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CORRECTION OF THE METHOD OF ASSESSING EXHAUST EMISSION DURING THE FLIGHT OF THE AIRCRAFT, INCLUDING IMPACT OF CHANGES IN FLIGHT ALTITUDE ON ENGINE PERFORMANCE PARAMETERS

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AGENDA

- INTRODUCTION
- METHODOLOGY
- RESULTS
- CONCLUSIONS

INTRODUCTION

- Air transport as an economic field,
- Direct impact on the state of the environment,
- Emission requirements,
- Limitations related to emission measurements,
- Estimation of the emission during the flight.

ICAO ENGINE EXHAUST EMISSIONS DATA BANK

SUBSONIC ENGINES

ENGINE IDENTIFICATION:	LEAP-1B28	BYPASS RATIO:	8.6
UNIQUE ID NUMBER:	18CM084	PRESSURE RATIO (π_{oo}):	41.5
ENGINE TYPE:	TF	RATED OUTPUT (F_{oo}) (kN):	130.4

REGULATORY DATA

CHARACTERISTIC VALUE:	HC	CO	NOx	SMOKE NUMBER
D_p/F_{oo} (g/kN) or SN	1.2	21.9	67.0	1.5
AS % OF ORIGINAL LIMIT	5.9 %	18.6 %	54.4 %	6.8 %
AS % OF CAEP/2 LIMIT (NOx)			68.0 %	
AS % OF CAEP/4 LIMIT (NOx)			74.4 %	
AS % OF CAEP/6 LIMIT (NOx)			81.7 %	
AS % OF CAEP/8 LIMIT (NOx)			91.6 %	

DATA STATUS

- \- PRE-REGULATION
- x CERTIFICATION
- \- REVISED (SEE REMARKS)

TEST ENGINE STATUS

- x NEWLY MANUFACTURED ENGINES
- x DEDICATED ENGINES TO PRODUCTION STANDARD
- \- OTHER (SEE REMARKS)

EMISSIONS STATUS

- x DATA CORRECTED TO REFERENCE (ANNEX 16 VOLUME II)

CURRENT ENGINE STATUS

(IN PRODUCTION, IN SERVICE UNLESS OTHERWISE NOTED)

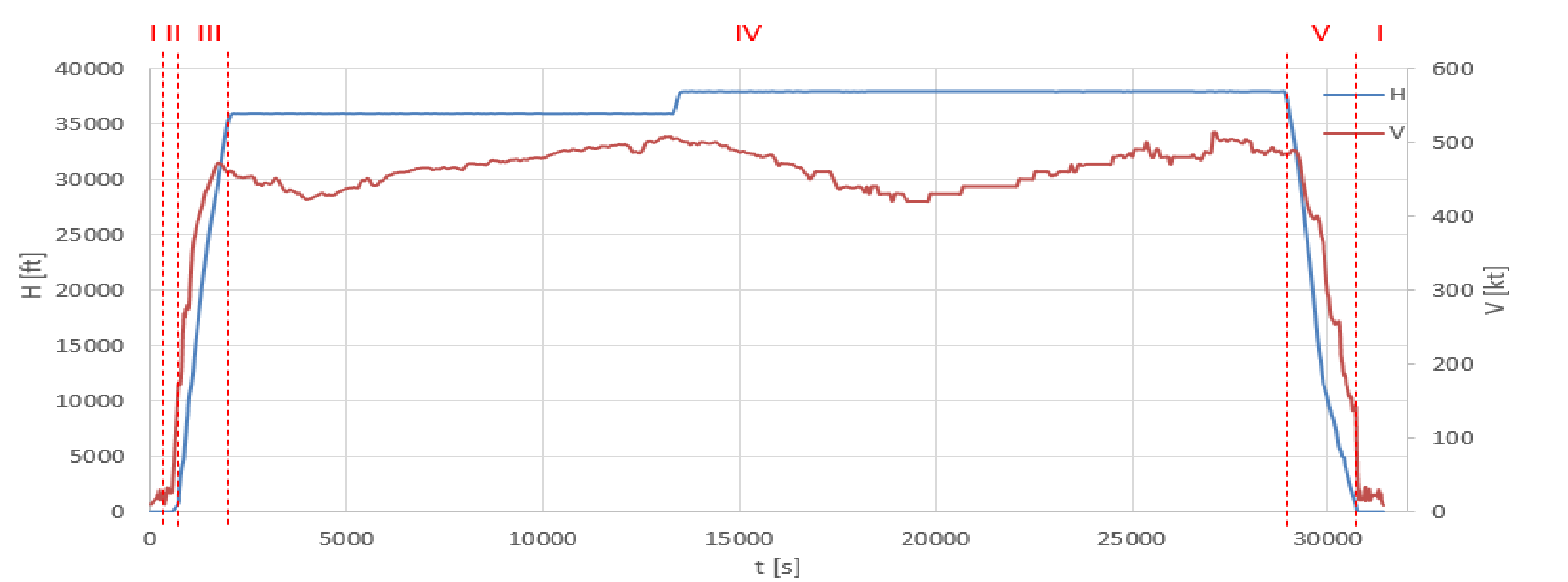
- \- OUT OF PRODUCTION
- \- OUT OF SERVICE

