

The European Commission's science and knowledge service

Joint Research Centre

VECTO Engine

2018 VECTO Workshop
Ispra, November, 2018



Content / Agenda

- Basic principles of engine test procedure
- Overview of content of engine test procedure (Annex V to Commission Regulation (EU) 2017/2400)
- Details of engine test procedure
- Engine pre-processing tool (VECTO Engine)
 - Description of tool and input data
 - Steps of data evaluation
 - VECTO Engine software demonstration
- Common mistakes
- Special topic: from measured FC to certified CO2
- Q&A (ca. 15 min)

Basic principles of engine test procedure

Overview of content of engine test procedure

Details of engine test procedure

Engine pre-processing tool (VECTO Engine)

Common mistakes

Special topic: from measured FC to certified CO₂

Q&A (ca. 15 min)

Basic principles of engine test procedure

- Close link to emission testing for type approval (EURO VI / UN/ECE R49)
 - minimum additional testing effort
 - ascertain compliance with emission limits (trade-off emissions vs. fuel consumption)
- Overview of necessary testruns
 - engine full load curve
 - engine motoring curve
 - WHTC (cold + hot)
 - *WHSC (for CoP only)*
 - **engine fuel-flow map** → **fuel-flow = f (speed, torque)**
- Boundary conditions for engine fuel-flow map
 - stationary measurement of fuel-flow at predefined grid of operation points
 - defined sequence of measured points
 - compliance with emission limits is checked according to extended WNTe/OCE requirements
 - fuel-flow map is valid for whole engine CO₂-family

according to
UN/ECE R49

dedicated new testrun
for CO₂ declaration

Basic principles of engine test procedure

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Common mistakes

Special topic: from measured FC to certified CO₂

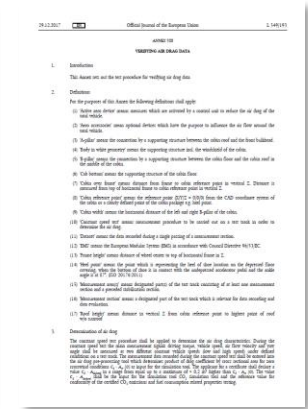
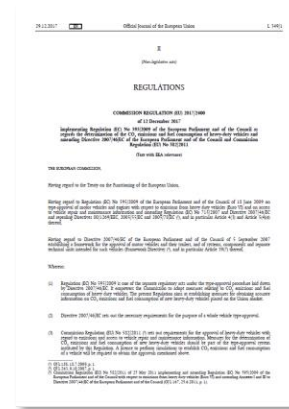
Q&A (ca. 15 min)

Overview of content of Annex V to Commission Regulation (EU) 2017/2400

- 1. Introduction
- 2. Definitions
- 3. General requirements (for all testruns)
- 4. Testing procedure
 - 4.3.1 Full load curve
 - 4.3.2 Motoring curve
 - 4.3.3 WHTC
 - 4.3.4 WHSC
 - 4.3.5 Fuel consumption mapping cycle (FCMC)
- 5. Post-processing of measurement data
- 6. Application of engine pre-processing tool

Mainly relevant for

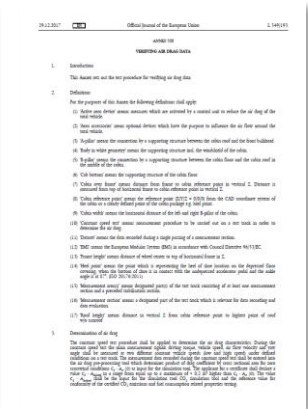
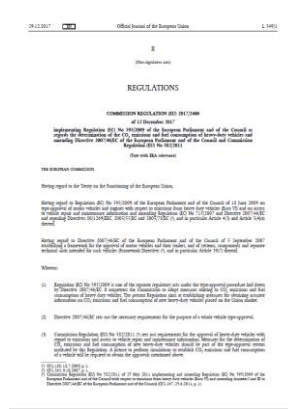
- engine testing
- data evaluation
- certification issues



Overview of Appendices to Annex V to Commission Regulation (EU) 2017/2400

- 1. Model of certificate
- 2. Engine Information Document
- ● 3. Engine CO2-Family
- ● 4. Conformity of the certified CO2 emissions and fuel consumption related properties
- 5. Determination of power consumption of engine components
- 6. Markings
- 7. Input parameters for the simulation tool
- 8. Important evaluation steps and equations of the engine pre-processing tool

- Mainly relevant for
- engine testing
 - data evaluation
 - certification issues



Basic principles of engine test procedure

Overview of content of engine test procedure

Details of engine test procedure

Engine pre-processing tool (VECTO Engine)

Common mistakes

Special topic: from measured FC to certified CO₂

Q&A (ca. 15 min)

General information about the engine test procedure (1/2)

Close link to emission test procedure (EURO VI / UN/ECE R49),
minimum additional testing effort

Amendments of Commission Regulation (EU) 2017/2400 to UN/ECE R49:

- Stricter limits for ambient conditions [*Point 3.1.1 of Annex V*]
- Engine installation acc. to UN/ECE R49
 - correction of AUX (special provisions for add. electric aux and fan – Appendix 5) [*Point 3.1.2 of Annex V*]
- Special provisions defined for engine cooling system on testbed [*Point 3.1.5 of Annex V*]
 - Thermostat (or simulated behavior on testbed) shall be used
 - In-vehicle situation shall be reproduced (temperatures, flow rates)
 - Extra rules for WHTC cold-start

General information about the engine test procedure (2/2)

Close link to emission test procedure (EURO VI / UN/ECE R49),
minimum additional testing effort

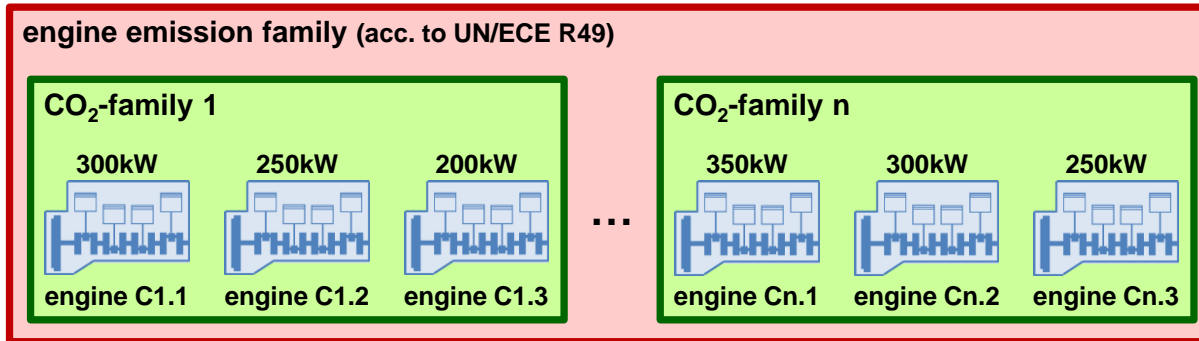
Amendments of Commission Regulation (EU) 2017/2400 to UN/ECE R49:

- Reference fuels of EURO VI regulation used for testing [*Point 3.2 of Annex V*]
 - Procedure and standards for determination of Net Calorific Value (NCV) defined
 - Exact same reference fuel shall be used for all testruns of one engine CO₂-family
→ exceptions for gas fuels (handling in smaller amounts in gas cylinders)
- Special provisions for lubricants used [*Point 3.3 of Annex V*]
 - Regular market oils, no special oils (low-friction) allowed
- More stringent requirements on accuracy of measurement equipment [*Point 3.5 of Annex V*]

Selection of engine to be tested (1/2)

