ULTRASONIC STATIONARY and CLAMP-ON LIQUID FLOW METERS ENERGOFLOW LF

DATASHEET

ENERGOFLOW AG

CONTENTS

INTRODUCTION

This Datasheet is intended to provide the design, installation, commissioning, calibration and maintenance procedures for the ENERGOFLOW LF stationary liquid flow meters (hereinafter flow meters).

LIST OF ABBREVIATIONS

AGC	Automatic Gain Control
ACS	Automatic Control System
ATX	Automatic Telephone Exchange
ADC	Analogue-digital Converter
EU	Electronics Unit
LCD	Liquid-Crystal Display
SW	Software
EAT	Electroacoustical Transducer
US	Ultrasonic Signal
PC	Personal Computer
DN	Diameter Nominal

The flow meters vary by number of channels and design (see Table 1).

Table 1

Type	Channels	EAT type (XX)	DC output signal	Interface for communication with PC	Power supply
LF 2XX	1	11 (clamp-on)	for one channel	RS-232 or RS-485 4…20 mA under special order	~ 230 *VAC* or =12 *VDC*
	1	21 (inserted)			
	1	01 (in-line section)			
	2	12 (clamp-on)	for one or two channels (the second one - on request)		
	2	22 (inserted)			
	2	02 (in-line section)			

The flow meters can operate both in the autonomous mode and under PC control of the ACS.

The flow meters are manufactured both in explosion-proof and general purpose industrial versions.

The electroacoustical transducers and in-line sections for the explosion-proof flow meters are suitable for installation both indoors and outdoors of explosion hazardous areas as per PUE (Electric Equipment Installation Rules), Chapter 7.3, PUE ESU 4 (DNAOP 0.00-1.32-01) and other Regulatory documents regulating the electric equipment application in the explosion hazardous areas.

The EU of the flow meters is designed for installation both indoors and outdoors out of the explosion hazardous zones. The connection between the EU and EAT is performed through the intrinsically safe circuits ‘Ex ib’.

The flow meters have a noise-free design.

Due to the constant modifications of the flow meter, some discrepancies with the present document may occur though these do not affect the metrological features and functionality of the device.

1 OVERVIEW AND OPERATION

1.1 Application

1.1.1. The flow meters are designed for measuring flow velocity and flow rate of the acoustically transparent liquid (hereinafter liquid) in the pressure pipelines both in forward and reverse direction of the flow, as well as current time and non-operational time of the flow meter.

1.1.2. The flow meters are designed for technological processes control in metallurgical, chemical and other industries; in water supply and disposal systems; for metering, including custody transfer metering, water, acids, alkalis, oil, refined products and other liquids in fully filled pressurized pipelines.

1.1.3. The flow meter performs measurement in one or two pipelines, provides output of the results, archive data, setup and configuration parameters to the local graphic display, as well output of the results in the form of pulse sequence and current signal.

1.1.4. Two-channel flow meters provide generation of a «combinatorial» channel by summing, subtracting or averaging the flow rate of two channels with further recording of results. This enables to use the flow meter for measuring total and differential flow in both pipelines or to perform measurements in one pipeline with particular accuracy (i.e. two-channel mode).

1.1.5. The flow meter provides metering, storing in the non-volatile memory and output to the LCD of the flow measurement results within archiving intervals (hourly, daily etc.) and out-of-limits conditions.

1.1.6. The flow meter provides output of the measurement, diagnostic, reference and archive data to the external devices through the serial interfaces RS-232 or RS-485.

1.1.7. Each flow meter channel is equipped with built-in crystal calibrator enabling to perform metrological calibration test without flow meter shutdown.

1.1.8. The flow meters are designed for continuous operation and require minimal maintenance. It is recommended to check the flow meter setup quarterly within routine maintenance.

1.1.9. Upon special requirements, the flow meters can be complete with a thickness gauge. While measuring, the thickness gauge is connected to the signal inputs of the first channel.

1.1.10. In case of a large supply of flow meters to one Customer, by agreement with the latter, the software for the EU and PC can be adjusted for extra services (e.g. several passwords with different priority, automatic creation and printing of records for every 8-hour shift, month, quarter etc.).

1.2 Performance Specifications

1.2.1. The flow meters provide measurement of liquids by means of different EAT types in the pipelines of various DN according to Table 2 (note: under special order, devices for other line sizes can be supplied).

Table 2

EAT type	DN, *mm*
clamp-on	from 70 to 3200
inserted	from 300 to 4000
in-line section	from 25 to 600

1.2.2. The clamp-on EAT are designed of two versions: standard and with «wide beam » (by special order).

1.2.3. The pipeline wall thickness for the clamp-on EAT— from 2 to 30mm.

1.2.4. The pipeline pressure for the clamp-on EAT is not limited. When using the inserted EAT, the excessive pressure should not exceed 2,5 MPa. The inserted EAT with maximum permissible pressure up to 6,3 MPa and in-line sections with maximum permissible pressure of 16 or 25 MPa can be supplied under special order.

