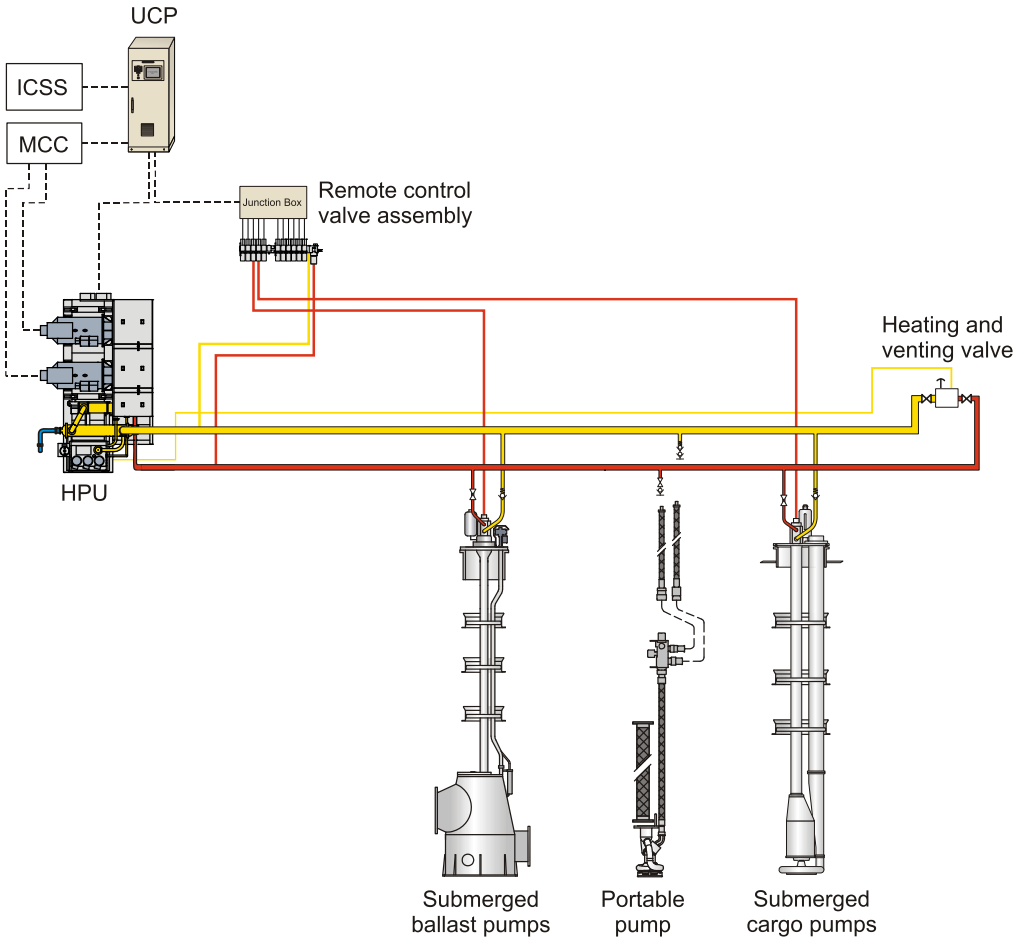
2 SYSTEM DESCRIPTION

2.1 Design / Hydraulic

The hydraulic pumping system is designed for a flexible and safe operation of all equipment installed. It consists of hydraulic motor driven submerged- and dry mounted pumps, portable pumps or other consumers, all connected via a hydraulic ring line system to a hydraulic power unit.

The submerged cargo pump is a single stage centrifugal pump with the impeller close to the tank top, giving a good pumping performance of all kinds of liquids. The hydraulic section is surrounded by a cofferdam that completely segregates the hydraulic oil from the cargo.



The hydraulic power unit consists of electric motor driven hydraulic power packs, where the hydraulic pumps are of axial piston type and swash plate design with variable displacement. The pump displacement is hydraulically controlled via the pressure regulator on each pump and by this system, the oil supply from the hydraulic pumps will always be the same as the oil consumption of the hydraulic motors. To control and limit the speed, a control valve is fitted for each hydraulic motor.