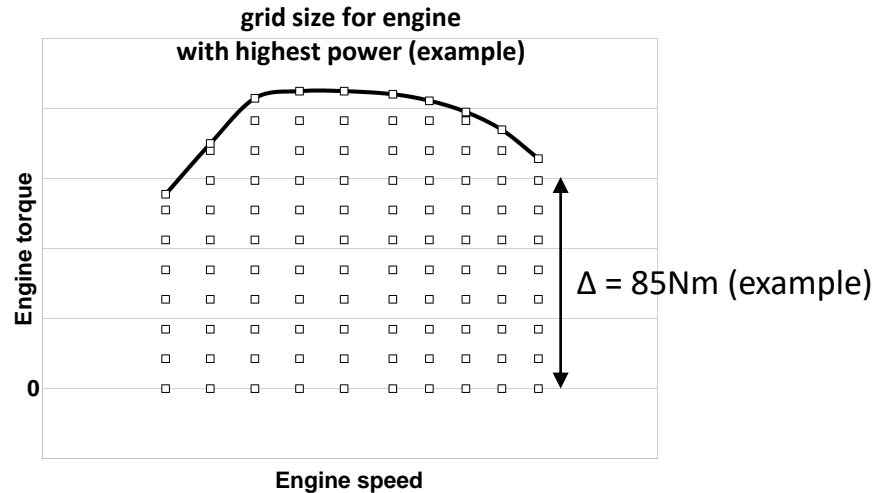
Engine CO₂-family concept:

- engine emission family definition existing for EURO VI (acc. to UN/ECE R49)
- engine CO₂-family is (smaller) subset of engine emission family
- engine CO₂-family is defined by fuel consumption affecting parts (hardware and controls)
 - If any of these parts are changed, a different family is created



Selection of engine to be tested (2/2)

- for each CO₂-family only one engine has to be measured: highest power rating
 - all lower ratings of a family use the same measured fuel-flow map
 - highest rating defines grid size of fuel-flow map
 - on OEM request additional members of a CO₂-family may be measured separately



Engine installation on testbed

- Power demand of auxiliaries in VECTO vehicle simulation vs. testbed
 - power demand of aux. already installed during fuel-flow mapping is included in FC map
→ no additional consideration in vehicle simulation necessary
 - power demand of additional aux. not included in FC map is considered in vehicle simulation
→ generic* values for each vehicle class and mission profile defined

Auxiliary system	VECTO vehicle simulation	Testbed (acc. to UN/ECE R49) FC mapping
fuel pump(s) water pump oil pump	no additional consideration (already included in FC map)	installed (included in FC map)
generator (supply of electrical system)	generic power demand per vehicle class/mission profile added in simulation *	not installed (or power correction) (not included in FC map)
fan steering pump air compressor AC compressor	generic power demand per vehicle class/mission profile added in simulation *	not installed (or power correction) (not included in FC map)

* detailed simulation of aux. power demand for buses

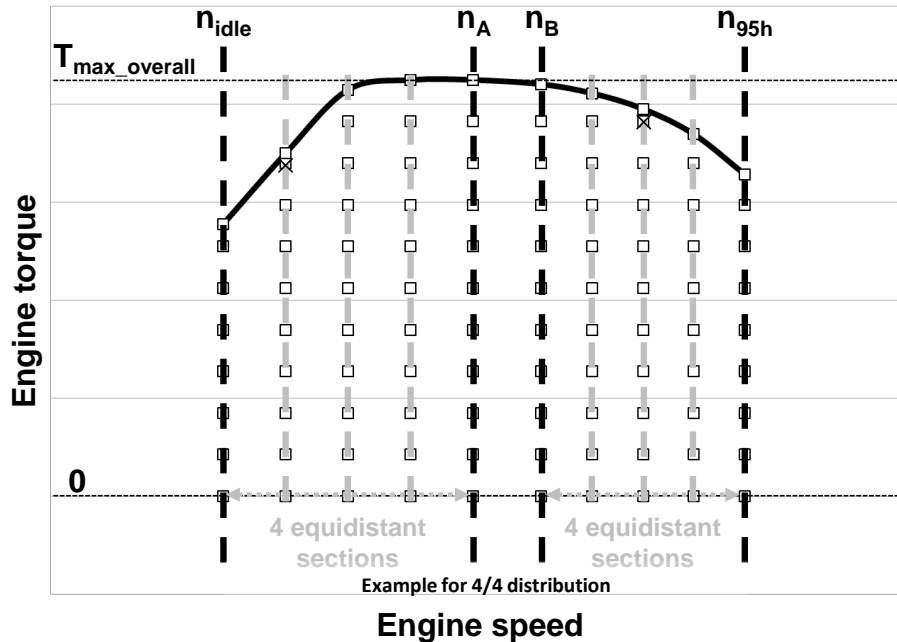
Overview of testruns to be performed

- 5 testruns in total
- 2 of those can be skipped for child engines within same engine CO2-family
- All but one testruns acc. to UN/ECE R49 (no changes)
- **EXCEPTION: fuel consumption mapping cycle (FCMC)**
→ dedicated new testrun for CO2 declaration

Testrun	Reference to paragraph	Required to be run for CO ₂ -parent engine	Required to be run for other engines within CO ₂ -family
Engine full load curve	4.3.1	yes	yes
Engine motoring curve	4.3.2	yes	no
WHTC test	4.3.3	yes	yes
WHSC test	4.3.4	yes	yes
Fuel consumption mapping cycle	4.3.5	yes	no

FCMC (1/4) – Target engine speed setpoints

- Definition of target engine speed setpoints [*Point 4.3.5.2.1 of Annex V*]
- Standard distribution of 4/4 intervals can change to 3/5 or 5/3 depending on shape of full load curve



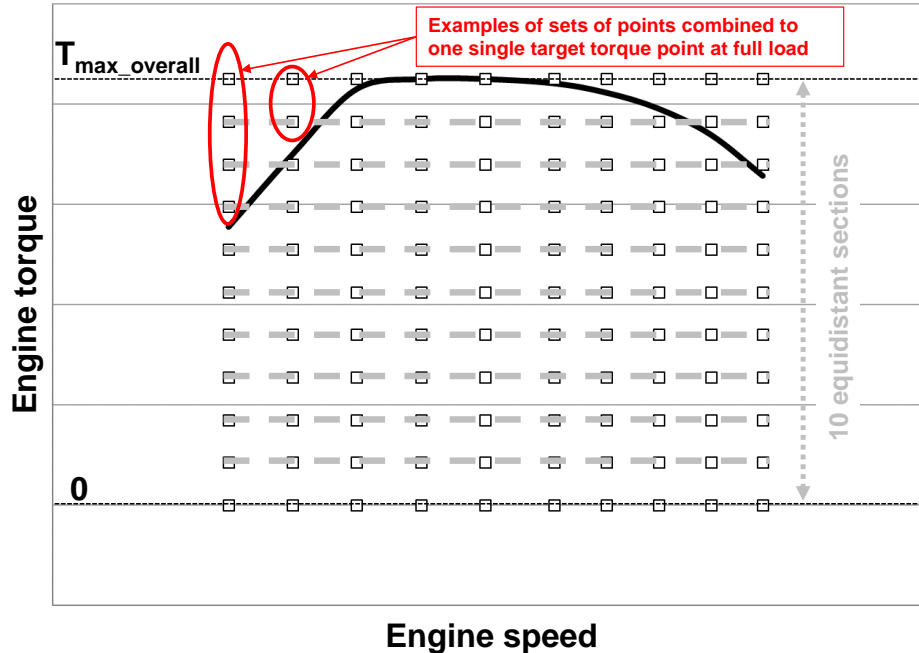
1. 4 base speeds

- n_{idle}
- n_A
- n_B
- n_{95h}

2. 6 additional speeds (equidistant between base speeds)

