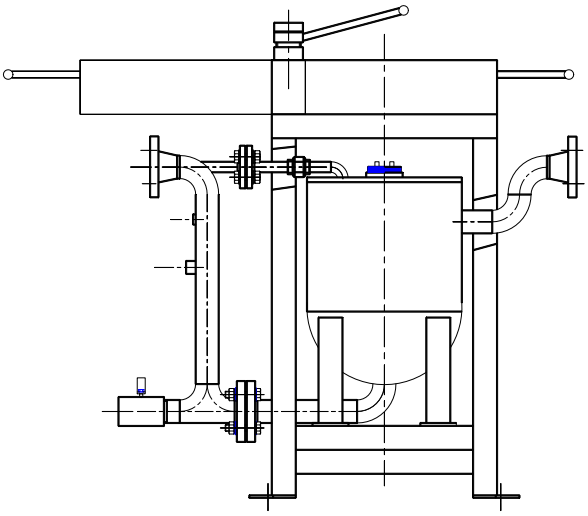
GAMMA LIQUID EFFLUENT MONITOR

CONTENTS



1. SAMPLE

1.1. TYPE OF RADIATION MEASURED : GAMMA RADIATION

- Energy range : 0.050 MeV – 2.0 MeV

1.2. DETECTION LIMITS / BACKGROUND READINGS - TYPICAL

Isotope	Energy [keV]	Discriminator window [keV]	Detection limit [kBq/m³]	Calibration factor [kBq/m³ per cps]	Background [cps]
Co-57	122	110-134	0.29 [7.8] *	4.99	0.39
I-131	364	320-400	0.43 [12] *	8.30	0.32
Cs-137	662	596-728	0.55 [15] *	14.4	0.17
Co-60	1173	962-1232	0.91 [25] *	22.69	0.19
	1332	1118-1386	0.98 [26] *	28.42	0.14
Integral		>100	0.41 [11] *	2.04	4.73

** : Values between brackets are expressed in nCi/m³*

Measurement conditions for detection limits :

- Ambient activity : < 0.2µSv/h
- Pump flow : 3m³/h
- Atmospheric pressure : 1020mbar
- Background measurement : Water pumped in closed circuit
- Background measuring time : 3600s
- Activity measurement : Solutions of Co-57 and Co-60 in Marinelli beakers
  Water pumped in closed circuit with solution of Co-60
  Water pumped in closed circuit with solution of I-131 and Cs-137 to determine calibration factors.

1.3. MEASURING RANGE FOR I-131 : 0.43 kBq/m³ to 3.3 x 10^9 Bq/m³ - typical

12 nCi/m³ to 89 mCi/m³ - typical

With : Maximum count rate = R_{sat} = 4 x 10^5 cps
Background = R_0 = 0.32 cps
Measuring time = Sampling time T = 3600s
Calibration factor = Cal. F. = 8.30 kBq/m³ per cps

Maximum of range calculated as : R_{sat} x Calibration factor
Minimum of range calculated as = MDC = Detection limit (DL) x Calibration factor

$$\text{I-131 DL} = 2 \times 1.96 \times \sqrt{2} \times \sqrt{\frac{R_0}{T}} = 0.052 \text{ cps}$$

I-131 MDC = 0.43 kBq/m³
to DIN 25 482 Part 1
Confidence level : 95%
$k_{1-\alpha} = k_{1-\beta} = 1.96$

1.4. MEASURING RANGE FOR Cs-137 : 0.55 kBq/m³ to 5.7 x 10^9 Bq/m³ - typical

(Same calculations as for I-131) 15 nCi/m³ to 150 mCi/m³ - typical

Cs-137 DL = 0.038 cps
Cs-137 MDC = 0.55 kBq/m³

1.5. **MEASURING RANGE FOR Co-57 :** 0.29 kBq/m³ to 1.9 x 10^9 Bq/m³ - typical
(Same calculations as for I-131) 7.8 nCi/m³ to 51 mCi/m³ - typical

