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Pilot Inst. Center No.	
Test Project No.	Title HEAT REJECTION TESTING ON A PHASE III, 4T-390 CASE/CUMMINS ENGINE
Other	Author M. Thommen
Date 4/29/81	
Dept. No. 0502	Dept. Name Engine Projects

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SUMMARY

PURPOSE: To define heat rejection of a Case/Cummins, Phase III 4T-390 turbo-charged engine with piston cooling jets.

SUMMARY: Test work was carried out in test cell 110. Results showed:

1) Heat rejection to cooling water varied from 17.5% (@ 2500 RPM) to 26% (@ 1000 RPM) of fuel energy for 230°F oil pan temperature and from 16% (@ 2500 RPM) to 24% (@ 1000 RPM) for 200°F oil pan temperature.
2) Heat rejection to oil varied from 3.5% (@ 2500 RPM) to 5.5% (@ 1000 RPM) of fuel energy for 230°F oil pan temperature and from 6% (@ 2500 RPM) to 7.5% (@ 1000 RPM) for 200° F oil pan temperature
3) Combined heat rejection to cooling water and oil exceeded to target (22% of fuel energy). Maximum is 30% (@ 1000 RPM and minimum is 23% (@ 2500 RPM).
4) Earlier heat rejection measurements on a Phase II engine (40521110) show very good agreement in heat rejection to oil at 230° F oil pan temperature.

ACTION: Keep data in file for upcoming heat rejection test work.

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DISCUSSION

Heat rejection test work was done on a 4-cylinder, Phase III engine 4T-390 (40521138). The engine has only been tested below 2500 RPM to prevent it from piston seizing. Actual engine performance is shown in Attachments 1 and 2. All results are presented in metric units and heat rejection also as a percentage of fuel energy (42.5 MT/kg). All measurements were taken at 200°F and 230°F oil pan temperature.

Turbine meters were used for both oil and water flow. On the oil circuit, two meters were installed; one at the entry of the oil cooler and the other one at the outlet. Since the oil flow meters are volume and viscosity calibrated, a calibration program was developed and used for each test configuration. Both oil flow meters agreed therefore always within about 2%.

Two sets of R.T.D.'s were used to determine the temperature, both for oil and water. Two temperature differential transducers were installed in parallel to verify the readings. A resolution of .1°C was subsequently obtained for temperature differential on all devices. This, together with the estimated error for flow measurements, indicates that rejection to water is accurate within ± 3% and to oil ± 4%.

Attachments 3 and 4 show detailed results of heat rejected to engine oil. Earlier measurements from a Phase II engine (40521110) with 230°F oil pan temperature are plotted into Attachment 3. Heat rejection to oil as a percentage of fuel energy remains more or less constant over the whole engine speed range.

Attachments 5 and 6 contain the detailed results of heat rejection to engine coolant water. Heat rejection to water as a percentage of fuel energy decreases over the whole engine speed range and can be explained easily by physics of heat transfer.

$q = h \cdot \Delta T$ and $Q = A \cdot q$

$Q = A \cdot h \cdot \Delta T$

$P = Q \cdot t = \int A \cdot h \cdot \Delta T \cdot dt$

$P = \frac{60}{RPM} \int A \cdot h \cdot \Delta T$

A = area
h = heat transfer coefficient
q = specific heat flow
Q = heat flow
P = total heat transferred in cycle
T = temperature
t = time

That is at higher engine speeds, there is less time for heat transfer per unit mass of fuel, so that heat transfer decreases. Of course, heat rejection to coolant water is not absolutely inversely proportional to engine speed as heat transfer coefficient h and temperature differential ΔT both will vary with engine speed. Therefore, the target of a constant heat rejection of 22% over the whole speed range may have to be revised because of colliding with physics of heat transfer.

Attachment 7 shows heat rejection to oil and water. Target cannot be met, as already explained above.

A distribution of fuel energy to the different media is shown in Attachments 8 and 9.

