TOPICS OF THE COURSE:

Concepts of Smart Metering and AMI Systems

NEDA Industries Cooperation

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Revision #2

1- Resources Those Will be Delivered During the Course

a. Standards
   i. **27 Volumes, 2234 Pages**
      1. LAST and Full Version of DLMS Color Books (Sept. 2011)
      2. IEC 62056 (including IEC1107)
      3. IEC 62052
      4. IEC 62053
      5. IEC 62058
      6. ISO 10012
      7. IDIS
      8. IP Protection
b. Articles and Papers

2- Brief History

a. 1880: Billing per number of lamps
b. Chemical and semi-electrical meters
c. 1894, Oliver Shallenberger from Westinghouse invented Electro-Mechanical Meters (Single Phase, Only Wh or Varh) [like in Aras dam]
d. Electro-Mechanical Meters (Poly Phase in one package)
   i. For both primary and secondary sides
e. Static or Electronic Meters with Rotary Numerators (like ACE1000)
f. Electronic Meters with LCD (also known as Revenue meters)
   i. Can Measure both active and reactive energy
   ii. Can Measure Demand
   iii. Can Apply Tariffs
g. 3 tariff meters improved to multi rate meters (User Configurable)
h. Measuring energy in both directions (especially in Europe for D.G.)
i. Measuring and logging power quality, PF, I, V (load Profile)
j. Communication Port: **Flag**; Stands for **F**erranti and **L**andis **A**nd **G**yre
k. IEC1107: As well-known and widely used standard for FLAG port
l. Adding other ports to meters like RS485, RS232, CLO, …
m. Adding pulse and control outputs to meters
   i. E-outputs (S0) not necessary metrological synchronies with LED
n. Popping up AMR systems for remotely reading meters
   i. 'Bazar Reza' wireless reading in Mashhad
o. The raise of prepaid meters [like in Kish island]
p. Gated Energy issue and reading Gas/Water meters by Energy meters
q. 1997: DLMS as Internationally Approved Metering Protocol
r. Grid metering is separated from SCADA due to development of power market and getting meters more and more complex
s. Now, there is International metering conferences as well as Metering Journals and reports (**EPRI, Berg Insight**), …

t. By increasing D.G.s, Need for added grid security and demand for energy conservation, smart metering is born about a decade ago
    i. Smart Grid in Italy (Enel) completed in 2005
    ii. Smart metering consisted of modern metering + remote full control over meter + load management
u. Smart Metering is a part of Smart Grid but not all of it

3- What Exactly Smart Metering Is?

a. Smart Metering is a "**System**" not a group of devices
b. Smart Metering Comprises of
    i. Smart Meters: Anti tamper meter+ Communication Modem+ Relay
    ii. Communication Media
    iii. Central System
    iv. Other Nodes like DCUs/Routers/Protocol Convertors/Gateways (e.g. PLC to GPRS) and ….
    v. Optional Managing Water and Gas meters
    vi. Optional having a user friendly UI for client (IHDs)
c. Main Objectives of Developing Smart Metering Systems
    i. In Iran: replacing old meters with new smart meters
        1. Decreasing technical losses
        2. Making anti-fraud features richer
        3. Improving metering accuracy
    ii. Automatic reading of meters plus billing with reduced cost
    iii. Frequent reading of meters and getting load profile on daily basis; it is useful for load analysis and load forecasting
    iv. Demand Response (e.g. reducing peak load)
    v. Better distribution system manageability/automation through MDM systems

4- What Does the Ideal Smart Grid Look Like?

a. Smart metering is a part of smart grid
b. We Have a HAN with all home appliances communicating with smart meter to know when to start and when to stop
c. Electric Cars (PV), solar panels and wind turbines communicating with smart meter to know when to export energy to grid (e.g. peak hours, tripping a power plant unit)
d. Smart meter talks to central system to get latest load and price information, so in smart grid clients can actively participate in power retail market which leads to more secure grid
e. Benefits of smart grid
    i. Energy Conservation
        1. Less carbon dioxide and so cleaner air
    ii. Energy cost reduction through demand management
    iii. Load Management