Co-57 DL = 0.058 cps
Co-57 MDC = 0.29 kBq/m³

1.6. **MEASURING RANGE FOR Co-60 :** 0.91 kBq/m³ to 9 x 10^9 Bq/m³ - typical
(962 keV - 1232 keV) 25 nCi/m³ to 243 mCi/m³ - typical
(Same calculations as for I-131)

Co-60 DL = 0.040 cps
Co-60 MDC = 0.91 kBq/m³

1.7. **MEASURING RANGE FOR Co-60 :** 0.98 kBq/m³ to 1.1 x 10^{10} Bq/m³ - typical
(1118 keV - 1386 keV) 26 nCi/m³ to 297 mCi/m³ - typical
(Same calculations as for I-131)

Co-60 DL = 0.035 cps
Co-60 MDC = 0.98 kBq/m³

1.8. **MEASURING RANGE FOR INT :** 0.41 kBq/m³ to 8.1 x 10^8 Bq/m³ – typical
(> 100 keV) 11 nCi/m³ to 22 mCi/m³ - typical
(Same calculations as for I-131)

INT DL = 0.201 cps
INT MDC = 0.41 kBq/m³

It should be noted that in practice a cocktail of gamma emitters is measured.

1.9. **AMBIENT :**
Temperature range flow : + 0.5°C to + 40°C
Surface water : low to medium polluted
Maximum particle size : < 10 mm

Typical delay time of liquid to reach inlet of vessel :

Length of tube [m]	Response [s]
5	10
10	20
15	30
20	40
25	50
30	60
35	70
40	80
45	90
50	100

Notes :
Maximum pump suction lift : 7m *
Average speed : 0.5m/s
Flow : 3m³/h
Maximum outlet pressure : 3bar *
Maximum tube length : 50m
Depending on sampling conditions and configuration
* If RM 1000 B2D-SSQ-AAA pumpis used

2. MONITOR

2.1. MEASURING VESSEL :

Construction material : Stainless steel 304L (Electro-Chemically Polished inner surface)
Volume : 25 liters, cupshaped outlet
100 % water tight

2.2. VESSEL INLET / OUTLET TUBES AND FLANGES :

Material flanges : Stainless steel 304L
Vessel inlet construction contains :

- Vessel inlet flange :
  - Fixed onto inlet of vessel
  - 4 holes for connection of counter flange
  - Sealing ring (9125-3010)
  - Stainless steel connecting screws
  - ANSI 1 1/2" 150 lb welding neck flange

Vessel outlet construction contains :

- Vessel draining valve : 1 1/2" ball valve in nickel-plated brass with 1 1/2" female pipe thread
- Vessel draining flange and counter flange
- Vessel outlet flange : Fixed onto outlet of vessel
- 4 holes for connection of counter flange
- Sealing ring (9125-3010) :
  - Stainless steel connecting screws
  - ANSI 1 1/2" 150 lb welding neck flange

2.3. LEAD SHIELD AROUND MEASURING VESSEL :

Type : 96% Pb + 4% Sb
Solid angle : 4π
Thickness (side shielding) : 50mm
Thickness (top shielding) : 100mm
Thickness (bottom shielding) : 50mm
Top shielding hinge mounted with lever for easy access to vessel and detector
Construction : 68 standard bricks / 21 special bricks
Assembly : Layer by layer
Painting : RAL 7032
Type : flat finishing
Thickness : 10µm

2.4. FRAME :

Material : Stainless steel 304L
Cover plates : Stainless steel 304L
Protection degree : IP20
Overall dimensions : (1022 x 890 x 475) mm (H x W x D)
Fixation : 4 holes Ø16 at distances (486 x 486) mm for floor fixation
Dimensions with swivel opened : (1022 x 1190 x 475) mm (H x W xD)
Floor requirements : Straight-edged ; reinforced to sustain 4000 kg/m^2
Weight : approx. 1000 kg (incl. : vessel + in- and outlet ; detector ; lead ; frame)

2.5. AMBIENT :

Pressure range vessel : - 700mbar to 8bar ; tested at 10bar
Maximum operating pressure vessel : 8bar
Vessel resistant against corrosion, caustic and acid solvents
Pressure drop @ f(flow rate) : Refer to graphs : "Water flow curves"