FCMC (2/4) – Target torque setpoints

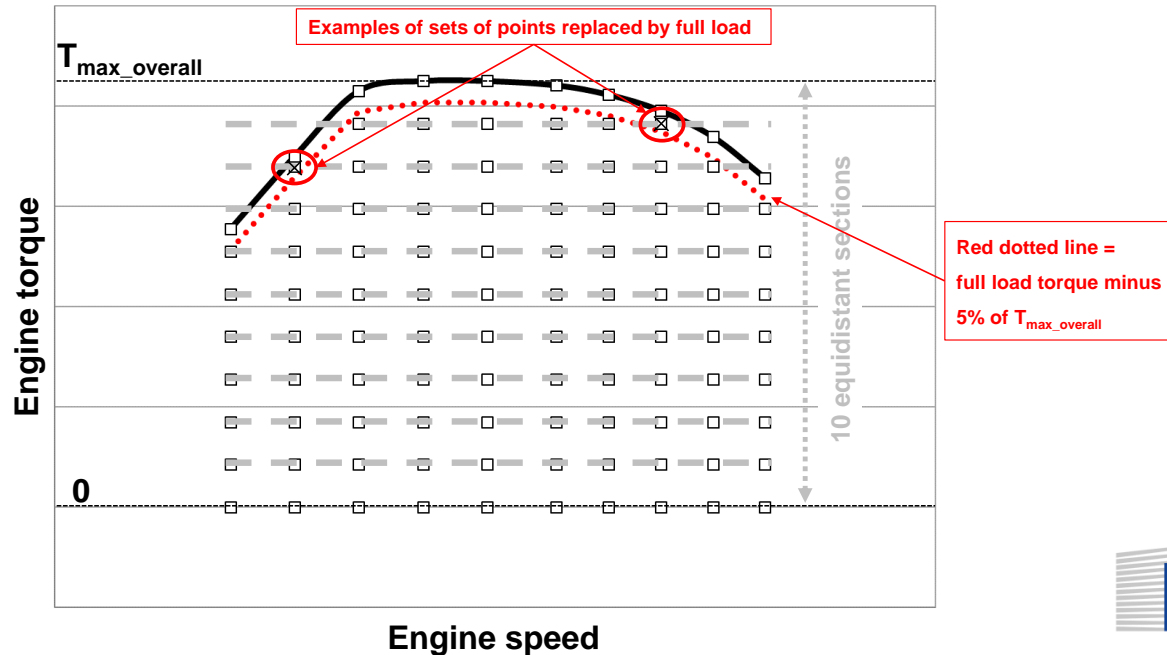
- Definition of target torque setpoints [*Point 4.3.5.2.2 of Annex V*]
- Points located above full load replaced by full load
(**BUT:** points at full load only measured once)



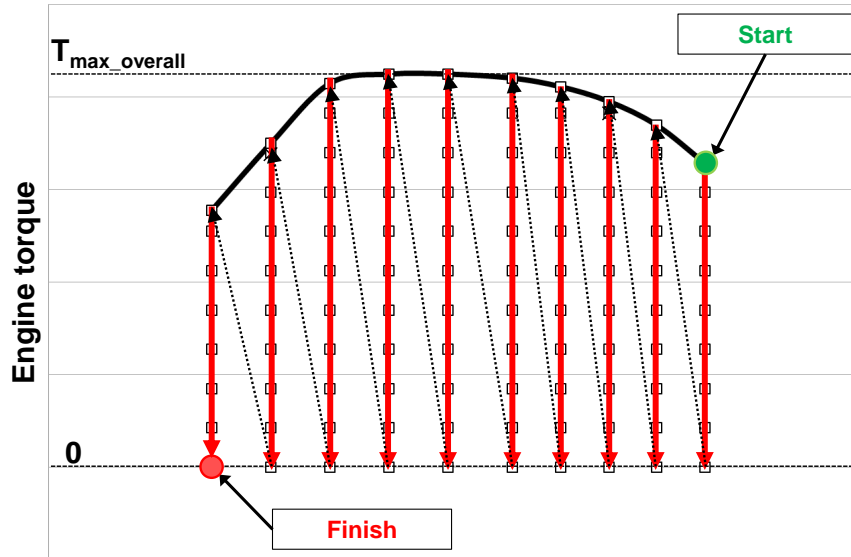
→ 10 equidistant intervals between 0 Nm and highest torque value that occurs in full load curve

FCMC (3/4) – Target torque setpoints

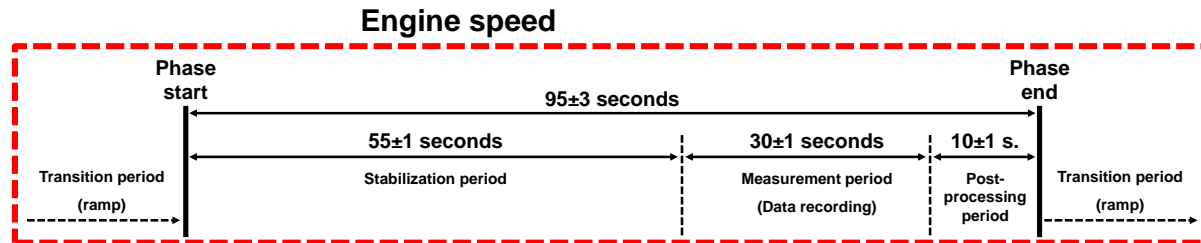
- Definition of target torque speed setpoints [*Point 4.3.5.2.2 of Annex V*]
- Points located above red tolerance limit replaced by full load
(**BUT** points at full load only measured once)



FCMC (4/4) – Test sequence [Point 4.3.5.5 of Annex V]



- preconditioning of 20 min at WHSC preconditioning mode 9
- ramp time of 20 sec for load change at constant speed (20-46 sec at speed and load changes)
- 55 sec stabilization time at each point
- 30 sec averaging (measuring) time at each point



Data post-processing (1/5)

Testrun	Input for VECTO Engine	Input for VECTO vehicle simu.	Other purpose
Full load curve <i>(acc. to UN/ECE R49)</i>	<ul style="list-style-type: none"> • Generation of input file for VECTO • Full-load curve for simulation of WHTC (calculation of WHTC-CF) 	Full-load curve for vehicle simulation	Generation of reference cycle for testbed
Motoring curve <i>(acc. to UN/ECE R49 Annex 4 paragraph 7.4.7 option (b))</i>	<ul style="list-style-type: none"> • Generation of input file for VECTO • Motoring curve for simulation of WHTC (calculation of WHTC-CF) 	Motoring curve for vehicle simulation	-
WHTC (cold + hot) <i>(acc. to UN/ECE R49)</i>	<p>Specific FC in g/kWh for calculation of correction factors</p> <ol style="list-style-type: none"> 1. measured g/kWh FC over 3 separate parts of hot WHTC 2. measured g/kWh FC over total cold + hot WHTC 3. CF for periodically regen. DPFs 	<p>Correction factors</p> <ul style="list-style-type: none"> ▪ <i>WHTC-CFs</i> ▪ <i>cold-hot balancing</i> ▪ <i>periodically regen. DPFs</i> 	Check compliance with emission limits
Fuel-flow mapping (FCMC)	<ul style="list-style-type: none"> • Generation of input file for VECTO • Fuel-flow map for simulation of WHTC (calculation of WHTC-CF) 	Fuel-flow map for vehicle simulation	-
WHSC <i>(acc. to UN/ECE R49)</i>	-	-	For conformity of CO ₂ emissions and fuel consumption related properties purpose only (Appendix 4 of Annex V)

VECTO-Engine pre-processing tool is mandatory for post-processing of measurements

