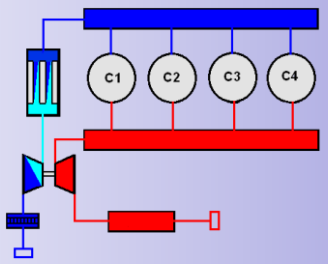

HERON Cycle Simulation Program

H C S

For Turbo Charged Combustion Engines

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Graz, March 2016

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HERON – Cycle Simulation Program H C S

M O T I V A T I O N

Gas dynamic pressure activities during the gas exchange process are negligible for turbo charged engines, especially in compactly designed DIESEL engines. It is therefore possible to calculate the complete thermodynamic process of the entire engine by means of the so-called “filling and emptying method”.

If all the relevant equations and required solving algorithms are successfully implemented into a prevalent data acquisition system, it is possible to quickly and easily solve all thermodynamic questions for a complete cycle period. This allows parameter studies of all important engine dimensions, such as valve size and timing, matching of the turbo charger sizes and cooler layout for TC and TCI engines. The most important engine dimensions can be defined, and predictions about the expected power/torque output and the fuel consumption can be made.

Time and cost intensive modelling of the engine model will thus be unnecessary. As a fast and simple tool, HCS can support the engine designer and development engineer.

NB:
HERON provides engine models which are adapted to the needs of the user (ready to be applied).

HERON – Cycle Simulation Program H C S

S T R A T E G Y

Defining a modular based engine simulation tool, including the arrangement and control of all applied components in the inlet and exhaust, as well as being solved in a common program environment.

The code used for solving the equations was Visual Basic (VB) – the data acquisition platform used was Microsoft EXCEL®.

This decision has several advantages:
Straightforward to use, very little introduction required. Furthermore, it is possible to combine (link) this program with other data sources for comparison (e.g. dyno data) or other EXCEL® based data systems.

In the initial stage, the program was written for simulating and studying various engine parameters with the focus on a simple-to-use input data sheet and a free adaptable post processing tool. In the next stage, the focus is on series calculation of entire full- or part-load curves.
In the long term, a simulation of complete pre-defined cycle periods as required for the prediction of the fuel consumption and emission output is intended.

HCS - MODULES (Status Jan. 10)

- **CYLINDER**

USER-Input:	Bore, stroke, con rod length, compression ratio, piston pin offset
	Area size and individual wall temperatures (liner-, piston- and cylinder surface values)
	Calculation of the heat transfer coefficients according to WOSCHNI, including the swirl number and DI or IDI
	Combustion modelling according to VIBE or measured values from pressure indication
	Fuel injection mass or LAMBDA, lower calorific heating value, calculation of gas properties according to ZACHARIAS
	Valve lift curves for intake and exhaust, flow coefficients (MYSIGMA or ALFA-K)
	Valve size and clearance, port surfaces and individual wall temperatures
Additional feature:	Simple data import for valve lift curves and valve shifting for timing investigations, ".ASCII" data interface

- **VOLUME**

USER-Input:	Volume size, surface area, wall temperature, flow coefficients

- **TURBO CHARGER**

USER-Input:	Turbine size, compressor- and turbine efficiency, compressor pressure ratio
Simulation modus:	A: Boost pressure calculation B: Turbine size layout C: Wastegate simulation

- **INTERCOOLER**

USER-Input:	Volume size, surface area, wall temperature

- **AIR FILTER**

USER-Input:	Pressure loss

- **AMBIENT**

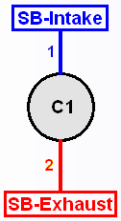
USER-Input:	Pressure and temperature

- **PROGRAM CONTROL**

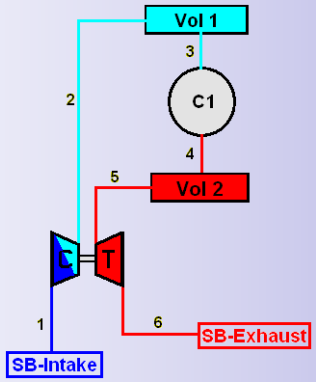
USER-Input:	Engine speed, number of cycles & time step interval -> 2 convergence criteria for error control

HCS - Models (Examples)

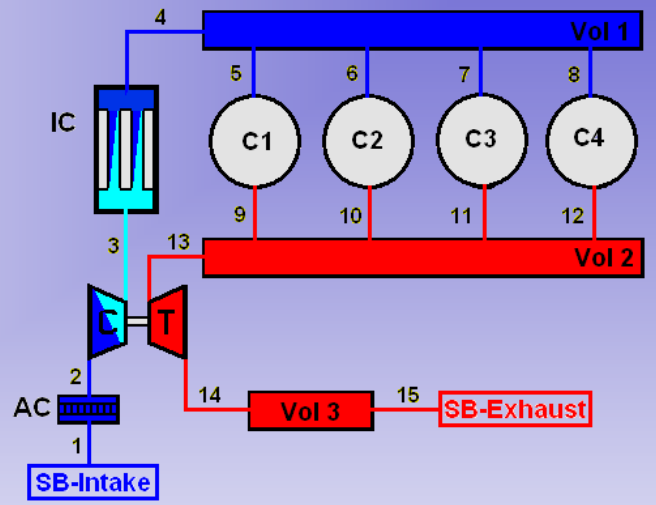
1C NA-Model



1C-TC Model



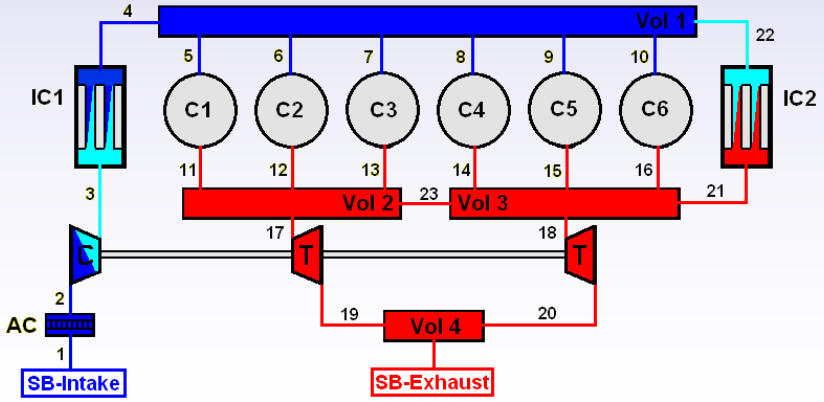
4C-TCI DIESEL Engine Model



HERON delivers the individual engine models -

The costumer only changes the required input data

6C-TCI Diesel Engine with externally cooled EGR



H C S - Input sheet (Example)

Program:	HCS_4C_TCI_v1.15
Created by:	HERON TECHNIK
Project ID:	4C - 5.1L (Example VE)

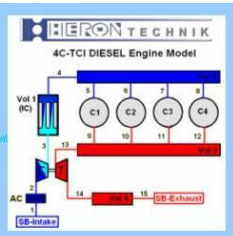
INPUT DATA		
BORE	110	mm
STROKE	135	mm
CONROD LENGTH	221	mm
Crankshaft-Offset	0	mm
COMPRESSION RATIO	17.5	-
Total Displacement	5.132	L

Engine Speed		2200	rpm
Timestep		1	deg
Number of Cycles		12	-
Number of Cylinders		4	

SB1 - INTAKE	Po1	1	bar
Ambient Conditions	To1	25	°C
= Ref. Condition	Pur1	1	-
SB2 - EXHAUST	Po2	1	bar
Ambient Conditions	To2	550	°C
	Pur2	0.1	-

FUEL DATA		
Stoichiometric A/F	14.7	kg/kg
Net Calorific Value	42700	kJ/kg
Friction Loss FMEP	1.65	bar

Fuelling	Mass	125	mg
Combustion		Vibe	Load ROHR
CombStart		-12	deg.CRA
CombDuration		64	deg.CRA
Vibe m		1.9	-
Vibe a		6.9	-



Number of INTAKE Valves	2	-
Dvi - INTAKE	32.70	mm
Intake Valve Clearance	0.4	mm
LIFT_intake.dat	Load INLET Valve	

INTAKE Timings	orig.	shift	new
IVO	355.0	deg	
max. Lift	459.4	0	
IVC	571.3		

Heat Transfer	Woschni	
Head to Bore Area	1.03	-
Piston to Bore Area	1.4	-
Piston to Head Distance	1	mm

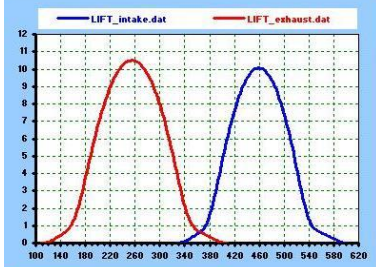
Air Cleaner AC		
Pressure loss	27	mbar

TC-Modus:	Wastegate Flow	
Compr. Eff.	72	%
P2 / P1	2.8	-
Turbine Eff.	71	%
Turbine Size Ø	24	mm
calc. Turbine Size Ø		mm
W.G. Flow Rate	18.8	%

Number of EXHAUST Valves	2	-	
Dvi - EXHAUST	30.70	mm	
Exhaust Valve Clearance	0.5	mm	
LIFT_exhaust.dat	Load EXHAUST Valve		
D:\HCS_Data\Projects\HCS_Examples_imples			

EXHAUST Timings	orig	shift	new
EVO	142.4	deg	
max. Lift	254.4	0	
EVC	372.0		

Head Temperature	291	°C
Piston Temperature	320	°C
Liner Temperature	230	°C
cu/cm	2	-
DI/IDI	DI	



INLET Flow Coeff.	
Lift/Diameter	forward
0	0
0.04	0.084
0.08	0.151
0.12	0.229
0.16	0.324
0.20	0.415
0.24	0.502
0.28	0.575
0.32	0.629
0.36	0.665
0.40	0.690

EXH. Flow Coeff.	
Lift/Diameter	forward
0	0
0.04	0.097
0.08	0.231
0.12	0.399
0.16	0.516
0.20	0.578
0.24	0.615
0.28	0.643
0.32	0.659
0.36	0.673
0.40	0.681

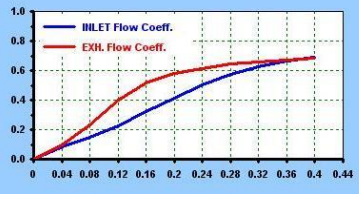
	AREA		TEMP.	
INLET Port	13075	mm²	80	°C
EXHAUST Port	9548	mm²	220	°C

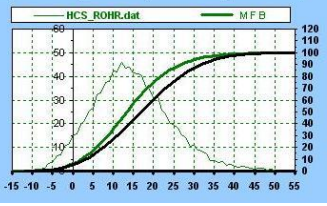
		I C	Vol 2	Vol 3	Vol 4
Volume	L	3	3.5	2	10
Surface	m²	5	0	0	0
Wall Temperature	°C	25	25	680	340
Diameter DIA	mm	40	90	80	100
ALFA IN	-	0.91	0.92	0.93	0.75
ALFA OUT	-	0.915	0.925	0.935	0.75

Program Version :	v1.15		
Licensed for :	HERON_02		
Code :	0851-DAC1	16:47:36	Start
Status :	44	16:48:07	End
Error :	-	31	dT [s]
Expire Date :	30/05/2011	16/04/2011	Date

... User INPUT data

... Calculation RESULTS

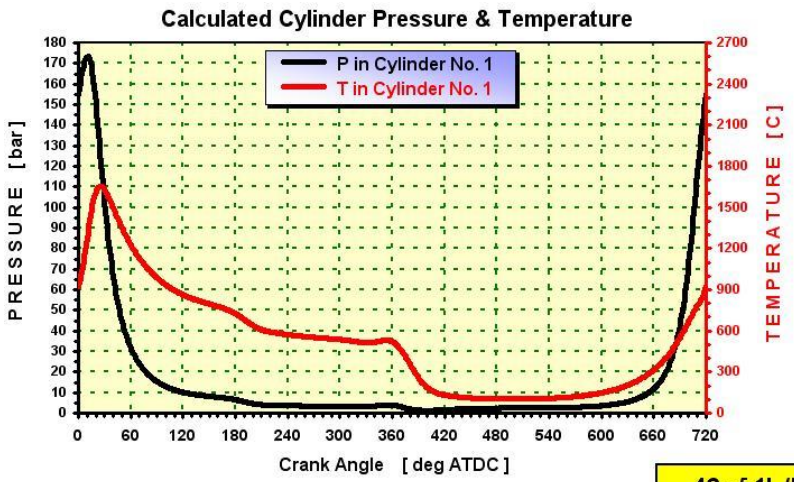


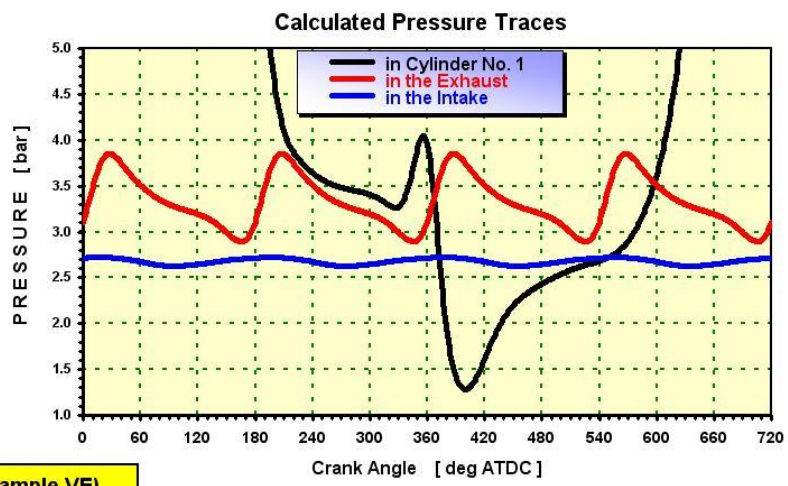


CALCULATION		Save last results	
Summary			DIFF
SPEED	2200 rpm	2200	100.0%
IMEP	18.37 bar	18.78	97.8%
BMEP	16.72 bar	17.13	97.6%
Power	157.3 kW	161.2	97.6%
Torque	683.0 Nm	699.5	97.6%
BSFC	209.7 g/kWh	204.8	102.4%
LAMBDA	1.75 -	1.75	100.1%
Fuelling	125.00 mg	125.00	100.0%
RGC	3.90 %	4.01	97.4%
P F P	163 bar	172	94.5%
PFP Position	7.0 deg	11.0	63.6%
MFB 5%	-0.2 deg	-0.2	80.1%
MFB 50%	17.0 deg	13.9	122.3%
MFB 90%	31.8 deg	27.2	117.1%
PMEP	-1.32 bar	-1.33	99.3%
PMEP Intake	2.25 bar	2.25	99.9%
PMEP Exhaust	-3.57 bar	-3.58	99.7%
ADR_SB1	214.4 %	214.2	100.1%
ADR_Vol2	85.4 %	85.4	100.1%
ETA_vol	82.1 %	81.9	100.2%
Air mass flow	850 kg/h	849	100.1%
Fuel mass flow	33.0 kg/h	33.0	100.0%
Exhaust flow	883 kg/h	882	100.1%
Piston Heat Flow	5.68 kW	6.07	93.5%
Head Heat Flow	4.43 kW	4.73	93.8%
Liner Heat Flow	4.64 kW	4.50	103.2%
P_Vol 2	2.680 bar	2.680	100.0%
T_Vol 2	45 °C	45	99.9%
P_Vol 3	3.333 bar	3.346	99.6%
T_Vol 3	624 °C	607	102.8%
P_Vol 4	1.150 bar	1.146	100.3%
W.G. Flow Rate	18.8 %	17.6	106.9%
M-Balance error	0.0 %	0.0	-58.9%
TC-Balance error	0.1 %	0.1	107.1%