1.2.5. The bulk concentration of suspended particles and air (gas) bubbles in the liquid should not exceed 1%.

Note — the flow meter application for more polluted liquids or gassed liquids shall be determined by trial measurement.

1.2.6. The flow meter power supply is performed via 187 - 242V AC system or 11-14 V DC power source (accumulator).

1.2.7. The capacity consumed through the AC line does not exceed 5VA.

Within accumulator powering the current consumed does not exceed 0,35A.

1.2.8. The operating mode setting time — 2 min after power supply enabling. The non-stop operating mode is provided.

1.2.9. The flow meters provide liquid flow rate measurement in the range of 0,1 - 10,0m/sec. Within the forward flow direction the flow rate is indicated with «plus», and within the reverse one — with «minus».

1.2.10. The flow meter calculates the current flow by the way of multiplication of the measured flow velocity and the internal cross-section square of the pipeline according to the formula:

$$Q = 2{,}827 \times 10^3 \times S_g \times V \times D^2, \quad (1)$$

where

Q — current flow, m3/h;
Sg — hydro-dynamical index ;
V — flow velocity, m/s;
D — pipeline internal diameter, m.

1.2.11. For the liquid flow and volume measurement the basic relative error of the flow meter is normalized according to two flow ranges Q:

— From the minimal Q1 to the transition value Q2;
— From the transition value Q2 to the maximal Q3.

The minimal, transition and maximal flow value are shown in Table 3.

Table 3 — Regulated flow values, m3/h

Value	**Clamp-on EAT**	**Embedded EAT, in-line sections**
Q1	282,7·10–6·D2	
Q2	Q1·830/D within D < 830 mm; Q1 within D ≥ 830 mm	Q1·400/D within D < 400 mm;Q1 within D > 400 mm
Q3	Q1·100	
D — numerical value DN, mm		

1.2.12. Limits of the permissible basic relative error of flow meter while the liquid flow rate and volume measurement (at the registration of the results by the LCD, pulse and digital output signals) are indicated in Table 4.

Table 4

EAT type	**For each channel**	
	Q3 ≥ q ≥ Q2	**Q2 > q > Q1**
Clamp-on EAT	± 1,5 %	± 4 %
Embedded, in-line sections	± 1 %	± 4 %

1.2.13. At the two-channel measuring mode of the flow meters with clamp-on EAT (the liquid flow in the pipeline is calculated as a mean of the both operating channels, measuring the flow in the same pipeline cross-section simultaneously) the basic relative accuracy of the flow range makes:

— from Q1 to Q2— ±2,5 %;
— from Q2 to Q3— ±1,0 %.

1.2.14. In case of need the flow meters can to measure the volume flow in the range of 3:1 (ex. within the flow rate from 3 m/s to 9 m/s) with relative error ± 0,5 %. This provides on condition that at least monthly calibration by means of instruments by class 0,15.

1.2.15. The foregoing metrological features of the flow meters are valid if the distance between the EAT and the hydroacoustic resistance is no less than indicated in Table 5.

1.2.16. The limits of basic relative error at the pipeline wall thickness measurement (for the devices equipped with the thickness gauge) do not exceed ± 0,2 mm.

1.2.17. The customer can set up the Qmin and Qmax limits of the expected flow values.
If the value Q exceeds the limits Qmin and Qmax the accumulated volume is not calculated.

Table 5 — Minimal distance between the flow meter EAT and hydraulic resistance

Hydraulic resistance	**Straight run length, in the DN**			
	Clamp-on EAT		**Embedded, in-line sections**	
	before	**after**	**before**	**after**
Bend or T-bend	25	5	12	3
Two or more bends, in one plane	25	5	15	5
Two or more bends, out-of-plane	50	10	25	5
Reducer	10	5	5	3
Diffusor	25	5	10	3
Abrupt contraction	20	5	10	2
Abrupt enlargement of a section	25	5	15	5
Fully opened valve	15	5	8	2
Pump	50	10	30	10

1.2.18. Each pulse of the passive output measurement pulse signal corresponds to the liquid volume increase into the fixed value (i.e. «pulse value»).

The passive pulse signal former has the output capability at least 0,5 *VA* (DC voltage 15 *V*, current 0,1*A*).

