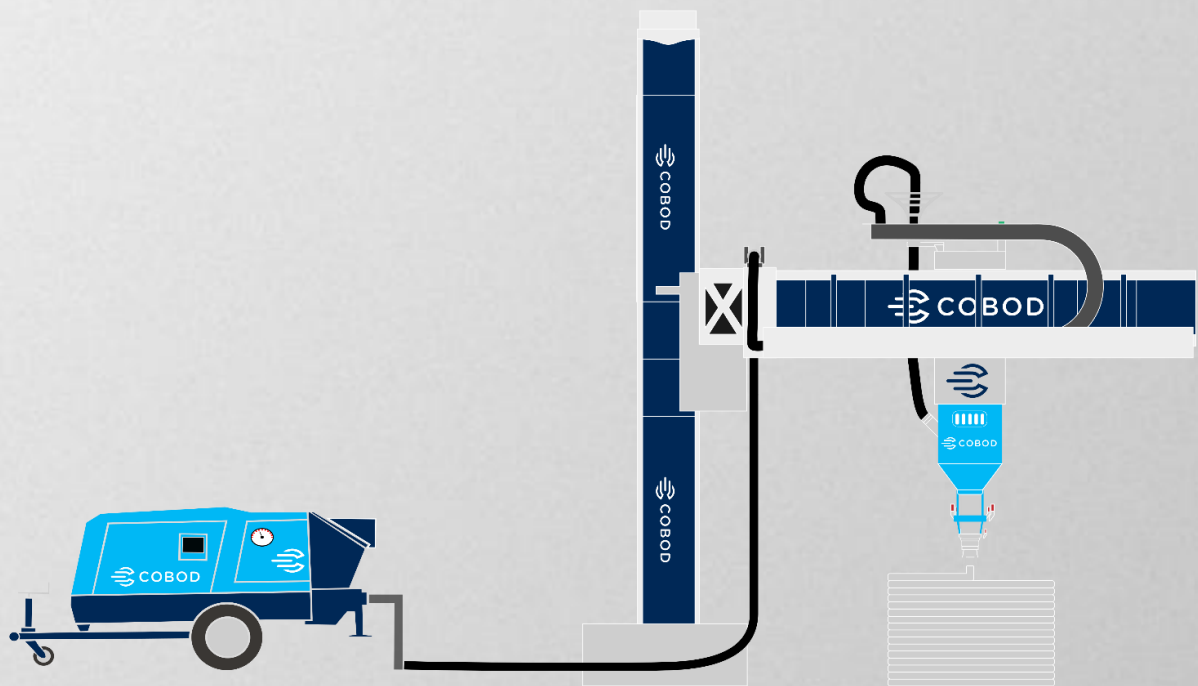


PISTON PUMP

STANDARD OPERATIONAL PROCEDURE



DOCUMENT VERSION

Date of issue: August 2022

This document is valid for the following versions of the product:

Item	Piston Pump	Operating System
Version	Electric	Local/Remote

Supplier information:

COBOD International A/S

Address:

Skudehavnsvej 17A
2150 Nordhavn
Denmark

Contact:

techsupport@cobod.com

Changelog:

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1.1 PURPOSE

This document aims to provide a details procedural description of the daily operation of the COBOD piston pump and concrete hose during 3D concrete printing.

1.2 SCOPE

This document discusses the daily operation of the concrete pumping system. The COBOD piston pump, Advanced hose management system (AHMS) and Pully hose management system (PHMS) are discussed.

This document does not aim to replace the function of the piston pump manual. If discrepancies are noted between this document and the manual, the manual should be followed. The piston pump manual is provided with this document.

This document should be used in parallel with the D.fab guide and SOP documents of the concrete batch plant and BOD 2 printer. Material-related problems are discussed here, but not addressed. Solutions for material-related issues can be found in the D.fab guide. Here only procedural solutions are discussed.

1.3 APPLICABILITY

This document provides all the literature of the daily operation of the concrete pumping system but is not intended to replace the training session. This document supports the Level 1 and 2 training provided by COBOD and should be used in parallel with the online and on-site training.

1.4 DEFINITIONS

Hydraulic pressure – The hydraulic pressure inside the pump.

Pumping pressure – The pressure inside the concrete hose. Typically, 3 times less (1/3) of the hydraulic pressure.

1.5 ROLES AND RESPONSIBILITIES

The concrete pump requires a full-time operator. This operator has the following responsibilities:

- ▶ Daily operation
- ▶ Maintenance and cleaning of the pumping equipment
- ▶ Health and safety around the pumping equipment
- ▶ Troubleshooting

1.6 TOOLS AND EQUIPMENT

The following tools are required:

- ▶ General concrete handling tools: buckets, scoopers, trowels, and spades.
- ▶ Waste management: big bags, waste concrete container/bin
- ▶ Grease gun
- ▶ Pressure Sprayer for form release oil
- ▶ High pressure water sprayer
- ▶ Bullet cleaning device
- ▶ Cleaning balls
- ▶ Big sledgehammer

1.7 ENVIRONMENTAL, HEALTH AND SAFETY (EHS)

Waste concrete and run-off water should be discarded correctly – according to local building regulations. All hazardous substances should be discarded in a safe manner.

Cement based products, like concrete or mortar, can cause serious skin problems such as dermatitis and burns. Therefore, workers should be protected against exposure to cement-based products.

Hearing and safety glasses protection is strongly recommended for pumping equipment operator. Gloves, trousers and long-sleeve shirts should be worn when handling concrete. A hardhat and safety shoes are recommended. A N95 mask is recommended for cement handling.

