Operating Instruction

STAG AFR

Wideband Oxygen Sensor Controller

(instruction available also in the **AC AFR** software and at **www.ac.com.pl**)

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AC S. A. ul. 42 Pułku Piechoty 50 I 15-181 Białystok, Poland I tel. +48 85 743 81 00, fax. +48 85 653 93 83

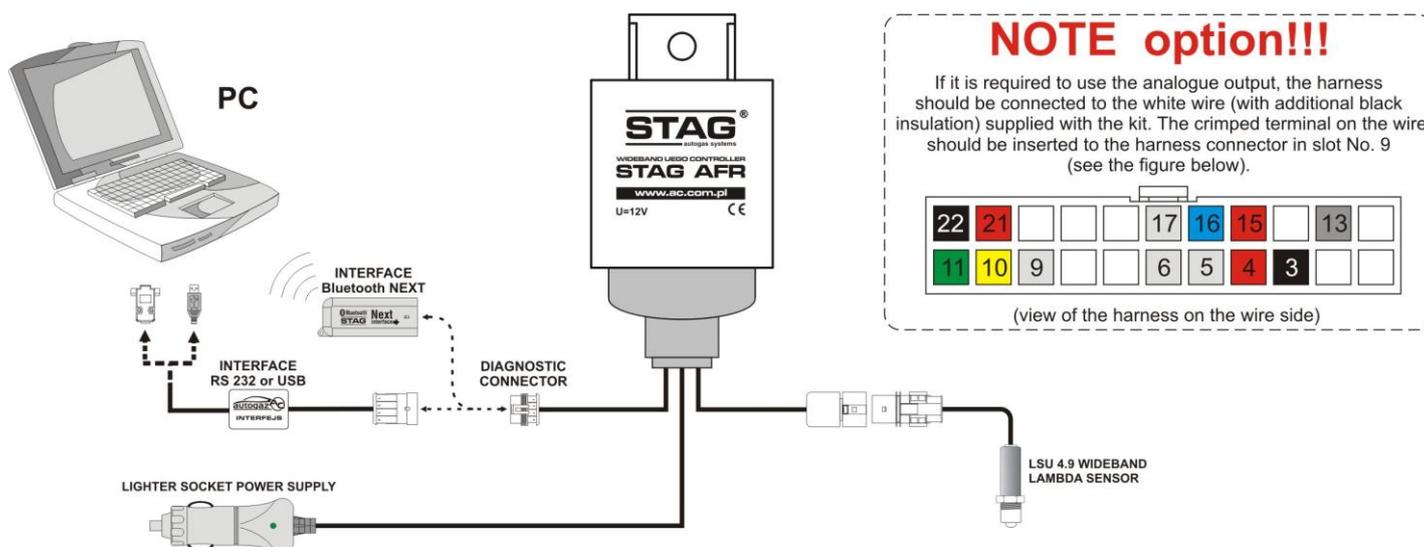## 1. Wiring diagram for STAG AFR connection

Figure 1. Wiring diagram for STAG AFR connection

2. Contents of the kit

➢ STAG AFR - wideband oxygen sensor controller
➢ Wideband oxygen sensor – Bosch LSU 4.9 (0 281 004 026)
➢ Wire harness
➢ Wiring diagram
➢ Oxygen sensor mounting sleeve
➢ Plug
➢ CD
➢ Additional cable for the analogue output (0-5V)

3. Purpose

The STAG-AFR controller for wideband oxygen sensors has been designed to determine the air-to-fuel ratio (AFR) for an internal combustion engine based on the measurement of oxygen in the exhaust gas. Measurements are made with a wideband oxygen sensor that may be used in engines fed with a wide range of fuels such as unleaded gasoline, diesel, LPG, natural gas, methanol and ethanol.

ATTENTION! The wideband oxygen sensor provided in the kit should not be used in leaded gasoline engines and two-stroke engines.
In both cases, the probe lifetime is dramatically reduced.

