The Quality system at INRiM: a Research and National Metrology Institute

The Quality System at INRiM: A Research and National Metrology Institute

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The Quality Management System (QMS) of the Istituto Nazionale di Ricerca Metrologica (INRiM), Italy, deals with calibration and measurement activities in accordance with the Mutual Recognition Arrangement (MRA), established to ensure the mutual acceptance of national standards and calibration certificates among signatory countries. The INRiM system also covers other scopes such as testing for the Association for the Certification of Electrical Equipment (ACAE) and the Low Voltage Agreement Group (LOVAG), production of certified reference materials, interlaboratory comparisons (ILCs), and provision of technical documentation and contract-based services using. The QMS complies with ISO/IEC 17025:2017, Option A, for calibration and testing, with ISO 17034:2016 for production of certified reference material and with ISO/IEC 17043:2023 for interlaboratory comparison provider. The INRiM QMS does not cover research activities. In 2024, INRiM maintained 448 Calibration and Measurement Capabilities (CMCs) and, between 2022 and 2024, issued 5336 certificates, 173 test reports, and 337 ILC reports. The INRiM organization, where a QMS coexists within a research environment and where scientific and technical personnel are involved in the three INRiM tasks, has a positive impact on all INRiM activities.

1. Introduction

The Comité International des Poids et Mesures (CIPM) Mutual Recognition Arrangement (MRA) [1] is an international agreement allowing national metrology institutes (NMIs) to demonstrate the international equivalence of their measurement standards and the mutual recognition of their calibration certificates. The CIPM MRA imposes that NMIs participate in key comparisons (KCs) and supplementary comparisons (SCs) of measurement standards to demonstrate the equivalence of their capabilities. NMIs publish their calibration and measurement capabilities (CMCs) in the key comparison database (KCDB), maintained by the International Bureau of Poids et Meaures (BIPM). These CMCs signify that the participating NMIs' measurement standards and calibration certificates are mutually recognized. A further requirement to support MRA is that the NMIs must implement a Quality Management System (QMS) in accordance with ISO/IEC 17025 [2]. CMCs are submitted to Regional Metrology Organizations (RMOs) for review. Several NMIs extended the scope of their QMS to cover additional activities in accordance with other standards. For example, QMSs of the following NMIs cover:

- Federal Institute of Metrology (METAS Switzerland): General Quality System (QS) [3], Calibration and Testing (C&T), Reference Materials (RMs) production [4], Conformity Assessment for Inspection bodies [5], Risk Management [6], Information security system [7];
- Physikalisch-Technische Bundesanstalt ((PTB Germany): QS, C&T, RMs production;
- National Physical Laboratory (NPL Great Britain): QS, C&T, RMs production, information security system and Proficiency Testing (PT) or Interlaboratory comparisons (ILCs) provider [8] all accredited by UKAS[2];
- Laboratoire national de métrologie et d'essais (LNE France): QS, C&T, RMs production,

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2 UKAS is the National Accreditation Body of United Kingdom for accreditation of organizations that providing certification, testing, inspection, calibration, validation and verification.

conformity assessment for bodies providing audit and certification of management systems [9];

- VSL National Metrology Institute, Netherland: C&T, RMs production and PT provider, all accredited by RvA[3];
- National Institute of Standards and Technology (NIST USA): C&T, RMs, PT provider and standard Reference data.

The conformity of INRiM's QMS with [2, 4, 8] is self-declared. Without a formal accreditation, INRiM is periodically subject to re-evaluation through peer reviews carried out by personnel and experts from other NMIs. For RMs production and ILCs provider activities, the INRiM QMS includes additional requirements, which are applied in addition to the requirements of [2]. INRiM is also a qualified laboratory within the Association for Certification of Electrical Equipment (ACAE), a network of qualified testing laboratories. ACAE is a certification body active in the fields of electrical low-voltage and high-voltage equipment. An ACAE-qualified laboratory is authorized by ACAE to carry out tests consistent with its technical capabilities and equipment. ACAE qualification implies the compliance by the laboratory to the requirements of [2], and ACAE specific requirements. The qualification process consists in the verification by ACAE assessors, documental and onsite, of the compliance to [2] and to the specific ACAE requirements. The maintenance of the qualification requires annual surveillance. In [10], it is demonstrated that stronger national Quality Infrastructures (NQIs), including NMIs, are generally associated with more robust economies. NMIs play a central role in NQIs through their connections with scientific and legal metrology, as well as with conformity assessment and accreditation bodies. These include the BIPM, CIPM, the International Organization for Standardization (ISO), the World Trade Organization (WTO), the International Laboratory Accreditation Cooperation (ILAC), and the International Accreditation Forum (IAF). NMIs often participate in committees with such organizations sharing and transferring advances in technology allowing these organizations to update their rules and accreditation/certification criteria.

