PROJECT: MSS54

CHAPTER:	1.05
MODULE:	DENSITY CORRECTION IN EVT MOMENT REALIZATION
FUNCTION:	DENSITY CORRECTION

AUTHORIZATION

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Changes: S380

version	Date	comment
S370	30.4.2004	1st version as separate module; Replacement of existing scopes in the EVT moment realization module
S370	11.05.2004	delivery status Open points: - Lists for operating modes
S370	04.07.2004	Delivery status Miniteam
S380	21.12.2004	ks: Documentation of the implementation

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1 FUNCTIONAL DESCRIPTION

The density correction DKR control module contains control functions that compensate for the influence of a changed intake air condition. However, intake pressure and temperature are included in the calculation differently. The compensation prevents a changed intake air condition from leading to a change in the fresh air charge, residual gas content, charge movement and, as a result, to a change in the indicated work at the corresponding operating point.

Operating altitudes between -300 and +3000 m above sea level correspond to pressure changes between +10% and -30% compared to a reference pressure of 960 mbar. For a reference temperature of 293 K, temperature changes of approximately +-10% result in the relevant operating range.
The inflow behavior, which is particularly important for the fresh air filling, is primarily determined by the air condition in the intake manifold. Therefore, the average intake manifold pressure is used as the input variable for calculating compensation measures.

The procedure implemented here is a pure correction of the inlet closing control edge with the aim of adjusting the fresh air filling to the applied value under reference conditions. The heating of the gas before re-exhausting at late intake closes is not explicitly taken into account.
Assuming that the outflow process is primarily influenced by the combustion, i.e. the indicated work, and less by the ambient conditions, the residual gas mass in the cylinder is not corrected. The influence of the charge movement is neglected.

The two calculation methods for the intake closing correction ÿ based on the cylinder volume at intake closing or the opening time of the intake valve ÿ as well as the subsequent limitation of the corrected intake closing control edge are described in more detail below.

1.1 PHYSICAL BACKGROUND

The intake closing correction uses two parallel calculation methods: With the focus on partial load operation with full valve lift, i.e. for operating points in which the fresh air filling is limited by the cylinder volume, the cylinder volume at intake closing is evaluated. Assuming that the gas density in the cylinder at this time is proportional to the ambient condition, the intake closing control edge is shifted so that the product of density and cylinder volume at intake closing is equal to the applied reference condition. With the cylinder volume *VES* as a geometric function of the intake closing crank angle and the relative air density in the intake manifold *rf_pt_korr_dichte,* the following applies:

$$VES,corr = rf\_pt\_korr\_density\ VES,ref = \frac{ÿ\, p/T\, ÿ_{ref}}{p/T}\, V_{ES,ref}$$

With early intake closing, reduced density leads to a larger cylinder volume, which means later intake closing.

This correction corresponds to the correction function up to control unit version R 360.
With late intake closing and reduced density, the necessary larger cylinder volume is achieved by an earlier intake closing. The cylinder volume as a function of the crank angle is symmetrical to the bottom dead center at 540°. However, to expand the application options, the intake closing control edges are transformed to late intake not closing [with ES := 1080 - ES] in the area of early intake closing. Instead, the cylinder volume function is stored separately for this area.

found. Density correction

With a focus on mini lift, i.e. for operating points in which the fresh air filling is determined by the inflow behavior of the intake valves, the opening time of the intake valve is evaluated. For operating modes with early intake closing, this is the distance between intake opening and intake closing. For operating modes with late intake opening, the start of the re-exhaust phase is relevant instead of intake opening; this time corresponds approximately to bottom dead center. With the relative intake mass flow *rf_pt_korr_drossel,* the opening time of the intake valve is as follows:

ESkorr - EO = (ESref - *EO) rf_pt_korr_drossel*

The throttle characteristic or a laminar-turbulent approach for the inlet mass flow can be stored in two characteristic curves for the dependence of pressure and temperature:

$$rf\_pt\_korr\_drossel = \frac{\dot{m}}{\dot{m}_{ref}}$$ ÿ f ÿ1pÿ f ÿT ÿ2

For operating points with high speeds or loads, a weighted average of both correction models is used. To weight the opening time-based correction, the specific load per cylinder and intake valve is used as the map input.

Before calculating the volume-related intake closing correction, the intake closing control edge can be shifted compared to the calculation of the cylinder volume. This allows dynamic effects (pressure waves, resonances) to be taken into account. As an alternative to the proportional weighting of the opening time-based correction, this intervention can also be used to take into account the inflow pressure losses at high loads and speeds.