MEASURED DATA

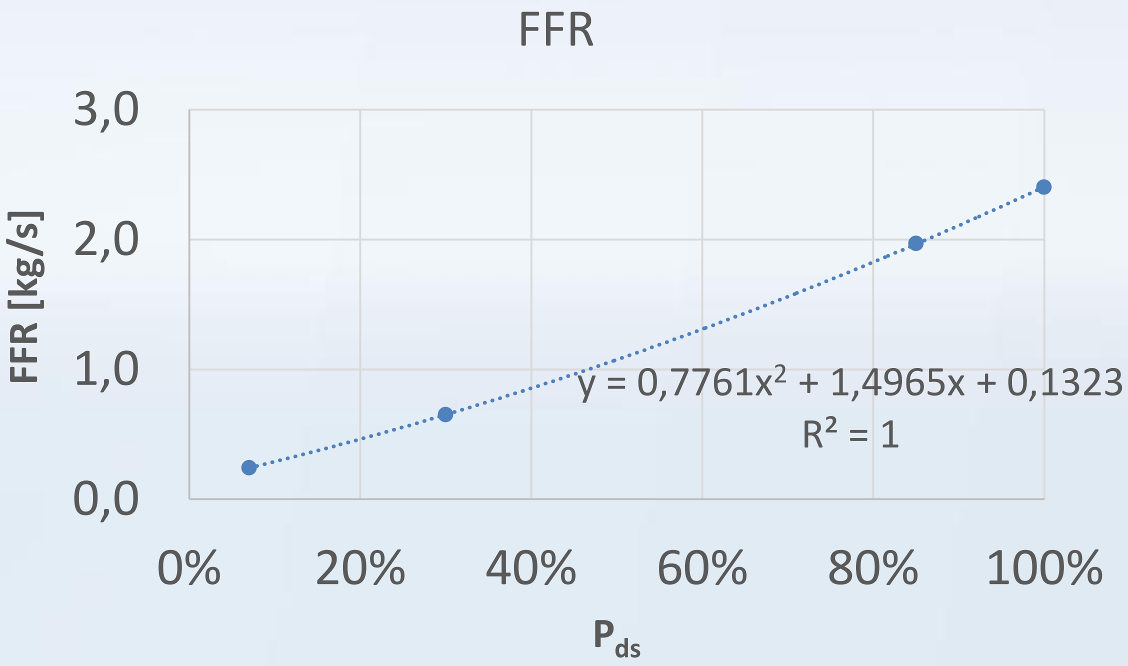
MODE	POWER SETTING (%F_{oo})	TIME minutes	FUEL FLOW kg/s	EMISSIONS INDICES (g/kg) HC	CO	NOx	SMOKE NUMBER
TAKE-OFF	100	0.7	1.061	0.05	0.18	60.67	0.94
CLIMB OUT	85	2.2	0.864	0.04	0.14	29.58	0.85
APPROACH	30	4.0	0.277	0.05	1.2	11.24	1.07
IDLE	7	26.0	0.098	0.57	14.62	4.64	0.8
LTO TOTAL FUEL (kg) or EMISSIONS (g)			378	97	2339	7534	-
NUMBER OF ENGINES				1	1	1	1
NUMBER OF TESTS				3	3	3	3
AVERAGE D_p/F_{oo} (g/kN) or AVERAGE SN (MAX)				0.74	17.94	57.78	1.16
SIGMA (D_p/F_{oo} in g/kN, or SN)				0.09	0.77	1.38	0.29
RANGE (D_p/F_{oo} in g/kN, or SN)				0.66 to 0.8	16.97 to 18.38	56.39 to 59.15	0.34 to 0.90

