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PRESENTACION / INTRODUCTION

Estimados amigos

Es un honor para mí presentar este nuevo número de INFOSIM, publicación del Sistema Interamericano de Metrología.

La importancia de tener una herramienta de difusión de la Metrologia en nuestra región fue vista por nuestros pioneros, cuando fundaron el SIM en 1979. Esa revista primigenia se llamó "Carta Metrológica". Su primer número salió de imprenta en agosto de 1979, publicándose 6 números, el último en abril de 1984. Por su comité redactor, pasaron quienes fueran los fundadores del SIM, entre ellos algunos presidentes como, Rafael Steimberg y Héctor Nava Jaimes. El contenido de la revista combinaba artículos de alto nivel técnico con notas de difusión de las actividades organizativas del SIM.

En el 2001, tras el relanzamiento del SIM, comienza a publicarse nuevamente un boletín informativo, ahora con el nombre de INFOSIM, del que presentamos ya su noveno número.

Paralelamente a la evolución de sus publicaciones, el SIM fue también evolucionando como Organización Metrológica Regional. En el nro 2 de Carta Metrológica se definía como objetivo del SIM: "*promover la cooperación entre los organismos competentes de los países participantes, para contribuir al perfeccionamiento de las actividades en las áreas de metrología legal, industrial y científica*".

El mismo objetivo sigue vigente hoy, pero las nuevas demandas tecnológicas en nuestros países y la necesidad de establecer acuerdos de reconocimientos con bases técnicas sólidas han ampliado esa idea original. Nuestro Plan Estratégico define hoy como misión del SIM: "*promover y soportar en las Américas una infraestructura de mediciones integrada, que posibilite a cada Instituto Nacional de Metrología estimular la innovación, la competitividad, el comercio, la defensa del consumidor y el desarrollo sostenible por medio de una participación efectiva en la comunidad metrológica regional*". De esta misión se deducen tres objetivos:

1. Desarrollar los Institutos Nacionales de

Dear friends

It greatly honors me to present this new issue of INFOSIM, a publication of the Sistema Interamericano de Metrología.

The importance of the means to spread the Metrology in this region was highly valued by our pioneers when they started the SIM in 1979. The original magazine, titled Carta Metrologica, published the first issue on August 1979, followed by 6 more, the latest on April 1984. The SIM founders actually contributed to the editorial board, Rafael Steimberg y Héctor Nava Jaimes among them. Its contents combined high technical level articles and news on the SIM organizational activities. In 2001, when the SIM restarted, the SIM informative bulletin resumed under the name INFOSIM, whose ninth issue is presented now.

On a parallel way to publications, SIM has being evolving as Regional Metrology Organization. The second issue of Carta Metrologica stated as SIM objectives "*to promote cooperation among the concerned organizations of the participating countries, aimed to contribute to the perfection of the activities dealing with legal, industrial and scientific metrology*".

The essence of that objective prevails today. Nevertheless, the new technological demands and the need of the mutual recognition arrangements have enlarged the starting idea. Today, our Strategic Plan states the SIM mission as "to promote and support an integrated infrastructure for measurements in the Americas, empowering the National Metrology Institutes to stimulate the innovation, competitiveness, trade, consumer rights and sustainable development by means of an effective participation in the regional metrological community". This mission launches three objectives:

1. To develop the National Metrology Institutes in the region.
2. To build up a robust organization.

Metrología en la región.
2. Construir una organización fuerte.
3. Cumplir con las obligaciones de una organización metrológica regional en el contexto del CIPM-MRA.

Para avanzar en el Objetivo 1, estamos desplegando acciones en tres planos: Metrologia para la Innovación, Metrologia para el Desarrollo Sostenible y Construcción de Capacidades. Estas acciones se sustentan en proyectos que cuentan con el apoyo del Banco Interamericano de Desarrollo (BID), la Organización de Estados Americanos (OEA), el PTB y el NIST.

Dentro del Objetivo 2, sobresale la concreción de un viejo anhelo: establecer al SIM como una entidad de derecho legal, que le de continuidad a la organización y una mayor autonomía para la ejecución de sus acciones. Esperamos concretar este enorme paso durante nuestra próxima Asamblea General en Montevideo.

El objetivo 3 ha merecido mucha atención de nuestra organización en los años recientes, debido a lo cual hemos consolidado un gran aprendizaje institucional que nos ha merecido el respeto de las organizaciones pares de otras regiones. La posición del SIM en la revisión del CIPM-MRA en curso busca fortalecer la necesidad de que este acuerdo mantenga los altos estándares de calidad actuales pero al mismo tiempo aumente la inclusión de los institutos en desarrollo.

En definitiva, el SIM es hoy una organización madura que sigue creciendo en la dirección correcta. Seguramente quienes fundaron el SIM nos miran con satisfacción. Lo que logramos es el fruto del trabajo y la cooperación de muchos metrólogos de nuestro continente a lo largo de casi 40 años. Los desafíos que enfrentamos requieren de la participación de todos. Invitamos a quien lee este INFOSIM a sumarse al trabajo por un SIM aún más grande.

Un cordial abrazo,

3. To fulfill the commitments as a Regional Metrology Organization within the CIPM-MRA framework.

To go along with the Objective 1, our actions are being performed along three axes: Metrology for Innovation, Metrology for Sustainable Development and Capabilities Building. These actions are realized as projects supported by the Interamerican Development Bank (IDB), the Organization of American States (OAS), the PTB and the NIST.

Concerning the Objective 2, the realization of the old desire to see the SIM as an entity legally constituted is highlighted. Achieving it will bring organizational continuity and a wider autonomy for performing our activities. We look forward to concrete this relevant step during our next General Assembly in Montevideo.

The objective 3 has deserved a lot of attention in the recent years, due to the consolidation of our learning that has called in the respect of our peers from other regions. During the CIPM-MRA review being done nowadays, the SIM position looks for strengthen the requirement of keeping the high quality standards, and, simultaneously, to increase the inclusion of NMIs under development.

Definitely, the SIM is now a mature organization that keeps moving up in the right course. We are sure that the SIM founders look at it with full satisfaction. Our achievements are due to hard work and cooperation among the SIM metrologists during almost 40 years. The challenges we face now demand the cooperation of everyone. We invite the readers of this INFOSIM issue to join our works looking forward an even greater SIM.

Heartly,

Héctor Laiz
Presidente del SIM

Developing Metrology in Small Island Developing States (SIDS) The Caribbean Community (CARICOM) Experience

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Abstract: *The development of metrology in the Caribbean has generally been adversely impacted by many of the specific social, economic and environmental vulnerabilities associated with their characterization as Small Island Developing States (SIDS). More specifically, in many countries of the Caribbean Community (CARICOM), whilst recognized by some of the major industries, metrology is often not high on the list of priorities for policy makers, and, is still more or less unknown to the majority of citizens, due in the main to the lack of awareness and appreciation of the impact of measurement science on their lives. Also, in addition to the limiting cross cutting theme of finance, many National Metrology Institutes (NMIs) are faced with the challenges of limited human and customer capital, weak regional transportation modalities, public misperception and the lack of suitable laboratory infrastructure. In order to address these challenges, the CARICOM NMIs have unified within the framework of CARIMET, the Caribbean sub-region of the Inter-American Metrology System (SIM) to pool assets and develop regional mechanisms to address the measurement demands across the region.*

Keywords: Metrology, CARIMET, CROSQ, SIDS, SIM

1. INTRODUCTION

Currently, the United Nations (UN) has identified three geographic regions;
1. the Caribbean,
2. the Pacific and
3. AIMS (the Atlantic, Indian Ocean, Mediterranean and South China Sea) as the location of Small Island Developing States (SIDS).

This paper presents an overview of the challenges being faced by the Caribbean Community (CARICOM) in the development of metrology capabilities in its Member States, the strategies being employed and lessons learnt in addressing them.

2. THE HISTORICAL AND ECONOMIC CONTEXT OF CARICOM

The sustainable development of Small Island Developing States (SIDS) continues to be a challenge for political leaders and policy makers. In addition to the issues faced by developing nations, SIDS grapple with peculiar vulnerabilities arising mostly from the disproportionate impact of expansive globalisation and climate change, insularity, high per unit transportation costs, limited natural resources and high import levels. Faced with these challenges many SIDS began banding together long before the term SIDS was coined. Seeing the potential benefits of cooperation along with the lessons learned from the British West Indies Federation, the political leaders of Barbados, Guyana, Jamaica and Trinidad & Tobago created the Caribbean Community and Common Market with the signing of the Treaty of Chaguaramas in 1973. Over the following three (3) decades the total number of signatories to this Treaty grew to fifteen (15). During this time the CARICOM Single Market and Economy (CSME) was established with the Grand Anse Declaration in July 1989 and the need for a revised Treaty was recognised. As a result, the Revised Treaty of Chaguaramas was signed on 5 July 2001 establishing the Caribbean Community (CARICOM).

CARICOM is made up of fifteen (15) SIDS of which 12 are the smallest economies of the 35 economies in The Americas as measured by their Gross Domestic Products (GDPs). The largest economy within CARICOM is Trinidad and Tobago followed by Jamaica [1].

Table 1. Gross Domestic Product of the Countries of the Americas [1].
(Members of the Caribbean Community (CARICOM) are highlighted in red.)

No.	State/Country	GDP (OER) in '000,000,000 USD (2014 est.)	No.	State/Country	GDP (OER) in '000,000,000 USD (2014 est.)
1	United States	$17 420	19	Trinidad & Tobago	$29.63
2	Brazil	$2 244	20	El Salvador	$25.14
3	Canada	$1 794	21	Honduras	$19.37
4	Mexico	$1 296	22	Jamaica	$13.92
5	Argentina	$536.2	23	Nicaragua	$11.85
6	Colombia	$400.1	24	Haiti	$8.919
7	Chile	$264.1	25	Bahamas, The	$8.649
8	Venezuela	$209.2	26	Suriname	$5.273
9	Peru	$208.2	27	Barbados	$4.277
10	Ecuador	$100.5	28	Guyana	$3.142
11	Cuba	$72.30	29	Belize	$1.666
12	Dominican Republic	$62.48	30	Antigua & Barbuda	$1.236
13	Guatemala	$58.30	31	Grenada	$0.839
14	Uruguay	$55.60	32	Saint Kitts & Nevis	$0.812
15	Costa Rica	$50.46	33	Saint Vincent & the Grenadines	$0.745
16	Panama	$44.69	34	Saint Lucia	$0.562
17	Bolivia	$34.08	35	Dominica	$0.514
18	Paraguay	$31.30	36	Montserrat	

In most of these countries the service based industries are the major contributor to GDP being the number one income earner for most countries with tourism, others such as banking and remittances also contributing significantly to GDP. Being former colonies, CARICOMSIDS have a long history of supplying natural resources such as sugar and spices to their respective metropolis and this tradition continues with industry in CARICOM being mostly focused on the supply of natural resources and raw materials, mostly agricultural and mining based, to developed nations. Manufacturing within CARICOM is mostly limited to five (5) countries, Belize, Guyana, Jamaica, Suriname and Trinidad & Tobago. Of these countries Trinidad & Tobago enjoys the largest share due to its indigenous source of fossil fuels. It is important to note that the Dominican Republic is not yet a member of CARICOM, although they have made a formal application to join which is under review. The Dominican Republic nonetheless is a part of CARIMET, the Caribbean sub-region of SIM.