After calculating the corrected intake closing control edge, this is limited to the physically reasonable range: Depending on the operating mode early or late intake closing, the limits here are the dead centers of the piston movement or the full load control times.

1.2 IMPLEMENTATION

In the signal flow, the density correction module converts the inlet closing control edge *es_bas* formed in the EVT torque realization module from the basic maps or the application intervention into a corrected inlet closing control edge *drk_es_aw* (previous name: *es_aw).*

The relative density *rf_pt_korr* is also provided for external calculations. This is set equal to the relative density for the volume-related inlet close correction *drk_rf_pt_korr_dichte.* The relative density *rf_pt_korr* is also provided for external calculations. The relative flow *drk_rf_pt_korr_drossel* is also used externally. All other variables calculated in this module are internal.

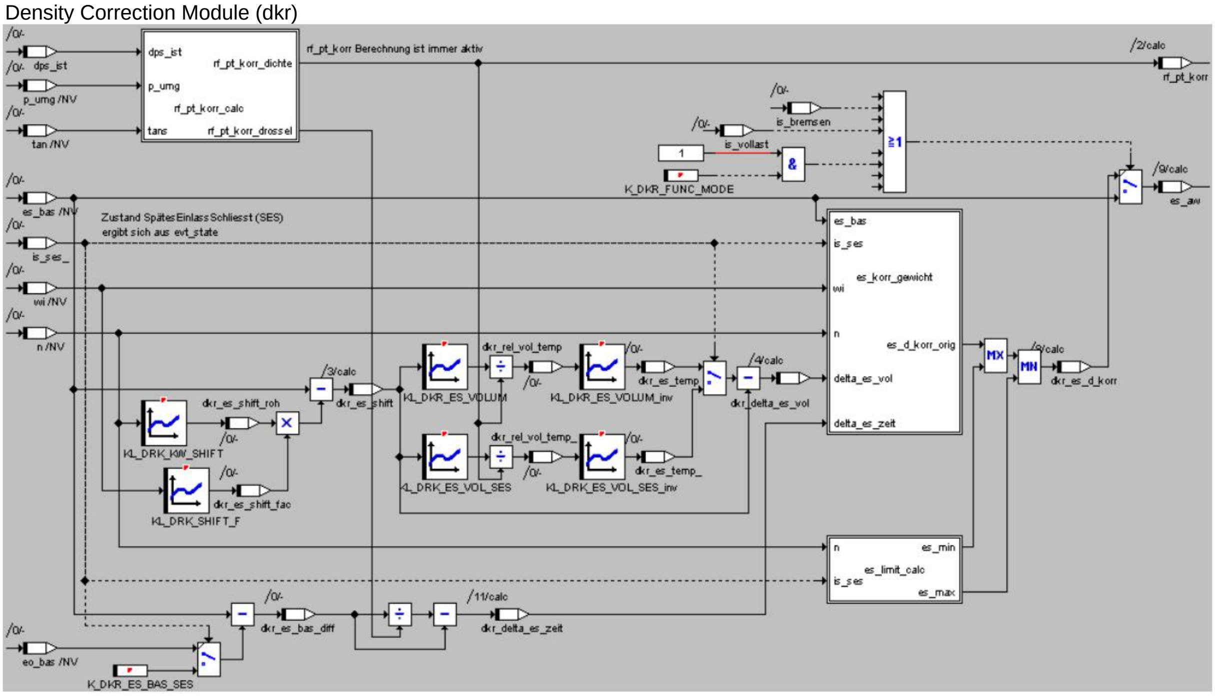
With the exception of the characteristic curve KL_STKN_ES_VL, all parameters in the module are internal.