3. DETECTOR

3.1. DESIGNATION : BAI 9305

Type : Ø2" x 3" NaI (Tl) photomultiplier integral line
Length housing : 283mm (without connectors)
Endcap : 0.5mm Aluminium (220 mg/cm^2)
Access to detector : Vessel dipstick
Sleeve material : PP ; 2mm thick
Sleeve inner diameter : 64mm with M65 x 1 socket fixation
Resolution Cs-137 : $\leq$ 8%
High voltage ; Type : LB 3892-2 : 0.4 to 1.4kV
Single channel analysers ; Type : LB 3815 (2x)
Temperature range : 0°C to +50°C
Temperature gradient : Maximum 5°C/h

3.2. TEMPERATURE STABILITY :

Measured in temperature range of +10°C to +40°C
Temperature drift in window (320 - 400) : -0.43%/°C - typical
Temperature drift in window (596 - 728) : -0.41%/°C - typical
Temperature drift in window (962 - 1232) : -0.20%/°C - typical
Temperature drift in window (1118 - 1386) : -0.67%/°C - typical
Typical value given by manufacturer for detector : -0.7%/°C for the range of 20°C to 40°C. A drift of -0.4 to -1%/°C is not exceptional.
The temperature drift is caused by the variation of amplification of the photomultiplier, meaning that the amplification drops by increasing temperature.

Drift calculated as :

$$\frac{\mathrm{cps}[10°\mathrm{C}] - \mathrm{cps}[40°\mathrm{C}]}{\mathrm{cps}[\mathrm{referencetemperature}] \times [\Delta \mathrm{T}]}$$

Temperature range measuring vessel : +0.5°C to +45°C

3.3. USED HARDWARE :

Designation housing : BAI 9479
Designation preamplifier : LB 3812
Mounted on side of monitor
Input : Charge-sensitive input for direct connection of scintillation probes without preamplifiers
Polarity : negative
Output : Dynamic range : 2V
Polarity : Positive
Ambient temperature : 0°C to +50°C

4. ELECTRONICS

4.1. DATA PROCESSING ELECTRONICS :

Euro style modular design integrated into 3 HE rack (LB 3800-65)
Designation : LB5340-1

- Microprocessor electronics of modular design integrated in 3 HE rack
- Self diagnosis software to monitor detector and system conditions (healthy / fault)
- Data storage of measurement data and parameters in memory buffer with battery backup
- All measurement parameters settable either locally or from remote system (file upload)
- Free adjustable parameters for : Alarm thresholds (2), Integral threshold (1), Failure, Registration times short time; long time ; release rate; integral release (determine the printout, data transfer interval and storage into FIFO for normal, alarm or failure conditions), Background subtraction, Dead time correction
  Local result read-out and parameter input with 7" TFT Graphical Touch panel display with 800x480 dots resolution display or external USB keyboard

- Password protected parameter settings
- Calculation of results in physical units i.e. µSv/h, Bq/m³, m³/h, ...
- Interfaces

Front panel : 2xRS232C/RS485 potential isolated, Ethernet and 1xUSB Host/Device switchable
On PC board
Side panel :USB Host (keyboard-mouse, printer or memory stick) / Ethernet RJ45 on enclosure
Internal communication between modules via CAN BUS

- Data buffers contain 1000 latest measurements available for up to 8 different central systems
- Automatic start-up of measurement after power up

Computer board
Designation module : Single Board computer with ARM9 CPU
32-64 MB SDRAM, 32-64 MB Flash Memory,
SD card slot 1GB

Operating system : Embedded OS (Windows CE)
Application : 8 channels (of which 2 analog input flow channels)
Read out in Bq/m³ or µSv/h (Channel 1 to 6)
Read out in m³/h (Flow Channel)
Power fail protection : Parameter storage in Flash or SD Memory
Communication with peripheral boards via CAN Bus
Short & Long sampling time adjustable between 1 and 100000 s
Integration time adjustable between 0 and 10^{20}
Station Identification 4 digits freely selectable via software

