8 Annex C1: Single Boiler Cascade

8.1 System setup

The Argus control can also be applied for multiple boiler systems in cascade setup. A system sensor input is available on the main board to measure the cascade system supply temperature. Also a CH pump output is available to run the system pump and a output for the DHW pump.

When the CH supply temperature is calculated based on an outdoor sensor, only one outdoor sensor is needed. This sensor is connected to the managing boiler and calculates the CH setpoint for the cascade system.

In case of cascade in combination with a domestic hot water tank a DHW pump can be connected to pump output of the managing boiler control. The storage sensor (*T_Tank*) or thermostat must be wired to the same control.

Cascade boiler pump connections for system configuration 1
System configuration for handling DHW store or central heating demand. All boilers handle **either** DHW store **or** CH heating demand at one time.

Fig 1: Example of multiple boiler setup for CH and DHW tank

Boiler designation	Depending boiler 16	…	Depending boiler 2	Managing boiler 1
Boiler pump connection				
Remarks				- The managing boiler CH Pump is used as System Pump. - The DHW Pump must be connected to the managing boiler. - The DHW store sensor/stat must be connected to the managing boiler t DHW out sensor input.

Cascade boiler pump connections for system configuration 2

System configuration for handling dhw store or central heating demand. All boilers handle **either** DHW store **or** CH heating demand at one time.

Fig 2: Alternative piping plan for multiple boiler cascade setup for CH and DHW tank

Boiler designation	Depending boiler 16	…	Depending boiler 2	Managing boiler 1
Boiler pump connection				
Remarks				- The managing boiler CH Pump is used as System Pump. - The DHW Pump should be connected to the managing boiler. - The DHW store sensor should be connected to the managing boiler t DHW out sensor/stat input. - The system sensor should be connected to the managing boiler.

8.2 Setting the boiler address

Argus Link connection and Power Switch S4:
All boilers must be connected in parallel to the Argus Link communication with plug J18 on the 850MN control. The managing boiler control provide the power for the communication bys. Therefore at the managing boiler switch S4 has to be in the ON position (pin S4 marking) and switch S4 off all dependent boiler controls must be in the OFF position (slider towards from S4 marking). See annex I for an image with the connections.

One boiler is the Managing (*boilers_address = 1*) and all other boilers work as dependent (address 2..16). Each boiler should have its unique address.

boiler_ address **Parameter Value**	**Boiler Operation**	**Function of sensor input J5(7-15)**	**LabVision Device Address**
0 (default)	No cascade boiler	No function	100
1	1st boiler (**Managing**)	System sensor	100
2	2rd boiler (dependent)	No function	101
	3rd boiler (dependent)	No function	102
4	4th boiler (dependent)	No function	103
↓	↓		↓
16	16th boiler (dependent)	No function	115

Once a boiler is defined as dependent (addresses 2..16) the display will show the boiler supply temperature and the boiler status.

The managing display (*boiler_address = 1*) and the managing boiler controls will be used to determine the demands for heat or DHW and shows system temperature *T_system*.

Communication with LabVision PC software
The Argus-to-USB device must be connected to J18 too. Default the LabVision device address is 100, which corresponds with the managing boiler. To read out boiler parameters of dependent boiler the device address in LabVision must be changed. LabVision device_address = boiler_address +99

8.3 Cascade – Heating only

Managing boiler

When a boiler is set as Managing (address = 1), the controller of this boiler will drive the cascade. The CH mode of this managing boiler applies to all other boilers. It is only required to set the CH mode on the managing boiler

- The outdoor temperature sensor connected to the MANAGING boiler will be outdoor sensor for the cascade operation
- The system sensor (*T_System*) connected to the MANAGING boiler will be the control sensor for the cascade supply temperature.
- The thermostat connected to the MANAGING boiler will be the CH heat demand input for the cascade system.