Note on implementation:

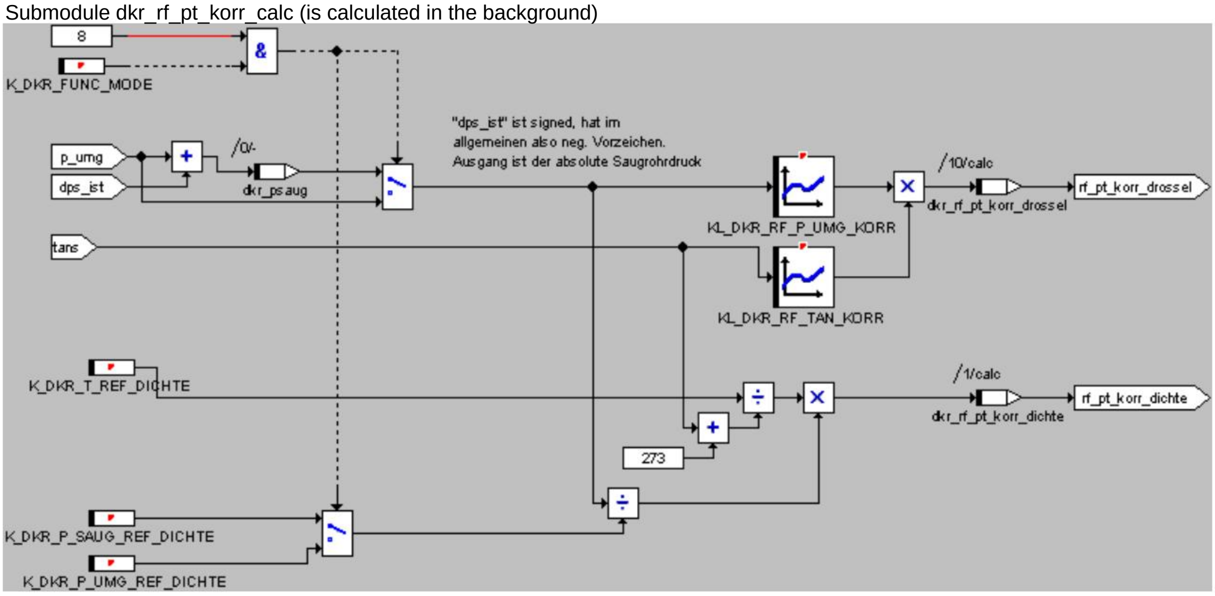
The function is very runtime-intensive, as large parts of it are calculated in the segment grid (with numerous interpolations). If the MSS54 is operated on an 8-cylinder engine, it is advisable to switch off the density correction (K_DKR_FUNC_MODE = DKRoff), as otherwise the performance is not sufficient for higher speeds. It may be necessary to rethink the design of the function in the future in order to get by with less computing time or calculation frequency.

1.3 FUNCTIONAL CIRCUIT DIAGRAM

Density Correction Module (dkr)



Submodule dkr_rf_pt_korr_calc (is calculated in the background)



