INTERNATIONAL COUNCIL OF
MARINE INDUSTRY ASSOCIATIONS

ICOMIA GUIDELINE 49-13
RECOMMENDED PRACTICE FOR ELECTROMAGNETIC COMPATIBILITY (EMC) OF SMALL CRAFT UNDER EU DIRECTIVE 2014/30/EU

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ICOMIA Guideline 49-13 Recommended Practice for Electromagnetic Compatibility (EMC) of Small Craft

1. Introduction and scope

This document follows the terminology used in the European Directive on electromagnetic compatibility 2014/30/EU[1] (further referred to as the EMC Directive or EMCD) and readers are recommended to read the definitions in clause 3 first. The authors of this document assume the users' familiarity with the regulatory framework of EU directives, the EMC Directive in particular and the supporting role of standards as means of compliance. For explanatory documents see references in the bibliography at the end of this document. This document applies to small craft less than 24m in length which are considered mobile installations by the EMCD. Its purpose is to provide a way to comply with the requirements of the EMCD when installing and connecting electric/electronic components on small craft.

The main goals of the EMCD are[2]:

(1) To ensure that the electromagnetic **disturbances** produced by an apparatus or mobile installation (e.g. a boat) do not affect the correct functioning of another apparatus or mobile installation (e.g. another boat) as well as radio and telecommunications networks and electricity distribution networks.

(2) To ensure that an apparatus has an adequate level of intrinsic **immunity** to electromagnetic disturbances to enable it to operate as intended.

Conformity with the requirements of the EMC Directive is affected by:

- The selection of equipment/components installed. **A key element in the application of this document is the use <u>as far as possible</u> of components that are already subject to compliance with the EMC Directive or other EMC specifications, as well as supported by a compliant Declaration of Conformity and installation instructions.**

Correct and adequate installation practice for both the equipment and its cabling. In order to address the capabilities of all members of the boatbuilding community, ICOMIA has produced this guidance document. The main goal is to present an alternative to EMC type testing of boats, which is considered as the final proof of compliance but given the size of boats is impracticable. The alternative approach presented in this document suggests an audit trail that highlights the relevant steps from design, manufacturing and documentation. By combining EMC compliant components with good engineering practice it is assured that components will maintain their individual electromagnetic compatibility, therefore contributing to the boat's total EMC performance as follows:

- Selection of components and wiring
- Implementing good engineering practice in design and installation
- System checks
- Documentation of product compliance

[1] Directive 2014/30/EU on the harmonisation of the laws of the Member States relating to electromagnetic compatibility (recast) and repealing Directive 2004/108/EC

[2] The EMC Directive does not regulate the safety of apparatus in respect of people, domestic animals or property. It is only concerned with the electromagnetic compatibility of equipment. Please consult the Directive 2013/35/EU on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields).

Prior to the writing of this document, sample installations and boats with electric installation as described in this document have been tested to the harmonised standard EN 55012. These have been found to be significantly within the limits set out in the standard. Note EN 55012 only covers part of the requirements of the EMCD and there are no standards covering the EMCD immunity requirements.

Given the application of harmonised standards is voluntary, this document is an appropriate alternative, but excluding the highest possible degree of legal reassurance (presumption of conformity provided by harmonised standards only). Manufacturers who wish to benefit from the full presumption of conformity should use harmonised standards which will generally require testing of completed (sub-) assemblies. Professional third party assessment and guidance can be obtained from bodies notified under the EMC Directive. Annex A provides further guidance. The document concludes how to assess boat conformity by showing the options for conformity assessment and necessary steps in producing the technical documentation and declaration of conformity. At the end of this process, the manufacturer places the CE mark on the product or on its builder's/data plate as proof of conformity.

Extent of EMC requirements under the EMC Directive
The EMC Directive's goals, as set out above, are that the apparatus as a whole, i.e. the entire boat shall not interfere with other apparatus in its environment, and shall not be affected by disturbances that may be found in its environment. It follows that the EMC Directive does not regulate the EMC *within the boat itself*. Thus good installation practice that is intended to ensure correct inter-operation and compatibility of the sub-systems *within* the boat (internal EMC) does not address compliance with the EMC Directive and is not the subject of this guidance document. Nevertheless, such practice may also contribute to good *external* EMC and is to be encouraged.