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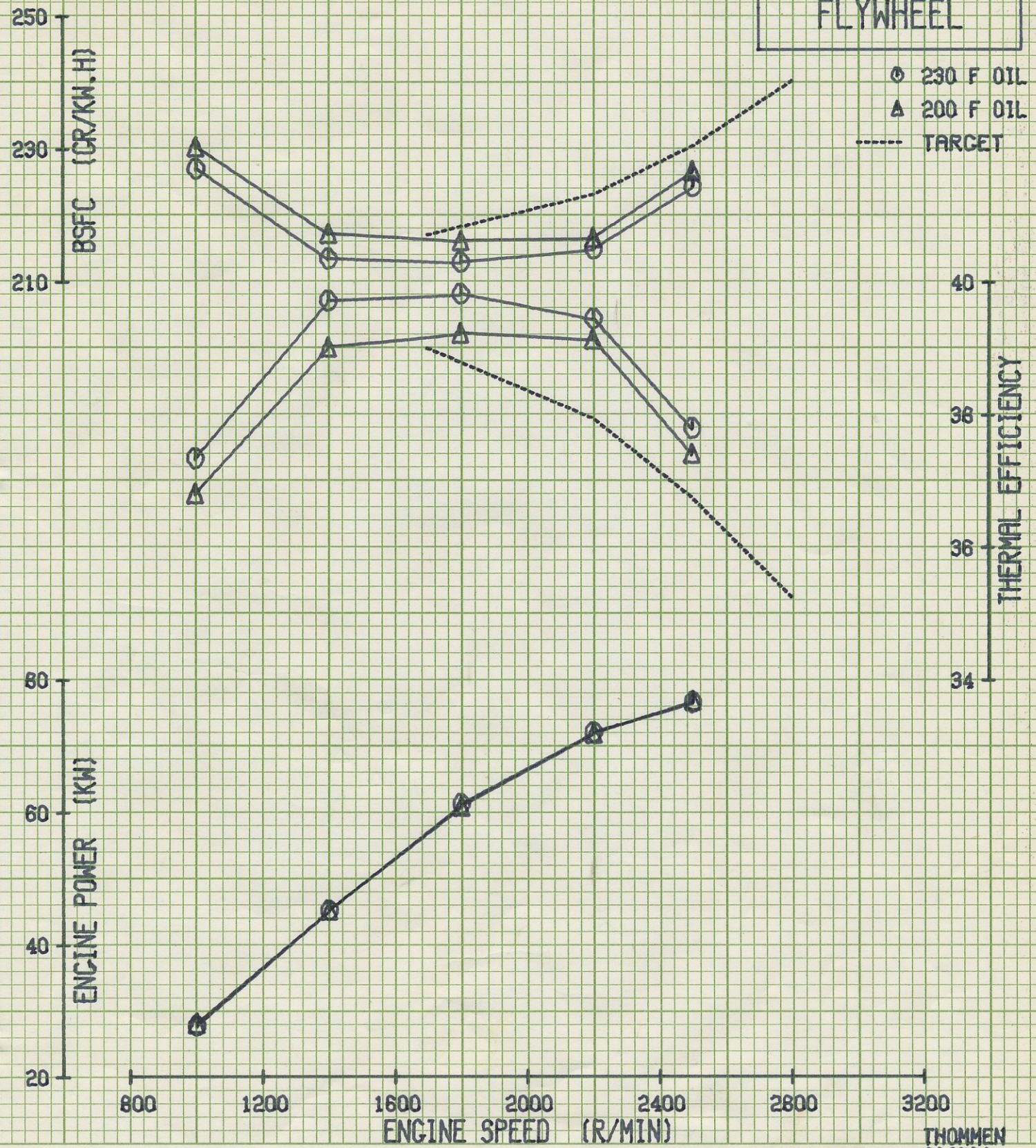
Attachments

4T-390 40521138	HEAT REJECTION FAMILY-1 PHASE-3 4CYL TURBOCHARGED

FLYWHEEL



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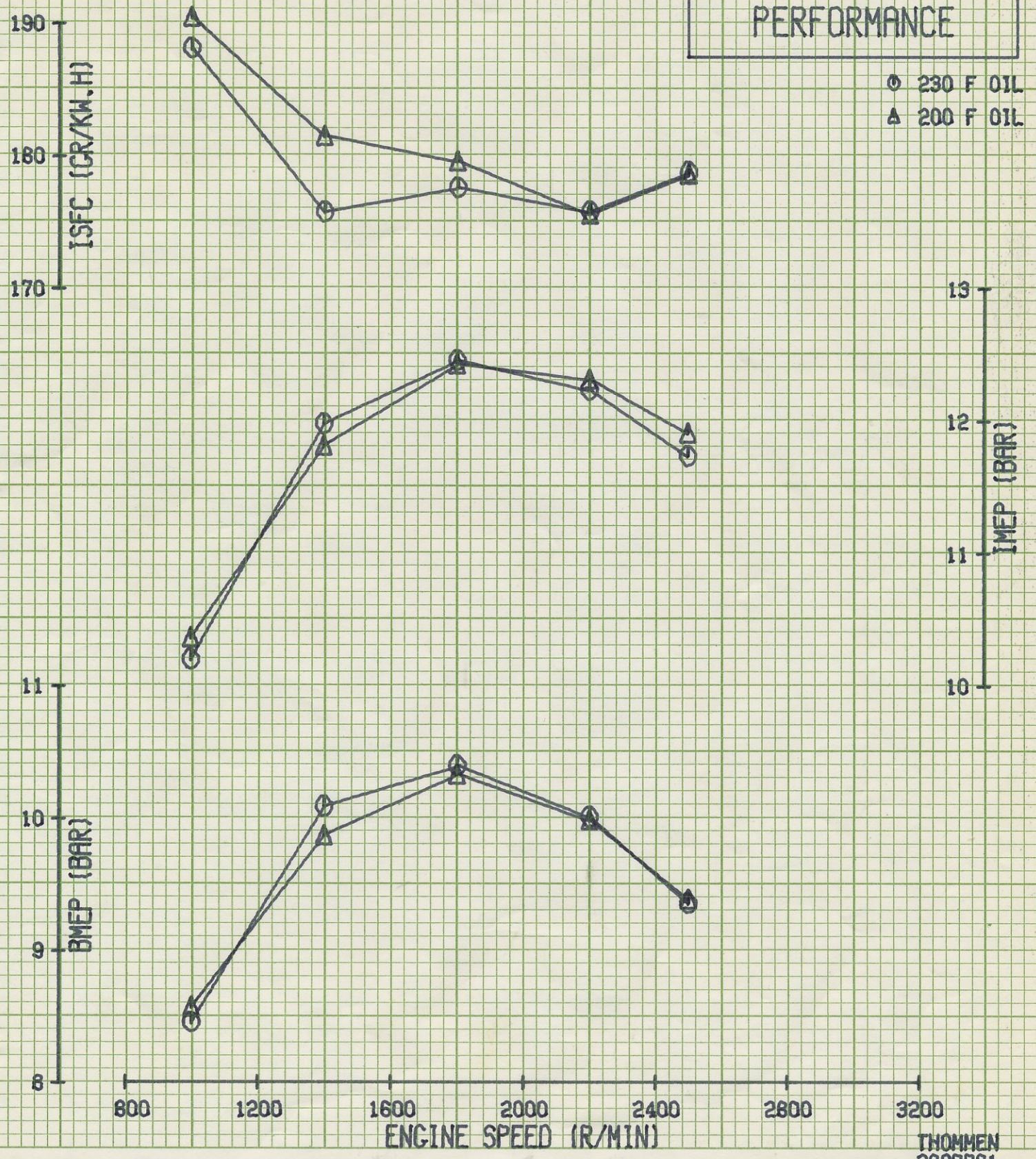
4T-390 40521138	HEAT REJECTION FAMILY-1 PHASE-3 4CYL TURBOCHARGED

