



# TA 1400-0159

Technical Instruction

## Type 4 cylinder optimization knock controller



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#### **UNCONTROLLED WHEN PRINTED OR TRANSMITTED ELECTRONICALLY**

## **1 General**

Because of differences in combustion between individual cylinders on type 4 engines due to manufacturing tolerances, large numbers of cylinders, different formation of deposits on biogas plants, etc. and in order to increase the availability of the engine, it is necessary to optimize the ignition point of individual cylinders. The knock control system is based on the principle of reducing the ignition point (retarding the ignition point) during knocking. Knocking is detected using a seismic sensor on each cylinder and evaluated by software.

The optimum ignition point to make cylinders less prone to knocking is found and maintained by the control system itself. When the engine is near to knocking during operation, the knocking cylinder is therefore retarded until the cylinder is knock-free. In this way, the engine runs in the near-knocking range with different ignition points for individual cylinders, which are kept constant for an adjustable time. The ignition point does not change continuously as is the case with the existing knock control system. A  $\Delta$ IP is set for the engine as a whole.

### **Advantages and improvements**

- Improved engine availability
- The engine can be kept stable at the optimum operating point in terms of efficiency (at the knock limit)
- Reduction in engine shutdowns due to knocking (especially in biogas plants)

- Reduction in component load and consequently a reduced risk of combustion chamber components failing
- Lengthening of combustion chamber cleaning intervals
- This controller can increase the knock limit from 1000 mV to 1200 mV.

The new *type 4 cylinder optimization knock controller* is an improved knock detection and control software package on the DIA.NE XT and does not require the replacement of components. The improved knock control system ensures that the engine operates more efficiently near the knock limit.

**IMPORTANT:**

- The parameters must be set correctly (see ⇒ Parameters)!
- This controller is not suitable when the engine is operating in isolated mode.
- The LEANOX (TI 1503-0043) must be set correctly and checked at every 2,000 OH service.

**Integrating the knock controller for cylinder optimization into the DIANE.XT version**

A beta version of the type 4 cylinder optimization knock controller has been integrated into DIA.NE XT 2.1x to 2.5x, which can be activated as required (see ⇒ Parameters for beta version). The knock controller is integrated and activated from DIA.NE XT Version 2.6x onwards.

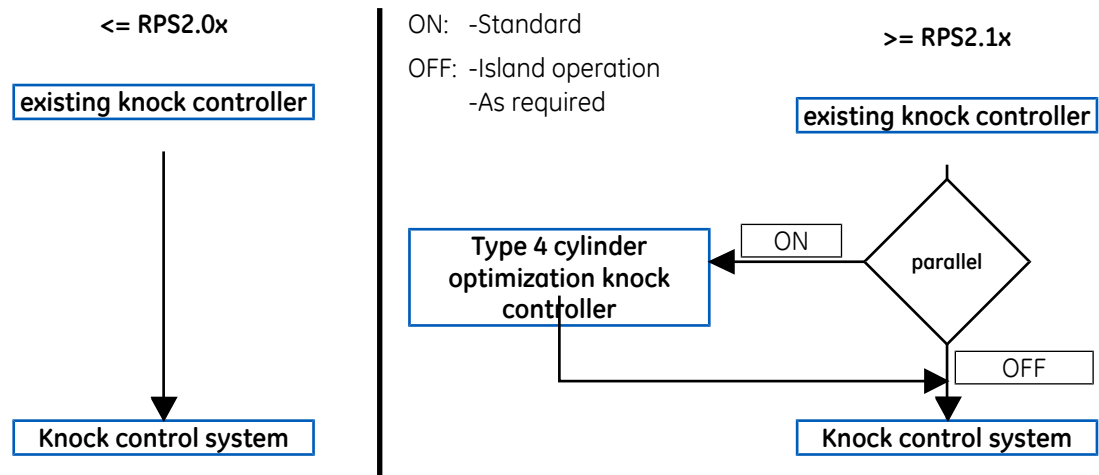
| Product range  | DIA.NE XT   | Knock controller   | Note         | Parameter                                |
|----------------|-------------|--|--------------|--|
| Prior to 2007  | 2.0x        | Existing knock control system  | -            | Standard                                 |
| 2007...2009    | 2.1x...2.5x | Existing knock control system<br>+<br>Alternative knock controller for cylinder optimization | Beta version | ANTI-KNOCK<br>+<br>RESERVE               |
| From Oct. 2009 | ≥ 2.6x      | Knock controller for cylinder optimization   | ACTIVE       | ANTI-KNOCK<br>+<br>CYLINDER OPTIMIZATION |

## 2 Function

### 2.1 Activation

In addition to the existing knock detection and control system, the CYLINDER OPTIMIZATION ACTIVE parameter can be used to switch the *type 4 cylinder optimization knock controller* for type 4 engines on and off so that it operates **in parallel** to the existing “old” knock control system.

Figure 1 below shows the difference between the existing predecessor knock control system and the new knock control system. In the existing “old” knock control system, the ignition point is reduced in proportion to the knock integrator. The “old” control behaviour of the parallel *type 4 cylinder optimization knock controller* remains the same. However, the ignition point at the knocking cylinder is not continuously reset to the rated ignition point but is reduced for an adjustable time, thereby preventing continuous knocking.