On basis of the system temperature (*T_System*) and the requested *Cascade_Setpoint* the managing boiler calculates a required boiler setpoint to achieve the requested *Cascade_Setpoint.* The managing boiler provides the calculated setpoint to all dependent boilers. The power of the dependent boilers is PID controlled on basis of the calculated setpoint and dependent boiler supply temperature

CH Mode
The required CH mode must only be set at the managing boiler

CH setpoint adaption for boilers

When the system temperature is not high enough the setpoint for all boilers will be adjusted. The boiler setpoint will be increased when the system temperature is below *Cascade_Setpoint* and decreased when it is above *Cascade_Setpoint* temperature. This is determined as following:

A PID-control loop over the system temperature (*Cascade_Setpoint/ T_System*) calculates the adjustment of the boiler setpoint. The output of the PID controller, which is a value between 1..255, is scaled between -10ºC (-18ºF) settable: *Max_Setp_Offset_Down)* and 20ºC (36ºF) *(*settable: *Max_Setp_Offset_Up).* This offset is added to the *Cascade_Setpoint.* In between the min/max the offset will be linear.

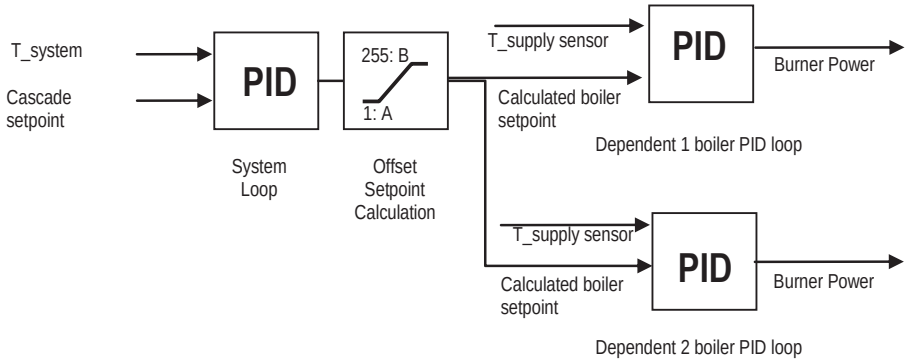
When the system temperature is above cascade setpoint, the calculated boiler setpoint will be decreased with maximum -10ºC (-18ºF). In case the system temperature is below cascade setpoint the calculated boiler setpoint to all boilers will be increased with maximum 20ºC (36ºF)

The calculated boiler setpoint will be limited at 85ºC (185ºF)

The PID calculation does not start immediately but after a certain delay period to stabilize the system first. The delay period is calculated by multiplying the *Delay_Period-Start_Next_Dependent* with the *Start_PID_Modulation_Delay_Factor (settable)*

The delay period is limited on 60 minutes. When setting the *Start_Modulation_Delay_Factor* at 0 this function is disabled.

The following diagram shows how the setpoint to the dependents is determined:



A: When PID output=1
Calculated setpoint = *cascade_setpoint* - 20ºC (18ºF) *(max_setp_offset_down)*

B: When PID output=255
Calculated setpoint = *cascade_setpoint* + 10ºC (36ºF) *(max_setp_offset_up)*

PID slew rate
The changes of the PID output can be limited with the *PID_Max_Slew_Rate (factory settable)* setting to avoid big setpoint changes to the boilers. The PID output is a value between 1 to 255, when for example the *PID_Max_Slew_Rate* is 10 it means the PID output change can be maximum +10 and -10 steps of the last result.

Dependent Boiler
In case a boiler is set as dependent (address = 2-16) the setpoint is always provided by the managing boiler. The power of the ALL boilers is PID controlled by the boiler self by comparing the calculated setpoint from the managing boiler and *T_Supply.* The managing boiler itself will be controlled in the cascade system as it would as it was a dependent boiler. Only the pumps and sensor inputs are used. When burning for the cascade system the hysterese up to shut down the boiler is ignored. Now the maximum temperature of the boiler is fixed on 91ºC (196°F). This is the maximum burning temperature.

8.4 Cascade – Domestic Hot Water

The 850MN boiler control supports two different configurations to prepare hot water.