3 Dutch Accreditation Council RvA.

2. INRiM: A Research and Metrology Institute

INRiM is a national public scientific research organization (Figure 1) supervised by the Ministry of University and Research. It serves as Italy's NMI. INRiM was established in 2006 merging the Istituto Elettrotecnico Nazionale "Galileo Ferraris" (IEN) with the Istituto di Metrologia "Gustavo Colonnetti" (IMGC). INRiM performs scientific research in metrology and develops advanced measurement standards and methods. As a signatory participant of the CIPM-MRA, INRiM maintains the national standards to ensure the metrological traceability and legal validity of the measurements across industry, commerce, scientific research, healthcare, and environmental protection. The INRiM NMI Role encompasses metrology activities for both internal and external clients, including C&T, ILCs provider and RMs production. INRiM also is active in the knowledge transfer (KT) and advancements in measurement and materials science, aiming to enhance national technology, quality of life, and public services. The INRiM scientific structure is led by a Scientific Director, and it is organized into three Departments:

- Applied metrology and engineering (AE);
- Metrology of innovative materials and life sciences (ML);
- Quantum metrology and nanotechnology (QN).

The QMS board and system operate at the highest level, reporting directly to the INRiM President.

Each department encompasses research and metrology activities relevant to their respective fields. AE covers the quantities of Mass and related ones, length, Electrical and electronic, and thermodynamics. QN covers the Time and Frequency quantities, as well as Photometry. ML is responsible for Acoustics, Ultrasound, and Magnetism. A structural change at INRiM mandated that all Departments participate in the institute's three tasks: Research, NMI and KT Roles. In the INRiM's previous organization, scientific departments were primarily involved in research activity. Within this framework, research outcomes were not readily accessible to the Department exclusively in charge of the NMI and KT roles. This change has enhanced the internal KT, as researchers and technicians now participate in all the three tasks, facilitating the application of research findings to