Data post-processing (2/5) – WHTC correction factors

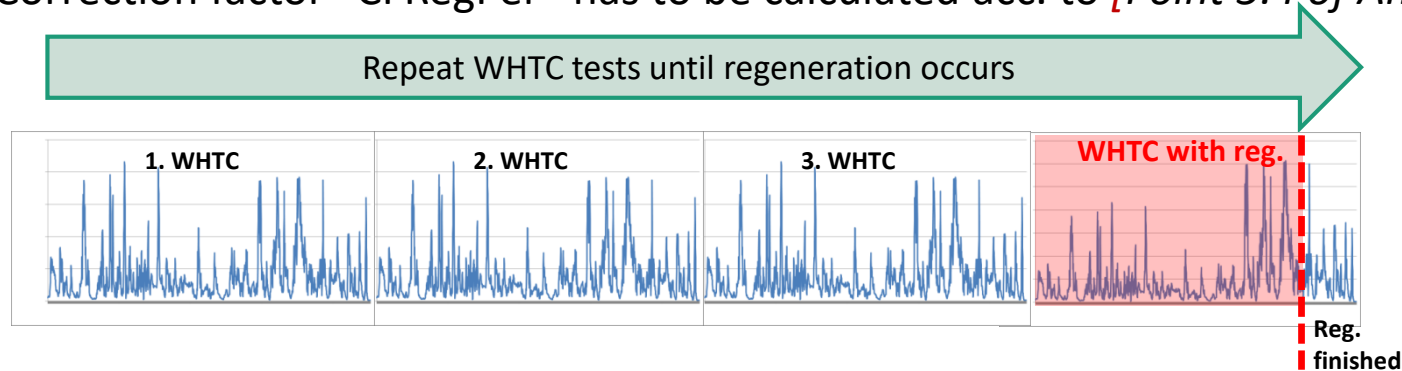
- Purpose to correct stationary fuel-flow in simulation for:
 1. transient engine operation
 2. inconsistencies in fuel consumption between the WHTC (hot part) and the stationary fuel-flow map (e.g. optimization at cost of higher pollutant emissions, heating strategies)
- Input data format
 - FC in g/kWh as integrated value over 3 different WHTC parts (urban, rural, motorway)
- Calculation of FC in g/kWh as input to pre-processing tool acc. to *[Point 5.1 to 5.3.1 of Annex V]*
- 3 WHTC correction factors (urban, rural, motorway) calculated automatically in pre-processing tool:
$$WHTC - CF_i = \frac{g/kWh_{\text{measured}}}{g/kWh_{\text{interpolated from map}}}$$

Data post-processing (3/5) – Cold-hot balancing factor

- Balancing of FC between cold and hot WHTC [*Point 6 of Appendix 8 to Annex V*]
 - penalty factor to avoid shifting pollutant emissions to cold test for lower FC in hot test
- Cold-hot balancing factor calculated automatically in pre-processing tool:
$$BF_{\text{cold-hot}} = 1 + 0.1 \times (\text{g/kWh}_{\text{measured,cold}} - \text{g/kWh}_{\text{measured,hot}}) / \text{g/kWh}_{\text{measured,hot}}$$
- Lower limit for $BF_{\text{cold-hot}}$ set to 1

Data post-processing (4/5) – Correction factor for periodically regen. DPFs

- Consider additional FC for periodically regenerated DPFs
- Definition of periodically regenerated DPFs acc. to UN/ECE R49
- Correction factor “CFRegPer” has to be calculated acc. to *[Point 5.4 of Annex V]* :



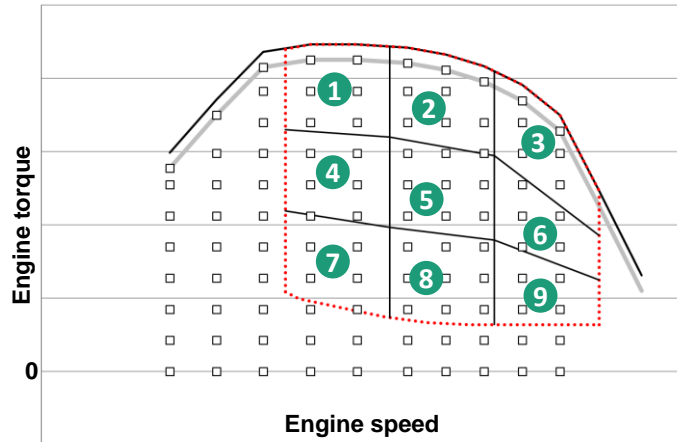
$$CF_{RegPer} = \frac{n \times (\text{avg } g/kWh_{all\ WHTC\ w/o_reg}) + n_r \times (\text{avg } g/kWh_{all\ WHTC\ with_reg})}{n + n_r}$$

n ... number of WHTC hot start tests without regeneration

n_r ... number of WHTC hot start tests with regeneration (minimum number is 1)

Data post-processing (5/5) – Emission monitoring in the engine test procedure

- Part 1: Tests in WHTC must comply with Euro VI limits for pollutant emissions
- Part 2: Screening of FCMC according to extended WNTe/OCE *[Points 4.3.5.6 and 4.3.5.7 of Annex V]*
 - For each cell the measured specific emissions in g/kWh for each FCMC point are averaged
 - Each cell is evaluated independently
 - Averaged emissions of each cell must comply with Euro VI WNTe/OCE emission limits
 - Lower boundary of control area defined by engine with lowest rating in CO₂-family



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Engine pre-processing tool (VECTO Engine)

Common mistakes

Special topic: from measured FC to certified CO₂

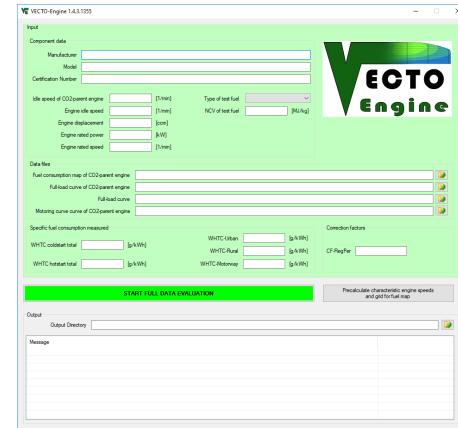
Q&A (ca. 15 min)

VECTO Engine – Basic features

- Written in VB.net
- Portable application (i.e. no installation required)
- File format conventions [*Point 6 of Annex V*]
 - CSV (Comma Separated Values) file type
 - List separator is Comma “,”
 - Decimal separator is Dot “.”
- According to Commission Regulation (EU) 2017/2400 the use of VECTO Engine is mandatory
- Output is one single XML file
 - File already hashed
 - Ready for use in VECTO vehicle simulation for declaration

VECTO Engine – Overview input data

- Input files required *[Point 6]*
 - FC map of CO2-parent engine
 - Full load curve of CO2-parent engine
 - Full load curve of actual engine to be certified
 - Motoring curve of CO2-parent engine
- Input values required in GUI *[Point 6]*



Manufacturer	Idle speed of the CO2-parent engine	Specific FC figures in g/kWh
Engine model name	Engine idle speed	CF _{RegPer}
Certification number	Engine displacement	
Type of test fuel	Engine rated power	
NCV of test fuel	Engine rated speed	

VECTO Engine – Input file

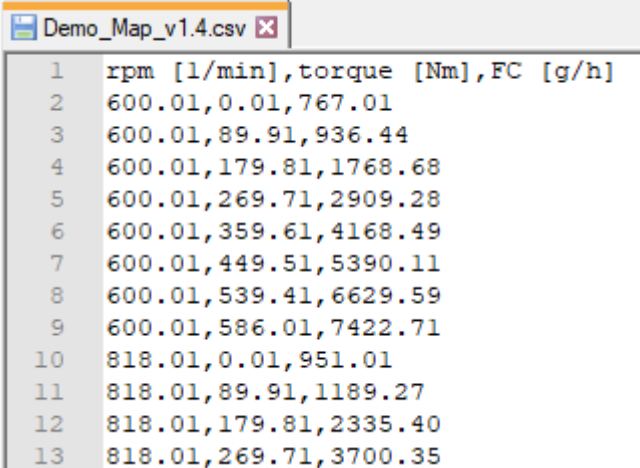
“FC map of CO2-parent engine”

- CSV file type

[Point 6.1.4 of Annex V]

Signal	Unit	Number of decimal places	Remarks
Engine speed	[min ⁻¹]	2	-
Engine torque	[Nm]	2	-
Fuel mass flow	[g/h]	2	-

Example



```
Demo_Map_v1.4.csv
1 rpm [1/min], torque [Nm], FC [g/h]
2 600.01, 0.01, 767.01
3 600.01, 89.91, 936.44
4 600.01, 179.81, 1768.68
5 600.01, 269.71, 2909.28
6 600.01, 359.61, 4168.49
7 600.01, 449.51, 5390.11
8 600.01, 539.41, 6629.59
9 600.01, 586.01, 7422.71
10 818.01, 0.01, 951.01
11 818.01, 89.91, 1189.27
12 818.01, 179.81, 2335.40
13 818.01, 269.71, 3700.35
```

