JTC Engineering VPCR Response

ISX12 Water Drain Tube Leaking from Check Valve into Turbo and CAC

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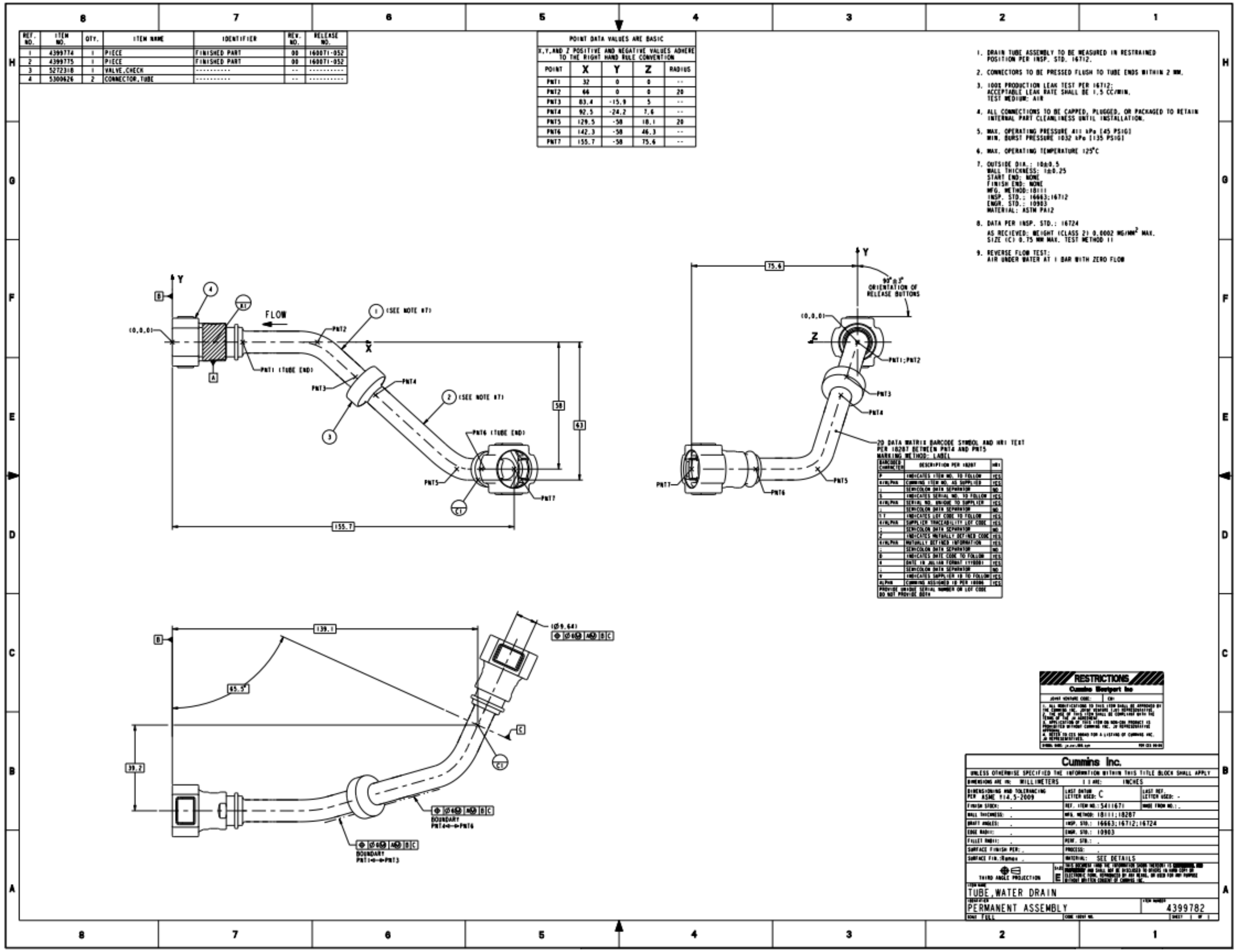
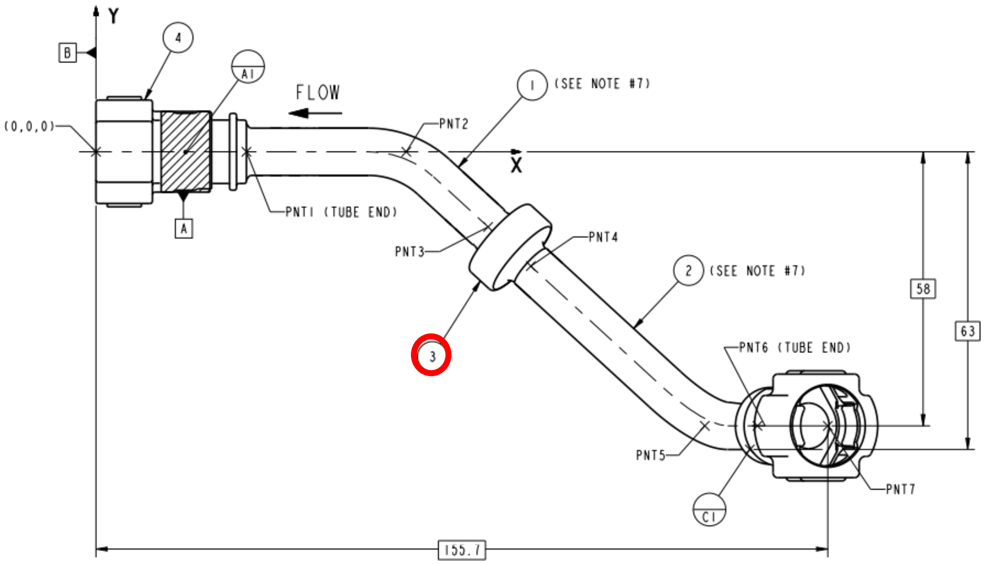
Date Opened: 8/16/2021