STAG AFR is an alternative to expensive exhaust gas analyzers. Due to high-speed measurements of lambda parameter (AFR - air-fuel ratio), it is possible to control air-fuel mixture not only in steady but also in transient engine operating states
The kit can be used, for example, for adjusting both carburettor and fuel injection systems, calibrating LPG/autogas systems of any fuel system diagnostic generation available on the market, diagnostics of fuel systems, diagnostics of factory installed oxygen sensors and control of air-fuel mixture during chip-tuning system calibration. Knowing a current air-fuel ratio for the mixture supplied to the engine, the user is able

to make precise adjustment of the fuel system to ensure optimum engine power, while having reasonable fuel consumption.

STAG AFR is provided with an analogue 0V to 5V output. It can be used to connect an external AFR indicator, as well as chassis dynamometers with an analogue input for the AFR reading, external data loggers and standalone/piggyback type ECM units. Activation of the option requires connecting an additional cable included in the kit to the harness, in accordance with fig. 1. Relation of the analogue output voltage level to the AFR and Lambda value has been presented in Table No. 1.

Lambda	AFR (Pb)	Voltage [V]
0,7	10,29	0
0,73	10,73	0,25
0,76	11,17	0,5
0,79	11,61	0,75
0,82	12,05	1
0,85	12,5	1,25
0,88	12,94	1,5
0,91	13,38	1,75
0,94	13,82	2
0,97	14,26	2,25
1	14,7	2,5
1,03	15,14	2,75
1,06	15,58	3
1,09	16,02	3,25
1,12	16,46	3,5
1,15	16,91	3,75
1,18	17,35	4
1,21	17,79	4,25
1,24	18,23	4,5
1,27	18,67	4,75
1,3	19,11	5

Table 1. Analogue output voltage vs. AFR and Lambda value.

4. Installation

The STAG AFR controller is designed to be used inside the passenger compartment of the vehicle. The controller should not be mounted inside the engine bay or other locations exposed to moisture or high temperature.

The controller is powered by a standard 12 V cigarette-lighter socket. Ensure that the oxygen sensor connector is connected to the controller harness properly before plugging in. When connected to the socket the green LED in the plug should be on. If this LED is off, while the plug is inserted properly and the socket is active (the key is put into the ignition at appropriate position), check the fuse in the power supply plug. Replace with a new one of current rating: 5-8 A.

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The wideband oxygen sensor that comes with the kit is factory calibrated and requires no periodic calibration. If the probe requires to be replaced, the sensor of the same code (0 281 004 026) should be used. The use of improper sensor will damage it. Before mounting remove the transport protective plastic cap from the sensor. The sensor should be tightened to 25 Nm.

⚠️ **ATTENTION!**

When the controller is powered and within several minutes after switching off, the oxygen sensor remains heated to a high temperature. Do not touch the hot sensor and do not let it touch inflammable components. Do not use the sensor near flammable liquid and gases. Failure to comply with the above instructions can cause severe burns and fire!

⚠️ **ATTENTION!**

Po After placing the oxygen sensor in the exhaust system, the probe has to be powered all the time when the engine is running. Disconnected or de-energized probe is exposed to exhaust gas it will be quickly damaged!