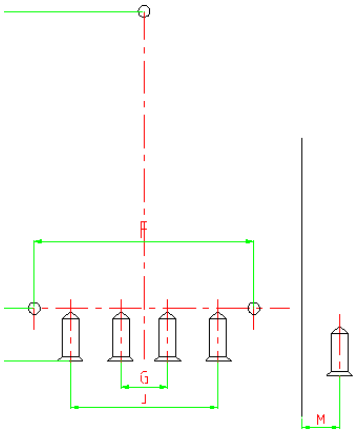
iv. More secure network by better monitoring and control
v. Self-Healing grid (e.g. smart meters report blackouts to central office and get orders back how to re-act and isolate faulty section of the grid)

5- Smart Metering vs. SCADA (Protection and Control Systems)

a. Smart Metering is penetrated inside homes/retailers while SCADA acts only on high voltage
b. Metering is not real time (in SCADA time resolution is less than 10 mSec)
c. Measuring accuracy in metering is much more (%0.2 compare to %5)
d. Security is more important in metering (e.g. AES in DLSM/COSEM)
e. Metering is “business critical” not “mission critical”
f. Main purpose of developing metering is optimizing cost while SCADA is just developed for engineering/technical issues

6- Digging into E-Meter?

a. Types
   i. SP
   ii. PP
      1. PP-DC
      2. PP-CT (LVCT)
      3. PP-CTPT (HVCT)
b. Form factor (housing)
      1. 92 * 92 standard as in voltmeters and watt-meters
      2. 144 * 144 standard
      3. Rail/ Rack mounted like ION 8800
      4. Wall mounted

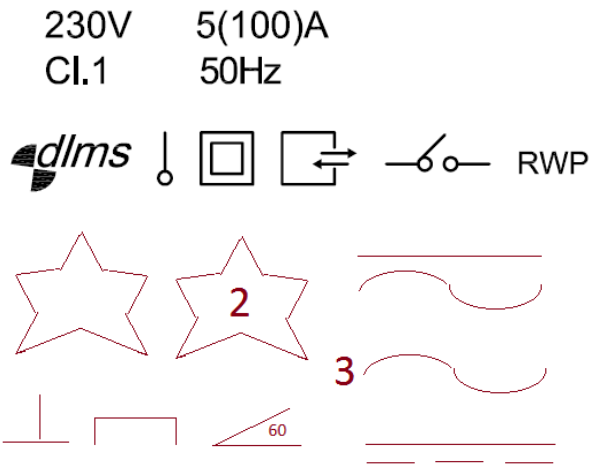


	D	F	G	J	M
BS	141.3(max)	103.2-106.4	20.6-23.8	68.2-71.4	17.4-
DIN	155	105	23	50	13.

a. ANSI housing (round meters)

c. Components
   i. Enclosure (poly carbonate + ABS, PBT for Base of ANSI Type)
      1. Back Plate

2. Face Cover
    a. Name plate printing technologies
        i. Laser engraving
        ii. Silk Screen printing
        iii. Hard or plastic paper name plates
    b. Name Plate symbols



3. Terminal Cover
    a. Transparent covers
    b. Cutouts for wires
4. Optional module enclosures
    a. At top (like in Elster meters)
    b. In middle (like in Landis meters)
    c. Cut-outs for external antenna(s)
5. Sealable button/buttons
6. Fixing mechanisms of face cover to back plate
    a. Screws
    b. Ultra sonic welding
    c. Gripping by hooks

ii. Terminals
    1. Material: Copper, Nickel plated steel
    2. Bended plate and extruding copper
    3. Screw type and lifting type

iii. Relay
    1. Contact point resistance ($AgSnO_2$)
    2. On load and off load switching count (1E4 and 1E5)
    3. Relay is a bottle neck for a smart meter

iv. Shunt/MCT

v. PCBA
    1. Measurement Chip
    2. MCU

3. LED/LEDs
4. Ports
    a. Jacks
    b. Spring Loaded Terminals
    c. Screw Type Terminals
5. Pulse/Control outputs
    a. Wet/dry
    b. 16 Hz limit of switching

vi. Power Supply
1. Transformer based
2. Switching type
3. Capacitive

vii. Internal and external batteries and super cap
1. .5F or so but capacitance decrease along the time
2. Lithium ion with 10 years of shelf life time
3. Lithium Thionyl Chloride (Li SOCL2) 20 years of life

viii. RTC backup battery

ix. LCD + Backlight
1. Dot Matrix
2. 7segment with 8 (or 7) digits for main number