The small size of the region's economies and limited demand for Quality Infrastructure (QI) has meant that in most CARICOM countries the National Standards Bureaus (NSBs) have responsibility for the four main pillars of QI (i.e. Standardisation, Metrology, Accreditation and Conformity Assessment). In most CARICOM Member States, both regulatory (legal) and non-regulatory (industrial) metrology services fall within the mandate of the NSB and there are different degrees of development between member states. In respect of scientific/research metrology, standards are adopted from the more advanced economies.

The variation seen in economic size and level of development of each country can also be seen in the maturity of the respective national metrology infrastructure. Jamaica has the longest history in developing metrology and the largest National Metrology Institute (NMI) within CARICOM, with over twenty-five (25) years of cooperation with the German NMI, PTB and assistance from other institutions such as the World Bank. Trinidad & Tobago, having the strongest manufacturing sector within CARICOM has been developing its NMI using national funds.

In all CARICOM SIDS the evolution of metrology has followed the historical pattern of the development of metrology as a service required to support the verification of conformance to regulations by the way of harmonized measurements in trade. In addition to the two aforementioned countries; other countries such as Grenada, Guyana and Saint Lucia have well-developed legal metrology programmes and growing industrial metrology services to support these legal metrology programmes. The remaining countries are at varied stages of development with The Bahamas and Suriname now working to establish their NMI within their respective National Standards Bureau.

2. CHALLENGES

Though there are unique challenges in each country which rules out the possibility of a "one size fits all" approach, many of the NMIs in CARICOM share similar challenges which can be resolved using regional initiatives. These common challenges are considered herein.

2.1 The Socio-Political Environment

As Developing States, the Governments of CARICOM SIDS have been mostly focused on grappling with economic shocks from the rapid expansion of globalisation, addressing energy demands and burgeoning public debt. As a result, the development of Quality Infrastructure including metrology has not yet become a high political priority. Conversely, many of the Governments in advanced economies have seen the vital link between metrology and the manufacturing sector and as such most of the advanced economies support the metrology programmes developed by their NMIs. These programmes are typically expensive to establish and maintain yet they support breakthroughs in other fields of science and spur innovation in manufacturing thereby justifying the investment in the NMI.

The social environment within which CARICOM NMIs operate also contributes to weak support for the development of metrology. This is due to the fact that the majority of citizens in CARICOM have low incomes and as a result are price conscious versus quality conscious. With this weak push from policy makers coupled with a weak pull from the public, Quality Infrastructure is usually forgotten until there is a crisis. However, there has been an increase in demand for calibrations and other QI services over the past five to ten years due to the increase in the number of companies in CARICOM that are implementing the ISO 9001 Quality Management System (QMS). These companies have recognised the role a functioning QMS plays in being more competitive in the international market and also in overcoming the technical barriers to trade (TBTs) that are silently working against them. This need for traceable measurements has been mostly driven by companies which are part of an international conglomerate, requirements from a franchisor or due to trade requirements with developed nations. It has been noted that the calibrations conducted for many of these companies are arguable more used to satisfy auditors rather than to improve the production process or quality of the final product.

The development of metrology is very resource-intensive and it has been accepted that the creation of a NMI requires significant monetary investment. The economic situation facing many CARICOM SIDS, due to decreases in their sources of income and increasing debt, has resulted in some countries finding it difficult to establish the industrial calibration services that are needed for national development. Additionally, some CARICOM NMIs are struggling to maintain the services that already exist. What makes the development of metrology even more challenging for SIDS is the fact that there is a limited or even declining amount of the other necessary domestic resources.

2.2 Human Resource Management

Critical to the success of any NMI is the hiring and retention of the scientists that are trained as metrologists. Within CARICOM there are not any dedicated metrology programmes or training courses available at any of the region's colleges or universities. As a result graduates with a natural science or engineering background are hired and trained on the job as metrologists. This training comes at considerable cost to the NMI, as training must be obtained either through programs are available outside of the country or by contracting external metrology experts to conduct training in country.

Notwithstanding these interventions and the increasing access to capacity building interventions from external sources such as the Inter-American Metrology System (SIM) and other NMIs, many CARICOM NMIs are challenged to retain the services of the professionals that they have trained. In the more industrialised CARICOM States, the small pool of scientists and engineers with a metrology background are highly prized by the manufacturing sector. This demand combined with the higher compensation packages available in industry has translated to a high rate of staff attrition at some NMIs. For example, one department in one CARICOM NMI that normally has twelve (12) metrologists on staff has lost seven (7) metrologists over the last five (5) years through normal means. This high staff attrition rate in many NMIs has restricted the development of certain metrology quantities as persons are continuously being replaced.

In addition to the financial cost of repeatedly training new scientists, these NMIs do not have the opportunity to build a strong technical reputation within SIM because of the changing representation at Metrology Working Group (MWG) activities. The risk of jeopardising the national and regional metrology development plans is further exacerbated when the NMI is small and has only two or three metrologists on staff. This limited number of metrologists forces each to be proficient in a wide number of metrology quantities and when one of these metrologists leaves this strikes a severe blow to the national and regional development plans. This was the case at one of the smaller CARICOM NMIs where there was one (1) senior metrologist and one (1) junior metrologist who both resigned within the span of two (2) years to fulfil personal and family obligations. At the time of his departure the competence of the junior metrologist was being developed using regional funds with the hope that he would one day become a regional resource in mass metrology.

2.3 Limited Client Base

From the establishment of the first NMIs in the late 19th century and throughout much of the 20th century, the NMIs of develop industrialised nations directly conducted calibrations for their industry clients. This changed in the 1970's when the number of calibrations being conducted overextended the NMIs. This gave way for the creation of private calibration laboratories that would serve the industry directly and obtain their calibrations, measurement traceability, procedures and recognition from the NMI. Although the number of calibrations done by the NMI would now be lower, each calibration done for the growing number of private calibration laboratory would serve as the reference for a large number of industrial calibrations [2]. As the number of private laboratories grew, prices were impacted by market forces and as a result each laboratory was spurred to increase its efficiency and competitiveness.

Similar to the early development of NMIs in advanced economies; the relatively new NMIs in CARICOM are now directly conducting industrial calibrations. However, with a small manufacturing sector in most CARICOM States there is very little potential for the workload of the NMIs to increase to the point of spurring the creation of national calibrations laboratories. Without this bridge between the NMI and the industry client, the cost of establishing and maintaining the metrological references, the national measurement standards for each quantity must be spread across the limited industrial clients. This limited client base makes the calibration costs comparatively higher than that offered by private calibration laboratories in developed countries. Even in the case where industrial clients in CARICOM are forced to use calibration services from outside the region they must bear either the freight costs to transport the artefacts or the travel and accommodation costs for the foreign metrologists to conduct in situ calibrations. This higher cost to the manufacturing sector in CARICOM contributes to the already high costs of production and operation potentially making Caribbean products less competitive.

2.4 Availability of Suitable Laboratory Infrastructure

The expansion of NMIs within the Caribbean sub-region of SIM (CARIMET) from legal metrology into industrial metrology means that metrology laboratories need to be established. These laboratories must be equipped with the requisite measurement standards and maintained within specific climatic requirements. The majority of CARIMET NMIs are presently housed in older buildings that were not designed with metrology in mind. These NMIs are currently in need of a significant capital investment in order to construct a new building or carry out significant retrofitting on the existing buildings.

Efforts to establish mass and length metrology laboratories within CARIMET have highlighted a lack of the necessary heating, ventilating and air-conditioning (HVAC) expertise in the Caribbean. Most Caribbean companies offering HVAC services have experience providing solutions for offices but not for laboratories requiring such precise temperature and humidity controls.

The maintenance of these laboratories has also been a challenge to the NMIs mostly due to the unavailability of local technicians to service the equipment. Most metrology equipment is very intricate in nature involving technologies that are the proprietary right of the manufacturer. This usually means that maintenance and repairs must be done by specialist technicians located outside of the Caribbean. This significantly increases the cost to CARIMET NMIs as they must either ship the equipment to the manufacturer or pay for the technicians to travel to the NMI.

Another factor affecting the maintenance of the laboratories is the geography of CARICOM SIDS especially those in the Eastern Caribbean. Many of these NMIs are situated within low-lying coastal towns affected by the negative impacts of climate change. The increasing occurrence of natural disasters in some of these countries has significantly impacted national debt leaving the NMIs with diminished budgets. Even without this threat, the harsh salt air from the nearby sea reduces the usable life of equipment such as the condensers for the air-conditioning units.

2.5 Weak Regional Transportation Infrastructure

Development of metrology within CARICOM has also been affected by the limited transportation infrastructure in the region. Land based travel between CARICOM Member States is only limited to Guyana and Suriname, sea travel is limited to small ferries between certain countries mostly in the Eastern Caribbean and the cost of air travel is high. In some cases it is cheaper to travel to developed nations such as the United States, Canada, England and Germany rather than to other CARICOM countries. In the past this issue was a major obstacle to information sharing between NMIs and even with the advent of modern communication technology this high cost of travel increases the cost of technical cooperation between CARICOM NMIs.

In recent years this lack of suitable inter-island transportation has resulted in significant damage to measurement artefacts being transported for calibration. With limited available commercial couriers, a number of CARIMET NMIs use international couriers only to find that their artefacts are destroyed during inspection at the couriers' logistics hubs. This issue almost ended the first CARIMET Inter-Laboratory Comparison in Mass Metrology in 2010 and later was the reason for Guyana having to replace one of its national mass sets, see Figure 1.

Figure 1. Damage sustained by a 2 kg mass piece shipped outside the region.

