

Cooling System Field Test

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1.0 Introduction — Why Test?

The intent of this Engine Data Sheet is to provide instructions to perform a series of qualifying cooling system tests on OEM-supplied fan and/or radiator components used with Caterpillar Engines. These tests and requirements have evolved over the years and have been successful in qualifying Caterpillar cooling systems controlled completely by the factory.

Although a complete factory offering of fan and radiator exists for Caterpillar Industrial Engines, there are many applications where these are not acceptable across-the-board. Some reasons are space limitations or unusually high heat loads. As such, the engine user can best work out with his supplier a suitable fan and/or radiator combination.

If in the planning phase (the OEM and his supplier should use the requirements on Page 4 as objectives), the cooling tests will be a confirmation of targets met. In other instances, the test series may disclose deficiencies that should be corrected. When the corrective steps are not apparent, it will become necessary to review the data with factory personnel.

The cooling system evaluation is divided into the following tests and examinations:

- | | |
|---------------------------|--------------|
| 1. Cavitation | Section 5.0 |
| 2. Drawdown | Section 6.0 |
| 3. Air Venting | Section 7.0 |
| 4. Heat Transfer | Section 8.0 |
| 5. Filling | Section 9.0 |
| 6. Reliability Assessment | Section 10.0 |

Each section is divided into Procedure, Log and Graph Sheet, and Test Results Review. The data procured as the result of these tests can be used to decide if the system has met the requirements stated on Page 4. In addition, if the requirements are not met, some diagnostic direction is given. Further review of the data may be necessary with factory personnel.

2.0 Requirements — Caterpillar's

1. **Engine Outlet:** 210°F maximum (7 psi capacity recommended).
2. **Cooling Ability:** System should be designed such that the ENGINE OUTLET coolant limit of 210°F is not exceeded at the engine rating and the maximum temperature of the cooling medium.
3. **Pump Cavitation Temperature (Tc):** At a temperature of Tc (at the pump), the loss of pump rise should not exceed 10% (20% on 3208 Engine). Tc = is equal to or greater than the highest coolant temperature expected at the pump under rated engine load and an outlet temperature of 210°F (29.6 in. Hg barometric pressure). Calculated as:

$$T_c = 210 - \frac{\text{Engine Heat Rejection (Btu/min)}}{8.1 \times \text{Pump Flow (gpm)}}$$

4. **Drawdown:** Coolant volume that can be removed from an expanded full system without exceeding a 10% loss of pump rise.

<u>Engine</u>	<u>Drawdown</u>
3208	9% of Total System Volume
All Other Models	12% of Total System Volume

5. **Air Venting:** The system should be capable of venting stated pints of air per minute, at a qualified low mark, without exceeding allowable percent loss of pump rise.

<u>Engine Models</u>	<u>Air Venting Pints/Minute</u>		<u>Allowable Percent Loss Of Pump Rise</u>
	<u>DI</u>	<u>PC</u>	
3204	0.5	—	35%
3208	1.1	—	35%
3114	0.5	—	35%
3116	0.7	—	35%
3304	0.7	1.5	35%
3306	1.1	2.2	35%
3406	1.5	3.0	35%
3408	1.9	3.8	35%
3412	2.9	5.7	35%
3508	3.6	—	35%
3512	5.5	—	35%
3516	7.3	—	35%
D348	—	6.2	35%
D349	—	8.2	35%
D379	—	6.8	35%
D398	—	10.2	35%
D399	—	13.6	35%

6. **Filling Capability:** Hose — With normal thermostats, the cooling system can be filled satisfactorily at a constant 5 gpm rate or greater. Bucket — With normal thermostats, the cooling system can be filled satisfactorily. "Satisfactorily" is defined as follows: after the water temperature is raised 5°F above the opening temperature of the thermostats, the quantity of "add" water to return the radiator top tank to its original brim-full status should not exceed the drawdown (No. 4) requirement.
7. **Reliability Audit of Components:** See Page 37.

3.0 Instrumentation

3.1 Instruments Required and Sources

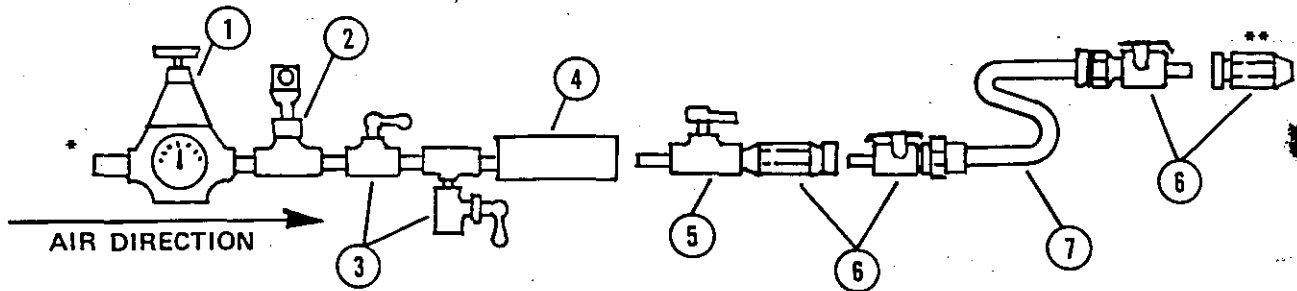
This is a checklist of instruments and material needed for the cooling test series. Sources of these items vary. Some instruments are available as part of existing Caterpillar service tools. Others can be procured from sources listed on referenced pages. Those items needing modifications for tests, such as the radiator pressure cap and engine thermostats, are also shown on referenced pages. Other materials listed are self-explanatory and easily procured.

<u>Instrument or Material</u>	<u>Source Reference</u>
Tachometer (0 rpm to 4000 rpm)	Cat Service Tool 4S6553
Temperature Measurement (0°F to 300°F)	Cat Service Tool 9S9102
Pressure Measurement Device (0 ft to 100 ft water pressure)*	Page 10
Pressure Measurement Device (15 ft water vacuum — 0 ft to 15 ft water pressure)	Page 10
Air Injection Device	Page 6
Radiator Cap (modified)	Page 9
Engine Thermostat(s) (blocked open)	Page 8
Speed Control Device	Page 7
Stop Watch	
Air Collecting Containers (pt, qt, 1/2 gal)	
Bucket (known volume — 8 qt to 12 qt range)	
Bucket (approximately 5 gal)	
Filling Hose (for cooling system)	
Cardboard (enough to block radiator)	
Tape Measure (at least 72 in.)	
Flashlight	
Ear Protection (noise devices)	

*Do not use Mercury (Hg) filled pressure devices.

3.2 Air Venting and Drawdown Test Apparatus

ORDER



*Source of Air Pressure
 **Hookup to Engine's Block Drain

Item	Source
① 1 — Air Pressure Regulating Valve	Model 11-002-019 Norgren Company 5400 South Delaware Street Littleton, Colorado 80120
② 1 — Metering Air Valve	"M" Series, #B2M4, 1/8 NPT Straight Pattern, Vernier Handle Nupro Company 15635 Saranac Road Cleveland, Ohio 44110
③ 2 — Toggle Valve	No. 395 — C 1/8 Imperial Eastman 6300 West Howard Street Chicago, Illinois 60648
④ 1 — Air Venting Sight Tube	Caterpillar 2P8278
⑤ 1 — Ball Valve	No. B-44F6 Whitey Company 5679 Landregan Street Oakland, California 94662
⑥ 2 — Coupler — Kwik-Connect	No. 298-PD, Brass 3/8 x 1/4 Imperial Eastman 6300 West Howard Street Chicago, Illinois 60648
⑦ 20 ft Tubing — Poly-Flow	No. 66P, 3/8, N Imperial Eastman 6300 West Howard Street Chicago, Illinois 60648

NOTE: Interconnecting parts, such as reducers and nipples, can be procured from local sources as needed. Brass material is recommended to avoid rusting.

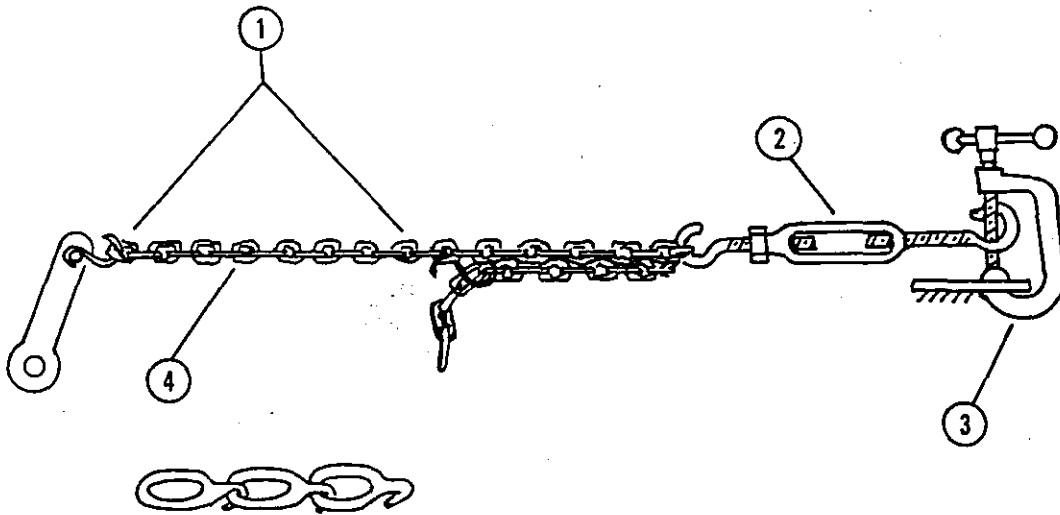
ORDER

3.3 Engine Speed Control Apparatus

As instructed in the Cavitation, Drawdown, and Air Venting test series, speed control is very critical to procure meaningful data. Some engine applications are equipped with vernier speed control devices and are suitable. If these are not available, a simple arrangement of locally procured "hardware store" parts is described in the sketch below.

Consists:

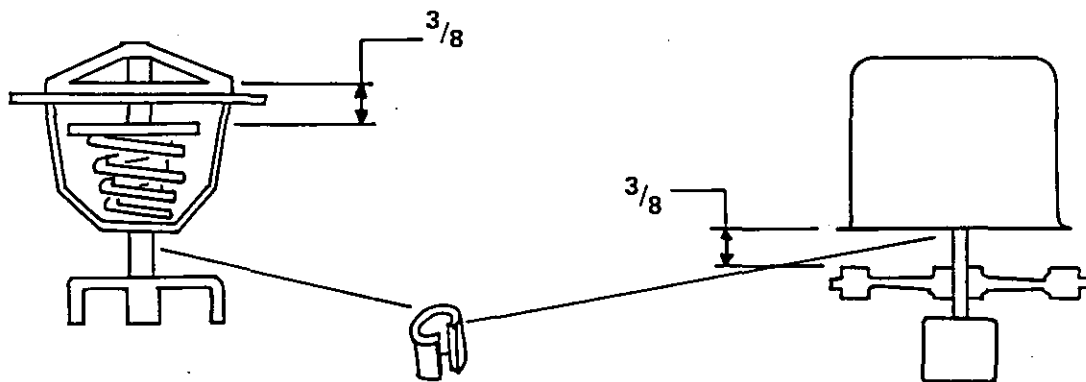
- ① 2 — "S" Hooks
- ② 1 — Turnbuckle
- ③ 1 — Small "C" Clamp
- ④ 10 ft of Flexible Chain



3.4 Engine Thermostat(s) Modification

Blocked open thermostat(s) should always be used for all the test series except for the FILLING TEST, Section 9.0. The blocked open position simulates the condition at the maximum operating coolant temperatures. Normal thermostat(s) must always be used for the FILLING TEST since this represents the condition prevailing during that process.