4.1 Lambda probe mounting location
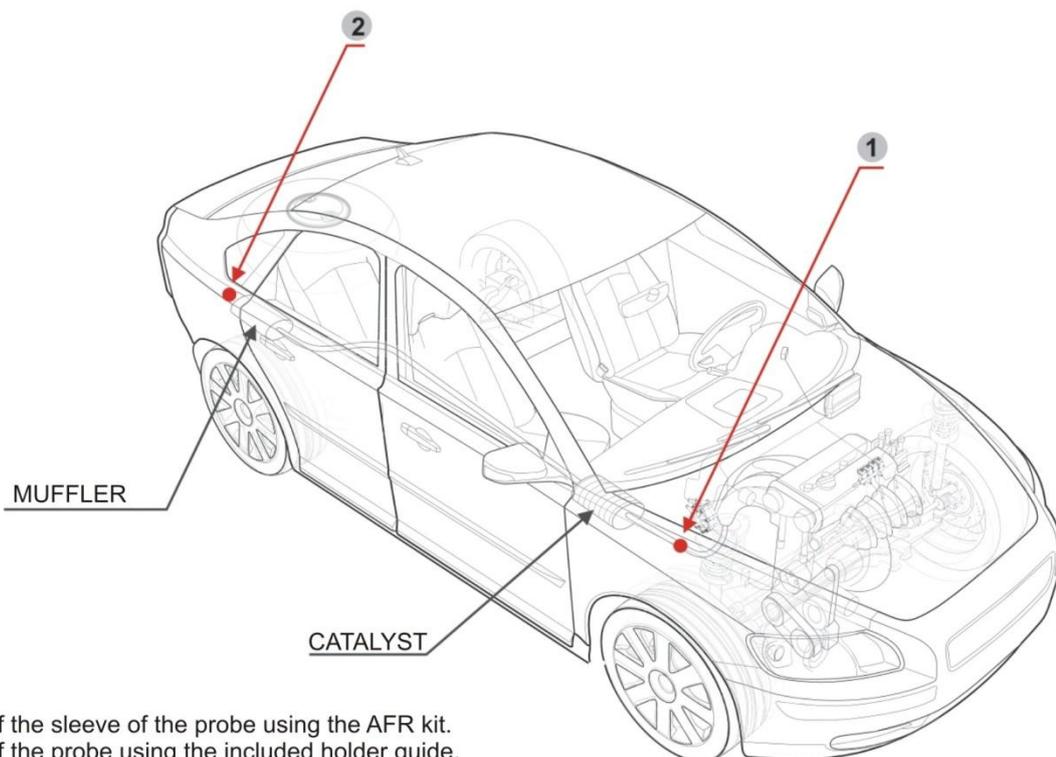
1. Installation of the sleeve of the probe using the AFR kit.
2. Installation of the probe using the included holder guide.

Figure 2. Wideband oxygen sensor mounting location

4.2 Mounting by using the mounting sleeve

It is recommended to mount the oxygen sensor in the exhaust system by using the mounting sleeve that comes with the kit. The sleeve dimensions are shown in Figure 2. The location of sleeve mounting will vary depending on the shape of the exhaust manifold used in the vehicle, but compliance with the guidelines below ensures maximum lifetime of the oxygen sensor and the highest measurement accuracy.

If the vehicle is equipped with a catalyst (catalytic converter), the sleeve should be placed upstream the catalyst. If the vehicle is equipped with a turbocharger, the sleeve should be mounted downstream the

turbocharger, as exhaust gas pressure variations upstream the turbocharger may cause a false reading. The sleeve should be placed at the maximum available distance from the cylinder head, and in turbocharged engines - from the turbocharger (50 cm minimum). Otherwise, the oxygen sensor can overheat and fail!

ATTENTION! When the probe is installed too close to the cylinder head it may overheat and fail! A gap of at least 50 cm should be kept.
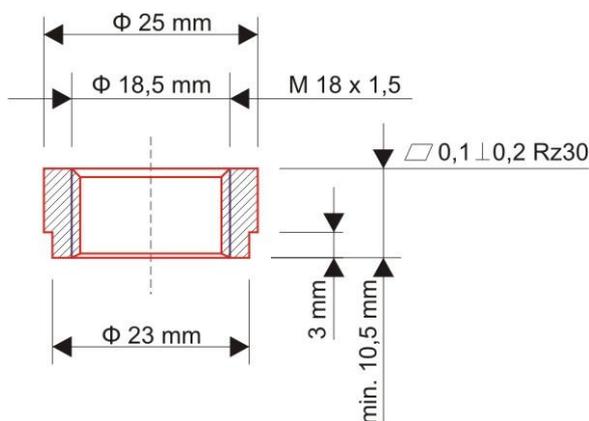

Figure 3. The recommended dimensions of the oxygen sensor mounting sleeve.

The oxygen sensor should be put in the exhaust gas stream in such a way so that atmospheric sensor does not affect the results of measurement (the exhaust system between the engine and measuring point should be tight).

The oxygen sensor mounting sleeve should be mounted in the upper part of the exhaust manifold (between 10 and 2 o'clock), as shown in Figure 3.

ATTENTION! When the probe is mounted with the harness faced downward the probe measuring element will be rapidly damaged by condensed water vapour!
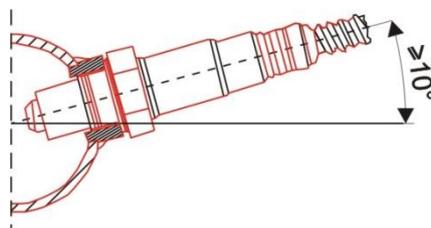

Figure 4. The minimum mounting angle of the oxygen sensor installed in the exhaust system.