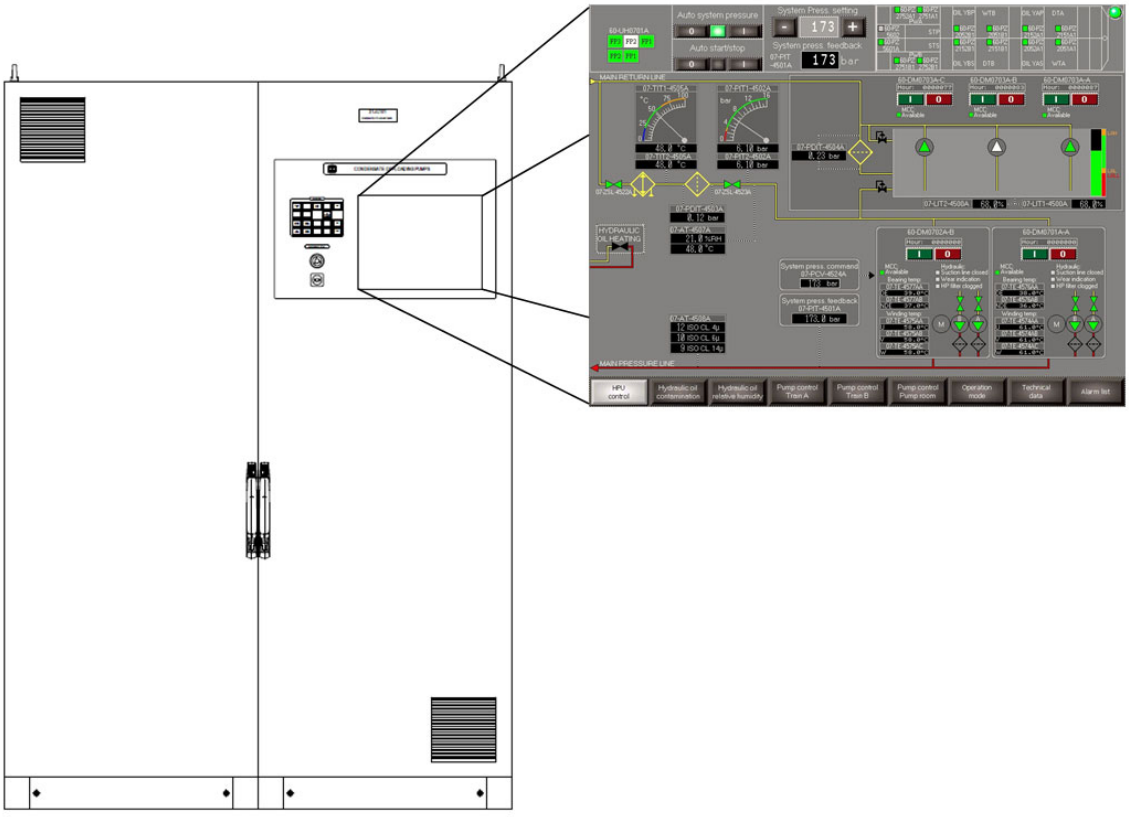
A full flow filter is installed in the main return line to keep the hydraulic oil clean. In addition, a kidney filter is installed for continuous fine filtration and water removal.
Hydraulic oil condition monitoring is installed (i.e. humidity and particle levels) for trending and alarm.

A full flow cooler is installed in the main return line and the cooling water supply is controlled from the UCP to regulate the hydraulic oil temperature.
An overpressure at approx. 3 bar is maintained in the system when not in operation, to prevent impurities from entering the hydraulic system.

The discharge from the pumps connected to the system may be remotely controlled from the UCP, from the ICSS via the UCP or locally at each pump via the control valve. The portable pump is controlled locally at the pump via the control valve.

2.2 Control system

The pumping system is controlled by a PLC installed inside the UCP, which is provided with a touch screen VDU as the operator's interface. The VDU is communicating with the PLC, both programmed by Framo, and provide the logic for safe operation of the system. Any modifications of these programs by others, without written consent from Framo, may affect the warranty of the system.



The pumping system can be fully monitored and operated from ICSS through communication link to, and controlled via, the UCP.

2.3 Control logic

2.3.1 Alarm system

When an alarm appears in the system, the text on the alarm list button and the alarm lamp in the right top window are flashing red, until the alarm is acknowledged.

