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RÉPUBLIQUE FRANÇAISE

MINISTÈRE DE LA DÉFENSE
MARINE NATIONALE

Paris, le 5 mai 2006
N° 164 SHOM/EG/NP

**SERVICE HYDROGRAPHIQUE ET
OCEANOGRAPHIQUE DE LA MARINE**

Bureau études générales

Dossier suivi par
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Destinataires in fine

Objet : ECDIS type approval.

Référence(s) : WEND 9 – INF5.

P. jointe(s) : 1) Letter n° 433 SHOM/EG/NP dated 27 October 2005.
2) Letter IEC TC 80 dated 23 January 2006.

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Dear colleagues,

Following the last WEND meeting (ref., action 2), I am pleased to provide you with the excellent report established by IEC TC 80, for your consideration.

France is going to pursue the investigation on this issue[1] with French maritime authorities.

With the development of HSC and other merchant vessels fitted with ECDIS, the likelihood of potential failures of ECDIS[2] or ECS will increase. SHOM considers that a careful monitoring and comprehensive report of such events should be implemented by maritime safety agencies in cooperation with HOs, to maintain safety of maritime navigation at the highest level.

Le directeur du service hydrographique et océanographique de la marine
par ordre et par empêchement du chef du bureau études générales,
l'ingénieur principal des études et techniques d'armement Serge Allain
adjoint,

[1] Beautemps Beaupré's case
[2] Whether they are strictly type-approved or not

Destinataire(s) : WEND chairman – CHRIS chairman

Copie(s) extérieure(s) : IEC TC80 (Dr Andy Norris) – BHI – EPSHOM

Copie(s) intérieure(s) : Archives générales - 7064

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RÉPUBLIQUE FRANÇAISE

MINISTÈRE DE LA DÉFENSE
MARINE NATIONALE

Paris, le 27 octobre 2005
N° 433 SHOM/EG/NP
NMR SITRAC : 2055

SERVICE HYDROGRAPHIQUE ET OCEANOGRAPHIQUE DE LA MARINE

Bureau études générales

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Mr Andy NORRIS
Chairman of IEC TC 80

Subject : ECDIS Type-approval testing standards.

Référence(s) : /

Enclosure(s) : A report.

-

Dear Sir,

Please find enclosed herewith a report which takes into account the defaults of functioning of an ECDIS yet duly certified as meeting the IMO A 817(19) requirements, in order to shed light on insufficiencies in the corpus of standards presently available.

This question has been raised at the last meetings of the International Hydrographic Organization Committees dealing with electronic charting [WEND (Worldwide Electronic Navigation chart Database) and CHRIS (Committee on Hydrographic Requirements for Information Systems)]. The 9th Meeting of WEND tasked France to contact IEC TC80 regarding recommended changes to ECDIS type -approval testing.

It is necessary to note the observed insufficiencies in the ECDIS certification standards and to supplement these standards with requirements on the design and development of software, as well as to give the means to control their implementation.

A simple solution would be to make reference to the IEC 61508 standard for all the electronic bridge equipments related to the safety of navigation. The drafting correction could be to re-use in the IEC 61924 standard, § 4.2.3 of IEC 60945 modified in order to quote IEC 61508 not only as an example but as an applicable standard, instead of making reference to the ISO 9000 series.

Destinataire(s) : CEI TC 80

Rep.: Q:\asecretariat\eg2005\400\433_IEC-TC-80.doc 27/10/05 14:10

Such a solution may be quickly implemented: it would however need to make explicit the provisions to be applied, and this would greatly benefit from the important work already done in the aeronautic domain with the DO-178 B standard, even if this standard has to be fitted to the maritime world.

It is urgent to create an expert group (HGE could be an example of such a group) for elaborating an effective quality standard for the design and development of the ECDIS software, and for up-dating the IMO A 817(19) resolution and thus IEC 61174 in order to take into account requirements concerning the safety of functioning (upstream enough from the development) in relationship with the manufacturers of the ECDIS equipment or of the cartographic kernels used in these ECDIS. This work should be extended to all the interlinked software of a bridge linked to the safety of navigation (IEC 60945 and IEC 61924).

The question is important for the safety of navigation and a quick answer seems advisable. SHOM is ready to provide any complementary information you could deem useful.