MANDATORY SIGNS	DESCRIPTION
	IT IS MANDATORY TO PROTECT THE EYES..
	IT IS MANDATORY TO PROTECT HEARING.
	IT IS MANDATORY TO PROTECT THE HANDS.
	IT IS MANDATORY TO PROTECT THE FEET.

Figure 1: Recommended personal protective equipment.

1.8 INDEPENDENT COMPONENTS

The concrete pumping system consists of the following components:

- ▶ COBOD piston pump
- ▶ Steel bend and 100 to 50 mm steel reducer pipe
- ▶ Hose
- ▶ Hose couplings (Victaulic or Camlock)
- ▶ Hose management system, either the Advanced hose management system (AHMS) and Pully hose management system (PHMS)

These components are combined to transport the concrete, as seen in Figure 2.

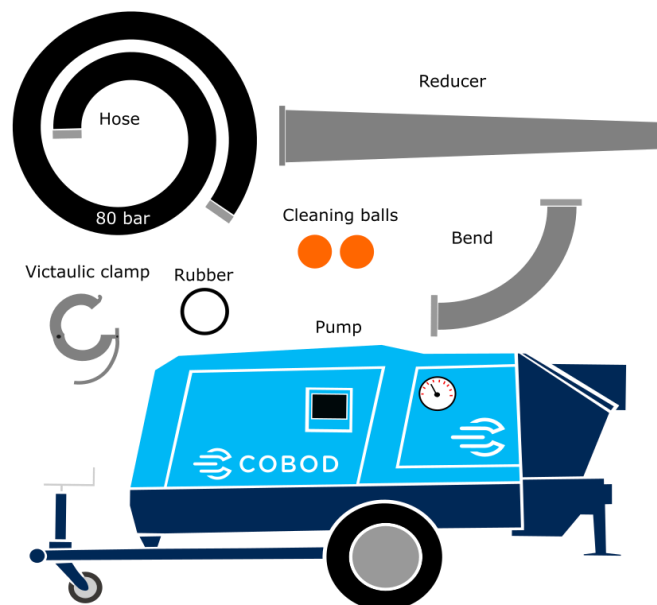


Figure 2: Independent component of concrete pumping system.

2. KEY PERFORMANCE INDICATORS

The following key performance indicators are relevant for the concrete pumping system:

1. *Pumpability* – The concrete mix can be transported from the mixer to extrusion with ease. This indicator is defined by the pumping pressure.
2. *Open time* – The concrete mix remains pumpable for an adequate amount of time after mixing, allowing for homogeneous placement. This indicator is defined by the pumping pressure.
3. *Cleaning time* – The time it takes to clean the concrete pumping system.

3. SYSTEM OVERVIEW

3.1 COBOD'S PISTON PUMP TECHNICAL SPECIFICATIONS

Table 1: Pump technical data.

Property	Unit	Value
Flow rate	m ³ /h	15
Maximum pressure on the concrete	Bar	80
Electric motor	kW	22
Number of revs	RMP	3000
Electrical tension	V	400 V – 50 Hz
Maximum pressure of hydraulic pumping circuit	Bar	180
Pressure of hydraulic switchover circuit	Bar	240
Pressure of hydraulic auxiliary circuit	Bar	180
Hydraulic circuit fluid change (ELF OLNA DS 46 - 75,0 l)		Every 1000 hours
Hopper capacity	l	200
Delivery distance (approximate)	M	150
Delivery height (approximate)	M	100
Outlet header	mm	100
Material delivery hose	mm	50, 75, 100
Pumpable particle size	mm	30
Acceptable environmental temperature	°C	-5 to 35
Guaranteed sound power level LWA	dB	104

The concrete pumping system consist of a pump and hose management system. Two hose management systems are available: 1) Pully hose management system (PHMS) (Figure 3) and 2) Advanced hose management system (AHMS) (Figure 4).