The alarms and information are divided into three groups:

a) Alarm and stop of the hydraulic system or individual power pack.
The reset button must be operated to reset the alarm.

b) Alarm only (warning).
The alarm will be reset automatically when the alarm condition is no longer present.

c) Information.
Information other than related to a) and b).

Note the following:

1. Alarm- and shut down functions including time delays are provided in separate documentation.
2. Process value for all transmitters is continuously checked. If signal is outside 4-20 mA range a fault alarm (out of range alarm) will be released.
3. Duplicated transmitters are provided with deviation alarms, which will be triggered if signals from the two transmitters deviates more than approx. +/- 5%.
4. Hydraulic oil condition monitoring signals are valid only when the HPU is in operation. "Invalid" messages are sent to ICSS to indicate that the related process values shall be discarded.
5. "Link failure" alarm is displayed on UCP when connection to ICSS is interrupted.
6. Also see alarm description in section 2.3.2 and 2.3.11

A hardwired "panel fault" alarm signal for remote indication is provided and initiated by:

- PLC failure (Hydraulic system stop)
- Power failure (alarm)
- 24 VDC insulation failure (alarm)
- UCP cooling failure (alarm)

Other hardwired signals may be applicable, depending on the actual installation.

2.3.2 Power supply

The UCP is supplied via two separate AC feeders.

The two feeders provide redundant internal 24 VDC supply via individual converters with diode modules, provided with insulation monitoring and power status alarm. The power supply for each PLC is also redundant.

The feeders, converters and circuit breakers are monitored.

A failure on any of the feeders/ converters or a tripped circuit breaker, will generate a power failure alarm.

2.3.3 Feed pumps

The feed pumps can be started and stopped from the UCP, the ICSS or the MCC (the latter depending on the actual installation).

One of the feed pumps must always be running when the system is not in operation (standby mode) to maintain an overpressure in the system and if it stops, "Protection pressure low" alarm is initiated.

When initiating start of a power pack, the second of the three feed pumps will start automatically (operation mode) before the power pack is started, if this is not already done by the operator.
Only two feed pumps can run simultaneously and interlocks are made to prevent running of all three.
When the power packs are stopped, one of the feed pumps will be stopped automatically after 10 minutes, if this is not done by the operator.

Automatic stop order is first in - first out and automatic start order is first out - first in, i.e. if all three pumps are available, only two of the pumps will be used and the third will stay in back-up.
To engage the third pump in the sequence, the pump must be started manually as number two (operation mode) and the last one stopped automatically will then take its place as back-up.

Two feed pumps running are required for sufficient feed pressure at the suction side of the main hydraulic pumps during operation of the system. If one of the feed pumps stops and the power packs are still running, the third feed pump will start automatically. If the running signal for this pump is not obtained within 1 second, the hydraulic system will be stopped.

At hydraulic system stop, the first power pack and the feed pumps stops immediately.

2.3.4 Power packs

The power packs can be started and stopped from the UCP, the ICSS or the MCC (the latter depending on the actual installation).

Manual mode:
The power packs can be started in any sequence. Maximum 4 starts should be made during an hour. Maximum 2 consecutive starts can be made, then 15 minutes between each, all controlled by the PLC.

Auto mode (from UCP or ICSS):
The first power pack must be started manually by the operator and the PLC will then, based on the hydraulic oil flow requirement, automatically start required number of power packs in subsequent order. The requirement is calculated by summation of the maximum consumption of the consumers in operation. This figure is compared to the hydraulic oil flow capacity, which is calculated by summation of the maximum supply of the power packs in operation. Depending on which figure is the largest, the PLC will automatically start (requirement > capacity) or stop (requirement < capacity) a power pack. The stop order is first in - first out and when sufficient surplus capacity is detected, a power pack will be stopped after a time delay of 20 minutes.

Not open valve on the suction line for each power pack will stop or prevent start of the corresponding power pack only. Alarm light is provided for each power pack to indicate closed valve.

If more than one power pack is loaded and the hydraulic oil temperature increases to 65°C, the control system will automatically unload all power packs in sequence except for one. Time delay between unloading of each power pack is 1 minute. The running indication will start flashing for the unloaded power packs. The power packs will automatically be reloaded in sequence when the hydraulic oil temperature has decreased below 60°C. Time delay between loading of each power pack is 1 second.