Optional boards:

DAQ Ampli-discriminator module LB39414 *(included in this version)*
For connection of NaI detector, including HV unit (x1) and 3x output dual SCA module
1 HV-supply unit up to 4 kV, 12 Bit Resolution
Preamplifier for GM-, Proportional-Counters and Scintillation detectors.
Software controlled Main Amplifier (8 Bit)
2 x Single Channel (Window), 1 x Integral Discriminator
3 Internal Counting Channels
2 HV-Outputs (1 x direct and 1 x over Voltage Tripler stage HVx3)
1 BNC Counter Input and 1 BNC Counter Output

Multi I/O board LB39417-01(not in this configuration)
4 Counter inputs
2 analogue Inputs 0/4-20 mA/0-5V
2 analogue Outputs 0/4-20 mA
4 digital Inputs
4 Detector HV control signals 0-5V
8 Open coll. Outputs
Connection peripherals via Phoenix 48-pole connector
Counter inputs
Function : detector / counter inputs
Number of inputs : 4
Signal type : CMOS +5V Schmitt trigger inputs, overvoltage clamping 5.1V, 1 kOhm input
Connection : Terminal strip back side of electronics rack
Digital signal inputs
Function : status inputs
Number of inputs : 4
Signal type : Opto coupler input connected to +5V, 390 Ohm series resistor, Low input = inactive
Connection : Terminal strip back side of electronics rack
Digital signal outputs
Function : status outputs

Number of outputs : 8
Output type : open drain SIP MOSFET, clamped to max. 18V with arrestor
Assignment : via software setup matrix
Connection : Terminal strip back side of electronics rack
Max. rating : 1.8W dissipation per output
Output max. ranges : Idrain max. < 650mA continuous; series resistor 33 Ohm
Analog signal inputs
Function : Input for flow signals
Number of inputs : 2
Input resistor : 243 Ohm, clamped at 18V with arrestor
Signal input 0-20 or 4-20 mA by software selection
Analog signal outputs
Function : Output for Channel data
Number of outputs : 2
Both outputs galvanically separated from rest of circuitry
Output series resistor : 200 Ohm, clamped at 18V with arrestor
Signal output 0-20 or 4-20 mA by software selection, active (+12V) or passive
HV Ctrl signals
Function : control signals for HV unit
Plateau take-up via software
Number of outputs : 4
Output series resistor : 100 Ohm,
Signal output 0-5 V

Pseudo coincidence board LB39415 (not in this configuration)
Function : Provide Signal proportional to natural activity contents
Pseudo-coincidence board with α,β,γ-counter
BNC Inputs for Radon progeny compensation.
Signal type : CMOS +5V Schmitt trigger inputs, overvoltage clamping 5.1V, 1 kOhm input
Connection : BNC connectors α,β,γ-counter
High Voltage outputs : dual 0-1.4 kV or 0-4.2 kV outputs for proportional counters.

5-fold Relay euroboard *IDN° 55806 (included in this version)*
5 x double pole, double trow relay (C,NO,NC), potential free
24VDC power supply, Imax 175 mA
CAN bus controller
Embedded software with *Watchdog* function (firmware V1.1)

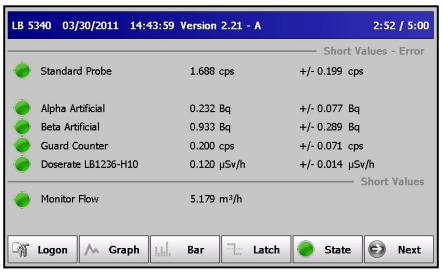
8-fold Relay board IDN° 49762 (not in this configuration)
8 x double pole, double trow relay (C,NO,NC), potential free, external
24VDC power supply, Imax 175 mA
CAN bus controller
Embedded software with *Watchdog* function (firmware V1.1)

LB 39418 Power supply *90-254VAC, 5V,15V,15V (9TE) (included in this version)*

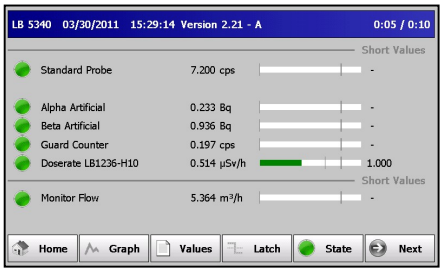
Evaluation Electronics LB5340-1

The versatile Electronics LB5340 with 7" TFT touch screen Display and trackball keyboard is used as Data logger electronics. It serves as data processing and evaluation unit with ABPD/AERD application program for parameter entry and visualisation of the Measurement results.