3.2 PULLY HOSE MANAGEMENT SYSTEM (PHMS)

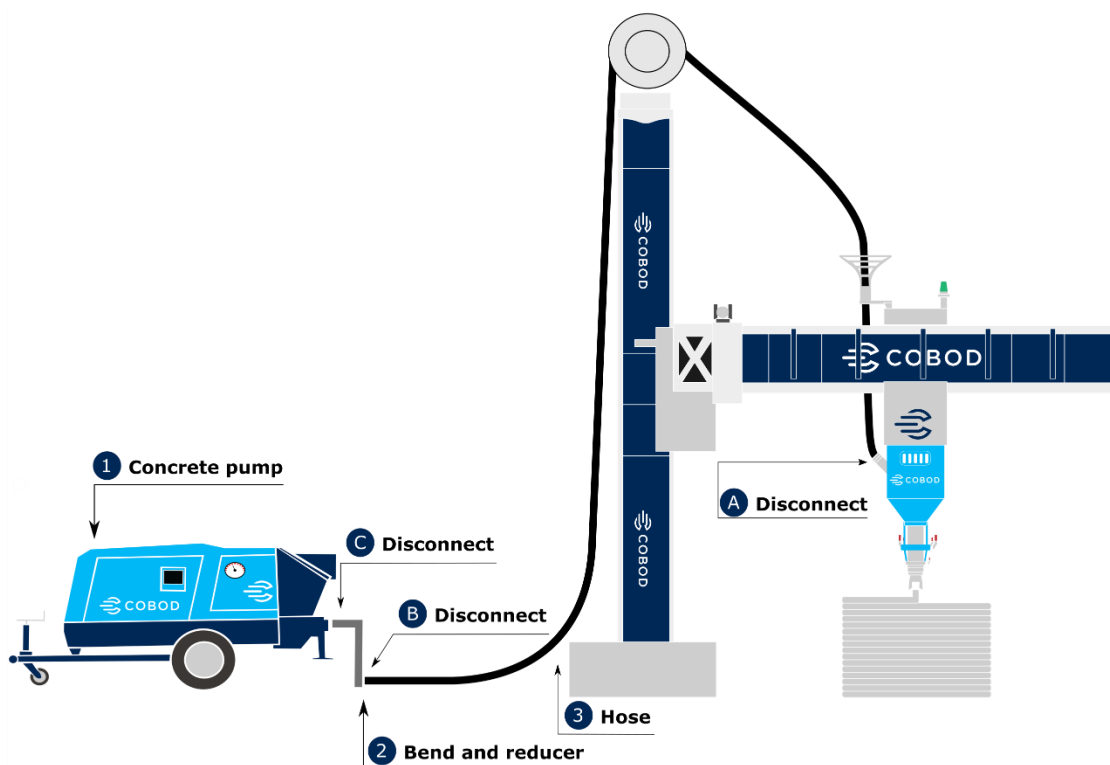


Figure 3: Concrete pumping system with pully hose management.

3.3 ADVANCED HOSE MANAGEMENT SYSTEM (AHMS)

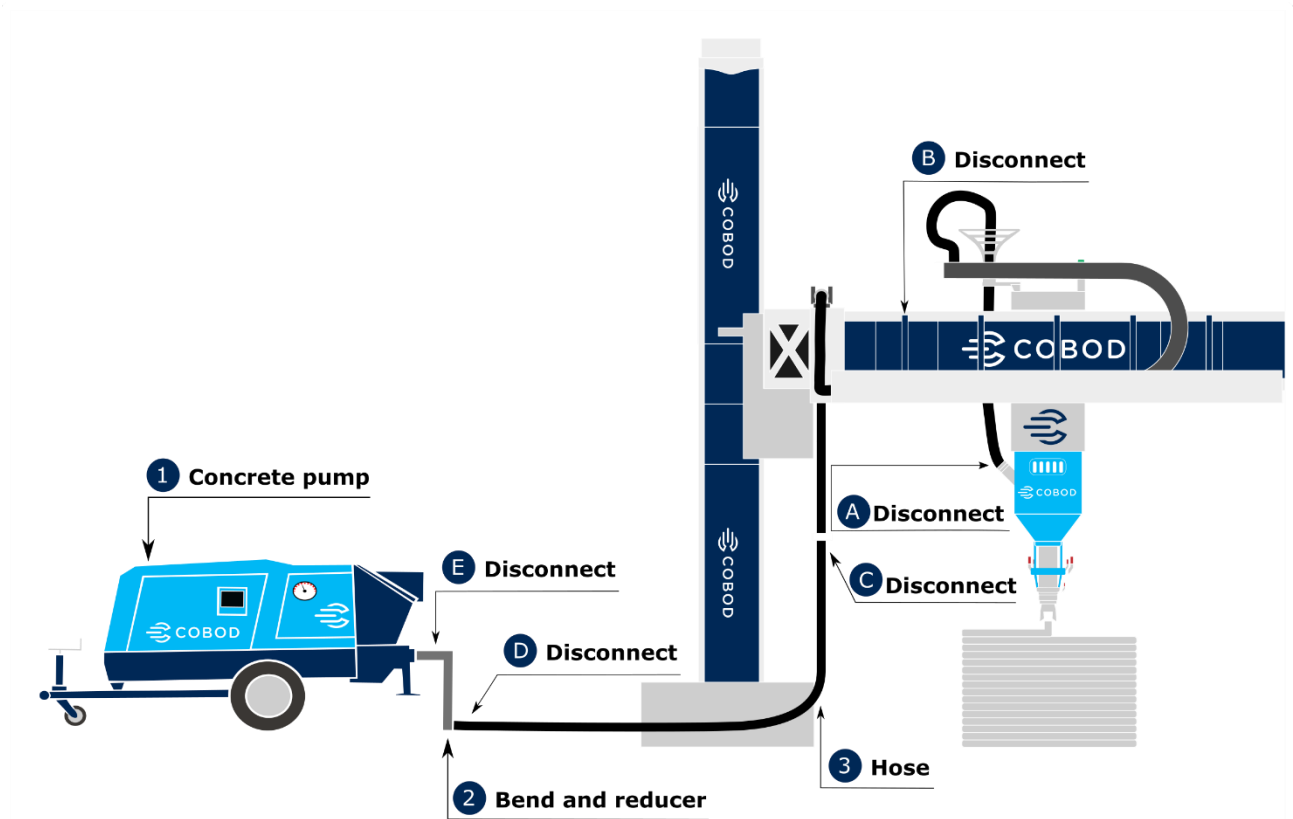


Figure 4: Concrete pumping system with advanced hose management.

4. PUMP CONTROLS

The following controls are used daily while operating the concrete pump (Figure 6):

- ▶ c1 - Machine switch-on/motor switch-off
- ▶ c3 - Motor start-up (sound of motor become audible)
- ▶ d1 - Pump start/stop (start/stop piston movement)
- ▶ d2 - Reverse pumping start/stop (reverse piston movement)
- ▶ e1 - Agitator start/stop
- ▶ e2 - Agitator reverse
- ▶ i1 - Machine control mode
 - Loc (local) – controlled by pump control panel
 - Rem (remote) – controlled by printer through soft-NA.
- ▶ f1 - Vibrating grid start/stop

If a password is required before start-up, us 4432.