4.3 Mounting by using the exhaust gas guiding pipe

If measurements are to be made on many vehicles, it is suggested to make an exhaust gas guiding pipe to facilitate quick mounting and dismounting of the kit. Shown below the exhaust guide allows the study of the composition of the mixture, regardless of the circumstances under which the measurement is performed.

For both studies the composition of the mixture only at maximum engine load (e.g. calibration of sequential autogas systems or fuel feed system equipped with a wideband oxygen sensor, where the air-fuel ratio at low and partial engine load is controlled by the engine controller), when the exhaust gas stream is strong, as well as the measurement at idle and at low engine loads when the ambient air might disturb the measurement at low gas flow, shown in (Fig. 5) guide allows the correct test.
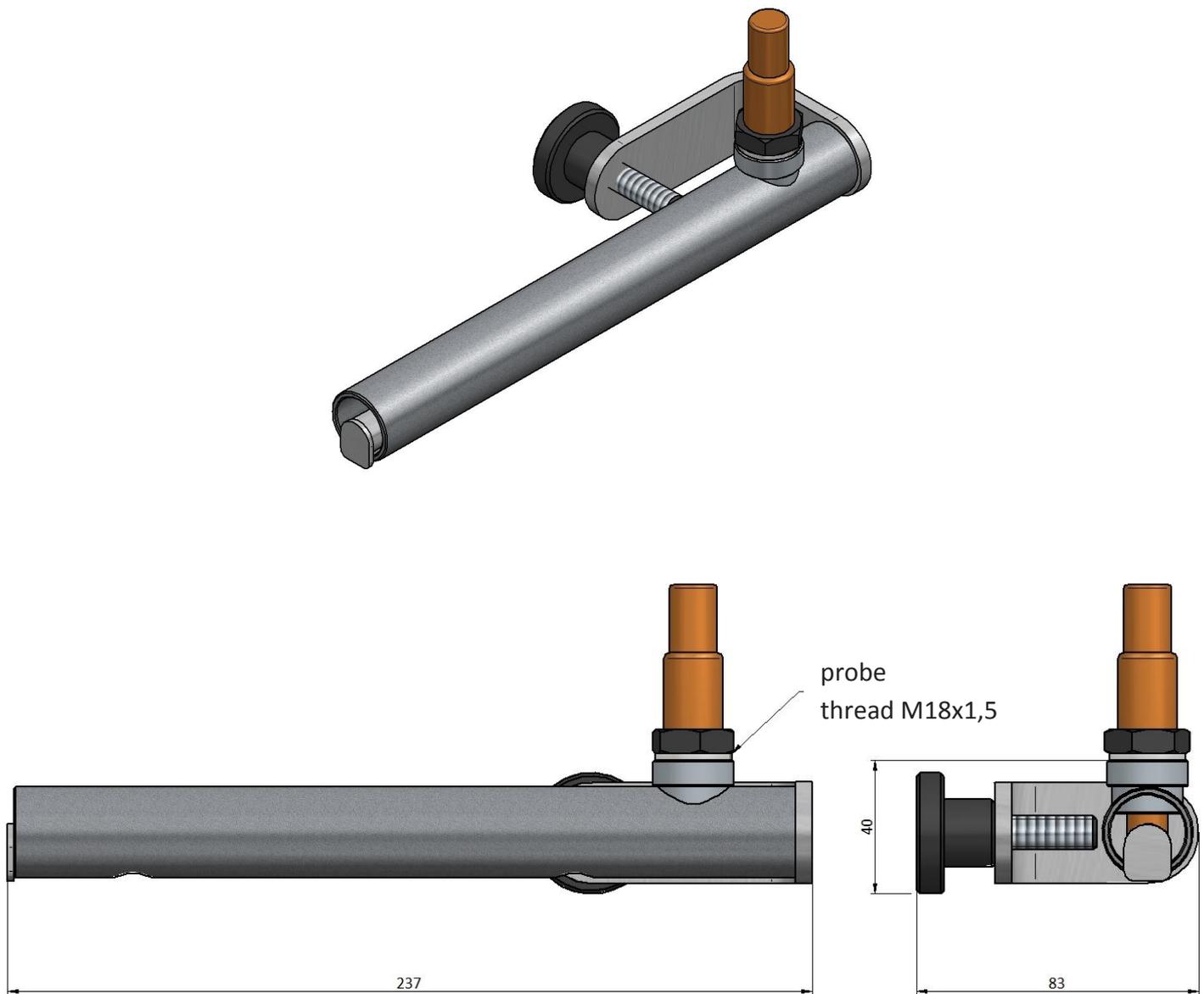

