only applies for modulating control. See also expansion options 3.1 and 4.1. % (Increments of 0.01)
5.1	OFF	 0 1 - 100	**Derivative Time:** With derivative action, the controller output is proportional to the rate of change of water level. This expansion option controls the time interval between the controller comparing the currer water level and the required water level points. If configured as OFF no derivative action is performed. This only applies modulating control. See also expansion options 5.2 and 5.3. OFF Seconds
5.2	10%	 1 - 50	**Derivative Deadband:** This expansion option is used to configure the margin above and below the required level within which there is no derivative action. This only applies for modulating control. See also expansion options 5.1 and 5.3. %
5.3	10%	 1 - 50	**Derivative Response Sensitivity:** This expansion option indicates the percentage of feedwater incre or decrease that is inflicted by the derivative action. This only applies for modulating control. See also expansion options 5.1 and 5.2. %
6.1	152	 50 - 4050	**Potentiometer Close Position:** Servomotor potentiometer feedback at close position. This is only required when configured for use with a motorized valve. See expansion option 6.2.
6.2	2432		**Potentiometer Open Position:** Servomotor potentiometer feedback at open position. This is only required when configured for use with a motorized valve. See expansion option 6.1.
7.1	3	 0 1 - 60	**Sudden Pressure Change - Time Between Readings:** Period of seconds over which the change o pressure is tested. OFF Seconds
7.2	1.5	 1 - 50	**Sudden Pressure Change - Delta Pressure (and clear band):** Amount of pressure drop over tim (specified in expansion option 7.1) that must occur for raised control point to be triggered. (Increments of 0.1)
7.3	1	 0 1 2 3	**Sudden Pressure Change - Percent Increase Slider:** Water level control point percent increase scale. Percentage of distance between control point and High water. 0% 25% 50% 75%
7.4	1.0	 5 - 100	**Sudden Pressure Drop- Pressure Slider:** Pressure scale - offset from Required value. (Increments of 0.1)
8.1	RUNS	 RUNS STOPS	**Burner Operation at High Water:** Sets whether the boiler should continue to run or stop when a hi water condition exists.
9.1	1.00%	 0 - 2.00	**Boiler Standing Losses:** Percentage of boiler Maximum Continuous Rating, for the purpose of steam flow metering only. % (Increments of 0.1)

Exp. Option	Factory Setting	Value	Description
10.1	**1.0%**	0 - 10.0	**Boiler Blow Down Losses:** Percentage of boiler Maximum Continuous Rating, for the purpose of steam flow metering only. % (Increments of 0.1)
10.2	**Constant**	Constant Proportion	**Boiler Blow Down Loss Calculation Method:** Fixed loss rate Loss rate proportioned to firing rate
11.1	**30%**	0 - 100	**Pump Turn Off Point:** When the water level increases above the control point the pump can be set to turn off at the point selected by this expansion option. The point is the percentage distance between the working control point and high water. This only applies when modulating control type is configured. %
12.1	**Enabled**	Enabled Disabled	**External Alarm Inputs:** If enabled the auxiliary mains voltage terminals for 2nd LOW, 1st LOW & HIGH WATER are brought into effect. These operate in addition to the two capacitance probes.
20.1	**10.0**	1-9999	**Make Up Flow Range:** Only relevant if deaerator feedwater method in use. Set value that represent flow at 20mA - Gallons per Minutes if Imperial Units, Litres per Second if Metric. (4mA represents zero f (Increments of 0.1)
20.2	**10.0**	1-9999	**Condensate Flow Range:** Only relevant if deaerator feedwater method in use. Set value that repres flow at 20mA - Gallons per Minutes if Imperial Units, Litres per Second if Metric. (4mA is zero flow). (Increments of 0.1)
21.1	**80 deg F** **27 deg C**	32 - 300 0 - 149	**Default Feedwater Temperature:** Feedwater temperature value used if Feedwater Temperature sensor(s) not fitted. Displayed as degF or degC according to Units set (M.M. Option 65). deg F deg C
22.1	**0**	0 1 2 3 4	**TB Output Function:** TDS Top Blowdown Feed water Relief - Above Switch Point Feed water Relief - Below Switch Point TDS Continuous Blowdown TDS Valve Open/Close Only
22.2	**20**	1 - 80	**TB Output Function - Switch Point:** (only relevant if expansion option 22.1 = 1 or 2) Feed water Relief Function - Switch Point (TB Output)
22.3	**10**	1 - 50	**TB Output Function - Switch Point Hysteresis:** (only relevant if expansion option 22.1 = 1 or 2) If 22.1 = 1 the TB output switches ON when the modulating value angle becomes greater than the switc point (22.2). The TB output switches OFF when the modulating value angle becomes less than the switch point minus the hysteresis amount (i.e. 22.2 minus 22.3). If 22.1 = 2 the TB output switches ON when th modulating value angle becomes less than the switch point (22.2). The TB output switches OFF when the modulating value angle becomes more than the switch point plus the hysteresis amount (i.e. 22.2 plus 22.3). In either case ensure the values entered are rational - i.e. in the case of a valve the ON/OFF poir are between 1 to 89 degrees.
23.1	**Disabled**	0 1	**Top Blowdown Management Operation:** If enabled the Top BlowDown Management screen will be displayed when appropriate - see Expansion Board Set-Up Guide. Expansion Option 22.1 must be set to 0, 3 or 4 so the TB output terminal performs the Top Blow Down function, or TB and TB2 perform t TDS Continuous Blowdown. Disabled Enabled

Exp. Option	Factory Setting	Value	Description
24.1	**Type 4**		**Expansion PCB Type: (N.B. These are approximate ranges only).**
		Type 1	First issue Water Level PCB (S/N <100)
		Type 2	Second Issue Water Level PCB - includes Top Blow Down & Deaerator facilities (S/N 100 - 1000)
		Type 3	Third Issue Water Level PCB - Rev1 - 7027 (S/N 1000 - 2000)
		Type 4	Fourth Issue Expansion PCB Rev2 - 7027 (S/N >2000)
25.1	**300**		**Test time to 1st low**
		30 - 600	Seconds
25.2	**300**		**Test time to 2nd low**
		30 - 600	Seconds
26.1	**75**		**Continuous Blowdown Proportional Band:** When using PID, the controller output is proportional to the error between the current TDS level and the required operating level. This only applies when TDS Continuous Blowdown is configured.
		0 - 100	%
27.1	**600**		**Continuous Blowdown Integral Time:** This expansion option is used to set a period of time 'n' for integral action. At these intervals a percentage (See Continuous Blowdown Integral Factor) of the prese offset from the TDS control point variable is added or subtracted to the present proportional value. Only applies when TDS Continuous Blowdown is configured.
		1 - 1000	Seconds
29.1	**5**		**Continuous Blowdown - Derivative time:** With derivative action, the controller output is proportio to the rate of change of the TDS level. This option sets the time interval between the controller comparin the current TDS level and the required TDS. Only applies when TDS Continuous Blowdown is configured
		1 - 1000	Seconds
32.1	**152**		**Continuous Blowdown - Potentiometer Close Position:** Servo potentiometer feedback at close position. This is only required when configured for use with a motorized valve. See also expansion option 33.1.
		50 - 4050	
33.1	**2432**		**Continuous Blowdown - Potentiometer Open Position:** Servo potentiometer feedback at open position. This is only required when configured for use with a motorized valve. See also expansion option 32.1.
		50 - 4050	
36.1	**0**		**Bottom Blowdown Operation**
		0	Disabled
		1	Old Style
		2	New Style
		3	New Style with Manual Trigger
36.2	**0**		**Bottom Blowdown Reduction Enable**
		0	Disabled
		1	Enabled, Minimum Blowdown Enforced
		2	Enabled, Minimum Blowdown Not Enforced
36.3	**0**		**Minimum Bottom Blowdown Time**
		0 - 60	Seconds
36.4	**0**		**Boiler Steam Production Rating** (units are set through M.M. option 77)
		0 - 1000	
37.1	**0**		**Second Low Probe Enable/Disable**
		0	Disabled
		1	Enabled

Exp. Option	Factory Setting	Value	Description
38.1	**0**		**Temperature Sensor Configuration - Steam or Heat Flow**
		0	**Disabled:** No Sensors
		1	**Steam Flow Using Default Values:** No Sensors
		2	**Steam Flow:** T1 Feed Water Sensor
		3	**Steam Flow with Economiser:** T1 Feed Water Sensor, T1A Make Up (After Economiser), T2 Make Up (Before Economiser)
		4	**Steam Flow with Deaerator:** T1 Make Up, T1A Condensate Return
		5	**Steam Flow with Deaerator and Economiser:** T1 Make Up (After Economiser), T1A Condensate Return, T2 Make Up (Before Economiser)
		6	**Steam Flow with Deaerator and Feed Sensor:** T1 Make Up, T1A Condensate Return, T2 Deaerator Output
		7	**Heat Flow using Default Values:** No Sensors
		8	**Heat Flow:** T1 Return
		9	**Heat Flow with Economiser:** T1 Return (After Economiser), T2 Return (Before Economiser)
40.1	**0**		**Draft Control - Enable:**
		0	Disable
		1	Enable
40.2	**1**		**Draft Control - Pressure Sensor:**
		1	0 - 1 PSI Pressure Sensor MM70005
40.3	**15**		**Draft Control - Minimum Baffle Angle Limit:** The smallest angle that the stack damper will drive to during any stage of operation. This is not the closed 0.0 angular position entered during commissioning.
		0 - 45	Degrees
40.4	**5**		**Draft Control - Delay Before Compensation:** The delay after the main flame is established before draft control operation commences. This is also the time set for the deactivation window, where the M.M must not see a change of the value set in expansion option 40.5 in this time for the PI to stop modulation and carry forward trim operates.
		5 - 30	Seconds
40.5	**10**		**Draft Control - Firing Compensation Deactivation Window:** If the offset from the commissioned draft servomotor angle set in this option is breached over the time period set in expansion option 40.4, PI stops modulations, and carry forward trim operates.
		0 - 60	Degrees
40.6	**1**		**Draft Control - Maximum Compensation:** This is the maximum trim forwards or backwards which the stack damper can move, during trim operation. If this is set to 10%, the stack damper can move to a maximum of 10% of the commissioned draft servomotor position, backwards and forwards.
		0	10%
		1	15%
		2	20%
40.7	**0**		**Action on Pressure Sensor Failure:** This sets whether the burner will lockout or the stack damper will go to its commissioned positions along the curve, should the draft air pressure sensor fail.
		0	Lockout
		1	Revert to commissioned curve
40.8	**0**		**Pressure Tolerance Before Fault:** This is the maximum allowable pressure change from commission draft air pressure values over 2 minutes before an error message is displayed on the screen.
		0 - 50	PSI (0.0 - 5.0 Bar)

Exp. Option	Factory Setting	Value	Description
41.1	**200**		**Draft Control P Multiplier** The P Multiplier % is used to calculate the P Value; the P value is used together with the I Value calculate from expansion option 41.2 to give a PI Total which determines the angle the draft servomotor moves tc during trim operation. The P value is the product of the present offset from the commissioned pressure (pressure error) and the P Multiplier %. Larger P Multipliers cause a larger movment in the damper for c pressure. Too large a P Multiplier can cause the system to overreact to small changes in the system.
		1 - 10,000	% (0.01) of Pressure Sensor Range e.g. 200 = 2.00%
41.2	**5**		**Draft Control I Multiplier** The calculated P Value (pressure error multiplied by the P Multiplier%) is multiplied by the I Multiplier % to give the I Value. This I Value is added to a running total of I Values. The amount of damper movemen is controlled by the sum of the most recent P Value and the running total of I Values. The running total o I Values is updated every 'n' seconds (set in expansion option 41.3). As the pressure approaches the commissioned value the P Value becomes progressively smaller, resulting in smaller changes to the I Tot
		1 - 250	% (0.01) e.g. 5 = 5.00%
41.3	**5**		**Draft Control I Timer:** This is the time between each I value update.
		1 - 30	Seconds
41.4	**15**		**Draft Pressure Filter Time:** The draft pressure filter time filters the pressure readings over this time se this option. Increase this value to remove excessive fluctuation in draft pressure reading. Decrease this value to improve the pressure sensor's responsiveness.
		1 - 60	Seconds
42.1	**0**		**Enable TDS and Feedwater Servo Checks**
		0	Feedwater and TDS Servo checks do not operate
		1	Feedwater and TDS Servo checks operate manually

Exp. Option	Factory Setting	Value	Description
A.1	10	1 - 20	**Probe Filtering Time:** Every second each probe takes 10 readings. This is then averaged over the value set in this expansion option. Seconds
B.1	5	1 - 100	**Control Element Update Time:** This is how often the modulating feedwater valve will be moved in response to variations in the water level. Seconds
C.1	2.0%	0 1 - 200	**Control Point Deadband:** No modulation occurs within this deadband. Off 0.1 - 20.0% (Increments of 0.1)
D.1	5	1 - 10	**Peak to Peak Sampling Period:** Highest/ lowest. Seconds
D.2	1	1 - 20	**Peak to Peak Update Time:** Seconds
E.1	1500	0 - 2000	**Minimum Mismatch:** Probe 1 is used as the reference based on the commissioing data. This probe assesses the value of probe 2 to establish if there is a mismatch present (outside this set value). Mismatch is a serious problem and is safety critical. If a probe mismatch occurs the probes may need cleaning. Hz (1500Hz = 3" or 75mm)
E.2	0	0 - 2000	**Maximum Mismatch:** Hz
E.3	1.5	10 - 100	**Mismatch Multiplier:** 1.0 - 10.0 (Increments of 0.1)
E.4	30	1 - 200	**Mismatch Time:** If the mismatch exceeds 30 seconds then the system will shut down. If the value of probe 2 moves back inside the 1500 window then this timer is reset. 1st low takes priority over mistmatch. Seconds
F.1	0.5	0 - 25	**Turbulence Factor:** The value set in this expansion option corresponds to the predicted water level. 0.0 - 2.5 (Increments of 0.1)
G.1	0	0 - 100	**Expansion Offset:** %
G.2	10	0 - 50	**Expansion Turbulence Time:** Seconds
G.3	10	1 - 100	**Expansion Turbulence Amount:**
H.1	1	0 1	**Control Point Method:** Probe 1: Works off the readings from probe 1 only - checks are still made between both probes. Averaged: Averages the data between both probes.
J.1	1	0 1 - 100	**Detect Turbulence Level:** Disabled mm. Non-movement detection: If the water is still, the frequency will drop below 10Hz and a fault occurs.
J.2	10	1 - 100	**Detect Turbulence Time:** Seconds Note: If expansion option J.1 is set to 0, then this function is disabled.

Exp. Option	Factory Setting	Value	Description
K.1	**0.5**	0 - 100	**Steam Flow Start Pressure Offset:** This is an offset of the required pressure. If within 5PSI of the required pressure, the system is deemed to be producing usable steam, so steam flow metering will commence. PSI. (0.0 - 10.0 Bar)
K.2	**0.5**	0 - 100	**Steam Flow Stop Pressure Offset:** This is an offset below the required pressure. If the pressure drops below 5 units, steam flow metering will stop. PSI (0.0 - 10.0 Bar)
L.1	**1000**	0 1 - 3000	**Maximum Probe Reference Drift:** Disabled Hz

2.3 Commissioning Water Level

2.3.1 Commissioning Procedure

When commissioning a burner with Autoflame water level cotnrol, the water level probes must be commissioned initially before the combustion curve is put in. Once the burner is commissioned with the Mk7 M.M., the water level probes will need to be recommissioned once the boiler is up to pressure, and water in the boiler is hot enough. If the water level control is optioned, the M.M. will be in error and cannot be commissioned until the probes have been set-up.

Prior to commissioning, follow the safety and installation checks in the Mk7 M.M. Installation and Commissioning Guide section 3.

Go into Commission mode when the system starts up and enter the password.

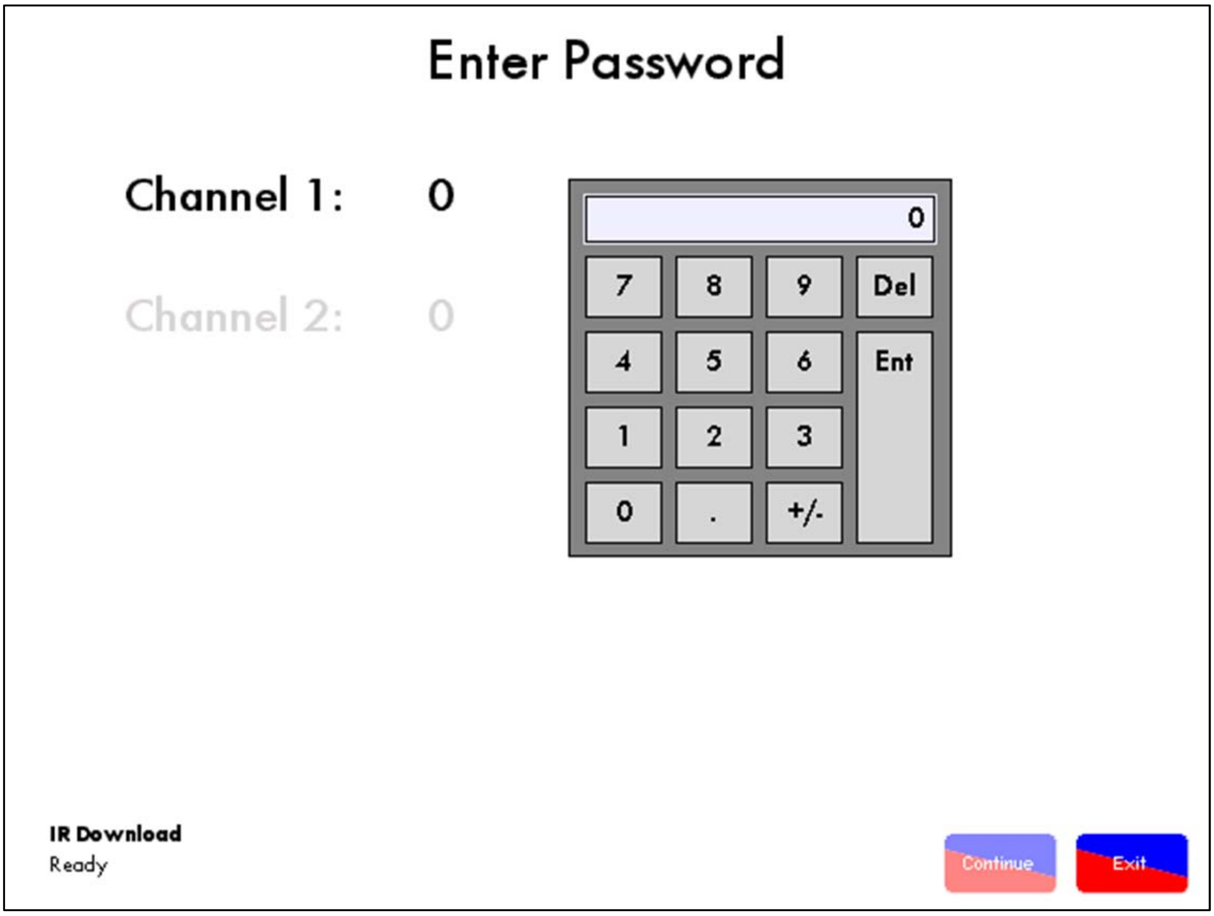


Figure 2.3.1.i Password Screen

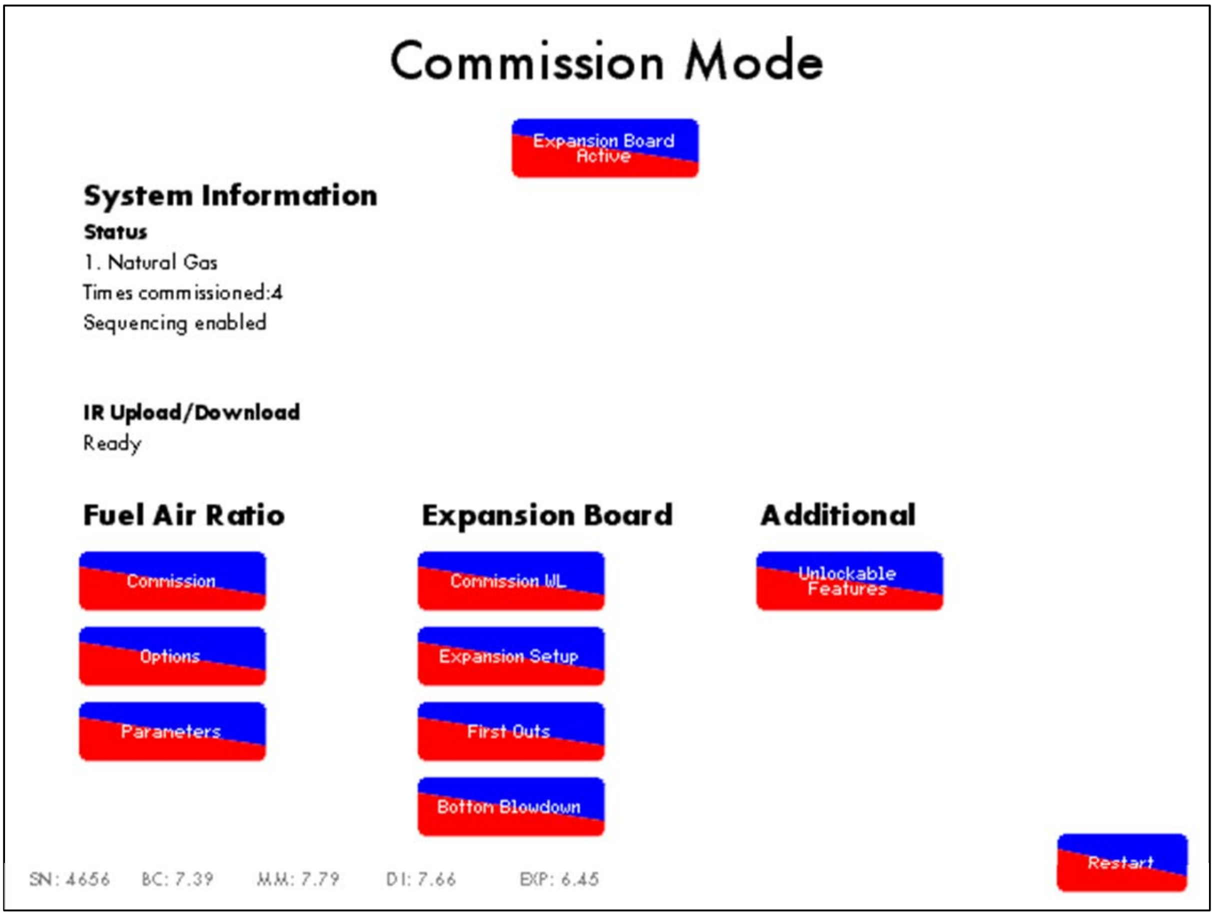


Figure 2.3.1.ii Commission Mode – Home Screen

Press the Disabled button and select 'Expansion Board Active' to activate the Expansion Board, and press 

to set the water level options, see section 2.2.

If any changes are made to the expansion options, restart the M.M. by pressing 

before continuing to commissioning.

Once the expansion setups have been set for the application, press 

to commission the water level probes. For commissioning the screen will be in Mk6 mode.

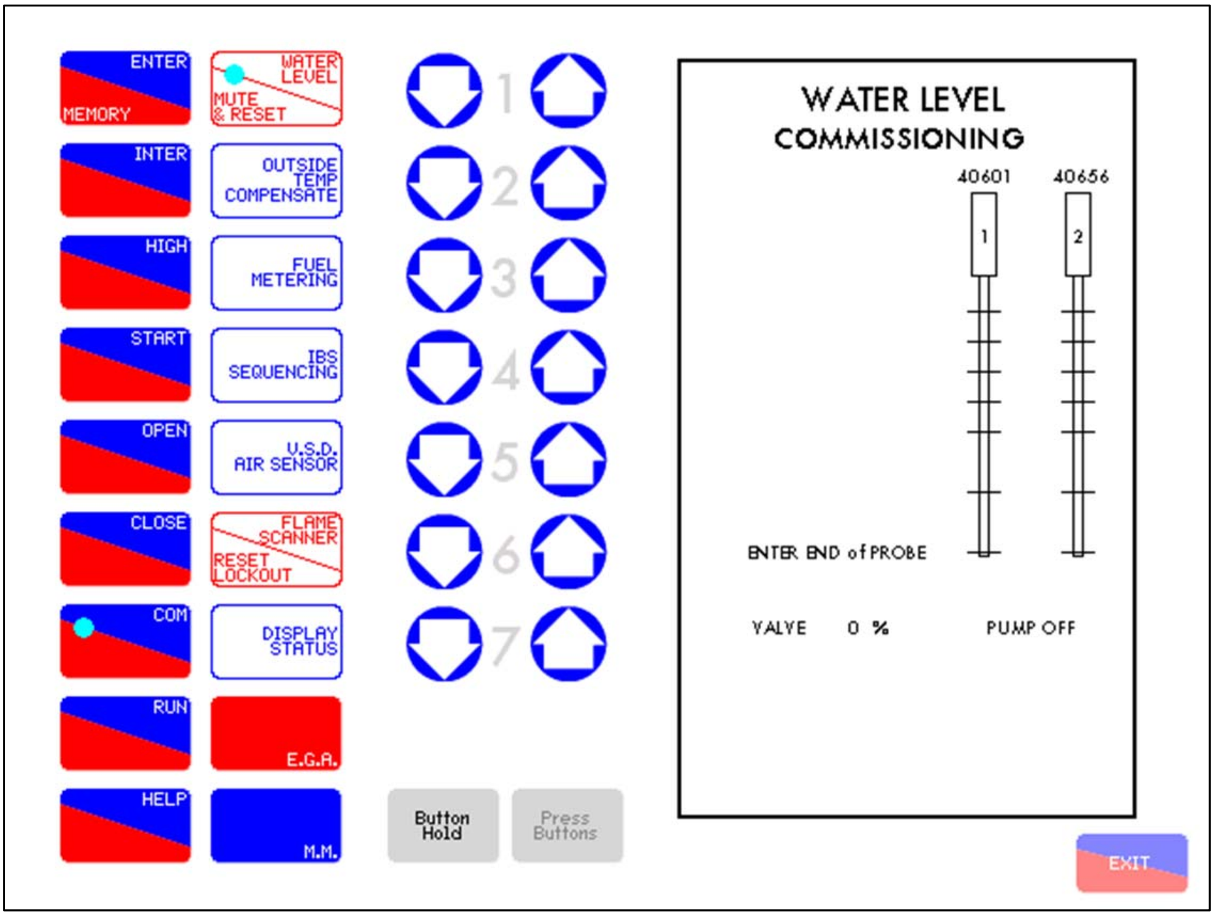


Figure 2.3.1.iii Commissioning Water Level Probes

Use CH2 (down) (up) to control the position of the feed water valve (if optioned) and CH1 to control pump operation (OFF (down) (up) ON).

The current position to be commissioned is indicated by a flashing message showing End of Probe. Increase the water level until it approaches the bottom of the probe. The End of Probe position should be entered as a minimum level of water in the boiler, indicated by the lowest water level visible in the site-glass. As the water level exceeds the end of the probe, the displayed probe values will begin to change. Once the desired point has been found, close the feed water valve and turn off the pump. After allowing some time for the values to settle, press [WATER LEVEL / MUTE & RESET] then [ENTER / MEMORY] to save that position for End of Probe.

Note: Each position must be greater than approximately 25mm (1") above the last stored value which equates to a minimum of 500Hz. We would recommend 800Hz between positions.

The display will then show '2nd Low' flashing. Increase the water level using CH1 and CH2. Once the desired point has been found, close the feed water valve and turn off the pump using CH1 and CH2. Again, after allowing some time for the values to stabilise, press [WATER LEVEL / MUTE & RESET] then [ENTER / MEMORY] to save the current water level.

Repeat these steps for the remaining water levels. The number of levels to be entered is dependent on the configuration of Expansion Options 1.1.

After entering the high position the RUN button will begin to flash. Before proceeding further, reduce the water level to the control point level. This will prevent the unit from registering a high water alarm immediately after the system has reset.

Once the capacitance probes have been commissioned, the water level operation must be checked for safety and alarms, then the burner can be commissioned and the probes re-commissioned when there is heat in the boiler.

2.3.2 Operational Checks

All local & national codes for safe operation of boiler plant must be respected. If in any doubt contact your local specialist authority.

Water level operation must be checked after commissioning or subsequent to modification of any setups. These operational checks are for boilers without a shunt switch, see section 5.6 for shunt switch.

Set the system to RUN mode and allow the burner to fire. With the boiler supplying steam at a steady rate check that the water level is maintained at the control point for modulating control. For on/off control, check that the boiler feed water pump turns on and off appropriately at the commissioned points. Ensure that all audible and visual alarm indicators are inactive.

Reduce the level of the water (by blow down or other suitable means). Check that a 1st low alarm occurs and the burner stops firing when the water level is just below the commissioned 1st low level.

Ensure that the 1st low audible and visual indicators are active. If fitted, press the external mute/reset button and check that the audible alarm is muted.

Reduce the level of the water further and check that the 2nd low alarm is displayed when the water level is just below the commissioned 2nd low level; the burner will remain off.

Ensure that the 2nd low audible and visual indicators are active. If fitted, press the external mute/reset button and check that the audible alarm is muted.

All 1st Low/2nd low alarm conditions must be cleared before proceeding to test the high water. To test high water it will be necessary to increase the water level to just above that of the commissioned high water position. If there is no means to manually increase the level of the water it is possible to select Water Level Commission mode and increase the level of the water manually. This can be performed by using the CH1 and CH2 controls. The unit can then be restarted by de-selecting and re-selecting the fuel. The unit will restart in RUN mode and should report a high water alarm. Check the burner operation runs or stops according to expansion option 8.1.

Ensure that the high water audible and visual indicators are active. If fitted, press the external mute/reset button to check that the audible alarm is muted.

Check the operation of the TB output terminal if using a contactor with solenoid valve.

Once the water level control has passed these operational checks, the burner can now be commissioned with a fuel to air curve, after which the probes are re-commissioned at boiler pressure.

2.4 First Outs Set-Up

When the control circuit has a long series chain of various thermostat and switching elements, it is sometimes difficult to identify which element has opened the control circuit.

It is possible to monitor a maximum of 15 different inputs in a series control circuit. Each input responds to a signal voltage of between 100V to 250Vac. The first element in the loop that changes state will alter from "normal" to "fail" as detailed above. This first out fail status will remain until reset.

To set First Outs in a Mk7 M.M. it is required to use the IR Upload/Download software to label the First Outs and specify what action is taken if a First Out fails.

First take a download of the M.M. On the IR Upload/Download software click the 'First Outs' tab bring up the First Outs screen shown in Figure 2.4.i.

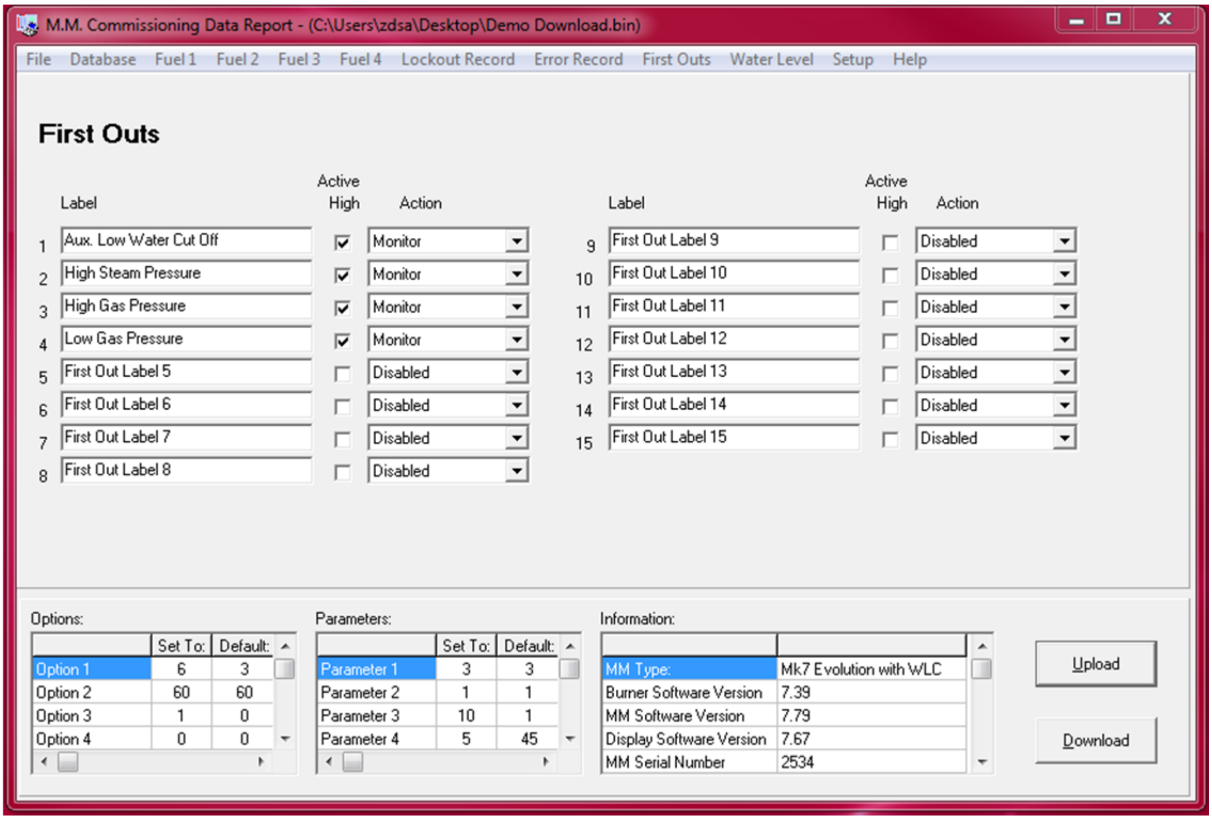


Figure 2.4.i First Outs IR UD Screen

From this screen it is possible to programme the First Outs to each systems needs and label each First Out individually.

To label a First Out just type in the description of what the First Out is into the 'Label' box. This label will appear on the First Out screen of the MM so that it is easy to see what First Out has failed. The Active High box is to define if a high voltage or a low voltage causes the First Out to fail; if the box is ticked, the M.M. will recognise the First Out as failing if there is a line voltage input into the relevant First Out terminal. If the box is un-ticked the M.M. will recognise the First Out as failing if there is no line voltage input to the relevant First Out terminal.

The Action box is to define what action the M.M. takes if the First Out fails.

Disabled – The First Out is disabled and the M.M. will not display the First Out or take any action if it fails.

Monitor – The First Out is only monitor, so the M.M. will display if the First Out if it fails but will not turn the burner off.

Recycle – If the First Out fails the M.M. will turn the burner off and the M.M. will turn the burner back on if the First Out is no longer failing with no manual reset required on the M.M.

Non–Recycle – If the First Out fails the M.M. will turn the burner off and the M.M. will not turn the burner back on until a manual reset has occurred on the M.M. even if the First Out is no longer failing.

When using First Out Annunciation with a Mk7 M.M. it is not always necessary to tie in switches to the burners run circuits as the Mk7 M.M. is fully capable of turning off the burner if the First Out has been set to Recycle or Non-Recycle. However, local codes may require some First Outs to be tied to the burner run circuit. In this instance it is good practice to tie in the First Out switches into Terminal 53 (Burner On/Off) as shown in the diagram below.

The reason for wiring the First Out Annunciation into Terminal 53 is because a break in this circuit will turn off the burner but will not cause a lockout on the M.M. Here, the First Out Annunciation will appear with what First Out has failed for better diagnosis of the problem. Wiring the First Out Annunciation into Terminal 54 (Air Proving Switch) for example, will cause the burner to turn off but the M.M. will lockout on having no air pressure rather than displaying the First Out that has failed.

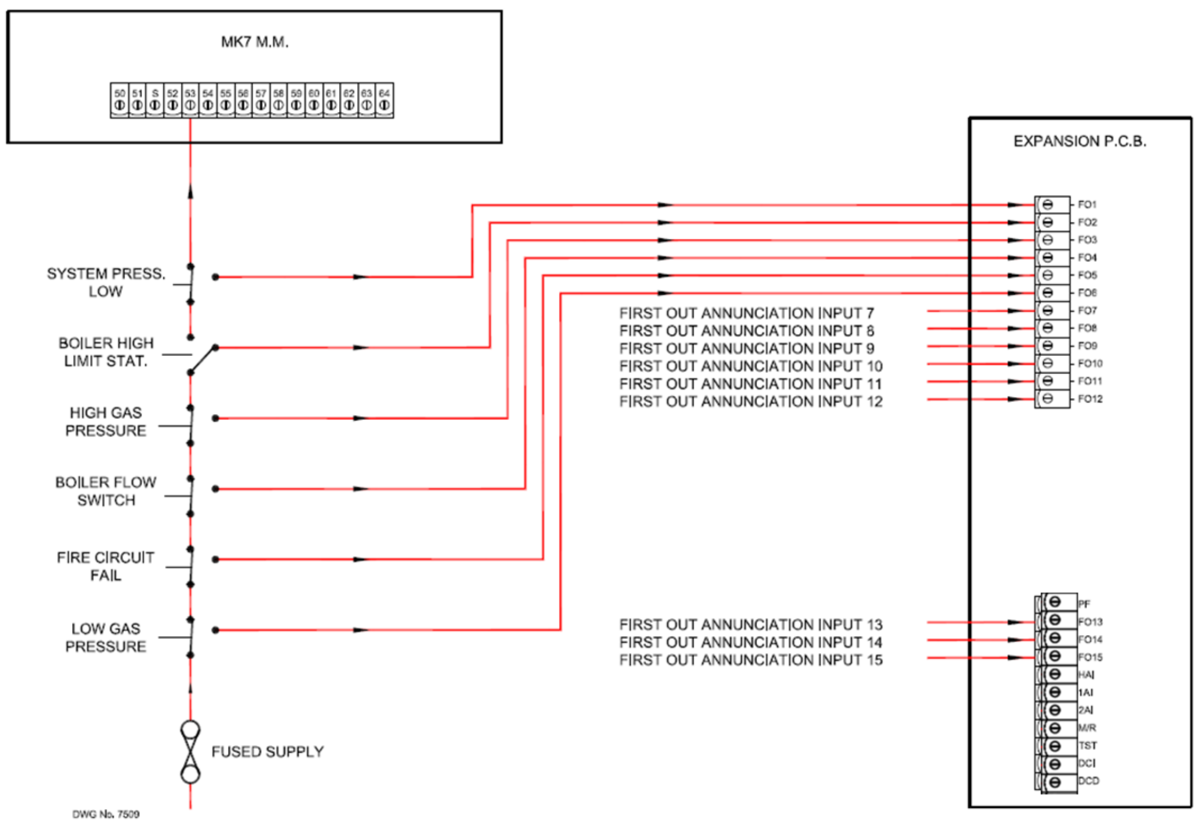


Figure 2.4.ii First Outs Wiring

2.5 Integrating Other Water Level Controls with Autoflame

It is possible to retain the site's existing float type level controls. Autoflame have allocated 3 terminals to accommodate "high", "1st low" and "2nd low". This is a user selectable facility which can be accessed by the expansion options. Shown below is the connection schematic which shows how this can be implemented if required.

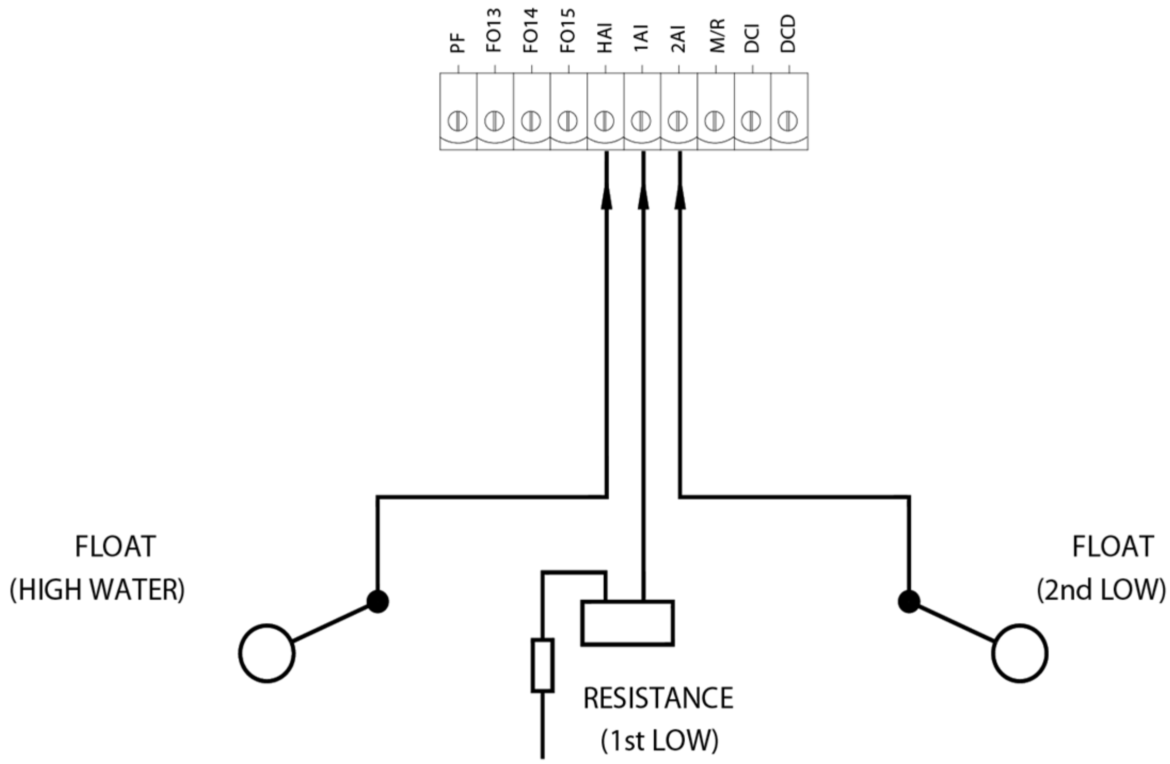


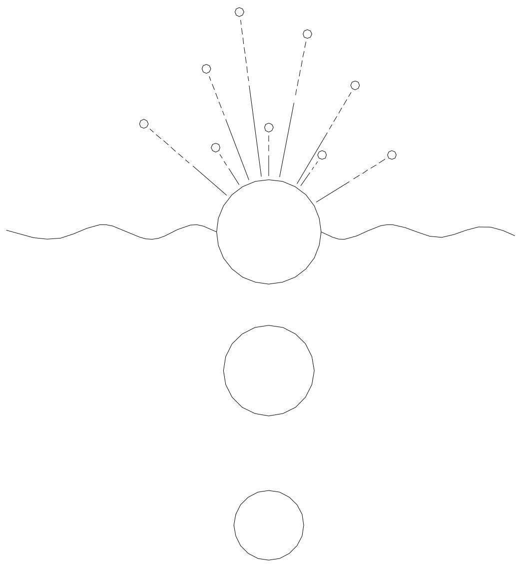
Figure 2.5.i External Water Level

Note: If any of the three inputs are not being used, a line voltage should be inputted to stop the unit alarming.

3 WATER LEVEL PROBES

3.1 Breaking Bubbles/Spray

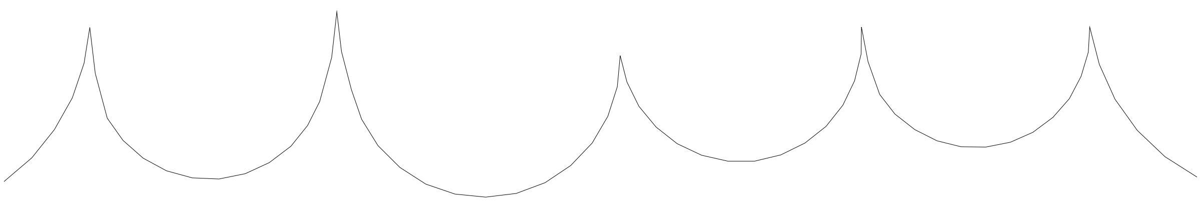
Breaking bubbles/spray refers to the bubbles of steam breaking at the boiler water level surface. These precipitate little droplets as spray several inches above the water surface in an upwards direction.



The droplets tend to coat the surface of the level probe which in turn will read as an increase in the water level. This situation is largely avoided by fitting anti surge pots inside the boiler shell. When the probes are fitted externally to the boiler shell this situation can not arise.