VECTO Engine – Input file

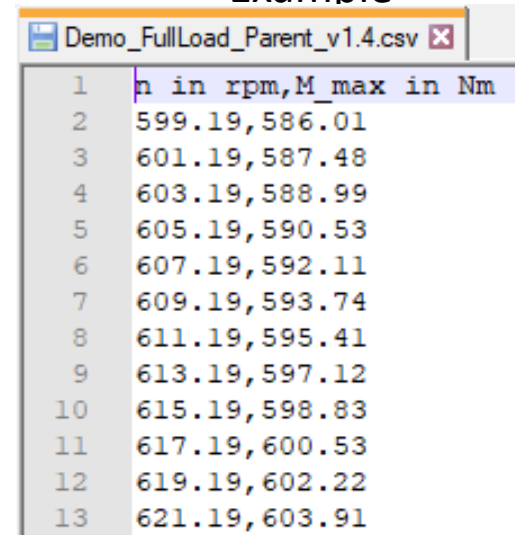
“Full load curve” and “Motoring curve”

- CSV file type

[Points 6.1.1 to 6.1.3 of Annex V]

Signal	Unit	Number of decimal places	Remarks
Engine speed	[min ⁻¹]	2	-
Engine torque	[Nm]	2	-

Example



	n in rpm	M_max in Nm
1	599.19	586.01
2	601.19	587.48
3	603.19	588.99
4	605.19	590.53
5	607.19	592.11
6	609.19	593.74
7	611.19	595.41
8	613.19	597.12
9	615.19	598.83
10	617.19	600.53
11	619.19	602.22
12	621.19	603.91

VECTO Engine – Overview evaluation algorithms (1/3)

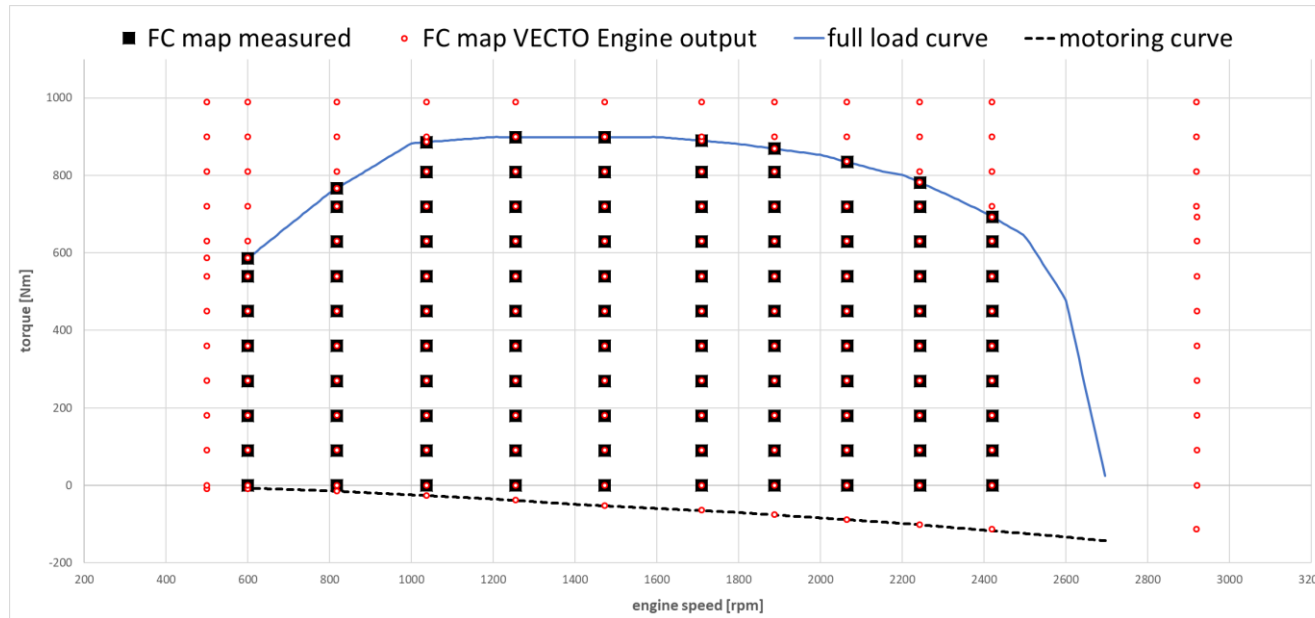
1. Reading of input files and automatic check of input data as set out in Annex V to Commission Regulation (EU) 2017/2400
2. Calculation of characteristic engine speeds (for denormalization of testcycles) from full load curves of CO₂-parent engine and actual engine for certification
3. Processing of fuel consumption (FC) map
 - Add FC values below n_{idle} to the map
 - Add FC values above n_{95h} to the map
 - Extrapolation of FC values to cover knees in the full load curve
 - Adding of FC = 0 g/h at motoring curve at all engine speed setpoints in the map
 - Adding of FC = 0 g/h below motoring curve at all engine speed setpoints in the map

VECTO Engine – Overview evaluation algorithms (2/3)

4. Simulation of FC and cycle work over WHTC and respective subparts for actual engine for certification
5. Calculation of WHTC correction factors
6. Calculation of cold-hot emission balancing factor
7. Correction of FC values in FC map to standard NCV
 - $FC_{\text{corrected}} = FC_{\text{measured}} \times NCV_{\text{meas}} / NCV_{\text{std}}$
 - No correction performed for Diesel fuel (B7)
8. Conversion of engine full load and motoring curve data to a logging frequency of the engine speed of 8 min^{-1} for the XML output
(only if average logging frequency of input data is $< 6 \text{ min}^{-1}$)

VECTO Engine – Overview evaluation algorithms (3/3)

→ Example of data processing through VECTO Engine for FC map

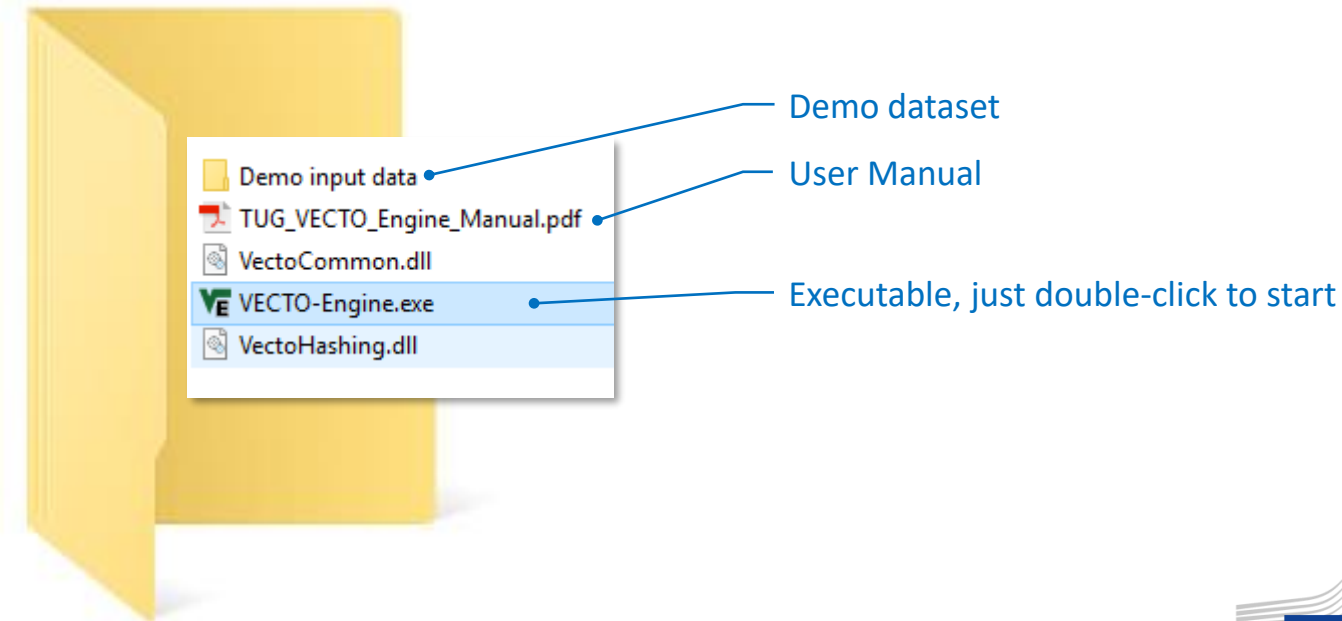


VECTO Engine – Software demonstration

Download package

Storyline for live demonstration and (maybe with reduced content) for video

Content of VECTO Engine package as downloaded from JRC server can be copied to any place on a PC/server