PERFORMANCE



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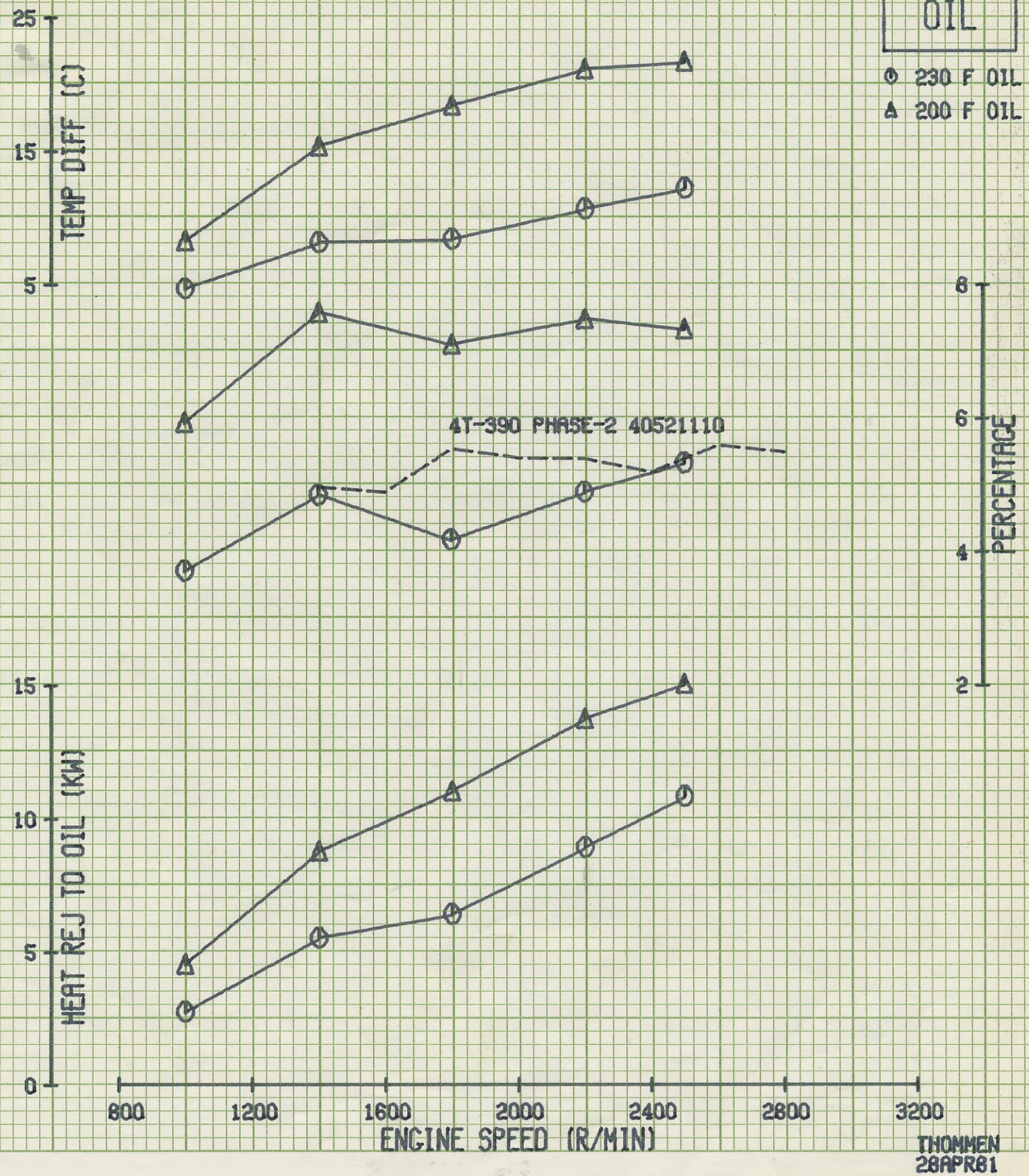
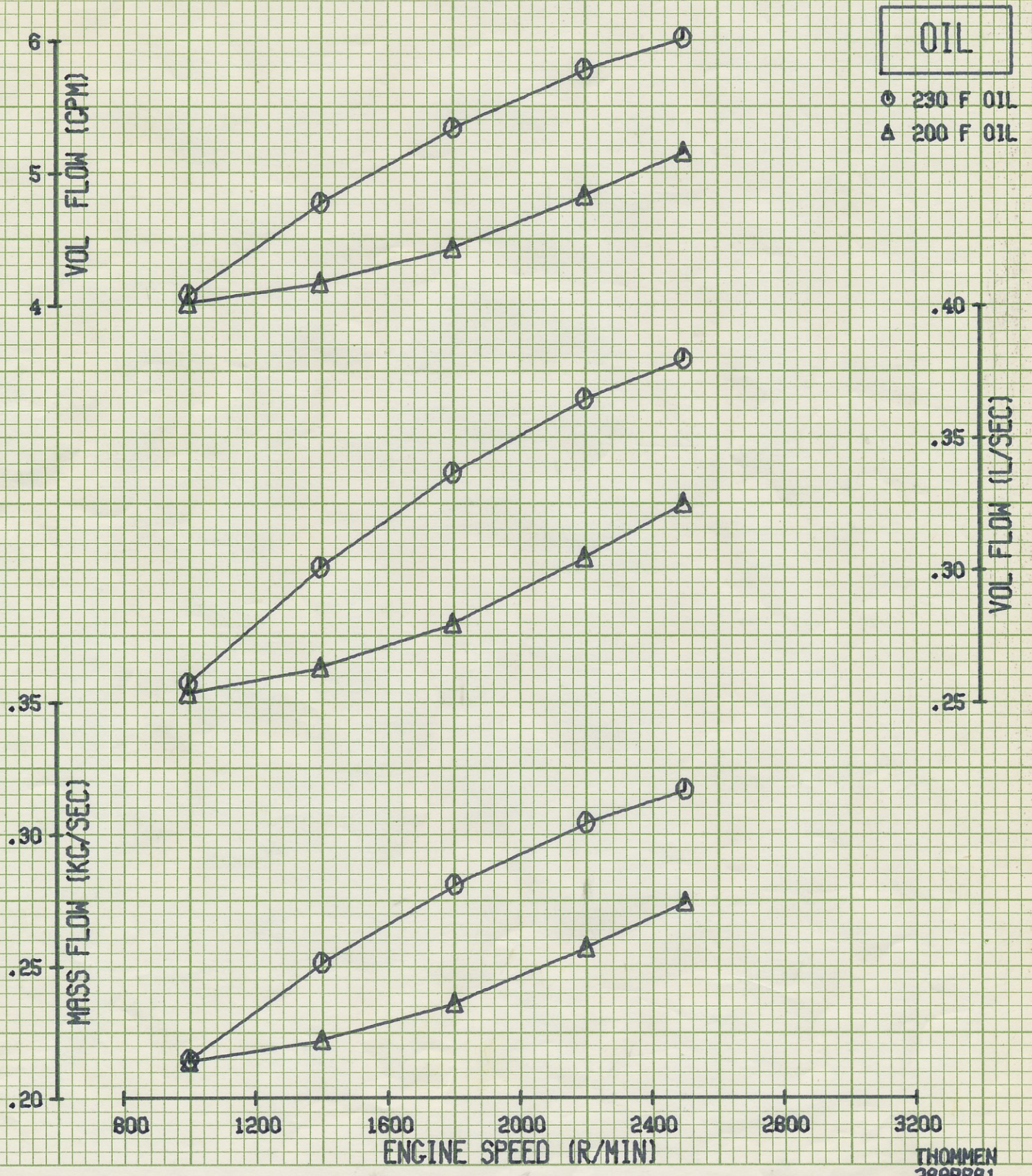
4T-390 40521138	HEAT REJECTION FAMILY-1 PHASE-3 4CYL TURBOCHARGED