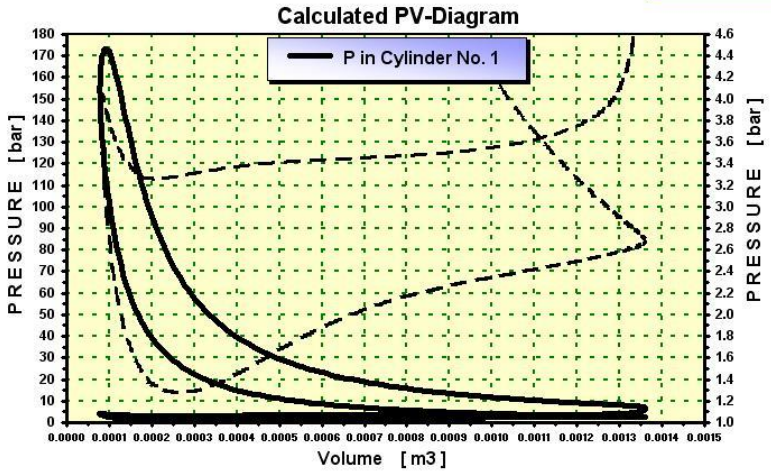
Input sheet (Example)

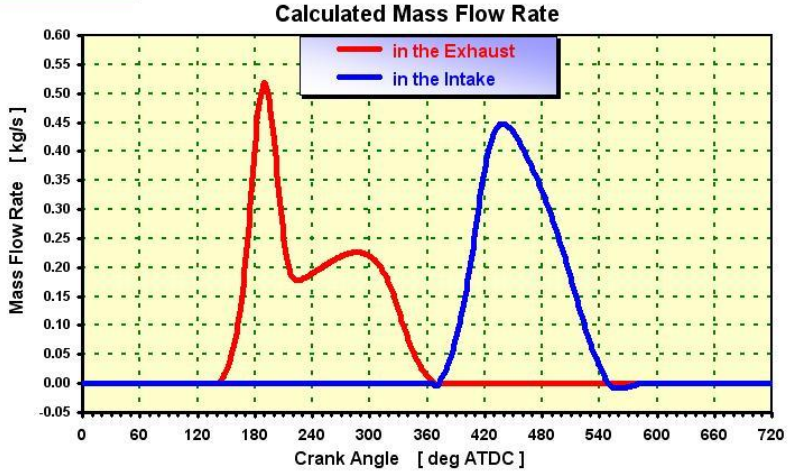
HCS - Output sheet (Example)



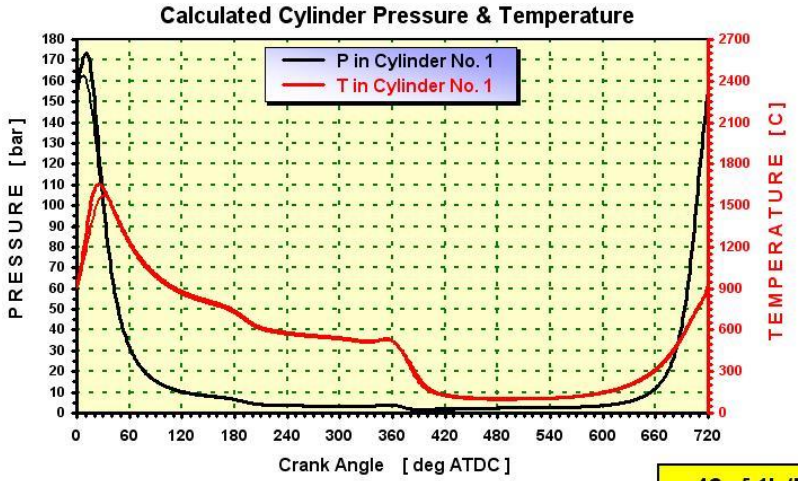


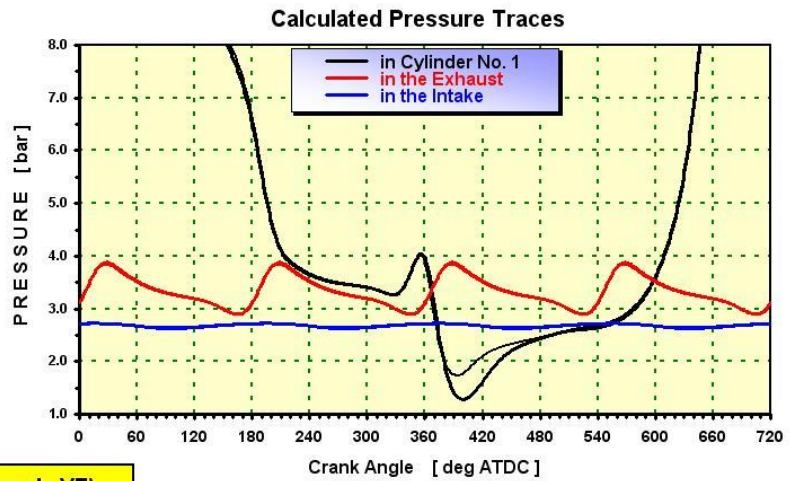
4C - 5.1L (Example VE)



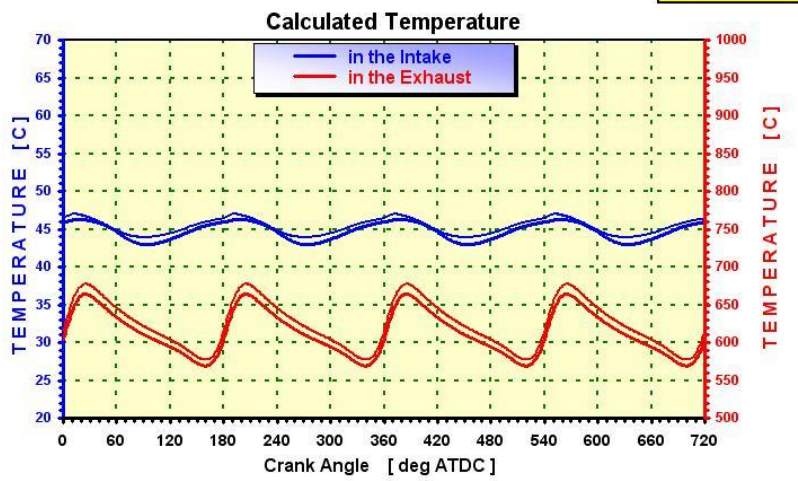


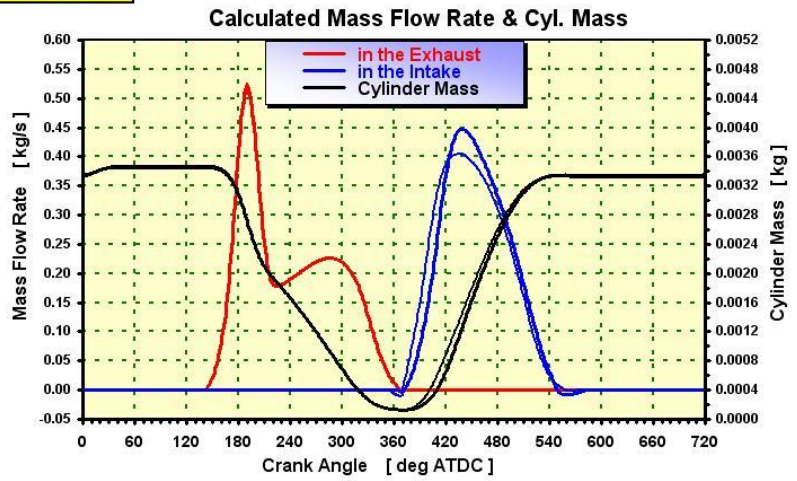
HCS - Output sheet (Example)





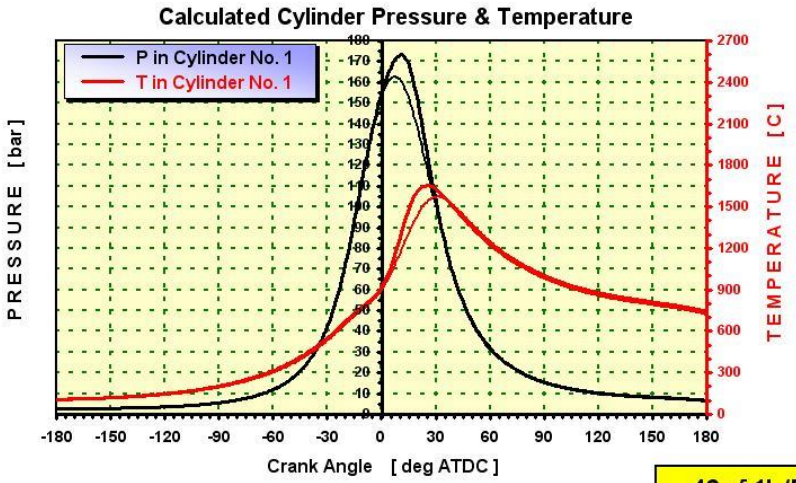
4C - 5.1L (Example VE)

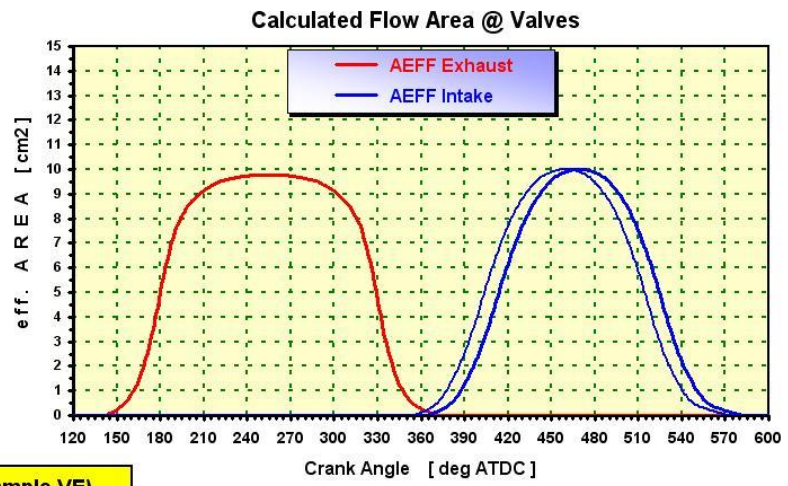




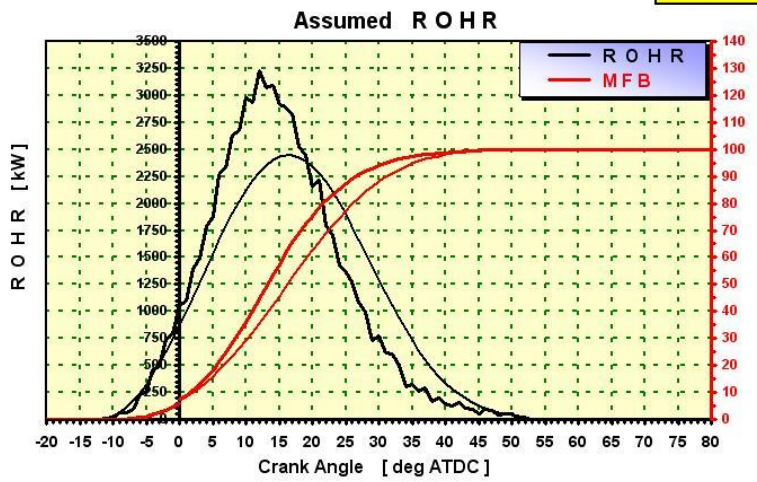
Modified input:
Intake cam 10 Deg retarded
and ROHR instead of VIBE combustion

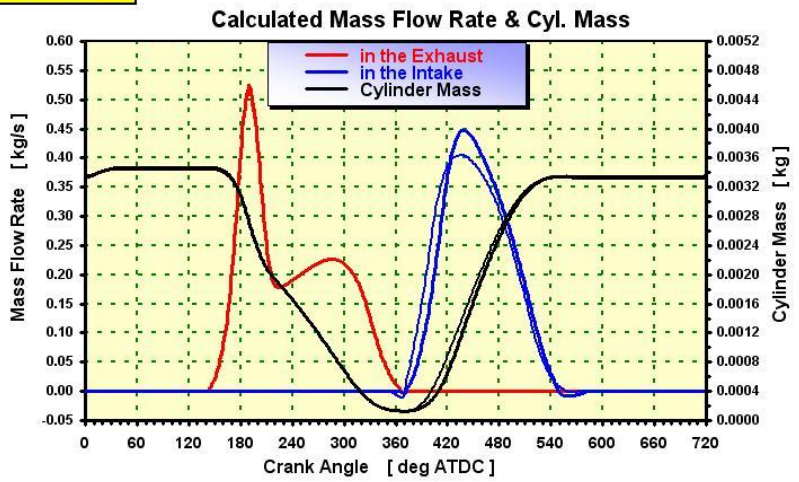
HCS - Output sheet (Example)