2.6 The Public Perception of the NMI as a Regulator

At independence most Caribbean SIDS inherited a system of weights and measures that was regulated by the Police. Post-independence Member States transferred these powers to the National Standards Bureaus and pursued a course of economic development which including preferential trade agreements and protectionist measures to promote the growth of their fledging manufacturing sectors. This national focus meant that the processes that were developed though similar still have elements that vary from Member State to Member State. From that time until the late 1990's the National Standards Bureaus built a strong reputation as regulators through their active role in standards development and enforcement, legal metrology inspections and conformity assessment of products. This reputation of policing has however presented some drawbacks which have impacted the effectiveness of the development of metrology. Because of this reputation there is

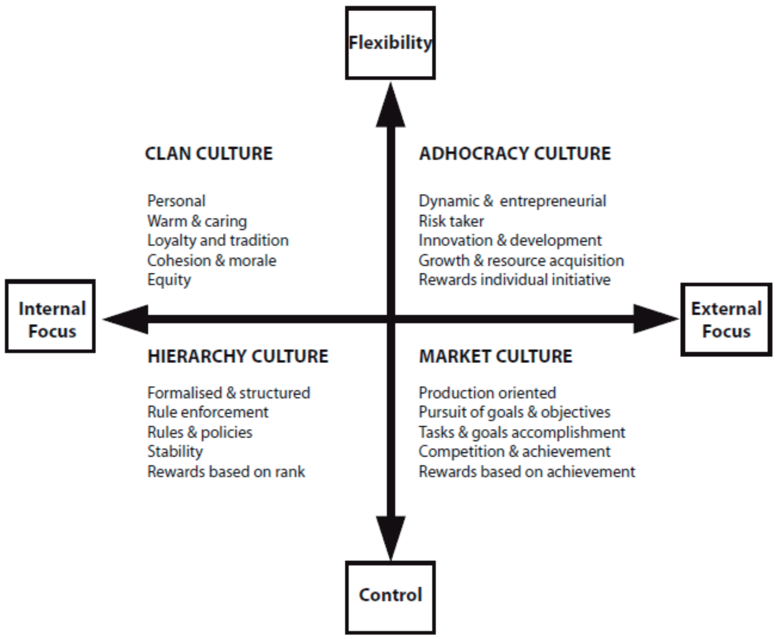

Figure 2. The competing values framework of organisational culture (Bradley and Parker 2001).

reluctance from private companies to share information about their operations or cooperate with the NMI which in the CARICOM context is the NSB. This has resulted in metrology services being developed that are underutilised in many countries because of reluctance on the part of the private sector to utilise the services of the NMI or due to limited market demand data.

2.7 Public Sector Culture

The culture of any organisation has a significant impact on its performance and on its employees [3]. Organisational culture in this sense refers "to the climate and practices that organisations develop around the handling of people, or to the espoused values and credo of an organization" [3]. According to the classification of organisational culture proposed in Bradley and Parker's (2001) Competing Values Framework (CVF) most CARICOM NMIs have a hierarchical culture emanating from being a part of the public service, see Figure 2. This culture creates an internal focus and coupled with being regulators, the NMIs have inherited a culture of clients be required to come to them instead of them having to focus on their client's demands. As a result, many NMIs do not have a good understanding of the actual demands of the market and many programmes are developed based on instructions from the political directorate, perceived demands or areas of interest to the NMI.

Additionally, the controlled structure of this organisational culture at many CARICOM NMIs coupled with the expensive artefacts and standards has created a fear of failure on the part of the metrologists. This is seen in reluctance on the part of some regional metrologists to experiment with the equipment, try new methods on their own, research or carry out operations outside of the established routine.

3. STRATEGIES

Considering the afore mentioned challenges the CARIMET NMIs have taken a position to strengthen metrology by using the following strategies.

3.1 Regional Support Mechanisms

As a response from CARICOM to promote sustainable production and trade of goods and services in the CSME, the CARICOM Regional Organisation for Standards and Quality (CROSQ) was created in February 2002 and given the mandate under Article 67 of the Revised Treaty of Chaguaramas to facilitate the development of regional standards, promote the harmonization of metrology systems and through that support the sustainable production and trade of goods and services in the CSME. The CROSQ Secretariat is located in Warrens, Barbados and is managed by a Chief Executive Officer (CEO) and governed by a Council made up of the fifteen (15) Directors of the region's NSBs/NMIs.

3.1.1 The Signing of the International Committee on Weights and Measures Mutual Recognition Agreement (*CIPM-MRA) as a Bloc of Nations*

As the regional pioneer in establishing a NMI it was understandable that Jamaica would actively pursue becoming a signatory to the CIPM-MRA and this was done on 21 July 2004. In the following year, on 12 October 2005, CROSQ signed the CIPM-MRA on behalf of the remaining eleven (11) established NMIs. This arrangement as a bloc of nations is unique to CARICOM and affords the Member States the benefit of sharing the financial obligations of being a signatory. Unfortunately, the region has not been able to fully utilise all the benefits afforded as signatories.

3.1.2 Adoption of CARIMET as a Special Committee of CROSQ

The region's next strategic move to support the development of metrology on a harmonised regional level was the adoption of CARIMET, the Caribbean sub-region of the Inter-American Metrology System (SIM), as a special committee of CROSQ. This was done at the twelfth (12th) meeting of the CROSQ Council held in Bridgetown, Barbados on 9-10 April 2008. Through this mechanism, CARIMET is able to access financial and administrative support from the CROSQ Secretariat. With this development CARIMET has been able to link the national goals of individual member states within the framework of a harmonised regional metrology system utilising SIM as the link to the international metrology system.

Using its position as an inter-governmental organisation representing the region, CROSQ has been able to leverage regional and donor funds to make interventions aimed at developing metrology as the region expanded out of a heavy standardisation focus. In order to access funding and technical assistance, CROSQ formed strategic relationships with such regional institutions as the Caribbean Development Bank (CDB) and the Inter-American Development Bank (IDB) and international institutions such as the German NMI PTB and the European Union (EU). These relationships however have not solely been for accessing donor funding but also have allowed CROSQ to use regional metrology expertise to guide bilateral interventions being implemented by these development partners.

3.1.3 Creation of the Position of Technical Officer of Metrology

To assist in coordinating the metrology development activities of CROSQ and the harmonisation of metrology processes in the region's NMIs, the CROSQ Secretariat created the position of Technical Officer of Metrology and hired a regional expert to fill this position in 2010. In addition to undertaking tasks assigned by the CEO of the CROSQ Secretariat, the Technical Officer of Metrology serves as a technical resource for the Member States providing them with guidance on technical topics or identifying suitable experts and resources that can assist with their national development plans. The Technical Officer of Metrology also serves as the Technical Secretary of CARIMET and is responsible for monitoring the progress of CARIMET activities, reporting on these activities to the CROSQ Council and providing the CARIMET Coordinator with administrative support as required.

3.1.4 Cooperation with the Dominican Republic

On 22 August 1998 the Dominican Republic and CARICOM signed an agreement establishing the free trade area between the two parties. Seven years later the Dominican Republic took action to strengthen this relationship by applying to become the 16th member of CARICOM. Although the Dominican Republic is not yet a member of CARICOM, the process of regional integration has continued within the framework of the Caribbean Forum (CARIFORUM) of the African, Caribbean and Pacific States (ACP). As a result, CROSQ began to collaborate with the Dominican Directorate General of Standards and Quality Systems (DIGENOR) which has since been replaced with the Dominican Institute for Quality (INDOCAL). This collaboration started with cooperation in the German Federal Government funded projects administered by the PTB and grew into INDOCAL being regular invitees to attend the Meeting of the CROSQ Council. In 2011, CROSQ, INDOCAL and PTB partnered to develop the 10th European Development Fund Caribbean Regional Indicative Programme (EDF-CRIP) Economic Partnership Programme Technical Barriers to Trade (EPA-TBT) Project which is now being jointly implemented by all three parties. In metrology, INDOCAL cooperates with CROSQ by actively participating in CARIMET. This has included assisting in shaping the CARIMET Strategic Plan for 2016-2020, participating in capacity building activities, hosting regional and international metrology fora and offering to host the Caribbean Reference Laboratory (CaRL) for Electrical Power Measurements. A system of reciprocating administrative support and mutual respect has fostered strong professional ties between CROSQ and INDOCAL.

3.1.5 Increased Participation in SIM

For many years, SIM has been and continues to be an important ally in the development of metrology in CARICOM. Not only because of the many training initiatives that are executed by SIM but also because of the atmosphere of camaraderie and technical assistance that permeates the organisation. Through SIM, CARIMET NMIs has benefited from bilateral assistance rendered from other NMIs.

CARIMET NMIs have relied on funding from the Organisation of American States (OAS) administered through SIM to support their participation in SIM activities however as funding from the OAS decreased so did CARIMET participation. As CARIMET implements its strategic plan for 2016-2020 (see 3.1.6), SIM's role will be even more important than before. This plan includes more active representation at the SIM Quality Systems Task Force (QSTF) and MWGs and increasing the number of submissions from CARIMET NMIs to the SIM-QSTF. As a result, additional funding must be allocated from national and regional initiatives to ensure the increased participation of CARICOM NMIs in SIM. Seeing this need, the 10th EDF-CRIP EPA-TBT Project was conceptualised to use CARIMET as the Technical Implementation Group (TIG) for the metrology component. In return for CARIMET's assistance in planning the annual operating plan for the project, the project partially supports the NMI's attendance at the SIM General Assembly and other MWG activities that are considered to be of regional importance. In recent years this partial funding has been graciously met with counterpart funding from the US National Institute of Standards and Technology (NIST) for the SIM General Assembly and SIM counterpart funding for the MWG meetings and training interventions thus guaranteeing the participation of CARIMET NMIs.

3.1.6 CARIMET Strategic Plan 2016-2020

In 2010, CARIMET recognised the need for a structured approach to the regional development of metrology which led to the creation of the first CARIMET Strategic Plan in Frigate Bay, Saint Kitts & Nevis in 2011. With the expiration of this first plan in 2015, CARIMET took the lessons learned from this plan to develop a more pragmatic plan for 2016-2020. Using this 2016-2020 Strategic Plan CARIMET hopes to bring the benefits of metrology into the mainstream of Caribbean industry and society.

3.2 Development of Regional Metrologists

Over the years, CARIMET has pursued various options to develop the competence of the regions metrologists. Many have benefited from training interventions organised by CROSQ or by Regional Metrology Organisations (RMOs) such as SIM and EURAMET. In addition to bilateral assistance within SIM there has been regional training provided by other more developed NMIs such as the German National Metrology Institute (PTB), the Mexican National Metrology Centre (CENAM), the Brazilian National Institute of Metrology, Quality and Technology (INMETRO), the Argentinian National Institute of Industrial Technology (INTI), the Peruvian National Institute of Quality (INACAL) and the US National Institute for Standards and Technology (NIST).

As the regional competence in metrology is improved by external interventions there has been an increase in the number of capacity building activities planned and implemented within CARIMET. In addition to planning workshops on topics of regional interest there has been an increase in the number of NMIs sending their experts to train other NMIs and also, the attachment of metrologists within CARIMET NMIs.

3.2.1 CARIMET Capacity Building Programme in Metrology

Metrology is a multifaceted science starting from the scientific theory and research that forms the basis for the realisation of measurements, to the application of these measurement standards to real world situations, the maintenance of adequate laboratory facilities and equipment, the statistical calculations that are required to instil confidence in the quality of the measurement taken and all the records and documentation that must be created and maintained. Appropriately then, the development of competence in metrology requires a varied approached to knowledge transfer. As a result, the CARIMET Capacity Building Programme in Metrology was conceptualised to combine workshops, work attachments and short term consultancies with the aim of stimulating the most professional growth within the shortest possible time

The aim of this programme is to simultaneous develop a cadre of regional experts in three (3) areas. In the first instance the areas of Mass Metrology, Thermometry and Volumetry will be developed within a period of one (1) year. Fifteen (15) metrologists will be selected from all CARIFORUM States, through a competitive application process to form three (3) groups of five (5) metrologists each focusing on one area.

