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**Automation, Software and Information Technology**

**Report about the type approval of the flame detectors series  
Sharpeye 40/40R, I, M, UB, LB, L4B  
of Spectrex Inc.**

**Report-No.: 968/EZ 348.00/09  
Date: 2009-02-27**

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Sharpeye 40/40R, I, M, UB, LB, L4B of Spectrex Inc.**

**Report-No.:** 968/EZ 348.00/09

**Date:** 2009-02-27

**Pages:** 15

**Test object:** Flame detectors series Sharpeye 40/40

**Customer/Manufacturer:** Spectrex Inc.  
218 Little Falls Road  
1 Cedar Grove  
NJ 07009  
United States of America

**Order-No./Date:** 63325 dated 2007-03-18

**Test Institute:** TÜV Rheinland Industrie Service GmbH  
Alboinstrasse 56  
12103 Berlin  
Germany

**Department:** Automation, Software and Information Technology (ASI)

**TÜV-Offer-No./Date:** 968/73/07 dated 2007-03-08

**TÜV-Order-No./Date:** 9713335 dated 2007-03-22

**Inspector:** Dipl.-Ing. Jürgen Lietzow

**Test location:** see Test Institute

**Test duration:** March 2007 to February 2009

The test results are exclusively related to the test samples.

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## 1. **Scope**

The report describes the type approval of the flame detectors series *Sharpeye 40/40* of Spectrex Inc. (in the following *Sharpeye 40/40* called).

This approval is based on the results of the successful approval of the flame detectors *Sharpeye 20/20* series of Spectrex Inc. (see /U 9/).

Purpose of this type approval was the evidence that the *Sharpeye 40/40* fulfils the requirements of the IEC 61508 for a Safety Integrity Level (SIL) 2.

## 2. **Standards forming the basis for the requirements**

### **/N 1/ IEC 61508 Part 1 - 7, 1998 and 2000**

Functional safety of electrical/electronic/programmable electronic safety-related systems

### **/N 2/ EN 54-10:2002 and EN 54-10/A1:2005**

Fire detection and fire alarm systems - Part 10: Flame detectors - Point detectors

### **/N 3/ SN 29500:1996-1998**

Failure rates of components

## 3. **Identification of the test object**

Test object are the flame detectors of the *Sharpeye 40/40* series with UV- and/or IR-sensors, which can be used for detection of Hydrocarbon-based fuel and gas fires, hydroxyl and hydrogen fires as well as metal and inorganic fires (see /U 1/).

The following variants are covered by this report:

(for XXXXX and details see /U 2/ and /U 3/)

- 40/40M-XXXXX: Multi IR Flame Detector
- 40/40I-XXXXX: Triple IR (IR3) Flame Detector
- 40/40LB-XXXXX: UV/IR Flame Detector
- 40/40L4B-XXXXX: UV/IR Flame Detector
- 40/40UB-XXXXX: UV Flame Detector
- 40/40R-XXXXX: Single IR Flame Detector

The *Sharpeye 40/40* are used e.g. in offshore platforms, in the petrochemical industry, in storage halls.

The sensors necessary for the flame detection are integrated in the housing of the *Sharpeye 40/40*. Their signals are prepared by input circuits and evaluated by a micro controller.

The alerting of a flame can be done by a 4 - 20 mA - interface and/or by potential-free relay contacts.

Depending of the results of the evaluation a specific current is set on the 4 - 20 mA - interface.

For models 40/40M, 40/40I, 40/40R

- Normal State (No flame): 5 mA
- Warning State (Increased intensity values): 10 mA
- Alarm State (Flame detection): 15 mA

For models 40/40LB, 40/40L4B, 40/40UB

- Normal State (no flame): 4 mA
- Warning State (increased intensity values): 16 mA
- Alarm State (flame detection): 20 mA

If faults are determined, a current of 0mA or 2mA is set (depend on the kind of fault).

Both variants (4 - 20 mA - interface and potential-free relay contacts) fulfil independently the SIL 2-requirements.

More detailed information about the factory-installed and user-specific parameterisation are described in the datasheets /U 2/ and User Guides /U 3/.

For non safety-related applications a RS 485- and a HART<sup>®</sup> - interface can be used.

