NCAT – National Center for Advanced Technology

National Vehicle and Fuel Emissions Laboratory
Office of Transportation and Air Quality
U.S. Environmental Protection Agency

The following material was prepared by FEV Engine Technology under EPA Contract EP-C-12-014 and describes the test procedures performed by FEV on the Jatco CVT8 transmission. Use of any NCAT material provided below, included as part of the complete test data package, should reference the suggested citation provided.

SUGGESTED CITATION: *2013 Nissan Jatco CVT8 Transmission Mapping – Test Data Package*. Version 2019-07. Ann Arbor, MI: US EPA, National Vehicle and Fuel Emissions Laboratory, National Center for Advanced Technology, 2019.

Prepared for

Environmental Protection Agency

Presented: May 23, 2016

Agenda

- Transmission Specifications
- Procurement & Break-In
- Strategy/Control Assessment in Vehicle
- Bench Test Setup and Spin Loss Testing
- Neutral Coast Down Testing
- Loaded Efficiency Testing
- Inertia Evaluation
- Oil Pump Efficiency Testing
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Nissan Altima CVT – Benchmark
Transmission Specifications

Contract No. EP-C-12-014, Work Assignment 4-11
May 23, 2016

OVERVIEW

- Transmission Model: Nissan CVT8
- Vehicle Application: 2013 Nissan Altima
- Transmission Torque Capacity: 250 Nm
- Transmission Weight: 87 kg
- Fluid Capacity : 7.4 L
  - Fluid Change Interval: 60k mi. normal use, 20k mi. if towing
- Transfer Design: PGS, Steel Belt
- 'Gear Ratios' (incl. final drive): 12.8 – 1.83
- 'Gear Ratios' (variator range): 2.65 – 0.38
- Final Drive: 4.829
- Ratio spread: 7:1

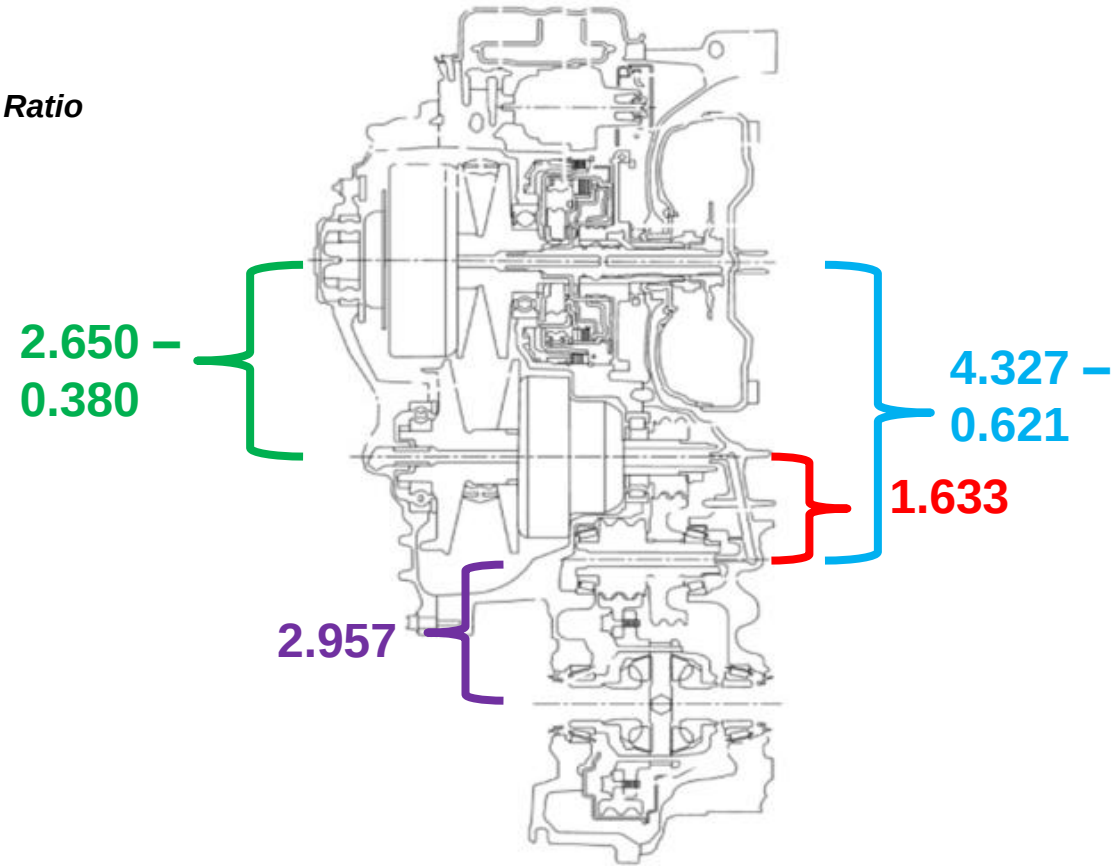
Nissan Altima CVT – Benchmark Transmission Specifications

Contract No. EP-C-12-014, Work Assignment 4-11
May 23, 2016

OVERVIEW

	Underdrive	Overdrive	Final
Variator Ratio	2.650	0.380	2.957
Variator Ratio incl. 1.633	4.327	0.621	

Gear Ratio



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Nissan Altima CVT – Benchmark
Procurement and Break-In

Contract No. EP-C-12-014, Work Assignment 4-11
May 23, 2016

OVERVIEW

- Purchased spare CVT transmission and install in EPA's test vehicle (CVT#2)
  - Perform 1,200 mi transmission break-in on road
  - Return vehicle to EPA after new transmission break-in
    - During break-in, pressure tap failed and transmission suffered minor damage due to pressure loss
    - Transmission remained in vehicle
- Prepared removed vehicle transmission for test bench (CVT#1)
  - Performed spin loss testing on 'vehicle' – transmission (CVT#1)
  - Transmission got damaged during first runs of loaded efficiency due to pressure sensor fault
    - Test transmission was replaced with a new unit (CVT#3)
    - Transmission break-in was performed on test bench
  - Remainder of 'complete' transmission tests performed on CVT#3
  - Oil pump testing was conducted on modified CVT#2
  - Both, CVT#2 and CVT#3 were transferred to cost analysis team upon completion of transmission efficiency assessment

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Nissan Altima CVT – Benchmark Strategy/Control Assessment In-Vehicle

Contract No. EP-C-12-014, Work Assignment 4-11
May 23, 2016

OVERVIEW

- Instrumented transmission in vehicle with pressure sensors to capture pulley, clutch and line pressures
- Tapped CAN bus and instrumented flexplate/half shafts to gather additional vehicle/transmission signals (e.g. TISS, ISS, TOSS, engine torque, etc.)
- Performed driving maneuvers (mainly on chassis dyno) to capture system pressures under proposed bench test conditions
  - Ran vehicle at constant ratio to achieve stable hydraulic operation (representative of ‘steady-state’ as intended on bench)
- Analyzed acquired data to evaluate relationship between system pressures and pulley ratio, pulley speed and engine/pulley torque
  - Secondary pulley pressure used during bench test to adjust belt clamping force (to prevent belt from slipping)
  - Pulley ratio adjustments done by modulating primary pulley pressure

Nissan Altima CVT – Benchmark Strategy/Control Assessment In-Vehicle

CVT CONTROL STRATEGY

- In modern CVTs manufacturers apply dynamic/varying safety factors which can result in system pressure trends that are more difficult to predict/extrapolate
  - Reason for varying/increased safety factor (=> varying system pressures) is mainly to protect the belt/pulleys (=variator) from slipping due to high torque impact events such as ABS braking, pot holes or ESP events
  - Increased system pressures result in lower transmission efficiency as the belt clamping forces and (thereby the friction losses) increase
- For the transmission bench test, FEV reproduced the system pressures as observed in vehicle, in order to reproduce real-world operating conditions
  - Beyond that, FEV took selected test points at elevated system pressures in order to gain insight to the transmission pressure sensitivity

Nissan Altima CVT – Benchmark
Strategy/Control Assessment In-Vehicle

VEHICLE TEST PROCEDURE

- Record system pressures at various (constant) ratio/load/engine speed conditions
- Highest of the pulley pressure is ‘dictating’ transmission line pressure
- Secondary pulley pressure is main focus, as this is used in vehicle to realize the clamping force that prevents the belt from slipping => function of transmission load, speed, ratio and safety factor
  - In cell, secondary pulley pressure were adjusted first to establish sufficient belt clamping force, then primary pulley pressure was adjusted to dial in the pulley ratio
  - KsKp was maintained to guarantee stable pulley ratio
- Forward clutch pressure is function of only transmission input speed and input load
- Altima CVT transmission has pressure balancing feature on secondary pulley that compensates for pressure increases as a result from centrifugal effects on at high speeds
  - It was observed that the pulley pressures do not change significantly with pulley speed

Nissan Altima CVT – Benchmark Strategy/Control Assessment In-Vehicle

Contract No. EP-C-12-014, Work Assignment 4-11
May 23, 2016

VEHICLE TEST RESULTS

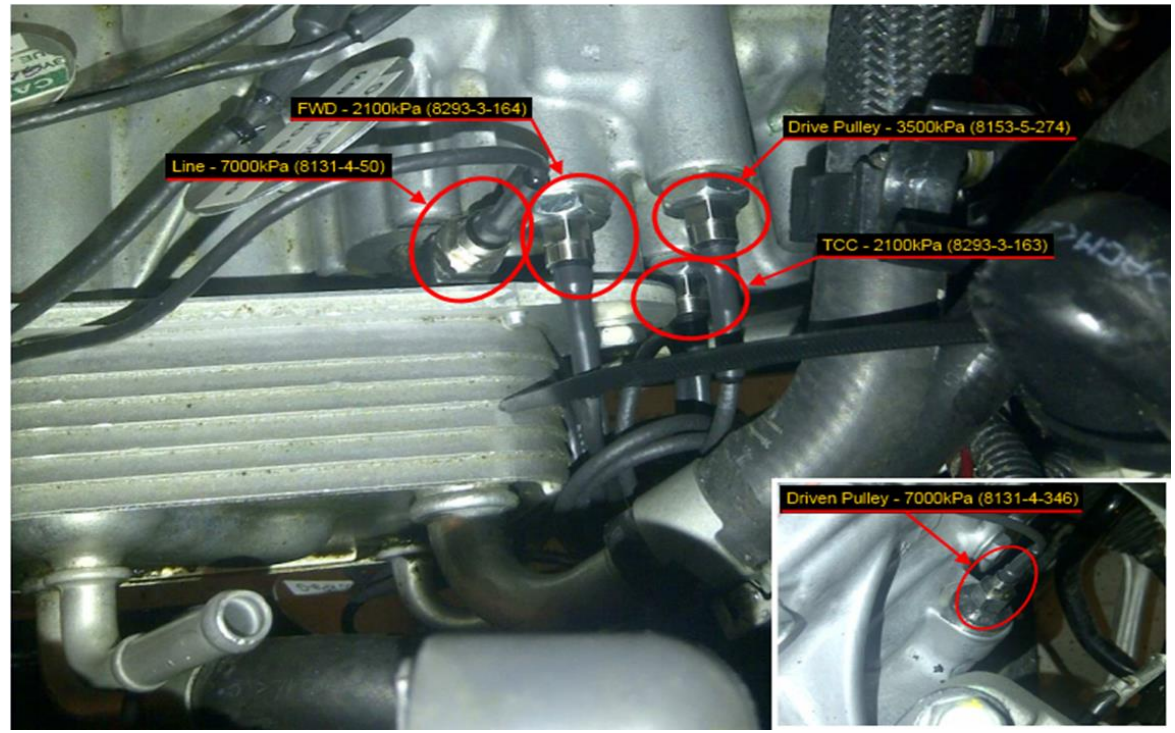
- The following relationships were determined in order to allow for transmission operation in test cell without the use of the TCM
  - Forward clutch pressure <> engine torque
  - Secondary pulley pressure <> engine speed
  - Secondary pulley pressure <> engine torque
  - Secondary pulley pressure <> pulley ratio
  - Line pressure <> engine torque
  - Line pressure <> secondary pulley pressure
  - Line pressure <> primary pulley pressure
- Main outcome of the vehicle strategy identification is a map that shows the relation between secondary pulley pressure, engine load and pulley ratio
- Further, the electric control signals for the transmission solenoids were monitored in order to be reproduced in the test cell

Nissan Altima CVT – Benchmark Strategy/Control Assessment In-Vehicle

Contract No. EP-C-12-014, Work Assignment 4-11
May 23, 2016

VEHICLE INSTRUMENTATION

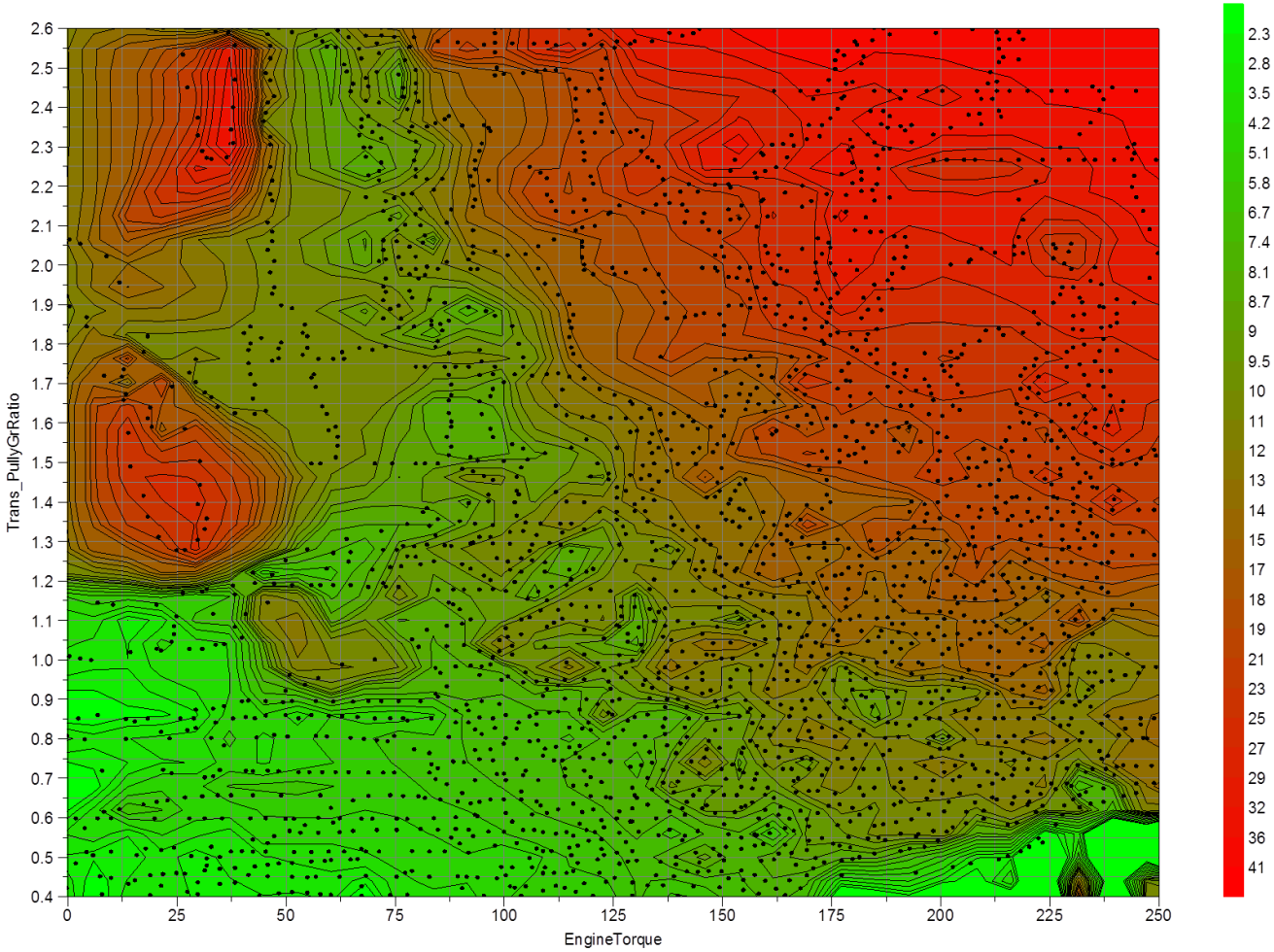
- Vehicle instrumentation updated with 5 additional pressure transducers:
  - Primary pulley pressure [kPa]
  - Secondary pulley pressure [kPa]
  - Forward clutch pressure [kPa]
  - Line pressure [kPa]
  - TCC pressure [kPa]
- The following CAN signals were recorded:
  - Engine speed [rpm]
  - Transmission input shaft speed [rpm]
  - Transmission output shaft speed [rpm]
  - Pulley speed ratio
  - Torque converter clutch state
  - Reported engine output torque [Nm]



Nissan Altima CVT – Benchmark Strategy/Control Assessment In-Vehicle

Contract No. EP-C-12-014, Work Assignment 4-11
May 23, 2016

VEHICLE TESTING RESULTS



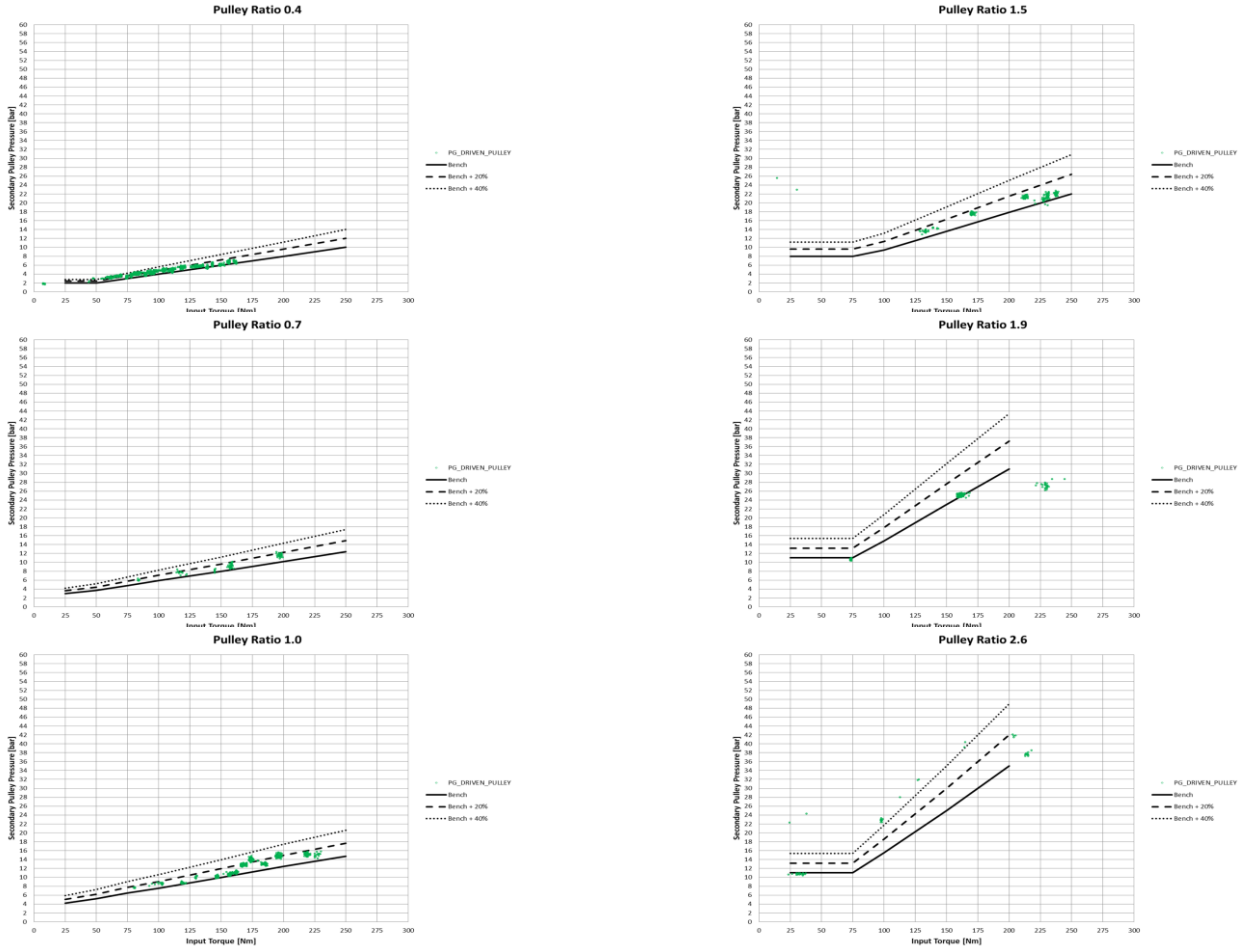
FEV Comments

- Chart shows secondary pulley pressure as a function of input torque and variator ratio
- General trend for driven pulley pressure can be seen:
  - Increasing pressure with increasing load and torque multiplication
- High pressure areas (low torque, high torque mult.) show dynamic safety factor strategy in CVT

Nissan Altima CVT – Benchmark Strategy/Control Assessment In-Vehicle

Contract No. EP-C-12-014, Work Assignment 4-11
May 23, 2016

VEHICLE TESTING RESULTS



FEV Comments

- Plots show secondary pulley pressure over engine load
- Used vehicle data to define lowest pulley pressure observed in vehicle (green points, black solid line)
- Calculated 20% overclamp pressures by multiplying vehicle pressures by 1.2 (dashed black line)

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Nissan Altima CVT – Benchmark
Bench Testing

Contract No. EP-C-12-014, Work Assignment 4-11
May 23, 2016

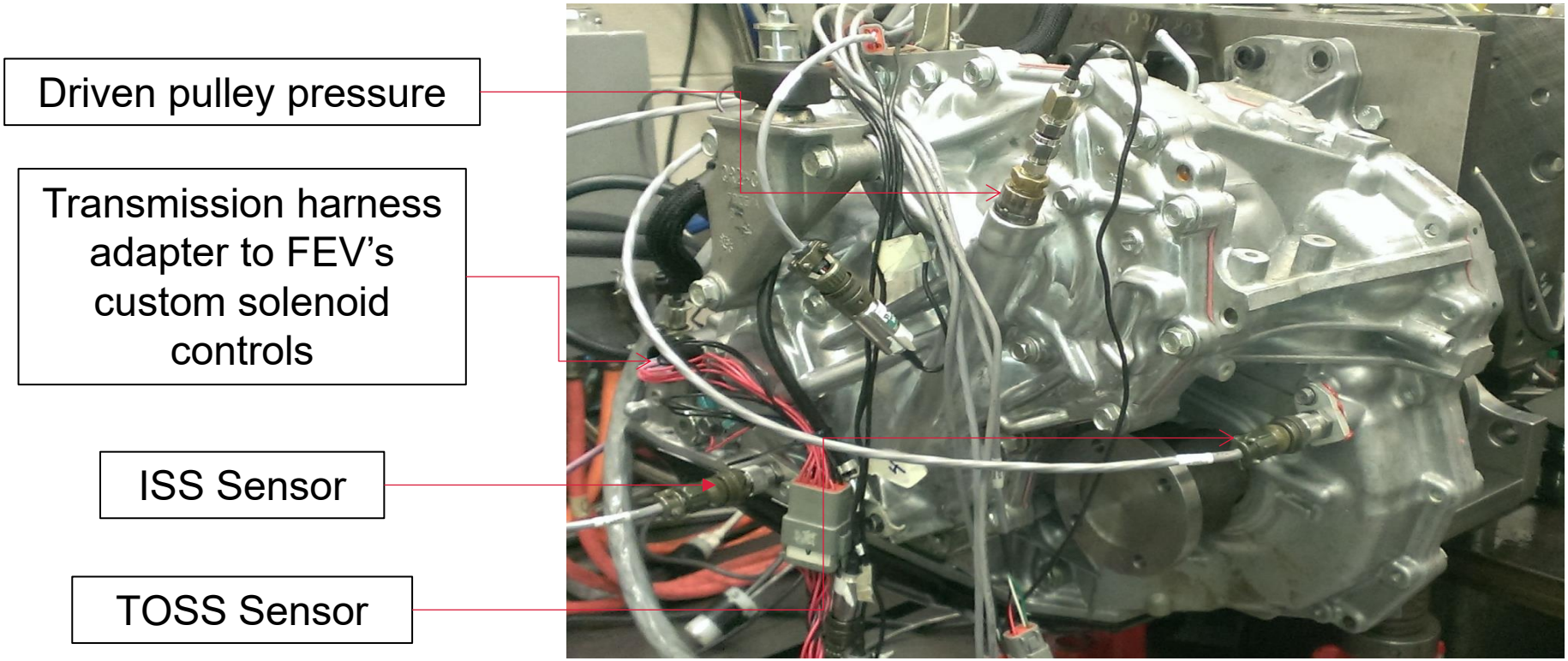
BENCH TEST OVERVIEW

- Spin loss
  - @ 3 temps, 1 pressure (in-car only)
- Neutral coastdown
  - @ 3 temps, 1 pressure (in-car only)
- Loaded efficiency
  - @ 3 temps, ~1.5 pressures (20% overclamp & partial 0% = in-car pressure)
    - Full matrix of in-car pressure-based LE calculated from measured 20% & 0% based sensitivities
- Inertia evaluation
  - @ 1 temp (40°C), 3 ratios (max/min/1.0)
- Oil pump efficiency
  - @ 3 temps, 4 pressures

Nissan Altima CVT – Benchmark Setup and Spin-Loss Testing

Contract No. EP-C-12-014, Work Assignment 4-11
May 23, 2016

BENCH TEST SETUP



Nissan Altima CVT – Benchmark
Setup and Spin-Loss Testing

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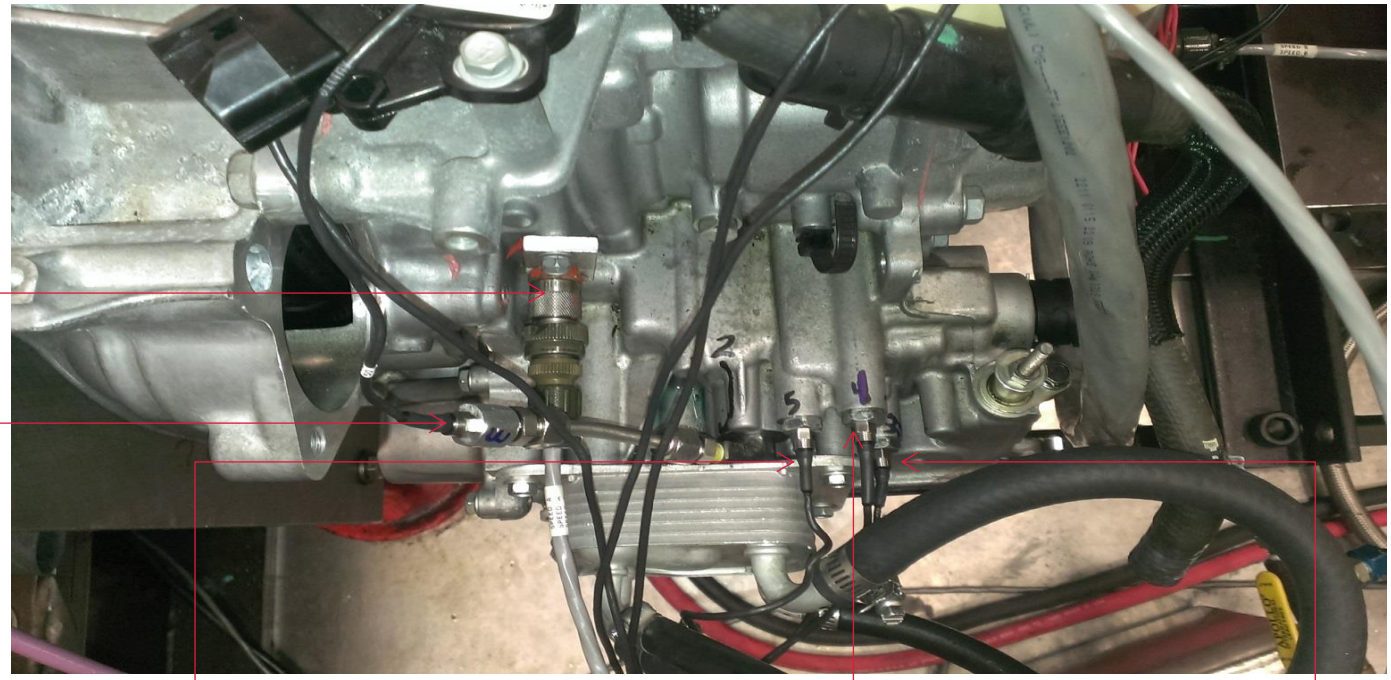
BENCH TEST SETUP



Nissan Altima CVT – Benchmark Setup and Spin-Loss Testing

Contract No. EP-C-12-014, Work Assignment 4-11
May 23, 2016

SPIN LOSS MEASUREMENT – BOUNDARY CONDITIONS

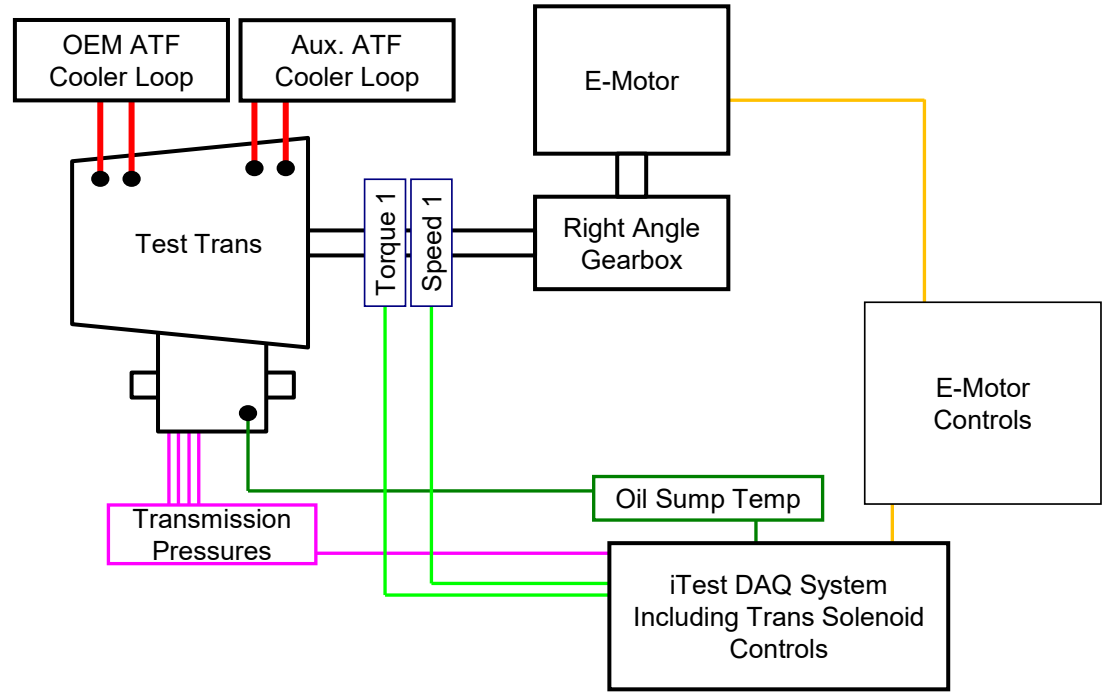
- Gear ratios (6)
  - 0.4 (1.932), 0.7 (3.381), 1.0 (4.83), 1.5 (7.245), 1.9 (9.177), 2.6 (12.588)
- Torque converter clutch locked for all tests
- Input speeds (11):
  - 500 … 5000 rpm (with required limitations for maximum overdrive ratio to avoid unrealistic output speeds)
- Transmission oil temperatures (3):
  - 40°C, 60°C, 85°C
- Transmission system pressures (1):
  - As observed in vehicle (reference table)

Spin Loss Pressure Matrix				
		Line Pressure	**Driven Pulley Pressure**	**Forward Clutch Pressure**
Ratio	**0.400**	4.00	2.00	3.00
	0.700	5.00	3.00	3.00
	1.000	6.00	4.20	3.00
	1.500	8.50	8.00	3.00
	1.900	12.00	11.00	3.00
	2.600	12.00	11.00	3.00

Nissan Altima CVT – Benchmark
Setup and Spin-Loss Testing

Contract No. EP-C-12-014, Work Assignment 4-11
May 23, 2016

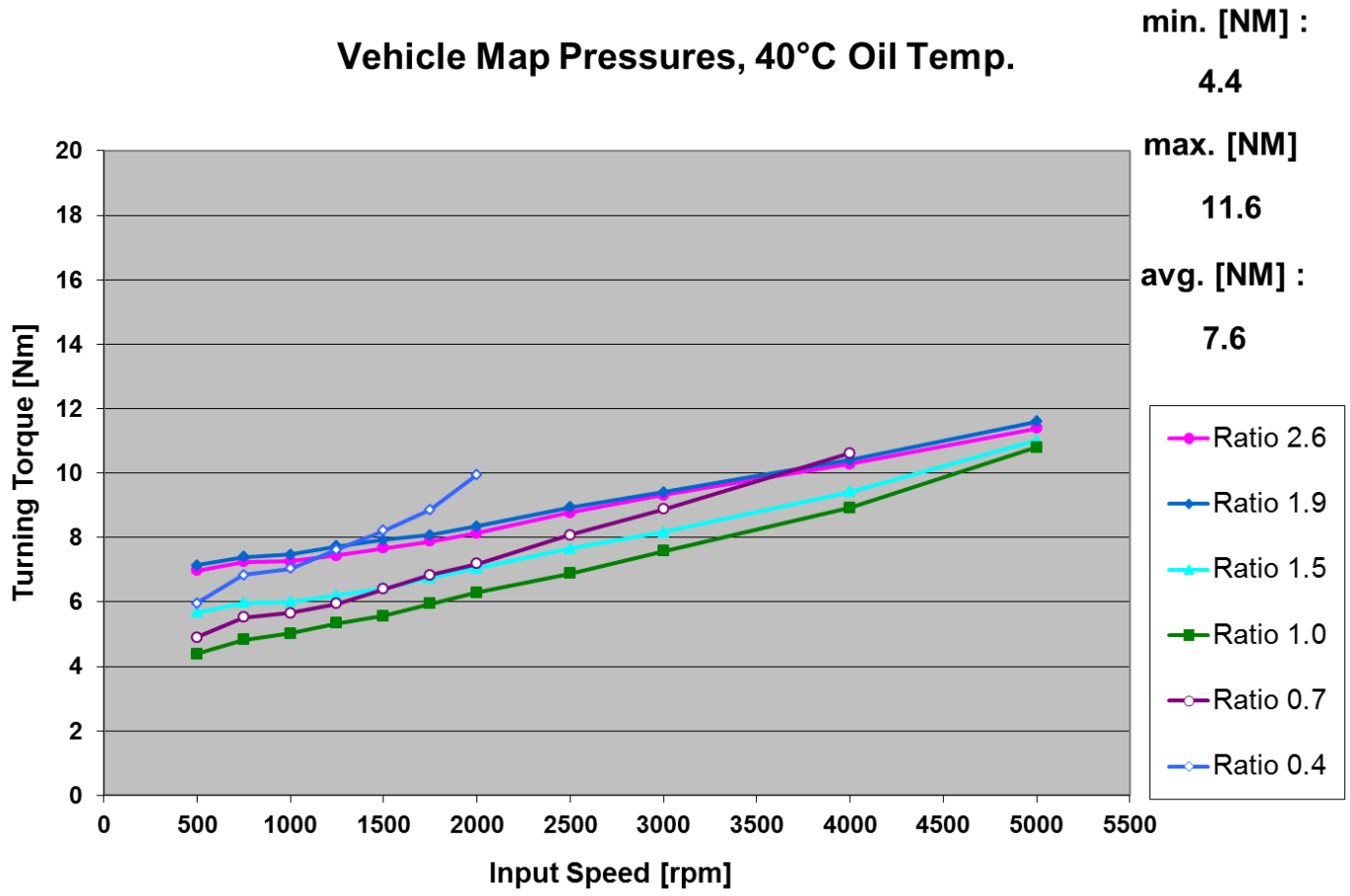
SPIN LOSS MEASUREMENT – SETUP SCHEMATIC



Nissan Altima CVT – Benchmark
Setup and Spin-Loss Testing

Contract No. EP-C-12-014, Work Assignment 4-11
May 23, 2016

SPIN LOSS MEASUREMENT – RESULTS



FEV Comments

- Chart shows linear progression of spin losses over input speed
- Ratio 1.0 shows the lowest losses of all tested ratios
  - Details to potential factors influencing the spin losses in appendix
- Ratio 0.4 shows highest losses at higher speeds, likely due to elevated differential speed

