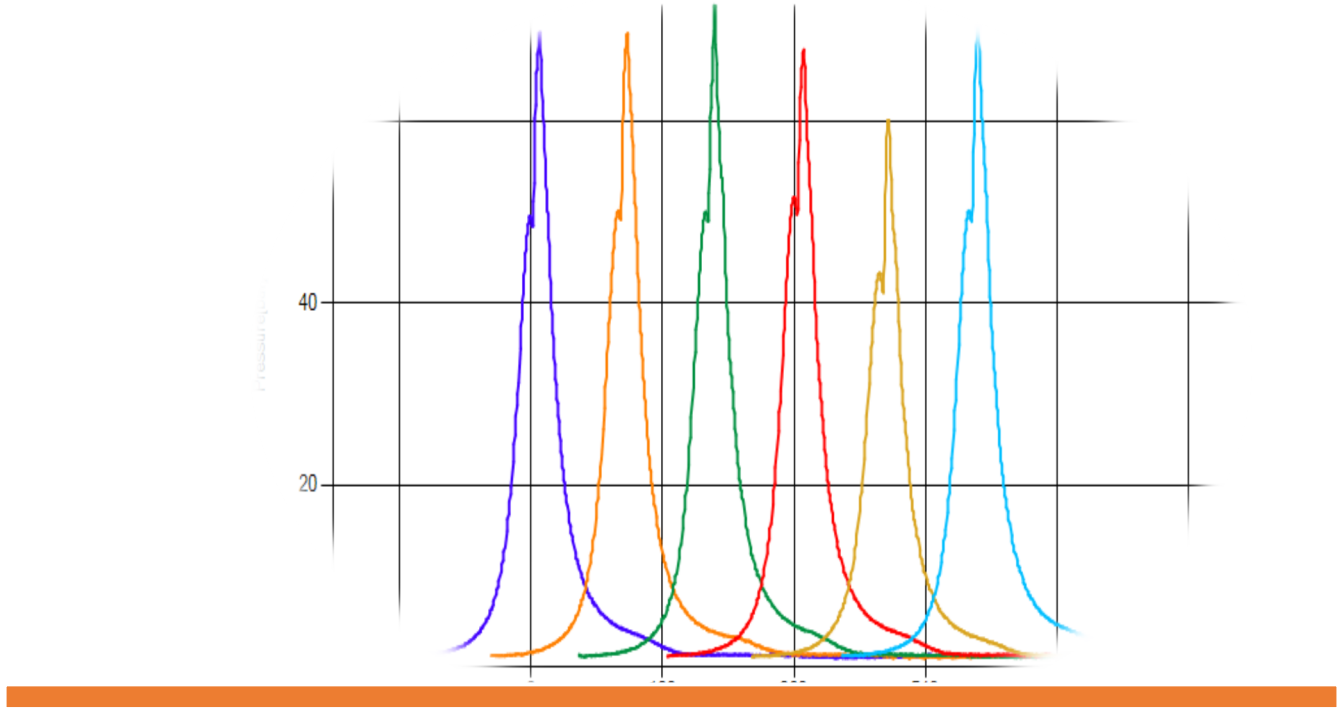
T.M.M.O.B

Gemi Makineleri İşletme Mühendisleri Odası

The Chamber of Marine Engineers

MODÜL-3

GEMİ DİZEL MOTORLARINDA PERFORMANS ANALİZİ



Prof.Dr.Adnan Parlak

MODÜL-3	GEMİ DİZEL MOTORLARINDA PERFORMANS ÖLÇÜM VE ANALİZİ – Prof. Dr. Adnan PARLAK
3.1	Fabrika Kabul Testi (FAT-Factory Acceptence Test, shop test) inceleme. Yük, Güç, Özgül Yakıt sarfiyatı, skavenç basıncı, türbin devri, hava kuleri çıkış sıcaklığı, hava kuleri fark basınç, yüke bağlı kompresyon ve yanma basınçlarının incelenmesi, yüke bağlı egzoz sıcaklık ilişkilerinin analizi.
3.2	Silindir içi performans ölçümü ve ölçüm sonuçlarının analiz edilmesi. Bu kapsamda yanma basınçlarının krank açısına göre değişimlerinin analizi, silindirler arası kompresyon basınç değişimlerinin analizi, Pmax-Pcomp fark analizi, silindirler arası Pmax değişim analizi, maksimum basıncın gerçekleştiği krank açısının önemi, silindirler arası güç ve yük dağılımının analiz edilmesi
3.3	Çevresel şartların yakıt sarfiyatına etkisinin ve özgül yakıt sarfiyatının ISO 3046 şartlarına indirgenmesi
3.4	Ölçülmüş performans grafikleri üzerinden hata analizi ve makinelerin fabrika ayarlarına geri getirmek için çözüm önerileri
3.5	Atölye çalışması (Kursiyerler 4 ya da 5 li gruba ayrılarak kendilerine verilen farklı ölçüm değerleri için çözüm önerisi içerir hazırlayacak ve sunacaklar)

Temel Tanımlar

Yakıt Tüketimi (FC) : ***Belirli bir yük ve devirde içten yanmalı bir motorun saatte tükettiği yakıt miktarıdır. Birim kg /h***

Özgül Yakıt Tüketimi (SFC) : ***Bir içten yanmalı motorun kWh başına tükettiği yakıt miktarını ifade eder. Birimi g/kWh***

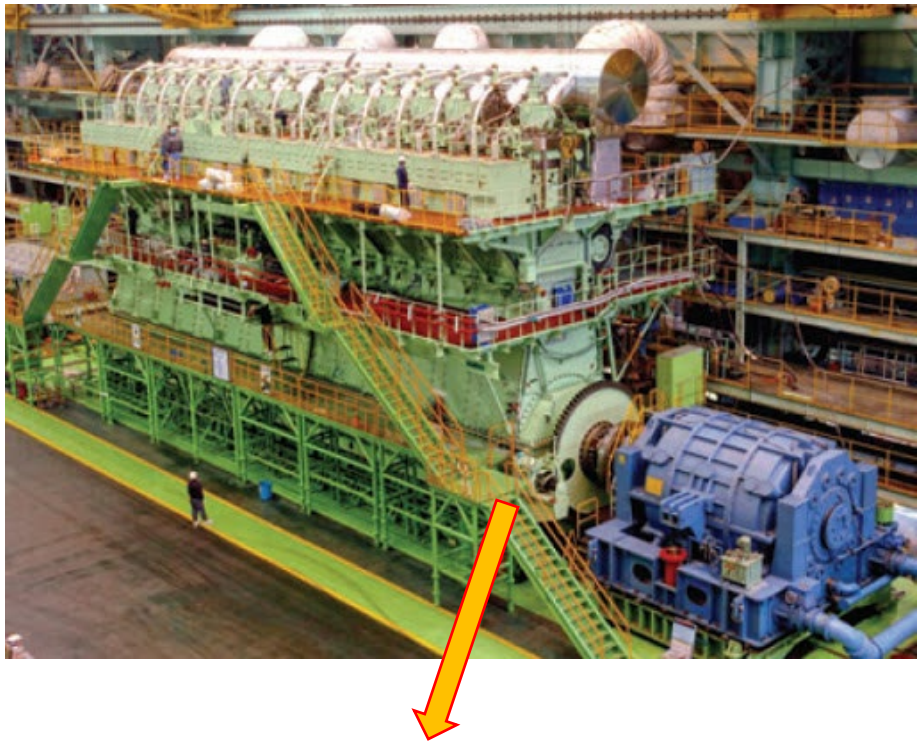
Fren veya Efektif Güç (kW) : ***İçten yanmalı motorun fren dinamometresi ile ölçülen güç değeridir. Fren gücü, silindirde üretilen belirtilen güçten sürtünme gücünün çıkarılmasıyla bulunur. Birimi kW***

Alt Isıl Değeri (LCV): ***Bir yakıtın ısıl değeri, yanması sırasında salınan ısı miktarıdır. Enerji veya kalori değeri olarak da adlandırılan ısı değeri, bir yakıtın enerji yoğunluğunun bir ölçüsüdür ve belirli bir miktar (ör. kilogram) başına enerji (joule) olarak ifade edilir. kJ/kg,MJ/kg***

Ortalama İndike Basınç /Mean Indicated Pressure (MIP): ***Silindire içerisinde bir çevrim boyunca oluşan basınçların ortalaması olarak ifade edilir.***

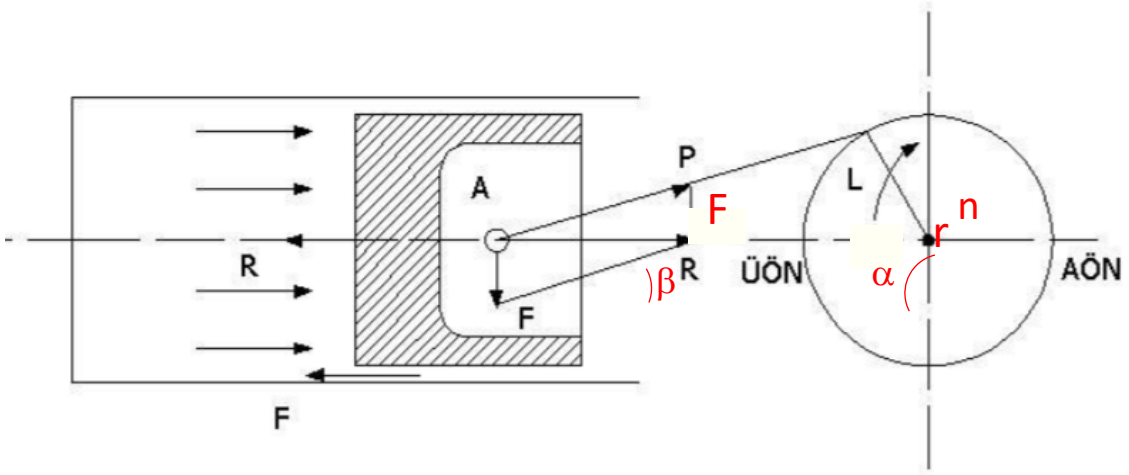
Moment (Tork): ***Bir cismi bir eksen etrafında döndürme etkisi,Nm***

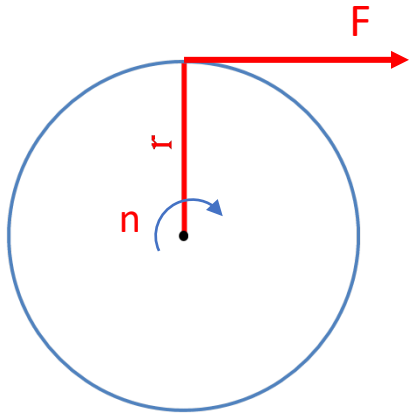
Güç/Power: ***Birim zamanda gerçekleşen iş sayısı,kW***

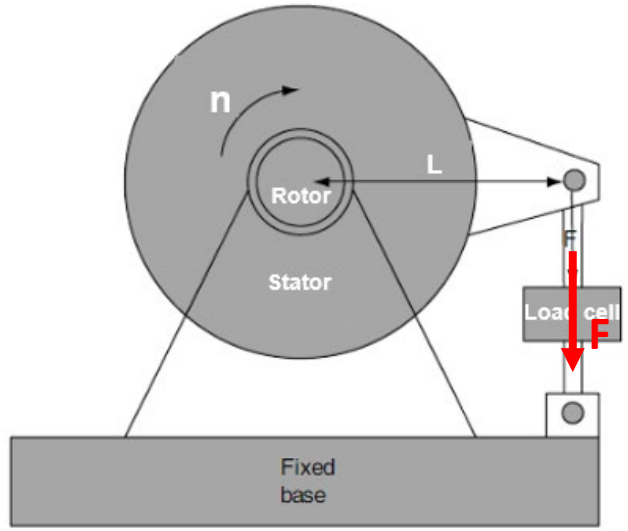


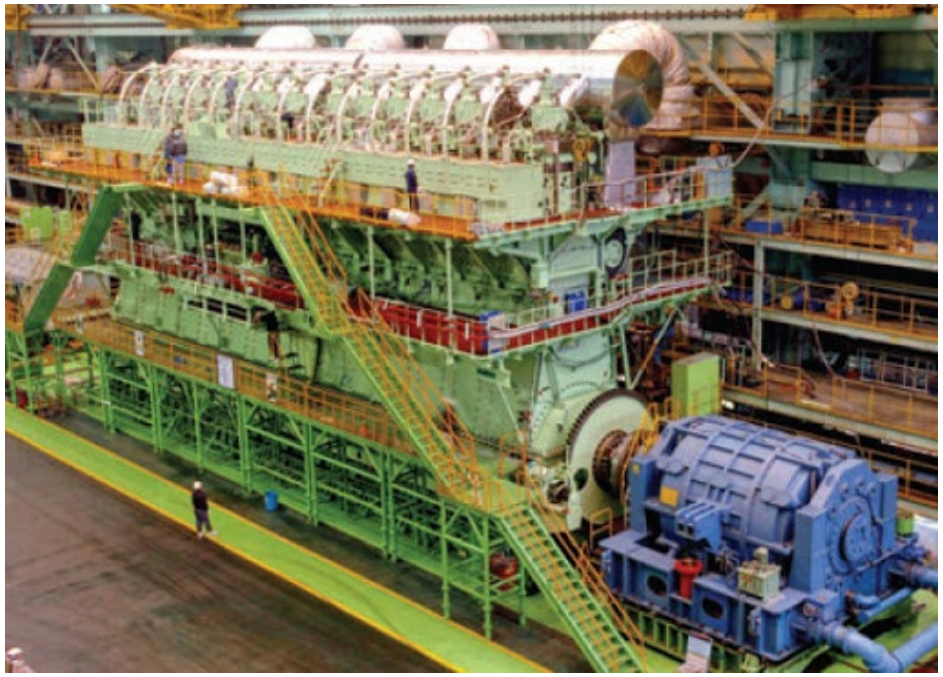
Fren yada Efektif Güç

Brake Power Formula









Engine Torque = Brake Torque

$$M_d = F.r \qquad M_{brake} = F.L$$

L=0,955 m
F→N

Engine Work

$$W_e = 2\pi Fr = F.(2\pi r)$$

Brake Work

$$W_b = 2\pi FL$$

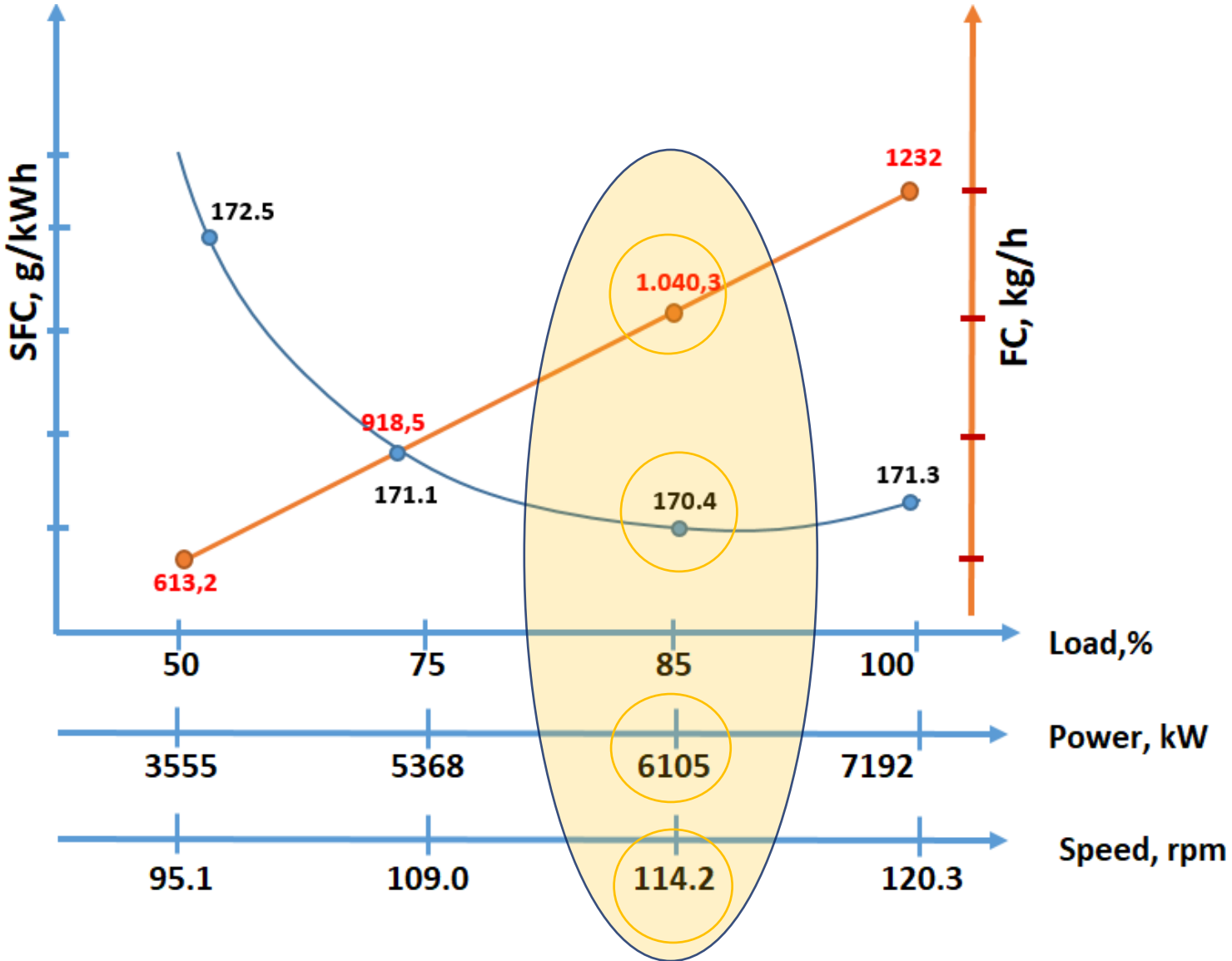
Engine Power

$$\dot{W}_e = 2\pi nFr = \omega.M_d$$

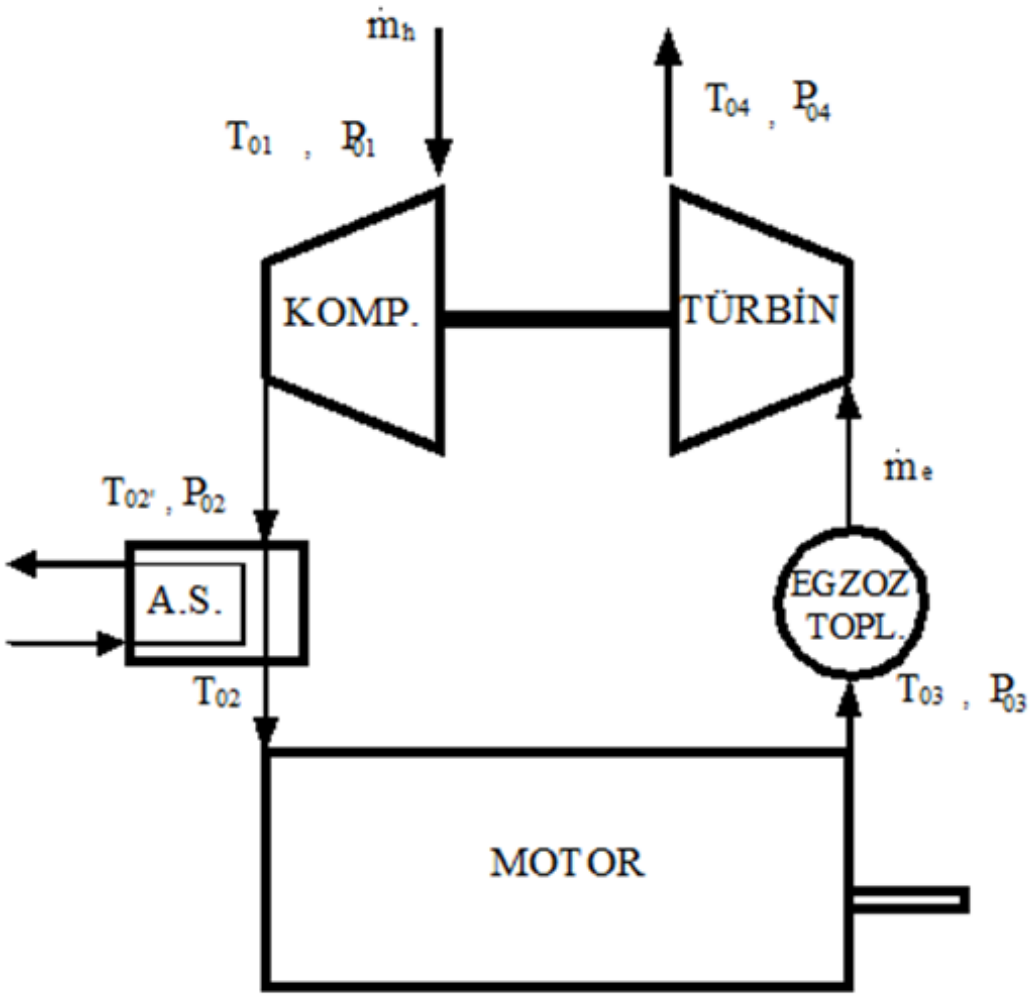
Brake Power

$$W_b = 2\pi FLn = \frac{F.n}{10^4} \quad [\text{kW}]$$

Engine Performance Curve (Shop Test)



Türbin Giriş-Çıkış Sıcaklığı ve Skavenç Basınç ilişkisi



Türbin ve Kompresör gücü arasındaki ilişki:

$P_K = \eta_m \cdot P_T$

Kompresör için gerekli olan güç

$$P_K = \frac{mh.C_p.(T_{02} - T_{01})}{\eta_K} = \frac{mh.C_p.T_{01}}{\eta_K}\left[\left(\frac{P_{02}}{P_{01}}\right)^{\frac{k-1}{k}} - 1\right]$$

Türbin gücü ise

$$P_T = m_e.\, C_{p,e.}\, \eta_T.\, (T_{03} - T_{04})$$

Türbin ve kompresör arasındaki ilişki

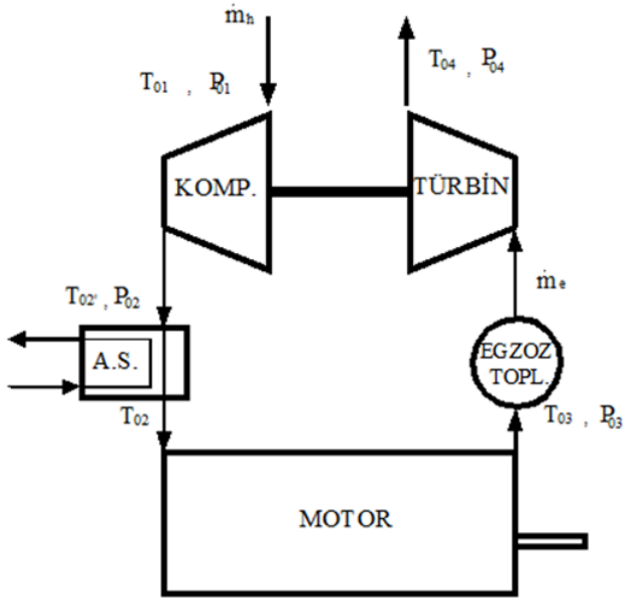
$$\dot{m}_e.c_{p,e}.(T_5 - T_6)\eta_T.\eta_K.\eta_m = \dot{m}_h.c_{p,h}.(T_2 - T_1)$$

Kompresör çıkış sıcaklığı:

$$T_2 = T_1 + \frac{\dot{m}_e.c_{p,e}.(T_5 - T_6)\eta_T.\eta_K.\eta_m}{\dot{m}_h.c_{p,h}}$$

Kompresör çıkış basıncı:

$$P_{02} = P_{01}\left(\frac{T_{02}}{T_{01}}\right)^{\frac{k}{k-1}}$$



k	1,4
T_{01}, C	25
p01 kPa	100
T01, C	25
T_{03}, C	**494**
T_{04}, C	**386**
η_T	0,9
η_K	0,9
η_m	0,9
Cp,a kJ/kgK	1,004
Cp,e kJ/kgK	1,044
m_h, kg/h	974
m_y,kg/h	16,6
m_e,kg/h	990,6

Kompresör çıkış Sıcaklığı, K	381,3	108,3
Skavenç Basıncı, kPa	236,88	kPa
Gauge Pressure,kPa	136,88	kPa

k	1,4
T_{01}, C	25
p01 kPa	100
T01, C	25
T_{03}, C	**494**
T_{04}, C	**400**
η_T	0,9
η_K	0,9
η_m	0,9
Cp,a kJ/kgK	1,004
Cp,e kJ/kgK	1,044
m_h, kg/h	974
m_y,kg/h	16,6
m_e,kg/h	990,6

Kompresör çıkış Sıcaklığı, K	370,5	97,5
Skavenç Basıncı, kPa	214,23	kPa
Gauge Pressure,kPa	114,23	kPa

k	1,4
T_{01}, C	25
p01 kPa	100
T01, C	25
T_{03}, C	**494**
T_{04}, C	**425**
η_T	0,9
η_K	0,9
η_m	0,9
Cp,a kJ/kgK	1,004
Cp,e kJ/kgK	1,044
m_h, kg/h	974
m_y,kg/h	16,6
m_e,kg/h	990,6