2.3.5 System pressure

System pressure is set from the UCP or the ICSS as an input to the PLC. The PLC output is amplified by a proportional valve driver card controlling the proportional pressure control valve for the system pressure. The set pressure is automatically set to zero until one of the power packs has been loaded.

Manual mode:
The set pressure is adjusted by ± 1 bar or by numeric keypad input, and is automatically compared to the feedback pressure. If a pressure drop occur (e.g. if starting too many consumers compared to number of power packs running), the PLC is limiting the output to maximum 50 bar above feedback pressure to avoid pressure peaks when starting another power pack or stopping a consumer.
In case of feedback transmitter failure, this system pressure limitation can be manually overridden in maintenance mode.

Auto mode:
For pressure drop compensation, the PLC adds a margin to the highest pump pressure feedback and use the calculated figure as system pressure.

2.3.6 Pump pressure

Pump pressure for each pump is set from the UCP or the ICSS as input to the PLC. The PLC output is fed directly into the proportional valves for torque (speed) control, with pressure feedback to the PLC. The set pressure is adjusted by ± 1 bar or by numeric keypad input.

2.3.7 Heating mode

The heating and venting valve is operated from the UCP or the ICSS and interlocks are made to ensure that the valve is operated with only one power pack running and system pressure less than 100 bar. During heating, the system pressure can be increased, but is limited to 150 bar.

2.3.8 Manual stop

The following arrangement is provided by Framo in accordance with class requirements:

- Emergency stop push buttons located on deck are stopping the pumps only.
  Ballast pumps, however, are not affected and there may also be other consumers not being affected depending on the actual installation.
- Emergency stop push buttons located on the UCP and at central location outside the HPU room are stopping the hydraulic system. It is important that these are used in an emergency situation only and not for operational stop of the system.

2.3.9 Hydraulic system stop

If stop of the hydraulic system is initiated, the PLC will stop the power packs in sequence. The first power pack and the feed pumps stops immediately, and the delay between each of the following power packs is 1.0 second.

The following conditions will initiate stop of the hydraulic system as described above:

- Hydraulic oil level low-low. *
- Hydraulic feed pressure low-low. *
- Return line service valves not open. *
- Operation of emergency stop push buttons located on the UCP and at central location outside the HPU room.

* In case of sensor failure, the signal can be manually overridden in maintenance mode.

2.3.10 Maintenance mode

The mode is available on UCP HMI and is used when an instrument is faulty or needs cablibration. Trip functions has got redundant transmitters. Descrepancy alarms are provided at approx. +/- 5% signal deviation. Fault alarms (out of range) are provided for all analogue signals. When setting one of the redundant sensors to maintenance mode, its functionality (alarm or trip) is automatically transferred to the the other sensor according to table below.

Limit switches on the hydraulic oil return line valves are not redundant. Therefore, when setting these limit switches to maintenance mode is important to make sure that the corresponding valve is locked in fully open position! It is recommended to locate a warning sign locally at the valve until maintenance mode is deactivated.

Avoid running in maintenance mode for longer periode og time. Calibrate or replace the instruments as required as soon as possible.

Note that manual emergency stop push buttons cannot be be set to maintenance mode.

Tag no.	Service	PLC action:
119-PT-4202A	Feed pressure indication & alarm	Indication & alarm function transferred to 119-PT-4202B sensor.
119-PT-4202B	Feed pressure shut down	Shut down function transferred to 119-PT-4202A sensor.
119-LT-4601A	Aux unit hydr. oil level indication & alarm	Indication & alarm function transferred to119-LT-4601B sensor.
119-LT-4601B	Aux unit hydr. oil level shut down	Shut down function transferred to 119-LT-4601A sensor
119-TT-4204A	Hydraulic oil temperature indication & alarm	Indication & alarm function transferred to 119-TT-4204B sensor.
119-TT-4204B	Hydraulic oil temperature control	Control function transferred to 119-TT-4204A sensor.
119-ZSC-4222	Service valve position, HPU cooler inlet	Set corresponding valves status to «open». See note in section 5.3.1 below.
119-ZSC-4223	Service valve position, HPU filter outlet	Set corresponding valves status to «open». See note in section 5.3.1 below.
119-PT-4201	System pressure indication & alarm.	Pressure command limitation inhibited. See Control System Functional Description section 2.3.9.