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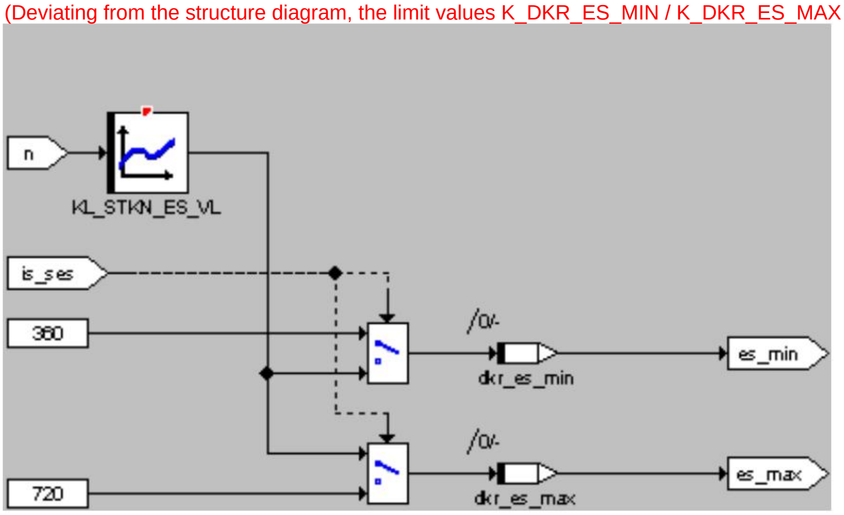
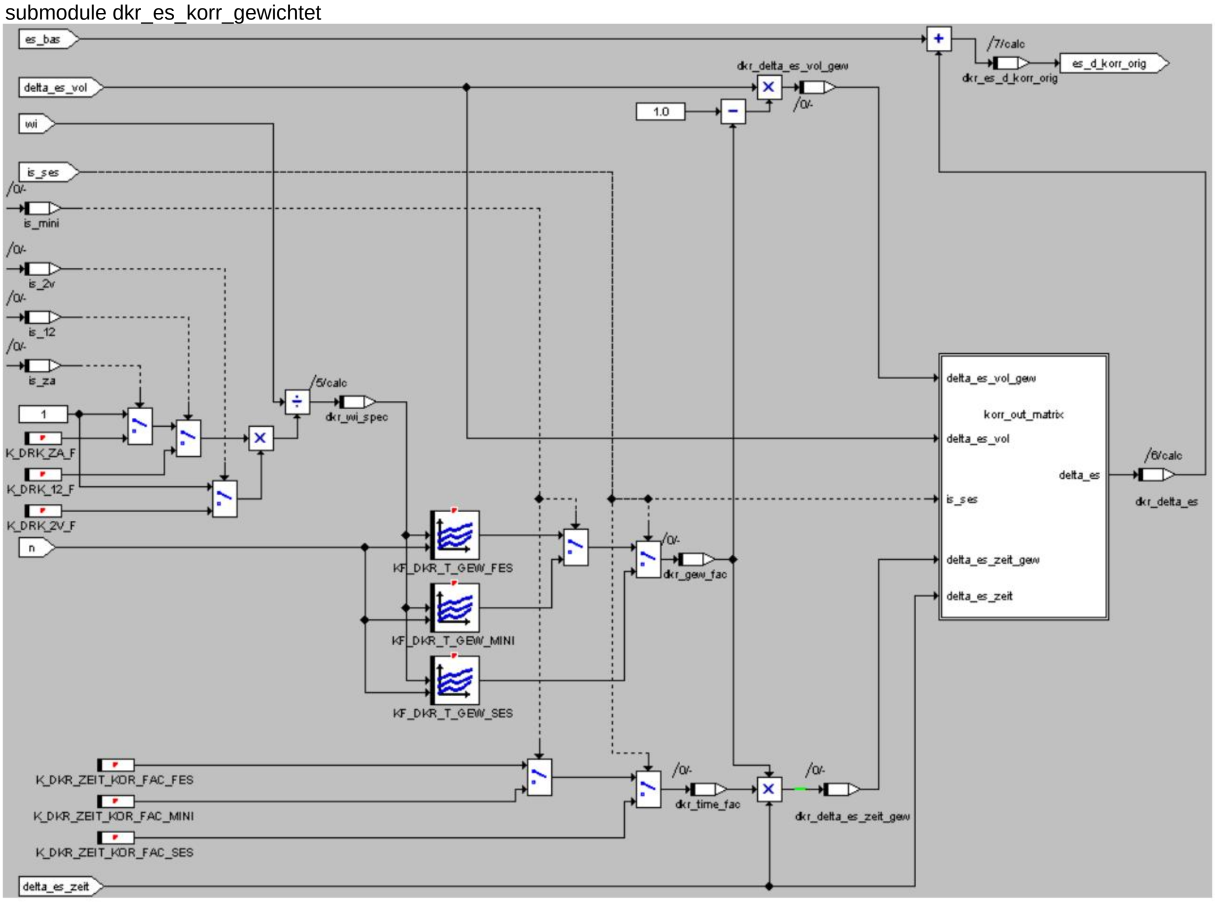
Submodule dkr_es_limit_calc