Kompresör çıkış Sıcaklığı, K	351,2	78,2
Skavenç Basıncı, kPa	177,69	kPa
Gauge Pressure,kPa	77,69	kPa

Efektif Güç

$$P_e = \frac{\eta_e . \eta_v . V_h . L . H_u . \rho_{h,g} . (Y/H)}{2}$$

Moment

$$T = \frac{\eta_e . \eta_v . V_h . H_u . \rho_{h,g} . (Y/H)}{4\pi}$$

Ortalama Basınç

$$P_{me} = \eta_e . \eta_v . H_u . \rho_{h,g} . (Y/H)$$

Ortalama Basınca göre güç hesabı

$$P_e = \frac{p_{me} . V_H . n . i}{60.000}$$

MAK 8M20

Diesel Engine
Acceptance Test Record

Sheet 1 of 1

Engine Type: 8 M 20	**Order No.: 251678**	**Engine No.: 31035**

Atmospheric conditions during test run — Ambient temperature: 26,0 °C — Atmospheric pressure: 0,986 bar — Relative humidity: 65 % — Altitude: 10 m

We used for the test run — Luboil type: SAE 40 — Heat value according to Fuel oil analysis: 42290 kJ/kg — Density: 0,884 kg/l — Test bed: 50 / 8 — Hydraulic brake: 12 U 2 N 86

Engine data: Four-stroke / direct injection / port engine / counter-clockwise rotation (viewed from the drive end) — Firing order: 1-3-5-7-8-6-4-2

Rated power: 1520 kW — Rated speed: 1000 1/min — Bore: 200 mm — Stroke: 300 mm

Charger type: KBB R 4 - 3 — Number: 733 — Max speed: 41500 1/min — t max: 650 °C — Specification: 2.448-00207 — Test: 3438 LEI 05

Fuel injection pump: Woodward MWA 205615 — Plunger diameter: 19,0 mm — Idle stroke 'X': 4,0 mm

Fuel injector: Mak A 3 / 5 — Opening pressure: 500 bar

Generator — Manufacturer: — Type:

Flywheel diameter: 1005 mm — 1° : 8,77 mm — Commencement of injection pump Cylinder 1 : 6,7° crank angle before T.D.C

Emissions data

Application : Constant Speed Main Propulsion
Cycle : E2
Test result of parent engineNOx : 9,9 g/kWh

Settings:		Cyl 1	Cyl 2	Cyl 3	Cyl 4	Cyl 5	Cyl 6	Cyl 7	Cyl 8
Distance from liner top edge to piston top edge in T.D.C. [mm]		12,5	12,5	12,5	12,5	12,5	12,5	12,5	12,4
Fuel injection pump thickness of the Steel Plate [mm]		2,7	2,4	2,5	2,2	2,5	2,3	2,2	2,2
Fuel injection pump rack position when control handle on 'stop' [mm]		0,0							
Fuel injection pump rack position [mm]	at rated power	26,0							
At control panel blocked at 26,0 mm	at no load	11,0							

Governor speed setting n = 1000 1/min — Maximum speed no load n = 1000 1/min — Minimum speed no load n = 597 1/min

Run time	Fuel	Output				Mean eff. press	Fuel consumption					Lubricating oil			Cooling water			Charge air cooler °C				Exhaust gas temperature °C									Turbocharger			
		Speed	Pe	Load			Quant	Run time	Consumption			Press.	Temp.		Press.	Temp.		Water		Air		Cylinder								aft. Turb.	Charge air pr. bef. cool.	Charge air pr. aft. cool.	Diff. press	Speed
										ISO			In	Out		In	Out					1	2	3	4	5	6	7	8					
min.	mm	rpm	kW	kN	%	pme bar	kg	s	g/kWh	g/kWh	kg/h	bar	°C	°C	bar	°C	°C	In	Out	In	Out										bar	bar	mbar	rpm
60	26,0	1000	1520	15,2	100	24,19	4,0	48,4	195,7	190,9	297,5	4,7	60	66	4,0	59	64	46	56	214	50	392	382	385	383	404	392	387	376	316	3,150	3,125	25	39000
30	28,0	1000	1672	16,7	110	26,61	4,0	43,7	197,0	192,2	329,4	4,7	62	70	4,0	59	64	46	58	232	51	420	407	411	408	431	416	412	405	324	3,510	3,480	30	40800
30	23,0	1000	1292	12,9	85	20,56	4,0	57,2	194,9	190,1	251,8	4,7	64	72	3,8	61	64	46	58	192	50	366	363	365	359	382	368	368	359	319	2,580	2,560	20	36500
30	21,5	1000	1140	11,4	75	18,14	4,0	64,5	195,8	191,0	223,2	4,7	64	72	3,9	62	65	46	55	177	50	354	354	355	354	371	359	357	354	323	2,250	2,235	15	35000
30	17,0	1000	760	7,6	50	12,10	4,0	90,9	208,4	203,6	158,4	4,7	63	70	3,9	63	65	44	52	129	48	337	343	342	338	359	343	348	338	354	1,250	1,240	10	28300
30	13,0	1000	380	3,8	25	6,05	4,0	160,7	235,8	230,7	89,6	4,7	65	69	3,9	62	63	41	42	72	46	341	355	344	335	360	348	337	334	356	0,410	0,400	10	18500

20 is basic value for crankweb deflection 1/100 mm

Cylinder 1

B.D.C.	Exhaust side		T.D.C.		Camshaft side	
	cold	warm	cold	warm	cold	warm
20	21,0	19,5	20,0	17,5	20,0	17,5

Caterpillar Confidential: green

Measured on test bed and coupled to hydraulic brake.
Measured with overhung flywheel.
Follow MaK instructions for installation.

Exhaust gas back pressure at full load: 0,011 bar

DICARE f. Windows / Version 2.0 / 20.01.2006

Notes:
Specific fuel consumption including 1 lubricating oil pump and 1 cooling water pump .
Engine elastically mounted .

1) No. 1 cylinder on flywheel end of engine
2) Cooling water temperature: Inlet oil cooler: 38 °C

Acceptance BV
BV 0626 HBR 06

Mechanic 17.02.2006 / Kahmann

Engineer 27.02.2006 / M. Mohr

Approved 27.02.06

SHOP TRAIL DATA

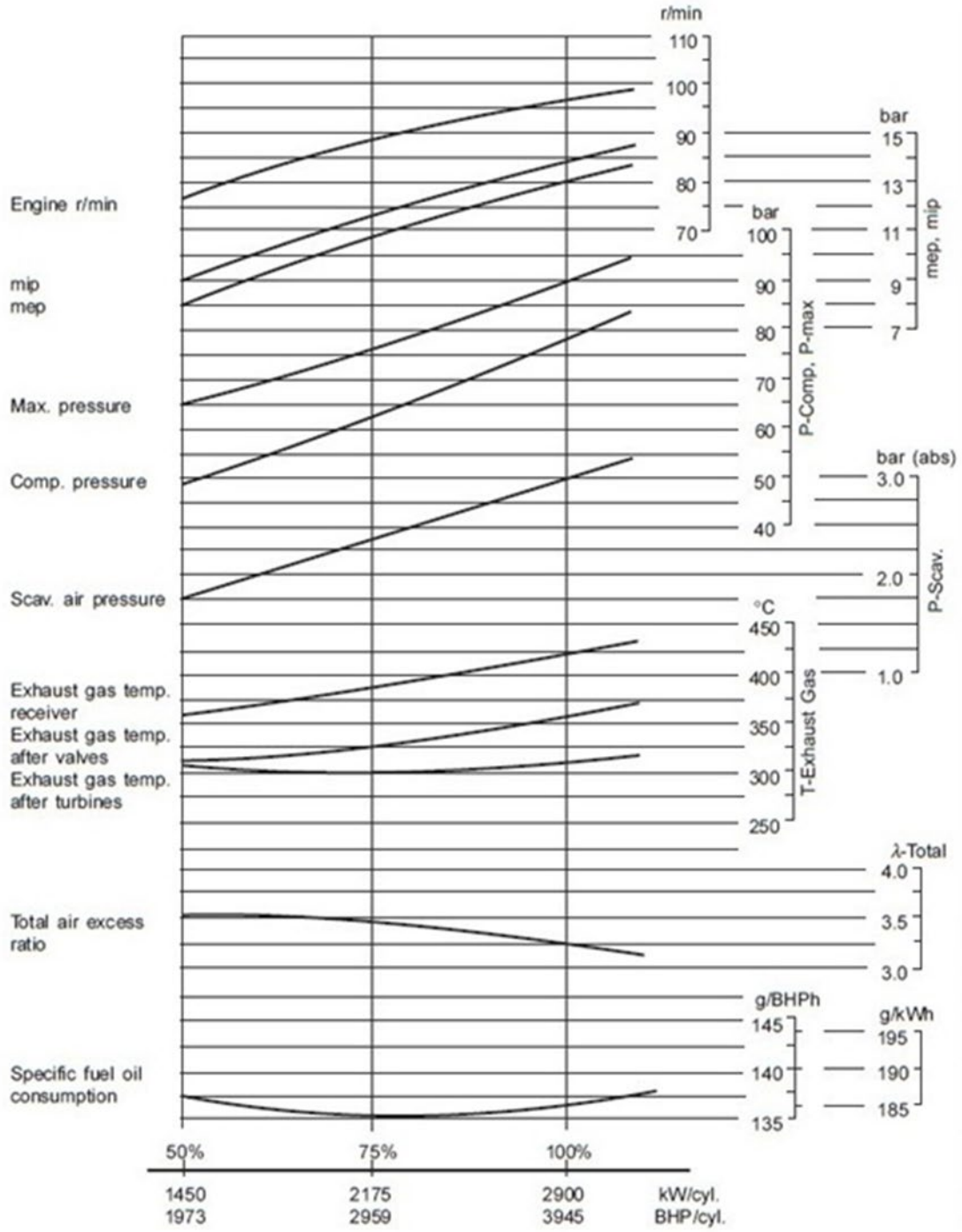
stx

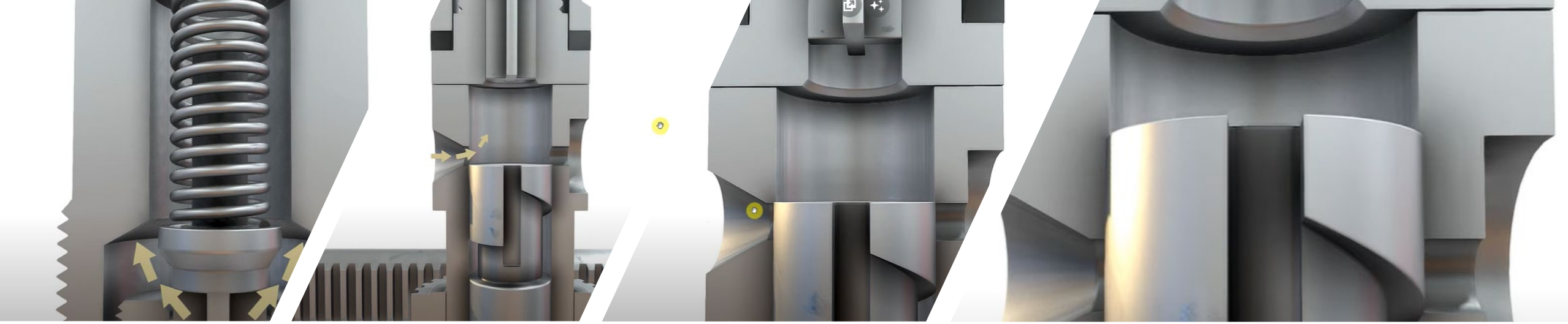
4. Summary Data of Shop Trial

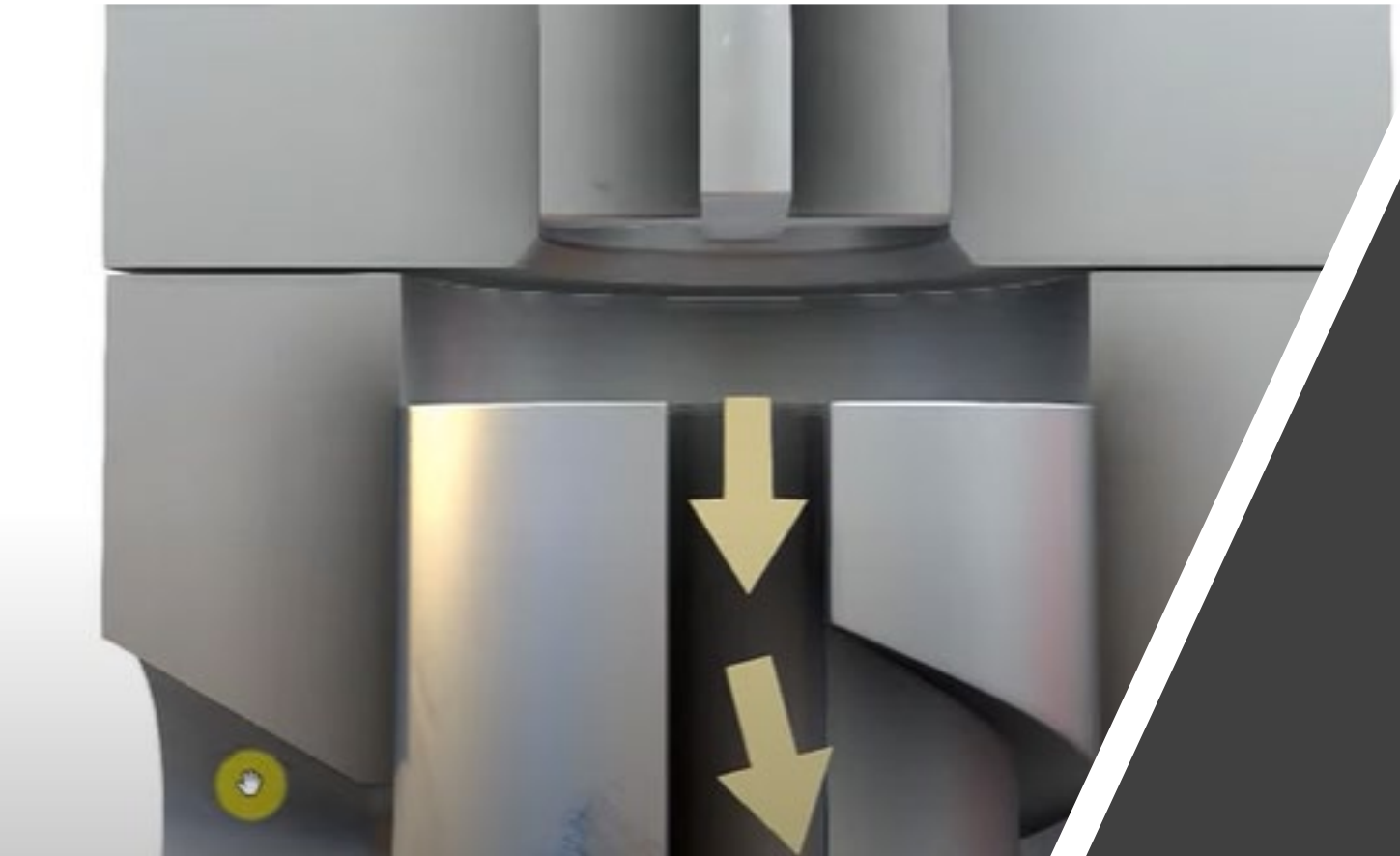
Checked by: S. H. Lee

Engine No. : SB6S50-7161	Owner		COSCO GROUP		Output		9,480	kW
Hull No. : ZS07035	Shipyard		COSCO ZHOUSHAN		Test Date		2008. 08. 12.	
	Unit	1	2	3	4	5	6	7
Load	%	25	50	75	90	100	110	
Engine speed	rpm	80.0	100.8	115.4	122.6	127.0	131.1	
Engine output	kW	2,370	4,740	7,110	8,532	9,480	10,428	
Room temperature	℃	29.0	29.0	28.0	30.0	31.0	31.0	
Room humidity	%	82.0	82.0	80.0	78.0	74.0	70.0	
Barometer pressure	mbar	1013	1013	1013	1013	1011	1010	
Fuel oil temperature	℃	36.0	38.0	38.0	38.0	38.0	38.0	
Fuel oil consumption	kg/h	444.6	843.0	1238.4	1491.0	1670.4	1863.0	
Fuel oil consumption	g/kW/h	187.59	177.85	174.18	174.75	176.20	178.65	
Fuel oil consumption (ISO.)	g/kW/h	186.16	176.38	172.78	173.17	174.67	177.10	
Max.Combustion pressure	MPa	7.47	10.08	13.27	14.98	14.98	14.95	
Compression pressure	MPa	4.50	7.02	9.93	11.52	12.38	13.65	
Mean effective pressure	MPa	0.75	1.20	1.57	1.77	1.90	2.03	
Fuel injection pump index	mm	39.0	53.3	66.2	75.0	80.0	86.0	
Exh.temp cylinder outlet	℃	282.5	298.3	298.3	315.0	333.3	360.8	
Exh.temp T/C inlet	℃	315.0	350.0	360.0	390.0	410.0	450.0	
Exh.temp T/C outlet	℃	275.0	270.0	240.0	240.0	250.0	265.0	
Turbocharger speed (X 1000)	rpm	5.8	10.1	12.7	13.7	14.4	15.1	
Scav.air temperature	℃	37.0	32.0	35.0	38.0	38.0	39.0	
Scav.air pressure	MPa	0.030	0.100	0.180	0.220	0.250	0.290	
Turbocharger gas inlet press	MPa	0.020	0.080	0.160	0.200	0.230	0.270	

Performans diyagramı



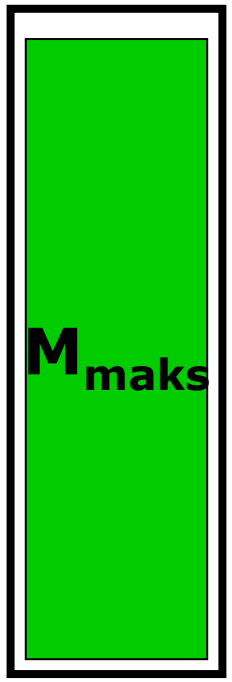


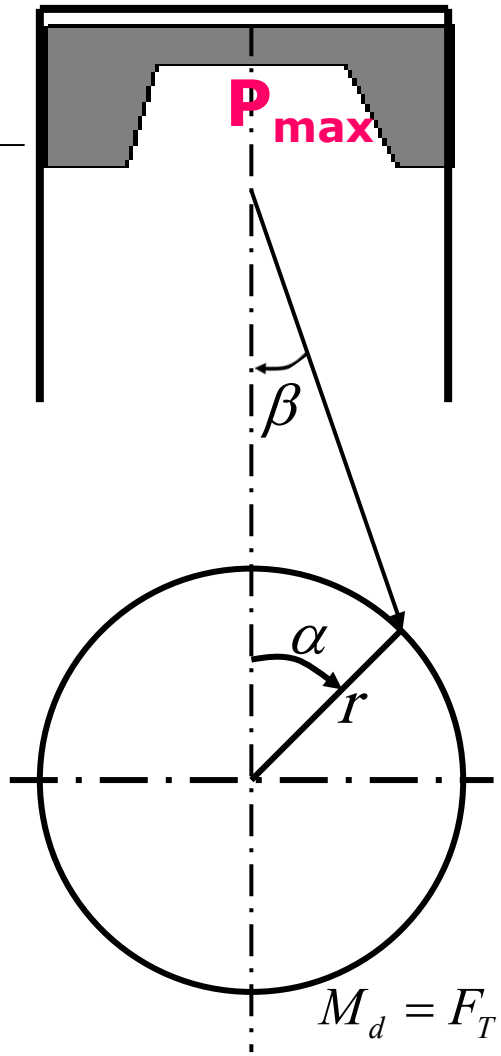


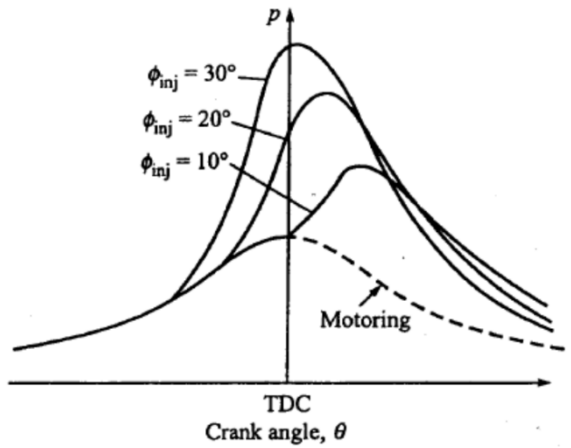
Pompa Basma başlangıcı ve Avans İlişkisi

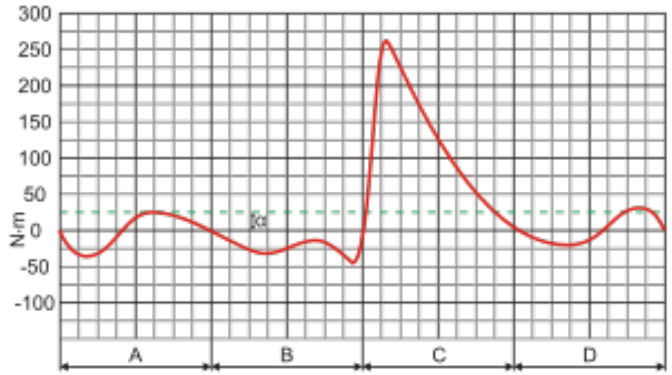
GÜÇ ve MOMENT ne ZAMAN MAKSİMUM

15-20 ^{0}KMA



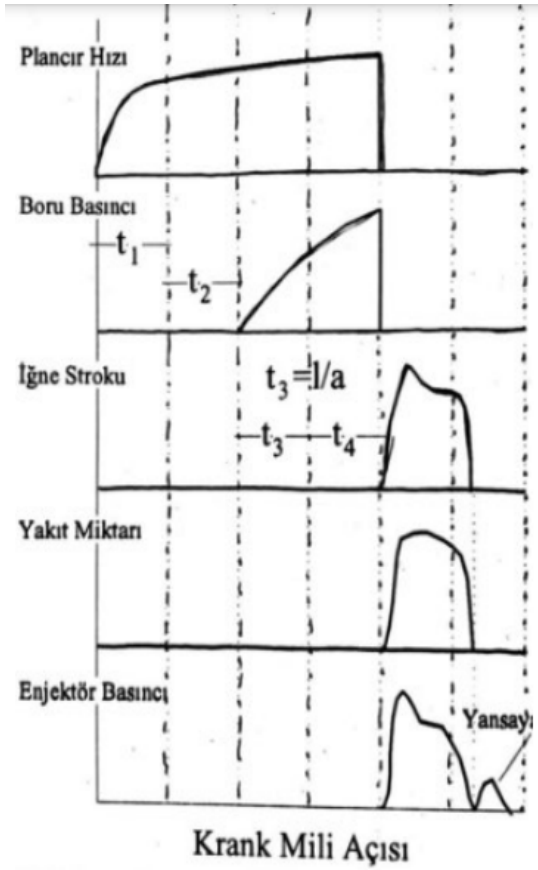






$$M_d = F_T.r = F_{yanma}\sin\alpha\left\{1+\frac{R.\cos\alpha}{\left[1-R^2\sin^2\alpha\right]^{1/2}}\right\}$$

Basma Başlangıcı-Püskürtme Gecikmesi-Püskürtme Gecikmesi



Şekil 1-Püskürtme gecikmesinin kademeleri

Püskürtme Kanunu: Püskürtülen yakıt miktarının krank mili açısına (veya zamana) göre değişimine denir. Püskürtme kanunu yanmanın gidişini etkiler. Buna göre püskürtme zamanlaması motordan en yüksek verim alınacak, ancak motorda mekanik ve ısıl zorlanma olmayacak şekilde ayarlanması gerekir. Bu, yanma sonucu oluşan maksimum basıncın ÜÖN dan 10-15 ^{0}KMA oluşması ile sağlanmaktadır.

Püskürtme Gecikmesi(t): Yakıt pompa plencerinin harekete geçmesiyle enjektör iğnesinin açılması arasında geçen zamandır. *Püskürtme gecikmesi* olarak adlandırılan bu süre çeşitli kademelerden oluşur. Bu kademeler,

$t=t_1+t_2+t_3+t_4$

t_1:Pompalama gecikmesi-pistonun hareket başlaması ile emme kanalının kapanma arasındaki zaman.

t_2:Sevk gecikmesi-Portun kapanmasıyla basın dalgasının yola çıkması arasındaki zaman.