3.1.1 Thermal Currents (heat energy in water)

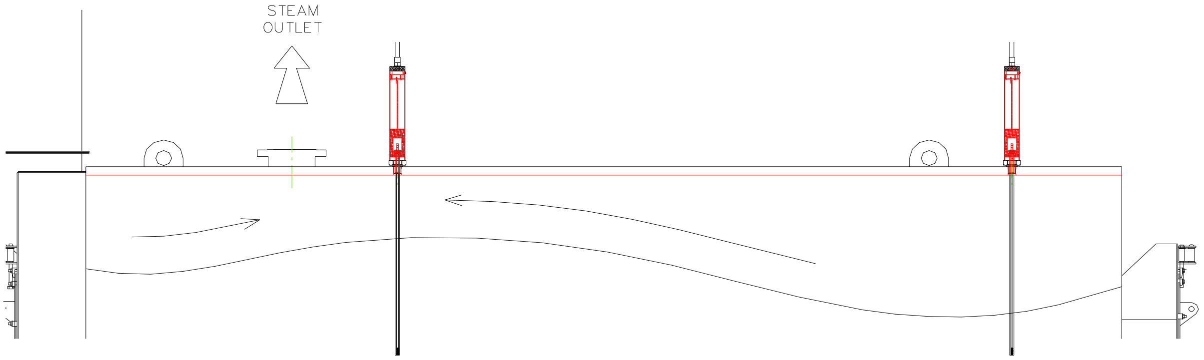
Many bubbles breaking simultaneously and thermal currents from the furnace tube and 2nd, 3rd, 4th pass smoke tube create their own turbulence/wave signature on the surface of the water. The typical result is short choppy/peaky wave patterns as below.



A second set of turbulence is the wave reflections off the sides of the boiler. The whole of the above is largely attenuated away by mounting the probes externally to the main boiler shell in a separate pot or pots.

3.1.2 Steam Flow Induced Surge

When the boiler is producing high quantities of steam, this steam travels over the surface and can produce swells and surging motions (long wave).



The above situation will be shown in high relief when the steam outlet is at one end of the boiler and one level probe is sited adjacent to the steam outlet and the second probe is sited at the opposite end of the boiler. The user adjustable probe disparity value may have to be increased to take this situation into account.

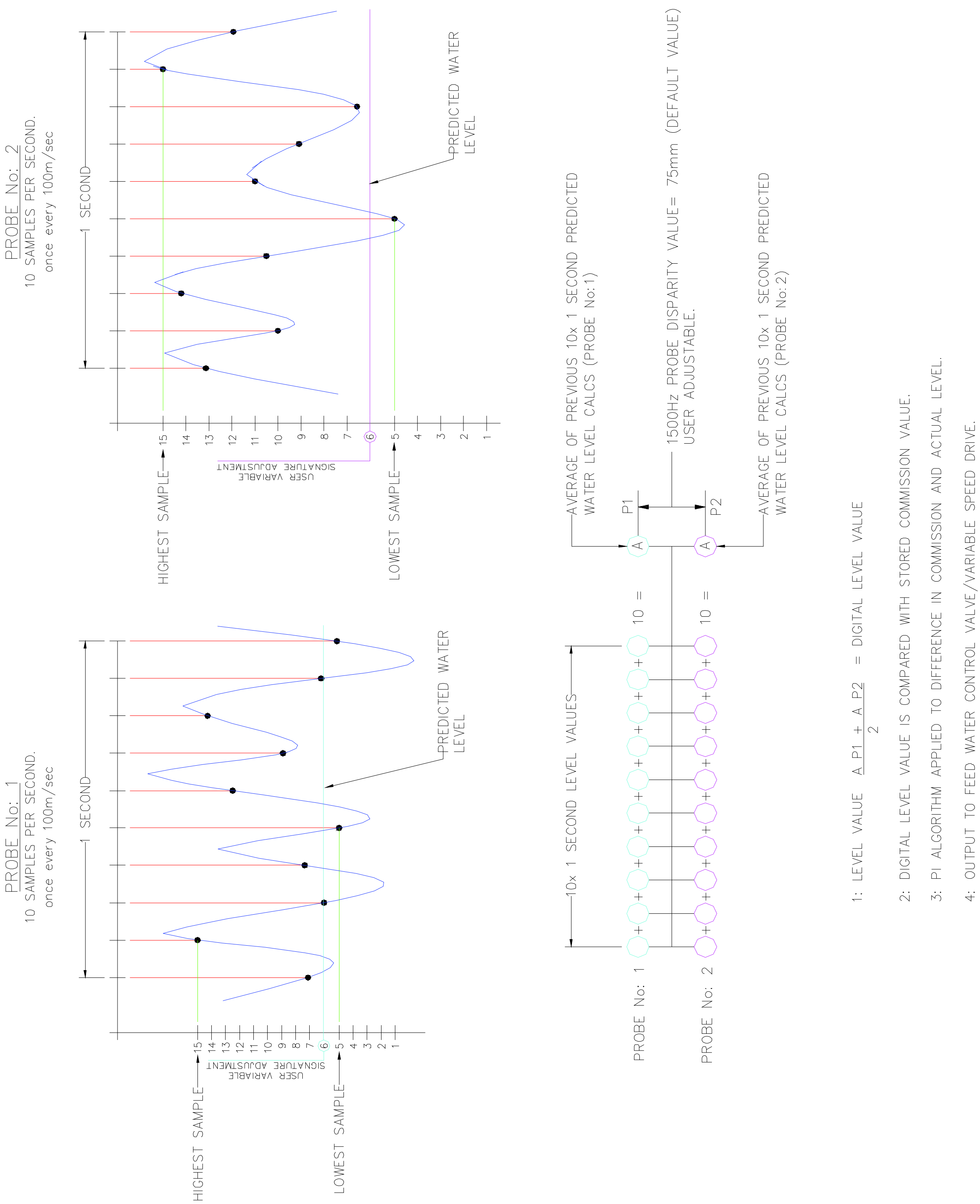
3.1.3 Foaming

Foaming on the surface of the boiler is brought about by a less than adequate blow down regime and/or not controlling and managing TDS in the appropriate manner. Incorrect or insufficient water treatment will exacerbate all of the above. Foaming will read as a step increase in water level. This situation should only ever occur in a badly managed boiler plant.

It can be seen from the above examples that wave signature will tend to be very installation specific. It is driven by boiler size, water treatment regime, position of heat transfer surface relative to water level and the load pattern imposed on boiler.

The Autoflame system takes into account all of these variables and uses them to create a control algorithm that produces perfect level control with absolute safety.

3.2 Schematic Explanation of the Water Level Probe Operation

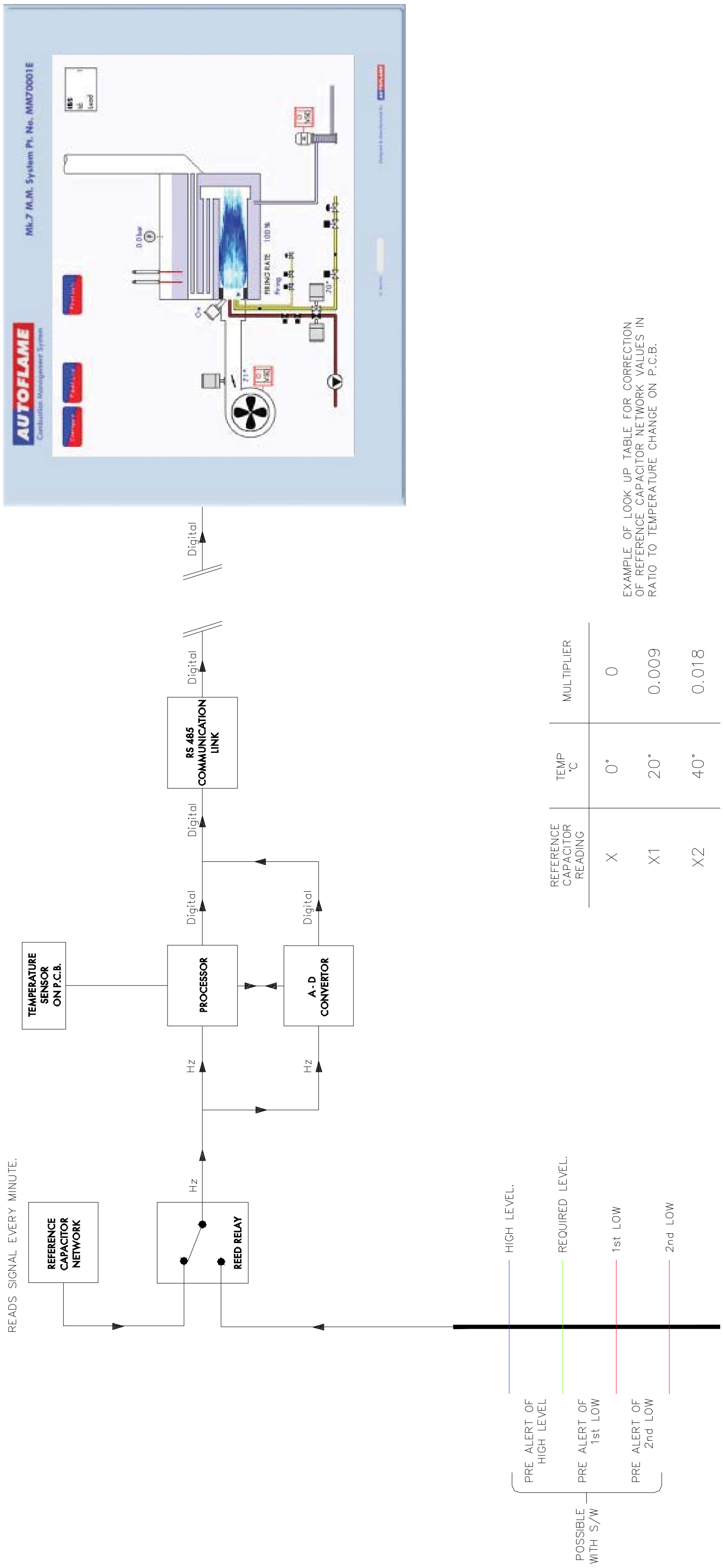


3.2.1 Capacitance Probe

Figure 3.2.1.i Capacitance Probe – External View

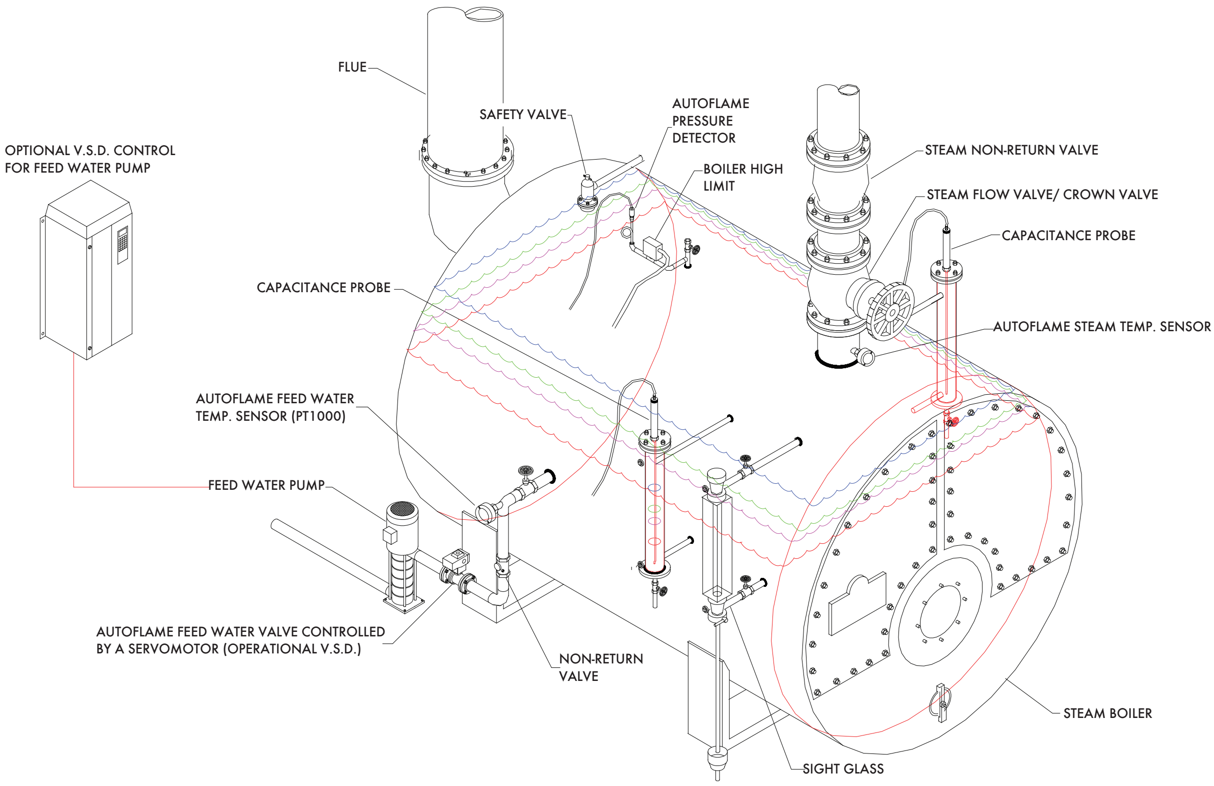
Figure 3.2.1.ii Capacitance Probe – Internal View

3.3 Schematic of the Probe Sampling Software



REFERENCE CAPACITOR READING	TEMP °C	MULTIPLIER
X	0°	0
X1	20°	0.009
X2	40°	0.018

3.4 Capacitance Probe – Externally Mounted Pots



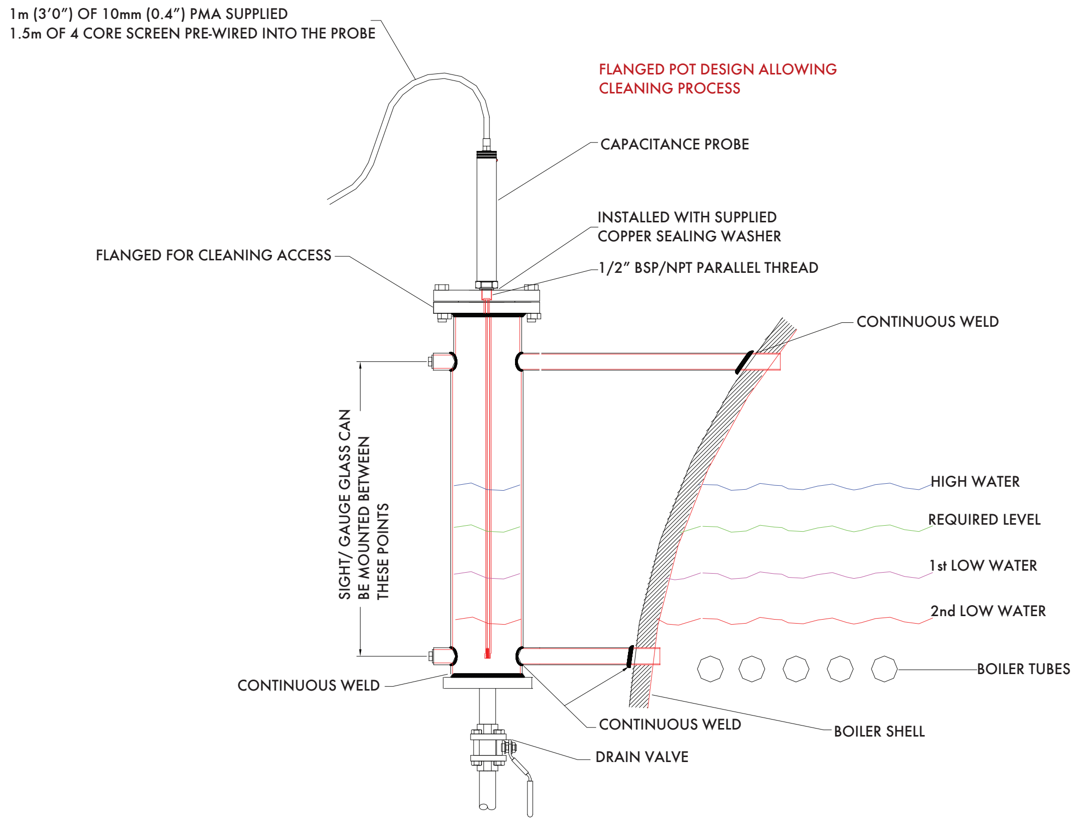
LEVEL PROBES MOUNTED EXTERNALLY
IN PURPOSED DESIGNED POTS

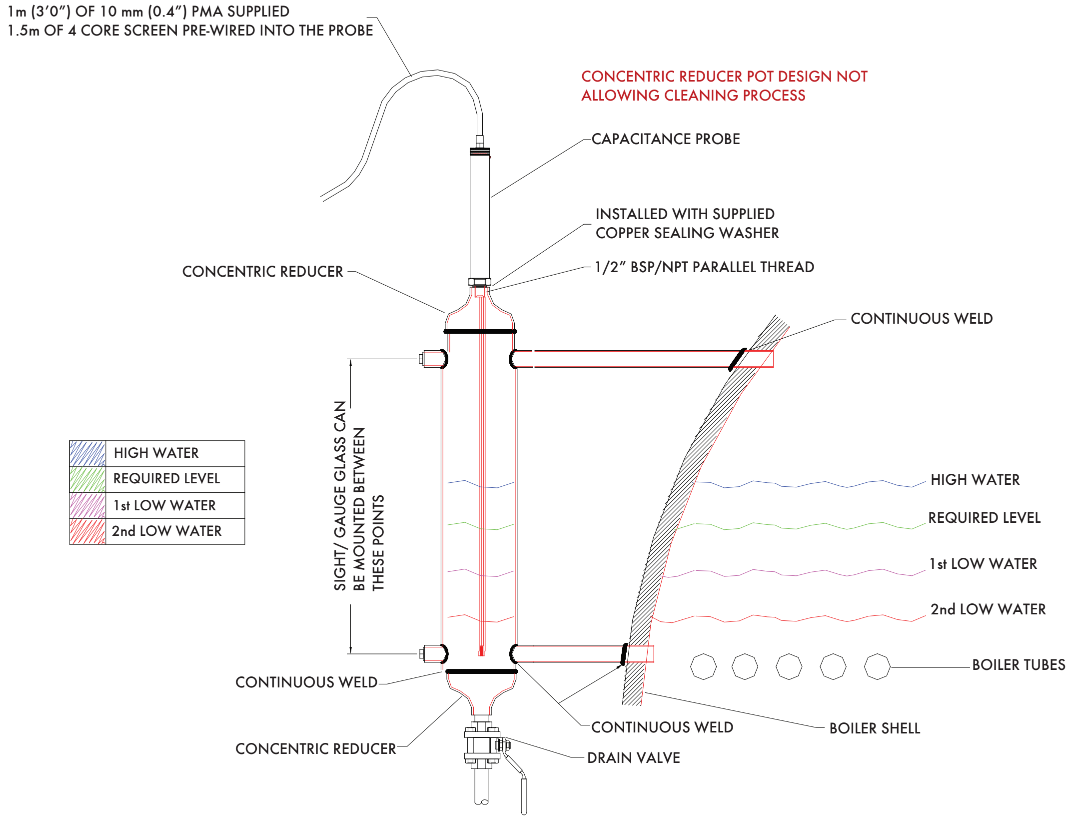
	HIGH WATER
	REQUIRED LEVEL
	1st LOW WATER
	2nd LOW WATER

*IMPORTANT NOTE: THE NOTES AND MECHANICAL EXECUTIONS IMPLICIT IN THESE DRAWINGS ARE FOR GUIDANCE PURPOSES ONLY. LOCAL, NATIONAL AND STATE CODES MUST BE ADHERED TO IN ALL CASES. IT IS IMPORTANT TO USE ONLY QUALIFIED AND EXPERIENCED INSTALLATION PERSONNEL. AUTOFLAME TECH CENTRES CAN ADVISE.
UNDER ALL CODES THAT AUTOFLAME ARE AWAR OF, IT IS NOT PERMITTED TO FIT 2 PROBES IN ON EXTERNAL POT.

IF IN DOUBT, PLEASE CONTACT AUTOFLAME.

3 Water Level Probes





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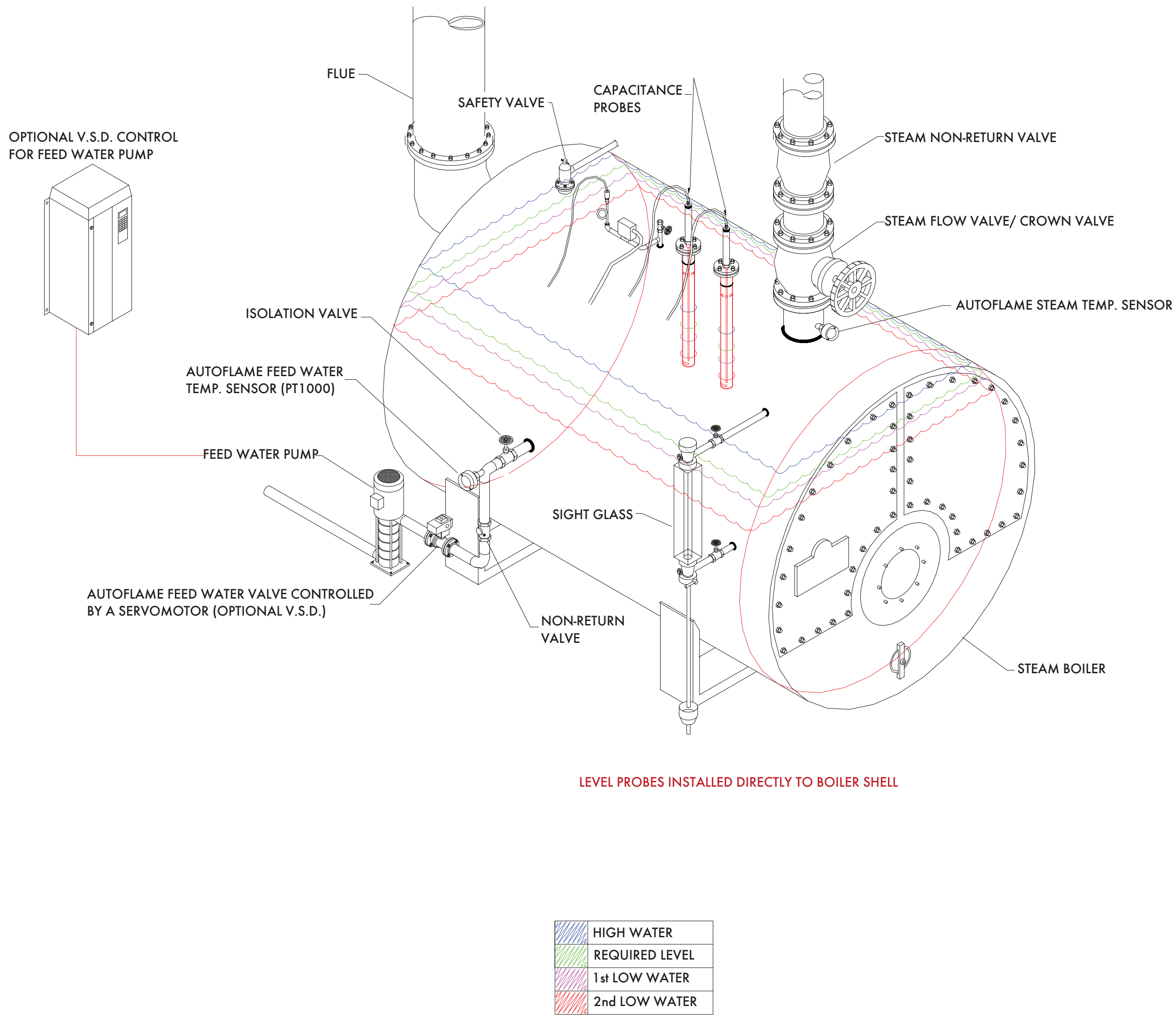
UNDER ALL CODES THAT AUTOFLAME ARE AWAR OF, IT IS NOT PERMITTED TO FIT 2 PROBES IN ON EXTERNAL POT.

IF IN DOUBT, PLEASE CONTACT AUTOFLAME.

3.5 Capacitance Probe – Internally Mounted Pots



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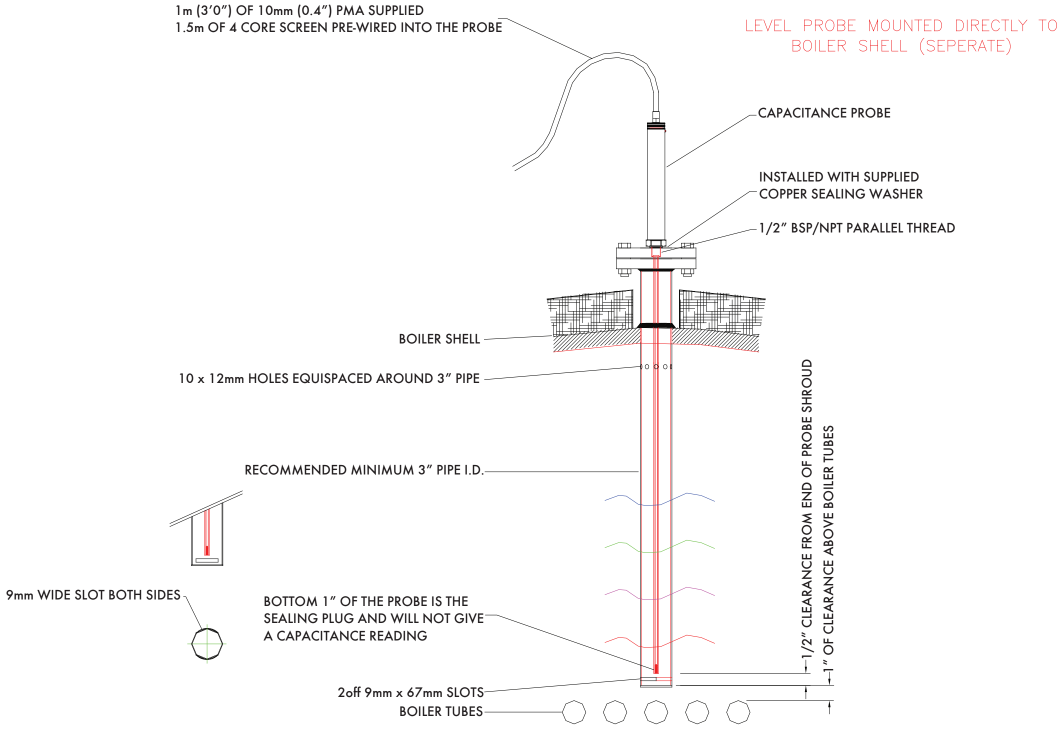
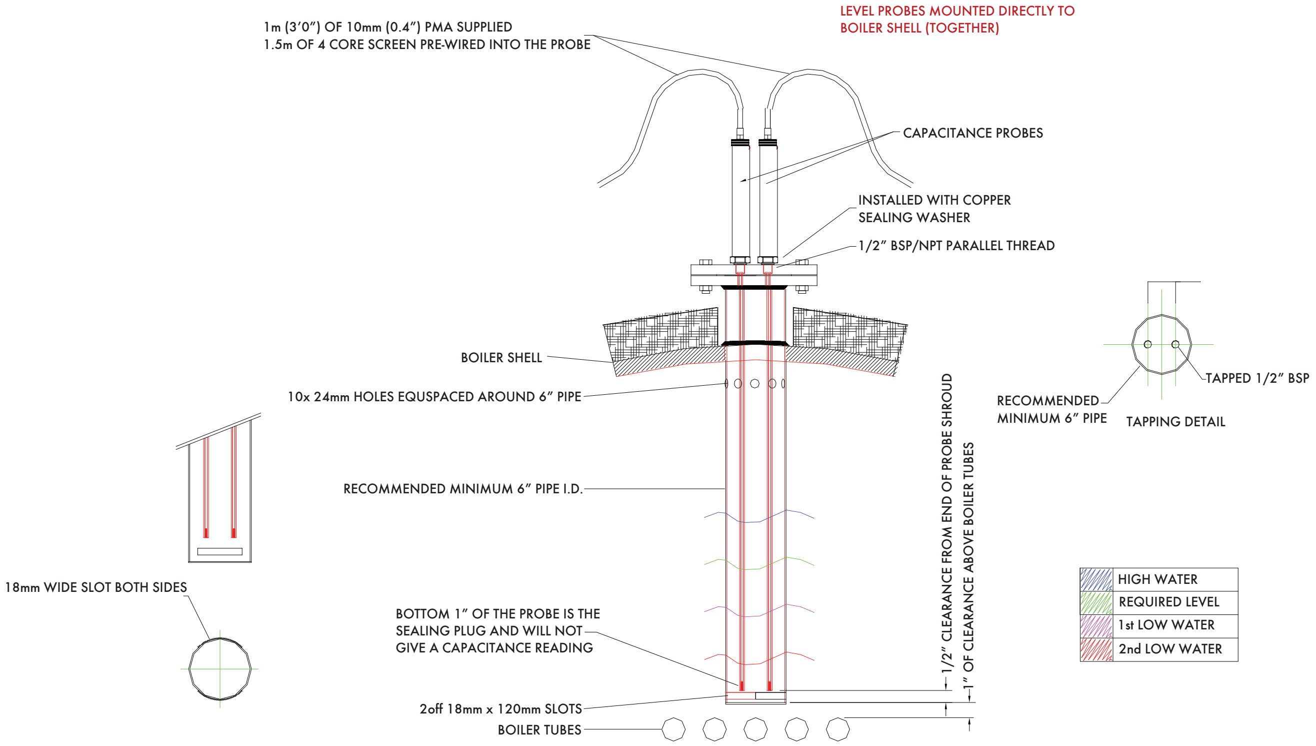
IF IN DOUBT, PLEASE CONTACT AUTOFLAME.

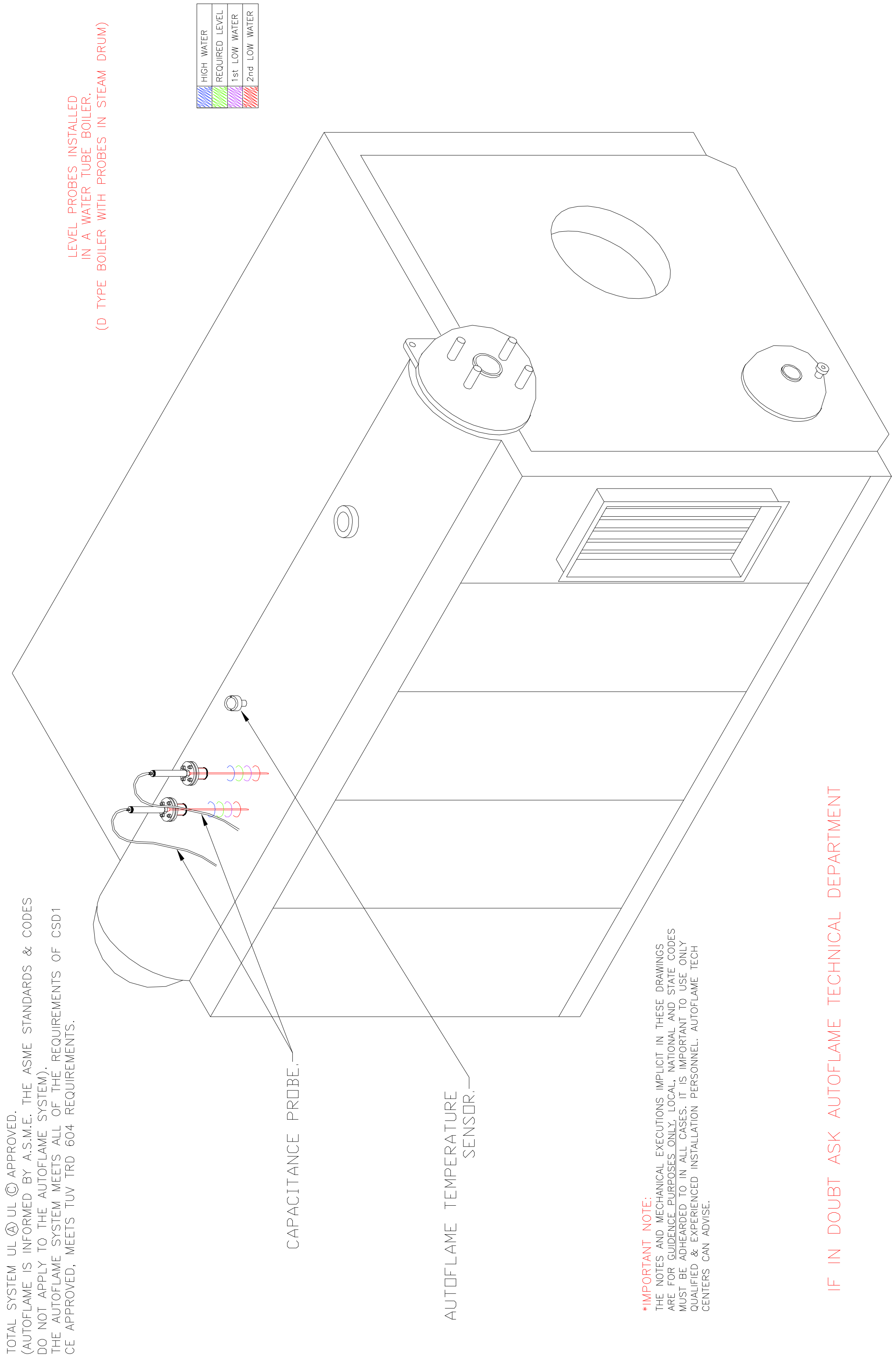




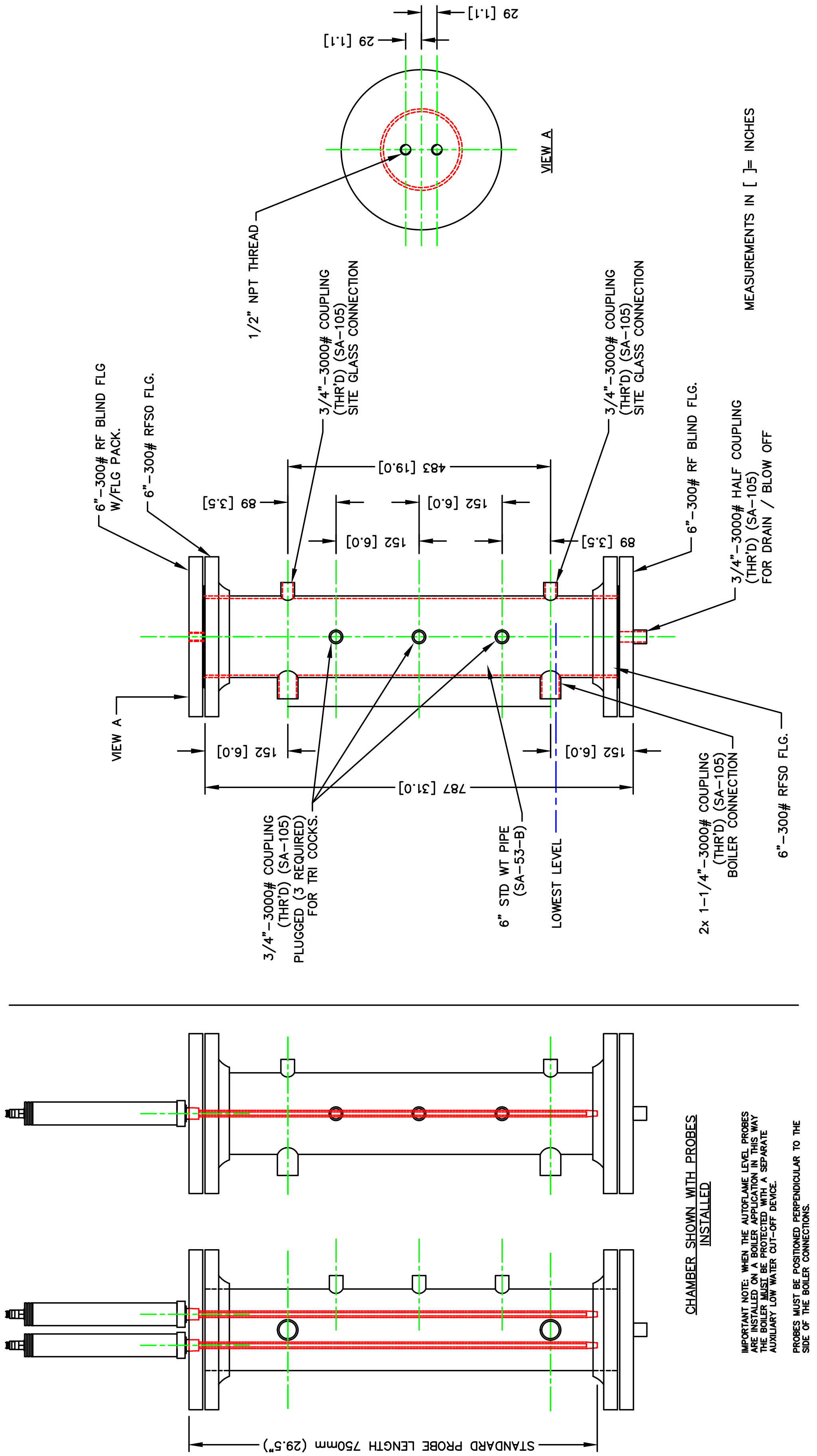
*IMPORTANT NOTE: THE NOTES AND MECHANICAL EXECUTIONS IMPLICIT IN THESE DRAWINGS ARE FOR GUIDANCE PURPOSES ONLY. LOCAL, NATIONAL AND STATE CODES MUST BE ADHERED TO IN ALL CASES. IT IS IMPORTANT TO USE ONLY QUALIFIED AND EXPERIENCED INSTALLATION PERSONNEL. AUTOFLAME TECH CENTRES CAN ADVISE.

IF IN DOUBT, PLEASE CONTACT AUTOFLAME.

3.6 Capacitance Probe – Installation for a Water Tube Boiler



3.7 External Probe Chamber Dimensions



3.8 Capacitance Probe Specification

Capacitance Probe Specification

Probe connection: ½" (13mm) – quick connect
Standard probe length: 20", 30", 40", 50" and 60" (508mm, 762mm, 1016mm, 1270mm and 1524mm)
Other probe lengths available upon request
Stainless steel probe
PTFE coated
IP 68 rating
Temperature rating of housing: 0 - 70°C (32 - 158°F) - ambient temperature of air around the boiler
Flying Lead Length: 2m

Note: The probes must not be cut. If the probes are cut this will act as a short between the positive and negative plates of the capacitor and will stop the probes from working.

If the probes are mounted directly into the boiler shell it is important to lag the flanges in order to avoid overheating of the electronics.

The following table illustrates the pressure tests on the probes:

Nominal Size of Line	Maximum Allowable Pressure	Maximum Allowable Temperature	Test Pressure
½" (15mm)	392 PSI (27 bar)	446°F (230°C)	870 PSI (60 bar)

3.8.1 Capacitance Probes Terminals

Probe No.1

Colour	**Description**	**Terminal**
Red	Power Supply +	1P+
Blue	Power Supply -	1P-
Green	Data Transmission +	1T+
Yellow	Data Transmission -	1T-

Probe No.2

Colour	**Description**	**Terminal**
Red	Power Supply +	2P+
Blue	Power Supply -	2P-
Green	Data Transmission +	2T+
Yellow	Data Transmission -	2T-

3.8.2 Water Level Treatment

The water treatment regime in any boiler installation has an effect on the life of the boiler and poor water quality can also affect the performance of capacitance probes. It is important to install any level controls in accordance with the local and national authorities' boiler inspection bodies, approval authorities and boiler manufacturer's guidelines. As well as this, it is vitally important to select a suitable water level treatment regime to ensure correct and safe operation of the Autoflame system. The water level treatment will also affect the long term operational life of the Autoflame capacitance probes. Water treatment companies should be able to assist with the selection and implementation of a suitable water treatment regime.

Generally, guidelines and standards for correct water treatment will be provided by your boiler manufacturer. The Autoflame water level capacitance probes are designed to work with steam boilers where the chemical treatment is maintained to the limits stated within these standards and guidelines. When the chemical treatment is maintained to levels under the maximum limits as stated in the standard's tables, the water level probes will work as expected.

It is important to remember that the guidelines set are limits that should not be exceeded at any time. If these guidelines and limits are not maintained then this can cause adverse effects on equipment installed as well reducing the longevity of your boiler and increasing ongoing maintenance requirements.

3.9 2nd Low Probe

The 2nd low probe measures the water level by a conductive technology, rather than the capacitance technology. This patented technology feature enables 2nd low electronic safety control with continuous software, electrical and mechanical self-checking.

The features and benefits of the 2nd low probe include:

- Certified low water cut off probe
- Internal relay self-checking
- Can be used with the Autoflame system, or as standalone
- Volt free contacts for external safety devices or circuits
- Stainless steel and PTFE construction
- Probe can be cut to length to suit application
- Quick connect multi-pin flying lead
- Offsite status logging via Mk7 D.T.I.
- Conductive technology completely different to capacitance probes

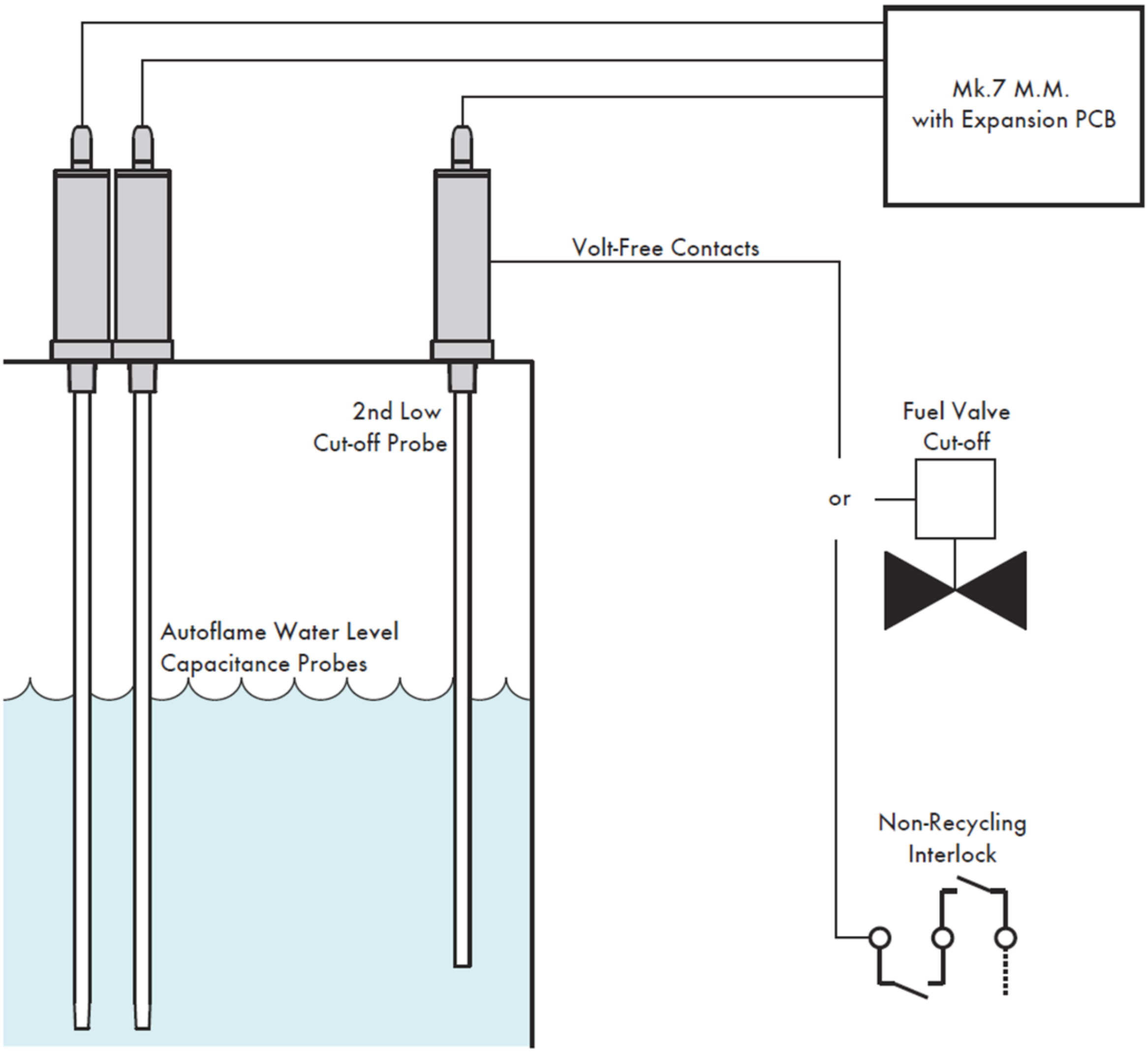


Figure 3.9.i 2nd Low Probe Diagram

To install the 2nd low probe, no commissioning is required; just simply enable expansion option 37.1. The bottom of the 2nd low probe should be at the capacitance probes 2nd low level or higher.

