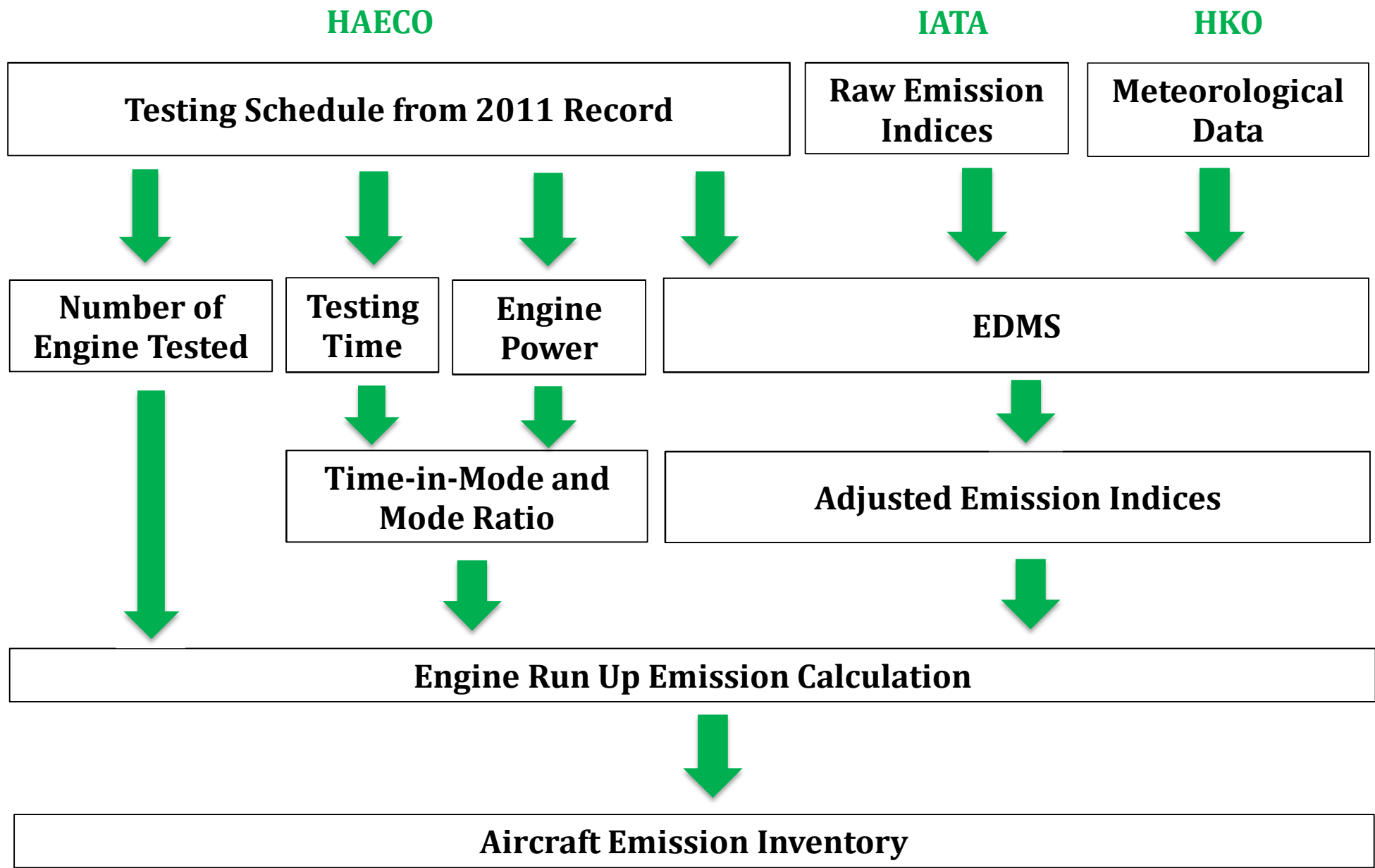


Basic Flow of Calculation of Engine Run Up Emission



Sample Calculation - Three Runway Scenario

Testing Record

Test Number	Start Hour Code	Finish Hour Code	Operator	A/C Type	Engine UID	Number of Engine Tested	Engine Power(%)	Total Testing Time (mins) [1]
5	010412	010413	Cathay Pacific	B747	1	1	90%	27

Note:
[1] Total testing time are provided by HAECO as the accumulated testing time by all the engines tested

Meteorological Condition

Test Number	Hour Code	Temperature (°C) T _{amb} [1]	Relative Humidity (-) [1]	Hourly Mean Sea Level Pressure (Pa) [1]
5	010412	20.1	0.76	101670

Insert into EDMS to obtain the adjusted engine emission indices/ fuel consumption based on hourly meteorological condition

Notes:
[1] Data from mm5 grid 10_27
CPAHDA as the aircraft is operated by Cathay Pacific.