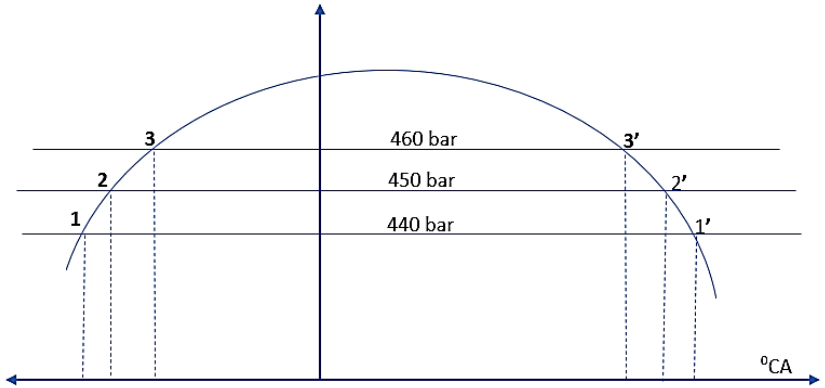
t_3:Yol gecikmesi-Dalganın harekete geçmesiyl enjektöre ulaşması arasındaki zaman

t_4:Açılma gecikmesi-Dalganın enjektöre ulaşmasıyla enjetörün açılması arasında geçen zaman

- Basma başlangıcı/start of Delivery
- Püskürtme Gecikmesi
- Tutuşma gecikmesi

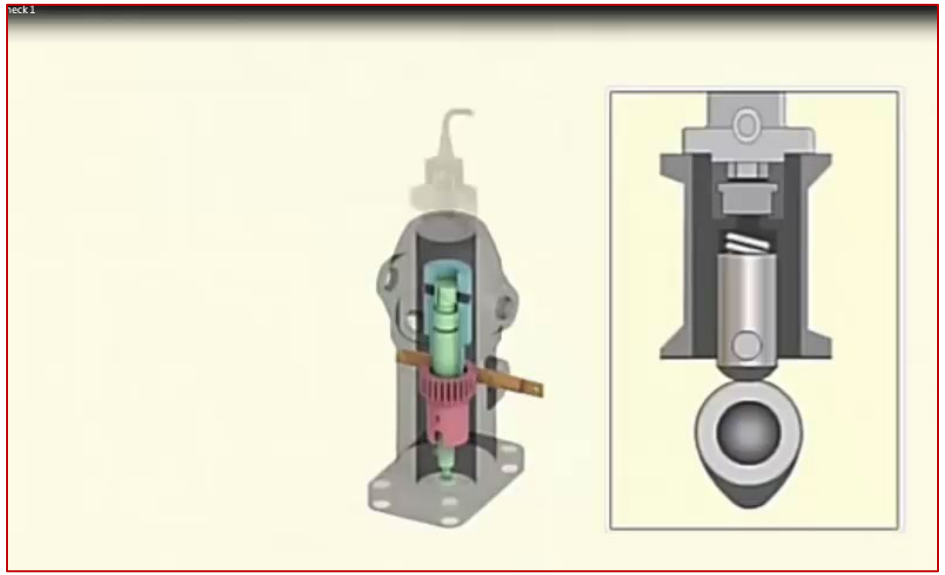
- ❑ Yakıt pompa delivery valf değişirse
- ❑ Enjektör yayı farklı olursa
- ❑ Pompa basma basıncı değirse
- ❑ Enjektör açma basıncı değişirse

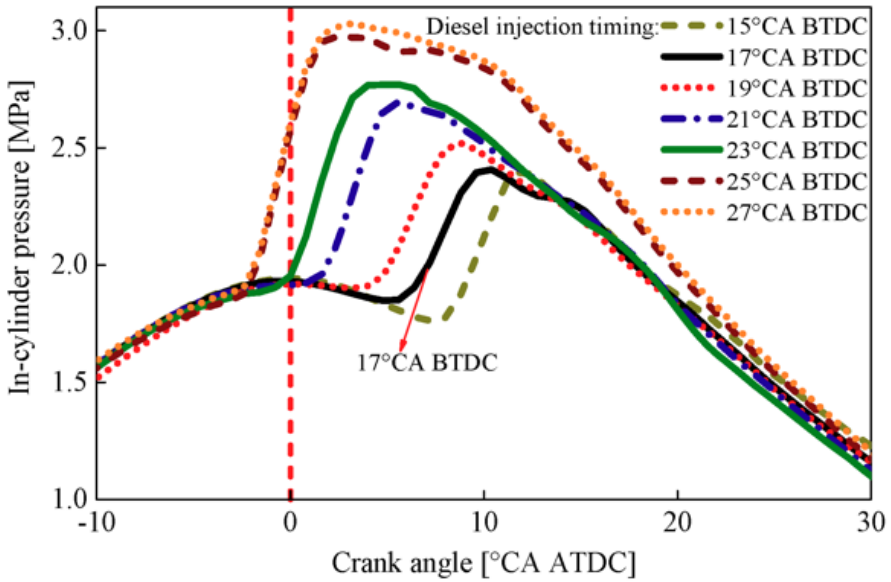
Püskürtme Avansı değişir.



Enjektör Açma Basınç Değişiminin Avansa etkisi

Yakıt Pompası Püskürtme Başlangıcı (Statik Avans)

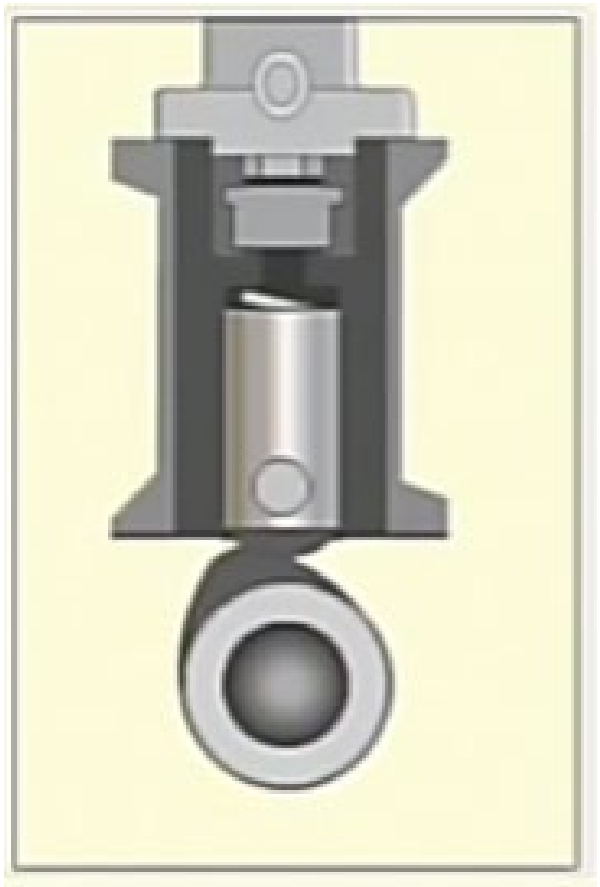


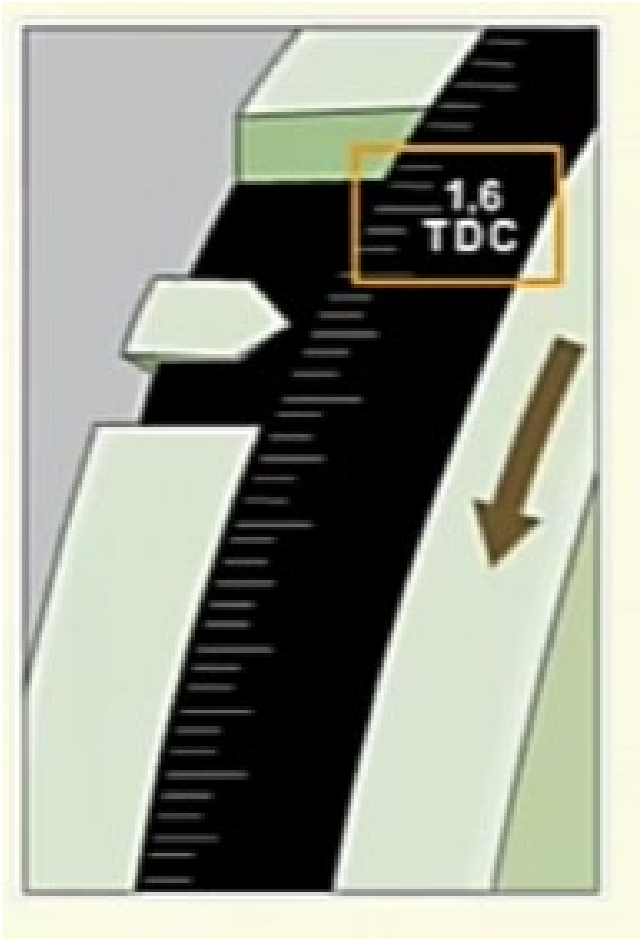


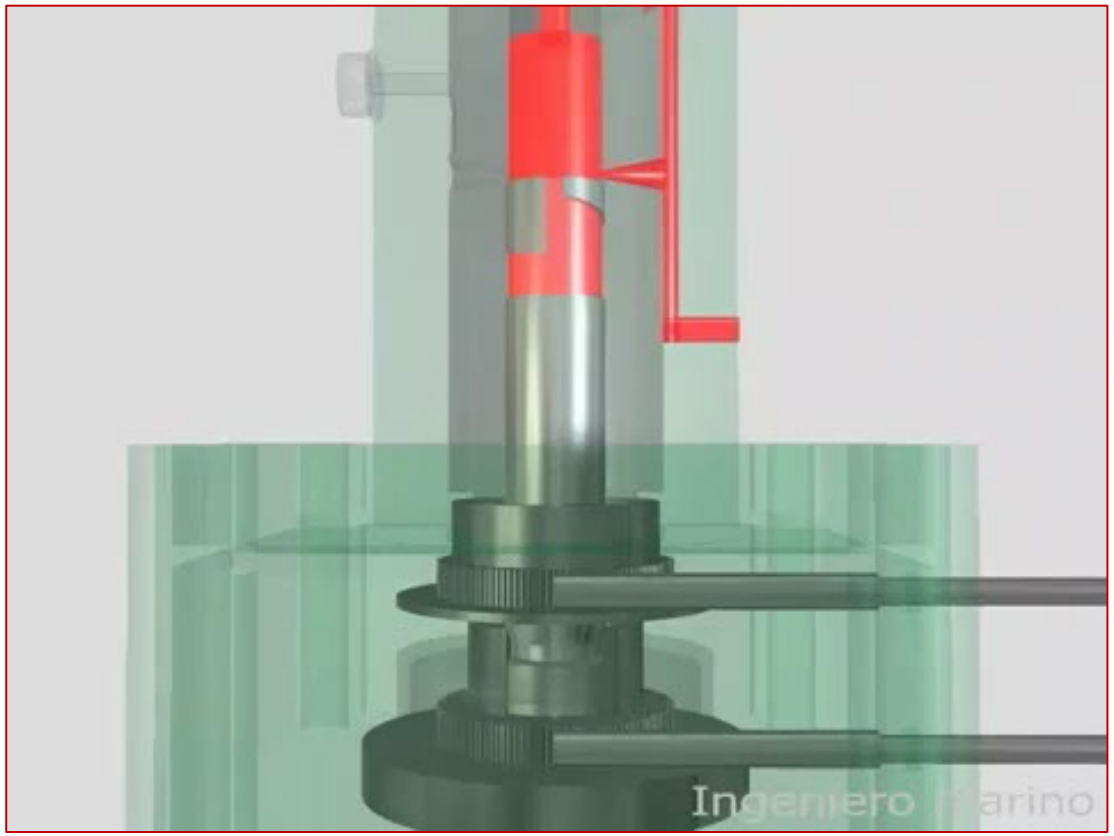
Püskürtme avansı, *yakıtın yanma odasına püskürtüldüğü zamanı ifade eder*. Yakıt özellikleri ve motor karakteristiğine bağlı olarak silindirde maksimum basıncın maksimum torku sağlayacak şekilde ayarlanır.

VIT-Püskürtme Avansını Ayarlama…

Püksürme Avansı VIT koluyla otomatik yapılmaktadır. Barıl hareket ettirilerek basma başlangıç açısı değiştirilmektedir.



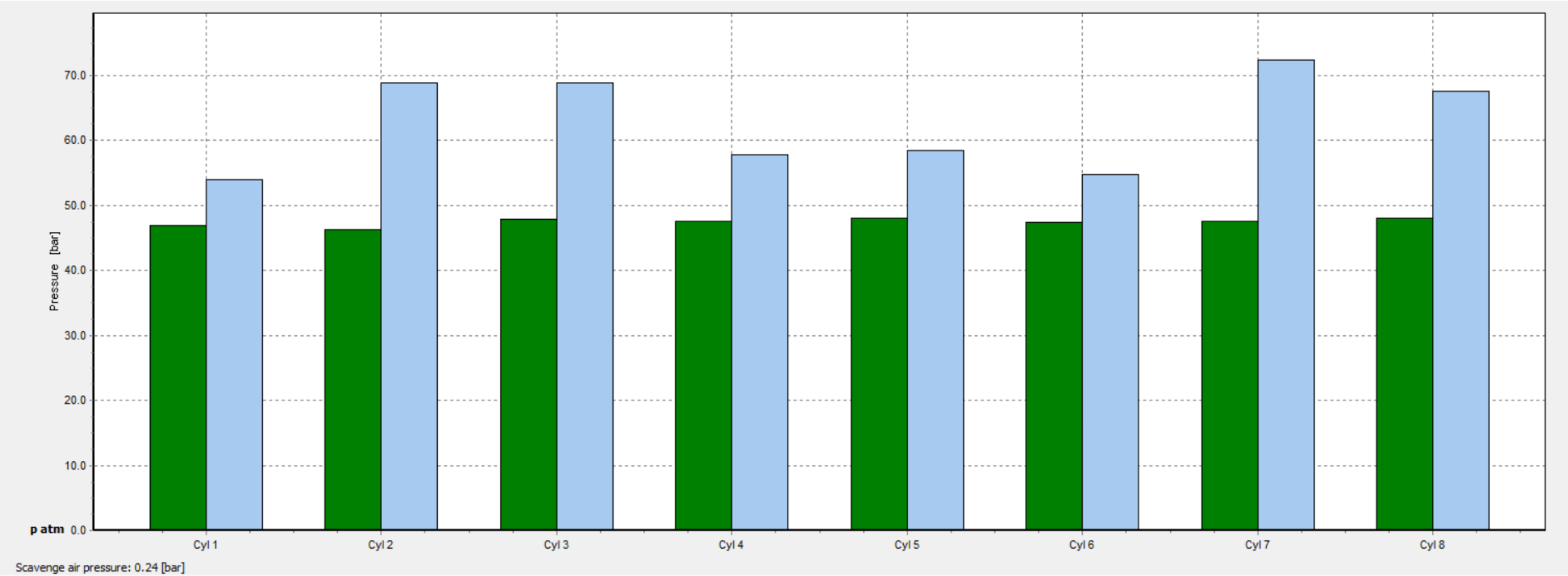




MAK 8M20

MAK 8M20

P_{max} ve P_{com} ölçümüne göre ölçüm yaptığınız ana makine hakkındaki yorumunuz ve çözüm öneriniz nedir?



Scavenge air pressure: 0.24 [bar]

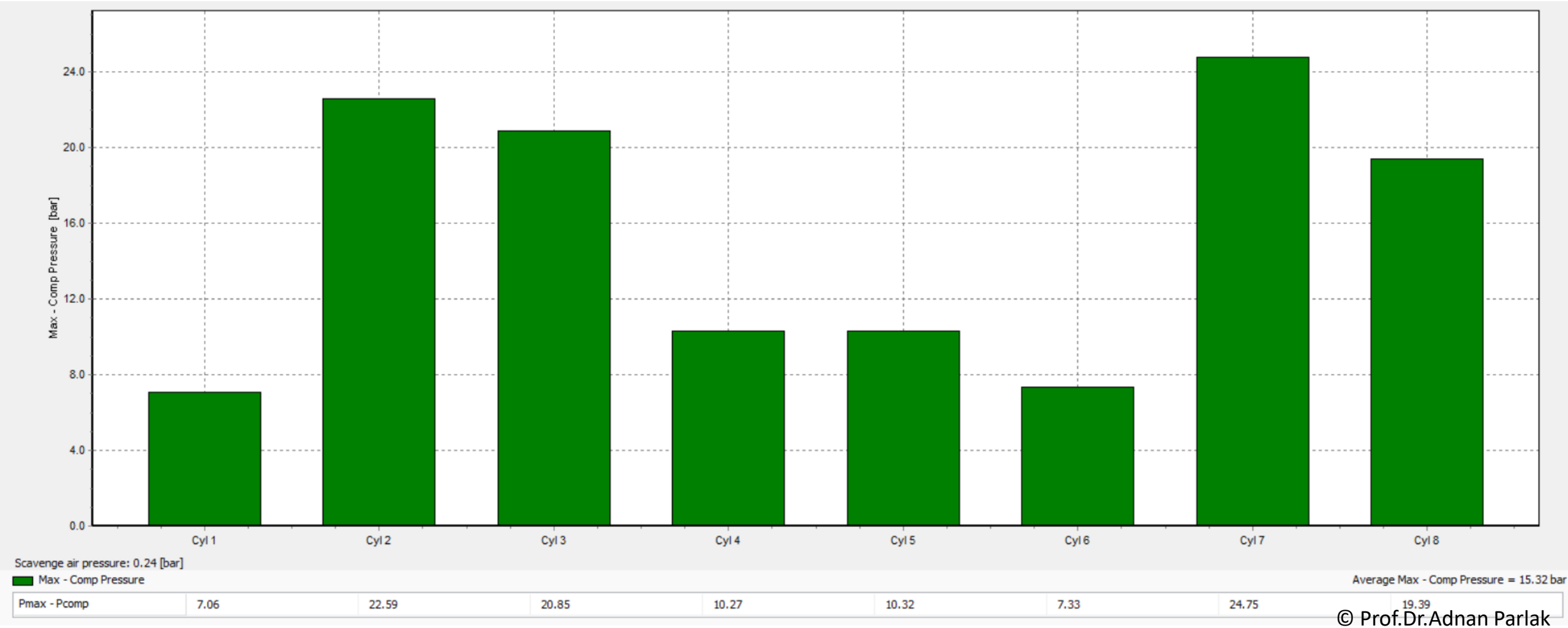
compression pressure | maximum pressure

Average p(comp) = 47.4 bar | Average p(max) = 62.8 ba

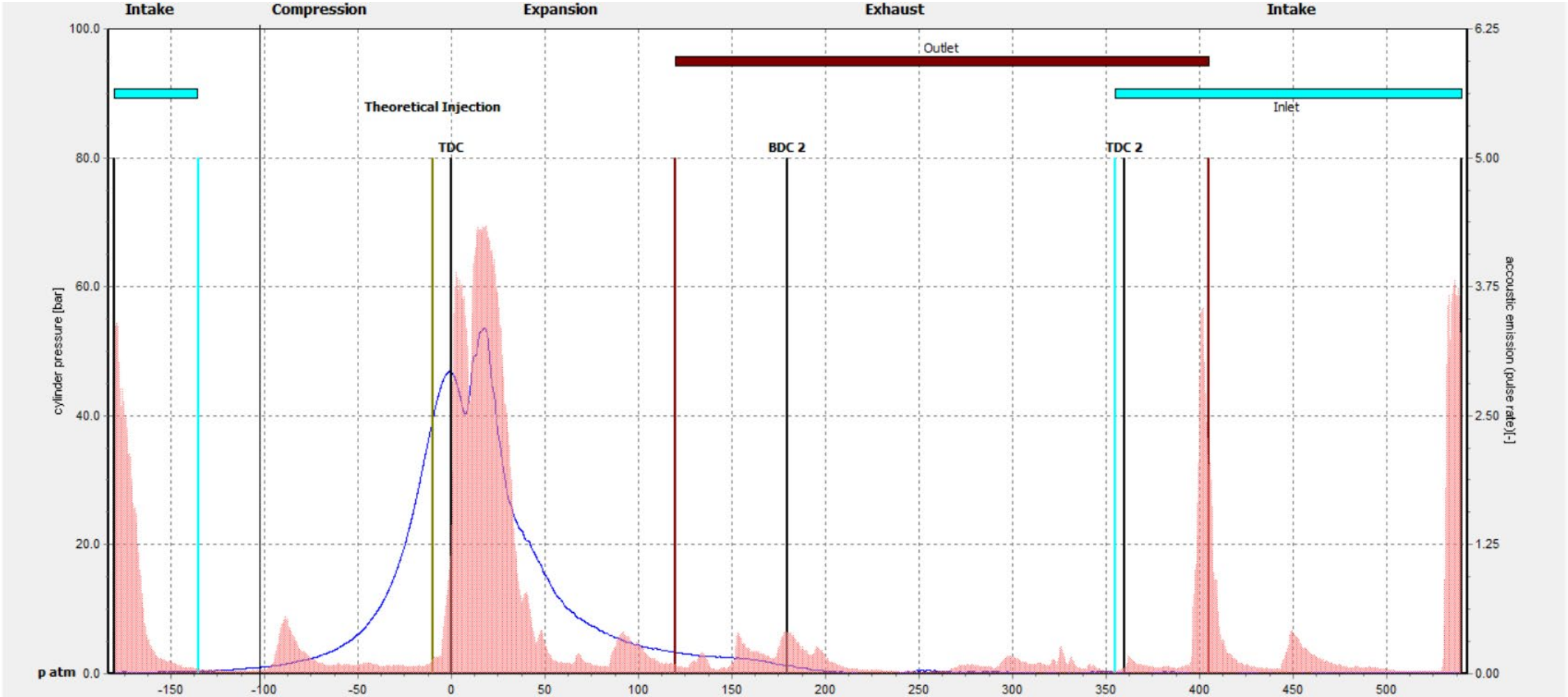
p comp	46.8	46.3	47.9	47.5	48.0	47.3	47.5	48.1
p max	53.9	68.9	68.7	57.8	58.3	54.7	72.3	67.5

Pmax-Pcom

Pmax-Pcomp arasındaki farklılığın sebepleri neler olabilir?