**Figure 1:** Existing knock detection system (left) and cylinder optimization knock controller switched in parallel to the existing knock detection system (right)

The type 4 cylinder optimization knock controller switched in parallel is automatically disabled in isolated operation. This controller is not suitable when the engine is operating in isolated mode.

If the knock controller is switched off by the CYLINDER OPTIMIZATION ACTIVE parameter, the control behaviour remains active for a certain time, i.e. the ignition point of the knocking cylinder remains reduced until the adjustable time has elapsed. However, the actions can be manually reset immediately by pressing a RESET button (see ⇒ Resetting the ignition points – RESET knock controller)

## 2.2 Ignition point setting

There is only one ignition point used as the general setting for the engine control system (rated ignition point)! It is set in the ignition parameter list (IGNITION POINT ADJUSTMENT WITH KNOCK MONITOR MAINS-PARALLEL GAS TYPE X). Each cylinder is controlled on the basis of this ignition point. As with all control systems in the type 4 engine, THE ANTI-KNOCK / IP ADJUSTMENT OFFSET VIA KNOCK CONTROLLER GAS TYPE X must be set to 0°C.

## 2.3 Control system

### 2.3.1 Control – continuous, light knocking

Action:

The engine is running near the knock limit and knocking is detected. The knock integrator of the cylinder concerned is gradually rising. An adjustable knock integrator limit (parameter: KNOCK INTEGRATOR LIMIT) has been exceeded.

Response:

The ignition point of the cylinder concerned is retarded by an adjustable value (parameter: IP ADJUSTMENT/INTERVAL).

If this action is unsuccessful, i.e. the integrator value does not fall below the adjustable knock integrator limit (parameter: MONITORING INTERVAL), the ignition point is again retarded after an adjustable time.

This procedure can be repeated as often as required until the minimum permissible ignition point is reached.

If the knock integrator value reaches the power reduction threshold, it is enabled in parallel to the ignition point adjustment.

If the controller has found the optimum ignition points of the cylinders which are at the knock limit, a medium ignition point is set for the engine as a whole. A possible scenario is shown in Figure 2 below.

The rated ignition point has been set at  $IP = 22^\circ \text{CA}$  (shown as  $IP_{MAX} = 22.0^\circ \text{CA}$ ). The knock-prone cylinders are cylinders 1 and 11, for which the controller has also reduced the ignition point and the knock integrator is at 0% (see arrow).

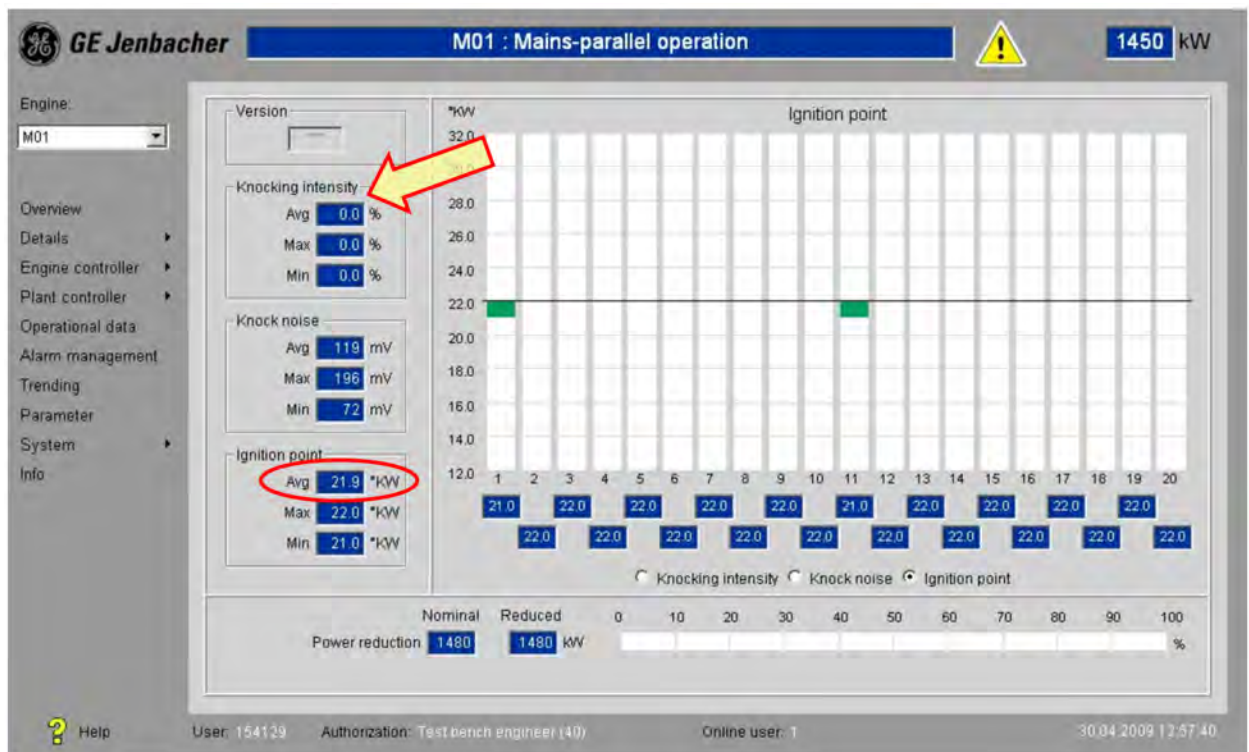


Figure 2: Example of adjusted condition

### 2.3.2 Control – short, sharp knocking

Action:

Very powerful knocking suddenly occurs and the integrator rises very rapidly, well above the adjustable knock integrator limit.