1.2.19. The pulse value depends on the internal pipeline diameter and is set up automatically (rf. Table 6).

Table 6 — Relation of the pulse value γ from the internal pipeline diameter *DN*

DN, m	**γ, *dm³***	***DN, m***	**γ, *dm³***
from 0,023 to 0,035 (on)	0,02	from 0,35 to 0,5 (on)	5
from 0,035 to 0,05 (on)	0,05	from 0,5 to 0,7 (on)	10
from 0,05 to 0,07 (on)	0,1	from 0,7 to 1,11 (on)	20
from 0,07 to 0,111 (on)	0,2	from 1,11 to 1,57 (on)	50
from 0,111 to 0,156 (on)	0,5	from 1,57 to 2,25 (on)	100
from 0,156 to 0,223 (on)	1	from 2,25 to 3,5 (on)	200
from 0,223 to 0,35 (on)	2	from 3,5 and more	500

1.2.20. Forming of the pulses indicated the volume increase is stopped if $Q \le Q_{min}$ and if $Q \ge Q_{max}$, as well as if V<0,1 m/s (with no regard to the Q_{min} value).

1.2.21. The flow meter current output unit provides current measurement in the range from 0 to 5 *mA* or from 4 to 20 *mA* (set up while configuring the flow meter) in proportion to the measured instant value flow.

While operating in the range from 0 to 5 *mA* the load resistance of the pulse former should not exceed 2 *kOhm*, and 500 *Ohm* in the range from 4 to 20 *mA*.

1.2.22. The current output unit is adjusted automatically so, that when Q changes from Q_{min} to Q_{max} the output current I_{out} is changed from the minimal value I_{min} to the maximal one I_{max}.

1.2.23. The functional relation of the output current of current output unit current from flow rate determined by the ratio:

$$I_{out} = I_{min} + (Q - Q_{min})\cdot(I_{max} - I_{min})/(Q_{max} - Q_{min}). \quad (2)$$

N o t e s :

1. If the flow is a negative value, or if the inequality $Q > Q_{max}$ takes place, for emergency indication the output current is set up equal to zero.
2. If the inequality $0 < Q < Q_{min}$ takes place the output current is equal to I_{min}.
3. If the data on the sum-balanced flow of both channels come to the current output unit the Q_{max} and Q_{min} are referred to the bigger and the smaller value determined for each channel correspondingly.

1.2.24. Upon special requirement, the two-channel flow meters can be equipped with the two-channel current output unit that can operate as:

– ***Two separate*** current outputs, where the ***first*** current output value is proportional to the ***positive*** flow value in the first measuring channel, and the ***second*** current output is proportional to the ***positive*** instant flow value in the second channel;
– ***one*** device, intended for complex signal output, where the ***first*** current output value is proportional to the ***positive*** instant flow in one of the measuring channels, and the ***second*** current output value is proportional to the ***negative*** instant flow in the same channel.

1.2.25. The limits of permissible reduced error is ± 0,5 *%* at the values transformation of volume flow into current output signal.

1.2.26. The flow meter permissible full-scale accuracy limits within conversion of the flow value into the current output signal are equal to 0–5 *mA* (4–20 *mA*) with no regard to the measurement accuracy of ± 0,5 *%*.

1.2.27. The flow meters make archives for all the channels indicating the liquid volume for the previous hours, days, months and years of operation (1080 hours, 548 days, 24 months, 12 years). When the archive is overflowed the earliest data are replaced with the recent ones.

1.2.28. For each operating channel the flow meters form the «Event archive» — fixing the start and the end points of measurement (archive volume — 256 records), and the total time of being disabled (pause in measurement) for the following reasons:

– break of the acoustical communication with EAT;
– the case when the instant liquid flow exceeds the value Q_{max}.

1.2.29. The flow meters fix the device on/off points in the separate archives. The archive volume makes 256 records. When the archive is overflowed the earliest data are replaced with the recent ones.

1.2.30. The flow meter calculates and store in the nonvolatile memory as separate records (from the point of the latest archive erasure) the total time intervals of:

– running time (being enabled);
– downtime because of the power supply disabling;
– state of disabling because of the device configuration emergency.

N o t e — configuration emergency occurs if the customer set up the mode non-proper for measuring: « Oscillograph », « Configuration», «Diagnostics», «Thickness gauge».

1.2.31. The absolute accuracy limits for time interval measurement make ± 2 *s* per 24 hours.

1.2.32. The archive data, running and down time, setup parameter values, programming data and built-in clock rate are stored at least for 10 years for cases when the power supply is disabled.

1.2.33. The EU spark-proof circuits parameters are as follows:

– Pulse voltage — up to 50 *V* for pulse duration up to 2 *μks* and recurrence frequency up to 10 *kHz*;
– Communication line between EU and EAT — Shielded twisted pair or coaxial cable with linear capacitance of 150 *pF/m*.

The permissible communication line capacitance - 15 *nF*, inductivity - 0,2 *mH*.