Date Closed: ____

System Background

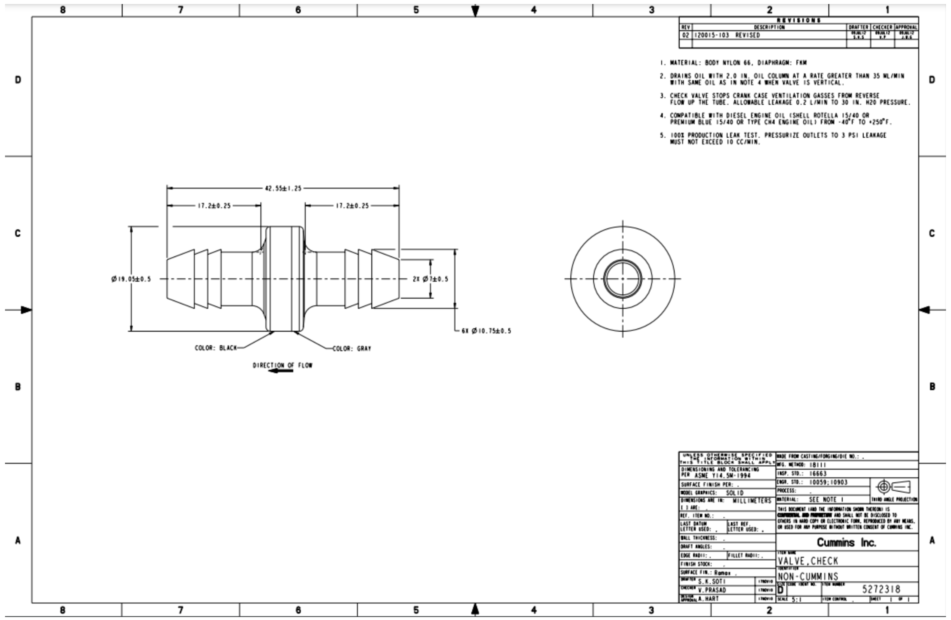


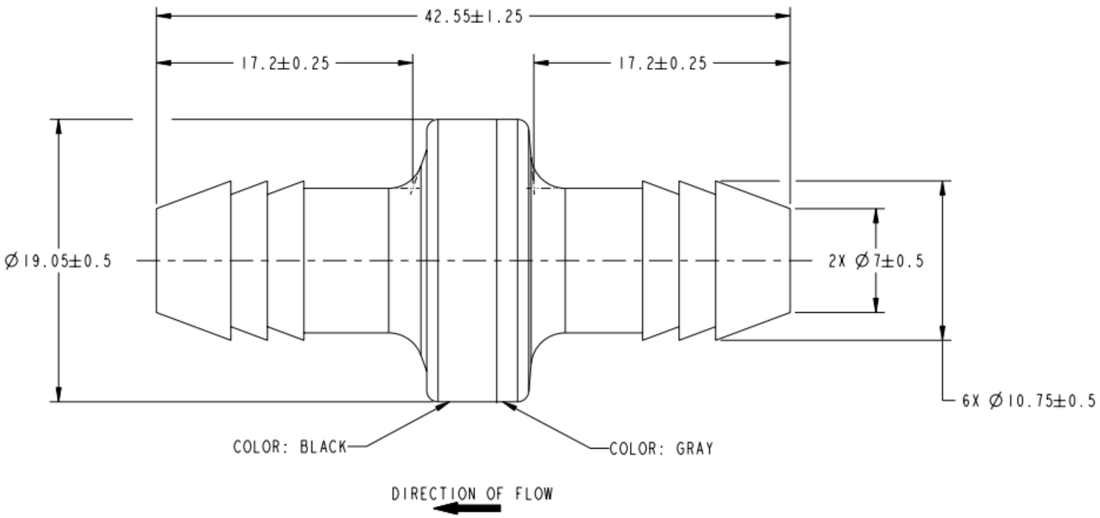
- ISX12, drains oil + water
- Drain Tube: 4399782
- Check Valve: 5272318



System Background

- Supplier: [redacted]
  - Supplier # [redacted]
  - [redacted]
- Check Valve:
  - Controls direction of oil flow
  - Membrane inside valve opens for flow
- System Specifications:
  - Max operating pressure = 411 kPa
  - Min burst pressure = 1032 kPa
  - Max operating temperature = 125 C





[redacted] = Censored for confidentiality

Failing Component and Effects

- Oil flows from the oil pan into the turbocharger and CAC
  - Check valve fails to control oil flow in correct direction
  - Some drain tubes are assembled in the wrong direction, causing a backwards check valve
  - This failure can damage both the turbocharger and CAC
- Drain tube is brittle, breaks, and experiences leaks
  - Internal system temperature exceeds material specs
  - Oil pressure loss
  - Oil found on other components
- Claims research supports theory of failed check valve causing oil backup
  - Failed check valve claims often report oil in the turbocharger or CAC as a result

Claims Research – RPH and CPE Plots

[redacted]

- Build volume: 12,302, Claims: [redacted], Average RPH = [redacted]
  - Failed check valve: [redacted], leaking drain tube: [redacted], installed backwards: [redacted]
- Average replacement cost = $2,163.26, Average CPE = $7.67

Failure Mode Investigation Results

- Check valve fails to control oil flow in correct direction
  - Drain tube installed backwards in the field / during service
  - Check valve membrane found broken in failed samples
    - Tube experiences high range of pressure fluctuation, including negative pressures
    - This may cause failure due to excess or fatigue stress
    - High internal temperature may weaken the membrane
  - Must choose new check valve with specs that match true operating conditions
- Drain tube becomes brittle and breaks upon removal or re-installation
  - Occurs on this hot side drain tube but also cold side oil drain tube
  - Regardless, exposure to high temperature over time is the cause of brittleness
    - Operating temperature exceeds material specifications at high duty cycle
  - Must choose new drain tube material with a higher specified temperature range