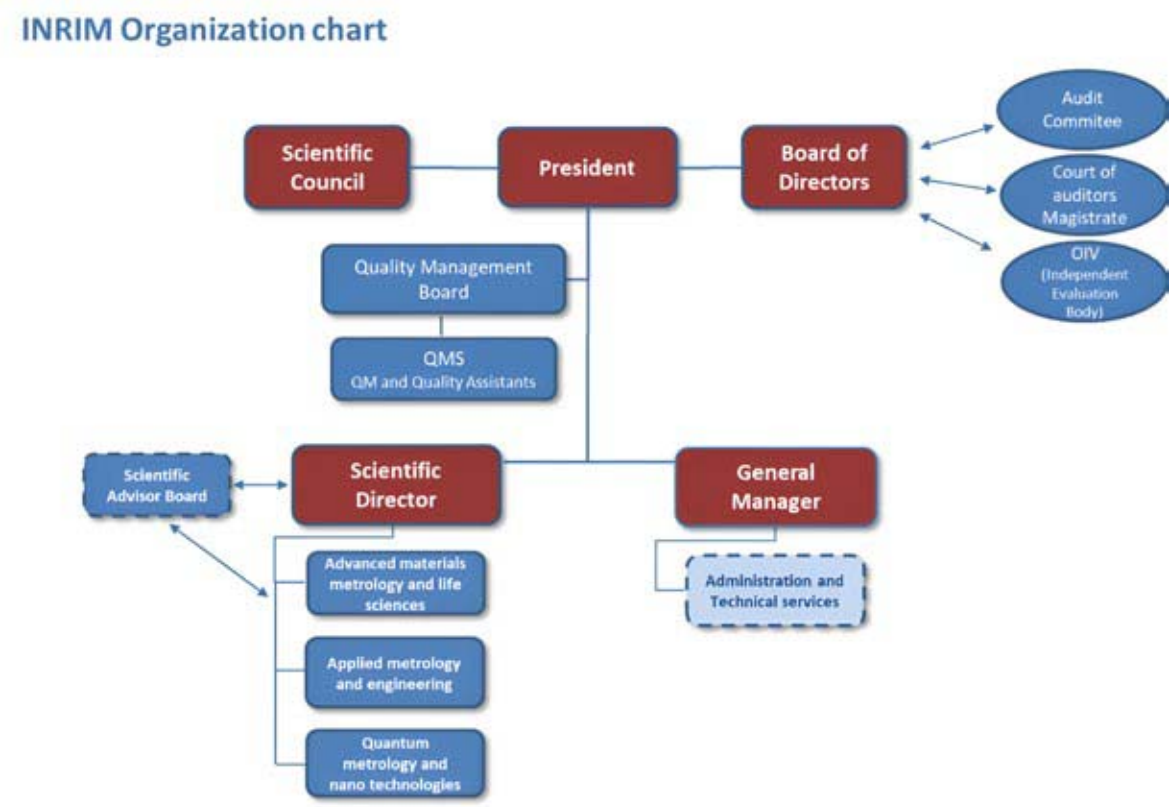

Figure 1. INRiM Organization chart.

metrology activities (C&T) especially for external customers. INRiM provides also technical support to the Italian accreditation body for calibration laboratories, ACCREDIA-DT, providing expertise and technical assessors for the accreditation processes. The INRiM QMS does not encompass research activities, as no formal standards for research currently exist. Nevertheless, in [11] it is stated that some organizations published schemes and guidelines for quality in research, but these were not generally accepted. The INRiM QMS was generally accepted by researchers, as its implementation was required for participation in the CIPM MRA and because it does not directly govern research activities, but only those related to the NMI role (calibration & testing, reference materials, ILCs provider). The current INRiM organization, in which a QMS coexists with research activities and where scientific, appears to be successful both for scientific productivity, dissemination of measurement units, and technology transfer, while preserving the scientific autonomy of researchers. This is demonstrated in Table 1 reporting the figures for INRiM's three core tasks from 2019 to 2024. The table shows that, starting from 2021, when the organizational change was implemented, the outcomes of research (no. of scientific publications, 1st column), of documents (certificates and reports for NMI role, 2nd column), and no of patents (for KT role, 3rd column).

2.1 Documents for the INRiM QMS

The INRiM QMS is made of 24 general procedures and of 236 technical procedures that support 63 laboratories. The QMS is primarily focused on the requirements outlined in [2] concerning the C&T activities, which represent the core service for both internal and external customers. Additional requirements concern the RMs production and ILCs provider activities. Therefore, specific additional requirements are detailed in dedicated management procedures. In [8, 12] specific rules to evaluate the ILCs results are given.

Year	Publications in Indexed Journals	Documents for External Customers	Patents
2019	167	1802	0
2020	176	1749	3
2021	175	2116	4
2022	194	1980	4
2023	205	2042	5
2024	208	1824	10

Table 1. Number of the three INRiM tasks from 2019 to 2024.

2.2 The LATFC Laboratory

Among the INRiM's laboratories, the Laboratorio Alte Tensioni e Forti Correnti (LATFC)-High Voltage and High Power Laboratory https://www.inrim.it/sites/default/files/2022-05/LATFC.pdf - stands out for its specialization and capabilities. LATFC is active on research and calibration of measurement systems testing of electrical equipment, including switchgear and controlgear assemblies, busbar systems, insulators, circuit breakers, fuses, contactors, instrument transformers, and similar devices. LATFC performs high-current tests such as short-circuit, withstand and prospective current tests, endurance tests, and temperature rise tests. It also performs high-voltage tests, including power-frequency tests (at 50 Hz) in both dry and wet conditions, as well as lightning and switching impulse tests. Under the ACAE qualification, carries out verifications of short-circuit conditions, dielectric withstand verification, temperature rise, overload releases, under-voltage and shunt releases, auxiliary circuits, mechanical operation, operational performance capability, lifting tests, and degrees of protection. By means of ACAE qualification, INRiM plays an important role in electrical safety and regulatory compliance by actively participating in European and international networks, such as LOVAG, the Low Voltage Agreement Group. The collaboration between INRiM - the only NMI laboratory recognized by LOVAG and certification networks such as LOVAG represents an effective model of integration between scientific metrology and technical conformity assessment. This synergy contributes to a safer, efficient, and competitive European electrical market. It enhances the product quality, fosters trust in the EU market, reduces business costs through mutual recognition, and supports innovation by ensuring that emerging technologies are both measurable and certifiable. LATFC is subjected to regular surveillance by ACAE in accordance with [2], as well as the applicable IEC and EN standards relevant to the qualified tests. ACAE imposes additional requirements for laboratories performing tests on its behalf such as the guidelines of the procedure "Current Technical Decisions" which provides authoritative interpretations of the applicable rules. The uncertainty associated with the tests must comply with the ACAE document: Instrument Accuracy Limits for low-voltage tests and with the Short-Circuit Testing Liaison procedure: "Handling of Measurement Uncertainties in Testing and Test Documents for high-voltage." ACAE signed an agreement with INRiM, outlining the criteria for operating as an ACAE-accredited laboratory.