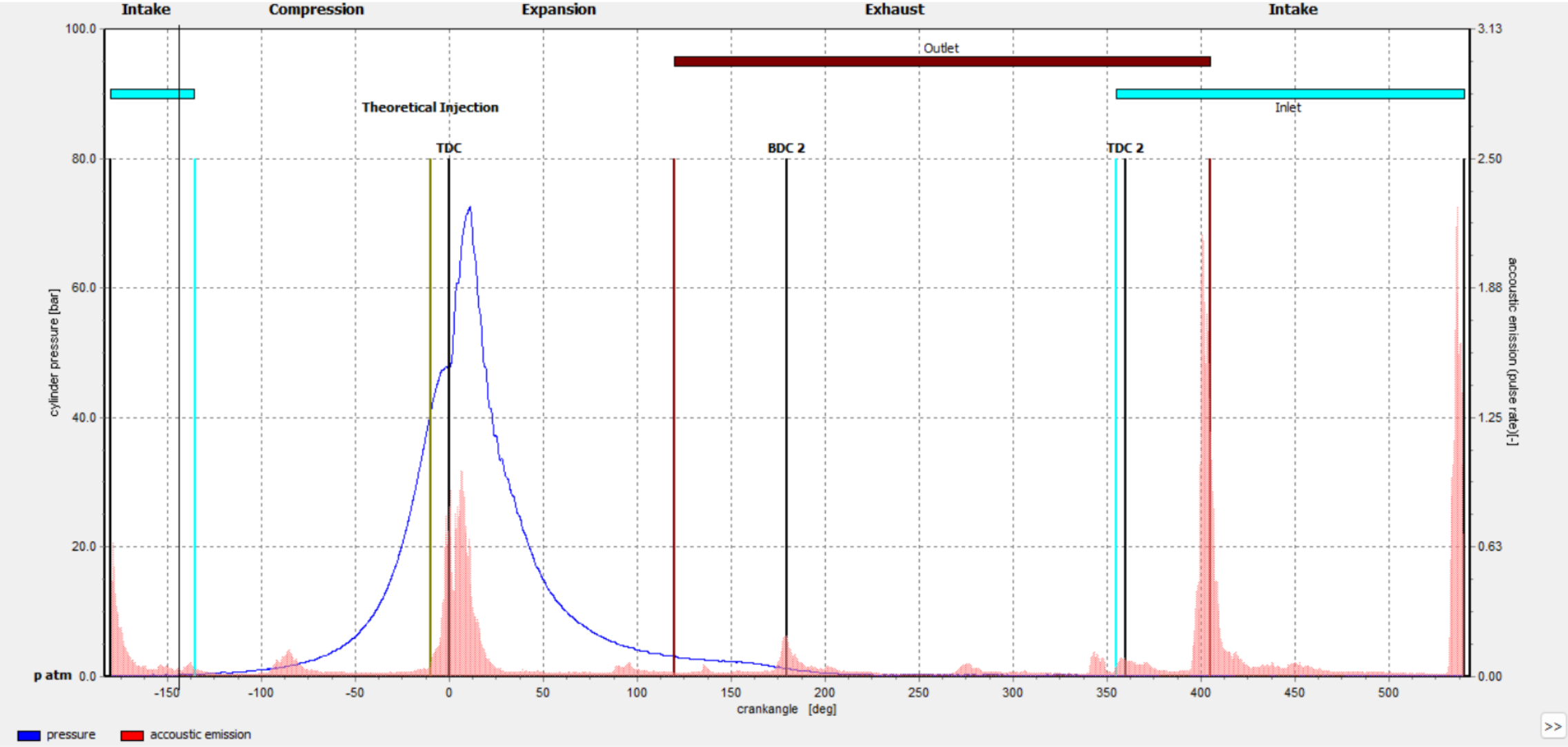


No:1 Silindire ait basınç gidişi ve püskürtme avansı hakkındaki görüşleriniz nedir?



p scav.	0.2	[bar]
p comp.	46.8	[bar]
p comp. theoretical	46.9	[bar]
p max.	53.9	[bar]
angle max.	17.8	[°CA]
Speed	977.0	[rpm]
Speed	97.7	[%]
ind. Power	46	[kW]
eff. Power	40	[kW]
Load	20.8	[%]
Probability of Leakage	< 5	[%]
delta Speed	2.5	[rpm]
bad cycles	---	[#]

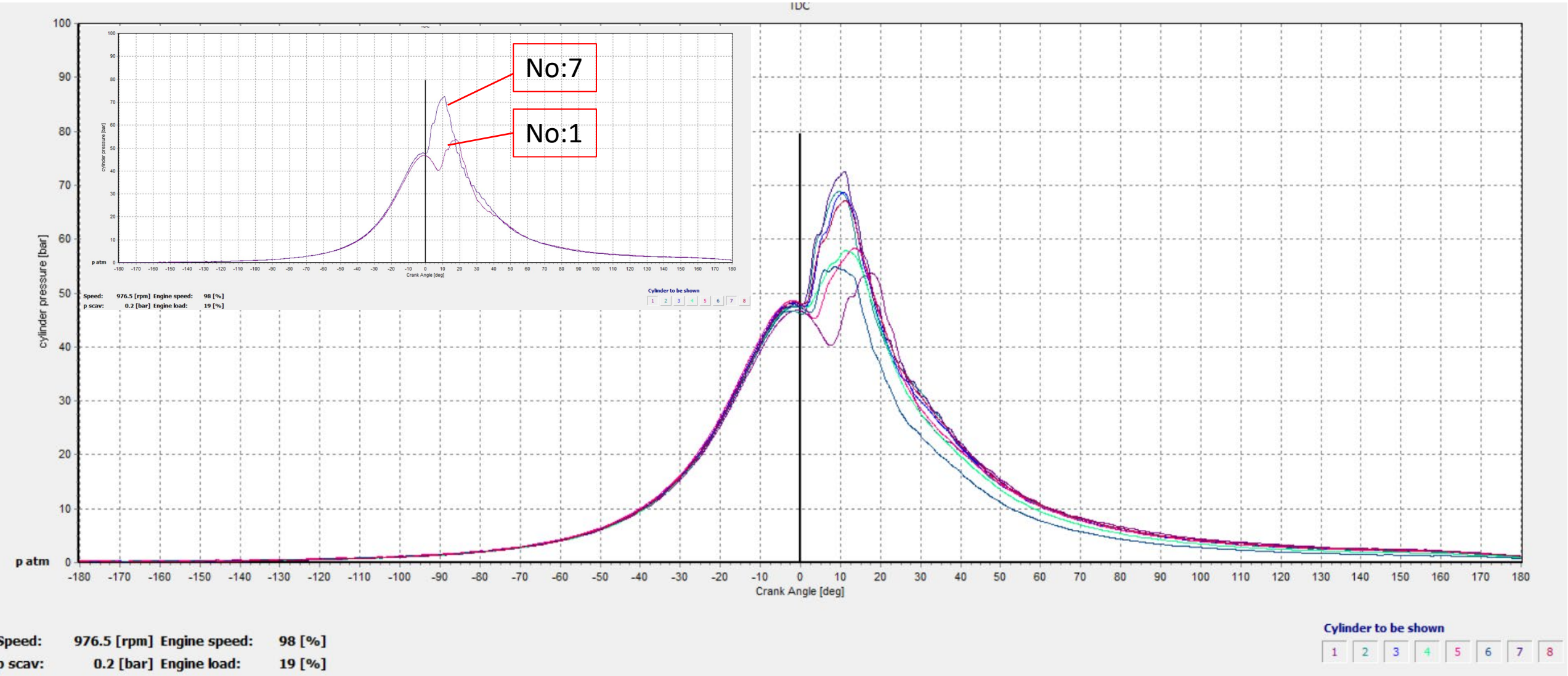
No:7 Silindire ait basınç gidişi ve püskürtme avansı hakkındaki görüşleriniz nedir?



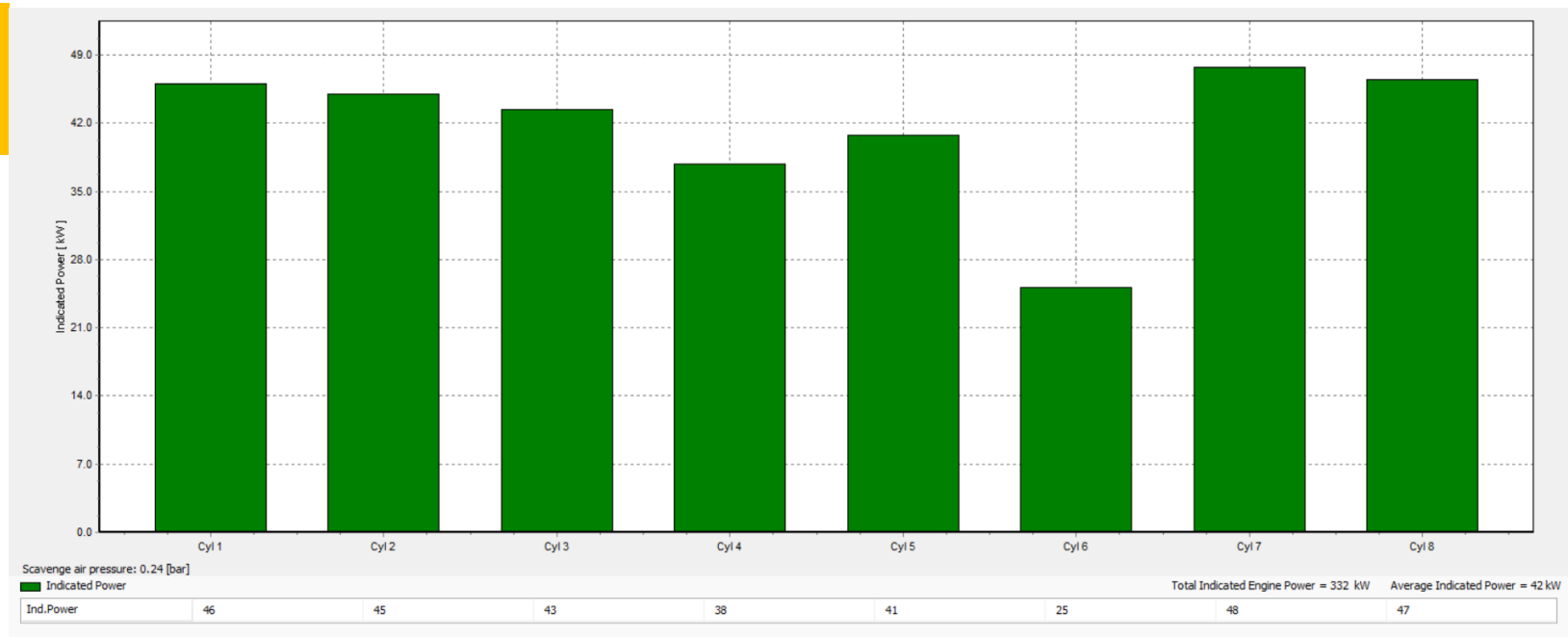
p scav.	0.2	[bar]
p comp.	47.5	[bar]
p comp. theoretical	48.6	[bar]
p max.	72.3	[bar]
angle max.	10.4	[°CA]
Speed	976.7	[rpm]
Speed	97.7	[%]
ind. Power	48	[kW]
eff. Power	41	[kW]
Load	21.6	[%]
Probability of Leakage	< 5	[%]
delta Speed	1.5	[rpm]
bad cycles	---	[#]

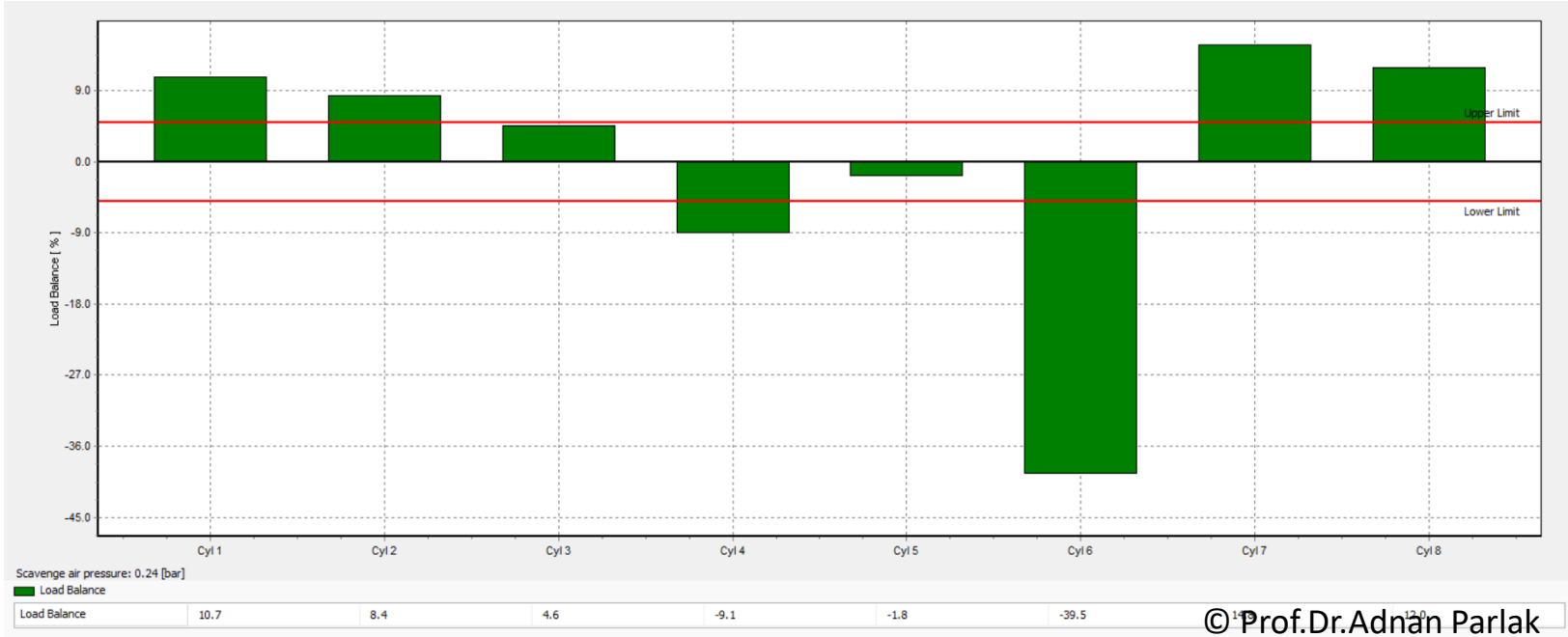
Angle to TDC [°]	-142.4
Pressure [bar]	0.42

%20 Yükte basınç_krank açısı diyagramı

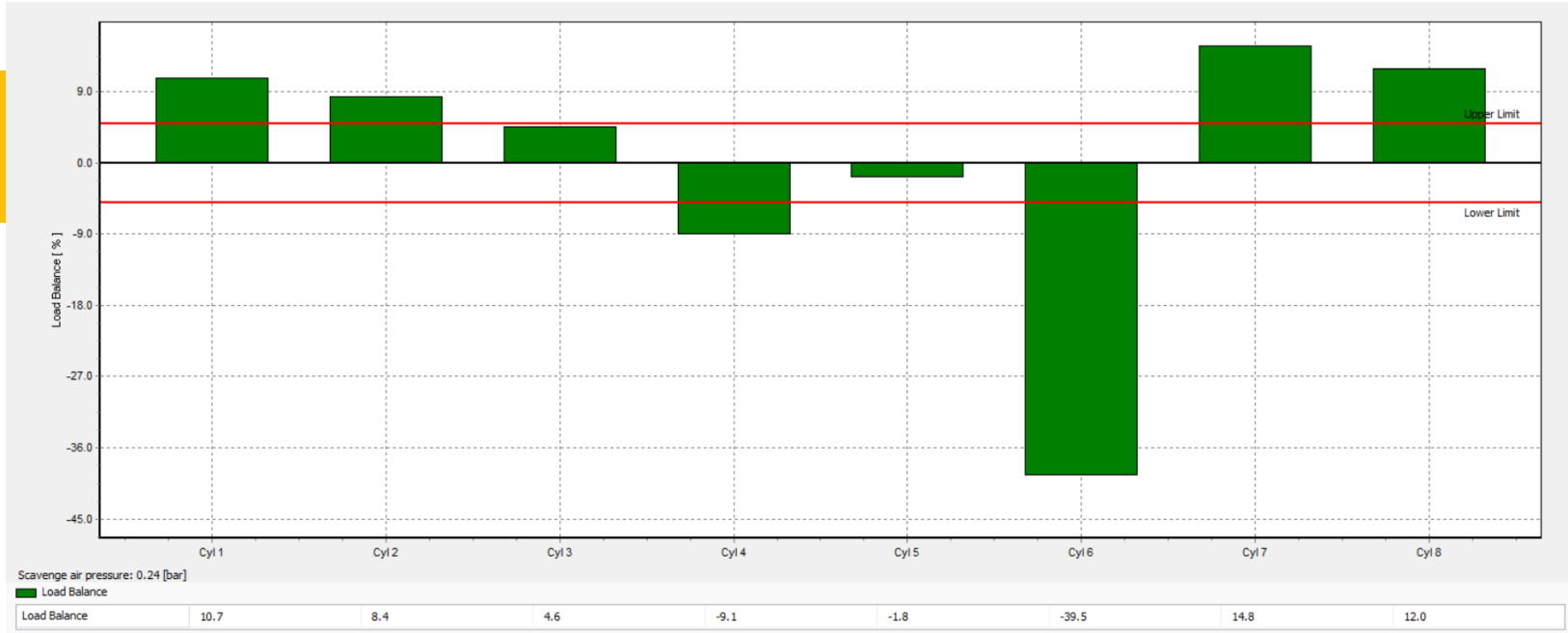


%20 yük Güç ve Yük Dağılımı





%20 yük Güç ve Yük Dağılımı



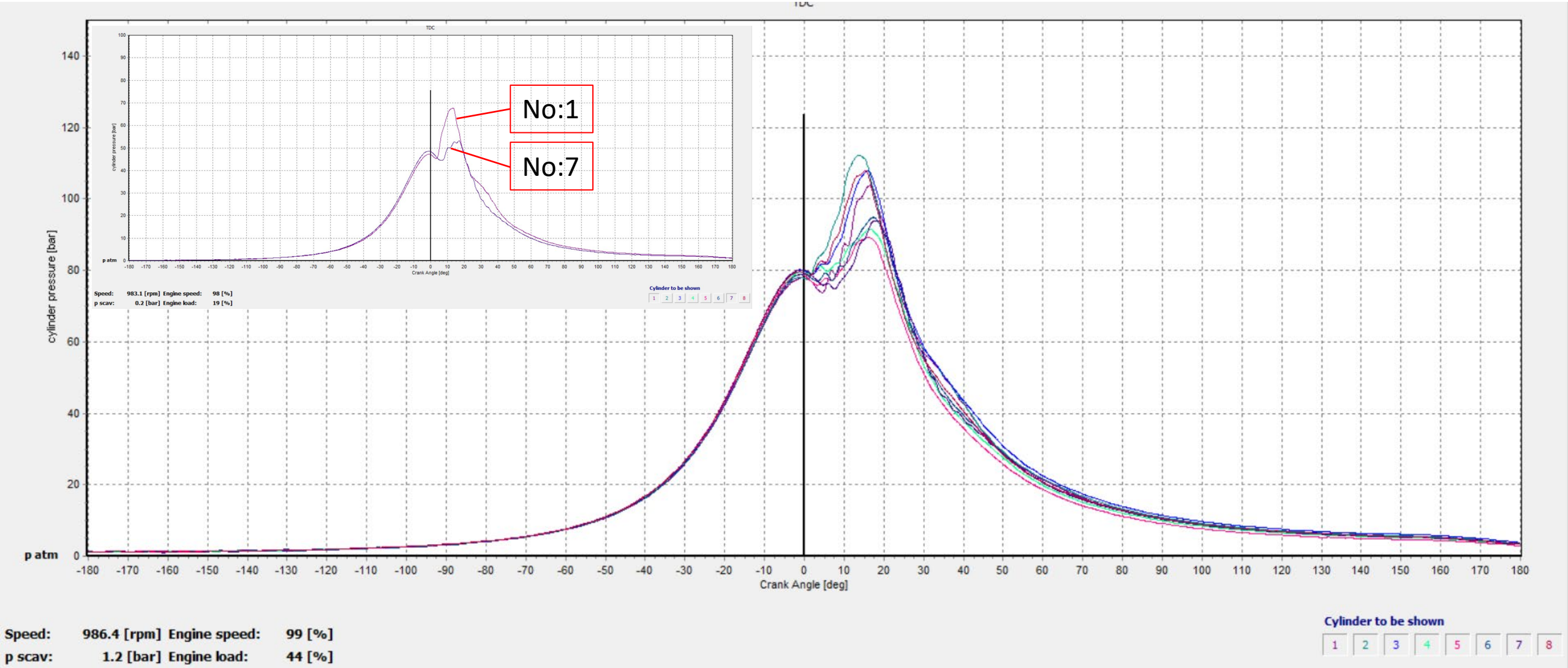
Load Balance	10.7	8.4	4.6	-9.1	-1.8	-39.5	14.8	12.0

ind. power: 332.5 [kW] -> mech. efficiency: 0.861 -> eff. power: 286.2 [kW] -> electrical efficiency: 0.94 -> el. power: 269.0 [kW]

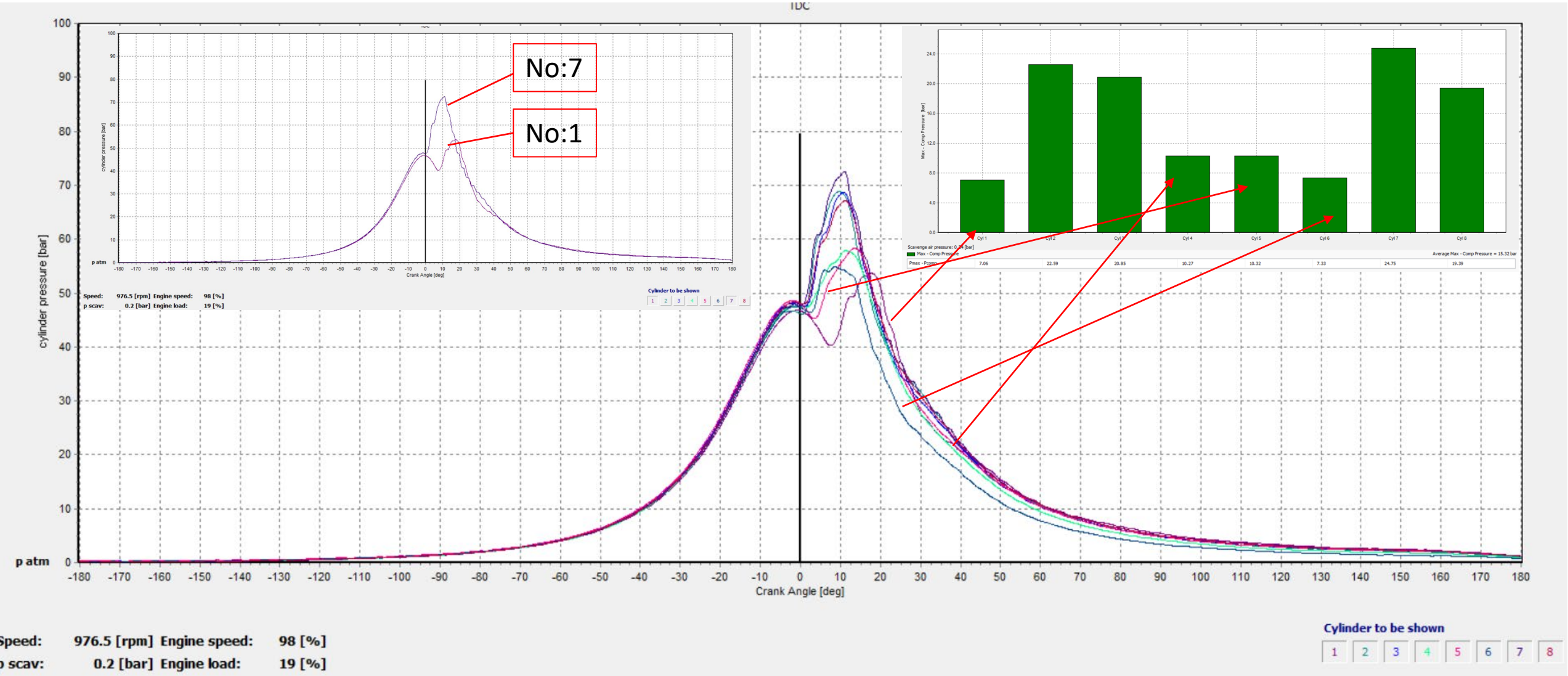
Scavenge air pressure: 0.24 [bar]

Value	Speed	Speed	p comp	p max	Angle p max	p comp/p scav	MIP	indicated Power	effective Power	Generator Power	Load	probable Leakage
Unit	[rpm]	[%]	[bar]	[bar]	[°Ca]	[-]	[bar]	[kW]	[kW]	[kW]	[%]	[%]
Cylinder 1	977.0	97.7	46.8	53.9	17.8	38.6	6.0	46.0	39.6	37.2	20.8	< 5
Cylinder 2	976.0	97.6	46.3	68.9	9.7	38.1	5.9	45.0	38.8	36.4	20.4	< 5
Cylinder 3	976.2	97.6	47.9	68.7	10.3	39.4	5.7	43.5	37.4	35.2	19.7	< 5
Cylinder 4	977.8	97.8	47.5	57.8	11.9	39.1	4.9	37.8	32.5	30.6	17.1	< 5
Cylinder 5	976.1	97.6	48.0	58.3	13.7	39.5	5.3	40.8	35.1	33.0	18.5	< 5
Cylinder 6	976.1	97.6	47.3	54.7	9.0	39.0	3.3	25.1	21.6	20.3	11.4	< 5
Cylinder 7	976.7	97.7	47.5	72.3	10.4	39.2	6.2	47.7	41.1	38.6	21.6	< 5
Cylinder 8	976.4	97.6	48.1	67.5	10.9	39.6	6.1	46.5	40.0	37.6	21.1	< 5
Total Value								332.5	286.2	269.0		
Average	976.5	97.7	47.4	62.8		39.1	5.4	41.6	35.8	33.6	18.8	
Maximum	977.8	97.8	48.1	72.3	17.8	39.6	6.2	47.7	41.1	38.6	21.6	
Minimum	976.0	97.6	46.3	53.9	9.0	38.1	3.3	25.1	21.6	20.3	11.4	
Difference	1.7	0.2	1.8	18.4		1.5	2.9	22.6	19.4	18.3	10.2	
Deviation [%]	0.2	0.2	3.8	29.4		3.7	54.3	54.3	54.3	54.3	54.3	