Sincerely Yours

Pour le directeur du service hydrographique et océanographique de la marine
et par ordre, l'ingénieur général de l'armement Michel Le Gouic
chef du bureau études générales,

REPORT

1. DYSFUNCTION OF A TYPE-APPROVED ECDIS

The French Navy Survey Ship Beautemps-Beaupré entered in service in January 2004. For electronic navigation, she is fitted with an ECDIS which has been certified by Det Norske Veritas as meeting the IMO A 817(19) requirements: for this certification IEC has developed the IEC 61174 standard for type approval and testing procedures: this standard uses IHO publications S57 and S52.

The experience gained with this type-approved ECDIS shows dysfunctions which are described schematically in annex and can be summed up as follows:

- lack of robustness of the system (route monitoring, errors due to a deficient sensor, ...)
- lack of reliability (system blockage and necessity to re-boot) due to the implementation of various components for which it seems that no "functioning safety" methodology has been applied.

Such an amount of deficiencies is not acceptable for the safety of an equipment which can lead to a catastrophe (grounding of a tanker or of a ferry for example).

2. THE TYPE-APPROVING TOOLS

IEC has developed the 61174 standard for type-approval of the ECDIS. This standard has no requirement for the software design and development, and is limited for the software aspects to performance tests.

As asked for by IEC, IHO has produced S64 publication "Test data sets for ECDIS" which is used by ECDIS type-approving organisms. It is of course possible to add new tests in order to take into account the defaults observed by SHOM onboard Beautemps-Beaupré.

But increasing the number of tests in order to take into account the defaults observed leads to a dead-end because the number of potentially abnormal situations increases dramatically with the number of states of the various parameters. S64 tests are necessary, at least to give evidences for the behaviour of the ECDIS system and for facilitating the understanding by the development teams, but the proofs which are provided are always incomplete because they concern only a limited sample of the entry states[1]. In order to validate a software tests are needed (which have to take into account its internal architecture as stated by the standards dealing with critical software) but it is also vital to give evidences on the conformity to a ECDIS software design and development standard.

3. THE OTHER IEC STANDARDS

IEC 60945 is quoted in the list of standards applicable to IEC 61174. IEC 60945 deals mainly with physical environment (mechanics, electric, electro-mechanics, …) but it however refers to software in a § 4.2.3 requiring the design and testing method to be described and the conformity with an internationally recognized quality standard: the ISO 9000 series are then quoted but only as an example (they are not referred in the applicable standards list) without explaining how they have to be applied!

As a part of an integrated bridge, ECDIS has to be in compliance with IEC 61924 which surprisingly does not deal with design and development of software even if there are a lot of interlinked systems within such a bridge.

[1] This is clearly stated in numerous publications, of which the « Software System Safety Handbook" of the US DOD.

In fact IEC standards exist which are dealing with functional safety of software (61508). These standards (in 5 books) have been developed by the IEC committee 65. They detail all aspects linked to design and development of software! In the introduction they provide that these standards are intended to be utilised by technical committees when preparing standards complying with IEC/ISO 104 and 51. It is obvious that the 80TC has not taken into account this 61508 standard when elaborating the 61174 standard, maybe because of its youth.

4. LESSONS FROM OTHER DOMAINS

In the aeronautic field the need to standardize requirements concerning the safety of functioning of software is clearly simply obvious.

An important deal of work concerning the safety of the aeronautic navigation software has led to the DO-178 B standard "software considerations in airborne systems and equipment certification" which is supported by a standardization corpus already published (for example ISO/IEC 12207, 12119 and 15504; EUROCAE/RTCA ED 76, RTCA DO 200 and 201).

DO-178 B could be a canvass[2] to give the proof of the good functioning of ECDIS software.

Maritime and airborne navigations present many similar aspects: kinematics are different but the decisions are to be taken in very short timeframe, and if the aircraft cannot stop, the ship has a high inertia which makes anticipation vital. It is irrational and even contrary to the know-how in software system engineering that the prevention measures of one of these domains could be considered as useless in the other domain.

[2] It defines, for example, 5 categories for the criticity linked to a default, and for these categories more or less constraining requirements are attached to the safety of a given software component: when defining these categories specificities of maritime navigation are to be taken into account, but it would be very surprising that none of the ECDIS software components were not identified in one of the critical categories of DO-178B.