Figure 5. The guide positioned exhaust from the probe.

When making the guiding pipe remember that the probe wire harness should be routed beyond the hot exhaust gas area.

![Attention triangle] **ATTENTION!** When using a guiding pipe, it should not be placed in the exhaust gas stream until the engine is initially warmed up. Large amounts of water vapour present in exhaust gases during start-up and warming up of cold engine may damage the oxygen sensor.

5. AC AFR Application

5.1. Connecting the controller to a PC

Just after the kit is mounted in the vehicle, a computer with AC AFR software installed should be connected to the controller by using an USB interface, RS232 or Bluetooth of AC S.A., and then the program AC AFR should be started. After starting the program, if serial port COM is selected properly, the controller should establish a connection to a diagnostic program, as indicated by the text "Connected" at the left bottom corner of the program screen.

If "No connection" is displayed at the left bottom corner of the program window, another port must be selected from the "Connections" menu, and then "Ports" at the top of the program window.

When connection to the controller is established successfully, current operating status of the controlled is displayed at the right bottom corner of the program screen. The following status can be displayed:

> *Warming up* – the wideband oxygen sensor is being warmed up, and this may last even two minutes depending on exhaust gas temperature and power supply voltage, however normally it takes less than one minute from switching the controller on.
> *Work* – the oxygen sensor reached its working temperature and started measurement
> *Update* – the controller software is being updated
> *Fault* – the possible causes are:
  - oxygen sensor is not connected to the controller
  - faulty oxygen sensor
  - damaged wire harness
  - damaged controller

5.2. AC AFR Application version

NThe version of AC AFR Application is shown at the top of the program screen. In Figures 6 to 11 the program in version 1.0.0 is presented.
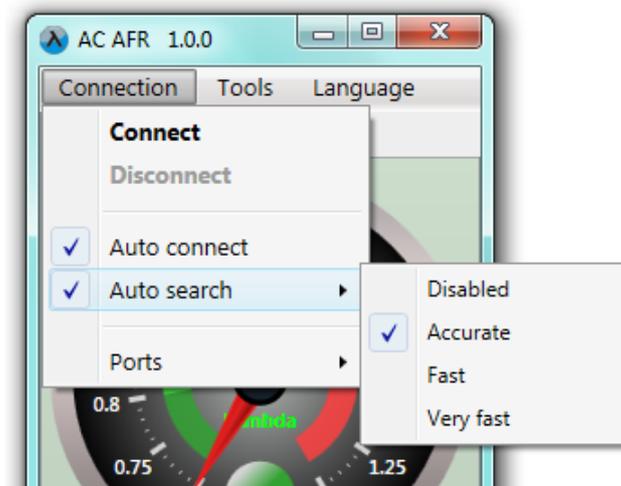
5.3. Main menu

Figure 6. Main menu

The following options are available in Main menu:
> *Connection*
  - *Connect* - enables connection to the controller to be established