Config 1: all boilers available for DHW

In this configuration the DHW storage is heated from the manifold, figure 1 and 2 above are showing this type of configurations.

Connections:
- The external tank sensor or thermostat should be wired to the dhw sensor input on the managing control.
- The pump or 3-way valve for DHW operation are connected to the managing boiler control.

Settings:
In the installer DHW menu of the managing boiler control the following setting should be made:
- *DHW_Mode* should be set at *1* or *2*

In the installer CASCADE menu of the managing boiler control the following setting should be made:
- *DHW_Boiler _Assign* must be set at *ALL*

When demand for dhw is detected the control functions as described in the DHW chapter from the manual.

Dependent Boiler
In case a boiler is set as dependent (address = 2-16) the DHW setpoint is always provided by the managing boiler, the internal control of the setpoint functions are disabled.

Managing Boiler
The managing boiler can go to burn on its own when there is no heat request for the cascade system and there is a Store warm hold demand for the tank. When there is a CH heat request the managing boiler abort the store warm hold function and will be available for the cascade demand.

Boiler rotation
When not all but one boiler is assigned for DHW this specific boiler will be started normally. With the option Inc. DHW boilers in rotation it can be selected if the DHW boilers are included in the boilers rotation or not. When not they will never be the first boilers to start.

8.5 Cascade – Start/Stop sequence

If there is a call from heat (CH or DHW) the boilers will start as following:

Starting Boilers.

1. When demand for CH is present and the system temperature is below *Cascade_Setpoint – Hyst_Down_Start_Boiler* the first boiler will start.
2. The managing boiler sends the calculated setpoint to the dependent boilers. The power of the boilers is PID controlled on basis of the *Calculated_Setpoint* and *T_Supply*.
3. The managing boiler waits for 3 minutes (*Delay_ Period_Start_Next_Dependent*, settable) before a next boiler can be started
4. When the power of the all the boilers is 80% (*start_rate_next dependent*, settable) or more and the system temperature is below *Cascade_Setpoint*, a next boiler is started. Again the delay period *Delay_ Period_Start_Next_Dependent* is started.
5. The managing boiler checks the power of all boilers that are burning. If the power of all boilers is above 80% rate (*Start_Rate_Next dependent*, settable), and the wait time has elapsed, the Managing boiler starts a next boiler.
6. Etc.

Stopping Boilers.

- When one boiler is below 30% *(stop_rate_next_dependent, settable),* the last boiler is stopped. A delay period follows *(Delay_ Period_Stop_Next_Dependent, settable)*
- When again the power of one boiler is below 30% a next boiler is stopped
- The boilers are allowed to stop when the system temperature is above *Cascade_Setpoint + Hyst_down_stop_boiler (settable)*. If the system temperature is below this point no boilers are stopped. Also when the boiler is burning below the *stop_rate_next_dependent*.
- All boilers are stopped when the header temperature *T_system* is above *Cascade_Setpoint + Hyst_Up_Stop_Boiler*

Optimization could be done by logging a cascade system with LabVision for 24 hours and testing different settings.

8.6 Cascade – Boiler Rotation

The control supports a function to rotate the boilers on a timely basis. With parameter *Boiler_Rotation_Interval* the number of days can be set after which the start and stop sequence of the cascade boilers changes.

When for example *boiler_rotation_interval*=5 the start sequence is as following (x is the last boiler)

Days	Start/Stop sequence
Day 0-1	1-2-3-4-5..x
Day 1-2	2-3-4-5..x-1
Day 2-3	3-4-5..x-1-2
Day 3-4	4-5..x-1-2-3
Day 4-5	5..x-1-2-3-5

When *boiler_rotation_interval = 0* boiler rotation is not active.

If one boiler is assigned for DHW demand this boiler will always be the last boiler in this start/stop queue.

8.7 Error handling

8.7.1 *Freeze Protection*

The frost protection function for cascade is related to the system sensor temperature. When the system sensor value is below the 10°C (50°F) the general and CH pump of the managing boiler start. The display shows “freeze protection”.