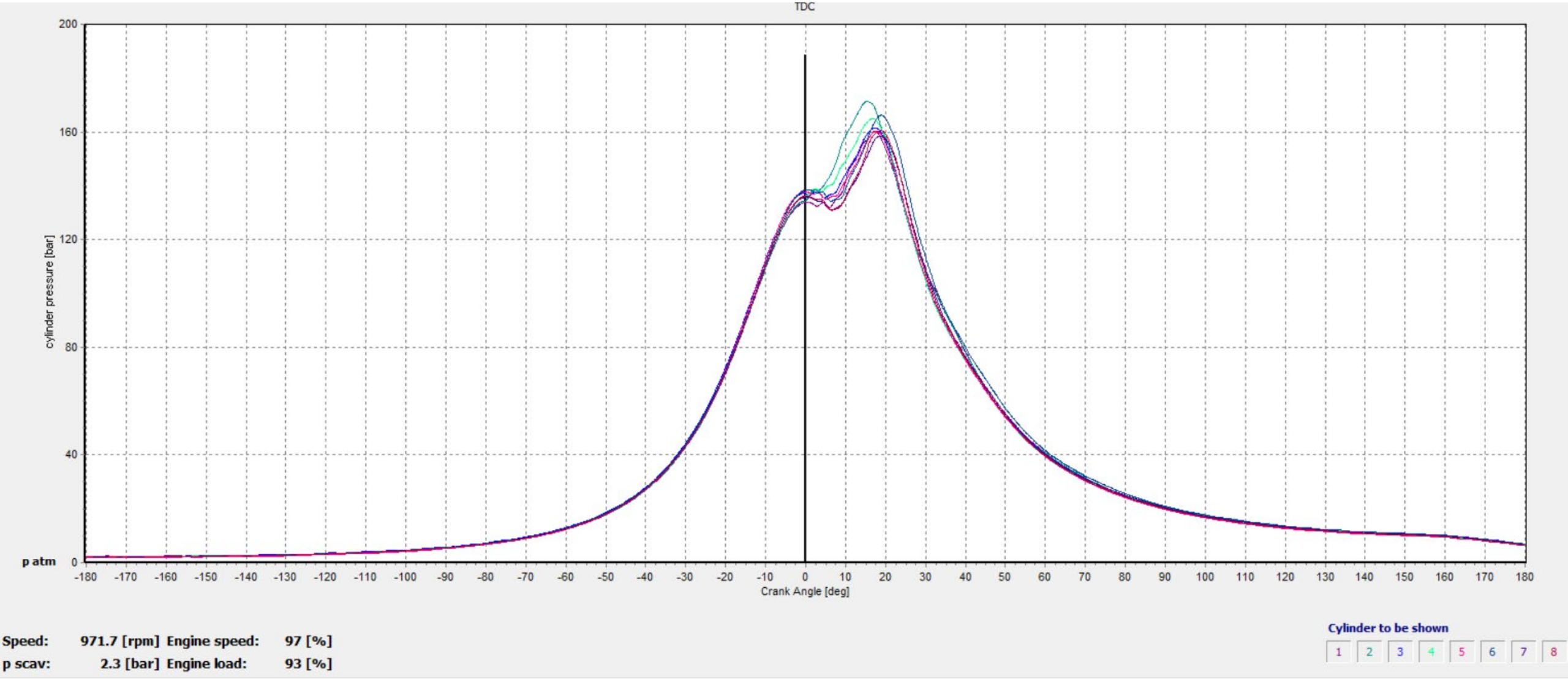
%44 Yükte basınç_krank açısı diyagramı



%20 Yükte basınç_krank açısı diyagramı



Pompa ve Enjektör değişimi ve ayarlama sonrası %93 yük

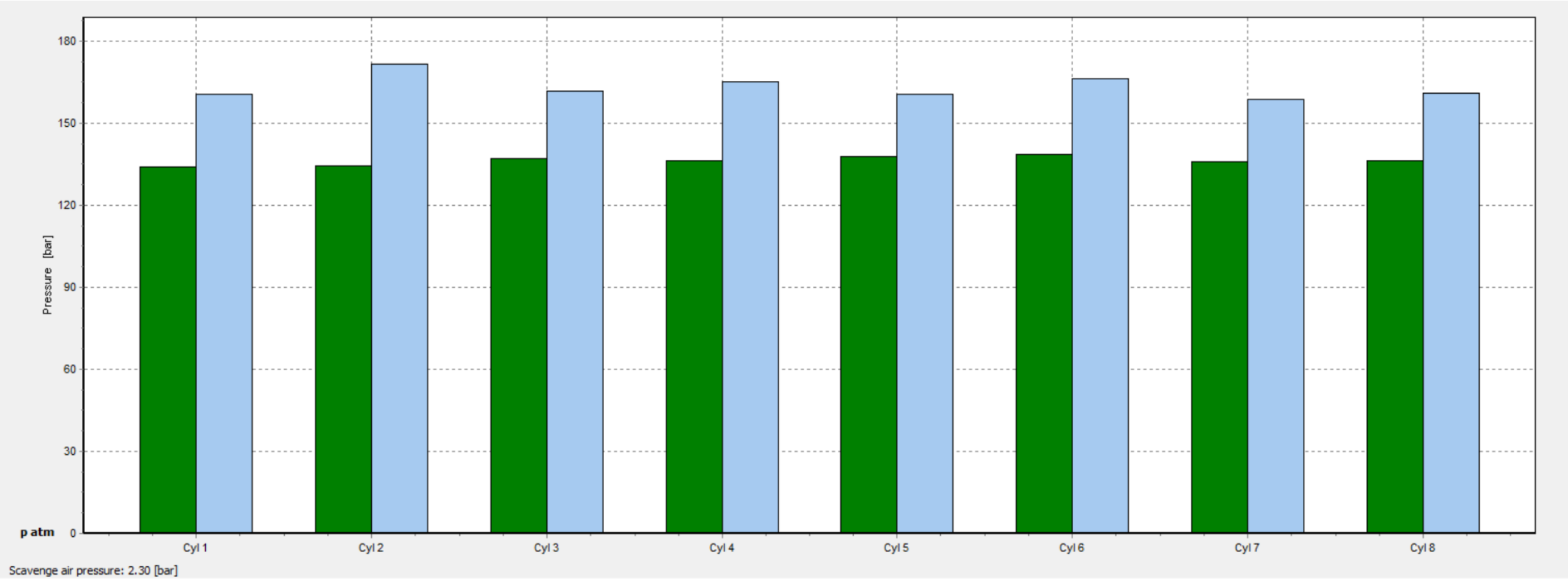


Speed: 971.7 [rpm] **Engine speed:** 97 [%]
p scav: 2.3 [bar] **Engine load:** 93 [%]

Cylinder to be shown

1 2 3 4 5 6 7 8

%93 yük Ayarlama sonrası Pmax ve Pcom değerleri



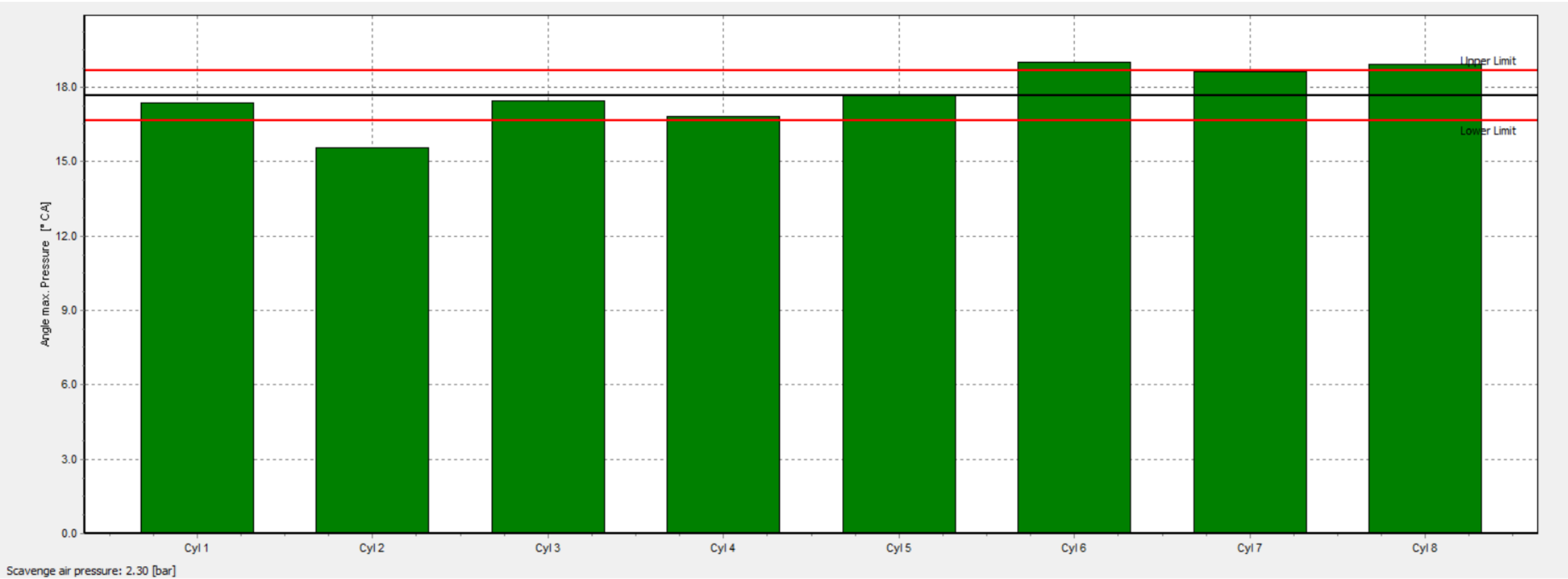
Scavenge air pressure: 2.30 [bar]

compression pressure maximum pressure

Average p(comp) = 136.2 bar Average p(max) = 163.1 bar

p comp	133.8	134.5	137.1	136.3	137.7	138.4	135.7	136.2
p max	160.5	171.4	161.6	165.1	160.4	166.3	158.6	160.8

%93 yük Ayarlama sonrası *aPmax* değerleri



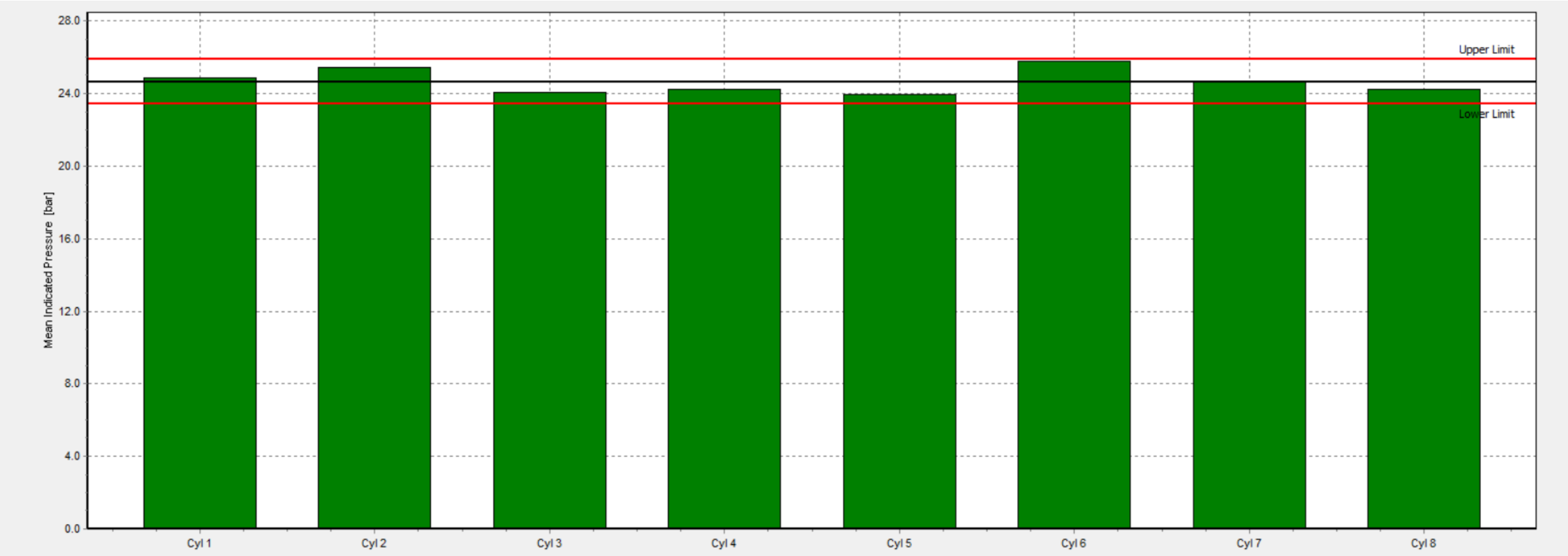
Scavenge air pressure: 2.30 [bar]

angle of maximum pressure

Average angle max. pressure = 17.7 °CA

Angle	17.4	15.6	17.4	16.8	17.7	19.0	18.6	18.9

%93 yük Ayarlama sonrası MIP (*Pmi*) değerleri



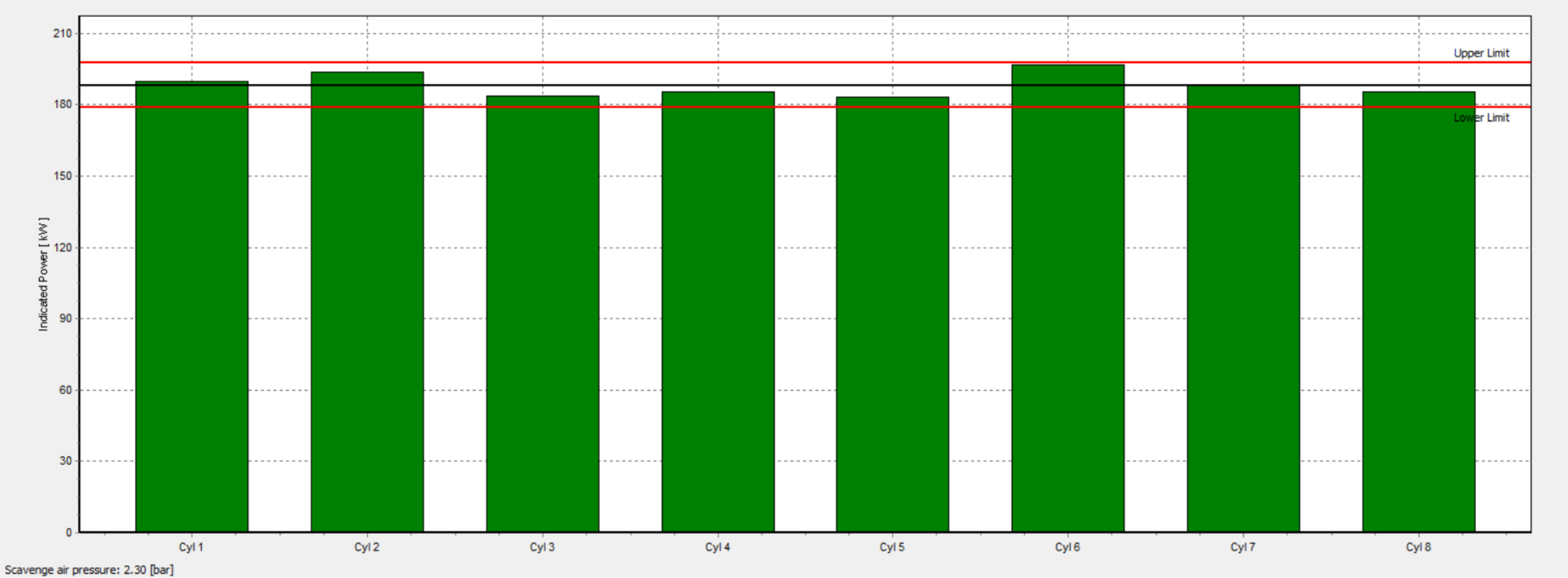
Scavenge air pressure: 2.30 [bar]

Mean Indicated Pressure (MIP)

Average Mean Indicated Pressure = 24.66 bar

MIP	24.86	25.45	24.07	24.24	23.98	25.81	24.63	24.25

%93 yük Ayarlama sonrası Güç (*Pe*) değerleri



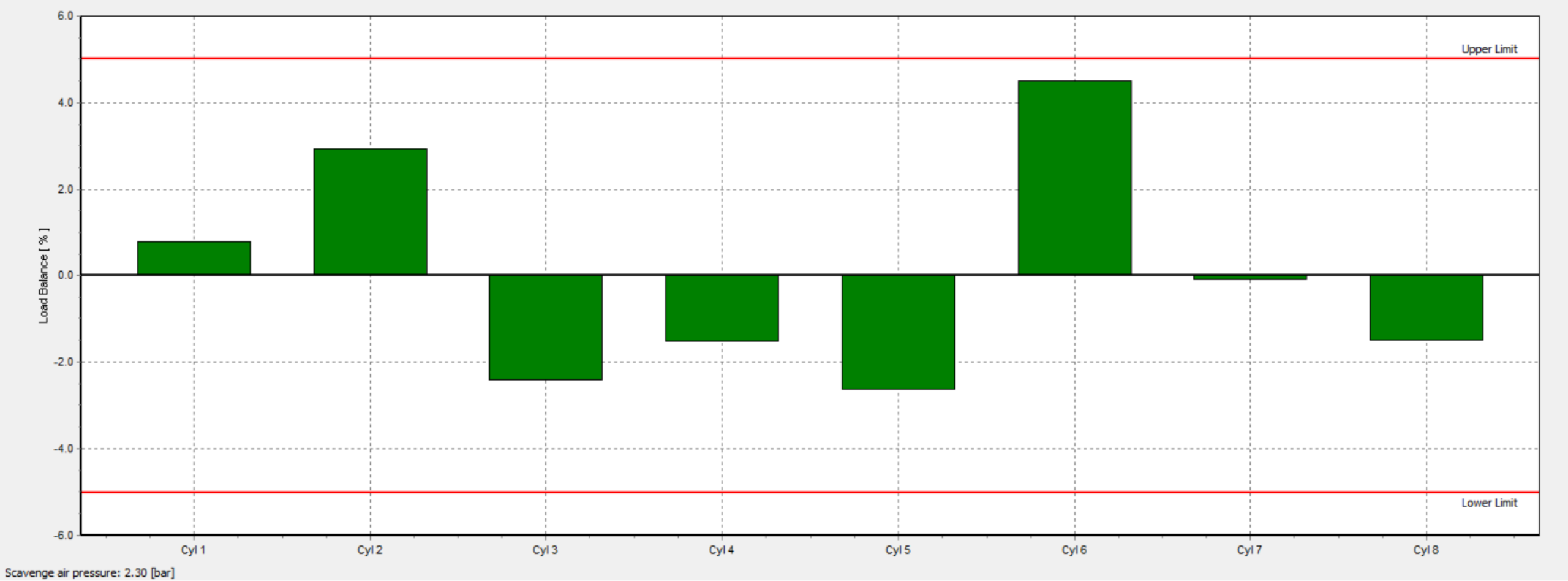
Scavenge air pressure: 2.30 [bar]

Indicated Power

Total Indicated Engine Power = 1505 kW Average Indicated Power = 188 kW

Ind.Power	190	194	184	185	183	197	188	185

%93 yük Ayarlama sonrası Güç (*Pe*) değerleri

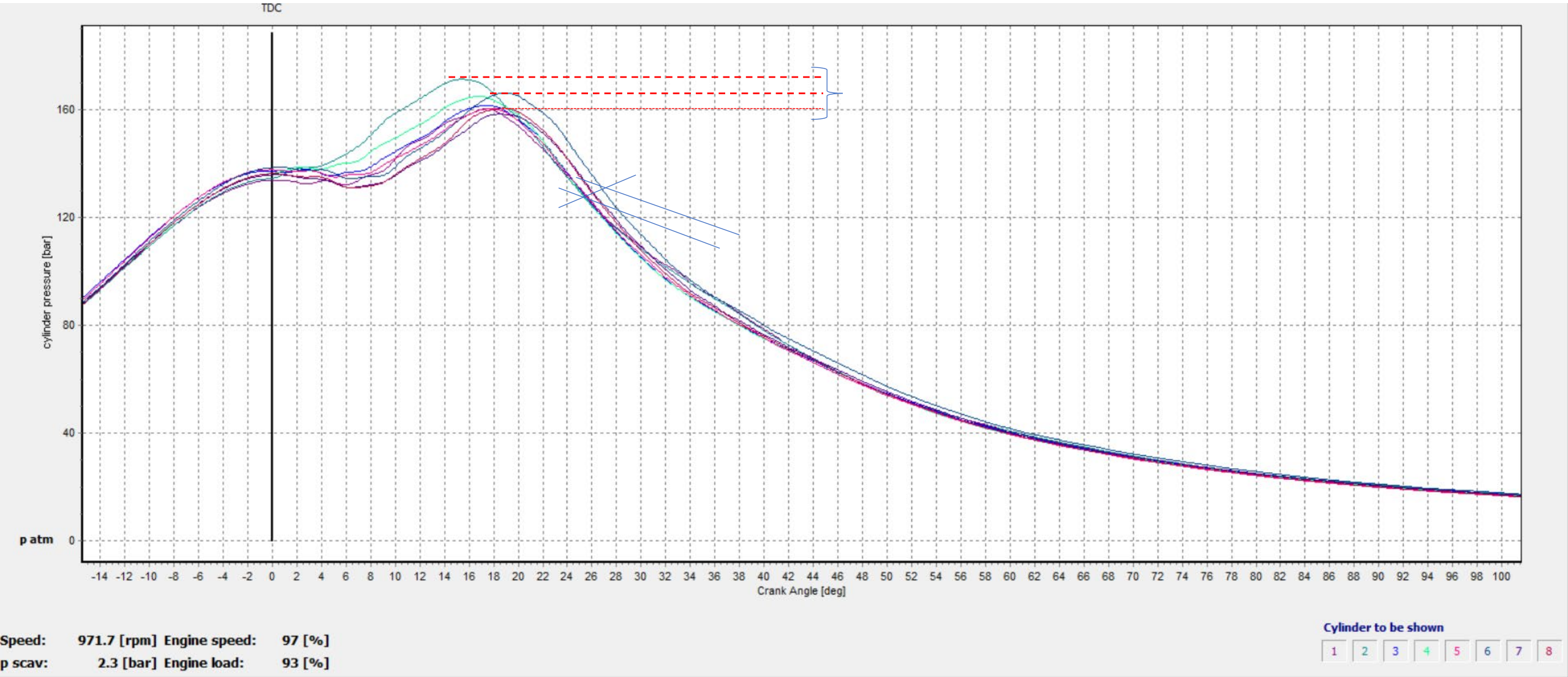


Scavenge air pressure: 2.30 [bar]

Load Balance

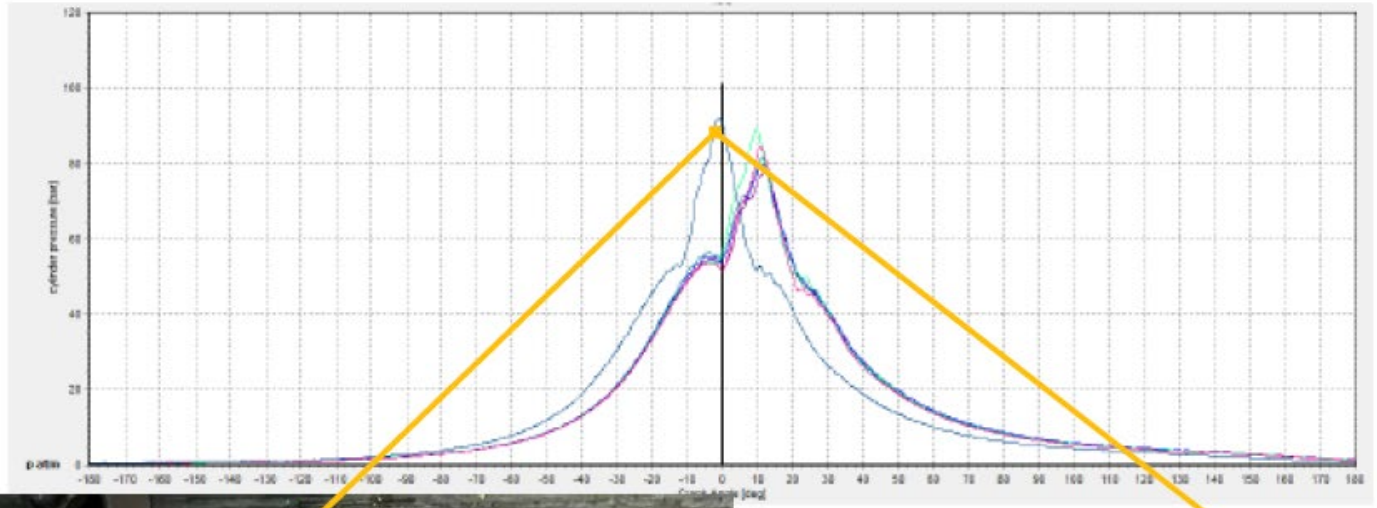
Load Balance	0.8	2.9	-2.4	-1.5	-2.7	4.5	-0.1	-1.5

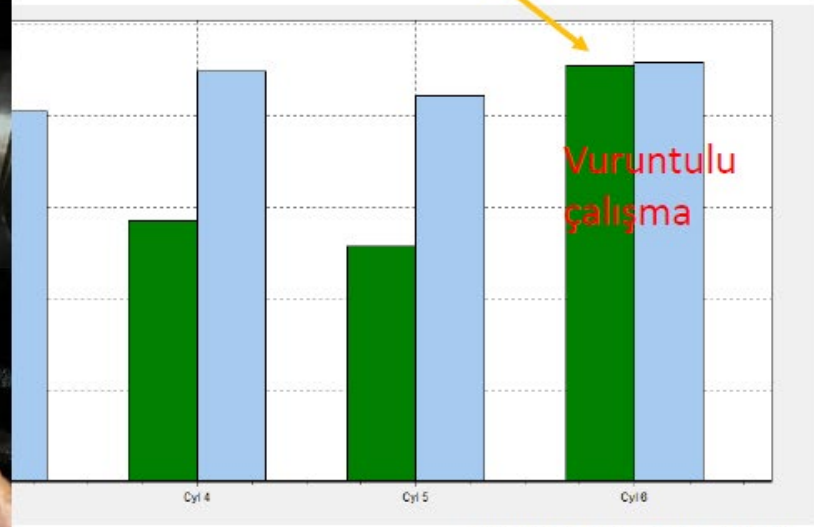
P_{max} değerlerinde farklılık var iken Yük dengesi ±5% lik dilim içerisinde düzgün dağılım sergiliyor?