2.3 INRiM Results Reports for C&T, RMs and ILCS Provider Activities

The technical documents issued by INRiM in the framework of its QMS are related to the CMCs in the Appendix C of the CIPM MRA https://www.bipm.org/kcdb/and/or to other activities made by INRiM as NMI according to the Italian law 273/91 instituting the Italian calibration system (SNT). Specifically, the issued documents are:

- Calibration certificates: concerning the calibration of a measurement standard, instrument or system;
- Measurement certificates: concerning a measurement activity;
- Test reports: concerning test activities on products or devices according to procedures and specifications defined by technical standards and/or agreed with customers;

- ACAE test reports concerning test activities issued in the framework of the ACAE qualification;
- Certificates of CRM: concerning Reference Material Certification activities;
- Information sheets of RM: concerning the produced Reference Material;

On the first page and inside of the calibration and measurement certificates covered by CMCs, the CIPM MRA logo and the CIPM MRA note[4] are respectively reported. Calibration and measurement certificates not covered by CMCs but issued in the capacity of the NMI designated under Italian Law No. 273 include the annex "ILAC Annex P10" /9/. This annex provides customers with the information required to ensure traceability in compliance with the same document. These certificates are issued for internal instruments.

2.4 Surveillance of the C&T, RMs and ILCS Provider Activities by the INRiM QMS

The C&T, RMs, and ILCs provider activities are monitored by the INRiM QMS through:

- Application of quality assurance to results, requiring laboratories performing these activities to monitor the validity of their results at planned intervals;
- Participation in national and international comparisons;
- INRiM has participated in 229 key comparisons (29 as pilot laboratory) and 86 supplementary comparisons (7 as pilot).
- Internal audits. INRiM carries out approximately 50 internal audits each year across all laboratories covered by the QMS. These audits include the assessments of technical procedures, their implementation, and the adequacy and effectiveness of the laboratories.
- Assessments under international agreements as the European Association of National Metrology Institutes (EURAMET), Technical Committee (TC) Quality: EURAMET TC-Quality has established a process for the continuous monitoring of the QMSs of its NMIs. Once a QMS is approved by EURAMET TC-Quality, all signatory NMIs and Designated Institutes (DIs) under the CIPM MRA are required to submit an annual report to the TC-Quality on the current status of their QMSs. The review of these annual reports ensures that institutes are maintaining their QMS, reviewing their services, and addressing any issues that could impact on their CMCs. Additionally, a periodic review of the QMS must be conducted at intervals not exceeding five years. To this end, INRiM, besides the QMS annual reports, presents a comprehensive five-year QMS activity report every five years to EURAMET TC-Q. This planned monitoring ensures that the QMS continues to cover the declared CMCs and that peer reviews remain valid.
- Peer visits performed by experts of other NMIs to INRiM facilities, activities and laboratories: INRiM is involved in the EURAMET Project 1123, "On-site Peer Review CEM, INRiM and IPQ." This joint audit project aims to support the development and improvement processes of NMIs, providing a tool for better international recognition and strengthening confidence in the fulfilment of the CIPM MRA requirements. The peer review program is scheduled on annual basis. Started in 2009, the project involves a program of cross-audits conducted each year. In general, each technical subfield is assessed every five years, while the overall QMS is reviewed every two years.
- Surveillance visits by the ACAE to the LATFC: Surveillance is conducted annually to determine whether the LATFC laboratory still meets the requirements of [2] and of ACAE specific requirements. Since INRiM is a non-accredited institution, the annual monitoring is carried out through inspections, planned in such a way that, within a three-year period, all the requirements of [2] are checked at least once.