3.10 Modulating Feed Water Valve

Water valves are universal for feedwater, TDS, and bottom blowdown function.

½" and ¾" water level valves must be used with large servomotors. Industrial unic 05 servomotors must be used 1" and 1 ½", and industrial unic 10 for 2" water valves. for water valves bigger than ¾".

Valve Type	Size	Part No.	Servomotor		
			Large	Unic 05	Unic 10
Threaded Feed Water BSP/ NPT	15mm (½")	WLCVO15	•		
	20mm (¾")	WLCVO20	•		
Flanged Feed Water PN40	25mm (1")	WLCVO25/FL		•	
	40mm (1 ½")	WLCVO40/FL		•	
	50mm (2")	WLCVO50/FL			•
Flanged Feed Water ANSI 300lb	25mm (1")	WLCVO25/FLU		•	
	40mm (1 ½")	WLCVO40/FLU		•	

Max operating pressure: 29 Bar (425 PSI)
Max operating temperature: 235°C (455°F)

Note: Autoflame water level probes are rated at a maximum 27 Bar (392 PSI) and 230°C (446°F).

Note: Please Valves and Servomotors manual for water level valve dimensions, drawings and information on service and maintenance.

3.10.1 Feed Water Valve Sizing

Obtain one value from the system relating to the units from the column headings, then compare with values using all tables and select the valve with the closest higher match, to size correctly. The feed water valves are available as threaded or flanged. The valves have a low pressure drop so when replacing an existing feed water valve, the valve size required may decrease by more than one.

Autoflame Part No. WLCV015 - ½" feed water valve water flow calculations @20°C								
Water Velocity		Pressure Drop Across Valve		Water Flow Rate			Steam Flow Rate	
Ft/sec	M/sec	ΔP PSI	ΔP Bar	G/hr (imp)	GPM (imp)	US GPM	lbs/hr	Kg/hr
6	1.82	1	0.07	160	2.6	3.2	1600	727
9	2.74	2	0.14	235	3.9	4.7	2350	1068
15	4.57	5	0.34	380	6.3	7.6	3800	1727
21	6.40	10	0.68	560	9.3	11.2	5600	2545
26	7.90	15	1.03	700	11.6	14	7000	3182
32	9.73	20	1.38	820	13.6	16.4	8200	3727

Autoflame Part No. WLCV020 - ¾" feed water valve water flow calculations @20°C								
Water Velocity		Pressure Drop Across Valve		Water Flow Rate			Steam Flow Rate	
Ft/sec	M/sec	ΔP PSI	ΔP Bar	G/hr (imp)	GPM (imp)	US GPM	lbs/hr	Kg/hr
8	2.43	1	0.07	460	7.7	9.2	4600	2090
12	3.65	2	0.14	665	11	13.3	6650	3022
19	5.79	5	0.34	1100	18.3	22	11000	5000
28	8.53	10	0.68	1630	27.1	32.63	16300	7409
34	10.34	15	1.03	2000	33.3	40	20000	9090
40	12.16	20	1.38	2400	40	48	24000	10909

Autoflame Part No. WLCV025 - 1" feed water valve water flow calculations @20°C								
Water Velocity		Pressure Drop Across Valve		Water Flow Rate			Steam Flow Rate	
Ft/sec	M/sec	ΔP PSI	ΔP Bar	G/hr (imp)	GPM (imp)	US GPM	lbs/hr	Kg/hr
13	3.96	1	0.07	1560	26	31.2	15600	7091
21	6.4	2	0.14	2300	38.3	46	23003	10456
32	9.75	5	0.34	3800	63.3	76	38005	17275
46	14.02	10	0.68	5600	93.9	112	56007	25458
60	18.24	15	1.03	7000	116.6	140	70008	31822
70	21.28	20	1.38	8200	136.6	164	82011	37278

Autoflame Part No. WLCV040 – 1 ½" feed water valve water flow calculations @20°C								
Water Velocity		Pressure Drop Across Valve		Water Flow Rate			Steam Flow Rate	
Ft/sec	M/sec	ΔP PSI	ΔP Bar	G/hr (imp)	GPM (imp)	US GPM	lbs/hr	Kg/hr
17	5.17	1	0.07	4700	78.3	94	47005	21366
25	7.60	2	0.14	6700	11.6	134	67007	30458
39	11.86	5	0.34	11200	186.6	224	112015	50916
60	18.24	10	0.68	16500	275	330	165022	75010
75	22.80	15	1.03	20000	333.3	400	200028	90922
90	27.36	20	1.38	24000	400	480	240033	109126

Autoflame Part No. WLCV050 - 2" feed water valve water flow calculations @20°C								
Water Velocity		Pressure Drop Across Valve		Water Flow Rate			Steam Flow Rate	
Ft/sec	M/sec	ΔP PSI	ΔP Bar	G/hr (imp)	GPM (imp)	US GPM	lbs/hr	Kg/hr
21	6.38	1	0.07	10000	166.6	200	100014	45461
31	9.42	2	0.14	15000	250	300	150020	68191
46	13.99	5	0.34	24000	400	480	240033	109106
72	21.89	10	0.68	36000	600	720	360049	163659
85	25.84	15	1.03	44000	733	880	440061	200028
110	33.44	20	1.38	51000	850	1021	510072	231851

4 TOTAL DISSOLVED SOLIDS MANAGEMENT

4.1 Philosophy of TDS Control System

Figure 4.1.i TDS Probe

To manage a steam boiler for optimum efficiency and reliability an important requirement is to ensure that the Total Dissolved Solids (TDS) in the water are measured and controlled to the right level for that boiler. It is generally accepted that for water tube boilers the level of TDS measured should not exceed 1,500 PPM by volume and for smoke tube boilers the TDS should not be higher than 2,500 PPM by volume. The figures stated are not definitive and in all applications the recommendations of the boiler manufacturer or water treatment chemist should be implemented.

It has been established that the conductivity of water is proportional to the measured TDS as long as the temperature remains constant. Any variations in temperature will affect the measured conductivity by nominally 2% per 1°C. It follows that the temperature of the water must be measured and the conductivity reading must be adjusted before a TDS reading can be extrapolated from this line of data. The Autoflame system incorporates a temperature measurement sensor in the steam drum to establish the steam temperature. This data stream is used to constantly correct the conductivity value.

A second variable that effects the conductivity measurement is polarization of the water sample. This occurs when electrical energy from the probe builds up a relatively tiny offset above or below the earth (0 volt value). This polarization value is typically noticeable when a continuous frequency is being emitted from the probe as part of the conductivity measurement method. The Autoflame system deals with the potential problem of polarization in the following manner. The probe measures any build-up of voltage potential above or below earth or 0V in the water sample. The measured polarization voltage data is used to modify the conductivity calculation. The Autoflame system emits electrical energy at a rate of 10x 300 microsecond pulses every second. This translates into a method where we are emitting electrical energy for 0.6% of the sample time. All other manufacturers who use the frequency method are emitting electrical energy for 100% of the sample time. It follows that the polarization problem in these cases would be 167 times greater!

A third problem that affects the accuracy of the TDS measurement is the build up of scale on the probe electrode. By design the water sampling container has been arranged so that the turbulence created during the blow down sequence will ensure that the probe remains effectively free of scale or deposited solids that could be held in suspension.

The sampling container has a known orifice size. From this it is possible to calculate the percentage losses due to surface blowdown. This is possible because the following parameters are known – hole size, temperature, pressure, pressure drop across the solenoid and the time that the solenoid is open for.

It can be seen from the above that the Autoflame TDS system deals succinctly with three of the main problem areas that are encountered when designing an accurate TDS control solution.

4.2 TDS Probe Calibration

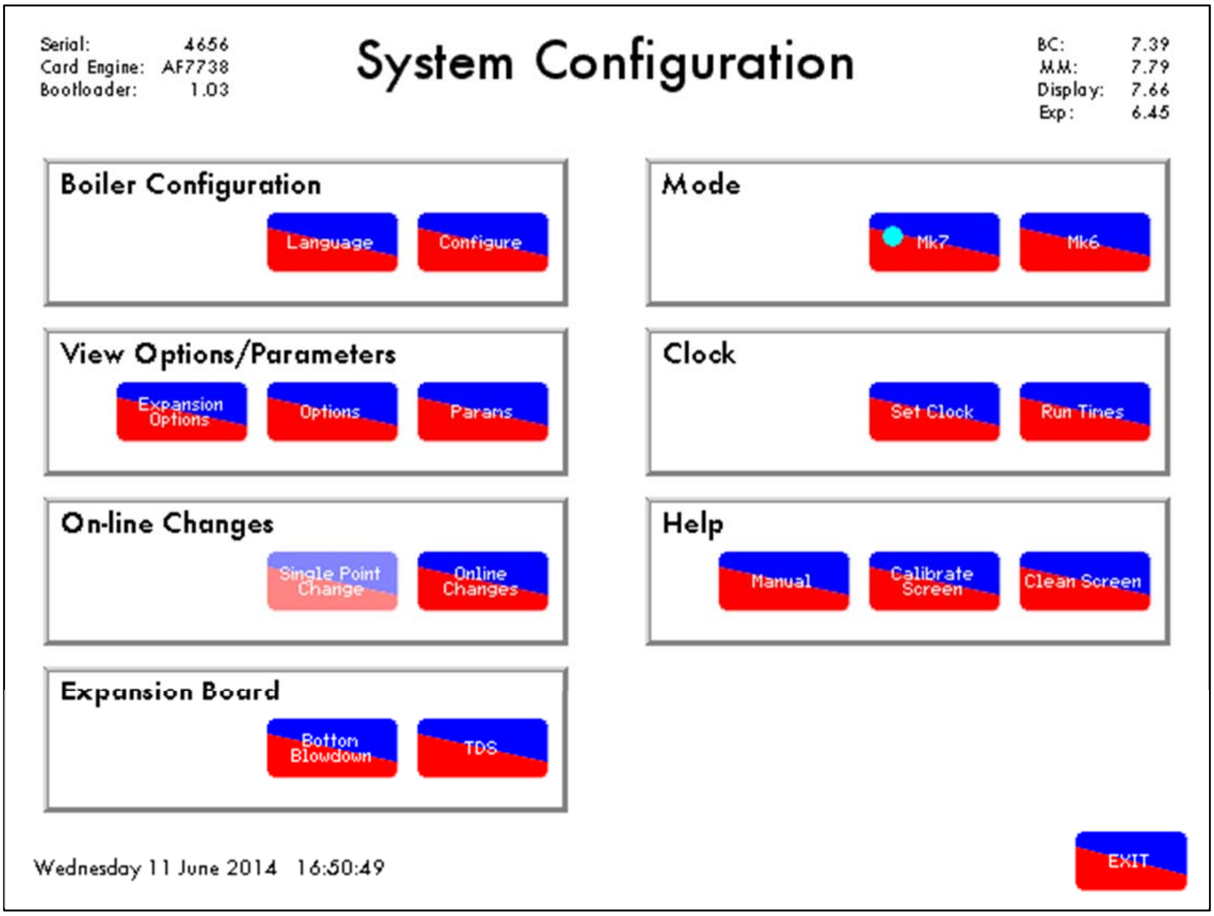
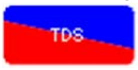


Figure 4.2.i System Configuration

Once the expansions have been set for the TDS probe, the probe must be calibrated. While the M.M. is in Run mode, press 

 and then press 

 in the System Configuration screen as in Figure 4.2.i.

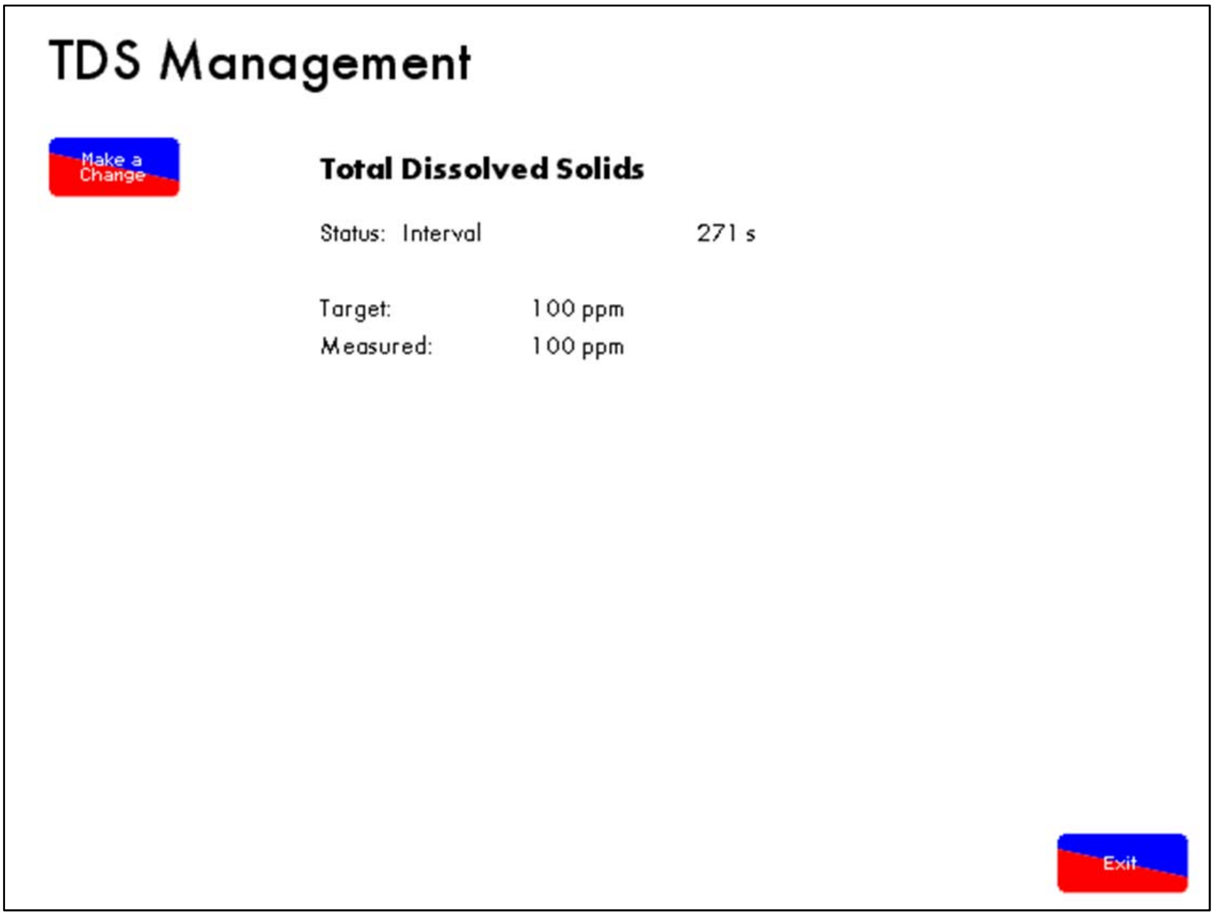


Figure 4.2.ii TDS Management Screen

Figure 4.2.ii shows the TDS management screen.

Press 

to calibrate the TDS probe. The TDS probe does not operate when the M.M. is in Make a Change mode or when the burner is not firing.

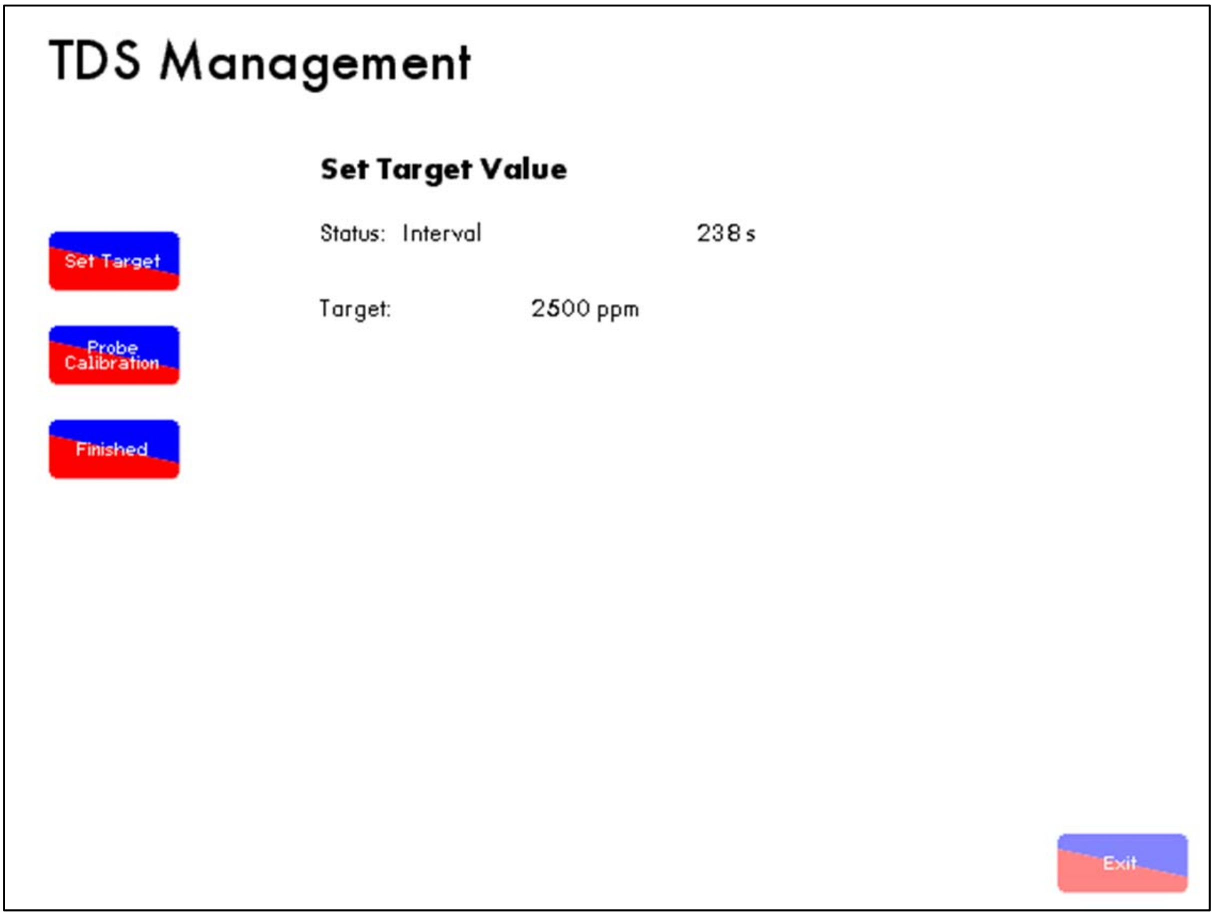


Figure 4.2.iii Set Target Value

In the Make a Change screen, pressing the 

button will allow you to type in a required TDS value, see Figure 4.2.iii. This TDS value is based on the boiler manufacturer's requirements.

Pressing 

allows the user to calibrate probes. After taking a manual sample of the TDS, press 

to take a fresh sample for the TDS probe. If TDS management is set-up for solenoid operation, the valve will open and close for the duration of the sample time set in the TDS adjusters. If the TDS management is set-up for continuous operation, the TDS valve will go to the fully open position for the sample time duration, and then go to fully closed. The sample settlement time is set in the TDS adjusters; once this time has elapsed, the sample measurement is recorded.

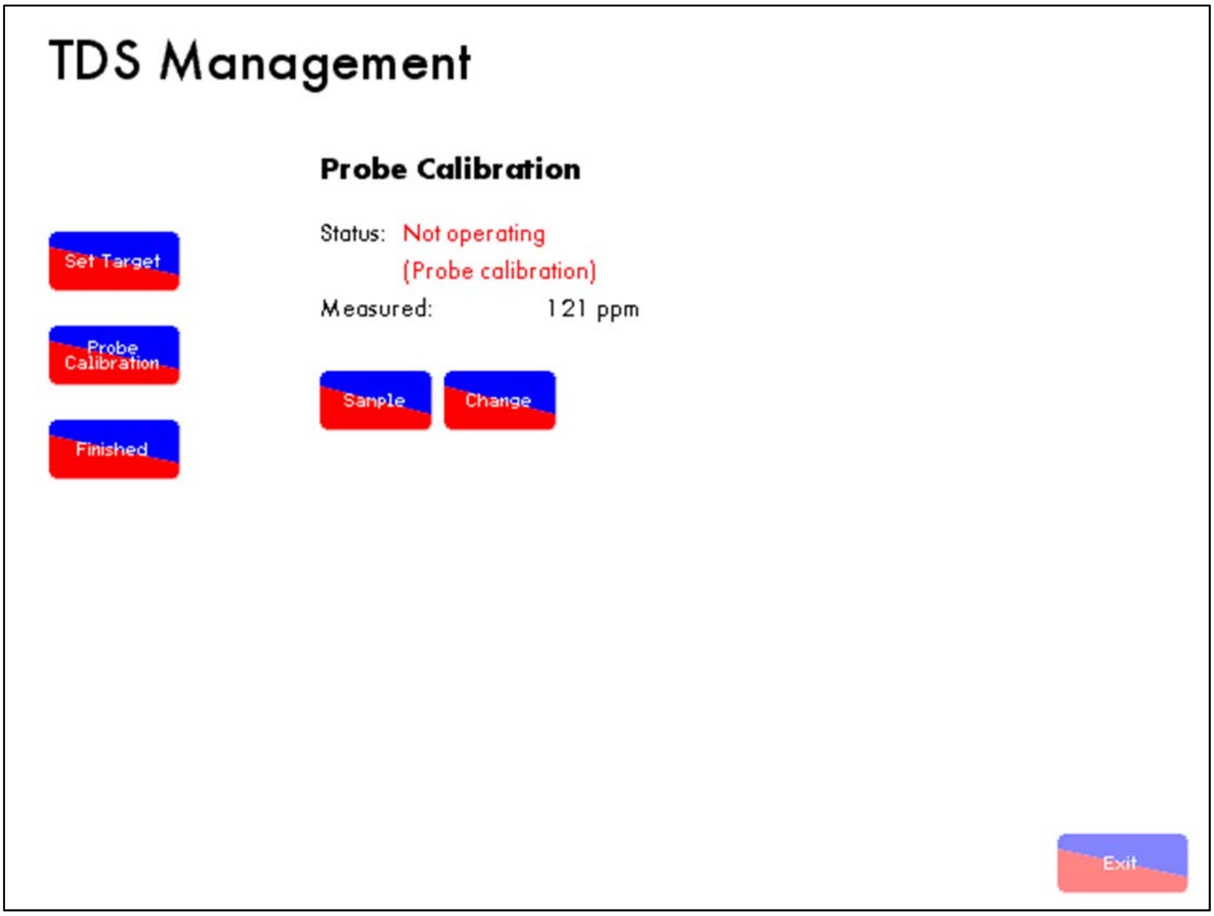


Figure 4.2.iv Probe Calibration

Once a fresh sample has been taken, press 

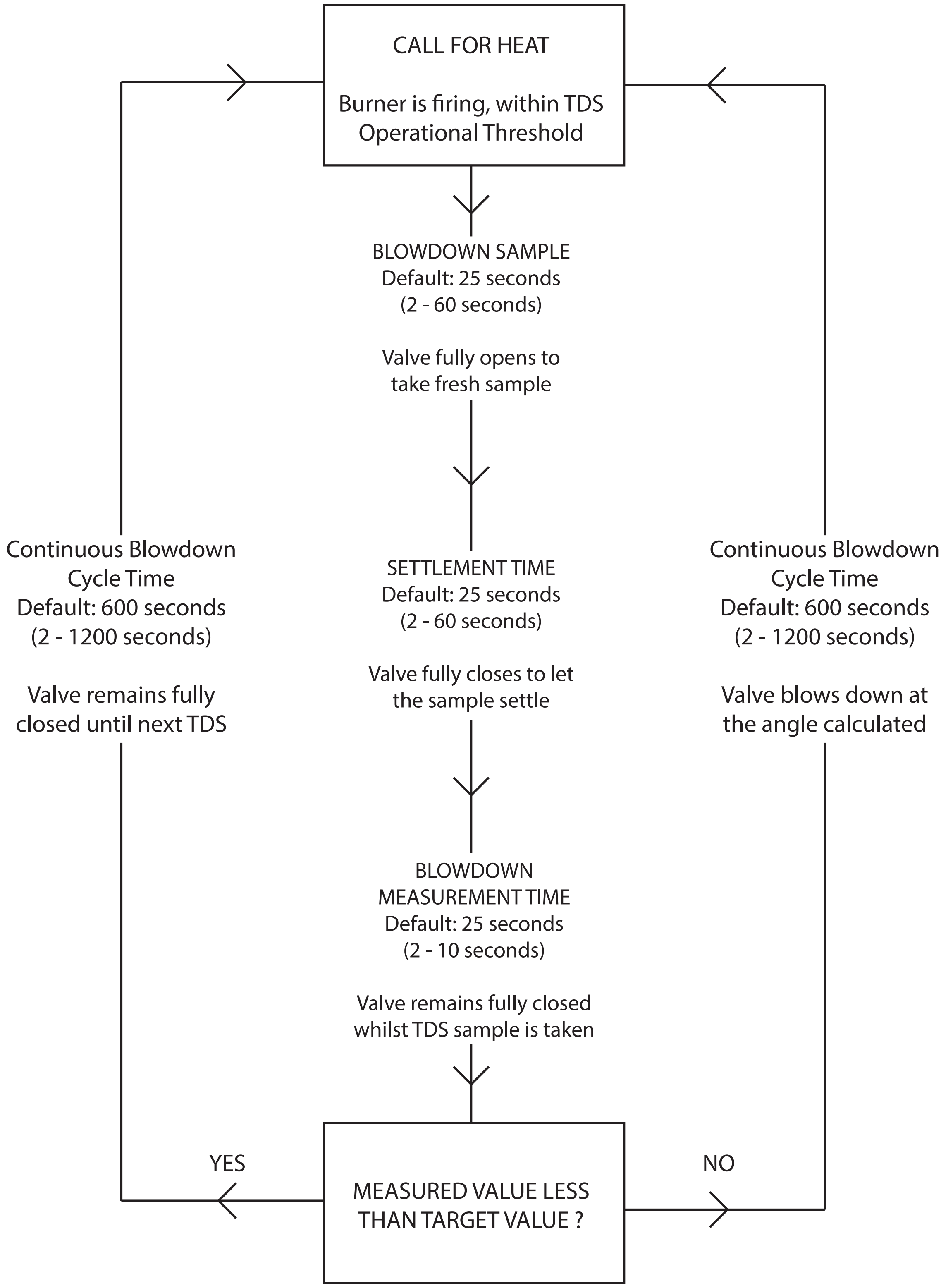
shown in Figure 4.2.iv, to enter a new calibrated value taken from the manual sample, which the probe will now be calibrated to. This value must be within 10% - 990% of the probe reading to avoid incorrect calibration. If there is an air lock, the TDS probe will not be calibrated as the reading will be 0ppm.

When the probe calibration is completed, press 

and exit this screen.

4.3 Method of TDS Control

4.3.1 Timing Diagram



4.3.2 Continuous TDS Blowdown

The new continuous TDS blowdown operates as continuous cycle; the interval timing is set via only one setup in the TDS adjusters, rather than two set-ups as before.

Note: The interval time setup is still available in the TDS adjusters, however this is only active when the solenoid valve is optioned and has no effect on the continuous blowdown cycle.

1. At the point of sample, the TDS valve fully opens to gain a fresh sample.

2. The valve then fully closes, and a after a settle time, the sample is then measured. This reading is used to evaluate the required valve position according to the internal PI control and the target value.

3. If the measured TDS value is above the target TDS value, the valve will open to its calculated position for the set blowdown cycle time (this will be displayed as 'blowdown time' on the screen). At the end of the cycle time, the sampling will be repeated and the cycle starts again.

4. If the measured TDS value is below the target TDS value, the valve will remain closed for the duration of the blowdown cycle time (this will be displayed as 'interval time' on the screen). At the end of the cycle time, the sampling will be repeated and the cycle starts again.

5. Once the TDS value has been reached or decreased to below the target TDS value, the valve shall remain closed for the duration of the blowdown cycle time.

6. Once the valve has been opened due to the measured TDS value being above the target TDS value, the valve will continue to drive open until the measured TDS value is more than 100ppm below the target TDS value.

4.3.3 Solenoid Valve TDS Blowdown

The sampling and control sequence of the top blowdown using the solenoid valve is detailed below:

1. If the boiler water sample is above the required TDS value the system will open the top blowdown control valve for 5-300 seconds. This time duration is user variable and is designated blowdown time.

2. After blow down the system invokes a 5 second settlement interval.

3. After the settlement period a 5 second measurement routine is carried out to establish the current TDS level.

4. If the boiler water sample is still above the required TDS value the system will repeat the top 'Blowdown Time' routine as detailed above in 1) BDT.

5. When the boiler water sample is measured as below the required TDS level, the system will then take a sample every 60-300 seconds. This sample time interval is user variable.

6. The duration of the sample time is 3-10 seconds. This is user variable.

7. The system then repeats this cycle.

4.3.4 Installation of TDS Probe Assembly

Illustrated below is the installation method for the T.D.S. probe incorporating Autoflame's sampling system. (All dotted components are to be supplied by the customer).

Note: There must be a minimum of 3ft (0.9m) straight pipe installed from the valve, of the same diameter as the actual valve.

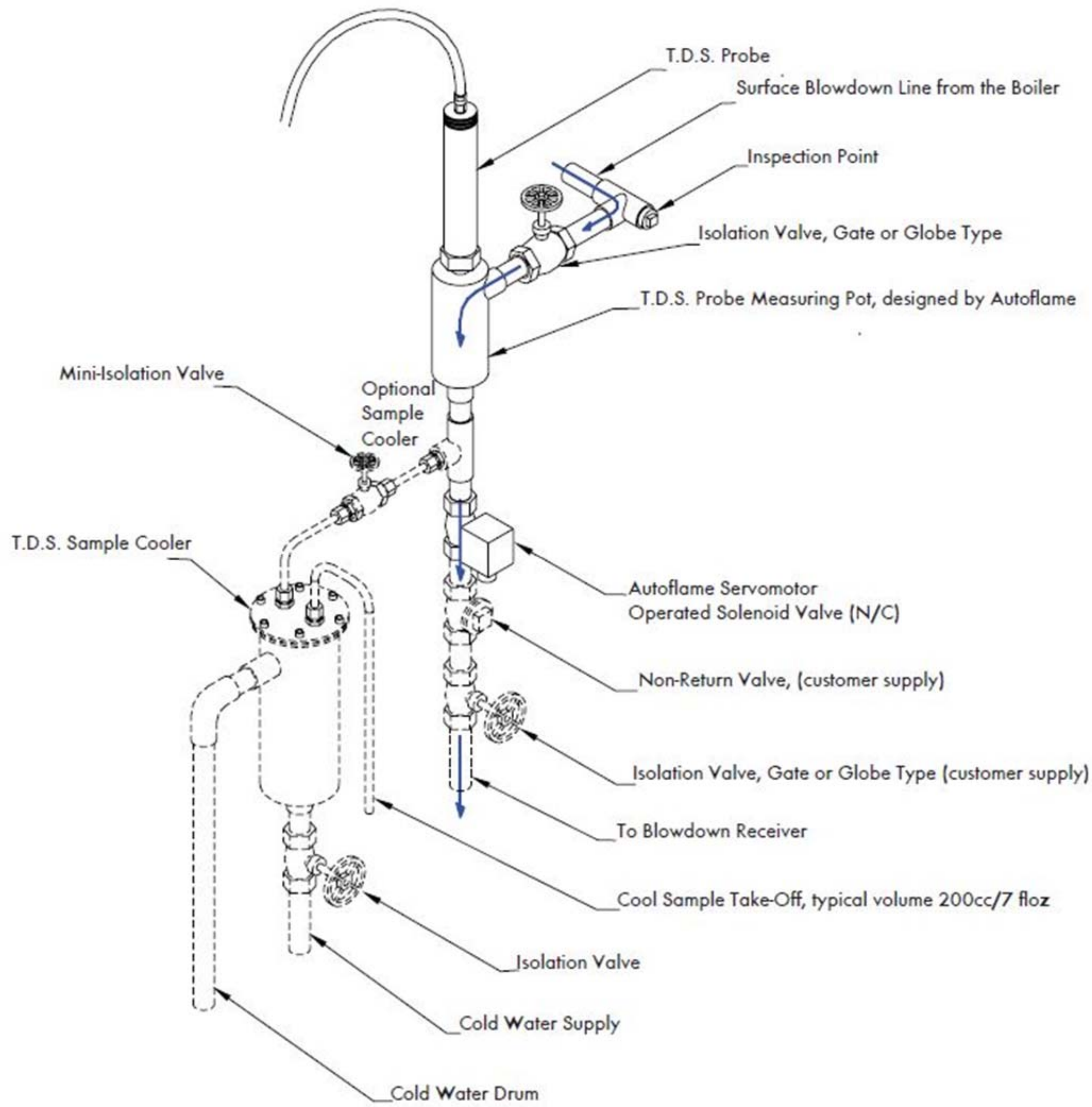
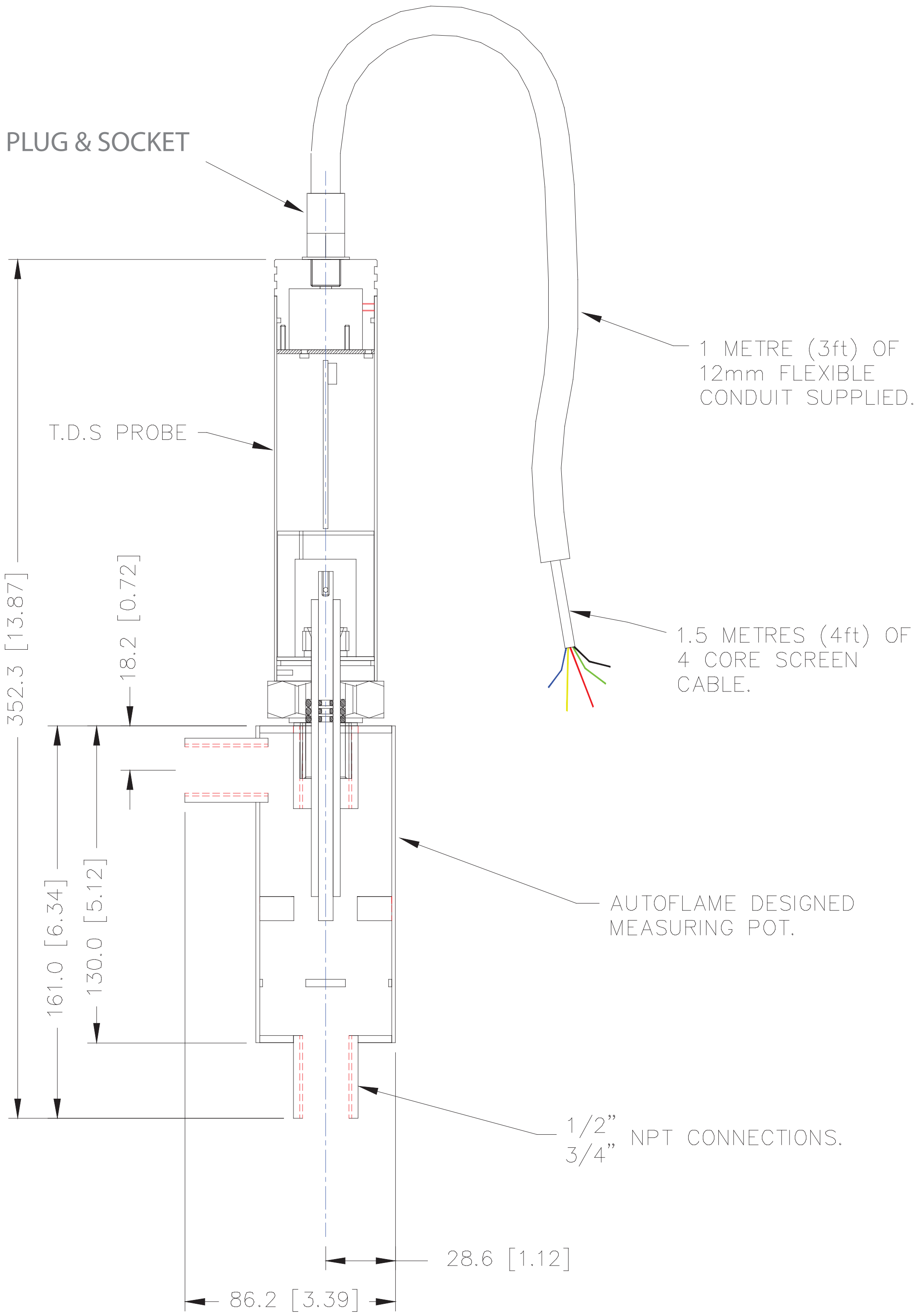


Figure 4.3.2.i Vertically Mounted

4.4 TDS Probe and Autoflame Sampling Vessel



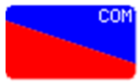
4.5 Top Blowdown Adjusters

By setting expansion option 23.1, and M.M. parameter 83 to 1 the following TDS adjusters are available in Mk6 mode.

The TDS Adjusters allow the Top Blowdown Operation to be adjusted to suit boiler's conditions.

These must be accessed in Mk6 mode. In Mk6 Mode, press the 

button until the day to day Top Blowdown Management screen is displayed.

Whilst the day to day Top Blowdown Management screen is being displayed press the 

button for 2 seconds so that the SET TDS TARGET VALUE screen is shown.

Press the 

button twice. The ADJUSTERS screen shown below should be displayed. Note while in this screen there is no top blowdown operation.

Use the channel 

buttons to select the item to be adjusted.

Use the channel 

buttons to adjust the value units. Where appropriate the channel 

buttons can also be used to change the value by 10.

Press RUN to return to normal operation. When the run button is pressed, all Adjuster values are stored in memory.

Factory Setting	Value	Description
600	2 - 1200	**Blowdown Time:** The continuous blowdown cycle time or time the solenoid valve is opened. Seconds
60	2 - 900	**Continuous Blowdown Cycle Time or Solenoid Valve Blowdown Time:** The blowdown cycle time for continuous TDS blowdown or the blowdown time for solenoid valve only. Seconds
0	0 1	**Sample Time Interval (Solenoid Valve Only):** Disabled The blowdown time is in prorportion to the firing valve for solenoid valve operation only.
70	20 - 100	**MicroSiemens to ppm factor (x100):** The TDS probe measures conducitivity in microSiemens. This factor derives the TDS value in ppm.
10	0 - 50	**Steam Pressure Threshold Offset Below Required:** If the M.M. actual value is less than the required value minus this offset, then the top blowdown does not operate. PSI. (0.0 -10.0 Bar)
0	0 - 1	**Reset Defaults:** Resets all TDS adjusters to the default values and the TDS probe to preset calibraiton. Select YES and then press RUN.
2500	50 - 9990	**TDS Target Value:** ppm
180	20 - 300	**Temperature Correction Value:**
1000	100 - 9990	**Calibration Correction:**
25	2 - 60	**Settlement Interval Time:** After a blowdown measure, this is a period where the sample can settle before the TDS is measured. Seconds
5	2 - 10	**Measurement Time:** This is how long the sample is measured to get an accurate TDS value. Seconds
0	0 1	**ppm or µS** ppm µS
0	0 1 - 5000	**Upper Limit Offset** Disabled Once this limits has been exceeded, terminal #79 will be set. On the top blowdown screen, a light blue dot will flash on the water level button. Press the water level button to mute the alarm. This will continue to flash until the measured TDS value has fallen below the limit value. Another alarm will not be generated until the measured TDS value has been continuously below the limit value for 10 minutes.

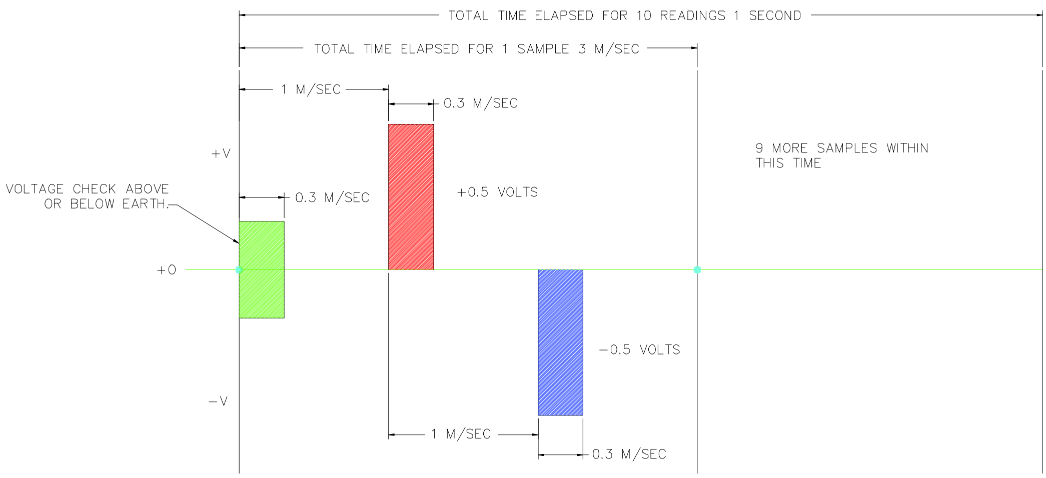
4.6 Sample Routine

The time for one complete measurement cycle is 3 Milliseconds. It can be seen that 10 measurement cycles are made within one second. These measurements are averaged over one second. Conductivity is calculated by dividing measured milliamps by 0.5 volts which gives a value in micro-siemens.

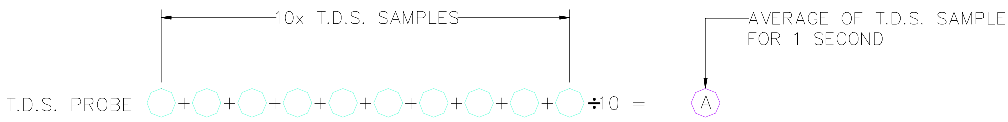
At the start of each measurement cycle the sample is checked for polarization. This background voltage effect is taken into the conductivity calculations.

Temperature and pressure is measured by the Autoflame system and this information is used to continually modify the calculated conductivity/TDS value from its calibrated point. Nominally for every 1 degree C increase or decrease, 2% is added or subtracted from the conductivity value. The exact figure is calculated by the system.

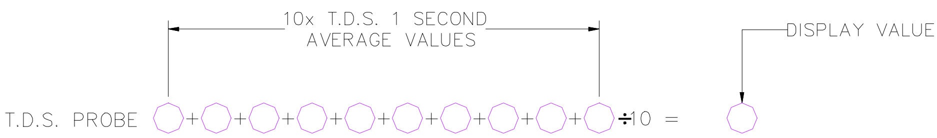
The system relates conductivity in micro siemens to TDS in ppm by a 0.7 multiplier. Within the control software there is an adjustment of ± 7% for this multiplier which is user variable.



The TDS system logs each of the samples within the 1 second time period, It takes all 10 sample values, adds them together then divides them by 10 to obtain the average TDS value for the one second period.



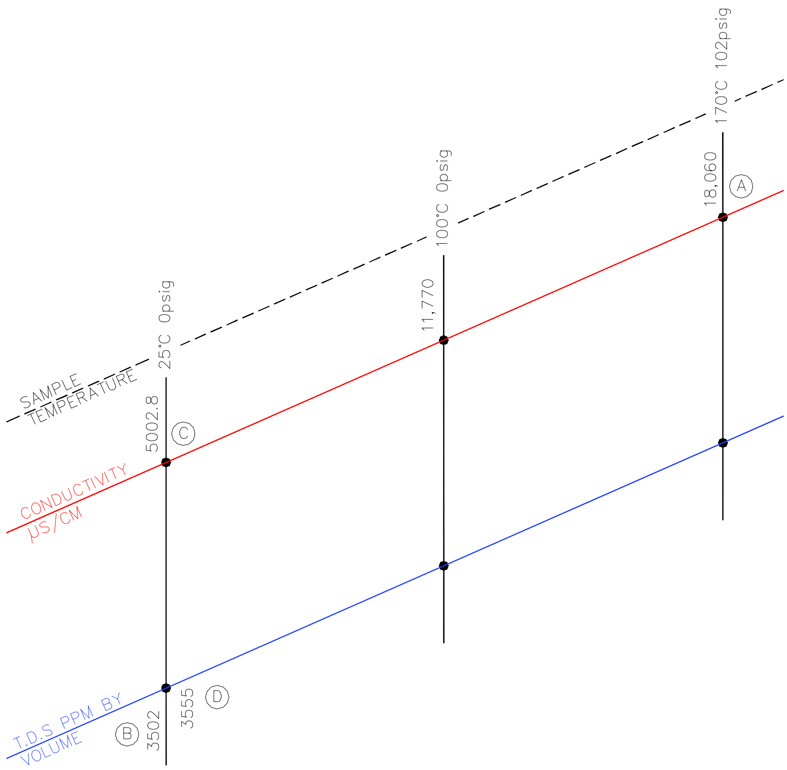
Once the TDS software has calculated the average TDS value for the 10 samples within one second, it will then extract these averages and add the last 10 together and divide them by ten to give the actual TDS reading. This value will be displayed on the M.M.