DEUTZ TBD 645 L6

Püskürtme Avansı bozuk silindirde Pcomp ve Pmax değişimi

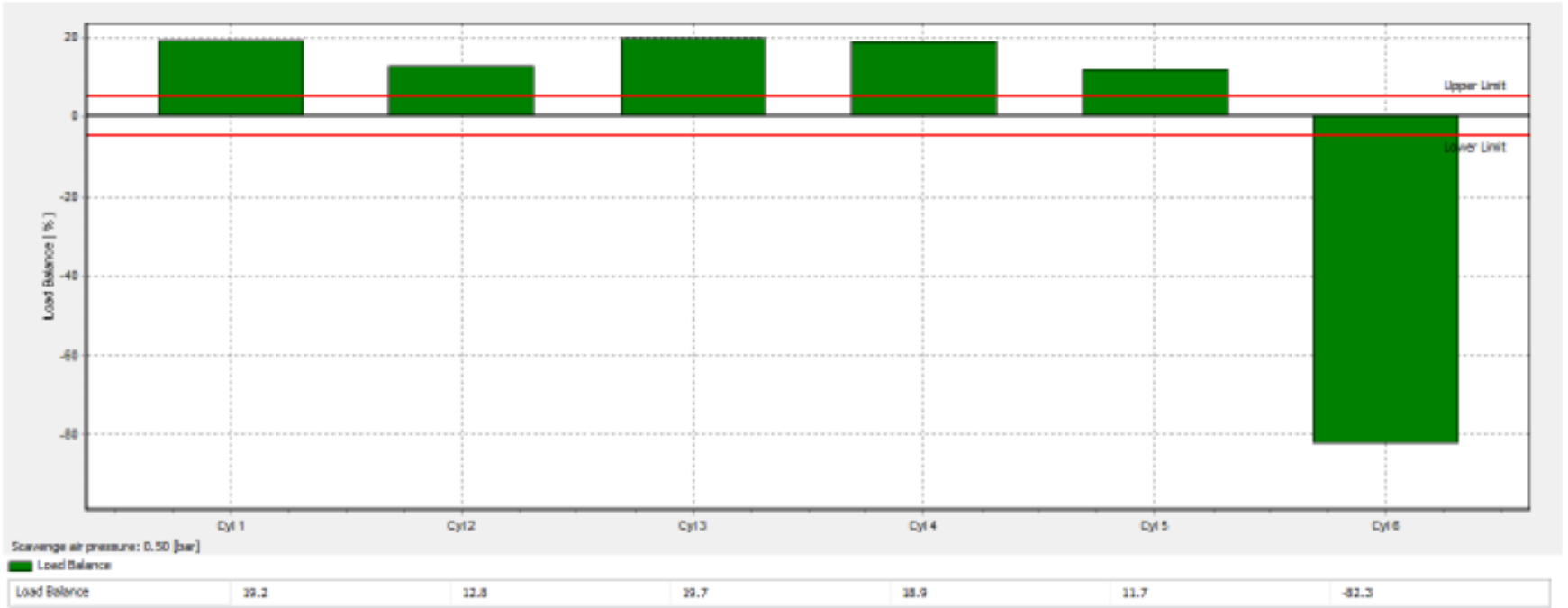




Average p(comp) = 60.5 bar Average p(max) = 84.6 bar

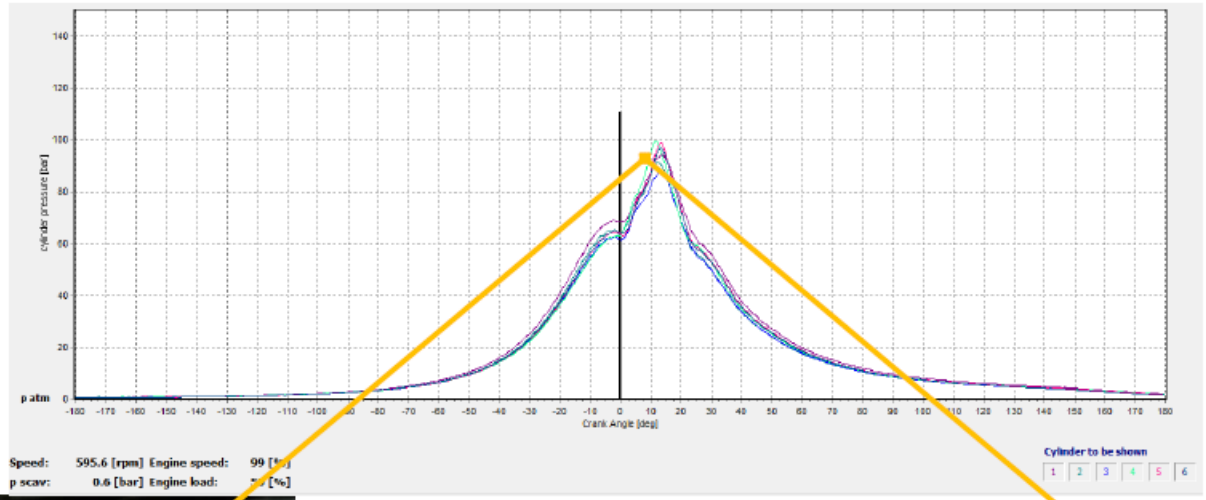
	57.1	51.7	90.9
	89.7	84.5	91.7

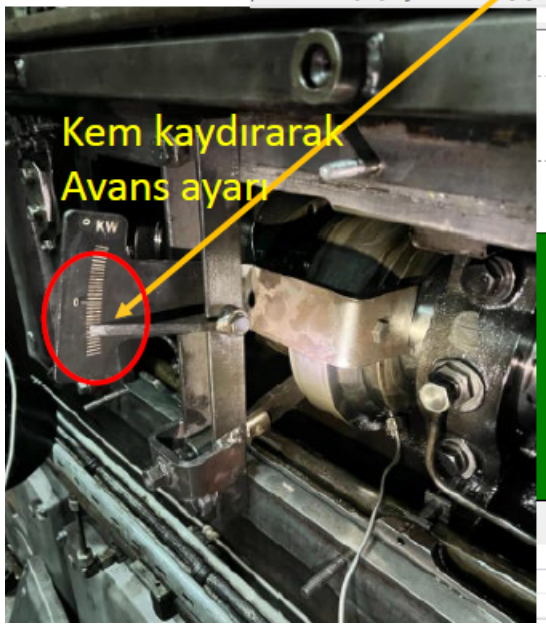
Silindirler arası yük dengesi bozuk ana makine

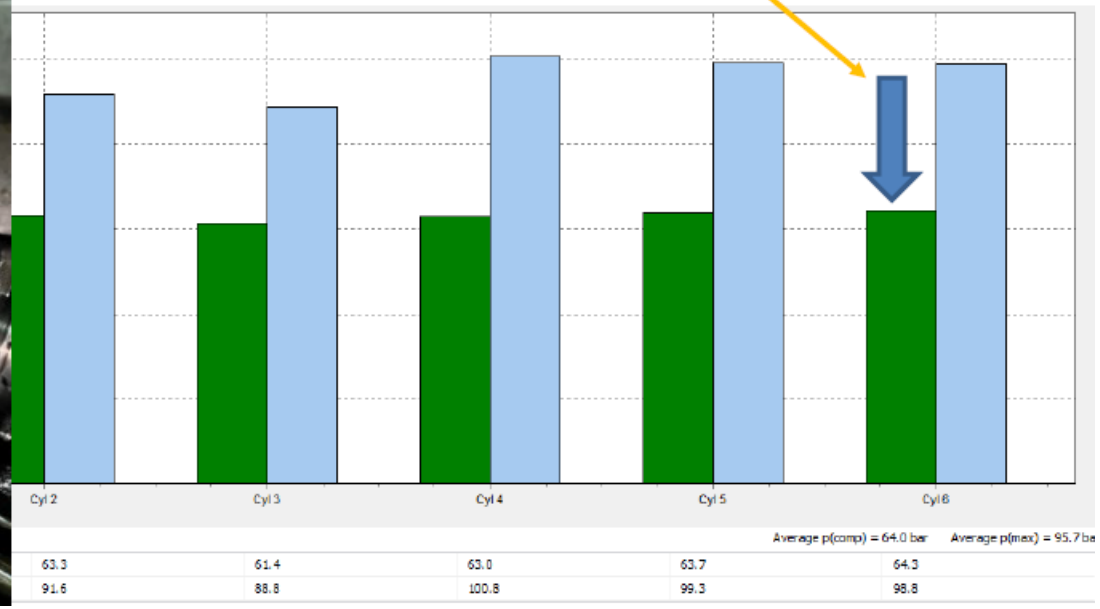


Silindirlerarası yük dengesi +-%5 limitinin çok üzerinde. Krank üzerine binen yük dengesiz.

PÜSKÜRTME AVANS AYARI DÜZELTİLMİŞ ANA MAKİNE



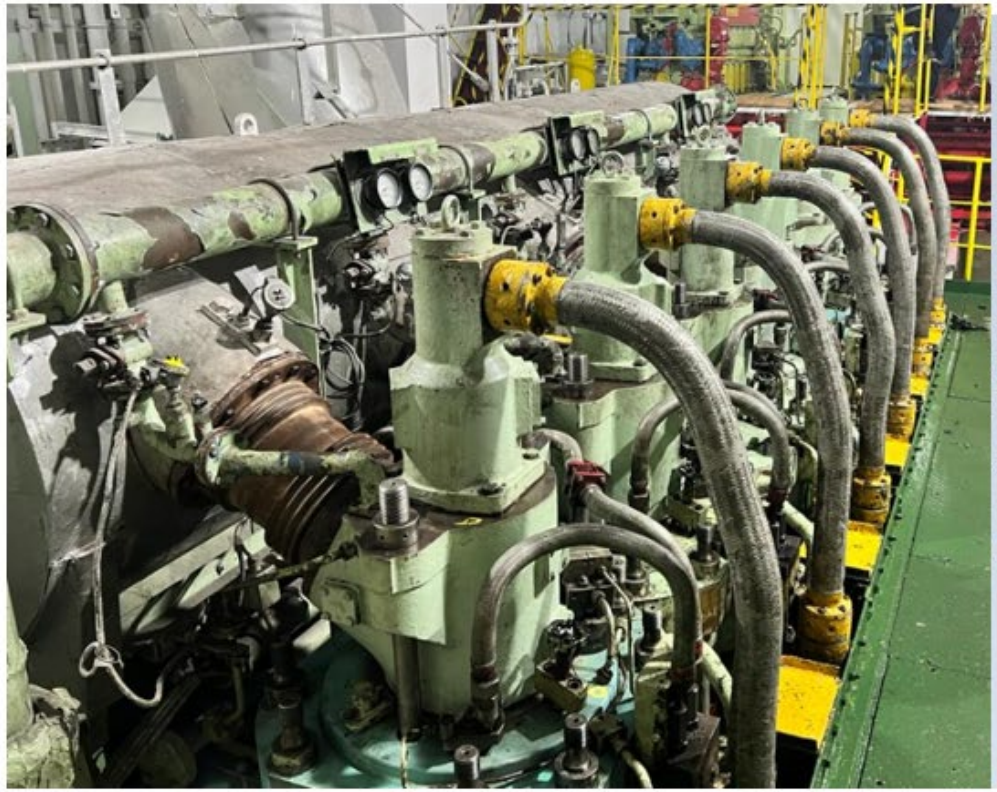


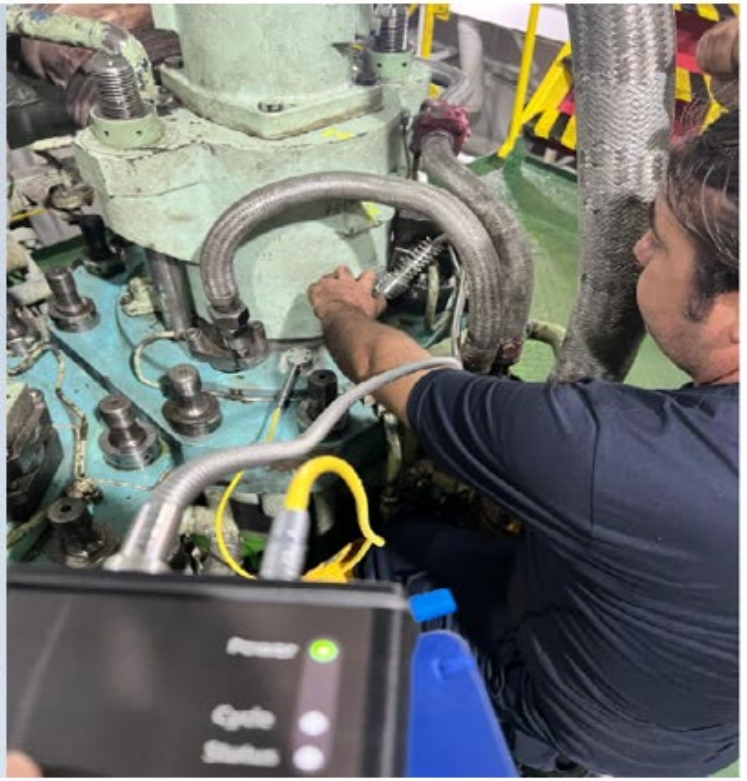


Püskürtme Avansı ve index ayarı yapılmış ana makinenin yük dağılımı

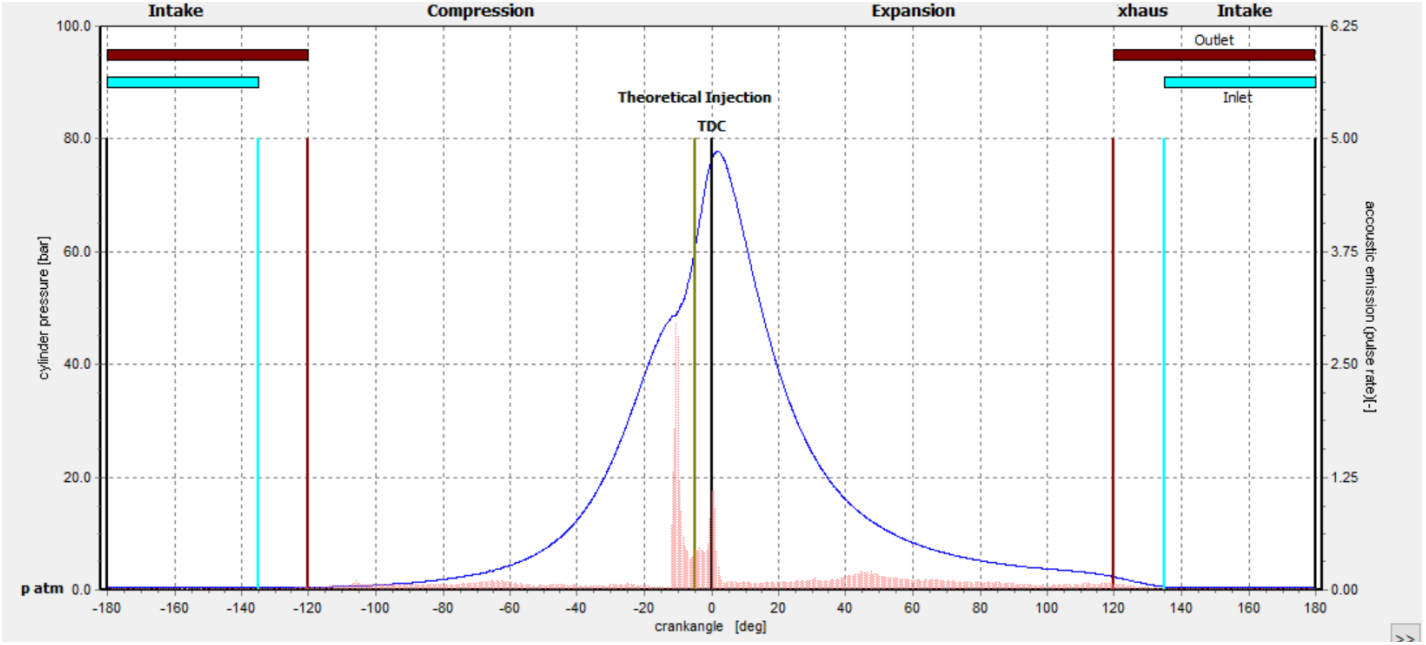
Load Balance	3,9	-2,8	-2,4	1,2	-2,5	2,6

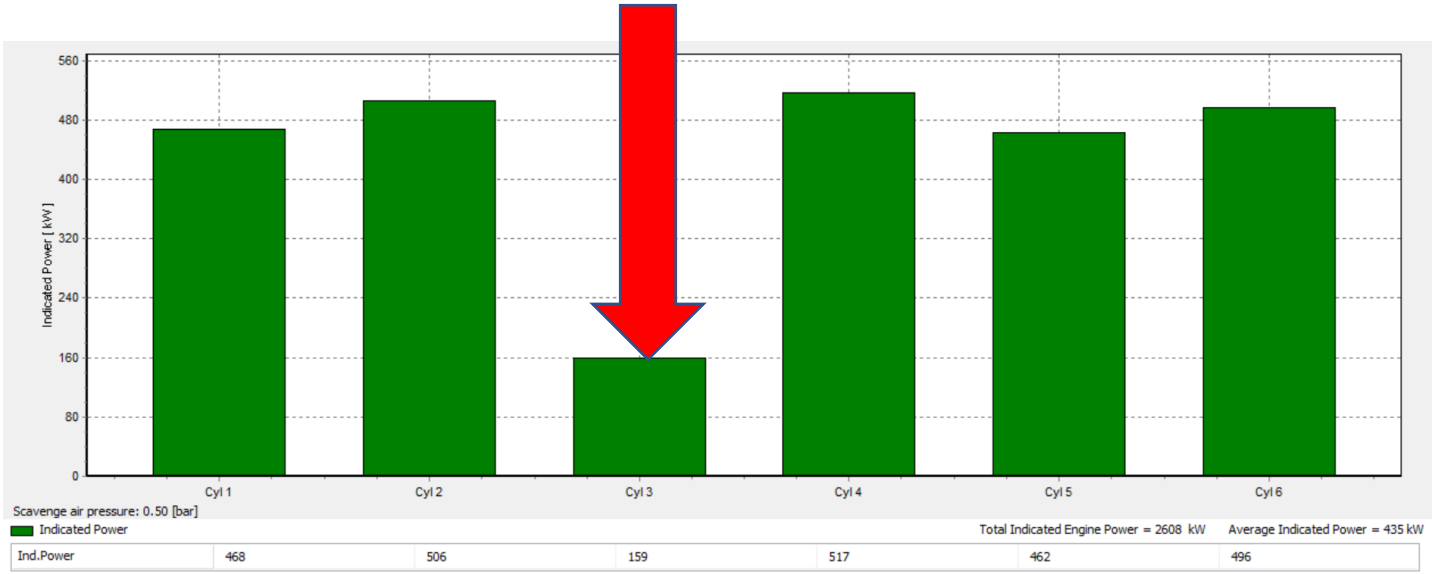
SULZER 6RTA48 ÖLÇÜM DEĞERLERİ

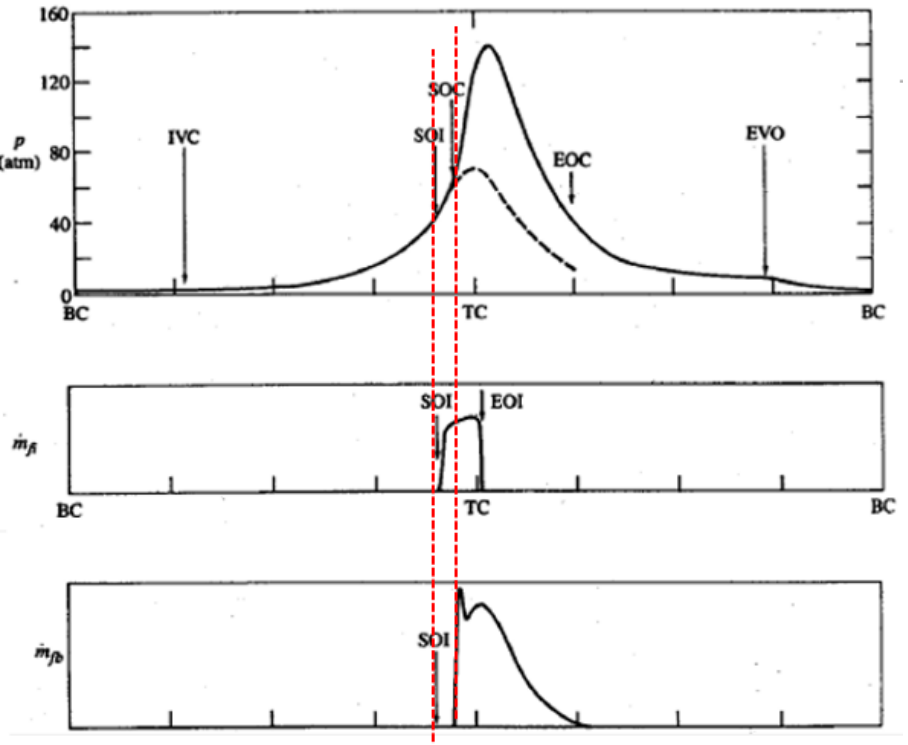


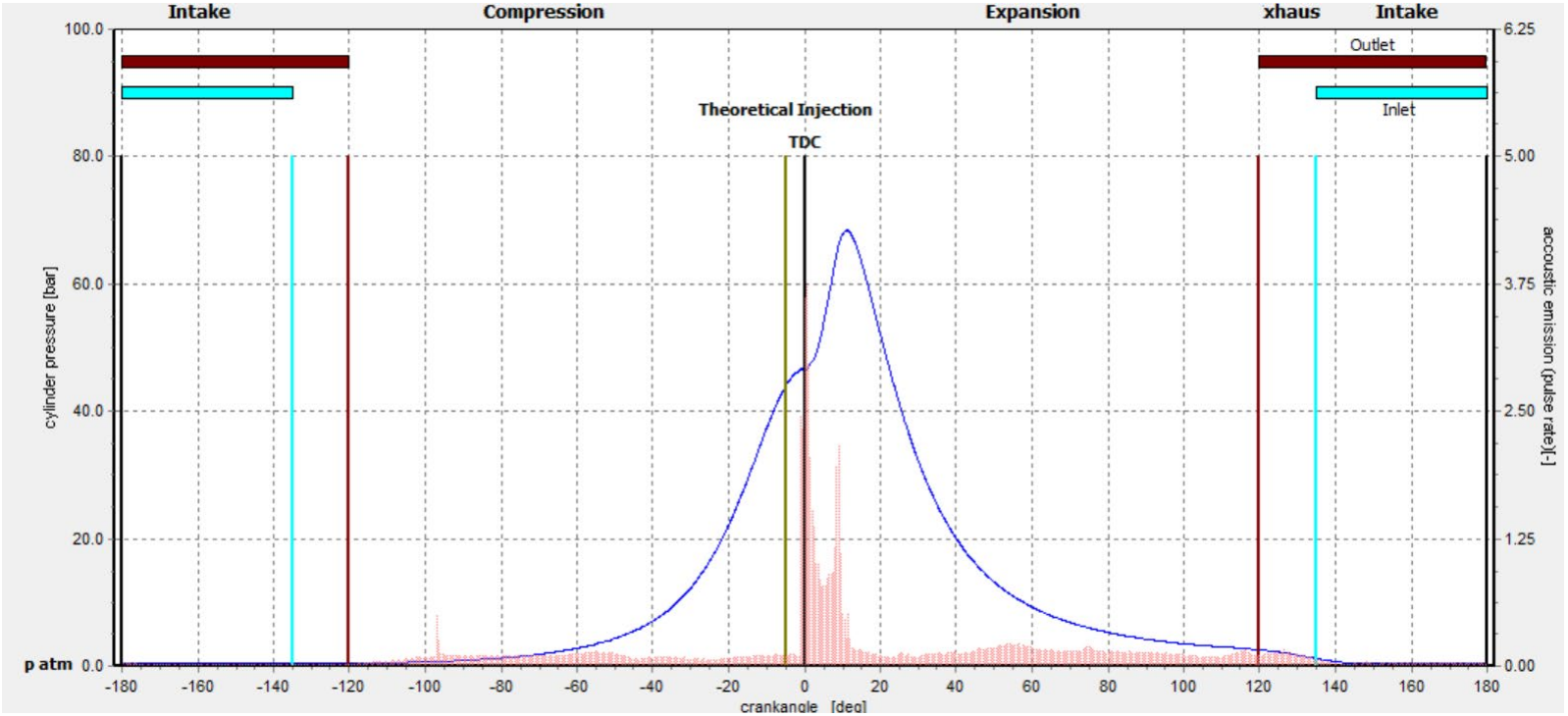


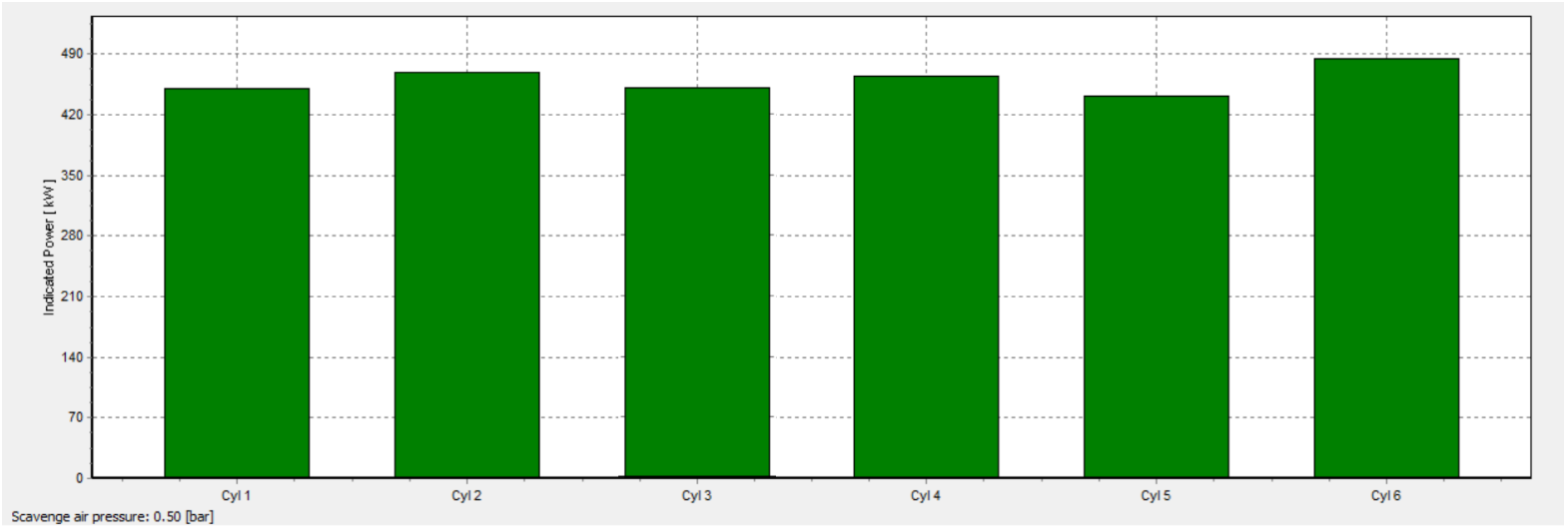
Avans Bozukluğu











TE3231 **FOR YOUR REFERENCE**

Data Sheet No. 3231110

Summary Data of Shop Trial

Remarks
Temperature of exh. gas at cylinder outlet is measured by ship's thermo-sensor.