1.2.34. The maximal permissible distance between EAT and EU (by the cable) makes 300 *m*, if the embedded sensors are used and the signal cables are protected by layout into the grounded metal tube of the DN from 15 to 30 *mm*.

For the explosion safety versions, the signal cable length is limited by its capacity (rf. p. 1.2.33).

1.2.35. For the PC connection, the flow meters are equipped with a shiftable interface unit (RS-232 or RS-485). The interface outlook is set up by shifting the jumper on the main circuit board (rf. p. 2.4.5.7). MODBUS-like protocol is applied.

1.2.36. The flow meter rate of exchange with the PC through the serial interfaces RS-232 or RS-485 — 9600 *bauds*.

1.2.37. The distance between the flow meter EU and the PC for the interface:

– RS-232 — up to 15 *m*;
– RS-485 — up to 1200 *m*.

1.2.38. The quantity of the flow meters with RS-485 interface unit, connected to the PC simultaneously by one connection line is up to 16.

1.2.39. The flow meter calibration is performed once per two years by means of the embedded crystal calibrators.

1.2.40. The data on the flow meter overall dimensions and weight of the units are indicated in the table 7. The flow meter outlook is represented in the appendix B.

Table 7

Flow meter unit	**Overall dimensions, *mm*, max**	**Weight, *kg*, max**
Electronics Unit	290 × 245 × 125	1,7
Electroacoustic transducer: – explosion safety design – industrial design	 60 × 40 × 35 65 × 40 × 40	 0,2 0,15

1.2.41. For the flow meters operating a range of in-line sections is available (rf. appendix C).

1.2.42. The flow meter units are available in the following climatic versions:

– Electronics units — for the working temperature range from 5 to 50*°C*, humidity up to 80*%*;
– embedded and clamp-on EAT, in-line sections — for the working temperature range from -25 to 150*°C*, humidity up to 100*%*, with moisture condensation.

N o t e :
– upon special requirement the flow meter can be equipped with the clamp-on EAT for operating at very low temperature (up to - 60 *°C*) or for operating at very high temperature (up to 250 *°C*).
– working medium temperature range from - 25 to 150*°C*

1.2.43. The construction corresponds Ingress protection level: EU — IP56; EAT — IP67.

1.2.44. The flow meter reliability: average operating lifetime — 15 *years*, average error-free running time — 25000 *h*.

1.3 Principle of Operation and Design

1.3.1. The flow meter consists of EU and several EAT, mounted in pairs on one or two pipelines and connected to the Electronics unit by the signal cables. EAT of each pair forms acoustic signal, crossing the liquid flow by chord or diameter.

1.3.2. According to its operating principle the flow meter belongs to the pulse-time ultrasonic flow meters with operation based on the difference of the time taken by the USS to pass through the pipeline sector with the flow stream and up the flow stream. USS forming and receipt is performed in turns by each EAT pair, installed at the measurement pipeline sector.

1.3.3. The electroacoustic transducers may be either clamp-on (mounted on the pipeline surface) or embedded (mounted in the holes made in the pipeline walls or in the embedded section).

1.3.4. Various flow meter versions have one or two flow measurement channels. Each channel can be used for measurement in a separate pipeline.

1.3.5. Measurement in the two channels are performed in turns in the time sharing mode. To obtain one pair of the instant flow measurement results it takes less than 1 s. The liquid volume is calculated by integrating the flow rate per second.

1.3.6. Turning the channels on/off, choosing the type of processing is provided within the configuration commissioning according to Table 8.

1.3.7. For the autonomous operating mode the flow meters are equipped with a keyboard and LCD, situated on the EU frontal panel.

1.3.8. The flow meters allow the remote control through PC. Upon the customer’s choice is it possible to output on the PC the data as follows:

– Measurement results — flow rate and direction, current flow, volume;
– Oscillogram of the signal passed through the acoustic channel;
– Flow meter setup and configuration parameters;
– Date and time;
– Archive data.

Table 8 — Flow meter configuration variants

Variant	Measurements in the channels 1 and 2	Type of processing in the combinational channel
0	Not performed	unavailable
1	Performed in the channel 1	
2*	Performed in the channel 2	
3*	Performed in the channels 1 and 2	
4*		Sum for two channels flow
5*		Weighted sum** for two channels flow
6*		Difference between two channels flow (1 minus 2)
7*		Difference between two channels flow (2 minus 1)
* — unavailable for one channel flow meter. ** — weighted sum of the values A and B is calculated by the form (A+ B)/2.		

1.3.9. Flow meter setup and configuration is performed by programming the built-in micro-controller through the EU keyboard or the PC.