Proposed Solutions

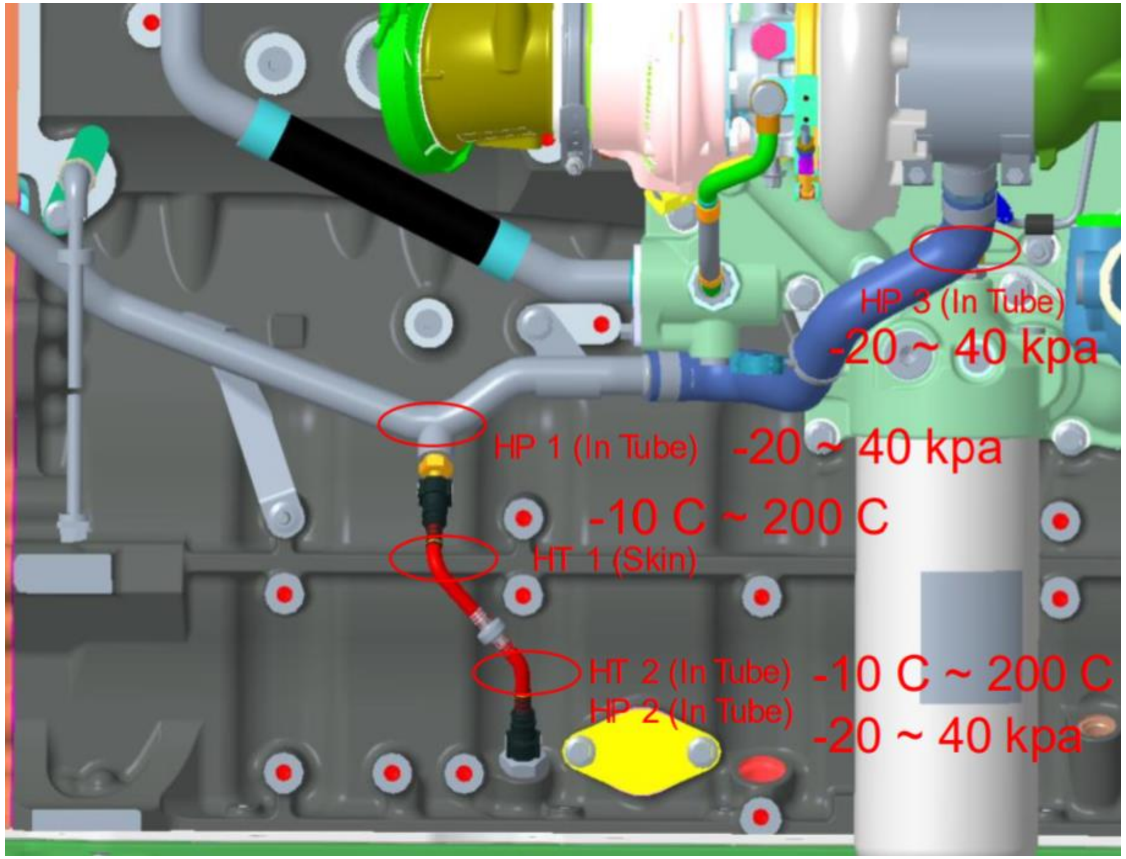
- Mark drain tube connectors to indicate direction of flow
  - This must prevent drain tubes from being installed backwards
- Choose new check valve
  - Must handle negative pressure values due to turbocharger
  - Must withstand the pressure range of the fluid within the drain tube
  - Must open to allow flow at the correct amount of pressure and close when pressure drops below this value
  - Compare specs of potential check valves with drain tube operating conditions
- Choose new tube material that can withstand greater temperature range
  - Use more heat-resistant material, must retain its ductility over time
  - Must not be prone to phase changes from long-term temperature fluctuations
  - Consider systems run at higher temperature than specs with high duty cycle