The approved *Sharpeye 40/40* is marked by the following versions:

Approved Software - Versions

- S77701I (CRC: 4305) for 40/40I and 40/40M Flame Detector
- S77702G (CRC: 24C6) for 40/40R Single IR Flame Detector
- S77703L (CRC: 2B13) for 40/40LB, 40/40L4B, 40/40UB Flame Detectors
- S88912F (CRC: 4DCE) for Secondary controller software for all types

Approved Hardware - Versions:

	DWG. NO.	REV	DESCRIPTION	DATE
<b>Block-diagram</b>	777008	D	Block & Wiring Diagram	31/03/08
<b>I/O-Board (for all types)</b>	777048	C	Electrical Scheme	04/11/08
	777049	A	I/O - P.C.B Assy.	05/11/08
	777050	C	Layout	27/11/08
	777052	C	I/O - P.C.Board	04/11/08
<b>Sensor and CPU-Board for 40/40 M,I,R - types</b>	777138 -1,-2,-3	G	Electrical Scheme	16/07/08
	777139	B	IR - P.C.B Assy.	11/06/08
	777144	E	IR - P.C.B SUB-Assy.	30/06/08
	777140	D	Layout	04/06/08
	777142	D	IR4 - P.C.Board	01/06/08

	DWG. NO.	REV	DESCRIPTION	DATE
<b>Sensor and CPU-Board for 40/40 L and U - types</b>	777038 -1,-2,-3	I	Electrical Scheme	03/08/08
	777039	B	IR - P.C.B Assy.	11/03/08
	777040	E	Layout	05/11/07
	777044	D	IR - P.C.B Assy.	20/07/08
	777042	E	IR - P.C.Board	29/10/07
<b>Interface - Board (for all types)</b>	777018 -1,-2	H	Electrical Scheme	13/05/08
	777019	C	Interface - P.C.B Assy.	10/04/08
	777020	F	Layout	24/02/08
	777024	C	Interface P.C.Board Sub-Assy.	03/08/08
	777022	F	Interface - P.C.Board	24/02/08

### 3.1. Safety-relevant information

#### 3.1.1. Safety function and safe state

The safety function of the *Sharpeye 40/40* is defined by recognizing of Hydrocarbon-based fuel and gas fires, hydroxyl and hydrogen fires as well as metal and inorganic fires (depend on the type, see /U 2/ and /U 3/) and announces this over the 4 - 20 mA - interface and/or by opening the alarm-relay-contact.

After detection of internal or external faults the safe condition will be fixed, that means that the 4 - 20 mA - interface is set to 0 mA or 2 mA and the "fault" - relay is de-energised.

#### 3.1.2. Detailed information on the safety-relevant conditions

The *Sharpeye 40/40* is intended for flame detection and must meet the requirements for SIL 2 of IEC 61508.

The flame detectors *Sharpeye 40/40I* and *Sharpeye 40/40M* can be operated in low demand mode and high demand mode or continuous mode (see /N 1/).

The flame detectors *Sharpeye 40/40 R*, *Sharpeye 40/40 UB* and *Sharpeye 40/40LB* and *40/40L4B* can be operated only in low demand mode.

The *Sharpeye 40/40* is internally realised by a single-channel. Two microcontrollers are used. The "Main" - controller records over the input channels the sensor data and evaluates these. The "Secondary" - controller essentially serves the 4 - 20 mA - interface.

Due to the use of high-complex circuits the *Sharpeye 40/40* is to be considered as a type B-subsystem in the sense of /N 1/. For SIL 2 thereby the Safe Failure Fraction must be in the range of 90 % - 99 % (see /N 1/).

Apart from this the sensors with its frequency-selective filters can be considered as a type A-subsystem. For this the Safe Failure Fraction must be in the range of 60 % - 90 %.

This is gained by different measures of fault detection. The most important of these are the following:

- Faults in the input channels for the recording of the sensor signals and a contamination of the window area of the sensors are detected by a cyclically dynamic monitoring of the channels and through plausibility tests. Beyond that faults are determined also by a cyclically accomplished optical examination.
- The correct function of the microcontrollers are supervised during the startup-phase and after this cyclically by different measures. The program memory is tested by an CRC algorithm. The RAM is tested at regular intervals by appropriate write/read tests.
- The correct program timing is supervised by an external Watchdog, and the logical program sequence through internal task monitoring.
- Power supply faults are detected by window comparators.
- The adjusted current value of the 4 - 20 mA - interface is read back cyclically and compared with the desired value.