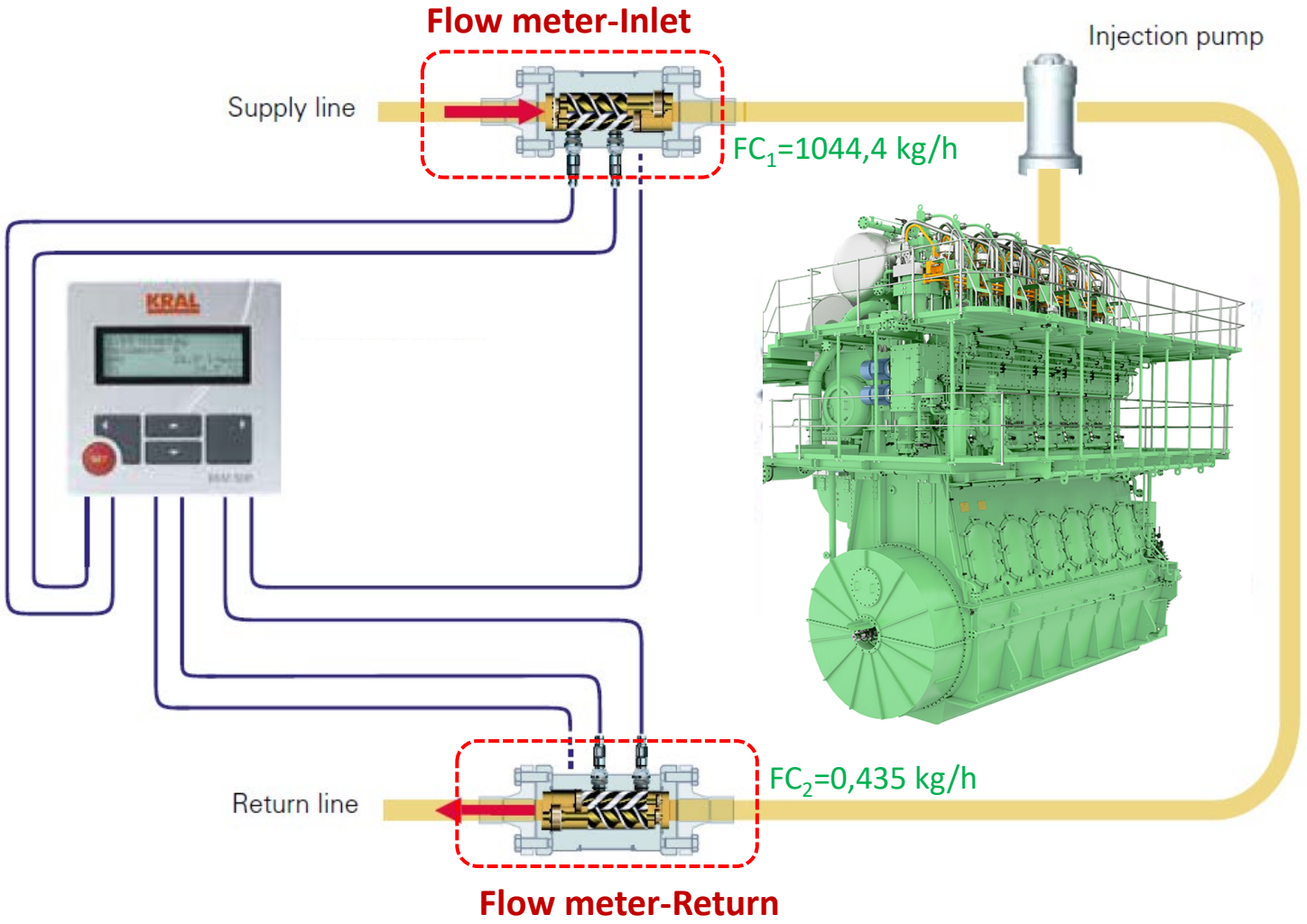
Approved | Checked | Drawn

Date		May 22, 2000							
Data Sheet No.		3231111	3231112	3231113	3231114				
Load	%	50	75	85	100				
Room Temp.	℃	18	18	19	19				
Barom. Press.	hPa	1014	1014	1014	1014				
Engine Speed	rpm	95.1	109.0	113.9	119.9				
Output	kW	3637	5379	6074	7170				
Fuel Oil Temp.	℃	34	35	35	35				
Specific Fuel Oil Consump. g/kW/Hr	Measured	172.8	170.3	170.4	171.7				
	1) LCV correction	171.1	168.7	168.8	170.0				
	2) ISO reference	—	—	169.4	—				
Pmax.	bar	93.2	121.8	132.2	140.2				
Pcomp.	bar	71.0	101.5	111.5	127.2				
Pump Mark Index		47.2	57.8	62.2	69.4				
Exh. Gas Temp. Cyl. Outlet	℃	310	314	319	339				
Scav. Air	Temp. ℃	23	27	29.6	32				
	Press. MPa	0.094	0.172	0.20	0.243				
Turbo Charger Speed	rpm No. 1	11000	14100	14900	15950				
	No. 2	—	—	—	—				
	No. 3	—	—	—	—				
	No. 4	—	—	—	—				
Exh. Gas Temp. T/C Inlet	℃ No. 1	330	330	340	370				
	No. 2	—	—	—	—				
	No. 3	—	—	—	—				
	No. 4	—	—	—	—				
Exh. Gas Temp. T/C Outlet	℃ No. 1	271	238	235	243				
	No. 2	—	—	—	—				
	No. 3	—	—	—	—				
	No. 4	—	—	—	—				

Note : 1) SFOC is corrected to LCV 42700 kJ/kg
2) SFOC is corrected to ISO reference conditions.

1. Geminin 12 knot (Eco Speed) ve 102 rpm'de çalıştığı varsayılmıştır.
2. Alt Isıl Değer (LCV) HSFO için 41.000 kJ/kg ve VLSFO için 42300 kJ/kg olarak alınmıştır.
3. Deniz sıcaklık değerleri *www.seatemperature.org* adresinden alınmıştır.
4. Hava sıcaklığı değerleri *https://www.meteoblue.com* adresinden alınmıştır.
5. Barometrik basınç 1014 hPa olarak alınmıştır.
6. Shop test değerleri referans alınmıştır. Motordaki bozunum ihmal edilmiştir.

Özgül Yakıt Tüketiminin Hesaplanması



Fuel Consumption :

$$FC = FC_{inlet} - FC_{return}$$

$$FC = 1.044.386 g/h - 4350 g/h = 1.040.036,4\ g/h$$

Brake or Effective Power (kW)

$$Power = P_{@85\%} = 6105\ kW$$

Specific Fuel Consumption (SFC)

$$SFC_{net} = \frac{FC}{P_{@85\%}} = \frac{1.040.036,4\ g/h}{6105\ kW} = 170,4\ g/kWh$$

LCV ye göre SFC Düzeltme

$$SFC_{LCV} = \frac{SFC_{meas} \, x \, LCV_{test}}{LCV_{std}}$$

$$= \frac{170,4 \; g/kWh \; x \; 42.331 \; kJ/kg}{42.700 \; kJ/kg}$$

$$= 168,4 \; g/kWh$$

Since the Lower Heat Value (LCV) value of the fuel used is lower than the standard value, this means that the main Engine will consume 2 g/kWh more fuel for the same power output.at 85% load.

Extra fuel consumption for the same power output of ME:

$$\Delta FC = 2g / kWh * 6105kW$$

$$= +12,2 \quad kg / h$$
$$= +293 \quad kg / day$$
$$= +8,79 \; MT / Month$$

6000h working condition

$$= 12,2(kg / h) * 6000 \, (h / Year) / 1000$$
$$= +73,2 \; MT/Year$$

Extra cost

$$= 73,2MT / Year \; x \; 500\$/MT = 36,600\$$$

If the LCV value is higher than the standard value, then SFC:

$$= \frac{168,4 \; g/kWh \; x \; 42.700 \; kJ/kg}{43.500 \; kJ/kg}$$

$$= 165,3 \; g/kWh$$

$$\Delta FC = 5,1g / kWh * 6105kW$$

$$= -31,1 \; kg / h$$
$$= -506 \; kg / day$$
$$= -15,2 \; MT / Month$$

6000h working condition

$$= -31,1(kg / h) * 6000 \, (h / Year) / 1000$$
$$= -186,6 \; MT/Year$$

Saving

$$= -186,6MT / Year \; x \; 500\$/MT = 93,300\$$$

ISO şartlarına göre SFC düzeltme (ISO SFC)

Parameters	Reference Condition	Conversion Factors
Room Temp.	25 ^{0}C	+0,2% /10 ^{0}C Rise
Barometric Pres.	1000 hbar	-0,02% /10 hPa Rise
Air Cool.Water Temp.	25 ^{0}C	+0,6% /10 ^{0}C Rise
Fuel Oil Lower Cal.Value (LCV)	42.700 kJ/kg	-1,0% /1% Rise

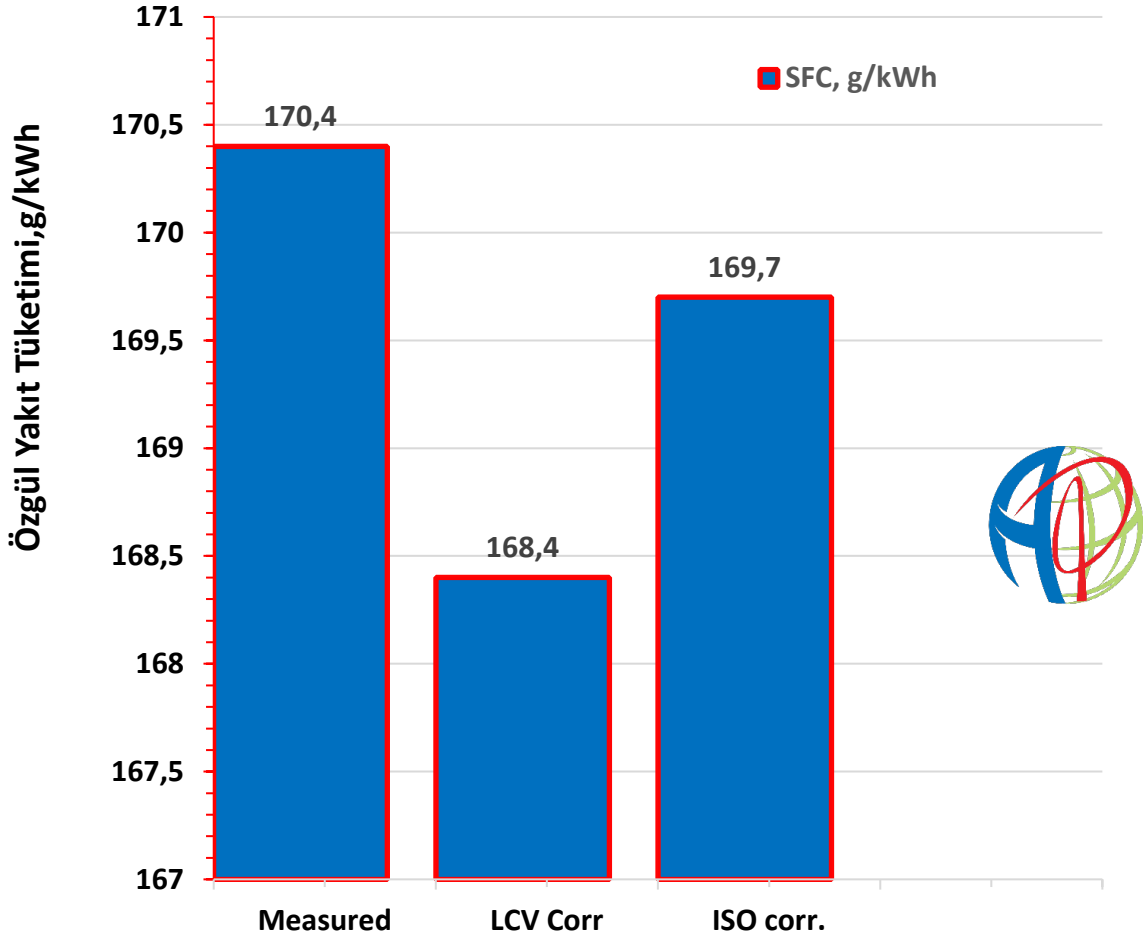
$$SFC_{ISO} = SFC_{meas} x \left(\frac{(25 - T_o) x 0{,}2 + (1000 - P_o) x (-0{,}02) + (25 - T_c) x 0{,}6}{1000} + 1 \right) x LCV_{meas} / 42.700$$

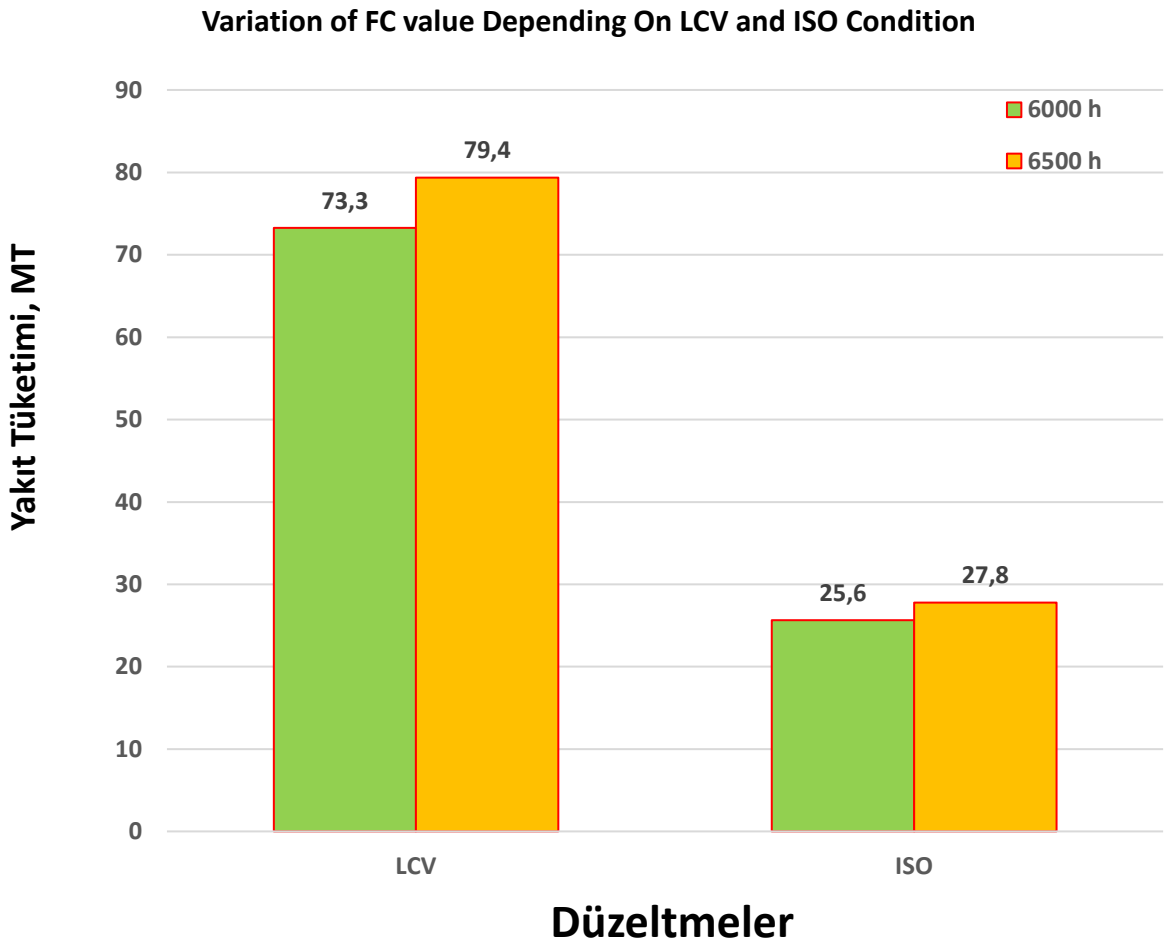
Servis Condition	ISO Condition
To = 10.3 °C	To = 25 °C
Po = 1024 hPa	Po = 1000 hPa
Tc = 22,7 °C	Tc = 25 °C

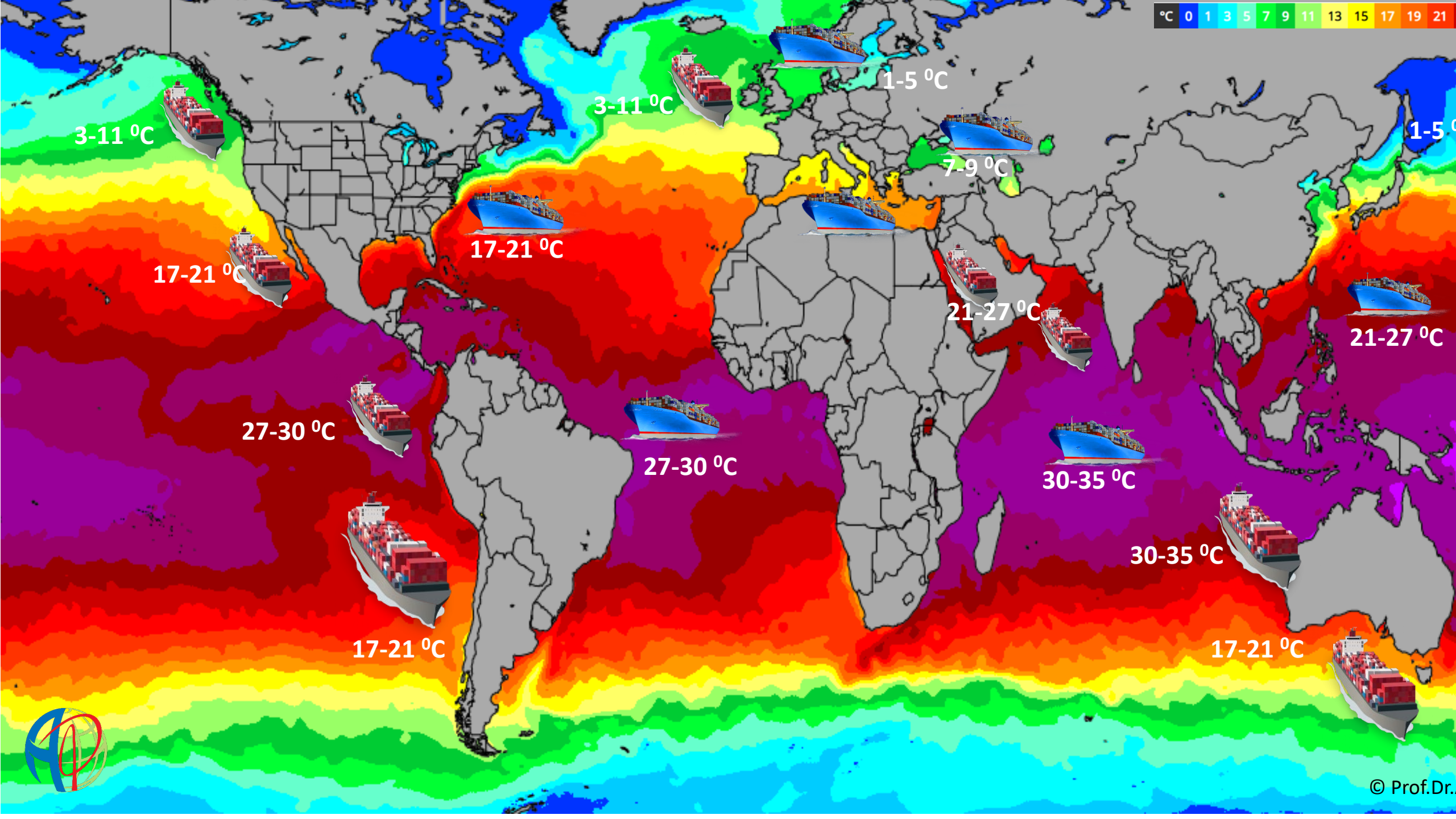
$$SFC_{ISO} = 170{,}4\ g/kWh\ x \left(\frac{(25 - 10{,}3) x 0{,}2 + (1000 - 1024) x (-0{,}02) + (25 - 22{,}7) x 0{,}6}{1000} + 1 \right) x 42.331\ kJ/kg / 42.700\ kJ/kg$$