Response:

The ignition point of the cylinder concerned is immediately retarded by the adjustable value. **At the same time**, the ignition point is continually reduced in proportion to the integrator value (existing "old" knock detection system). This function is used to protect the engine against knocking and not to equalise the cylinders. If the integrator continues to rise, where a power reduction to half load has been enabled or in the event of an integrator value of  $\geq 100\%$ , the engine will shut down.

### 2.3.3 Control during normal operation (no knocking):

|           |   |
|-----------|---|
| Action:   | If the knocking situation settles down again (e.g. after a gas quality fluctuation), the knock integrator reduces again and eventually falls below the adjustable limit.  |
| Response: | After an adjustable time (parameter: RESET FOR OPTIMIZATION), the ignition point is advanced again by the factor (parameter: IP ADJUSTMENT/INTERVAL). This process is repeated until the rated ignition point stated in the parameter list has been reached (when no knocking is detected). |

### 2.3.4 Control – reaching the minimum ignition point

|           |   |
|-----------|---|
| Action:   | The engine is at the knock limit, i.e. deposits accumulate over the running period and the LEANOX controller is not adjusted (see ⇒ LEANOX adjustment – LEANOX re-adjustment). The controller reduces the ignition timing points of all the cylinders to the knock-free optimum and one cylinder reaches the minimum ignition point (see Figure 3, $IP_{RATED} = 22^\circ \text{ CA}$ and $IP_{MIN} = 14^\circ \text{ CA}$ ). |
| Response: | A further ignition point reduction is not possible as the minimum has been reached. The controller reduces the engine output by an adjustable value (parameter: POWER ADJUSTMENT/INTERVAL) for the duration of an adjustable time (parameter: RESET FOR OPTIMIZING P RED).  |

If the engine adjusts to the minimum ignition point (parameter: IP MINIMUM GAS TYPE X) of a cylinder, servicing is required:

- LEANOX to be adjusted to rated ignition point.
- Rated output to be reduced as the engine is no longer able to operate at full load as a result of gas quality or deposits, for example.
- Combustion chamber to be cleaned.