Nissan Altima CVT – Benchmark
Setup and Spin-Loss Testing

Contract No. EP-C-12-014, Work Assignment 4-11
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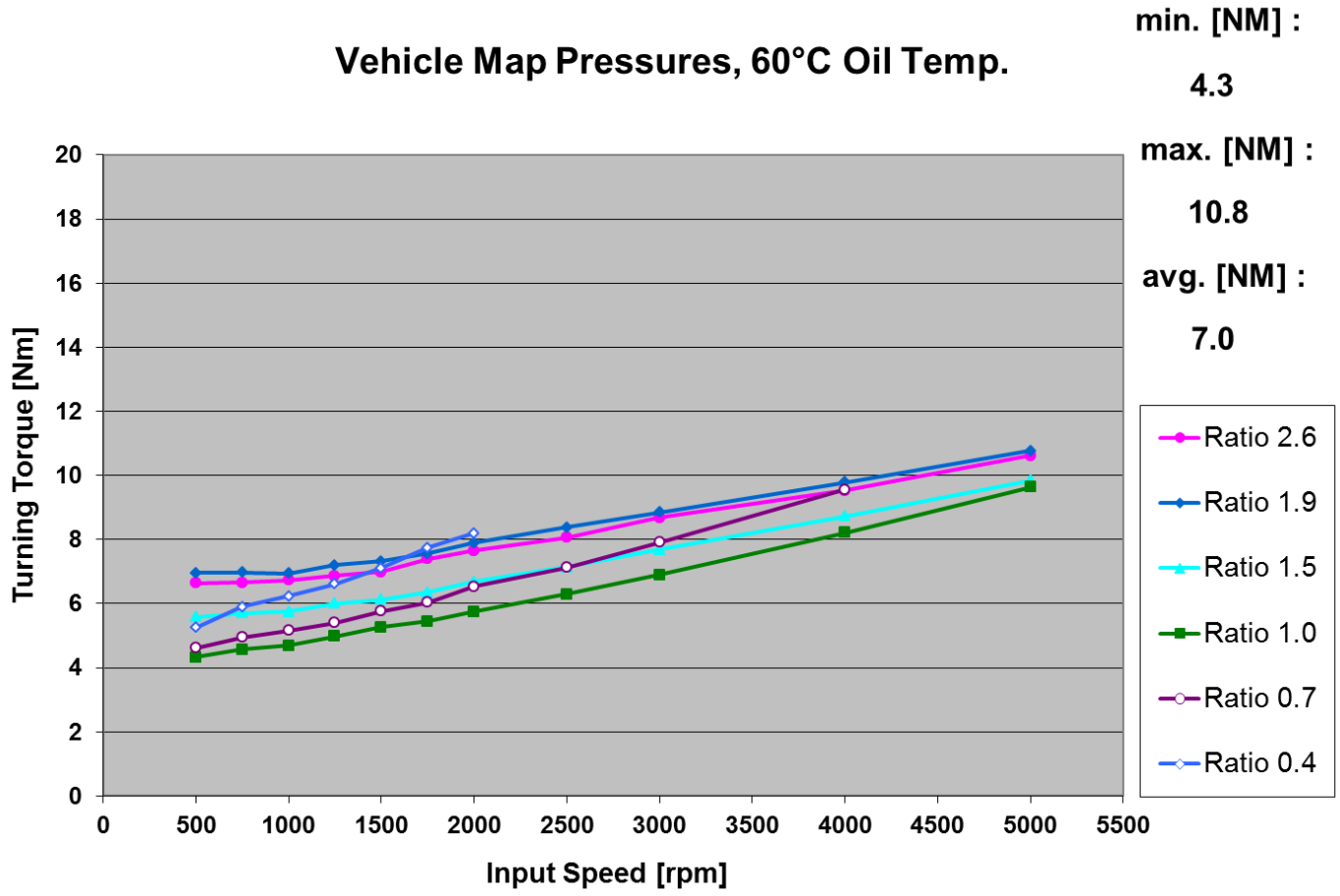
SPIN LOSS MEASUREMENT – RESULTS



FEV Comments

- Chart shows linear progression of spin losses over input speed
- Ratio 1.0 shows the lowest losses of all tested ratios
  - Details to potential factors influencing the spin losses in appendix
- Ratio 0.4 shows highest losses at higher speeds, likely due to elevated differential speed
- Lower than expected drop in losses at 60°C

Nissan Altima CVT – Benchmark
Setup and Spin-Loss Testing

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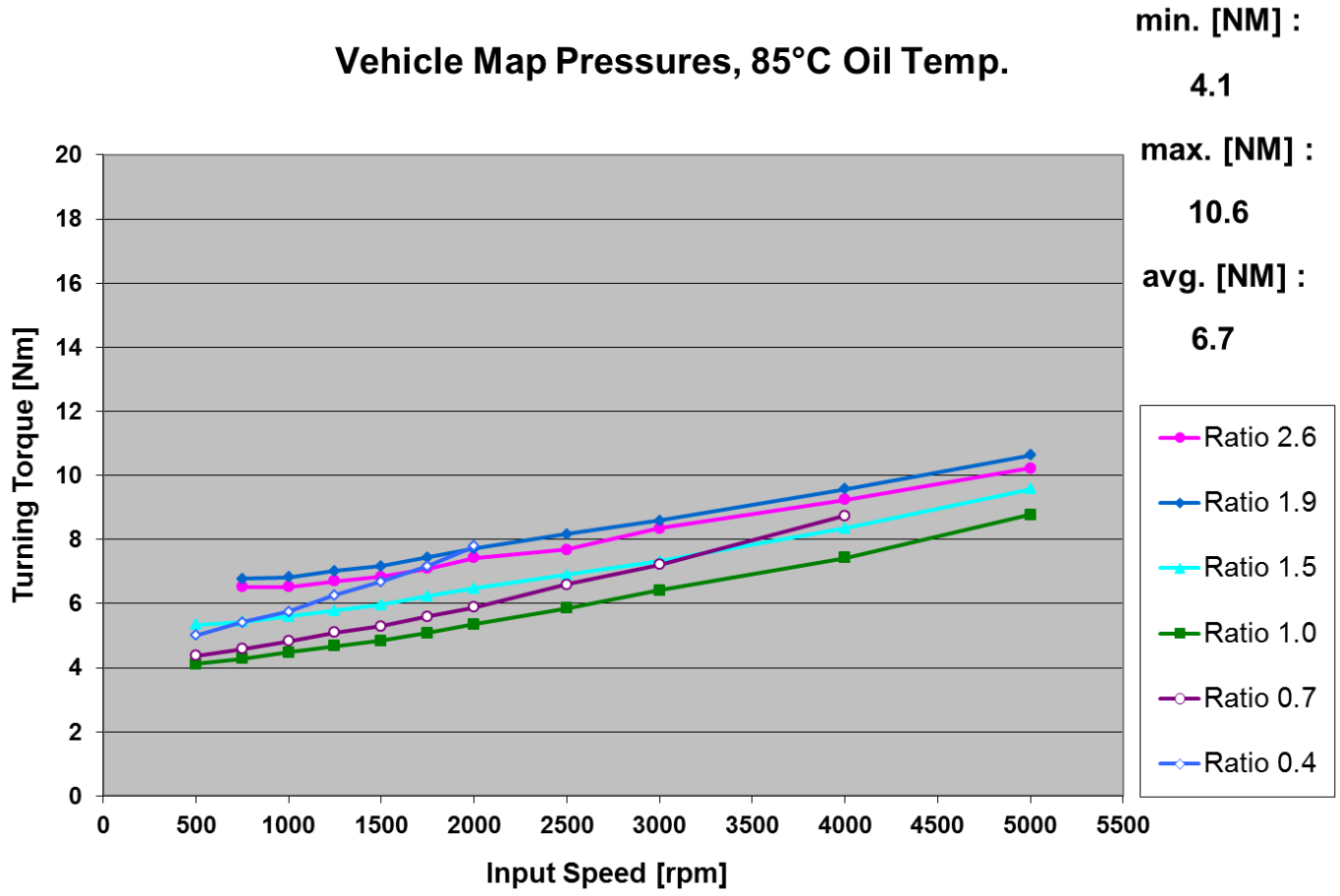
May 23, 2016

SPIN LOSS MEASUREMENT – RESULTS



FEV Comments

- Chart shows linear progression of spin losses over input speed
- Ratio 1.0 shows the lowest losses of all tested ratios
  - Details to potential factors influencing the spin losses in appendix
- Ratio 0.4 shows highest losses at higher speeds, likely due to elevated differential speed
- Minimal drop in losses compared to 85°C

Nissan Altima CVT – Benchmark
Setup and Spin-Loss Testing

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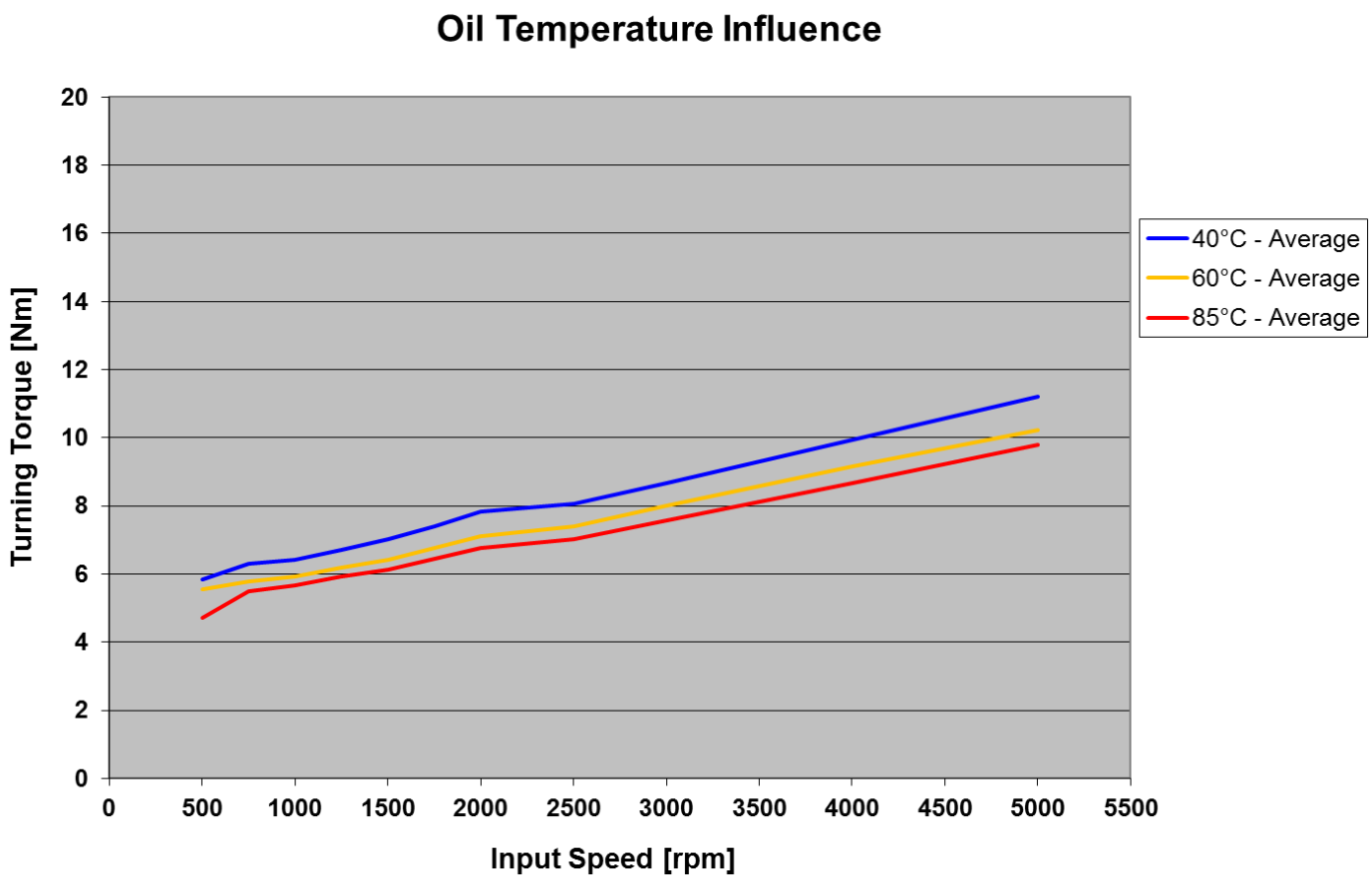
May 23, 2016

SPIN LOSS MEASUREMENT – RESULTS



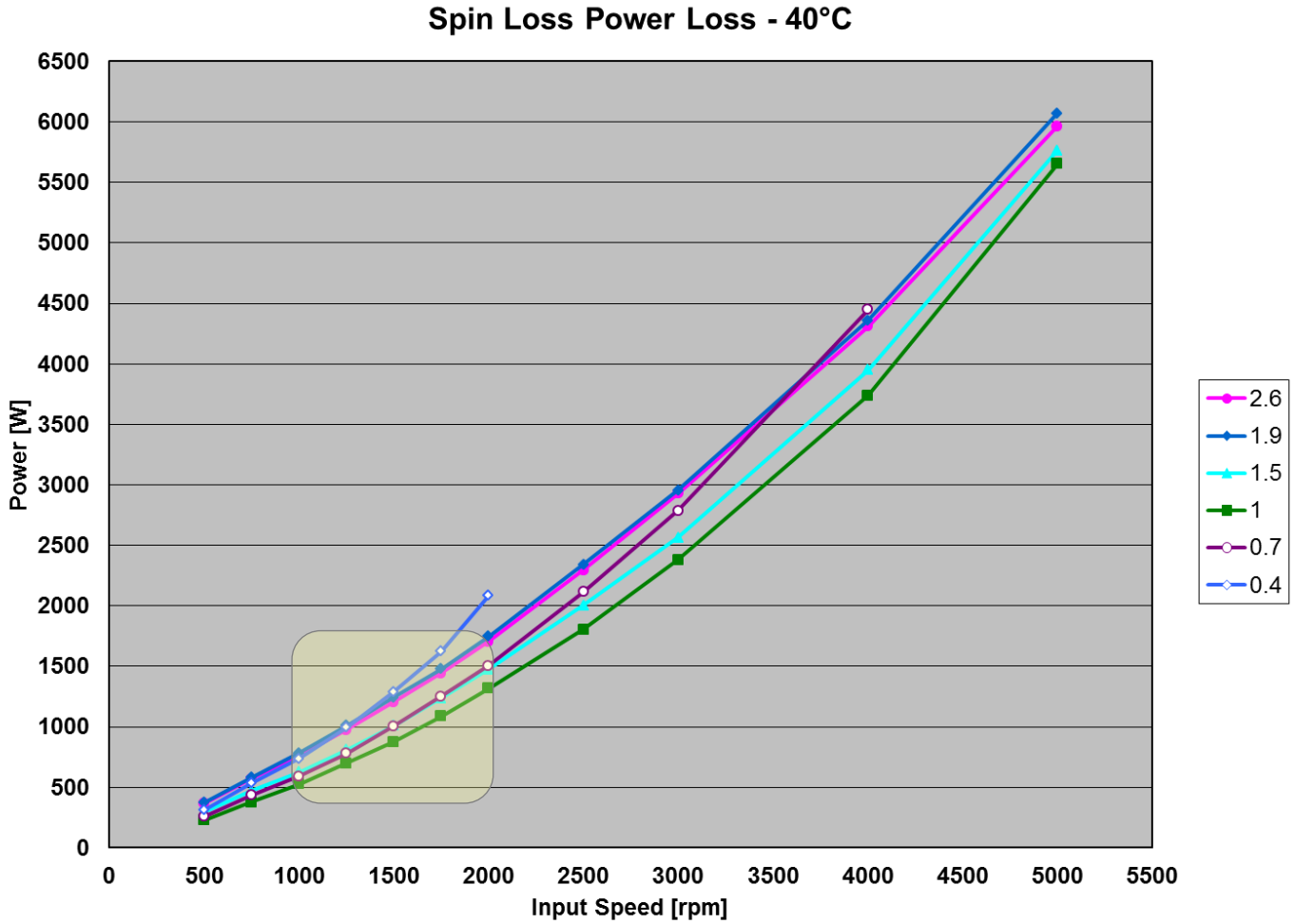
FEV Comments

- Very low influence of oil temperature on losses
- Assuming the change in oil level at higher temperatures (due to density change) affects losses
- Ratio 0.4 only tested at input speeds ≤ 2000 rpm. This causes the inflection at 2000 rpm.
- Jatco information indicates that the drive pulley is partially submerged in oil

Nissan Altima CVT – Benchmark Setup and Spin-Loss Testing

Contract No. EP-C-12-014, Work Assignment 4-11
May 23, 2016

SPIN LOSS MEASUREMENT – RESULTS



FEV Comments

- Power loss between 250 and 1,500W in FE-cycle range (1,000 – 2,000 rpm)
  - 0.4 ratio power loss about 750 – 2,000W in FE cycle range

Nissan Altima CVT – Benchmark Setup and Spin-Loss Testing

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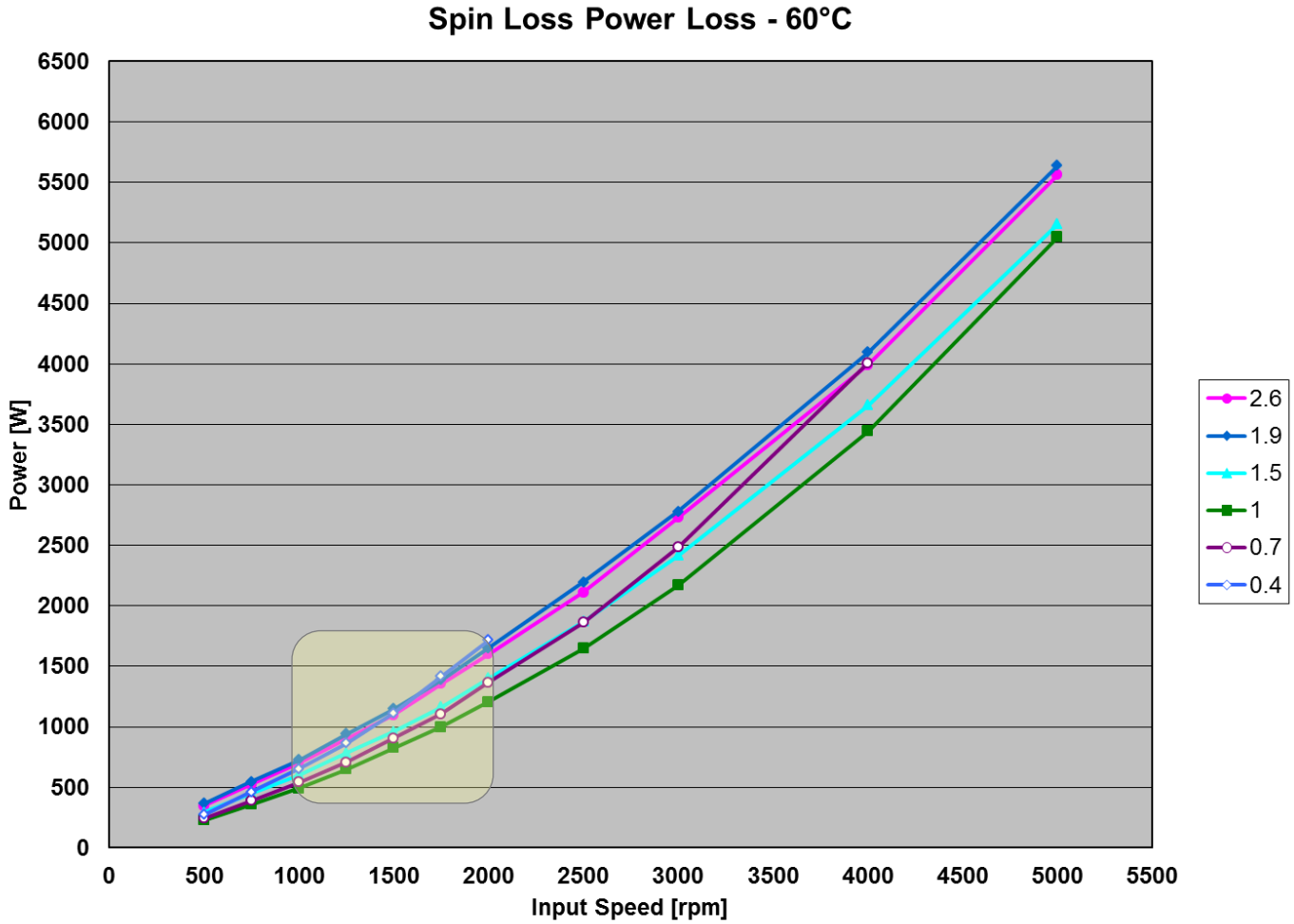
SPIN LOSS MEASUREMENT – RESULTS



FEV Comments

- Power loss between 250 and 1,250W in FE-cycle range (1,000 – 2,000 rpm)
  - 0.4 ratio power loss about 700 – 1,750W in FE cycle range

Nissan Altima CVT – Benchmark Setup and Spin-Loss Testing

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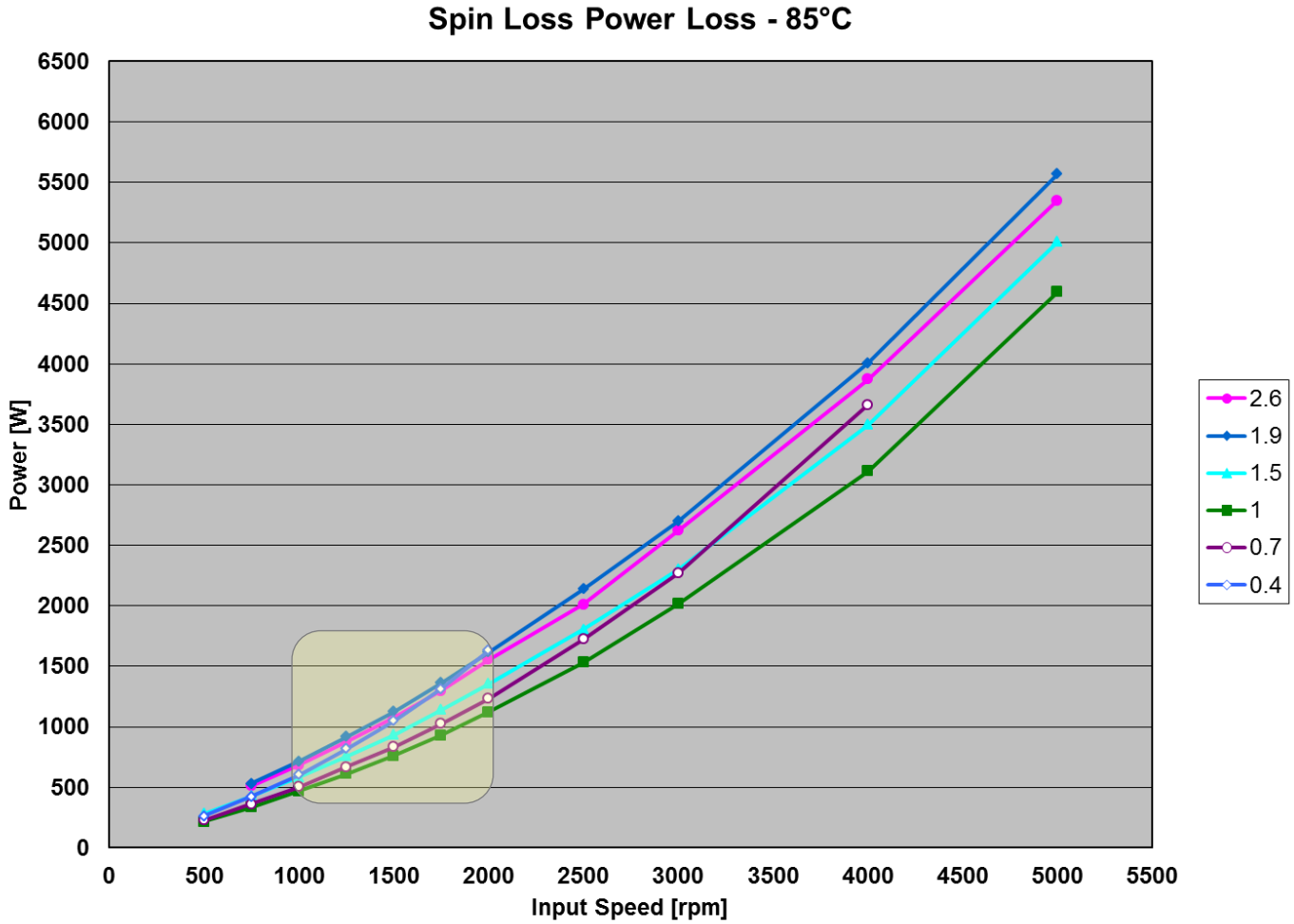
May 23, 2016

SPIN LOSS MEASUREMENT – RESULTS



FEV Comments

- Power loss between 250 and 1,250W in FE-cycle range (1,000 – 2,000 rpm)
  - 0.4 ratio power loss about 250 – 1,600W in FE cycle range

Nissan Altima CVT – Benchmark
Setup and Spin-Loss Testing

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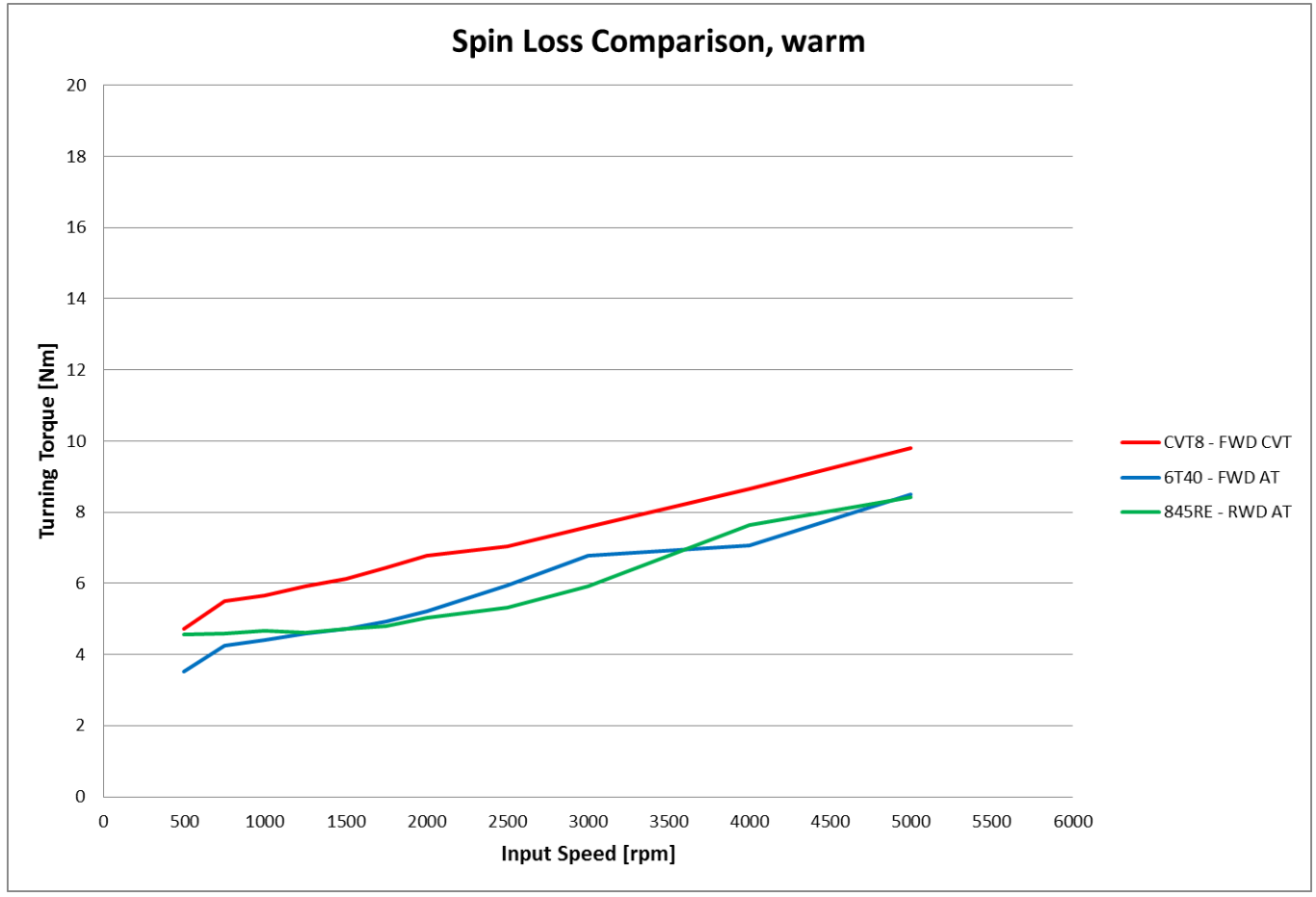
May 23, 2016

SPIN LOSS MEASUREMENT – RESULTS



FEV Comments

- All 3 transmissions have been interpolated to 4 bar line pressure
- Higher spin losses in CVT due to more pump losses and unique architecture

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Nissan Altima CVT – Benchmark
Neutral Coast Down

Contract No. EP-C-12-014, Work Assignment 4-11
May 23, 2016

NEUTRAL COAST DOWN – BOUNDARY CONDITIONS

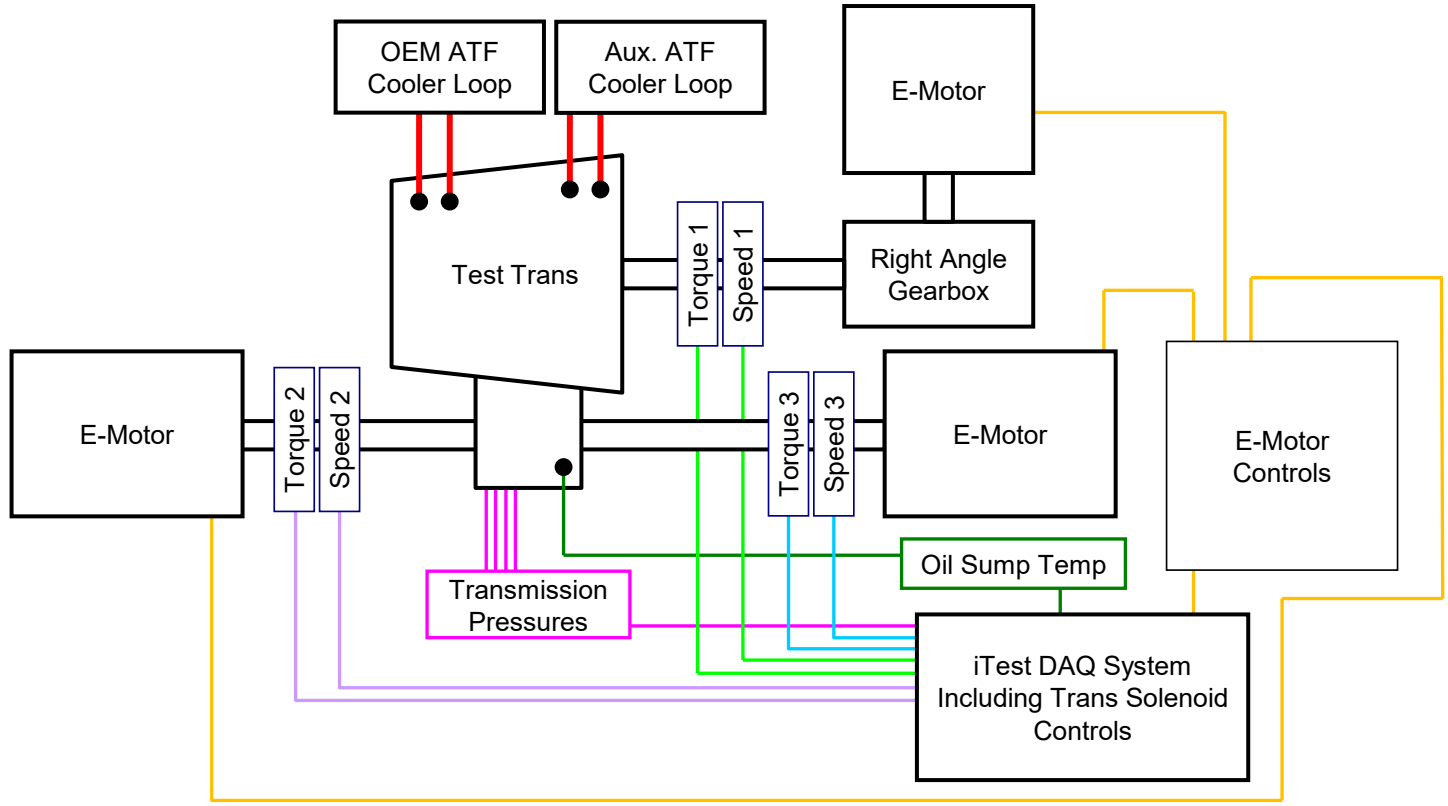
- Gear ratios (various)
  - As observed in vehicle during NCD
- Torque converter clutch open
- Transmission oil temperatures (3):
  - 40°C, 60°C, 85°C
- Input speeds (1):
  - Engine idle speed
- Output speeds (17):
  - Representative of and 80-0 mph vehicle coast down in increments of 50 rpm
- Transmission system pressures (1):
  - As observed in vehicle (see table above)

Input Speed [rpm]	Output Speed [rpm]	Vehicle Speed [mph]	Line Pressure [bar]	Driven Pressure [bar]	CVT Ratio
650	1046.0	80	7.06	2.02	0.39
650	1000.0	76.3	6.69	1.26	0.39
650	950.0	72.5	6.50	1.27	0.39
650	900.0	68.6	6.20	1.28	0.39
650	850.0	64.8	5.50	1.28	0.39
650	800.0	60.9	5.51	1.29	0.39
650	750.0	57.2	5.56	1.33	0.39
650	700.0	53.3	5.52	1.28	0.39
650	650.0	49.6	5.54	1.30	0.39
650	600.0	45.7	5.47	1.25	0.40
650	550.0	41.8	5.54	1.32	0.43
650	500.0	38.1	5.50	1.29	0.48
650	450.0	34.3	5.52	1.31	0.53
650	400.0	30.4	5.56	1.34	0.60
650	350.0	26.6	5.51	1.29	0.68
650	300.0	22.9	5.48	1.27	0.76
650	250.0	19	5.46	1.24	0.91