4C - 5.1L (Example VE)





Modified input:
Intake cam 10 Deg retarded
and ROHR instead of VIBE combustion

H C S - Results (Example)

All crank angle based simulation results from the last cycle are available for further processing

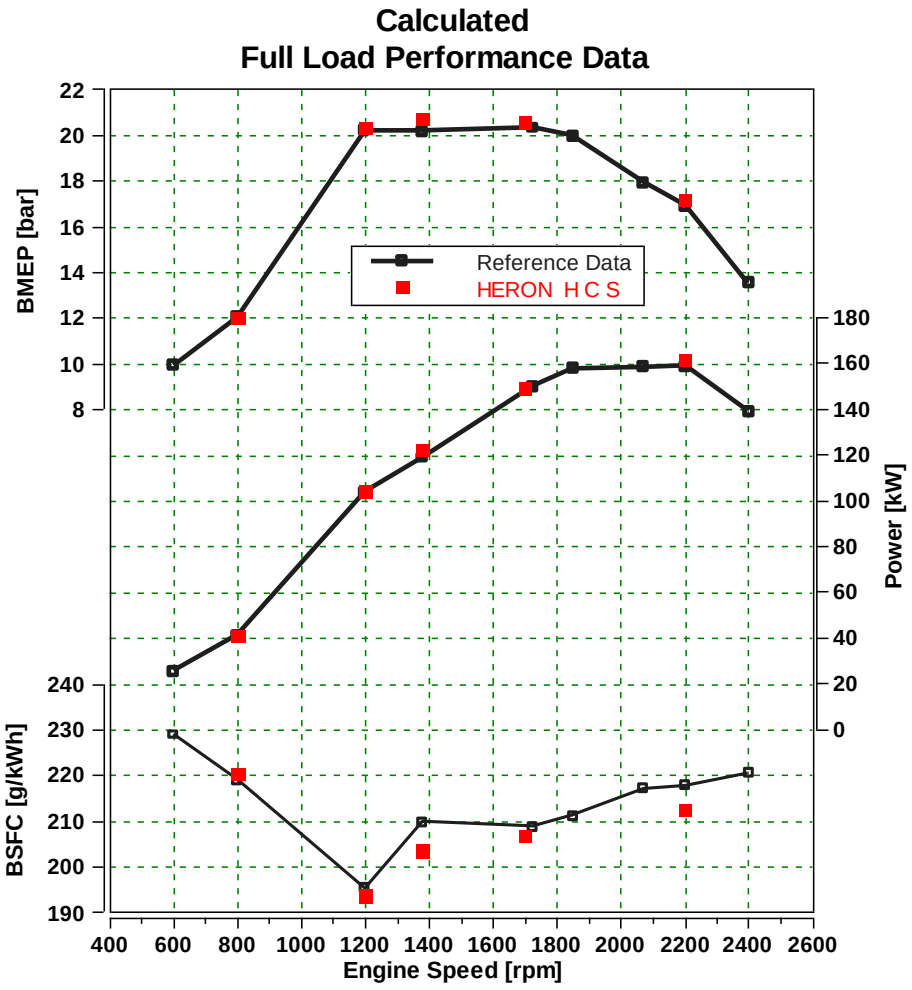
	A	B	C	D	E	F	G	H	I	J
1										
2										
3										
4										
5										
6										
7										
8										
9										
10			**Volume 1**							
11	Crank Angl	CRA - Cycl	Pressure	Temperatur	Air Purity	Mass	Volume	Indicated Pc	Heat Transf	Heat Flow
12	degree	degree	bar	°C	%	kg	m³	kW	W/m²/K	kW
13	0	-720	2.7234445	43.669304	99.999999	0.0089868	0.003	0	45.718583	4.2676706
14	1	-719	2.7235893	43.664203	99.999999	0.0089874	0.003	0	39.388433	3.6757686
15	2	-718	2.7237274	43.660013	99.999999	0.008988	0.003	0	33.31375	3.108175
16	3	-717	2.7238499	43.656316	99.999999	0.0089885	0.003	0	28.201723	2.6307013
17	4	-716	2.7239285	43.651436	99.999999	0.0089889	0.003	0	25.946485	2.4196961
18	5	-715	2.7239423	43.643695	99.999999	0.0089891	0.003	0	26.719104	2.4907141
19	6	-714	2.7239042	43.633085	99.999999	0.0089893	0.003	0	29.749405	2.7716159
20	7	-713	2.7238219	43.619541	99.999999	0.0089894	0.003	0	34.412271	3.2037035
21	8	-712	2.7237135	43.603741	99.999999	0.0089895	0.003	0	39.900896	3.7115297
22	9	-711	2.7235836	43.585833	99.999999	0.0089896	0.003	0	46.15754	4.2893818
23	10	-710	2.723433	43.565852	99.999999	0.0089897	0.003	0	53.112673	4.93041
24	11	-709	2.723262	43.543824	99.999999	0.0089897	0.003	0	60.740824	5.6318359
25	12	-708	2.7230714	43.519836	99.999999	0.0089898	0.003	0	68.951107	6.3848159
26	13	-707	2.722863	43.49406	99.999999	0.0089898	0.003	0	77.637427	7.1791561
27	14	-706	2.7226384	43.466687	99.999999	0.0089899	0.003	0	86.735925	8.0086261
28	15	-705	2.722398	43.437848	99.999999	0.0089899	0.003	0	96.254075	8.8735901
29	16	-704	2.7221423	43.407704	99.999999	0.0089899	0.003	0	106.14289	9.7692345
30	17	-703	2.7218713	43.376403	99.999999	0.0089899	0.003	0	116.40692	10.695703
31	18	-702	2.721586	43.34414	99.999999	0.0089899	0.003	0	126.9821	11.646887
32	19	-701	2.721287	43.311108	99.999999	0.0089899	0.003	0	137.86154	12.621988
33	20	-700	2.7209746	43.277481	99.999999	0.0089898	0.003	0	149.05735	13.621964
34	21	-699	2.720645	43.243251	99.999999	0.0089897	0.003	0	160.74802	14.662832
35	22	-698	2.7202953	43.208462	99.999999	0.0089895	0.003	0	173.05644	15.755458
36	23	-697	2.7199257	43.173324	99.999999	0.0089893	0.003	0	185.62437	16.867059
37	24	-696	2.7195434	43.138366	99.999999	0.008989	0.003	0	198.41652	17.994758
38	25	-695	2.7191522	43.103943	99.999999	0.0089887	0.003	0	211.25431	19.12268
39	26	-694	2.7187569	43.070452	99.999999	0.0089884	0.003	0	223.9852	20.237569
40	27	-693	2.7183621	43.038245	99.999999	0.008988	0.003	0	236.49083	21.329397
41	28	-692	2.7179711	43.007603	99.999999	0.0089876	0.003	0	248.689	22.391464
42	29	-691	2.717587	42.978759	99.999999	0.0089871	0.003	0	260.51017	23.418248
43	30	-690	2.7172118	42.951874	99.999999	0.0089867	0.003	0	271.92475	24.407794
44	31	-689	2.7168468	42.927063	99.999999	0.0089862	0.003	0	282.90669	25.35843
45	32	-688	2.7164929	42.904389	99.999999	0.0089856	0.003	0	293.45879	26.271002
46	33	-687	2.7161504	42.883889	99.999999	0.0089851	0.003	0	303.57845	27.145816
47	34	-686	2.7158195	42.86556	99.999999	0.0089845	0.003	0	313.28511	27.985069
48	35	-685	2.7155001	42.84939	99.999999	0.0089839	0.003	0	322.58579	28.789798
49	36	-684	2.7151919	42.835345	99.999999	0.0089833	0.003	0	331.49475	29.561616
50	37	-683	2.7148961	42.823446	99.999999	0.0089827	0.003	0	339.96686	30.296904
51	38	-682	2.7146513	42.815292	99.999999	0.0089821	0.003	0	345.89547	30.811143
52	39	-681	2.7144624	42.810747	99.999999	0.0089816	0.003	0	350.91328	31.250139
53	40	-680	2.7142905	42.807899	99.999999	0.0089811	0.003	0	355.74656	31.675494
54	41	-679	2.7141236	42.806156	99.999999	0.0089806	0.003	0	360.51678	32.09709
55	42	-678	2.7139581	42.805342	99.999999	0.0089801	0.003	0	365.25952	32.517854
56	43	-677	2.7137931	42.805417	99.999999	0.0089795	0.003	0	369.97223	32.937549
57	44	-676	2.7136287	42.806372	99.999999	0.008979	0.003	0	374.64878	33.355678
58	45	-675	2.7134657	42.808236	99.999999	0.0089784	0.003	0	379.25563	33.769369
59	46	-674	2.7133047	42.811021	99.999999	0.0089777	0.003	0	383.77854	34.177438
60	47	-673	2.7131475	42.814782	99.999999	0.0089771	0.003	0	388.15018	34.574054
61	48	-672	2.7129948	42.819524	99.999999	0.0089765	0.003	0	392.38063	34.96018
62	49	-671	2.7128464	42.825193	99.999999	0.0089758	0.003	0	396.48695	35.337282
63	50	-670	2.7127016	42.831732	99.999999	0.0089752	0.003	0	400.48926	35.707087
64	51	-669	2.7125599	42.839093	99.999999	0.0089745	0.003	0	404.39657	36.070341
65	52	-668	2.7124209	42.847234	99.999999	0.0089738	0.003	0	408.22022	36.428008
66	53	-667	2.7122846	42.856121	99.999999	0.0089731	0.003	0	411.96202	36.780218
67	54	-666	2.7121506	42.865725	99.999999	0.0089724	0.003	0	415.62781	37.12746
68	55	-665	2.7120191	42.876021	99.999999	0.0089716	0.003	0	419.21548	37.469523
69	56	-664	2.7118901	42.886988	99.999999	0.0089709	0.003	0	422.71667	37.80564
70	57	-663	2.7117651	42.898666	99.999999	0.0089701	0.003	0	426.07096	38.130508
71	58	-662	2.711645	42.911054	99.999999	0.0089694	0.003	0	429.27984	38.444272
72	59	-661	2.7115299	42.924113	99.999999	0.0089686	0.003	0	432.34529	38.74703
73	60	-660	2.7114193	42.937791	99.999999	0.0089679	0.003	0	435.28312	39.040088
74	61	-659	2.7113129	42.95203	100	0.0089671	0.003	0	438.10538	39.324405
75	62	-658	2.7112102	42.966779	100	0.0089664	0.003	0	440.8245	39.600982
76	63	-657	2.7111109	42.981995	100	0.0089656	0.003	0	443.44659	39.870272
77	64	-656	2.7110149	42.997637	100	0.0089648	0.003	0	445.9789	40.132832
78	65	-655	2.7109219	43.013674	100	0.0089641	0.003	0	448.42345	40.388769
79	66	-654	2.7108318	43.030073	100	0.0089633	0.003	0	450.78438	40.638378
80	67	-653	2.7107447	43.04681	100	0.0089625	0.003	0	453.06144	40.881568
81	68	-652	2.7106604	43.063856	100	0.0089618	0.003	0	455.25706	41.118489
82	69	-651	2.710579	43.081189	100	0.008961	0.003	0	457.36977	41.348945
83	70	-650	2.7105004	43.098784	100	0.0089603	0.003	0	459.4011	41.573006
84	71	-649	2.7104248	43.11662	100	0.0089595	0.003	0	461.34901	41.790423
85	72	-648	2.7103521	43.134676	100	0.0089587	0.003	0	463.2106	42.000869
86	73	-647	2.710283	43.152952	100	0.008958	0.003	0	464.96304	42.202258
87	74	-646	2.7102178	43.171437	100	0.0089572	0.003	0	466.60571	42.39448
88	75	-645	2.7101565	43.190104	100	0.0089565	0.003	0	468.13805	42.577398
89	76	-644	2.7100992	43.208921	100	0.0089558	0.003	0	469.56562	42.751417
90	77	-643	2.7100455	43.227855	100	0.0089551	0.003	0	470.89319	42.916864