Engine Emission Indices

Test Number	Engine Type	Combuster Model (if any)	Out of Service (if)	Engine Type (J- Jet; T-Turboprop; P-Piston)	ICAO Engine	Mixed Turbofan	Bypass Ratio	Rated Engine Output (kN)	Unadjusted Fuel Flow - Takeoff	Unadjusted Fuel Flow - Climbout	Unadjusted Fuel Flow - Approach	Unadjusted Fuel Flow - Idle
5	CPAHDA		FALSE	J	FALSE		8.54058	332.96238	2.71629	2.19766	0.70087	0.24291

Insert into EDMS in user-created aircraft

Test Number	Adjusted Fuel Flow (kg/s) [1][2]			
	Approach (30%)	Idling (7%)	Takeoff (100%)	Climb Out (85%)
5	0.6566	0.2454	2.5199	2.0448

Notes:
[1] Extracted from EDMS, installation effect for Takeoff, Climbout, Approach and Idle are 1.01, 1.013, 1.02, and 1.1 respectively. D-4, Baughcum, S.L., T.G. Tritz, S.C. Henderson, and D.C. Pickett. "Scheduled Civil Aircraft Emission Inventories for 1992: Database Development and Analysis." NASA CR 4700. April 1996.
[2] IATA suggested that there should be a 0.5% improvement on fuel consumption rate up to 10 years. This rate has been applied into the calculation of the fuel flow rate.

Raw Emission Indices

Test Number	Engine Type	CO Raw Emission Index - (Takeoff)	CO Raw Emission Index - (Climbout)	CO Raw Emission Index - (Approach)	CO Raw Emission Index - (Idle)
5	CPAHDA	0.39499	0.38603	1.61368	17.54045

Input to EDMS and extract adjusted emission factor based on hourly climatical condition with cancellation of 0.5% fuel consumption improvement

Test Number	NOx Raw Emission Index - (Takeoff)	NOx Raw Emission Index - (Climbout)	NOx Raw Emission Index - (Approach)	NOx Raw Emission Index - (Idle)
5	34.93978	25.15788	10.99656	4.39993

Input to EDMS and extract adjusted emission factor based on hourly climatical condition

Test Number	HC Raw Emission Index - (Takeoff)	HC Raw Emission Index - (Climbout)	HC Raw Emission Index - (Approach)	HC Raw Emission Index - (Idle)
5	0.01182	0.00796	0.01815	0.97913

Input to EDMS and extract adjusted emission factor based on hourly climatical condition with cancellation of 0.5% fuel consumption improvement

Test Number	Adjusted CO Emission Index (g/kg)				Adjusted NOx Emission Index (g/kg)				Adjusted THC Emission Index (g/kg)			
	Approach (30%)	Idling (7%)	Takeoff (100%)	Climb Out (85%)	Approach (30%)	Idling (7%)	Takeoff (100%)	Climb Out (85%)	Approach (30%)	Idling (7%)	Takeoff (100%)	Climb Out (85%)
5	1.7936	19.4965	0.4341	0.4341	10.0573	4.0241	31.9556	23.0092	0.0202	1.0883	0.0110	0.0110

Test Number	Adjusted TOG Emission Index (g/kg)				Adjusted VOC Emission Index (g/kg)				Adjusted NMHC Emission Index (g/kg)			
	Approach (30%)	Idling (7%)	Takeoff (100%)	Climb Out (85%)	Approach (30%)	Idling (7%)	Takeoff (100%)	Climb Out (85%)	Approach (30%)	Idling (7%)	Takeoff (100%)	Climb Out (85%)
5	0.0233	1.2583	0.0127	0.0127	0.0232	1.2518	0.0126	0.0126	0.0233	1.2583	0.0127	0.0127

Note: According to the conversion factor extracted from EDMS database, the conversion rate from TOG to NMHC is 1.0.
According to the conversion factor extracted from EDMS database, the conversion rate from TOG to VOC is 0.9947855.
According to the conversion factor extracted from EDMS database, the conversion rate from THC to TOG is 1.156234049.
According to the conversion factor extracted from EDMS database, the conversion rate from RSP to FSP is 1.0.