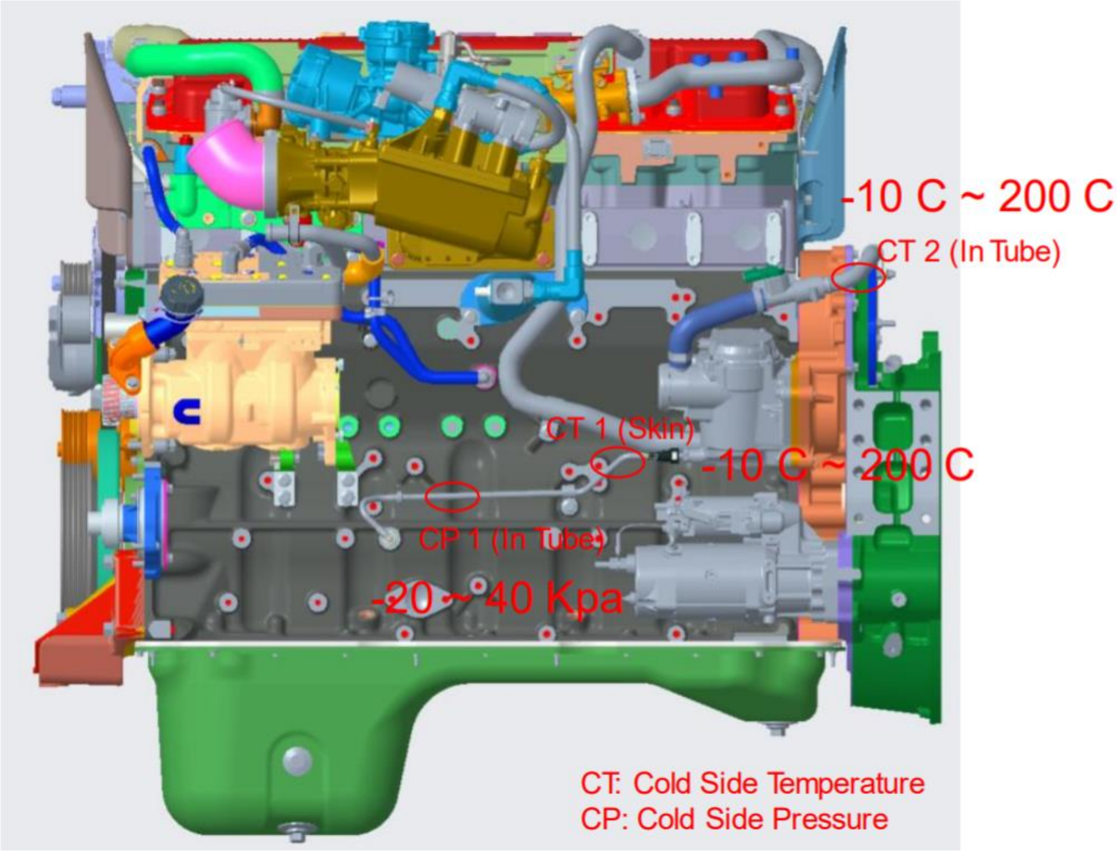
Solution Validation

- New check valve
  - Gather pressure readings from inside of drain tube during field test / operation
    - Find pressure at which check valve opens and closes
  - Investigate check valve limit specs, compare to operational pressure readings
  - Test new potential check valves and compare to current valve
    - Must open at same pressure specified (not actual) for current check valve
    - Must have pressure limits that allow for measured pressure range within drain tube
    - Full test procedure and criteria:
    - https://cummins365-my.sharepoint.com/:w:/g/personal/ss378_cummins_com/ESrmfl7stqVCureIX9nykTABcPYmfusn3SgHqatR1KYV9w?e=YO1gno
- New tube material
  - Measure the internal operating temperature range during field test / operation
  - Compare temperature specs of current material to potential new materials
- Connector markings to indicate direction