VECTO Engine – Software demonstration

General GUI elements

Storyline for live demonstration and (maybe with reduced content) for video

The screenshot shows the VECTO-Engine 1.4.3.1355 interface. It is divided into several sections:

- Input (Component data):** A red dashed box highlights fields for Manufacturer, Model, Certification Number, Idle speed of CO₂-parent engine, Engine idle speed, Engine displacement, Engine rated power, Engine rated speed, Type of test fuel, and NCV of test fuel.
- Data files:** A purple dashed box highlights fields for Fuel consumption map of CO₂-parent engine, Full load curve of CO₂-parent engine, Full-load curve, and Motoring curve curve of CO₂-parent engine.
- Specific fuel consumption measured:** An orange dashed box highlights fields for WHTC coldstart total, WHTC-Urban, WHTC-Rural, WHTC hotstart total, WHTC-Motorway, and Correction factors (CF-RegPer).
- Control buttons:** A red line points to a button labeled "START FULL DATA EVALUATION" and another button labeled "Precalculate characteristic engine speeds and grid for fuel map".
- Output:** A green dashed box highlights the "Output Directory" field.
- Message window:** A blue dashed box highlights the "Message" area at the bottom.

External labels with colored lines pointing to these elements are:

- Input fields for component data (red)
- Input fields for component files (purple)
- Input fields for specific FC figures and CF_{RegPer} (orange)
- Input field for output directory (green)
- Message window (blue)
- Control buttons (red)

VECTO Engine – Software demonstration

Test evaluation (1/3)

Storyline for live demonstration and (maybe with reduced content) for video

1. Input all component data

2. Browse for input files

3. Input all values for specific FC figures and CF_{RegPer}

4. Browse for output directory

VECTO-Engine 1.4.3.1355

Input

Component data

Manufacturer

Model

Certification Number

Idle speed of CO₂-parent engine [1/min] Type of test fuel

Engine idle speed [1/min] NCV of test fuel [MJ/kg]

Engine displacement [ccm]

Engine rated power [kW]

Engine rated speed [1/min]

Data files

Fuel consumption map of CO₂-parent engine

Full-load curve of CO₂-parent engine

Full-load curve

Motoring curve curve of CO₂-parent engine

Specific fuel consumption measured

WHTC coldstart total [g/kWh] WHTC-Urban [g/kWh]

WHTC hotstart total [g/kWh] WHTC-Rural [g/kWh]

WHTC-Motorway [g/kWh] CF-RegPer

Correction factors

START FULL DATA EVALUATION

Precalculate characteristic engine speeds and grid for fuel map

Output

Output Directory

Message

5. Press green “Start” button for full data evaluation

OPTION: “Precalculate”
→ see next slide

6. Status of evaluation displayed in message window

→ Upon completion a VECTO XML input file is created

VECTO Engine – Software demonstration

Test evaluation (2/3)

Storyline for live demonstration and (maybe with reduced content) for video

For **precalculation** of grid for fuel map before FCMC testrun:

Only 2 inputs needed:

- idle speed of CO₂-parent engine
- full load curve of CO₂-parent engine

VECTO-Engine 1.4.3.1355

Input

Component data

Manufacturer

Model

Certification Number

Idle speed of CO₂-parent engine [1/min]

Engine idle speed [1/min]

Engine displacement [ccm]

Engine rated power [kW]

Engine rated speed [1/min]

Type of test fuel

NCV of test fuel [MJ/kg]

Data files

Fuel consumption map of CO₂-parent engine

Full-load curve of CO₂-parent engine

Full-load curve

Motoring curve curve of CO₂-parent engine

Specific fuel consumption measured

WHTC coldstart total [g/kWh]

WHTC-Urban [g/kWh]

WHTC-Rural [g/kWh]

WHTC-Motorway [g/kWh]

WHTC hotstart total [g/kWh]

Correction factors

CF-RegPer

START FULL DATA EVALUATION

Precalculate characteristic engine speeds and grid for fuel map

Output

Output Directory

Message

Press press grey “Precalculate” button to precalculate grid for fuel map from CO₂-parent full-load curve

→ result is displayed in message window

VECTO Engine – Software demonstration

Test evaluation (3/3)

Storyline for live demonstration and (maybe with reduced content) for video

Further important remarks:

- Messages displayed
 - Clear explanations for all relevant errors (ref. to regulation or indication of datapoint)
 - Warnings vs. Errors:
 - A valid XML results file is only created if no errors occur (non-conformity with requirements in regulation)
 - Warnings give a hint that something might be wrong with the input data
 - XML result file is valid despite warnings
 - **BUT:** warnings should be investigated together with TAA / technical service
- Only one single XML file is created as output
 - File already hashed
 - Ready for use in VECTO vehicle simulation for declaration

VECTO Engine – Software demonstration

Example XML input file for VECTO

Storyline for live demonstration and (maybe with reduced content) for video

```
<?xml version="1.0" encoding="utf-8"?>
<tns:VectoInputDeclaration schemaVersion="1.0" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xmlns="http://www.w3.org/2000/09/xmldsig#">
  <tns:Engine>
    <Data id="ENG-cf2bb842a2b44b0fae4a">
      <Manufacturer>ofjdsofi</Manufacturer>
      <Model>fdskjfkad</Model>
      <CertificationNumber>lkfdsjflk</CertificationNumber>
      <Date>2018-03-26T11:48:25.281637Z</Date>
      <AppVersion>VECTO-Engine 1.4.3.1043</AppVersion>
      <Displacement>12000</Displacement>
      <IdlingSpeed>600</IdlingSpeed>
      <RatedSpeed>2200</RatedSpeed>
      <RatedPower>130000</RatedPower>
      <MaxEngineTorque>899</MaxEngineTorque>
      <WHTCUrban>1.0000</WHTCUrban>
      <WHTCRural>1.0423</WHTCRural>
      <WHTCMotorway>1.0776</WHTCMotorway>
      <BFColdHot>1.0000</BFColdHot>
      <CFRegPer>1.5000</CFRegPer>
      <CFNCV>0.9953</CFNCV>
      <FuelType>Diesel CI</FuelType>
      <FuelConsumptionMap>
        <Entry engineSpeed="500.00" torque="-108.88" fuelConsumption="0.00" />
        <Entry engineSpeed="500.00" torque="-8.88" fuelConsumption="0.00" />
        <Entry engineSpeed="500.00" torque="0.01" fuelConsumption="767.01" />
        <Entry engineSpeed="500.00" torque="89.91" fuelConsumption="936.44" />
        <Entry engineSpeed="500.00" torque="174.81" fuelConsumption="1768.68" />
        <Entry engineSpeed="500.00" torque="269.71" fuelConsumption="2909.28" />
      </FuelConsumptionMap>
    </Data>
  </tns:Engine>
</tns:VectoInputDeclaration>
```

```
<Entry engineSpeed="2624.00" maxTorque="364.10" dragTorque="-113.39" />
<Entry engineSpeed="2632.00" maxTorque="325.78" dragTorque="-113.39" />
<Entry engineSpeed="2640.00" maxTorque="287.46" dragTorque="-113.39" />
<Entry engineSpeed="2648.00" maxTorque="249.14" dragTorque="-113.39" />
<Entry engineSpeed="2656.00" maxTorque="210.82" dragTorque="-113.39" />
<Entry engineSpeed="2664.00" maxTorque="172.50" dragTorque="-113.39" />
<Entry engineSpeed="2672.00" maxTorque="134.18" dragTorque="-113.39" />
<Entry engineSpeed="2680.00" maxTorque="95.86" dragTorque="-113.39" />
<Entry engineSpeed="2688.00" maxTorque="57.54" dragTorque="-113.39" />
<Entry engineSpeed="2696.00" maxTorque="25.34" dragTorque="-113.39" />
</FullLoadAndDragCurve>
</Data>
<Signature>
  <Reference URI="#ENG-cf2bb842a2b44b0fae4a" xmlns="http://www.w3.org/2000/09/xmldsig#">
    <Transforms>
      <Transform Algorithm="urn:vecto:xml:2017:canonicalization" />
      <Transform Algorithm="http://www.w3.org/2001/10/xml-exc-c14n#" />
    </Transforms>
    <DigestMethod Algorithm="http://www.w3.org/2001/04/xmldsig-core-schema#sha256" />
    <DigestValue>JDOqOj6nEQAnEMzD4FVdsdF6TazewtNuB0pZ3NyaYoc</DigestValue>
  </Reference>
</Signature>
</tns:Engine>
</tns:VectoInputDeclaration>
```