1.3.10. In the course of setup it is corrected the clock rate, are chosen the optimal places of EAT mounting on the pipeline, set the receiver gain, switched on/off the automatic control, including the automatic gain control (referred to as – AGC) and tracking (in time) the signal passed through the liquid.

On the operator's command, the flow meter built-in micro-controller fixes in the memory all the alterations.

1.3.11. In the flow meter mode «Oscillograph» it is possible to observe on the LCD (PC display) the form of each channel measurement signal passed by the acoustic channel through the liquid, to regulate the receiver gain separately for the forward and reverse radiation direction , to estimate the time shift between the measurement signals, caused by the liquid flow.

1.3.12. In certain periodicity the flow meter micro-controller performs diagnostics and correction of the receiver operating modes for each channel. If the useful signal level at the receiver output is insufficient for normal operating, the "No I signal" warning appears on the LCD, where **I** is the channel number.

1.3.13. The flow meter micro-controller constantly controls powering. The power supply disabled measurements are stopped, the emergency time indication starts. Though all the settings, clock rate, archives are saved. Power supply enabled the flow meter starts operating automatically.

1.3.14. The flow meter Electronics Unit is equipped with passive measurement pulse signal former and (upon requirement) with active 0–5 *mA* (4–20 *mA*) DC output measurement signal former. Upon the customer's choice the data on each channel flow or on the combinational flow can be supplied to the former outputs (the combinational channel should be set into the weighted summation mode).

1.3.15. For each channel and for the combinational channel it is constantly formed the integrated volume by progressive total, beginning from the point of archive erasure. The volume data of all the channels for the reporting intervals (hourly, daily, etc.) are archived in the nonvolatile memory.

1.3.16. The flow meters perform the emergency state time indication with second accuracy and save the data on each channel breaks into the nonvolatile memory.

1.3.17. To provide calibration each flow meter channel is equipped with crystal calibrator.

In the course of check-up the calibrator brings into the signals, passing through the liquid in the pipeline, unequal (for forward and reverse direction) standard LCD delays, multiple to the entire quantity of periods of the flow meter crystal generator.

In the course of check-up the calibrator operation is controlled by the PC with special software.

1.3.18. The meter provides the following protection measures from unauthorized intervention.
In the meter enclosure, in the compartment for cables connection, a group of three pins is arranged. By closuring pins 1 and 2 by a jumper, the access to the configuration and settings is blocked. To provide configuration options and settings, it is required to close contacts 2 and 3. Group of pins is covered with a lid, which must be sealed at the end of setup.

Software protection is provided by the calculation of the checksum of metrologically important parts of the meter firmware (which is responsible for configuring, tuning, and the algorithm flow calculations). The checksum is available for viewing on the meter LCD.

1.4 Explosion Safety

1.4.1. The flow meter explosion safety is provided by the circuit and construction solutions:

– a) by galvanic isolation of the power circuits and the output spark-safety circuits through the network transformer WT and signal transformers XW;
– b) by galvanic isolation from the external PC — through RS-232/RS-485 interface units with at least 1500 V galvanic isolation level;
– c) by galvanic isolation from the external registering devices connected to the pulse and current outputs with at least 1500 V galvanic isolation level.

1.5 Marking and Sealing

1.5.1. On the plate, attached to the flow meter body the following data are indicated:

– manufacturer;
– flow meter model;
– year of production;
– the flow meter serial number according to the manufacturer's numeration system.

1.5.2. The intrinsically safe version of the flow meter Electronics Unit has extra marks:

– explosion safety marking «ExibIIB »;
– inscription «Spark-safety circuits. C_{add} = 15000 pF, L_{add}=0,2mH» on EU connectors for EAT;

1.5.3. The plate attached to the clamp-on EAT contains:

– explosion safety marking «1ExibIIBT3 » (for the explosion safe EAT version);
– «ENERGOFLOW LF» flow meter model (for the conventional EAT version);
– year of production;
– arrow to follow for two EAT mutual orientation while mounting the flow meter.

1.5.4. EU sealing after adjustment is performed with sealing grease on both fastening screw, fixing the two opposite (by diagonal) corners of the EU frontal panel.