Solution Validation – Field Test

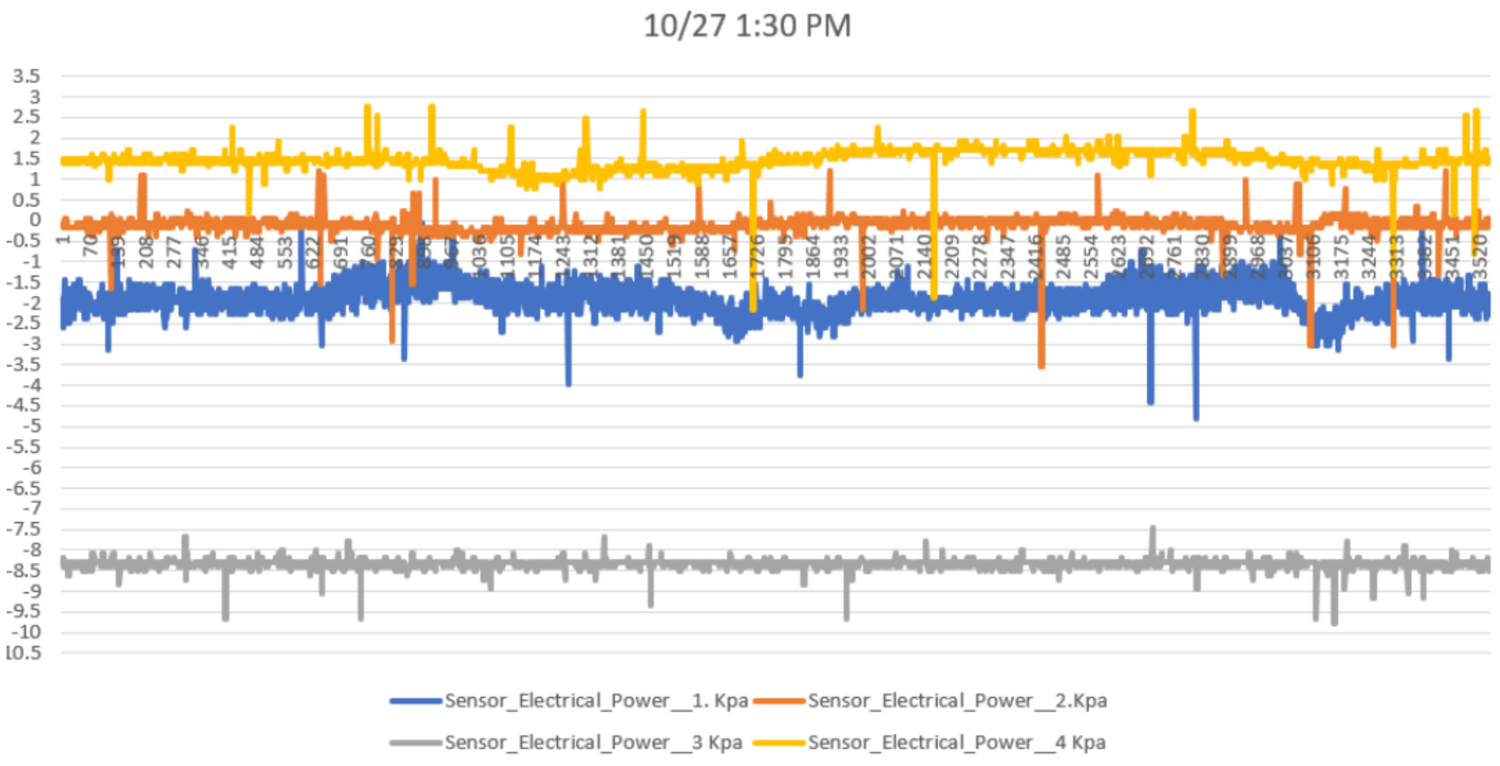
- Internal operating pressure and temperature gauge locations





Solution Validation – Field Test

- Peak measured operating temperature = 130 C
- Measured internal operating pressure at each gauge location



Solution Validation – New Check Valve

- Current check valve: 5272318
- Field test pressure measurement observations
    - Pressure in drain tube above check valve (sensor 1) is consistently negative
    - Pressure in drain tube below check valve (sensor 2) averages 0 kPa
    - Check valve opens:
        - To allow drainage when internal pressure above check valve rises or below drops
        - When pressure within the tube above the check valve exceeds the pressure below
- Alternate check valve test criteria, based on drain tube function / conditions
    - Must open / close at same pressure difference as the current check valve
    - Must withstand a pressure range of -5 to 1.5 kPa by a reasonable margin
        - Pressure range determined by measured internal pressure during operation
    - Must not allow reverse flow, pass reverse flow test

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Solution Validation – New Check Valve

- Alternate check valve specifications and test results comparison table:

Check Valve (Part #)	System assembly #	Assembly description	Specifications								Measured Quanitites			
			Valve diameter [mm]	Tube diameter [mm]	Length [mm]	Allowable leakage [L/min]	Min. allowable temperature [F]	Max. allowable temperature [F]	Oil compatible?	Fluid transfer rate standard	Opening pressure (delta p) [kPa]	Closing pressure (delta p) [kPa]	Flow rate at pressure of 3 kPa [L/M]	Burst pressure (delta p) [psi]
5272318	4399782	Water drain tube	19.05	10.75	42.55	0.2	-40	250		> 35 mL/min	>0	< -0.1433	17.67	49.67
5442592	5402614	Air transfer tube	30	7.4	57.7	0.2	-40	250	Yes	0.5 to 1 CFM	>0	< -0.2367	1.36	>90
5588864	5567571	Oil drain tube	20.2	9.6	44									
5589463	5588854	Fuel drain tube	11	5	36.2	0.045		266	Yes	> 33 L/h				
5592641	5590792	Oil drain tube	19.1	9.75	42.5	0.2	-40	250	Yes	> 35 mL/min	>0	< -13.8		
4998310	4325210	Oil drain tube	19.05	8.8	43.4		-40	257			>0	< -0.1867	53.5	51.33

- None of these check valves meet criteria
  - No closing pressure magnitude is lower than current check valve
    - Closing pressure instrumentation not accurate due to low pressure measurements
  - Neither flow-tested check valve has a similar flow rate to current valve
- Conduct test on other check valve part numbers using written procedure

Solution Validation – New Tube Material

- Evaluated properties of alternate materials to find a replacement material
  - Current material: ASTM PA12
- Must have a maximum operating temperature above 130 C
- Material comparison chart:

Material	Applicable Standards	Ductile material?	Formable hose?	Max. operating temperature [C]	Min. operating temperature [C]	Oil and water compatible?	Piece price with material
ASTM PA12	ASTM F2785, MPAPS F-7134	Yes	Yes	82	-40	Yes	$7.43
ASTM PA1010	2017-01-0490, MPAPS F-7134	Yes	Yes	N/A	N/A	Yes	
Flexible reinforced silicone hose	25043	Yes	Yes	219	-54	Yes, ASTM D6210	High cost, premium material
Fluorosilicone liner		Yes		219	-54	Yes, ASTM D6210	High cost, premium material
HNBR - GH100	From Eaton, N/A	Yes	No	150	-40	Yes	
HNBR - GH101	From Eaton, N/A	Yes	No	150	-40	Yes	
Silicone	Not available	Yes	Yes				
Peroxide-cured FKM liner		Yes					
Reinforced silicone	25055	Yes	Yes	150		Yes	High cost, premium material
Compounded fluorocarbon liner		Yes		150		No	High cost, premium material
Silicone rubber (VMQ)	Silicone rubber: 23274, Fluorosilicone liner: 25043	Yes	Yes	180	-54	Yes	
Fluorosilicone liner		Yes		219	-54	Yes, ASTM D6210	

Solution Validation – New Tube Material

- Chosen material: **Silicone rubber (VMQ) with fluorosilicone liner**
- Disqualifying features of other materials:
  - Fails to meet the max operating temperature needed
  - Not a formable hose
  - Incompatible with oil or coolant
  - Is a premium material that would likely yield a high cost
- Favorable qualities to prevent embrittlement:
  - Large operating temperature range with high maximum
  - Compatible with oil and coolant used
- Favorable qualities to prevent failure due to embrittlement:
  - High tensile strength, high strain at break or yield
  - Low modulus of elasticity

My Recommendation

- New check valve identification
  - If possible, retest these check valves and others with my procedure and more precise instrumentation to determine pressure needed to close check valve
    - Find a check valve that closes at a lower pressure magnitude than current valve
  - Check valve pressure testing does not suggest that new / undamaged current check valves allow a significant level reverse flow
    - May have to re-evaluate initial failure mode investigation
    - If current check valves do not allow reverse flow as determined by vacuum pressure re-test, determine conditions in operation that cause check valve to either allow reverse flow or not open for a positive pressure difference
- New material implementation
  - Obtain quote from drain tube supplier for chosen new tube material, create CR
    - If supplier does not confirm that this material is adequate, evaluate new materials


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