ANNEX TO THE REPORT

Dysfonctions of ECDIS onboard Beautemps-Beaupré – safety of functionning

1- Used documents

Information given in paragraphs 2 and 3 hereafter come from following documents:

- « Liste de problèmes survenus aux équipements passerelles » en provenance du Beautemps-Beaupré (de mai 2004 à juillet 2004).
- N-E n°184 EPSHOM/INF/NP of 14 June 2002 « Evaluation de l'ECDIS Seamap-Kongsberg ».
- Note n° AA/03/218039 SPN/ASM/COM « Dysfonctionnements des systèmes de visualisation de cartes électroniques » of 7 October 2003, giving a synthesis of the feedbacks concerning the Beautemps-Beaupré ECDIS.
- List of guarantee trial minutes from SPN and related to Beautemps-Beaupré ECDIS.

2- Observed dysfonctions

2-1 LIST GIVEN BY THE CREW OF BEAUTEMPS-BEAUPRÉ

Date –Equipment	*Problems and solutions*
May 2004 ECDIS SM10	Doctor Watson at the end of a monitored track in AUTOTRACK mode on/off and back to the nominal situation
May 2004 ECDIS SM10	Doctor Watson at the end of a monitored track in AUTOTRACK mode on/off and back to the nominal situation
June 2004 ARPA starboard	Alarm + window « system running out of virtual memory », automatic stop manual restart and back to the nominal situation
June 2004 ECDIS SM10	Window « system running out of memory". Screen non legible. Bug Off, manual restart and back to the nominal situation
June 2004 ARPA port	Window « system running out of virtual memory, please close some application »
June 2004 ARPA port	Automatic stop. Loss of the automatic pilot. Alarm on the 2 radars et on the ECDIS.
June 2004 ECDIS	Window « system process out of virtual memory. Tour system is running low on virtual memory. Please close some application » closing of the window.
June 2004 ARPA port	Window « system running low on virtual memory, please close some application »
June 2004 ECDIS SM10	Total failure after the message "system running out of virtual memory" Off, manual restart and back to the nominal situation.
June 2004 ARPA port and starboard	Window « system running low on virtual memory, please close some application ». The radar image is frozen restart.
June 2004 ARPA port	Window « system running low on virtual memory, please close some application ».
June 2004 ECDIS SM10 et PL10	A monitored route for casting off is erased off and manual restart : the route is recovered

June 2004 PL10	Total failure when recording a validated route
July 2004 automatic pilot on ECDIS	The follow of a route is unsatisfactory in TRACK mode. The ship tacked 10 m left to 10 m right of the monitored track change the mode in heading mode
July 2004 ECDIS SM10	After pressing the offset key, blue screen. When reinitializing, window Doctor Watson on/off and back to the nominal situation

Nota. The restarts for solving the problems described in the above table take less than 5-6 min.

Other points reported by the crew of Beautemps-Beaupré :

- ECDIS autotrack mode ineffective, due to the base of the loch,
- Total failures, and slowing down of PL 10 disappeared after implementation of a 256Mb RAM,
- Impossibility to find an ARCS chart which had been used before.

2-2 SYNTHESIS OF SPN TESTS (SPN : SERVICE OF THE FRENCH DEFENCE PROCUREMENT AGENCY IN CHARGE OF THE NAVAL PROGRAMMES)

(extracts)

- Lost of the position tracking when the ground longitudinal speed is close to 0 and the surface longitudinal speed is not null. It seems that the ECDIS calculates an infinite radial speed: the ship position is moved of several 10th of miles from the previous position. There must be some division by zero,
- At sea, it has been impossible to use the tracking mode of the ECDIS to follow a route : shifts from the route, when the system does not fail, are greater than 20 m and reach 200 m,
- Several times, it has been impossible to have the control of the main display unit of ECDIS,
- Impossible to use ARCS charts, both on the navigation and preparation display units,
- The ECDIS being in route tracking mode, following events appeared regularly during 3 weeks:

  Freezing of the system, with a fix image, no operative function except on/off. No problem or alarm after restart,

  Freezing of the system, the screen goes out, no operative function. No problem or alarm after restart,

  Freezing of the system, with a blue screen full of memory addresses, the system indicates an insufficiency of memory, no operative function. No problem or alarm after restart,

We can note that no alarm is given during these freezing, which is particularly dangerous when the image is fixed, all the more in narrow passages,

- During several weeks, the use of ECDIS is very difficult due to the extreme slowness of the running of the programme. Changing a scale takes up to 30s, changing a menu 25s. When creating complex routes the software regularly fails and stops, with a lost of the work which has not been recorded.
- In the route preparation mode, the screen becomes frozen, full of figures and letters and the following message is displayed : "beginning dump of physical memory, physical memory dump complete". After on/off back to the nominal situation.