3.2.2 Inter-Laboratory Comparisons

Inter-Laboratory Comparisons are important tools in demonstrating the equivalence and competence of measurement capabilities of different NMIs. By comparing their results with other NMIs, this allows the laboratories to identify any deficiencies or areas for improvement after which they can take the required action. For the metrologist this is also an important for demonstrating his/her competence in comparison with his peers and can be an important learning and confidence building tool. This demonstration of the technical and professional competences of metrologists is critical for their development to the point of being considered “experts” in their respective areas of focus. Within CARIMET the largest two (2) NMIs, the Bureau of Standards Jamaica (BSJ) and the Trinidad & Tobago Bureau of Standards (TTBS) have been actively participating in comparisons planned by SIM and other RMOs in areas of national importance. CARIMET knowing the value of these comparisons and recognising the need for other CARIMET NMIs to participate in comparisons began to plan its own.

The first CARIMET comparison, SIM-M.M-S7: Interlaboratory Mass Comparison between Laboratories Belonging to CARIMET [4] was conducted between 2009 and 2010 and involved seven (7) CARIMET NMIs. For five (5) of these NMIs it was their first time participating in a comparison published on the International Bureau of Weights and Measures (BIPM) Key Comparison Database (KCDB). The pilot laboratory was the BSJ and since this was their first time in this role as pilot laboratory the then Chair of the SIM Mass & Related Quantities Working Group (MWG 7), Mr. Francisco Garcia of Chile’s Centre of Measurement Studies and Quality

Certification (CESMEC) served as coach. The results are shown in the Figure 3.

The second CARIMET comparison that is now being implemented is the CARIMET Comparison at 20 Litre Volume. This comparison has a total of nine (9) CARIMET NMIs and CENAM will be providing the link to the BIPM KCDB. Additionally, invitations have been extended to the Kenya Bureau of Standards (KEBS) and the Cuban National Research Institute of Metrology (INIMET). The BSJ is also the pilot laboratory for this comparison and they are being coached by Mr. Roberto Arias of CENAM.

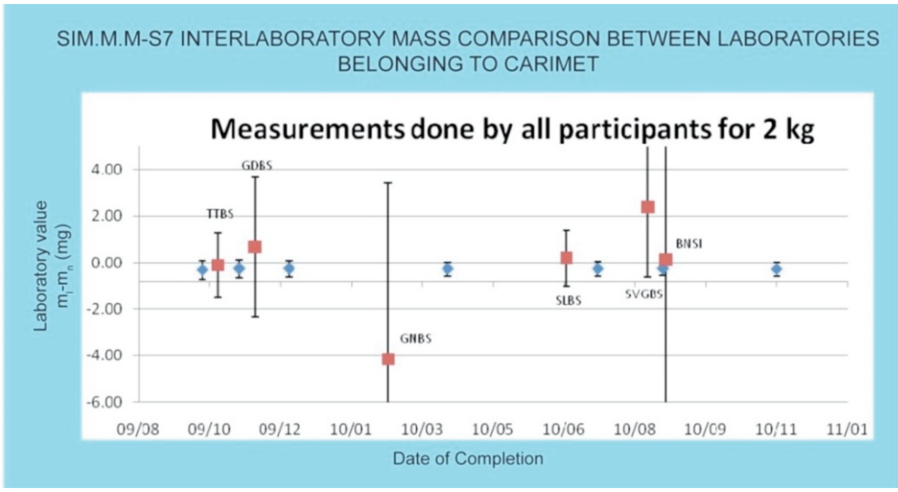

Figure 3. The 2 kg results of SIM.M.M-S7 supplementary mass comparison

3.3 Regional Cooperation Schemes

The individual markets of most Caribbean countries are too small to sustain all the calibration services required to support trade. As a result, private investors have no interest in establishing calibration laboratories in many of these islands leaving the manufacturing sector looking to the Government for support. In order to ease the burden on individual states and assist in accelerating their access to metrology services two (2) regional cooperation schemes have been conceptualised and are now being implemented.

3.3.1 Caribbean Reference Laboratory (CaRL) Scheme

In order to ensure the traceability of their national reference standards to the International System of Units (SI), each CARICOM NMI would independently try to identify the most cost effective calibration service provider. This could either be another NMI or a private calibration laboratory. In an attempt to ensure that the national reference standards in all NMIs are calibrated by another NMI and at the same time reduce the cost of these high level calibrations the concept of the Caribbean Reference Laboratory (CaRL) was developed in 2010.

A Caribbean Reference Laboratory, (CaRL), is a metrology laboratory within a National Metrology Institute (NMI) or Designated Institute (DI) in CARIMET recognized by the CROSQ Council as a regional reference laboratory providing traceability for a measurement quantity within a defined scope. This capability must be demonstrated by either internationally recognized accreditation and/or the publication of the laboratory's Calibration and Measurement Capabilities (CMCs) on the BIPM KCDB.

The development of CaRLs first starts with the identification of areas of demand based on the requests for support from all the NMIs within CARICOM. Once a metrology quantity is identified as requiring a regional reference, expressions of interest are then made to CARIMET from those who have the capability or potential to serve as the CaRL for this measurement quantity. An NMI or NMIs (depending on the interest and demand for this service) are then selected by CARIMET for development and ratified by the CROSQ Council based on the technical competence of the metrologists working in each laboratory, the level of development of the existing service, and the sustainability of that service based on the NMI's own national demand. Regional funds are then allocated to complement the national development plans for each laboratory. After receiving international recognition for their measurement capability each laboratory would then be official recognised as a CaRL by the signing of a Memorandum of Understanding (MOU) between the parent NMI and the CROSQ Council.

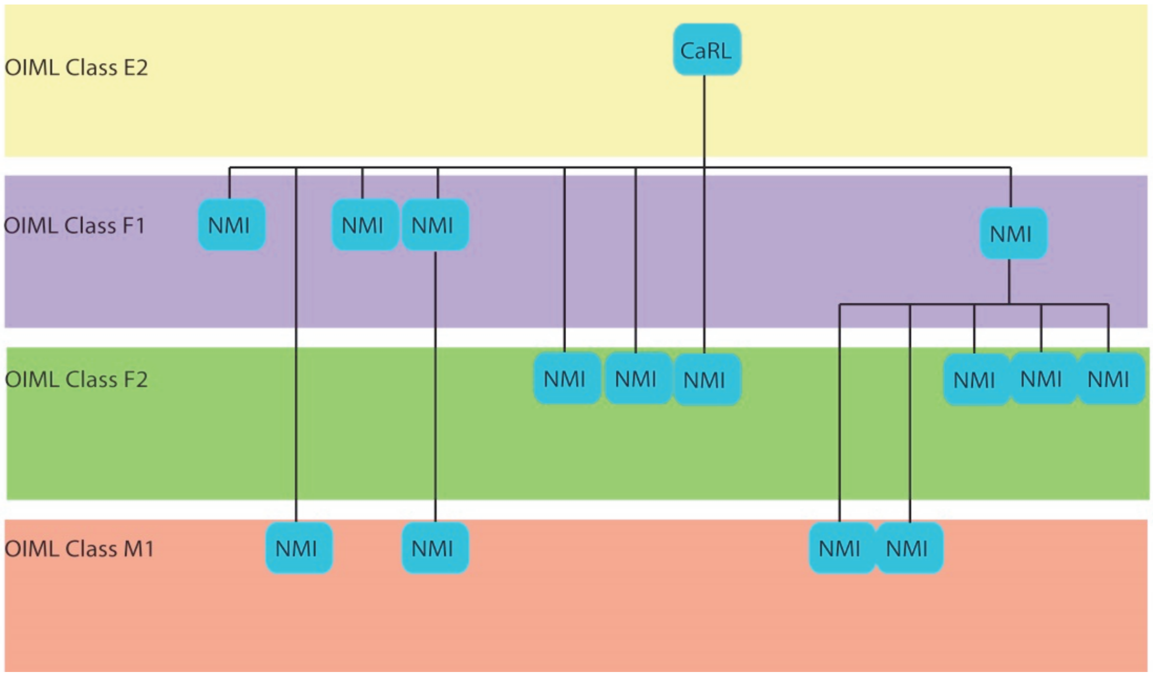

Figure 4. Map of the Planned Utilisation of the Mass CaRL

If we treated the unified CARICOM region as one nation then in this model, the CaRL would be operating as the NMI for the region. This would therefore allow each NMI to operate like a national calibration laboratory and focus on fulfilling only the sustainable demand within their country. Any demand outside of this scope could then be cared for directly by the CaRL.

On 1 February 2013, the Mass Laboratory of the BSJ was recognised as the region's first CaRL. This was to provide mass calibrations for the range 1mg to 20 kg according to OIML Class E2. Since that time the BSJ has been having challenges with the environmental climate control in the laboratory and the scope has been downgraded to OIML Class F1. However, the BSJ is taking corrective action and with a national project funded by the World Bank they plan to have the service restored to OIML Class E2 within two (2) years.

Two (2) more CaRLs are currently being developed and there are plans for the development of three (3) more CaRLs in the short to medium term. The two (2) laboratories currently being developed with funding from the 10th EDF-CRIP EPA-TBT Project are the thermometry laboratory at the TTBS and the Volumetry laboratory at the BSJ. Technical Assistance for the development of these two (2) CaRLs is being kindly provided by fellow SIM NMIs. The SNM–INDECOPI has kindly provided their thermometry expert; Mr. Edwin Guillen to guide the TTBS in the development of the Thermometry CaRL and NIST has provided Dr. John Wright as a resource for the Volumetry CaRL at the BSJ. The development of a CaRL for Electrical Power Measurements at INDOCAL and the Pressure and Humidity CaRLs at the TTBS are in the early planning phase.

3.3.2 Mobile Calibration Service

The first indication of the need for a regional mobile calibration service was that most CARIMET NMIs own a large number of 20 kg and higher weights procured using their own national funds or through support from development partners. For example in 2012, twenty (20) 20 kg weights along with two (2) 50 kg weight baskets totalling 500 kg were delivered to the CARIMET NMIs through support from the German Government funded project entitled "Establishment of a demand-oriented and regionally harmonized quality infrastructure in the Caribbean" which was being implemented by PTB. In addition to these 20 kg and 50 kg weights, most NMIs already owned a number of metric and in some cases imperial weights. These weights all require regular calibration in order to maintain their traceability to the SI. Without this traceability, the use of these weights is almost pointless as there is no documented means of proving the acceptability of the values. In many cases these weights go uncalibrated due to the undeveloped national mass metrology service and the economic infeasibility of shipping a large number of 20 kg weights to Jamaica, Trinidad & Tobago or elsewhere for calibration.