All thermostats should be blocked open $3/8$ in., regardless of the variation of type or size. After the thermostat is forced open to the $3/8$ in. distance, a predetermined length of slitted copper tubing should be crimped around the area as shown in the sketches below. A hole should be drilled into the power pill to permanently deactivate it. Obviously, these thermostats thereafter will be suitable only for the cooling test series.



ORDER

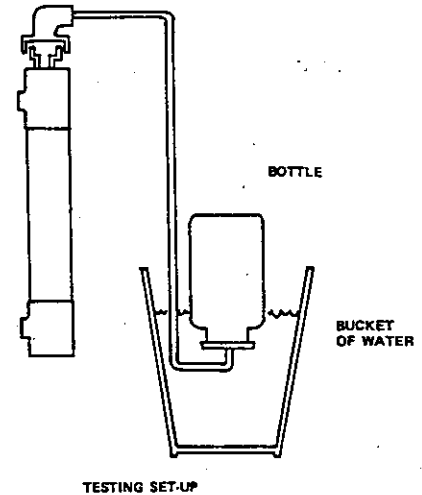
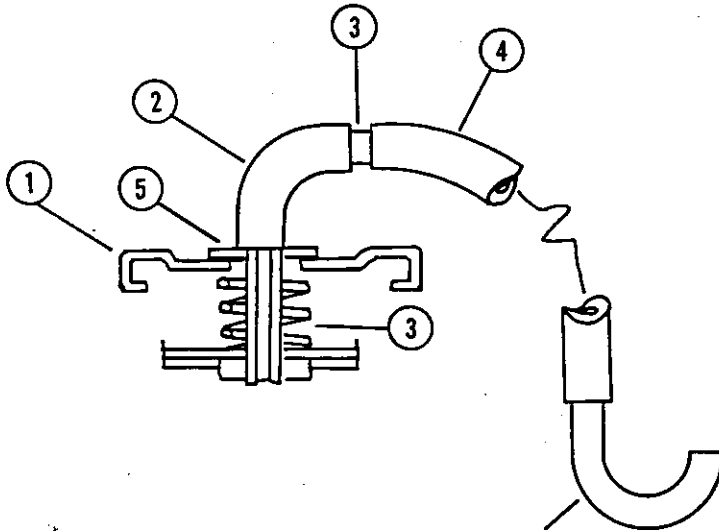
3.5 Radiator Cap Modification

As instructed in the Cavitation, Drawdown, and Air Venting test series, a modified pressure cap is required. General instructions to modify the pressure cap on the test unit are shown in the sketch below. Variation of pressure cap designs may dictate a different approach than shown. Regardless of the method of rework, the modified pressure cap should seal at the filler neck yet provide an unrestricted air flow path through the designated vent tube. For this, 3/8 O.D. copper tubing and fittings should be utilized. The 3/8 I.D. plastic tubing is used primarily during the AIR VENTING test.

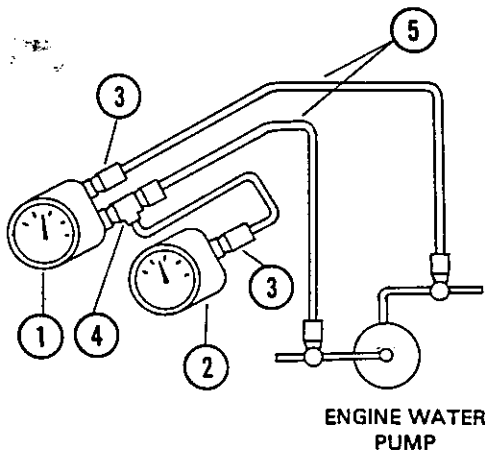
Consists:

- 1 1 — Radiator Cap Reworked as Shown
- 2 1 — 3/8 I.D. Copper Elbow
- 3* 3 — Short Lengths of 3/8 O.D. Copper Tubing
- 4 10 ft of 3/8 I.D. Flexible Plastic Tubing
- 5 1 — Washer, 7/16 I.D.

*These items have to be cut to lengths dictated by the cap design.



3.6 Method of Measuring JW Pump Pressures



- ① 1 — Differential Pressure Gauge, Midwest Model 109-FG-00-YO
Specify 0-100 Ft. H₂O range

Source:
 Mid-West Instrument
 286 Executive Drive
 Troy, Michigan 48084
 Telephone (313) 585-0900

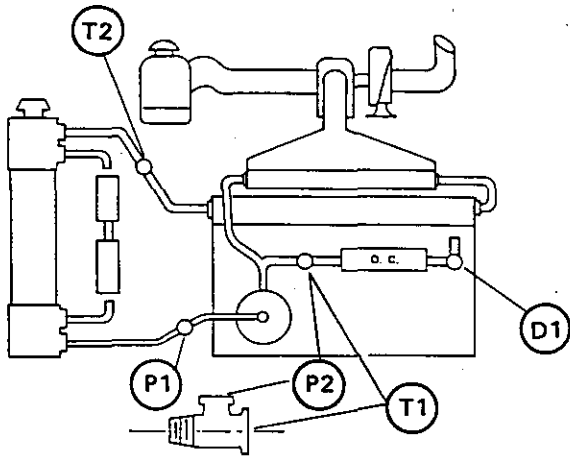
ORDER

- p ② 1 — Compound Pressure Gauge, Ashcroft Model 1377SS-02B
Specify (-30 in. Hg) to (0) to (±15 psig)

Source:
 Ashcroft Instrument Div.
 250 E. Main Street
 Stratford, Ct. 06497
 Telephone (203) 378-8281

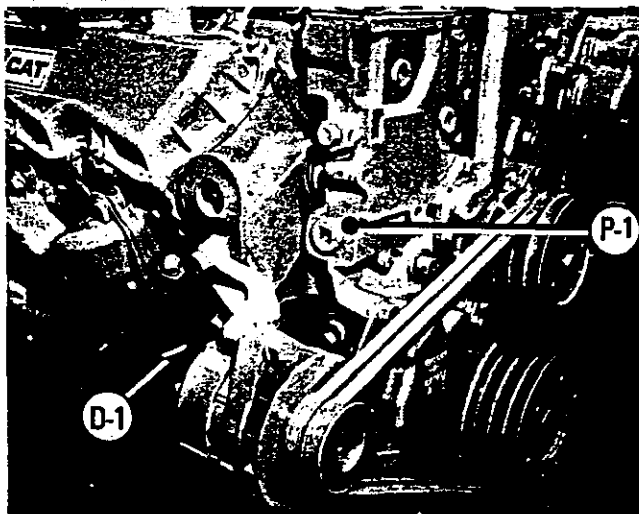
- ③ No. 298 PD, brass, 1/4 x 1/8 Kwik-Connect coupler
- ④ Street pipe tee, 1/8 x 1/8 NPT brass
- ⑤ Imperial Eastman No. 44P, 1/4, N, Poly-Flow tubing

3.7 Probe Locations on Engine



Use of 1/4 NPT street tee and suitable bushings permit P2 and T1 to use common opening.

3208:



Temperatures:

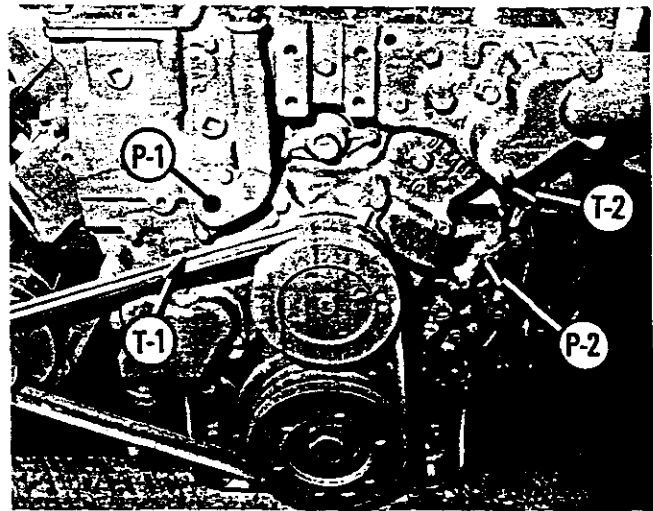
- T1 — JW to Engine
- T2 — JW from Engine

Pressures:

- P1 — Pump Inlet
- P2 — Pump Outlet

D1:

This is a JW drain point for use in the Air Venting and Drawdown Tests.



Note:

Openings do not exist at all designated probe locations. Make provisions as follows for testing:

- P1 — Drill and tap 1/8 NPT.

Temperatures:

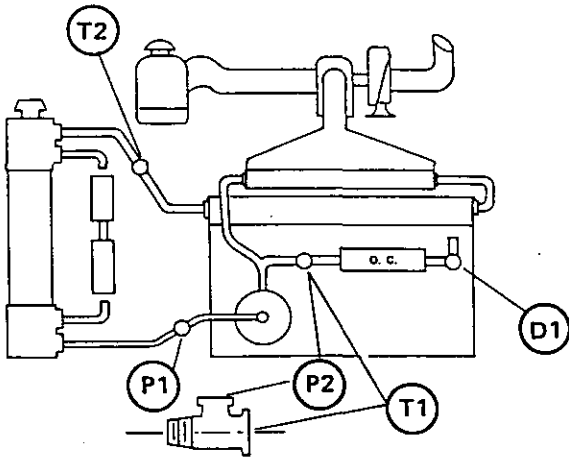
- T1 — JW to Engine
- T2 — JW from Engine

Pressures:

- P1 — Pump Inlet
- P2 — Pump Outlet

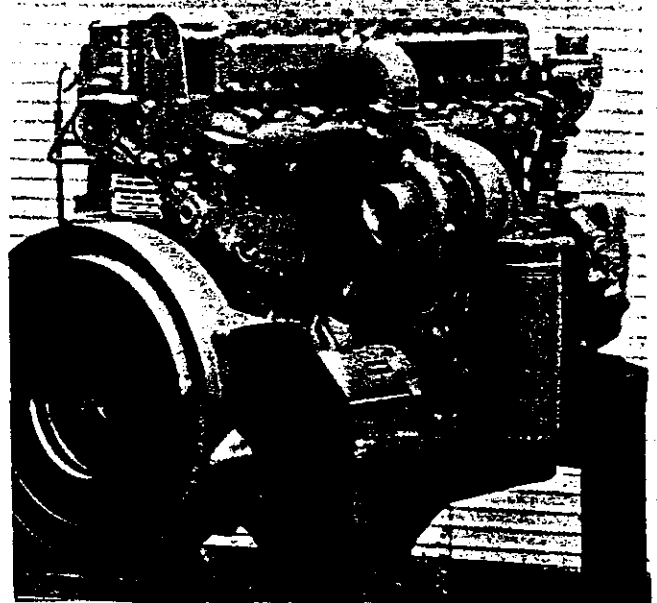
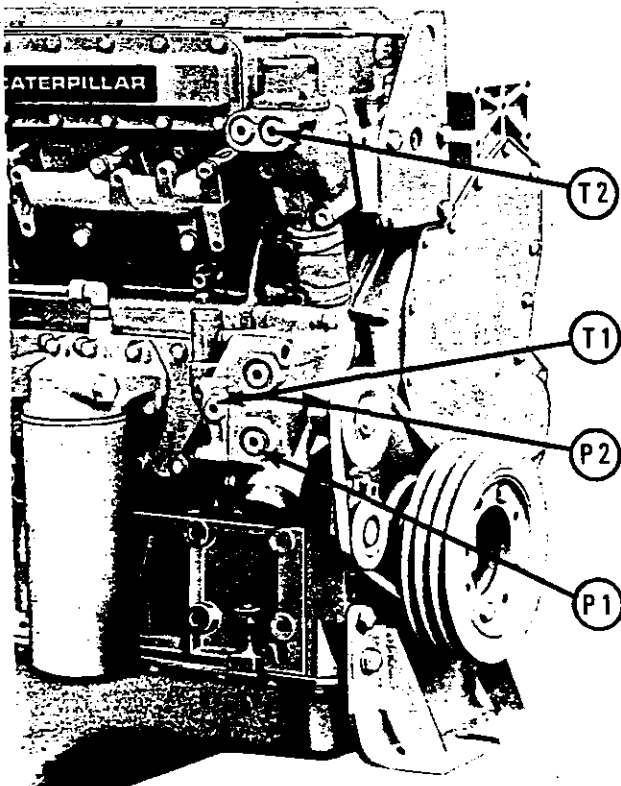
D1:

This is a JW drain point for use in the Air Venting and Drawdown Tests.



Use of 1/4 NPT street tee and suitable bushings permit P2 and T1 to use common opening.

3114, 3116:



Temperatures:

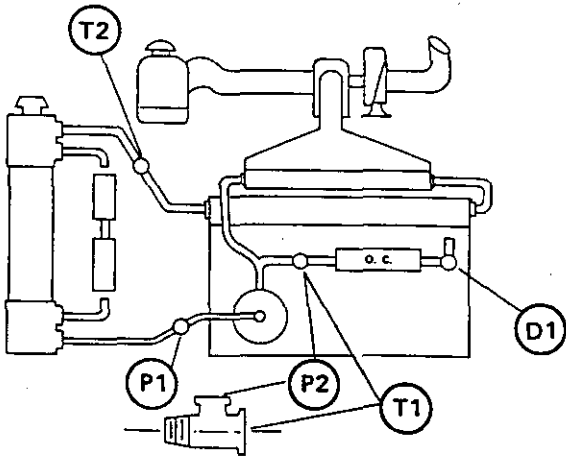
- T1 — JW to Engine
- T2 — JW from Engine

Pressures:

- P1 — Pump Inlet
- P2 — Pump Outlet

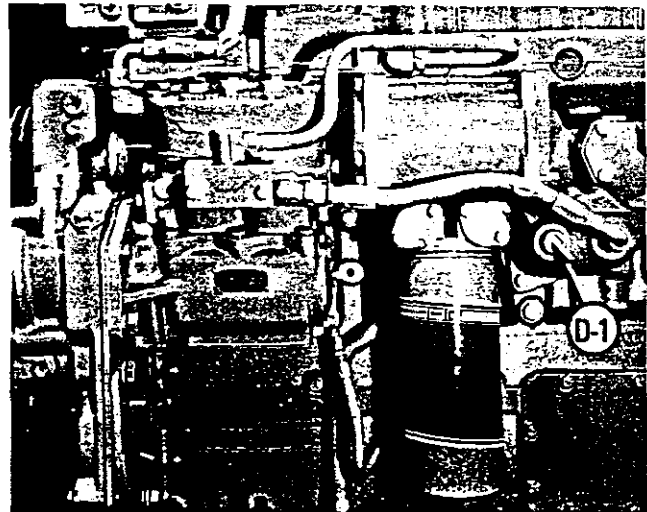
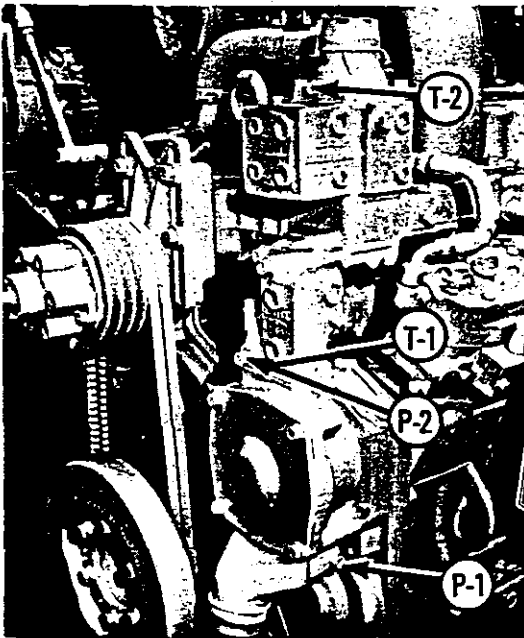
D1:

This is a JW drain point for use in the Air Venting and Drawdown Tests.



Use of 1/4 NPT street tee and suitable bushings permit P2 and T1 to use common opening.

3304, 3306:



Temperatures:

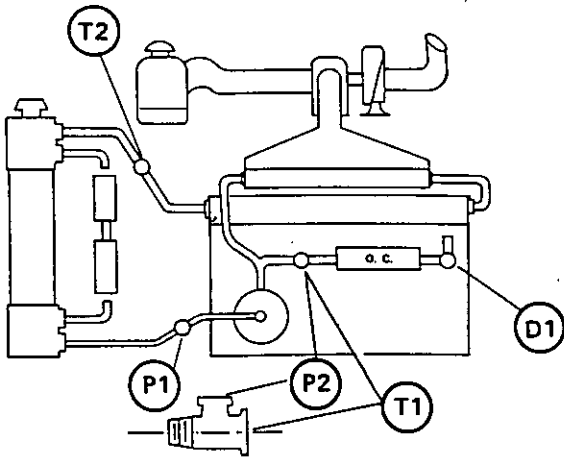
- T1 — JW to Engine
- T2 — JW from Engine

Pressures:

- P1 — Pump Inlet
- P2 — Pump Outlet

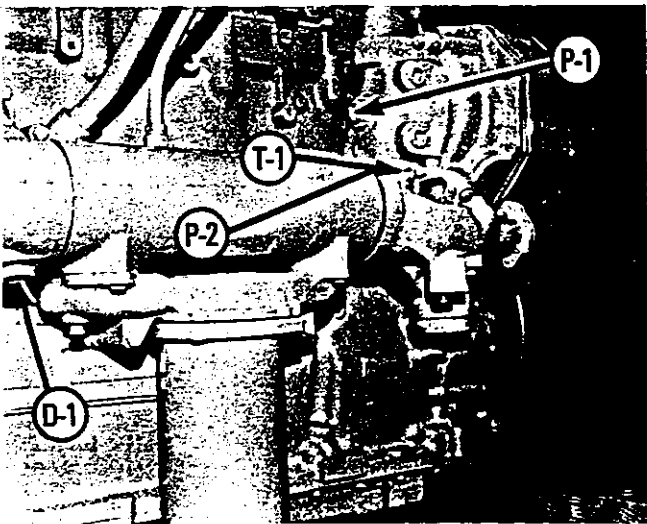
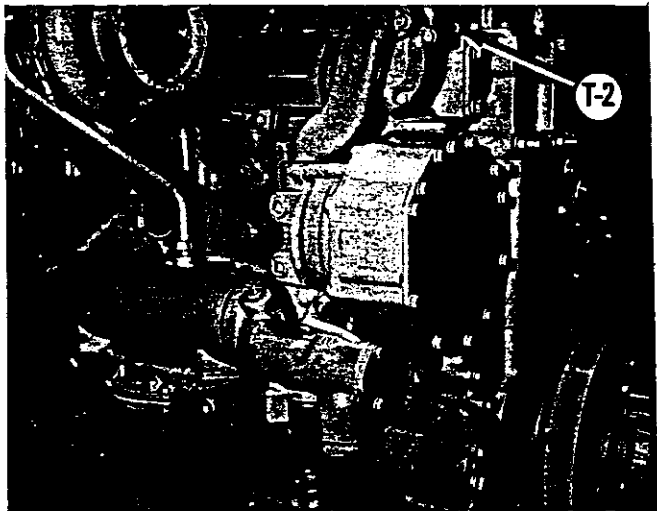
D1:

This is a JW drain point for use in the Air Venting and Drawdown Tests.



Use of 1/4 NPT street tee and suitable bushings permit P2 and T1 to use common opening.

3406:



Temperatures:

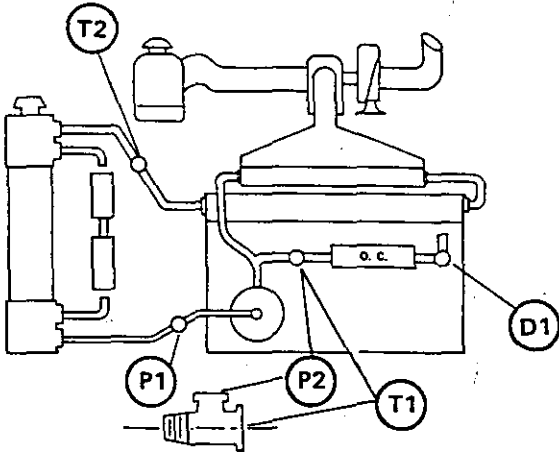
- T1 — JW to Engine
- T2 — JW from Engine

Pressures:

- P1 — Pump Inlet
- P2 — Pump Outlet

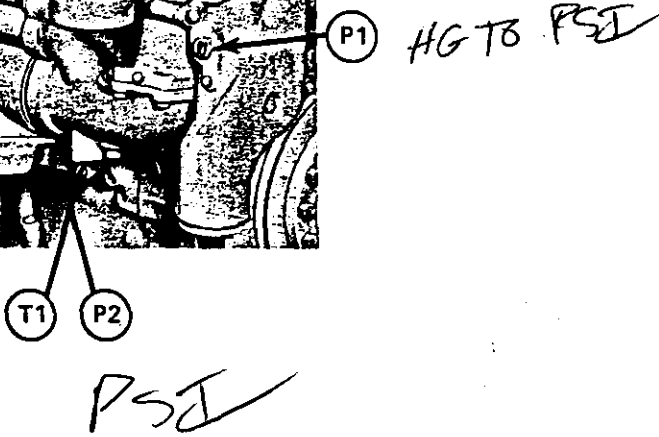
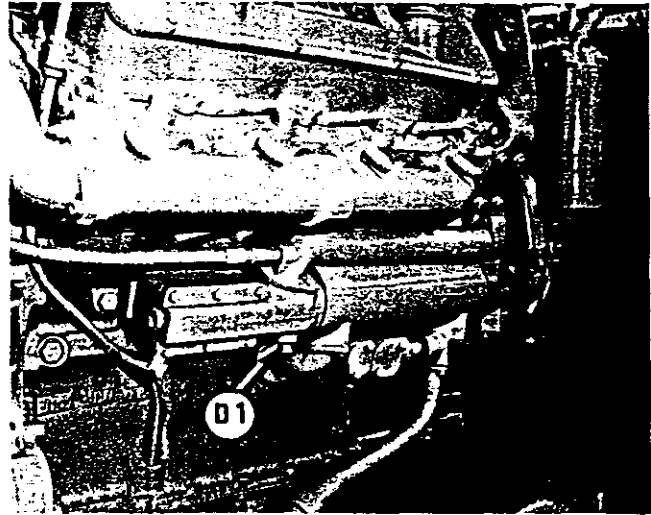
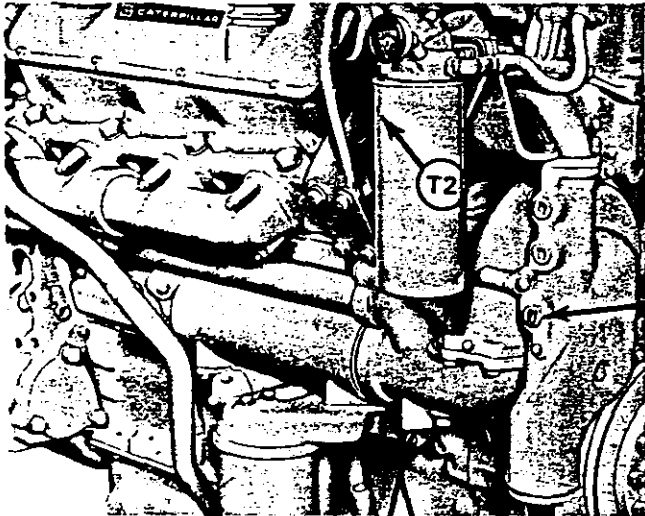
D1:

This is a JW drain point for use in the Air Venting and Drawdown Tests.



Use of 1/4 NPT street tee and suitable bushings permit P2 and T1 to use common opening.

3412, 3408:



Temperatures:

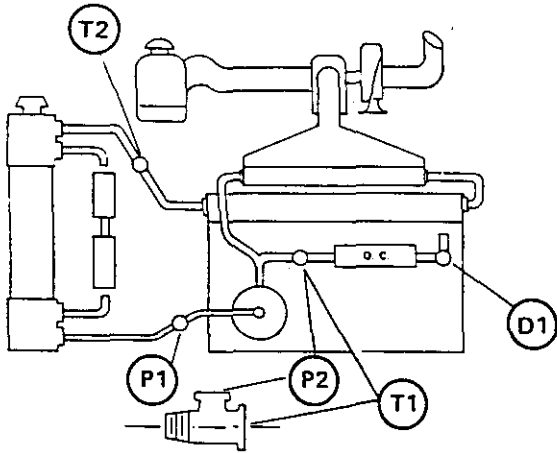
- T1 — JW to Engine
- T2 — JW from Engine

Pressures:

- P1 — Pump Inlet
- P2 — Pump Outlet

D1:

This is a JW drain point for use in the Air Venting and Drawdown Tests.



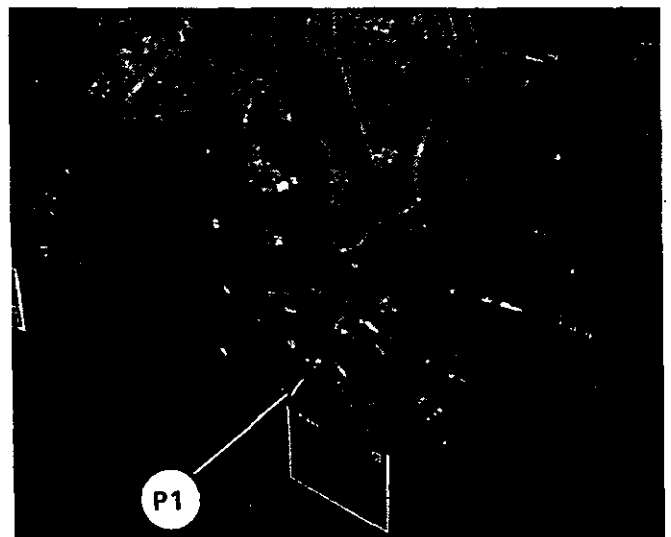
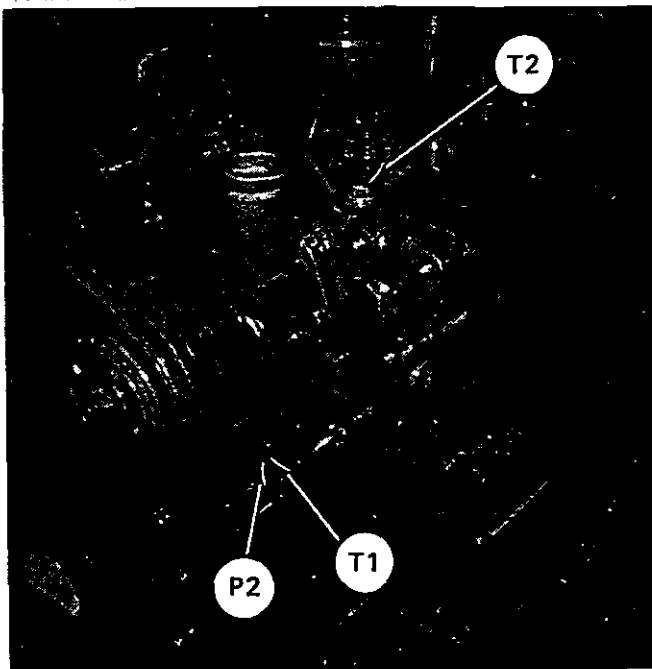
Note:

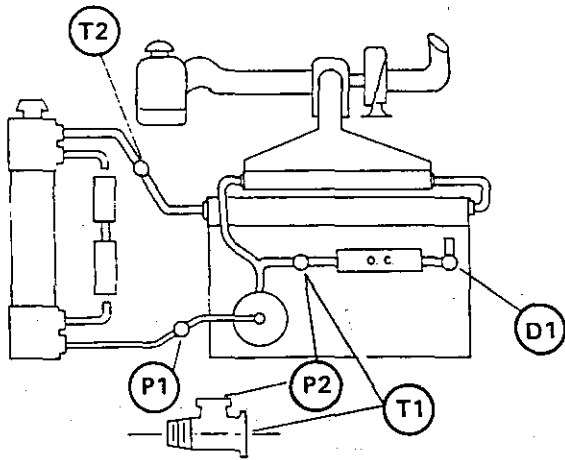
Openings do not exist at all designated probe locations. Make provisions as follows for testing:

- T1 — Drill and tap 1/8 NPT.
- P2 — Drill and tap 1/8 NPT.

Use of 1/4 NPT street tee and suitable bushings permit P2 and T1 to use common opening.

3204:





Temperatures:

- T1 — JW to Engine
- T2 — JW from Engine

Pressures:

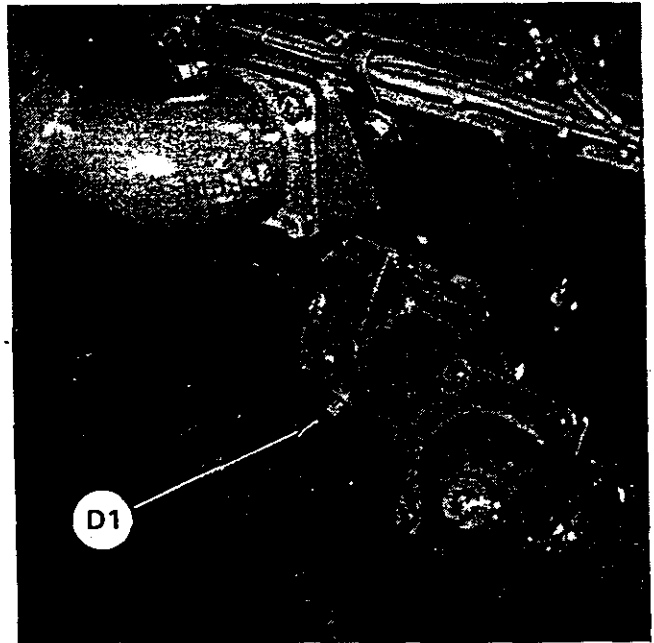
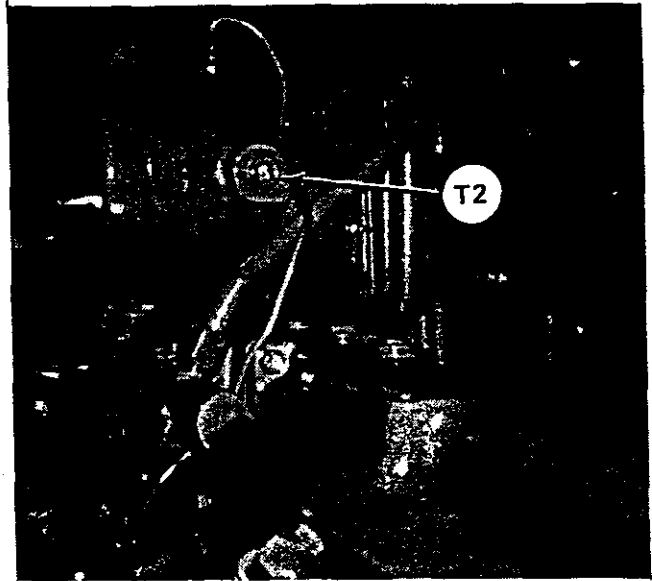
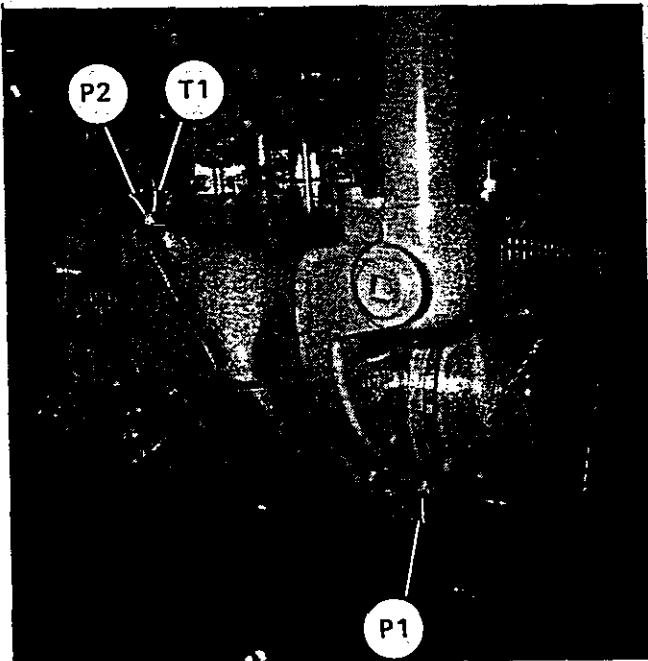
- P1 — Pump Inlet
- P2 — Pump Outlet

D1:

This is a JW drain point for use in the Air Venting and Drawdown Tests.