Nissan Altima CVT – Benchmark
Neutral Coast Down

Contract No. EP-C-12-014, Work Assignment 4-11
May 23, 2016

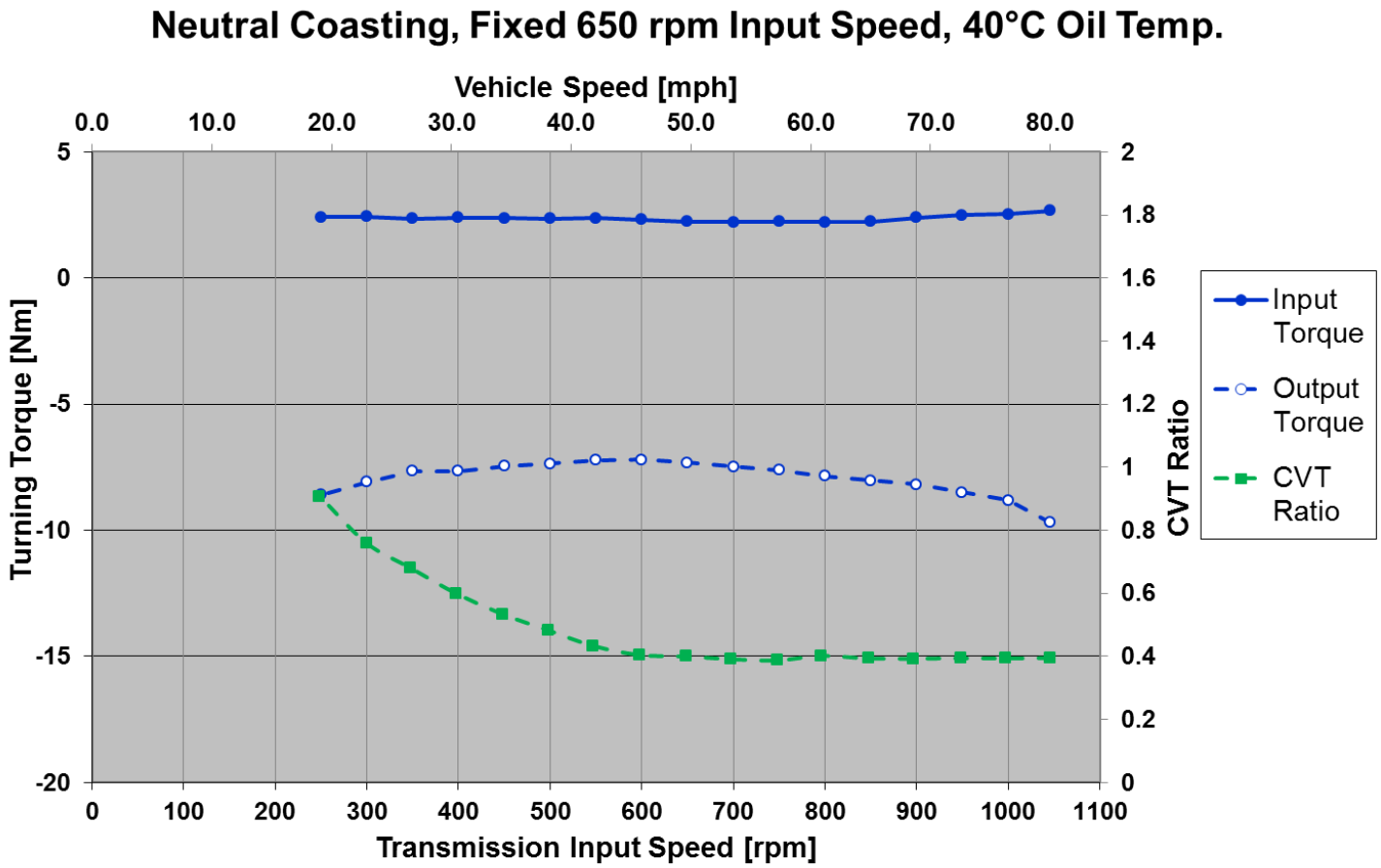
NEUTRAL COAST DOWN – SETUP SCHEMATIC



Nissan Altima CVT – Benchmark
Neutral Coast Down

Contract No. EP-C-12-014, Work Assignment 4-11
May 23, 2016

NEUTRAL COAST DOWN – RESULTS



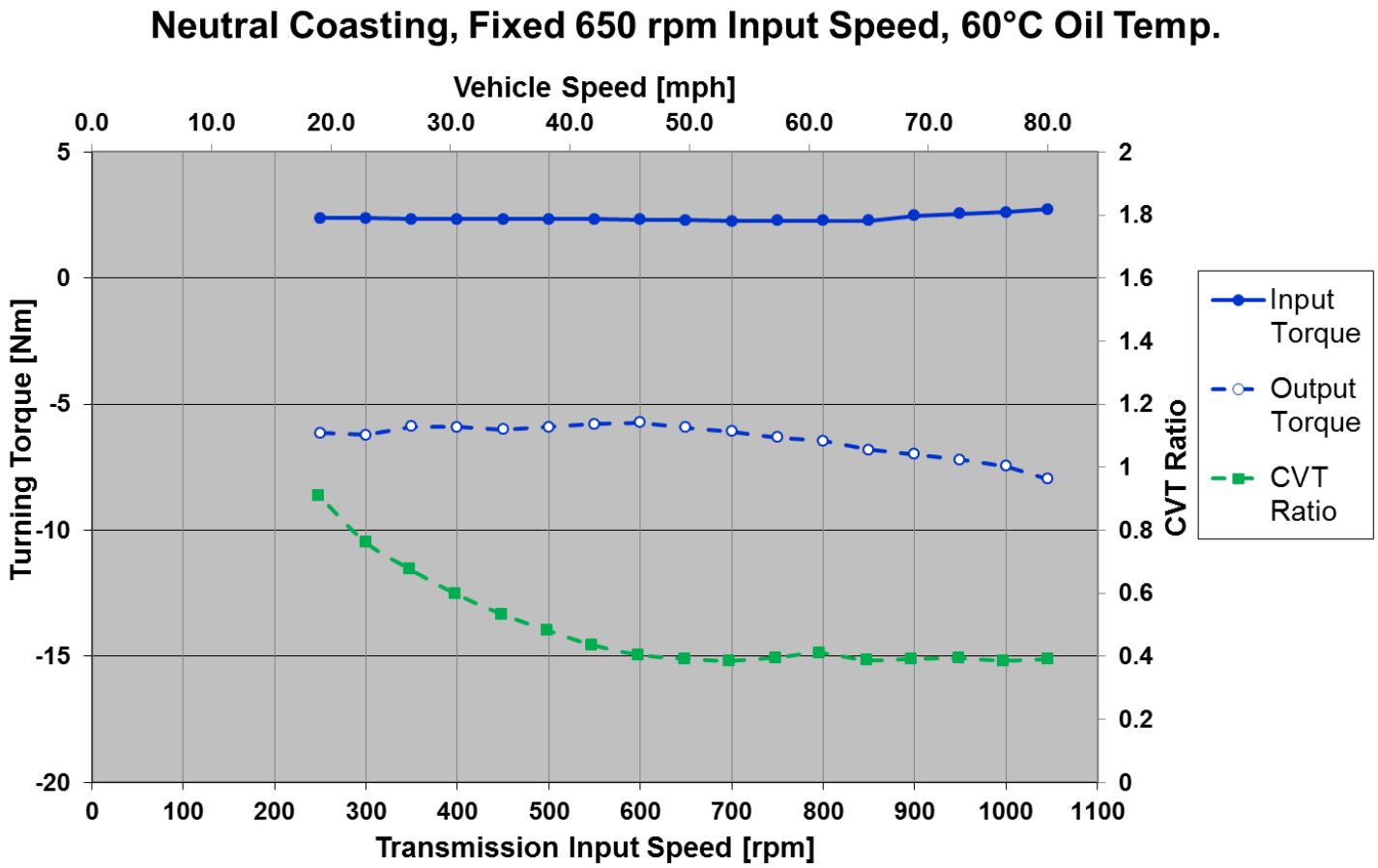
FEV Comments

- During NCD, the torque converter and forward clutch remain open/unlocked
- Sum of both output shaft torques is highest at max. vehicle speed (~10Nm) and lowest at the slowest speed of max. overdrive (~7Nm)
- Ratio change towards LOW increases drag on output shafts
- Input shaft torque is constant at ~2.5 Nm

Nissan Altima CVT – Benchmark
Neutral Coast Down

Contract No. EP-C-12-014, Work Assignment 4-11
May 23, 2016

NEUTRAL COAST DOWN – RESULTS



FEV Comments

- During NCD, the torque converter and forward clutch remain open/unlocked
- Sum of both output shaft torques is highest at max. vehicle speed (~8Nm) and lowest at the slowest speed of max. overdrive (~6Nm)
- Ratio change towards LOW increases drag on output shafts
- Input shaft torque is constant at ~2.5 Nm

Nissan Altima CVT – Benchmark
Neutral Coast Down

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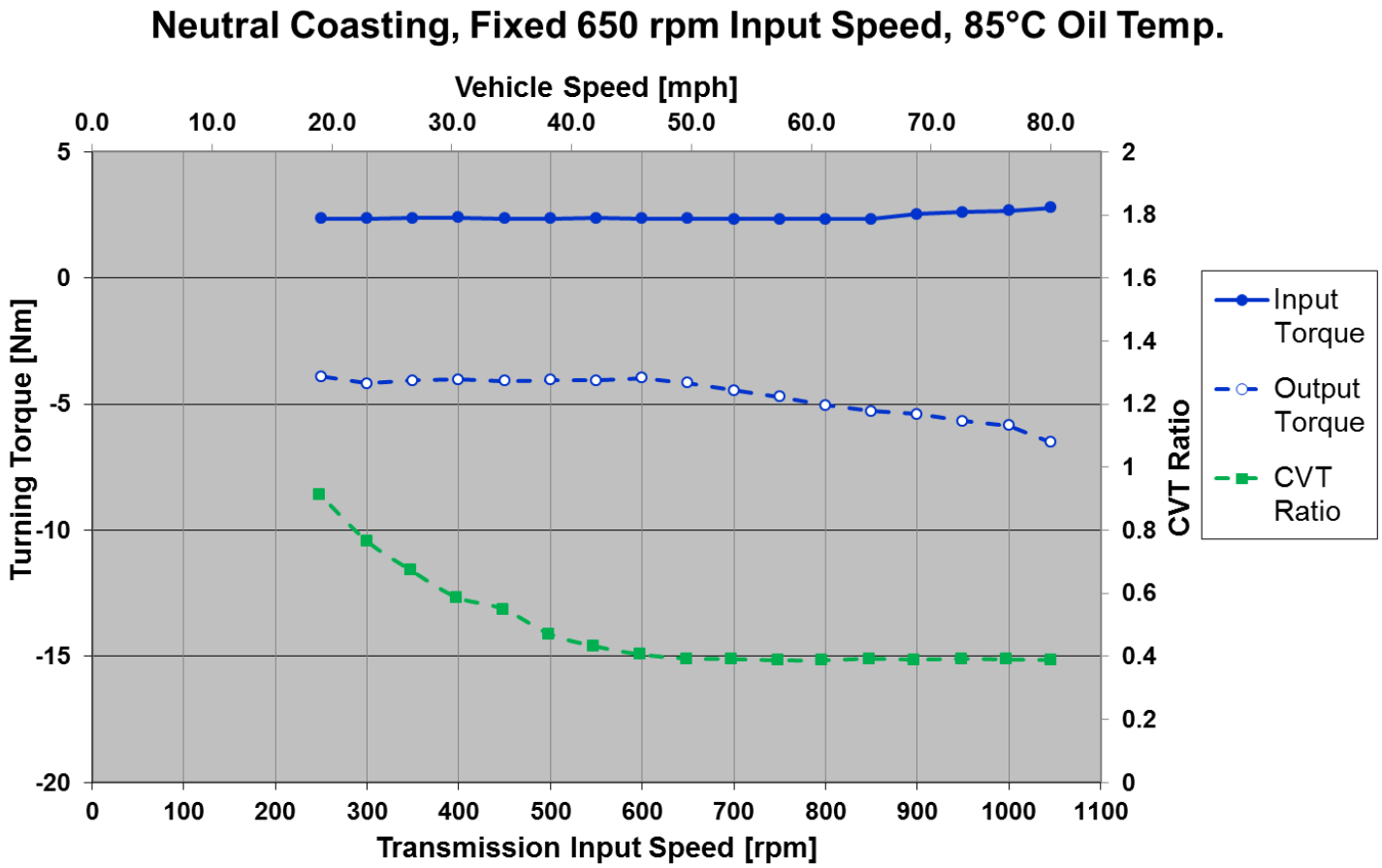
May 23, 2016

NEUTRAL COAST DOWN – RESULTS



FEV Comments

- During NCD, the torque converter and forward clutch remain open/unlocked
- Sum of both output shaft torques is highest at max. vehicle speed (~7Nm) and lowest at the slowest speed of max. overdrive (~4Nm)
- Input shaft torque is constant at ~2.5 Nm

Nissan Altima CVT – Benchmark
Neutral Coast Down

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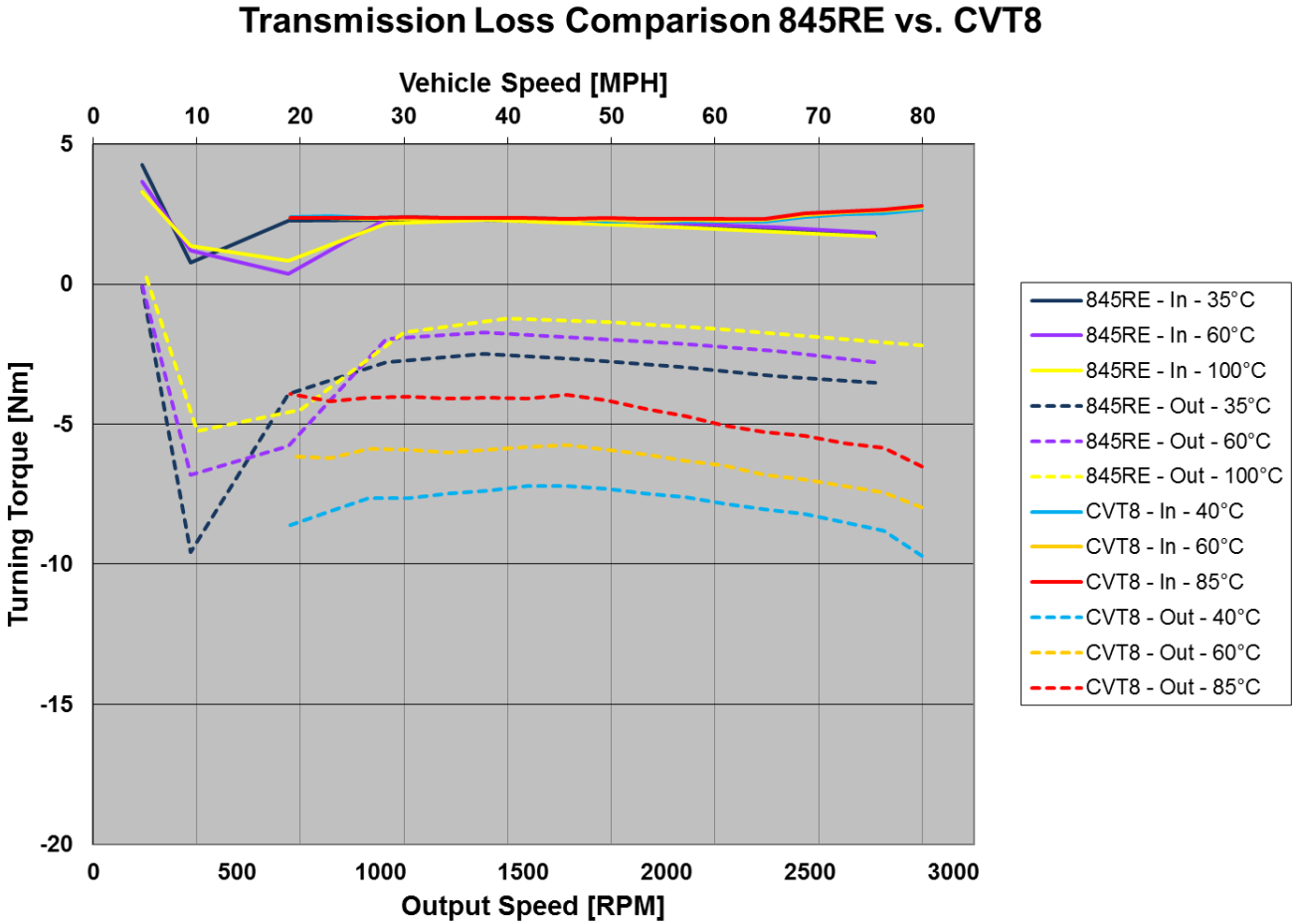
NEUTRAL COAST DOWN – RESULTS



FEV Comments

- CVT8 shows higher losses on transmission output shaft during neutral coasting than 845RE
  - Cause for this is likely the differential that is included in the CVT8 but not the 845RE

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Nissan Altima CVT – Benchmark
Loaded Efficiency Testing

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May 23, 2016

LOADED EFFICIENCY TESTING – BOUNDARY CONDITIONS

- Gear ratios (6)
- Torque converter clutch locked for all tests
- Transmission oil temperatures (3):
  - 40°C, 60°C, 85°C
- Input speeds (11):
  - 500-5000 rpm
  - Limitations for maximum overdrive ratio to avoid unrealistic output speeds
- Input Loads (7):
  - 25-250 Nm (with limitations for maximum underdrive ratio to avoid unrealistic output loads
- Transmission system pressures (1.5):
  - 20% over-clamp
  - Selected points at pressures observed in vehicle

Over clamp pressure values were calculated using observed vehicle pressures

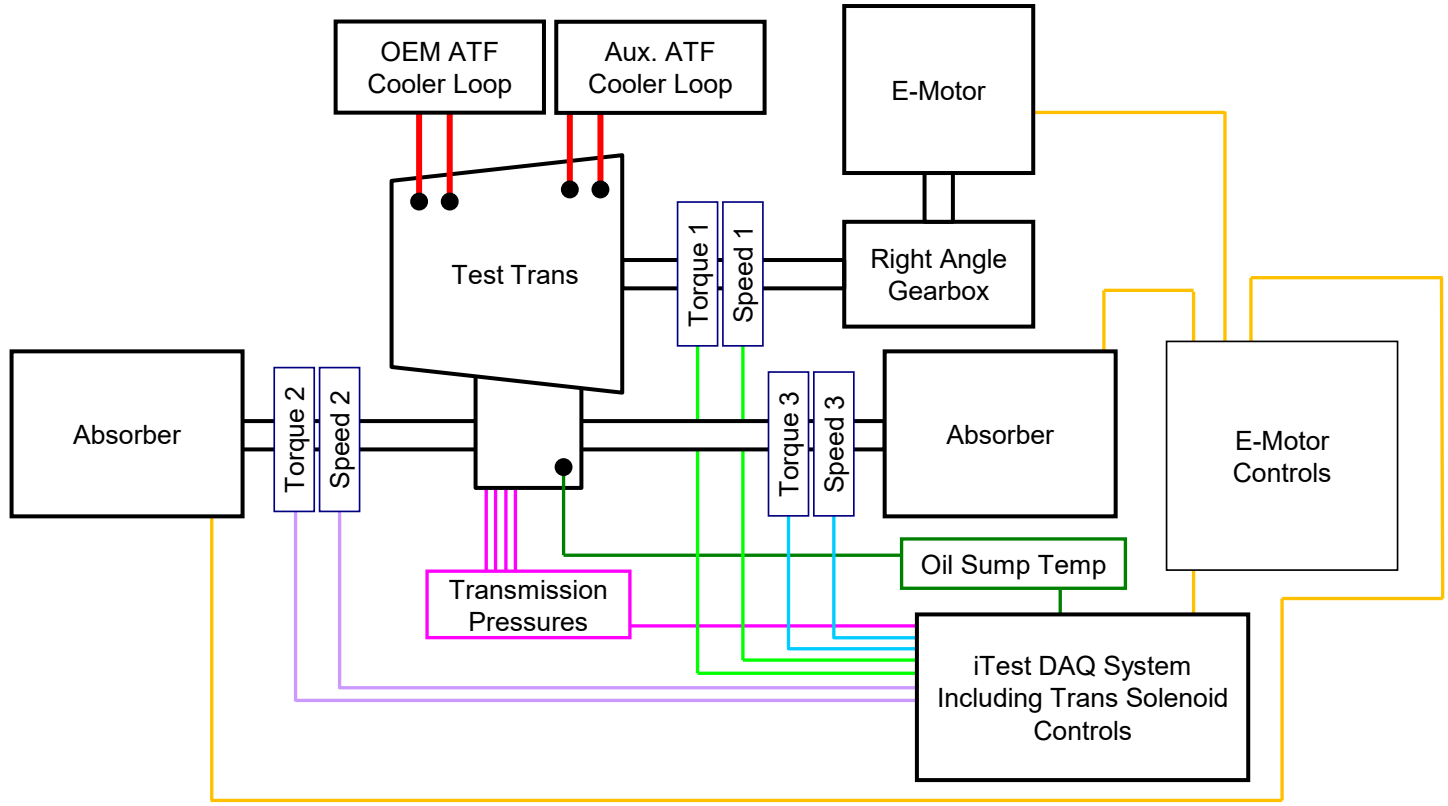
	Driven Pulley Pressure						
Base	25	50	75	100	150	200	250
0.400	2.00	2.00	3.00	4.00	6.00	8.00	10.00
0.700	3.00	3.70	4.80	5.90	8.00	10.20	12.40
1.000	4.20	5.18	6.44	7.56	9.94	12.46	14.70
1.500	8.00	8.00	8.00	9.40	13.60	17.90	22.00
1.900	11.00	11.00	11.00	14.80	23.00	31.00	
2.600	11.00	11.00	11.00	15.50	25.00		

20% Overclamp	25	50	75	100	150	200	250
0.400	2.40	2.40	3.60	4.80	7.20	9.60	12.00
0.700	3.60	4.44	5.76	7.08	9.60	12.24	14.88
1.000	5.04	6.22	7.73	9.07	11.93	14.95	17.64
1.500	9.60	9.60	9.60	11.28	16.32	21.48	26.40
1.900	13.20	13.20	13.20	17.76	27.60	37.20	
2.600	13.20	13.20	13.20	18.60	30.00		

Nissan Altima CVT – Benchmark
Loaded Efficiency Testing

Contract No. EP-C-12-014, Work Assignment 4-11
May 23, 2016

LOADED EFFICIENCY TESTING – SETUP SCHEMATIC



Nissan Altima CVT – Benchmark
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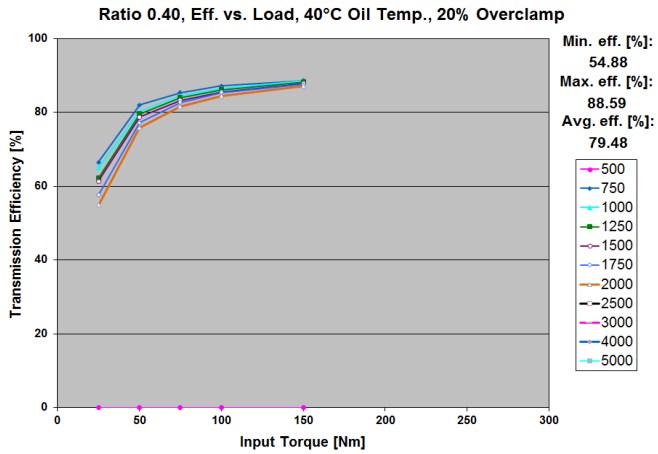
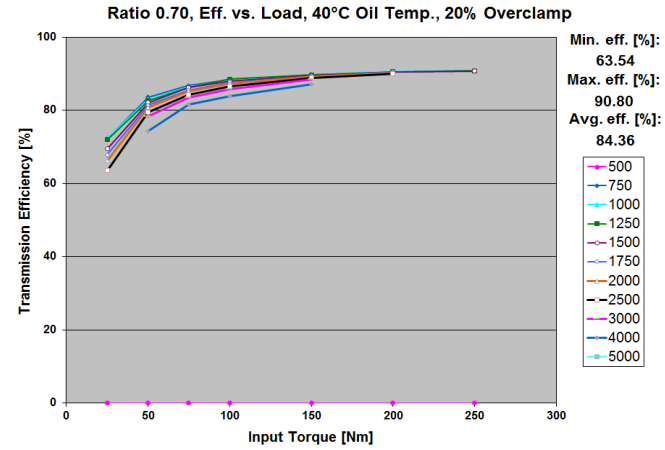
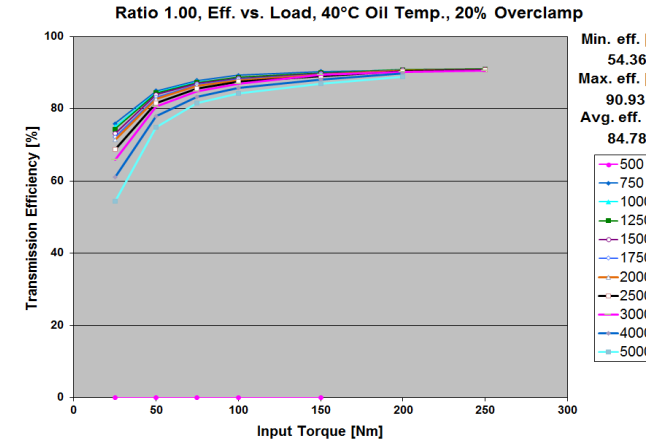
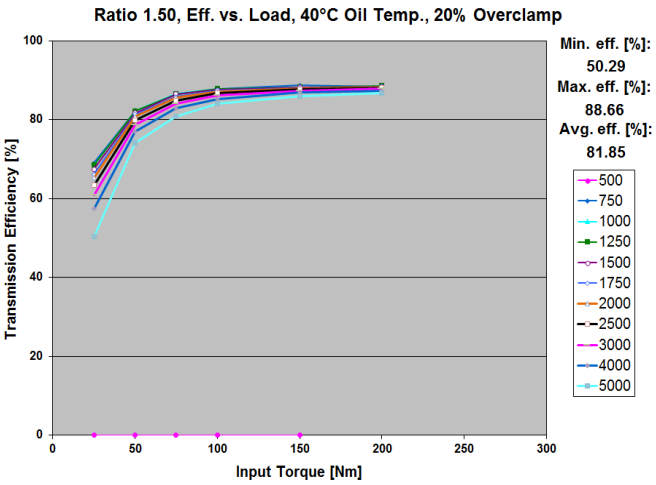
Contract No. EP-C-12-014, Work Assignment 4-11

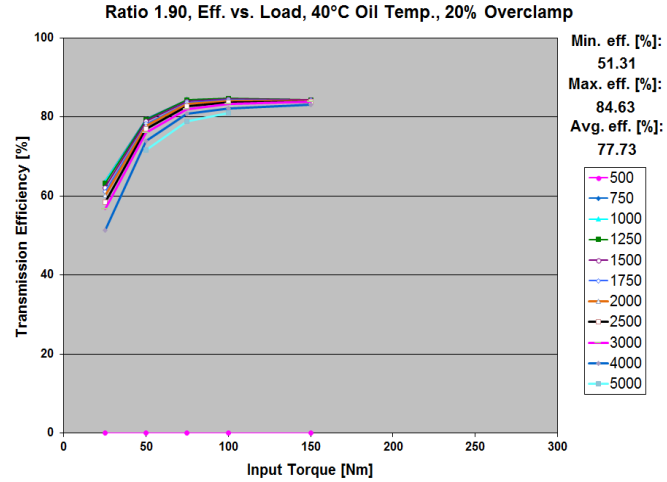
LOADED EFFICIENCY TESTING – RESULTS

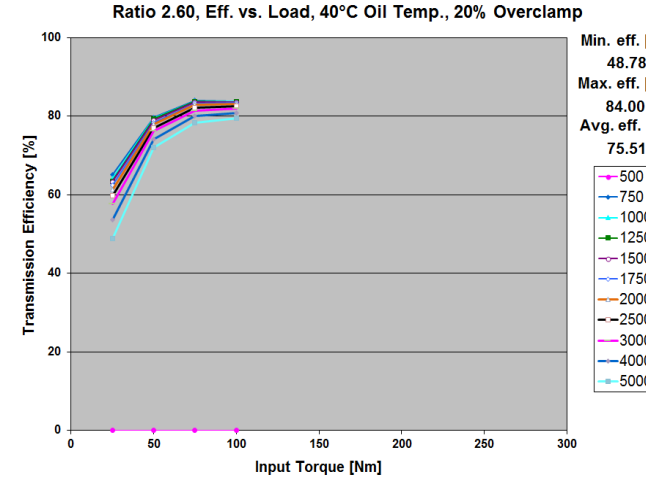












Nissan Altima CVT – Benchmark
Loaded Efficiency Testing

Contract No. EP-C-12-014, Work Assignment 4-11
May 23, 2016

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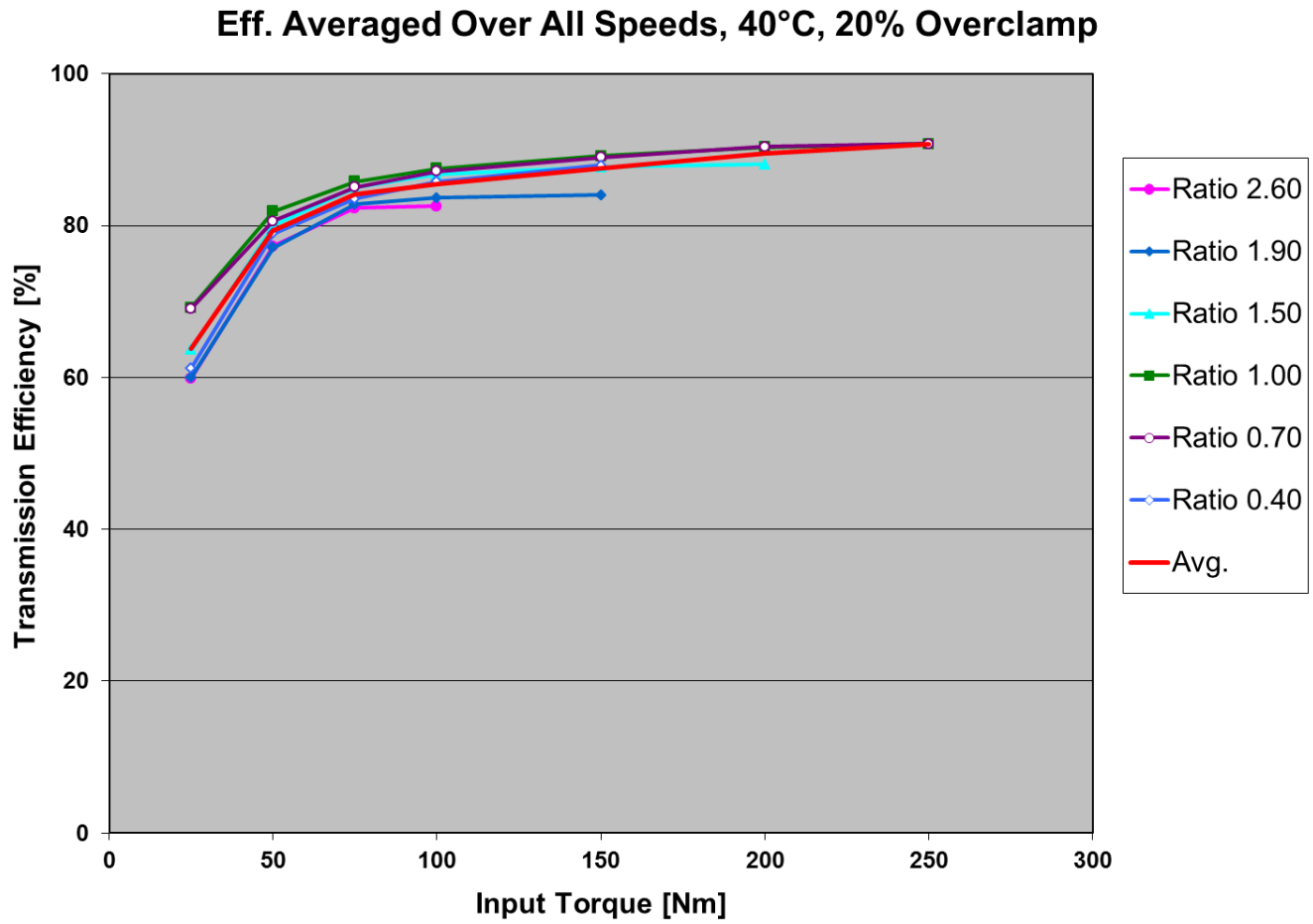

FEV Comments

- Data shown was measured at vehicle pressure + 20%
- Similar to spin losses, ratio 1.0 shows the highest efficiency

Nissan Altima CVT – Benchmark
Loaded Efficiency Testing

Contract No. EP-C-12-014, Work Assignment 4-11

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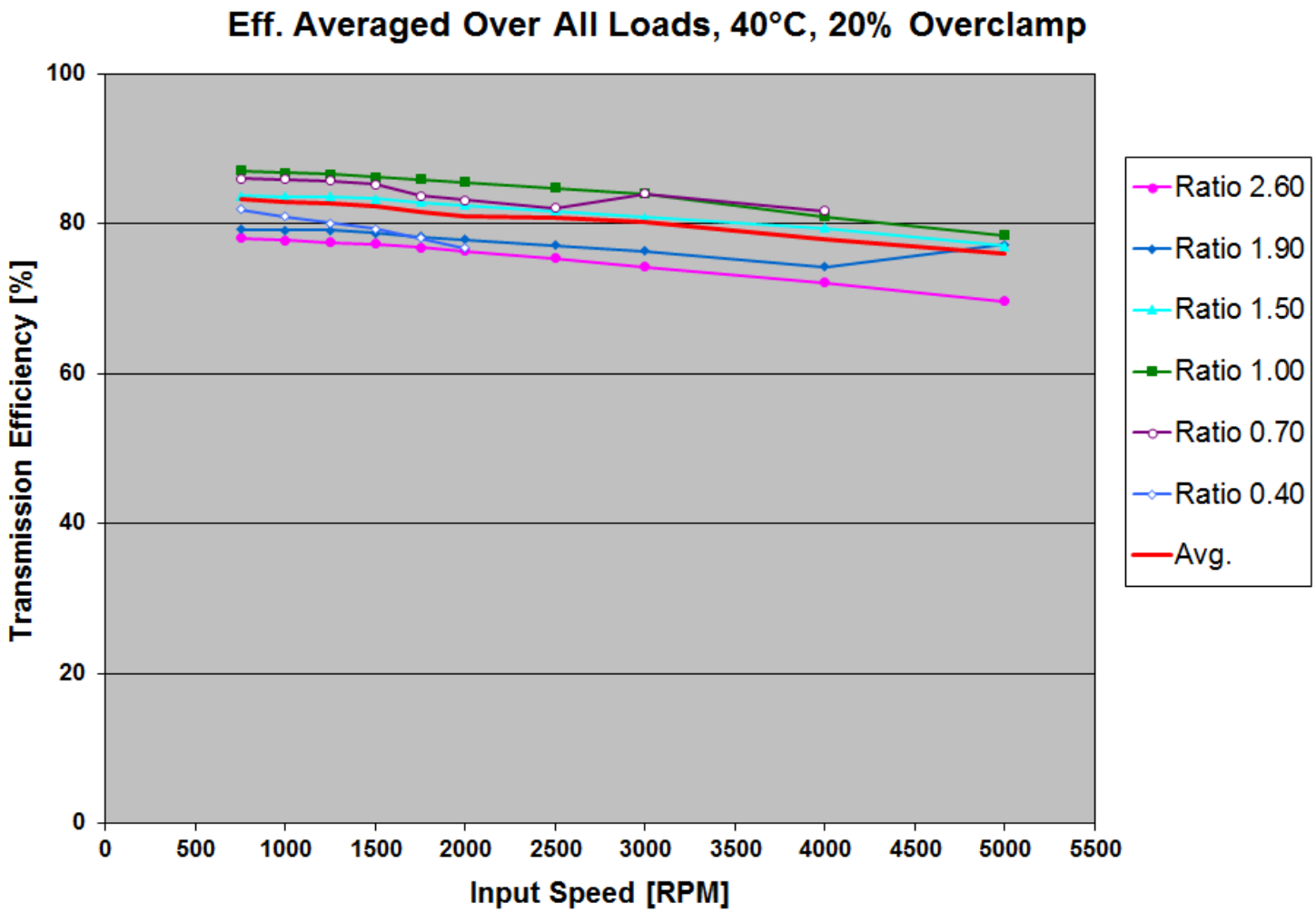