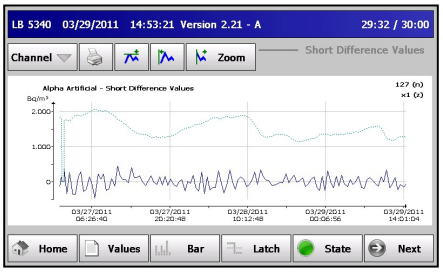
Averaging algorithms (ratemeter or moving average) can be selected. Pre-alarm and alarm thresholds can be set on short and long time values, activity on filter (Bq/Filter) , volumetric activity (Bq/m³) and derived units for the different counting channels.



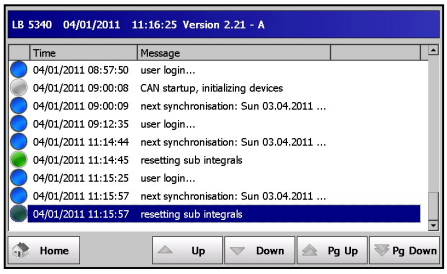
Different screens are available to present the measurements and graphics. They can show bar graphs with embedded thresholds for short, long, difference, sub integral and integral values as well as time based graphs with measured values.



All screens are predefined and the user has the possibility to select which screens are shown.



An scrollable Alarm and status page gives an event log of the monitor status.



A zoom function can be set to show an enlarged view of up to 4 measurement values. This feature enhances the display readability from a greater distance.

Intelligent µ-controller modules with field proven CAN-Bus interface are used for front end signal processing and detector interfacing. Five different intelligent boards (modules) are available for measurement applications. In the basic version of the LB150DR monitor the LB5340-1 contains an ABPD module, a Multi I/O module and a power supply module. If additional analogue or relay outputs are required simply adding extra modules allows for the extension. The LB5340 application software allows to perform Service & maintenance functions such as Plateau take-up, Background measurement, Efficiency calibration, automatic determination of Pseudo-coincidence factors, recurrent testing.

For data communication or print out of all relevant Measurement data and Parameters several interfaces are available. The data are kept in a FIFO data buffer of up to 1000 results deep.

- 2 Password protected levels : user & administrator
- FIFO Data buffer with 1000 results per Channel
- Embedded Watchdog function when Relay board is used
- Module communication via proven CAN-Bus technology
- Intelligent, self monitoring Modules with µ-Controllers
- Single board computer with 7“ TFT-Monitor and Touch screen
- Relais board with 5 potential free Relais with dual changeover contacts
- Remote access and configuration import & export is supported via USB and Ethernet ports and LB5340 remote configuration utility software.
- Interfaces :
- Back panel: 2 x RS 232/RS 485 electrically insulated, Ethernet, 1 x USB (Host/Device switchable)
- Front panel: USB Host (keyboard-mouse, printer or memory stick)

4.2. ENCLOSURE :

Designation : BAI 9860
Wall mount system enclosure containing electronics rack 19”
Dimensions : (215 x 600 x 390) mm (H x W x D)
Height : 3HE (effective height units)
Painting : RAL 7030 mat
Cable glands : 4 x PG13.5 (max. 13mm OD) : Mains, detector and pump signals

4.3. CABLES :

High voltage power supply detector :
Connection between : detector and electronics rack
Type : BAI 9415
Length : 7m

Detector signal :
Connection between : preamplifier and electronics rack
Length : 5m