XML file already hashed by VECTO Engine pre-processing tool

```
<Entry engineSpeed="2920.00" torque="809.15" fuelConsumption="3908.73" />
<Entry engineSpeed="2920.00" torque="899.06" fuelConsumption="44420.98" />
<Entry engineSpeed="2920.00" torque="988.97" fuelConsumption="49743.13" />
</FuelConsumptionMap>
<FullLoadAndDragCurve>
  <Entry engineSpeed="592.00" maxTorque="586.01" dragTorque="-8.88" />
  <Entry engineSpeed="600.00" maxTorque="587.58" dragTorque="-8.88" />
  <Entry engineSpeed="608.00" maxTorque="592.80" dragTorque="-9.11" />
  <Entry engineSpeed="616.00" maxTorque="599.52" dragTorque="-9.35" />
  <Entry engineSpeed="624.00" maxTorque="606.28" dragTorque="-9.58" />
</FullLoadAndDragCurve>
```

Beginning of section for FC data

Beginning of section for full load and motoring data

Basic principles of engine test procedure

Overview of content of engine test procedure

Details of engine test procedure

Engine pre-processing tool (VECTO Engine)

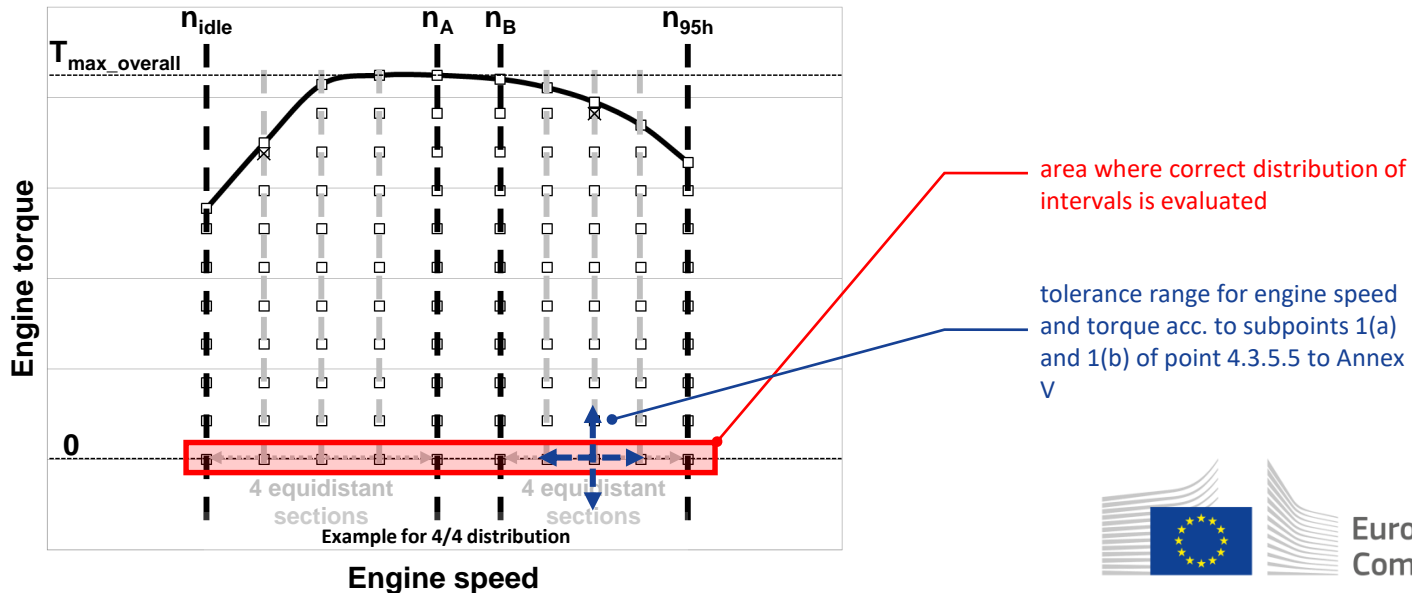
Common mistakes

Special topic: from measured FC to certified CO₂

Q&A (ca. 15 min)

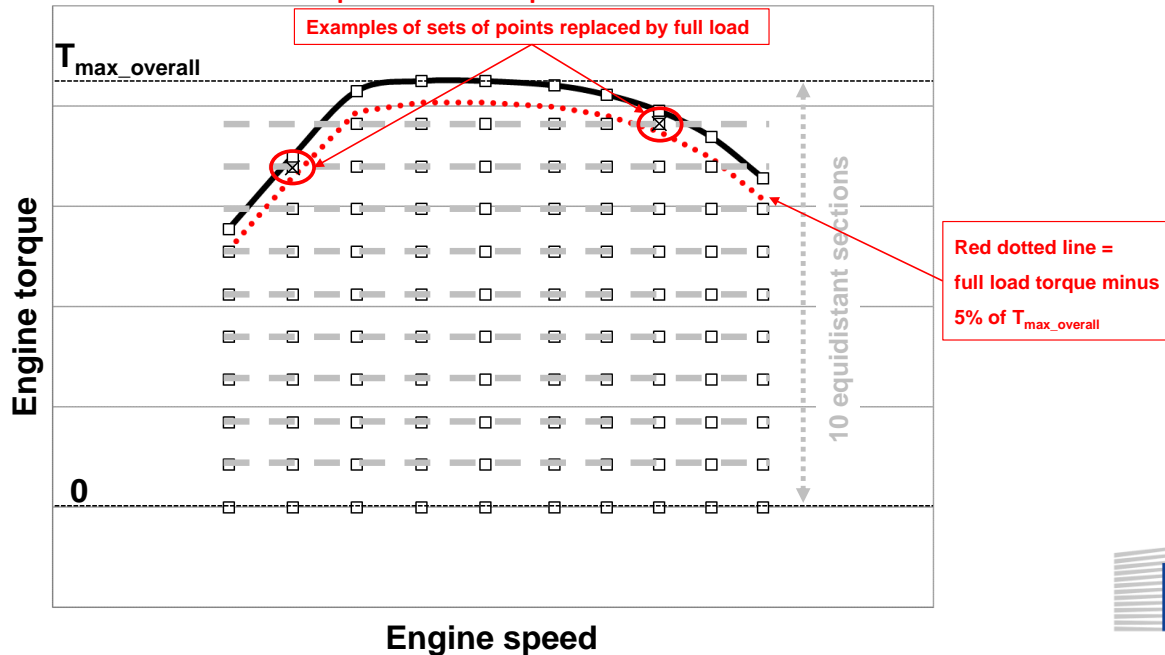
Common mistakes (1/2)