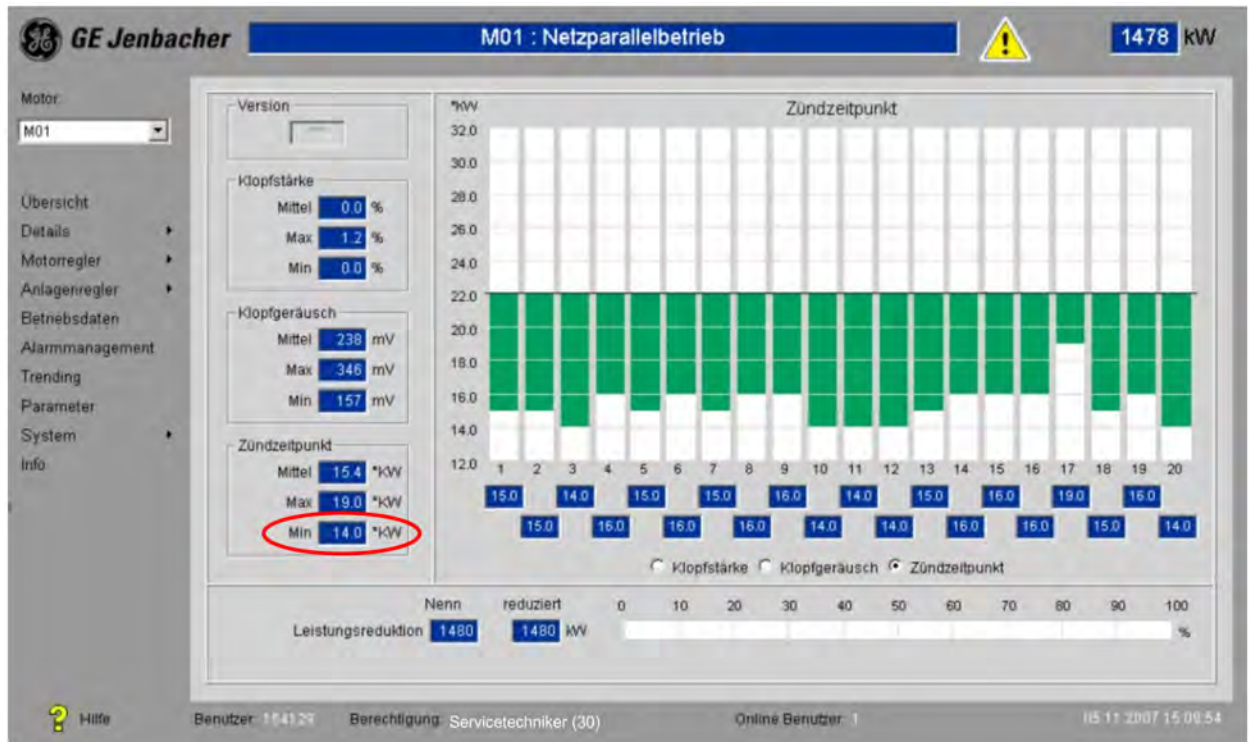


Figure 3: Example showing minimum ignition point being reached

## 2.4 Resetting the ignition points – RESET knock controller

The optimized ignition points are preserved even when the engine is at a standstill (only engine operating hours count for the reset time). From „Advanced customer“ level (15) and higher, a RESET button can be used to reset and restart the cylinder optimization knock controller (this is necessary for LEANOX adjustment). Once the RESET button has been actuated, the ignition points of all cylinders go slowly along a ramp to the rated ignition point, as does the output to rated output.

Figure 4 below shows the schedule for resetting the knock controller on the DIA.NE XT2. The ignition points can be displayed digitally by choosing the ignition option in the CYL menu. A field is displayed at the bottom of the window which is set to ZERO by default (USER LEVEL: 15). Set to ONE to reset the knock controller. This can be checked from the change in the ignition points (advance setting).

The knock controller in the DIA.NE XT control system can also be reset in the event of a cold start, as an "emergency measure".



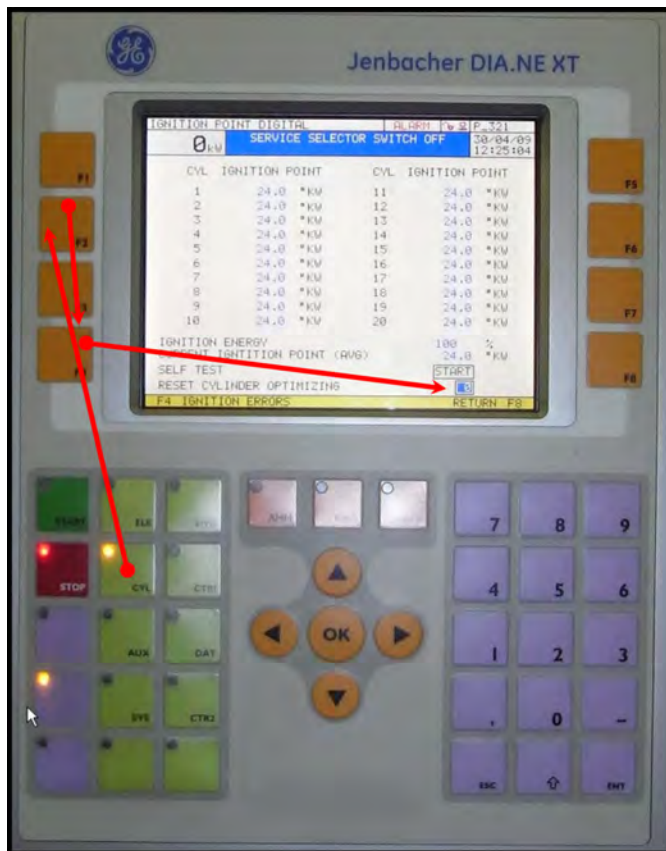


Figure 4: Schedule for resetting the knock controller (USER LEVEL 15) - XT2

Figure 5 below shows the schedule in the DIA.NE XT3.

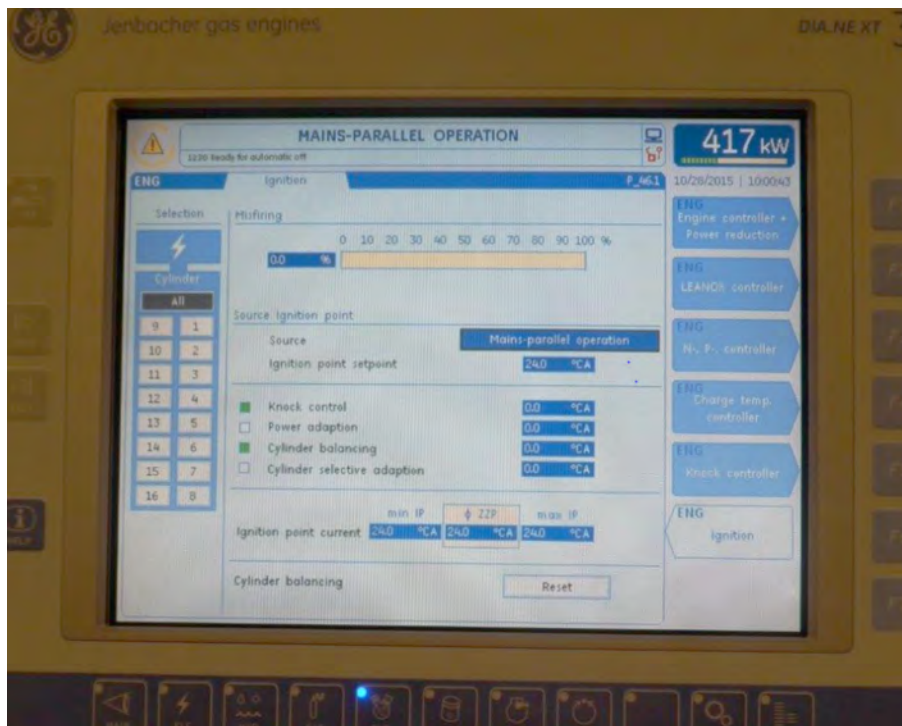
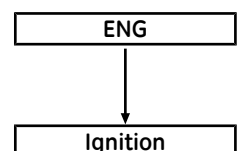
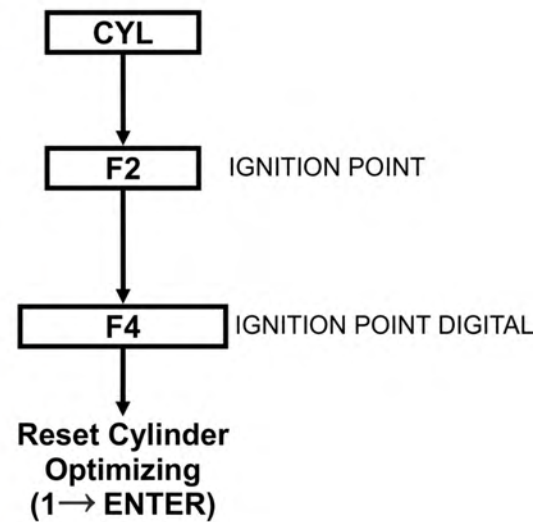