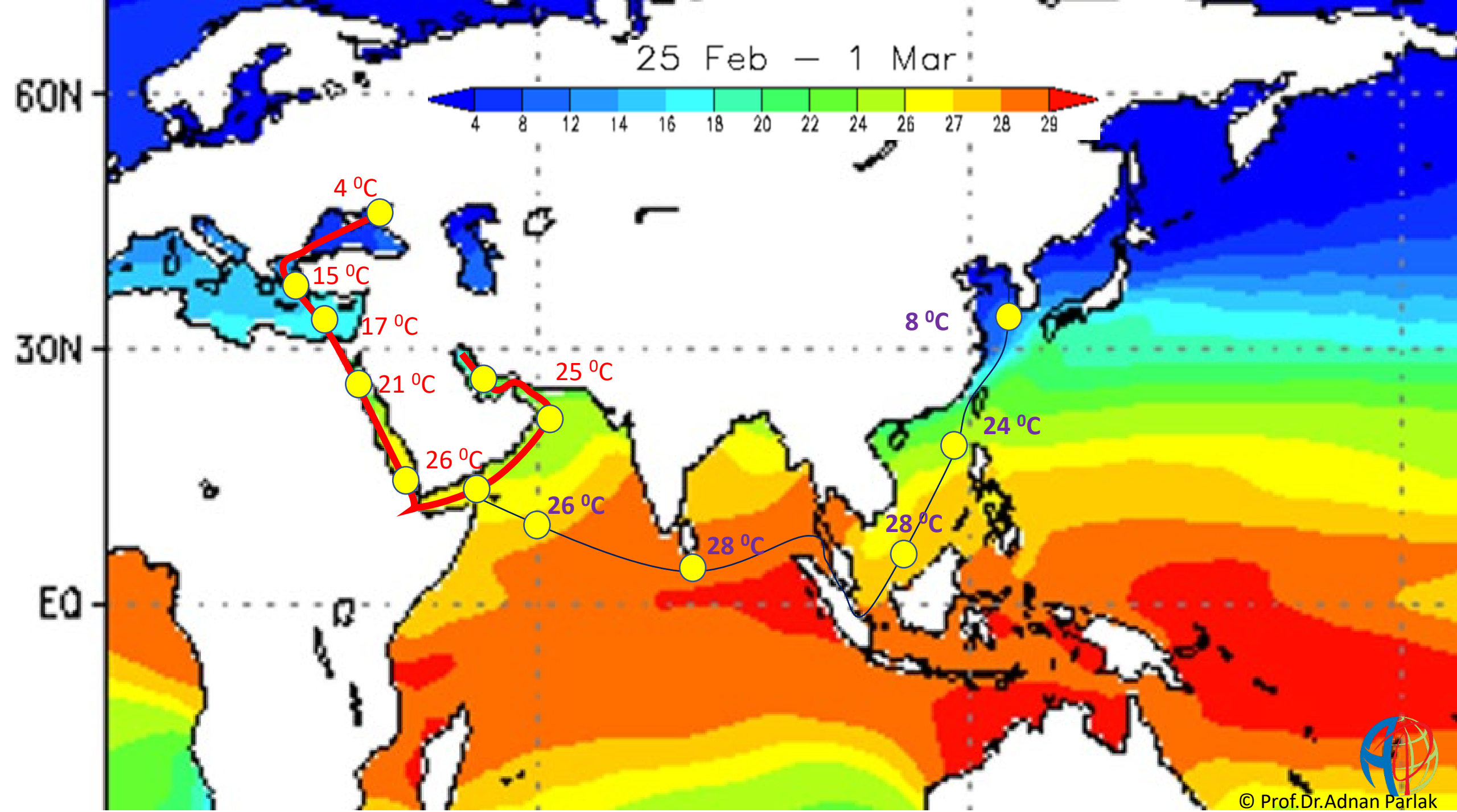
$$= 169{,}7\ g/kWh$$

Çevresel şartlara ve LCV nin SFC ve FC üzerine etkileri



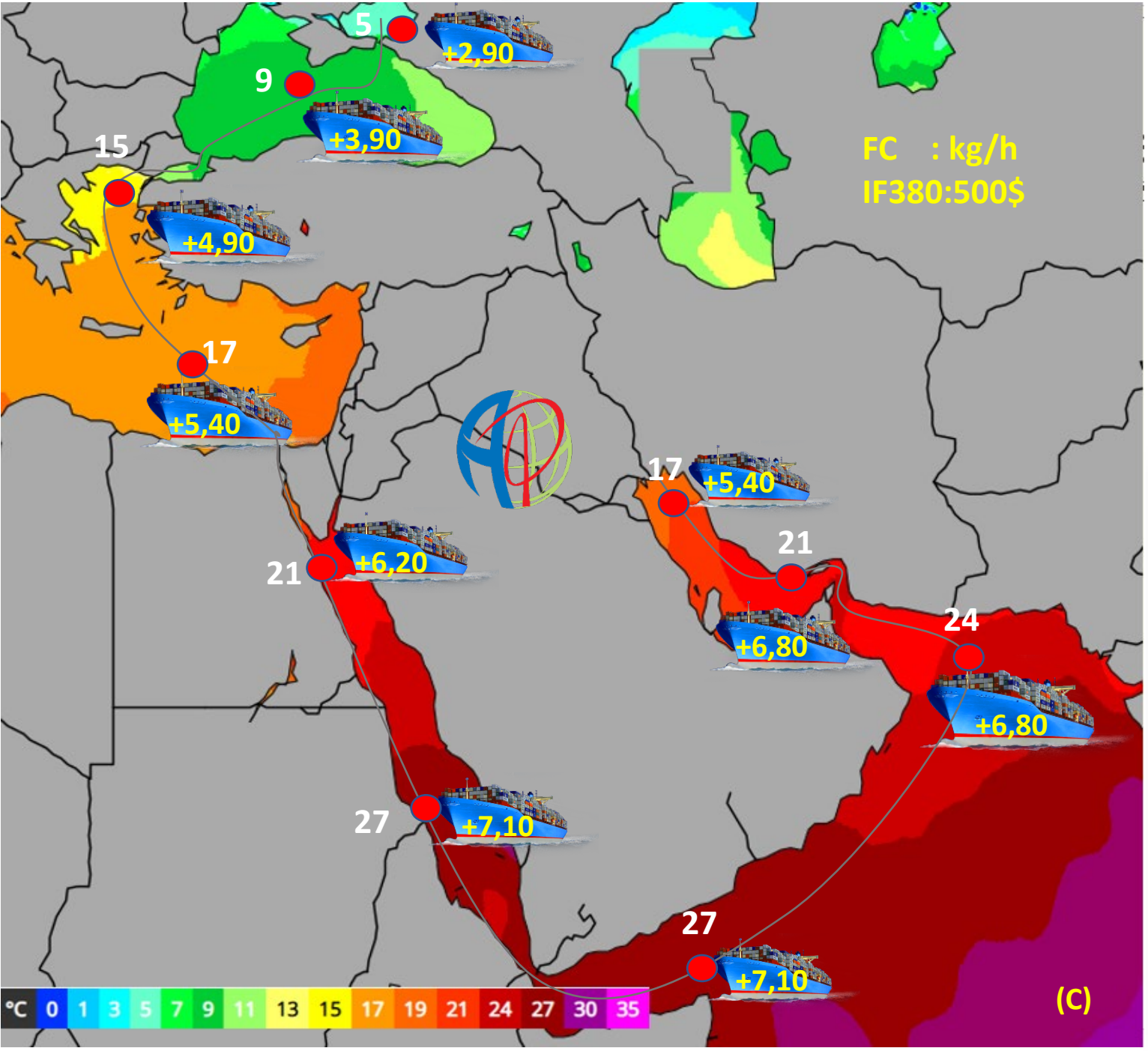



°C 0 1 3 5 7 9 11 13 15 17 19 21
3-11 °C
3-11 °C
1-5 °C
1-5 °C
7-9 °C
17-21 °C
17-21 °C
21-27 °C
21-27 °C
27-30 °C
27-30 °C
30-35 °C
30-35 °C
17-21 °C
17-21 °C
© Prof.Dr.


25 Feb – 1 Mar
4 8 12 14 16 18 20 22 24 26 27 28 29
60N
30N
EQ
4 °C
15 °C
17 °C
21 °C
25 °C
26 °C
26 °C
28 °C
8 °C
24 °C
28 °C
© Prof.Dr.Adnan Parlak

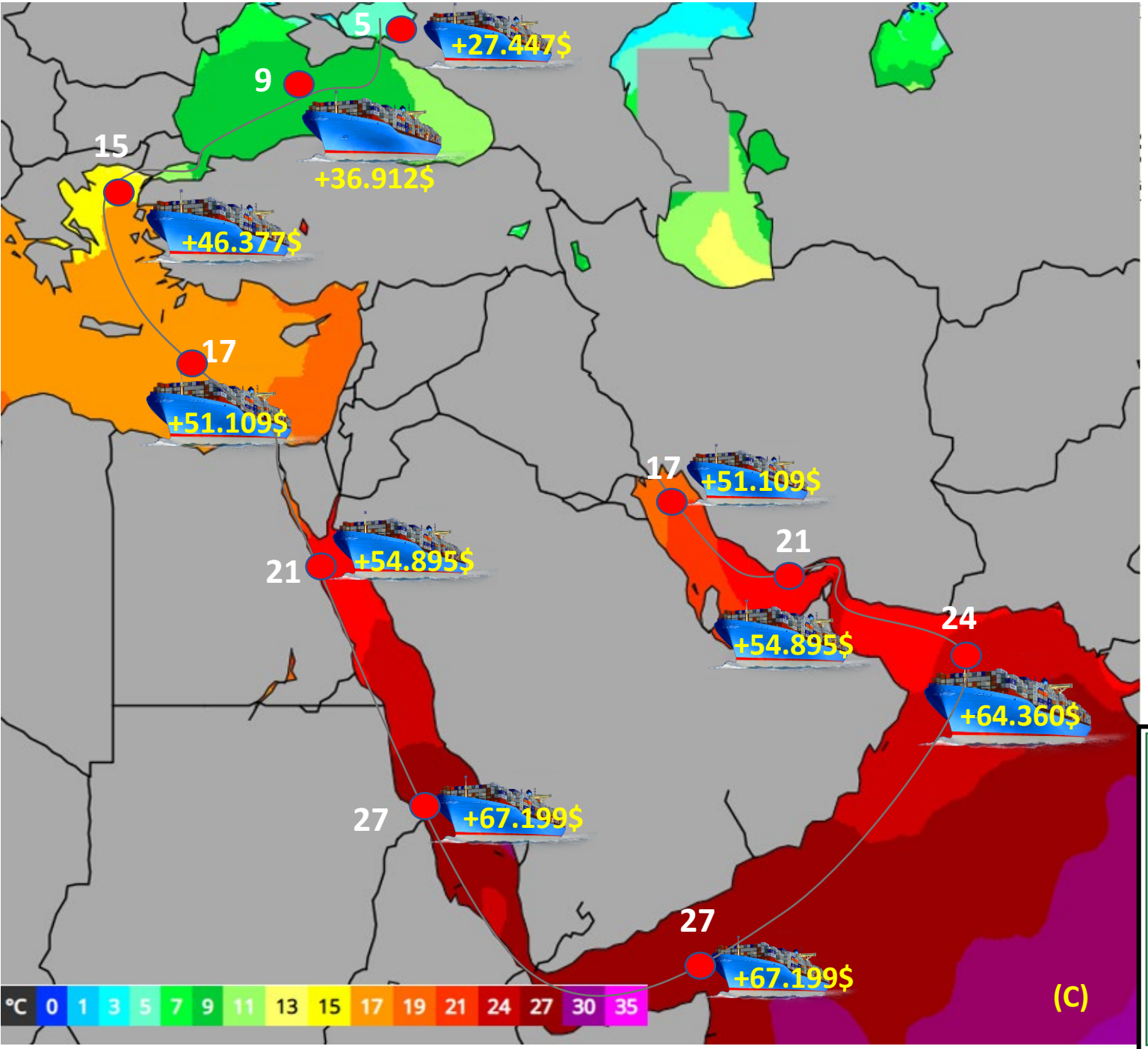
- ***Çevre Şartları ve Yakıt Isıl Değerinin Yakıt Tüketimi Üzerine Etkileri***

Çevre şartlarına göre Özgül yakıt tüketimindeki değişim



LCV :41.000 kJ/kg.

Çevre şartlarına göre yakıt tüketim maliyeti



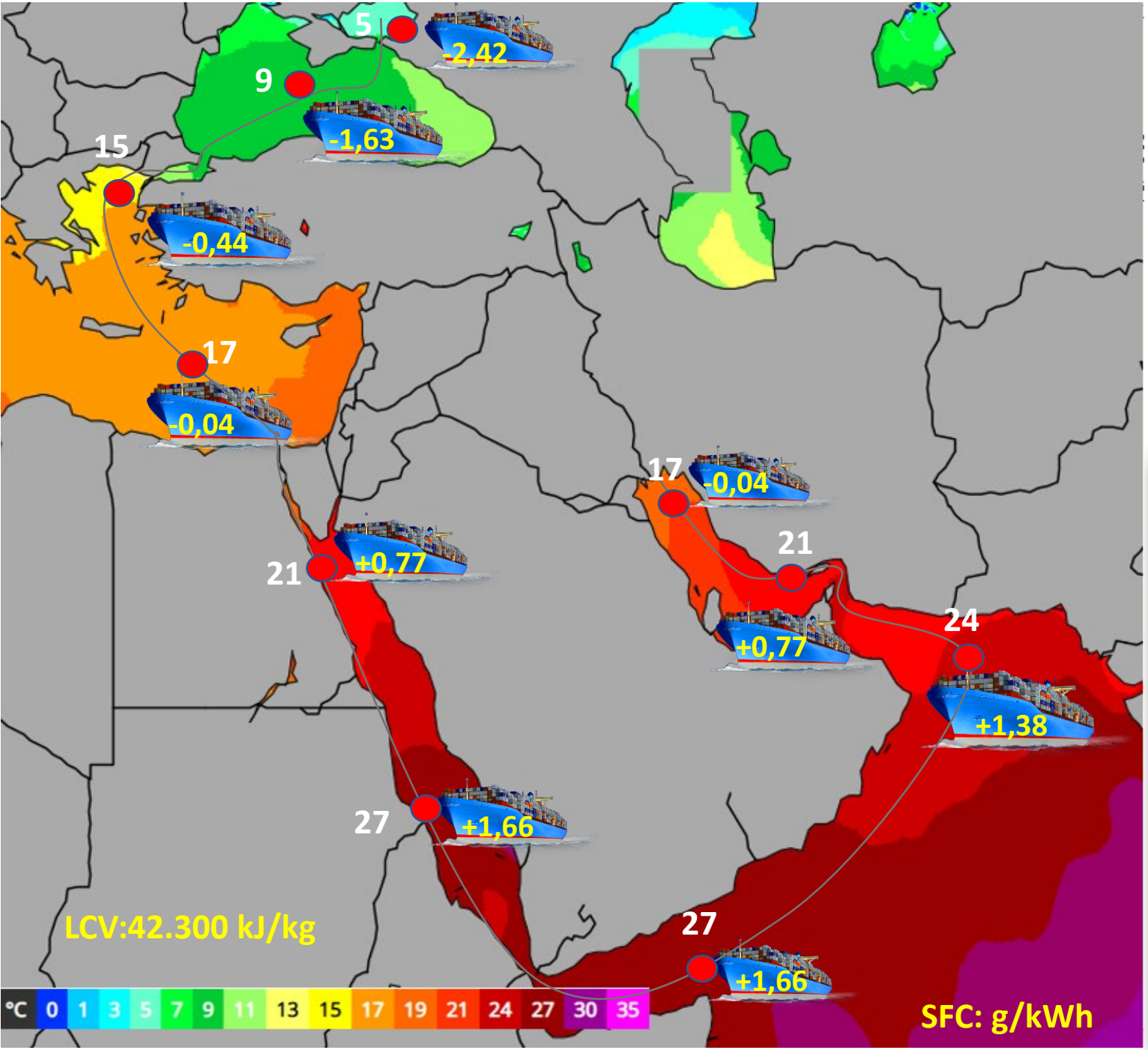
LCV : 41.000 kJ/kg.

Deniz suyu	Hava Sıcaklığı	LCV:41.000 kJ/kg				ΔFC,kg/h		
		SFC_LCV	FC_ISO	ΔSFC	ΔFC,kg/h	6000h	6500h	7000h
5	5	172,90	18,70	2,90	13,07	27.447,6	29.734,9	32.022,2
9	9	173,90	18,80	3,90	17,58	36.912,3	39.988,4	43.064,4
15	15	174,90	18,90	4,90	22,08	46.377,0	50.241,8	54.106,5
17	17	175,40	18,97	5,40	24,34	51.109,4	55.368,5	59.627,6
19	19	175,80	19,01	5,80	26,14	54.895,3	59.469,9	64.044,5
21	21	176,20	19,06	6,20	27,94	58.681,1	63.571,2	68.461,3
24	24	176,80	19,13	6,80	30,65	64.360,0	69.723,3	75.086,6
27	25	177,10	19,16	7,10	32,00	67.199,4	72.799,3	78.399,3
30	26	177,60	19,21	7,60	34,25	71.931,7	77.926,0	83.920,3
35	28	177,60	19,25	7,60	34,25	71.931,7	77.926,0	83.920,3

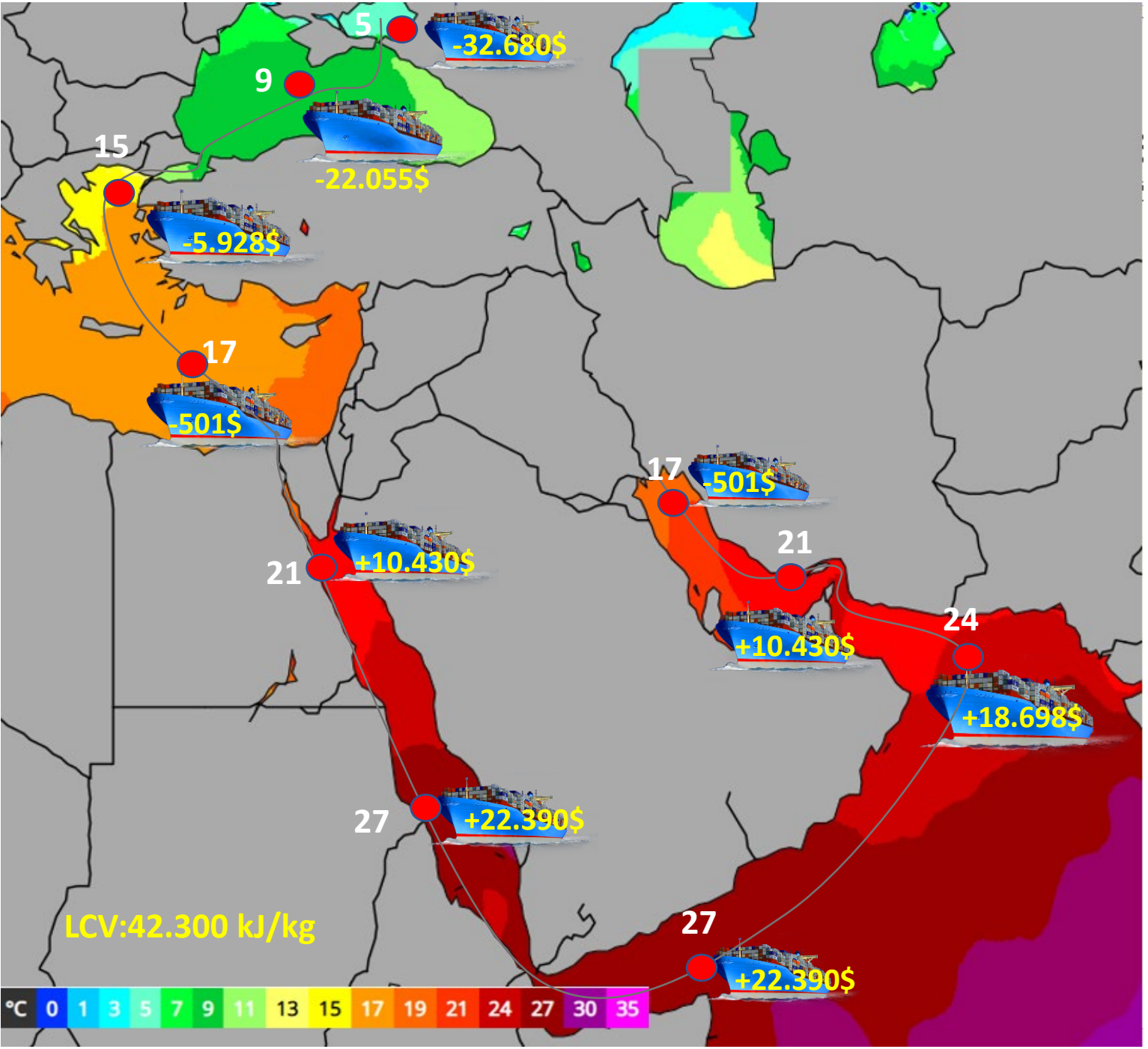
Çevre Şartları ve LCV nin Yakıt tüketimi üzerine etkileri

Çevresel Şartlarının SFC üzerine etkileri

LCV: 42.300 kJ/kg.



Variation of FC According to Environment Conditions in case of VLSFO Usage.



LCV of HSFO is taken as 42.300 kJ/kg. The figures can show some changes according to LCV

Deniz suyu	Hava Sıcaklı	LCV:42.300 kJ/kg				ΔFC,kg/h		
		SFC_LCV	FC_ISO	ΔSFC	ΔFC,kg/h	6000h	6500h	7000h
5	5	167,58	18,13	-2,42	-10,89	-32.680,6	-35.404,0	-38.127,4
9	9	168,37	18,21	-1,63	-7,35	-22.055,0	-23.892,9	-25.730,8
15	15	169,56	18,34	-0,44	-1,98	-5.927,7	-6.421,6	-6.915,6
17	17	169,96	18,38	-0,04	-0,17	-500,8	-542,5	-584,2
19	19	170,37	18,43	0,37	1,65	4.952,0	5.364,6	5.777,3
21	21	170,77	18,47	0,77	3,48	10.430,7	11.300,0	12.169,2
24	24	171,38	18,54	1,38	6,23	18.698,2	20.256,3	21.814,5
27	25	171,66	18,57	1,66	7,46	22.389,8	24.255,7	26.121,5
30	26	171,93	18,60	1,93	8,70	26.093,4	28.267,8	30.442,3
35	28	172,45	18,65	2,45	11,02	33.070,3	35.826,1	38.582,0

stx

6. Calculation sheet of fuel oil consumption

Checked by: S. H. Lee

Date	:	2008-08-12
Ship owner	:	COSCO GROUP
Ship yard	:	COSCO ZHOUSHAN SHIPYARD
Ship No.	:	ZS07035
Engine Type	:	6S50MC-C7
Engine No.	:	SB6S50-7161
Engine output	:	9,480 kW
Engine speed	:	127 rpm
Fuel oil specific gravity at 15 ℃	:	0.8660
Fuel oil lower calorific value	:	10,152 kcal/kg

Engine load (%)	25%	50%	75%	90%	100%	100%	110%
Engine output (kW)	2,370 kW	4,740 kW	7,110 kW	8,532 kW	9,480 kW	9,480 kW	10,428 kW
Measuring quantity (kg), AL	74.1 kg	140.5 kg	206.4 kg	248.5 kg	278.4 kg	277.1 kg	310.5 kg
Measuring time (s), B	600 s	600 s	600 s	600 s	600 s	600 s	600 s
Specific fuel oil consumption (Measured, g/kW-h), B3=(ALX3600X1000)/(BXkW)	187.59	177.85	174.18	174.75	176.20	175.38	178.65
Ambient temperature (℃) , T1	29.0 ℃	29.0 ℃	28.0 ℃	30.0 ℃	31.0 ℃	31.0 ℃	31.0 ℃
Charge air coolant temperature (℃) , T2	29.0 ℃	30.0 ℃	30.0 ℃	31.0 ℃	30.0 ℃	30.0 ℃	30.0 ℃
Ambient pressure (mbar) , P	1013 mbar	1013 mbar	1013 mbar	1013 mbar	1011 mbar	1013 mbar	1010 mbar
Conversion factor by ambient temperature, T1F=0.002X(25-T1)/10	-0.00080	-0.00080	-0.00060	-0.00100	-0.00120	-0.00120	-0.00120
Conversion factor by boost Air coolant temperature, T2F=0.006X(25-T2)/10	-0.00240	-0.00300	-0.00300	-0.00360	-0.00300	-0.00300	-0.00300
Conversion factor by ambient pressure, PF=0.0002X(P-1000)/10	0.00026	0.00026	0.00026	0.00026	0.00022	0.00026	0.00020
Conversion factor by lower calorific value , HF=(H-10200)/10200	-0.00470588	-0.00470588	-0.00470588	-0.00470588	-0.00470588	-0.00470588	-0.00470588
Total conversion factor , TCF=T1F+T2F+PF+HF	-0.00765	-0.00825	-0.00805	-0.00905	-0.00869	-0.00865	-0.00871
Converted value of F.O consumption based on ISO (g/kW-h) , B1=B3+(B3*TCF)	186.16	176.38	172.78	173.17	174.67	173.86	177.10
Guarantee of fuel oil consumption at CSR (Load : 90%)	168.9 g/kW-h + 5.0% = (177.3g)						

1E30L6

CALCULATION for SPECIFIC FUEL OIL CONSUMPTION (S.F.O.C.)

At 85% Load

CALCULATION FORMULA for MEASURED S.F.O.C.

S.F.O.C.(MEAS.) = F.O.WEIGHT(kg) × 60 × 60 × 1000 / TIME(sec.) / OUTPUT
F.O. DRAIN = F.O.DRAIN AMOUNT(g) × 60 × 60 / TIME(sec.) / OUTPUT
S.F.O.C.(NET) = S.F.O.C.(MEAS.) - F.O. DRAIN

Parameter	Measured weight	Measured time
S.F.O.C.(MEAS.)	120 (kg)	408.14 (sec)
F.O. drain	1260 (g)	360 (sec)

S.F.O.C.(MEAS.) = 120 × 60 × 60 × 1000 / 408.14 / 6467 = 163.7 (g/kW-h)
F.O. DRAIN = 1260 × 60 × 60 / 360 / 6467 = 1.9 (g/kW-h)
S.F.O.C.(NET) = 163.7 - 1.9 = 161.8 (g/kW-h)

CALCULATION FORMULA for S.F.O.C.CORRECTED to ISO CONDITION

$$S.F.O.C.(ISO) = S.F.O.C.(NET) \times \left(\frac{(25 - To) \times 0.2 + (1000 - Po) \times (-0.02) + (25 - Tc) \times 0.6}{1000} + 1 \right) \times LCV / 42700$$

Parameter	ISO condition	Conversion factors	Measured values
To : T/C intake air temp.	25 (℃)	+0.2% ／10℃ Rise	17.8 (℃)
Po : Barometric press.	1000 (hPa)	-0.02% ／10hPa Rise	1017.0 (hPa)
Tc : A/C water inlet temp.	25 (℃)	+0.6% ／10℃ Rise	22.2 (℃)
LCV : F.O. Lower Calorific Value	42700 (kJ/kg)	-1%／1% Rise	42070 (kJ/kg)

$$S.F.O.C.(ISO) = 161.8 \times \left(\frac{(25 - 17.8) \times 0.2 + (1000 - 1017) \times (-0.02) + (25 - 22.2) \times 0.6}{1000} + 1 \right) \times 42070 / 42700$$

= 160.0 (g/kW-h)

* Guaranteed value at ISO condition is 160.5 (g/kW-h) + 5 % (= 168.52 g/kW-h)

Egzoz Sıcaklığının Çevre Şartlarına göre düzeltilmesi

CALCULATION FORMULA for TURBO CHARGER Exh. GAS OUTLET TEMP. CORRECTED to DESIGN CONDITION

At C.S.O. Load

$$\text{T/C Exh. GAS OUT TEMP.(CORRECTED)} = (273+Texh.) \times \left(\frac{(25 - To) \times 3.16 + (25 - Tc) \times 0.18}{1000} + 1 \right) - 273$$

Parameter	Measured values	Design values	Corrected value
Texh. : T/C Exh. gas outlet temp.	205 (℃)	218 (℃) ± 15℃	216 (℃)
To : T/C intake air temp.	17.8 (℃)	25 (℃)	
Tc : A/C water inlet temp.	22.2 (℃)	25 (℃)	

$$\text{T/C Exh. GAS OUT TEMP.(CORRECTED)} = (273+ 205) \times \left(\frac{(25 - 17.8) \times 3.16 + (25 - 22.2) \times 0.18}{1000} + 1 \right) - 273$$

$$= 216 \quad ℃$$