- Correct distribution of intervals for target engine speed setpoints ([Point 4.3.5.2.1 of Annex V]) is checked by VECTO-Engine using points at 0 Nm torque
- Points outside of the measurement tolerance range ([Point 4.3.5.5 of Annex V]) are not considered
- Error message states that **“number of points located in interval ‘ $n_{idle} - n_A$ ’ or ‘ $n_B - n_{95h}$ ’ is incorrect”** (additional hint to check tolerance for 0 Nm points is given)



Common mistakes (2/2)

- Correct location of measured FC map points is checked by VECTO-Engine (*[Point 4.3.5.2.2 of Annex V]*)
- Points located very close to full load (above tolerance limit) are replaced by full load
- Otherwise error message states that an “invalid torque value in FC map (at xxx [rpm] yyy [Nm])” exists and that the “expected torque value = full load”



Basic principles of engine test procedure

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Details of engine test procedure

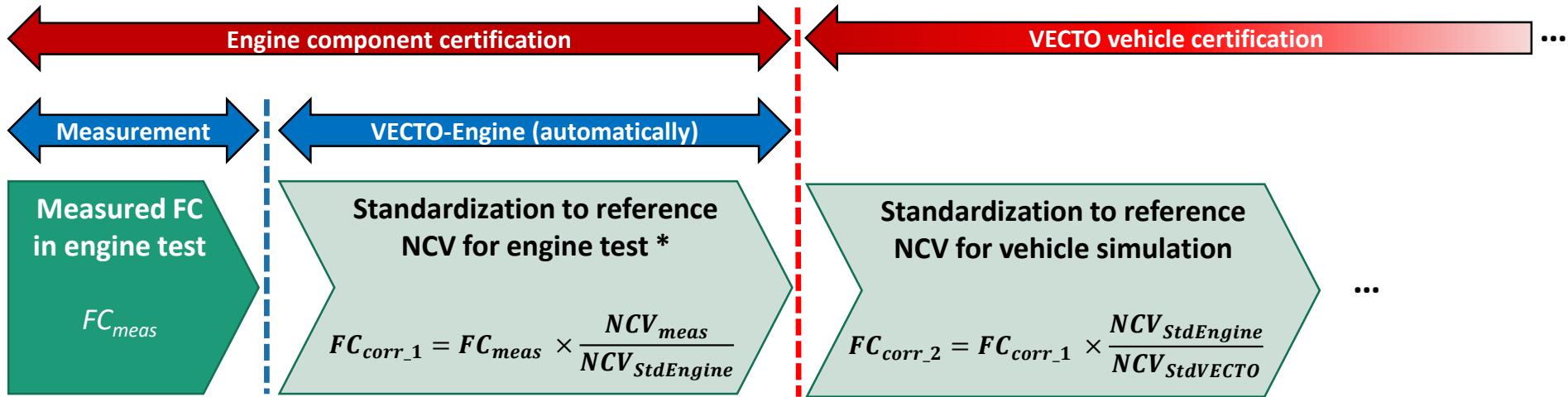
Engine pre-processing tool (VECTO Engine)

Common mistakes

Special topic: from measured FC to certified CO₂

Q&A (ca. 15 min)

From measured FC to certified CO2 (1/3)



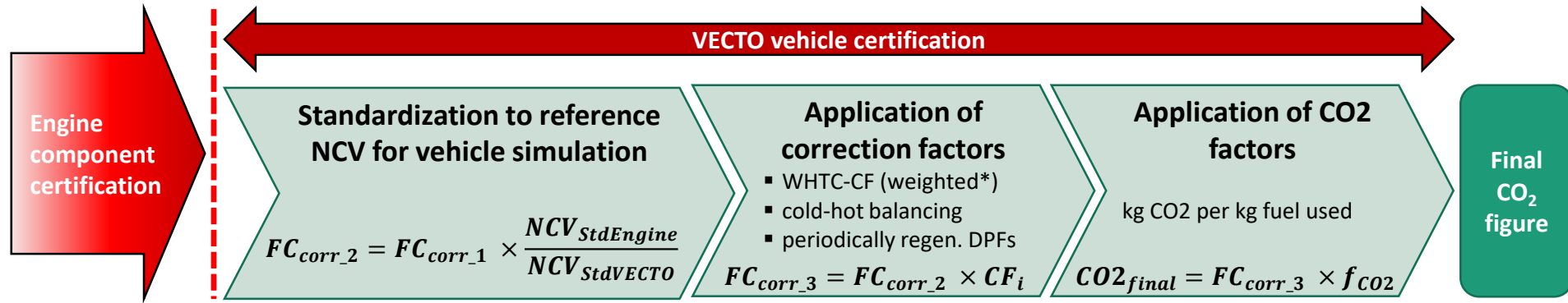
* Not performed for Diesel fuel (B7)

NCV_{meas} ... Net calorific value of the fuel used during testing [Point 5.3.3.1 to Annex V]

$NCV_{StdEngine}$... Standard net calorific values of fuel types [Point 5.3.3.1 to Annex V]

$NCV_{StdVECTO}$... Net calorific value defined as reference value for vehicle CO₂ certification

From measured FC to certified CO2 (2/3)



* explained on next slide

$NCV_{StdEngine}$... Standard net calorific values of fuel types [Point 5.3.3.1 to Annex V]

$NCV_{StdVECTO}$... Net calorific value defined as reference value for vehicle CO₂ certification

CF_i ... Combined correction factor (= WHTC-CF x $BF_{cold-hot}$ x CF_{RegPer})

f_{CO2} ... Standard factors for kg CO₂ per kg fuel combustion in VECTO

From measured FC to certified CO2 (2/3) – Details on WHTC correction factor

- WHTC-CFs calculated for 3 different WHTC parts (urban, rural, motorway) in VECTO-Engine automatically (see slide 20)
- Weighted WHTC correction factor calculated for each vehicle automatically in VECTO vehicle simulation by using WHTC weighting factors defined for each mission profile

$$CF_{\text{vehicle}} = CF_{\text{urban}} \times WF_{\text{urban}} + CF_{\text{rural}} \times WF_{\text{rural}} + CF_{\text{motorway}} \times WF_{\text{motorway}}$$

mission profile	WF _{motorway}	WF _{rural}	WF _{urban}
long haul	89%	0%	11%
regional	53%	30%	17%
urban	4%	27%	69%
municipial utility	2%	0%	98%
construction	6%	32%	62%
citybus	0%	0%	100%
interurban bus	19%	36%	45%
coach	78%	22%	0%

Annex: Fuel properties

Commission Regulation (EU) 2017/2400

Table 4 of Annex V

Table 4
Standard net calorific values of fuel types

Fuel type / engine type	Reference fuel type	Standard NCV [MJ/kg]
Diesel / CI	B7	42,7
Ethanol / CI	ED95	25,7
Petrol / PI	E10	41,5
Ethanol / PI	E85	29,1
LPG / PI	LPG Fuel B	46,0
Natural Gas / PI	G ₂₅	45,1

G_R as reference fuel for NG proposed by draft Commission Regulation amending Regulation (EU) 2017/2400

Values in VECTO until V3.3.0.1250

Engine Fuel Type ⁽¹⁾	Reference Fuel	Density	CO ₂ content	Lower Heating Value
	[-]	[kg/m ³]	[g_CO ₂ /g_Fuel]	[MJ/kg]
Diesel / CI	B7	836	3.13	42.7
Ethanol / CI	ED95	820	1.83	25.7
Petrol / PI	E10	750	3.04	41.5
Ethanol / PI	E85	786	2.09	29.1
LPG / PI	LPG Fuel B	not required	3.02	46.0
NG / PI	G25	not required	2.54	45.1
	(fuel for testing)		(representing typical CNG real world fuel)	

Figures might be revised in release Dec 2018. LNG to be added



Basic principles of engine test procedure

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Common mistakes

Special topic: from measured FC to certified CO₂

Q&A (ca. 15 min)