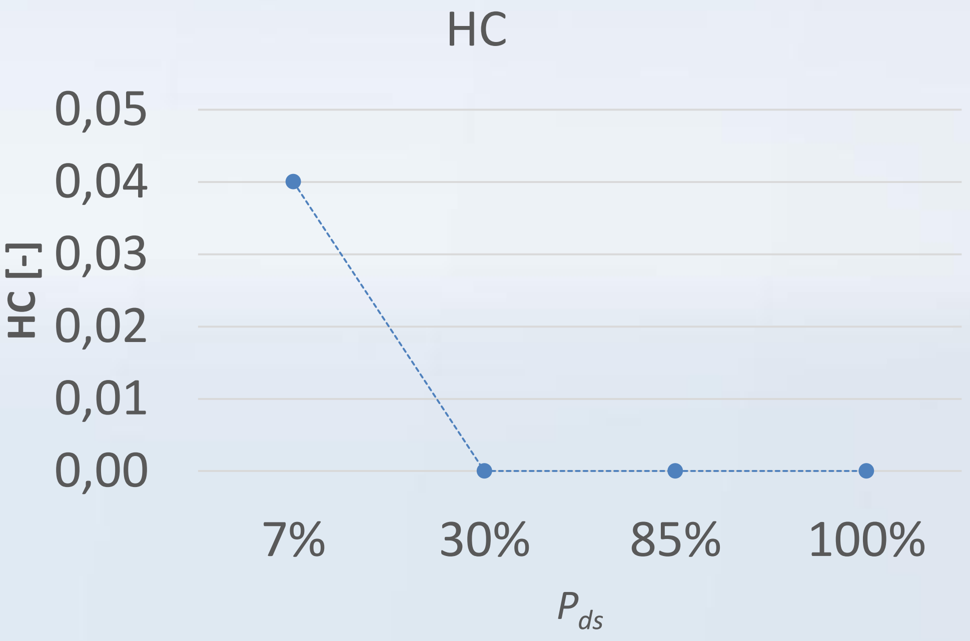
METHODOLOGY

- The basis for determining the emission of harmful exhaust gasses,

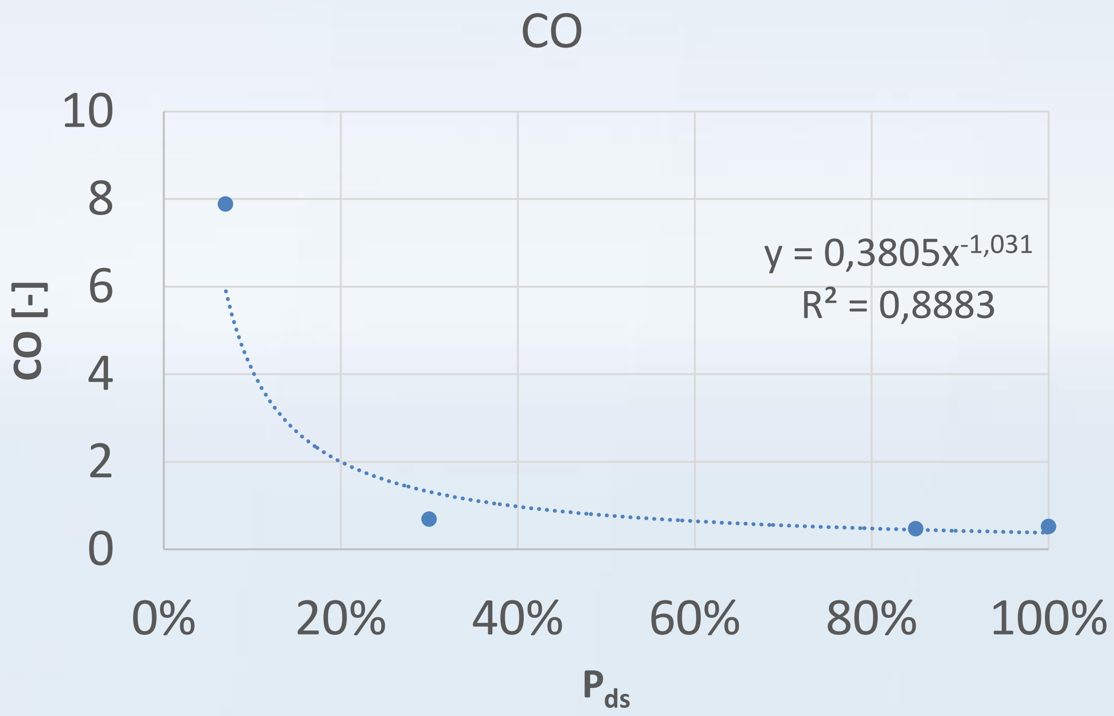


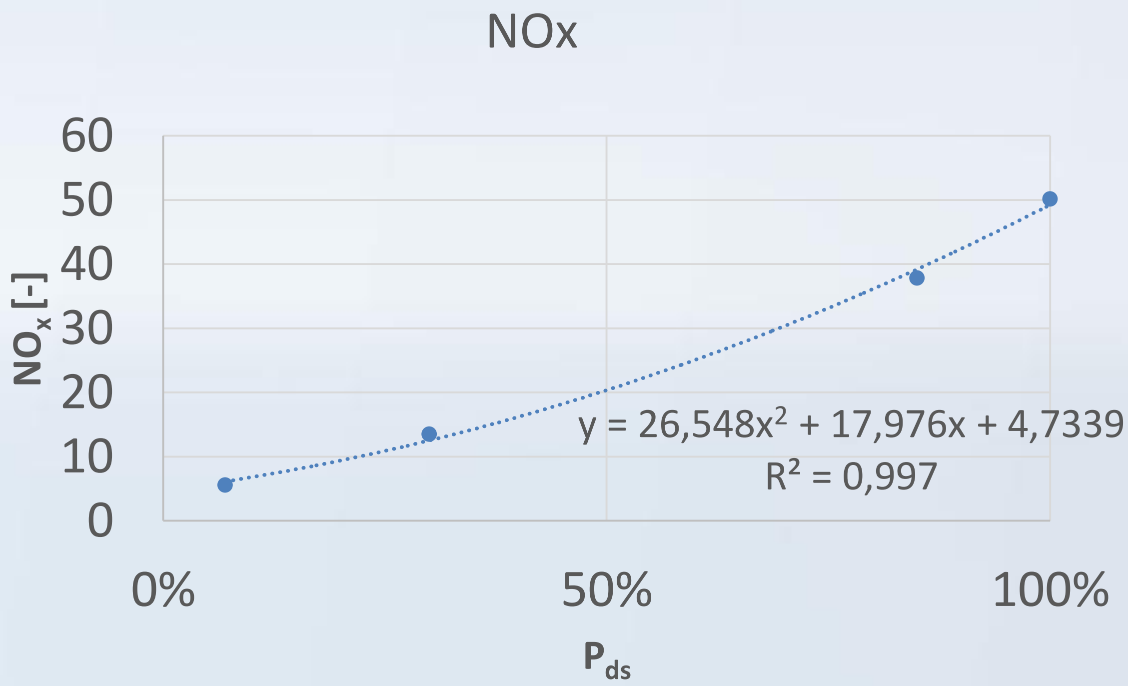
METHODOLOGY





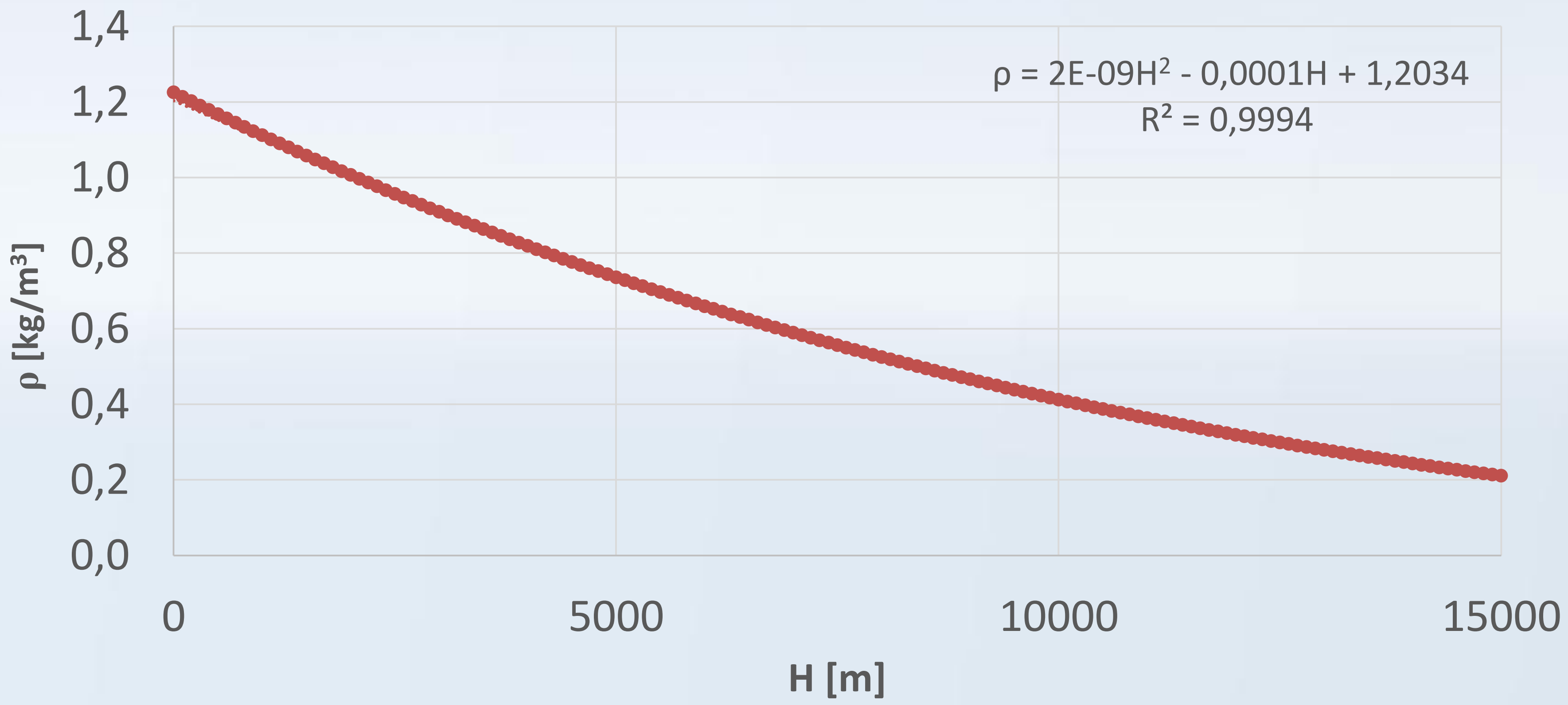
METHODOLOGY





METHODOLOGY

METHODOLOGY



METHODOLOGY

The results of the correction factor calculation

λ	
Low engine load	High engine load
7	4
Air mass per 1 kg of fuel	
102,9	58,8
Air volume per 1 kg of fuel	
85,8	178,0
Correction factor	
0,48	

$$Fuel\ consumption = \sum(TIM \cdot FFR_{Phase}) \cdot NE$$

Where:

TIM - Time in Mode [s]
FFRphase - Fuel Flow Rate [kg/s]
NE - Number of engines on the aircraft [-]

Calculated fuel consumption: 43818 kg

Fuel consumption (provided by PLL LOT): 46424 kg

METHODOLOGY

- Calculation of the emission of a particular harmful compound:

$$EPC_{pol.mode} = TIM \cdot FFR \cdot EF \cdot NE$$

Where:

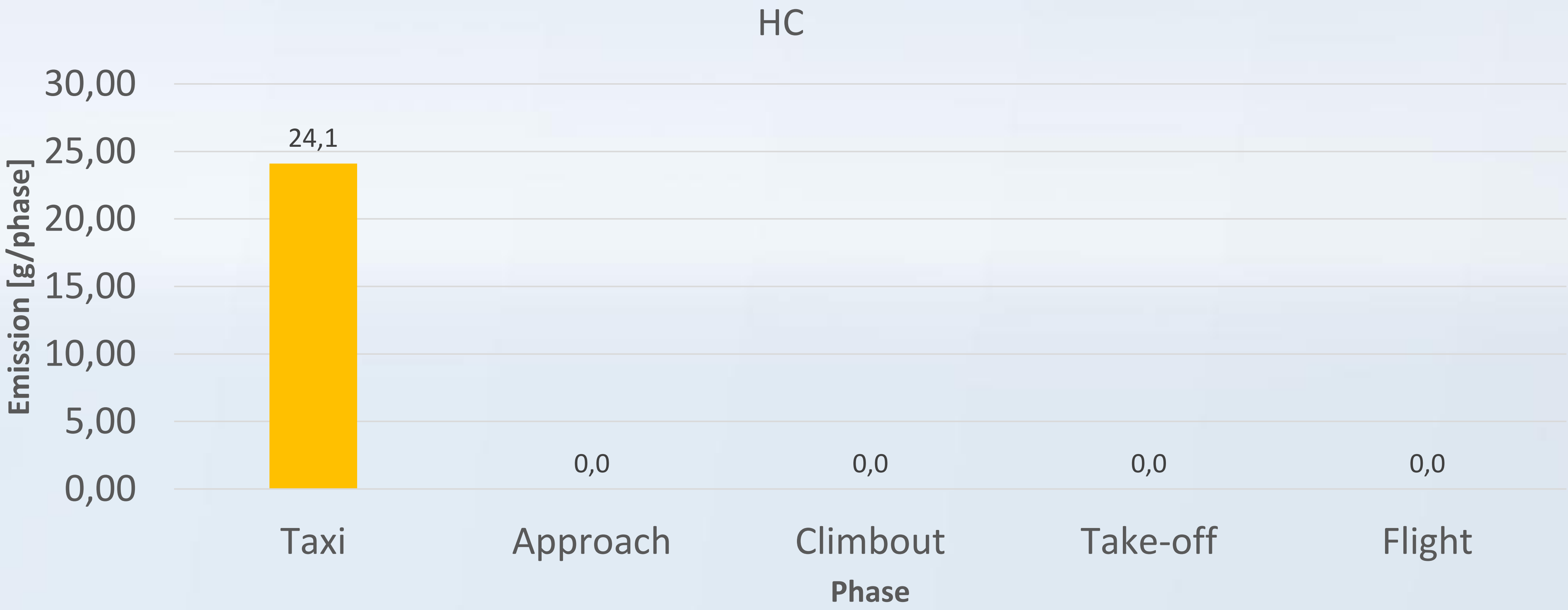
$EPC_{pol,mode}$	Emissions per cycle for a particular pollutant during a particular mode [g]
TIM	Time in Mode [s]
FFR	Fuel Flow Rate [kg/s]
EF	Emission Factor [-]
NE	Number of engines on the aircraft [-]

METHODOLOGY

Emission results for climbout and approach operations

LTO phase	HC [g/phase]	CO [g/phase]	NO_x [g/phase]	PM [g/phase]
Approach	0,00	1749,37	9895,18	2822,82
Climbout	0,00	1114,27	116453,20	5079,32

