COUPP-0.1 FMEA

Manual valves

Type	Tag	Service	Description	Failure or Error Mode	Hazard or Effect	Hazard Class	Remarks
MV	003	Mineral oil	Expansion regulation needle valve	Fails open	Expansion rate cannot be modified	Safe	Rate of expansion cannot be modified.
MV	003	Mineral oil	Expansion regulation needle valve	Fails closed	Chamber cannot be expanded	Safe	Expansion of chamber by normal means is unachievable.
MV	004	Mineral oil	Fill line high-pressure valve	Fails open	High- and low-pressure systems cannot be refilled independently	Safe	High-pressure region extends to MV-016. High- and low-pressure lines cannot be refilled independently.
MV	004	Mineral oil	Fill line high-pressure valve	Fails closed	High-pressure line cannot be refilled	Safe	High-pressure system cannot be directly refilled. No mineral oil will leak out. System could be refilled by filling low-pressure line, bleeding out old fluid / air, and running pump.
MV	005	Mineral oil	Mineral oil fill port	Fails open	Mineral oil reservoir cannot be removed	Safe	MV-005 is closed off from the operational pressure system by MV-004, MV-006, and MV-016. No risk of forceful fluid expulsion. If the reservoir remains attached, MV-017 can act in the same capacity.
MV	005	Mineral oil	Mineral oil fill port	Fails closed	System cannot be filled or degassed	Safe	If the system is already filled and degassed, operation can continue as normal until the next fill becomes necessary.
MV	006	Mineral oil	Fill line low-pressure valve	Fails open	High- and low-pressure systems cannot be refilled independently	Safe	Low-pressure region extends to MV-016. High- and low-pressure lines cannot be refilled independently.
MV	006	Mineral oil	Fill line low-pressure valve	Fails closed	Low-pressure line cannot be refilled	Safe	Low-pressure lines cannot be directly refilled. No mineral oil will leak out. System can be refilled by filling high-pressure line, bleeding out old fluid / air, and running pump.
MV	010	C3F8	C3F8 vacuum pump-down port	Fails open	Mineral oil leaks out		System cannot be pressurized. If system is pressurized above atmospheric upon failure, mineral oil will be forcefully expelled. If pressurization is attempted after failure, it will be unsuccessful and expel more mineral oil.
MV	010	C3F8	C3F8 vacuum pump-down port	Fails closed	C3F8 cannot be degassed	Safe	Vacuum pump cannot be connected. System cannot be degassed.
MV	011	C3F8	Bubble chamber fill valve	Fails open	C3F8 leaks or boils out		Bubble chamber cannot be pressurized. If system is pressurized above atmospheric upon failure, C3F8 will be forcefully expelled. If pressurization is attempted after failure, it will be unsuccessful and expel more C3F8.
MV	011	C3F8	Bubble chamber fill valve	Fails closed	Bubble chamber cannot be filled directly	Safe	Bubble chamber cannot be filled.
MV	012	C3F8	Bubble chamber bleed valve	Fails open	C3F8 leaks or boils out, system cannot be bled		Bubble chamber cannot be pressurized. If system is pressurized above atmospheric upon failure, C3F8 will be forcefully expelled. If pressurization is attempted after failure, it will not be successful and will expel more C3F8.
MV	012	C3F8	Bubble chamber bleed valve	Fails closed	System cannot be bled	Safe	Air bubbles may collect near top of pressure chamber.
MV	016	Mineral oil	Fill line isolation valve	Fails open	Small quantity of mineral oil leaks out	Safe	Mineral oil between MV-004, MV-006 and fill point may leak out of system.
MV	016	Mineral oil	Fill line isolation valve	Fails closed	Mineral oil system cannot be refilled	Safe	MV-016 is isolated from the operational pressure system.
MV	017	Mineral oil	Reservoir drain valve	Fails open	Mineral oil may spill if reservoir is removed	Safe	MV-017 and MV-005 are redundant when the reservoir is connected to the filled hydraulic system. If the reservoir is to be removed from the system, the oil in the line between the reservoir and MV-017 may leak out.
MV	017	Mineral oil	Reservoir drain valve	Fails closed	System cannot be filled or degassed	Safe	If the system is already filled and degassed, operation can continue as normal until the next fill becomes necessary.
MV	018	Mineral oil	Reservoir fill valve	Fails open	System cannot be filled or degassed	Safe	The mineral oil reservoir can no longer be sealed in this condition, and any oil that enters the reservoir will immediately flow back into the source bottle.
MV	018	Mineral oil	Reservoir fill valve	Fails closed	System cannot be filled by normal procedure	Safe	The hydraulic system can be filled by opening the degassing canister and pouring fluid directly in. However, this is inconvenient and may lead to oil contamination.
MV	019	Mineral oil	Reservoir vacuum pump-down port	Fails open	Vacuum pump must be run constantly during filling.	Safe	Since the reservoir is the only point in the hydraulic system at which vacuum is applied, the pump can be left on in lieu of sealing the system.
MV	019	Mineral oil	Reservoir vacuum pump-down port	Fails closed	System cannot be filled or degassed	Safe	Vacuum is necessary to the filling of the hydraulic system.
MV	020	Water	Water bath supply valve	Fails open	Water pump cannot be switched off or removed while system is operational	Safe	The pump should not be switched off or removed anyway.
MV	020	Water	Water bath supply valve	Fails closed	Water bath will not circulate; temperature control will be lost	Safe	Could result in bubble suppression or false data.