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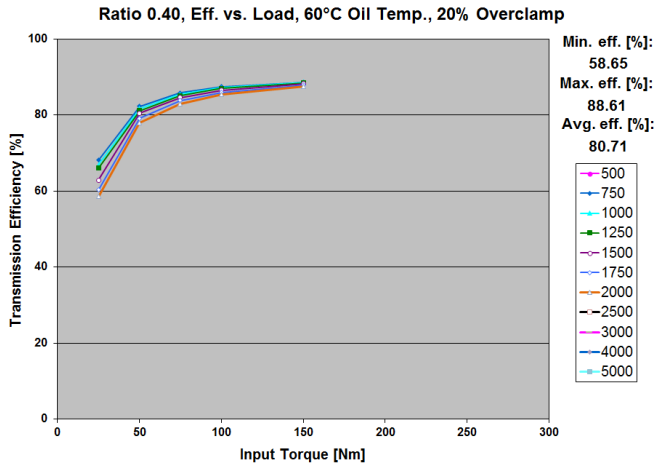
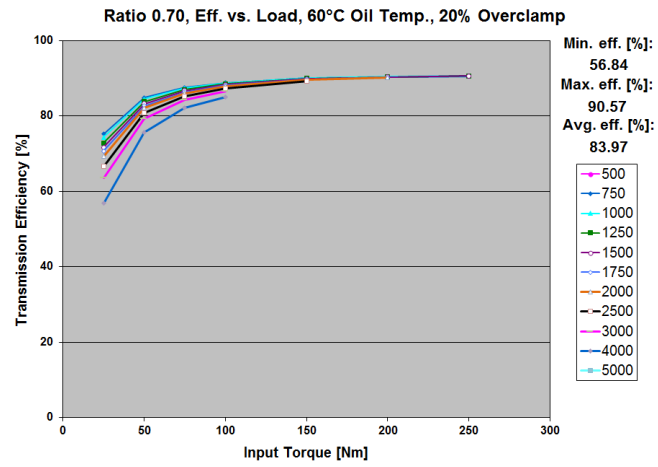
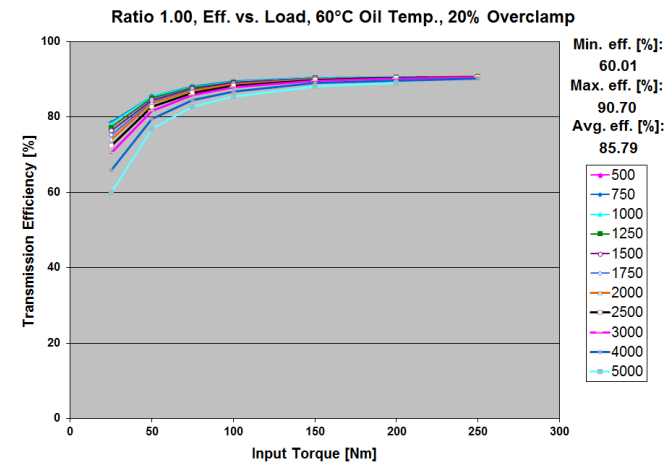
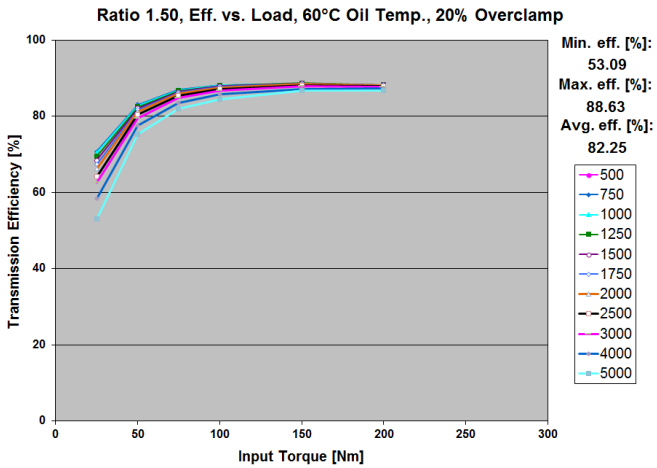
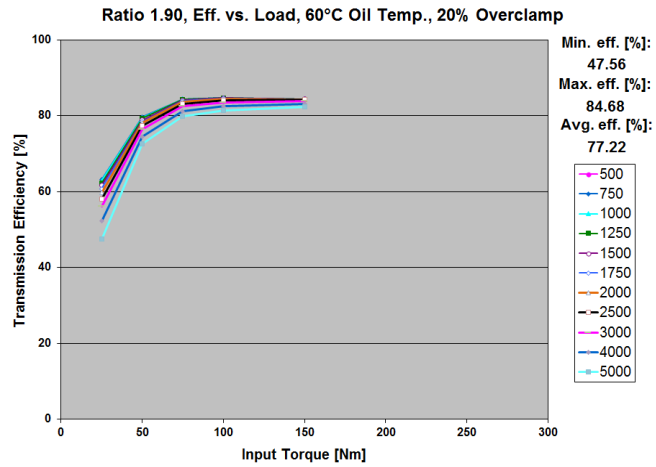
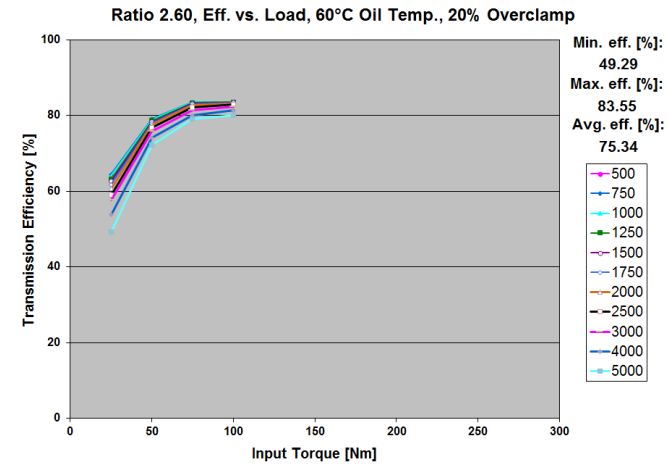








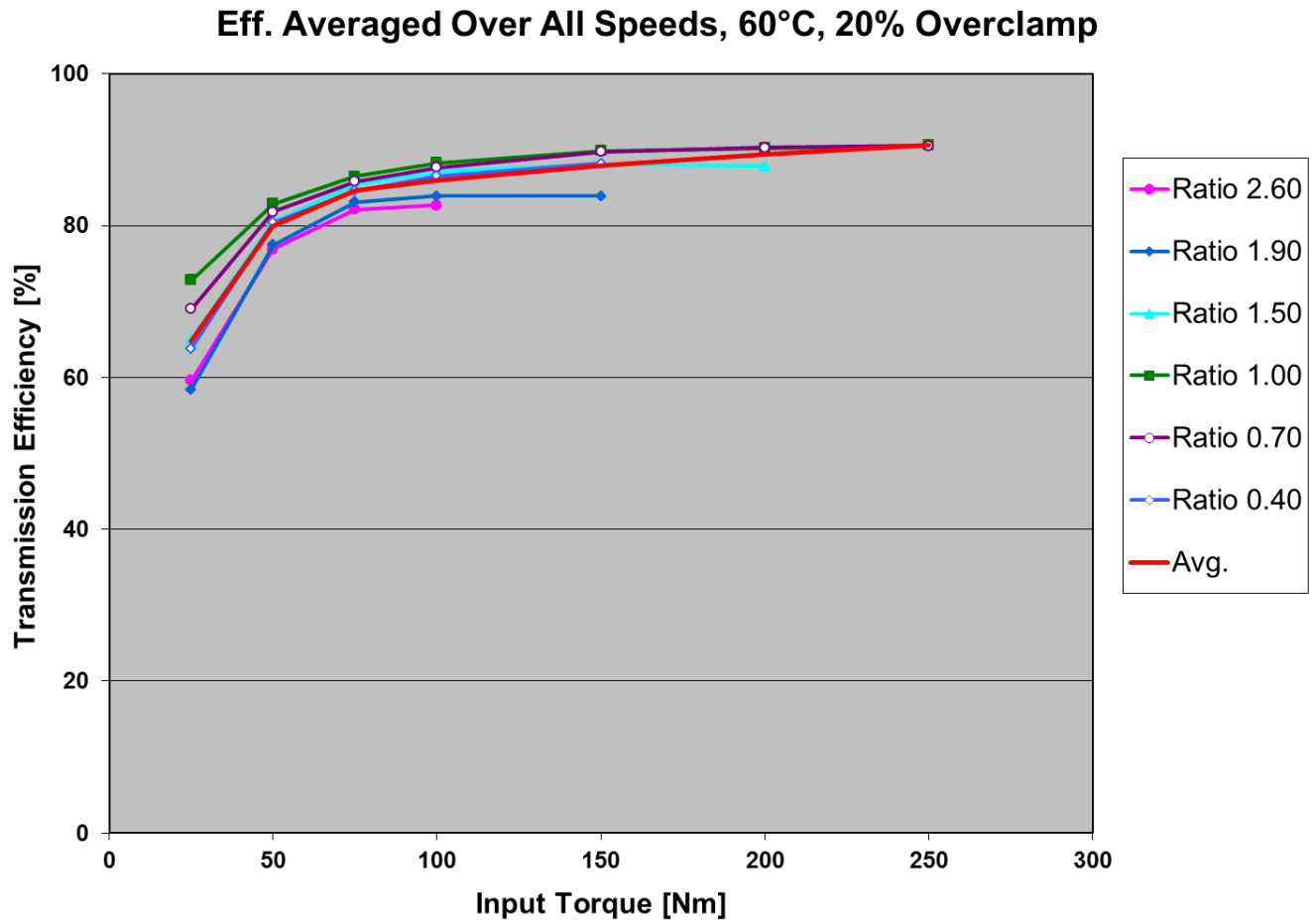




Nissan Altima CVT – Benchmark
Loaded Efficiency Testing

Contract No. EP-C-12-014, Work Assignment 4-11
May 23, 2016

LOADED EFFICIENCY TESTING – RESULTS



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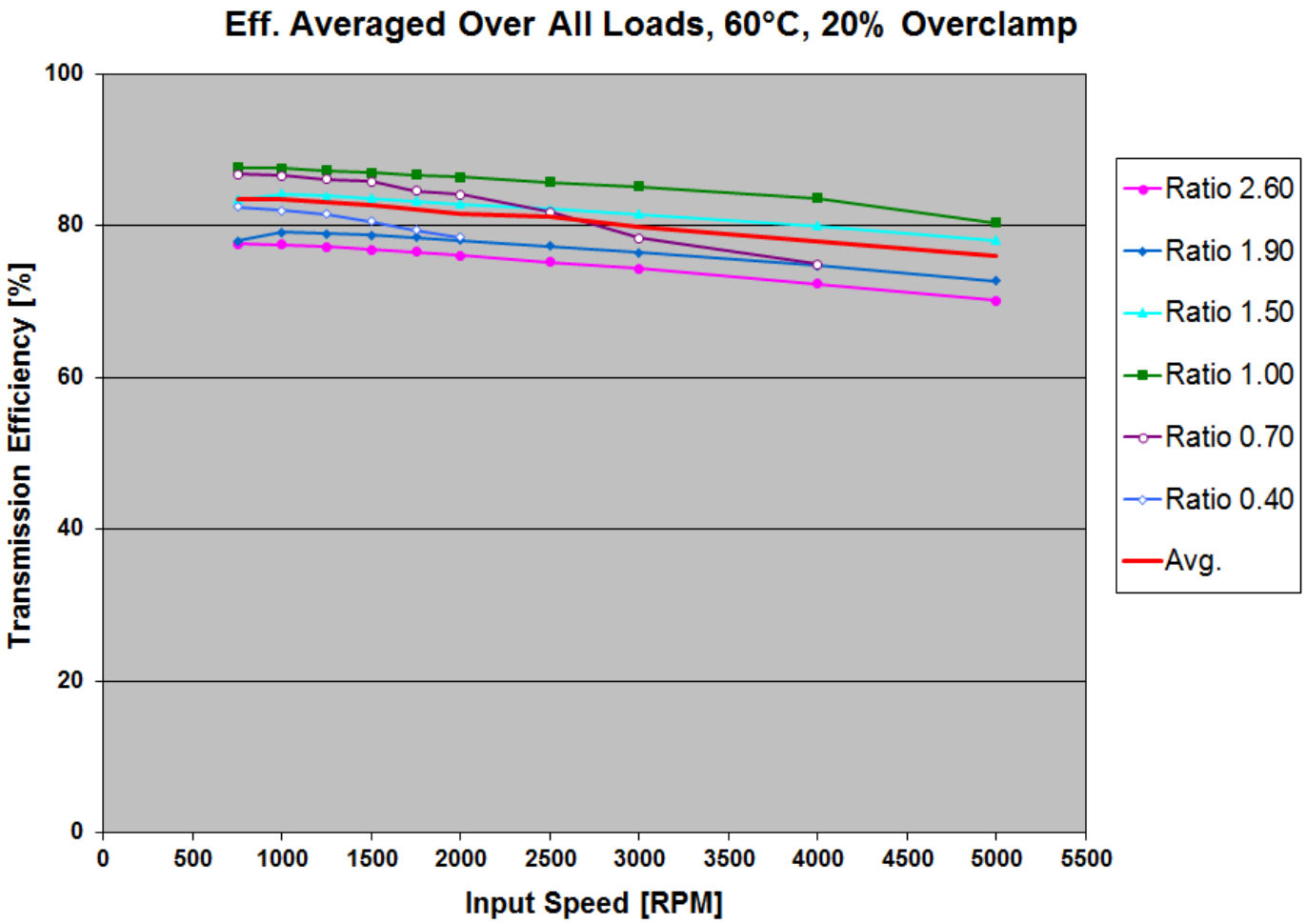
Nissan Altima CVT – Benchmark
Loaded Efficiency Testing

LOADED EFFICIENCY TESTING – RESULTS



Nissan Altima CVT – Benchmark
Loaded Efficiency Testing

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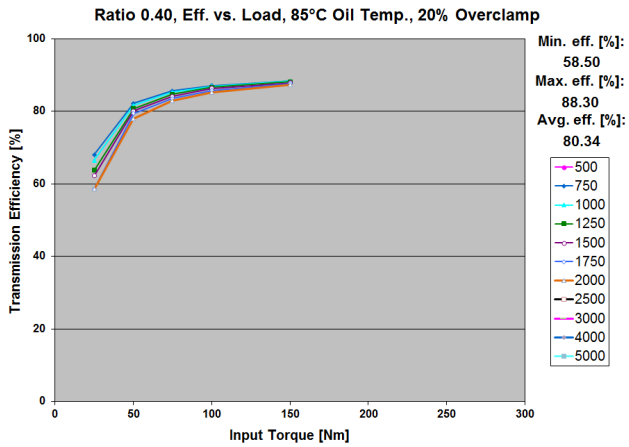
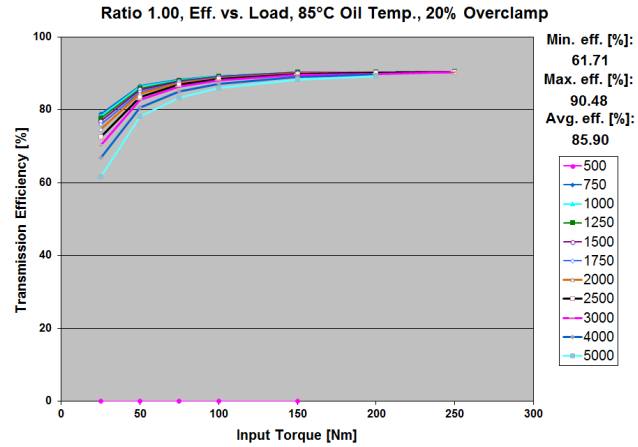
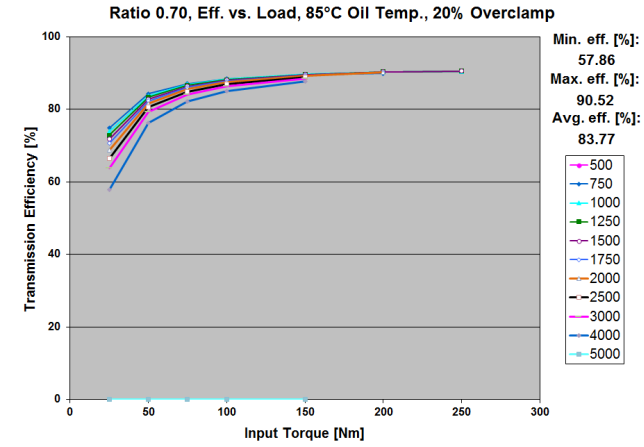
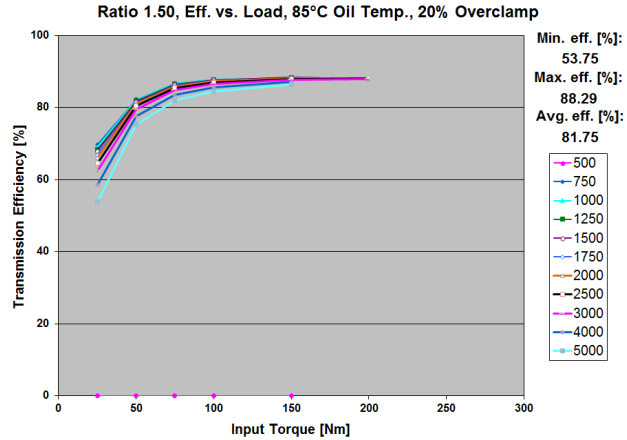
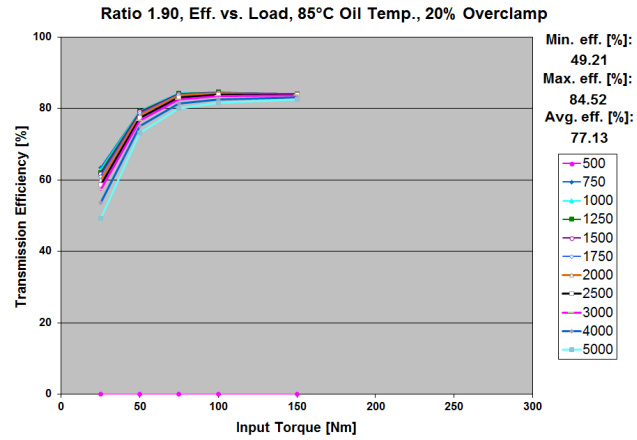
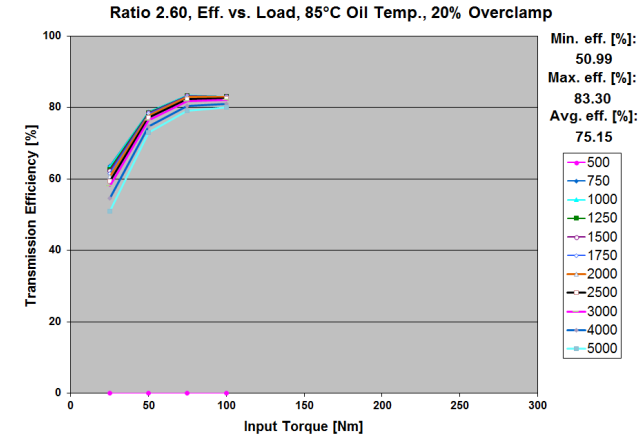








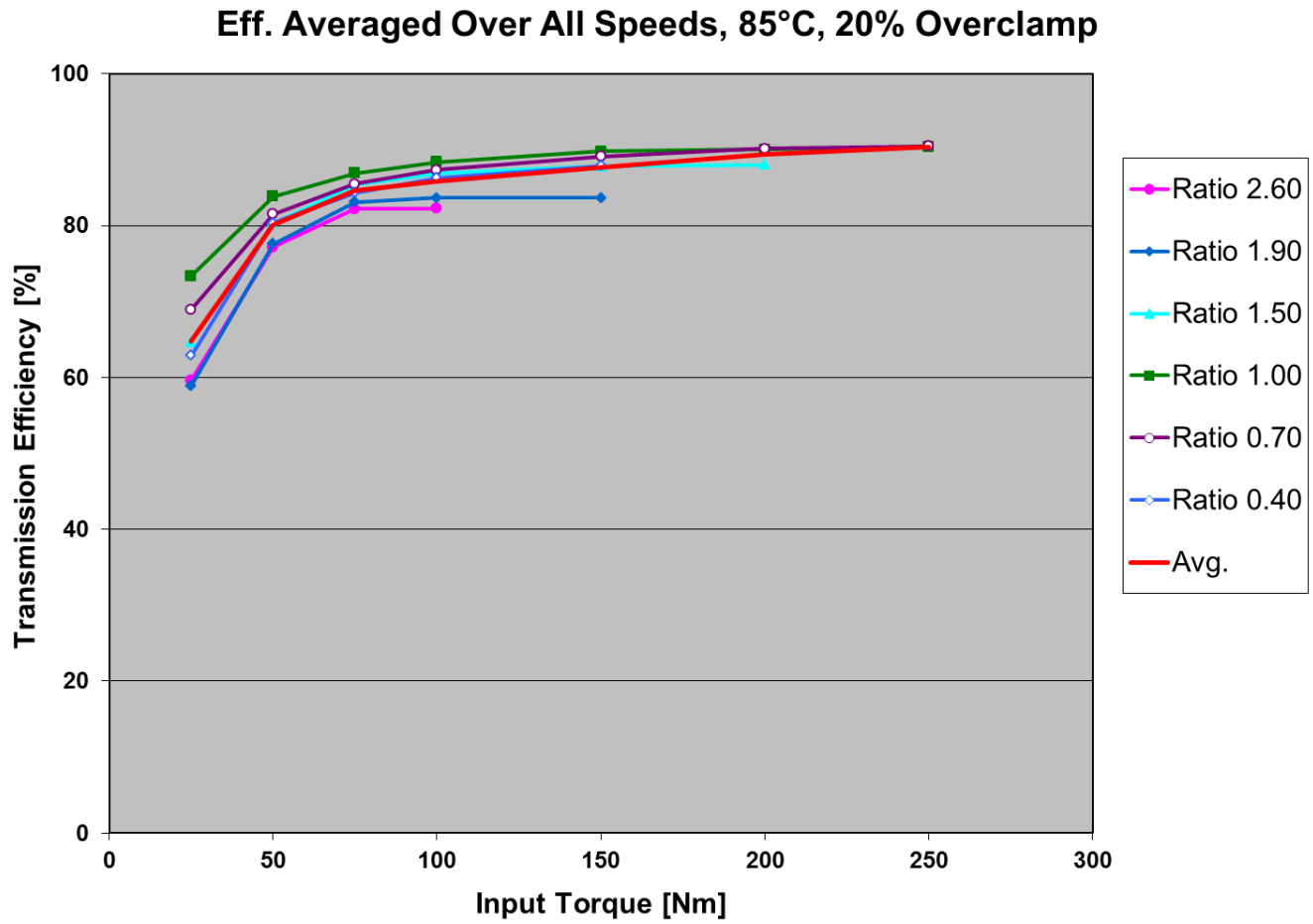




Nissan Altima CVT – Benchmark
Loaded Efficiency Testing

Contract No. EP-C-12-014, Work Assignment 4-11
May 23, 2016

LOADED EFFICIENCY TESTING – RESULTS



FEV Comments

- Data shown was measured at vehicle pressure + 20%
- Similar to spin losses, ratio 1.0 shows the highest efficiency

Nissan Altima CVT – Benchmark
Loaded Efficiency Testing

Contract No. EP-C-12-014, Work Assignment 4-11

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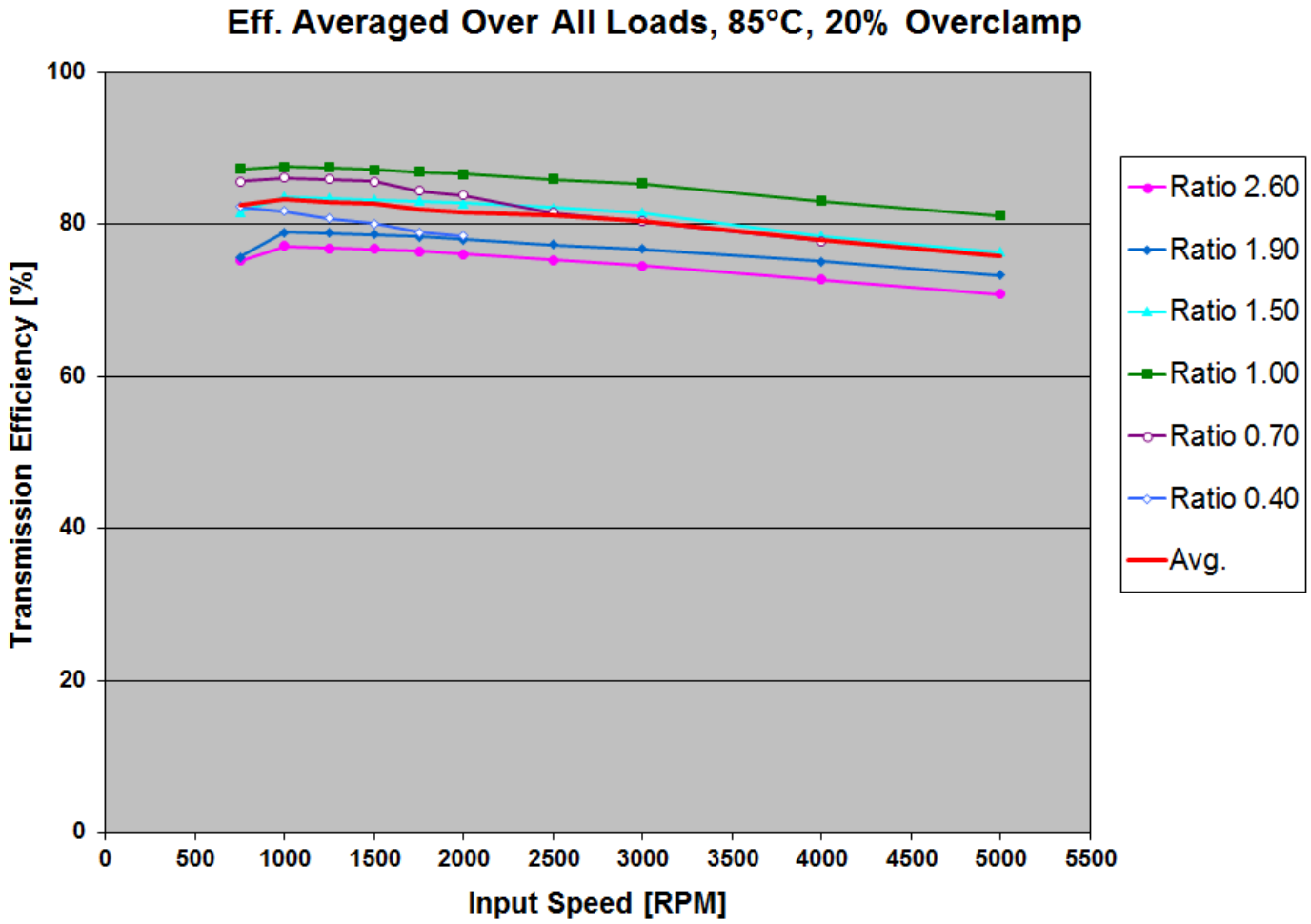


Nissan Altima CVT – Benchmark
Loaded Efficiency Testing

LOADED EFFICIENCY TESTING – CALCULATION METHOD FOR VEHICLE PRESSURE DATA

- The complete test matrix was run at measured vehicle pressure + 20%. Additionally, selected points were run at the measured vehicle pressure.
- Using both the vehicle pressure data and the vehicle pressure + 20% data, the pressure sensitivity was calculated

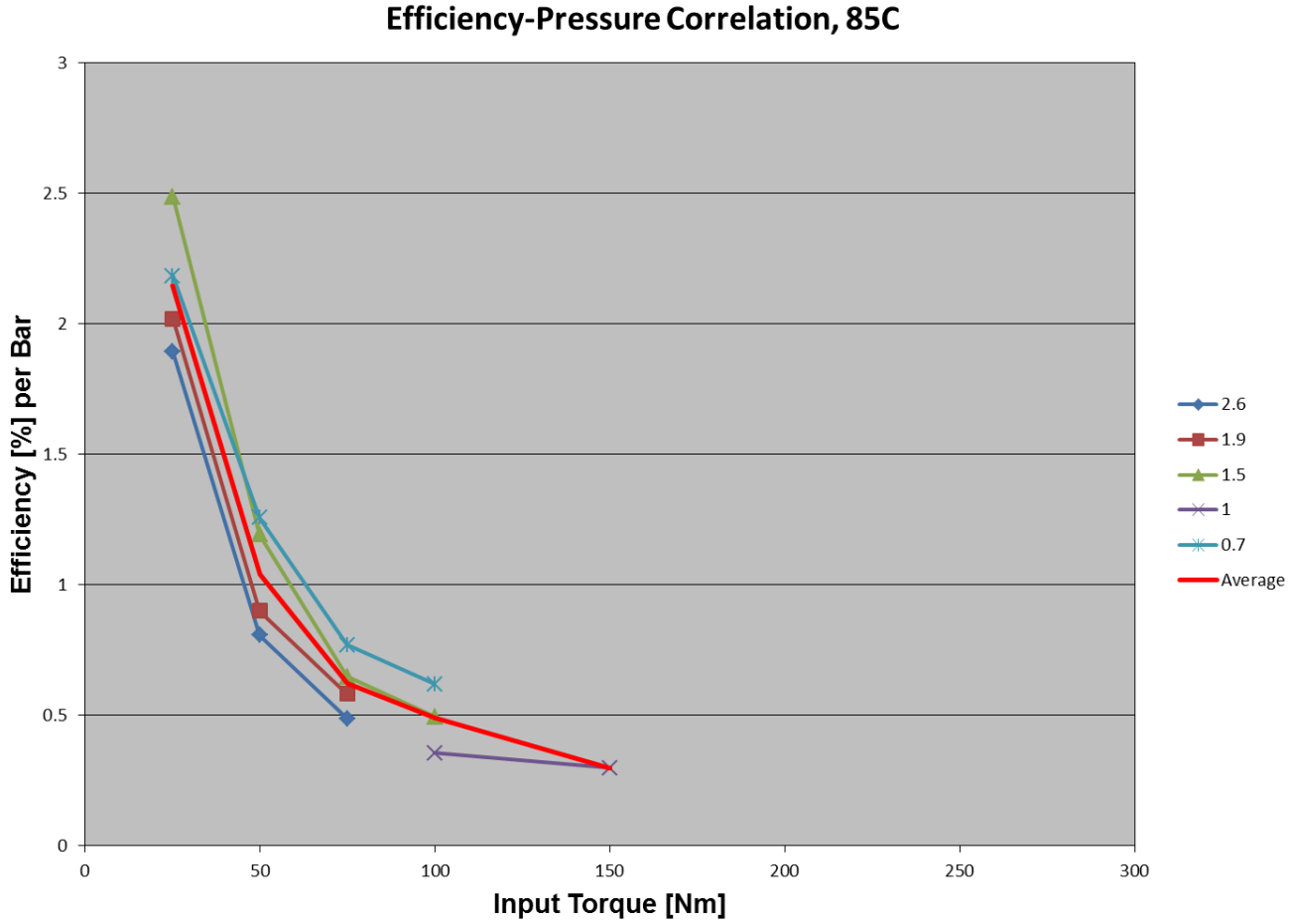
  $$\frac{\Delta \eta}{\Delta P}$$

- The pressure sensitivity is different at each input torque, so a different sensitivity value was needed for each load

Nissan Altima CVT – Benchmark
Loaded Efficiency Testing

Contract No. EP-C-12-014, Work Assignment 4-11
May 23, 2016

LOADED EFFICIENCY TESTING – CALCULATION METHOD FOR VEHICLE PRESSURE DATA



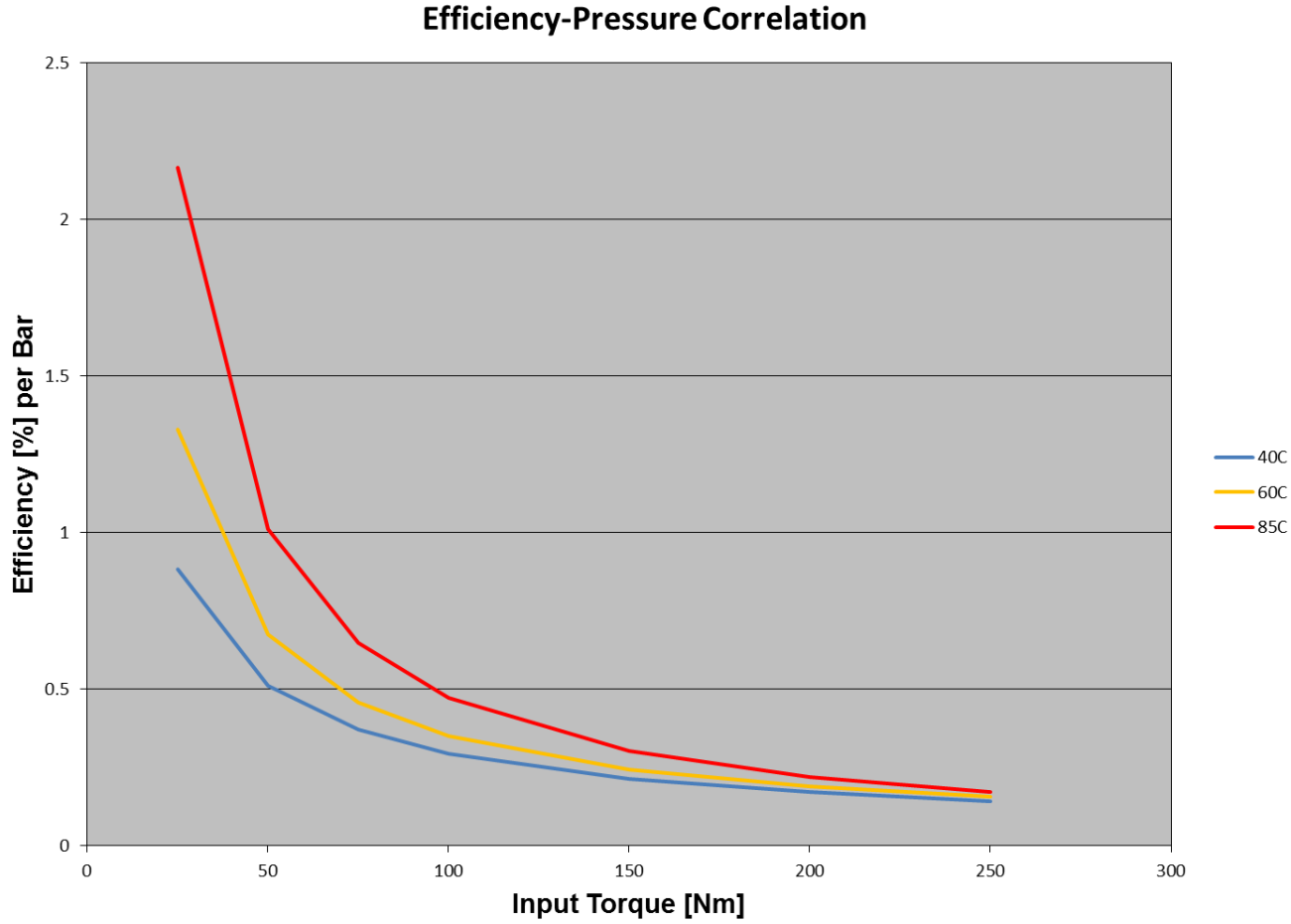
FEV Comments

- For each test temperature, all the tested ratios showed the same trend

Nissan Altima CVT – Benchmark
Loaded Efficiency Testing

Contract No. EP-C-12-014, Work Assignment 4-11
May 23, 2016

LOADED EFFICIENCY TESTING – CALCULATION METHOD FOR VEHICLE PRESSURE DATA



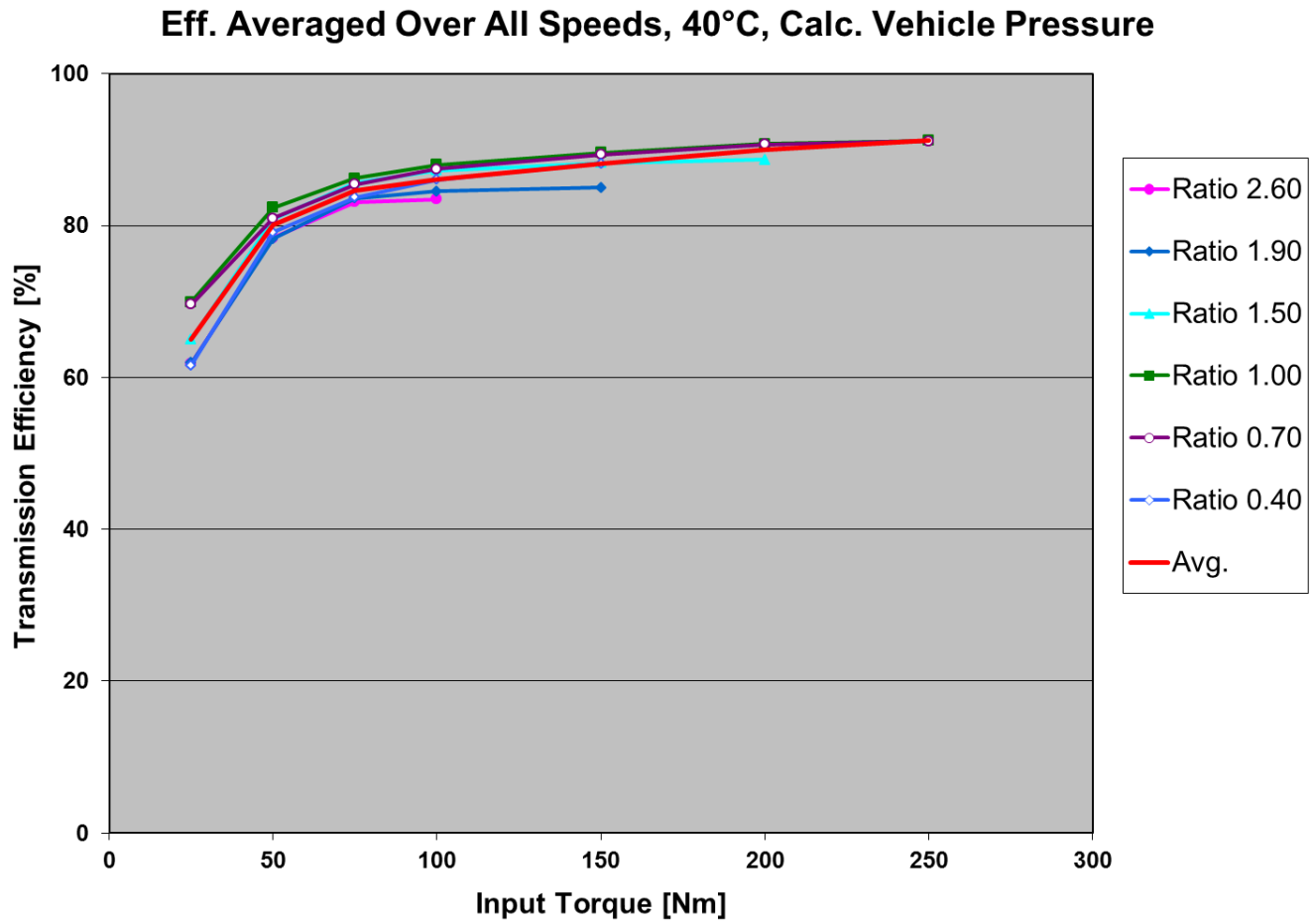
FEV Comments

- The data for each temperature was average over all tested ratios to create a pressure sensitivity curve for the three temperatures
- This was then applied to the vehicle pressure + 20% data to create the following charts.