Cummins

4T-390 40521138	HEAT REJECTION FAMILY-1 PHASE-3 4CYL TURBOCHARGED



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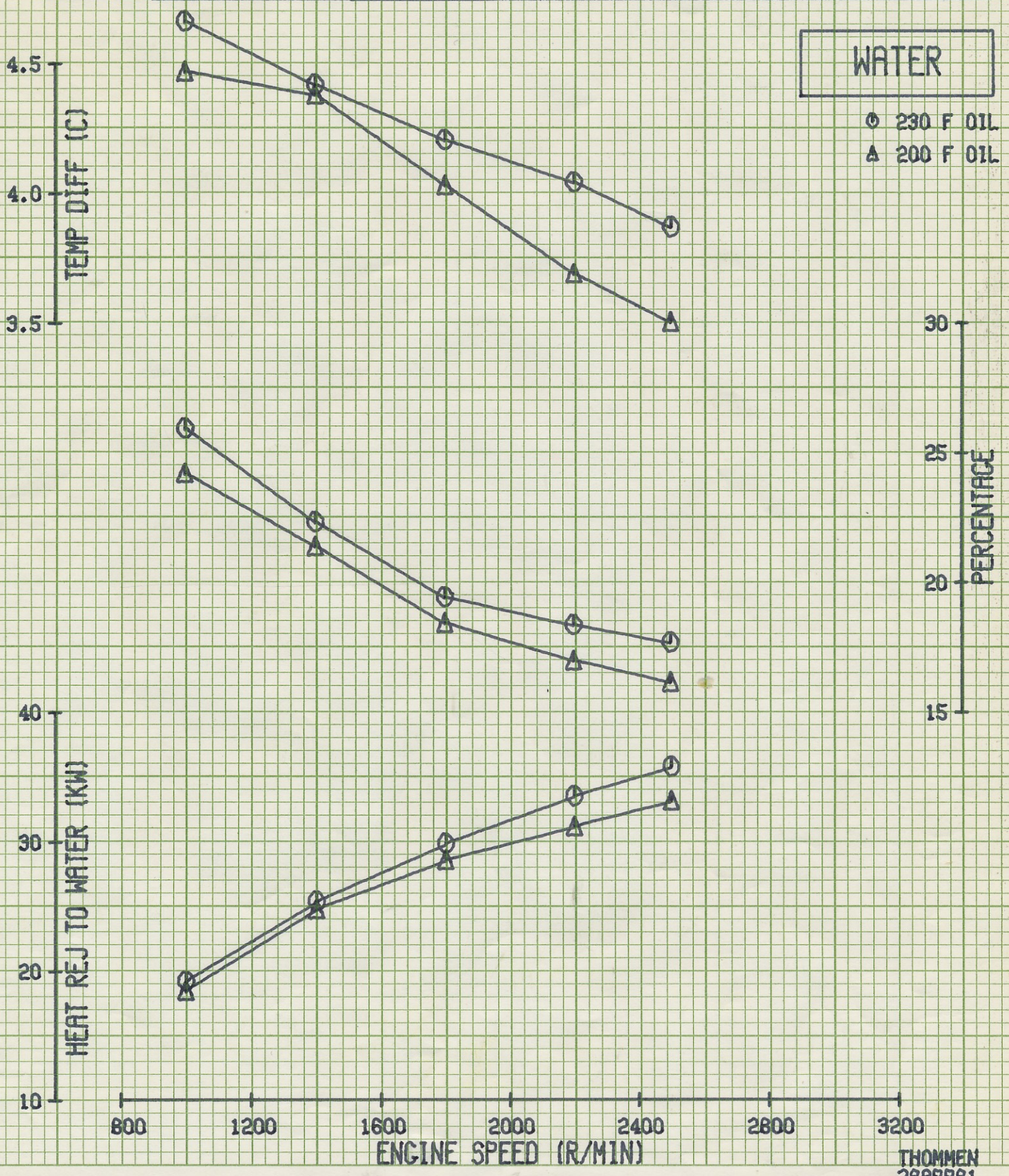
4T-390 40521138