2. Reference documents

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60945 Edition 4.0 (2008-04-14) Maritime navigation and radiocommunication equipment and systems - General requirements - Methods of testing and required test results.

EN 60945:2002 Maritime navigation and radiocommunication equipment and systems - General requirements - Methods of testing and required test results.

Note: these two standards include requirements for the EMC of marine electrical and electronic equipment. EN 60945 is a harmonised standard under the EMC Directive and is equivalent to IEC 60945 Edition 3. It should be expected that equipment which is intended for the marine environment will be compliant with this standard and its CE Marking declaration of compliance will reference it accordingly. However the boat as a whole cannot be CE Marked against this standard.

EN 55012: 2007, Vehicles, boats and internal combustion engines - Radio disturbance characteristics - Limits and methods of measurement for the protection of off-board receivers

This standard is designed to provide protection for broadcast receivers in the frequency range of 30 to 1 000 MHz when used in the residential environment. It applies, inter alia, to boats propelled by an internal combustion engine, electrical means or both and applies limits to be verified by testing the whole boat at a 10m distance on an outdoor test site. It is a harmonised standard under the EMC Directive but does not cover the immunity requirements.

IEC 60533 Edition 2.0 (1999-11-16) Electrical and electronic installations in ships - Electromagnetic compatibility

Note: This standard does not apply to recreational craft but to ships that are covered by IMO Resolution A.813 (19):1995, ***General requirements for electromagnetic compatibility (EMC) for all electrical and electronic ship's equipment****. It is not a harmonised standard under the EMC Directive. Nevertheless it does give guidelines and recommendations on the measures to achieve EMC in the electrical and electronic installations of equipment groups that are found on recreational craft.*

Directive 2014/30/EU on the harmonisation of the laws of the Member States relating to electromagnetic compatibility (recast) and repealing Directive 2004/108/EC (document available via this link)

Guidance document of Q&A on the EMCD transition from 2004/108/EC to 2014/30/EU (document available via this link)

The 'Blue Guide' on the implementation of EU product rules (document available via this link)

(Editors' note – More documents used by industry equipment manufacturers are being added as they are revealed.)

3. Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
Apparatus
Any finished appliance, or combination thereof made commercially available (i.e. placed on the market) as a single functional unit, intended for the end-user, and liable to generate electromagnetic disturbance, or the performance of which is liable to be affected by such a disturbance (EMC Directive Art. 2 (1)). For the purpose of the application of this guideline a completed recreational craft subject to the scope of the EMC Directive is considered an apparatus.

NOTE: For understanding of the EMC Directive, it is relevant to introduce additional terms used in its vocabulary: a "mobile installation" is described as an apparatus intended to be moved and operated in a range of locations.

3.2
Equipment/Finished appliance
An equipment/finished appliance is any device or unit that delivers a function and has its own enclosure (EMC Guide Ch. 1.2.1). Equipment may include electronic equipment, engines with electronic/electric controls, pumps, etc. For the purposes of the application of this guideline and where equipment is within the scope of the EMCD (i.e. not considered as inherently benign, and intended for supply to the end user in the EU) it shall be compliant with the EMC Directive indicated by the CE marking and accompanied by a Declaration of Conformity.

3.4
Inherently benign
Equipment is considered inherently benign in terms of electromagnetic compatibility if:

- Its inherent physical characteristics are such that it is incapable of generating or contributing to electromagnetic emissions which exceed a level allowing radio and telecommunications equipment and other equipment to operate as intended; and,

- It will operate without unacceptable degradation in the presence of the electromagnetic disturbance normally present in its intended environment

Both conditions need to be met in order to classify equipment as inherently benign. For examples see EMC Guide, Ch. 1.1.4. In general, any equipment which incorporates electronic devices cannot be considered benign, nor can equipment such as an electric motor which creates electrical disturbances while operating. On the other hand, electric-mechanical controls which may only create occasional transient disturbance, such as switches, relays or contactors, can be considered as benign. See also Annex B.