When a new average of the 1 second samples is obtained the software will utilize the last 9 averages, it will then add the new average to them and divide it by 10 to obtain the new TDS value.

4.7 Relationship between Conductivity, Temp and TDS Values

A	=	These values measured by probe & sensors at operating steady state conditions.
B	=	This value is conductivity value multiplied by 0.7 (TDS in PPM)
C	=	This conductivity value temperature corrected to 25 degrees C / 77 degrees F.
D	=	This is measured TDS value entered into the system to effect a user "calibration."



1. Conductivity measurement corrected at 2% per 1°C.
2. At 25°C TDS in ppm is calculated by multiplying the conductivity value by 0.7.
3. Both of the above multipliers are user variable to accommodate specific site conditions.

At the time of manufacture every TDS probe has buried in its electronics memory a "Calibration Correction Coefficient" or CCC This is effected as set out below.

The TDS probe in a sampling vessel is immersed in a boiler water sample of a known TDS (i.e. 3500ppm for example). This is carried out at 25°C (77°F) which would give a reading in micro-siemens of 5000. If the reading from the probe electronics does not agree with this a correction multiplier or divider is implanted into this specific probes electronic memory. This is its own dedicated CCC value.

5 BOTTOM BLOWDOWN

5.1 Overview of Bottom Blowdown

5.1.1 Features and Benefits

Bottom blowdown is used to remove solids which build up at the bottom of steam boilers. In the Autoflame system, there are options to either manage the blowdowns through automatic timings, or to manually trigger them. The programmable electronic automatic blowdown ensures repeatable blowdown timings, without the need of a compressed air supply. A pulsed bottom blowdown is used to disturb settled solids at the bottom of the boiler, making the evacuation effect more efficient. The timings and intervals of the bottom blowdowns are user configurable. The benefits of the Autoflame bottom blowdown system include:

- Full stainless steel valve construction with replaceable bronze liner
- 24V DC Autoflame Unic 5 servomotor for control and repeatability
- Electronic proof of open/close end switches
- Lithium ion battery technology ensures guaranteed closure on power failure
- Total electronic operation – no compressed air supply
- Timed blowdown with manual/automatic operation
- Bottom blowdown sequence logging
- Up to 4 timed blowdowns over a 24 hour period
- Repeatable up to 10 times from 1 to 60 seconds for each blowdown
- 'Parked' position to reduce valve opening time
- Quick servomotor disconnect facility for manual actuation
- Rotary operation ensures water tight shutoff
- Sealing design concept ensures no leaks

<u>Valve Specifications</u>
Power Supply: 24V DC
Flange Connection: 400lb/ PN40
Valve Sizes: 1", 1 ½", and 2"

Figure 5.1.1.i Bottom Blowdown Valve and Industrial Unic 5 Servomotor

Note: Please Valves and Servomotors manual for water level valve dimensions, drawings and information on service and maintenance.

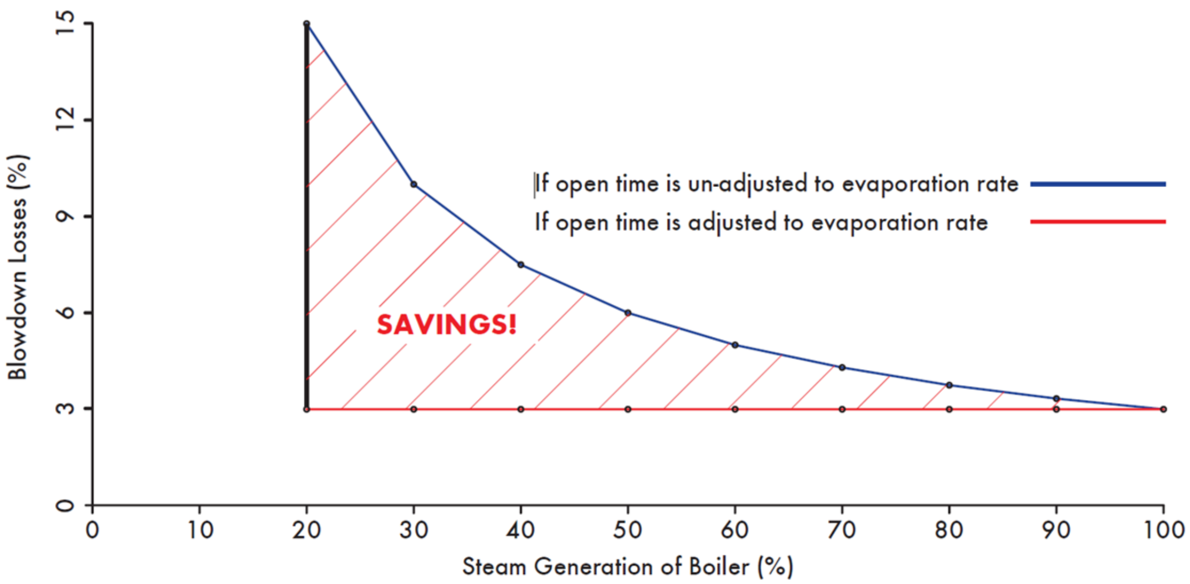
5.1.2 Bottom Blowdown Time Reduction

Calculated Bottom Blowdown Losses

With a typical loss in steam generation of 3% from the conventional bottom blowdown management, Autoflame have developed a Bottom Blowdown Time Reduction feature to minimise these losses which occur when keeping the boiler heat transfer surfaces clean.

It follows that blowdown time can be reduced as a function of the rate of steam generation. Silt and sludge formation within the boiler is always in ratio to work done or steam generation. Therefore the reduction in the blowdown valve open time can be made, as long as the reduced open time is in ratio to the evaporation rate or steam generation rate.

- Blowdown savings in the region of 1-2% are possible on total fuel usage (dependant on boiler load)
- Blowdown timing automatically reduced in ratio to steam generation
- Blowdown timings set by users
- Operators may only trigger pre-set timings, eliminates excessive blowdown by operator
- Ensures minimal blowdown to satisfy removal of solids, silt and sludge



For time reduced bottom blowdown, steam flow metering is required, this can be set through expansion option 38.1 (see section 2.2). The accurate burner rating must be set through M.M. options 33 and 77, as well accurate fuel flow metering through M.M. option 57.

Time Reduced Bottom Blowdown with M.M.

For timed reduced bottom blowdown with M.M. the maximum steam production used to base how the bottom blowdown time is scaled down to, is set through expansion option 36.4. The blowdown time is reduced according to the ratio of the actual steam production to the maximum steam production for that period. If the blowdown is calculated above the stored blowdown time set by the user in the bottom blowdown screen, than the extra time will get carried over to the next timed blowdown. This extra time will remain getting carried over to the following blowdowns until the steam production has lowered and the blowdown is therefore lowered.

There can be up to 4 blowdowns over a 24 hour period, with each blowdown:

Blowdown Time	BD_1	BD_2	BD_3	BD_4
Time between Blowdowns	T_1	T_2	T_3	T_4

The configured blowdown time for that period x which has been set by the user is:

$$BD_x = Blowdown\ time\ (\text{sec})$$

The time between the blowdowns which is sent by the user is:

$$T_x = Time\ between\ Blowdowns\ (hours)$$

Therefore over a 24 hour period:

$$T_1 + T_2 + T_3 + T_4 = 24hours$$

The blowdown time for that 24 hour period is then:

$$BD_1 + BD_2 + BD_3 + BD_4 = BD_T$$

So the maximum blowdown period can be calculated as:

$$BD_{max}(seconds) = \left(\frac{BD_T}{24}\right) \times T_x$$

The maximum steam flow which is set in expansion option 36.4 is:

$$SF_{max}$$

The average steam flow for that period which is given from steam flow metering is:

$$SF_x$$

The calculated steam flow ratio for that period is then:

$$SF_{c_x} = \frac{SF_x}{SF_{max}}$$

The adjusted blowdown time according to steam production is then:

$$BD_A = \frac{SF_{c_x} \times T_x \times BD_T}{24}$$

If the adjusted blowdown time is calculated higher than the maximum blowdown time, the time is carried over to the next blowdown operation:

$BD_A > BD_{max}$ *Extra time is carried over to next blowdown operation*

If the adjusted blowdown time is calculated lower than the minimum blowdown time set in expansion option 36.3, and expansion option 36.2 is set for minimum blowdown enforced then:

$BD_A < BD_{min}$ *, then Minimum blowdown time is enforced*

Example

The maximum steam flow rate which is set through expansion option 36.4 as 20,000lb/hour.

Blowdown Time	BD_1	BD_2	BD_3	BD_4
Time between Blowdowns	T_1	T_2	T_3	T_4

In this example the 4 blowdowns are configured with the total blowdown timings (Repeats x Duration) as:

BD_1	=	10s	at	T_1	00:00
BD_2	=	10s	at	T_2	06:00
BD_3	=	10s	at	T_3	14:00
BD_4	=	10s	at	T_4	18:00

For period 2, if the average steam flow rate for that period from the M.M. steam flow metering is 12,000lb/ hour, than the calculated steam flow ratio is then:

$$SF_{c_2} = \frac{SF_2}{SF_{max}} = \frac{12{,}000lb/hr}{20{,}000lb/hr}$$

$$SF_{c_2} = 0.6$$

The total configured blowdown time over the 24 hours is:

$$BD_T = BD_1 + BD_2 + BD_3 + BD_4 = 10s + 10s + 10s + 10s$$

$$BD_T = 40s$$

The maximum blowdown time for period 2 is:

$$T_x = T_2 - T_1 = 06{:}00 - 00{:}00 = 6\ hours$$

So therefore the adjusted blowdown time is then:

$$BD_A = \frac{SF_{c_x} \times T_x \times BD_T}{24hours} = \frac{0.6 \times 6hours \times 40secs}{24hours}$$

$$BD_A = 6s$$

The Maximum blowdown time for period 2 is 13s. Therefore a full 6s blowdown will be carried out.

The maximum blowdown time for period 3 at full steam rate of 20,000lb/hr is:

$$T_x = T_2 - T_1 = 014{:}00 - 06{:}00 = 8\ hours$$

So therefore the adjusted blowdown time is then:

$$BD_A = \frac{SF_{c_x} \times T_x \times BD_T}{24hours} = \frac{1 \times 8hours \times 40secs}{24hours}$$

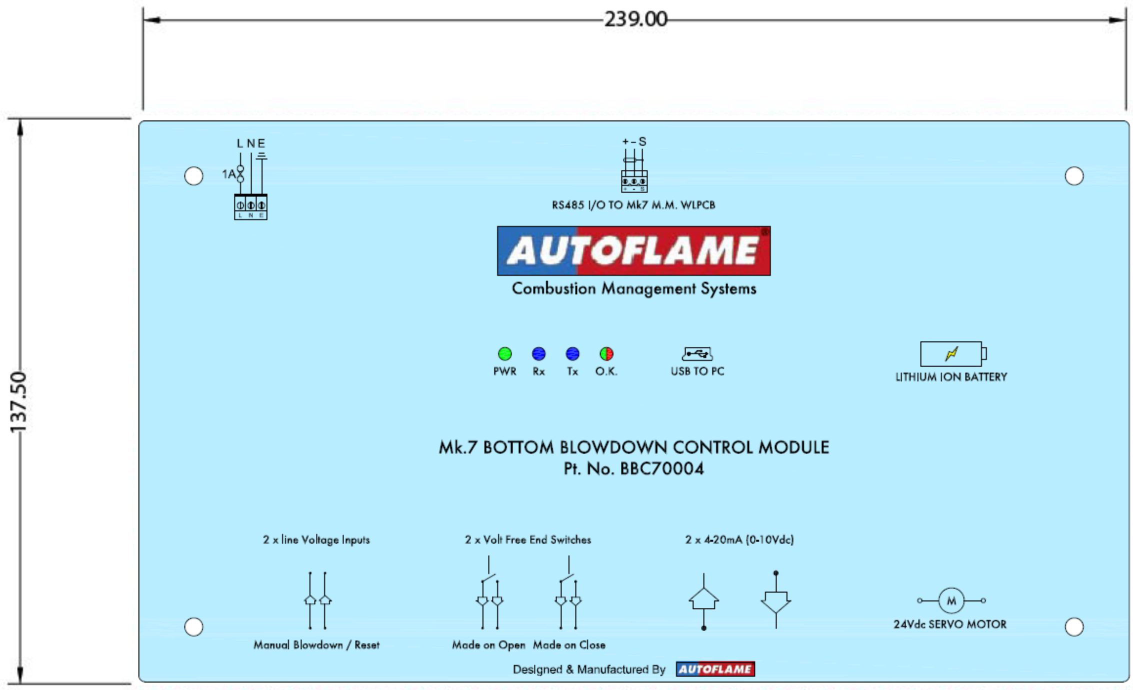
$$BD_A = 13.3s$$

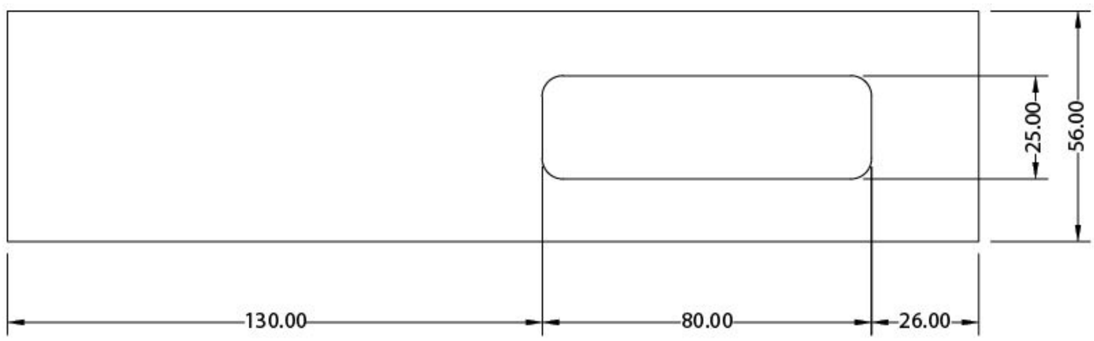
The Maximum blowdown time for period 3 is 10s. Therefore 3.3s is carried over to period 4.

Time Reduced Bottom Blowdown for Standalone

When using the time reduced bottom blowdown in standalone operation, the maximum steam flow rate and the average steam flow rate are taken from the 4-20mA input to the bottom blowdown module.

5.1.3 Bottom Blowdown Module Dimensions





5.2 Bottom Blowdown Configuration

5.2.1 Bottom Blowdown Options

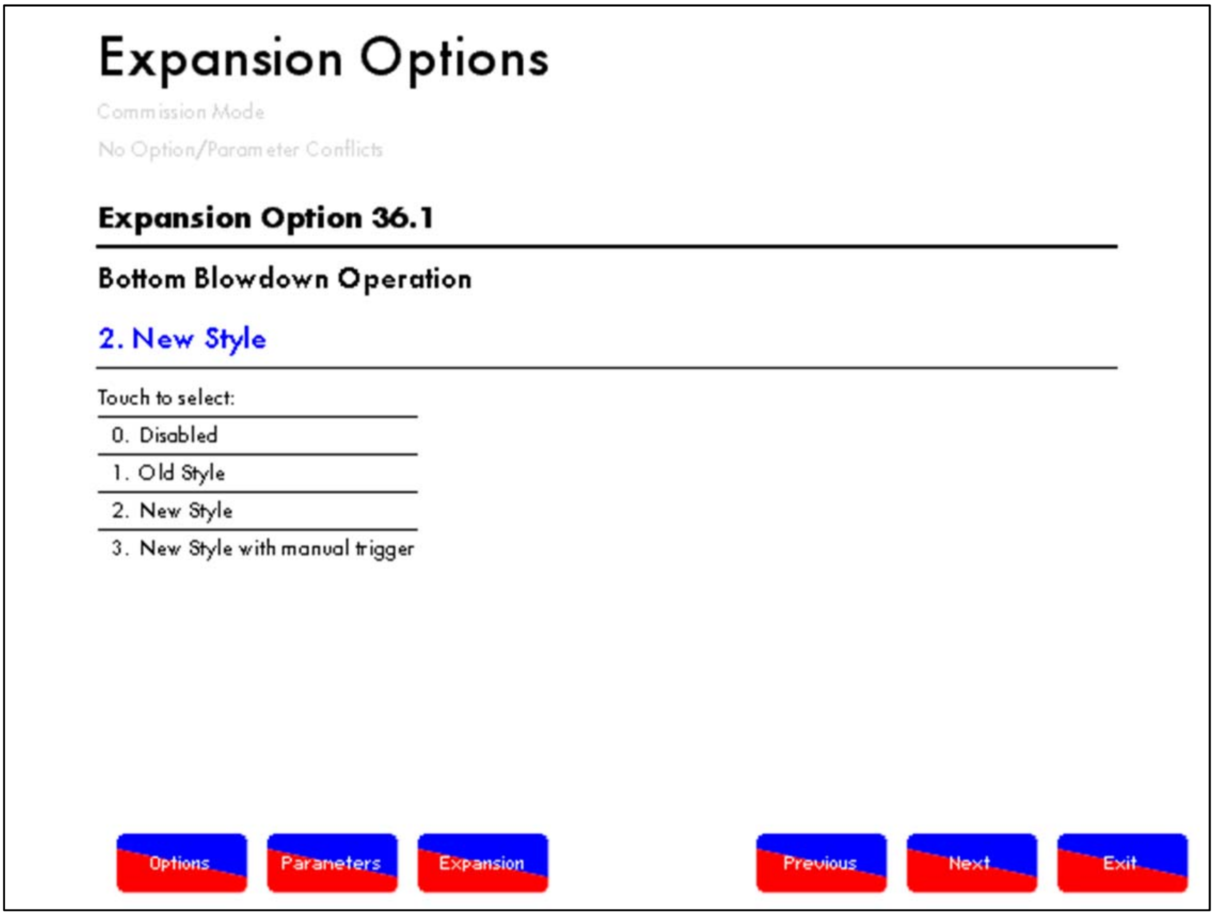


Figure 5.2.1.i Expansion Option 36.1

The available settings for expansion option 36.1 are:

0. Disabled
   Autoflame controlled bottom blowdown does not operate.

1. Old Style
   Terminal #BB on expansion board output to be used with 3rd party solenoid valve for up to 4 automatic blowdowns over 24 hours.

2. New Style
   Autoflame bottom blowdown module, bottom blowdown valve and 24V DC Unic 5 servomotor required for up to 4 timed blowdowns with configurable timings and intervals with no manual trigger needed for blowdown to commence.

3. New Style with Manual Trigger
   Autoflame bottom blowdown module, bottom blowdown valve and 24V DC Unic 5 servomotor required for up to 4 timed blowdowns with configurable timings and intervals, however a manual trigger is required for blowdown to commence.

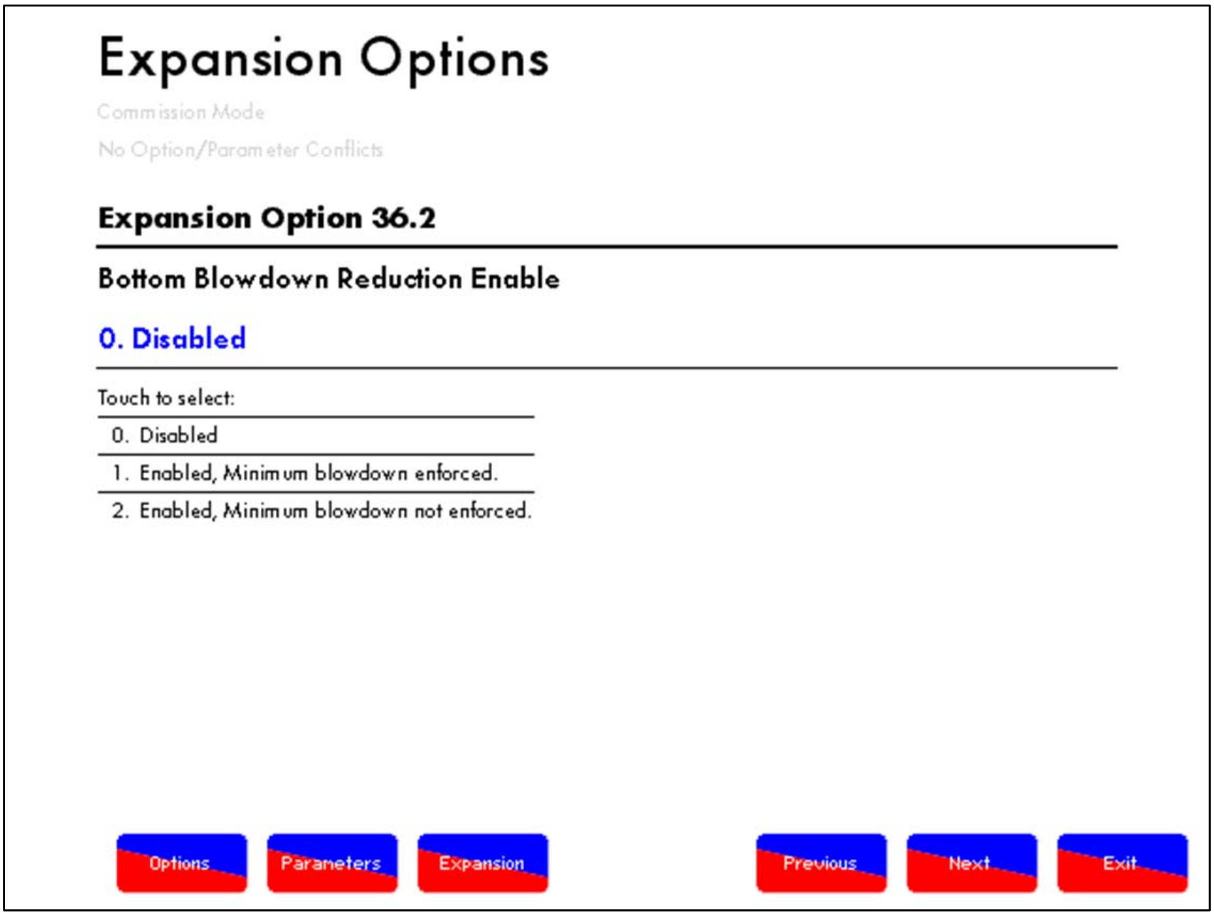


Figure 5.2.1.ii Expansion Option 36.2

The available settings for expansion option 36.2 are:

0. Disabled
   Bottom blowdown time reduction is disabled.

1. Enabled, Minimum Blowdown Enforced
   Bottom blowdown timing is adjusted according to the boiler's steam production. If there is no steam contribution, a minimum blowdown time set in expansion option 36.3 may be set to avoid missed blowdowns.

2. Enabled, Minimum Blowdown Not Enforced
   Bottom blowdown timing is adjusted according to the boiler's steam production. If there is no steam contribution, no blowdown will take place.

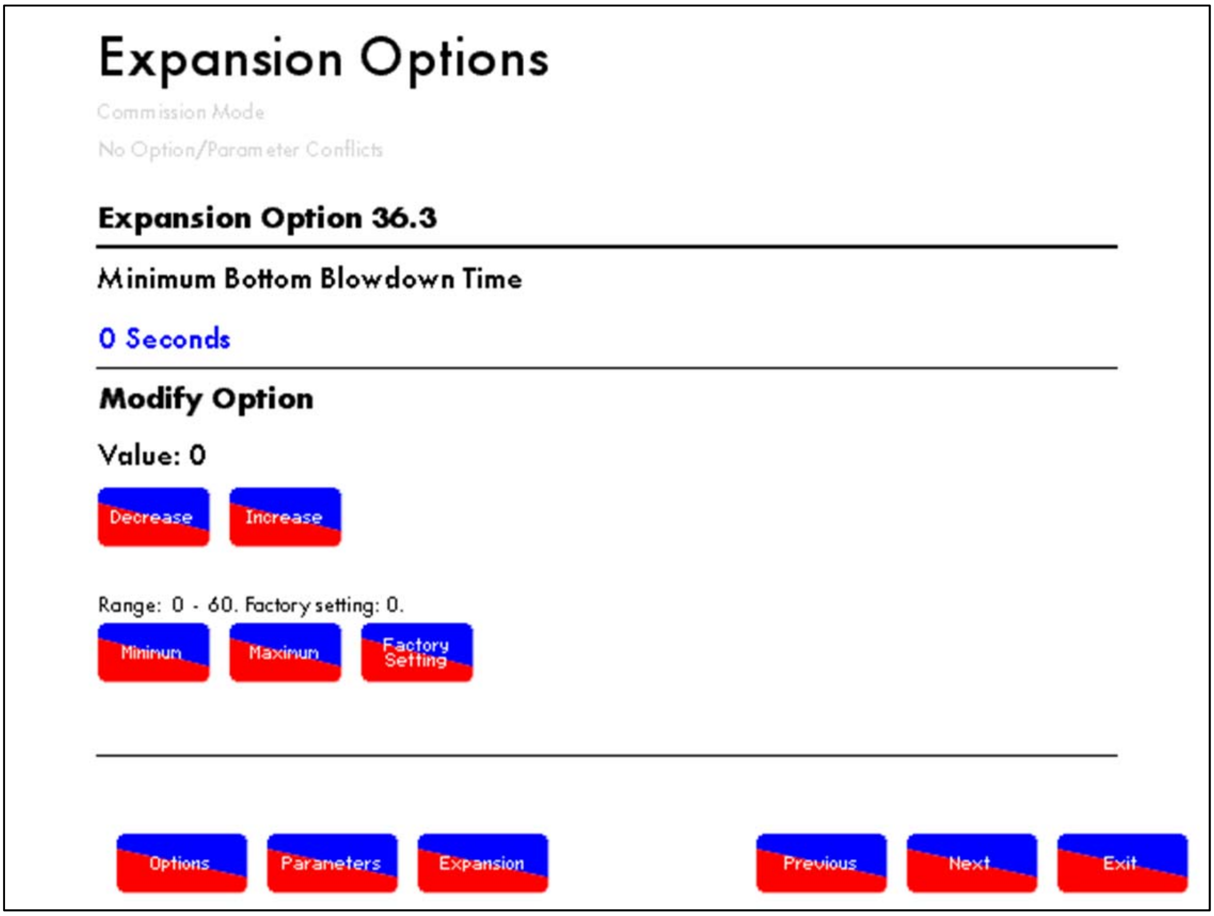


Figure 5.2.1.iii Expansion Option 36.3

Expansion option 36.3 sets the minimum blowdown time when expansion option 36.2 is set for minimum blowdown enforced.

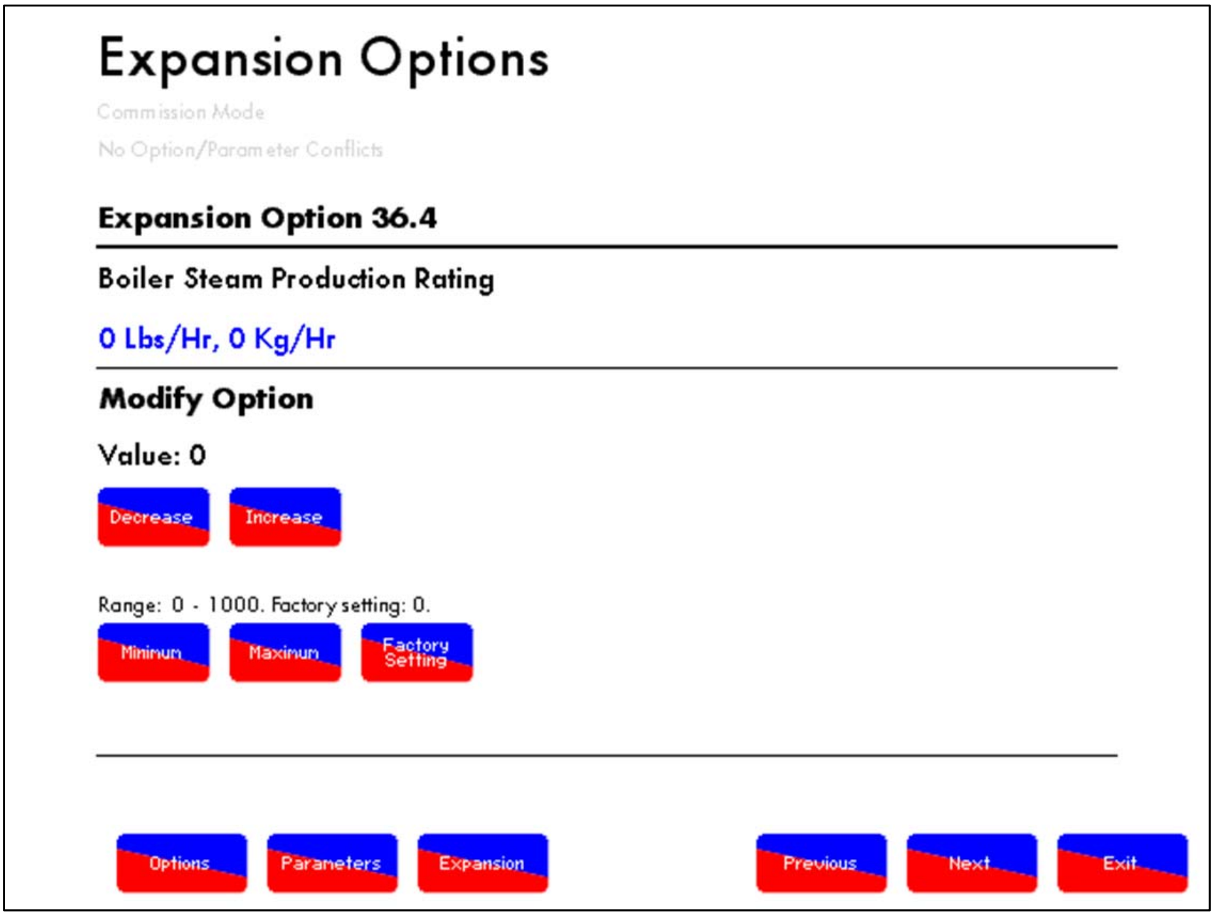


Figure 5.2.1.iv Expansion Options

Expansion option 36.4 allows the user to define the maximum steam production for the boiler so that the M.M. can use this rating to calculate the ratio of time decreases allowed in bottom blowdown time reduction according to the steam production.

5.3 Commissioning Bottom Blowdown Module

For a new installation, after checking the wiring, performing safety installation checks, and settings the options, parameters and expansion options (as in the Mk7 M.M. Installation and Commissioning Guide), the order of commissioning the burner must follow:

1. Commission bottom blowdown module
2. Commission water level probes
3. Commission fuel to air ratio
4. Re-commission water level probes at operating temperature/pressure

WARNING: COMMISSIONING OR START-UP MUST ONLY BE CARRIED OUT BY A FACTORY TRAINED TECHNICIAN

The bottom blowdown module will be configured for battery operation with 35degrees from closed for the parked position.

When the bottom blowdown module is used as standalone, it must be configured using the bottom blowdown configurator PC software. Please see section 5 in the Autoflame PC Software Guide for more information.

There are 4 expansion options to configure the bottom blowdown.

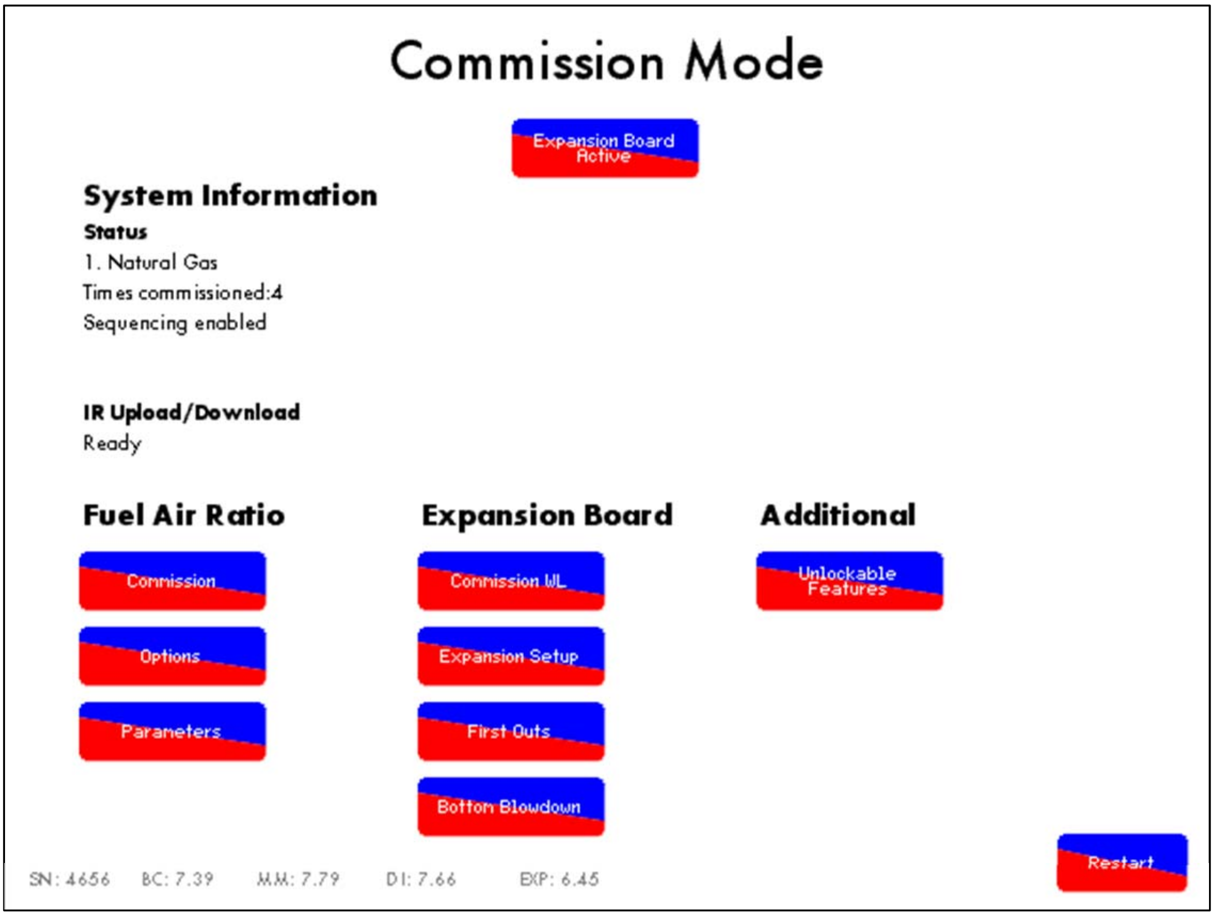


Figure 5.3.i Bottom Blowdown Button

Once the expansion options have been configured for bottom blowdown, the 

will appear in the Commission Mode screen shown in Figure 5.3.i. Press this button to set the closed and open positions for the bottom blowdown valve as well as to test the battery back-up operation.

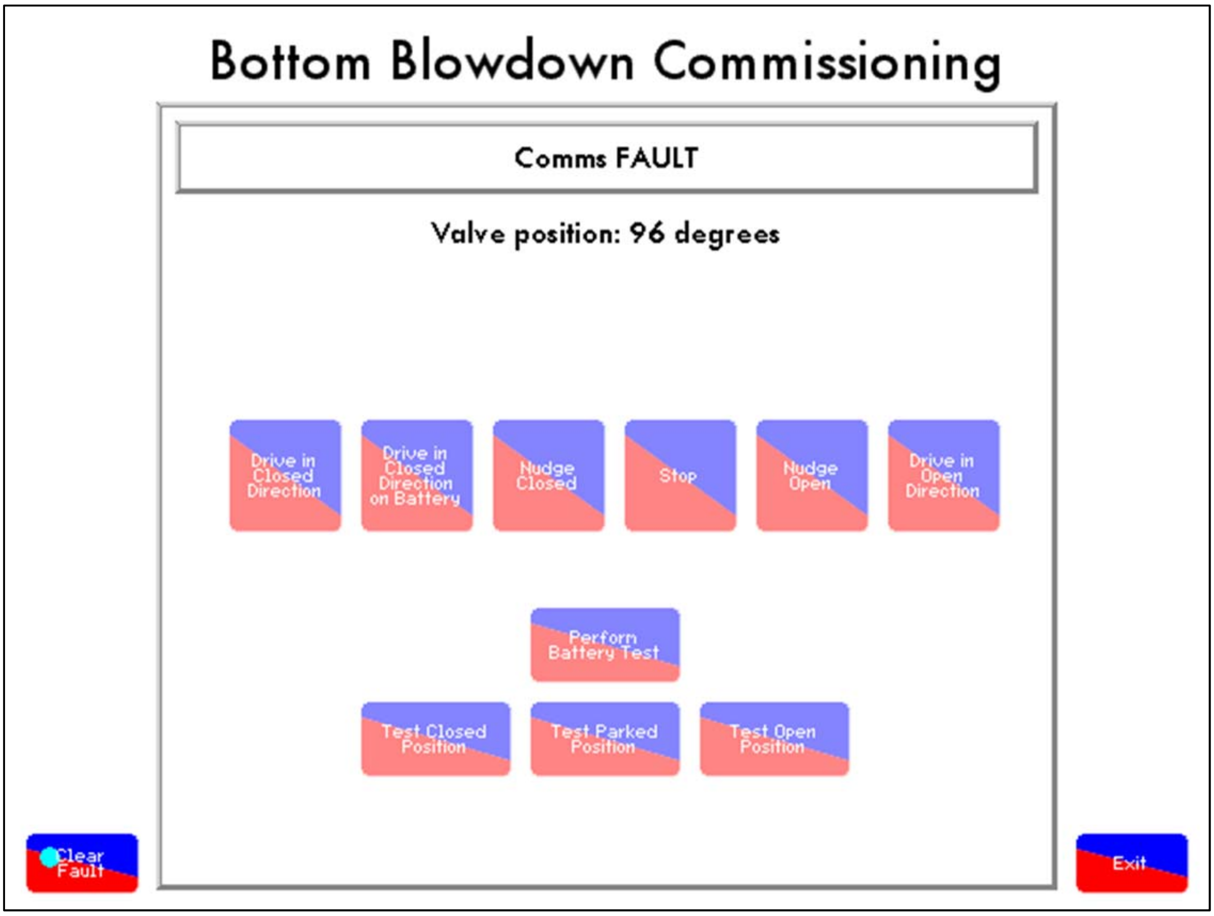


Figure 5.3.ii Bottom Blowdown Commissioning Screen

When the bottom blowdown module is first configured, the red and green LEDs will flash on the module indicating a fault; there is a fault because the module has not been configured yet. To clear the fault, press 

as shown in the bottom blowdown module screen in Figure 5.3.ii.

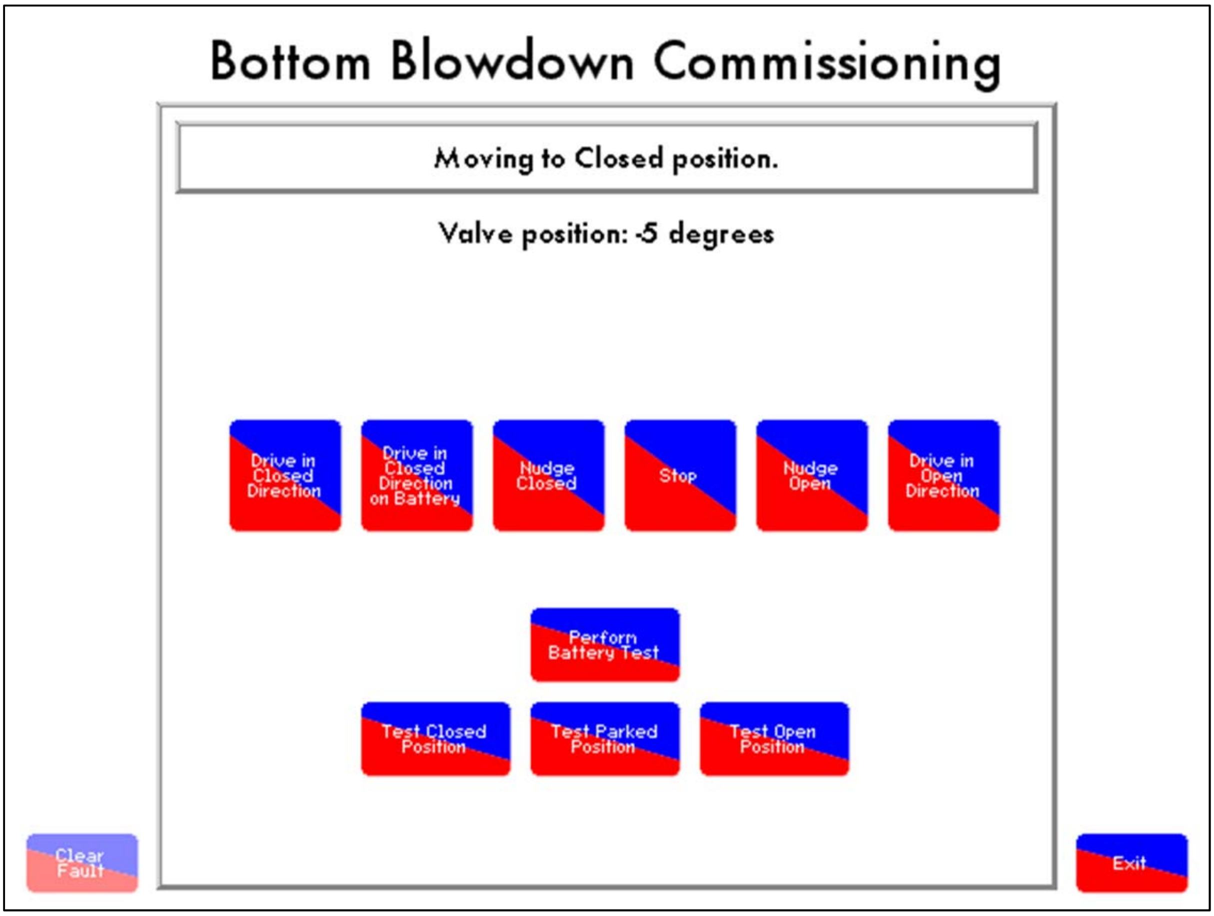


Figure 5.3.iii Moving to Closed Position

To set the closed position of the bottom blowdown, press either 

which will drive the servomotor in the direction of the closed position continuously until the 

button is pressed, or press 

which will make a small valve movement towards the closed position. The closed position should be set at 0 degrees; adjust the potentiometer if necessary. To set the open position, use the corresponding buttons for the driving the valve towards the open position.

The parked position is a just closed position, and is set as a constant at 35 degrees away from the fully closed position set by the user. During blowdown, in the valve closed interval, the valve moves to the parked position rather than the fully closed position, and then to the open position to blow out the sludge. It takes 3 seconds quicker to go from the open position to the parked position, than to go from the open to the closed position.

Press 

, 

and 

to check the positions that have been set.

5.4 Battery Test

Pressing 

will the move the valve position towards the close position by using the battery power. A working battery will have 13V + in the cells, if this falls below 12.4V, there will not be enough voltage in the battery to drive the valve to the closed position should a power failure occurs.

To test the battery operation, drive the valve to the closed position, then press 

. The valve is then opened to the parked position using mains power, and then it is driven to the closed position using the battery power to test the battery. If the battery cannot drive the valve to the closed position, a 24V fault will appear.

The bottom blowdown module is now commissioned, press 

and then proceed to commission the water level probes, see section 2.3.1. After the M.M. has been commissioned for water level probes and fuel-to-air ratio, the timings and intervals of the bottom blowdown can be set.