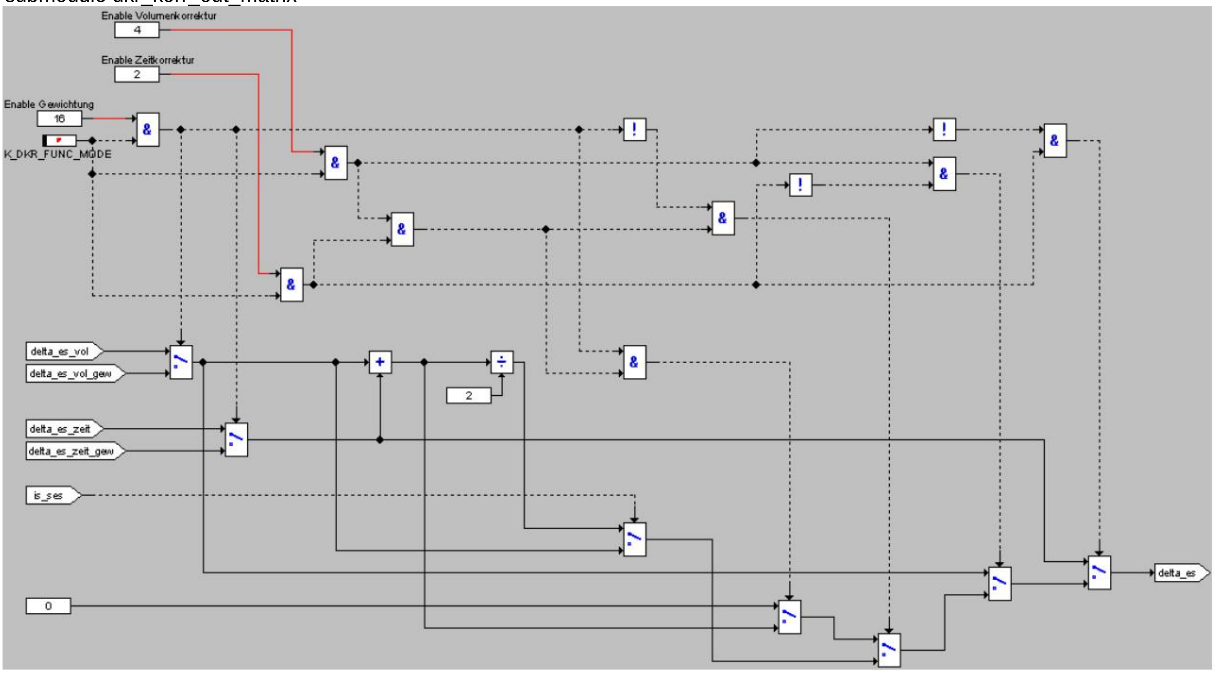
(Deviating from the structure diagram, the limit values K_DKR_ES_MIN / K_DKR_ES_MAX are used in “dkr_es_limit_calc”.)



submodule dkr_es_korr_gewichtet



submodule dkr_korr_out_matrix



1.4 APPLICATION INSTRUCTIONS

The reference ambient condition is 960 mbar at 20°C. With an intake manifold vacuum of 50 mbar at most operating points, the reference intake manifold condition has an air pressure of 910 mbar.

2 MODULE DATA

The function is calculated segment-synchronously in the slave.
rf_pt_korr calculations are done in the background

	Winkel	background	1ms	10ms	20ms	100ms	1s
task	dkr	dkr_rf_pt_korr_calc					

2.1 VARIABLES

The module does not contain any static variables, all sizes are global.

variable [Output]	Initialization Unit Range		(physical)	Quant.	Impl.	Page
dkr_es_aw		°	0 - 720	0.1	word	
	Crank Angle Inlet Closes Outlet Density Correction					
	globally available output variable					
rf_pt_korr		-	0 - 2.5	x/128	byte	
	1 rf_pt_korr set to external functions as rf_pt_korr_dichte					
	Calculated from: p_umg, dps_ist, tan					
dkr_rf_pt_korr_drossel	1 byte	-	0 - 2.5	x/128		
	rf_pt_korr (relative mass flow) for density correction via inlet valve opening time					
	Calculated from: p_umg, dps_ist, tan					

variable [Local]	initialization	Unit	Area (physical)	Quant.	Impl.	Page
dkr_rf_pt_korr_dichte	1	-	0 - 2.5	x/128	byte	
	rf_pt_korr (relative density) for density correction via cylinder volume					
dkr_delta_es_vol	0 0.1	°	-180 - 180		word	
	Inlet Closes Crank Angle Correction from Cylinder Volume					
dkr_delta_es_zeit	0 -180 - 180 0.1	°			word	
	Intake Excludes crank angle correction from intake valve opening time					
dkr_delta_es	0 0.1	°	-180 - 180		word	
	Inlet Closes Crank Angle Correction					
dkr_es_d_korr_orig		°	0 - 720	0.1	word	
	Crank angle intake closes after density correction without min/max limitation					
dkr_es_d_korr		°	0 - 720 words	0.1		
	Crank angle intake closes in density correction calculated (return value of "dkr()")					
dkr_es_min		°	0 - 720	0.1	word	
	minimum value limitation					
dkr_es_max		°	0 - 720	0.1	word	
	maximum value limit					
dkr_es_shift		°	0 - 720	0.1	word	
	Working value in "dkr()"					
dkr_wi_spec		kJ/l	like "wi"		word	
	Work value in "dkr_es_korr_gewichtet()"					
dkr_gew_fac			0 - 1	0.05	byte	
	Work value in "dkr_es_korr_gewichtet()"					
dkr_time_fac			0 – 12.7	0.05	byte	
	Work value in "dkr_es_korr_gewichtet()"					
dkr_delta_es_zeit_gew 0		°	-180 - 180	0.1	word	
	Work value in "dkr_es_korr_gewichtet()"					
dkr_delta_es_vol_gew	0	°	-180 - 180	0.1	word	
	Work value in "dkr_es_korr_gewichtet()"					