Use of 1/4 NPT street tee and suitable bushings permit P2 and T1 to use common opening.

3500:



Temperatures:

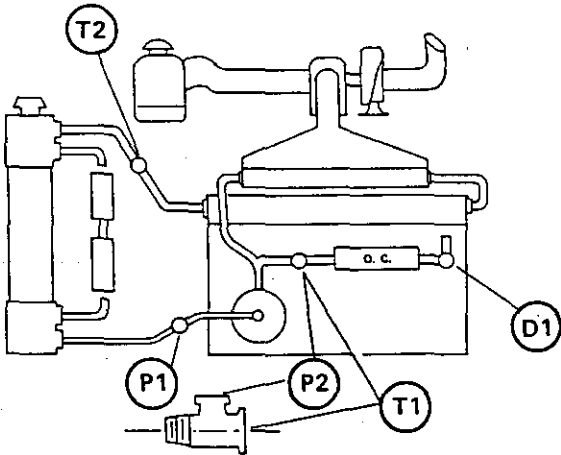
- T1 — JW to Engine
- T2 — JW from Engine

Pressures:

- P1 — Pump Inlet
- P2 — Pump Outlet

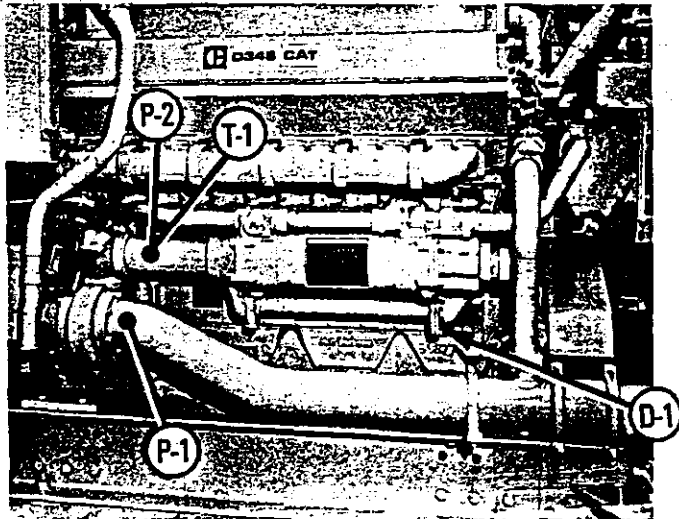
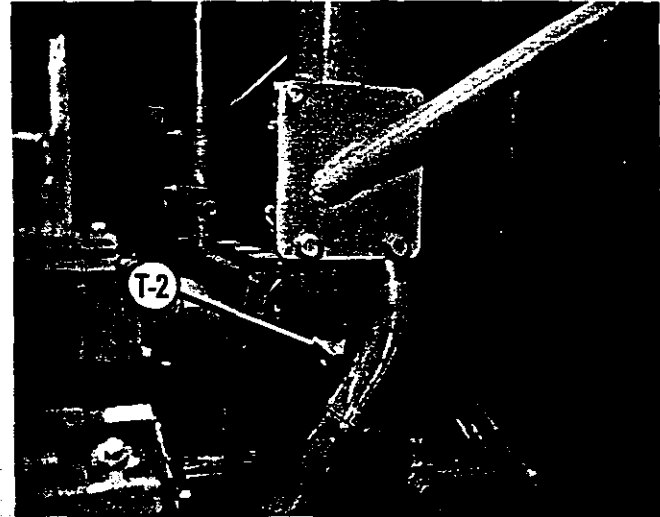
D1:

This is a JW drain point for use in the Air Venting and Drawdown Tests.



Use of 1/4 NPT street tee and suitable bushings permit P2 and T1 to use common opening.

D348, D349:



Note:

Openings do not exist at all designated probe locations. Make provisions as follows for testing:

- P1 — Weld or braze 1/8 NPT pipe coupling.
- P2, T1 — Weld or braze 1/4 NPT pipe coupling.

Temperatures:

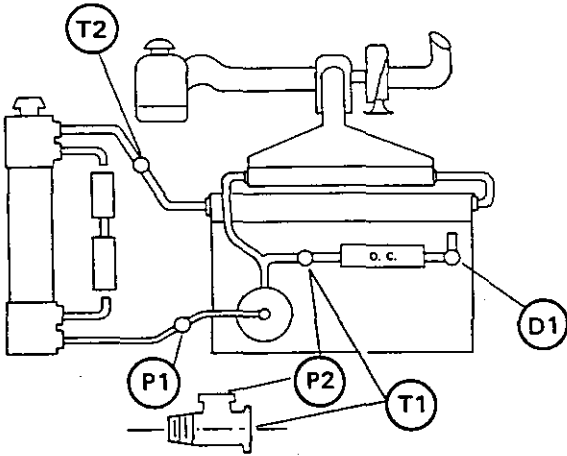
- T1 — JW to Engine
- T2 — JW from Engine

Pressures:

- P1 — Pump Inlet
- P2 — Pump Outlet

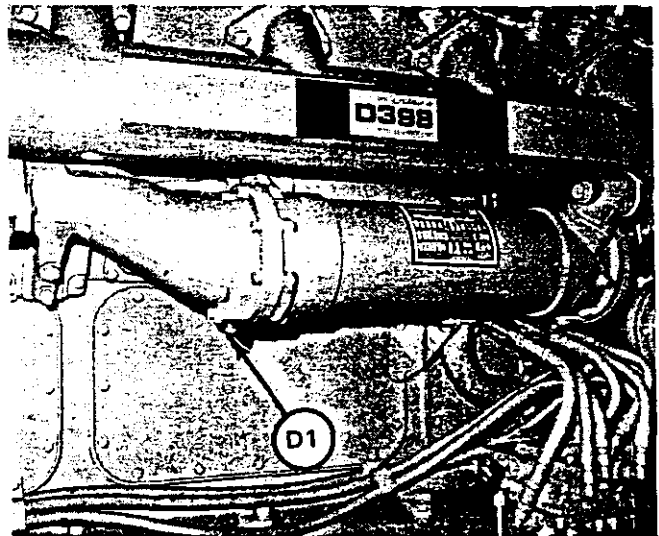
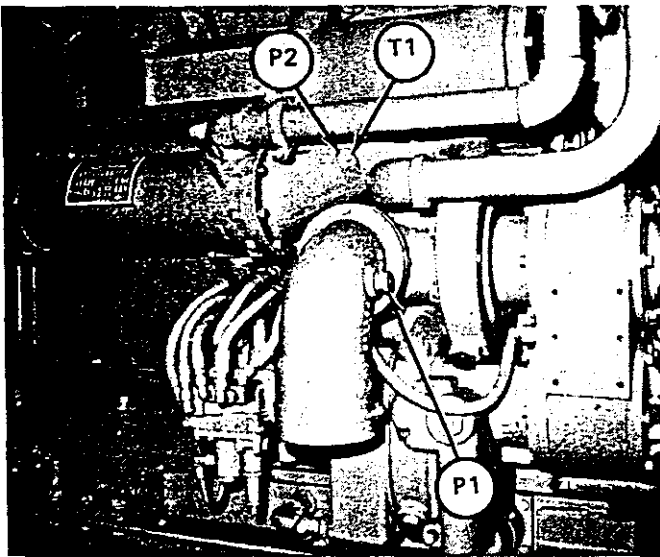
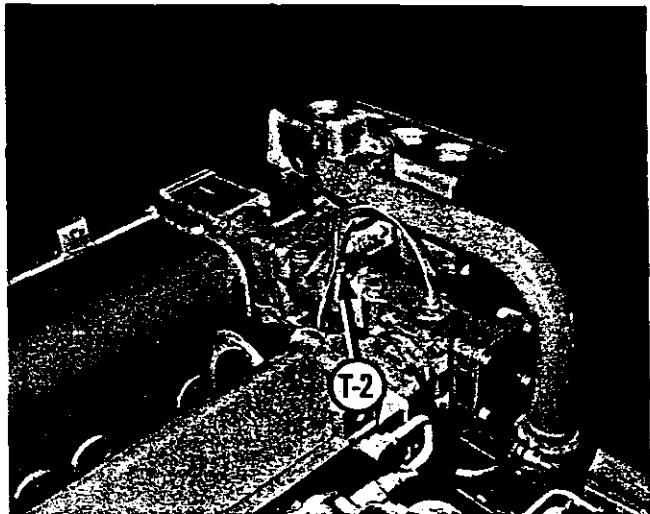
D1:

This is a JW drain point for use in the Air Venting and Drawdown Tests.



Use of 1/4 NPT street tee and suitable bushings permit P2 and T1 to use common opening.

D379, D398, D399:



4.0 Test Preparation Considerations

For safety reasons, the test should be conducted at an unhurried pace. However, good planning allows the test series to proceed at an efficient utilization of time. The following categories are considered in advance:

1. All Equipment Available at Test Location

All instruments are available and workable. Section 3.0 can serve as a checklist to be sure all equipment is assembled.

2. Test Personnel Are Familiar with Test Procedures

All COOLING TEST SERIES instructions should have been reviewed recently by the test operators. To expedite this, each test is explained on a single sheet. Also, available log sheets 5.2, 6.2, 7.2, 8.2, and 9.4 provide a consistent means of recording and plotting the data.

3. Test Location Considerations

Two types of areas are needed to complete the cooling system test series. Sometimes the same location is suitable for all the tests.

Group I Tests (Cavitation, Drawdown, Air Venting, and Filling):

These tests can be conducted in one location with the following considerations: (Water only must be used in the engine for cooling system tests.)

High Water Temperature Alarm:

For Test Only — Disconnect to avoid engine shutdown during the CAVITATION TEST.

Noise:

Avoid a location where personnel unassociated with the test are in close proximity. Also, it is recommended that the test operators wear protection devices.

Exhaust:

If weather permits, test can be run outdoors where exhaust fumes will not be a problem. An indoor location requires some means of ducting the exhaust fumes outdoors.

Water Source:

A water hose and water source are needed for the filling test and should be available at the test site. If this is impossible, the test unit could be moved to another location where a water hose is available.