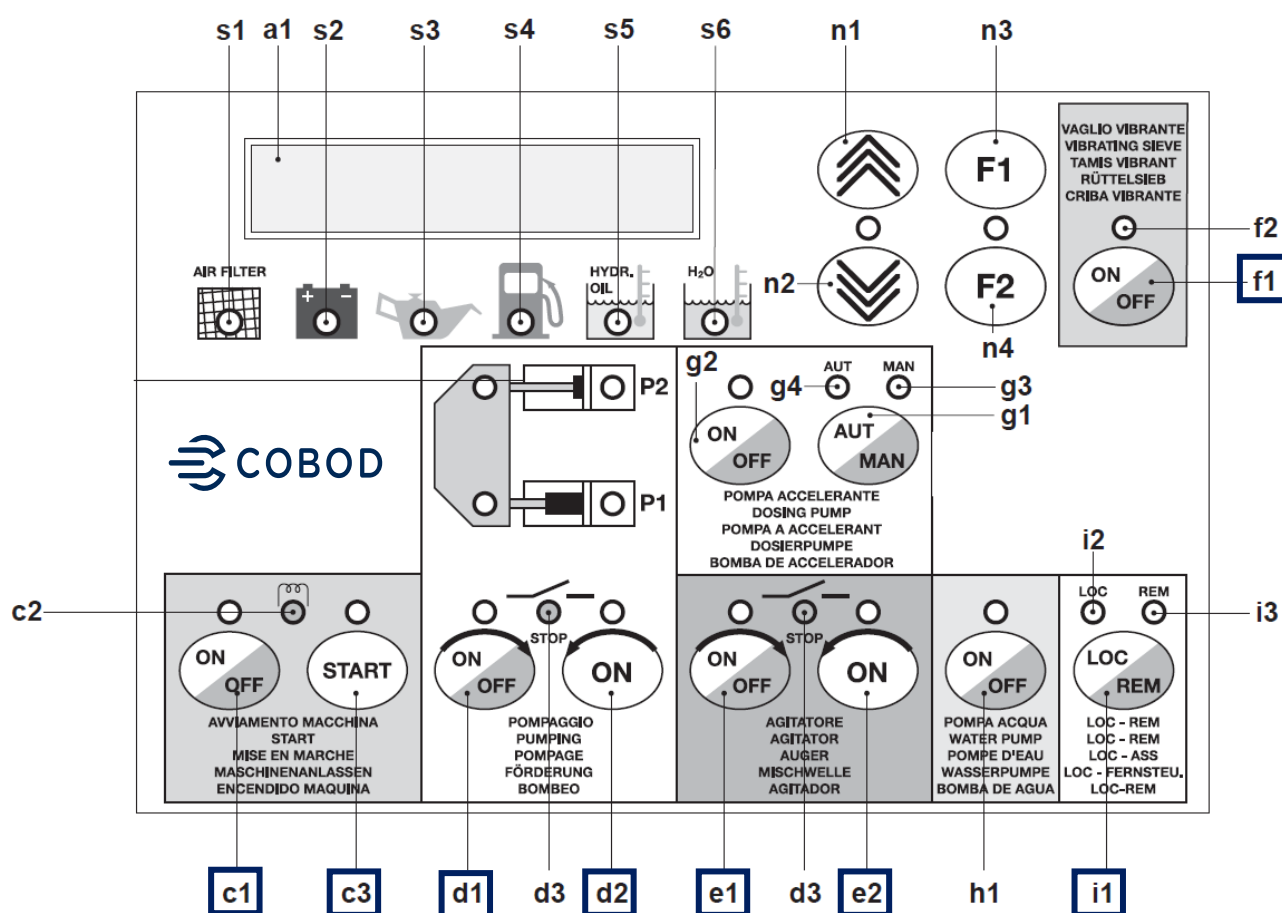


Figure 5: Concrete pump controls.

The following controls are used daily while operating the concrete pump (Figure 7):

- ▶ k1 – Hydraulic pressure exerted on pumping pistons
- ▶ k2 – Hydraulic pressure exerted on agitator
- ▶ r1 – Concrete flow rate (pumping speed) adjuster
- ▶ q1 – Emergency stop button

See the pump manual for more information.

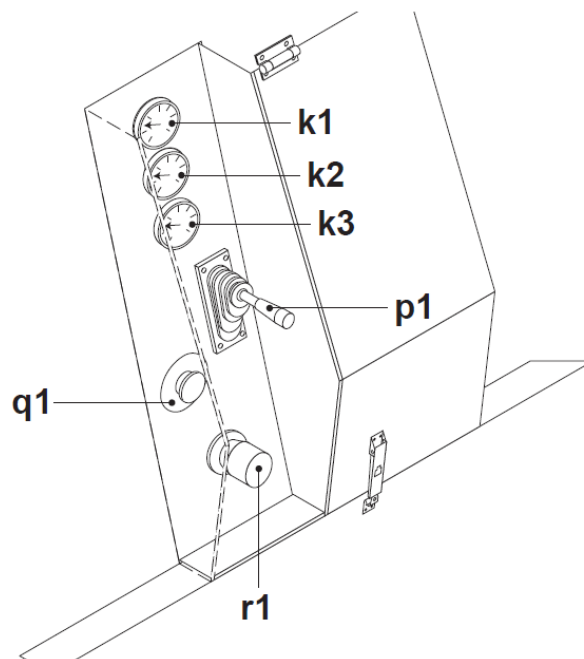


Figure 6: Concrete pump controls.

5. MAINTENANCE

Conducting regular maintenance on the concrete pump is essential. A set amount of time (weekly) or run-time hours (50 h) has been specified – whichever comes first. The maintenance schedule in Table 3 is recommended:

Table 2: Maintenance schedule.