If errors are determined, the safe condition is taken (s. chap. 3.1.1).

More detailed description of the measures of fault detection in the *Sharpeye 40/40* are contained in the following listed documents and in documents listed in /U 9/.

### 3.2. Documentation

The following documents were used for the type approval:  
 (additional documents are listed in /U 9/)

**/U 1/ The 40/40 series Flame Detectors and Accessories / April 2008**  
 Spectrex Inc.

**/U 2/ Datasheets**  
**DS-F-40/40I November 2008**  
**DS-F-40/40M November 2008**  
**DS-F\_40/40R November 2008**  
**DS-F\_40/40U-UB November 2008**  
**DS-F\_40/40UV/IR November 2008**  
 Spectrex Inc.

**/U 3/ User Guide**  
**TM-F\_40/40I September 2008**  
**TM-F\_40/40M September 2008**  
**TM-F\_40/40R September 2008**  
**TM-F\_40/40U September 2008**  
**TM-F\_40/40L September 2008**  
 Spectrex Inc.

**/U 4/ PRIMARY MICRO SOFTWARE DESCRIPTION for**  
**- 40/40I and 40/40M FLAME DETECTORS (TM 77701) / April 2008**  
**- 40/40R SINGLE IR FLAME DETECTOR (TM 77702) / April 2008**  
**- 40/40LB, 40/40L, 40/40L4, 40/40L4B, 40/40U, 40/40UB FLAME DETECTORS**  
**(TM 77703) / April 2008**  
 Spectrex Inc.

- /U 5/ Source Code for Main Controller**  
**S777011 / 2008-10-10**  
**S77702G/ 2008-10-16**  
**S77703L / 2009-02-09**  
Spectrex Inc.
- /U 6/ SECONDARY MICRO-CONTROLLER SOFTWARE DESCRIPTION / 2007-08-15**  
Spectrex Inc.
- /U 7/ Source Code for Secondary Controller S88912F / 2008-05-19**  
Spectrex Inc.
- /U 8/ Hardware documentation (see chap. 3)**  
Spectrex Inc.

### **3.3. Previous test report**

- /U 9/ Report-No.: 968/EZ 305.00/08 dated 2008-07-03**  
TÜV Rheinland Industrie Service GmbH

### **3.4. Test sample**

Test samples are the Sharpeye 40/40 - detectors which were used for the „Additional Software - Test cases“ (see /D 2/ and /D 4/). They are deposited at the Test Institute.

## **4. Tests and test results**

### **4.1. General**

The measuring and test equipment, which has been used by the TÜV Rheinland Group in the tests described in the following, is subject to regular inspection and calibration. Only devices with valid calibration have been used. The devices used in the various tests are recorded in the inspector's documentation.

All considerations concerning uncertainty of the measurements, so far applicable, are also stated in the inspector's documentation

In cases where tests have been executed in an external test lab or in the test lab of the manufacturer and where the results of these tests have been used within this documented approval, this has occurred after a positive assessment of the external test lab and the achieved test results in detail according to the Quality Management procedure QMA 3.310.05.

### **4.2. Extent of the type approval**

The type approval described in this report is based on the type approval of the Sharpeye 20/20 - series. The results of the examination of the product-related verification and validation measures and the quality and safety management respectively the evaluation of fault avoidance measures were taken over (see /U 9/).

For the *Sharpeye 40/40* the following examinations were accomplished:

- Inspection of the Sharpeye 40/40 - documentation
- Inspection of the fault avoidance measures
- Inspection of the measures for control of failures during operation

- Examination of the software
- Calculation of safety related parameters
- Evaluation of the results of environmental tests
- Evaluation of the results of EMC tests
- Considerations for electrical safety

During these examinations the following documents were generated by the Test Institute or by accredited laboratories, in which the details of the investigations were recorded. These documents are deposited at the Test Institute.