Water Drainage:

A floor drain close to the test unit is desirable for an indoor location. When the floor drain feature is lacking, suitable containers should be available when the engine's cooling system is drained. A similar consideration exists for an outdoor location — but is not absolutely necessary as normal outdoor drainage paths will dispose of the water.

Air Source:

A 40 PSI air pressure source is needed at the test site for the air venting test.

Group II Test (Heat Transfer):

This test location will vary greatly, depending on how a known load can be applied to the test unit's engine. For most types of engine applications, loading devices other than "on-site" exist. Some of these are chassis and towing dynamometers, electrical load banks, and more recently "GO POWER" devices.

However, because of the test unit type, an "on-site" or field evaluation is the only way of conducting a heat transfer test. The best judgment of how the engine can be loaded is reserved for the test unit manufacturer and test operators. The most important consideration for any heat transfer test is that a stabilized cooling differential is reached at a known engine load. Test Sheet 8.1 expands on this point.

4. Safety is Considered

The following listing illustrates some safety concerns before and during the test series:

Before Test:

All instrumentation wires or plastic tubes should be safely secured to avoid rubbing or entanglement on moving parts such as fans, fan belts, pulleys, etc.

All hose clamps are tight to avoid a sudden loss of water.

All hoses clear moving parts.

Fan belts are tensioned properly.

During Test:

Check noise for potential trouble indicated by smoke, water, steam, or unusual noise.

Preparation for a quick engine shutdown should have been considered. If two test operators are at the site, a prearranged agreement should exist as to what signals to use to alert each other to shut down the engine. An example of this is when a wheel dynamometer is used. Truck tires can become overheated and not noticed by the operator in the cab. A second operator outside the cab can alert the operator in the cab of a possible problem.

5.0 Cavitation Test

This test is to determine if the engine's coolant circulating pump performance is satisfactory throughout the expected coolant temperature operating range.

Engine Preparation

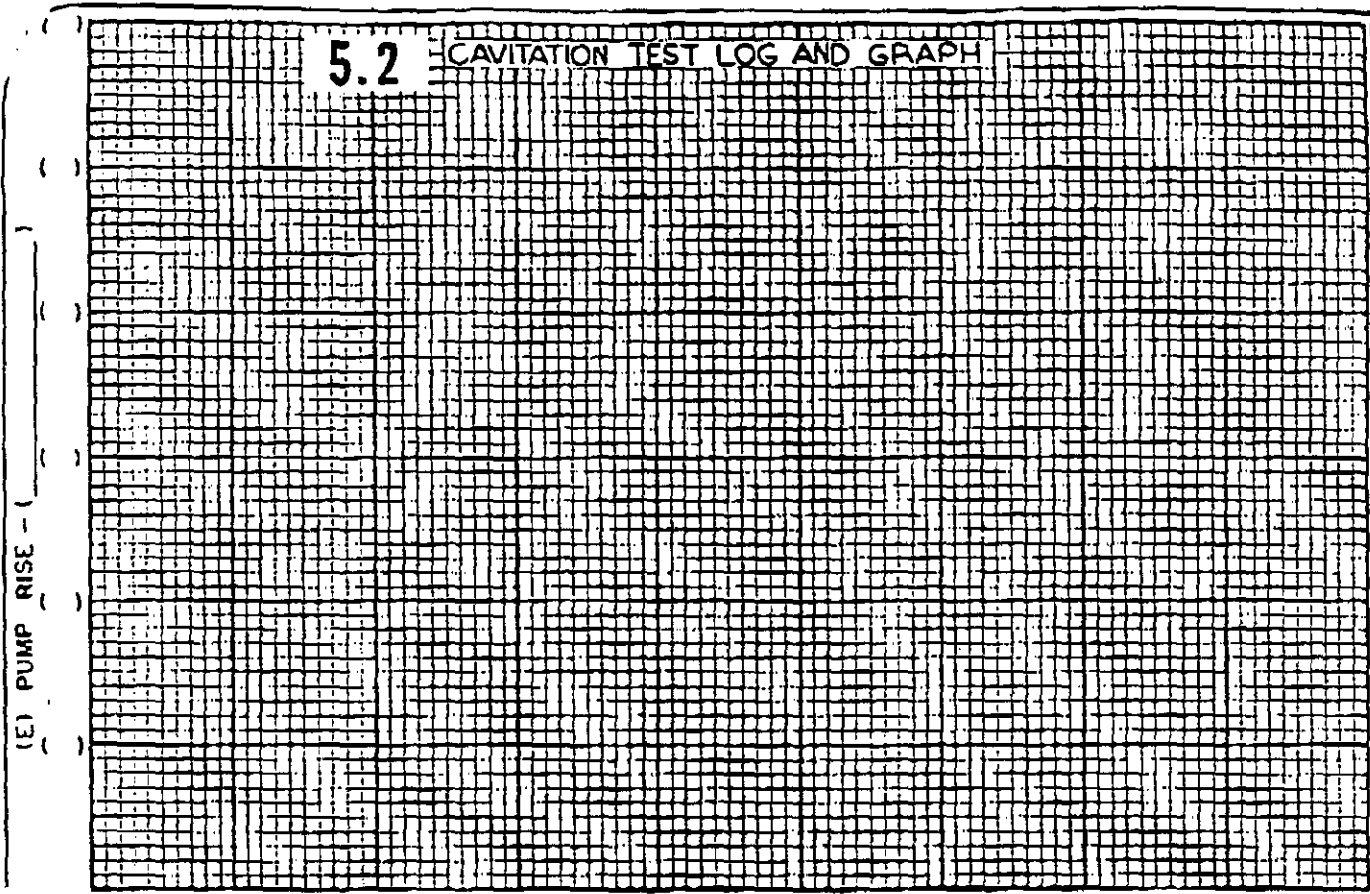
- Blocked Open Thermostats
- Cooling System Completely Filled with Water
- Method to Control Engine Consistently at Rated Speed
- Specially Prepared Vented Radiator Cap with Vent Line
- Check Engine Lubrication Level
- Radiator in a Level Position

5.1 Procedure

1. Start engine and idle for approximately 5 minutes. At this time recheck the cooling system to make sure it is at a brim-full level. If not, add water to completely fill system. Replace special vented cap with the vent line end positioned to discharge into a bucket. The vent line should not be kinked. At no time should the end be submerged in any of the overflow water in the bucket.
2. Raise engine to **rated** rpm and apply the speed control apparatus. Maintain a constant rated engine speed throughout the test. This is very important since variations will give a false indication of pump performance when no problem exists.
3. Note water temperature at the pump outlet before adding cardboard (impeding airflow) to the radiator — to raise water temperature. If the temperature is far below the 120°F base and reference point, add **some** airflow-blocking cardboard. The object is to raise water temperature slowly to log meaningful pump pressures. Although the base point is 120°F, it is wise to log the pressures at 115°F, also. It is important that the 120°F reference point is not hastily established, caused by water temperature climbing too rapidly. Remove cardboard if necessary to establish a good, stabilized 120°F pump pressure condition.
4. As the water temperature is increased, record pump pressures at the temperature points indicated on a copy of the prepared Cavitation Temperature Test Log and Graph. Add cardboard as necessary to raise the water temperature to the temperatures indicated. The temperatures of the water should be raised at an approximate rate of 5°F in 2-3 minutes. Special care should be exercised to examine the 185°F to 210°F pump pressure characteristics. It is in this temperature range that the water pump will start to cavitate. The cavitation temperature depends on the external cooling system capability. This is evidenced by the drop-off (reduction or loss) of pump pressure rise. The test should continue beyond the prescribed cavitation test goals until the 210°F temperature is reached or to a temperature where the pump pressure rise is reduced to maximum as described on Page 3, whichever occurs first. After this point in the test is reached, the temperature can be reduced to 180°F to begin the **Drawdown Test**.

Note: Refer to 5.3 Test Results Review, Page 23, to process and interpret data.

5.2 CAVITATION TEST LOG AND GRAPH



(120) (130) (140) (150) (160) (170) (180) (190) (200)
 °C (50) (55) (60) (65) (70) (75) (80) (85) (90)
 (A OR B) PUMP INLET TEMPERATURE

	A*	B*	C	D	E
J/W PUMP OUTLET TEMP. (C)	115				
J/W PUMP OUTLET TEMP. (F)	120				
J/W PUMP INLET PRESS. ()					
J/W PUMP OUTLET PRESS. ()					
J/W PUMP RISE (D-C) IF NOT MEASURED DIRECT					
46					
49					
54					
60					
65					
71					
77					
82					
88					
89					
90					
91					

	A*	B*	C	D	E
J/W PUMP OUTLET TEMP. (C)	198				
J/W PUMP OUTLET TEMP. (F)	200				
J/W PUMP INLET PRESS. ()					
J/W PUMP OUTLET PRESS. ()					
J/W PUMP RISE (D-C) IF NOT MEASURED DIRECT					
92					
93					
94					
95					
96					
97					
98					

BAR. PRESS. _____ INS. HG. _____

SEE INSTRUCTIONS ON PAGE 23 TO:
 1. PLOT AND INTERPRET DATA.
 2. REVIEW POSSIBLE SOLUTIONS IF REQUIREMENTS ARE NOT MET.

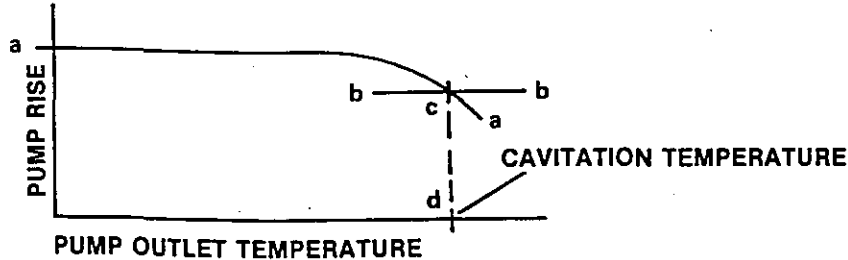
CAVITATION TEMP. _____ MEETS REQUIREMENTS
 RESULTS YES
 REQUIREMENTS NO

* DEPENDING ON INSTRUMENTATION USE (A) OR (B). AS SHOWN (A) IS NOT A DIRECT EQUIVALENT OF (B).

TEST DATE	
ENGINE MODEL AND S/N	
ENGINE SPEED	
ENGINE APPLICATION	
TEST PERFORMED BY	

5.3 Cavitation Test Results Review

To establish that the Cavitation requirement is met, a series of curves will have to be developed on the graph section provided as part of the Log and Graph, Page 22. The resulting series of curves will appear as shown in the sketch below. Directions to formulate the series of curves are described below:



First, develop curve a-a by simply plotting the appropriate logged data on the graph section. Indicate units of pressure and temperature used.