	K	L	M	N	O	P	Q	R
10	**Volume 2**							
11	Pressure	Temperatur	Air Purity	Mass	Volume	Indicated Pc	Heat Transf	Heat Flow
12	bar	°C	%	kg	m³	kW	W/m²/K	kW
13	2.7217437	46.297193	99.878267	0.0103913	0.0035	0	0	0
14	2.722226	46.336556	99.875231	0.0103918	0.0035	0	0	0
15	2.722663	46.374634	99.87216	0.0103923	0.0035	0	0	0
16	2.7229964	46.406173	99.869484	0.0103925	0.0035	0	0	0
17	2.7230931	46.418392	99.868295	0.0103925	0.0035	0	0	0
18	2.7229893	46.415222	99.868241	0.0103922	0.0035	0	0	0
19	2.7227381	46.406612	99.86825	0.0103915	0.0035	0	0	0
20	2.7223772	46.394277	99.868262	0.0103905	0.0035	0	0	0
21	2.7219502	46.37967	99.868276	0.0103894	0.0035	0	0	0
22	2.7214485	46.362494	99.868293	0.010388	0.0035	0	0	0
23	2.720872	46.342732	99.868313	0.0103865	0.0035	0	0	0
24	2.7202177	46.320276	99.868338	0.0103847	0.0035	0	0	0
25	2.7194911	46.295297	99.868367	0.0103827	0.0035	0	0	0
26	2.7186993	46.268021	99.868401	0.0103806	0.0035	0	0	0
27	2.7178455	46.238547	99.868441	0.0103783	0.0035	0	0	0
28	2.7169265	46.20676	99.868486	0.0103758	0.0035	0	0	0
29	2.7159466	46.172792	99.868537	0.0103732	0.0035	0	0	0
30	2.7149036	46.136558	99.868595	0.0103704	0.0035	0	0	0
31	2.7138043	46.098279	99.86866	0.0103674	0.0035	0	0	0
32	2.7126477	46.057913	99.868732	0.0103643	0.0035	0	0	0
33	2.7114307	46.015351	99.868812	0.0103611	0.0035	0	0	0
34	2.7101302	45.969816	99.868899	0.0103576	0.0035	0	0	0
35	2.7087285	45.918461	99.868996	0.0103539	0.0035	0	0	0
36	2.7072817	45.867604	99.869102	0.01035	0.0035	0	0	0
37	2.7057829	45.814791	99.869218	0.010346	0.0035	0	0	0
38	2.7042564	45.760843	99.869344	0.0103419	0.0035	0	0	0
39	2.7027219	45.706418	99.869479	0.0103379	0.0035	0	0	0
40	2.701195	45.652046	99.869625	0.0103338	0.0035	0	0	0
41	2.6996871	45.598126	99.86978	0.0103298	0.0035	0	0	0
42	2.6982091	45.545025	99.869945	0.0103258	0.0035	0	0	0
43	2.6967662	45.492933	99.870119	0.010322	0.0035	0	0	0
44	2.6953637	45.442044	99.870302	0.0103183	0.0035	0	0	0
45	2.6940031	45.392409	99.870494	0.0103147	0.0035	0	0	0
46	2.6926865	45.34412	99.870694	0.0103112	0.0035	0	0	0
47	2.6914127	45.297147	99.870903	0.0103079	0.0035	0	0	0
48	2.6901827	45.25153	99.871119	0.0103047	0.0035	0	0	0
49	2.6889961	45.207275	99.871342	0.0103015	0.0035	0	0	0
50	2.6878615	45.164678	99.871573	0.0102986	0.0035	0	0	0
51	2.6867361	45.122332	99.871809	0.0102956	0.0035	0	0	0
52	2.6855757	45.078783	99.872049	0.0102926	0.0035	0	0	0
53	2.6843858	45.034225	99.872293	0.0102895	0.0035	0	0	0
54	2.6831731	44.988892	99.87254	0.0102863	0.0035	0	0	0
55	2.6819399	44.942865	99.872791	0.0102831	0.0035	0	0	0
56	2.6806912	44.89632	99.873046	0.0102798	0.0035	0	0	0
57	2.6794303	44.849372	99.873305	0.0102765	0.0035	0	0	0
58	2.6781689	44.80242	99.873567	0.0102732	0.0035	0	0	0
59	2.6769113	44.755626	99.873833	0.0102699	0.0035	0	0	0
60	2.6756817	44.709806	99.874103	0.0102667	0.0035	0	0	0
61	2.674473	44.664731	99.874375	0.0102635	0.0035	0	0	0
62	2.673281	44.620263	99.874651	0.0102603	0.0035	0	0	0
63	2.6721008	44.576242	99.87493	0.0102572	0.0035	0	0	0
64	2.6709317	44.532648	99.875212	0.0102542	0.0035	0	0	0
65	2.6697712	44.489402	99.875497	0.0102511	0.0035	0	0	0
66	2.6686204	44.446549	99.875784	0.0102481	0.0035	0	0	0
67	2.6674783	44.404055	99.876074	0.0102451	0.0035	0	0	0
68	2.666347	44.361997	99.876367	0.0102421	0.0035	0	0	0
69	2.6652318	44.320559	99.876662	0.0102391	0.0035	0	0	0
70	2.6641577	44.2806	99.87696	0.0102363	0.0035	0	0	0
71	2.6631204	44.241973	99.877259	0.0102336	0.0035	0	0	0
72	2.6621203	44.204695	99.877561	0.0102309	0.0035	0	0	0
73	2.661152	44.168584	99.877865	0.0102284	0.0035	0	0	0
74	2.6602127	44.133551	99.878171	0.0102259	0.0035	0	0	0
75	2.6592991	44.099487	99.878478	0.0102235	0.0035	0	0	0
76	2.6584108	44.066374	99.878787	0.0102212	0.0035	0	0	0
77	2.6575459	44.034154	99.879098	0.0102189	0.0035	0	0	0
78	2.6567049	44.002846	99.879409	0.0102167	0.0035	0	0	0
79	2.655887	43.972422	99.879723	0.0102145	0.0035	0	0	0
80	2.6550933	43.942924	99.880037	0.0102124	0.0035	0	0	0
81	2.6543234	43.914336	99.880353	0.0102104	0.0035	0	0	0
82	2.6535788	43.88671	99.880669	0.0102084	0.0035	0	0	0
83	2.6528592	43.860041	99.880987	0.0102065	0.0035	0	0	0
84	2.6521664	43.834385	99.881305	0.0102046	0.0035	0	0	0
85	2.6515024	43.809815	99.881625	0.0102029	0.0035	0	0	0
86	2.6508784	43.786709	99.881945	0.0102012	0.0035	0	0	0
87	2.6502928	43.765014	99.882265	0.0101997	0.0035	0	0	0
88	2.6497463	43.744752	99.882586	0.0101982	0.0035	0	0	0
89	2.6492366	43.725842	99.882908	0.0101969	0.0035	0	0	0
90	2.6487624	43.708237	99.883229	0.0101956	0.0035	0	0	0

	S	T	U	V	W	X	Y	Z
10	**Volume 3**							
11	Pressure	Temperatur	Air Purity	Mass	Volume	Indicated Pc	Heat Transf	Heat Flow
12	bar	°C	%	kg	m³	kW	W/m²/K	kW
13	2.8016387	599.46066	39.983174	0.0022313	0.002	0	0	0
14	2.8172616	602.48253	39.983237	0.002236	0.002	0	0	0
15	2.8359777	605.82529	39.983304	0.0022422	0.002	0	0	0
16	2.8577521	609.4658	39.983376	0.0022501	0.002	0	0	0
17	2.8826699	613.39335	39.983451	0.0022597	0.002	0	0	0
18	2.9106666	617.57827	39.98353	0.0022709	0.002	0	0	0
19	2.9417063	621.99509	39.983612	0.0022837	0.002	0	0	0
20	2.9756585	626.60715	39.983697	0.0022982	0.002	0	0	0
21	3.012413	631.3814	39.983785	0.0023143	0.002	0	0	0
22	3.0518029	636.27872	39.983875	0.0023319	0.002	0	0	0
23	3.0936684	641.26257	39.983967	0.002351	0.002	0	0	0
24	3.1378232	646.29476	39.984061	0.0023715	0.002	0	0	0
25	3.1840735	651.33882	39.984155	0.0023932	0.002	0	0	0
26	3.2319692	656.33696	39.98425	0.0024161	0.002	0	0	0
27	3.2801861	661.1607	39.984344	0.0024395	0.002	0	0	0
28	3.328473	665.78835	39.984437	0.0024631	0.002	0	0	0
29	3.3764265	670.18894	39.984527	0.0024869	0.002	0	0	0
30	3.42385	674.35245	39.984616	0.0025107	0.002	0	0	0
31	3.4705405	678.27041	39.984702	0.0025345	0.002	0	0	0
32	3.5163021	681.93678	39.984786	0.002558	0.002	0	0	0
33	3.56092	685.34591	39.984867	0.0025812	0.002	0	0	0
34	3.6040917	688.48785	39.984946	0.0026039	0.002	0	0	0
35	3.6451703	691.33215	39.985022	0.0026258	0.002	0	0	0
36	3.6839466	693.88173	39.985094	0.0026467	0.002	0	0	0
37	3.7201084	696.13384	39.985163	0.0026664	0.002	0	0	0
38	3.7535469	698.09901	39.985228	0.0026849	0.002	0	0	0
39	3.7841747	699.78873	39.985291	0.0027021	0.002	0	0	0
40	3.8119276	701.21527	39.98535	0.0027179	0.002	0	0	0
41	3.8367493	702.39066	39.985406	0.0027323	0.002	0	0	0
42	3.8585927	703.32667	39.985459	0.0027452	0.002	0	0	0
43	3.8773698	704.03213	39.985508	0.0027565	0.002	0	0	0
44	3.8930929	704.52044	39.985555	0.0027663	0.002	0	0	0
45	3.9057599	704.80317	39.985599	0.0027745	0.002	0	0	0
46	3.9154607	704.89544	39.98564	0.0027811	0.002	0	0	0
47	3.9223099	704.81222	39.985679	0.0027862	0.002	0	0	0
48	3.9264491	704.56848	39.985715	0.0027898	0.002	0	0	0
49	3.9280386	704.17883	39.985748	0.0027921	0.002	0	0	0
50	3.9272634	703.65783	39.98578	0.002793	0.002	0	0	0
51	3.9243232	703.01966	39.98581	0.0027928	0.002	0	0	0
52	3.9194288	702.27805	39.985838	0.0027914	0.002	0	0	0
53	3.9127771	701.44521	39.985864	0.002789	0.002	0	0	0
54	3.9046055	700.53453	39.985889	0.0027858	0.002	0	0	0
55	3.8951381	699.55821	39.985913	0.0027819	0.002	0	0	0
56	3.8846069	698.5283	39.985935	0.0027773	0.002	0	0	0
57	3.8732261	697.45566	39.985957	0.0027722	0.002	0	0	0
58	3.8611896	696.34996	39.985979	0.0027668	0.002	0	0	0
59	3.8486658	695.21949	39.985999	0.002761	0.002	0	0	0
60	3.8357999	694.07136	39.98602	0.0027551	0.002	0	0	0
61	3.8227121	692.91142	39.98604	0.002749	0.002	0	0	0
62	3.8095024	691.74454	39.986059	0.0027428	0.002	0	0	0
63	3.7962502	690.57462	39.986079	0.0027366	0.002	0	0	0
64	3.7830197	689.4048	39.986098	0.0027304	0.002	0	0	0
65	3.7698595	688.23751	39.986118	0.0027242	0.002	0	0	0
66	3.7568093	687.07473	39.986137	0.0027181	0.002	0	0	0
67	3.7438978	685.91794	39.986156	0.002712	0.002	0	0	0
68	3.7311489	684.76837	39.986175	0.002706	0.002	0	0	0
69	3.7185792	683.62692	39.986194	0.0027002	0.002	0	0	0
70	3.7062025	682.49434	39.986213	0.0026944	0.002	0	0	0
71	3.6940274	681.37116	39.986233	0.0026887	0.002	0	0	0
72	3.6820612	680.2578	39.986252	0.0026831	0.002	0	0	0
73	3.6703078	679.15455	39.986271	0.0026777	0.002	0	0	0
74	3.6587708	678.06168	39.98629	0.0026723	0.002	0	0	0
75	3.647451	676.9793	39.986309	0.0026671	0.002	0	0	0
76	3.6363498	675.90758	39.986328	0.002662	0.002	0	0	0
77	3.6254663	674.84655	39.986348	0.002657	0.002	0	0	0
78	3.6148005	673.79629	39.986367	0.0026521	0.002	0	0	0
79	3.6043503	672.75678	39.986386	0.0026474	0.002	0	0	0
80	3.594115	671.72806	39.986405	0.0026428	0.002	0	0	0
81	3.5840919	670.71007	39.986424	0.0026382	0.002	0	0	0
82	3.5742795	669.70281	39.986444	0.0026338	0.002	0	0	0
83	3.5646748	668.70621	39.986463	0.0026295	0.002	0	0	0
84	3.555276	667.72024	39.986482	0.0026254	0.002	0	0	0
85	3.5460798	666.7448	39.986502	0.0026213	0.002	0	0	0
86	3.5370827	665.77979	39.986521	0.0026173	0.002	0	0	0
87	3.5282764	664.82485	39.98654	0.0026135	0.002	0	0	0
88	3.5196593	663.87997	39.986559	0.0026097	0.002	0	0	0
89	3.5112281	662.94506	39.986578	0.0026061	0.002	0	0	0
90	3.5029816	662.02009	39.986598	0.0026026	0.002	0	0	0