Nissan Altima CVT – Benchmark
Loaded Efficiency Testing

Contract No. EP-C-12-014, Work Assignment 4-11
May 23, 2016

LOADED EFFICIENCY TESTING – RESULTS



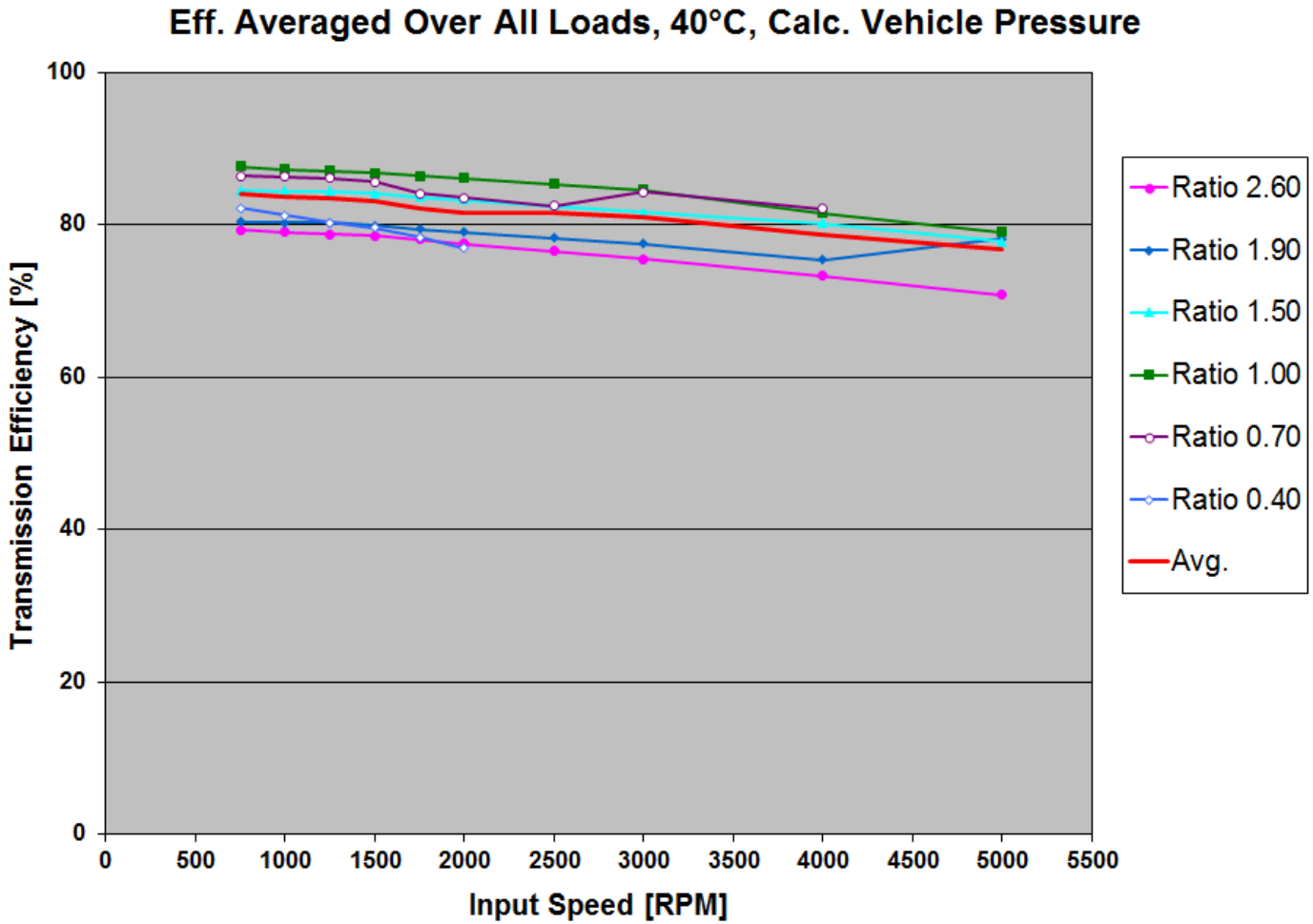
FEV Comments

- Data shown was calculated using the measured vehicle pressure + 20% data and the pressure sensitivity curves
- Similar to spin losses, ratio 1.0 shows the highest efficiency

Nissan Altima CVT – Benchmark
Loaded Efficiency Testing

Contract No. EP-C-12-014, Work Assignment 4-11

LOADED EFFICIENCY TESTING – CALCULATION METHOD FOR VEHICLE PRESSURE DATA



Nissan Altima CVT – Benchmark
Loaded Efficiency Testing

Contract No. EP-C-12-014, Work Assignment 4-11
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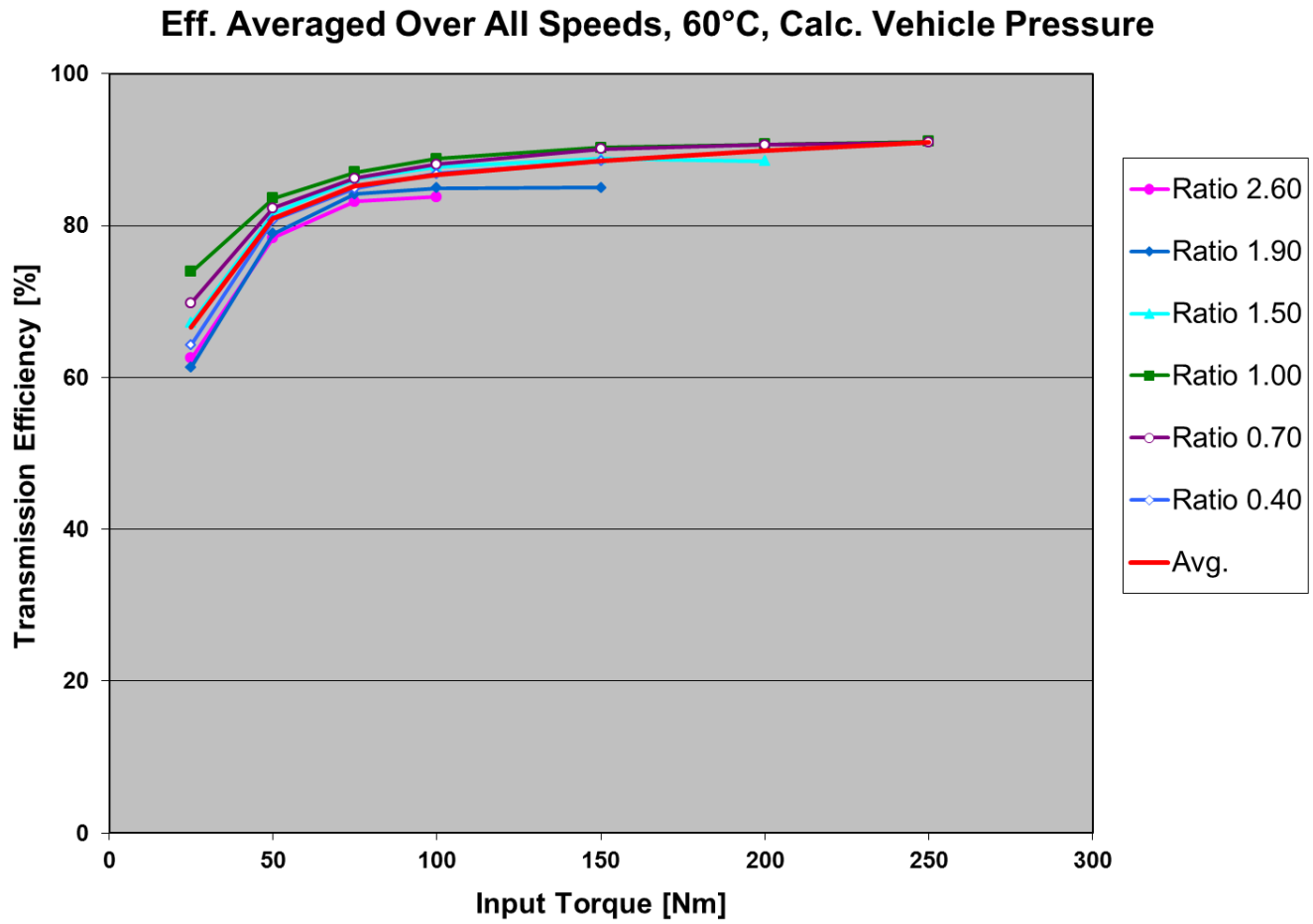
LOADED EFFICIENCY TESTING – RESULTS



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Nissan Altima CVT – Benchmark
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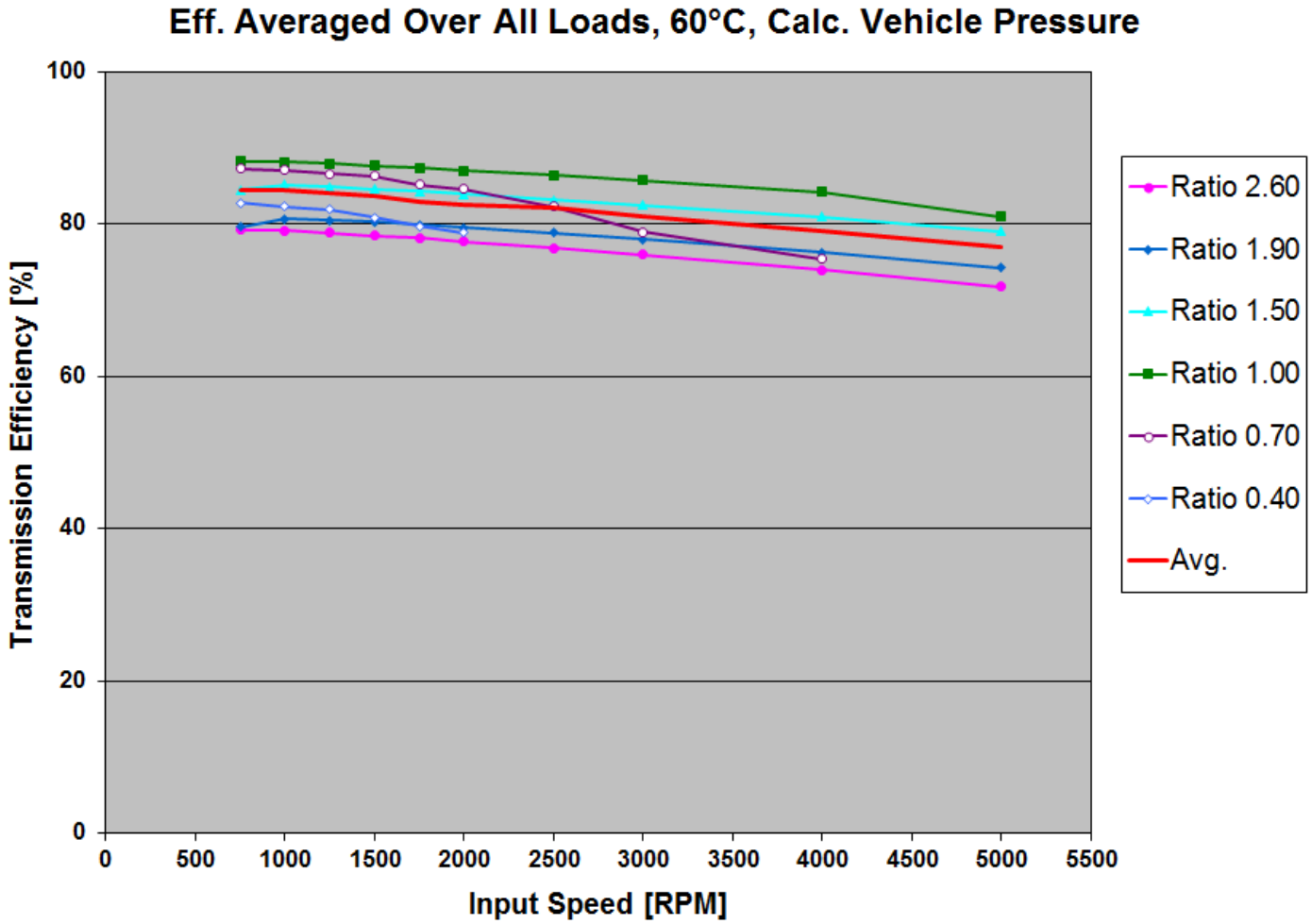
LOADED EFFICIENCY TESTING – CALCULATION METHOD FOR VEHICLE PRESSURE DATA



Nissan Altima CVT – Benchmark
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Contract No. EP-C-12-014, Work Assignment 4-11
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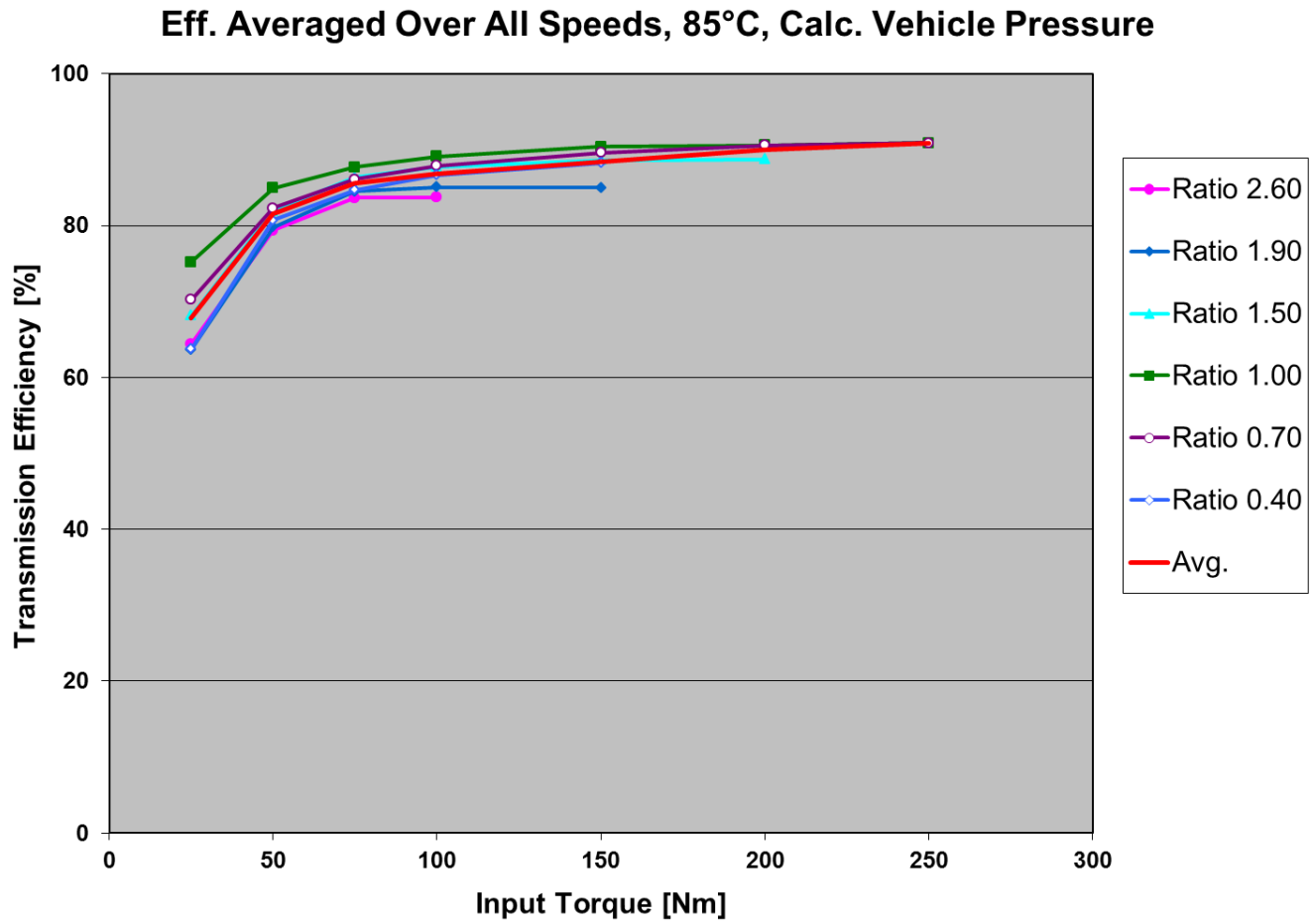

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Nissan Altima CVT – Benchmark
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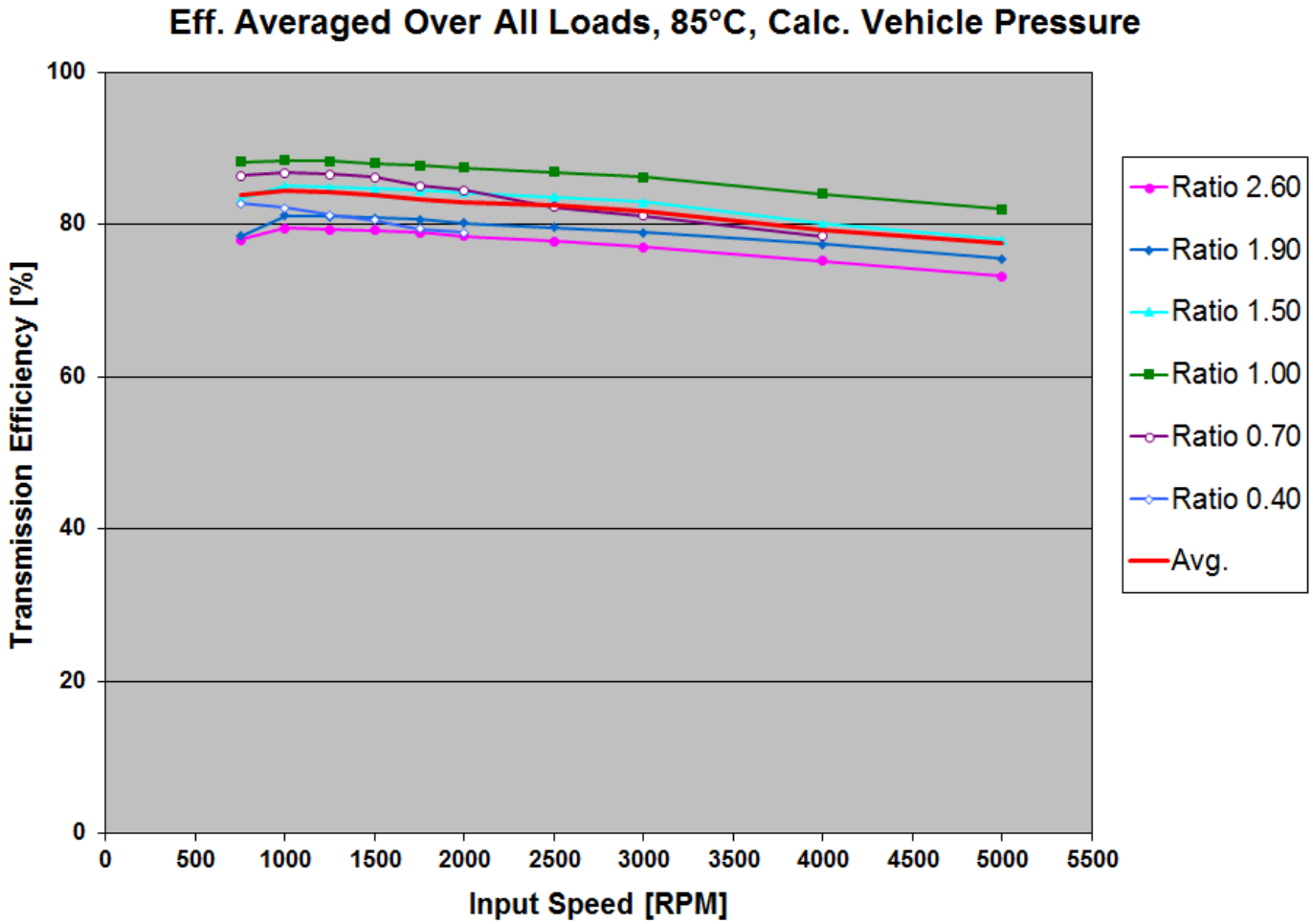

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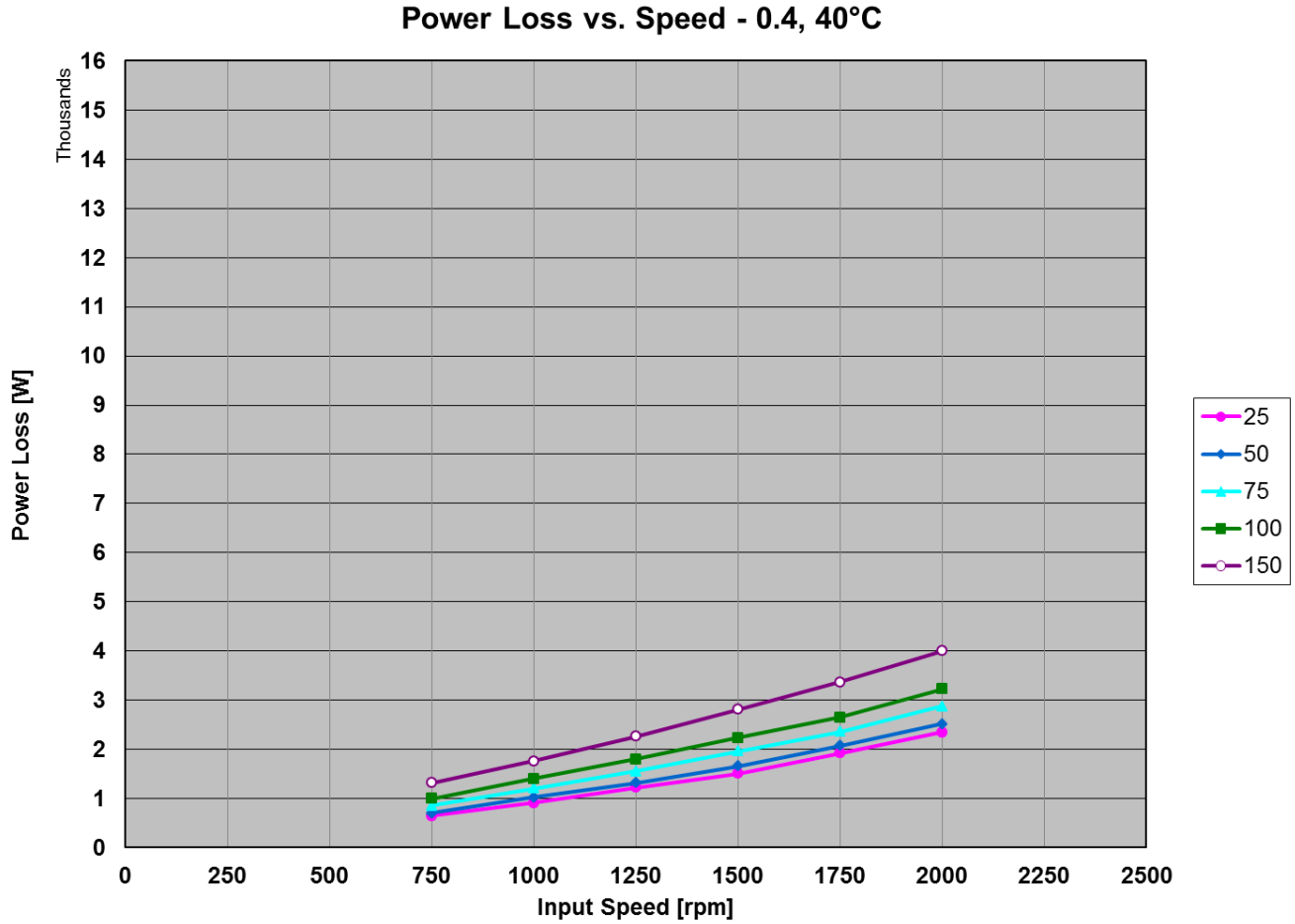

FEV Comments

- Power loss at ratio 0.4 ranges from ~1,000 - ~3,000W
  - At typical FE-cycle loads (50 – 100 Nm) the losses range from ~800 – 3,000W

Nissan Altima CVT – Benchmark
Loaded Efficiency Testing

Contract No. EP-C-12-014, Work Assignment 4-11
May 23, 2016

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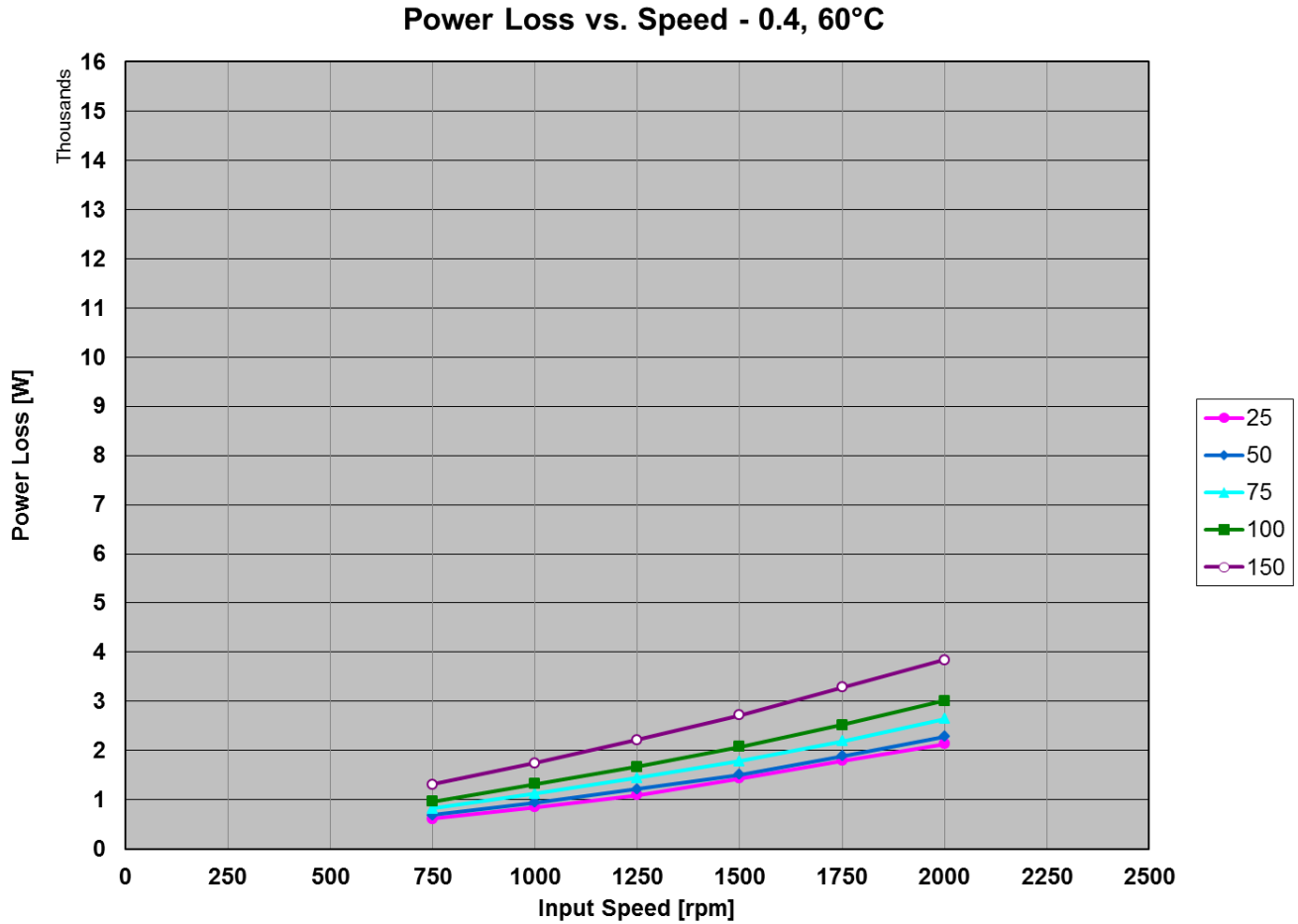

FEV Comments

- Power loss at ratio 0.4 ranges from ~1,000 - ~2,500W
  - At typical FE-cycle loads (50 – 100 Nm) the losses range from ~800 – 2,500W

Nissan Altima CVT – Benchmark
Loaded Efficiency Testing

Contract No. EP-C-12-014, Work Assignment 4-11
May 23, 2016

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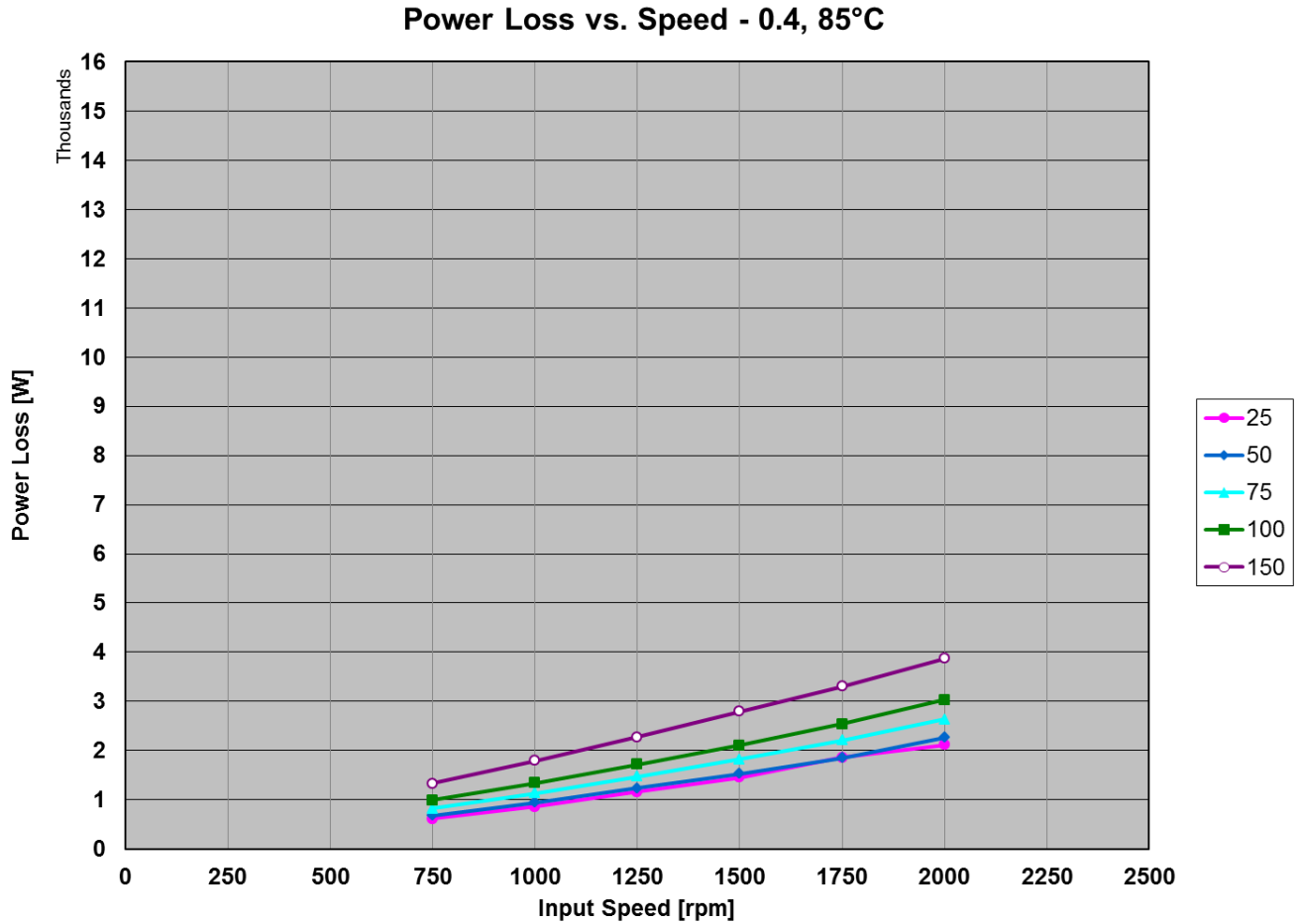