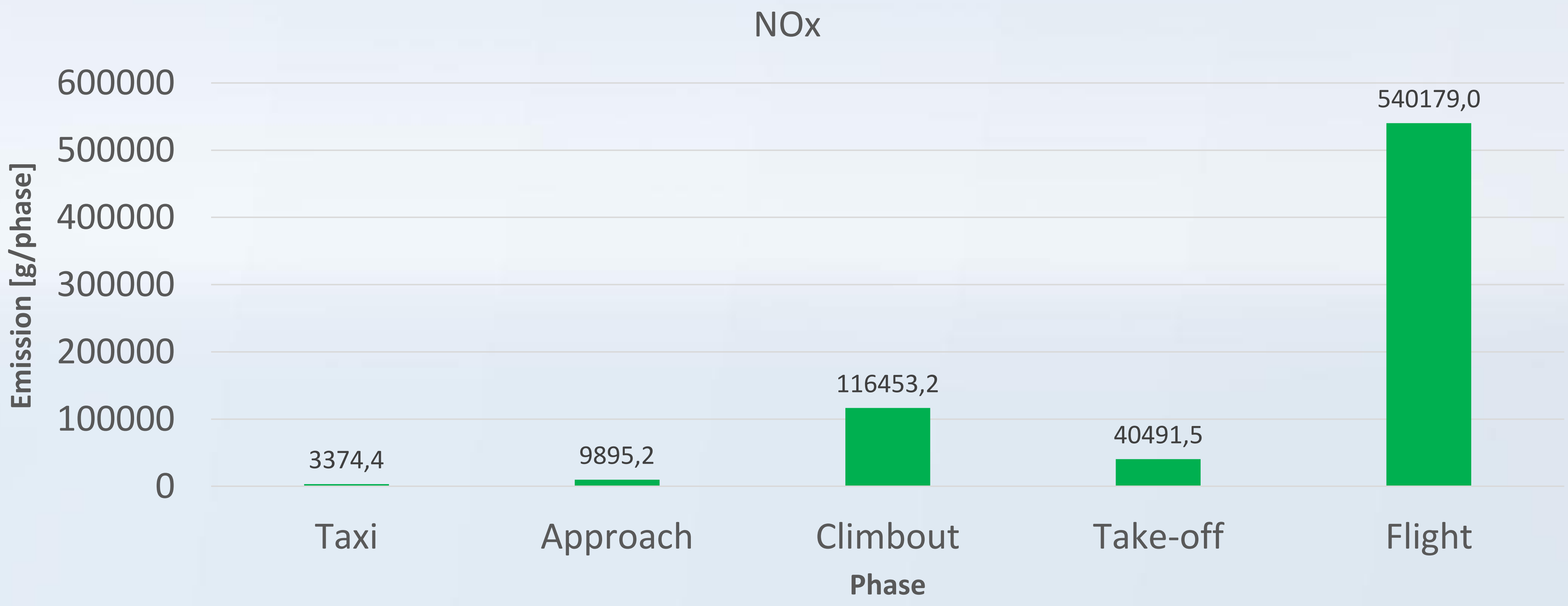
RESULTS


HC
30,00
25,00
20,00
15,00
10,00
5,00
0,00
Emission [g/phase]
24,1
0,0
0,0
0,0
0,0
Taxi
Approach
Climbout
Take-off
Flight
Phase

RESULTS

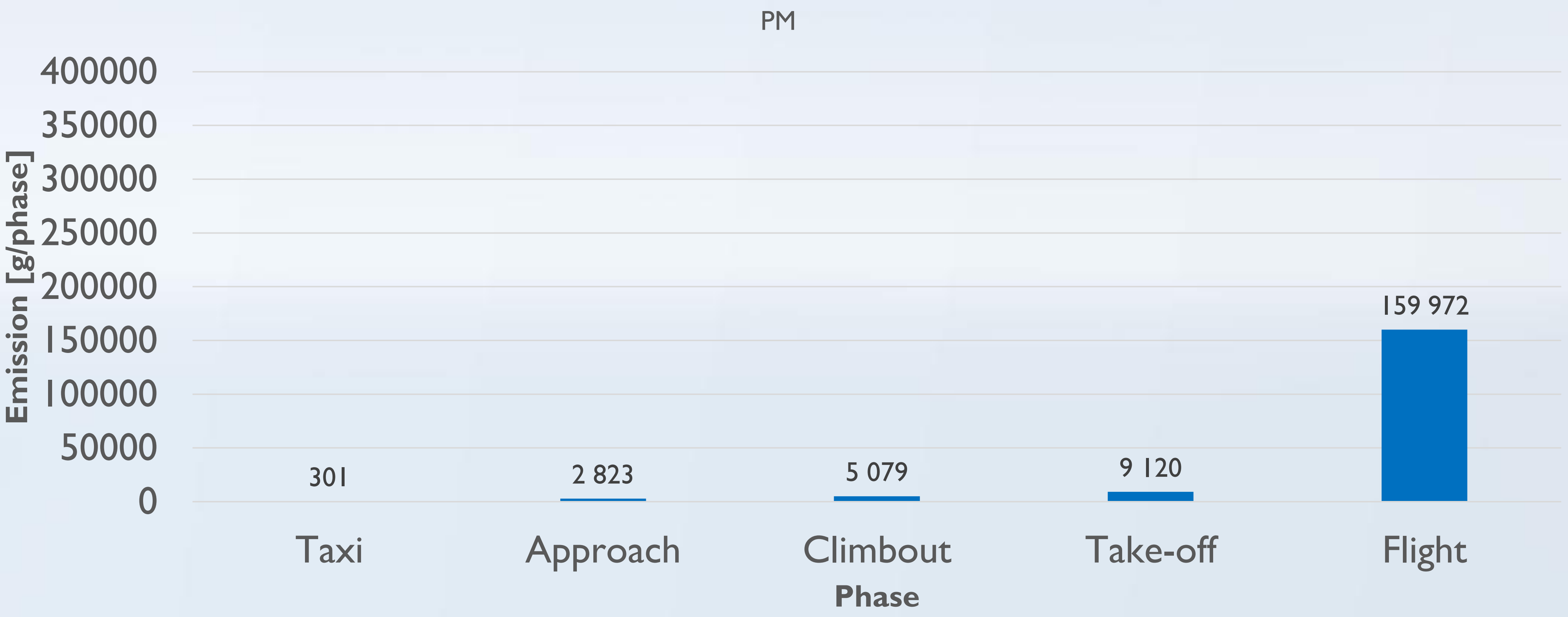

CO
50000
40000
30000
20000
10000
0
Emission [g/phase]
4748,3
1749,4
1114,3
419,9
45609,0
Taxi
Approach
Climbout
Take-off
Flight
Phase