4 This certificate is consistent with the capabilities (CMCs) that are included in Appendix C of the CIPM MRA drawn up by the CIPM. Under the CIPM MRA, all participating institutes recognize the validity of each other's calibration and measurement certificates for the quantities, ranges and measurement uncertainties specified in the KCDB. For details see https://www.bipm.org/kcdb/.

- Analysis of risks and opportunities according to the relevant procedure "Risks and opportunities." This analysis is reviewed every year during the management review.
- Continuous improvement of the QMS applying the relevant managing procedure "Improvement," in which Key Performance Indicators (KPIs) are established and annually evaluate. They mainly concern: Performance adequacy, system compliance, product compliance and customer's satisfaction. For example, one of these KPIs is defined as the ratio between the no. of work orders completed during the year and the no. of quotes issued during the year.
- Management review outputs, which report on the effectiveness of the QMS and its processes, the improvement of the activities of the laboratories, the adequacy of resource provision, and any identified need for changes.

2.5 INRiM Numbers in the Years 2022-2024 for C&T, RMs and ILCS Provider Activities

The metrological areas covered by the MRA include: EM (Electricity and Magnetism), T (Temperature) TF (Time and Frequency), L (Length), M (Mass and related quantities), AUV (Acoustics, Ultrasound and Vibration), QM (Amount of Substance), PR (Photometry and Radiometry).

Metrology Area	No. of INRiM CMCs
EM	135
M	71
T	111
L	51
AUV	41
PR	17
QM	12
TF	10

Table 2. Number of the INRiM CMCs per metrological area in 2024.

As of the end of 2024, INRiM maintains 448 CMCs published in the KCDB, distributed across these metrological areas, as shown in Table 2. In the following, data on activities conducted under the INRiM QMS between 2022 and 2024, divided by metrological area, are provided.

Figure 2 shows the percentage distribution of the INRiM's issued C&M certificates per metrological area over the three-year period 2022–2024, when 5336 certificates were issued.

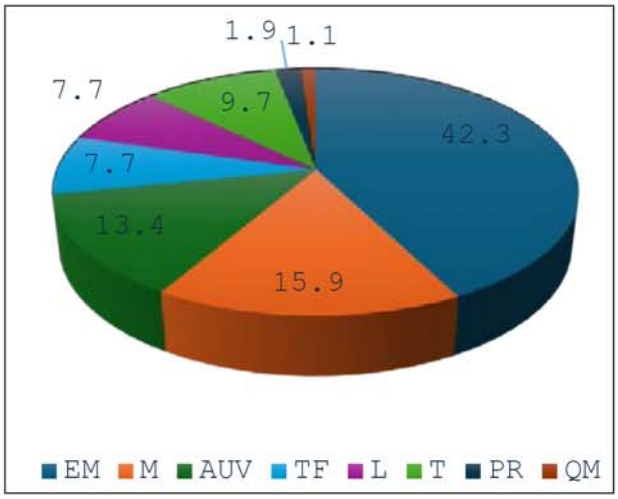

Figure 2. Percentage distribution of C&M certificates issued by INRiM per metrological area in the period 2022-2024.

Figure 3 shows the number of ILCs provided by INRiM per metrological area from 2022 to 2024. During this period, INRiM provided 113 ILCs with an average of 54 participants per year and issued a total of 337 ILC reports.

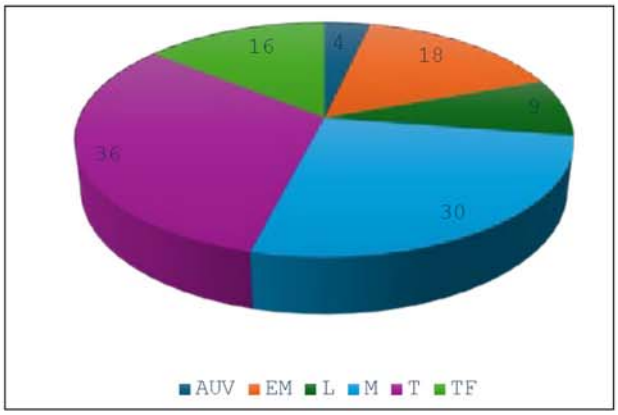

Figure 3. Number of ILCs provided by INRiM in the period 2022-2024 per metrological area.