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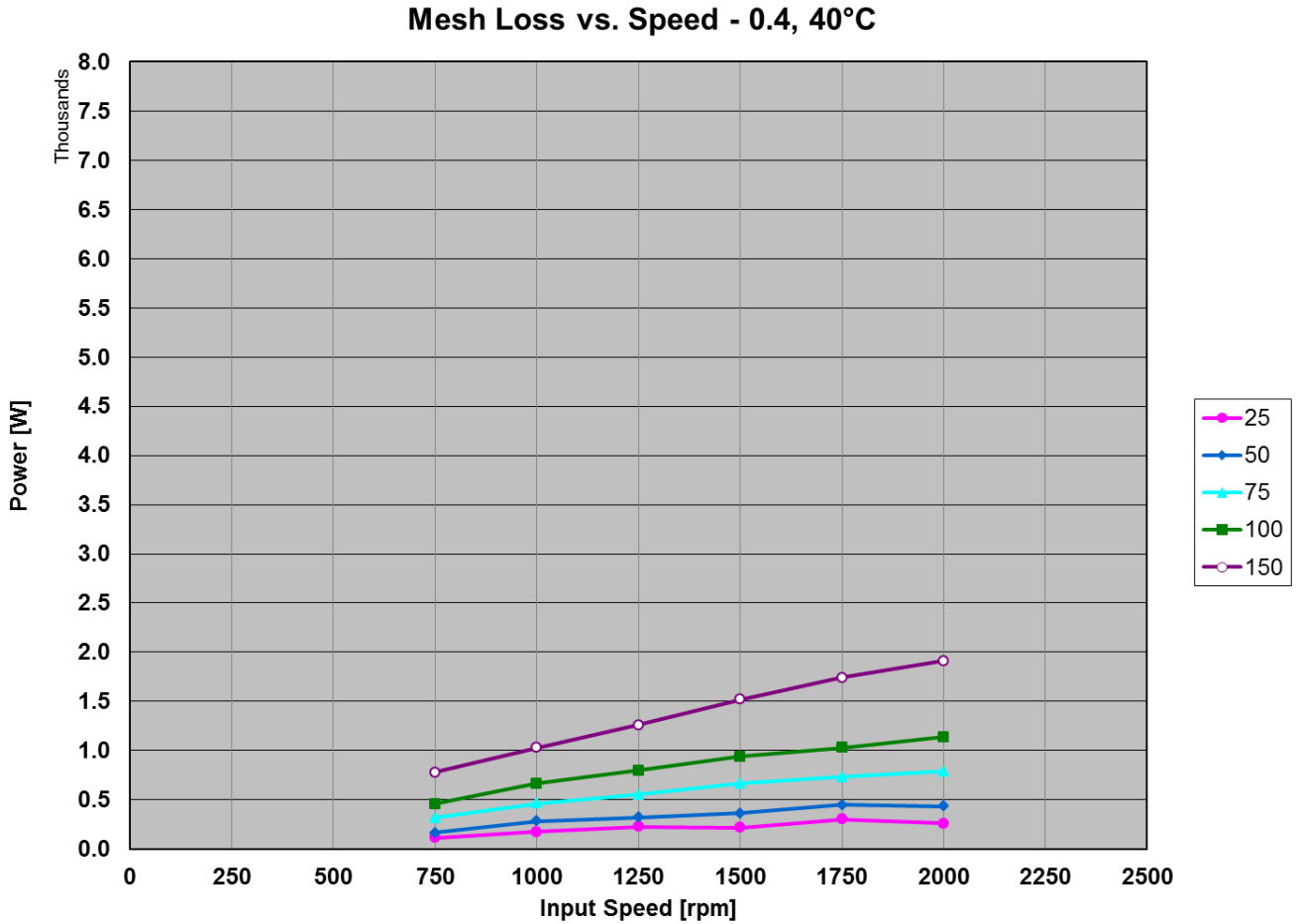


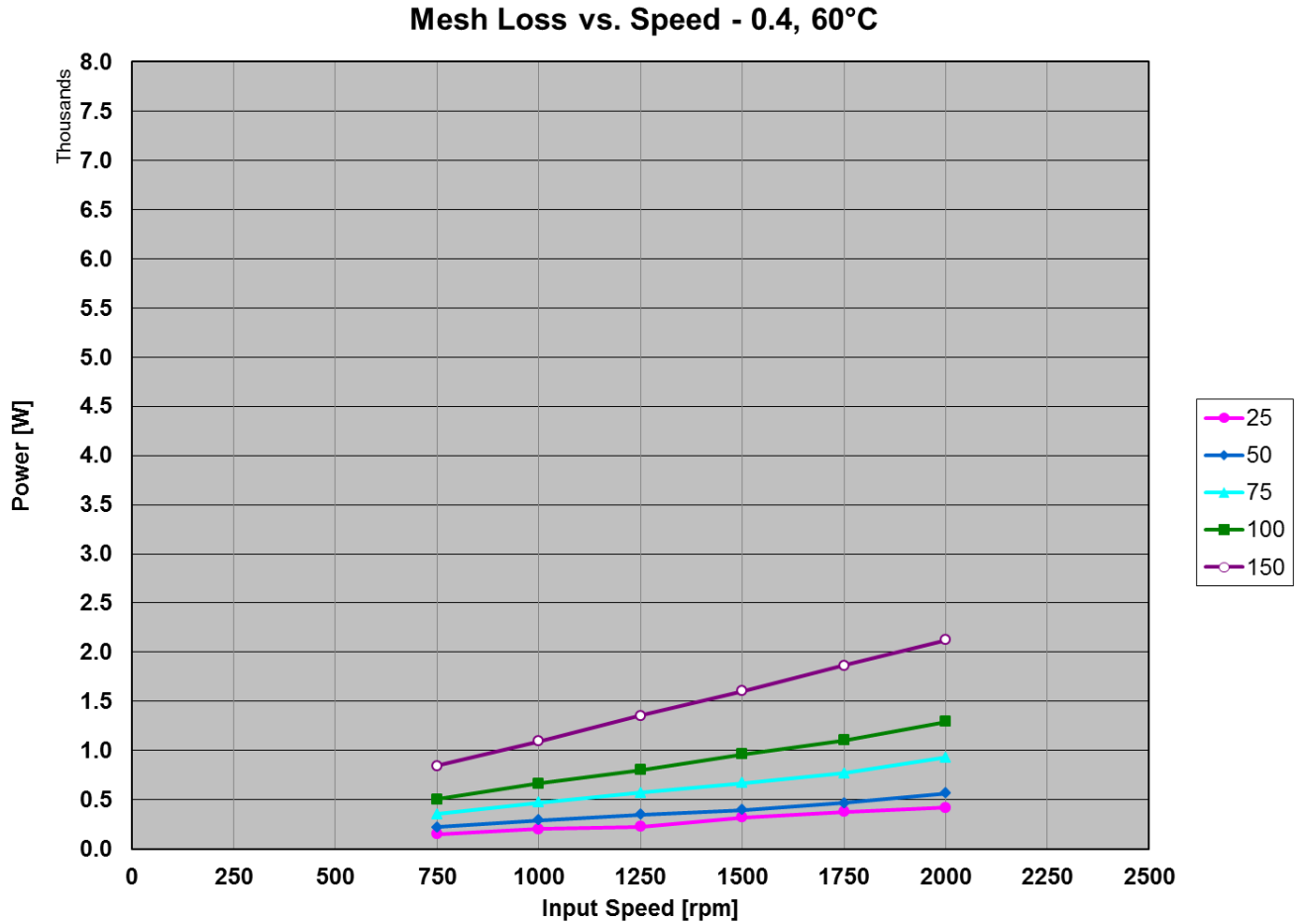
FEV Comments

- Mesh losses represent all load-dependent losses (Total power loss minus spin power loss)
- Mesh loss at ratio 0.4 ranges from ~500 - ~1,000W
  - 250 – 600W in FE range

Nissan Altima CVT – Benchmark
Loaded Efficiency Testing

Contract No. EP-C-12-014, Work Assignment 4-11
May 23, 2016

LOADED EFFICIENCY TESTING – RESULTS



FEV Comments

- Mesh losses represent all load-dependent losses (Total power loss minus spin power loss)
- Mesh loss at ratio 0.4 ranges from ~500 - ~1,200W
  - 250 – 700W in FE range

Nissan Altima CVT – Benchmark
Loaded Efficiency Testing

Contract No. EP-C-12-014, Work Assignment 4-11
May 23, 2016

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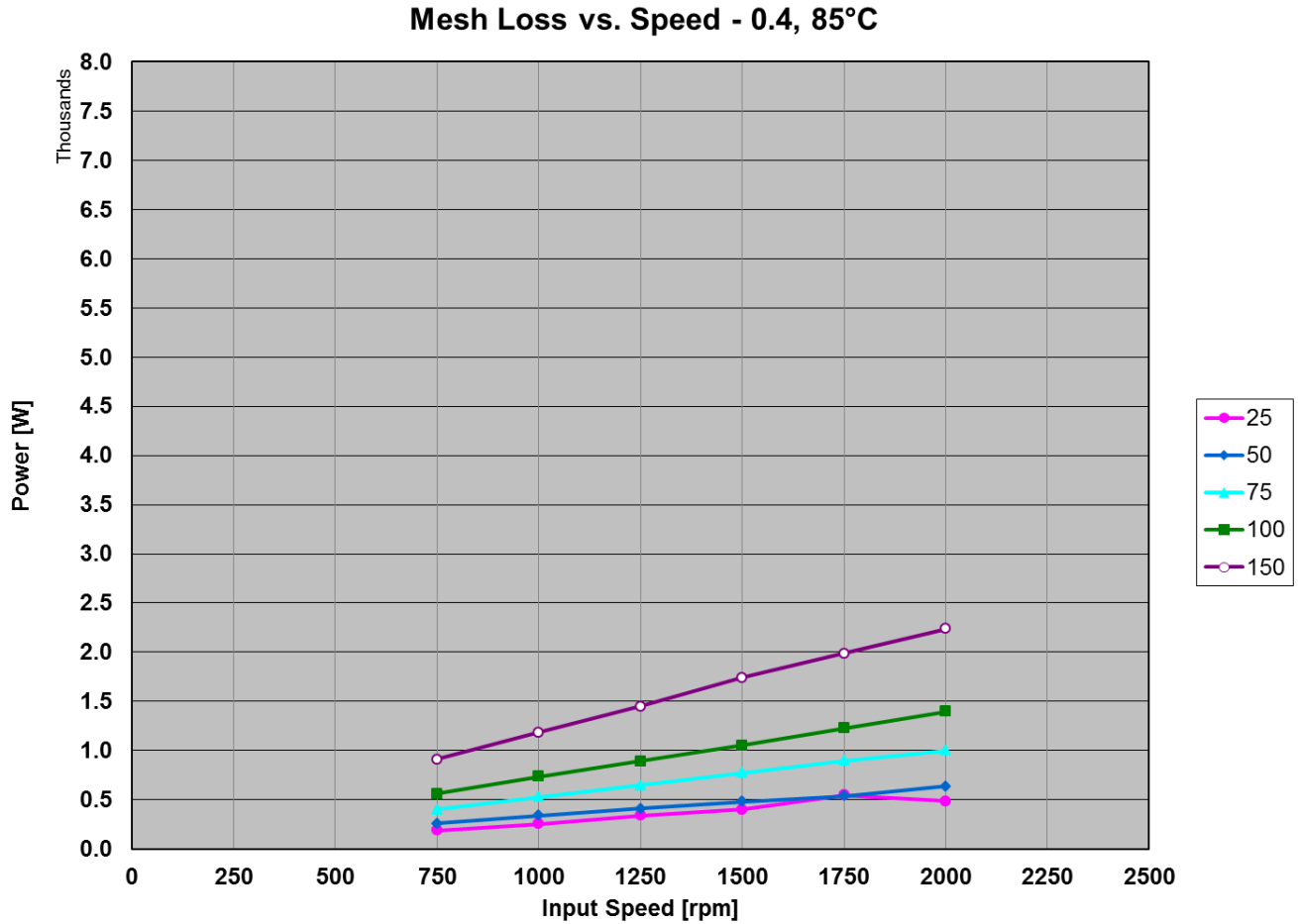


FEV Comments

- Mesh losses represent all load-dependent losses (Total power loss minus spin power loss)
- Mesh loss at ratio 0.4 ranges from ~500 - ~1,500W
  - 300 – 1,000W in FE range
- Increase in mesh losses with increasing temperature

Agenda

- Transmission Specifications
- Procurement & Break-In
- Strategy/Control Assessment in Vehicle
- Bench Test Setup and Spin Loss Testing
- Neutral Coast Down Testing
- Loaded Efficiency Testing
- Inertia Evaluation
- Oil Pump Efficiency Testing
- Appendix

Nissan Altima CVT – Benchmark
Inertia Evaluation

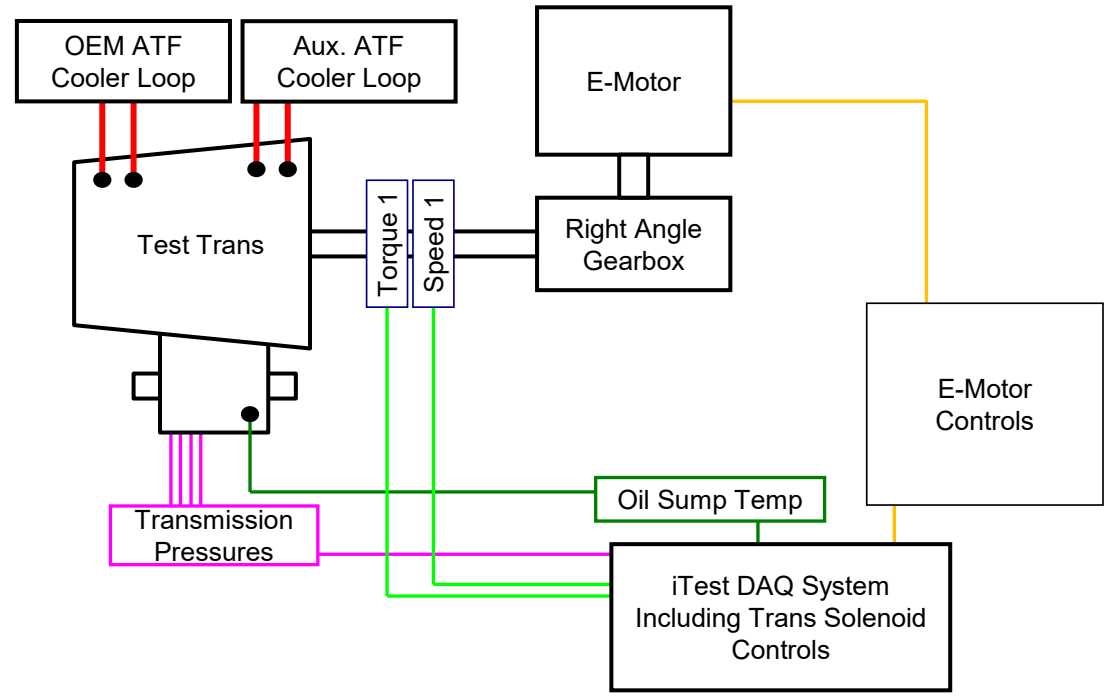
INERTIA EVALUATION – BOUNDARY CONDITIONS

- Gear ratios (3):
  - Min, max, 1.0
- Torque converter clutch locked for all tests
- Speed sweep (1):
  - 500 … 5000 rpm at constant acceleration rate (with limitations for maximum overdrive ratio to avoid unrealistic output speeds)
- Transmission oil temperatures (1):
  - 60°C
- Transmission system pressures (1):
  - As observed in vehicle

Nissan Altima CVT – Benchmark
Inertia Evaluation

Contract No. EP-C-12-014, Work Assignment 4-11
May 23, 2016

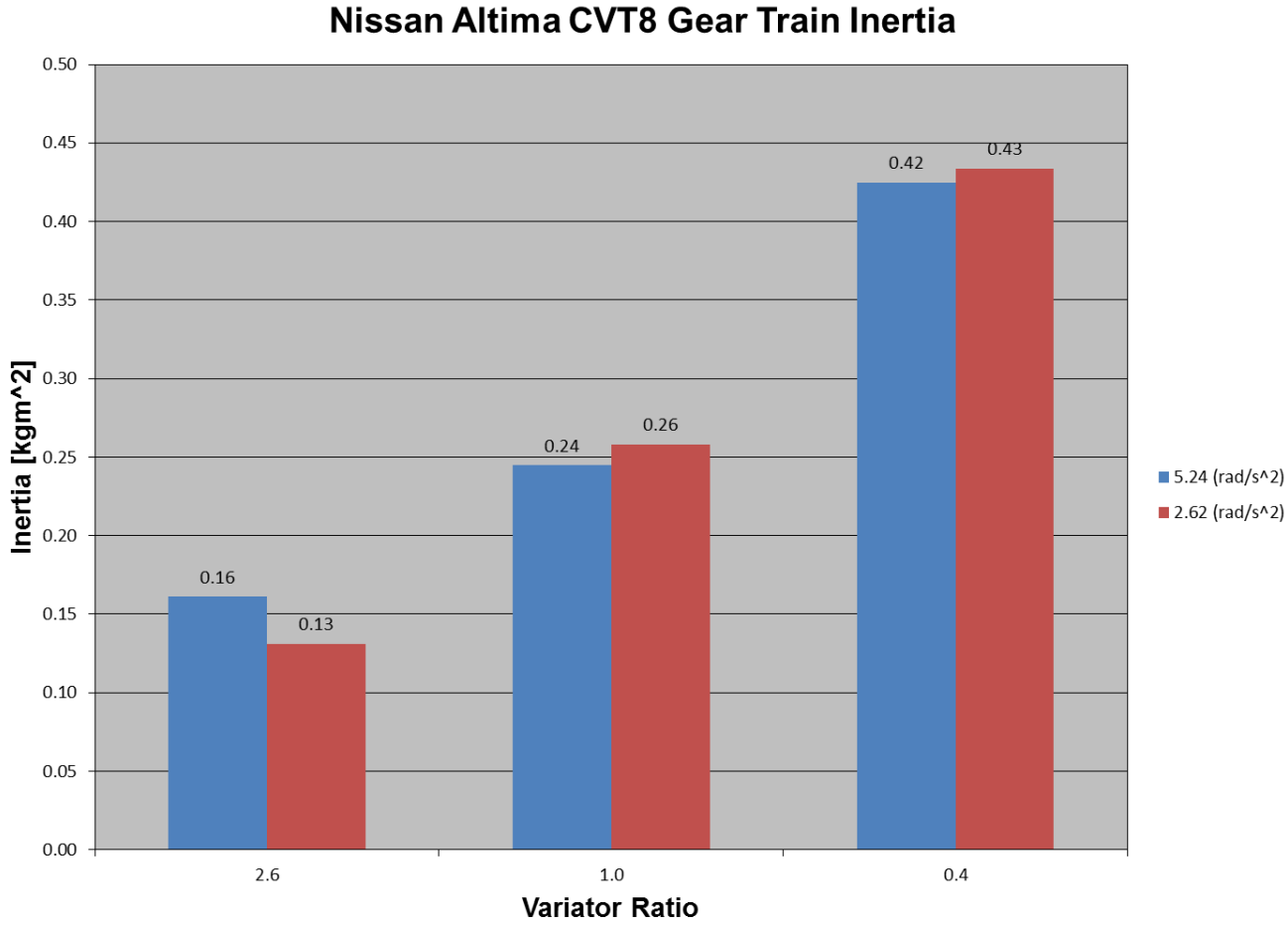
INERTIA EVALUATION – SETUP SCHEMATIC



Nissan Altima CVT – Benchmark
Inertia Evaluation

Contract No. EP-C-12-014, Work Assignment 4-11
May 23, 2016

INERTIA EVALUATION – RESULTS



FEV Comments

- Inertia includes all rotating components of the transmission (oil pump, torque converter, PGS, pulleys, clutch)

Agenda

- Transmission Specifications
- Procurement & Break-In
- Strategy/Control Assessment in Vehicle
- Bench Test Setup and Spin Loss Testing
- Neutral Coast Down Testing
- Loaded Efficiency Testing
- Inertia Evaluation
- Oil Pump Efficiency Testing
- Appendix

Nissan Altima CVT – Benchmark
Oil Pump Efficiency Testing

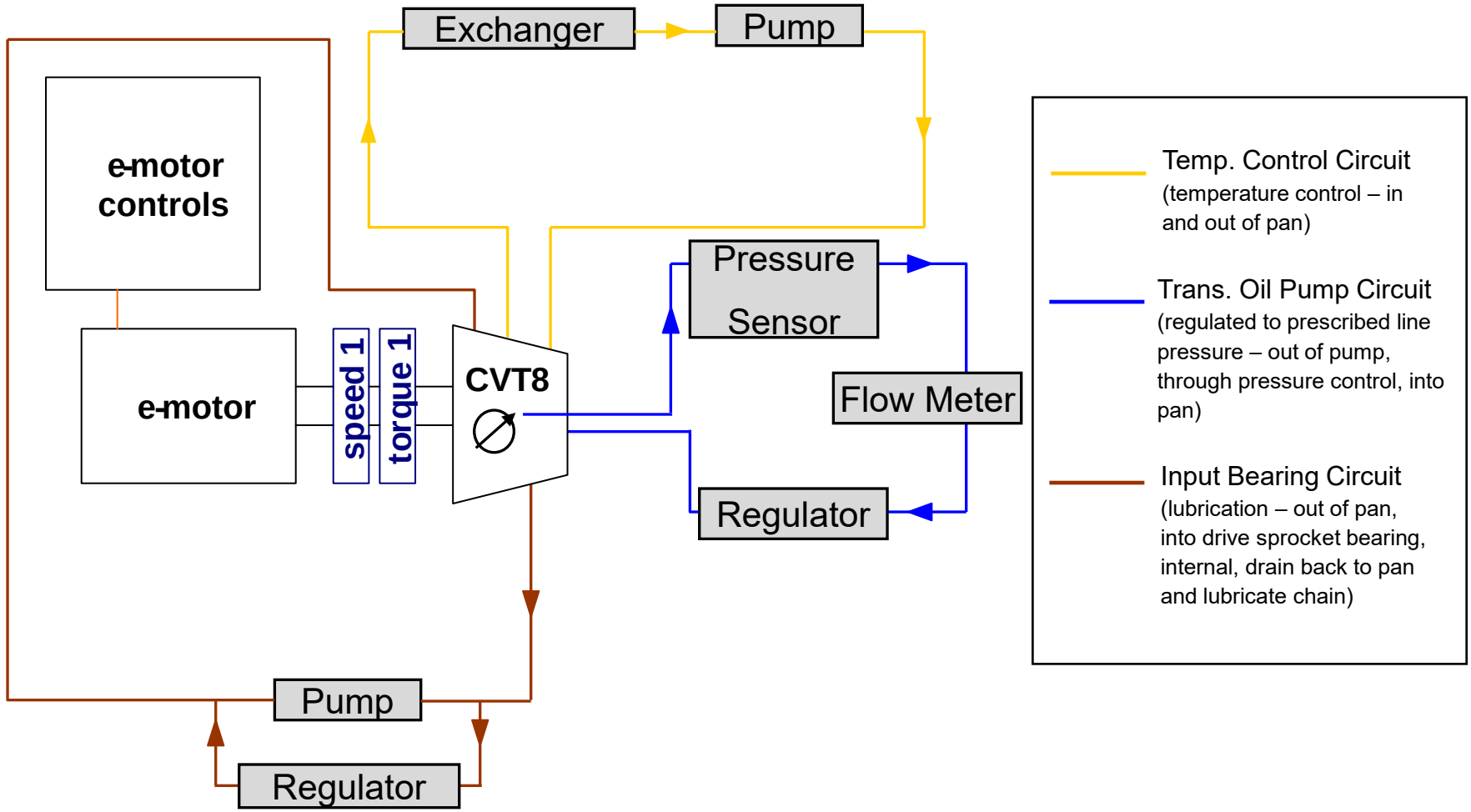
OIL PUMP EFFICIENCY – BOUNDARY CONDITIONS

- Input speeds (11):
  - 500-5000 rpm
- Transmission oil temperatures (3):
  - 40°C, 60°C, 85°C
- Line pressures (4):
  - 5, 15, 25, 40 bar
- Measured values include the following losses:
  - Drive sprocket bushing losses
  - Pump chain losses
  - Driven sprocket bearing losses
  - Pumping losses

Nissan Altima CVT – Benchmark
Oil Pump Efficiency Testing

Contract No. EP-C-12-014, Work Assignment 4-11
May 23, 2016

OIL PUMP EFFICIENCY TESTING – SETUP SCHEMATIC



Contract No. EP-C-12-014, Work Assignment 4-11
May 23, 2016

OIL PUMP EFFICIENCY TESTING – PUMP DISPLACEMENT

- ISO8426 Pump Displacement Calculation
  - The displacement per revolution (V_i) is calculated using the following equation

$$V_i = \left\{ \left(\frac{1}{k} \cdot \sum_{i=1}^{k} q_i \right) - \left[\frac{\frac{1}{k} \cdot \sum_{i=1}^{k} (\Delta p_i . q_i) - \frac{1}{k^2} \cdot \left(\sum_{i=1}^{k} \Delta p_i \right) \left(\sum_{i=1}^{k} q_i \right)}{\left(\frac{1}{k} \cdot \sum_{i=1}^{k} \Delta p_i^2 \right) - \left(\frac{1}{k} \cdot \sum_{i=1}^{k} \Delta p_i \right)^2} \right] \left(\frac{1}{k} \cdot \sum_{i=1}^{k} \Delta p_i \right) \right\} \frac{1}{n}$$

where

q_i is the flow rate at $\Delta p = 0$, expressed in litres per minute;

n is the shaft rotational frequency, expressed in revolutions per minute;

Δp is the differential pressure, that is, the difference between the outlet and inlet pressures, expressed in megapascals (bar);

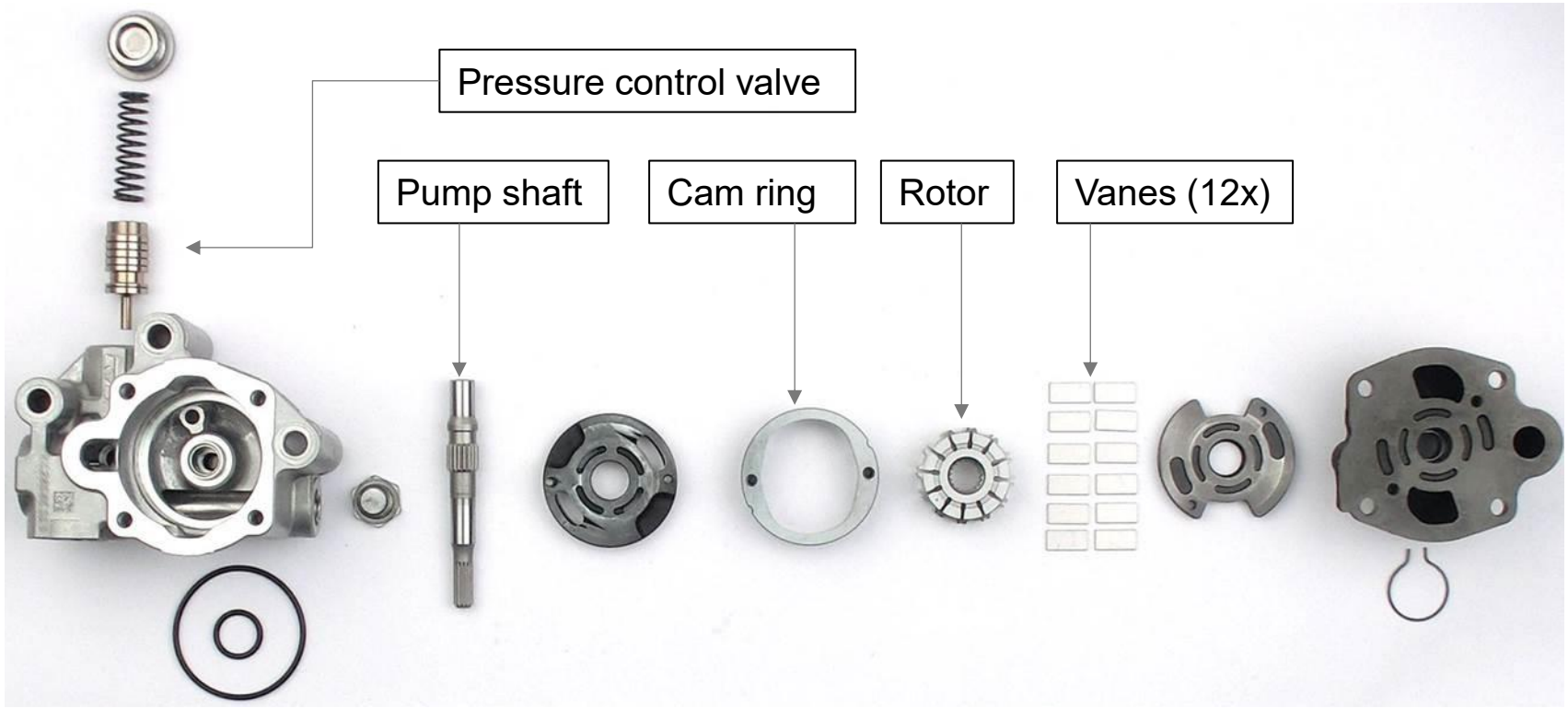
Δp_i is the differential pressure at a particular pump outlet or motor inlet pressure level, expressed in megapascals (bar);

k is the number of pump outlet or motor input pressures used during the test.

Nissan Altima CVT – Benchmark
Oil Pump Efficiency Testing

Contract No. EP-C-12-014, Work Assignment 4-11
May 23, 2016

OIL PUMP EFFICIENCY TESTING – PUMP COMPONENTS

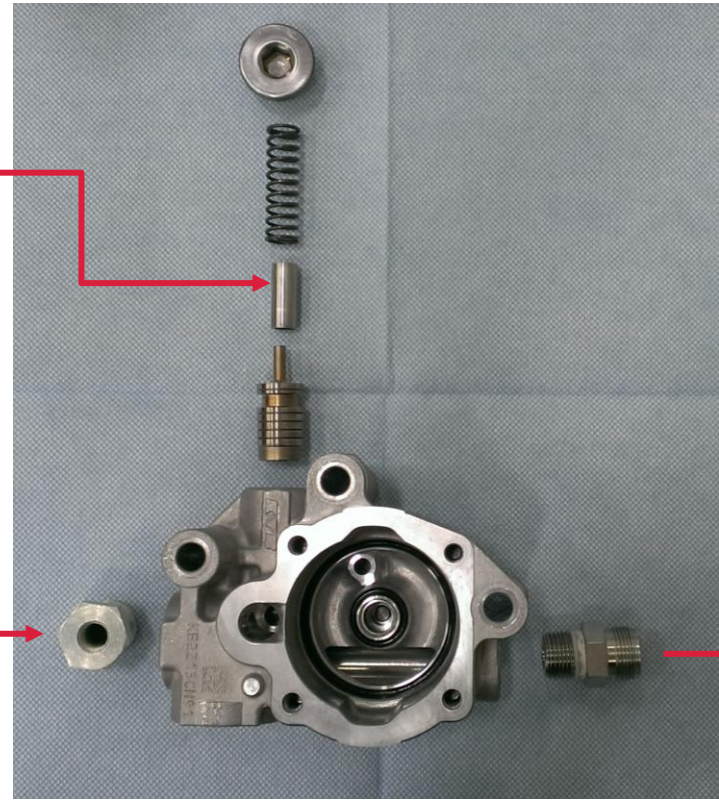


Nissan Altima CVT – Benchmark
Oil Pump Efficiency Testing

Contract No. EP-C-12-014, Work Assignment 4-11
May 23, 2016

OIL PUMP EFFICIENCY TESTING – PUMP MODIFICATIONS

Steel tube used to hold pressure relief valve closed



Machining plug removed and replaced with fitting to measure inlet pressure/temperature

Pump housing tapped to reroute pump discharge outside of transmission

Nissan Altima CVT – Benchmark
Oil Pump Efficiency Testing

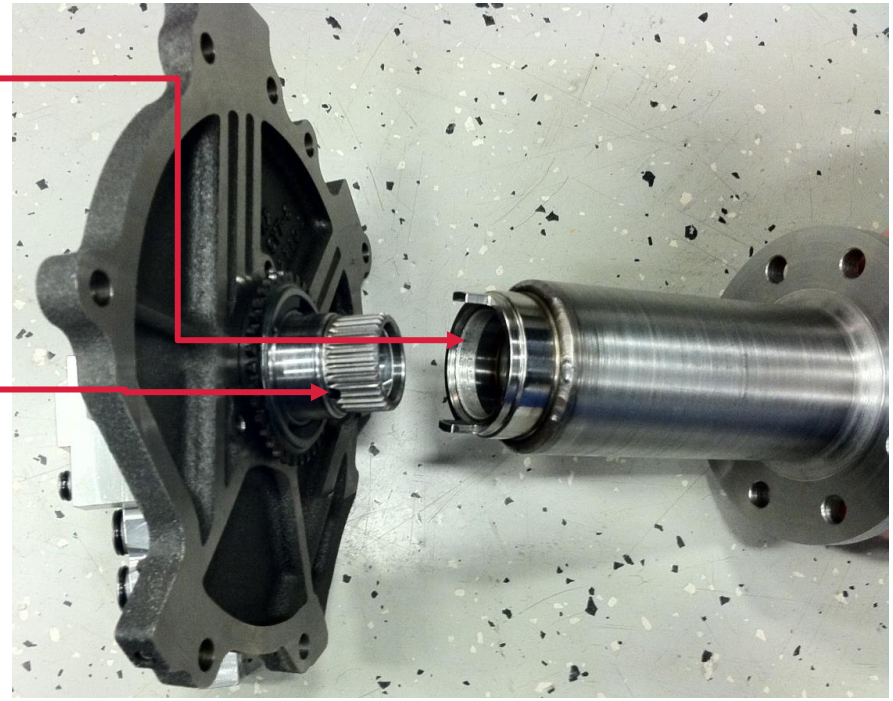
Contract No. EP-C-12-014, Work Assignment 4-11
May 23, 2016

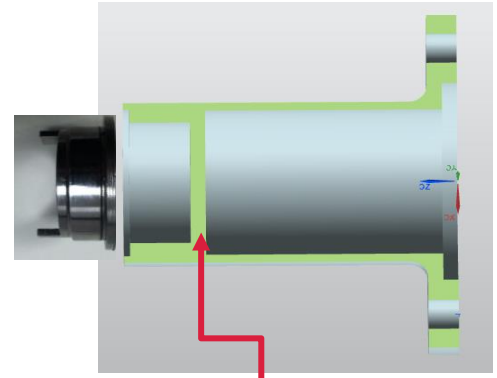
OIL PUMP EFFICIENCY TESTING – LUBRICATION CIRCUIT MODIFICATIONS

Input drive bushing

Oil is fed through the center section to lubricate input drive bushing

Back of stator has been welded shut to force oil through the bushing





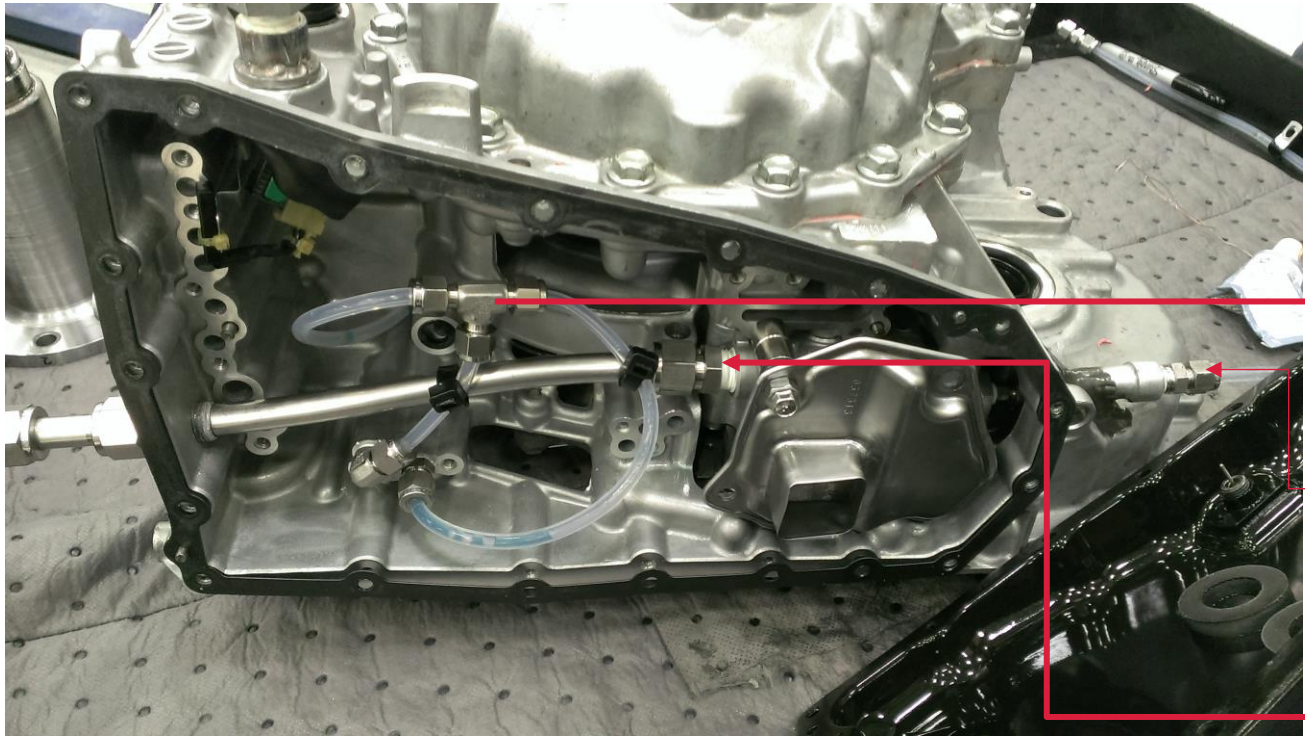
Input drive adapter closed off inside to force lube oil through the bushing when exiting the cavity