4. Selecting equipment for installation on small craft

The principle of using compliant equipment
Any electrical or electronic equipment which is placed on the market to the end user in the EU is required to comply with applicable Directives, which in this context include the EMC Directive. Compliance is signified by the CE Mark. Boat builders will typically source such equipment, which is used on their product, from external suppliers and because in many cases these will also supply such equipment to the end user, it will already be certified appropriately. Usually this will involve the application of the relevant harmonised standards as described in Article 6 of the EMC Directive, but this is not mandatory.

As long as such equipment is correctly installed then it is reasonable to suppose that it will allow the total assembly of equipment, i.e. the boat, also to be compliant with the essential requirements of the EMC Directive. It is the boat-builder's responsibility to certify such compliance.

The requirement of the EMC Directive in Annex II is that the boat-builder shall carry out and document an EMC Assessment of the apparatus with a view to meeting the protection requirements. This shall take into account all normal intended operating conditions and in all the possible configurations identified as representative of its intended use. The EMC Assessment can be achieved by confirming that all electrical/electronic equipment that is to be installed on the boat does in fact comply individually with the Directive under such conditions and configurations, and that its installation respects any requirements that are needed to maintain such compliance.

The exercise that carries out this confirmation can be documented and such documentation forms the record of the EMC Assessment. This is the basis for the procedure outlined in this Recommended Practice.

Practical steps for an EMC assessment

Catalogue the non-benign equipment used on the boat
Any equipment which can create or suffer from electromagnetic disturbances is subject to the compliance requirements. In a typical recreational craft there may be many such items, which may be used for the proper functioning of the craft (e.g. navigation or propulsion) or for subsidiary purposes such as entertainment or subsistence. All equipment which is part of the original fit must be catalogued so that in each case its compliance status can be confirmed. Annex B gives examples of the type of equipment that should be considered.

Since any given boat design must already include a list of its components, extra activity related to this procedure can be limited to identifying whether such equipment must be considered for EMC purposes, or not.

Assess the EM environment
Compliance of equipment is normally linked to the electromagnetic environment of its intended use. In the case of recreational craft, this is principally the marine environment, whose characteristics can be represented in EMC terms by the requirements of IEC 60945. This lays down radio frequency emission and

immunity requirements, as well as transient immunity and power supply compatibility. Thus for the normal marine environment (inshore or) any equipment used offshore which complies with this standard, which is harmonised for the EMC Directive, can be assumed to be acceptable without further analysis. The craft may also be operated within a marina environment which could involve proximity to residential locations. The emissions requirements of EN 60945 may not give the same protection to external radio receivers in this situation, as its emissions limits (with the exception of the marine VHF communications band) are more relaxed than the equivalent limits for residential areas. In such cases an assessment of the extra separation distance that should be applied from the boat to the nearby residential environment may provide adequate assurance.

The opposite situation may also occur: equipment, particularly subsidiary items such as kitchen or entertainment products, may be said to be compliant for the residential environment (for instance by stating compliance to EN 55014-1, EN 55015, EN 61000-6-3 or EN 55022 class B) but this does not necessarily make it compliant for the marine environment, where particular care needs to be applied to radio frequency emissions in the marine band according to EN 60945. While the principal effect of this would be interference *within* the boat to its own VHF marine band reception, and therefore outside the scope of the EMCD, the possibility of interference to other nearby boats should be considered. Again, an assessment of separation distance, and/or individual operational checks, may provide adequate assurance.

Confirm that each item in the catalogue has a compliance statement

Each item identified as non-benign should be linked to a statement of its EMC compliance. It will be necessary to negotiate with the equipment supplier to ensure that this statement is available and valid for the equipment that will actually be installed. It is not essential that the statement of compliance relates directly to the EMC Directive, although this would usually be preferable. Equipment sourced from outside the EU, that is not intended for supply to an end user in the EU, does not need to comply directly with the EMCD. In such cases, a declaration of compliance to equivalent relevant international standards should be sought. Any shortfall against the essential protection requirements should be investigated and remedied. Even for CE Marked items, it is necessary to have the detail of the standards with which compliance is claimed, in order to be able to complete the EMC Assessment.