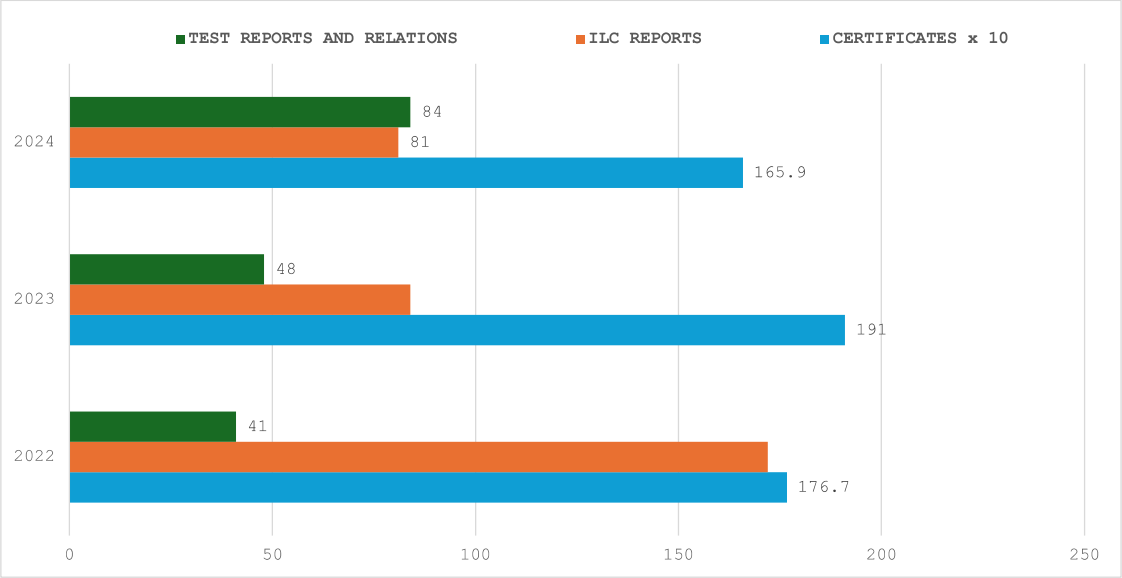

Figure 4. Number of documents issued by INRiM in the years 2022-2024 according to their typology.

During the three-year period, INRiM issued 173 technical reports, most of which were provided by the EM area. In 2024, INRiM issued the first certificate for a RM. Finally, Figure 4 shows the number of the documents issued by INRiM according to their typology in the same three-year period.

3. Discussion

The INRiM experience suggests that QMS and research activities can successfully coexist within a research environment, preserving scientific autonomy of the researchers whit potential mutual benefits. The collaboration between INRiM and LOVAG is an effective example of integration between scientific metrology and the conformity framework to improve the reliability of the electrical market. Furthermore, the peer review process under the CIPM MRA assessessing the conformity of the INRiM's QMS and of the laboratories represents a collaborative framework that facilitates the exchange of best practices, promotes mutual trust and reinforces international partnerships. This peer review process offers greater flexibility than a formal accreditation, being well-suited to meet the evolving needs of emerging and technologically advanced sectors, an essential characteristics for any research institution.

On the basis of this integrated QMS, INRiM is strategically positioned to address the challenges of an increasingly interconnected context and to fully harness the opportunities arising from digital transformation; since July 2025, as a direct outcome of the QMS implementation, INRiM issues documents as certificates and reports in electronic format.

Acknowledgements

The authors wish to thank P. Roccato of LATFC for his advice on the activity of LATFC concerning ACAE and relevant documentation.

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[3] ISO 9001:2015 Quality management systems — Requirements.

[4] ISO 17034:2016 "General requirements for the competence of reference material producers.

[5] ISO/IEC 17020:2012 Conformity assessment—Requirements for the operation of various types of bodies performing inspection.

[6] ISO 31000:2018 Risk management — Guidelines.

[7] ISO/IEC 27001:2022 Information security, cybersecurity and privacy protection-Information security management systems Requirements

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