The trial minutes show that the trials at quay have been rather limited and often refer to the fact that the ECDIS has been type approved by « DET NORSKE

VERITAS », in accordance with IHO/IMO resolutions and IEC standard (in particularly 61174).

2-3 NOTE BY EPSHOM/INF (COMPUTER CENTRE OF SHOM)

Three main problems have been identified :

- Impossibility to take into account official updates a little bit more elaborated than those of the « IHO-DATASETS-TESTS »,
- Impossibility to read the planned routes used during a previous session and to restore recorded routes.
- The failures need a full restart, with a non negligible loss of time.

2-4 OBSERVATIONS BY EPSHOM ENC PRODUCTION DIVISION *(DURING THE ACCEPTANCE PHASE OF THE ECDIS)*

It seems that the ECDIS of Beautemps-Beaupré is mainly based on a cartographic CMAP kernel (CMAP-SDK 3.4.4). The added value is to be found in the interface design which is used for operating the functions of this kernel. Due to this architecture, it was difficult for the manufacturer to modify its software when the dysfunctions concern one of the functions of the kernel (for example the impossibility to import certain updates is due to the kernel).

September 2002 : the admission of the ECDIS realised by EPSHOM, shows dysfunctions and deviations from IMO standards. For instance there is no alarm when the system does not take into account such or such up-date, and this is a major problem since nearly 40% of the updates are rejected...
October 2003 : a part of the previously rejected updates is now accepted by the ECDIS. This has been solved thanks to a modification of the kernel. But 10% of the updates are still rejected...
None of the other mentioned problems have been solved.

3- <u>Comments on safety aspects</u>

Firstly, there is no formal requirement for system safety in the design of ECDIS (there is no reference in IMO OMI A.817(19), even if there are some requirements concerning the back-up). From the examples above, the consequence seems to be:

- lack of robustness of the system (route tracking, dysfunctions link to a failing sensor like the loch...),
- lack of reliability (freezing of the system and necessity to restart), due to the on the shelf components integration for which no integration method complying with safety requirements seem to be applied.
- maintainability : the ECDIS of Beautemps-Beaupré is still under guaranty an is regularly upgraded. The support teams of the manufacturer operate 24/24 and 7/7 in order to take into account the dysfunctions. Worth to be noted is the fact that such a support will cease at the end of the guaranty period, with foreseeable problems for the taking into account of the evolutions of the standards (eg S63). No clear answer on this point from the manufacturer.
- the availability of the system relies on a back-up system and on a set of paper charts.

A quick reading of IEC 61174 shows that the tests realized are relevant for the functionalities of an ECDIS as defined in the IMO resolution A.817 (19), and give a possibility to a rough functioning control of the ECDIS, but one more time in a safety perspective (a requirement level has to be defined) and this seems to be insufficient (a posteriori consideration).

Copie(s) extérieure(s) : UTE/TC80 (Mme Delort) – DAM (s/direction sécurité de la navigation) – BHI – EPSHOM – WEND Chairman (Mr Parsons) – CHRIS Chairman (Mr Ward)

Copie(s) intérieure(s) : Archives générales - 7064

Dr Andy Norris Chairman IEC TC80

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23 January 2006

Your ref: No 433 SHOM/EG/NP
NMR SITRAC : 2055

Dear M Le Gouic

Thank you for your letter dated 27 October 2005. As you know, I promised to give you a detailed reply but indicated that it would take some time to gather and assess the relevant information. This letter forms the considered response of IEC TC80. I would be grateful if you would convey its contents to the WEND and CHRIS Committees of the International Hydrographic Organization.