RESULTS

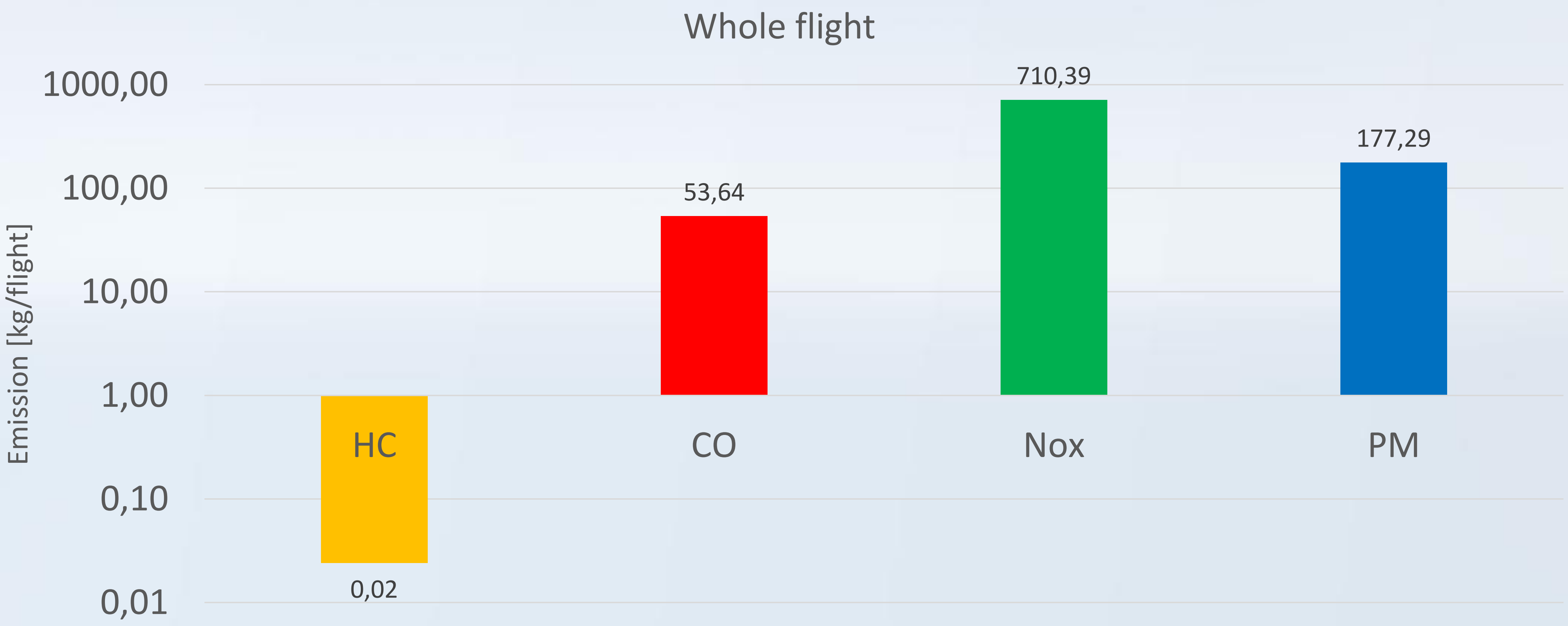


NOx
600000
500000
400000
300000
200000
100000
0
Emission [g/phase]
3374,4
9895,2
116453,2
40491,5
540179,0
Taxi
Approach
Climbout
Take-off
Flight
Phase

RESULTS


PM
400000
350000
300000
250000
200000
150000
100000
50000
0
Emission [g/phase]
301
2 823
5 079
9 120
159 972
Taxi
Approach
Climbout
Take-off
Flight
Phase

RESULTS


Whole flight
Emission [kg/flight]
1000,00
100,00
10,00
1,00
0,10
0,01
0,02
53,64
710,39
177,29
HC
CO
Nox
PM

CONCLUSIONS

- The calculation scheme presented in this article makes it possible to estimate the emission of individual harmful compounds during the flight of an aircraft.
- A novelty in the presented calculation scheme are calculations of emission values in the climbout and approach phases, taking into account the influence of the change in flight altitude on engine operation parameters.
- The highest value of hydrocarbon emission occurs in the taxiing phase. It is influenced by low engine load and warming up.
- The highest values of emissions of carbon oxides, nitrogen oxides and particulate matter were observed in the flight at flight level phase.
- The lowest emission values of harmful compounds in the engine exhaust of the Boeing 787-9 Dreamliner aircraft were registered for hydrocarbons.
- It can be concluded that the tests are carried out with an estimation error of 5,6 %.

THANK YOU FOR ATTENTION