In an attempt to ensure the traceability of these weights, a mobile calibration service for 20 kg and 50 kg masses up to OIML Class M1 will be developed at the Saint Lucia Bureau of Standards (SLBS). This service will have international recognition through either accreditation from a recognised Accreditation Body or through the CMCs being published on the BIPM KCDB. The preferred route will be to utilise the systems within SIM to support the publishing of CMCs.

Two (2) mass metrologists from the SLBS who fulfil pre-established criteria will be further trained in the performance of this service; it will be preferable to support this infrastructure with attaches' from other NMIs in due course. These technicians must already possess a strong competence in handling mass metrology weights and equipment and must be available to travel to other regional NMIs to conduct the calibrations.

In addition to this mass metrology service other calibration services will be developed as a regional need is identified.

3.4 Technical Assistance with Laboratory Climate Control Specifications

In order to establish the required laboratories within CARIMET NMIs it will be necessary to either construct new buildings or retrofit the existing building. To support all NMIs with this process technical assistance is being provided through CROSQ to NMIs that are now being built or retrofitted. The lessons learned, specifications developed and contacts made in assisting these NMIs would then be compiled and made available to all the other NMIs.

3.5 Engagement of Regional Customs Agencies and Airlines

In an attempt to ensure the safe transportation of national standards sent overseas for calibration CROSQ has made direct representation on behalf of CARIMET to both major regional airlines and also to the grouping of CARICOM Customs Agencies. Although the two previously mentioned incidents of damage were experienced when the artefacts were outside of the region, the representation to the Customs Agencies was only a formal action meant to reinforce the delicate nature of the national standards. However, there is already a strong relationship that exists throughout the region between each Customs Agency and their respective NSB/NMI and the risk of damage at this stage is low.

As the CaRL and other regional work sharing schemes grow and as the number of CARIMET comparisons increase, it is anticipated that there will be an increase in the number of measurement artefacts that need to be transported within the region. In order to reduce the need for artefacts to be transhipped through the United States, CARIMET has decided that it will use the cargo services of both regional airlines as much as is possible to transport measurement artefacts. The intention behind the representation made to both major airlines was to educate them on the sensitive nature of the measurement artefacts and the importance of their safe transportation. This system has since been tested with one (1) of the airlines and there has been positive feedback from the three (3) NMIs who safely received artefacts.

In an attempt to address the issues outside the region, the CROSQ Secretariat sought guidance from NIST as to the methods they use to ensure the safe transportation of their artefacts. With guidance from the NIST Shipping Department, each CARIMET NMI was provided with a list of recommendations including a list of preferred couriers that are utilised by NIST. By implementing these recommendations provided by NIST it is envisaged that the incidents of damage will be reduced.

3.6 Development of Regional Marketing and Communications Strategy and Action Plan.

With the national perception that the CARICOM NMIs are a standards-setting regulator with the power to detain products and shut down manufacturers it has been difficult to accurately determine the true needs of the manufacturing sector and this makes it challenging for the NMIs to develop sustainable calibration services. To assist in changing this perception a regional Marketing and Communications Strategy and Action Plan was developed by the Marketing, Information, Knowledge and Education (MIKE) Committee of the CROSQ Council [5]. This plan entails two (2) fundamental strategies, the first one being a direct engagement of the national stakeholders by assigning at least one (1) dedicated person to the building and maintaining of the relationship between each stakeholder group. This person would also be responsible for building outreach to these groups in order to gain consensus, support and agreement on interventions being planned. Critical to this strategy's success is a structured stakeholder management system. The second (2) strategy is a mass communication strategy focused at the end users of metrology services geared towards repositioning the CROSQ and national NMI brands in a favourable light. The effectiveness of this strategy hinges on the NMI's ability to clearly connect real market needs with impactful metrology solutions combined with appropriate messaging and branding.

3.7 Collection of Demand Data

In order to ensure the sustainable development of metrology services it is critical that each NMI understands the demand for their services. Since most CARIMET NMIs had no data on the actual calibrations needs in their respective country there must be a concerted effort on their part to collate this data. Although it was possible from the beginning to gather this information using an external consultant it was thought that since this would have to be an activity that must be periodically repeated it would be best if it were undertaken at a national level by the NMI. In an attempt to stimulate the collection of this data the 10th EDF-CRIP EPA-TBT project began the procurement of equipment for those Member States who had completed and submitted this data to the CROSQ Secretariat. Through this process in combination with some assistance for a few Member States where resources were particularly low, the Project was able to get an understanding of the demand in all CARICOM countries.

4. LESSONS LEARNED

The following are the major lessons learned over the last five (5) years of developing a regional metrology system:

i. *The strength of the regional metrology system is the national capabilities.*

ii. *Regional activities must be developed in such a way that they are not perceived by the NMIs as additional work but as beneficial steps leading to the success of national development plans.*

iii. *An inclusive approach at the planning stage regardless of the NMIs' level of development creates greater buy-in and is educational for the lesser developed NMIs.*

iv. *The management of strong relationships at all levels within the NMIs is critical to the success of regional cooperation.*

v. *The administration of all benefits must have clear criteria and a transparent process.*

5. CONCLUSION

Notwithstanding the fact that the global metrology community has over a century of history in the development of NMIs with empirical data demonstrating the contribution of metrology to economic and social sustainable development, the development of metrology in CARICOM SIDS continues to prove challenging to individual Member States and as a result a regional approach has been developed. This plan has at its core the identification of the demand for calibration services in each country and then developing sustainable calibration services in each country and using regional mechanisms to meet those needs that cannot be met nationally. In the case of CARICOM, the following summary of challenges and strategies to overcome these challenges can be made:

1) The Socio-political environment which places metrology low in the order of priorities at both a governmental and consumer level is being addressed by developing regional support mechanisms. These have included signing the CIPM-MRA as a bloc of nations, the adoption of CARIMET as the metrology special committee of the CROSQ Council, the creation of the regional position of Technical Officer of Metrology to coordinate the regional development of metrology and the increased participation in SIM.

2) The development and management of the metrologists in the region is being addressed by the implementation of regional capacity building initiatives to ensure that a pool of skilled metrologists is available for the region. Additionally, inter-laboratory comparisons are being used to strategically build competence and confidence and also to demonstrate the technical capability of CARIMET.

3) Developing sustainable calibration services has proved to be a challenge to many countries due to the limited number of industrial clients in each country. As a result NMIs are being developed to address those demands that are sustainable and to complement this CARIMET is developing regional resource sharing and cooperation schemes. These schemes are the Caribbean Reference Laboratory (CaRL) which establishes a cost-effective entry point for traceability into the CARICOM region and the mobile calibration services that will enable one (1) NMI to perform calibrations throughout the region on behalf of the home NMI where an international recognised service is not available.

4) The detached geographical nature of SIDS presents more transportation challenges than countries that share a land border. In the case of CARICOM there is a weak regional transportation infrastructure and this has made the calibration costs for national standards higher and also increases the risk of damage to these standards. As a result it has been important to ensure that the standards that are being shipped from one CARIMET NMI to another do not have to be transhipped outside of the CARICOM SIDS. To assist in this endeavour the two (2) major regional airlines have been directly engaged as the preferred means of shipping artefacts and the Customs Agencies have been engaged to ensure measurement artefacts are not damaged during inspection.

5) To address the negative image of the NMI as regulator intent of closing down manufacturers the region has developed a regional Marketing and Communications Strategy and Action Plan to guide the Member States.

6) The culture inherited from being a part of the public service can only be corrected by directly engaging the stakeholders at a national level. As a result considerable effort has been placed on encouraging each NMI to engage the manufacturers in order to determine the true needs and to continuously repeat this process.

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Comparación SIM-CAMET para volumen de líquidos de 100 ml y 5 ml

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Resumen: *Este artículo presenta los resultados obtenidos por seis Institutos Nacionales de Metrología (INMs), participantes en una comparación para volumen de líquidos en donde se utilizan dos matraces volumétricos de 100 mL y dos pipetas volumétricas de 5 mL con una línea de graduación o aforo como patrones de transferencia. Se aplica el método gravimétrico para la determinación del volumen y se estima la incertidumbre de medida de los resultados de cada uno de estos artefactos. De igual manera, se realiza un análisis estadístico de las mediciones obtenidas por cada uno de los patrones de transferencia, para evidenciar la consistencia o no de los resultados.*

Palabras clave: Comparación de volumen de líquidos, calibración de matraces volumétricos, calibración de pipetas volumétricas.

1. INTRODUCCIÓN

Esta comparación se realiza en el marco del "Programa Regional de Apoyo a la Calidad y a la Aplicación de Medidas Sanitarias y Fitosanitarias en Centroamérica"(PRACAMS), financiado por la Unión Europea, con el fin de comparar los resultados obtenidos en cada una de las mediciones de volumen de los laboratorios participantes de CAMET, utilizando dos matraces volumétricos de 100 ml, fabricados de acuerdo con ISO 1042 [1] (ver figura 1), y dos pipetas de 5 ml con una sola línea de aforo fabricadas de acuerdo con ISO 648 [2] (ver figura 2).

El principal objetivo de la comparación fue proporcionar evidencia que apoye las capacidades de calibración y medición (CMCs) de los laboratorios participantes.

Figura 1. Matraces volumétricos de 100 ml.

Figura 2. Pipeta de 5 ml, con una marca de aforo.

Los cuatros patrones de transferencia (TS por sus siglas en inglés) fueron fabricados de vidrio borosilicato con un coeficiente de expansión térmica cúbico de $9{,}9 \times 10^{-6}\,K^{-1}$.

Cada uno de los patrones de vidrio, fue identificado de manera única, como se detalla en la Tabla 2.

Tabla 2. Identificación asignada a cada patrón de transferencia utilizado en la comparación.

Descripción	Identificación
Matraz volumétrico de 100 ml.	01.15
Matraz volumétrico de 100 ml.	03.03
Pipeta de 5 ml, con una línea de aforo.	4
Pipeta de 5 ml, con una línea de aforo.	7

Protocolo

En junio de 2014 en la Ciudad de Panamá se llevó a cabo la reunión de apertura de la comparación, en la cual participaron los representantes de cada INM interesado. En esta reunión se aprobó el protocolo basado en las directrices del Buró Internacional de Pesas y Medidas (BIPM) y se planificó la agenda de la comparación, dando inicio en junio 2014. El término de la comparación fue en el mes de agosto 2014.

Durante la reunión de inicio se acordó que cada participante tendría un período de una semana para recibir las pipetas y matraces, realizar las mediciones y llevar personalmente los dispositivos de transferencia al siguiente INM participante; excepto el laboratorio piloto, que tendría dos semanas al inicio y dos semanas al final de la comparación con el fin de verificar la estabilidad de los patrones viajeros.

El laboratorio CENAMEP AIP, fue designado como laboratorio piloto para esta comparación, por lo que fue el encargado de realizar las mediciones para matraces y pipetas al inicio y al final de la ronda de medidas entre los diferentes INMs participantes.