- • **Disconnect** - enables connection to the controller to be ended
- • **Auto Connect** - when this function is active, connection to the controller is established automatically after disconnecting and re-connecting USB interface to the computer
- • **Auto search**
  - ▪ **Disabled** - if connection to the controller via a selected port cannot be established, no attempts to establish connections via other available ports to be made
  - ▪ **Accurate** - if connection to the controller via a selected port cannot be established, attempts to establish connection via all other available ports will be made one by one (this setting is recommended, especially when Bluetooth interface is used)
  - ▪ **Fast, Very fast** - if connection to the controller via a selected port cannot be established, attempts to establish connection via all other available ports will be made but within reduced time for individual ports
- • **Ports** - allows communication port to be changed
- ➢ **Tools**
  - • **Settings** - opens a window enabling controller and application settings to be changed
  - • **Update** - opens a window enabling controller software to be updated
  - • **Operating Instruction** - opens this Instruction
  - • **About the program** - information on application and the manufacturer's contact data
- ➢ **Language** - allows application language to be changed
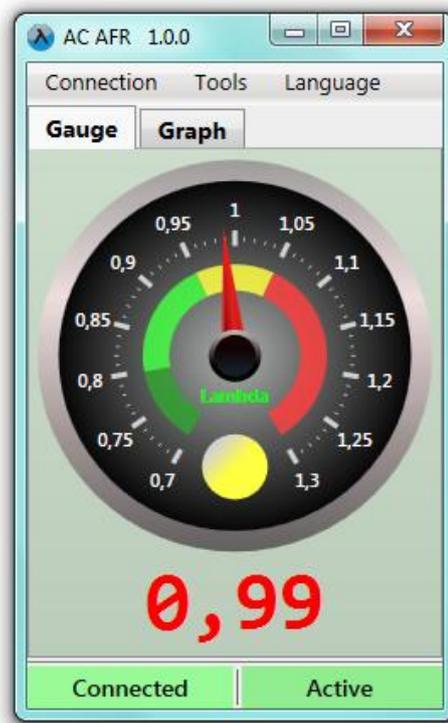
5.4 "Gauge" tab

Figure 7. Main window ("Gauge" tab).

The Gauge tab contains a dial indicator of the measured value (default: AFR - lambda parameter) and corresponding numerical value is displayed below it.

The dial indicator has colour-coded ranges that facilitate visual evaluation of the air-fuel ratio with no necessity to read an accurate value. For spark-ignition engines the lambda parameter or AFR values within individual ranges have the following meaning:

- ➢ **Dark green** – very rich mixture, the value within this range is correct at maximum engine load only, especially for turbocharged engines, where the air-fuel mixture may be particularly rich,

➤ **Green** – rich mixture, for engines with factory installed oxygen sensors, the value within this range is correct at maximum engine load only, otherwise such values may occur at any engine load and rpm,

➤ **Yellow** – stoichiometric mixture (air-fuel ratio ensuring complete fuel combustion), for engines with factory installed oxygen sensors, the value within this range is correct at low and partial engine loads,

➤ **Red** – lean mixture, the value within this range is unacceptable (except a situation when fuel feed is cut off at idle engine).

5.5 "Graph" tag

The "Graph" tag contains an oscilloscope screen. The measured value (default: lambda parameter) is displayed on the oscilloscope.
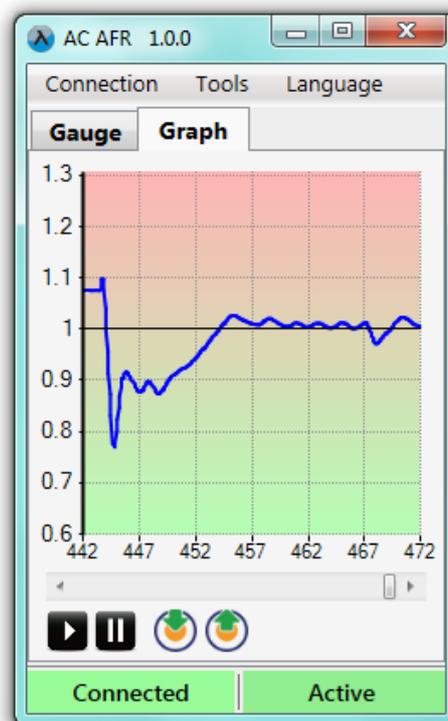

Figure 8. Main window ("Graph" tag).