HEAT REJECTION
FAMILY-1 PHASE-3
4CYL TURBOCHARGED



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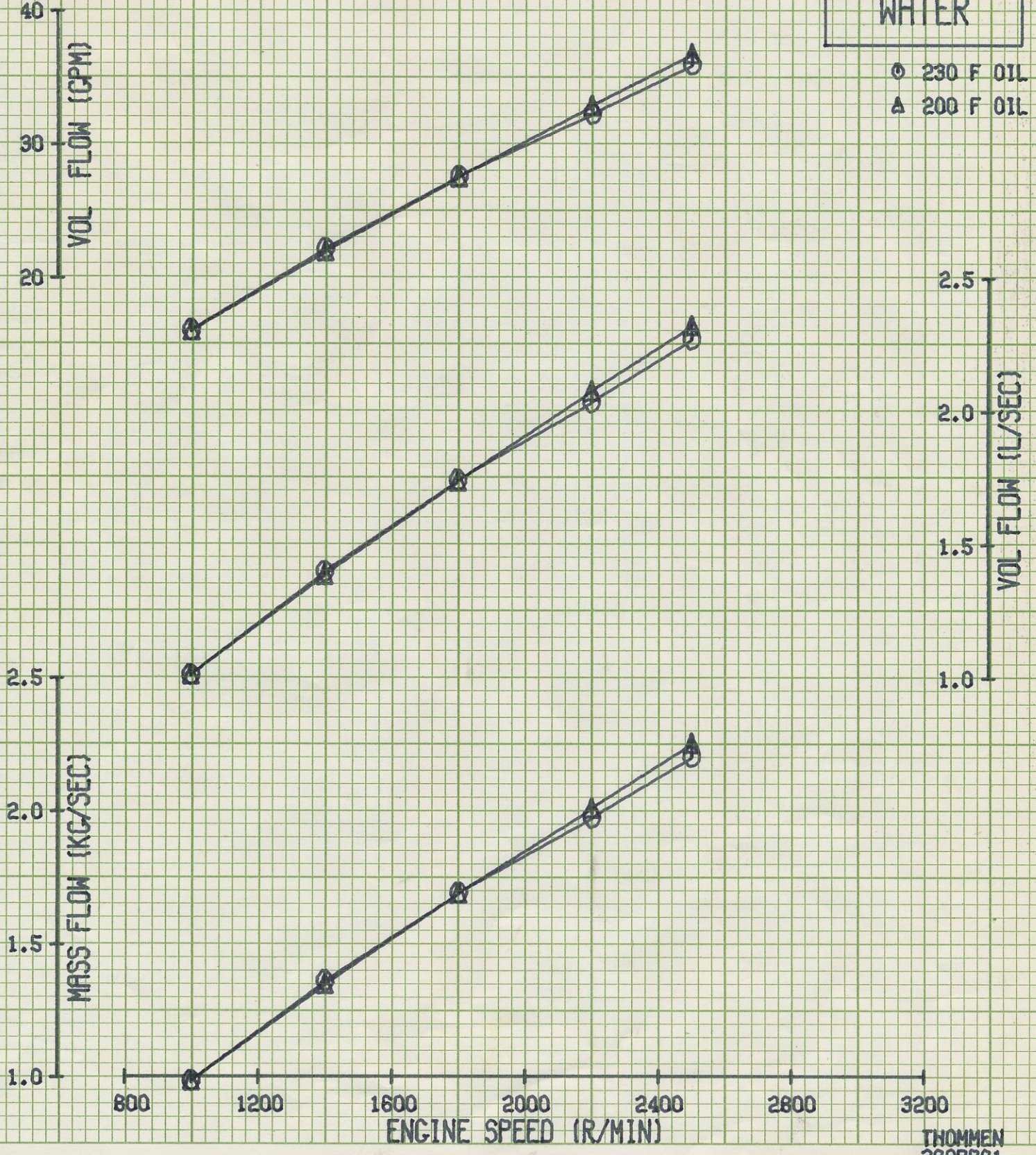
4T-390 40521138	HEAT REJECTION FAMILY-1 PHASE-3 4CYL TURBOCHARGED