La comparación se realizó de acuerdo con el programa que se muestra en la Tabla 1.

Tabla 1. Calendario e INMs participantes

N	INM/País	Contacto	Fecha de recepción
1	CENAMEP AIP/ Panamá	Yanisareth Chow Orlando Pinzón	2014-06-16
2	CIM/ El Salvador	Douglas Brito	2014-06-30
3	LACOMET/ Costa Rica	Luis Damian Rodriguez	2014-07-07
4	CENAME/ Guatemala	Darwin Jocholá	2014-07-14
5	CEHM/ Honduras	Wendy Chinchilla	2014-07-21
6	LANAMET/ Nicaragua	Mainor Ortega	2014-07-28
7	CENAMEP AIP/ Panamá	Yanisareth Chow	2014-08-04

2. MATERIALES Y MÉTODOS

Para determinar la cantidad de agua que entregan las pipetas o la cantidad de agua que contienen los matraces se utilizó el método gravimétrico, en donde cada laboratorio participante podría utilizar el modo de pesada directa o simple sustitución, ajustando a la temperatura de referencia de 20 °C de acuerdo con la norma ISO 4787 [3], tomando como modelo la ecuación (1).

$$V_{20} = (I_l - I_E) \times \frac{1}{\rho_W - \rho_A} \times \left(1 - \frac{\rho_A}{\rho_B}\right) \times [1 - \gamma(t - 20)] \quad (1)$$

Donde:

V_{20} volumen a 20 °C, expresado en mL

l_l indicación de la balanza cuando se coloca sobre ella el recipiente lleno de líquido, expresado en g

l_E indicación de la balanza cuando se coloca sobre ella el recipiente vacío, expresado en g

ρ_W densidad del agua, expresada en g/mL, referida a la temperatura t de calibración en °C

ρ_A densidad del aire, expresada en g/mL

ρ_B densidad de las masas usadas durante la medición (sustitución) o durante la calibración de la balanza, expresada en mg/mL

γ coeficiente de expansión térmico cubico del vidrio borosilicato, expresado en °C $^{-1}$

t temperatura del agua utilizada en la calibración, expresada en °C

El Valor de Referencia de la Comparación (CRV por sus siglas en inglés), se calculó para cada dispositivo de transferencia como la media ponderada, utilizando los inversos de los cuadrados de las incertidumbres típicas asociadas de acuerdo a la metodología propuesta por Cox [4].

El grado de equivalencia d_i, de cada uno de los resultados de los INMs participantes se expresa cuantitativamente como la desviación del valor de referencia de la comparación CRV y la incertidumbre $U(d_i)$ de esta desviación con un nivel de confianza del 95 %, aplicando las siguientes ecuaciones [4].

$$d_i = x_i - x_{ref} \quad (2)$$

$$U(d_i) = 2 \times u(d_i) \quad (3)$$

Donde $u(d_i)$ viene dada por

$$u^2(d_i) = u^2(x_i) + u^2(x_{ref}) \quad (4)$$

INM	Pesada 100 mL y 5 mL	Tipo de agua	Fórmula Densidad	Conduc -tividad (μS/cm)
1	PD	DI	Tanaka	0,15
2	PD	OI	Kell	5,8
3	SS	BD	Tanaka	0,8
4	SS	D	Tanaka	0,2
5	PD	D	Tanaka	0,53 a 1,05
6	PD	OI	Tanaka	3,4

Los valores discrepantes fueron identificados cuando $|d_i| > 2\,u(d_i)$.

Los resultados obtenidos por cada laboratorio se compararon con el valor de referencia CRV, utilizando para ello la herramienta estadística del error normalizado E_N:

$$E_N = \left|\frac{d_i}{U(d_i)}\right| \quad (5)$$

En los casos en donde los resultados del E_N, estuvo entre -1 y 1, la medición se consideró como aceptable y los valores medidos consistentes con el valor de referencia.

Se determinó además, el grado de equivalencia, $d_{i,j}$, entre pares de resultados de mediciones de los respectivos NMIs participantes, el cual se expresa cuantitativamente de acuerdo con el método de Cox [4] tomando en cuenta los dos términos siguientes:

a) la diferencia de sus desviaciones con el valor de referencia de la comparación, CRV;
b) la incertidumbre de esta diferencia con un nivel de confianza de 95 %.

3. RESULTADOS Y DISCUSIÓN

El tipo de agua usada para la determinación del volumen fue obtenida por cada participante mediante diferentes procesos. Un resumen se muestra en la Tabla 3. Cabe observar que la formulación de Tanaka et al [5] se utilizó como referencia para el cálculo de la densidad del agua por la mayoría de los participantes. La conductividad fue determinada por cada laboratorio, notando que uno de ellos presentó un valor mayor al valor máximo permitido de 5 μS/cm para agua grado 3, de acuerdo con ISO 3696 [6].

Tabla 3.Métodos de pesada y de purificación de agua utilizados por los participantes.
PD: Pesada directa, **SS:** Simple sustitución, **D:** Destilada
DI: Des-ionizada, **OI:** Ósmosis Inversa, **BD:**Bidestilada

3.1 Estabilidad de los patrones de transferencia

El laboratorio CENAMEP AIP, como el laboratorio piloto en esta comparación, realizó las mediciones de los matraces y pipetas, al inicio y al final de la ronda de medidas. El volumen de cada TS se midió tres veces por el laboratorio piloto, a excepción de la pipeta No.4, que se midió sólo dos veces. Las tres mediciones fueron realizadas en días distintos, en los cuales se mantuvieron las condiciones requeridas para estas calibraciones.
El objetivo de realizar estas mediciones al inicio y final de la comparación fue comprobar la consistencia de los valores de volumen de los TS.
Los resultados de las pruebas de estabilidad se dan en las Tablas 5 y 6.

Tabla 5. Resultados del volumen de los matraces volumétricos de 100 mL obtenidos por el laboratorio piloto.

Matraz Volumétrico	Fecha	Valor inicial	
		V/mL	*U*/mL *k*=2
01.15	2014-06-24	100.007	0.031
	2014-06-25	99.990	0.031
03.03	2014-06-24	100.035	0.032
	2014-06-25	100.041	0.032
Matraz Volumétrico	**Fecha**	**Valor final**	
		V/mL	*U*/mL *k*=2
01.15	2014-08-06	100.013	0.031
03.03	2014-08-07	100.041	0.031

Tabla 6. Resultados del laboratorio piloto de las pipetas con una sola marca de aforo de 5 mL, de acuerdo con los resultados de medición obtenidos por el laboratorio piloto.

Pipeta con una marca de aforo	Fecha	Valor Inicial	
		V/mL	*U*/mL *k*=2
4	2014-06-24 2014-06-26	4.997 4.995	0.003 0.004
7	2014-06-23	5.000	0.003
Pipeta con una marca de aforo	**Fecha**	**Valor Final**	
		V/mL	*U*/mL *k*=2
4	2014-08-08	4.995 4.995	0.004 0.004
7	2014-08-08	4.999	0.004

3.2 Resultados de los laboratorios

El Valor de Referencia de la Comparación (CRV), se calculó para cada artefacto como la media ponderada, utilizando como factores de ponderación los inversos de los cuadrados de las incertidumbres típicas asociadas. Los CRVs de los diferentes TS se muestran en las Tablas 7 y 8.

Tabla 7. Resultados de la medición del volumen y la incertidumbre estándar para los matraces volumétricos de 100 mL.

100 mL	Matraz Volumétrico 01.15		Matraz Volumétrico 03.03	
	V/mL	$u(x_i)$/mL	*V*/mL	$u(x_i)$/mL
CENAMEP	100.007	0.015 0	100.035	0.016 0
CIM	99.965	0.005 3	99.988	0.005 4
LACOMET	100.005	0.009 6	100.034	0.009 7
CENAME	99.723	0.005 6	100.014	0.005 2
CEHM	100.029	0.016 8	100.011	0.015 8
LANAMET	100.013	0.009 4	100.012	0.009 2
	CRV/mL	*U*(*CRV*)/mL	*CRV*/mL	*U*(*CRV*)/mL
CRV	100.011 1	0.011 5	100.017 8	0.007 7
Método	Media Ponderada		Media Ponderada	

Tabla 8. Resultados de la medición del volumen y la incertidumbre estándar para las pipetas de 5 mL.

5 mL (TS)	Pipeta con una línea de aforo **No. 4**		Pipeta con una línea de aforo **No. 7**	
	V/mL	$u(x_i)$/mL	*V*/mL	$u(x_i)$/mL
CENAMEP	4.997 0	0.001 6	5.000 0	0.001 6
CIM	4.994 5	0.000 8	4.992 8	0.000 6
LACOMET	4.993 9	0.001 0	4.997 5	0.001 2
CENAME	4.990 9	0.000 6	4.996 4	0.000 5
CEHM	4.998 0	0.002 8	5.000 0	0.002 8
LANAMET	4.992 7	0.000 6	4.994 3	0.000 6
	CRV/mL	*U*(*CRV*)/mL	*CRV*/mL	*U*(*CRV*)/mL
CRV	4.993 6	0.000 86	4.996 9	0.000 88
Método	Media Ponderada		Media Ponderada	

3.3 Prueba de consistencia

Previo al cálculo a la media ponderada se analizó la existencia de posibles inconsistencias entre los resultados, según recomienda Cox [4]. Para tal fin se aplicó una prueba chi-cuadrado,

$$\chi^2_{obs} = \frac{(x_1-y)^2}{u^2(x_1)} + \cdots + \frac{(x_n-y)^2}{u^2(x_n)}$$

(6)

donde el número de grados de libertad está dado por: $\nu = n - 1$.

La consistencia de los resultados es rechazada si la probabilidad $Pr\{\chi^2(\nu) > \chi^2_{obs}\} < 0.05$.

3.3.1 Matraz volumétrico 01.15

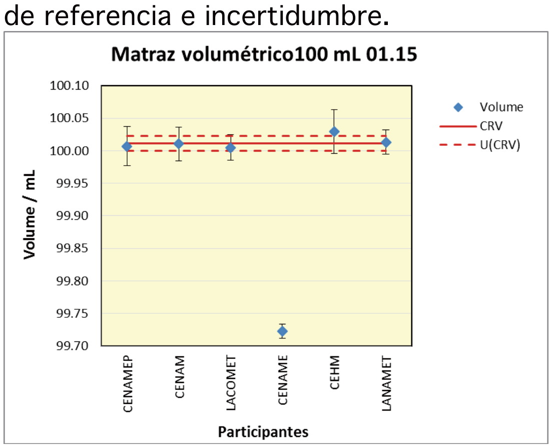
El valor de referencia CRV obtenido para el matraz volumétrico 01.15, fue de 99.900 mL y la incertidumbre expandida

$U = 2 \times u(y)$ del valor de referencia 0.006 4 mL.