Your letter gives an example of a vessel fitted with an ECDIS which has been certified by Det Norsk Veritas as meeting the IMO A.817(19) requirements and cites a long list of failures of that particular equipment. It comes to the conclusion that these failures are due to inadequacies in the IEC standards 61174 and 60945.

Incidentally, the reported faults contained within your letter also refer to ARPA equipment - about half of the failures concerned ARPA. I do not know whether the installed ARPA equipment met the requirements of IEC 60872-1. Interconnecting non type approved equipment to approved equipment can also create problems.

However, on reading the list of failures concerning the ECDIS/ARPA configuration I became convinced that competent type approval testing of the equipment to relevant IEC standards would have uncovered the deficiencies in the system and therefore no compliance certificate should have been issued.

For this reason I suspected that the equipment, in the version that had been supplied to the French Navy, had probably not been tested to the requirements of IEC 61174/60945, whether at a test house or by the manufacturer. Another possibility was that type approval had not been diligently undertaken and that the equipment had inappropriately been given approval. A third possibility was, of course, that the standards of IEC allowed type approval of unsatisfactorily performing equipment. While the latter was assumed in your letter, there is no indication that the first two possibilities were investigated.

I therefore followed the matter up with Det Norsk Veritas. The detailed response from them included the following statement. "The manufacturer of the product has developed additional functionality after type approval, and most of the problems were related to these special functions introduced for this delivery, and some for the handling in C-Map SDK [software] of French S57 charts".

Furthermore, DNV stated, "The manufacturer confirms that the failures occurred due to the fast reprogramming of additional functions in the system, and the quality of the internal software approval was not sufficient". I was also informed by DNV that the manufacturer had understood that the French Navy did not need the product to be type approved to IEC standards.

Since the system was not tested to IEC standards and neither were modifications made according to the software code of practice of the manufacturer, I am lead to the conclusion that the unfortunate experience of the French Navy cannot be credibly used to indicate that the IEC standards themselves are deficient and therefore of safety concern. (This is not to say that IEC TC80 standards are 'perfect' and cannot be improved).

Requirements on the software development standards of both ECDIS and ARPA are specified within IEC 60945, which is a normative reference to those standards. For information, the relevant Sections of IEC 60945 concerning software development are appended to this letter. In your letter, you state that IEC 61508 should be mentioned as a potential future reference within IEC 60945. This potential way forward has previously been under consideration by the Secretariat of TC80 and will be properly reviewed in 2007, when IEC 60945 is due for revision. At present, IEC 61508 appears within the bibliography to IEC 60945 but is not a normative reference.

IEC TC80 is keen to hear about the effectiveness of the present standard in this area and so your letter is both welcome and helpful. However, to date, TC80 has not been made aware of any other serious concerns on the effectiveness of marine software developed under IEC 60945 requirements.

Perhaps its generally perceived effectiveness in this area is ensured because two particular requirements within the standard are ably checked by competent type approval authorities:

1. The code of practice employed in the design and testing of the software integral to the operation of the equipment must be specified and conform to a control system audited by a competent authority

2. The code of practice must define the methodology used in the development of the software and the standards applied.

A government-audited test house would almost certainly be competent in assessing whether the offered software code of practice would be suitable for the type of equipment under test.

It is particularly important to understand that DNV reports the manufacturer as admitting to not following its own software development procedures (software code of practice) for the modifications required by the French Navy. Type approval authorities do allow changes to previously approved software to be performed by the manufacturer, without necessitating re-approval, provided: the changes are minor; that they are performed under the manufacturers approved and audited software code of practice; and that the changes are properly reported to the authorities. This allows the authorities to take the final decision as the whether the changes are, in fact, of a minor nature.

The changes made to conform to the French Navy's requirements are unlikely to have been considered minor and, furthermore, it appears they had not been submitted to DNV. It is important to understand that even if the manufacturer's written procedures had been to IEC 61508 requirements, the manufacturer could still circumvent them. No standards can prevent manufacturers taking short cuts if they wish to take the implied risks, even when audit trails exist.

It should also be taken into consideration that the equipment was submitted for trials use and it was likely that the manufacturer was aware that the software build would not formally meet the requirements of IEC 60945. More importantly, it is unlikely that they would treat production software in the same way. It must not be forgotten that commercially available systems do not only have to meet type approval standards, they must necessarily also meet the actual requirements of end users. Software that continually fails, even on a single vessel, would not only be a commercial disaster but it would inevitably lead to the buyer bringing it to the attention of the type approval authority.