	Installation	Daily	Weekly/ 50 h	Monthly/ 250 h	500 hours	1000 hours
Check all emergency stop functions	x	x				
Check oil level on gearbox	x	x				
Check lubrication water	x	x				
Grease all moving parts	x	x				
Check the tightness of the pumping sensors, the safety and the hydraulic oil temperature sensor			x			
Check the tightness of the nuts and wheels			x			
Radiator check				x		
Check the material delivery header for wear				x		
Check the cooling circuit hoses for wear				x		
Clean s-valve flange					x	
Replace outside oil filter					x	
Replace inside oil filter						x
Change the fluid in the hydraulic circuit						x
Change the filter in the oil tank of the hydraulic circuit.						x
Check all the hoses and the couplings.						x
Inspect the electrical system.						x

5.1 DAILY

- ▶ Test emergency stops
- ▶ Grease all lubricating nipples (figure 7 a). There are also nipples on the other side of the pump, and on the inside above the s-valve hydraulic pistons.
- ▶ Check lubrication water and refill if necessary (figure 7 b). Antifreeze can be added if needed.
- ▶ Check hydraulic oil levels and refill if necessary (figure 7 c). The oil type is specified in the manual.

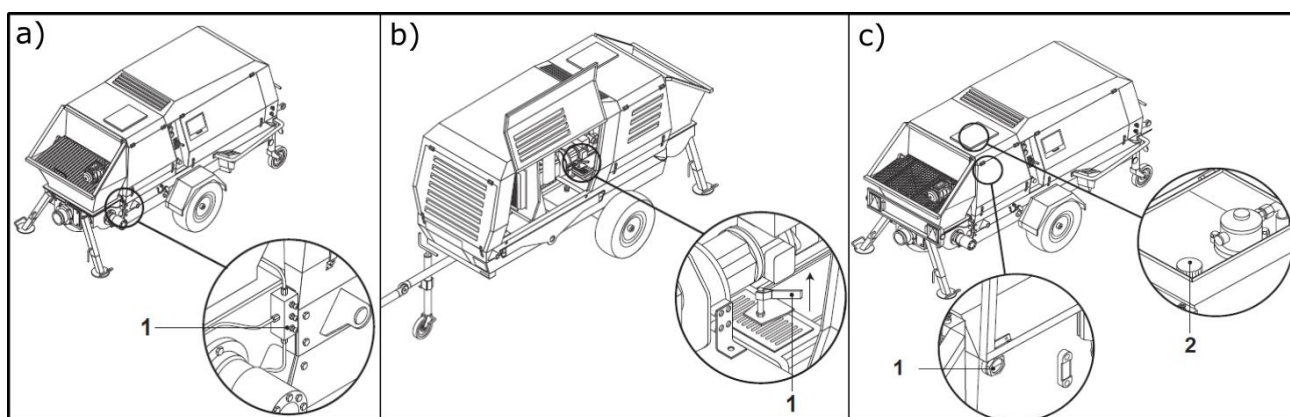


Figure 7: Daily maintenance.

5.2 MONTHLY

Remove the s-valve flange to clean. During pumping cement paste enters between moving parts of the s-valve. When the cement paste hardens the s-valve is prevented from switching between the pistons. The issue can be addressed by removing flange and removing the paste buildup inside the flange groove (Figure 9). Remember to grease the flange before re-assembly.

Occasionally, it is also necessary to remove the s-valve completely to remove the concrete buildup inside the s-valve bend.

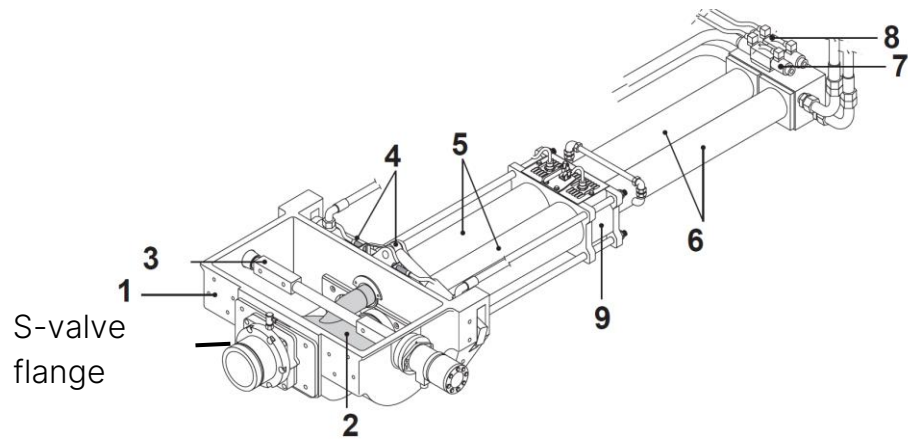


Figure 8: S-valve and pump pistons.

6. DAILY OPERATING PROCEDURE

This section is structured in the following chronological order: a) startup, b) operation, c) cleaning and d) shutdown.