Cuando se aplica la prueba chi- cuadrado para $\nu = 5$ se obtiene un valor de $\chi^2(\nu) = 11.07 > \chi^2_{obs} = 1523\ 4$. Por lo tanto, los resultados y el valor de referencia no son consistentes entre sí según este estadístico.

Removiendo el resultado de CENAME por ser el valor más discrepante, y realizando un nuevo cálculo del CRV de acuerdo con el procedimiento de Cox, se obtiene $\nu = 4$, $\chi^2(\nu) = 9.49 > \chi^2_{obs} = 36.38$, nuevamente la prueba detectó inconsistencia. El procedimiento se repitió removiendo esta vez el resultado del CIM (el valor más discrepante, en esta segunda ronda) del subconjunto y un nuevo cálculo del CRV fue realizado. La prueba de consistencia finalmente pasó con $\nu = 3$, $\chi^2(\nu) = 7.81 > \chi^2_{obs} = 1.65$; es decir, los valores restantes y el nuevo valor de referencia de 100.011 mL con incertidumbre expandida de 0.012 mL, fueron consistentes entre sí. Todos los resultados de la medición, el valor de referencia e incertidumbre se presentan en la Figura 3.

Figura 3. Resultados de la medición del matraz volumétrico 01.15 con su valor de referencia e incertidumbre.



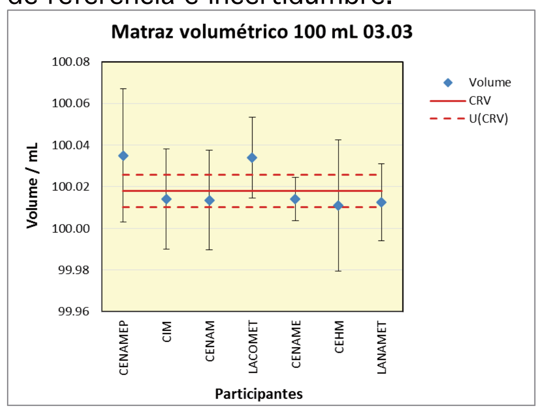
3.3.2 Matraz volumétrico 03.03

El CRV obtenido para el matraz volumétrico 03.03 de 100 mL fue de 100.008 mL, y la incertidumbre expandida $U = 2 \times u(y)$ del valor de referencia 0.006 3mL.

La prueba de chi-cuadrado aplicada para $\nu = 5$ arrojó un valor de $\chi^2(\nu) = 11.07 > \chi^2_{obs} = 25.30$. Por lo tanto, los resultados y el valor de referencia no son consistencia entre sí desde el punto de vista estadístico.

Cuando se remueve el resultado de CIM por ser el valor más discrepante, y se realiza un nuevo cálculo del CRV de acuerdo con el procedimiento de Cox, se obtiene $\nu = 4$, $\chi^2(\nu) = 9.49 > \chi^2_{obs} = 5.06$. Por lo tanto, los valores restantes son consistentes entre sí con el nuevo valor de referencia de 100.018 mL e incertidumbre expandida de 0.007 7 mL, como se muestra en la Figura 4.

Figura 4. Resultados de la medición del matraz volumétrico 03.03 con su valor de referencia e incertidumbre.



3.3.3 Pipeta No. 4

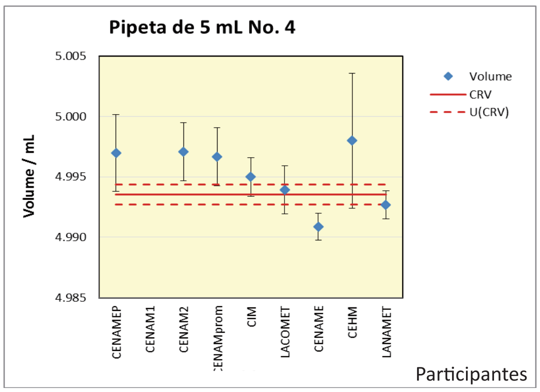
El CRV obtenido para la pipeta con una línea de aforo No. 4 fue 4.992 9 mL, y la incertidumbre expandida $U = 2 \times u(y)$ del valor de referencia 0.000 68 mL.

La prueba de chi- cuadrado para $\nu = 5$ arrojó un valor de $\chi^2(\nu) = 11.07 > \chi^2_{obs} = 26.09$. Por lo tanto, los resultados y el valor de referencia no son consistentes entre sí según este estadístico.

Removiendo el resultado de CENAME por ser el valor más discrepante, y realizando un nuevo cálculo del CRV de acuerdo con el procedimiento de Cox, se obtuvo $\nu = 4$, $\chi^2(\nu) = 9.49 > \chi^2_{obs} = 10.39$, nuevamente la prueba detectó inconsistencia. El procedimiento se repitió removiendo esta vez el resultado de CENAMEP AIP (el valor más discrepante, en esta segunda ronda) del subconjunto y un nuevo cálculo de los CRV fue realizado. La prueba de consistencia finalmente pasó con

$\nu = 3, \chi^2(\nu) = 7.81 > \chi^2_{obs} = 6.07$; es decir, los valores restantes y el nuevo valor de referencia de 4.993 6 mL con incertidumbre expandida de 0.000 86 mL, fueron consistentes entre sí. Todos los resultados de la medición, el valor de referencia e incertidumbre se presentan en la Figura 5.

Figura 5. Resultados de la medición de la pipeta con una línea de aforo No. 4 con su valor de referencia e incertidumbre.



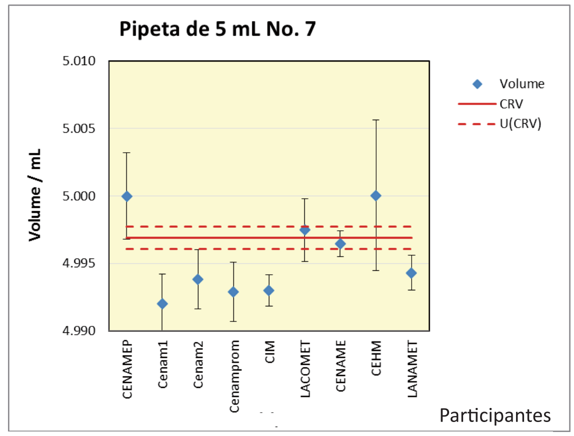
3.3.4. Pipeta No. 7

El CRV obtenido para la pipeta con una línea de aforo No. 7 fue 4.995 2 mL, y la incertidumbre expandida $U = 2 \times u(y)$ del valor de referencia 0.000 61 mL.

La prueba de chi- cuadrado para $\nu = 5$ muestra un valor de $\chi^2(\nu) = 11.07 > \chi^2_{obs} = 39.61$. Por lo tanto, los resultados y el valor de referencia no son consistentes entre sí según este estadístico.

Removiendo el resultado del CIM del subconjunto por ser el valor más discrepante, y realizando un nuevo cálculo del CRV de acuerdo con el procedimiento de Cox, obteniéndose $\nu = 4$, $\chi^2(\nu) = 9.49 > \chi^2_{obs} = 18.52$, nuevamente la prueba detectó inconsistencia. El procedimiento se repitió removiendo esta vez el resultado de LANAMET (el valor más discrepante, en esta segunda ronda) del subconjunto y se realiza un nuevo cálculo del CRV. La prueba de consistencia finalmente pasa con $\nu = 3, \chi^2(\nu) = 7.81 > \chi^2_{obs} = 6.23$; es decir, los valores restantes y el nuevo valor de referencia de 4.996 9 mL con incertidumbre expandida de 0.000 868 mL, muestran consistentes entre sí. Los resultados de la medición, el valor de referencia e incertidumbre se presentan en la Figura 6.

Figura 6. Resultados de la medición de la pipeta con una línea de aforo No. 7 con su valor de referencia e incertidumbre.



3.4 Grados de Equivalencia

3.4.1 Grados de Equivalencia, d_i, relacionados con CRV

El grado de equivalencia, *di*, y el error normalizado E_{Ni} para los matraces de 100 mL y pipetas de 5 mL de una línea de aforo, se muestran en la Tabla 9 y en la Tabla 10, respectivamente.

Tabla 9. Grados de equivalencia, d_i, para los matraces aforados de 100 mL.

100 mL TS	**Matraz volumétrico 01.15**			**Matraz volumétrico 03.03**		
	d_i	$U(d_i)$	$E_{N,i}$	d_i	$U(d_i)$	$E_{N,i}$
	x 10^{-3}mL			x 10^{-3}mL		
CENAMEP	-4,2	28	0,15	17	31	0,55
CIM	-46	5	10	-30	7,5	4,0
LACOMET	-6,2	15	0,40	16	18	0,90
CENAME	-288	3,0	97	-3,9	7.0	0,56
CEHM	18	32	0,56	-6,9	31	0,23
LANAMET	2,0	15	0,13	-5,5	17	0,33

Tabla 10. Grados de equivalencia, d_i, para las pipetas de 5mL.

100 mL TS	Pipeta No.4			Pipeta No. 7		
	d_i	$U(d_i)$	$E_{N,i}$	d_i	$U(d_i)$	$E_{N,i}$
	x 10^{-3}mL			x 10^{-3}mL		
CENAMEP	3,4	3,0	1,2	3,1	3,1	1,0
CIM	0,94	1,4	0,76	-4,1	0,82	4,2
LACOMET	0,34	1,8	0,22	0,60	2,2	0,26
CENAME	-2,7	0,84	3,6	-0,50	0,48	1,0
CEHM	4,4	5,5	0,81	3,1	5,5	0,57
LANAMET	-0,86	0,84	1,1	-2,6	0,8	2,7

3.4.2 Grados de Equivalencia, d_{ij}, entre laboratorios

El grado de equivalencia $d_{i,j}$ entre los laboratorios *i* y *j* en esta comparación se muestra en las Tablas 11 a 14.

Tabla 11. Grados de equivalencia para el volumen de líquido de 100 mL, matraz aforado 01.15.