1.5.5. For the explosion safety versions the EU glands for the spark-safety circuits and peripherals should be sealed.

APPENDIX A

Typical (Complete) Order Code for the Ultrasonic Liquid Flow Meter ENERGOFLOW GF

No. of measurement channels

x – number of channels of measurement

0 - Flanged section with Electro Acoustic Transducers

1 – Clamp-on stationary Electro Acoustic Transducers

2 – hot-tapped installation of Electro Acoustic Transducers in pipeline wall

3 – Customer specific applications

P – Portable version

x – number of EAT pairs

Application

A – standard applications

H – High pressure applications

O – Customer specific applications

Ambient temperature

L - Low temperature version (-60 …. +40 deg C)

S - Standard version (-30 …. +40 deg C)

H - High temperature version (-30 …. +70 deg C)

Installation data

DNxxxx – Pipe nominal diameter, mm

Accuracy of measurement

N – normal (1,5 % for Qt to Qmax, 3% for Qmin to Qt)

S – Standard (1 % for Qt to Qmax, 2% for Qmin to Qt)

C – high accuracy measurements upto 0.5%

O – Customer specific up to 0.25%

Process connection

N – no flanges, hot-tapped sensors

D – Flanges DIN

xxx – PN, bar

A – Flanges ANSI

xxxx – class

C – clamp-on sensors

O – Customer specific

Electronics block

I – integrally mounted electronics block with display

R – Remote mounted electronics block

W – Electronic junction box without local display

Hazardous area certification

I – Exi certification (ATEX)

W – without certification (for non hazardous applications)

Power supply

A – 220 VAC power supply system with intrinsic barriers and communication interface

D – 24 VDC power supply system with intrinsic barriers and communication interface

O – Customer specific

W – without power supply, customer to provide required power input

B – Power supply from on board battery (battery to be replaced every 3 years)

Accessories (optional)

F – Meeting flanges with nuts and studs to be supplied with flow meter

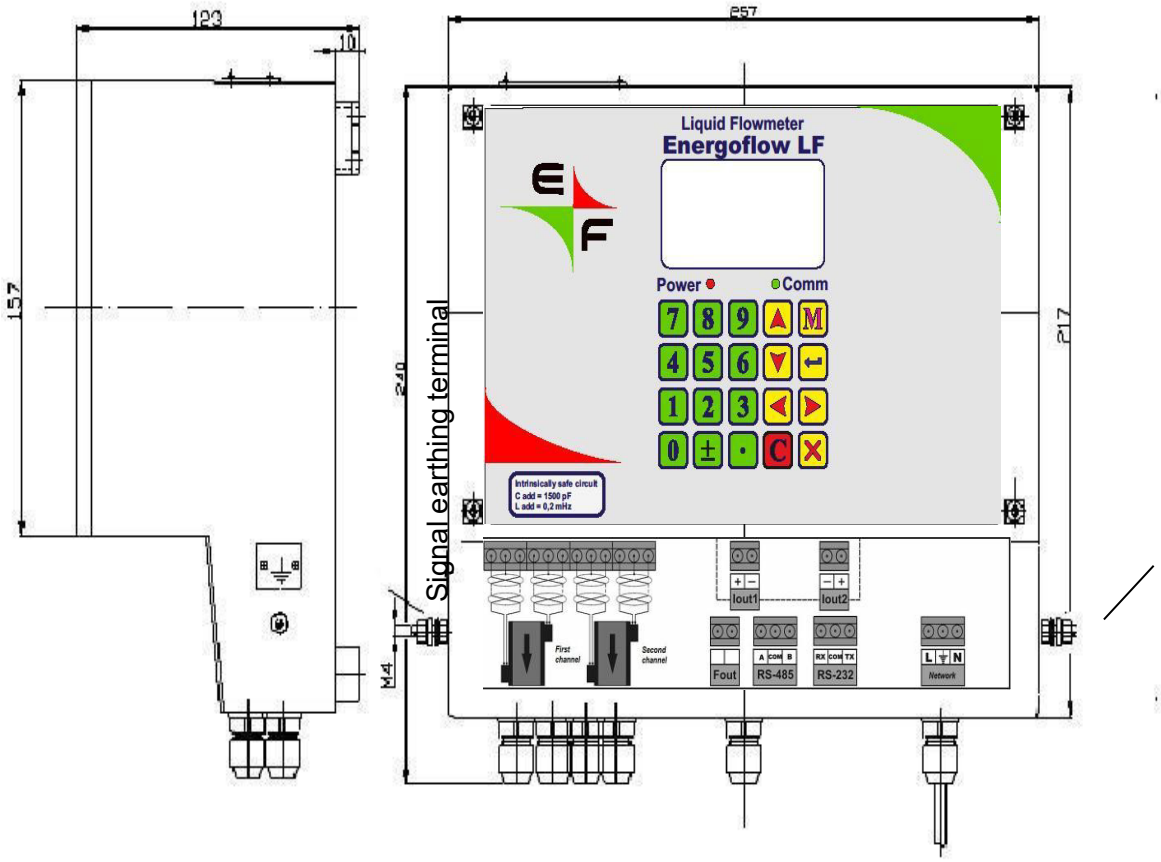
R – straight pipe-runs to be supplied with flow meter