Figure 5: Schedule for resetting the knock controller (USER LEVEL 15) - XT3

Figure 6 below shows the schedule in the DIA.NE XT4.



RESET-button is visible, if following parameter is on:  
„Antiknock\Cylinder optimizing\Cylinder optimizing active“

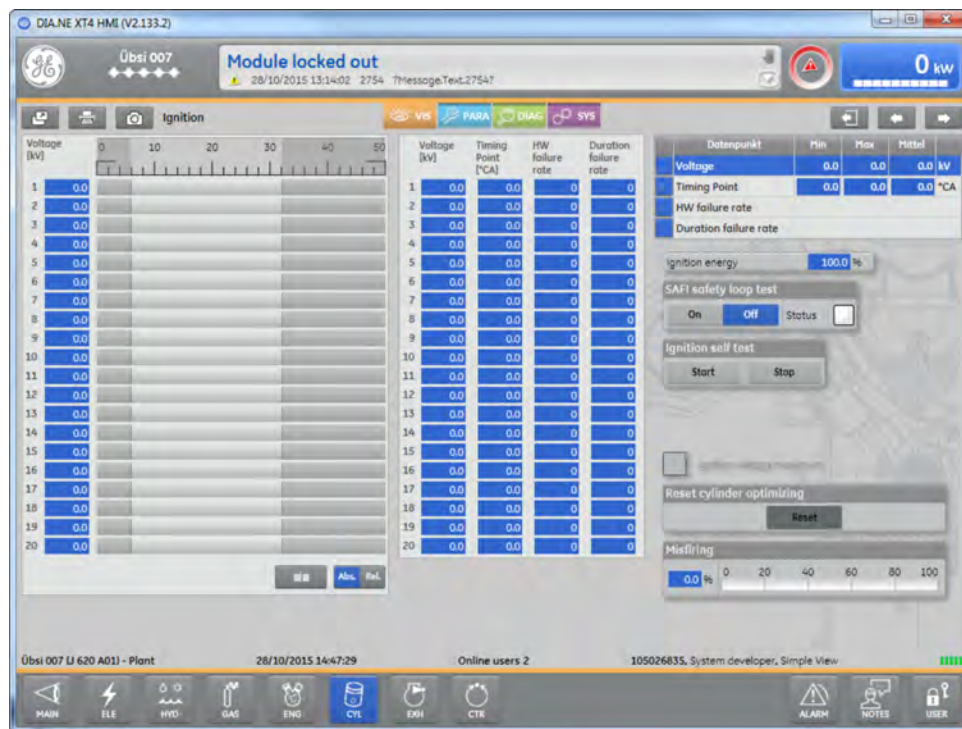
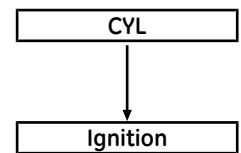


Figure 6: Schedule for resetting the knock controller (USER LEVEL 15) – XT4



RESET-button is visible, if following parameter is on:  
„Antiknock\Cylinder optimizing\Cylinder optimizing active“

## 2.5 LEANOX adjustment – LEANOX re-adjustment

If the engine is operating close to the knock limit, the knock controller will optimize the ignition point of each individual cylinder and the average ignition point for the engine as a whole will differ from the general rated ignition point (in mains-parallel operation: 24° CA). To achieve optimum engine efficiency, the average ignition point should be close to the rated ignition point (e.g. where  $IP_{\text{RATED}} = 24^\circ \text{ CA} \rightarrow IP_{\text{Average}} = 22 \dots 24^\circ \text{ CA}$ ). This can be set using the LEANOX controller.