5.5 Bottom Blowdown Timer Configuration

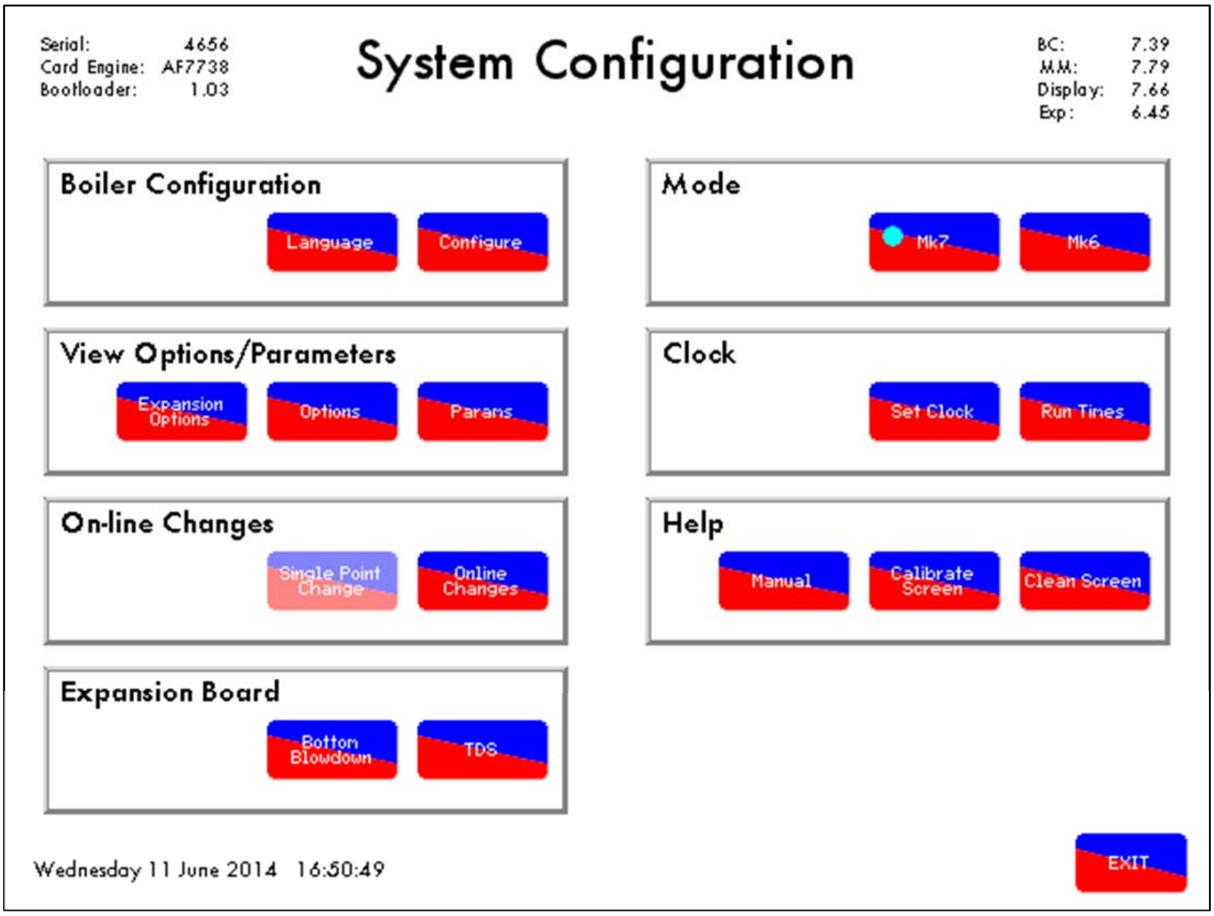


Figure 5.5.i Configure Screen – Run Mode

In the Configure screen of Run mode, a 

button will appear, see Figure 5.5.i. Pressing this button will take you to the timings and intervals adjustment screen.

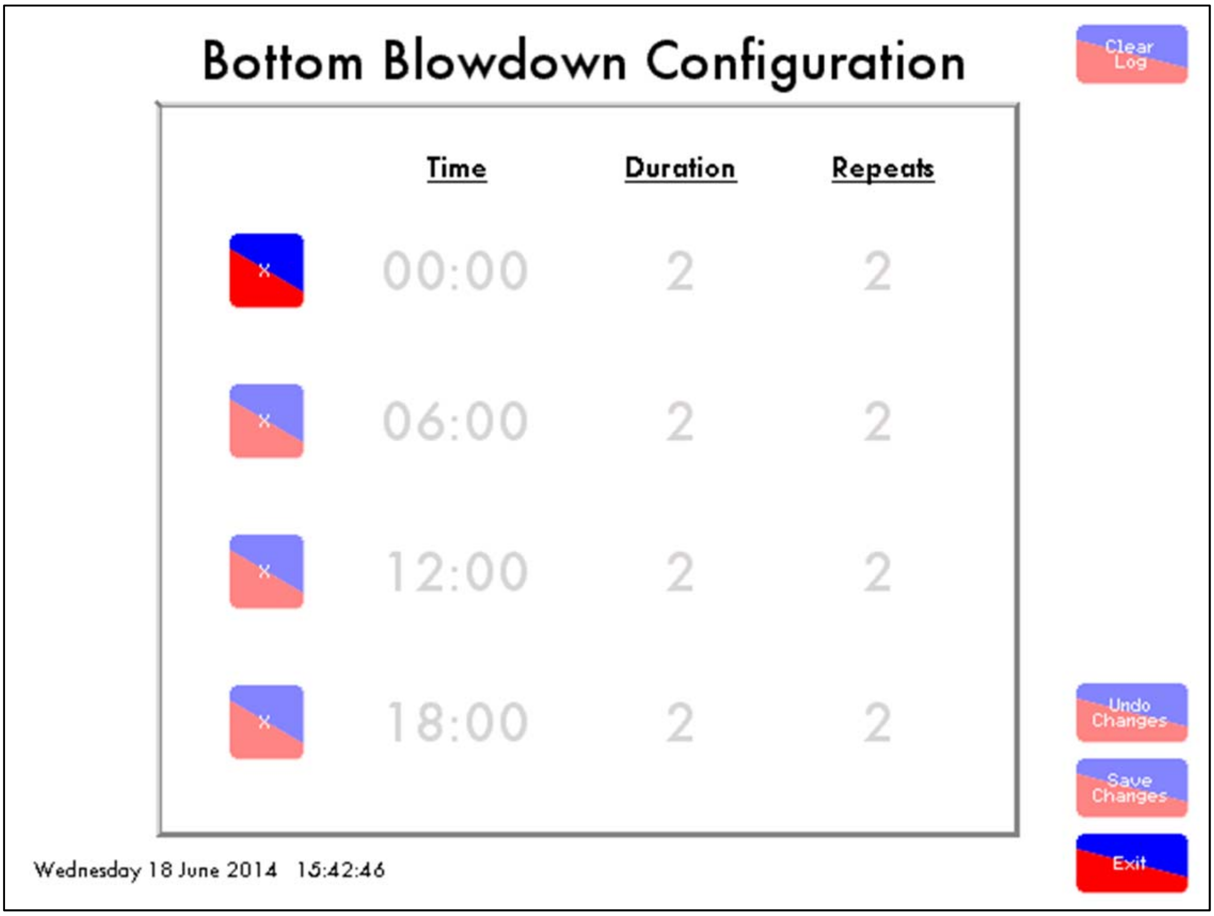


Figure 5.5.ii Bottom Blowdown Configuration Screen

Figure 5.5.ii shows the Bottom Blowdown Configuration screen, here up to 4 blowdowns can be selected with their corresponding times, durations and repeats. Each blowdown can be a maximum of 60 seconds, with a maximum of 10 repeats. Press 

and then 

.

Figure 5.5.iii Setting Blowdowns

To activate a blowdown, press 

, then press the time for that blowdown, ± will appear above and below the time. Use these + and - buttons to adjust the timing. Then press ± buttons on the duration and repeats to set the total blowdown time required.

Once all the required blowdown times have been configured, press 

before exiting the screen.

5.6 Bottom Blowdown Operation

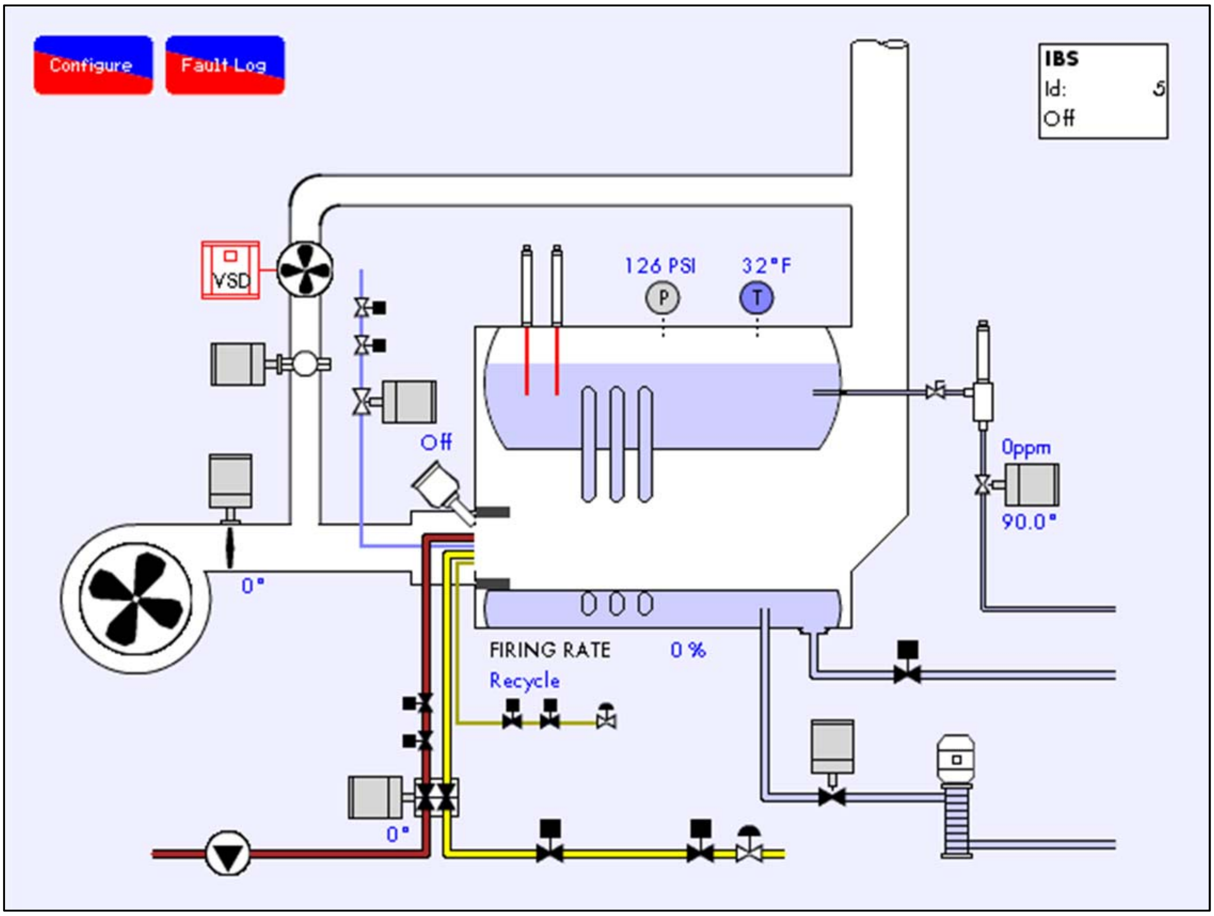


Figure 5.6.i Boiler Screen

Go into the water level screen on the M.M. to see what stage the bottom blowdown is in. Press the feed water valve in the bottom right corner of the main boiler screen to access the bottom blowdown status information.

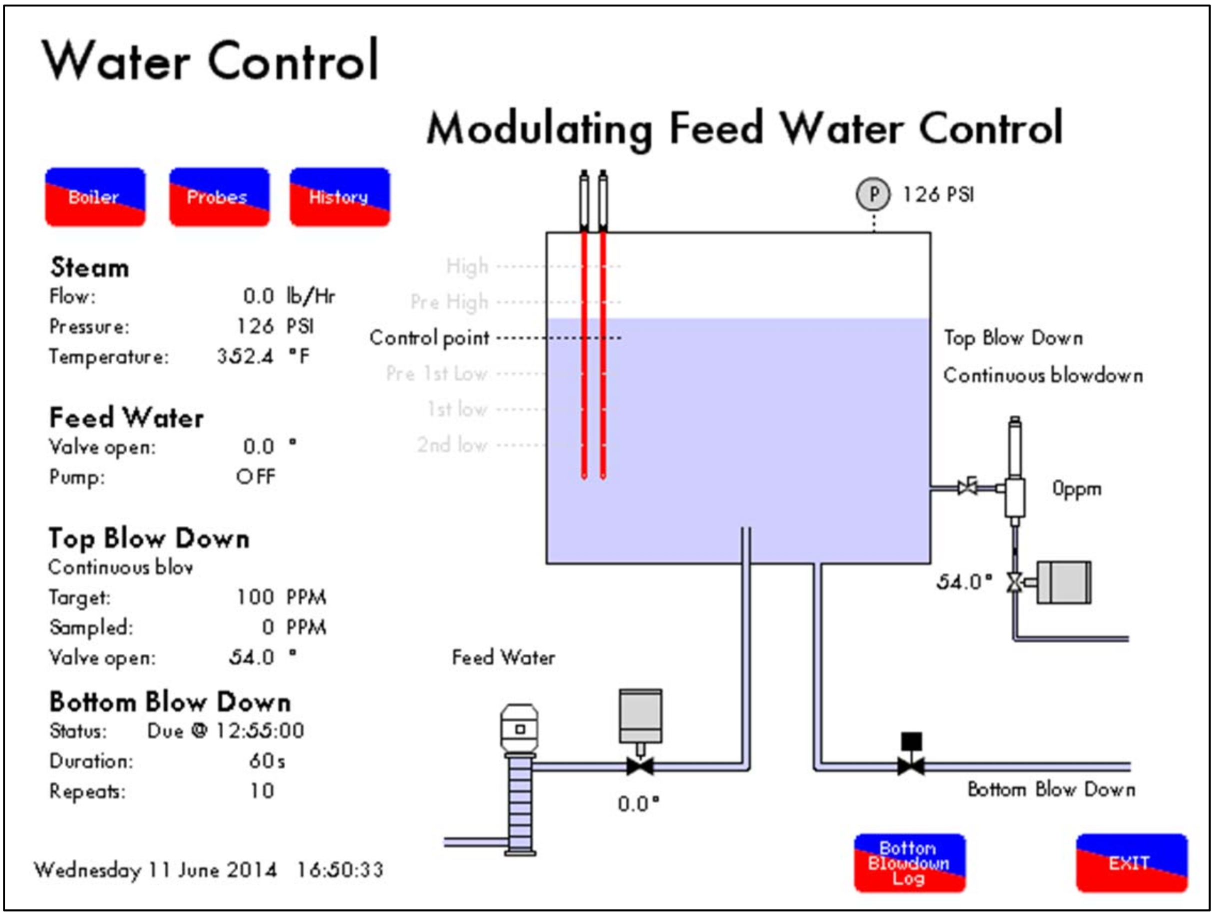


Figure 5.6.ii Water Level Screen

The next time for the bottom blowdown will show in the bottom right corner of the screen, see Figure 5.6.ii, as well as the duration of that next blowdown with its repeats. When it is due, the status will show IMMINENT, and when it begins this will change to IN PROGRESS.

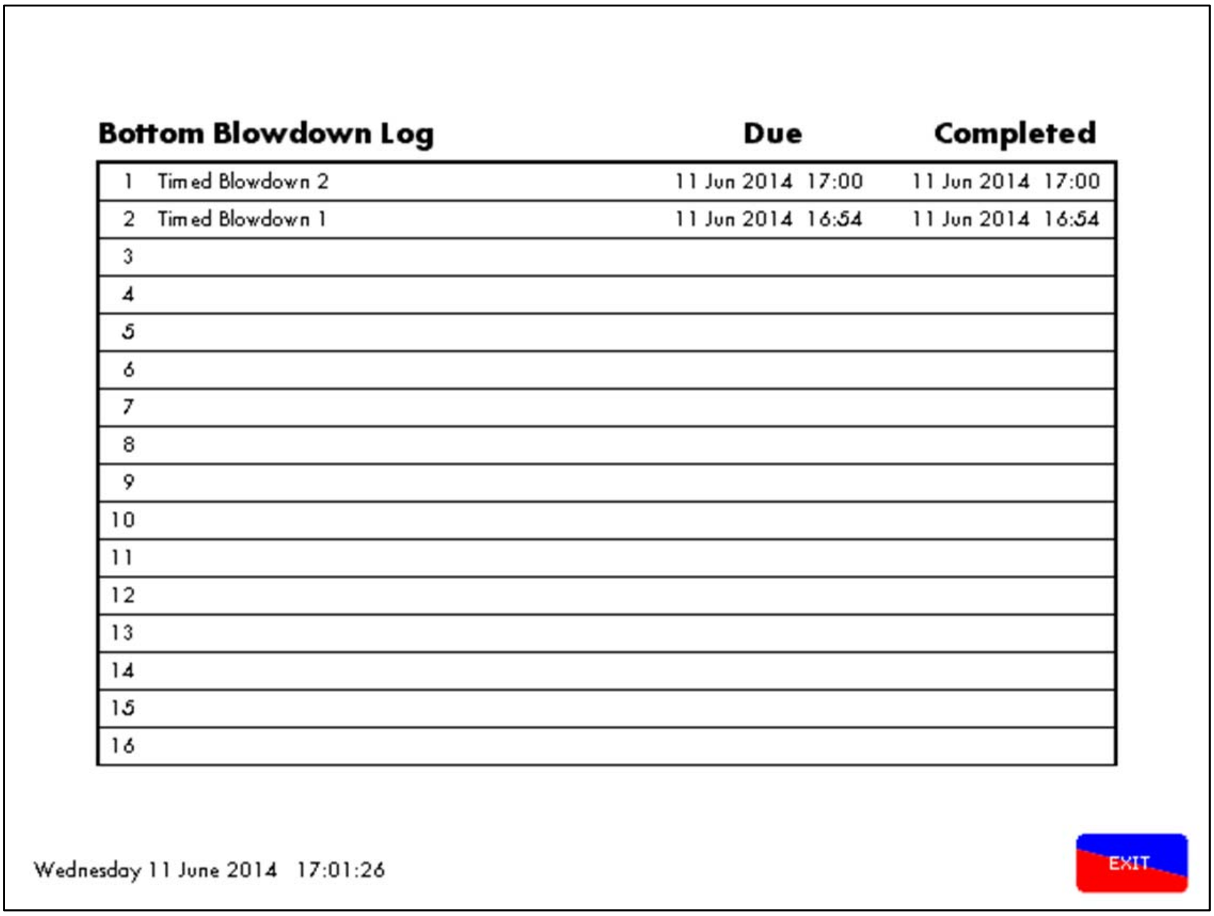


Figure 5.6.iii Bottom Blowdown Log

To go to the bottom blowdown sequence log screen, press 

, see Figure 5.6.iii.

5.7 Further Bottom Blowdown Time Reduction Savings Calculations

Bottom blowdown time reduction is used to control the opening time in ratio to the steam production. In this way, the losses incurred from bottom blowdown can be lowered.

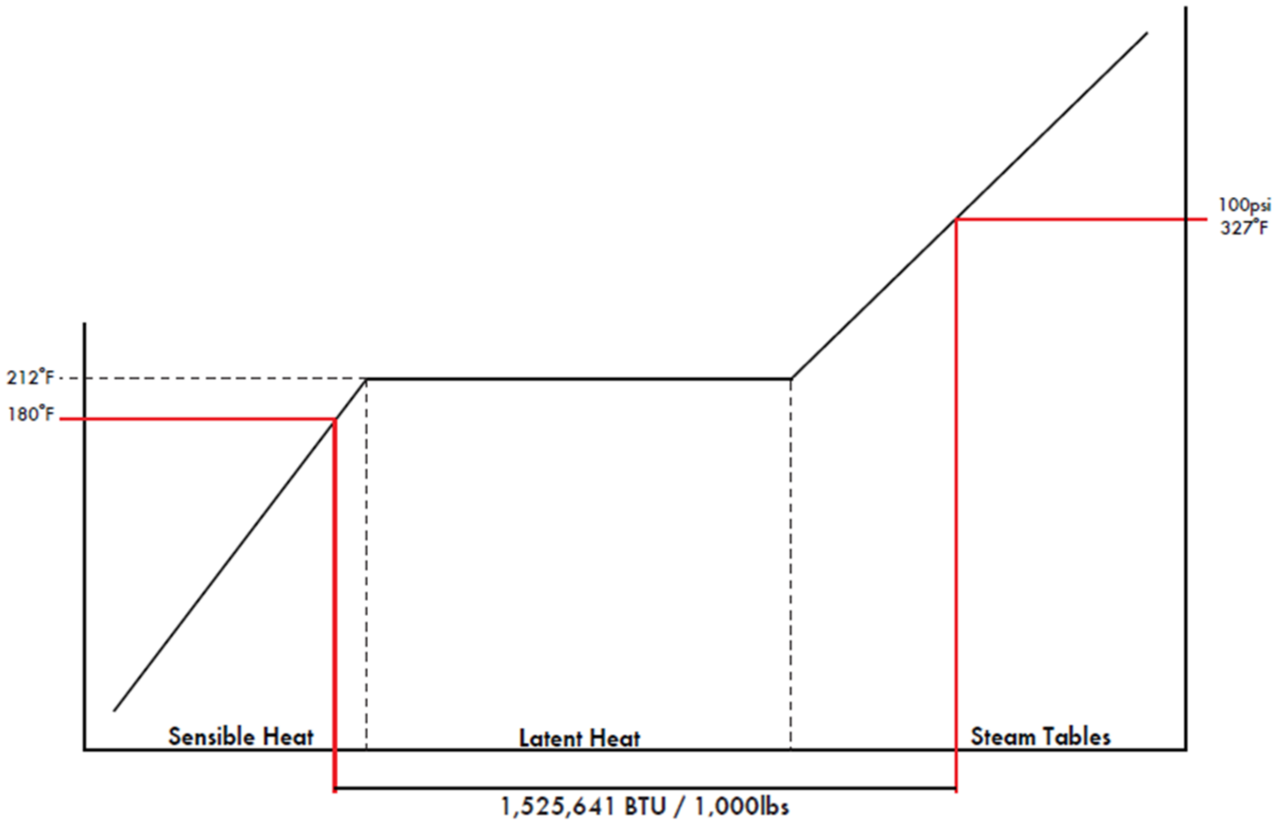
The example below is based on the heat required to generate steam from feed water at 180degF to steam at 100 PSI (327degF). It is recognised in the steam industry that a typical steam boiler will lose 3% of its energy in steam generation to bottom blowdown management.

If a 20,000lb/hr boiler firing on natural gas is operating at Maximum Continuous Rating (M.C.R.), the total required heat input would be 25,000,000 BTU/hr including 20% stack losses and 2% standing losses.

Therefore for a typical shift cycle of 8 hours at 20,000lb/hr, which is approximately 200,000,000 BTU in heat. The typical blowdown losses of 3% would then be 6,000,000 BTU.

Assuming that £10.25 ($15.62) gives 1,000,000 BTU for firing on natural gas, the cost of conventional bottom blowdown management at M.C.R. over 8 hours would be £61.50 ($93.62).

Assuming that £14.96 ($22.80) gives 1,000,000 BTU for firing on no.2 oil, the cost of conventional bottom blowdown management at M.C.R. over 8 hours would be £85.27 ($129.94).



In the example below, all savings are based on a 20,000lb/hr boiler operating over a 24 hour period for 8 hours at M.C.R., for 8 hours at 20% of M.C.R.. and 8 hours standby (banked).

- 8 hours High Fire, 8 hours Low Fire, 8 hours Standby – Blowdown without open time adjustment to evaporation rate:

	Natural Gas (£10.25/1MBTU)	**No.2 Oil (£14.96/1MBTU)**
Average Steam Cost	£19.22/1000lb	£26.20/1000lb
Steam Production	144,538 lbs/day	145,042 lbs/day
Cost to Run Boiler (day)	£2,460 /day	£3,374.98 /day
Cost to Run Boiler (year)	£897,900 /year	£1,231,866 /year

- 8 hours High Fire, 8 hours Low Fire, 8 hours Standby – with open time adjustment to evaporation rate:

	Natural Gas (£10.25/1MBTU)	**No.2 Oil (£14.96/1MBTU)**
Average Steam Cost	£17.23 / 1000 lb	£ 23.49 /1000lb
Steam Production	148,571 lbs / day	149,136 /day
Cost to Run Boiler (day)	£2,460 / day	£3,374.98 /day
Cost to Run Boiler (year)	£897,900 / year	£1,231,866 /year
Steam Production	52,756,302 lb/year	52,940,336 lb/year

From this data, and keeping the same fuel consumption as before, using the reduced time bottom blowdown would give savings:

Typical Annual Savings (Gas)	£25,373.49
Typical Annual Savings (Oil)	£35,101.27

Efficiency Equations for Bottom Blowdown Losses

Constants:

Natural Gas Constant	K_1	=	0.38
Fuel Oil Constant	K_2	=	0.0083
Ambient Air Temperature	T_A	=	77deg F (25deg C)
Flue Gas Temperature	T_G	=	392deg F (200 deg C)
	CO_2	=	10.5%

$$\text{Efficiency} = 100 - \left[\frac{[K_1\ (T_G - T_A)]}{CO_2} + (K_2\ (1121.4 + (T_G - T_A)\right]$$

$$\text{Efficiency} = 100 - \left[\frac{[0.38\ (200 - 25)]}{10.5} + (0.0083\ (1121.4 + (200 - 25)\right]$$

$$\text{Efficiency} = 100 - \left[\frac{[66.5]}{10.5} + (0.0083 \times 1296.4)\right]$$

$\text{Efficiency} = 100 - [6.33 + 10.76]$
$\text{Efficiency} = 82.91\%$

Net Efficiency = Usefuel Input − (Standing Losses + Blowdown Losses)
Net Efficiency = 82.91% – (1% + 3%)
Net Efficiency = 78.91%

Gross Heat Input into Boiler = 25,000,000 BTU/Hr

Net Heat Input into Boiler = 25,000,000 × 78.91%
Net Heat Input into Boiler = 19,727,500 BTU/Hr

Gross Input = 25,000,000 BTU/Hr
Gross Input = 7,321.87 Kw

$1kW$ = £0.034

Fuel Cost = £248.94/Hr

Energy required to raise 1lb steam from 180°F to 327°F = 1040 BTU

$$\frac{19{,}727{,}500\ BTU}{1{,}040\ BTU/Hr} = 18{,}968.75\ lb/Hr$$

Fuel Cost = £13.12/1000$lb\ Steam$

Constants:

Natural Gas Constant	K_1	=	0.38
Fuel Oil Constant	K_2	=	0.0083
Ambient Air Temperature	T_A	=	77deg F(25deg C)
Flue Gas Temperature	T_G	=	302deg F(175 degC)
	CO_2	=	9.5%

$$\text{Efficiency} = 100 - \left[\frac{[K_1\,(T_G - T_A)]}{CO_2} + (K_2\,(1121.4 + (T_G - T_A)\right]$$

$$\text{Efficiency} = 100 - \left[\frac{[0.38\,(175-25)]}{9.5} + (0.0083\,(1121.4 + (175 - 25)\right]$$

$$\text{Efficiency} = 100 - \left[\frac{[57]}{9.5} + (0.0083 \times 1271.4)\right]$$

$$\text{Efficiency} = 100 - [5 + 10.55]$$
$$\text{Efficiency} = 84.45\%$$

$$\text{Net Efficiency} = \text{Usefuel Input} - (\text{Standing Losses} + \text{Blowdown Losses})$$
$$\text{Net Efficiency} = 84.45\% - (1\%\,[of\ \max input] + 3\%\,[of\ \max input])$$
$$\text{Net Efficiency} = 84.45\% - (250{,}000\ BTU/Hr + 750{,}000\ BTU/Hr)$$
$$\text{Net Efficiency} = 84.45\% - (2.1\% + 6.2\%)$$
$$\text{Net Efficiency} = 84.45\% - 8.3\%$$
$$\text{Net Efficiency} = 76.15\%$$

$$\text{Gross Heat Input into Boiler (Mid} - \text{Fire)} = 12{,}500{,}000\ BTU/Hr$$
$$\text{Net Heat Input into Boiler} = 12{,}500{,}000 \times 84.45\% - 1{,}000{,}000\ BTU/Hr$$
$$\text{Net Heat Input into Boiler} = 9{,}556{,}250\ BTU/Hr$$

$$\text{Gross Input} = 12{,}500{,}000\ BTU/Hr$$
$$\text{Gross Input} = 3660.93\ Kw$$
$$1kW = £0.034$$
$$\text{Fuel Cost} = £124.47/Hr$$

Energy required to raise 1lb steam from 180^{o}F to 327^{o}F = 1040 BTU

$$\frac{9{,}556{,}250\ BTU}{1{,}040\ BTU/Hr} = 9188.7\ lb/Hr$$

$$\text{Fuel Cost} = £13.55/1000lb\ Steam$$
$$\text{Fuel Cost} = £124.47/Hr$$

Fuel Cost per day (16 hours operation) = £1991.52
Fuel Cost per year (365 days operation) = £726,904.80
Total Steam Production = 53,662,008 lbs

Constants:

Natural Gas Constant	K_1	=	0.38
Fuel Oil Constant	K_2	=	0.0083
Ambient Air Temperature	T_A	=	77deg F(25 deg C)
Flue Gas Temperature	T_G	=	302 degF (175 degC)
	CO_2	=	9.5%

$$\text{Efficiency} = 100 - \left[\frac{[K_1\,(T_G - T_A)]}{CO_2} + (K_2\,(1121.4 + (T_G - T_A)\right]$$

$$\text{Efficiency} = 100 - \left[\frac{[0.38\,(175 - 25)]}{9.5} + (0.0083\,(1121.4 + (175 - 25)\right]$$

$$\text{Efficiency} = 100 - \left[\frac{[57]}{9.5} + (0.0083 \times 1271.4)\right]$$

$$\text{Efficiency} = 100 - [5 + 10.55]$$
$$\text{Efficiency} = 84.45\%$$

By halving blowdown losses:

$\text{Gross Heat Input into Boiler (Mid} - \text{Fire)} = 12{,}500{,}000\ BTU/Hr$
$\text{Net Efficency} = \text{Useful Input} - (\text{Standing Losses} + \text{Blowdown Losses})$
$\text{Net Efficiency} = 84.45\% - (1\%\ [of\ \max input] + 1.5\%\ [of\ \max input])$
$\text{Net Efficiency} = 84.45\% - (250{,}000\ BTU/Hr + 375{,}000\ BTU/Hr)$
$\text{Net Efficiency} = 84.45\% - (2.1\% + 3\%)$
$\text{Net Efficiency} = 84.45\% - 5.1\%$
$\text{Net Efficiency} = 79.45\%$

$\text{Gross Heat Input into Boiler (Mid Fire)} = 12{,}500{,}000\ BTU/Hr$
$\text{Net Heat Input into Boiler} = 12{,}500{,}000 \times 79.45\%$
$\text{Net Heat Input into Boiler} = 9{,}931{,}250\ BTU/Hr$

$\text{Gross Input} = 12{,}500{,}000\ BTU/Hr$
$\text{Gross Input} = 3660.93\ Kw$
$1kW = £0.034$
$\text{Fuel Cost} = £124.47/Hr$

Energy required to raise 1lb steam from 180°F to 327°F = 1040 BTU

$$\frac{9{,}931{,}250\ BTU}{1{,}040\ BTU/Hr} = 9549.28\ lb/Hr$$

$\text{Fuel Cost} = £13.03/1000lb\ Steam$

$\text{Fuel Cost} = £124.47/Hr$
Fuel Cost per day (16 hours operation) = £1991.52
Fuel Cost per year (365 days operation) = £726,904.80
Total Steam Production = 55,767,795 lbs

Therefore: Per year (with an 50% boiler output):

Total Steam Production with Standard Blowdown = 53,662,008 lbs

Total Steam Production with Time Adjusted Blowdown = 55,767,795 lbs

An additional 2,105,787 lbs of steam produced for the same cost.

If producing the same amount of steam the following saving is deduced:
£0.01303 x 2,105,787 = £27.438.40 savings
3.77% overall savings

5.8 Shunt Switch

5.8.1 Shunt Switch Philosophy

The ability to implement a controlled by-pass of the low water cut off's during a manual water column blowdown, boiler blowdown or evaporation test is available on the Mk7 M.M. with water level control. This is incorporated into the Autoflame controller so as to avoid the requirement for any additional push buttons/key switches on the control panel. The operation of the shunt switch can only be accessed in Mk6 mode. Please follow this procedure:

1. While the burner is either firing or in the standby state, press the 'Water Level' and 'Enter Memory' buttons simultaneously.

2. The Mk.6 screen will show "Implement level Control Test Procedure".

3. The operator will have to either confirm that he wanted to proceed by pressing 'Water Level' and 'Enter Memory' simultaneously or press 'Run' to exit.

4. If the operator proceeded to press the 'Water Level' and 'Enter Memory' button, the Mk.6 screen would then display 'Feed Water Valve Shut' and close the feed water valve.

5. The burner would continue to operate. At this time the operator would either let the water evaporate automatically or physically blow down the water column or boiler. A user-definable amount of time (time A) is set in expansion option 25.1, during which time the 1st Low must be reached. If not, the burner will revert back to the run condition.

6. The 1st Low Alarm would be initiated and the alarm would sound. The operator has the option of muting the alarm. The burner continues to operate.

7. The operator would continue to decrease the water level in the column or boiler or allow the water to continue evaporating. A user-definable amount of time (time B) is set in expansion option 25.2, during which time the 2nd Low must be reached. If not, the burner will turn off.

8. The 2nd Low Alarm would be initiated and the alarm would sound. The operator again has the option of muting the alarm. The burner continues to operate.

9. 3 seconds after the 2nd Low Alarm has been initiated the Mk.6 screen would display 'Feed Water Valve Open'. The water level would start to increase.

10. The Mk.6 would expect to see the water level rise above the 2nd Low Level within 300 seconds (default value) or time B of the valve opening. Should the level not increase a 2nd Low Alarm will be initiated, causing the burner to turn off and a lockout to occur, requiring a manual reset to recycle the system.

11. Once the water level increased above the 2nd Low Level the Mk.6 would allow a further 300 seconds (default value) or time A for the water level to rise above the 1st Low Level. Again should the level not increase a 1st Low Alarm will be initiated, causing the burner to turn off and an alarm to sound. The system would automatically recycle the system once the water level is above the 1st Low Level.

12. Once the level returns to above the 1st Low Level the screen would display 'Test Complete, Normal Operating Level Restored'

6 STEAM AND HEAT FLOW METERING

6.1 Steam Flow Metering

Autoflame steam flow metering is available in the water level control; it has been granted an international patent. By the addition of one temperature detector it is possible to extrapolate steam flow from a boiler both as an instantaneous value and a totalised amount over time. A full steam flow metering package is available with just the addition of one temperature sensor to the expansion board, avoiding the cost of an expensive steam flow meter and orifice plate that is typically accurate at the higher firing rates only.

An explanation of this is detailed below in the example:

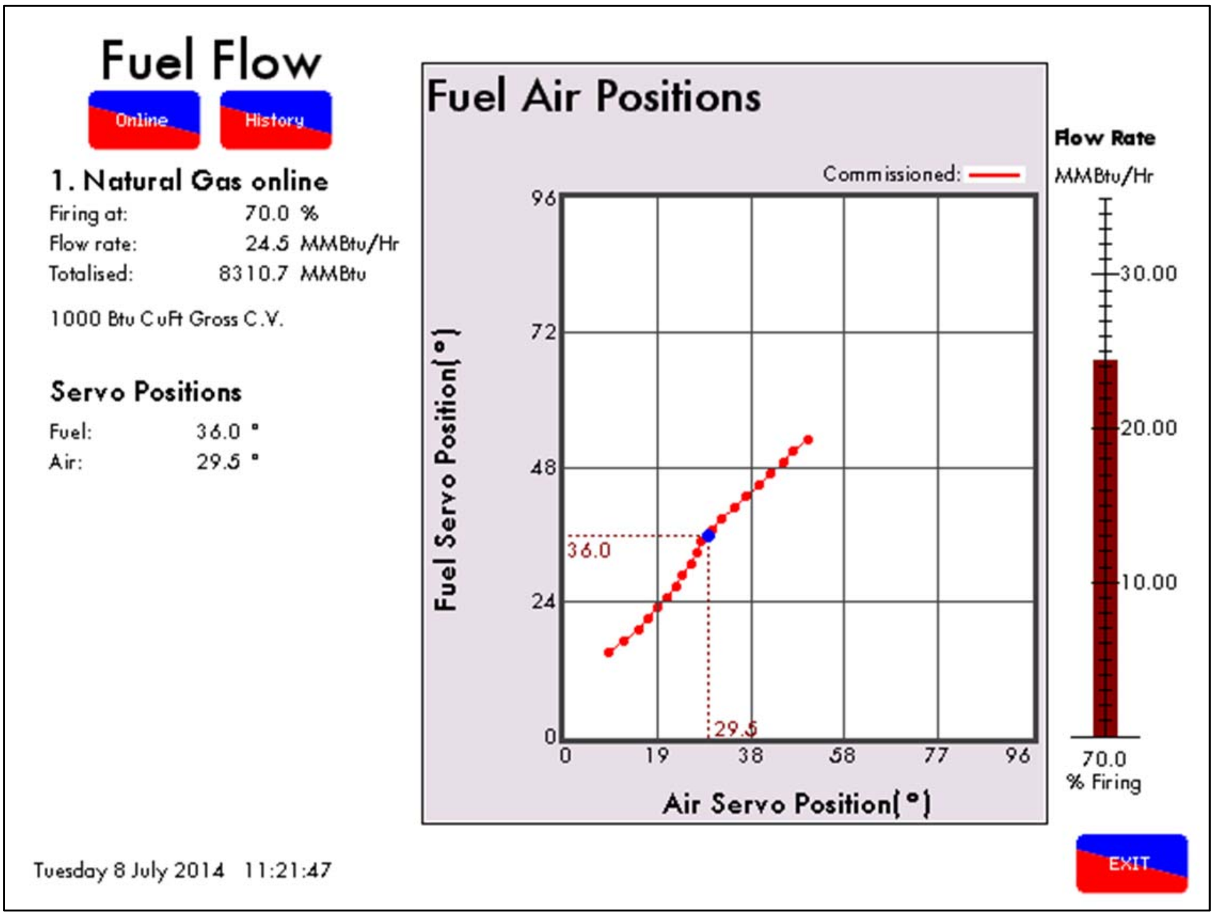


Figure 6.1.i Fuel Air Positions

From Fuel Flow Metering it can be seen that the fuel gross calorific heat input is 24.5 million BTU/hr.

Therefore	24,500,000	BTU/hr	(gross fuel calorific value)
Less	245,000	BTU/hr	(1% loss standing losses, expansion option 9.1)
Less	4,410,000	BTU/hr	(18% stack loss)
Equals	19,845,000	BTU/hr	(net calorific value of the fuel into the wet side of the boiler)

Note: If an E.G.A. is used, the stack loss is taken from the E.G.A. greater accuracy.

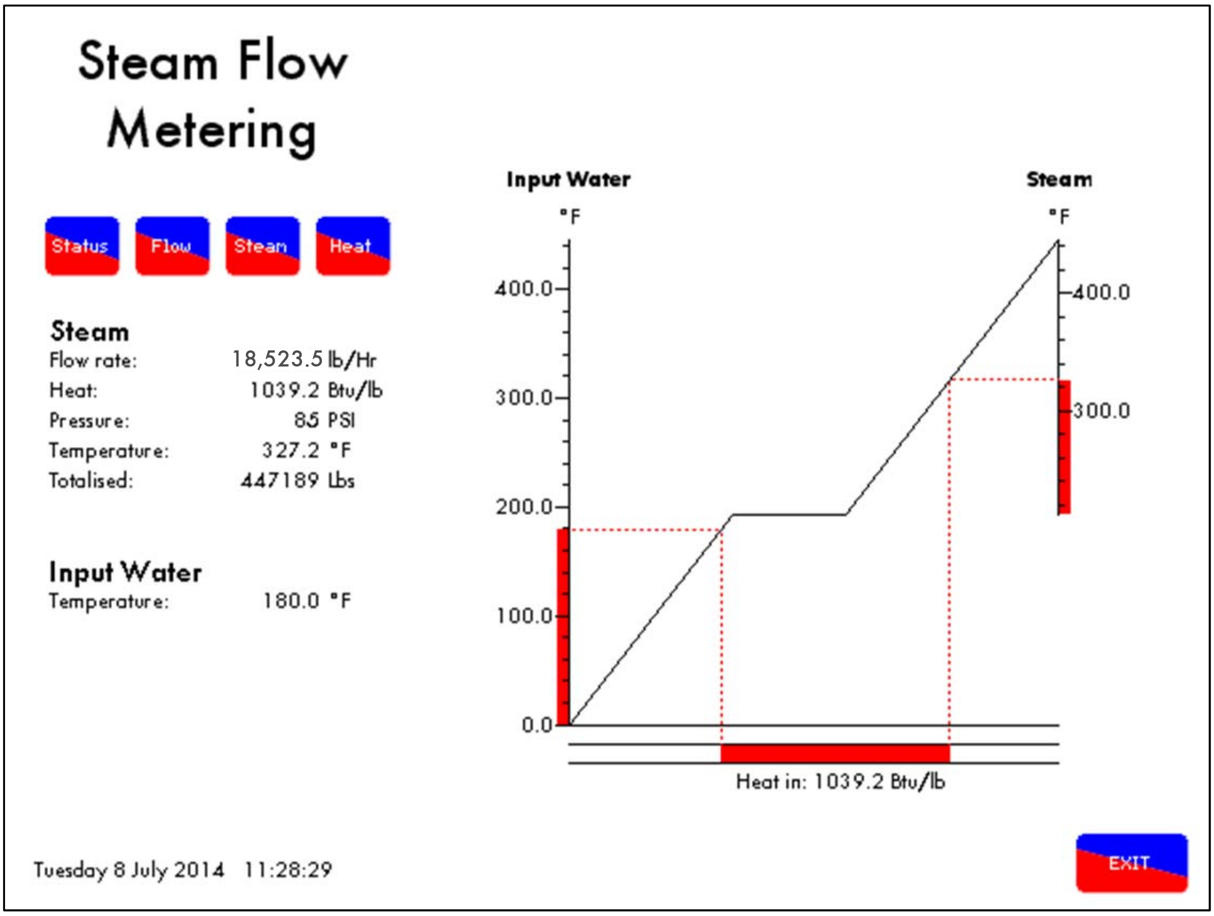


Figure 6.1.ii Steam Flow Metering Status

The steam flow metering status gives information on the flow rate, pressure, temperature, input water and the totalised steam production.

From Steam Flow Metering it is possible to calculate the amount of heat necessary to raise 1lb of water from 180 degrees F (feed water temp) to 85 PSI G steam at 327 degrees F. From standard steam tables the amount of heat required is calculated to be 1039.2 BTU for 1lb. This figure is the latent heat of liquid into steam (gas) plus the sensible heat components.

Note: Feed water temperature can be measured by the temperature sensors for greater accuracy.

$$\frac{19{,}845{,}000\ \text{BTU}}{1039.2\ \text{BTU/lb/hr of steam}} = 19{,}096.4\ \text{lb/hr}$$

If blow down losses are set as 3% through expansion option 10.1 the system allows this correction to be entered.

$$19{,}096.4 \times 0.97 = 18{,}523.5\ \text{lbs/hr Steam Flow}$$

Instantaneous values are calculated using the above. Totalized values for steam flow use the same mechanism but sample values are taken every 5 seconds and integrated over the run time of the boiler burner system.