6.1 SYSTEM START-UP

1. Ensure the pump hopper is clean
2. Spray form oil on inside of hopper
3. Grease pump
4. Check oil levels
5. Check water level inside pump
6. Close grid (the pump will not start if the grid is open or the sensor is disconnected)
7. Pump motor ON, pump motor start-up, pumping ON
8. Ensure S-valve is switching between pistons
9. Agitator ON
10. Vibrator ON
11. Test emergency stop, release emergency switch
12. Move pump in place under batch plant
13. Connect printer to pump and test connection during dry run
14. Ensure hose is empty (no water)
15. Ensure steel reducers and bend is debris-free
16. Connect pump to bend, reducer and hose. Remember, coupling pins and whip-check cable
17. Connect outlet of hose to printhead
18. Ensure stiffener is entering printhead by manually activating dosage system pump
19. Fill containers with 300 l of clean water

6.2 OPERATION

1. Close pump hopper gate
2. Pump motor on, start motor
3. Fill pump hopper with slurry
4. Agitator on
5. Piston pumping on
6. Select the speed to have pumping for longer periods than idling. A value between 1 and 2 is typical.
7. Stop pumping when agitator shaft becomes visible. Do not pump empty
8. Open bottom hopper gate. Discard remainder of slurry. Rinse hopper. Close hopper gate
9. Discharge concrete mix into pump hopper (figure 10 a)

10. Communicate with printer operator
11. Switch to remote pumping
12. Ensure batch plant operator keeps concrete level above agitator shaft
13. Extrude material through nozzle and monitor consistency
14. Activate stiffener pump. Start with 300 ml/h
15. Extrude material until desired consistency is achieved
16. Start printing
17. Continuously monitor pumping pressure
18. Stop the pump immediately if the pressure exceeds 120 bar
19. Normal operation pressure is below 80 bar

6.3 CLEANING

1. Pump until concrete level reach top of agitator shaft
2. Pump reverse for two switches of s-valve, this relieves the pressure inside the hose
3. Stop pumping
4. Open hopper gate and remove excess concrete from pump hopper
5. Use pressure washer to remove 80% of concrete build-up. Only spend 5-10 min on this. The hose is priority.
6. Close gate
7. Fill pump hopper with clean water from containers filled during start-up. Also add water continuously
8. Disconnect hose from steel reducer
9. Pump until only water is discharged from reducer
10. Insert two cleaning balls
11. Reconnect hose to reducer. The balls separate the water from mixing with the concrete, this separation is important to prevent segregation blockages (figure 9 b)
12. Disconnect hose outlet from printhead and place in waste container (bigbag)
13. Start pumping until balls exit hose
14. Stop forward pumping. Give two pumps in reverse
15. Open coupling between reducer and hose to insert cleaning balls
16. Run cleaning balls again
17. Stop when pump hopper is empty
18. Disconnect all hose couplings
19. Move pump out from under batch plant
20. Open gate to remove water
21. Use pressure washer to clean pump hopper and grid
22. Clean s-valve by inserting pressure washer into pump discharge hole (pump should be switched off at this stage)
23. Reverse pump to ensure pistons are empty
24. Ensure s-valve and flange is clean

- 25. Clean reducer and bend
- 26. Remove any water from hose

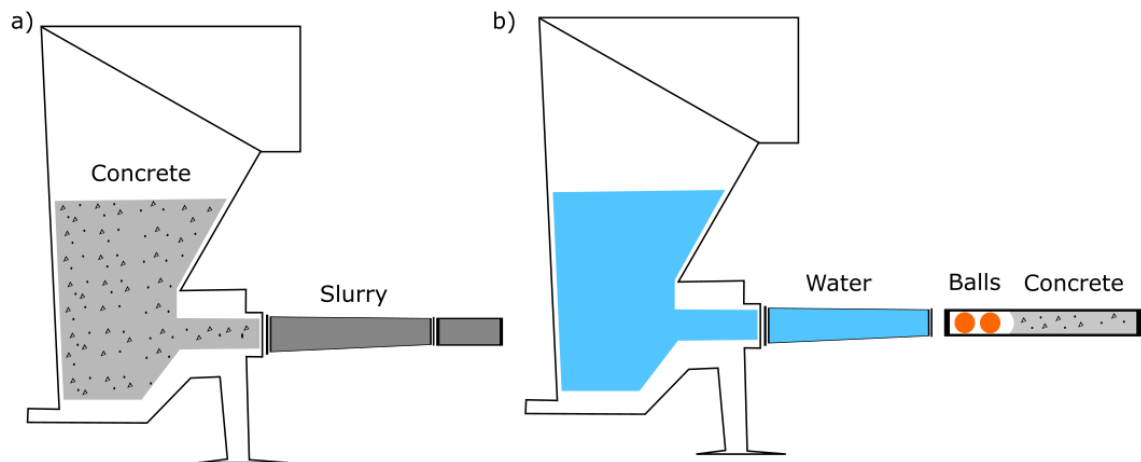


Figure 9: a) Start-up and b) cleaning procedure.

6.4 SHUT-DOWN

- ▶ Let pump idle for 5 min before shut-down
- ▶ Lubricate the hopper walls and s-valve with form oil

7. TROUBLESHOOTING

7.1 PUMP OPERATION

Table 3: Pump operation troubleshooting.

Problems	Causes	Solutions
Piston pressure (k1) rise above 200 bar and concrete extrusion stops	1. Blockage in the hose (low k1 pumping pressure on reverse pump) 2. S-valve not switching (high k1 pressure on reverse pumping)	1. Follow procedure in hose troubleshooting section 2. Remove and clean s-valve flange as seen in maintenance section
Control board does not switch on	1. No electric power supply 2. Circuit board breakdown	1. Check main fuse, the direction switch on power box should be on 1, ON/OFF switch on power box. 2. Contact COBOD at techsupport@cobod.com
Pump motor does not start	1. Mixer grid open 2. Mixer grid connection	1. Close the mixer grid. 2. Check connection of mixer grid.
Pump stops	1. Mixer grid open 2. Insufficient hydraulic oil level. 3. Hydraulic oil temperature too high 4. Breakdown of one of the control electrovalves of the S-valve and/or the pumping pistons control.	1. Close the mixer grid. 2. Top-up the hydraulic oil tank. 3. Check the hydraulic oil level and clean the hydraulic oil radiator, wait for the oil to cool with diesel engine running. 4. Check the electric wiring of the position
Mixer does not turn	1. Function not active on the control panel. 2. Hopper grid open. 3. Presence of a foreign body that blocks the mixer. Check the pressure on the manometer (k2).	1. Press the button (e1) on the control panel. 2. Close the hopper grid. 3. Remove the foreign body. 4. Check mixer electrovalve wiring and relative relay (see wiring diagram in manual).