WATER

⊙ 230 F OIL

△ 200 F OIL



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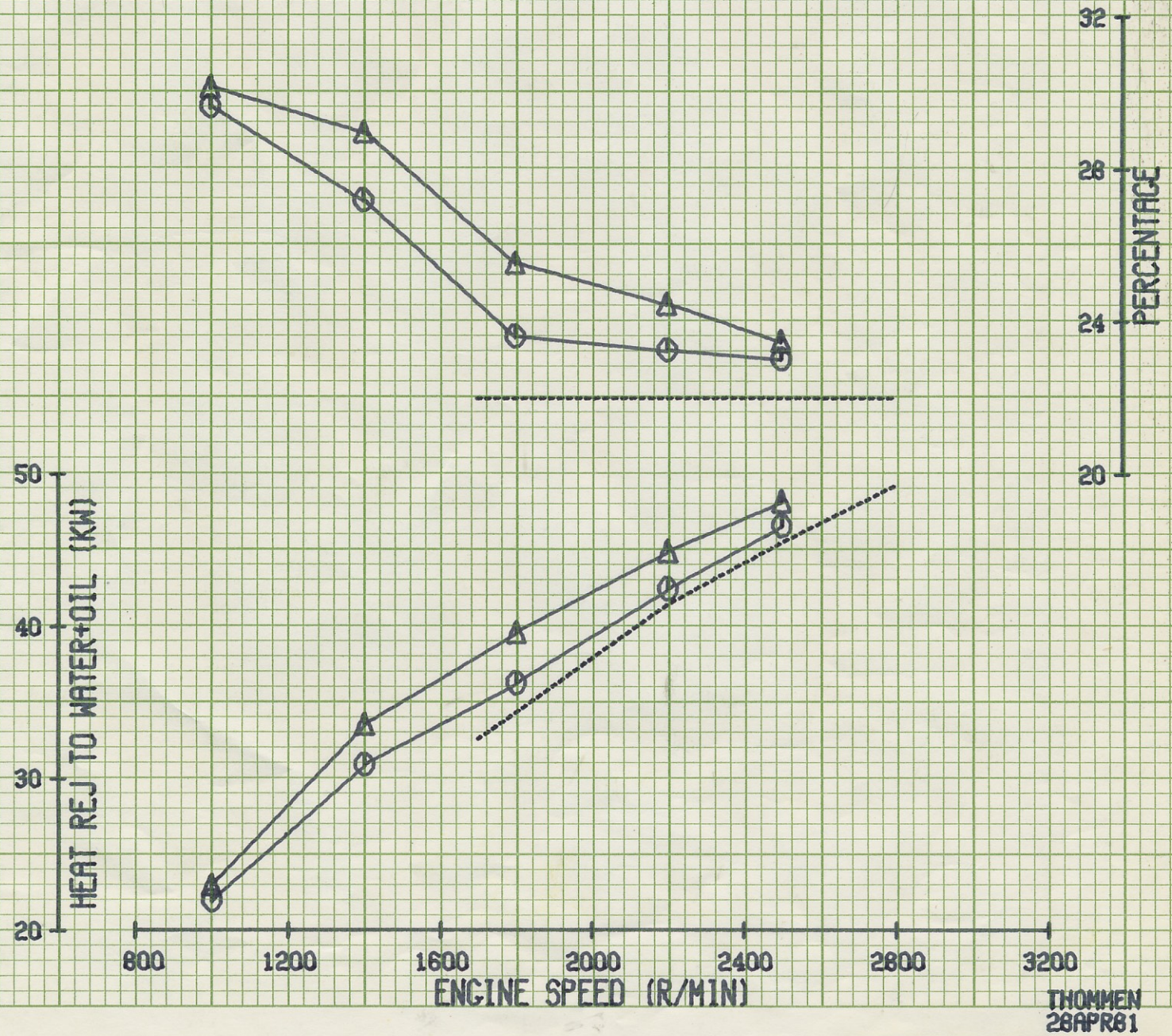
4T-390 40521138	HEAT REJECTION FAMILY-1 PHASE-3 4CYL TURBOCHARGED