When there is a CH call for heat, the freeze protection will be overridden and the control will start for CH.

Managing Boiler
Once cascade freeze protection is activated the managing boiler will operate as an individual boiler in freeze protection mode. If the boiler supply temperature drops below 5°C (41°F) the burner starts at minimum power and continues burning until the lowest of both supply and return temperatures are above 15°C (59°F).

After the burner is switched off the general pump runs for a period of *CH_General_Post_Pump_Period* and CH pump for *CH_ Post_Pump_Period.*

Dependent Boiler
If the supply temperature of a dependent boiler drops below the freeze protection function of this boiler also starts and the boiler will operate like an individual boiler.

8.7.2 *Emergency Mode*

Open/Shorted system sensor

When the system sensor is open or shorted all boilers will go to permanent heat demand operation and using the actual *Cascade_Emergency_Setpoint* (settable via installer menu).

The managing boiler display shows “EMERGENCY MODE” and a system sensor error.

The emergency mode is default active for each boiler, however an individual boiler can be switched off via the *“Permit_Boiler_Emergency_Mode”* setting in the user menu of that boiler. When not permitted only freeze protection can become active.

Loss of cascade communication

The loss of cascade communication is detected by the dependent boilers. The individual boilers will show an error on the display when there is no communication anymore. The boiler will go to permanent heat demand operation and using the actual *Cascade_Emergency_Setpoint* (settable via installer menu). This parameter must be set per boiler as it cannot be transferred via Argus Link.

Managing boiler error

When the managing boiler is in error mode this boiler is not used anymore for the cascade system. However dependent on the error code the pumps connected by the managing boiler still can be controlled for the cascade system.

With following errors the cascade system can NOT operate anymore:
A04 - Gas valve relay error,
A05 - Safety relay error
E27 - Water pressure error,
E31 - Low water cutoff.

8.8 Cascade Parameter List

Specific Parameters		Level	(Default) Value		Range	
			ºC	ºF	ºC	ºF
Permit_Boiler_Emergency_Mode	[-]	1: User	yes		yes/no	
Cascade_Setpoint Cascade CH Setpoint	[ºC/ºF]	1: User	80	160	40..93	104..200
Boiler_Address	[-]	2: Installer	0		0..15	0..15
Cascade_Emergency_Setpoint	[ºC/ºF]	2: Installer	45	113	20..65	68..149
Delay_ Period_Start_Next_Dependent Start Delay Time	[min]	2: Installer	3		1..15	
Delay_ Period_Stop_Next_Dependent Stop Delay Time	[min]	2: Installer	3		1..15	
Hyst_Down_Start_Boiler Start Boiler Diff	[°C/°F]	2: Installer	5	9	0..20	0..36
Hyst_Up_Stop_Boiler Stop Boiler Diff	[°C/°F]	2: Installer	2	18	0..20	0..36
Max_Setp_Offset_Down Calculated setpoint Max offset down	[ºC/ºF]	2: Installer	4	36	0..20	0..36
Max_Setp_Offset_Up Calculated setpoint Max offset up	[ºC/ºF]	2: Installer	10	18	0..20	0..36
Start_Modulation_Delay_Factor	[-]	2: Installer	5 0=disabled		1..60	
Next_Boiler_Start_Rate	[%]	2: Installer	80		10..100	
Next_Boiler_Stop_Rate	[%]	2: Installer	30		10..100	
Boiler_Rotation_Interval	[days]	2: Installer	1		0..30 0=disabled	

DHW_Boiler_Assign	[-]	2: Installer	All		All,1..16	Not available
Calc_Setp_PID_P	[ºC/2]	3: Factory	20		0..255	
Calc_Setp_PID_I	[sec]	3: Factory	40		0..255	
PID_Slew_Rate	[-]	3: Factory	1 0=disabled		0..255	
System_Pump_Post_Pump_Time	[sec]	2: Installer	30 seconds		1…90	