x. Communication Module
1. Separate power supply(its burden is excluded from meter's)
2. PLC on one phase of poly phase meter

d. Important parameters of a meter
i. Wiring types supported
1. 4 wire wiring (4 voltage, 3 current)
2. Arun: 3 voltages, 2 current
3. Open delta: 2 voltage, 2 current

ii. Accuracy of active and reactive energy measurement
iii. Nominal Voltage
iv. Nominal Frequency
v. Nominal Current (I_n)
vi. Maximum permanent current (Imax)
vii. Meter constant
viii. Starting current (.001 I_n)
ix. Maximum transient current (20 Imax for .5 sec)
x. Burden
xi. Insulation Protection (Protection class I or II)
xii. Working and storage temperature range

e. Major functionalities of a meter
i. Energy measurement
ii. Instantaneous parameters measurement
iii. Harmony measurement (usually 31)
iv. Power quality parameters measurement (sag, swell, …)
v. TOU, tariffication and calendar (up to 8 tariffs)
vi. Demand management

vii. Billing and EOB accounting
viii. LP (LS) logging
ix. DST
x. Event logging
xi. Tamper logging
    1. Magnetic field (200 mT)
    2. Partial grounding
        a. Due to neutral measurement capability
    3. Over/under voltage
    4. Opening terminal cover/face cover
    5. Wrong wiring
    6. Reverse energy flow
    7. Current unbalance
    8. Existing of current despite 1 or 2 voltages
    9. Illegal access to meter with wrong password
    10. Billing reset/ configuration changed

f. Meter Calibration
    i. It can be done only in factory and in factory mode
    ii. There is a possibility of losing calibration data in meter's memory
    iii. 3 point vs. 1 point calibration
    iv. Metrological drift
    v. Factory calibration and life time accuracy

7- Meter Testing

a. Defining Accuracy and Precision (shooting example)
    i. Precision is bound to concept of repeatability
b. Concept of resolution
c. Accuracy class of tester should be 5 to 10 times of testing device
    i. We have testers with %.01 accuracy
d. Testers consist of 3 major parts
    i. Reference (tester part)
    ii. Dummy or phantom load (vs. on circuit testing)
    iii. LCD (UI)
e. Direct or clamp connection
f. Loose connection
g. Calibration certificate
h. IEC 62058.21
    i. Acceptance test for electromechanical meters .5s, 1s and 2s
i. IEC 62058.31
    i. Acceptance test for static meters .2s, .5s, 1s and 2s
j. Testing equipment
    i. Mobile devices
    ii. Stationary reference devices
    iii. Test benches for meter manufacturers
k. Vendors: Zera and MTVS and SAA (Sanjesh Afzar Asia)

l. Calibration and accuracy tests in factory
    i. Calibration, heat and humidity chamber, calibration again
    ii. Accuracy for both active and reactive energy
    iii. Accuracy for both imported and exported energy
    iv. Load points: different V, I, F, PF and injection of THD
m. Non accuracy test in factory
    i. Spring hammer test
    ii. Case flammability test
    iii. IP test for water penetration
    iv. IP test for dust penetration
    v. Passive temperature test
    vi. Active temperature test (kind of accuracy test)
    vii. Humidity test
    viii. Over voltage test
    ix. Under voltage test
    x. Fast Transient Burst Test (2 Kv or 4 Kv)
    xi. Electrostatic Discharge test (on enclosure)
    xii. Immunity against RF test
    xiii. Over current test
    xiv. Starting current test
    xv. No load test
    xvi. Salt spray test
    xvii. Vibration test
    xviii. Magnetic field test
    xix. RTC accuracy test (5 ppm)

8- What is DLMS/COSEM

a. DLMS User Association (DLMS UA) Formed in 1997 in Geneva
b. Standardized as IEC62056 in 2002 by Adding 1107 & 61334 and … *(So DLMS is only a part of 62056)*
c. Now, DLMS User Association has 160+ Members in more than 40 Countries and more than 120 Products are Certified
d. First Stand for *Distribution Line Message Specification*
e. Then for *Device Language Message Specification*
f. COSEM Stand for *COmpanion Specification for Energy Metering*
g. Around Year 2000, DLMS upgraded to xDLMS which we use Today
h. COSEM is a Data Model, COSEM Objects
i. Concept of Class, Object, Attribute and Method
j. DLMS/COSEM Can Be Run Over The Following Communication Protocols
    i. HDLC
    ii. TCP
    iii. PLC (61334)
k. DLMS/COSEM is Mainly Developed for Metering
l. DLMS/COSEM in North America & EU