Assess whether each compliance statement is adequate and rigorous

The boat-builder is responsible for his own eventual compliance statement. If, as outlined herein, he is relying on statements of compliance from his suppliers, it is necessary to be sure of the validity of each such statement. This may involve assessing the quality system of his suppliers, the depth of assessment linked to the likely implications of non-compliance in each case. Even if the validity of the compliance is not in question, its relevance and adequacy in the context of the boat's system needs to be confirmed. This is linked to an understanding of the different EM environments as discussed above.

It is recommended that the contract with the supplier includes the delivery of the Declaration of Conformity (DoC) pursuant to the EMC Directive or to product specific legislation (including other jurisdiction) and standards which separately formulates equivalent EMC requirements.

NOTE: Examples of legislation implementing EMC requirements are listed below:

- Radio equipment (VHF, FM, AM, single side band) – Radio Equipment Directive (2014/53/EU) which has been applicable since 13th June 2016.
- Compliance with other EMC related regulation and standards applicable outside Europe (such as the FCC in the United States or the C-Tick from Australia) are a partial substitute if proven as equivalent conformity through their technical documentation.
- The DoC received from the supplier shall be inspected to determine that the standards quoted support the requirements of the EMCD. For a list of applicable European standards see

https://ec.europa.eu/growth/single-market/european-standards/harmonised-standards/electromagnetic-compatibility_en

Check whether special installation conditions are required for any item
There may be specific installation requirements that a piece of equipment needs for its EMC compliance to be maintained. Examples are the use, termination and/or routing of particular types of cable, or the implementation of a grounding structure, or specific segregation distances. It is a condition of the EMC Directive that any such instructions should be provided by the manufacturer (Article 18. 1), and therefore the boat builder should check whether such instructions exist and, if so, confirm that they have been respected and are in place in the installation. It can be assumed that if no such instructions are provided, the equipment's EMC performance is not sensitive to installation conditions.

The documentation and installation instructions received with equipment used must be complete, updated and in conformity with any requirements for specific installation precautions as set out in EMC Directive Art. 18. 1. Notified Bodies under the EMC-Directive can assist in the confirmation of suitable equipment.

Carry out any sub-system tests that may be identified
The EMC Assessment so far may have uncovered areas for particular items that do not fully detail the compliance with the EMC Directive's essential protection requirements. Examples may be where information from the supplier of the equipment is incomplete, inadequate to cover all the requirements, or is not properly relevant to the EM environment that will be encountered by the boat. In this case the boat-builder can commission limited tests on parts, which may or may not be related to the harmonised standard tests, in order to fill in gaps in the data for the EMC Assessment.
Alternatively, the system checks referred to in section 9 can be tailored to fulfil this aspect.

Document these steps
The results of all the procedures outlined above should be collated into a technical documentation file that will support the declaration of conformity.

Make DoC referring to this documentation
As required by Annex II.5 of the Directive, the boat-builder must attest the compliance of the complete apparatus with all relevant essential requirements via an EC declaration of conformity. This must make dated reference to the specifications under which conformity is declared, in this case, the technical documentation file that has been created using the above procedure.

Installation measures
This section describes measures that can be taken into account in electrical installations in order to minimize possible EMC problems, both internally and externally. Note that these measures do not by themselves ensure compliance with the EMCD's essential requirements.

Always follow the information of the manufacturer on any specific precaution that must be taken so that, when put into service, the apparatus is in conformity with the requirements of the EMC Directive. This information should be included in the boat's documentation. In cases where different manufacturers' instructions are in conflict – for instance, Manufacturer A's instructions may demand screen termination at both ends, while Manufacturer B may demand that the same signal's screen is terminated only at one end – it is the boat-builder's responsibility to resolve the contradiction, if necessary by seeking specialist advice.

Electrical systems in general should be installed in compliance with ISO 13297 for AC systems and ISO 10133 for DC systems.

Cable routing and segregation should follow the principles stated in IEC 60533.