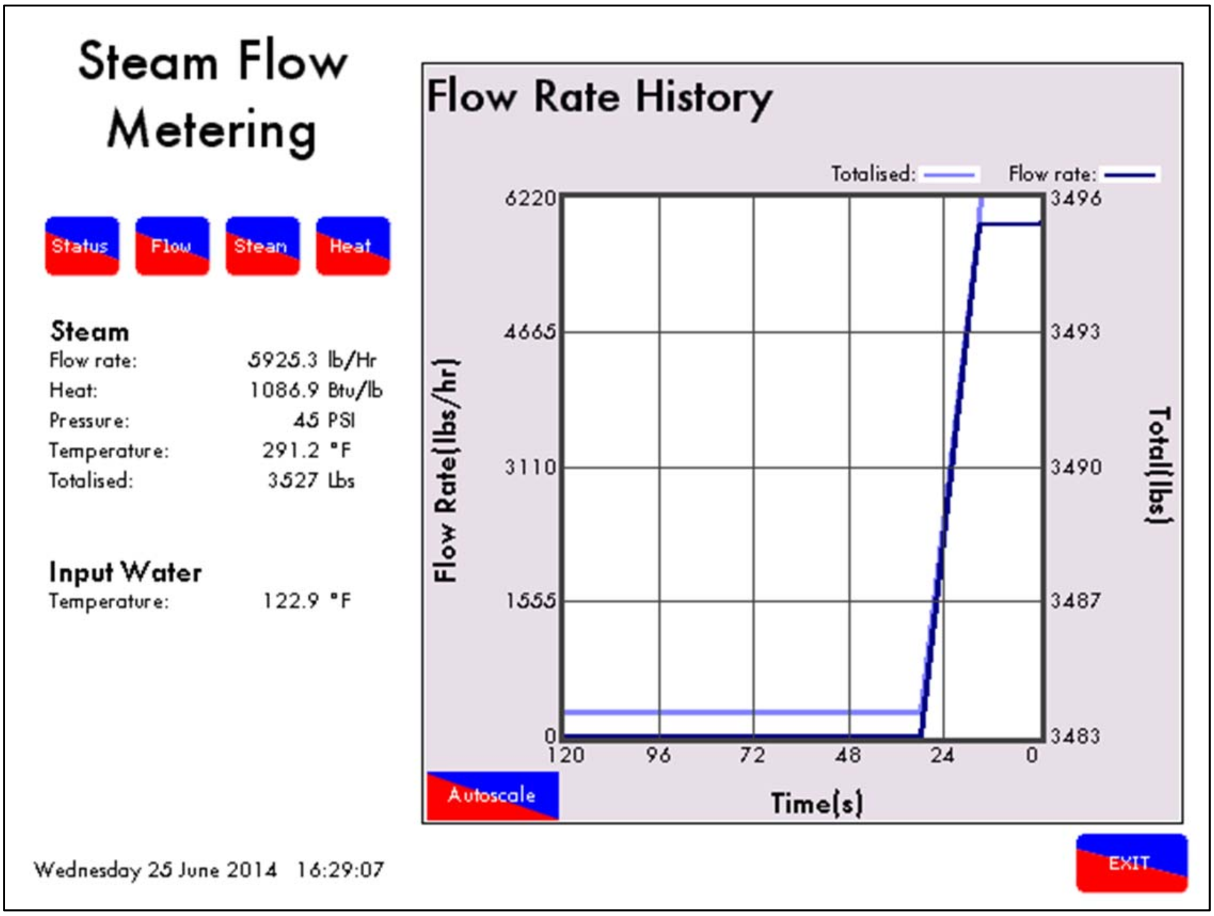


Figure 6.1.ii Steam Flow Rate History

The steam flow rate history screen logs the flow rate and totalised steam production for up to 24 hours.

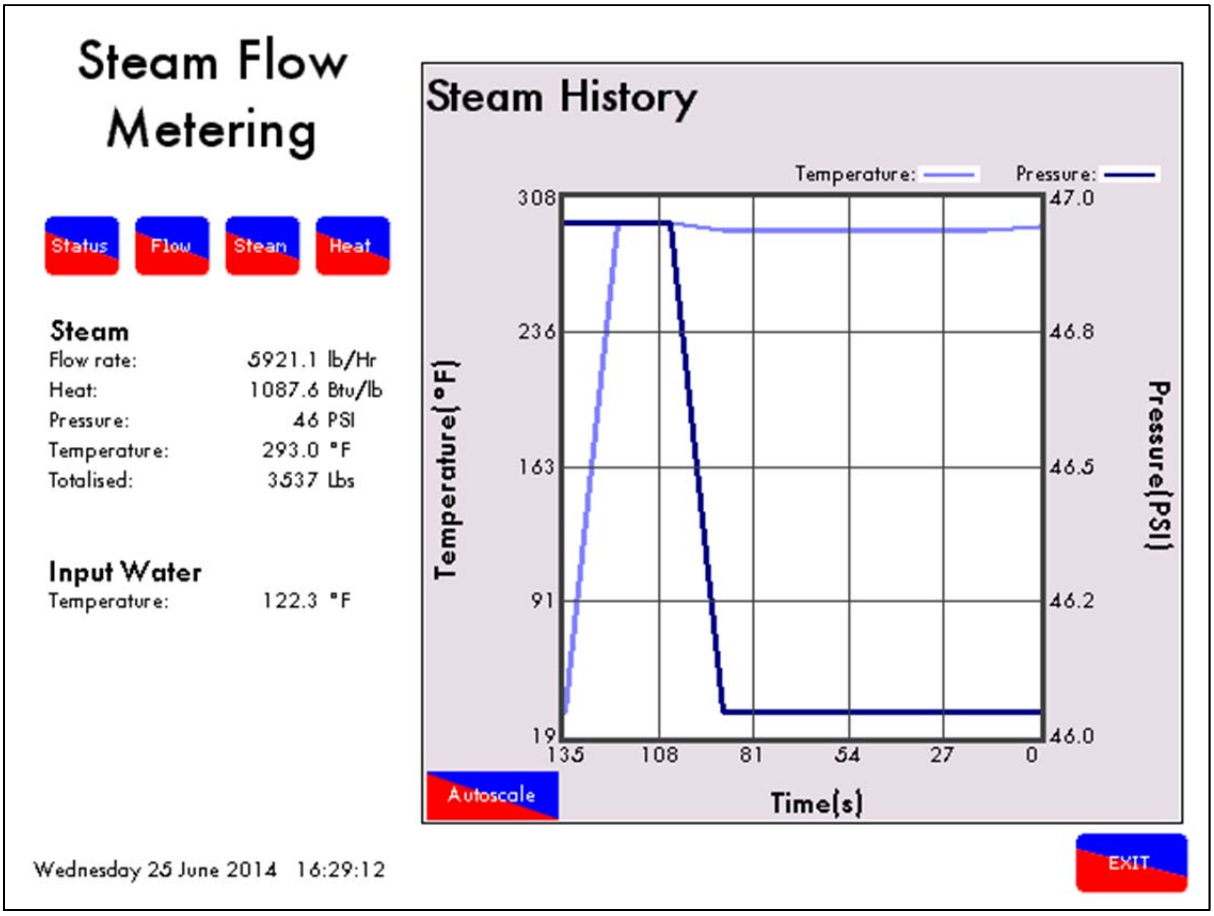


Figure 6.1.iii Steam Flow Metering Steam History

The steam history logs the boiler actual pressure and the calculated temperature from the steam tables.

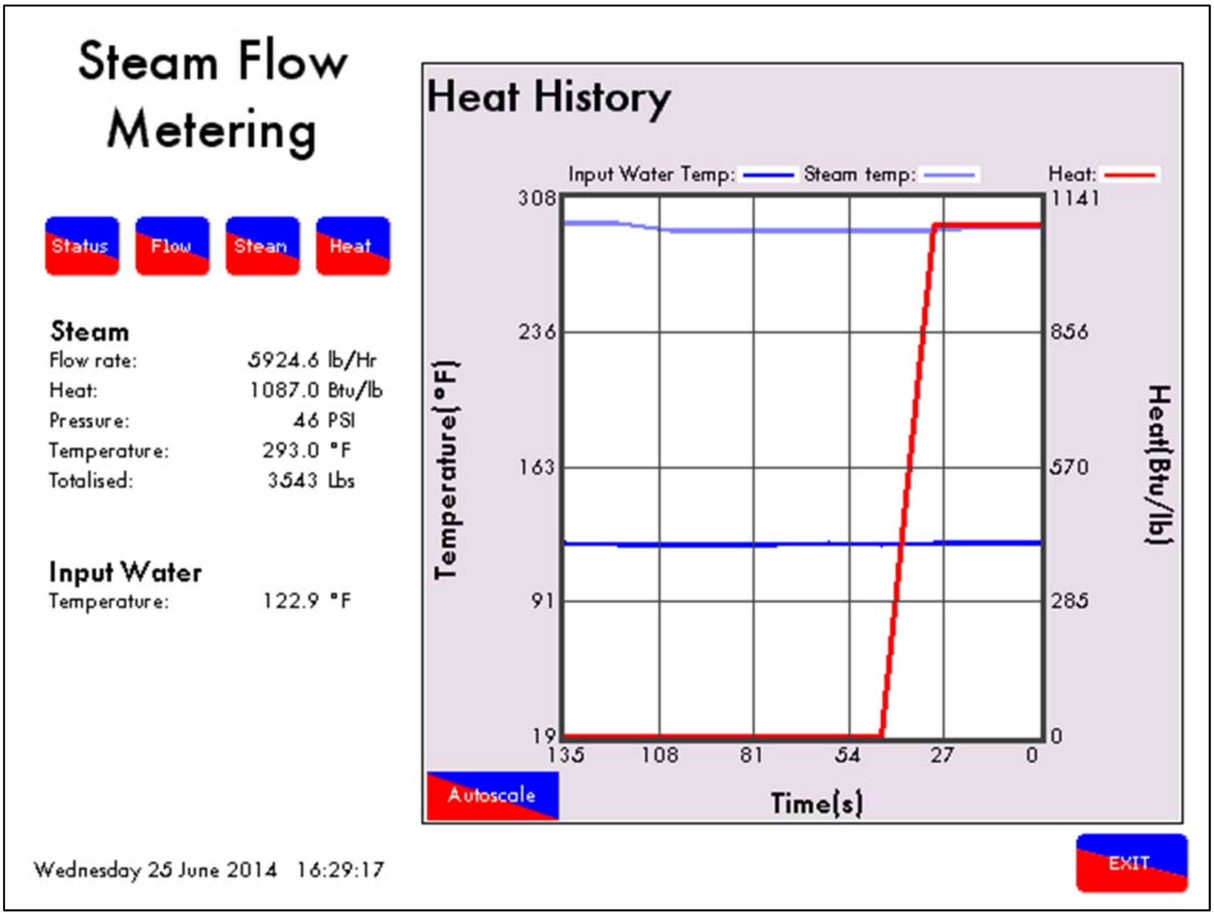


Figure 6.1.iv Steam Flow Metering Heat History

The heat history screen logs the input water temperature, steam temperature and the heat value for up to 24 hours.

6.1.1 Steam Flow Metering Incorporating a Deaerator

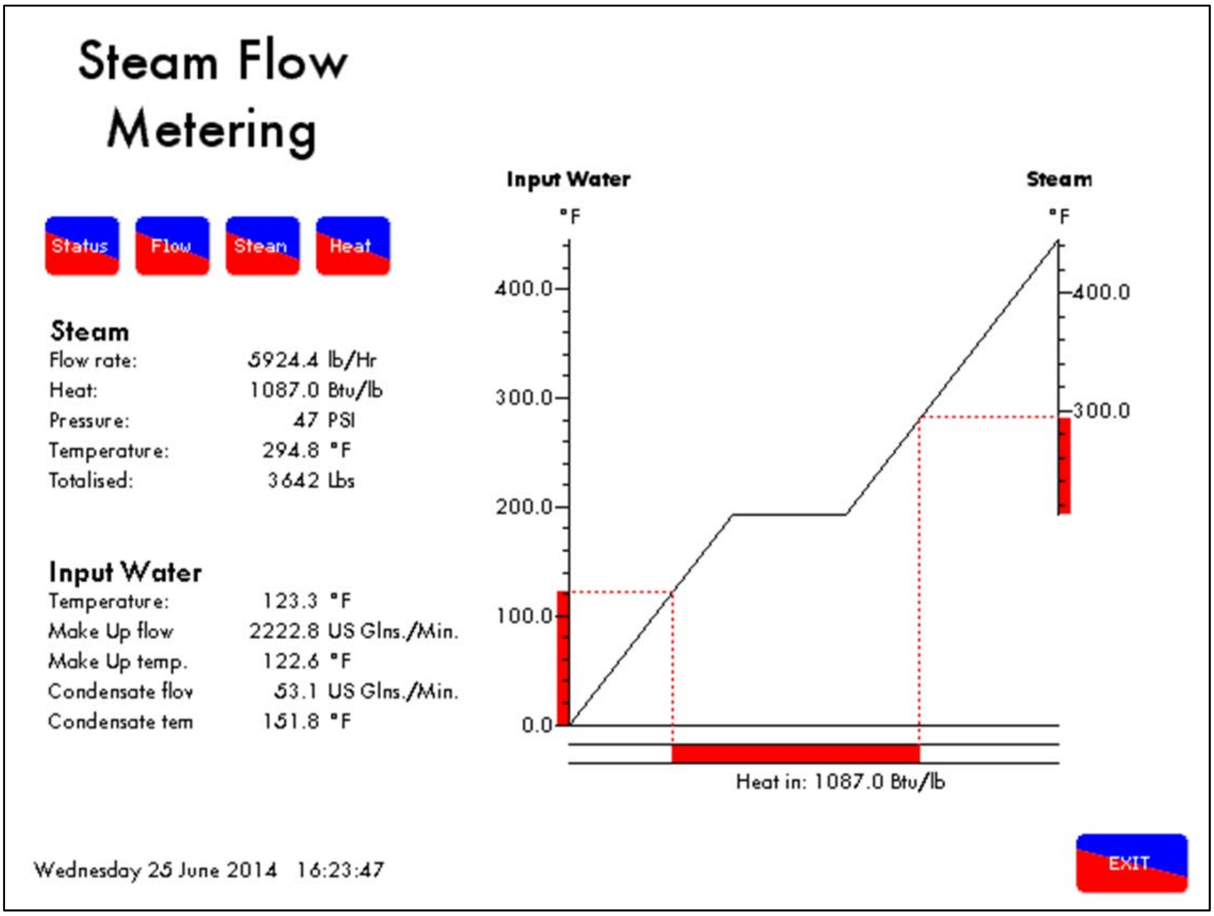


Figure 6.1.1.i Steam Flow Metering with Deaerator

A common practice in steam generation is the use of a "deaerator" to remove the oxygen from the feed water and hence reduce the incidence of oxygen corrosion in the boiler, steam and condensate pipe work.

The principle of a deaerator is to mix the make-up water with the condensate return and live steam direct from the boiler in a tank. Flash steam may also be directed back to the tank. The effect is to mechanically "scrub" the oxygen from the feed water and also to preheat it before it is pumped to the boiler.

In the system as set out above it is no longer valid to measure the temperature of the feed water just before it enters the boiler as the inlet temperature for the "steam meter" calculation. This water has already been preheated by steam from the boiler and therefore this additional energy should not be taken into the software calculation.

The solution is to treat the boiler and deaerator as one system. The energy into the system is supplied by the burner and the inlet temperature is the "weighted average" of the condensate return temperature and makeup water temperature. The outlet steam temperature is measured by a temperature sensor in exactly the same way as in a system without a deaerator.

6.1.2 Calculations for Steam Flow Metering with Deaerator

1: First the percentage "Make up" in the "Feed water" must be calculated.

Where %Mu = % Cold make up water
V1 = Volume flow rate of condensate return water
V2 = Volume flow rate of cold make up water

$$\%Mu = \frac{100 \times V2}{(V2+V1)}$$

Example: 1
Steam boiler with a volume of condensate return at 40 GPM and make up water at 8 GPM

$$\text{Make up } \% = \frac{100 \times 8}{(8+40)} = 16.7\%$$

To calculate the second part to establish the "Weighted Average Temperature" the following equation is used.

Where Tave = Weighted Average temperature
T1A = Temperature of condensate
T1 = Temperature of make up water
%Mu = Percentage of make up water

$$Tave = T1A - \frac{(\%Mu \times (T1A\text{-}T1))}{100}$$

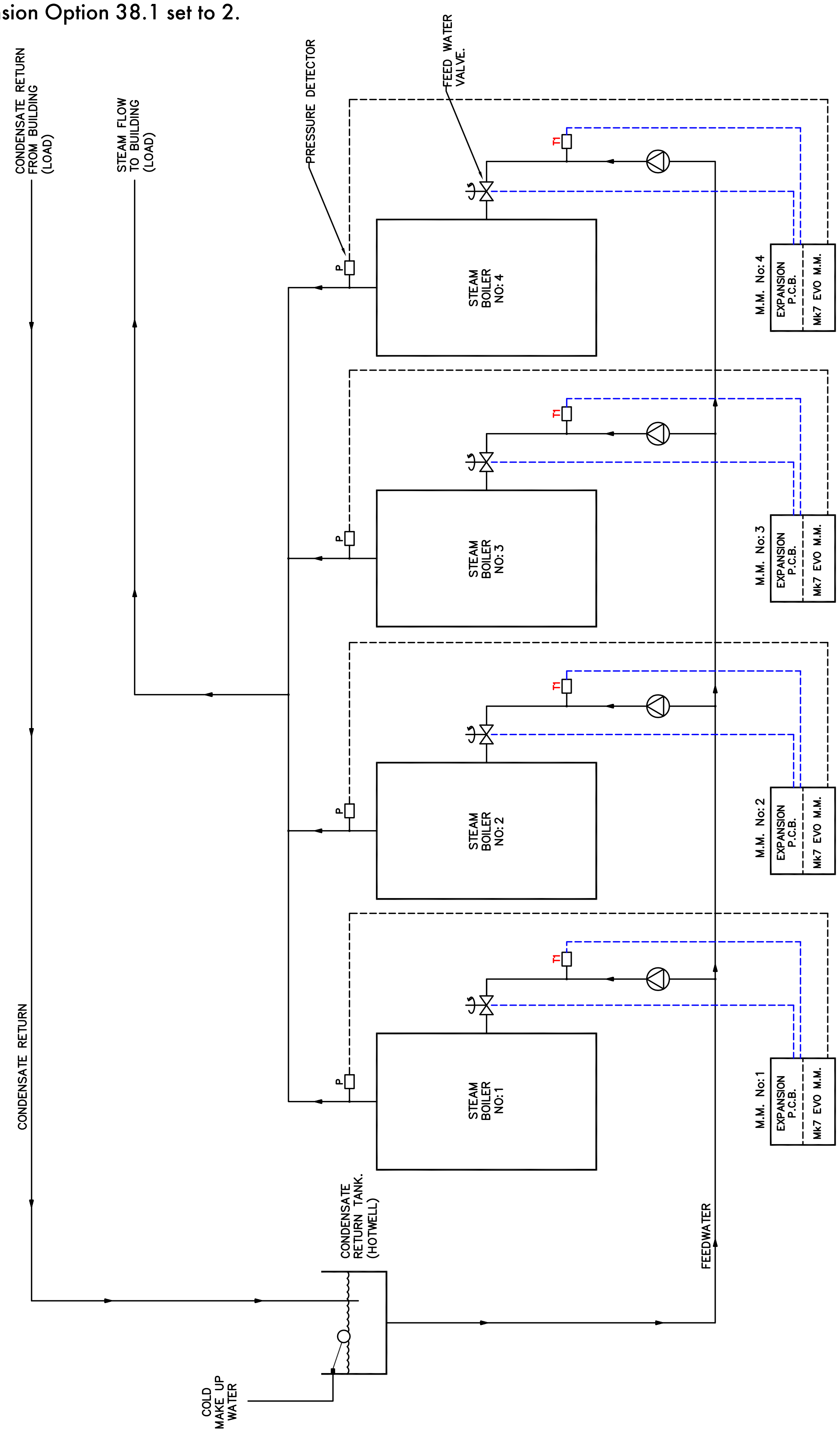
Steam boiler with condensate return temperature of 176°F and a make up water temperature of 41°F. From the above example (1) the make up percentage is 16.7%

$$\text{Weighted Average} = 176 - \frac{(16.7 \times (176 - 41))}{100} = 153.4°F$$

To implement the above control form the following calculations have been imbedded in the revised software to obtain the "Weighted Average Temperature" (T ave).

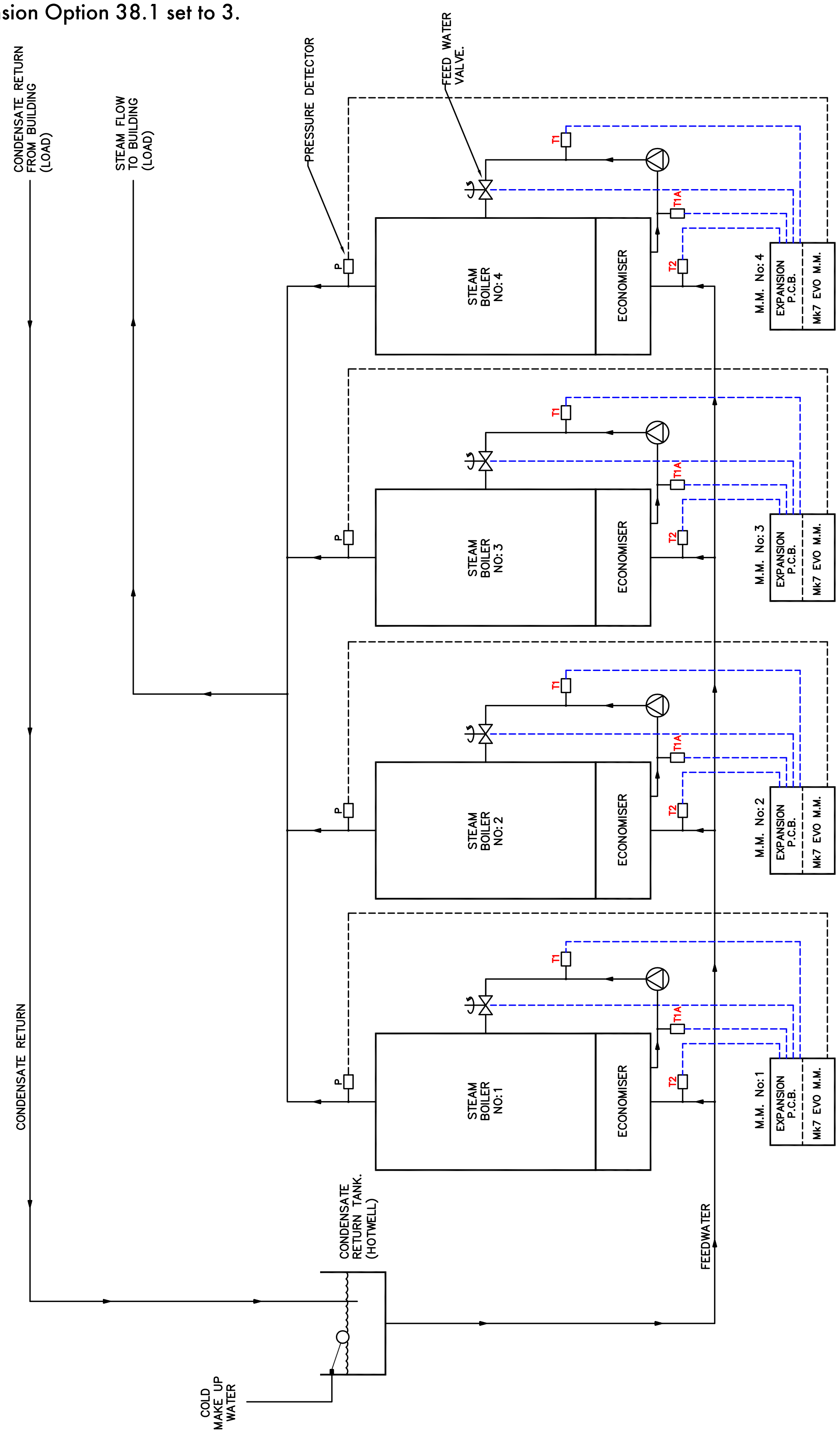
6.1.3 Steam Flow Metering without Deaerator

Expansion Option 38.1 set to 2.



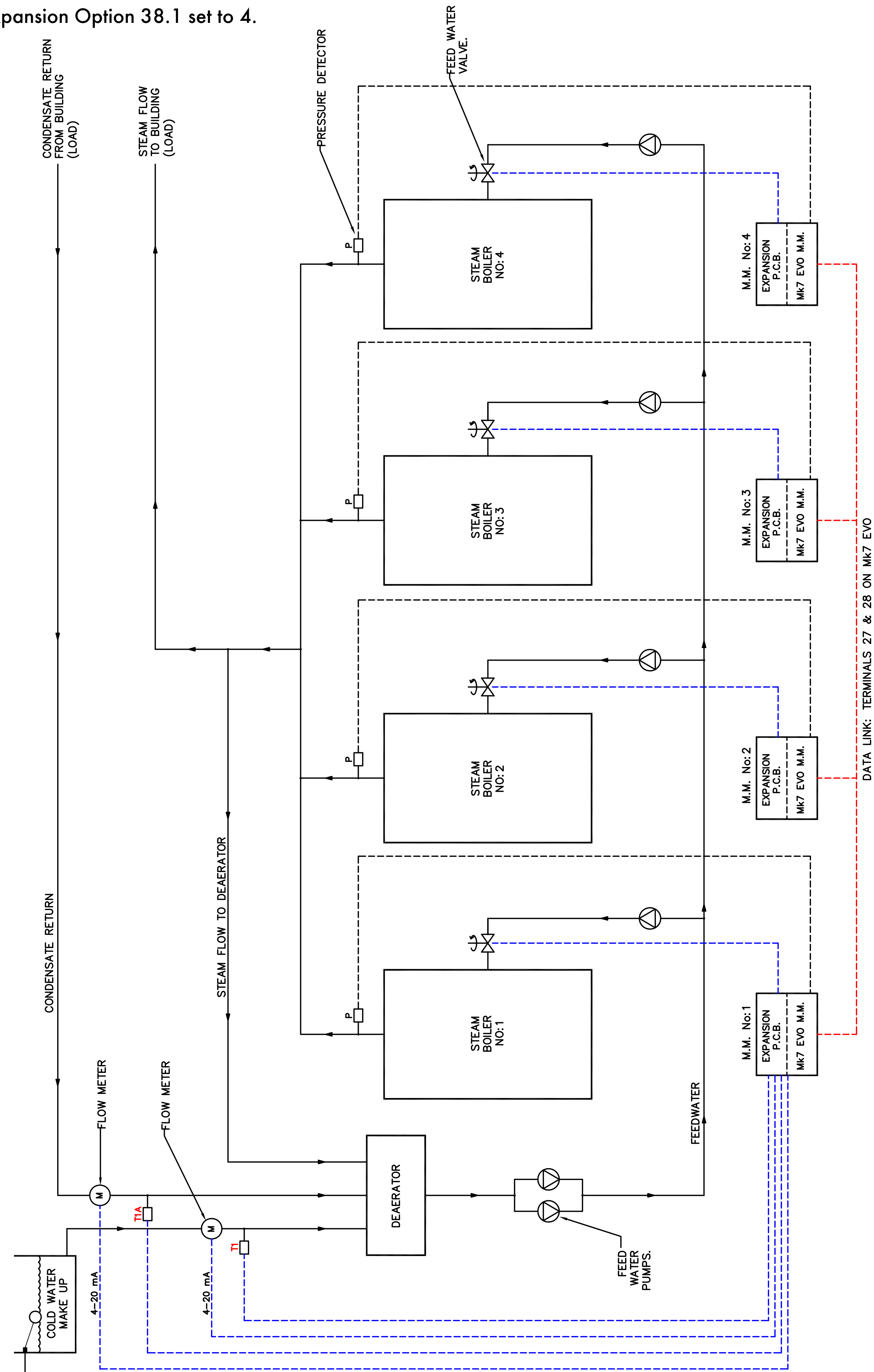
6.1.4 Steam Flow Metering without Deaerator, with Economiser

Expansion Option 38.1 set to 3.



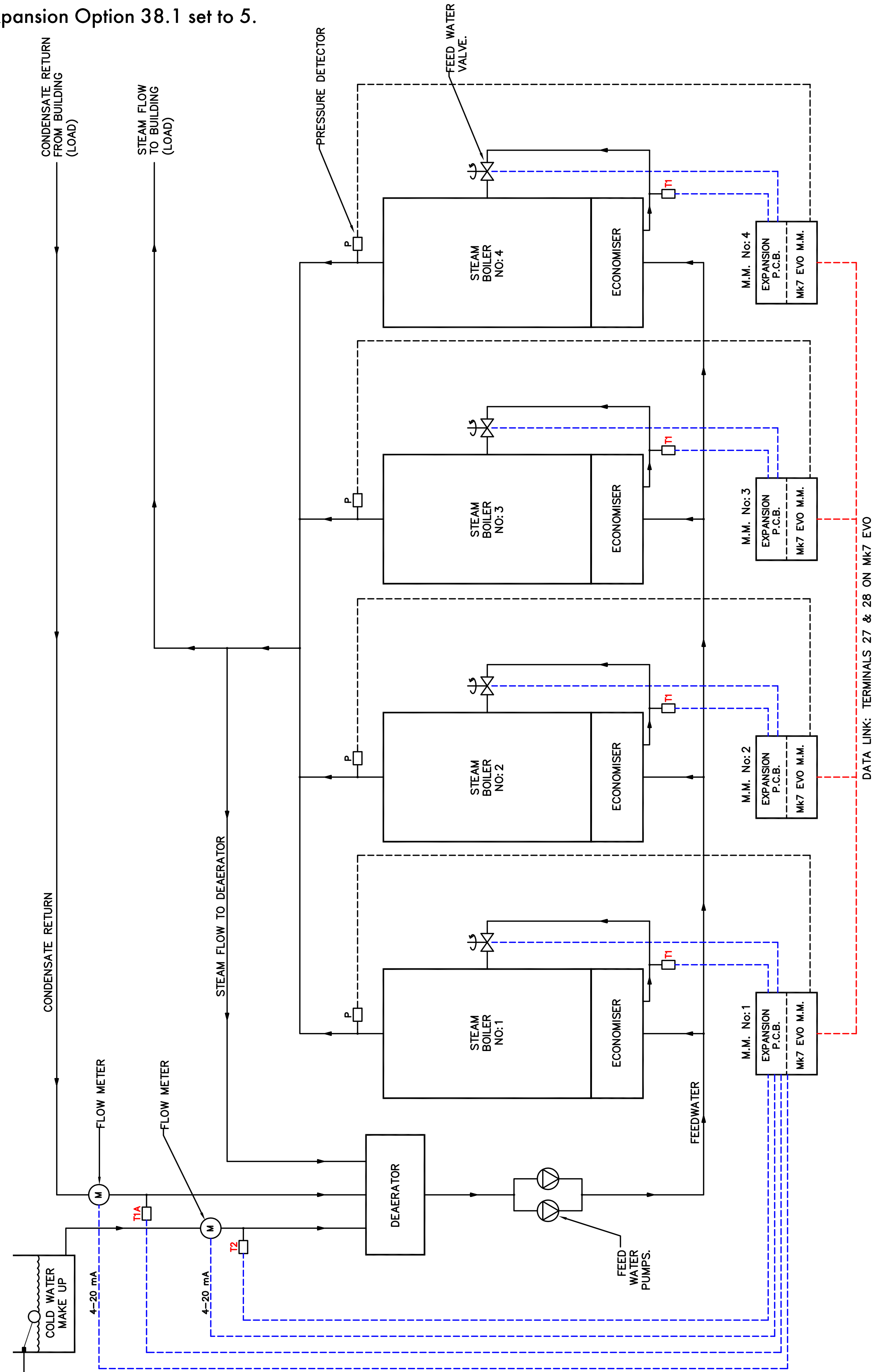
6.1.5 Steam Flow Metering with Deaerator

Expansion Option 38.1 set to 4.



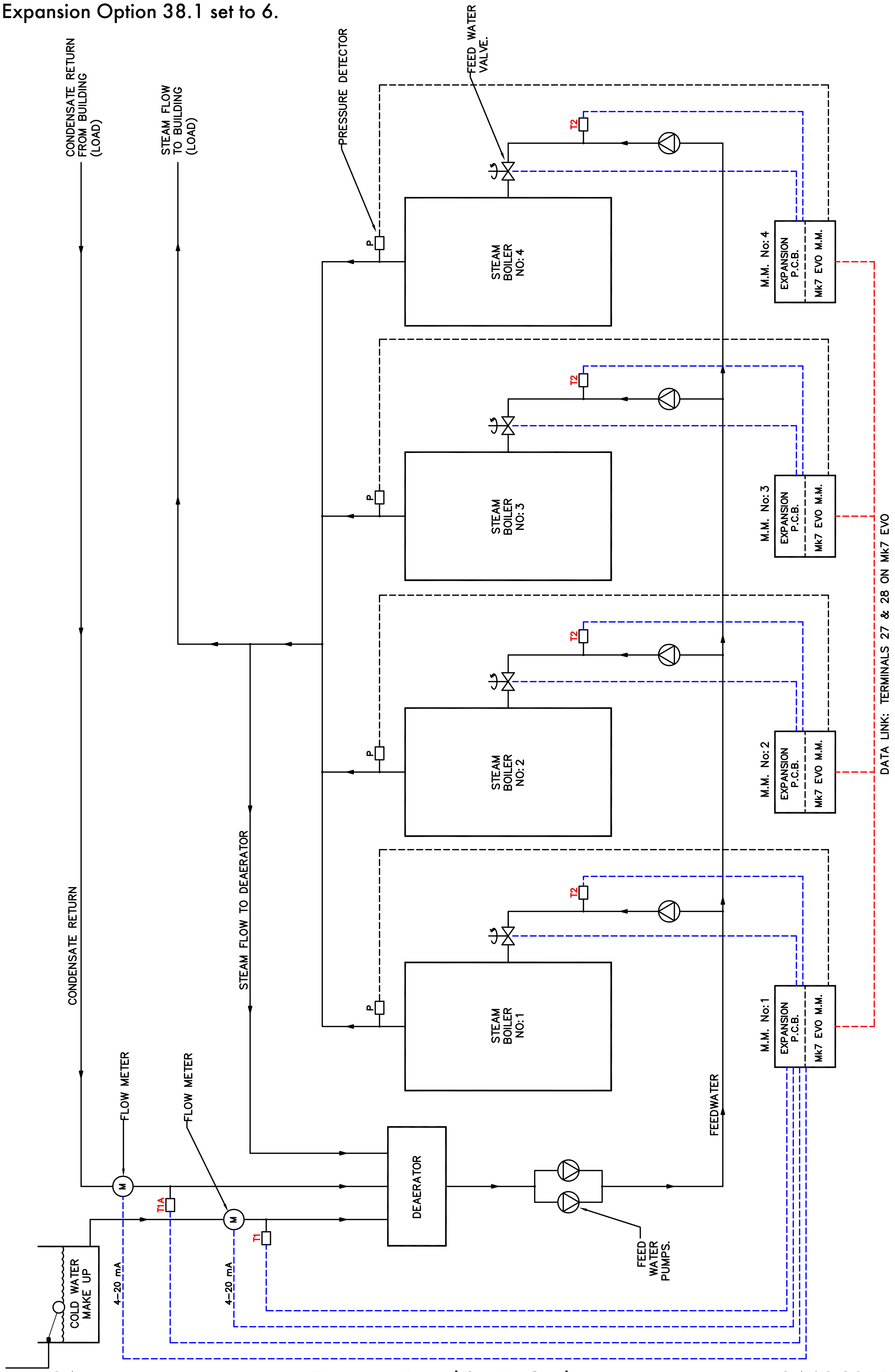
6.1.6 Steam Flow Metering with Deaerator and Economiser

Expansion Option 38.1 set to 5.



6.1.7 Steam Flow Metering with Deaerator and Feed water Sensor

Expansion Option 38.1 set to 6.



6.2 Heat Flow Metering

Heat Flow Metering is simply measuring the amount of heat being transferred to the water by a hot water boiler. If we know the stack losses and the standing losses of the boiler at any moment then whatever energy is left over must be going into the water.

From the E.G.A. stack losses = 100 – combustion efficiency

Radiation losses are specific to the boiler, 1% radiation losses are typical for a packaged boiler operating at maximum continuous rating. The loss is constant regardless of boiler output so at 50% firing rate it would be 2% of the energy input.

The total heat in at any time is given by the heat flow metering so we can calculate the instantaneous heat going into water. By integrating these values we can get a totalised value.

6.2.1 Calculation for Heat Output and Volume Flow

$$\text{Efficiency \%} = 100\% - \left(\text{Stack loss} + \frac{\text{Radiation Losses} \times 100}{\text{Firing Rate}}\right)$$

$$\text{Useful Heat into Water} = \text{Total Heat} \times \frac{\text{Efficiency}}{100}$$

$$\text{Volume Flow in lbs/hr} = \frac{\text{Useful heat MBTU/Hr}}{\text{SP Ht BTU/lb/°F} \times (\text{Flow Temp} - \text{Return Temp})}$$

$$\text{Volume Flow in cu ft Hr} = \frac{\text{Volume Flow in lbs/hr}}{\text{Density of Water at Return Temperature}}$$

$$\text{Since 1 cu ft Hr} = 0.124676 \text{ US G.P.M.}$$

$$\text{Volume Flow in US G.P.M.} = \text{Volume Flow in cu ft Hr} \times 0.124676$$

6.2.2 Heat Flow Metering Calculation

Set out below is an example together with relevant calculation, these calculations are embedded in to the software in the Mk7 version of the expansion PCB.

Example

A boiler firing at 75% has an input of 20,472,840 BTU/Hr (6MW). The temperature of the flow (MM Temperature detector) out is 185°F and the temperature of the return T1 is 167°F. The combustion efficiency is 82% (Mk7), Radiation losses are 1% at maximum continuous rating.

Description	Imperial units	Metric Units
Firing rate	75%	75%
Input	20.47 MMBTU/HR	6MW
Return Temperature	167°F	75°C
Flow Temperature	185°F	85°C
Sp Ht water	1.0 BTU/lb/°F	4.18KJ/KG/°C
Density Water	60.68lb/cuft @176°F	972 kg M³ @80°C
Combustion Efficiency	82%	82%

$$\text{Efficiency }\% = 100\% - \left(18\% + \frac{1\% \times 100}{75\%}\right)$$
$$= 80.67\%$$

$$\text{Useful Heat into Water} = \text{Total Heat } \times \frac{\text{Efficiency}}{100} = 20{,}472{,}840 \times \frac{80.67}{100}$$

$$= 16{,}514{,}440 \text{ BTU/hr}$$

$$\text{Volume Flow in lbs/hr} = \frac{16{,}515{,}440}{1 \times (185 - 167)}$$

$$= 917{,}524.4 \text{ lbs/hr}$$

$$\text{Volume Flow in cu ft Hr} = \frac{\text{Volume Flow in lbs/hr}}{\text{Density of Water at Return Temperature}}$$

$$= \frac{917{,}524.4}{60.68} = 15{,}120.7 \text{ cu ft Hr}$$

$$\text{Volume Flow in US G.P.M.} = 15{,}120.7 \text{ cu ft Hr} \times 0.124676 = 1{,}885.2 \text{ US G.P.M.}$$

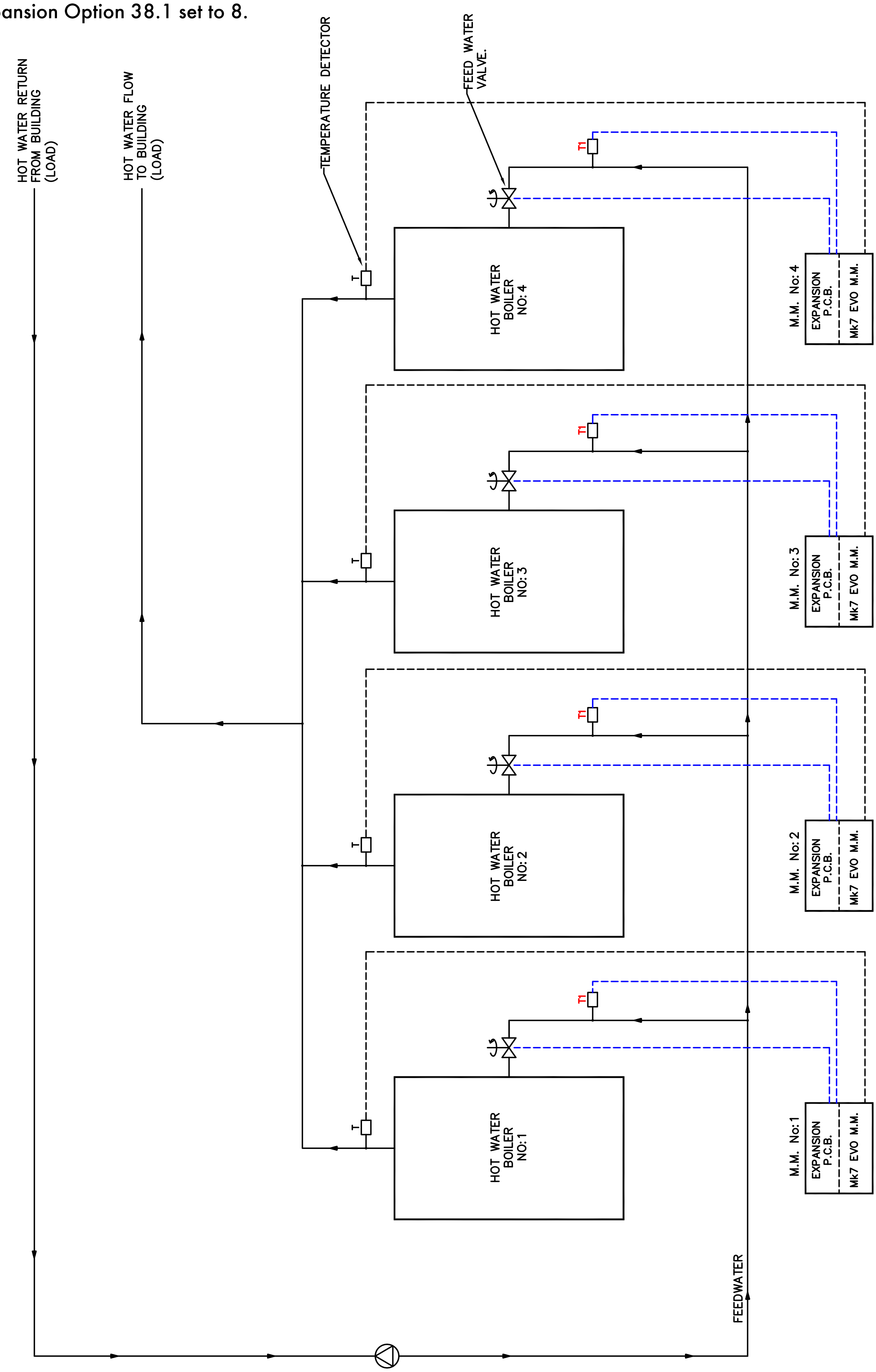
It can be seen from the above that by adding the expansion P.C.B. and a return temperature detector to the Mk7 M.M. system that you get the following additional useful information.

"Useful heat into water" (BTU/hr) &
"Volume flow" (US G.P.M)

This is displayed on the screen of the Mk7 M.M.
The direct benefit is that you have a "Heat meter" and "Flow meter" for any hot water boiler.

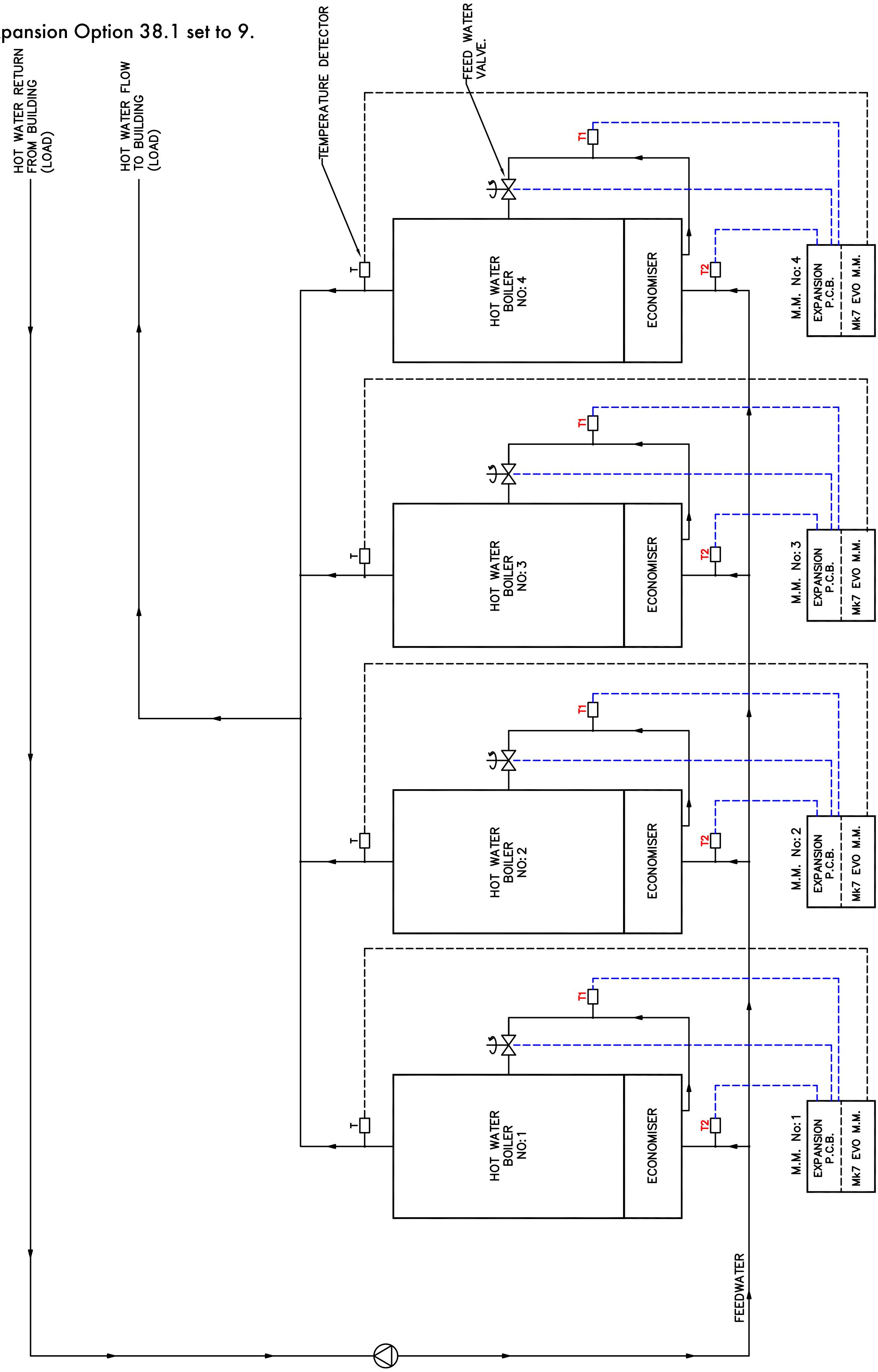
6.2.3 Heat Flow Metering

Expansion Option 38.1 set to 8.