- /D 1/ Documentation of Hardware – FMEA – 40/40 / 2007-12-18**  
TÜV Rheinland Industrie Service GmbH
- /D 2/ Protocols of Hardware - Fault insertion Test /2008-06-17**  
TÜV Rheinland Industrie Service GmbH
- /D 3/ Results of Software – Reviews / 2008-05-19**  
TÜV Rheinland Industrie Service GmbH
- /D 4/ Protocols of Software - Test cases / 2008-06-17**  
TÜV Rheinland Industrie Service GmbH
- /D 5/ Accreditation Papers for Qualitech Experts Ltd.**  
American Association for Laboratory Accreditation (A2LA)
- /D 6/ Environmental & mechanical laboratory Test report Flame Detector /2008-05-28**  
**Report No: 20080528-0944**  
**(Mechanical and Environmental)**  
Qualitech Experts Ltd.
- /D 7/ EN54-10 Test Report – No. TE 243256 (a) and (b) / 2009-02-05**  
BRE Global Ltd.
- /D 8/ Accreditation Papers for BRE Global Ltd. / 2009-01-05**  
**(Schedule of Accreditation)**  
United Kingdom Accreditation Service (UKAS)
- /D 9/ Calculation of the safety-relevant characteristics / 2008-10-13**  
**(PFH, PFD,SFF,DC)**  
TÜV Rheinland Industrie Service GmbH
- /D 10/ Test documentation / 2008-10-28, 2009-02-11**  
Spectrex
- /D 11/ EC Type-Examination Certificate – No.: Sira 07ATEX1250**  
Sira Certification Service
- /D 12/ Samples of creepage- and clearance distances / 2009-02-26**  
TÜV Rheinland Industrie Service GmbH

### **4.3. Examination of the fulfilment of the requirements of IEC 61508**

#### **4.3.1. Inspection of the Sharpeye 40/40 - documentation**

The inspection of the documentation were carried out essentially in the review of the documents, which contained information about the suitability of the Sharpeye 40/40 for the intended purpose as flame detector and the necessary extensions for the fulfilment of the SIL 2 - requirements (s. /U 1/ to /U 3/).

##### Result:

The inspection and evaluation of the documentation resulted in the requirements of IEC 61508 for SIL 2 being met.

#### **4.3.2. Evaluation of the fault avoidance measures**

The IEC 61508 demands the evidence about the implementation of fault avoidance measures over the entire life cycle of the system. Since the examination of the *Sharpeye 40/40* was based on the type approval of the *Sharpeye 20/20 – System* (s. /U 9/) the following fault avoidance measures are also applicable for the *Sharpeye 40/40*:

- Modification of the hardware and software by Spectrex Inc. with application of a certified quality management process
- Manufacturing of the *Sharpeye 40/40* by Spectrex Inc. with application of a certified quality management process
- Usage of computer-aided tools for the hard- and software development
- Usage of programming guidelines for avoidance of software faults
- Verification of the adherence of the programming guidelines
- Use of well-known and proven compilers
- Execution of EMV- and environmental checks (s. chap. 4.4)

##### Result:

The applied measures for measures for fault avoidance during hardware and software development are also estimated as sufficient for the *Sharpeye 40/40*.

#### **4.3.3. Examination of the software**

The examination of the software of the Sharpeye 40/40 was divided into an investigation of the modified IR - sensor functions and an analysis of additional functions, which were implemented to fulfil the requirements of IEC 61508 for SIL 2 for the UV - sensors.

The software investigation began with the analysis of the software design, that is described in the documents /U 4/ and /U 6/ and was continued with the review of the safety-relevant source code.

The software functions taking part in fault detection and control were analysed by comparing with the Sharpeye 20/20 - functions for fault detection and control.

During these examinations different software test cases were defined, which were accomplished with the client and in co-operation with the developer after conclusion of the theoretical analyses.

Additional test cases were accomplished by the client to verify hard- and software modifications during the type approval.

Result:

By the examination of the software no errors were detected, which would lead to a critical state. Detailed information of the software investigation and their results are contained in /D 3/ and /D 4/.

The additional test cases were also accomplished successfully (/D 10/).

#### **4.3.4. Evaluation of the measures for control of failures during operation**

To fulfil the requirements for SIL 2 appropriate measures were taken to control failures during operation. For this purpose the fault models specified in IEC 61508 are to be applied. Thereby the type of fault model depends on the evaluated component.

That means for the examination of the Sharpeye 40/40 that the additional monitoring mechanisms were proven theoretically and practically.

Most of the measures for control of failures were take over from the *Sharpeye 20/20* - System

To verify the effectiveness of the measures for fault detection and -control an FMEA was carried out at component level.