Grounding conductors should be routed directly to a common bus, or series of buses, sized appropriately for the amperage they are expected to carry.
NOTE: A significant source of interference can be created by improper terminations. Incomplete crimping procedures can cause connections to come apart over time when subjected to normal shock and vibration. This may also be the result of inadequate torquing of fasteners. The correct termination of screened cables and their connectors, where these are necessary for compliance reasons, will be critical to achieving compatibility and may need to be the subject of special assembly instructions.

5. System check

Rem: This testing covers the so called "internal EMC" (interferences within a system), which is important for the builder, but not part of the EMC-Directive. However, following this test procedure may provide extra assurance that the requirements of the EMC Directive for external EMC have been met.

Electrical system checks in consideration of electromagnetic interference shall be completed on the craft. This testing requires the boat is in water (test tank or open water) and fitted as it would be delivered to the customer including batteries and all electrical accessories.

Following the flowchart in figure 1, document the procedure used to energize all electrical circuits and loads.

Having normally sensitive electronics (e.g. radios, televisions and computers) energized during the testing and observing any degradation in performance can be an indicator of an electromagnetic interference problem that needs attention. Should sustainable, repeatable abnormal operation of these components be observed, further isolation of the circuits must be carried out to determine the cause of the interference.

The same test shall be repeated through the full operating range of the propulsion engine(s) to determine system compatibility with engine components.

A checklist of possible components is included in Annex B.