This is very effective in keeping manufacturers compliant to the relevant standards, when necessary changes in hardware or software are required to be made to production software. The faults that occurred in the French Navy trials would also not have been acceptable to any commercial customer. (The same pressures also result in any weaknesses of TC80 standards being quickly communicated to the TC80 Secretariat by type approval authorities).

Your letter references aeronautical standards of software development. There is no doubt that software developed to such standards leads to a high quality of the product, with fewer errors in delivered systems compared to many other standards. However, it has also been acknowledged that developing aeronautical software to such a high standard can cost up to 10 times more than comparable functionality (professional) marine software. Also, equipment costs, again where comparable, are roughly 10 times higher in aeronautical systems than in marine. An ECDIS developed to aeronautical standards would therefore be liable likely to cost in excess of $100,000. If this was the market price, the undoubted safety improvements that ECDIS gives would not be realised, simply because the equipment would be unaffordable.

If software fails on an aircraft there is likely to be a devastating accident. Software failure on a ship would only have such dire consequences in very rare circumstances. Importantly, no standard software/equipment used in marine navigation meets the need for it to be formally considered as 'Safety Critical', as is applied to certain aircraft equipment and some industrial processes, including nuclear. This is not to say that marine navigation software is not related to safety, nor that marine software can be developed haphazardly, or without standards. However, the optimum standards taking into account all factors are unlikely to be replicas of aeronautical standards, such as DO-178B. This is not to say that lessons cannot be learnt from such standards.

Another reason why the software element of aircraft systems is more reliable than most marine systems is that a complete system certification is undertaken on aircraft. This is seen on ships to be an impractical requirement and does occasionally lead to unforeseen problems. This is probably not a significant issue in the case under consideration.

I hope that you find this letter helpful and would welcome a response and a continuing dialogue with the IHO over all matters concerning maritime safety and the effectiveness of IEC TC80 standards. Such matters are taken very seriously by TC80. Any further questions and comments that you may have will be seriously considered.

Yours sincerely

Andy Norris

Dr Andy Norris
On behalf of IEC TC80

Excerpt from IEC 60945

4.2.3 Software

4.2.3.1 General

(See 6.3.1)

The code of practice employed in the design and testing of the software integral to the operation of the equipment under test shall be specified and conform to a quality control system audited by a competent authority. The code of practice shall define the methodology used in the development of the software and the standards applied. It shall, amongst others, include the following criteria:

- complex software shall be structured to support separate testing of single modules or of groups of associated modules. Functions of safety protection linked with control functions shall always give priority to safety.
- the structure shall support maintenance and up-dates of software by minimising the risk of undetected problems and failures.

The manufacturer shall supply documentation demonstrating that the software of the EUT is developed and tested according to the code of practice and the requirements of 4.2.3 e.g. by block, data flow or status diagram.

4.2.3.2 Safety of operation

(See 6.3.2)

Facilities shall be provided to protect all operational software incorporated in the equipment.

Any software required in an equipment to facilitate operation in accordance with its equipment standard, including that for its initial activation/reactivation, shall be permanently installed with the equipment, in such a way that it is not possible for the user to have access to this software.

It shall not be possible for the operator to augment, amend or erase any program software in the equipment required for operation in accordance with the equipment standard. Data used during operation and stored in the system shall be protected in such a way, that necessary modifications and amendments by the user cannot endanger its integrity and correctness.

Default values shall be inserted whenever relevant to facilitate the required operation of the equipment.

Display and update of essential information available in the equipment as well as safety related functions shall not be inhibited due to operation of the equipment in any particular mode e.g. dialogue mode.

When presented information is uncertain or derived from conflicting sources, the equipment shall indicate this.

4.2.3.3 Monitoring

(See 6.3.3)

Means shall be provided to monitor the operational software and stored data of the equipment automatically. The check should be carried out during system start-up and at regular intervals , as indicated in the manufacturer's documentation. In the case of a non-automatically recoverable error or failure, the system shall release an independent alarm observable to the user on the workstation.

4.2.3.4 Operation

(See 6.3.4)

The system may allow function keys to speed up selection of common sequences.