The results of this Hardware-FMEA formed the basis for the in chap. 4.3.5 described calculation of the safety-relevant parameters (PFH/PFD; SFF; DC) and for the function and fault injection tests. These tests verified the effectiveness and correct implementation of the measures for control of failures during operation.

The correct function of the Sharpeye 40/40 was proven during the accomplished fault injection tests. Details of these examinations are described in /D 2/ and /D 4/.

Result:

The examination of the measures for fault-detection and -control resulted in the requirements for SIL 2 of IEC 61508 concerning diagnostic coverage and fault-detection and -control being fulfilled.

The results to the Hardware-FMEA are contained in /D 1/. Details of the fault injection tests and function tests are described in /D 2/.

#### **4.3.5. Calculation of the safety related parameters**

Based on the system structure of the Sharpeye 40/40 and in accordance with the definitions in IEC 61508 a Hardware-Failure-Tolerance = 0 was identified for the calculation of safety related parameters.

Adapted from this and with the failure rates of components in /N 3/ the Safe-Failure-Fraction (SFF), the probability of dangerous failures per hour (PFH) and the probability of a dangerous failure on demand (PFD<sub>avd</sub>) were calculated with the procedures described in part 6 of IEC 61508.

Starting point for the calculations was the Component - FMEA mentioned in chapter 4.3.4 for the definition of the safety-relevant signal-paths and the elements in it.

The Safe-Failure-Fraction was calculated as follow:

- For IR - Sensors: SFF= 95 %
- For UV - Sensors: SFF= 97 %

The following PFD<sub>avd</sub>- / PFH - values were calculated for the interval between 2 maintenance cycles T for different variants:

- Variant A: Using only the Alarm - relay for Alarming
- Variant B: Using the 4-20 mA - Interface for Alarming
- n.a.: Not allowed for high demand or continues mode

**4.3.5.1. Maintenance cycles T = 30 days**

***Sharpeye 40/40R***

	<b>PFD<sub>avd</sub></b>	<b>PFH(1/h)</b>
Variant A	1,7E-04 (~2% of SIL 2)	n.a.
Variant B	1,8E-04 (~2% of SIL 2)	n.a.

***Sharpeye 40/40I***

	<b>PFD<sub>avd</sub></b>	<b>PFH(1/h)</b>
Variant A	1,8E-04 (~2% of SIL 2)	n.a.
Variant B	1,9E-04 (~2% of SIL 2)	1,5E-07 (~15% of SIL 2)

***Sharpeye 40/40M***

	<b>PFD<sub>avd</sub></b>	<b>PFH(1/h)</b>
Variant A	1,9E-04 (~2% of SIL 2)	n.a.
Variant B	1,9E-04 (~2% of SIL 2)	1,6E-07 (~16% of SIL 2)

***Sharpeye 40/40UB***

	<b>PFD<sub>avd</sub></b>	<b>PFH(1/h)</b>
Variant A	2,5E-05 (~0,2% of SIL 2)	n.a.
Variant B	2,8E-05 (~0,3% of SIL 2)	n.a.

***Sharpeye 40/40LB,L4B***

	<b>PFD<sub>avd</sub></b>	<b>PFH(1/h)</b>
Variant A	1,9E-04 (~2% of SIL 2)	n.a.
Variant B	1,9E-04 (~2% of SIL 2)	n.a.

#### 4.3.5.2. Maintenance cycles T = 180 days

##### *Sharpeye 40/40R*

	<b>PFD<sub>avd</sub></b>	<b>PFH(1/h)</b>
Variant A	2,4E-04 (~2% of SIL 2)	n.a.
Variant B	2,6E-04 (~3% of SIL 2)	n.a.

##### *Sharpeye 40/40I*

	<b>PFD<sub>avd</sub></b>	<b>PFH(1/h)</b>
Variant A	3,0E-04 (~3% of SIL 2)	n.a.
Variant B	3,2E-04 (~3% of SIL 2)	1,5E-07 (~15% of SIL 2)

##### *Sharpeye 40/40M*

	<b>PFD<sub>avd</sub></b>	<b>PFH(1/h)</b>
Variant A	3,3E-04 (~3% of SIL 2)	n.a.
Variant B	3,6E-04 (~4% of SIL 2)	1,6E-07 (~16% of SIL 2)

#### 4.3.5.3. Maintenance cycles T = 365 days

##### *Sharpeye 40/40R*

	<b>PFD<sub>avd</sub></b>	<b>PFH(1/h)</b>
Variant A	3,2E-04 (~3% of SIL 2)	n.a.
Variant B	3,6E-04 (~4% of SIL 2)	n.a.