m. Implementations by Landys&Gyr, ACTARIS, Iskra, EDMI, and …
n. KalkiTec in India as a Provider for Source Codes and Tools
o. American Equivalent: ANSI C12.19
p. Brief About IDIS (Landis, Actaris and Iskra)
q. IEC61334-5-1 as a MAC Layer for DLMS in PLC Applications (sFSK)
    i. DLMS is tied to PLC rather than other Infrastuctures
r. Advantages of DLMS/COSEM
    i. Connection Oriented (Disadvantage when Infrastructure is Radio)
    ii. Not Only in Electricity Industry but in Gas & Water Industries
    iii. COSEM Objects Prevents Unambiguous Interpretation of Data Elements in Metering.
    iv. Secure (Encryption + Authentication)
    v. Covers Simplest Devices to the Most Complex Ones.
    vi. Open Standard Makes Interpretability Better
    vii. Low Overhead and Efficient
    viii. IEC62056 is Media Independent
    ix. Can be Run Over Internet
    x. Selective Access to All Objects (e.g. Partial Load Profile Reading)
s. DLMS UA Publishes 4 Books
    i. White Book
        1. Glossary of Terms (FREE)
    ii. Yellow Book
        1. Conformance Test Plans
        2. DLMS Conformance Tool Description and How to get Certificate (CTT)
            a. Can Be Done by Meter Manufacturer
        3. DLMS Explorer by Kalkitech
    iii. Blue Book
        1. IEC62056-61:Interface Classes
        2. IEC62056-62:OBIS
            a. Described in 3. ObjectNaming.pdf in Kalkitech's Training Course Material
    iv. Green Book
        1. IEC62056-53:COSEM Application Layer
        2. IEC62056-47: COSEM Transport Layer for IPv4
        3. IEC62056-46: HDLC
        4. IEC62056-42: Physical Layer (PHY)
        5. IEC62056-21: Direct Data exchange

9- IEC1107 Now a Part of DLMS/COSEM

a. IEC 1107 Now is a Part of DLMS/COSEM as IEC62056-21
b. **Flag**: Stands for **F**erranti and **L**andis **A**nd **G**yre
c. Schlumberger Has Optical Port Identical to Flag but With Different Software Protocol
d. ANSI Type 2 or ANSI C12.18 is Equivalent to IEC1107

e. IEC 1107 is Usually Half Duplex and Usually over Infra-Red Interface
f. IEC1107 Baud: Always Starts at 300 then negotiates to reach 9600 bps
g. Server (Meter)/Client (PC) Model
    i. Only Client Can Initiate Communication
h. Mode E
    i. Mode E is new and added by DLMS/COSEM to 1107
    ii. Peripheral can Talk to Meter with DLMS only if Communication Starts in Mode E (not A, B, C or D) However it can Continue in Mode E
    iii. Peripheral can Start Communication with Meter by Direct HDLC

10-Metering Standards

a. Type test and accredited laboratories (KEMA, NMI, COFRAQ)
    i. Accreditation trace chain and ILAC
b. Environment protection (digits: dust + water as in Appendix A and B)
    i. IP 51 (indoor)
    ii. IP 54 (outdoor)
c. Metering
    i. IEC 62052.11 (Vocab)
        1. Metering equipments and casing, heating, env. , …
    ii. IEC 62052.21 (Vocab)
        1. Reference current and voltage, … for Tariff devices
    iii. IEC 62053.21
        1. Meters of accuracy of 1 and 2
    iv. IEC 62053.22
        1. Active energy requirements
    v. IEC 62053.23
        1. Reactive energy requirements
    vi. IEC 62053.31
        1. Pulse output
    vii. IEC 62053.61
        1. Power consumption and supply voltage
d. Protocol
    e. IEC 62056-21: Direct Local Data Exchange
        i. 3d edition of IEC 61107
        ii. Communicating of HHUs to Tariff Devices
        iii. Description of Modes: A, B, C, D and E
    f. IEC 62056-31: Using LAN on Twisted Pair
        i. Extension to IEC61142
    g. IEC 62056-41: Using PSTN to Connect to WAN
    h. IEC 62056-53: COSEM Application Layer
        i. COSEM Hierarchy: Physical Device, Logical Device and COSEM Object
            1. It is Common to Have 3 Logical devices for Each Meter
        ii. LLS (Low Level Security) is Used on Secure Channel