	AA	AB	AC	AD	AE	AF	AG	AH	AI
10	**Volume 4**								**Cylinder 1**
11	Pressure	Temperatur	Air Purity	Mass	Volume	Indicated Pc	Heat Transf	Heat Flow	Pressure
12	bar	°C	%	kg	m³	kW	W/m²/K	kW	bar
13	1.1244367	490.8569	39.974873	0.0051174	0.01	0	0	0	147.78661
14	1.1240073	490.73905	39.9749	0.0051162	0.01	0	0	0	149.62413
15	1.1236191	490.63478	39.974926	0.0051151	0.01	0	0	0	151.1513
16	1.1232763	490.54531	39.974954	0.0051142	0.01	0	0	0	152.36911
17	1.1229833	490.4718	39.974981	0.0051133	0.01	0	0	0	153.28106
18	1.1227442	490.41537	39.975009	0.0051126	0.01	0	0	0	153.89265
19	1.1225629	490.37708	39.975037	0.005112	0.01	0	0	0	154.21085
20	1.1224433	490.35789	39.975065	0.0051116	0.01	0	0	0	154.24363
21	1.1223886	490.35864	39.975094	0.0051114	0.01	0	0	0	153.99959
22	1.1224019	490.38009	39.975124	0.0051113	0.01	0	0	0	153.48768
23	1.1224859	490.42283	39.975154	0.0051114	0.01	0	0	0	152.71705
24	1.1226429	490.48735	39.975184	0.0051117	0.01	0	0	0	151.69696
25	1.1228748	490.574	39.975216	0.0051121	0.01	0	0	0	150.43686
26	1.1231829	490.68294	39.975247	0.0051128	0.01	0	0	0	148.94642
27	1.1235669	490.81387	39.97528	0.0051137	0.01	0	0	0	147.23564
28	1.1240252	490.96612	39.975313	0.0051148	0.01	0	0	0	145.31502
29	1.1245556	491.13886	39.975346	0.005116	0.01	0	0	0	143.19562
30	1.1251556	491.33115	39.97538	0.0051175	0.01	0	0	0	140.88917
31	1.1258223	491.54195	39.975415	0.0051191	0.01	0	0	0	138.40816
32	1.1265527	491.77018	39.97545	0.0051209	0.01	0	0	0	135.76484
33	1.1273432	492.01466	39.975486	0.0051228	0.01	0	0	0	132.97542
34	1.1281904	492.27417	39.975523	0.0051249	0.01	0	0	0	130.05327
35	1.1290898	492.54729	39.97556	0.0051272	0.01	0	0	0	127.01372
36	1.1300364	492.83248	39.975597	0.0051296	0.01	0	0	0	123.87254
37	1.1310251	493.12818	39.975635	0.0051321	0.01	0	0	0	120.6459
38	1.1320502	493.43277	39.975673	0.0051347	0.01	0	0	0	117.35011
39	1.1331066	493.74469	39.975712	0.0051374	0.01	0	0	0	114.00149
40	1.1341886	494.06241	39.975751	0.0051402	0.01	0	0	0	110.61618
41	1.1352909	494.38442	39.97579	0.005143	0.01	0	0	0	107.20995
42	1.1364084	494.7093	39.975829	0.0051459	0.01	0	0	0	103.79803
43	1.1375356	495.03564	39.975869	0.0051488	0.01	0	0	0	100.39494
44	1.1386675	495.36209	39.975909	0.0051517	0.01	0	0	0	97.014384
45	1.1397989	495.68737	39.975949	0.0051547	0.01	0	0	0	93.668343
46	1.1409251	496.01028	39.975989	0.0051576	0.01	0	0	0	90.370351
47	1.1420415	496.3297	39.976029	0.0051605	0.01	0	0	0	87.129714
48	1.1431438	496.64463	39.97607	0.0051633	0.01	0	0	0	83.95586
49	1.1442282	496.95415	39.97611	0.0051662	0.01	0	0	0	80.857082
50	1.1452911	497.25744	39.97615	0.0051689	0.01	0	0	0	77.840393
51	1.1463293	497.55381	39.97619	0.0051716	0.01	0	0	0	74.911645
52	1.1473402	497.84264	39.97623	0.0051742	0.01	0	0	0	72.075535
53	1.1483213	498.12342	39.97627	0.0051768	0.01	0	0	0	69.335651
54	1.1492706	498.39574	39.97631	0.0051792	0.01	0	0	0	66.694536
55	1.1501865	498.65926	39.976349	0.0051816	0.01	0	0	0	64.153758
56	1.151068	498.91375	39.976389	0.0051838	0.01	0	0	0	61.713989
57	1.151914	499.15905	39.976428	0.005186	0.01	0	0	0	59.375088
58	1.1527242	499.39509	39.976467	0.0051881	0.01	0	0	0	57.136195
59	1.1534983	499.62184	39.976506	0.00519	0.01	0	0	0	54.995818
60	1.1542364	499.83933	39.976545	0.0051919	0.01	0	0	0	52.951928
61	1.1549388	500.04764	39.976583	0.0051936	0.01	0	0	0	51.002044
62	1.1556058	500.24688	39.976621	0.0051953	0.01	0	0	0	49.143321
63	1.1562381	500.43718	39.97666	0.0051969	0.01	0	0	0	47.372633
64	1.1568361	500.6187	39.976698	0.0051983	0.01	0	0	0	45.686644
65	1.1574008	500.7916	39.976735	0.0051997	0.01	0	0	0	44.081878
66	1.1579328	500.95607	39.976773	0.005201	0.01	0	0	0	42.554776
67	1.1584329	501.11229	39.97681	0.0052022	0.01	0	0	0	41.102153
68	1.158902	501.26045	39.976847	0.0052033	0.01	0	0	0	39.719721
69	1.159341	501.40073	39.976884	0.0052043	0.01	0	0	0	38.397292
70	1.1597506	501.53334	39.976921	0.0052053	0.01	0	0	0	37.140583
71	1.1601318	501.65846	39.976958	0.0052061	0.01	0	0	0	35.945688
72	1.1604853	501.77629	39.976994	0.0052069	0.01	0	0	0	34.808961
73	1.1608121	501.887	39.97703	0.0052076	0.01	0	0	0	33.727004
74	1.161113	501.99079	39.977067	0.0052083	0.01	0	0	0	32.696643
75	1.1613887	502.08783	39.977103	0.0052089	0.01	0	0	0	31.714917
76	1.1616401	502.1783	39.977138	0.0052094	0.01	0	0	0	30.779057
77	1.161868	502.26237	39.977174	0.0052099	0.01	0	0	0	29.886479
78	1.1620731	502.34022	39.97721	0.0052103	0.01	0	0	0	29.034763
79	1.1622562	502.41202	39.977245	0.0052106	0.01	0	0	0	28.22165
80	1.1624181	502.47791	39.97728	0.0052109	0.01	0	0	0	27.445021
81	1.1625595	502.53807	39.977315	0.0052111	0.01	0	0	0	26.702895
82	1.162681	502.59264	39.97735	0.0052113	0.01	0	0	0	25.993416
83	1.1627834	502.64178	39.977385	0.0052114	0.01	0	0	0	25.314843
84	1.1628674	502.68563	39.97742	0.0052115	0.01	0	0	0	24.665544
85	1.1629335	502.72434	39.977454	0.0052115	0.01	0	0	0	24.043988
86	1.1629826	502.75805	39.977488	0.0052115	0.01	0	0	0	23.448738
87	1.1630151	502.78689	39.977523	0.0052115	0.01	0	0	0	22.878443
88	1.1630316	502.81099	39.977557	0.0052114	0.01	0	0	0	22.331836
89	1.1630329	502.83048	39.977591	0.0052113	0.01	0	0	0	21.807722
90	1.1630194	502.84549	39.977625	0.0052111	0.01	0	0	0	21.304981

HCS - Example & Comparison

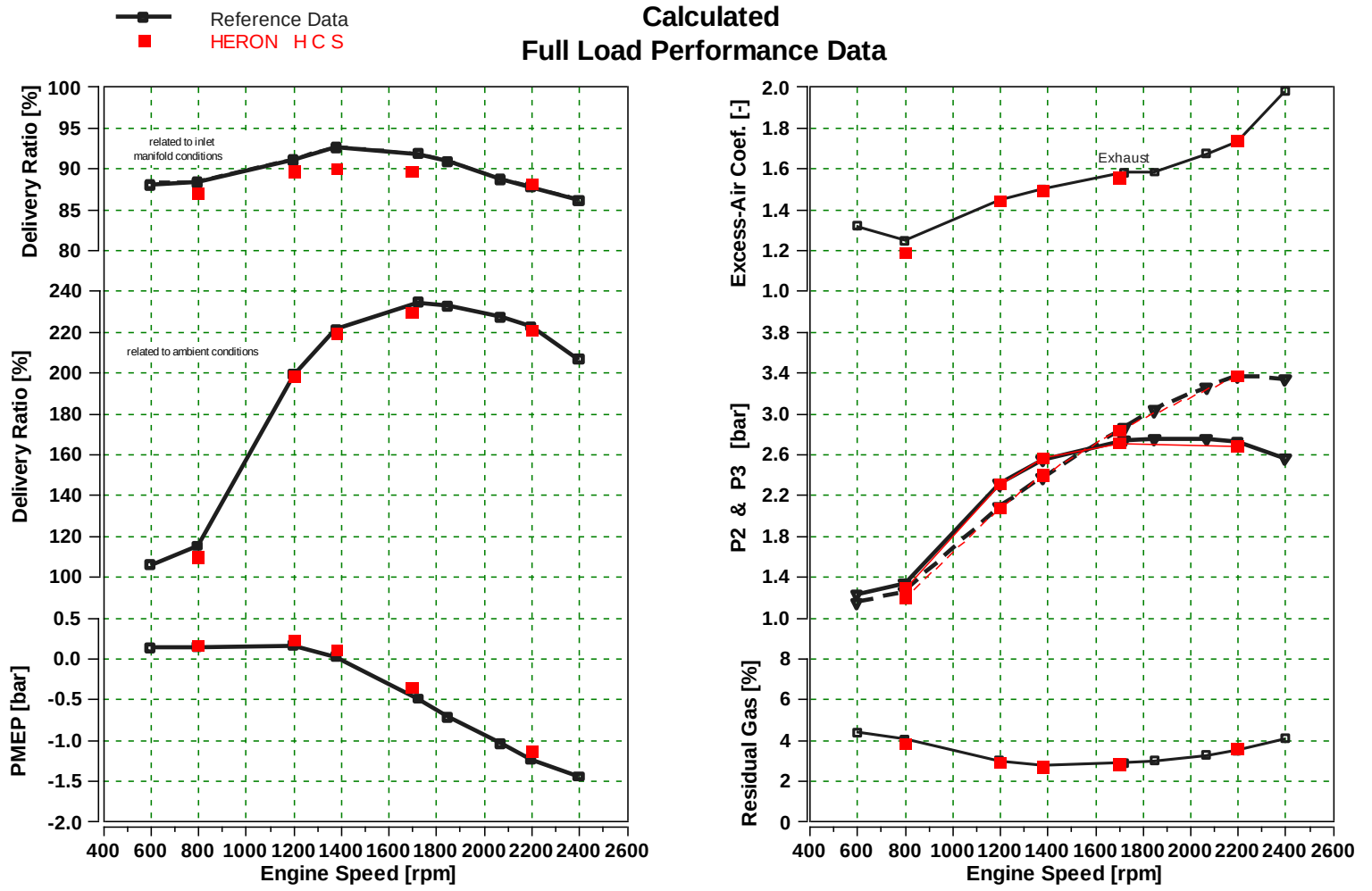


Lower Heating Value: 42700 kJ/kg
Stoich. A/F-Ratio: 14.70 kg/kg

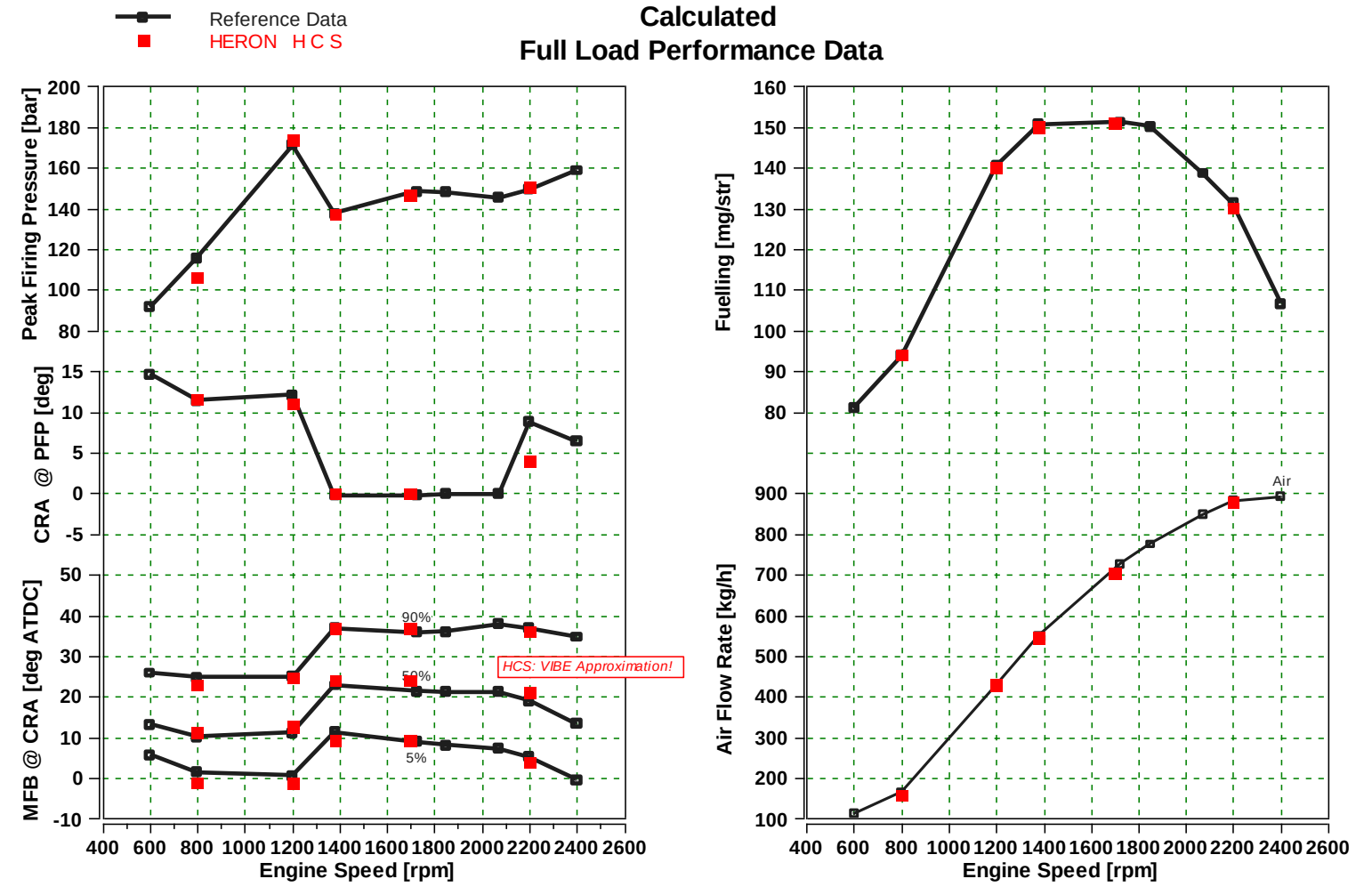
Ambient Conditions:
p = 1.000 bar
T = 25.0 °C