6.2.4 Heat Flow Metering with Economiser

Expansion Option 38.1 set to 9.



7 DRAFT CONTROL

7.1 Introduction to Draft control

Draft control is used to manage the excess draft from stacks, in both fire-tube and water-tube applications, so heat transfer from the hot gases to the boiler tubes can be optimised. Both heat transfer rate and combustion rate depend on the motion of the flue gases; any changes in boiler pressure can affect the amount of combustion air entering the burner, possibly resulting in unburnt fuel. An excess of unburnt fuel can lead to unsteady combustion with dangerous consequences. A tall stack is susceptible to a changing pressure which is caused be stack temperature and wind velocity.

The main benefits of maintain stack pressure through draft control include:

- Improves heat transfer
- Improves combustion efficiency
- Reduces room heat loss
- Improves flame stability while reducing chance of pilot light failure
- Improves flame retention
- Reduce soot accumulation

7.2 Autoflame Fully Integrated Draft Control

The Autoflame draft control stores pressure conditions at the commissioning stage and modulates with the firing curve to maintain this, irrespective of changing firing rate and stack conditions. Normally there is a vertical main stack which has a horizontal cross connection from the boiler flue gas outlet; this is then connected into the main stack. The boiler only works at optimum efficiency when all of the conditions that effect its operation are held at good commissioned values. Therefore under the new arrangement, a butterfly valve driven by a positioning motor, is placed in the horizontal back flue typically two or three metres from the boiler. A differential pressure sensor is then inserted into the flue that is between the boiler outlet and the butterfly valve. As stack energy alters, the suction or pressure would vary at this point. It can be seen that by measuring the pressure of the draft at the position of the damper could be adjusted to bring the pressure or suction back to its commissioned value, the complete system would then be operating at optimum efficiency again.

Figure 7.2.i Stack with Draft Control

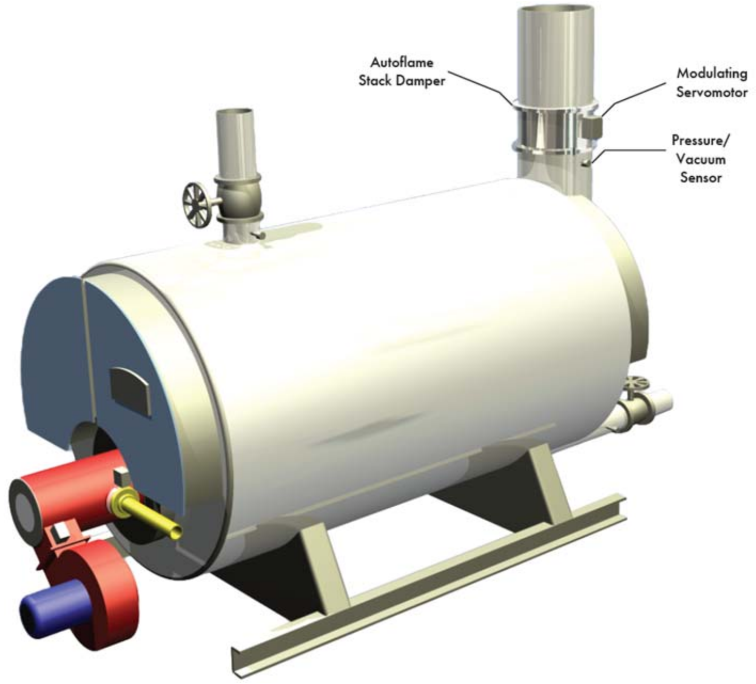


Figure 7.2.ii Autoflame Draft Control

After commissioning is completed, every fuel and air position will have a stack damper position together with a stored draft pressure. The stack pressure is controlled by air pressure sensor, stack damper and PI loop. When the system is in run mode the stack damper will be positioned according to the stored commissioning pressure. If the stack draft reading measured by the differential air pressure sensor reads a different condition to the stored value, then the stack damper butterfly valve will be adjusted to ensure that the stack pressure is brought back to its commissioned value.

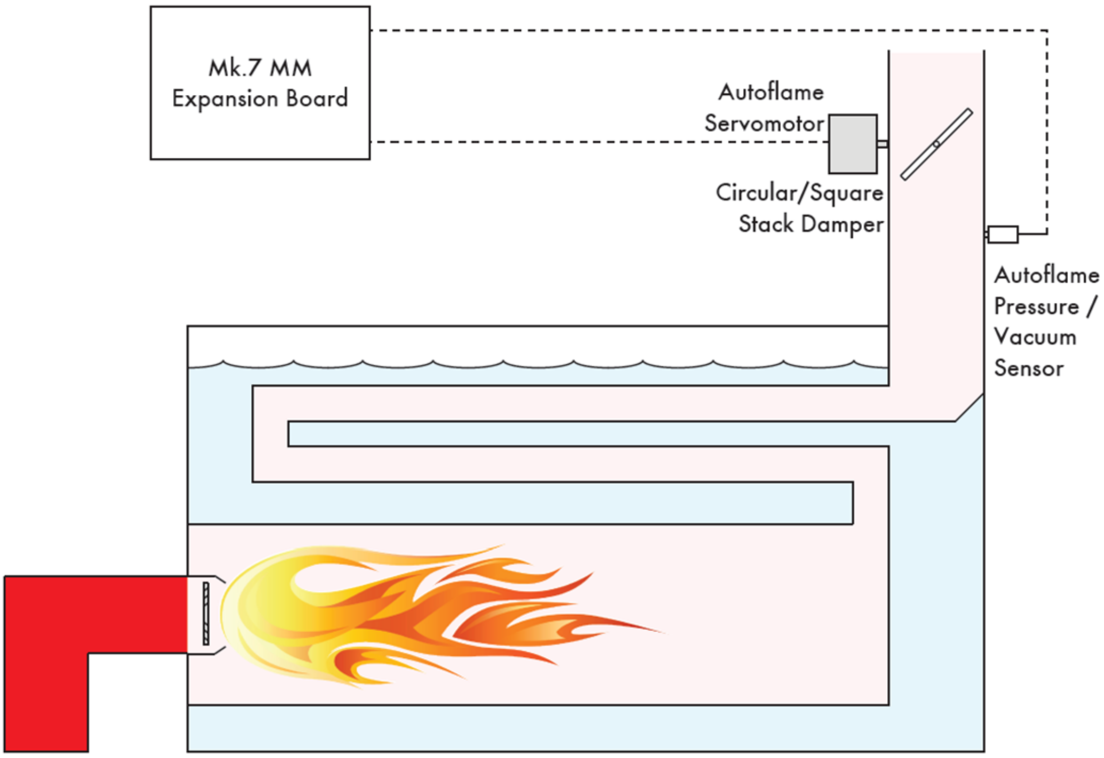


Figure 7.2.iii Draft Control Schematic

7.3 Set-Up

To maintain the stack pressure through the Autoflame draft control system, the following is required:

- Mk7 M.M. with Expansion Board
- Air Pressure Sensor MM70005 (SN 100 upwards)
- Industrial Servomotor

Note: A small or large servomotor can be used for smaller applications, however an industrial servomotor is recommended for the appropriate softened error checking for a large damper. If the site requires a new damper for draft control, please contact Autoflame Technical Support.

7.3.1 Terminals

The following terminals on the expansion board are used for the Autoflame draft control:

DPC	Draft air pressure sensor (check)
DPS	Draft air pressure sensor (signal)
DP-	Draft pressure sensor & motorised draft control damper voltage –ve
DP+	Draft pressure sensor & motorised draft control damper voltage +ve
DPW	Motorised draft control damper potentiometer wiper
DCI	Motorised draft control damper servomotor – increase (output switched neutral)
DCD	Motorised draft control damper servomotor – decrease (output switched neutral)

7.3.2 Draft Control Expansion Options

The draft control system can be configured through the following expansion options.

Exp. Option	Factory Setting	Value	Description
40.1	0		**Draft Control - Enable:**
		0	Disable
		1	Enable
40.2	1		**Draft Control - Pressure Sensor:**
		1	0-1 PSI Pressure Sensor MM70005
40.3	15		**Draft Control - Minimum Baffle Angle Limit:** The smallest angle that the stack damper will drive to during any stage of operation. This is not the closed 0.0 angular position entered during commissioning.
		0 - 45	Degrees
40.4	5		**Draft Control - Delay Before Compensation:** The delay after the main flame is established before draft control operation commences. This is also the time set for the deactivation window, where the M.M. must not see a change of the value set in expansion option 40.5 in this time for the PI to stop modulation, and carry forward trim operates.
		5 - 30	Seconds
40.5	10		**Draft Control - Firing Compensation Deactivation Window:** If the offset from the commissioned draft servo angle set in this option is breached over the time period set in expansion option 40.4 , PI stops modulations, and carry forward trim operates.
		0 - 60	Degrees
40.6	1		**Draft Control - Maximum Compensation:** This is the maximum trim forwards or backwards which the stack damper can move, during trim operation. If this is set to 10%, the stack damper can move to a maximum of 10% of the commissioned draft servomotor position, backwards and forwards.
		0	10%
		1	15%
		2	20%
40.7	0		**Action on Pressure Sensor Failure:** This sets whether the burner will lockout or the stack damper will go to its commissioned positions along the curve, should the draft air pressure sensor fail.
		0	Lockout
		1	Revert to commissioned curve
40.8	0		**Pressure Tolerance Before Fault:** This is the maximum allowable pressure change from commissioned draft air pressure values over 2 minutes before an error message is displayed on the screen.
		0 - 50	PSI (0.0 - 5.0 Bar)
41.1	200		**Draft Control P Multiplier** The P Multiplier % is used to calculate the P Value; the P value is used together with the I Value calculated from expansion option 41.2 to give a PI Total which determines the angle the draft servomotor moves to, during trim operation. The P value is the product of the present offset from the commissioned pressure (pressure error) and the P Multiplier %. Larger P Multipliers cause a larger movment in the damper for a given pressure. Too large a P Multiplier can cause the system to overreact to small changes in the system.
		1 - 10,000	% (0.01) of Pressure Sensor Range e.g. 200 = 2.00%
41.2	5		**Draft Control I Multiplier** The calculated P Value (pressure error multiplied by the P Multiplier%) is multiplied by the I Multiplier % to give the I Value. This I Value is added to a running total of I Values. The amount of damper movement is controlled by the sum of the most recent P Value and the running total of I Values. The running total of I Values is updated every 'n' seconds (set in expansion option 41.3). As the pressure approaches the commissioned value the P Value becomes progressively smaller, resulting in smaller changes to the I Total.
		1 - 250	% (0.01) e.g. 5 = 5.00%
41.3	5		**Draft Control I Timer:** This is the time between each I value update.
		1 - 30	Seconds
41.4	15		**Draft Pressure Filter Time:** The draft pressure filter time filters the pressure readings over this time set this option. Increase this value to remove excessive fluctuation in draft pressure reading. Decrease this value to improve the pressure sensor's responsiveness.
		1 - 60	Seconds

7.4 Commissioning with Draft Control

The Autoflame draft control system is commissioned during the burner commissioning process. As with all M.M. commissioning procedures on burners, safety must be taken in every step. Once the installation and all burner adjustments are completed, the entire burner control system should be tested in accordance with the manufacturer's instructions. The procedure should verify the correct operation of:

1. Each operating control (temperature, pressure, etc.)
2. Each limit switch (temperature, pressure, low water cut-off, etc.)
3. Each interlock switch (airflow switch, high and low fuel pressure or temperature switches, purge and low fire switches, fuel valve proof of closure interlock, etc.)
4. Pilot flame failure response and lockout
5. Main flame failure response and lockout
6. Tight shut off of all valves

<u>Operational Checks</u>

1. Close manual main shut-off valve
2. Recheck all limit circuit wiring for proper operation and correct connection
3. Confirm that the automatic main fuel valves are wired correctly
4. Power the control, and electronically check the proper sequence of operation
5. After assuring yourself that all the interlocks and valves are properly wired and that the sequence of operation is correct, open the manual main shut-off fuel valve and proceed cautiously through the boiler light off process. Check all safety interlocks for proper shutdown of the boiler.

The M.M. commissioning procedure is explained in detail 'Mk7 Manual: M.M. Installation and Commissioning Guide – Section 3,' however the added steps for the commissioning with draft control are as follows.

<u>WARNING: COMMISSIONING OR START-UP MUST ONLY BE CARRIED OUT BY A FACTORY TRAINED TECHNICIAN</u>

<u>Commissioning Procedure</u>

1. Check all wiring between the M.M. and external components are correct
2. Set all required options, parameters and expansion-setups.
3. Set up servomotors
4. Program fuel/air positions and draft positions

On a previously commissioned system, it is possible to omit steps 1 to 3.

A CH 7 has been added to the commissioning procedure which enables control of the draft control damper. In addition to the CH 7, a draft pressure is visible on the M.M. screen whilst commissioning. This is to aid in the commissioning procedure whilst using the draft control.

Use CH7 to change the draft damper angle to maintain the boiler's ideal stack pressure throughout the commissioning curve.

Note: If on the day of commission, there are extreme conditions such as heavy wind, the stored angles for the draft damper along the commissioned curve may not be relevant for a day without heavy wind over the stack.

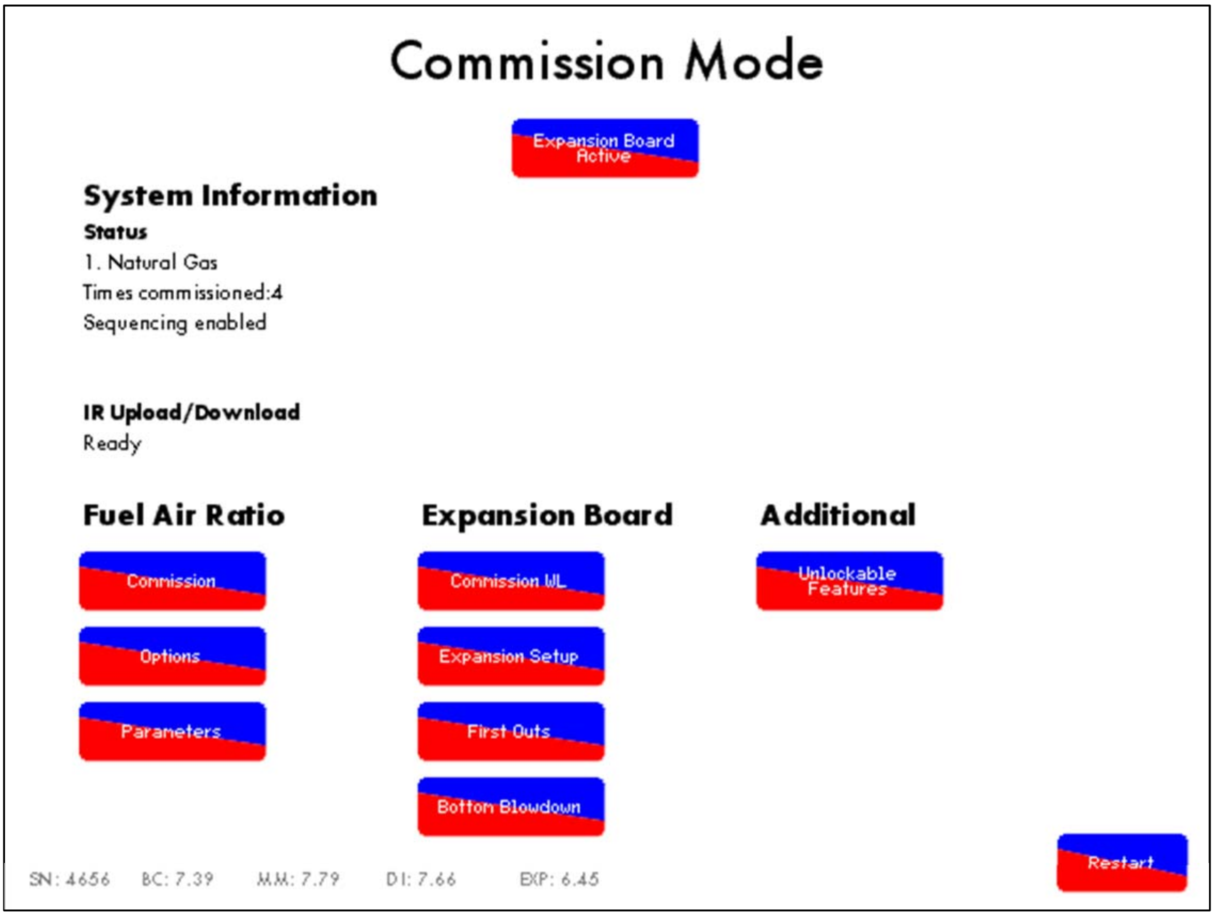
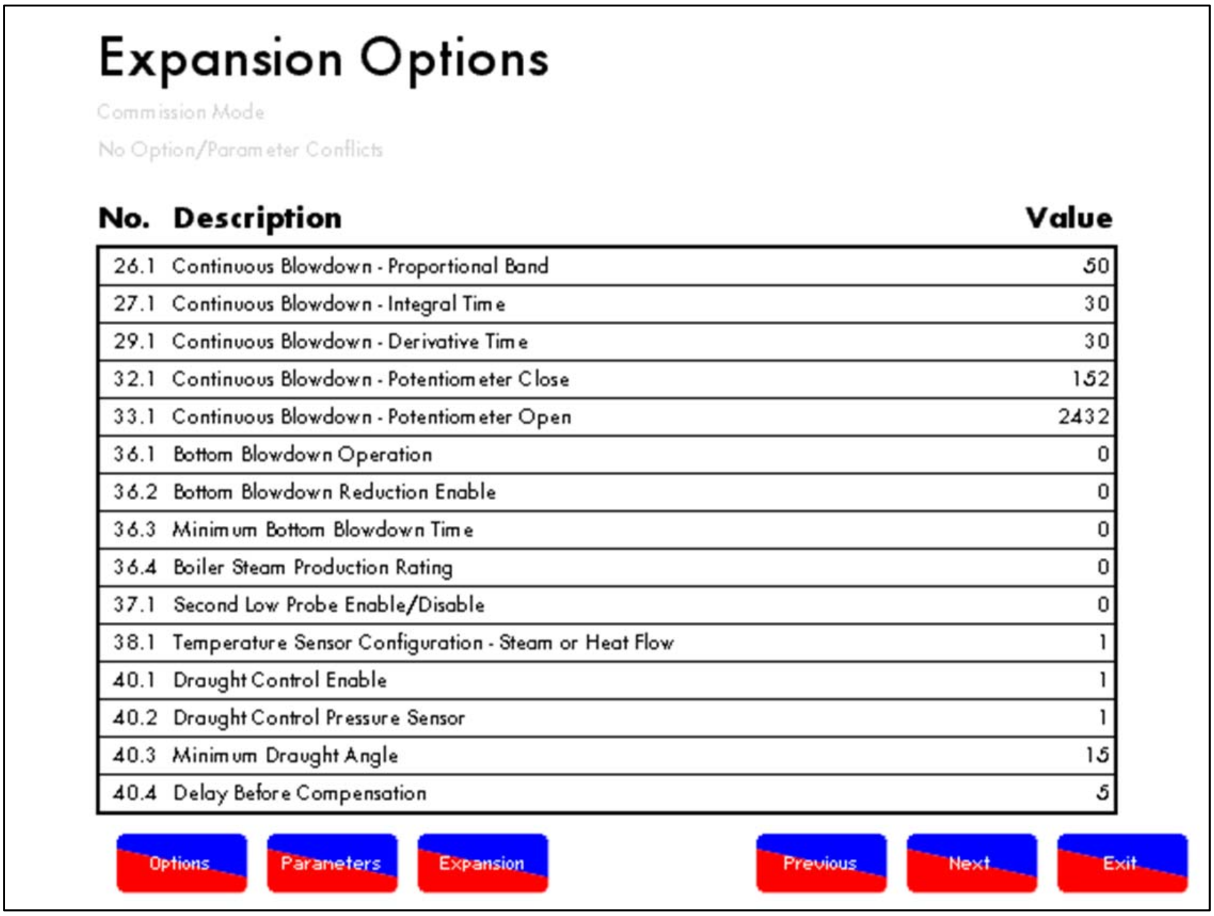


Figure 7.4.i Commission Mode Screen

1. Power on the unit, and press the commission button. Make sure the expansion board is activated.



Expansion Options

Commission Mode

No Option/Parameter Conflicts

No.	Description	Value
26.1	Continuous Blowdown - Proportional Band	50
27.1	Continuous Blowdown - Integral Time	30
29.1	Continuous Blowdown - Derivative Time	30
32.1	Continuous Blowdown - Potentiometer Close	152
33.1	Continuous Blowdown - Potentiometer Open	2432
36.1	Bottom Blowdown Operation	0
36.2	Bottom Blowdown Reduction Enable	0
36.3	Minimum Bottom Blowdown Time	0
36.4	Boiler Steam Production Rating	0
37.1	Second Low Probe Enable/Disable	0
38.1	Temperature Sensor Configuration - Steam or Heat Flow	1
40.1	Draught Control Enable	1
40.2	Draught Control Pressure Sensor	1
40.3	Minimum Draught Angle	15
40.4	Delay Before Compensation	5

Figure 7.4.ii Draft Control Expansion Options

2. Configure expansion options 40.1 to 41.4 for the draft control operation. It is recommended that P and I options are set to default. If changes to either the P or the I are required, it is suggested that small changes are done to each at a time, to avoid less than satisfactory or excessive trim on the stack damper.

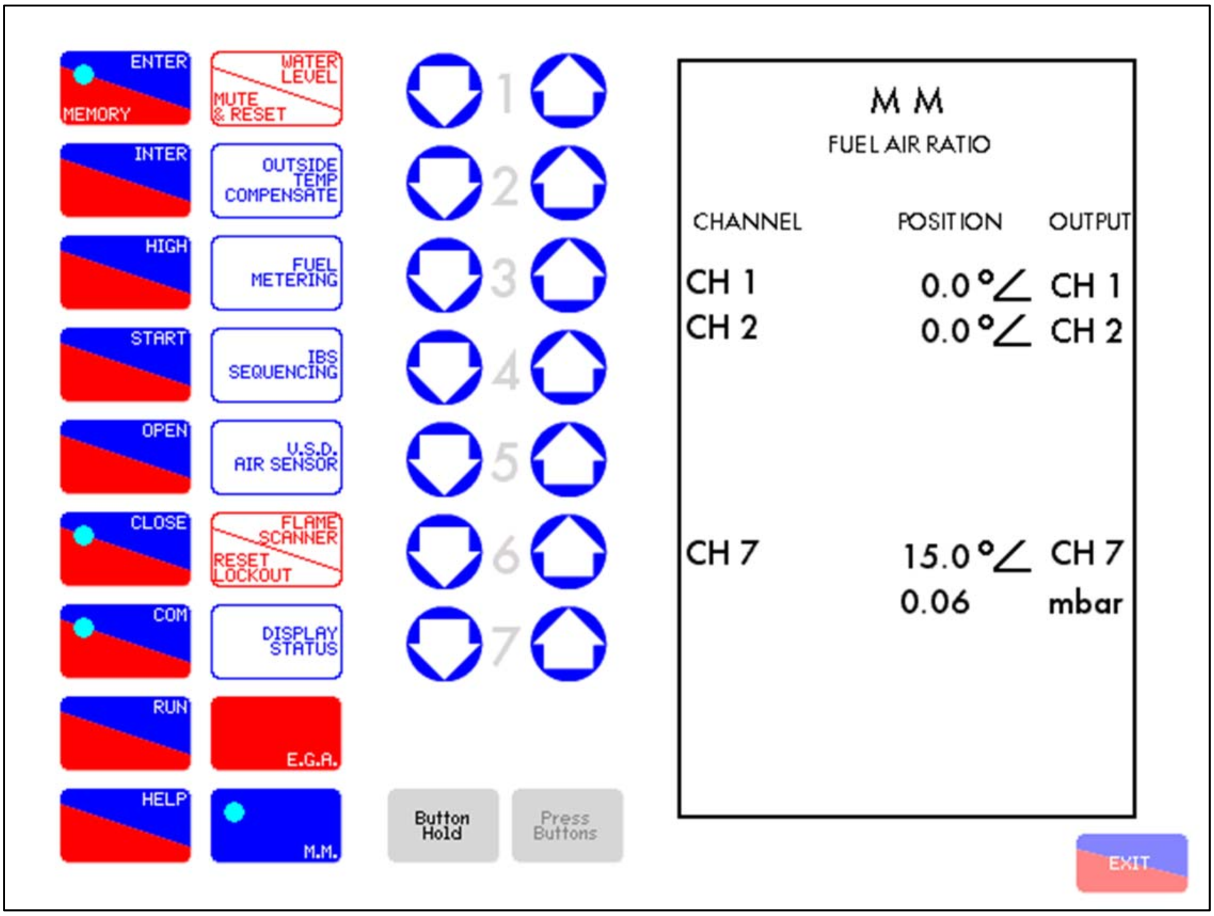


Figure 7.4.iii Close Position

3. Enter commissioning mode.

4. Enter the CLOSED position (please note that the draft control minimum angle is set by expansion set-up 40.3). The draft control damper can be increased/ decreased using CH 7 up and down arrows  .

Note: Once a CLOSE position is entered the draft servomotor will drive to the minimum baffle angle limit, expansion option 40.3.

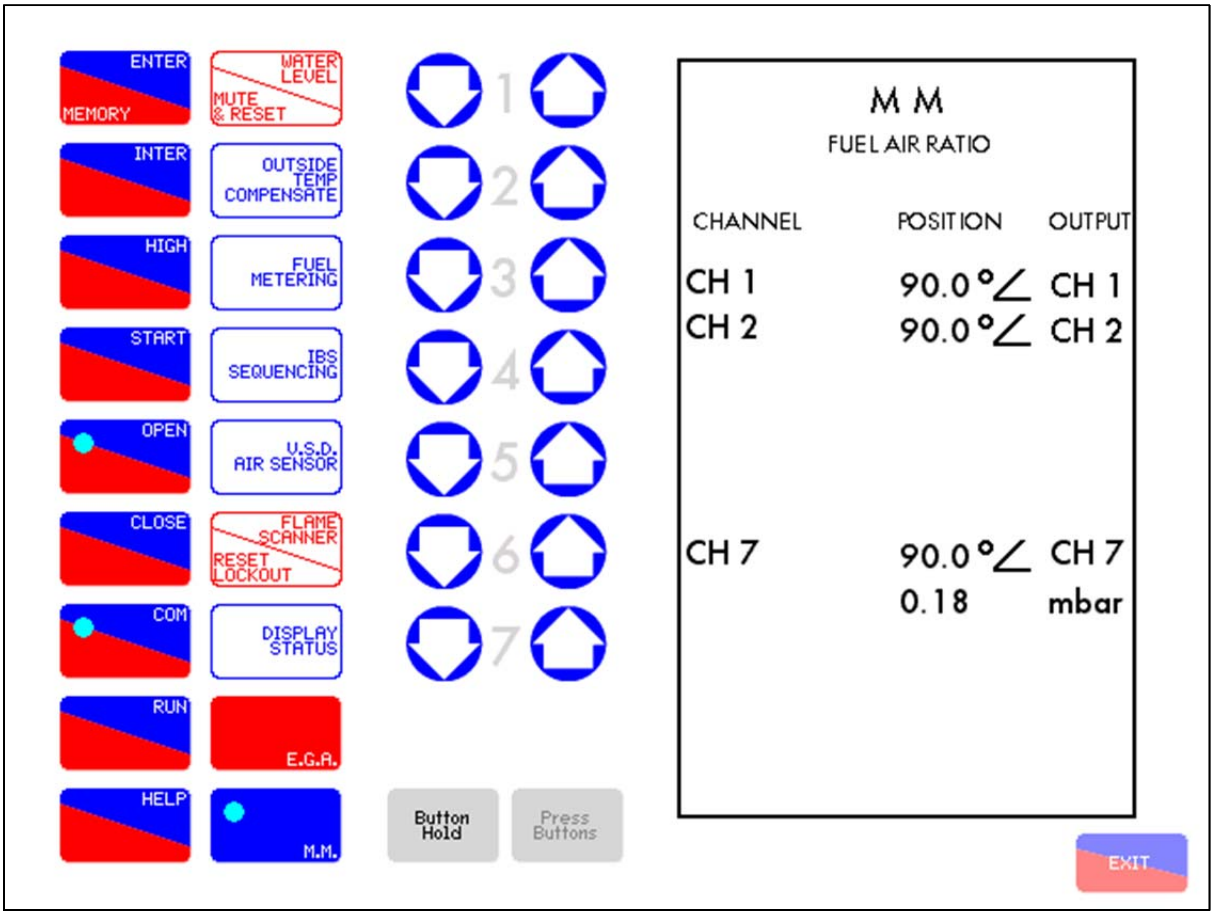


Figure 7.4.iv Open Position

5. Enter the OPEN position. A draft pressure is stored at each recorded position during the commissioning process.

6. Enter the STARTt position (this position is not stored within the M.M., but is used as an initial light off position).

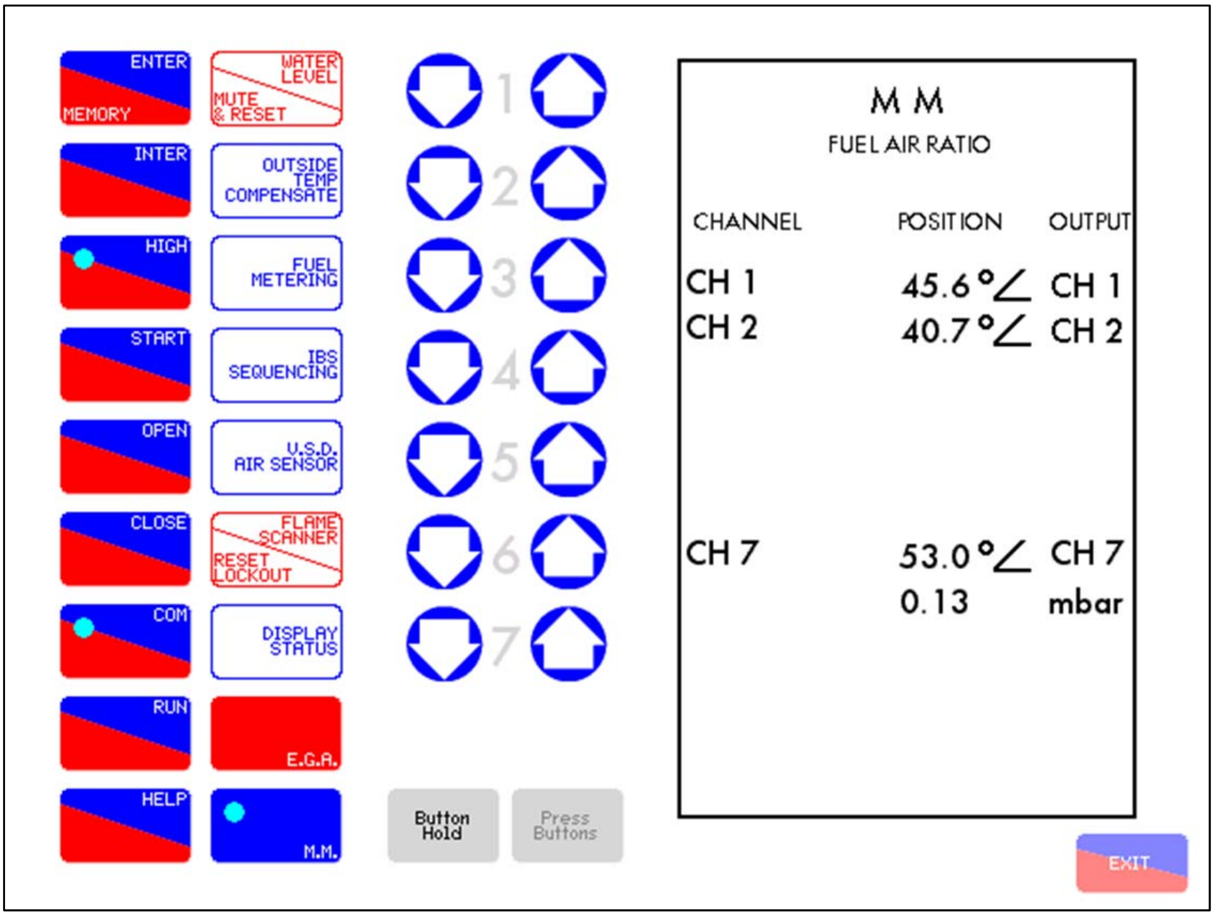


Figure 7.4.v High Position

7. Drive the servomotors up to HIGH FIRE position and then press Enter.

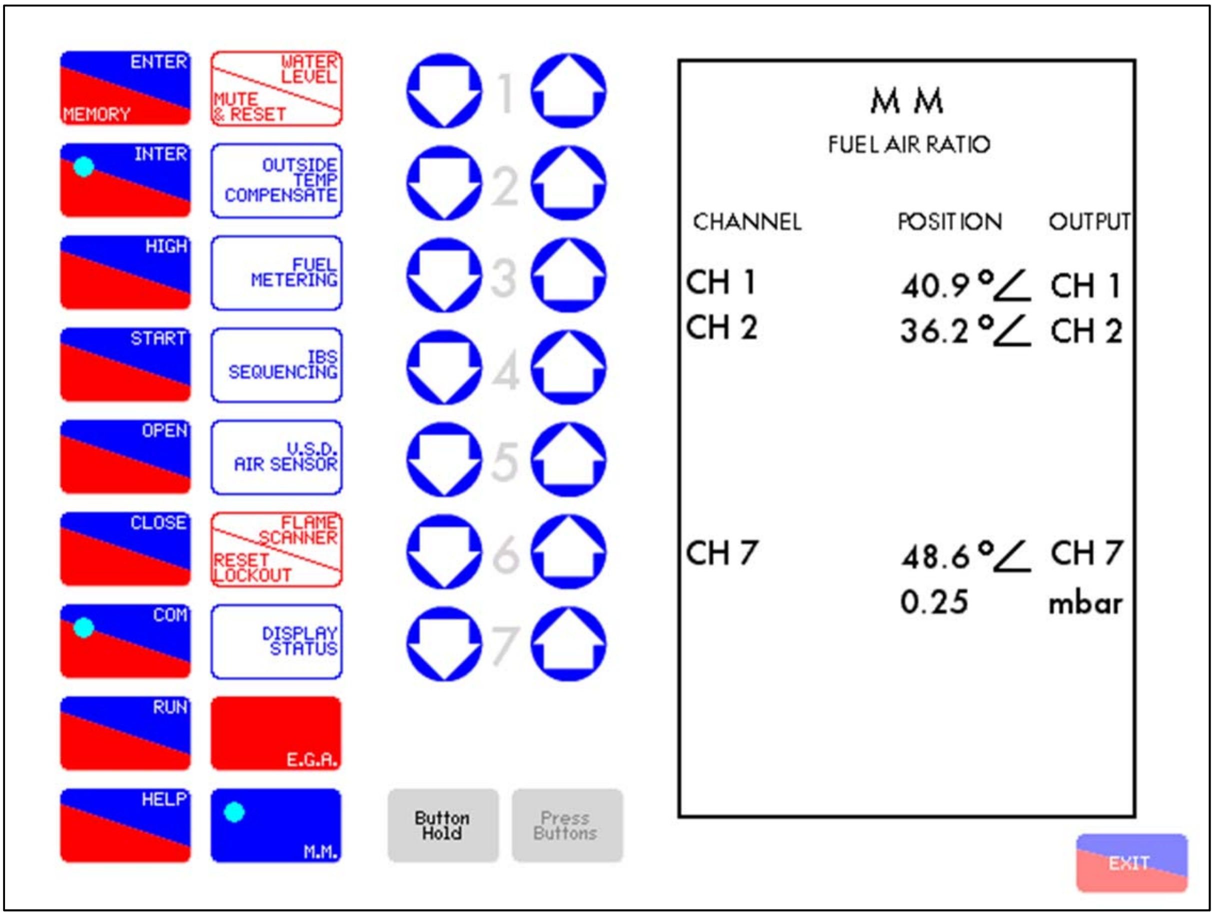


Figure 7.4.vi Inter Position

8. Enter up to 15 inter positions to make up the firing curve (minimum 3 inter positions).

Note: It is not possible to drive the draft servomotor past the minimum baffle angle limit, expansion option 40.3

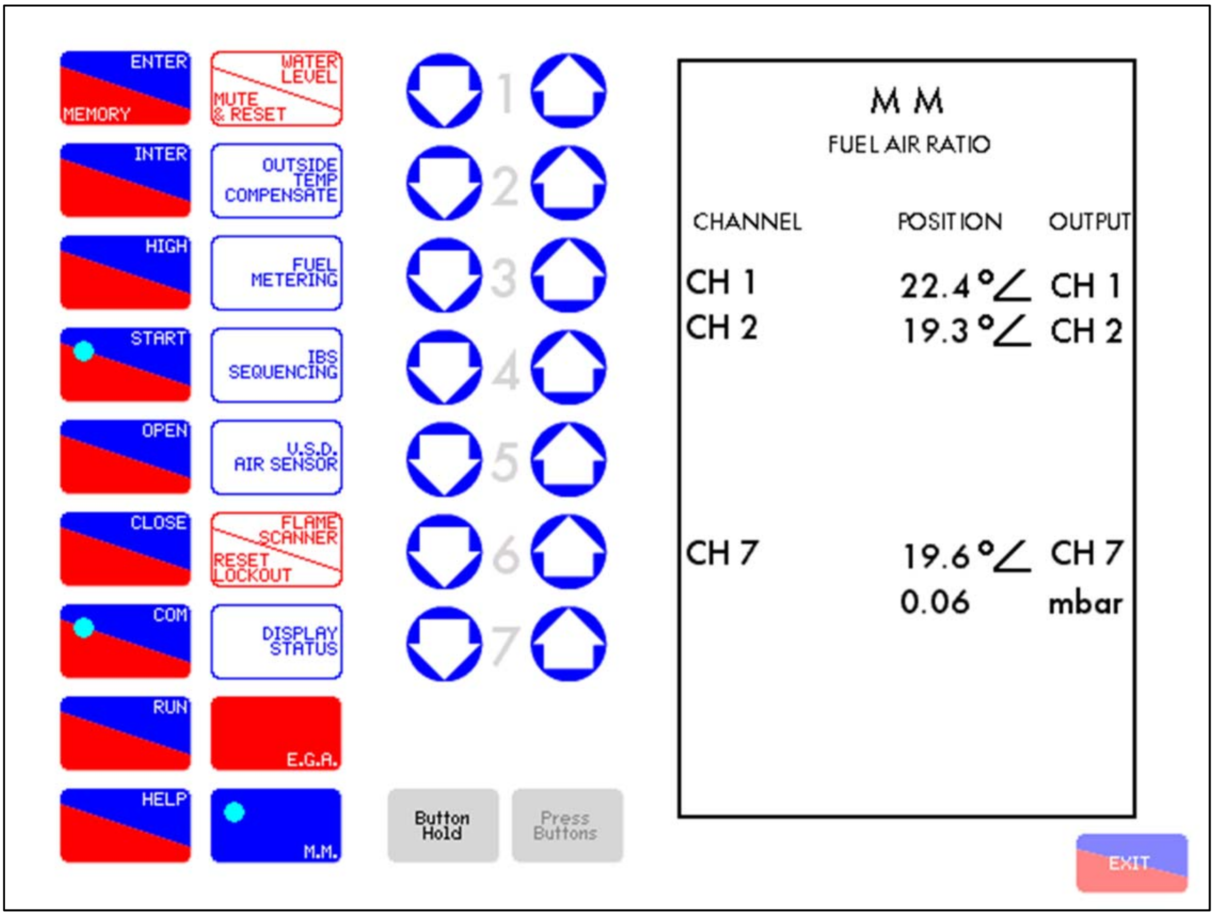


Figure 7.4.vii Start Position

9. Once all the required inter points have been entered, choose a low fire START position, press Enter and then press Run to save the combustion curve.

Note: It will not be possible to adjust CH 7 below its minimum angle as set in expansion option 40.3. if the angle is too high, either enter the position and adjust in a single point change once the option has been changed or change the expansion option and start commissioning from the beginning.

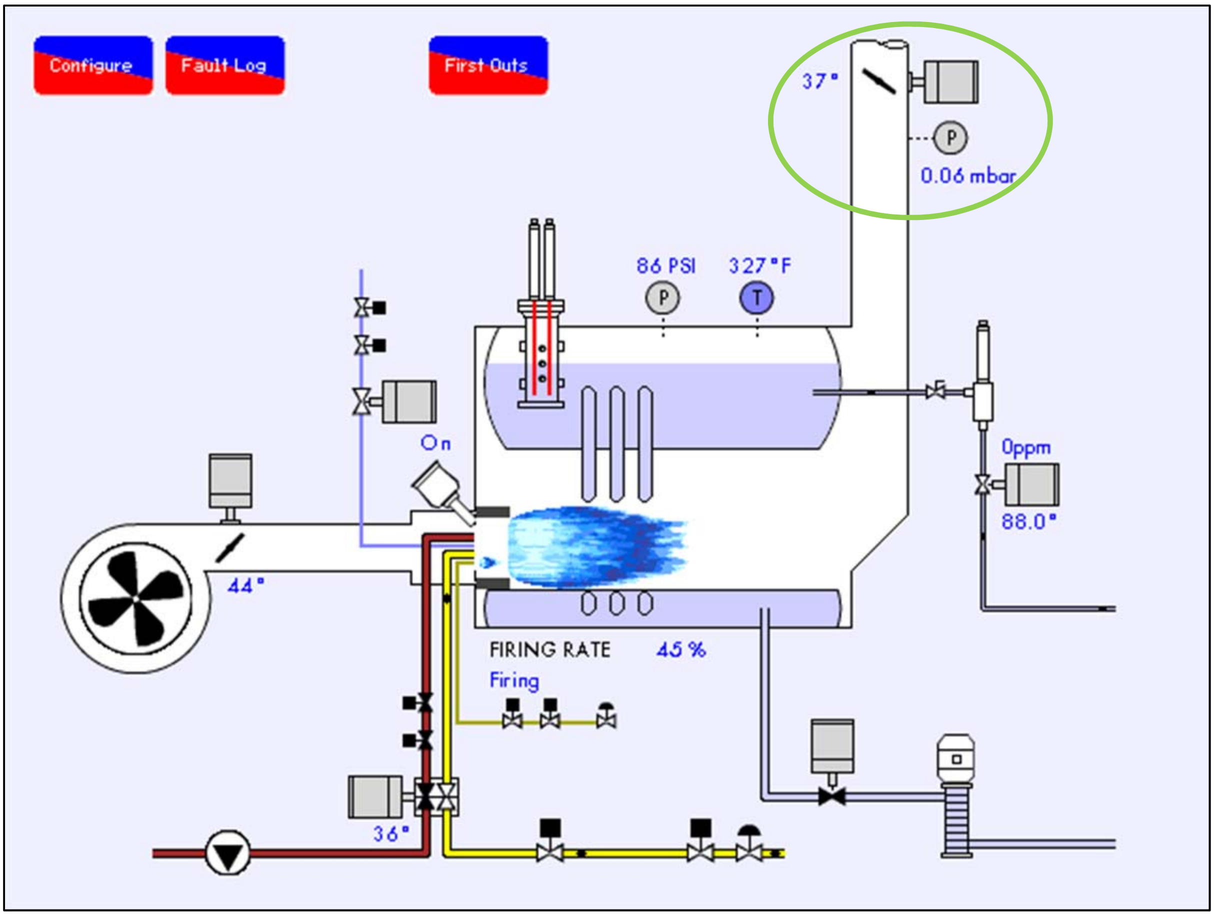


Figure 7.4.viii Home Screen

10. The M.M. will then release to modulation. Draft control information can be viewed on the M.M. screen by pressing on the pressure sensor located on the stack in the boiler home screen.