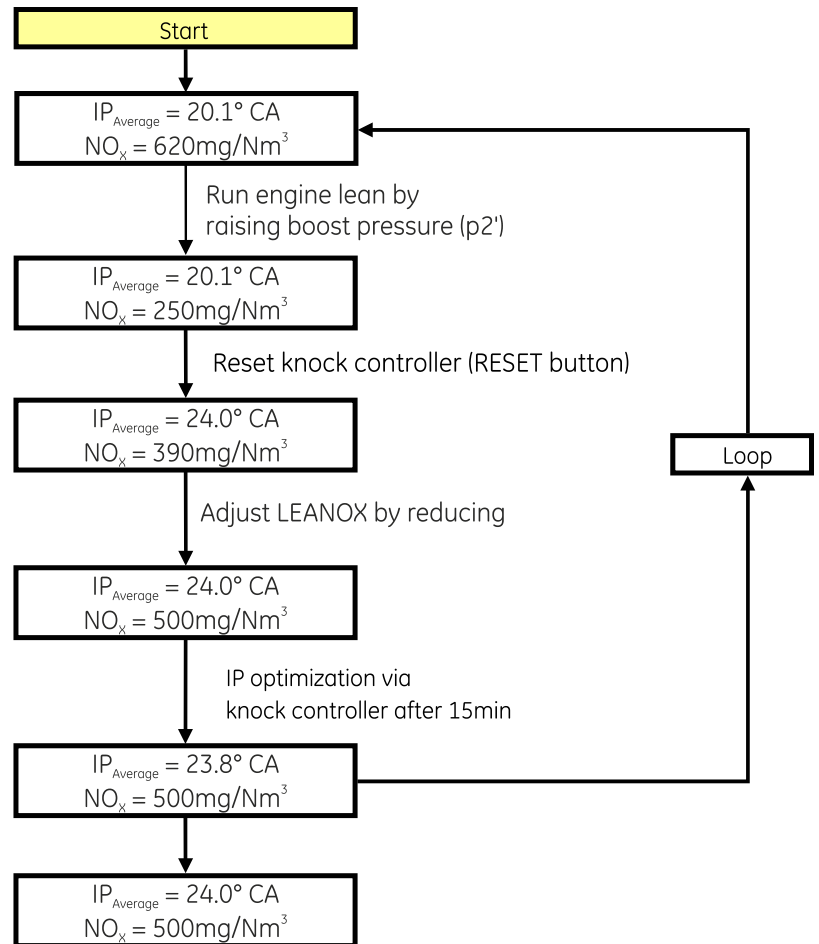
### LEANOX adjustment/re-adjustment (USER LEVEL 15)

When the LEANOX is adjusted or re-adjusted (when the cylinder optimization knock controller is active and at full-load point), the engine must run somewhat leaner, the cylinder optimization knock controller must be reset (RESET button, see ⇒ Resetting the ignition points – RESET knock controller) and the LEANOX (point 1 – Full-load point and point 2 – Half-load point) must be adjusted to an average ignition point near the rated ignition point (ideally  $IP_{\text{RATED}} = IP \Rightarrow$  Resetting the ignition points – RESET knock controller) (see diagram below, Figure 5). If this is not possible in the first run-through, it can be repeated in further loops until the desired engine operating point has been set.

If the engine has substantial deposits in the combustion chamber (e.g. when used with landfill gas) and it is not (or no longer) possible to set the desired engine operating point exactly because the engine is knocking severely or misfiring at rated output, rated ignition point and desired NOx level, the LEANOX adjustment process must be aborted after the first loop. The engine can no longer be operated close to the rated ignition point. The knock controller automatically sets the earliest possible ignition point.

Boundary conditions:

- $IP_{RATED} = 24^{\circ}KW$
- $NO_{x,SET} = 500mg/Nm^3$  (at 5%  $O_2$ )
- $P_{el} = 1414kW$



**Figure 5: Diagram for LEANOX re-adjustment (USER LEVEL 15)**

### LEANOX adjustment/re-adjustment (USER LEVEL 30)

The LEANOX can also be adjusted as follows:

1. Running the engine more leanly
2. Switching off the parallel type 4 cylinder optimization knock controller
3. LEANOX re-adjustment
4. Switching on the type 4 cylinder optimization knock controller

However, this requires USER LEVEL 30.

## 3 Parameters

The following parameters are also required for the cylinder optimization knock controller. The values quoted in this document apply, i.e. the current values in the parameter list must always be used.

| WIN designation | Zylinder Optimierung aktiv   |
|-----------------|--|
| XT designation  | CYLINDER OPTIMIZATION  |
| Description     | This parameter is used to enable (1) or disable (0) the cylinder optimization knock controller. The cylinder optimization knock controller always runs in parallel with the conventional knock control system. |
| Parameter list  | ANTI-KNOCK   CYLINDER OPTIMIZATION   |

| WIN designation | Zylinder Optimierung aktiv  |
|-----------------|---|
| Read password   | Advanced customer (15)  |
| Write password  | Service engineer (30)   |
| Guide value     | 1   |
| Help text       | TRUE=Approved for cylinder optimization.<br>See Technical Instruction No.: 1400-0159. |

| WIN designation | KlopfinTEGRator Limit   |
|-----------------|---|
| XT designation  | KNOCK INTEGRATOR LIMIT  |
| Description     | If a cylinder's knock integrator exceeds this value, ignition point optimization is enabled for this cylinder. The ignition point is reduced by an adjustable value (IP ADJUSTMENT/INTERVAL). The monitoring interval and the reset time are started for this cylinder. |
| Parameter list  | ANTI-KNOCK   CYLINDER OPTIMIZATION  |
| Read password   | Advanced customer (15)  |
| Write password  | Service engineer (30)   |
| Guide value     | 4.0   |
| Help text       | Limit value for the knock integrator  |