##### *Sharpeye 40/40I*

	<b>PFD<sub>avd</sub></b>	<b>PFH(1/h)</b>
Variant A	4,5E-04 (~5% of SIL 2)	n.a.
Variant B	4,9E-04 (~5% of SIL 2)	1,5E-07 (~15% of SIL 2)

##### *Sharpeye 40/40M*

	<b>PFD<sub>avd</sub></b>	<b>PFH(1/h)</b>
Variant A	5,1E-04 (~5% of SIL 2)	n.a.
Variant B	5,6E-04 (~6% of SIL 2)	1,6E-07 (~16% of SIL 2)

#### Result:

The calculation of safety related parameters resulted in the relevant requirements of the IEC 61508 being fulfilled. The details of the calculation are documented in /D 9/.

#### 4.4. Evaluation of the results of environmental and EMV-tests

The tests were accomplished by a accredited test laboratory (s. /D 5/ and /D 8/).

The following environmental and EMV-tests were accomplished:

##### Climatic tests:

EN 54-10; Chap. 5.7	Dry heat (operational)
EN 54-10; Chap. 5.8	Cold (operational)
EN 54-10; Chap. 5.9	Damp heat, cyclic (operational)

##### Mechanical tests:

EN 54-10; Chap. 5.13	Impact (operational)
EN 54-10; Chap. 5.14	Vibration, sinusoidal (operational)
EN 54-10; Chap. 5.15	Vibration, sinusoidal (endurance)

##### EMC tests:

<i>EN 54-10; Chap. 5.17 a)</i>	<i>Electrostatic discharge</i>
<i>EN 54-10; Chap. 5.17 b)</i>	<i>Radiated electromagnetic fields</i>
<i>EN 54-10; Chap. 5.17 c)</i>	<i>Conducted disturbances induced by electromagnetic fields</i>
<i>EN 54-10; Chap. 5.17 d)</i>	<i>Fast transient bursts</i>
<i>EN 54-10; Chap. 5.17 e)</i>	<i>Slow high energy voltage surges</i>

##### Result:

The Reviews of the environmental checks were successfully completed. The described positive results of the environmental tests can be included in the type approval (see /D 6/, and /D 7/).

#### 4.5. Considerations for electrical safety

The Sharpeye 40/40 is powered with an operating voltage of 24 VDC, which is reduced to lower voltages for the individual functional units. The function voltages are monitored for over and/or under voltage.

The maximum contact rating of the relays is 30VDC (see /U 3/).

Due to the requirement that only power supplies shall be used, which meet the requirements for SELV- / PELV voltages, a safe isolation is ensured (s. chap. 5). For this reason no further examinations are required.

#### 4.6. Examination of adequate creepage- and clearance distances concerning functional isolation

Based on the result of the ATEX - EC Type Examination et al. for IP67 - Protection (see /D 11/) a pollution degree of 2 was assumed for the examination of creepage- and clearance distances concerning functional isolation.

The creepage- and clearance distances were examined by random sampling based on the pollution degree 2 and the maximum rating of the relay contacts of 30VDC and operating voltage of 24VDC.

Result:

The examination of adequate creepage- and clearance distances concerning functional isolation didn't result in lacks. Details are contained in /D 12/.

**5. Summary**

The type approval of the flame detector series *Sharpeye 40/40* of Spectrex Inc. was performed for SIL 2 according to the relevant parts of IEC 61508.

The flame detectors series Sharpeye 40/40 of Spectrex Inc. fulfils the requirements of the IEC 61508 for a Safety Integrity Level (SIL) 2 and can be used for detection of different kinds of flames (s. /U 3/), when the conditions in the appendix E of the User Guides /U 3/ are considered.

Berlin, 2009-02-27  
TIS/ASI/Kst. 968 lie-nie

Report released after review:  
Date: 2009-02-27

The inspector



Dipl.-Ing. Jürgen Lietzow



Dipl.-Ing. Gernot Klaes