There is a scrollbar enabling observation of previously recorded data and control buttons below the oscilloscope. The buttons perform the following functions, when viewing from left to right:
➤ *Start Oscilloscope (next click clear the oscilloscope)*
➤ *Pause Oscilloscope*
➤ *The current oscilloscope screen is written to a file*
➤ *Load oscilloscope file*
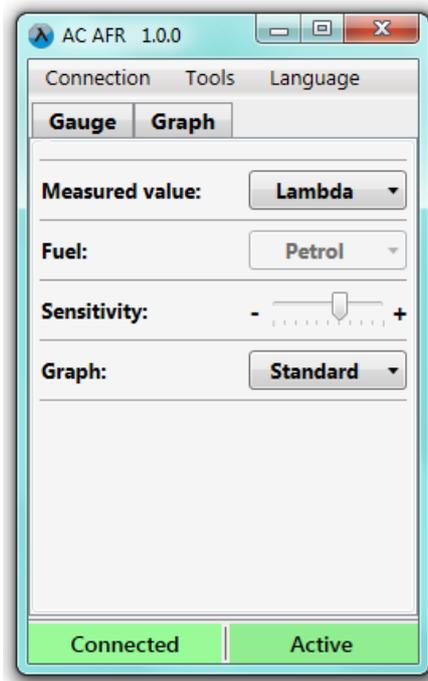
5.6 "Settings" window

Figure 9. "Settings" window

This window enables controller and application settings to be changed. The following options are available:

➢ ***Measured value***
- ***Lambda*** – lambda parameter is recommended to visualize measurements for spark-ignition engines, as lambda does not depend on fuel type fed to the engine (lambda is always 1 for stoichiometric mixture),
- ***AFR*** – Air/Fuel Ratio) expresses the mass ratio of air to fuel present in the mixture; the value of this parameter is not measured directly, but computed based on the value of lambda parameter and type of fuel fed to the engine, thus requiring an appropriate fuel type to be selected (lambda parameter for stoichiometric mixture depends on fuel type, and for example is 14.7 for gasoline),
- ***Oxygen*** – oxygen content indicator is a known method of measurement visualization for spontaneous combustion engines, since it allows the air-fuel ratio to be observed for a very wide range of lean mixtures,
➢ ***Fuel*** – used to indicate what fuel type is currently fed to the engine (only for computing AFR),
➢ ***Sensitivity*** – when the oxygen sensor is installed to close to engine exhaust valves, the result of measurement may change too rapidly, thus making its interpretation difficult; in such a case sensitivity should be reduced to smooth rapid variations in measurements ,
➢ ***Graph*** – enables the oscilloscope axis to be reversed to adapt measurement visualization to user's preferences,
- ***Normal*** – higher lambda values are shown at higher positions on the oscilloscope (leaner mixture),
- ***Reversed*** – lower lambda values are shown at higher positions on the oscilloscope (richer mixture).
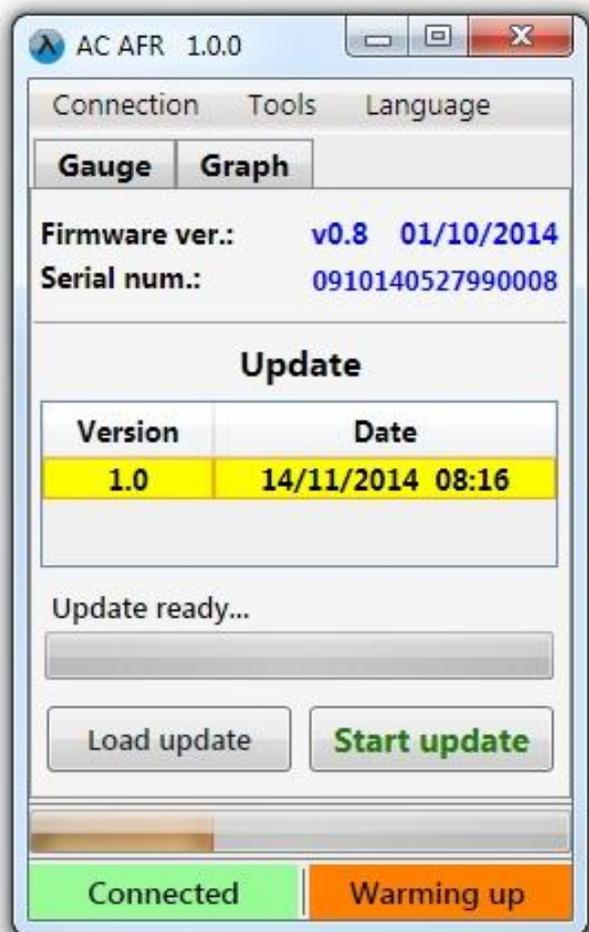
5.7 "Update" window

Figure 10. "Update" window

The software version of the controller being currently connected is displayed in upper part of the window.