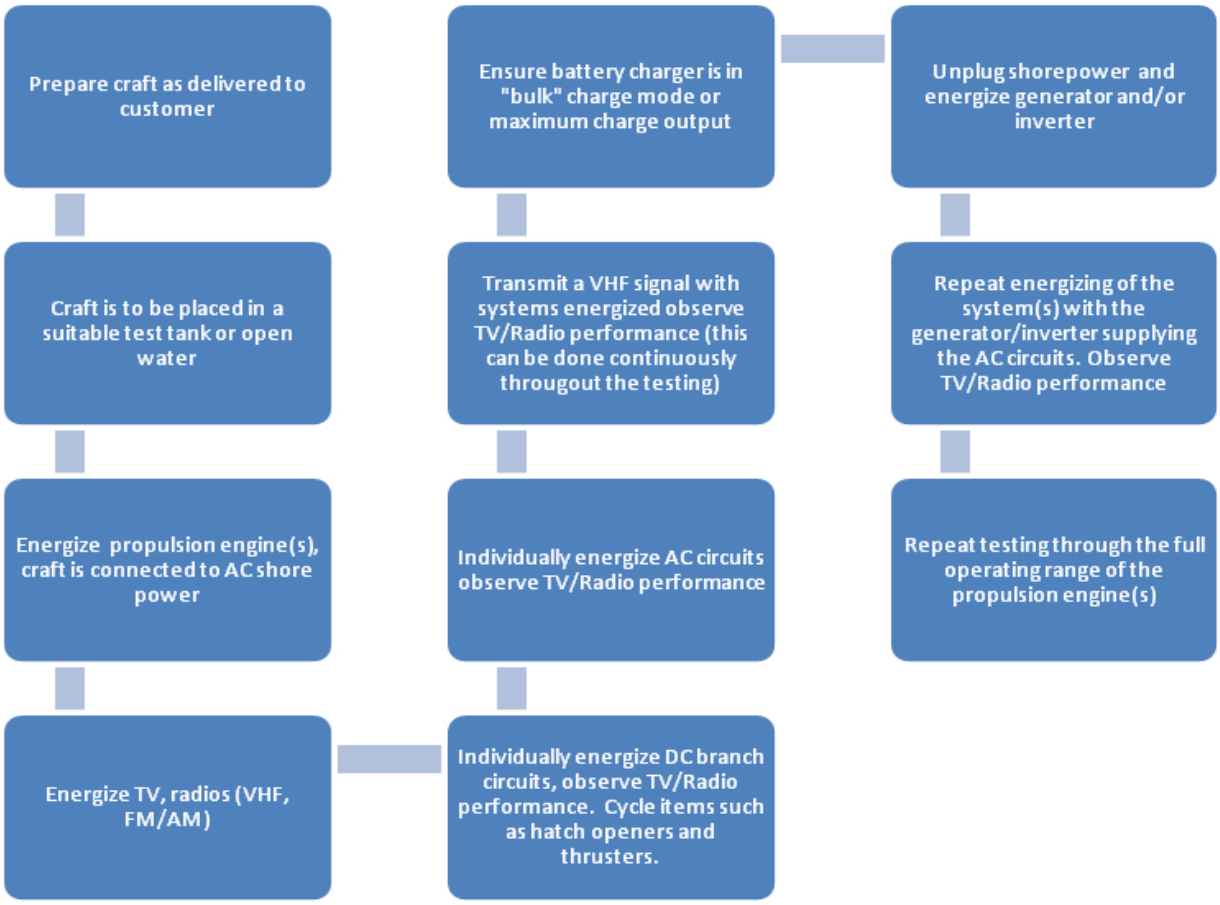


Figure 1 – System check flowchart

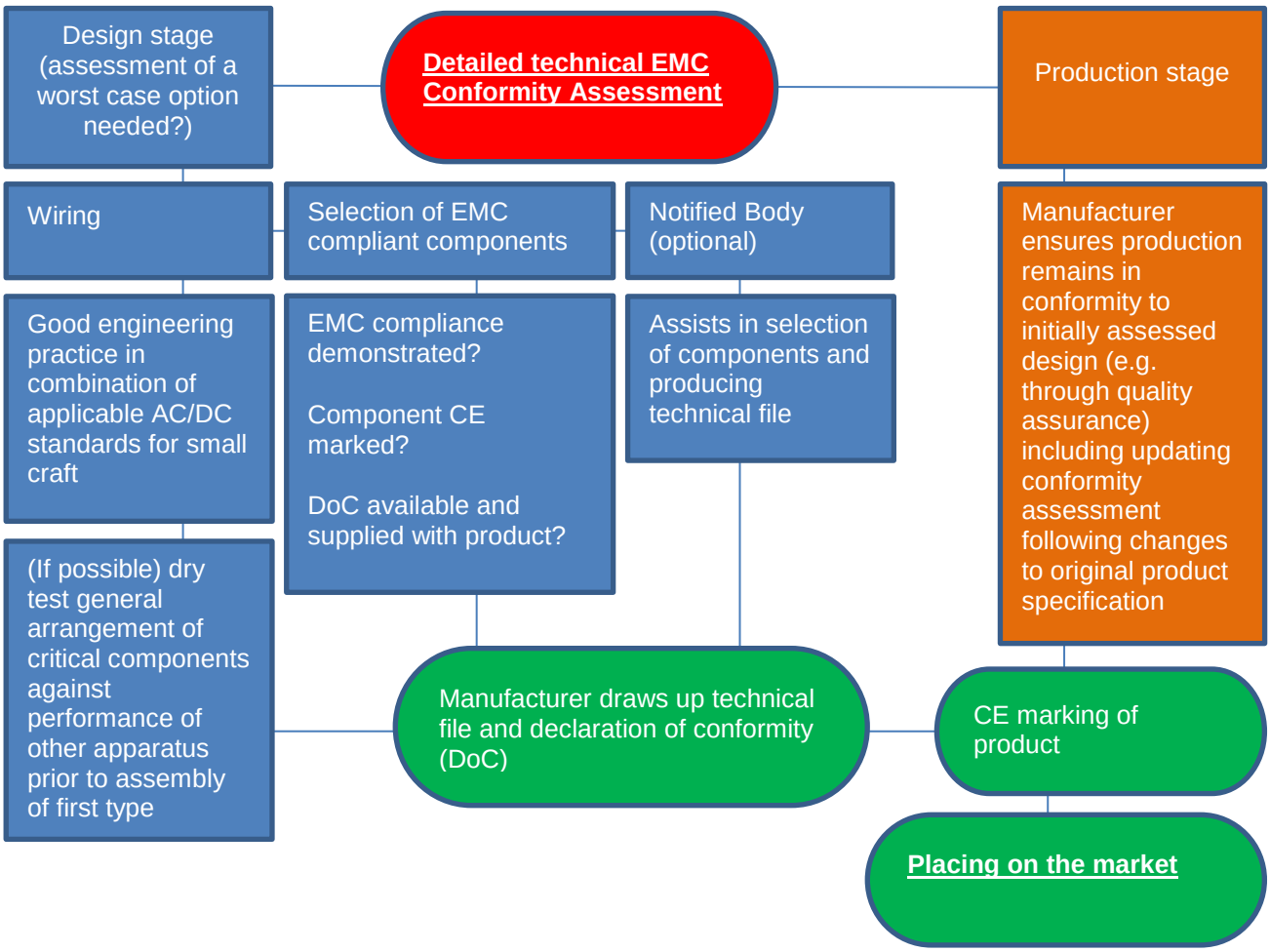
Annex A

Guidance to meet the EMC Directive's legal requirements on product conformity assessment, technical file and CE marking

By CE marking a product, a manufacturer declares conformity with <u>all</u> applicable EU legislation that foresees the CE mark. On a typical boat carrying an electrical installation, this implies primarily conformity with the Recreational Craft Directive (RCD) but also the EMCD. Hereafter only the conformity assessment procedure under the EMCD is described. A Declaration of Conformity (DoC) can state proof of compliance with all applicable legislation. Below is guidance how to state EMC compliance by including it in the RCD DoC.

Affixing the CE mark on a product is the final step in a process described by the term "conformity assessment". The flowchart below shows the relevant steps when applying this document[3]. Conformity assessment includes not only the direct examination of the product's conformity, but also documenting it in the technical file and producing a DoC. The formal/legal description of conformity assessment is in Annex II of the EMCD. On completion, the manufacturer draws up and signs the DoC, prior to affixing the CE marking to the apparatus. This must be done in accordance with the instructions set out in Annex V of the EMCD.

[3]Reader to bear in mind there are other routes for conformity assessment, e.g. application of standards recognised as supporting the EMCD if available for the product concerned (see reference to harmonised standards in the introduction)



Need for a notified body?
Under the EMC conformity assessment procedures, the manufacturer is obliged to perform an EMC assessment of the apparatus. Unlike other directives, the EMC Directive does not require the assessment being carried out by a third party, i.e. the employment of a Notified Body. However, the manufacturer or his authorised representative in the Community can present the technical documentation to a Notified Body which will review it and assess whether the technical documentation properly demonstrates that the requirements of the Directive have been met. If this is the case, the Notified Body will issue a statement confirming it. This statement shall be part of the technical documentation.