C – Flow conditioner to be supplied with flow meter

N- No additional accessories

APPENDIX B

Flow meter Electronics Unit dimensions



APPENDIX C

Flow meter connection schemes

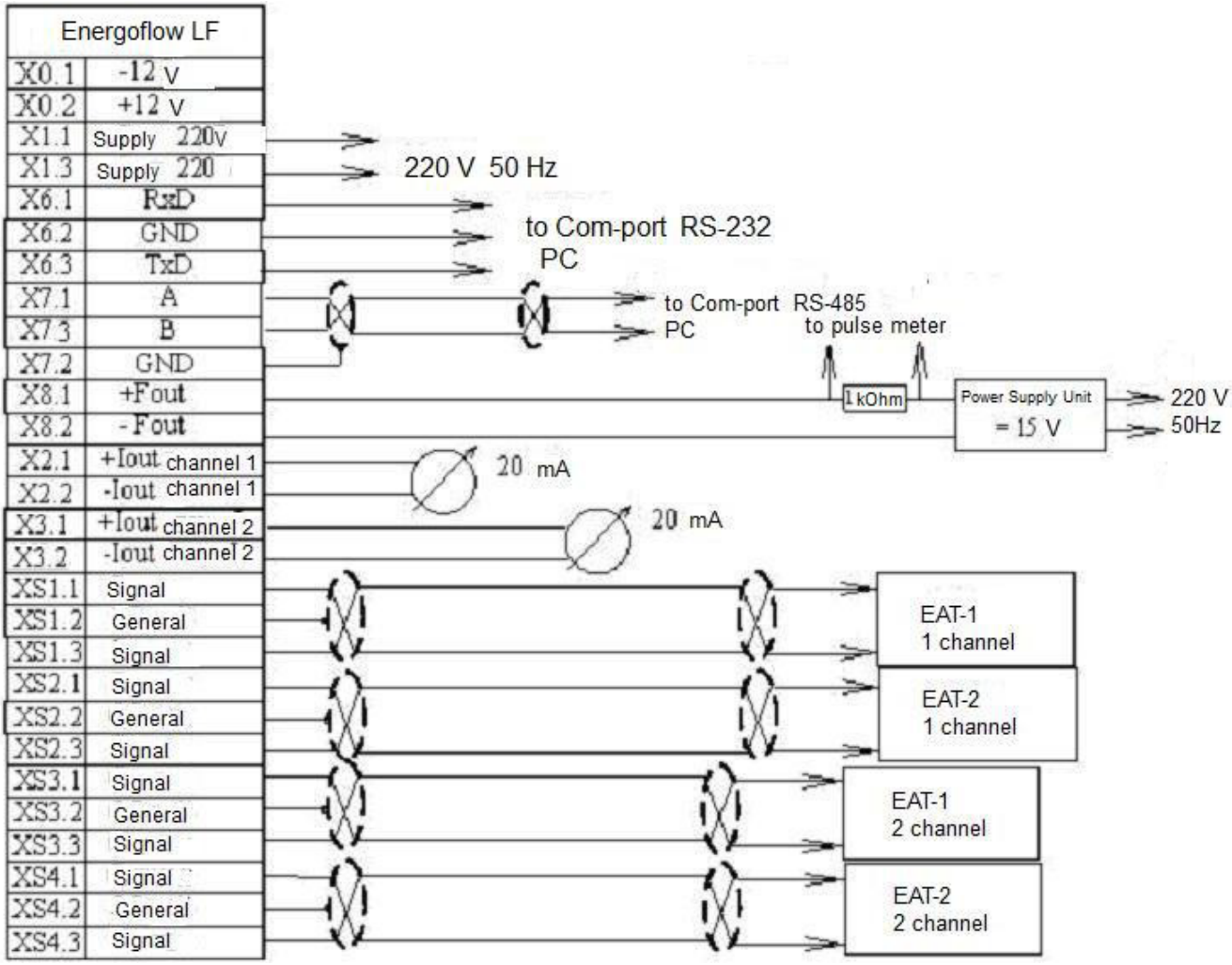


Figure D.1 — Diagram of EAT connection with twisted pair cables