1. Just Pass Password to the COSEM-Open's 'Calling_Authentication_Value' Argument
2. In LLS passwords are passed in Plain Text
3. In LLS only Client is Authenticated

iii. HLS (High Level Security) is Used on Non Secure Channel
1. Describe Algorithm
2. HLS Uses AES Encryption Algorithm with 128 bit Key
   a. AES is Successor of DES
   b. AES is Published in 2001
   c. AES keys are 128 or 192 or 256 bit
   d. AES Encrypts data in 128 bit Chunks
   e. AES is a Symmetric Key Cryptography
   f. AES is Approved by NSA
   g. AES is Adopted by US Government
   h. Some Companies Implement AES-GCM (beside, data and key we have a random string input)
3. In HLS both Client and Server are Authenticated
4. We Have Master Key, Global Key and Session Key (also known as dedicated key)

i. IEC 62056-61: Object Identification System (OBIS)
   i. Have a General Review on the Entire Groups & Codes
j. IEC 62056-62: Interface Classes (ICs)
   i. Meaning of Inheritance
k. IEC 62056-42: Physical Layer Services and Procedures for Connection-Oriented Asynchronous Data Exchange
l. EC 62056-46: Data link Layer
   i. Coprises 2 Sub-layers
      1. LLC (Logical Link Control)
         a. Thin Sub-layer
         b. IEC 8802
         c. Offers Connection-less Services on Connection-Oriented MAC
      2. MAC (Medium Access Control)
         a. Enhanced Version of HDLC
         b. IEC 13239
m. IEC 62056-47: COSEM Transport Layers for IPv4 Networks
n. IEC 62056-51: Application Layer Protocols
   i. Entire APDUs are Discussed
o. IEC 62056-52: Communication Management Protocol, DLMS Server

11-Telecommunication

a. RS232
   i. Point to point
   ii. Maximum length and speed

b. RS485
    i. Point to multi point
    ii. RS485 bus and daisy chaining instead of 'master-slave'
    iii. Maximum length and speed
    iv. 2 wire and 4 wire and their interconnections
    v. External powered RS485
c. M-Bus
    i. Stands for Meter Bus
    ii. Developed for Gas and Electricity meters
    iii. EN13757
    iv. PHY can be twisted pair or wireless
d. Optical port
    i. ANSI
    ii. Flag
e. GSM (Data Mode)
    i. Circuit switch
    ii. SMS service
    iii. Activation of data service and getting data number
    iv. Disable PIN request by a cell phone
f. GPRS
    i. Packet switch
g. PLC (DLC)
    i. Modulation
        1. S-FSK (61334) Baud 2400 bps, 60 KHz
        2. PRIME (OFDM) 20 Kb/s, 145 KHz
        3. G3 (OFDM)
    ii. Coupling
        1. Inductive vs. Capacitive
h. BPL
    i. Up to 10 Km, 200 Mb/s, 2-30 MHz
i. ZigBee Pro
    i. Due to IEC 802.15.4
    ii. Bluetooth Like short range radio
    iii. Ideal for WPAN (Wireless Personal Area Network)
    iv. Can be used for walk by meter reading method
    v. Jumping (Hopping) through nodes
    vi. Designed for 2.4 GHz but can run on 868 and 433 MHz
    vii. Speed: about 250 Kb/s
    viii. Modulation QPSK
    ix. Range: 100m to 1 Km
    x. Output power: 1 to 100 mW (in Iran 10 mW)
    xi. Receiver sensitivity: around -100 dBm
j. Inmarsat
    i. Began from 1982
    ii. International Mobile Satellite Organization
    iii. 4 satellite and 4 regions and poles

iv. Old services and the new ones with I4 satellites (IP based)
v. Inmarsat A or E
    1. Withdrawn in 2007
vi. Inmarsat C
    1. Telex
vii. Inmarsat B
    1. Stationary land applications only
viii. Inmarsat D
    1. Offline, message based
ix. Inmarsat Mini-M
    1. Data/fax/ voice up to 24000 bit/s with mobile terminal
x. BGAN
    1. Broadband Global Area Network
    2. Up to 492 Kbit/s
    3. Beam antenna, so very easy adjustment