The list of available updates is presented in table below To load an update file from outside of the program catalogue, press the "Load" and select an update file. The loaded update will appear on the list of available updates. The "Update" key starts to upgrade controller software by using a selected update file. When upgrading is done, connection to the controller is temporarily broken and established one again. A new software version should be displayed in upper part of the window, in compliance with the selected update file.

If the upgrading process fails, the "Update" window will open automatically after connection to the controller is restored. The upgrading process should be repeated.

5.8 "About the program" window

Rysunek 11. "About the program" window

This window shows the contact data of the company AC S.A. – the manufacturer of the controller and software.

6. Guidelines for use of the STAG AFR controller

In gasoline engine, the optimum air-fuel mixture composition (AFR - Air/Fuel Ratio) is one gram of fuel per 14.7 grams of air. For this ratio, all oxygen available in supplied air is theoretically used to completely burn all of the fuel. This is so called "stoichiometric" air-fuel ratio and differs for various fuels:

- ➢ unleaded gasoline – 14.7
- ➢ diesel oil – 14.6
- ➢ LPG – 15.5
- ➢ CNG – 17.2

The lambda parameter is the ratio of the current mixture content to the stoichiometric one. For example, for a gasoline engine when the mass ratio of fuel to air is 14.7, the lambda parameter is 1. When an engine is running on a rich mixture, the value of lambda parameter drops below 1. For lean mixtures the lambda value is greater than 1. Generally, spark-ignition engines equipped with a narrowband oxygen sensor at low and medium loads, automatically maintain the lambda parameter close to 1. They reach its maximum power at slightly enriched mixture (lambda between 0.8 and 0.9 in intake low engines; between 0.75 and 0.85 in turbocharged engines).

6.1 Adjustment of LPG/CNG systems in gasoline engines

To adjust autogas installation properly in an engine equipped with a narrowband oxygen sensor (usually of voltage-control type) the mixture content should be checked at full load. The value of lambda parameters on gasoline and gas under the same conditions (identical gear and rpm) should be identical.

If a car has not been factory equipped with a oxygen sensor, the full range of loads and rpm should be set so that the lambda parameter remains almost unchanged after fuel conversion.

6.2 Adjustment of LPG/CNG direct injection in spontaneous combustion engines

Diesel engines are adapted to be fed with a lean mixture. To measure composition of very lean mixtures occurring at low and medium loads, it is necessary to observe oxygen content (in %) in exhaust gas (the "Measured value" should be set to "Oxygen" in controller settings, as described in section 5 of this instruction).

Depending on engine model, oxygen content in exhaust gas varies typically between a dozen of percents at low loads and several per cents at high engine loads.

If at certain engine load range, oxygen content in exhaust gas drops to around 0% (this is indicated by intensive smoke from the exhaust because the smoke limit is exceeded), it means that gas direct injection or its increase has not justified (increased gas injection will cause no increase in engine power and decrease in diesel oil consumption).

If oxygen content in exhaust gas is too high (12% can assumed as a reasonable limit, but this value will vary depending on engine design), injected gas will not be burnt completely and will escape from the exhaust in the form of not burnt hydrocarbons. In such situation no direct gas injection is recommended.

7. Technical data

Supply voltage	12[V] -20% ÷ +30%
Maximum input current	2A
Operating temperature	-40°C ÷ 70°C
Protection Class	IP40

8. Warranty terms and conditions

Warranty does not cover the wideband oxygen sensor provided in the kit. This is a consumable component subject to natural wear.

Warranty also does not cover:
- damages resulting from improper use of the device,
- damages resulting from not keeping the set operating conditions (e.g. installation at locations not consistent with installation instructions or in locations exposed to water or high temperature; supply from a source of voltage exceeding the allowable range)
- mechanical damages,
- systems modified or repaired without authorisation,
- mechanically damaged systems on user's fault, in particular:
  - damages to connectors,
  - damages to connectors due to use of chemical cleaning agents,
  - damages to housing,
  - damages to PCB's,
- systems damaged electrically due to connection of communication interfaces incompatible with installation instruction,
- other damages on user's fault.