Nissan Altima CVT – Benchmark
Oil Pump Efficiency Testing

Contract No. EP-C-12-014, Work Assignment 4-11
May 23, 2016

OIL PUMP EFFICIENCY TESTING – TRANSMISSION CASE MODIFICATIONS

- Transmission case and pump housing modifications



Modified lube circuit for external pump

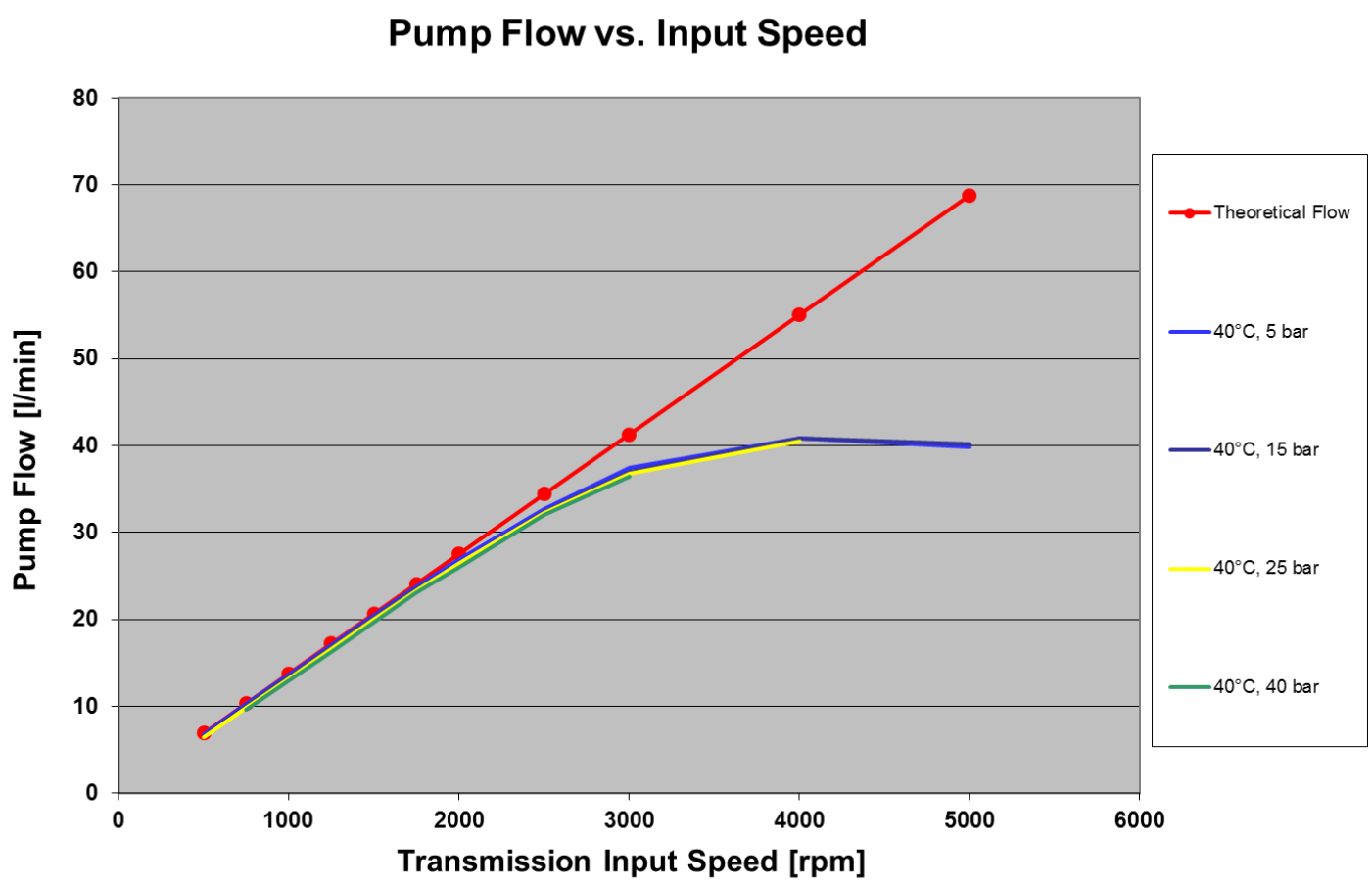
Pump housing tapped for inlet pressure and temperature

Original pump discharge port blocked and flow routed outside of case

Nissan Altima CVT – Benchmark
Oil Pump Efficiency Testing

Contract No. EP-C-12-014, Work Assignment 4-11
May 23, 2016

OIL PUMP EFFICIENCY TESTING – RESULTS 40°C



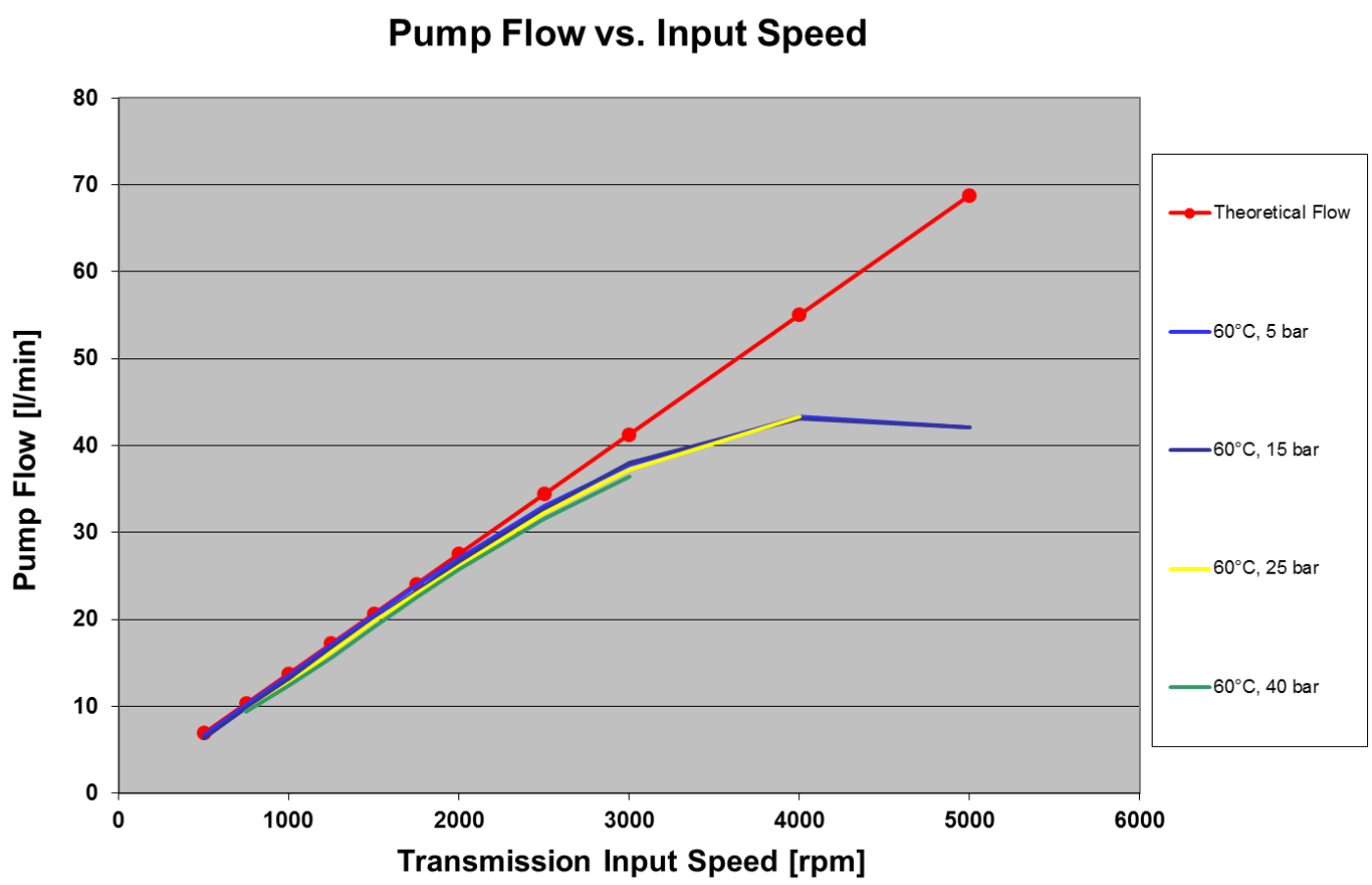
FEV Comments

- Theoretical pump displacement calculated using ISO8426 (13.76 cc/input speed rev)
- CVT8 oil pump shows significant deviation from theoretical flow above 3,000 rpm at all tested pressures
- Increase in pressure does not seem to decrease the actual flow equivalently

Nissan Altima CVT – Benchmark
Oil Pump Efficiency Testing

Contract No. EP-C-12-014, Work Assignment 4-11
May 23, 2016

OIL PUMP EFFICIENCY TESTING – RESULTS 60°C



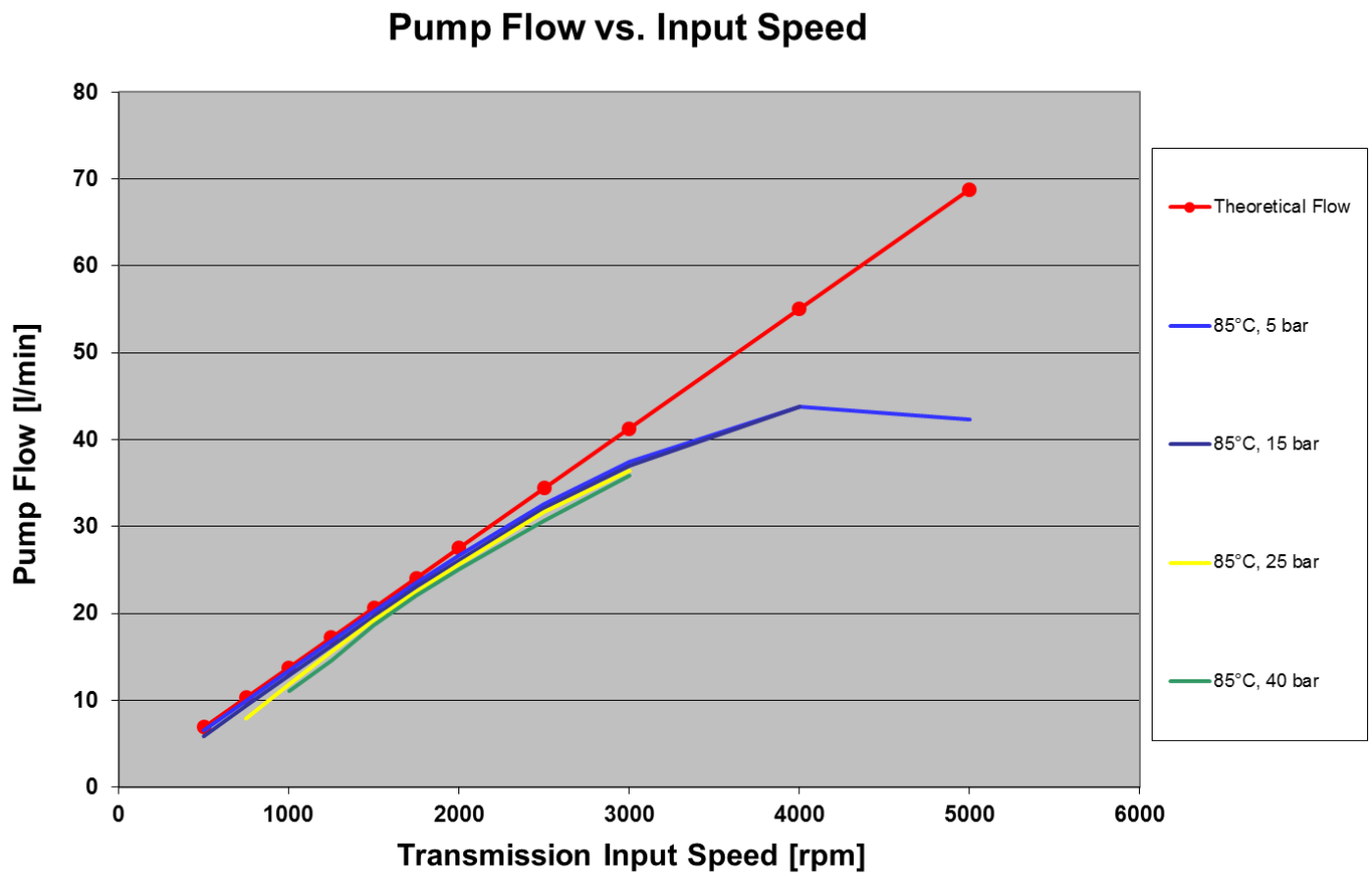
FEV Comments

- Theoretical pump displacement calculated using ISO8426 (13.76 cc/input speed rev)
- Slightly more flow at warmer oil temperatures can indicate that flow deficiency is related to incomplete pump chamber filling

Nissan Altima CVT – Benchmark
Oil Pump Efficiency Testing

Contract No. EP-C-12-014, Work Assignment 4-11
May 23, 2016

OIL PUMP EFFICIENCY TESTING – RESULTS 85°C



FEV Comments

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Nissan Altima CVT – Benchmark
Oil Pump Efficiency Testing

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May 23, 2016

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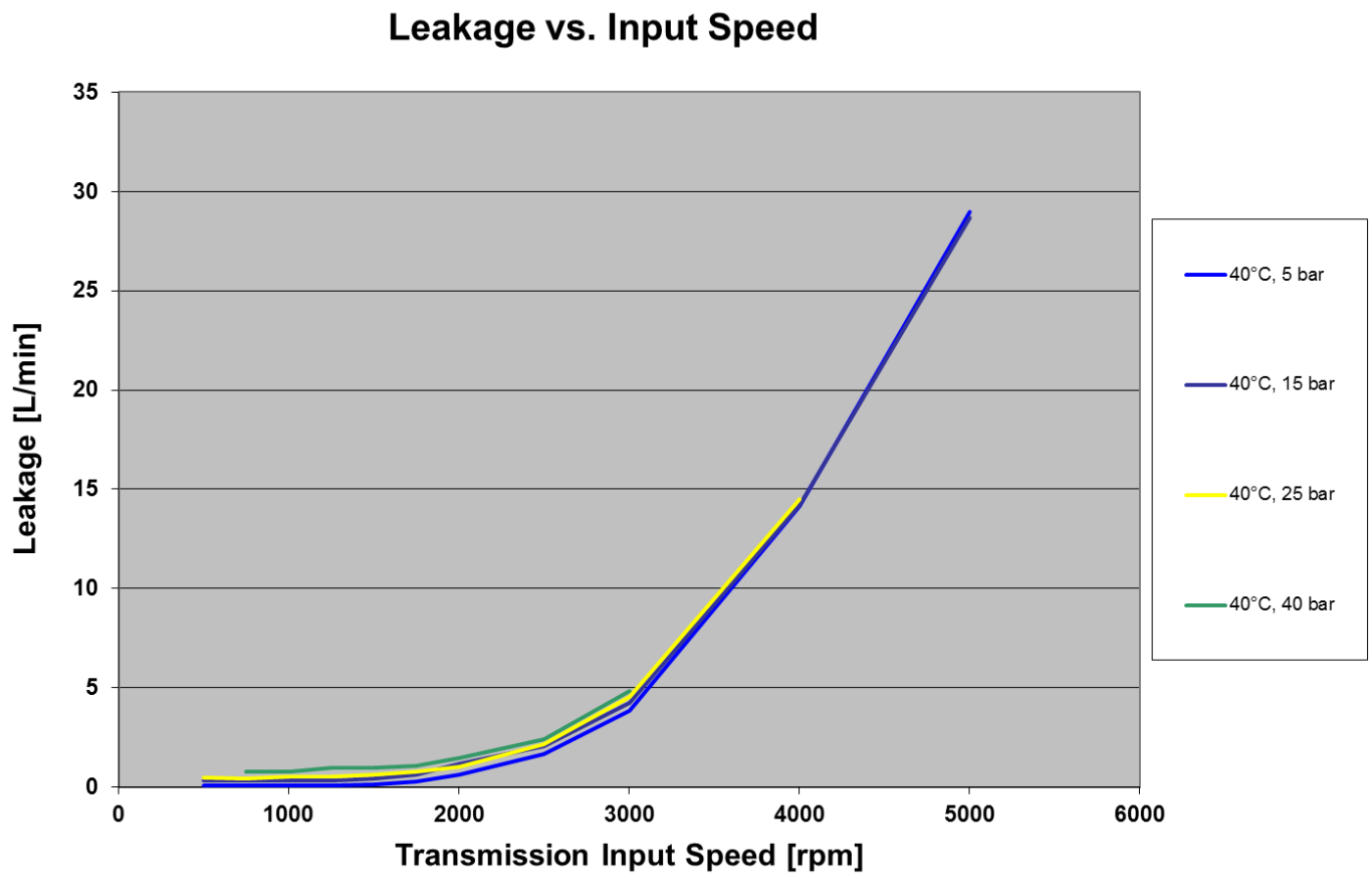

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Nissan Altima CVT – Benchmark
Oil Pump Efficiency Testing

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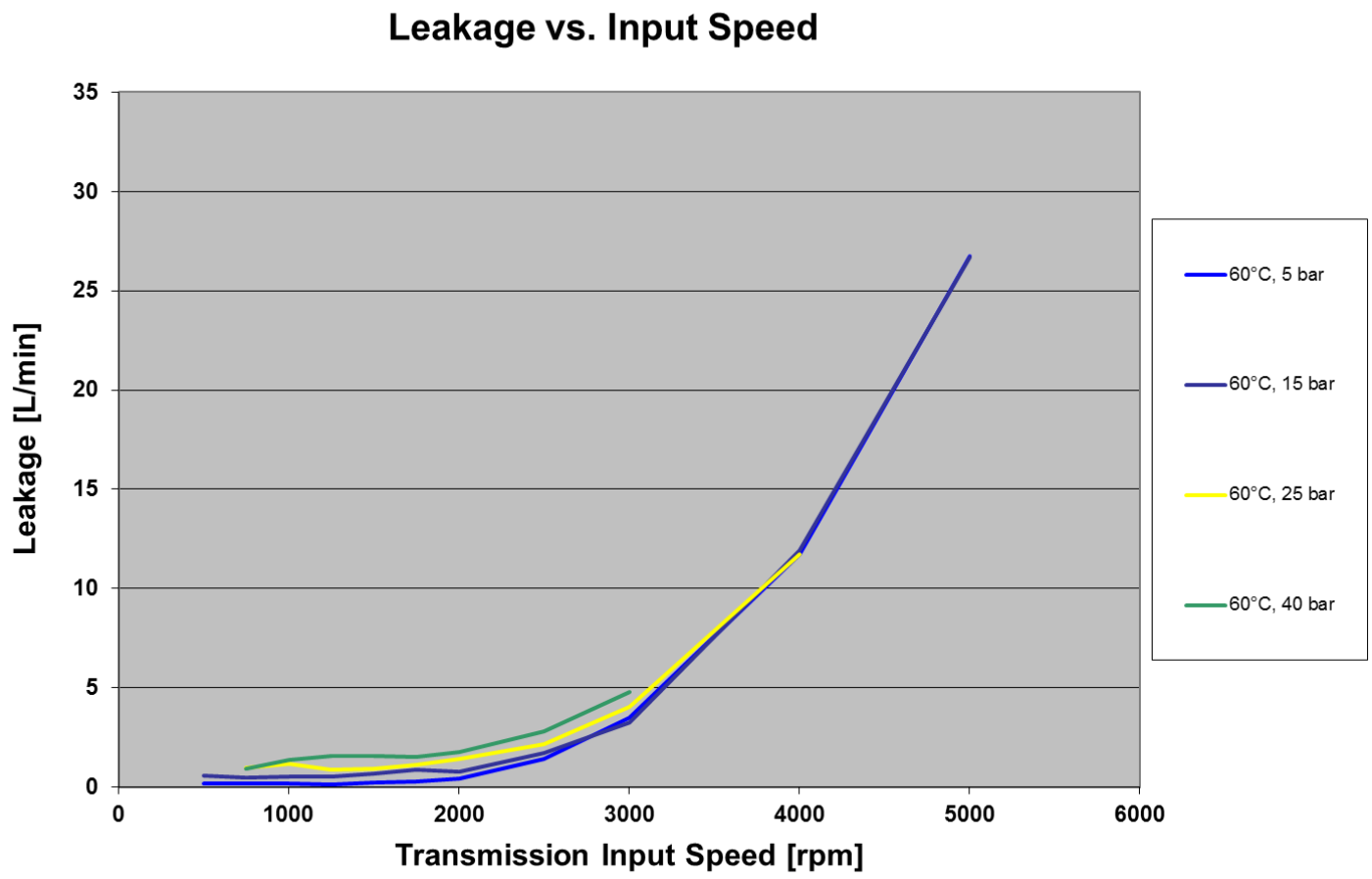

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Nissan Altima CVT – Benchmark
Oil Pump Efficiency Testing

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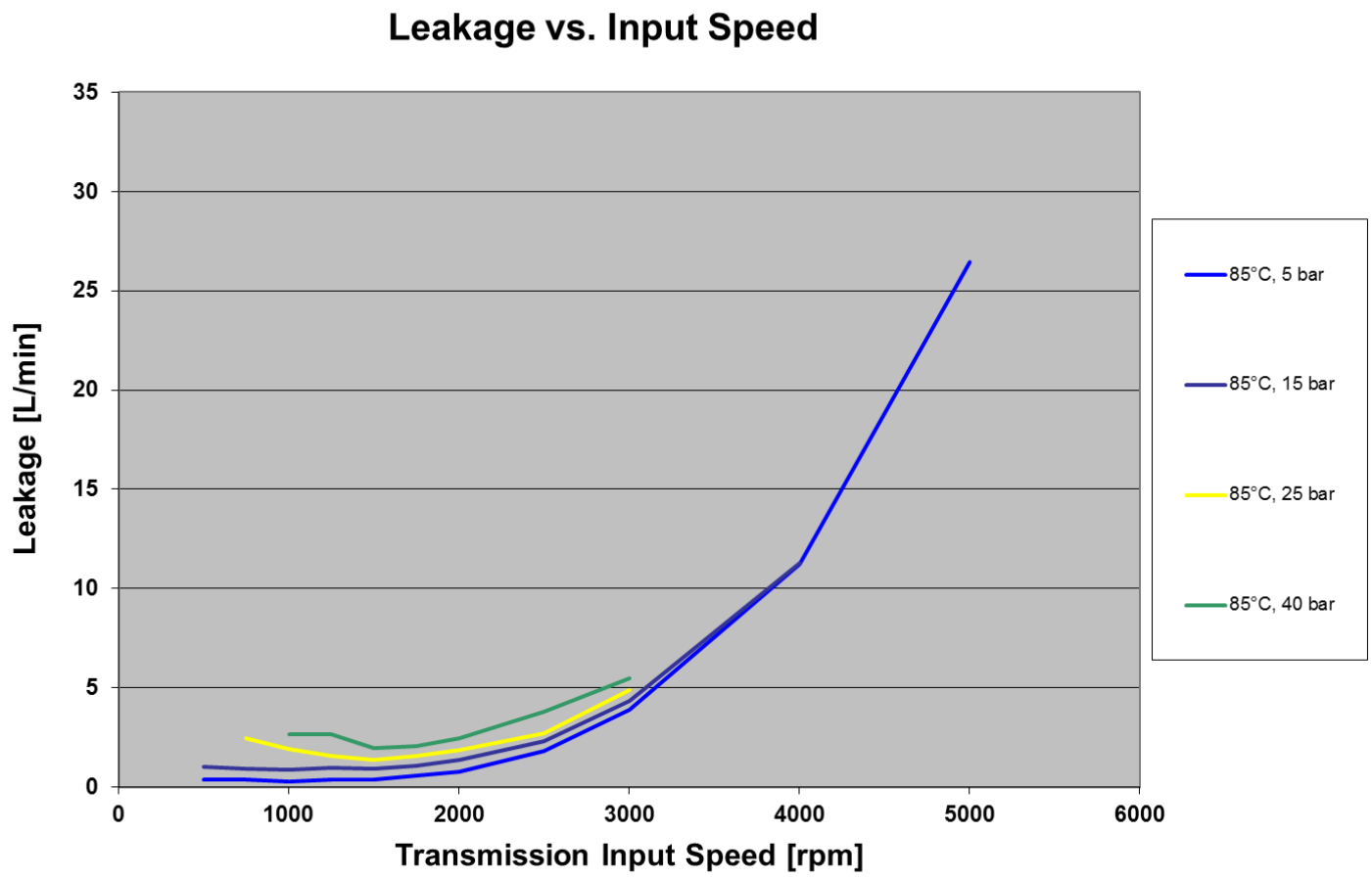

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Nissan Altima CVT – Benchmark
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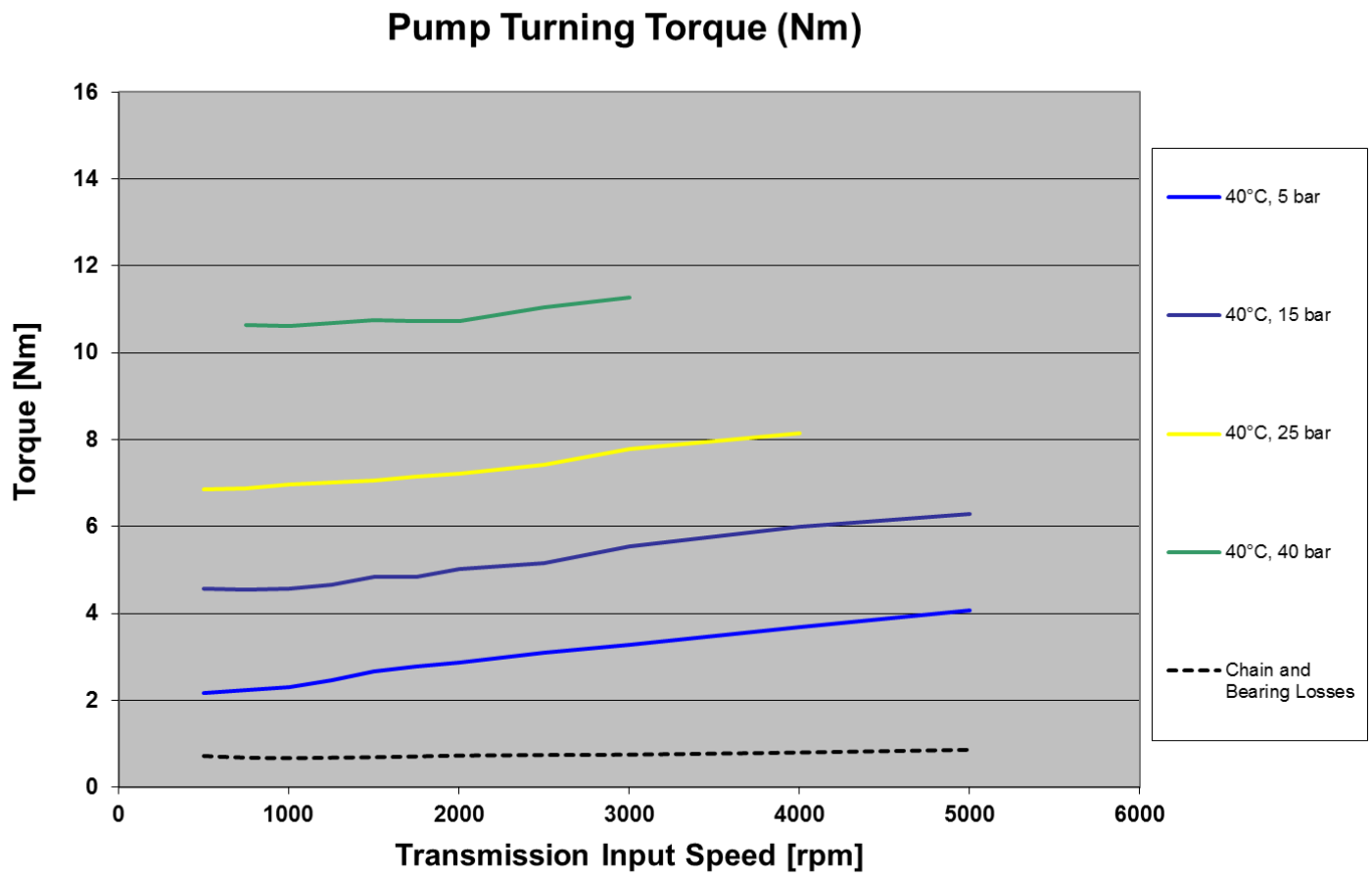

FEV Comments

- Chain and bearing losses measured by removing shaft/rotor/vanes from the oil pump and spinning only the sprocket/chain assembly

Nissan Altima CVT – Benchmark
Oil Pump Efficiency Testing

Contract No. EP-C-12-014, Work Assignment 4-11
May 23, 2016

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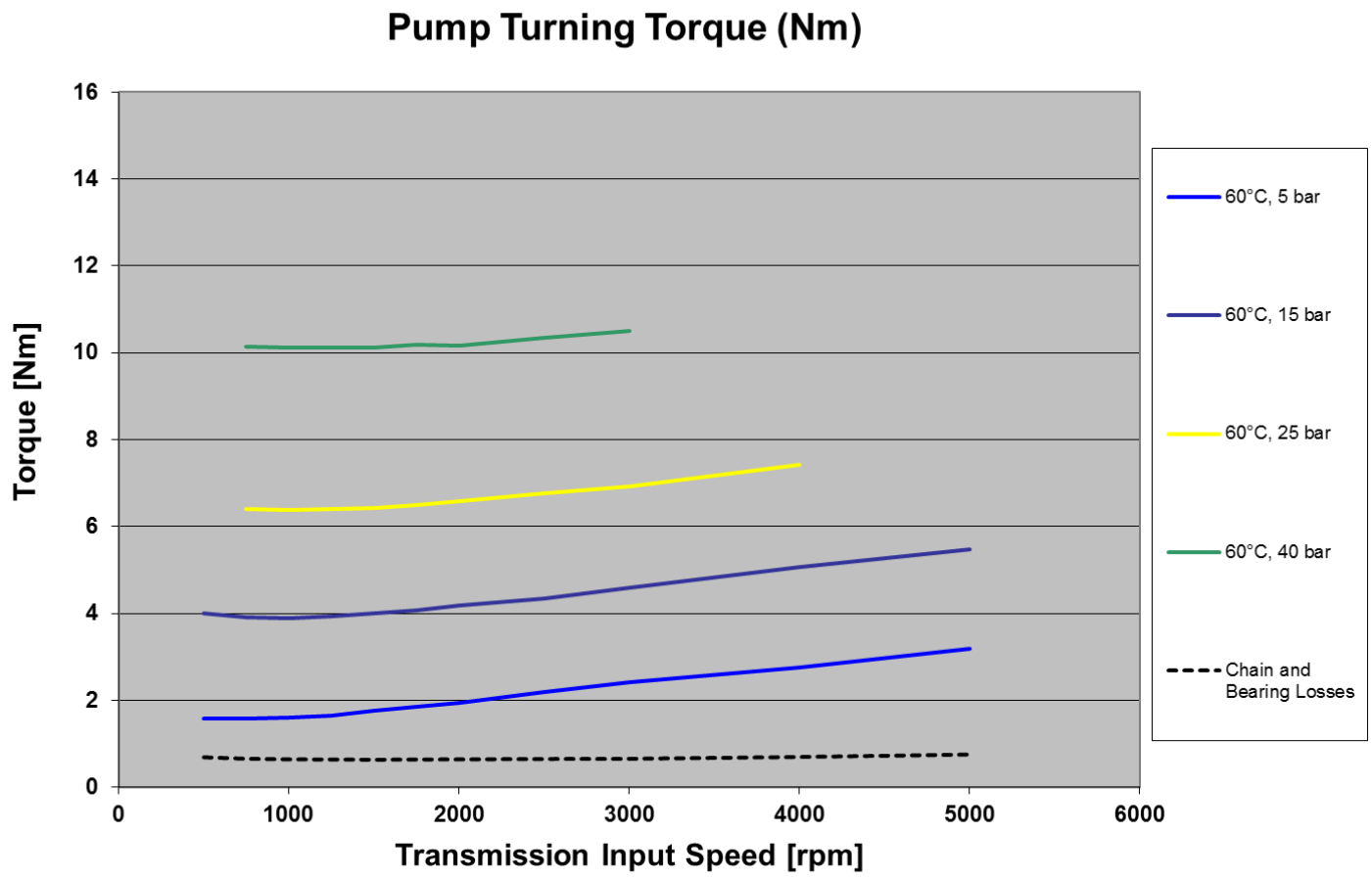

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May 23, 2016

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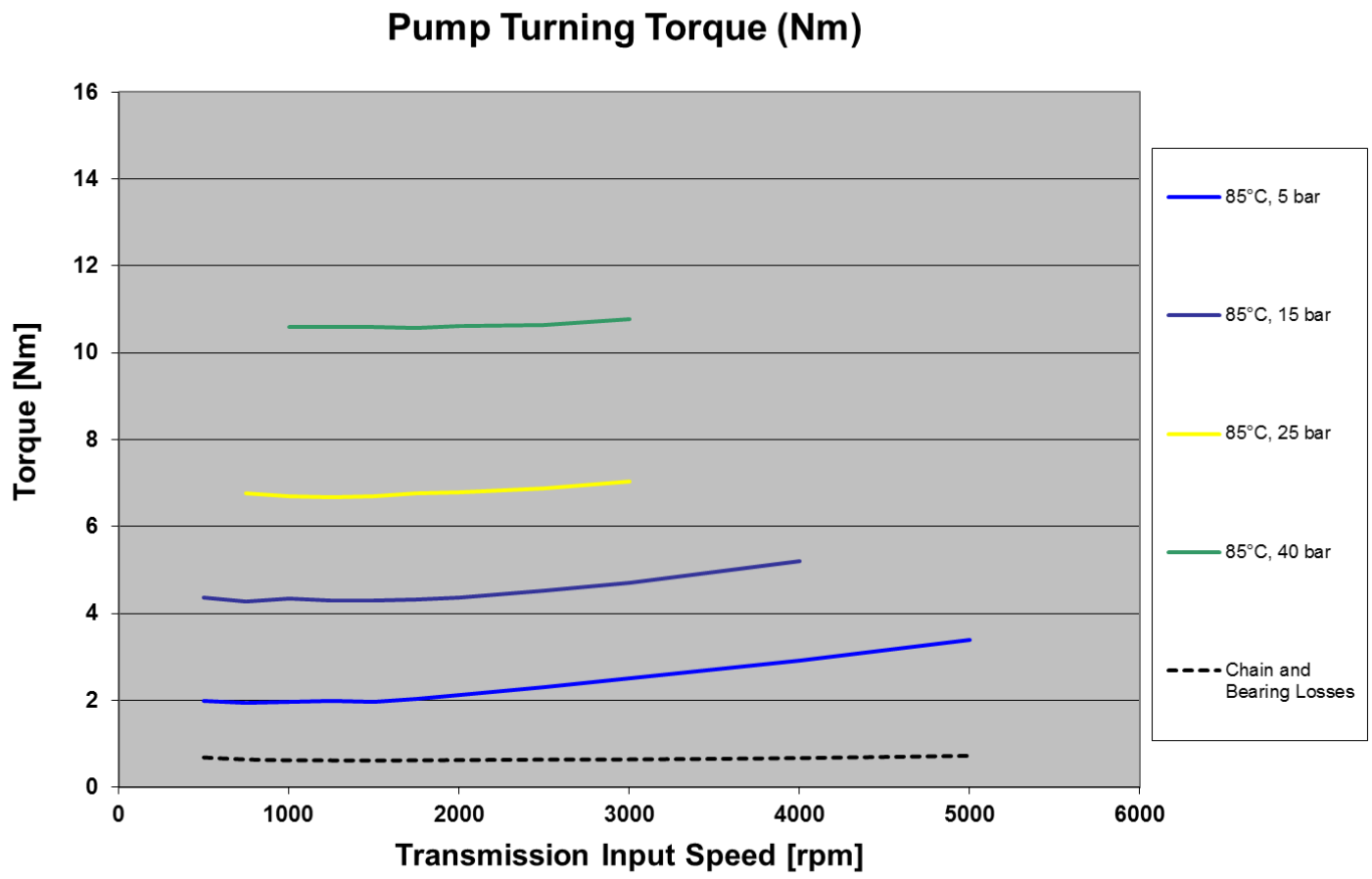