| WIN designation | ZZP Anpassung / Intervall   |
|-----------------|---|
| XT designation  | IP ADJUSTMENT/INTERVAL  |
| Unit            | [degrees CA]  |
| Description     | This parameter is used to show the level of ignition point adjustment per monitoring interval. This process can be repeated as often as required until the minimum permissible ignition point is reached. After the reset time has elapsed, the ignition point is advanced again by this value. |
| Parameter list  | ANTI-KNOCK   CYLINDER OPTIMIZATION  |
| Read password   | Advanced customer (15)  |
| Write password  | Service engineer (30)   |
| Guide value     | -1.0  |
| Help text       | Ignition point adjustment per monitoring window   |

| WIN designation | Monitoring interval   |
|-----------------|---|
| XT designation  | MONITORING INTERVAL   |
| Unit            | [min]   |
| Description     | The monitoring interval is the period after which another check is carried out to ascertain whether the knock integrator value of the cylinder concerned exceeds the limit. |
| Parameter list  | ANTI-KNOCK   CYLINDER OPTIMIZATION  |
| Read password   | Advanced customer (15)  |
| Write password  | Service engineer (30)   |
| Guide value     | 3   |
| Help text       | Monitoring interval   |

| WIN designation | Reset für Optimierung  |
|-----------------|--|
| XT designation  | RESET TIME FOR OPTIMIZATION  |
| Unit            | [min]  |
| Description     | <p>After the reset time has elapsed, the ignition point is advanced again by the ignition adjustment value. This process is repeated until either the preset ignition point on the parameter list is reached or the knocking recurs.</p> <p><b>Entry:</b> 60 means that the ignition point is reset by the IP ADJUSTMENT PER INTERVAL VALUE to "early" after 60 minutes.</p> |
| Parameter list  | ANTI-KNOCK   CYLINDER OPTIMIZATION   |
| Read password   | Advanced customer (15)   |
| Write password  | Service engineer (30)  |
| Guide value     | <b>60</b>  |
| Help text       | Reset time for cylinder optimization   |

| WIN designation | Leistungsanpassung / Intervall   |
|-----------------|--|
| XT designation  | POWER ADJUSTMENT/INTERVAL  |
| Unit            | [%Pnom]  |
| Description     | <p>Where a cylinder has reached the minimum ignition point, the controller reduces the power by the set value for the duration of the preset period.</p> <p><b>Entry:</b> 10 means that the power is reduced by 10% of the rated output for the duration of the preset period.</p> <p>Depending on the application (e.g. biogas plants), a larger power reduction may have the advantage of preventing engine shutdowns.</p> |
| Parameter list  | ANTI-KNOCK   CYLINDER OPTIMIZATION   |
| Read password   | Advanced customer (15)   |
| Write password  | Service engineer (30)  |
| Guide value     | <b>10</b>  |
| Help text       | Power adjustment per monitoring window   |

| WIN designation | Reset für Optimierung P red   |
|-----------------|---|
| XT designation  | RESET TIME FOR OPTIMIZING P RED   |
| Unit            | [min]   |
| Description     | <p>After the reset time has elapsed, the power reduction is withdrawn and the engine again operates at nominal load. The amount of the reset time for optimizing P red must exceed the reset time for optimization so that the controller has the opportunity to retard the ignition point to knock-free operation.</p> <p>Depending on the application, it may be advantageous to increase the value (e.g. to allow for the unmanned operation of the engine).</p> |
| Parameter list  | ANTI-KNOCK   CYLINDER OPTIMIZATION  |



| WIN designation | Reset für Optimierung P red  |
|-----------------|--|
| Read password   | Advanced customer (15)   |
| Write password  | Service engineer (30)  |
| Guide value     | <b>120</b>   |
| Help text       | Reset time for power reduction   |
| WIN designation | Integrationszeit belasten Zylinderoptimierung  |
| XT designation  | INCREASE INTEGRATION TIME CO   |
| Unit            | [s]  |
| Description     | If the cylinder optimization knock controller is switched on, the knock integrator is loaded with this value instead of the value from ANTI-KNOCK/ INTEGRATION TIME. |
| Parameter list  | ANTI-KNOCK   CYLINDER OPTIMIZATION   |
| Read password   | Advanced customer (15)   |
| Write password  | Service engineer (30)  |
| Guide value     | <b>400</b>   |
| Help text       |  |