Next develop and overplot b-b as follows: Multiply the pump rise value recorded at 120°F by the decimal value of 100% minus the percent of allowable pump rise loss acceptable for the engine model being reviewed. Refer to Page 4 for the acceptable values of allowable pump rise loss. Plot b-b to intersect a-a. The projection of the intersect point, c, downward establishes the cavitation temperature value, d, of the system. This value should be entered in the designated box on Page 22. If the barometric pressure during test varies from the standard barometric reading of 29.60 in. Hg, a correction should be made to the measured cavitation temperature, d. For every 0.5 in. Hg below 29.60, the cavitation temperature should be increased 1°F. For every 0.5 in. Hg above 29.60, the cavitation temperature should be decreased 1°F.

If the test value is equal to or exceeds the requirement, the cavitation temperature of the system is satisfactory.

Possible Difficulties if Cavitation Requirement is Not Met:

1. Restriction prior to the pump inlet is too high. This can be the result of the following deficiencies:
 - a. Piping too restrictive because of size, routing, number, or severity of bends.
 - b. Bottom tank of radiator too shallow or contains excessive restrictive components such as oil coolers.
 - c. Radiator does not contain enough tubes to provide adequate coolant flow path internally.
2. A shunt type of system can have the following deficiencies:
 - a. Shunt line I.D. too small.
 - b. Shunt line length too long.
 - c. Vent tube too large.
 - d. Baffle in radiator top tank is leaking.

J Drawdown Test

This test determines the reserve quantity of the cooling system and the correct position of the low mark in the radiator top tank.

Engine Preparation

This test usually follows the **Cavitation Test**, and the only preparation is to cool the water to $180^{\circ}\text{F} \pm 2^{\circ}\text{F}$. The water temperature is controlled by varying the amount of cardboard blocking airflow to the radiator. Engine rpm is controlled at rated speed.

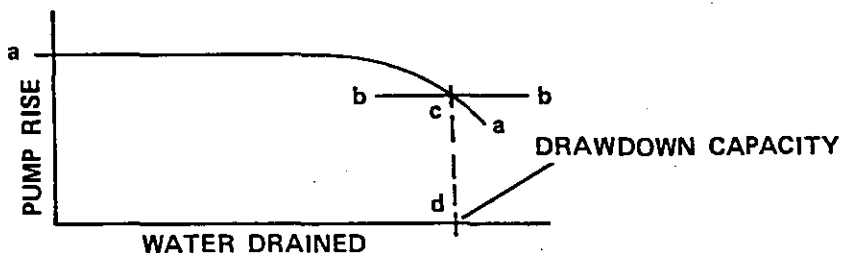
6.1 Procedure

1. While engine is running, remove the special vented radiator cap (Page 9) and add water to a brim-full condition. Some shrinkage occurs from the cooldown after the **Cavitation Test**.
2. Record the pump pressures on the **Drawdown Test Log and Graph** sheet on Page 25 to establish a base point.
3. While holding the temperature constant, drain water from the engine in increments of 1 qt. After each unit of water is removed, record data.
4. As the pump pressure rise begins to drop off, reduce volume increments to one pint, continuing until the water pump rise has decreased at least 15% below the reference point established in Step No. 2.
5. Add water in pint increments until the water pump rise has reached the base point identified in Step No. 2.
6. Remove the special vented radiator cap and record the water level relative to the low mark. Note whether the water level is above, even, or below the low mark if one exists. If no low mark baffle exists, record distance from top of filler neck to water level.
7. Reinstall the special vented radiator cap. The engine/cooling system is now ready for the **Air Venting Test**.

Note: Refer to 6.3, Test Results Review, Page 26, to process and interpret data.

4.3 Drawdown Test Results Review

To establish that the drawdown requirement is met, a series of curves have to be developed on the graph section provided as part of the Log and Graph, Page 25. The resulting series of curves will appear as shown in the sketch below. Directions to formulate the series of curves are described below:



First, develop curve a-a by simply plotting the appropriate logged data on the graph section. Indicate units of pressure and temperature used.

Next develop and overplot b-b as follows: Multiply the pump rise value recorded at 120°F during the previous **Cavitation Test** by the decimal value of 100% minus the percent of the allowable pump rise loss acceptable for the engine model being reviewed. Refer to Page 4 for acceptable values of allowable pump rise loss. Plot b-b to intersect a-a. The projection of the intersect, c, downward establishes the drawdown capacity, d, of the system. This value should be entered in the designated box on the page.

If the test value is equal to or exceeds the requirement, the drawdown capability of the system is satisfactory.

Possible Difficulties if Drawdown is Not Met:

1. Reserve volume in the radiator top tank is not large enough.
2. Shunt line on a shunt type of system is located too high in the radiator, or vortex action is drawing air into the system.

Note: The solutions to the above problems may have to be reviewed with Cat factory personnel.

7.0 Air Venting Test

This test is to determine the air/combustion gas-leak-purging ability of the cooling system.

Engine Preparation

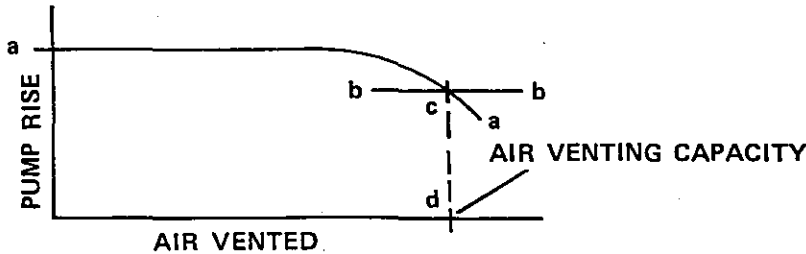
This test usually follows the **Drawdown Test**, and the only preparation is to prepare and connect the air injection and air measuring equipment. During this test, the water temperature is controlled to $180^{\circ}\text{F} \pm 2^{\circ}\text{F}$ by varying the amount of cardboard blocking airflow to the radiator. Engine rpm is controlled at rated speed. Adjust water level to either the lower water plate or, in its absence, the defined low water level (12% of total system volume, etc.).

7.1 Test Procedure

1. Record the pump pressures and temperature on the **Air Venting Test Log and Graph**. This establishes the base point of zero air injection into the engine's cooling system.
2. With the air venting needle valve in the off position, adjust the pressure regulating valve to 25 psi.
3. Gradually open the air needle valve until air can be observed passing through the bubble chamber.
4. Continue to open the air needle valve until some air is seen bubbling from the special vented radiator cap overflow tube that has been submerged in a bucket of water.
5. Fill the measuring bottle with water and invert in the bucket of water. Place the end of the overflow tube into the inverted pint bottle and record how long it takes to displace the water with the vented air. Record this time and the pump pressures. Repeat this air venting measurement at the same air needle valve setting.
6. If the pump pressure rise has not decreased below 6% during Step 5, increase the air needle valve opening. Measure the air venting rate again.
7. If the pump pressure rise is radically reduced during the testing, close off the air supply valve and allow the system to purge itself. When the pump pressure rise is fully recovered, repeat the last air venting trial with a reduced air injection needle valve setting.
8. Take enough variations of air needle valve settings to establish the air purging capability from zero air injection to maximum as described in Engine Cooling Requirements.

7.3 Air Venting Test Results Review

To establish that the air venting requirement is met, a series of curves will have to be developed on the graph section provided as part of the Log and Graph, Page 28. The resulting series of curves will appear as shown in the sketch below. Directions to formulate the series of curves are described below:



First, develop curve a-a by simply plotting the appropriate logged data on the graph section. Indicate units of pressure and temperature used.

Next develop and overplot b-b as follows: Multiply the pump rise value recorded at 120°F during the previous **Cavitation Test** by the decimal value of 100% minus the percent of allowable pump rise loss acceptable for the engine model being reviewed. Refer to Page 4 for acceptable values of allowable pump rise loss. Plot b-b to intersect a-a. The projection of the intersect point, c, downward establishes the air venting capability value, d, of the system. This value should also be entered in the designated box.

If the test value is equal to or exceeds the requirement, the air venting capability of the system is satisfactory.

Possible Difficulties if Air Venting Requirement is Not Met:

Nonshunt-Type of Cooling System:

1. Excessive water velocity in radiator top tank.
2. Engine water entering radiator top tank is aerated.

Shunt-Type of Cooling System:

1. Excessive water velocity below baffle.
2. Vent tube too small.
3. Vent tube too close to water entrance.
4. A dome in the baffle at the vent tube location may permit localized velocity reduction and better air removal capability.

Note: The solutions to the above problems may have to be reviewed with Cat factory application personnel.

8.0 Heat Transfer Test

This test is to determine at what ambient air temperature the maximum Engine Outlet Temperature Design Limit will be reached.

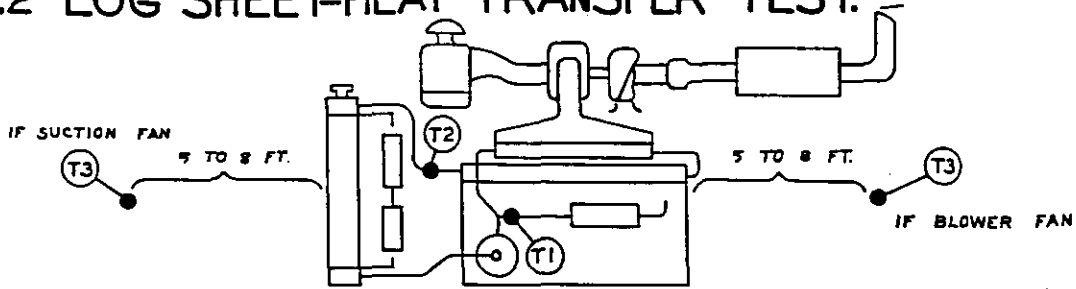
Engine Preparation

- Blocked Open Thermostat(s)
- Cooling System **Completely** Filled with Water
- Standard Pressure Cap
- Engine Lubrication Level Adequate
- Method of Loading Engine
- Instrumentation as Described in Pages 10 through 18
- Cab heater(s) closed (if so equipped)

8.1 Procedure

1. Prior to applying the load to the engine, increase the water temperature leaving the engine to approximately 200°F. Use cardboard to block the air flow to the radiator to increase the water temperature. The purpose of this is to minimize loaded time by prewarming the engine.
2. Apply full or a known load to the engine and then remove the cardboard. Begin recording data using the Log Sheet on Page 31. Continue to log data every 5 minutes until the temperature difference between the ambient and water out of the engine is stabilized. A minimum of 30 minutes is usually required for this condition to occur. Obviously, remove the load and stop the test if the water temperature out of the engine exceeds 210°F or the limitation of the engine loading method has been reached.
3. Refer to Test Results Review on Page 32 for interpretation of data.