WATER+OIL

⊕ 230 F OIL
Δ 200 F OIL
------ TARGET



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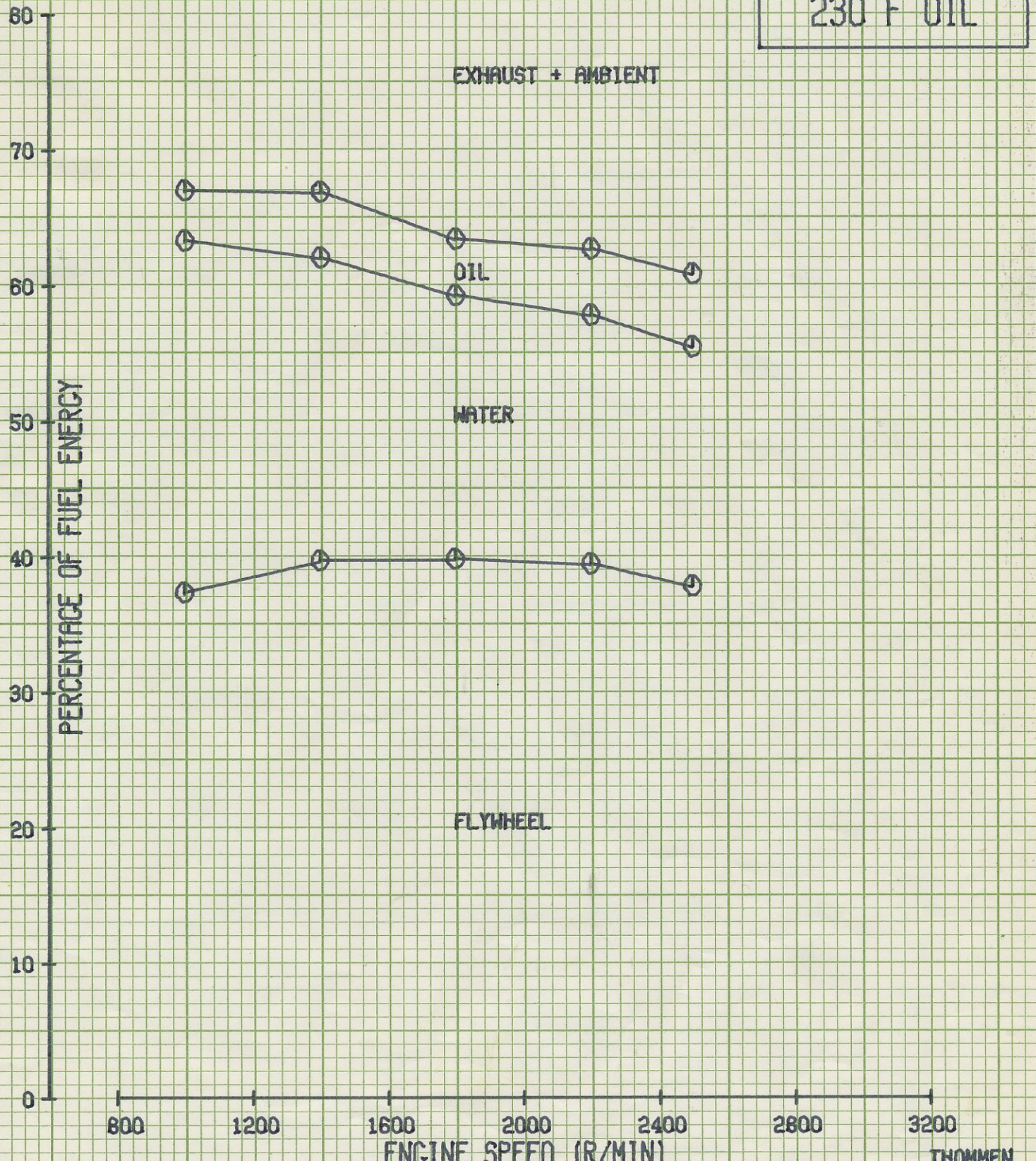
230 F OIL