The following parameters from the standard knock controller are important for ensuring that the controller is operating properly:

|  |   |            |
|--|---|------------|
| ANTI-KNOCK/IP ADJUSTMENT<br>OFFSET VIA KNOCK<br>CONTROLLER GAS TYPE X  | 0   | degrees CA |
| ANTI-KNOCK/IP ADJUSTMENT<br>MAXIMUM VIA KNOCK<br>CONTROLLER GAS TYPE X | 10  | degrees CA |
| Calculations:  | IP WITH KNOCK CONTROL X GAS TYPE X minus IP MINIMUM<br>GAS TYPE X<br>For example: 24 – 14 = 10 degrees CA |            |
| ANTI-KNOCK / UNLOAD<br>INTEGRATION TIME                                | 25  | s          |
| ANTI-KNOCK / LOAD<br>INTEGRATION TIME                                  | 3000  | s          |
| ANTI-KNOCK/KLS98/SAFI/<br>KNOCK LIMIT LEVEL                            | 1200  | mV         |
| IGNITION/IP WITH KNOCK<br>CONTROL MAINS-PARALLEL<br>GAS TYPE X         | 24  | degrees CA |
| IGNITION/IP MINIMUM GAS<br>TYPE X                                      | 14  | degrees CA |

#### 4 Alarm entries:

The cylinder optimization knock controller operates without additional alarm management entries.

The existing entries remain enabled with and without the cylinder optimization knock controller.

Example:

B2141 Ignition point reduction due to knocking  
B2125 P-RED knocking



A3073 Knocking in cylinder 1  
up to  
A3092 Knocking in cylinder 20

## 5 Information

### 5.1 Alarm management messages

|                     |  |
|---------------------|--|
| Priority 1 shutdown | Reason for shutdown: Gas valves closed, generator switch open, ignition off Reset is required and is only possible when the operation mode selector switch is in "OFF" position.   |
| Priority 2 shutdown | Reason for shutdown: Gas valves closed, generator switch on when $P < 10\%$ or after 2 seconds. Resetting is required and is only possible when the operation mode selector switch is in "OFF" position.                     |
| Priority 3 shutdown | Shutdown as when requirement is removed (P ramp + 1 min after-run). Resetting is required and is only possible when the operation mode selector switch is in "OFF" position.   |
| Warning             | Engine continues to run. There is only a display in alarm management (AMM)! The display disappears when the warning is no longer detected and is reset. Resetting is possible at any operating mode selector switch setting. |
| Operational message | Engine continues to run. There is only a display in AMM. An operating notification disappears in AMM when it is no longer detected. Resetting is not therefore necessary.  |

### 5.2 User level

|    |                        |
|----|------------------------|
| 5  | Observer               |
| 10 | Customer               |
| 15 | Advanced customer      |
| 30 | Service engineer       |
| 40 | Test engineer          |
| 45 | Advanced test engineer |
| 50 | Applications developer |

### 5.3 Parameters for beta version

In versions 2.1x to 2.5x, a beta version of the knock controller is integrated into the DIA.NE XT engine control system. To activate the controller, proceed as follows:

- 1) If the reserve parameters have not been activated, activate them in consultation with the Competence Centre (Tel. 0043 5244 600 -2000)
- 2) Set the parameters in accordance with the default recipe values for the appropriate version of DIA.NE XT, in particular: ANTI-KNOCK, ANTI-KNOCK/KLS98/SAFI and IGNITION

3) Set following parameters – ANTI-KNOCK and RESERVE / parameters 61-70:

**ANTI-KNOCK**

IP ADJUSTMENT 0 degrees CA  
 OFFSET VIA KNOCK  
 CONTROLLER GAS  
 TYPE X

IP REDUCTION 10 degrees CA  
 MAXIMUM VIA KNOCK  
 CONTROLLER GAS  
 TYPE X

UNLOAD INTEGRATION 25 s  
 TIME

LOAD INTEGRATION 400 s  
 TIME

UNALLOCATED 62 /  
 CYLINDER  
 OPTIMIZATION = 1

**ANTI-KNOCK/KLS98/SAFI**

LIMIT LEVEL FOR 1200 mV  
 KNOCKING

**RESERVE / parameters 61-70**

Parameter 62 value 1

Parameter 62 description CYLINDER OPTIMIZATION  
 English

Parameter 63 value 40

Parameter 63 description KNOCK INTEGRATOR LIMIT (1/10%)  
 English

Parameter 64 value -10

Parameter 64 description IP ADJUSTMENT/INTERVAL (1/10°)  
 English

Parameter 65 value 3

Parameter 65 description MONITORING INTERVAL (min)  
 English

Parameter 66 value 1

Parameter 66 description RESET TIME OPTIMIZATION (h)  
 English

**Resetting the knock controller – Reset button**

The controller can be restarted by pressing the RESET button. See ⇒ Resetting the ignition points – RESET knock controller This is possible from User Level 30 (Service engineer).

**Switching off the type 4 cylinder optimization knock controller**

When the knock controller is disabled (CYLINDER OPTIMIZATION = 0), the unload integration time must be reset to 3000 s.

## 6 Revision code

| Revision history |            |  |  |
|------------------|------------|--|--|
| Index            | Date       | Description / Revision summary   | Expert<br>Auditor                          |
| 3                | 11.04.2019 | GE durch INNIO ersetzt / GE replaced by INNIO  | <b>Opoku</b><br><i>Pichler R.</i>          |
| 2                | 29.12.2015 | Änderung 1 und 2.4 / Update 1 and 2.4  | <b>Unterrainer R.</b><br><i>Boewing R.</i> |
| 1                | 27.07.2010 | Umstellung auf CMS / Change to Content Management System<br>ersetzt / replaced Index: a1 | <b>Schartner</b><br><i>Licht</i>           |