12-Between Smart Meter and Central Office

a. DCU
    i. Number of meters can support
    ii. Modularity and variety of modules
    iii. Architecture
        1. Intel Atom or ARM9
        2. Amount of RAM
        3. Ports
            a. RS485
            b. USB
            c. Fast or Gigabit Ethernet
            d. GPRS
            e. PLC
            f. WiFi
        4. Linux OS or …
b. Gateways (e.g. PLC to GPRS)
c. HHU
d. IHD

13-Central Office

a. MDM and AHE (Head End)
b. AMI systems evaluation indexes
    i. Car example
    ii. General indexes
        1. Evaluating the provider (ISTQB example)
        2. Evaluating Implemented Algorithms
            a. Load Estimation with similar day or MLP

3. Scalability (stress test)
4. Using any exclusive/'out of date' products/technologies
5. Modularity
6. Security (white hat hackers)
7. Redundancy
8. Reliability/Robustness and Availability (5 9)
9. Compatibility with other systems including legacy systems
10. Connectivity to other systems
11. Performance
12. Features
13. User friendliness (shorter training period)
14. Maintenance free systems
15. Cost

iii. AMI Modules

1. Hardware drivers for Meter/DCU
2. Protocol drivers
3. Encryption/Decryption modules
4. Automatic Bulk Parallel Meter Reader
5. Scheduler
6. Load Balancer
7. VEE (verifying, editing and estimation)
8. Data Import/Export
9. Manual data entry/manipulation
10. Audit Trail
11. User/Permission Manger
12. UI
13. Reporting System
14. WFM (Work Flow Manager)
15. Tamper Manager (SMS sender and …)
16. Task Manager
17. Data Base
18. Optional: Network Manager (e.g. radio networks)
19. Optional: CIS (Customer Information System)
20. Optional: Billing
21. Optional: Asset management
22. Optional: GIS system
23. Optional: Outage Management
24. Optional: Load Forecast module (for power market or …)

Appendix A: Description of First Digit of IP Number

First characteristic numeral	Degree of protection	
	Brief description	Definition
0	Non – protected	-
1	Protected against solid foreign objects of 50 mm Ø and greater	The object probe, sphere of 50mm Ø, shall not fully penetrate
2	Protected against solid foreign objects of 12.5 mm Ø and greater	The object probe, sphere of 12.5mm Ø, shall not fully penetrate
3	Protected against solid foreign objects of 2.5 mm Ø and greater	The object probe, sphere of 2.5mm Ø, shall not fully penetrate
4	Protected against solid foreign objects of 1.0 mm Ø and greater	The object probe, sphere of 1.0mm Ø, shall not fully penetrate
5	Dust – protected	Ingress of dust is not totally prevented, but dust shall not penetrate in a quantity to interfere with satisfactory operation of the apparatus or to impair safety
6	Dust – tight	No ingress of dust

Appendix B: Description of Second Digit of IP Number

Second characteristic numeral	Degree of protection	
	Brief description	Definition
0	Non – protected	-
1	Protected against vertically falling water drops	Vertically falling drops shall have no harmful effects
2	Protected against vertically falling water drops when enclosure tilted up to 15°	Vertically falling drops sha11 have no harmful effects when the enclosure is tilted at any angle up to 15° on either side of the vertical
3	Protected against spraying water	Water sprayed at an angle up to 60° on either side of the vertical shall have no harmful effects
4	Protected against splashing water	Water splashed against the enclosure from any direction shall have no harmful effects
5	Protected against water jets	Water projected in jets against the enclosure from any direction shall have no harmful effects
6	Protected against powerful water jets	Water projected in powerful jests against the enclosure from any direction shall have no harmful effects
7	Protected against the effects of temporary immersion in water	Ingress of water in quantities causing harmful effects shall not be possible when the enclosure is temporarily immersed in water under standardized conditions of pressure and time
8	Protected against the effects of continuous immersion in water	Ingress of water in quantities causing harmful effects shall not be possible when the enclosure is continuously immersed in water under conditions which shall be agreed between manufacturer and user but which are more severe than for numeral 7