2011/03/14

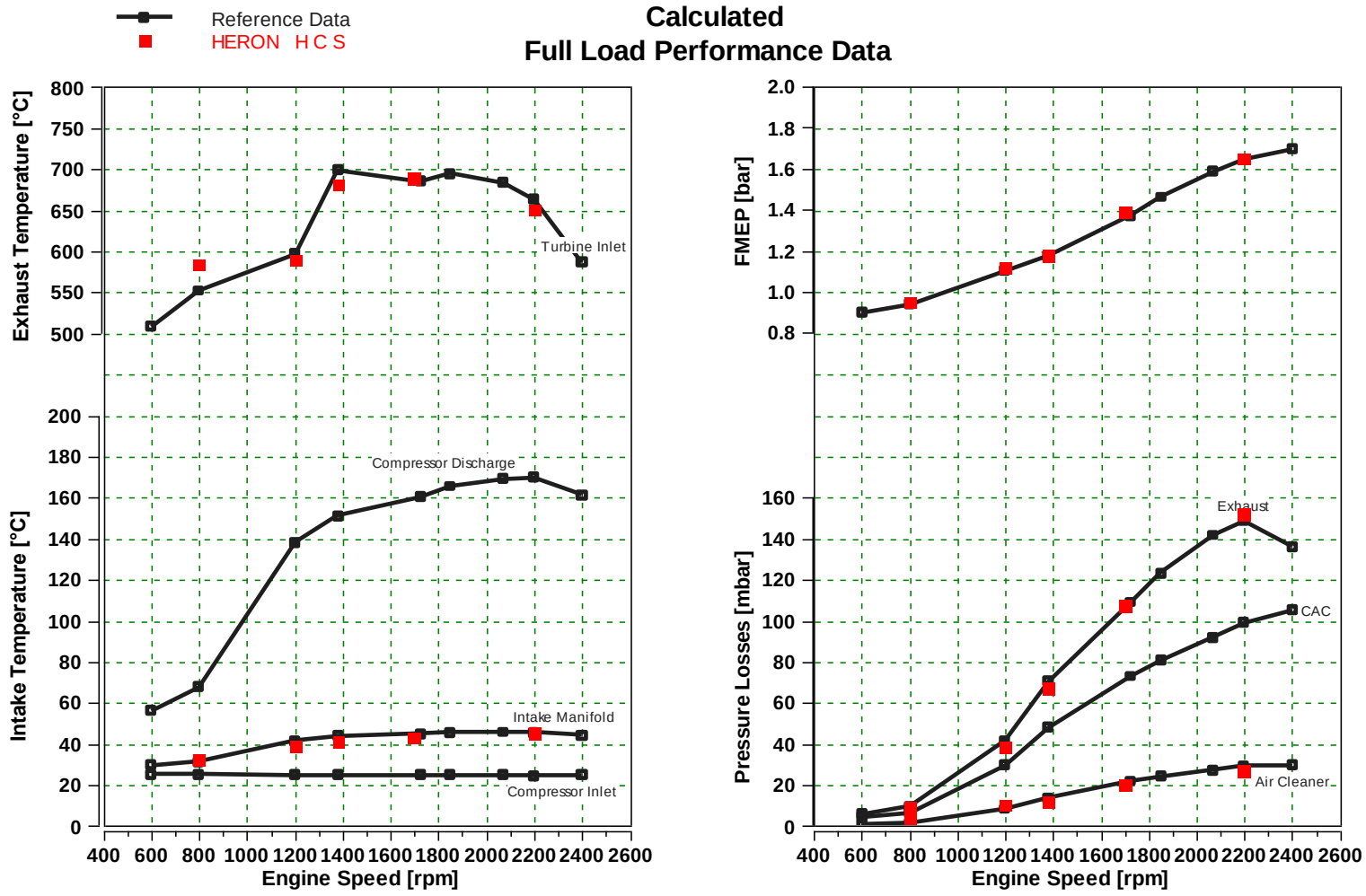
HCS - Example & Comparison



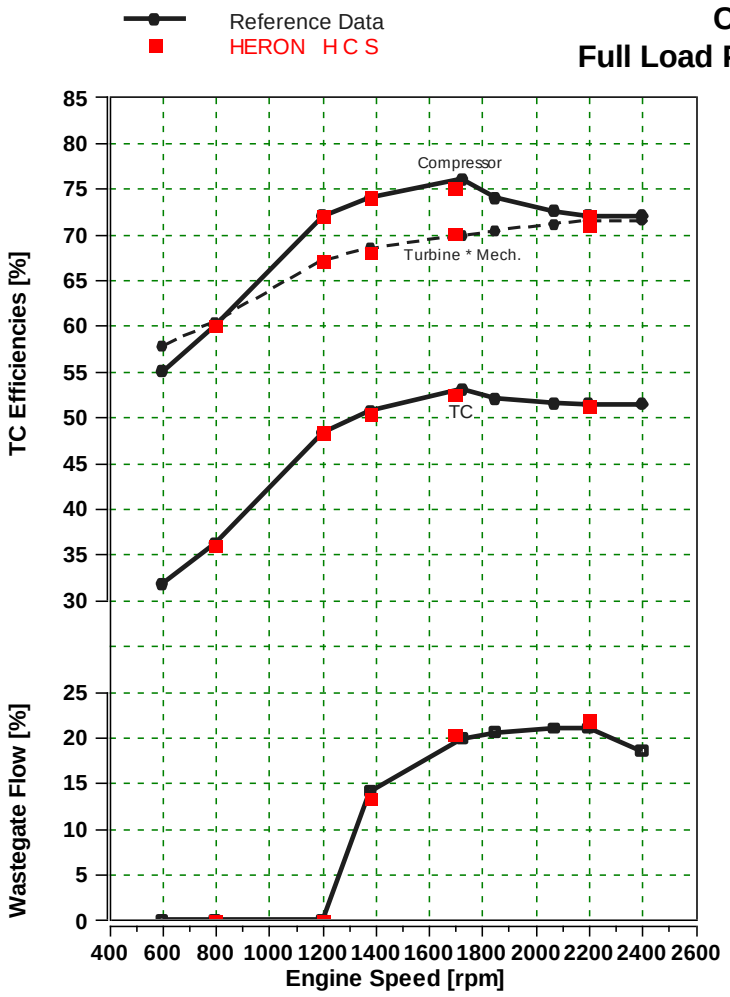
HCS - Example & Comparison

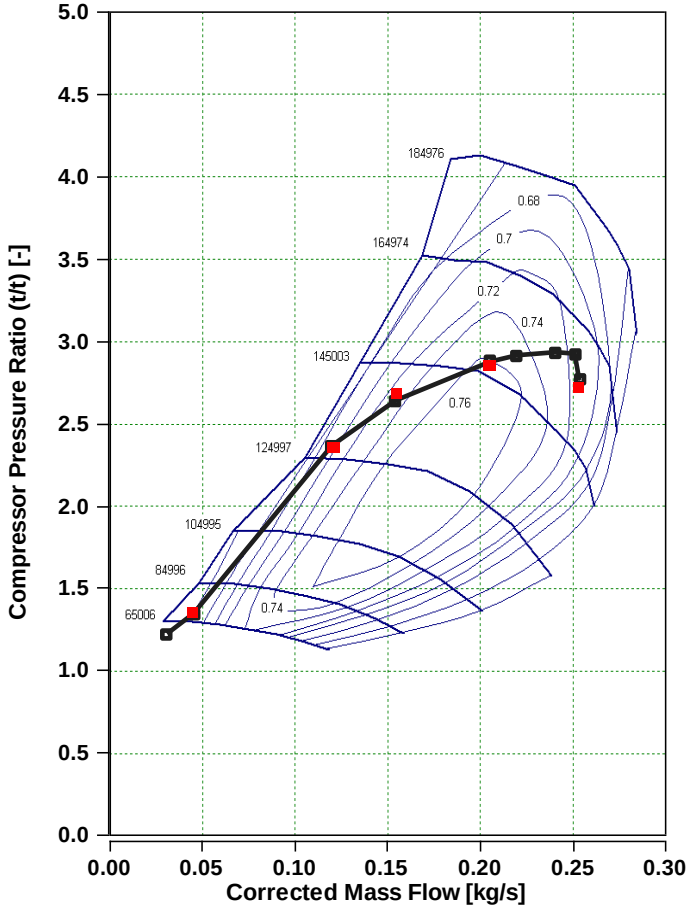


HCS - Example & Comparison



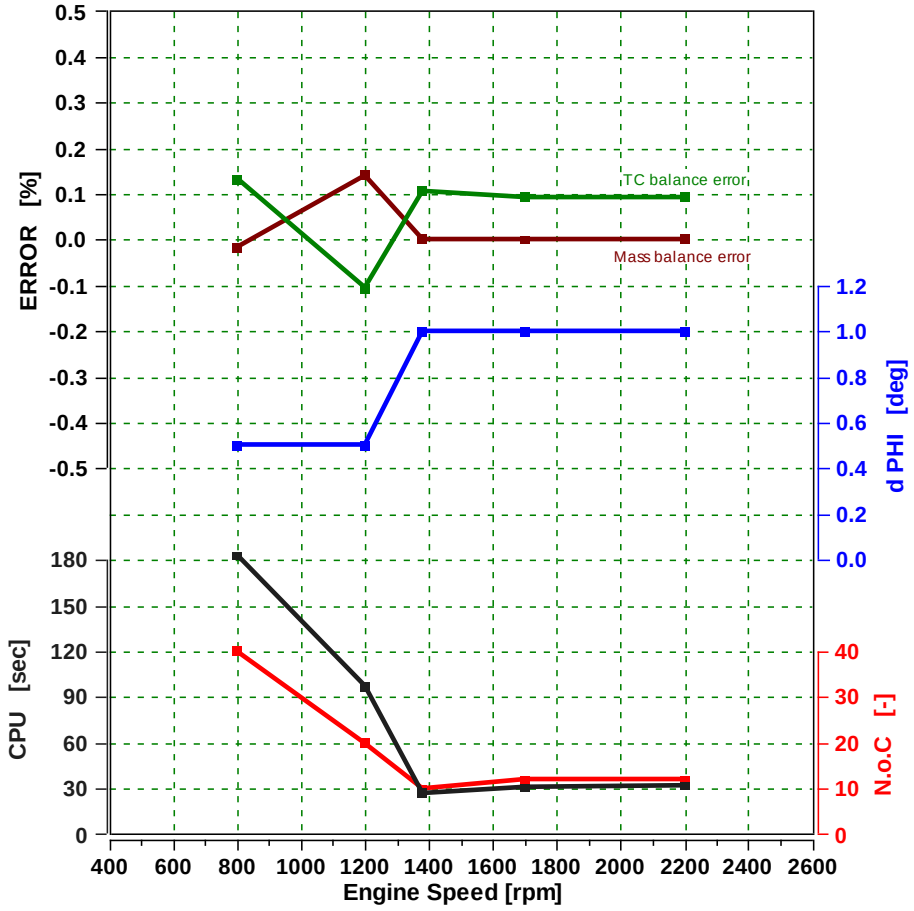
HCS - Example & Comparison

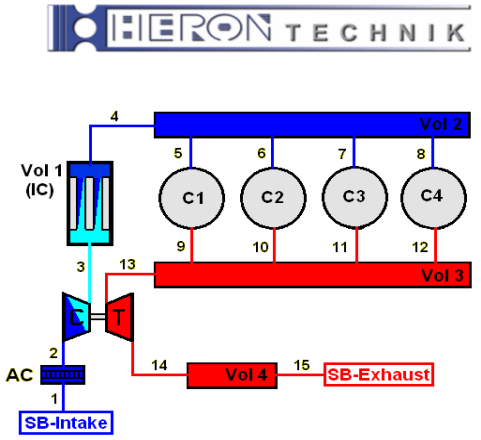




HCS - Example & Comparison

HCS: General Information

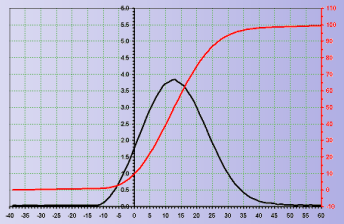




4C-TCI DIESEL Engine Model

d PHI	Calculation Step	[deg CRA]
N.o.C	Number of Cycles	[-]
CPU	Calculation Time	[sec]
MBE_c	Mass Balance Error	[%]
TCE_c	T C Balance Error	[%]

Applied Program Version: V_1.14 (March-2011)



Cycle Pressure Trace Analysis

C P T A

For Combustion Data Evaluation

Dr. Hans Alten - CEO
Graz, March 2011

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8010 Graz
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HERON – Cylinder Pressure Trace Analysis CPTA

MOTIVATION

First feedback from customers for a tool to evaluate the input data for the combustion simulation similar to the “real engine”.

Therefore, a supplement to the HERON cycle simulation program HCS is under development to evaluate the ROHR data and a VIBE approximation from measured in-cylinder pressure traces.