Then the manufacturer draws up the Declaration of Conformity (DoC) to declare on his sole responsibility conformity to the relevant Directive which is a legal obligation.

To find the Notified Bodies appointed by the Member States to carry out conformity assessment, the manufacturer should consult the NANDO database – the New Approach Notified and Designated Organisations. They can search for Notified Bodies by Directive or by country via the NANDO homepage. A list of notified bodies under the EMC Directive is available from
http://ec.europa.eu/growth/tools-databases/nando/index.cfm?fuseaction=directive.notifiedbody&dir_id=153681

Check conformity
The conformity assessment process for apparatus covered by the EMC Directive consists of an internal production control procedure carried out by the manufacturer (self-assessment and certification). This entails checking that the equipment meets the electromagnetic compatibility requirements set out in Annex I of the EMCD (disturbance and immunity). Amongst various options, the correct application of good engineering practice through this guidance document and its subsequent detailed documentation/declaration is a way to comply.

Technical documentation

Annex II, point 3 and Annex III, point 3(c)of the EMCD describes the legal requirements of technical documentation. It must include a general description of the apparatus, a description of the EMC Assessment, and where available results of design calculations made, examinations carried out, test reports, etc. should be included. Where a notified body has been involved in producing the technical documentation, a statement in accordance to EMCD Annex III, point3 shall be included. The manufacturer or his authorised representative established in the European Community is requested to keep copies of the technical documentation for a period of 10 years after the last product was placed on the market.