2.3.11 Cooling water

The cooling water valve at the cooler inlet of the HPU is controlled by the PLC, based on the hydraulic oil temperature. The valve will receive an open command at hydraulic oil temperature above 50°C and a close command at 30°C. If no power packs are running, the valve will receive an open command at 55°C and a close command at 49°C. A mismatch between the PLC command- and the cooling water valve feedback signals, will release an alarm after 1 minute.

2.3.12 Pump priming system, casing level controlled (SB-pumps)

An air driven ejector is used for evacuation of air on the suction side of the pump and is automatically controlled by the PLC, based on the level of water inside the pump casing. Time delay for start and stop is 2 seconds and interlocks are made to prevent start of the ejector if none of the power packs are running and the pump command pressure is less than 30 bar.

2.3.13 Interface to ICSS

The pumping system can be operated from the UCP or the ICSS (through communication link). Selection of control station in command may be from the ICSS or the UCP, depending on the philosophy for the actual installation, and operation can only take place from the one in command with monitoring only at the other one.
The communication link is monitored by watchdog counter and in case of link failure, an alarm will be released on the UCP.

All alarms are transferred individually to ICSS from the UCP and for uniform time stamping of alarms, the PLC clock is synchronized with ICSS once every 24 hours.

Depending on the actual installation, the following may be provided for:

- PSD signals for stopping each pump.
- ESD or PSD signal for stopping the hydraulic system. *

* Stop of power packs as described in section 2.3.9.

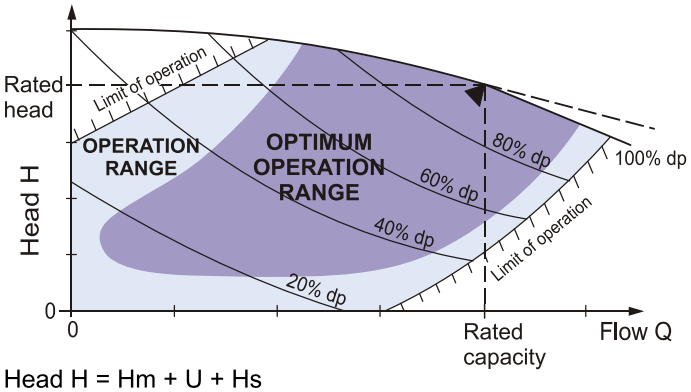
2.3.14 Pump start-up

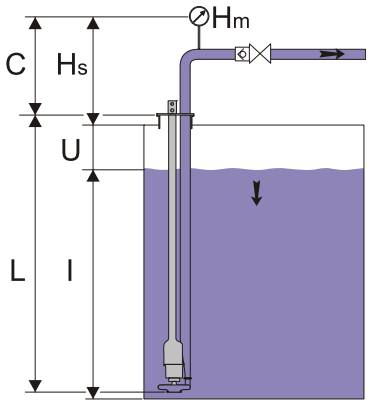
The pump pressure command is limited to 35 bar for 1 minute during start-up.
This normally applies to all submerged pumps except for ballast pumps, and is made to avoid cargo hammering.

2.3.15 Pump out of operation range

When operating a pump outside the operation range, an alarm will be released after 1 minute.
This normally applies to all submerged pumps except for ballast pumps, and is made to alert the operator for proper action to avoid that the pump is running at:

- High discharge head and low capacity (indicating closed or partly closed discharge valves).
- Low discharge head and high capacity (typically during transfer to other tanks).





Head H = Hm + U + Hs
~ Hm + L - I + C,

whereof: Hm = Discharge pressure
L = Pump length
I = Tank cargo innage
C = Constant (1 m)

The logic is dependent on the following signals available from ICSS:

- Discharge pressure (Hm in bar or Pa)
- Tank cargo innage (I in mm)

2.3.16 Stop of pump at low level

Pump speed to be reduced at cargo level of approximately 2 meter. Speed reduction at lower cargo levels to be verified during operation at site. Pump to be stopped at a level above stiffeners (if any), and minimum 1 meter. This to prevent loss of suction, which in long term may harm the pump.
As long as level of crude oil in cargo tanks is maintained higher than 2m above cargo tank bottom the cargo pumps, cavitation shall not be expected, and the cargo pumps can operate flawlessly at their nominal speed. At these conditions NPSHr is not considered to be a factor for cargo pumps operation as long as they are operated within operating range.