DEVELOPMENT

Stage 1: Simplified calculation in EXCEL - finished

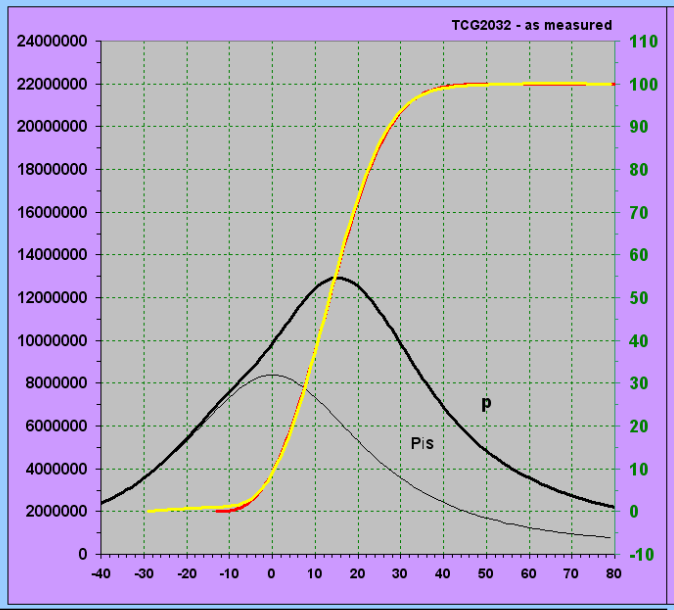
Stage 2: Advanced calculation in FORTRAN - finished

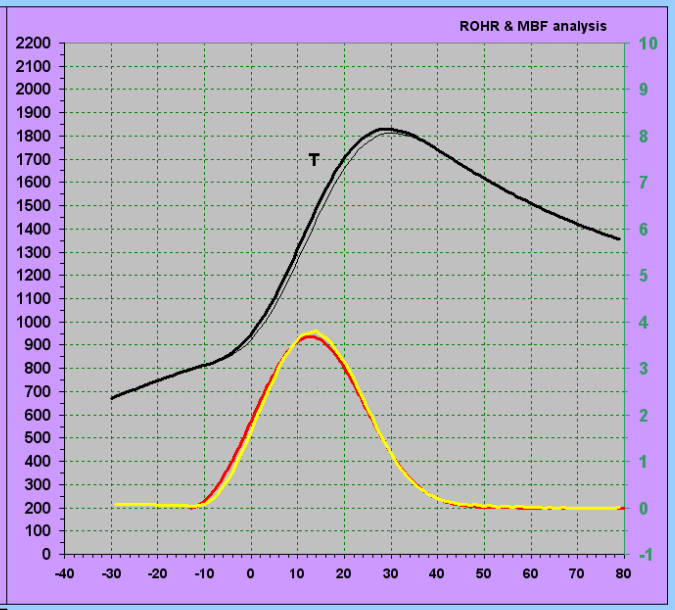
Stage 3: Implementation in HCS (VBA) - in progress

Graz, 12th March 2011

COMBcalc

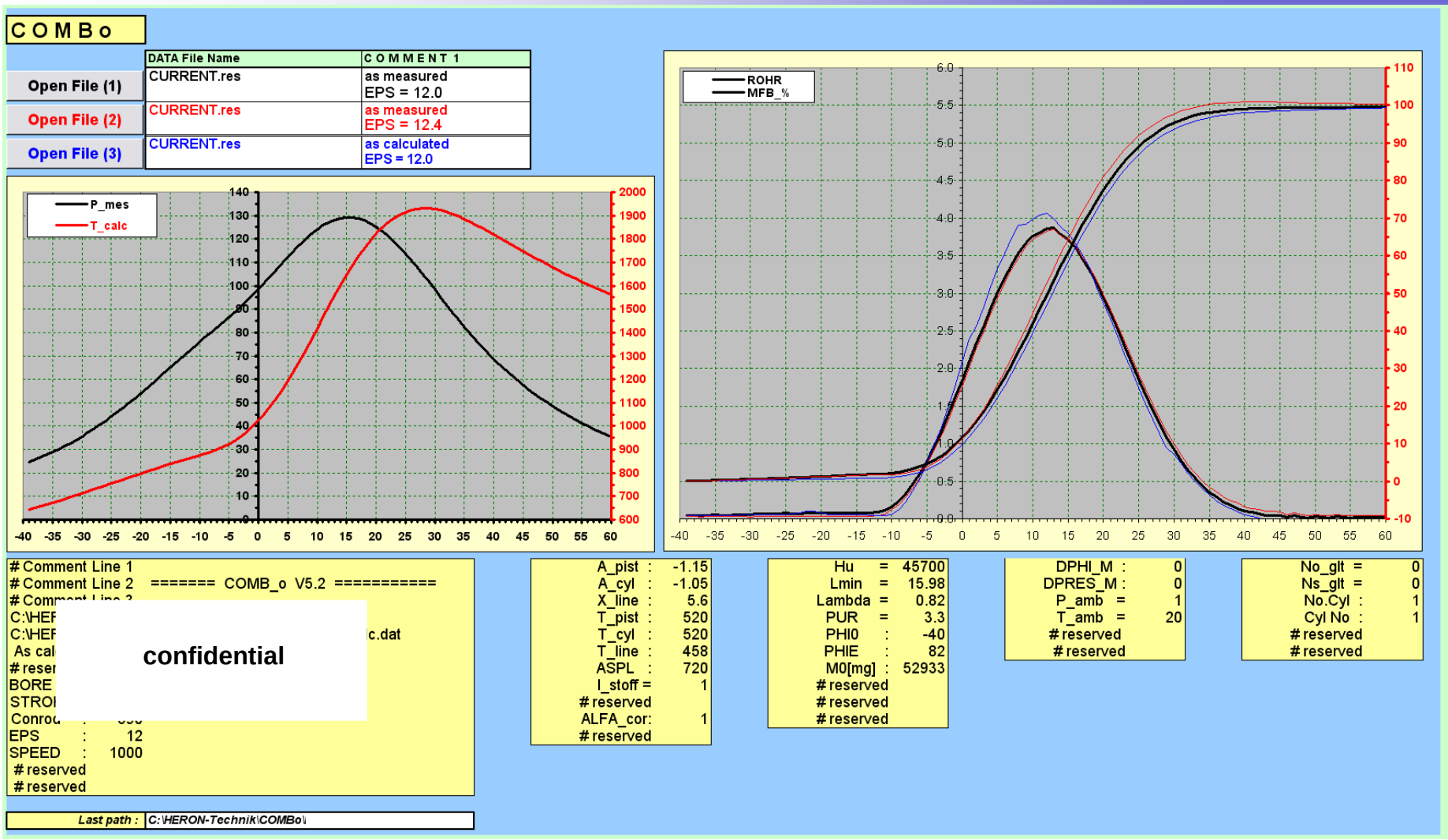
	DATA File Name	COMMENT 1	COMMENT 2	BORE [mm]	STROKE [mm]	C.R.L. [mm]	VH [L]	IMEP [bar]	EPS	ETA	Corr1	Corr2	SOC	DUR	m
Open File (1)	TCG2032_as_measured.txt	TCG2032 - as measured	ROHR & MBF analysis	260	320	560	16.990	21.85	12.00	2.50	1	1	-13	60	1.8
Open File (2)															
Open File (3)															
Open File (4)															
Open File (5)															



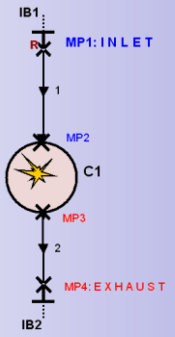


Last path : C:\HERON-Technik\ _P39

Stage 1: Simple EXCEL Sheet with fixed gas properties and without heat transfer



Stage 2: Advanced FORTRAN program, including all key functionalities (EXCEL Pre- & Postprocessing)



Cycle Pressure Trace Analysis

C P T A _ 1 C

For Combustion Data Evaluation

and Gas Exchange Analysis

Dr. Hans Alten - CEO
Graz, March 2011

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Mobile +43 (0)664 526 7009

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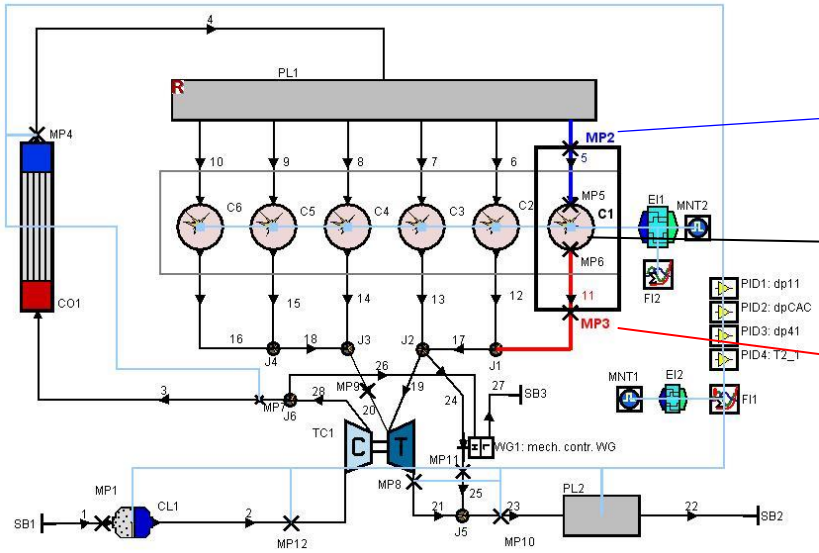
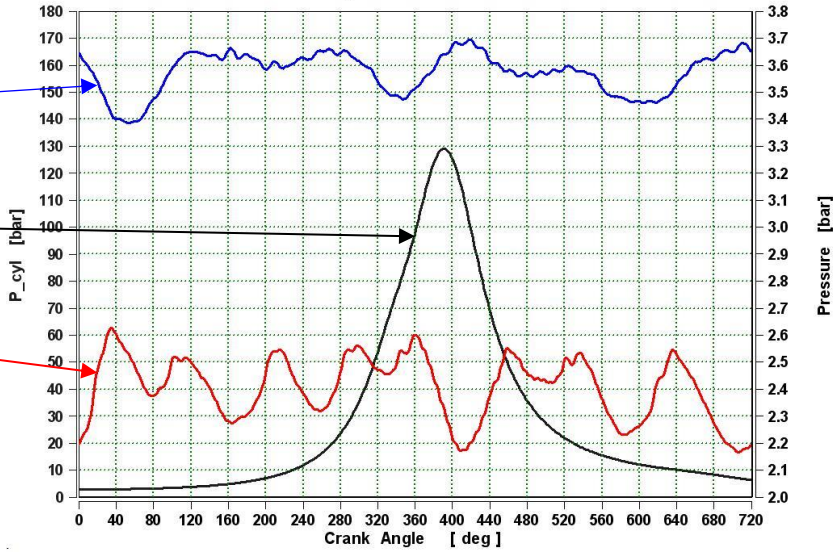
Step No. 1:

High- and low pressure measurements

Test bed installation

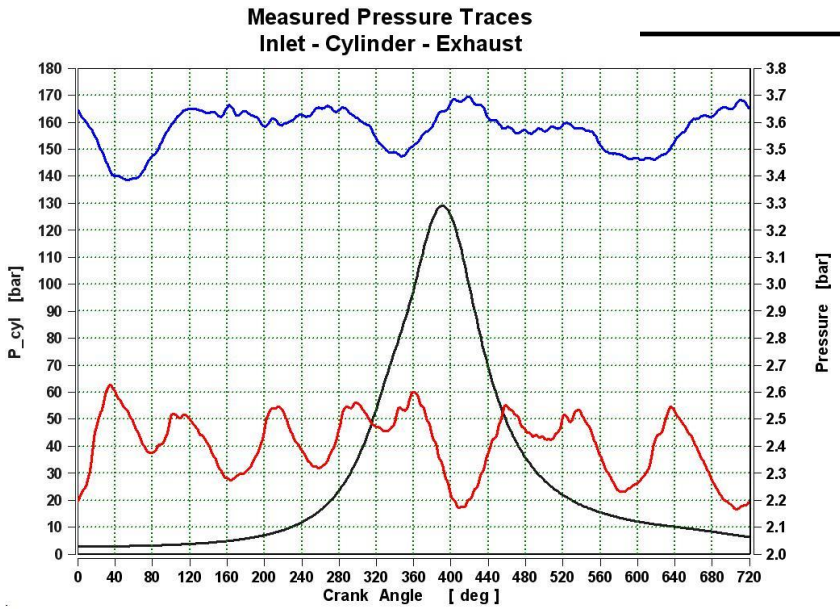


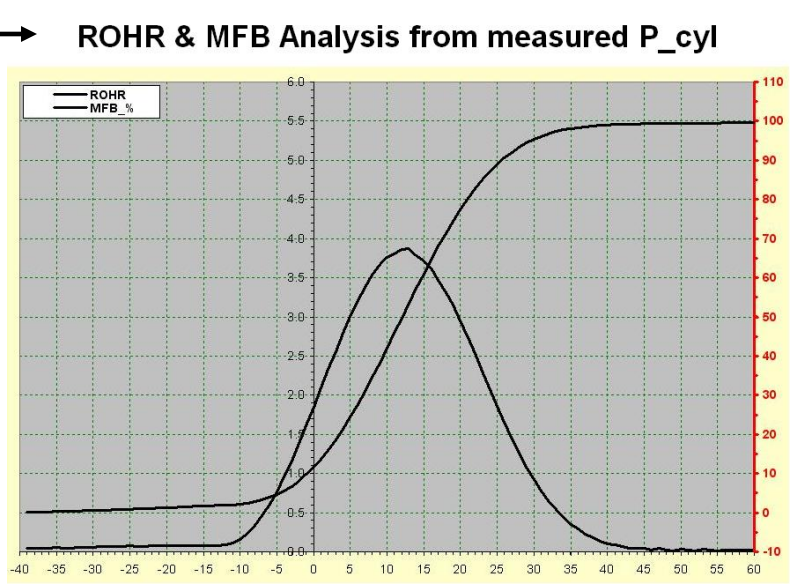
Measured Pressure Traces
Inlet - Cylinder - Exhaust



Step No. 2:

Combustion data analysis from measure cylinder pressure signal by applying CPTA_1C