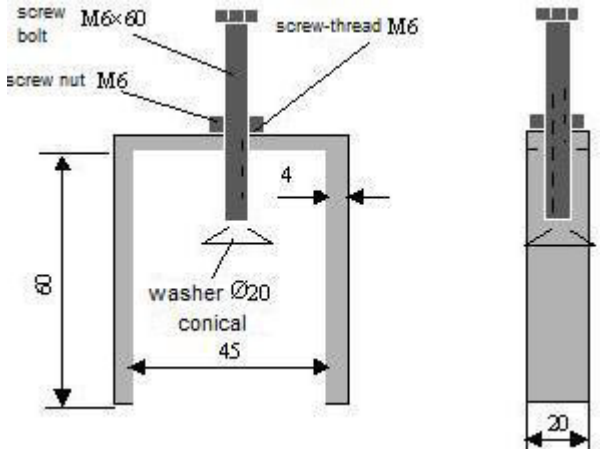


Figure D.2— Mounting clamp for clamp-on EAT

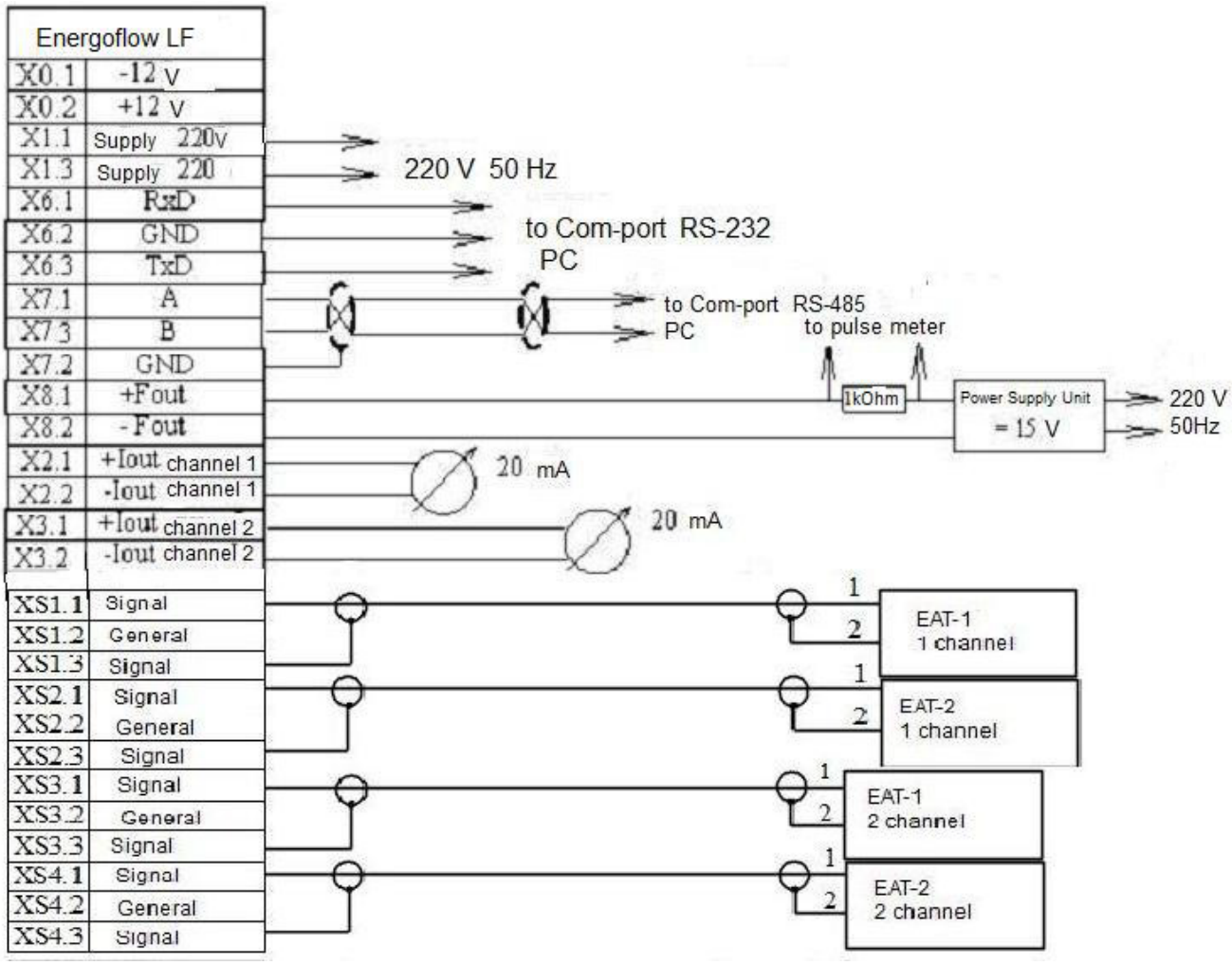


Figure D.3 — Diagram of EAT connection with coaxial cables

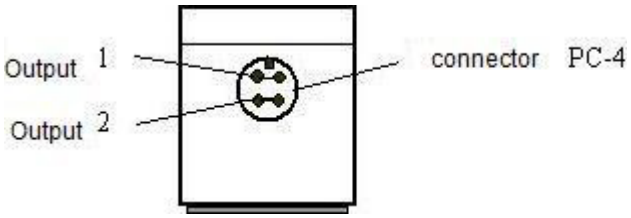


Figure D.4 — Pin diagram of the clamp-on EAT