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May 23, 2016

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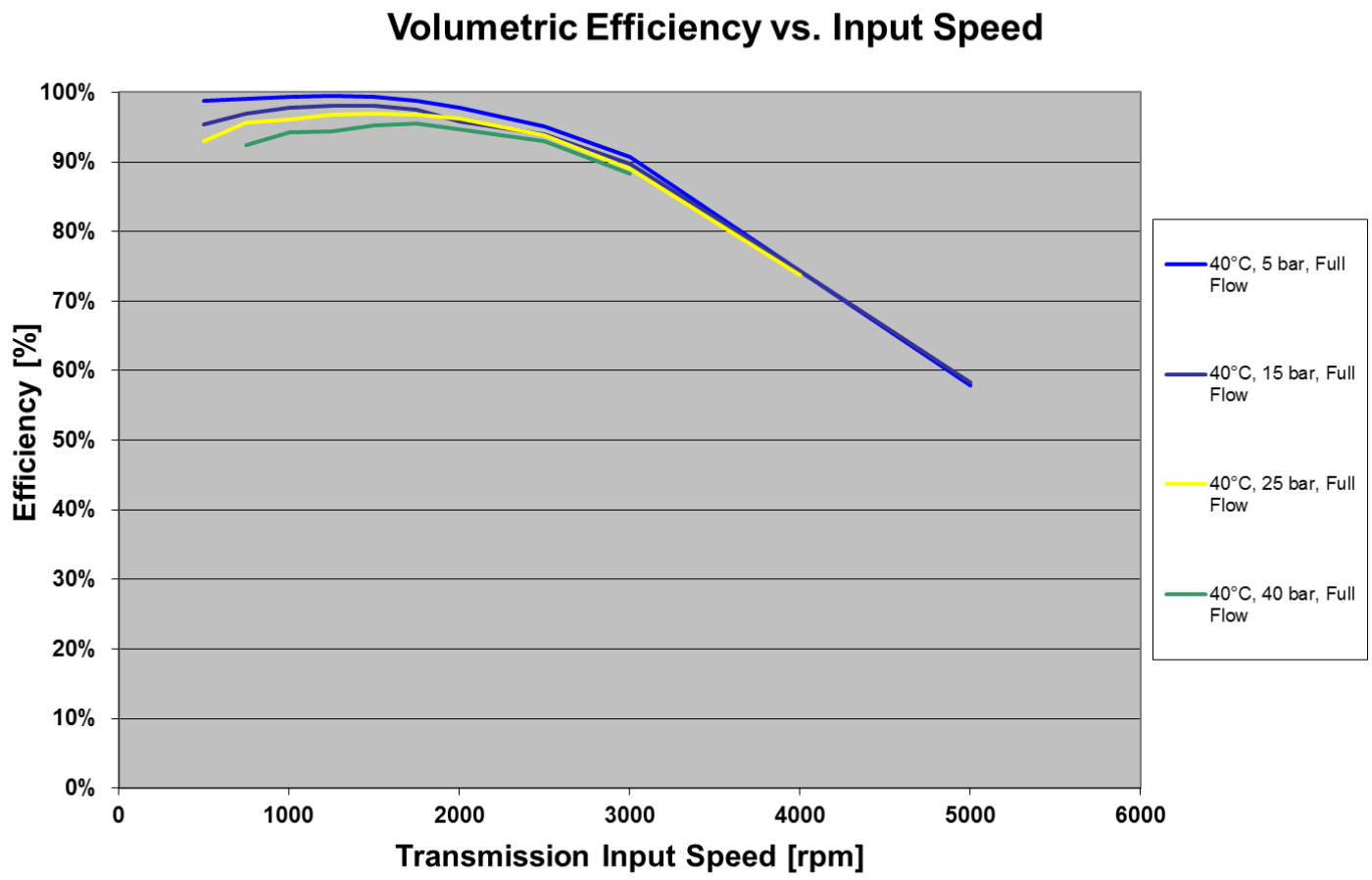

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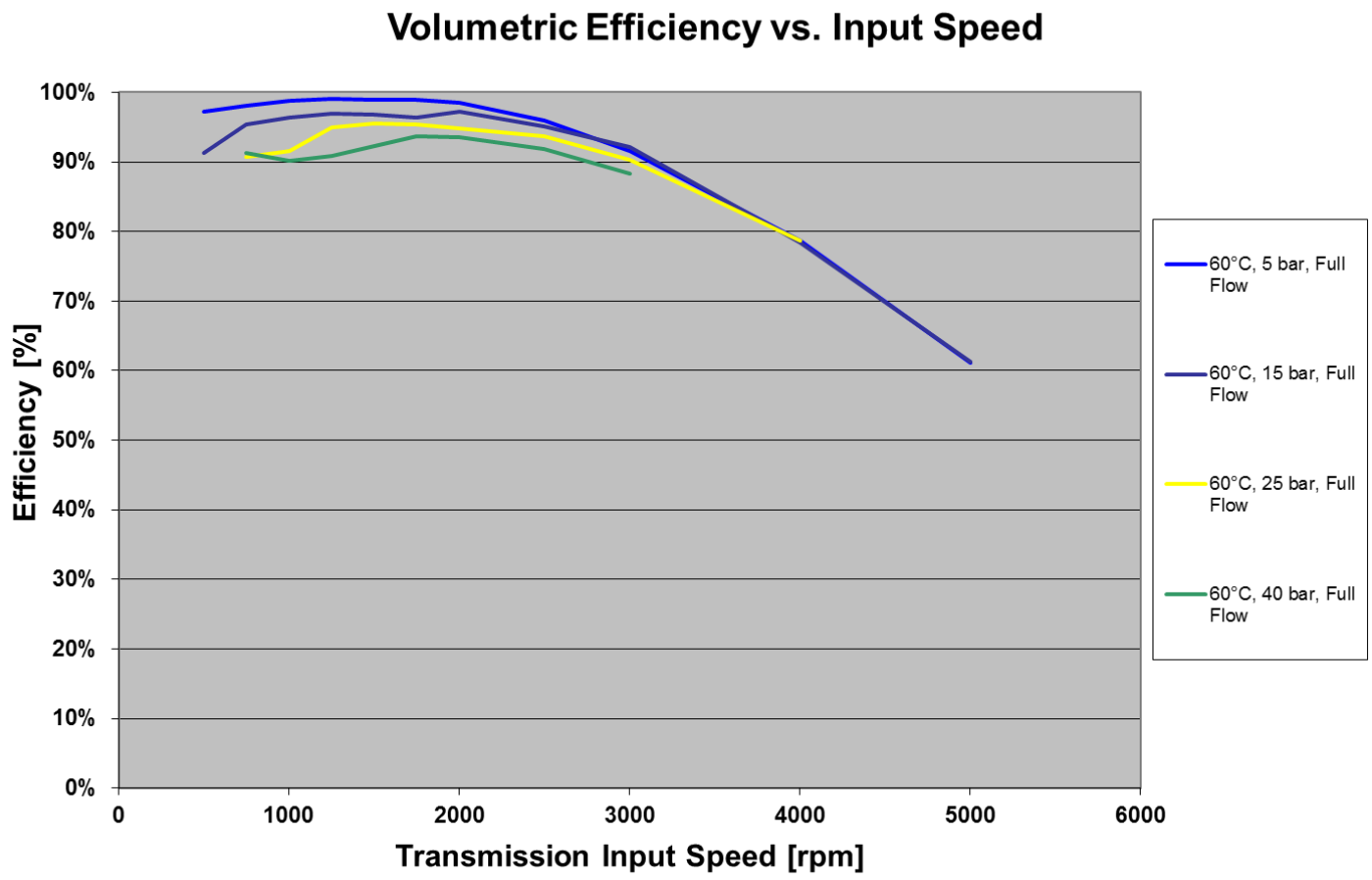

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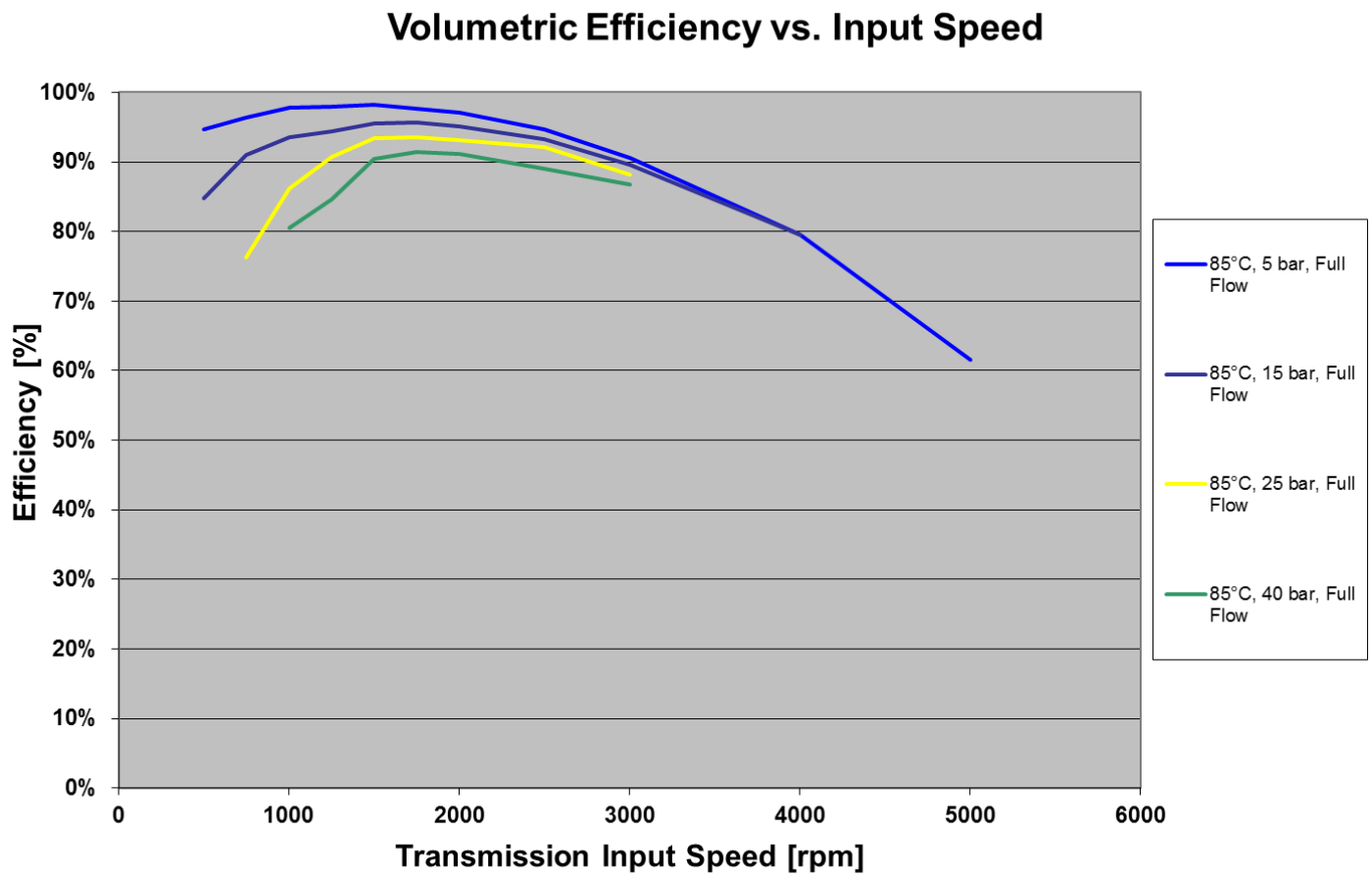

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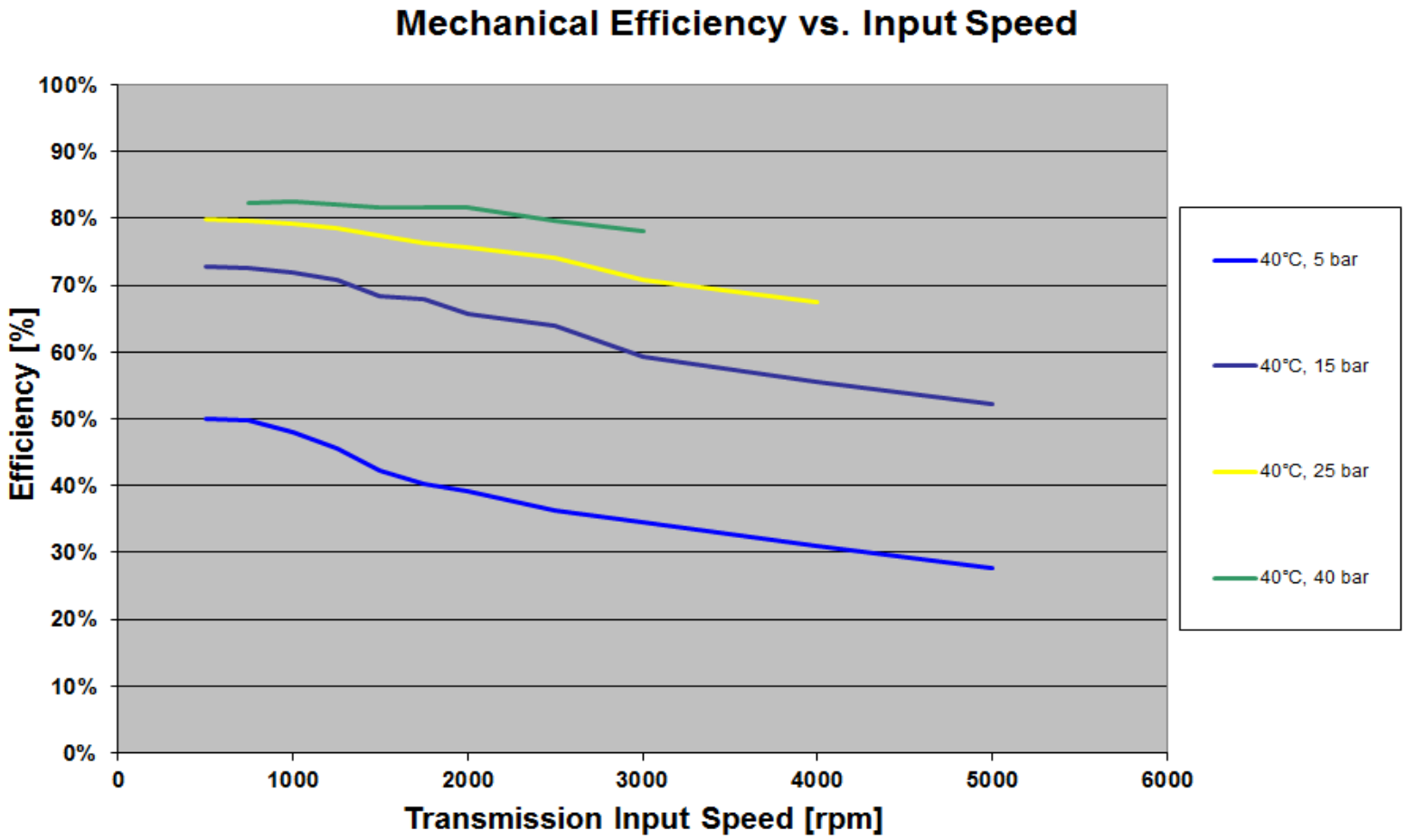

Nissan Altima CVT – Benchmark
Oil Pump Efficiency Testing

Contract No. EP-C-12-014, Work Assignment 4-11May 23, 2016

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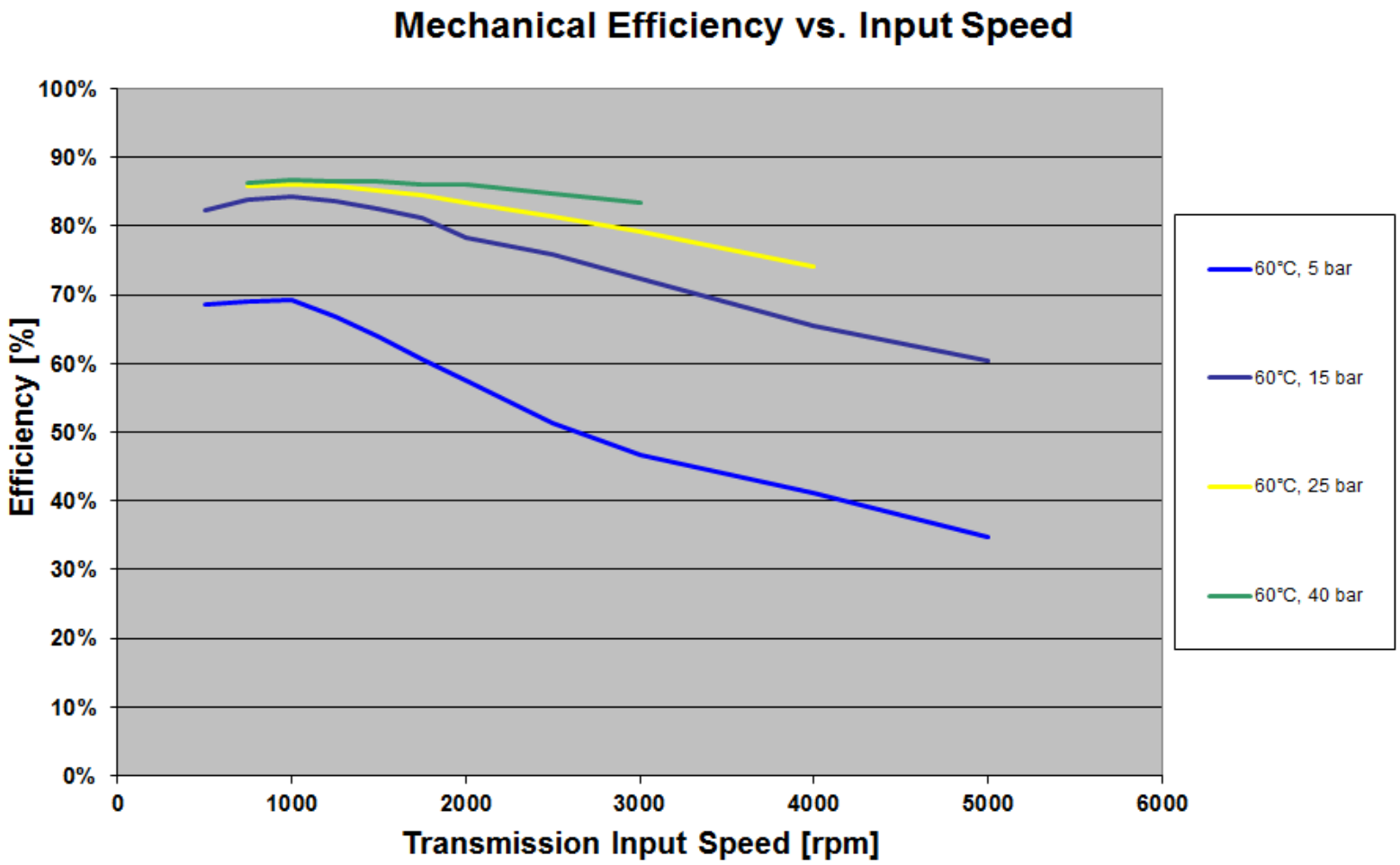

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May 23, 2016

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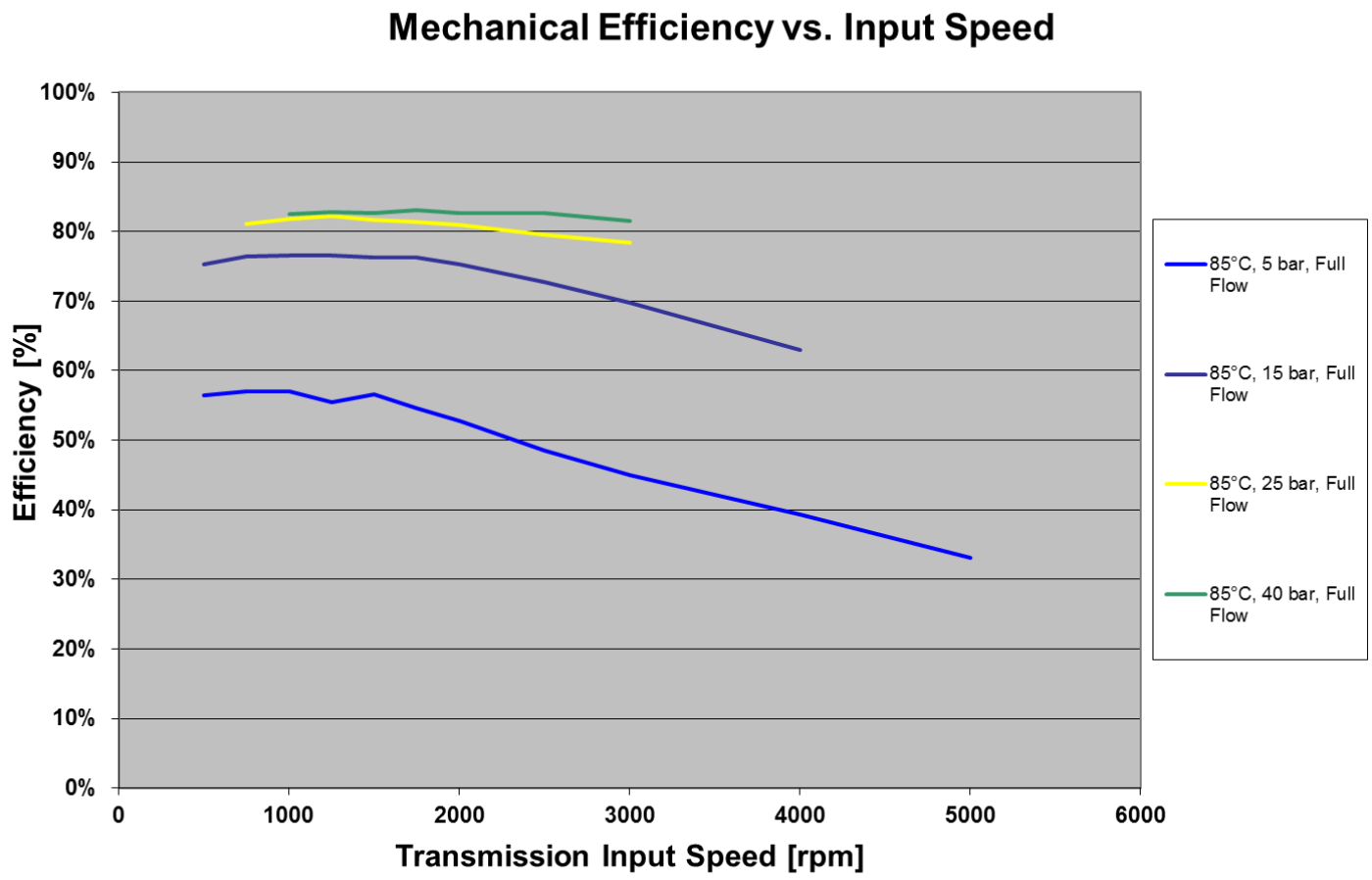

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Oil Pump Efficiency Testing

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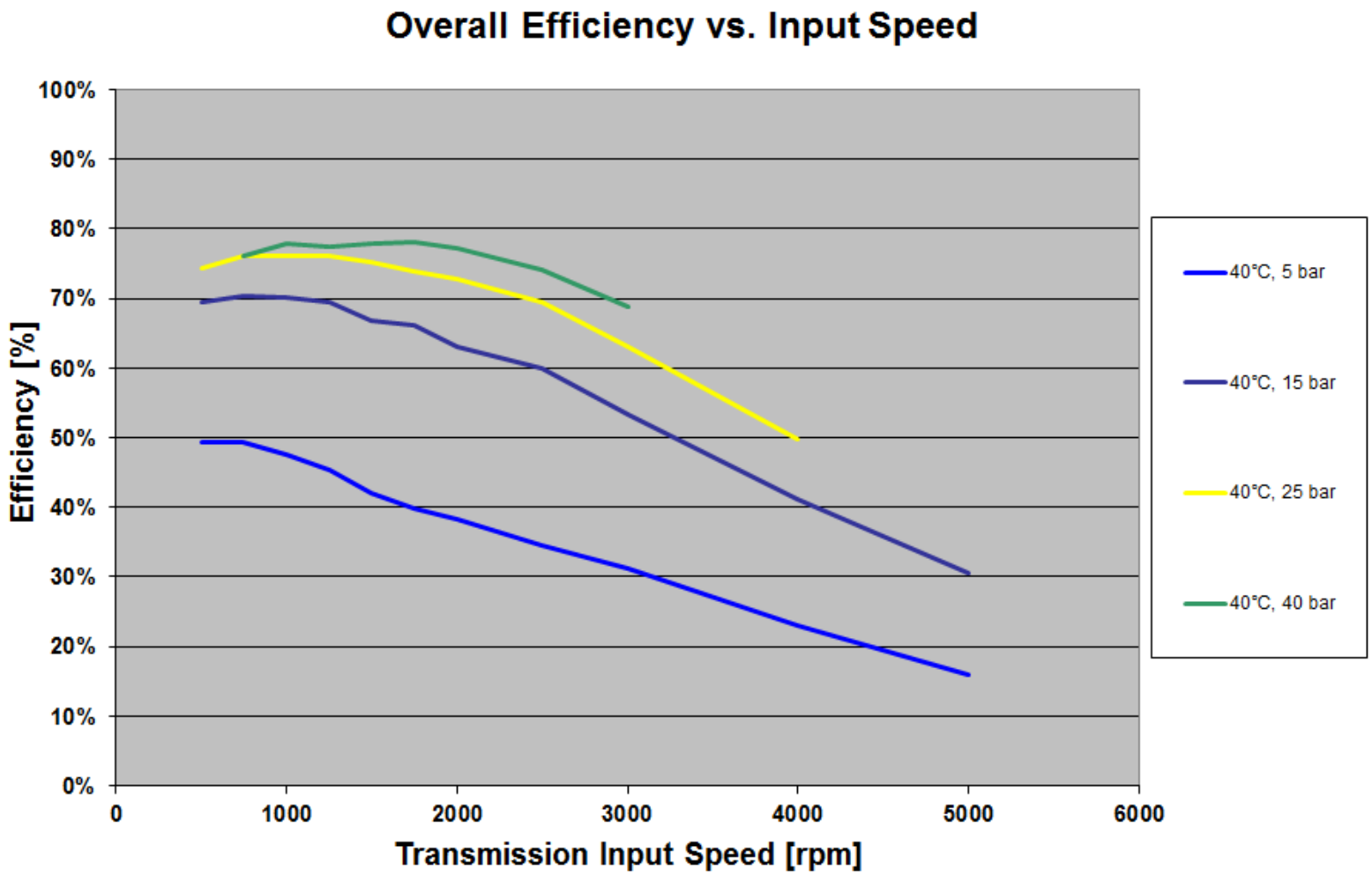

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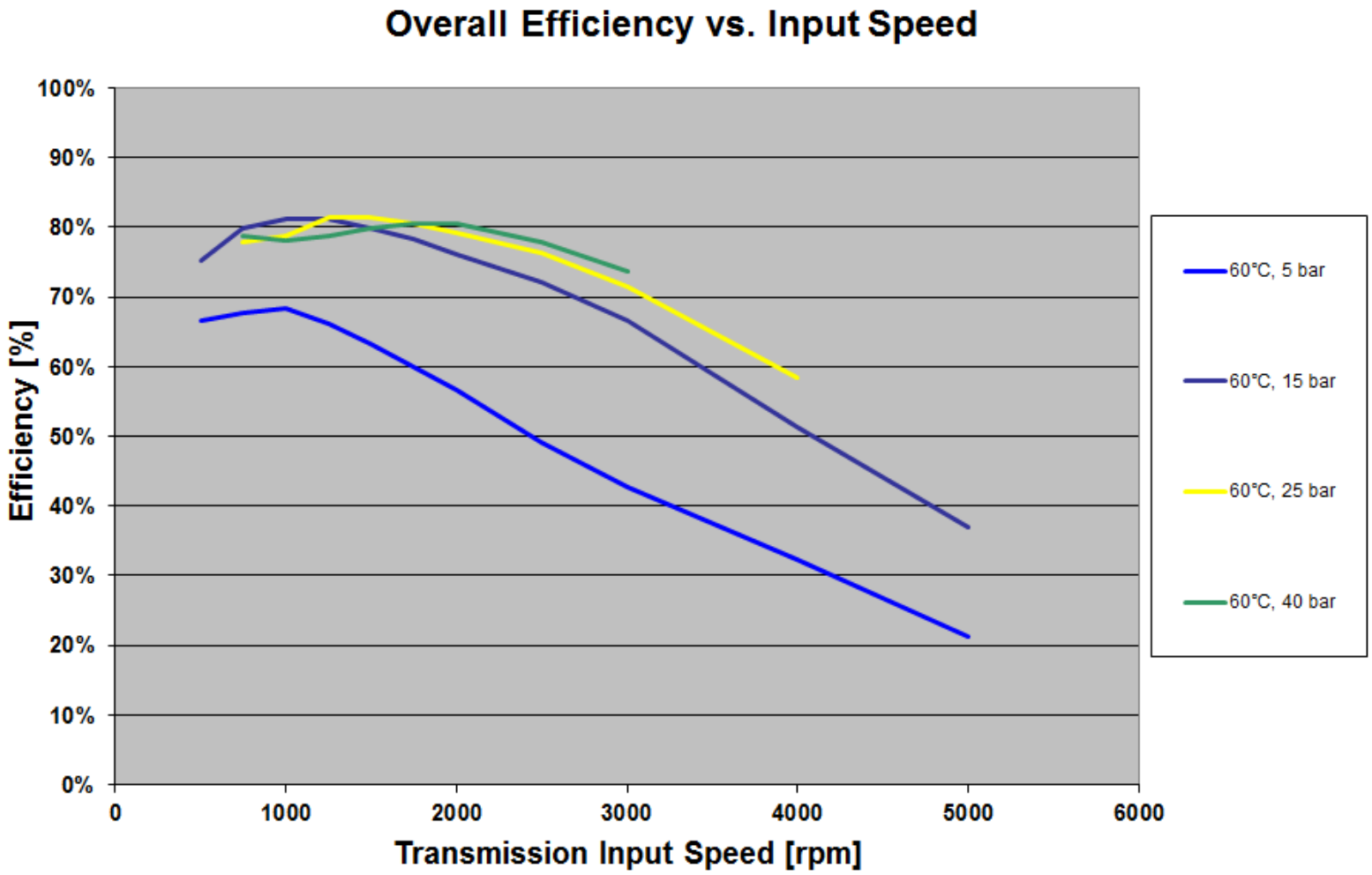

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Oil Pump Efficiency Testing

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May 23, 2016

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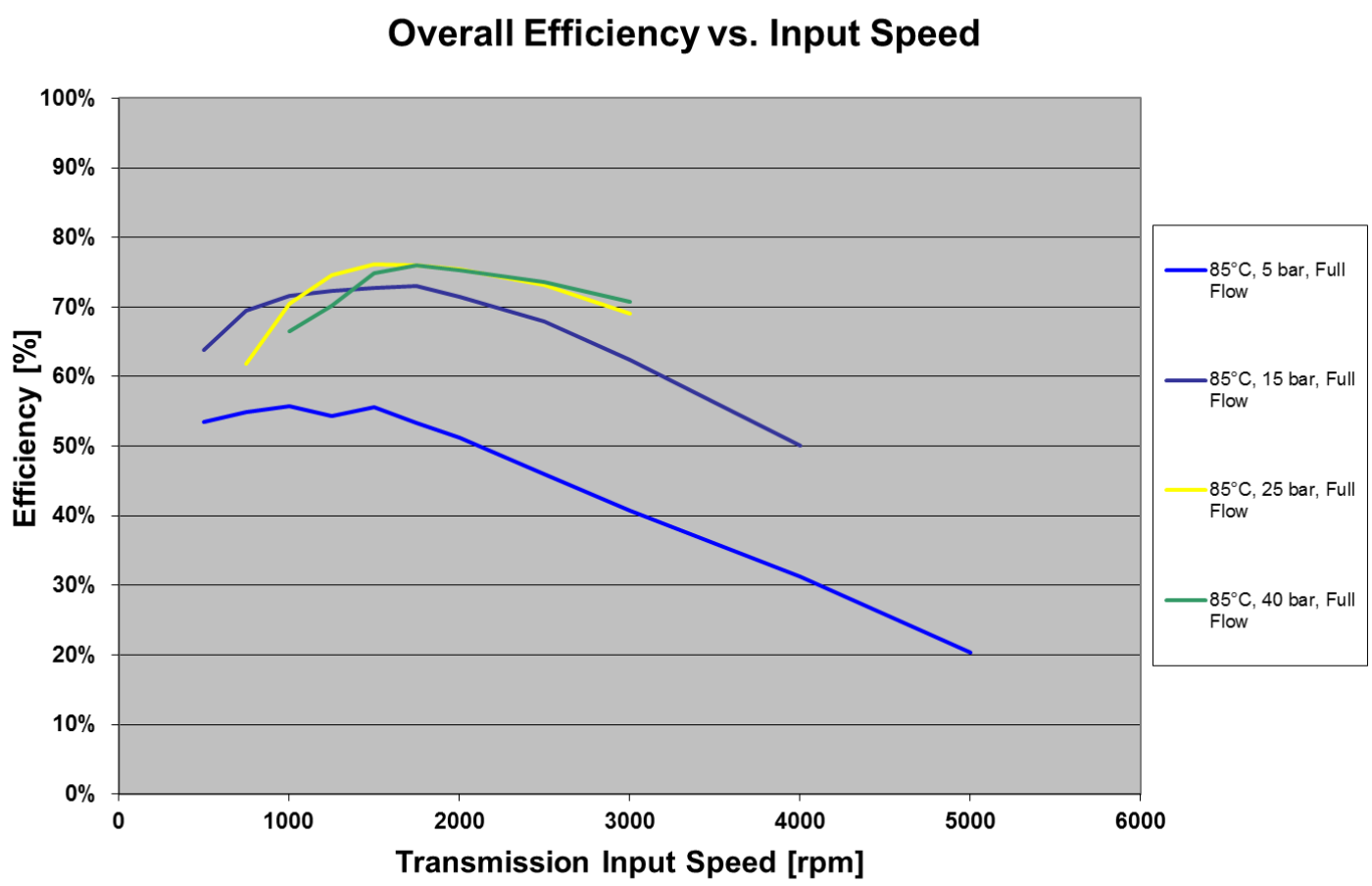

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Nissan Altima CVT – Benchmark
Transmission Loss Analysis

CVT TRANSMISSION LOSS ANALYSIS

- Losses in CVT transmissions can be grouped as follows:
  - Parasitic losses (not load-dependent)
    - Drag in seals, bearings and gears
    - Oil churning losses
    - Friction within belt*
    - Belt clamping*
  - Mesh losses (load-dependent)
    - Additional drag in loaded bearings
    - Additional drag from increased belt clamp force*
    - Friction within loaded gear meshes
  - Oil pump losses
    - Friction in oil pump
    - Generation of oil pressure
    - Leakage

Contract No. EP-C-12-014, Work Assignment 4-11
May 23, 2016

CVT TRANSMISSION LOSS ANALYSIS

- Friction within belt
  - Belt elements are held in place by stacks of steel rings
  - Varying belt radius at pulley causes friction of belt elements on steel rings
  - Steel ring packs are in motion relative to the belt elements, except at the pulley ratio of 1.0 – here the belt radii on both pulleys are the same
    - Results in lowest belt friction at ratio 1.0

Contract No. EP-C-12-014, Work Assignment 4-11
May 23, 2016

CVT TRANSMISSION LOSS ANALYSIS

- Friction within belt
  - Belt misalignment
  - Belt runs perfectly straight only in one ratio (usually max. overdrive)
    - One sheave is axially stationary while the other one moves to adjust the belt running radius
    - As the belt radius increases, the belt rides up on the sheave and shifts following the sheave angle