Pressure regulators

PR	001	air	Accumulator pressurizing regulator	Incorrect pressure – high	Low-pressure accumulator pressure too low	Safe	Low-pressure accumulator may drop to atmospheric pressure. Expansion will be faster and less controlled.
PR	001	air	Accumulator pressurizing regulator	Incorrect pressure – low	Low-pressure accumulator pressure too high	Safe	Regulator can supply up to 100psi. Accumulator is rated for 3500psi. No risk of failure. Bubble chamber expansion would be slow and limited to regulator pressure.

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Type	Tag	Service	Description	Failure or Error Mode	Hazard or Effect	Hazard Class	Remarks
PR	002	air	Pressure gauge/regulator on building air line	Incorrect reading - low	Supplied air pressure too low	Safe	May be impossible to pressurize bubble chamber to desired level.
PR	002	air	Pressure gauge/regulator on building air line	Incorrect reading - high	Supplied air pressure too high	Safe	Pressure regulator will supply appropriate pressure for system.
Pressure transmitters							
PT	001	Mineral oil	Steady-state pressure vessel transducer	Incorrect pressure – high	System pressure too low	Safe	Chamber could fail to compress to desired pressure. C3F8 could boil. Could generate false bubble sightings.
PT	001	Mineral oil	Steady-state pressure vessel transducer	Incorrect pressure – low	System pressure too high	Safe	Chamber could be overcompressed, affecting operation. Quartz rated for 1160psi, pump can provide 150psi – no safety risk.
PT	002	Mineral oil	High-pressure manifold transducer	Incorrect pressure – high	High-pressure line pressure too low	Safe	Chamber compression could be impossible. C3F8 could boil. Could generate false bubble sightings.
PT	002	Mineral oil	High-pressure manifold transducer	Incorrect pressure – low	High-pressure line pressure too high	Safe	Chamber could be overcompressed, affecting operation. Quartz rated for 1160psi, pump can provide 150psi – no safety risk.
PT	003	Mineral oil	Low-pressure manifold transducer	Incorrect pressure – high	Low-pressure line pressure too low	Safe	Low-pressure accumulator may drop to atmospheric pressure. Expansion will be faster and less controlled.
PT	003	Mineral oil	Low-pressure manifold transducer	Incorrect pressure – low	Low-pressure line pressure too high	Safe	Regulator can supply up to 100psi. Accumulator is rated for 3500psi. Bubble chamber expansion would be slow and limited to regulator pressure.
PT	004	Mineral oil	Bubble chamber pressure transducer	Incorrect reading – high	Chamber pressure too low	Safe	C3F8 could boil. Could generate false bubble sightings.
PT	004	Mineral oil	Bubble chamber pressure transducer	Incorrect reading – low	Chamber pressure too high	Safe	Chamber could be overcompressed, affecting operation. Quartz rated for 1160psi, pump can provide 150psi.
PT	006	Mineral oil	Transient pressure vessel transducer	Incorrect pressure – high	System pressure too low	Safe	Chamber compression could be impossible. C3F8 could boil. Could generate false bubble sightings. Failure to raise pressure to appropriate level should be detected by steady-state transducer.
PT	006	Mineral oil	Transient pressure vessel transducer	Incorrect pressure – low	System pressure too high	Safe	Chamber could be overcompressed, affecting operation. Quartz rated for 1160psi, pump can provide 150psi – no safety risk. Failure to raise pressure to appropriate level should be detected by steady-state transducer.
Pumps							
PU	001	Mineral oil	Accumulator rebalancing pump	Fails on	High-pressure accumulator pressurized above design	Safe	Accumulator is rated for 3500psi, pump is rated for 150 psi. Pump will fail before accumulator. After pump fails, chamber cannot be compressed after expansion.
PU	001	Mineral oil	Accumulator rebalancing pump	Fails off or cannot provide pressure	High-pressure accumulator cannot be compressed	Safe	Compression may not be possible after expansion. C3F8 could boil. Could generate false bubble sightings.
PU	001	Mineral oil	Accumulator rebalancing pump	Slow leak	Accumulators gradually equalize in pressure	Safe	Running pump will repressurize high-pressure accumulator. Fast compress could fail if pressure is not monitored and adjusted as necessary.
Solenoid valves							
EV	001	Mineral oil	Fast compress valve	Fails open	Chamber cannot be expanded	Safe	Pressure chamber is permanently connected to high-pressure accumulator. After expansion, pump compresses against pressure chamber and entire high-pressure system rather than accumulator alone.
EV	001	Mineral oil	Fast compress valve	Fails closed	Fast compress capability lost	Safe	Chamber can still be compressed with slow-compress valve. System will be safe but nonfunctional.
EV	002	Mineral oil	Slow compress valve	Fails open	Chamber cannot be expanded	Safe	Pressure chamber is permanently connected to high-pressure accumulator. After expansion, pump compresses against pressure chamber and entire high-pressure system rather than accumulator alone.
EV	002	Mineral oil	Slow compress valve	Fails closed	Slow compress capability lost	Safe	Chamber can still be compressed with fast-compress valve.
EV	003	Mineral oil	Expansion valve	Fails open	Chamber cannot be compressed	Safe	Chamber compression could be impossible. C3F8 in bubble chamber evaporates. Could generate false bubble sightings.
EV	003	Mineral oil	Expansion valve	Fails closed	Chamber cannot be expanded	Safe	No means of connecting chamber to low-pressure system.
Pressure relief valves							
PRV	003	Mineral oil	Hydraulic system pressure relief valve	Fails to rupture upon overpressure	Hydraulic system overpressurized		System fails to vent to safe condition. This should be impossible as the pump, which generates the system's high pressures, is not capable of developing enough pressure to trip PRV-003.
PRV	003	Mineral oil	Hydraulic system pressure relief valve	Ruptures without overpressure	Hydraulic system vents immediately	Safe	If the hydraulic system is under pressure, it will rapidly vent itself into the water bath. The system will be depressurized.