	4. Breakdown of the mixer control electrovalve. Check switch-on of the relative LED.	
Worsening of machine performance.	1. Wear plate and/or disc worn 2. Pumping pistons worn.	1. Adjust the S-valve (See manual) 2. Replace the pumping pistons
Dirty water in the pistons cooling tank	Pumping pistons worn	Replace the pumping pistons
Vibrating sieve does not work	1. Function not active on the control panel. 2. No electric power supply.	1. Press the button (f1) on the control panel. 2. Check the wiring, the insertion of the plug into the relevant socket and functioning of the relative relay (see wiring diagram in manual).
Pressure drop on the manometer (k1) or repeated blocking of the s-valve	1. There is play between the S-valve and the wear plate	Adjust the S-valve (See manual)

7.2 HOSE BLOCKAGE

The following procedural measures prevents hose blockages:

1. Ensure there is no water inside the hose at startup. The water dilutes the slurry and causes blockages.
2. Slurry should be of mayonnaise consistency. The quantity should be at least 2 l per 1 m of hose plus an additional 20 l (40 m hose = 100 l slurry).
3. The aggregates should not contain any stones larger than 16 mm.
4. Pump the cleaning balls twice to ensure the hose is clean.
5. Clean to prevent hardened concrete from entering the system.

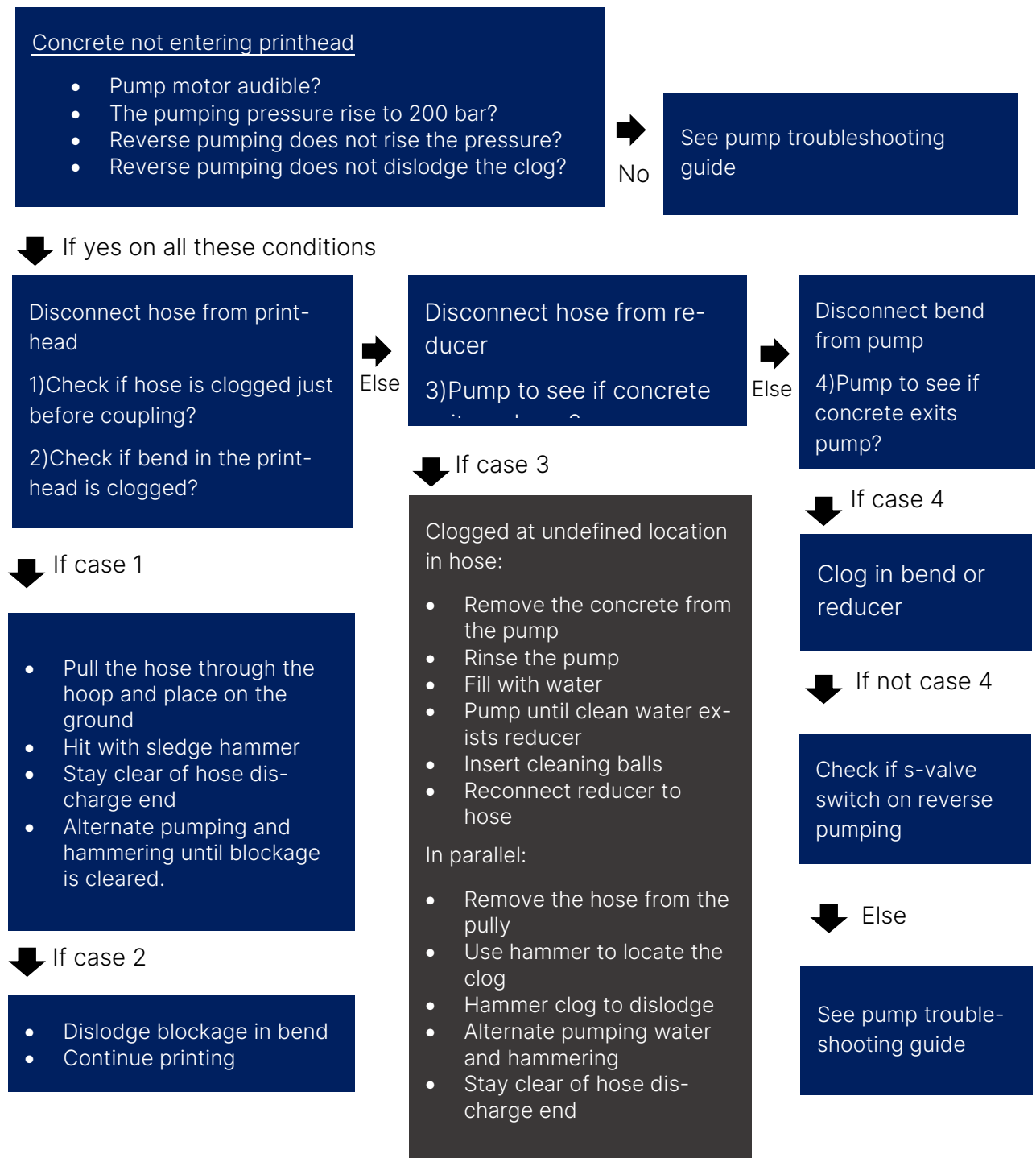
Blockages in the hose occur due to one of the following reasons, in descending order of likelihood:

Table 4: Reasons for hose blockages.