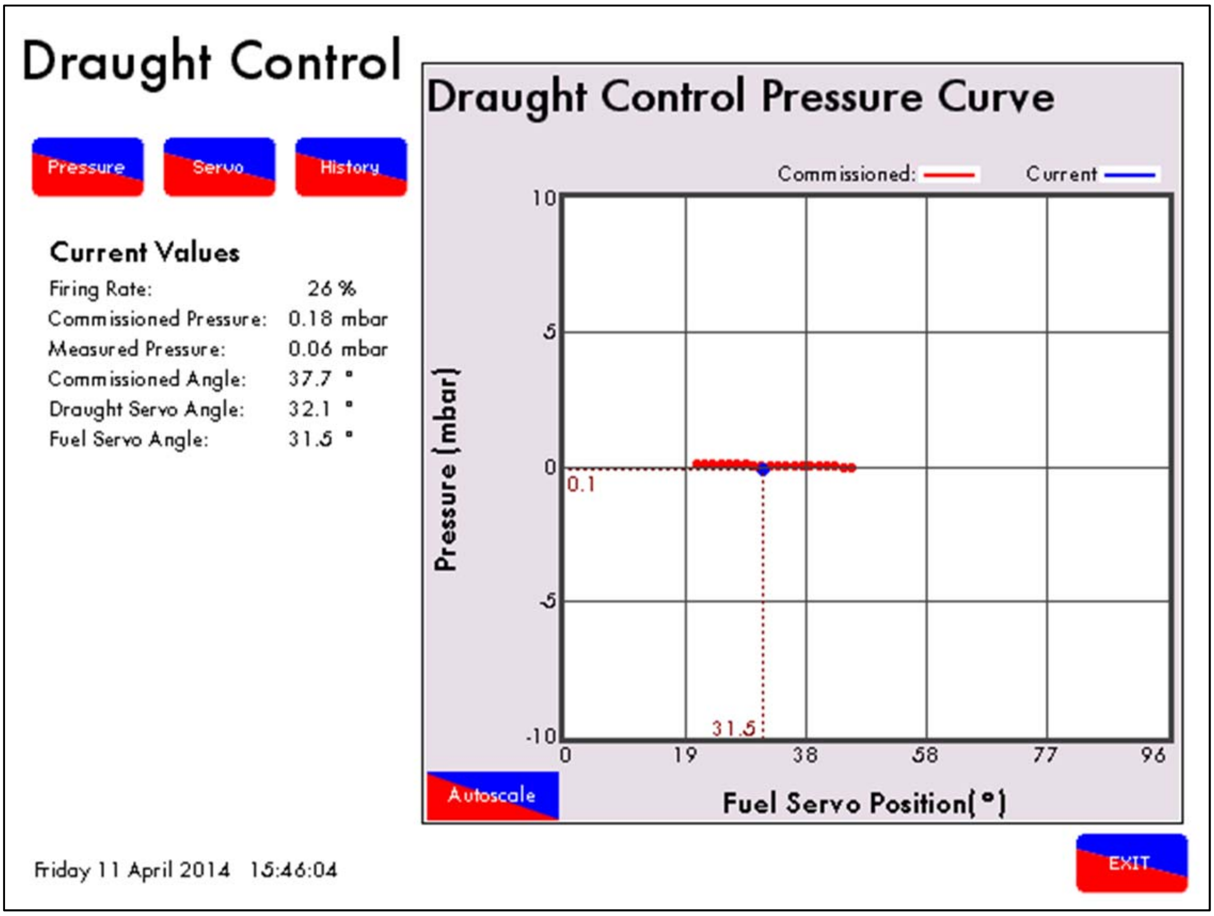


Figure 7.4.ix Draft Control Pressure Curve

11. In the draft control screens, you are able to view instantaneous data in comparison to the commissioned data. The draft control pressure curve displays the current draft pressure in comparison to the commissioned value in relation to the current fuel valve position. In addition the pressure trend for the whole firing rate is visible.

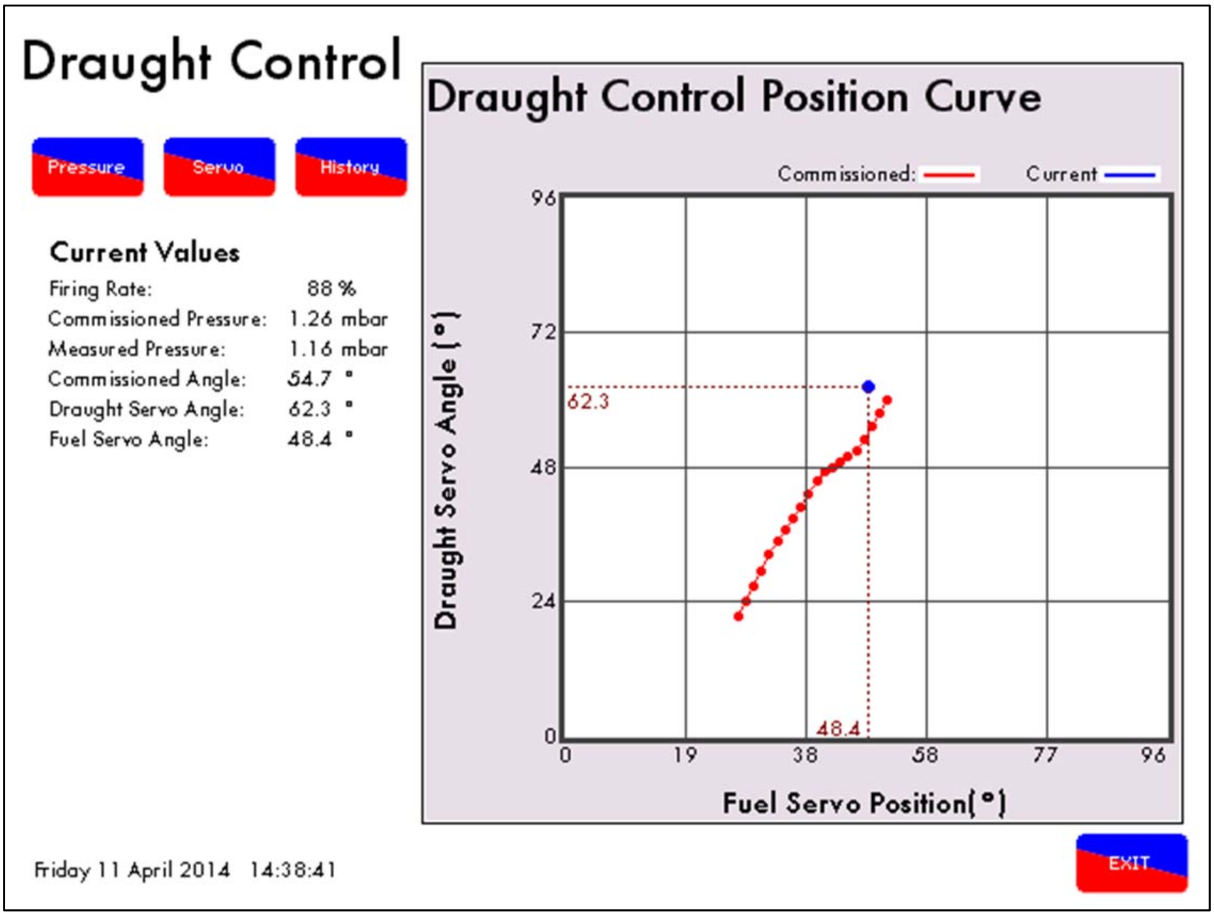


Figure 7.4.x Draft Control Position Curve

12. The draft control position curve displays the commissioned stack damper values, and displays the amount that the damper is trimming to maintain the commissioned stack pressure in relation to the current fuel valve position. In addition the commissioned servomotor positions for the whole firing rate are visible.

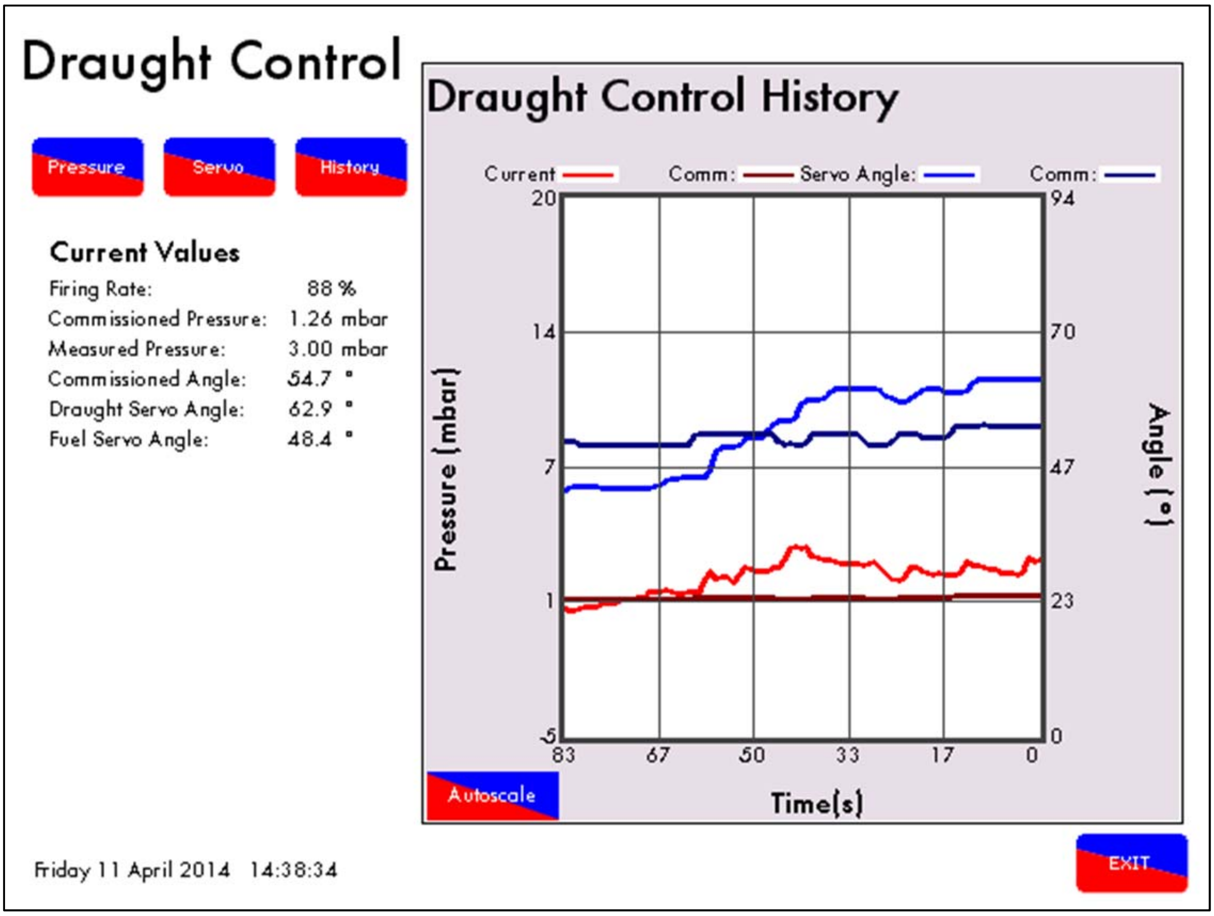


Figure 7.4.xi Draft Control History Screen

13. The draft control history, displays the draft pressure and servomotor position, running values and respective commissioned values at that stage, over a 96 minute period.

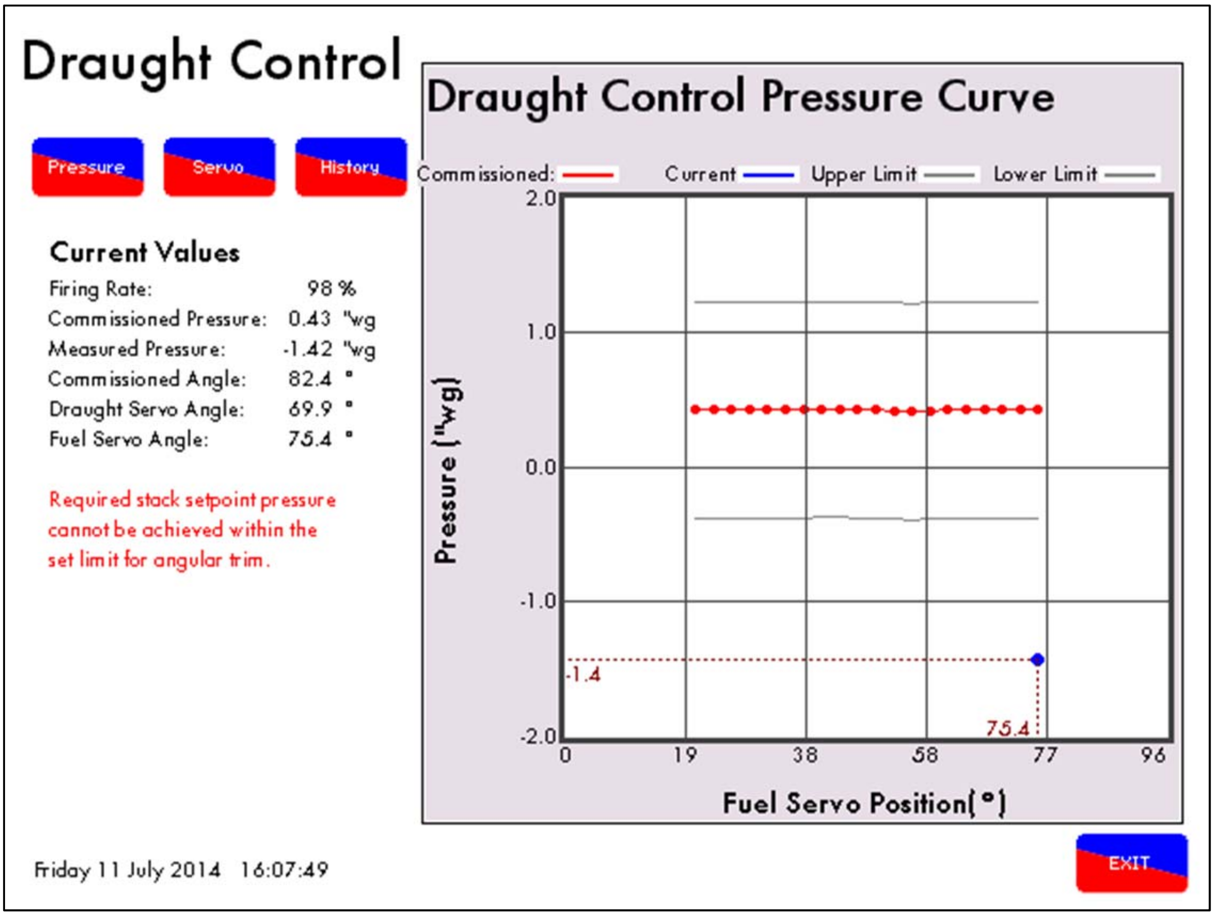


Figure 7.4.xii Pressure Not Maintained

14. If the air pressure sensor fails, or the pressure has reached its limit set through expansion option 40.8, a message will appear on the draft control screens. Expansion option 40.8 sets the maximum pressure tolerance before a fault occurs; if the current stack pressure exceeds this maximum change from the commissioned stack pressure over 2 minutes, than an error message will appear.

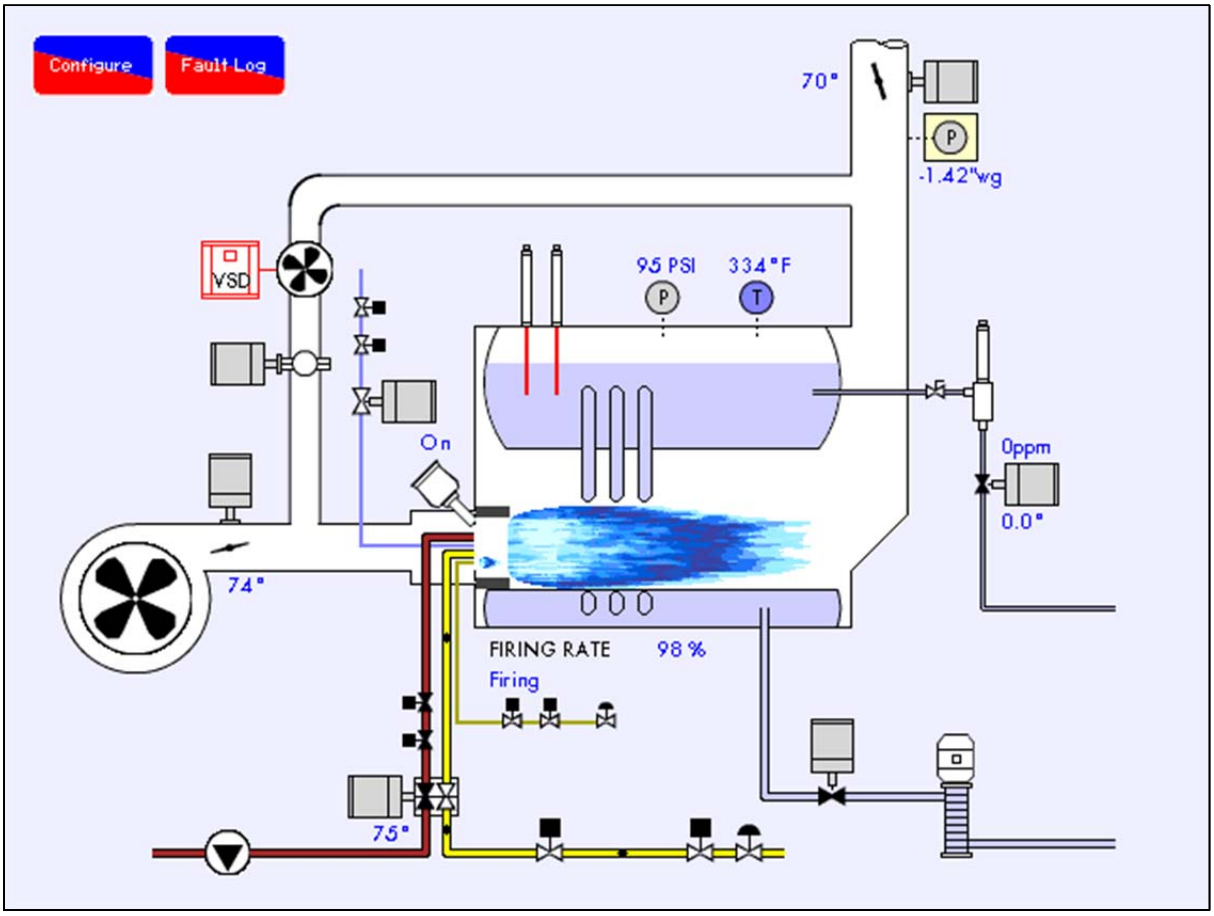
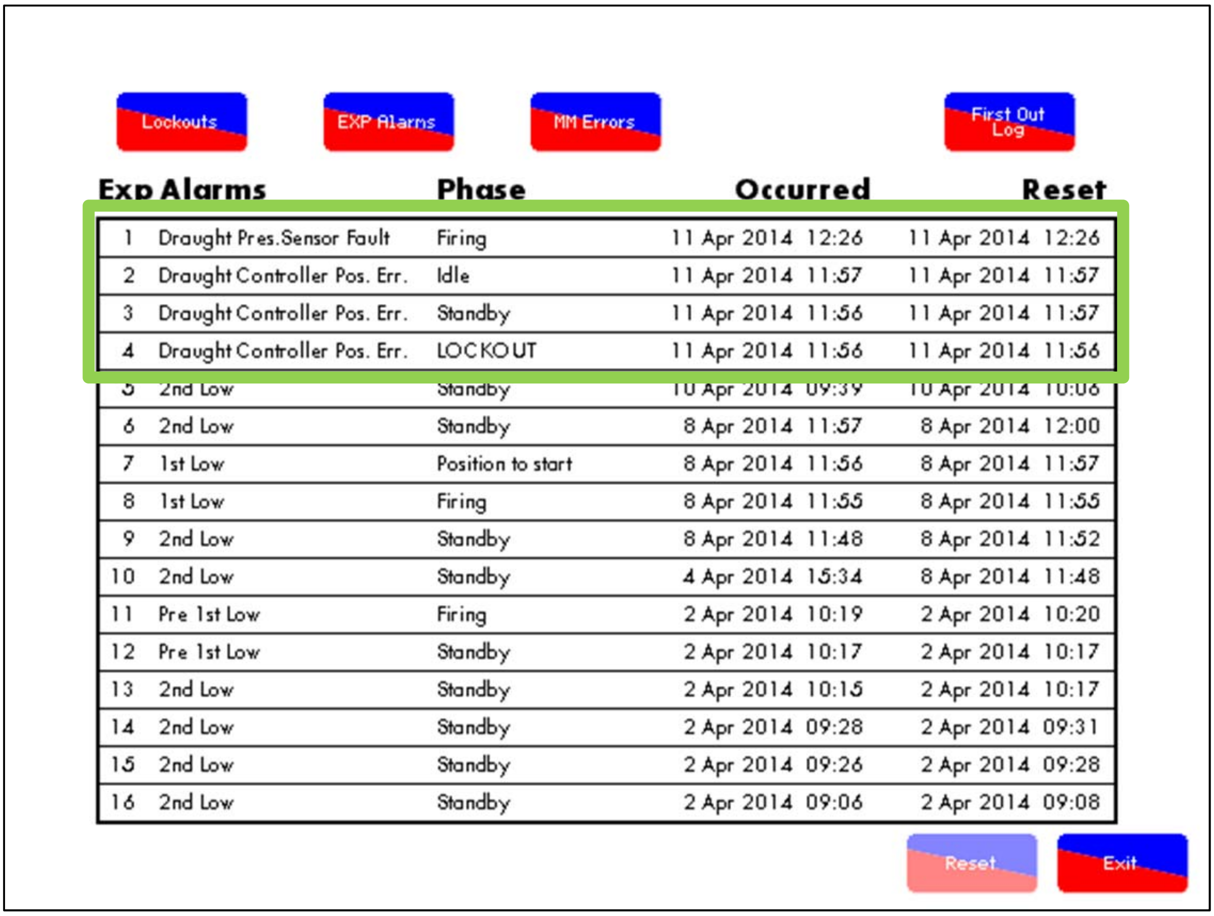


Figure 7.4.xiii Pressure Not Maintained – Home

15. When the pressure cannot be maintained, the pressure a yellow box will flash as an indication that the air pressure sensor in the stack is reading outside of limits.



Exp Alarms		Phase	Occurred	Reset
1	Draught Pres.Sensor Fault	Firing	11 Apr 2014 12:26	11 Apr 2014 12:26
2	Draught Controller Pos. Err.	Idle	11 Apr 2014 11:57	11 Apr 2014 11:57
3	Draught Controller Pos. Err.	Standby	11 Apr 2014 11:56	11 Apr 2014 11:57
4	Draught Controller Pos. Err.	LOCKOUT	11 Apr 2014 11:56	11 Apr 2014 11:56
5	2nd Low	Standby	10 Apr 2014 09:39	10 Apr 2014 10:06
6	2nd Low	Standby	8 Apr 2014 11:57	8 Apr 2014 12:00
7	1st Low	Position to start	8 Apr 2014 11:56	8 Apr 2014 11:57
8	1st Low	Firing	8 Apr 2014 11:55	8 Apr 2014 11:55
9	2nd Low	Standby	8 Apr 2014 11:48	8 Apr 2014 11:52
10	2nd Low	Standby	4 Apr 2014 15:34	8 Apr 2014 11:48
11	Pre 1st Low	Firing	2 Apr 2014 10:19	2 Apr 2014 10:20
12	Pre 1st Low	Standby	2 Apr 2014 10:17	2 Apr 2014 10:17
13	2nd Low	Standby	2 Apr 2014 10:15	2 Apr 2014 10:17
14	2nd Low	Standby	2 Apr 2014 09:28	2 Apr 2014 09:31
15	2nd Low	Standby	2 Apr 2014 09:26	2 Apr 2014 09:28
16	2nd Low	Standby	2 Apr 2014 09:06	2 Apr 2014 09:08

Figure 7.4.xiv Draft Control Alarms

16. The draft control alarms will appear in the Expansion Alarm log. Draft pressure sensor alarms can be configured so that they either lockout the burner, or keep the burner running with the draft servomotor position returned to its commissioned position along the firing curve. Any servomotor errors will result in a burner shutdown which will not permit the burner to be restarted until rectified.

7.5 Draft Control Operation

The draft control trim functionality follows the same ideology to the E.G.A., where corrections are made to air damper to compensate for the changes in exhaust gas values from their commissioned values, caused by fluctuations in ambient conditions. For Autoflame draft control, corrections are made to the stack damper to compensate for changes in wind and ambient conditions which cause the stack pressure to differ from the commissioned stack pressure along the fuel curve.

Once the burner starts up and the main flame stabilised, there is a time delay where no draft control operation occurs, set in expansion option 40.4. After this time delay elapses, as the air going into the burner is increased from low fire to high fire, the boiler pressure may change and the draft servomotor will move to follow these changes as commissioned. If the atmospheric or stack pressures have changed from their commissioned values along the curve, the air damper will either move in the open, or close direction to adjust the air pressure in the stack back to its set value.

The smallest angle that the draft damper can drive to while running is defined by expansion option 40.3; when the burner turns off, the draft damper will go to commissioned closed position to maintain heat within the boiler.

If draft control is optioned off after being commissioned, then the draft servomotor will drive to the open position and re-commissioning is not required. The draft servomotor must remain connected and is still in operation so any channel errors will still shutdown the burner and generate an on screen indication. A full re-commission with this turned off will be required to remove the servomotor from the system. The air pressure sensor has no effect once draft control is optioned off and can be disconnected without any lockouts occurring.

7.5.1 Deactivation Window

There is a deactivation window, outside of which no trim occurs, and the air damper remains at the previously trimmed position until back within the window and trim is required. This deactivation window is defined by expansion options 40.4 - delay before compensation and 40.5 - firing compensation deactivation window. If the draft servomotor has moved more than the set angular degrees "x", within the time period set "y", than no trim functionality will operate, if trim has been performed prior to this deactivation then the trim is carried forward.

For example, when the burner is first switched on with a high demand, or if the burner comes out of warming in lead-lag control, or is switched from low flame hold to auto mode. In these situations the firing rate may ramp up quickly to meet load demand, at this point if the draft servomotor is required to move greater than the set amount (40.5) quicker than the set time (40.3) then no trim functionality will occur and any trim % will be carried forward.

See figure 7.5.1.i for a graphical representation of draft activation window.

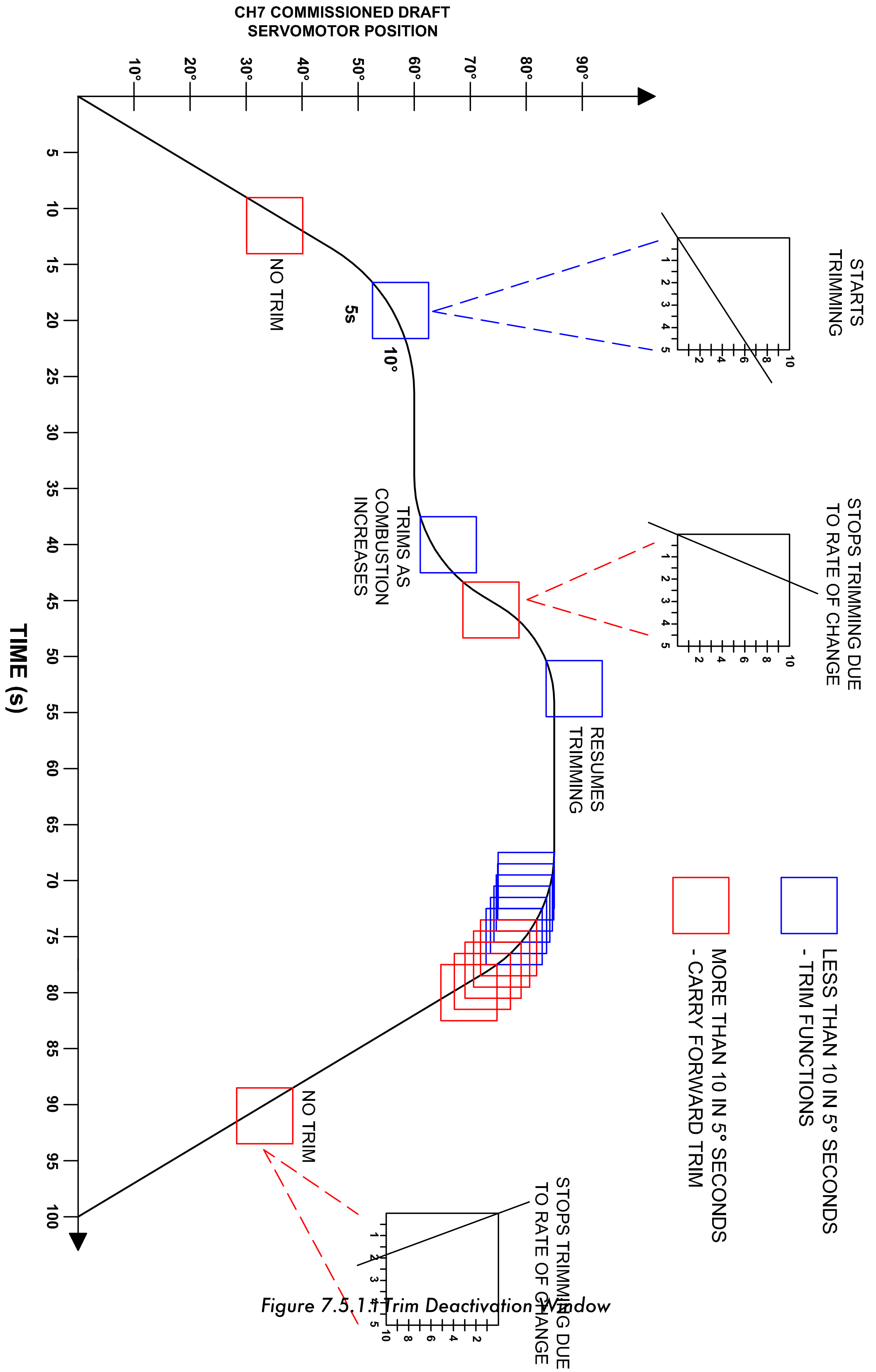


Figure 7.5.1.1 Trim Deactivation Window

7.5.2 Trim Operation

If within the trim window, the trim functionality is controlled by the maximum forward or backward trim set by expansion option 40.6, and also by the PI settings in 41.1, 41.2 and 41.3. The 'maximum compensation' set in expansion option 40.6 is the maximum percentage of the commissioned draft servomotor angle to which the stack damper will trim negative or positive. See figure 7.5.2.i for a graphical representation of example trim angles.

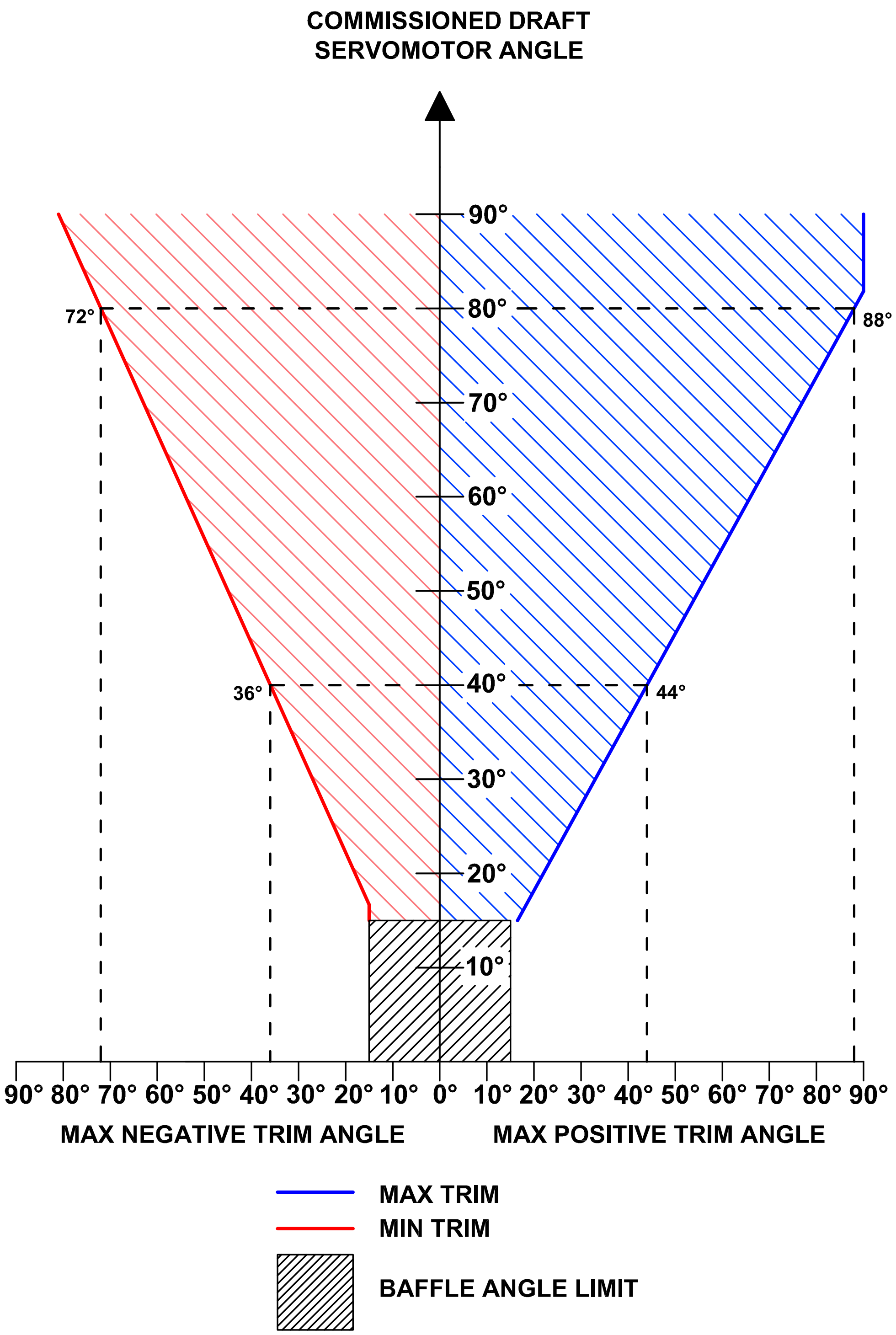


Figure 7.5.2.i Trim Angle

8 TROUBLESHOOTING

8.1 Expansion Alarms

The M.M. will display up to 16 expansion alarms. Please find to the expansion alarms bellow:

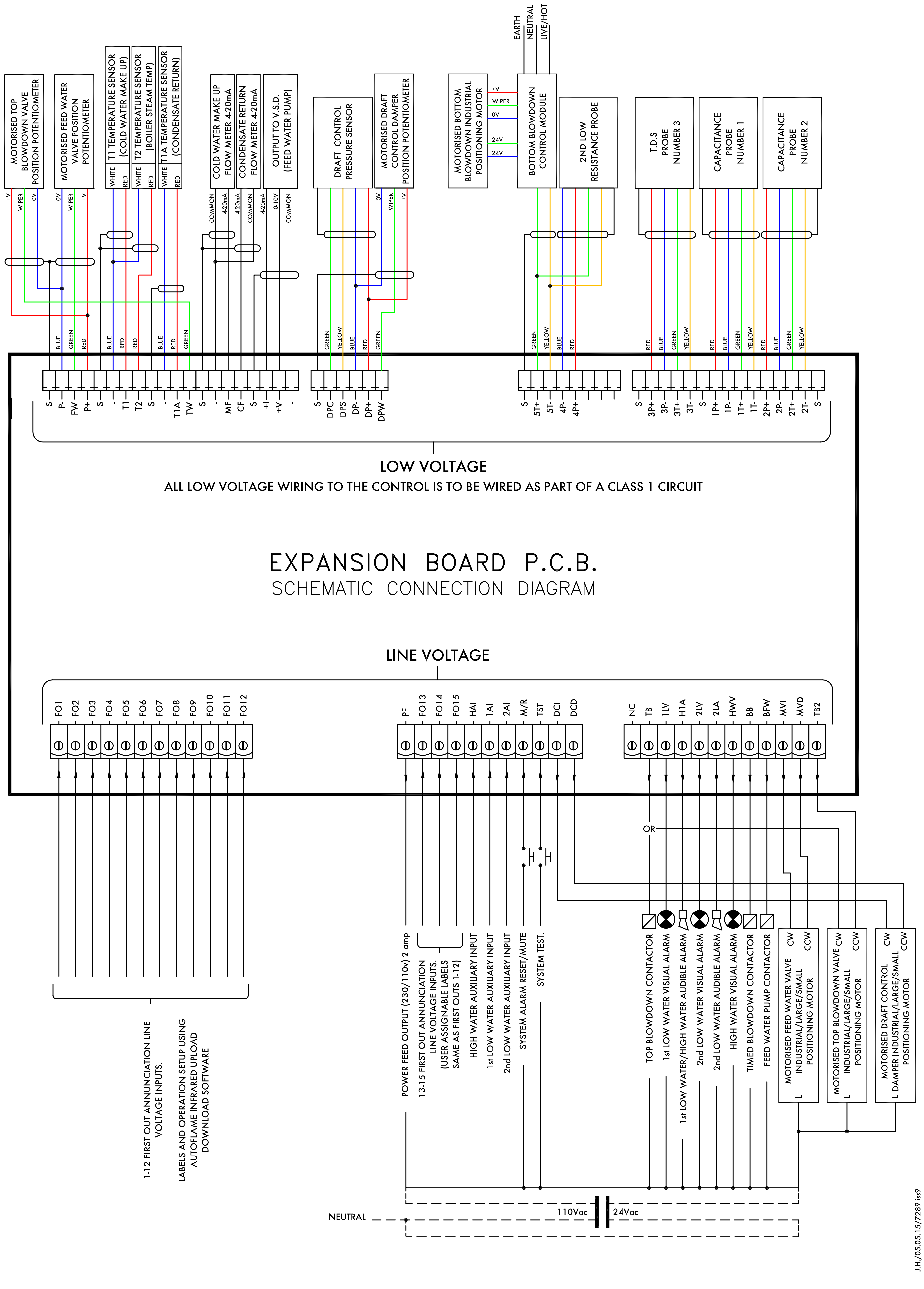
1	**2nd Low Level**	The water level has fallen below the commissioned 2nd Low position. If the alarm was preceded by a 1st Low alarm, the 1st Low entry will be automatically replaced within the alarm log.
2	**Probe 1 Comms Fault**	The communications between the water level control and probe 1 have failed, exceeding the maximum allowed period of 3 seconds. Check probe wiring/ failed probe.
3	**Probe 2 Comms Fault**	The communications between the water level control and probe 2 have failed, exceeding the maximum allowed period of 3 seconds. Check probe wiring/ failed probe.
4	**Probe 1 Short**	Probe 1 has short circuit failure. This probe's water level is currently outside of the normal operating limits range. This may be caused by a probe hardware failure. Contact an Autoflame technology centre.
5	**Probe 2 Short**	Probe 2 has short circuit failure. This probe's water level is currently outside of the normal operating limits range. This may be caused by a probe hardware failure. Contact an Autoflame technology centre.
6	**Probe Mismatch**	The probe levels are not currently in line with commissioned levels suggesting a probe failure or alteration. This can also be caused by overheating of the electronics. It is important to lag the flanges if the probes are mounted directly into the boiler shell. Try cleaning and re-commissioning the probes.
7	**Probe 1 TC**	Probe 1 has a temperature compensation failure. This probe's water level is currently outside of normal operating conditions when compensating the water level. Check the wiring, clean the probes, and re-commissioning the probes. This could be probe hardware failure.
8	**Probe 2 TC**	Probe 2 has a temperature compensation failure. This probe's water level is currently outside of normal operating conditions when compensating the water level. Check the wiring, clean the probes, and re-commissioning the probes. This could be probe hardware failure.
9	**Permanent Reset**	The water level control or M.M. mute/reset button was pressed for longer than 10 seconds. To reset this alarm ensure that both buttons are not pressed for at least 10 seconds. This will become a keystuck-reset alarm.
10	**Permanent Test**	The water level control test input button was pressed for longer than 60 seconds.

11	**Perm Reset Cleared**	This is now a keystuck-reset alarm.
12	**EEprom PU Corrupt**	On power up, the EEprom test has failed; the water level control has not been used before, has a faulty EEprom. If the problem persists after resetting the error, contact Autoflame.
13	**Bogus PU State**	The EEProm is in a bogus state, if the problem persists after resetting the error, contact Autoflame.
14	**Control Cfg Mismatch**	The configuration and commission data do not have matching control type options. This would occur if the configuration has been changed after commissioning.
15	**Probe 1 Com Data**	Probe 1 has corrupt commissioning data. Restart and re-commission the probes if error persists after resetting error.
16	**Probe 2 Com Data**	Probe 2 has corrupt commissioning data. Restart and re-commission the probes if error persists after resetting error.
17	**Config Range Check**	One or more of the configuration options is outside of the allowed range.
18	**1st Low Level**	The water level is currently below the commissioned 1st Low position. If the alarm precedes a 2nd Low alarm, it will be automatically replaced by a 2nd Low alarm in the log. Once the water returns to a level above the commissioned 1st Low, the error will remain within the log but it will be automatically reset.
19	**High Water Level**	The water level is currently above the commissioned High Water position. This alarm will clear automatically when the water level is reduced below the commissioned High Water position.
20	**Probe 1 Still Water**	The signal from probe 1 appears static indicating that the probe is not in the water.
21	**Probe 2 Still Water**	The signal from probe 2 appears static indicating that the probe is not in the water.
22	**Probes Diverse**	One probe is reading above high water, the other is below 1st Low water. Usually caused by auxiliary inputs incorrectly connected/ optioned. See expansion option 12.1
23	**Pre 1st Low**	The water level is below the commissioned Pre 1st Low position.
24	**Pre High Water**	The water level is above the commissioned Pre High Water position.
25	**Btm Blowdn Software Fault**	Bottom blowdown software fault. Please contact Autoflame.
26	**Btm Blowdn Comms Fault**	Bottom blowdown board has a comms failure.
27	**Btm Blowdn 24V Fault**	Bottom blowdown board – main power failed

28	**Btm Blowdn Battery Fault**	Bottom blowdown board – battery power failed
29	**Btm Blowdn Opening Fault**	Bottom blowdown valve failed to move while opening
30	**Btm Blowdn Closing Fault**	Bottom blowdown valve failed to move while closing
31	**2nd Low Probe – No Water**	The 2nd Low probe detects no water.
32	**2nd Low Probe System Error**	Please contact Autoflame.
33	**2nd Low Probe Comms Fault**	The 2nd Low probe has a communications failure, check wiring.
34	**TDS Probe Comms Error**	The TDS probe has a communications failure, check wiring.
35	**TDS Limit Breached**	The TDS limit has been breached, check configuration options and water conditions.
36	**TDS Valve Position Error**	The TDS valve has a positioning error, check wiring.
37	**Feed water Valve Position Error**	The feed water valve has a positioning error, check wiring.
38	**Draft Controller Position Error**	The draft control servomotor has a positioning error, check wiring and feedback.
39	**Sensor T1 Fault**	The temperature sensor wired in terminal #T1 has a fault.
40	**Sensor T1A Fault**	The temperature sensor wired in terminal #T1A has a fault.
41	**Sensor T2 Fault**	The temperature sensor wired in terminal #T2 has a fault.
42	**Flow meter fault**	The steam flow meter has a fault.
43	**Draft Pressure Sensor Fault**	The draft control pressure sensor has a fault, check wiring.
44	**Draft Pressure Tolerance Fail**	The draft control pressure tolerance is outside the configured tolerance band for longer than 2 minutes.
45	**Bottom BD Not Commissioned**	The bottom blowdown operation has not been commissioned.
254	**WL Board Reset**	Please contact Autoflame.

Notes

IF IN DOUBT ASK AUTOFLAME TECHNICAL DEPARTMENT



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