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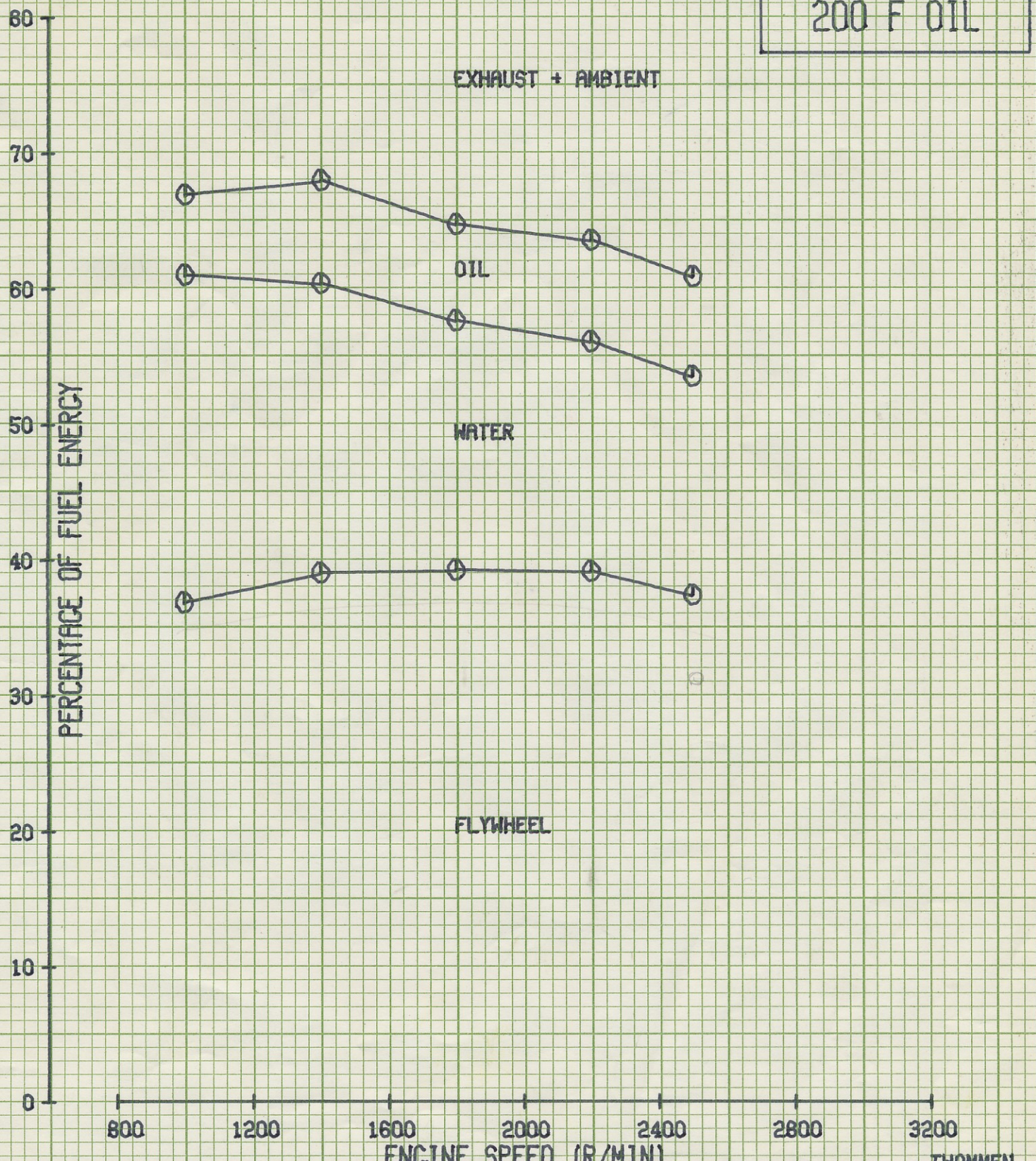
4T-390 40521138	HEAT REJECTION FAMILY-1 PHASE-3 4CYL TURBOCHARGED

200 F OIL



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