variable [Input]	source	Unit	Area (physical)	Quant.	Impl.	Page
eo_bas	EVT-Momentenreal.	Deg				
	Control edge inlet opens					
es_bas	EVT-Momentenreal.	Deg				
	Base Control Edge Inlet Closes					
evt_state	EVT-Momentenreal.	-				
	operating mode					
tan		°C				
	intake air temperature					
p_umg		mbar				
	ambient pressure					
wi		kJ/l				
	indexed work					
n		rpm				
	speed					
dps_ist		mbar				
	intake manifold vacuum (average)					

2.2 PARAMETER

application size	standard value	unit	area (physical)	Quant.	Impl.	Page
K_DKR_FUNC_MODE	DKR OFF	-	0x00: DKR=0 (ineffective) 0x07: DKR[t/V/ups/Gew]=1 0x13: V/Gew=0 0x15: t/weight=0 0x17: Gew=0 0x03: V=0 0x05: t=0 0x0F: ups=0 0x1B: V/ups/Gew=0 0x1D: t/ups/Gew=0 0x1F: ups/Gew=0 0x0B: V/ups=0 0x0D: t/ups=0 0x80: DKR OFF (disabled)	-	byte	
	Switch: Inlet Closes Deactivate/toggle density correction intervention					
K_DKR_ES_BAS_SES	540 bytes		500 - 755	1		
	Crank angle: start of outflow at SES					
K_DKR_ES_MIN	400		500 - 755	1	byte	
	Limit value in "dkr_es_limit_calc" (deviating from the structure diagram)					
K_DKR_ES_MAX	660		500 - 755	1	byte	
	Limit value in "dkr_es_limit_calc" (deviating from the structure diagram)					
K_DKR_P_REF_DICHTE	910	mbar	850 - 1105	1	byte	
	reference intake manifold pressure for air condition					
K_DKR_ZEIT_KOR_FAC_FES 1 0.05		-	0 - 12.7		byte	
	Additional weighting factor: Opening time-related admission Closes correction for FES					
K_DKR_ZEIT_KOR_FAC_Mini 1 0.05		-	0 - 12.7		byte	
	Additional weighting factor: Opening time-related inlet Closes correction for mini-stroke					
K_DKR_ZEIT_KOR_FAC_SES 1 0.05		-	0 - 12.7		byte	
	Additional weighting factor: Opening time-related admission Closes correction for SES					

K_DKR_T_REF_DICHTE	293	K 270 - 525		1	byte	
	reference temperature for air condition					
K_DRK_ZA_F	2	-	0 - 5	0.02	byte	
	Multiplication factor for cylinder load during cylinder deactivation					
K_DRK_2V_F	2	-	0 - 5	0.02	byte	
	Multiplication factor for cylinder load at 2V operation					
K_DRK_12_F	3	-	0 - 5	0.02	byte	
	Multiplication factor for cylinder load in 12-stroke operation					

2.3 CHARACTERISTIC CURVES

application size	support points	unit area		Quant. Impl.		Page
KL_DKR_ES_VOLUM	8 x KW	°	465 - 720	1	16 * bytes	
		-	0 – 2 (3)		16* byte	
	Cylinder volume = f(crank angle); characteristic curve must be invertible					
KL_DKR_ES_VOL_SES	8 x KW	°	465 - 720	1	16 * bytes	
		-	0 - 1		16 * bytes	
	Cylinder volume = f(crank angle) for SES; characteristic curve must be invertible					
KL_DKR_RF_P_UMG_KORR 8 xp		mbar 600 - 1110 8 byte		2	*	
		-	0 - 2.5	x/128	8 * bytes	
	KL_DKR_ES_VOLUM stored inversely					
KL_DKR_RF_TAN_KORR	8 xt °C -40 - 85			1	8 * bytes	
		-	0 - 2.5	x/128	8 * bytes	
	KL_DKR_ES_VOLUM stored inversely					
KL_DKR_KW_SHIFT	32 x KW	rpm 0 - 7500		50	32 * bytes	
		deg	-30 - 120	x/128	32 * bytes	
	Crank angle shift intake closes to cylinder volume calculation					
KL_DKR_KW_SHIFT_F	8 x wi kJ/l 8 byte		0 - 1.5	0.01	*	
		-	0 - 2.5	0.01	8 * bytes	
	Load-dependent weighting of the crank angle shift					
KL_STKN_ES_VL		rpm				
		deg				
	Base Control Edge Inlet Closes Full Load (included from the load module)					