8.2 LOG SHEET-HEAT TRANSFER TEST.



(SEE PAGE 10 THRU 18 FOR PROBE LOCATIONS)

JW = JACKET WATER

MINIMUM DATA NEEDED			1	2	3	4	5	6	7	8	9	10	11
A	READING NO.												
B	TIME												
C	ENGINE SPEED	RPM											
D	ENGINE LOAD	*											
E	JW TO ENGINE	T1											
F	JW FR ENGINE	T2											
G	AMBIENT	T3											
H	JW ENG. RISE	T2-T1											
I	COOLING DIFF.	T2-T3											
J	MAX. AMB. CAP. 210 - (T2-T3)												

SEE INSTRUCTION ON PAGE 34 TO:

1. PLOT AND INTERPRET DATA.

2. REVIEW POSSIBLE SOLUTIONS IF REQUIREMENTS ARE NOT MET.

* HP OR KW AS INDICATED BY
LOAD MEASURING DEVICES

MINIMUM DATA NEEDED			12	13	14	15	16	17	18	19	20	21	22
A	READING NO.												
B	TIME												
C	ENGINE SPEED	RPM											
D	ENGINE LOAD	*											
E	JW TO ENGINE	T1											
F	JW FR ENGINE	T2											
G	AMBIENT	T3											
H	JW ENG. RISE	T2-T1											
I	COOLING DIFF.	T2-T3											
J	MAX. AMB. CAP. 210 - (T2 - T3)												

RESULTS

MEETS REQUIREMENTS

REQUIREMENTS

YES

NO

TEST DATE		APPLICATION	
ENG. MODEL & S/N		PERFORMED BY	
RATING & SPEED			

8.3 Test Results Review — Heat Transfer

Although the log sheet is mostly self-explanatory, additional guidance is presented for the processing of data.

1. Logged Data:

When T1, T2, and T3 are processed by Steps H and I, the maximum ambient capability, J, will develop for each column. Generally, the first J values do not represent the true ambient capability because temperatures have not stabilized yet. Stabilization conditions exist when (a) engine speed and full load have been constant for at least 15 minutes, and (b) consecutive sets of readings obtained within a 5-minute interval are identical. Record the J value that meets the stabilization criteria in the "Results" block on the log sheet.

2. Correction Factors:

There are times when adjustments will have to be made to the cooling differential, I, as developed on the log sheet, because test conditions were not ideal. The subsequent J value will change, too.

The following testing circumstances require an adjustment:

Antifreeze:

Since the heat transfer test is conducted with water as a base, an additional correction is required if a 30% to 50% ethylene glycol antifreeze solution will be used year-round. Increase the differential, I, 6°F.

Engine Load Below Rating:

Increase the differential, I, by multiplying by the ratio of the engine rating over the actual test load.

If fuel rate data is available, increase the differential, I, 1°F for each 1% that the measured full rate drops below rated fuel rate.

Test Ambient Below 90°F:

Increase the differential, I, 0.5°F for each 10°F test temperature below 90°F.

Highway Trucks:

Headwind — Reduce the differential, I, 5°F if a 15 mph headwind is not available.

Air Conditioner — Increase the differential:

- a. 3°F, with radiator-mounted condenser core installed but with the unit not operating.
- b. 7°F, when no radiator-mounted condenser core is installed but will be offered later on that truck model.

3. Final Interpretation:

After the appropriate correction factors are applied, insert the final J value (maximum ambient capability) in the "Results" block on the Heat Transfer Log Sheet, 8.2. Compare the J value with the value previously placed in the "Requirements" block. Obviously, the "Results" value should be equal to or exceed the "Requirements" value to be satisfactory.

Altitude:

If the test is performed above sea level, decrease the differential, I, 2.5° per 1,000 ft.

4. Problems:

Not Meeting Requirements:

Several paths exist to improve heat transfer capability depending on the seriousness of the deficiency. The following steps range from the simple to more extensive work:

- a. Tighten up loose fan belt.
- b. Reduce air recirculation around radiator.
- c. Minimize air flow restriction to and from radiator.
- d. Improve fan and radiator shroud relationship.
- e. Increase fan to core distance.
- f. Increase fan speeds within limits of fan tip speeds and fan belt capacity.
- g. Increase heat transfer surface:
 - (1) More Fins per Inch
 - (2) Closer Tube Spacing
 - (3) Deeper Core
 - (4) Larger Frontal Area

9.0 Filling Test

This test is to determine if the cooling system has a false filling characteristic using a bucket or hose method. A second purpose is to measure the volume of the cooling system.

9.1 Engine Preparation

- Engine drained completely prior to the bucket and hose fill test.
- Normal thermostats.
- Use Log Sheet, Page 33, to record data.
- Cab heater(s) open (if so equipped).

9.2 Bucket Fill (Test Procedure)

Pour the contents of a known bucket volume (12 quarts recommended) into the radiator top tank as quickly as possible. When the water level has disappeared, pour in another bucket of water. Repeat this procedure, allowing the water to come to rest between bucket additions, until the filler neck overflows.

Start the engine and run at low idle for a few minutes without the radiator cap. Then increase the engine rpm to rated speed and note if the water pump is developing pressure and whether the water level is dropping in the top tank. Hold rated engine speed until the thermostats start to open (165°F to 190°F) at the pump. This permits the trapped air, if any, to be purged from the block. Reduce engine speed to low idle and permit the system to cool down.

Stop the engine and measure the amount of water required to fill the system to brim-full. Record this amount.

9.3 Hose Fill (Test Procedure)

Fill the system at a constant 5 gpm rate. Measure the amount of time from initiating the fill until the filler neck overflows. Recheck the hose flow rate after the fill to verify the rate has not changed. Start the engine as in the bucket method to ascertain the pump does not air lock and to determine the hose fill make-up volume. The hose fill make-up volume must be less than 12% (9% 3208) of the total system volume to be acceptable.

9.4 Log Sheet — Filling Tests

Bucket Filling Test:

Cooling System Drained Completely

1. Add incremental buckets of water to completely fill system.

																Volume of Bucket	<input type="text"/>
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16		
○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○		
17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32		
○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○		

System's Volume (Before Starting Engine) (a)

2. Start engine and follow test procedure on Page 32. Is water level below low mark?

Yes No

Water Added to Brim Full (b)

Total System Volume (a + b)

Summary:

Results: (b)

Meets Requirement: Yes

Requirement:

No

Hose Filling Test:

Cooling System Drained Completely

1. Use a water hose and follow procedure on Page 32.

2. Start engine and follow test procedure.

3. Is water below low mark? Yes No

Summary:

Water Added to Brim Full:

Meets Requirement: Yes

Requirement*:

No

* Determine this requirement from the Drawdown Test. "Water Added to Brim Full" should be less than the requirement to pass the test.

9.5 Filling Test Results Review

Difficulties in meeting filling requirements are usually traceable to either manufacturing assembly or design. Each one of these are discussed briefly.

Manufacturing:

Since the passageways for removing the air in the filling process are small, it is important that all machining is completed. Holes not drilled to sufficient depth would fail to vent air out of the system. A careful review of the parts involved in the air-venting path is needed to define this problem.

Assembly:

An omission of scheduled external venting components, such as vent lines, is a possibility. This is especially true with the advent of the "shutterless" system on the truck engines. This system requires all internal bleed lines be blocked to stop coolant leakage to the radiator when the thermostats are closed. An external line has to be implemented that connects the downstream side of the thermostats to the **upper** chamber of the typical shunt-type radiator. If this external line was not installed, a serious filling problem would exist.

Another assembly problem involves the shunt line itself. If this line does not slope continuously downward from the radiator to the engine or is installed with kinks, the flow path of the coolant will be slowed down.

Design:

Several areas of possible design deficiencies exist:

1. Air vented from system has to pass through a layer of incoming coolant.
2. The shunt line I.D. is too small. This is not only critical for filling but will affect the cavitation temperature.
3. Exit or entrance of shunt line is too restrictive.
4. Shunt line runs horizontal after it exits from the radiator top tank, or an equivalent situation occurs within the top tank. An air lock will tend to occur, especially with the bucket-filling procedure.

10.0 Reliability Assessment of System

A sometimes overlooked aspect of cooling system design is the reliability of its components to survive a reasonable life span. A system may pass all of the measurable requirements, as specified on Page 3, but fails prematurely. The following areas should be reviewed to avoid premature failures:

10.1 Clearances

1. Provide adequate space between all moving or rotating parts (such as fans, pulleys, and Vee belts) and stationary components (such as hoses, brackets, shrouds, etc.).
2. Fasten with durable straps, brackets, etc., any components that may come into contact with moving parts after a period of time.
3. Provide space and heat-transfer shielding to protect components such as hoses from hot exhaust manifolds.

10.2 Piping — Radiator Inlet and Outlet

1. All piping should have beaded ends whenever rubber hose connectors are used.
2. Brackets should be used to support piping rather than rely on hose connectors.
3. Pipe I.D. should be equal to or larger than the inlet and outlet of the engine.

10.3 Hoses

1. Material should be compatible with the temperatures and pressures of coolant expected.
2. Ideally, inlet hoses should be short and limited to the connection of pipe. Long hoses on the pump inlet will be susceptible to collapsing if a vacuum exists.

10.4 Hose Clamps

1. Do not use spring loaded wire clamps.
2. Use hose clamps with hexagonal bolt heads for adequate wrench torquing.
3. Use wider clamps on silicon hoses to maintain tension.

10.5 Pulley Belt

1. The belt-tightening mechanism should be accessible.
2. Vee belt horsepower capacity should be reviewed if a different fan or a higher speed ratio drive is considered.

10.6 Coolant Drain Hardware

1. Conventional pipe plugs or straight plugs with copper washers **are recommended**.
2. **Avoid** thumb-tightened drain plugs susceptible to opening from vibration or accidental jarring.

11.0 Summary

Engine Model and Rating _____

Application _____

11.1 Cooling System Components

Radiator	Fan
Manufacturer	Manufacturer
Manufacturer No.	Manufacturer No.
User's No.	User's No.
Core Width & Height	Diameter
Frontal Area	No. of Blades
Core Type	Blade Angle
Core Depth	Fan Drive Ratio
Fins Per Inch	Fan Speed
Fin Type	Fan hp @ Rated Engine Speed
Tube Size	Fan to Radiator Core Clearance
No. of Tubes	
Rows of Tubes Deep	
Pressure Cap Setting	

1.2 Test Results (From Sections 5.2, 6.2, 8.2, and 9.2)

Test	Results	Requirements	Meets Requirements Yes or No
Cavitation			
Drawdown			
Air Venting			
Filling			
Hose			
Bucket			

Review of Section 10 (Reliability Assessment of System)

Satisfactory _____

Unsatisfactory _____

Caterpillar NPR Response: 22Apr96 3:23:18 PM 0466553
PTN: 48-6553 GC: 00 NPR: 1 COD: D SEQ: PAG LBS: 23.00 KLG: 10.433

(2) PART NAME	(3) SERVICE PART NO	(4) WHERE USED OR SIZE	SEQ
#0	* 1-1U5470 ✓	* DEALERS TOOL-DIAGNOSTIC	001
INSTRUMENT G	* 1-9U7400	*	
ENGINE	* SEH97341	*	
ENG CHGS- 00	* SMJA2681 F19E10	*	
END	* SMMA3081 F19J3	*	
	* SMFE0182 F22A10	*	
	* TEFE1782 F1E2	*	

NPRS 1234 7

001 SEQ 001

\$2000
MULTI TACH 11 947900
V PRESS GRP 1U5470
14000