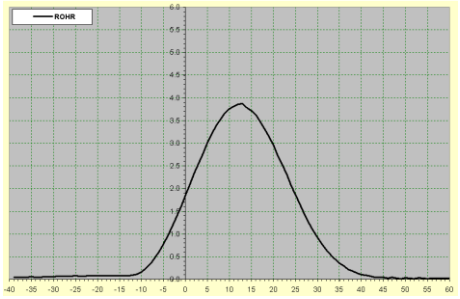


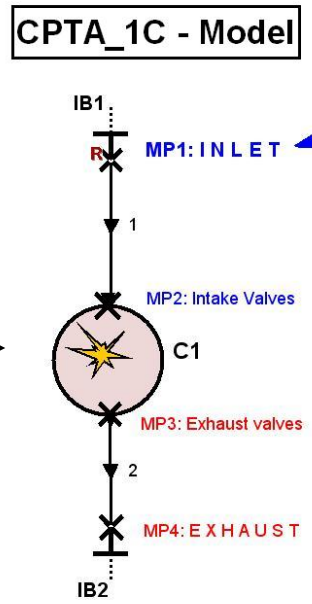


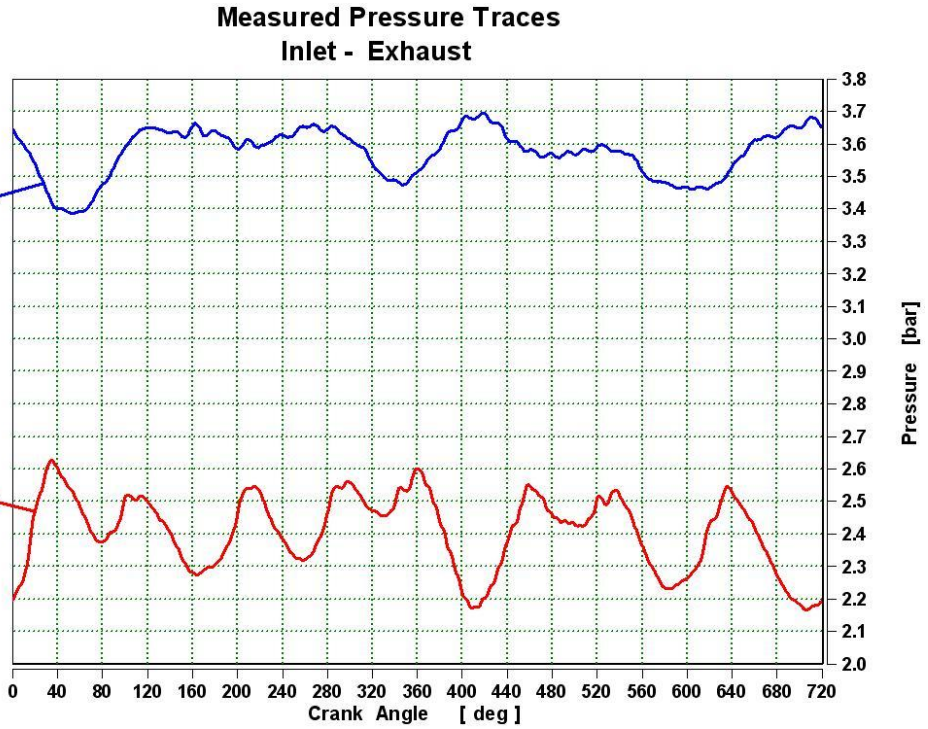
Step No. 3:

Gas exchange analysis with CPTA_1C and the measured data

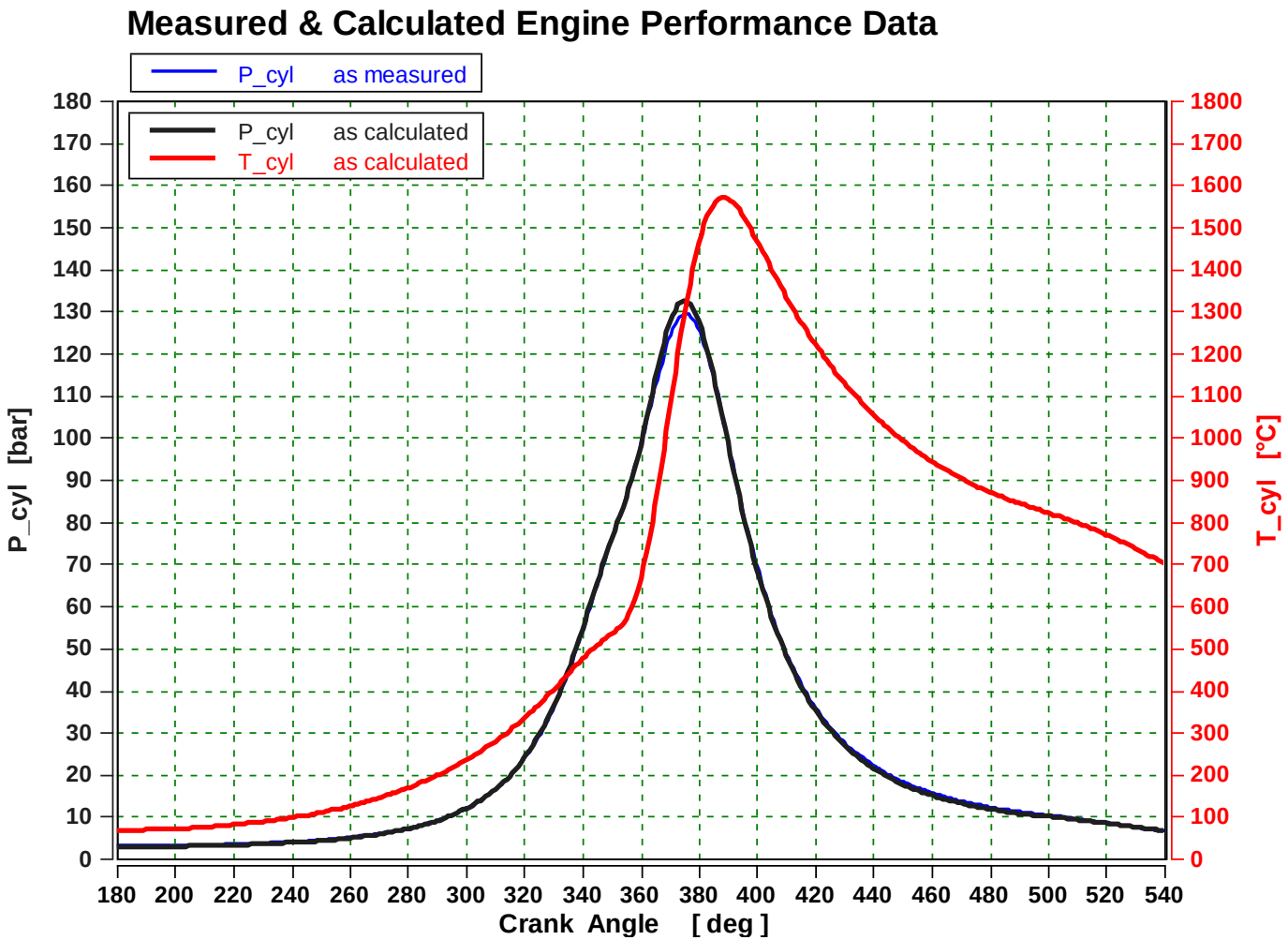
ROHR: Input data for simulation





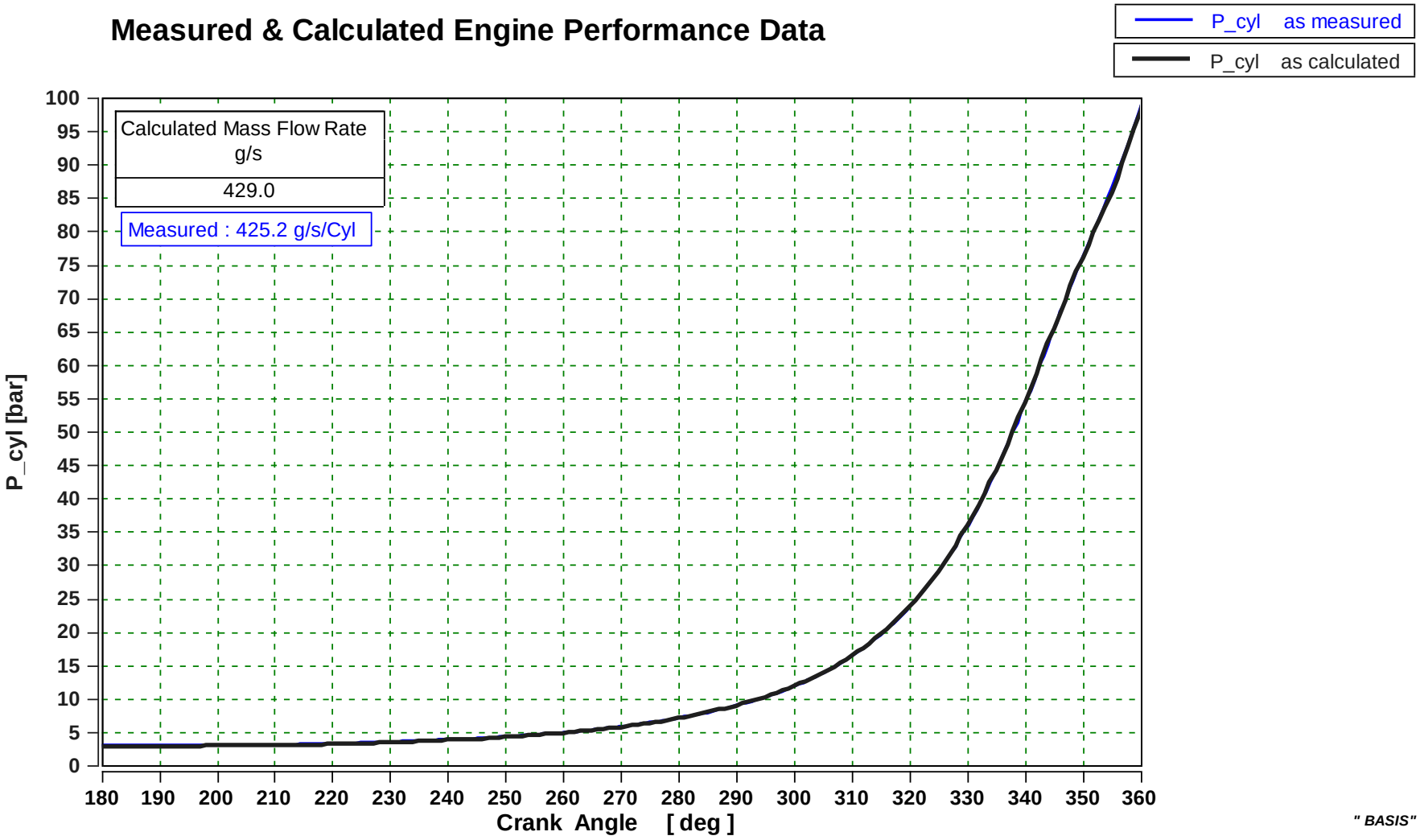


Results



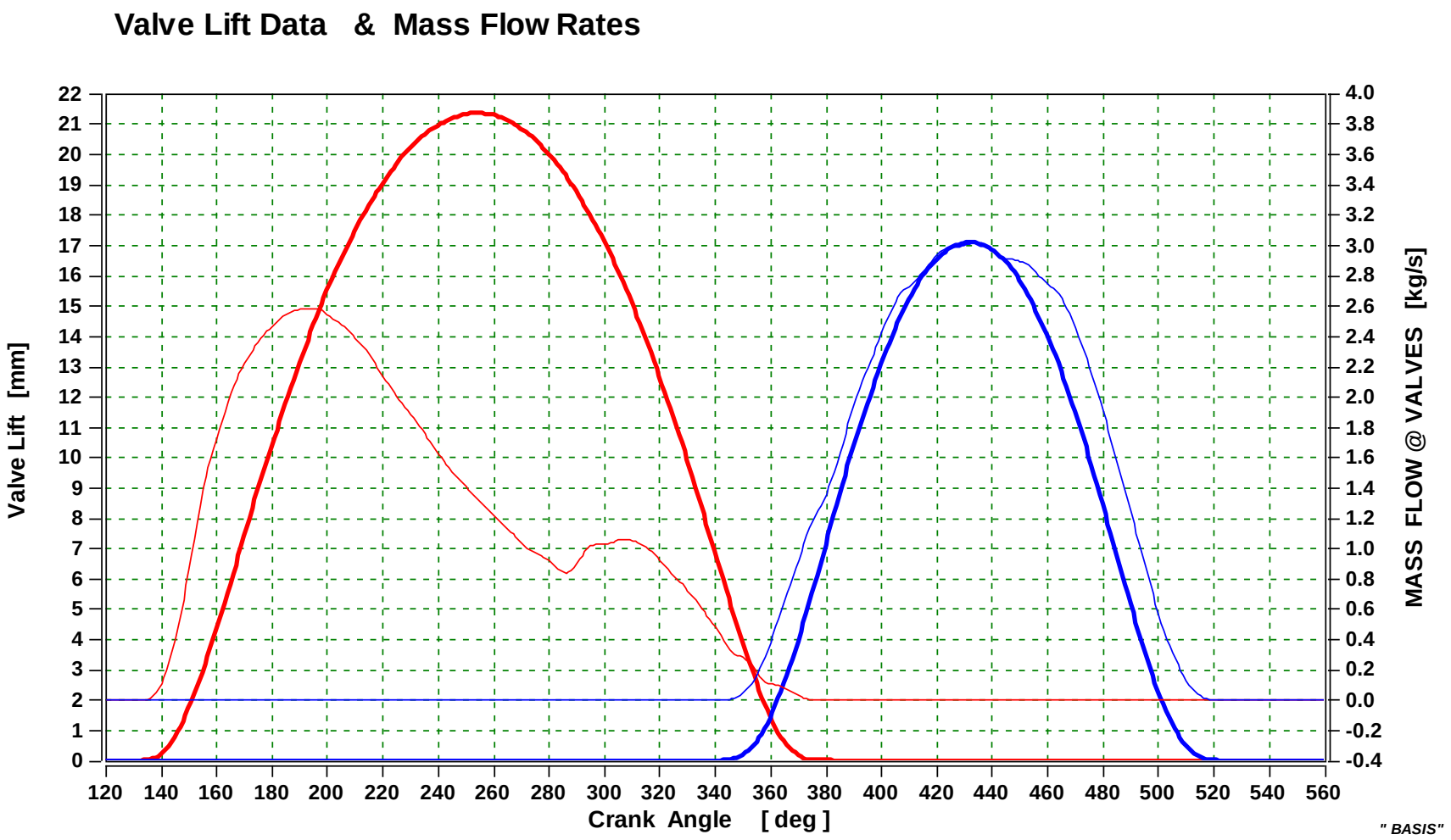
" BASIS"

Results



" BASIS"

Results


Valve Lift Data & Mass Flow Rates
Valve Lift [mm]
MASS FLOW @ VALVES [kg/s]
Crank Angle [deg]
" BASIS"

Results

Parameter investigation:

Influence of reduced

inlet port flow capacity

Assumption: -10% reduction