Test Number	Adjusted PM Emission Index (g/kg)				Adjusted SO ₂ Emission Index (g/kg)		with Sulphur Content	0.068%
	Approach (30%)	Idling (7%)	Takeoff (100%)	Climb Out (85%)	Approach (30%)	Idling (7%)	Takeoff (100%)	Climb Out (85%)
5	0.0630	0.0643	0.0685	0.0672	1.3274	1.3274	1.3274	1.3274

Input to EDMS

Takeoff PM EI = (0.062702 - 0.0432)+ (0.72*0.068) = 0.06846

Empirical Equation: PMEI = (REI-0.0432)+(0.72*S%)

Test Number	Engine Model	PM REI from EDMS (g/kg Fuel) [1][2]			
		Approach	Idle	Takeoff	Climb Out
5	PW1127G	0.057246	0.058533	0.062702	0.061481

Notes:
[1] PM REI are weighted average value. See Appendix 5.3.8-3 for details

Mode Ratio of Emission Indices at Different Power Settings

% POWER	MODE	REMARK	Takeoff %	Climbout %	Approach %	Idle %
90%	21	CLIMBOUT+TAKEOFF	33%	67%	0%	0%

Notes: From Appendix 5.3.8-4
For power setting between 85% and 100%, emission is calculated from the weighted average between the two modes at Takeoff and Climbout.
For example, if the power setting is 90%, the weighted average emission E_w is calculated as follows: E_w = E_c x (100-90)/(100-85) + E_t x (90-85)/(100-85), where E_c and E_t are pollutant emissions for Climbout and Takeoff modes respectively taken from EDMS for the respective aircraft and engine type.

Calculation of Emission

Test Number	Start Hour Code	Finish Hour Code	Operator	A/C Type	Engine UID	Number of Engine Tested	Engine Power(%)	Total Testing Time (mins) [1]	Approach									
									Fuel (g)	CO (g)	THC (g)	NMHC (g)	VOC (g)	TOG (g)	NOx (g)	SO ₂ (g)	PM10 (g)	PM2.5 (g) [2]
5	010412	010413	Cathay Pacific	B747	1	1	90%	27	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Emission is 0 as mode ratio is 0.

Total Emission at each TIMs

[1] Emission (kg) = Emission Index (g/kg fuel) * Fuel consumption (kg fuel/s) * Time in Mode (min/mode) * No. of Engines * 60(s/min) / 1000 (g/kg) *Mode Ratio
[2] It is assumed by EDMS that the conversion factor from PM10 to PM2.5 is 1.0

Test Number	Idle										Startup [1]									
	Fuel (g)	CO (g)	THC (g)	NMHC (g)	VOC (g)	TOG (g)	NOx (g)	SO ₂ (g)	PM10 (g)	PM2.5 (g) [2]	Fuel (g)	CO (g)	THC (g)	NMHC (g)	VOC (g)	TOG (g)	NOx (g)	SO ₂ (g)	PM10 (g)	PM2.5 (g) [2]
5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	246.4812	284.9899	283.5039	284.9899	0.0000	0.0000	0.0000	0.0000

Emission is 0 as mode ratio is 0.

STARTING EMISSIONS (grams of THC) = 1 *(0.5* 332.96238 + 80)

Note:
[1] Aircraft main engine startup produces only THC, VOC, NMHC, and TOG emissions.
STARTING EMISSIONS (grams of THC) = Number of Engines *(0.5* Thrust Rating (KiloNewtons) + 80)
The constants "0.5" and the "80" are empirically derived from proprietary engine cycle decks from Rolls Royce, Pratt and Whitney, and General Electric.
This methodology is based on certified jet engines and should therefore only be applied to those aircraft engines. Therefore, EDMS version 5.1 results come with the caveat that "Startup emissions are not included for all aircraft".
Based on the assumptions:
- that all combustion inefficiency has been conservatively attributed alone to HC with no correction for starting CO
- speciation of HC emission will not be performed
- the analysis is based on testing results for typical day engine starting conditions
- engines analyzed are of a current production standard based on modern combustor architecture
- engine start NOx emissions are negligible compared to LTO NOx emissions
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Test Number	Takeoff										Climb Out									
	Fuel (g)	CO (g)	THC (g)	NMHC (g)	VOC (g)	TOG (g)	NOx (g)	SO ₂ (g)	PM10 (g)	PM2.5 (g) [2]	Fuel (g)	CO (g)	THC (g)	NMHC (g)	VOC (g)	TOG (g)	NOx (g)	SO ₂ (g)	PM10 (g)	PM2.5 (g) [2]
5	1360.7344	590.6365	14.9532	17.2893	17.1992	17.2893	43483.0652	1806.1844	93.1588	93.1588	2208.3874	958.5664	24.2680	28.0595	27.9132	28.0595	50813.1209	2931.3251	148.4948	148.4948

Emission (kg) = Emission Index (g/kg fuel) * Fuel consumption (kg fuel/s) * Time in Mode (min/mode) * No. of Engines * 60(s/min) / 1000 (g/kg) *Mode Ratio
Emission (kg) = 0.0109890348339527 * 2.51987848202387 * 27 * 1 * 60 / 1000 * 33% = 14.9532

Test Number	Total									
	Fuel (kg)	CO (kg)	THC (kg)	NMHC (kg)	VOC (kg)	TOG (kg)	NOx (kg)	SO ₂ (kg)	PM10 (kg)	PM2.5 (kg)
5	3569	1.55	0.29	0.33	0.33	0.33	94.30	4.74	0.24	0.24

Total emission