Why	Solution
Area reduction	1. Prevent kinks in hose. 2. Use Victaulic connectors.
Segregation of cement paste and aggregates	1. Slurry consistency, water in the hose 2. Mix design, see D.fab guide
Hardened concrete or aggregates blocking the flow	Sieve aggregates and clean better.

8. UNBLOCKING PROCEDURE

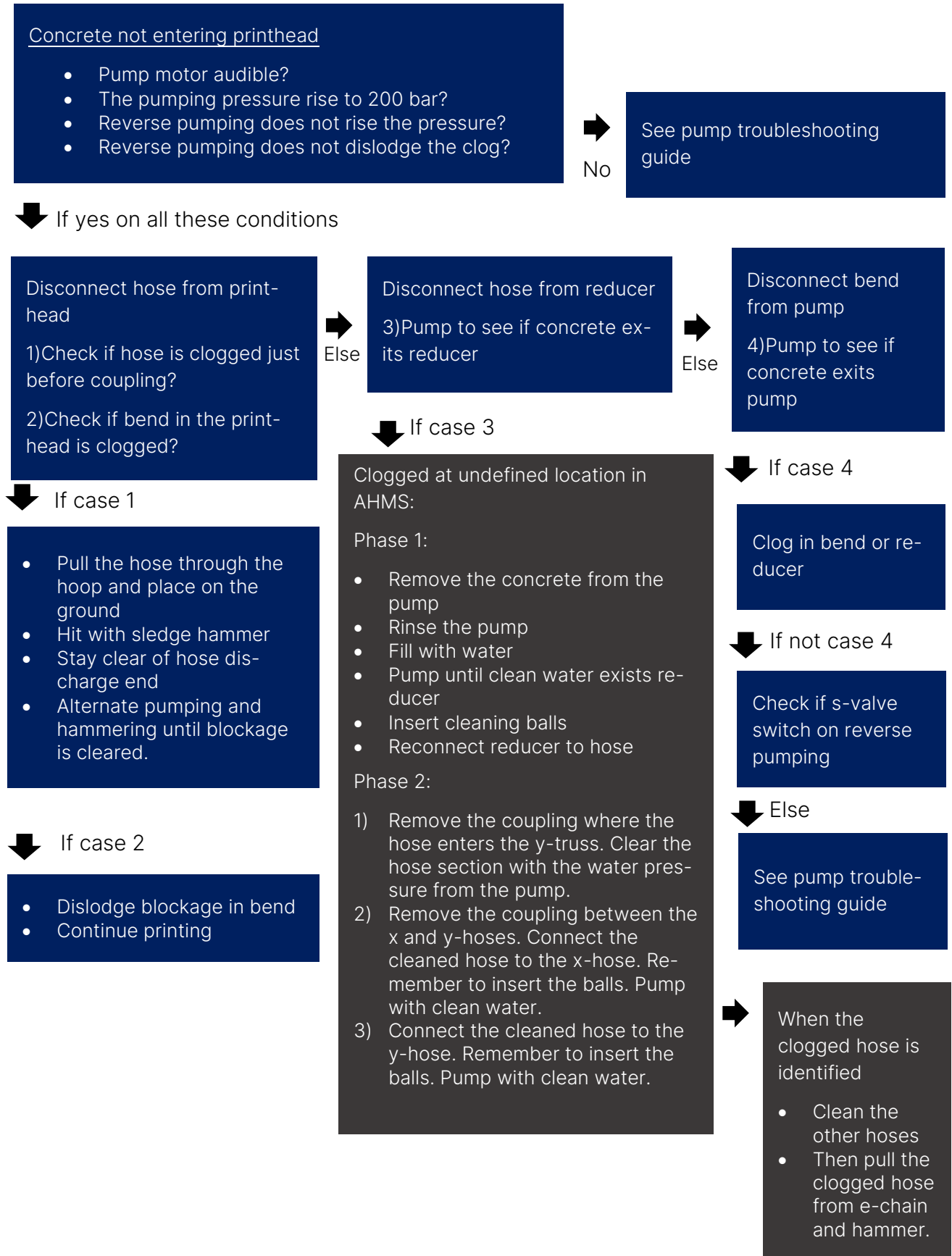
PULLY HOSE MANAGEMENT SYSTEM UNBLOCKING PROCEDURE: The following procedure is recommended for unblocking the pully hose management system.



The printing process should be restarted if the blockage occurs in an undefined location in the hose. For all the other cases, printing can continue if the blockage is addressed quickly.

ADVANCED HOSE MANAGEMENT SYSTEM UNBLOCKING PROCEDURE

The following procedure is recommended for unblocking the advanced hose management system:



The printing process should be restarted if the blockage occurs in an undefined location in the hose. For all the other cases, printing can continue if the blockage is addressed quickly.

8.1 NOZZLE BLOCKAGES

In some case material stops flowing from the nozzle, even at excessive extrusion values. This is because the nozzle is blocked. In the short-term, this can be addressed by removing the nozzle, clearing the blockage, and continuing the print. The long-term solution is discussed in Table 6.

Table 5: Troubleshooting nozzle blockages.

Why	Solution
Fibre caused blockage	Reduce fibre dosage
Flow disruption inside the nozzle	If the nozzle is not flush with the connector piece. Tighten the nozzle or seal the grove with silicon
Material is too stiff at nozzle	Reduce stiffener dosage Increase open time, see D.fab guide
Large aggregate in the nozzle	Remove. Sieve aggregates before use. Clean better.

9. RELATED DOCUMENTS AND TOOLS

The following additional documents are relevant, and are attached to this document:

- ▶ Pump manual
- ▶ COBOD Concrete Pumping checklist