4.4. AMBIENT :

Maximum ambient temperature : 0°C to +40°C
Humidity range : 10 < RH $\leq$ 95% (non-condensing)
Protection degree enclosure : IP55
Weight (Rack + housing) : approx. 16kg
Not qualified for applications requiring shock / seismic / vibration certification (IEEE 304)

4.5. MAINS :

Voltage : 230V +6% / -10% single phase
Frequency : 50Hz / Sine shaped
Earth requirements : Section : 0.75mm^2
Resistance : $\leq 2\Omega$
Fusing : 2 x 1.6A slow
Consumption : 0.5A at 230V (without analogue I/O boards)

5. STANDARDS

Mains dropout conform to ECMA
EMI : conform to IEC 801-2 II
CISPR 22 (1985)
VDE 0871 CLASS B
Safety : IEC 435 / IEC 950 instruments class I
HD 472 S1
EN 50160

6. OPTIONS

6.1. AIR COMPRESSOR FOR PNEUMATIC CHECK SOURCE SYSTEM :

Designation : BAI 9461
Standard motor : 230V / 50Hz
Motor capacity : 0.018W ; 0.65A
Consumption : 18W
Weight : approx. 2kg

Pressure : 2bar
Maximum pumping speed : 12 l/min (Atmospheric pressure)
Activated in test mode : all channels at the same time (local activation and remote control)
Connection cable : BAI 9420 (To electronics)

6.2. CHECK SOURCE ACTUATOR :
Designation : BAI 9461-5
Source : Cs-137
Activity : approx. 370kBq ± 6%
Overall uncertainty : ±4%
Lead shielding : 2cm
Check source influence : approx. 3cps - typical

6.3. HYDRAULICAL FLUSHING KIT WITH HIGH PRESSURE CLEANER :
Designation : BAI 9470-1
Components :
- High pressure cleaner and hose
- Reduction with elbow
- Spraying nozzle with carrier

High pressure cleaner :
- Type : HD 700
- Flow : 150 - 600 l/h
- Working pressure : 10 - 130bar
- Voltage : 230V / Monophase / 50Hz
- Power ratings : 3.1kW / 13.5A
- Power : 2.3kW
- Maximum water temperature : 60°C
- Suction lift : 1m
- Dimensions : (511 x 302 x 387) mm
- Weigth : approx. 25kg

6.4. MANUAL BY-PASS SYSTEM :
To connect to a tap water source for rinsing
Designation : BAI 9470
Overall dimensions : approx. (1535 x 510 x 128) mm (L x H x D)
Material : Stainless steel
Operating pressure : 3bar nominal
Pressure range : maximum 8bar

6.6. OVERFLOW PAN :
Consists of a 3mm thick SST plate construction with 2 draining pipes welded to the bottom. Is used as a drip-collector is case any leakage may occur due to worn out sealing rings between flanges. Note : Designed for use in a portakabin.

6.7. OVERFLOW PAN WITH VIBRATION ABSORBERS :
Consists of a 3mm thick SST plate construction with 2 draining pipes welded to the bottom. Is used as a carrier for a pump unit and a drip-collector in case of leakage. Note : Designed for use in a portakabin.

7. ADDITIONAL INFORMATION

7.1. PRESSURE DIFFERENTIAL CALCULATION

7.1.1. Flow coefficient

$$k_v \left[\frac{l/min}{\Delta P\ 1\ bar} \right] = 378.84\ l/min$$

7.1.2. Calculating a pressure differential for a given flow

$$\Delta P = \left(\frac{Q}{k_v} \right)^2 \times \rho\ [bar]$$

with : Q = flow in l/min
k_v in l/min
ρ = densitiy in kg/dm³
ΔP in bar

7.1.3. Example

Flow = 3m³/h = 50l/min
ρ_{water} = 1 kg/dm³

What is the pressure differential over the BAI 9125 ?

$$\Delta P = \left(\frac{50}{378.84} \right)^2 \times 1 = 0.0174\ bar$$

Note : These figures are only applicable for the BAI 9125 monitor itself. This means from the inlet flange to the outlet flange. Not including any in- or outlet hose or piping.

7.2. WATER FLOW CURVES