The technical documentation must enable the assessment of the conformity of the appliance with the requirements of the Directive. Where applicable the technical documentation should comprise:

- A general description and definition of the apparatus operating conditions and its intended purpose;

- Conceptual design and manufacturing drawings and schemes of components, system drawings, sub-assemblies, circuits, etc. (including EMC design considerations and/or calculation results);

- Descriptions and explanations necessary for the understanding of said drawings and schemes and the operation of the product. This can include cables (routing, connections, board), power generators and batteries (location, type, protection), wiring diagrams, fuses, switch shielding, grounding/bonding; GFCI (ground-fault circuit interrupter) devices; panels design; power source system;

- Specification, descriptions and classification of the environments in which the apparatus will be used. Mobile installations such as boats must have emission and immunity characteristics appropriate for several environments (in marina/off shore/inland waters or a plausible selection of the worst case). This selection is the responsibility of the manufacturer based on knowledge of the electromagnetic environment and awareness of the statistical aspects involved;

- Clear specification of relevant sources and effects of the electromagnetic phenomena covered and compatibility levels applied;

- Specification of the EMC immunity performance criteria of the apparatus. These should be set taking account of the reasonable expectations of the user;

- A description and explanation of the solutions adopted to fulfill the essential requirements of the EMCD (and the conformity assessment used). When using this document as compliance guideline, the technical documentation must include a description of the components and how they were selected (including providing the supporting documentation of conformity with the EMCD). Particular attention must be given to components relevant to the safe operation of the boat such as (remote) steering systems which have their own standards including EMC requirements;

- Information where applicable on shielding, cable screening and routing, filters, ferrites etc.;

- Any description of particular solutions adopted in order to comply with the protection requirements;

- Assessment of whether any specific precautions have to be taken when the apparatus is assembled, installed, maintained or used, in order to ensure that, when put into service, the apparatus is in conformity with the protection requirements;

- Worst case selection criteria for series of apparatus with similarities.

Declaration of Conformity (DoC)

The Declaration of Conformity must include:

- a reference to the Directive,
- an identification of the apparatus (i.e. boat),
- the manufacturer's details such as name and address,
- a dated reference of the specifications under which conformity is declared,
- the date of the declaration,
- the identity and signature of the person empowered to bind the manufacturer or his authorized representative.

For boats, it is recommended producing a combined DoC that covers all applicable directives. Templates for the Recreational Craft Directive are available for free in a selection of official EU languages from ICOMIA (see this link or go to www.icomia.com and search for "Declaration of Conformity" in the online library). These templates allow stating compliance with other applicable directives such as the EMCD.

As proof of successful conformity assessment, the manufacturer applies the CE mark to the product (see Articles 16 and 17 in the EMCD). Manufacturers need to consider the need to apply recurring conformity checks during the production life, as well to re-assess the product on changes in equipment or layout.

Annex B

(informative)

Typical small craft components not considered inherently benign

A.1 General

The following items are examples of equipment that could contribute to EMI issues on board recreational craft if not installed in a compliant manner. This list can be utilized as a checklist for applicable systems during the test outlined in section 9 and for the equipment compliance audit outlined in section 5. This list is not exhaustive.

- Battery charger and or inverter
- Horn
- Windshield wiper motor
- Propulsion trim pump
- Electric hatch lift
- Bilge pump
- Bilge blower
- Fresh water pump
- Windlass
- Electronic toilette items (vacuum pump, macerator, etc.)
- Electrical thruster motors, bow/stern
- LED, low energy and fluorescent lighting (includes interior and navigation) (tungsten filament and halogen lighting is benign)
- Helm electronics (radar, autopilot, chart plotter, depth sounder, sonar)
- Stereo and associated equipment
- All radio equipment
- TV amplifier (NOTE passive antennae are considered benign equipment)
- Trim tabs
- Engines
- Refrigerator/freezer/ice maker/wine chiller and other compressor driven appliance
- Any type of information technology equipment (personal computers, network connection equipment, video displays, multimedia products etc.)

NOTE: Water heaters and electric stove elements may be considered benign equipment. Cabling of itself is passive and therefore benign; however its selection and installation may affect the compliance of the equipment to which it is connected. Therefore relevant cabling characteristics should form part of the EMC Assessment.

NOTE: Batteries are considered benign equipment and do not require individual testing to the EMC directive unless constructed with an electronic battery management system that may affect or be affected by EMC phenomena.