2.4 CHARACTERISTICS

application size	support point n	unit area		Quant. Impl.		Page
KF_DKR_T_GEW_FES		rpm kJ/	0 - 6500		8 * byte	
		l	0 - 1.5		8 * byte	
		-	0 - 1	0.05	8*8 * byte	
	Weighting factor for opening time-based density correction for FES					
KF_DKR_T_GEW_MINI		RPM 0 - 6500 kJ/l 0 - 1.5			8 * byte	
		0 - 1			8 * byte	
		-		0.05	8*8 * byte	
	Weighting factor for opening time-based density correction for mini-stroke					
KF_DKR_T_GEW_SES		RPM 0 - 6500 8 kJ/l 0 - 1.5 0 - 1			* byte	
					8 * byte	
		-		0.05	8*8 * byte	
	Weighting factor for aperture time-based density correction for SES					

3 INITIAL DATA

The following is an initial setting for all application values. For some parameters, additional values are given to implement the functionality of the old density correction (R360): In this case, the opening time-based correction and the shift between intake closing crank angle and cylinder volume calculation are neutralized.

3.1 PARAMETER

K_DKR_B_DRK_OFF	0	
K_DKR_ES_BAS_SES	540 °	
K_DKR_ES_MIN	400 °	
K_DKR_ES_MAX	660 °	
K_DKR_P_REF_DICHTE	910 mbar (= 960 - 50)	
K_DKR_T_REF_DICHTE	293 K	
K_DKR_ZEIT_KOR_FAC_FES	1	for stand R360: 0
K_DKR_ZEIT_KOR_FAC_Mini	1	for stand R360: 0
K_DKR_ZEIT_KOR_FAC_SES	1	for stand R360: 0
K_DKR_ZA_F	2	
K_DKR_2V_F	2	
K_DKR_12_F	3	

3.2 CHARACTERISTICS

KF_DRK_T_GEW_FES:	constant 0
KF_DRK_T_GEW_SES:	constant 0
KF_DRK_T_GEW_MINI:	constant 1

3.3 CHARACTERISTIC CURVES

KL_DKR_ES_VOLUM

characteristic curve must be invertible

From 540 to 543 two support points with gradient 1! Data analogous to current status, linearly extrapolated

KW 360 390 460 540 Output [ ] 0.088 0.097 0.168 0.372 0.696 0.925 1	370		420		500		720	
							3	

Parameters taken from old software version without DKR.

KL_DKR_ES_VOL_SES

Characteristic curve must be invertible; data analogous to current status, mirrored at 540°, linearly extrapolated

KW	540	550 630 650 0.991 0.920 0.761 0.469 0.266 0.130 0.088	570	600		660		720
output [ ]	1							

Parameters taken from old software version without DKR.

KL_DKR_RF_P_UMG_KORR

P_UMG	599	749	800	851	899	959	1040 1100	
Exit [-]	0.62	0.78	0.83	0.88	0.94	1	1.08 1.14	

KL_DKR_RF_TAN_KORR

TAN	-40	-20		20	40	60	80	100
Output [Nm] 1.26		1.16	0 1.07	1	0.94	0.88	0.82	0.73

KL_DRK_KW_SHIFT

Calculated as full load inlet closes - 540° with limitation not negative.

If full load is operated with a different DISA position, values may need to be modified.

N 400		800	1200 1600 2000 2400 2800				
Output [ ] 0		0	0 12		7	13	20

3200 3600 4000 4400 4800 5200 5600 6000 6400								
26 44 51	34		46		60	74	93	120

To achieve stand R360, this or the characteristic curve KL_DRK_KW_SHIFT_F must be set to a constant 0. Had to be reduced to 16 support points!

KL_DRK_KW_SHIFT_F

wi 0		0.2	0.4	0.6	0.8	0.9		1.4
Output [ ] 0		0.2	0.4	0.6	0.8	0.9	1 1	1