TS 01.15	CENAMEP		CIM		LACOMET	
	$d_{i,j}$	$Ud_{i,j}$	$d_{i,j}$	$Ud_{i,j}$	$d_{i,j}$	$Ud_{i,j}$
CENAMEP			-0.04	0.03	0.00	0.04
CIM	0.04	0.03			0.04	0.02
LACOMET	0.002	0.04	-0.04	0.02		
CENAME	0.28	0.03	0.24	0.02	0.28	0.02
CEHM	-0.02	0.05	-0.06	0.04	-0.02	0.04
LANAMET	-0.01	0.04	-0.05	0.02	-0.01	0.03

...continúa tabla 11

TS 01.15	CENAME		CEHM		LANAMET	
	$d_{i,j}$	$Ud_{i,j}$	$d_{i,j}$	$Ud_{i,j}$	$d_{i,j}$	$Ud_{i,j}$
CENAMEP	-0.28	0.03	0.02	0.05	0.01	0.04
CIM	-0.24	0.02	0.06	0.04	0.05	0.02
LACOMET	-0.28	0.02	0.02	0.04	0.01	0.03
CENAME			0.31	0.04	0.29	0.02
CEHM	-0.31	0.04			-0.02	0.04
LANAMET	-0.29	0.02	0.02	0.03		

Tabla 12. Grados de equivalencia para el volumen de líquido de 100 mL, matraz aforado 03.03

TS 03.03	CENAMEP		CIM		LACOMET	
	$d_{i,j}$	$Ud_{i,j}$	$d_{i,j}$	$Ud_{i,j}$	$d_{i,j}$	$Ud_{i,j}$
CENAMEP			-0.05	0.03	0.00	0.04
CIM	0.047	0.03			0.05	0.02
LACOMET	0.001	0.04	-0.05	0.02		
CENAME	0.02	0.03	-0.03	0.01	0.02	0.02
CEHM	0.02	0.04	-0.02	0.03	0.02	0.04
LANAMET	0.02	0.04	-0.02	0.02	0.02	0.03

...continúa tabla 12

TS 03.03	CENAME		CEHM		LANAMET	
	$d_{i,j}$	$Ud_{i,j}$	$d_{i,j}$	$Ud_{i,j}$	$d_{i,j}$	$Ud_{i,j}$
CENAMEP	-0.02	0.03	-0.02	0.04	-0.02	0.04
CIM	0.03	0.01	0.02	0.03	0.02	0.02
LACOMET	-0.02	0.02	-0.02	0.04	-0.02	0.03
CENAME			-0.003	0.03	0.002	0.02
CEHM	0.003	0.03			0.001	0.04
LANAMET	0.002	0.02	0.001	0.04		

Tabla 13. Grados de equivalencia para el volumen de líquido de 5 mL, pipeta con una línea de aforo No. 4

4	CENAMEP		CIM		LACOMET	
	$d_{i,j}$	$Ud_{i,j}$	$d_{i,j}$	$Ud_{i,j}$	$d_{i,j}$	$Ud_{i,j}$
CENAMEP			-0.002	0.003	-0.003	0.004
CIM	0.002	0.001			-0.001	0.003
LACOMET	0.003	0.004	0.001	0.003		
CENAME	0.006	0.003	0.004	0.002	0.003	0.002
CEHM	-0.001	0.006	-0.003	0.006	-0.004	0.006
LANAMET	0.004	0.003	0.002	0.002	0.001	0.002

...continúa tabla 13

4	CENAME		CEHM		LANAMET	
	$d_{i,j}$	$Ud_{i,j}$	$d_{i,j}$	$Ud_{i,j}$	$d_{i,j}$	$Ud_{i,j}$
CENAMEP	-0.006	0.003	0.001	0.006	-0.004	0.003
CIM	-0.004	0.002	0.003	0.006	-0.002	0.002
LACOMET	-0.003	0.002	0.004	0.006	-0.001	0.002
CENAME			0.007	0.006	0.002	0.002
CEHM	-0.007	0.000			-0.005	0.006
LANAMET	-0.002	0.002	0.005	0.006		

Tabla 14. Grados de equivalencia para el volumen de líquido de 5 mL,pipeta con una línea de aforo No. 7

7	CENAMEP		CIM		LACOMET	
	$d_{i,j}$	$Ud_{i,j}$	$d_{i,j}$	$Ud_{i,j}$	$d_{i,j}$	$Ud_{i,j}$
CENAMEP			-0.004	0.003	0.001	0.004
CIM	0.007	0.003			0.005	0.003
LACOMET	-0.001	0.004	-0.005	0.003		
CENAME	0.000	0.003	-0.004	0.002	0.001	0.003
CEHM	-0.003	0.006	-0.007	0.006	-0.003	0.006
LANAMET	0.003	0.003	-0.001	0.002	0.003	0.003

...continúa tabla 14

7	CENAME		CEHM		LANAMET	
	$d_{i,j}$	$Ud_{i,j}$	$d_{i,j}$	$Ud_{i,j}$	$d_{i,j}$	$Ud_{i,j}$
CENAMEP	0.000	0.003	0.003	0.006	-0.003	0.003
CIM	0.004	0.002	0.007	0.006	0.001	0.002
LACOMET	-0.001	0.003	0.003	0.006	-0.003	0.003
CENAME			0.004	0.006	-0.002	0.002
CEHM	-0.004	0.006			-0.006	0.006
LANAMET	0.002	0.002	0.006	0.006		

Como referencias para la elaboración de este documento se consideraron [7], [8] y [9].

4. CONCLUSIÓN

La comparación en volumen de 100 mL con matraces y de 5 mL con pipetas, se realizó en el marco del programa PRACAMS con el propósito de comparar los resultados obtenidos en cada una de las mediciones de volumen de los laboratorios participantes de CAMET, utilizando dos matraces volumétricos y dos pipetas de una sola línea de aforo.

Los dispositivos de transferencia seleccionados mostraron un volumen estable durante todo el período de comparación verificada por el laboratorio piloto, CENAMEP AIP.

La comparación se evaluó teniendo en cuenta algunos resultados discrepantes. Se realizó un total de 24 mediciones (cuatro materiales volumétricos fueron medidos por cada laboratorio), de los cuales se encontraron siete valores discrepantes en comparación con el valor de referencia. Según el estadístico de chi-cuadrado con un nivel de confianza de 95 % el 29.2 % de los valores de medición se consideraron como inconsistentes.

5. REFERENCIAS BIBLIOGRÁFICAS

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[7] *Final Report on SIM.M.FF-K4 CIPM Regional key comparison for Volume of Liquids at 20 L and 100 mL;* BIPM-KCDB.

[8] *Final report on SIM.M.FF-S5 Regional supplementary comparison for volume of liquids at 50 mL*; BIPM-KCDB.

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Quality Infrastructure for Reliable Measurements in Drinking Water

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1. INTRODUCTION

The Bolivian Government is making progress in reducing poverty. Several goals have been established to achieve a significant reduction before 2025. One of these goals is to improve services (water, sewage, electricity, gas and telecommunications) by making them available to the population. In the current State's Political Constitution, its Chapter Five on Water Resources, Section 373, establishes: "Water is a most fundamental right to life under the sovereignty of the people", also stating that "the State shall protect and guarantee the priority use of water for life. The State should manage, regulate, protect and plan the appropriate and sustainable use of water resources, with social participation, ensuring access to water for all its inhabitants".

To realize this statement the water and sanitation sector faces the challenge of improving the performance of their institutions and infrastructure, and strengthening existing capabilities.

Since 2009 the Bolivian Institute of Metrology (IBMETRO) runs the program "Promotion of Quality Infrastructure that supports measurement and testing of drinking water" with the technical cooperation of the National Metrology Institute of Germany, the Physikalisch-Technische-Bundesanstalt (PTB).

Figure 1. Drinking water for population.

The program aims to strengthen the technical skills and improve the reliability of measurements of quantity and quality of drinking water in Bolivia, through IBMETRO and its Technical Accreditation Directorate (DTA).

Figure 2. Access to water in rural areas in Bolivia.

The Bolivian technical standard NB-512:2010 "Drinking Water Requirements" establishes the quality requirements for drinking water. The Ministry of Environment and Water issued a regulation for the Suppliers of Water and Sewage Services (EPSAs, according to the Spanish acronym), defining four types of controls (minimum, basic, supplementary and special) according to technical and economic feasibility of each EPSA. This has been an important step in the regulation of the water sector.

During the initial phase of the Program, IBMETRO performed a diagnostic study using survey interviews, to identify the limitations on technical capabilities for obtaining accurate and reliable results.

The lack of implementation and the poor knowledge of the ISO/IEC 17025 standard and the paucity of awareness in both managerial and technical personnel concerning the importance of the quality of results; the missing of internal controls for measurement results, due to lack of reference materials and the nationwide absence of suppliers of proficiency tests, were the main problems revealed.

Figure 3. pH Reference Material produced by IBMETRO.

2. THE WORKS

According to these surveys results, the

program designed a Working Plan focused on three action lines. One was to improve the reliability of the tests and measurements carried out by the EPSAs. A training program was conducted for EPSAs laboratories with the objective of building up the capability to implement a Quality Management System based on ISO-IEC/ 17025:2005. The program also provided technical assistance in specific topics for the validation of testing methods, estimation of measurement uncertainty and metrological assurance.

To ensure the success of this activity the Authority for the Regulation and Control of Drinking Water (AAPS) invited the companies to join this program. Great effort was invested with EPSA authorities until covenants were signed by the water companies, compromising the companies' executives to ensure the continuity of trained personnel and to maintain the allocation of resources necessary to achieve QMS implementation. In total there was a positive response from 12 companies, which cover services of approximately 75% of the population in Bolivia. Nowadays, 9 of 12 laboratories have received the accreditation for parameters pH and free chlorine.

The second action line was devoted to strengthen IBMETRO technical skills to implement measurement and calibration capabilities, to respond to the demand for services, particularly those related to the quality parameters required by the NB 512 such as pH, electrolytic conductivity, heavy metals contents, micro and macro measurements of water flow. This action line addressed the adequacy of infrastructure and the acquisition of equipment as well.

The aim of this action line was to provide reference materials to EPSAs laboratories, suitable to perform quality controls to ensure metrologically reliable results for the control authorities. This has also proved benefits since former reference materials were imported, which is disadvantageous in terms of the prompt availability and the cost of materials.

In order to do so, IBMETRO participated in two international comparisons in the pH scale. The results of the comparisons were successful. Besides, comparisons on other variables, such as electrolytic conductivity and heavy metals, are being sought within the Inter-American Metrology System (SIM) framework.

Figure 4. Microbiological items for Bolivian PT.

To complement the efforts, annual rounds of proficiency tests for water have been taken place since 2010. Until 2012 the scopes of these proficiency tests were aimed at evaluating the results of physic-chemical tests, such as pH and electrolytic conductivity. Initially a challenge was the scarce participation of EPSAs laboratories, maybe due to a natural resistance that these exercises generate because of possible unwanted outcomes and the cost of participation, despite the fact that a percentage of costs for participating companies were covered by the program in the first 3 years.

It is noted that in order to enable IBMETRO to become a competent provider of proficiency testing services, and as another important technical benefit of the program multiple training activities on ISO / IEC 17043: 2010 "Conformity assessment - General requirements for proficiency testing" and ISO 13528: 2005 "Statistical methods for use in proficiency test by interlaboratory comparisons" were delivered.

Since 2013 proficiency tests consider, besides pH and electrical conductivity, others such as free chlorine contents, turbidity and thermo-tolerant coliforms, aiming to implement the conformity assessment of the whole parameters required by the Bolivian technical standard NB 512: 2010 "Drinking Water - Requirements".

This has been achieved through joint efforts between IBMETRO and the Central Laboratory of the EPSAS-La Paz. The role of the EPSAS laboratory was to prepare microbiological and free chlorine samples which have special features for its known short stability. Several studies were conducted, until a suitable material was obtained, which was sent across the country to ensure that its values are maintained, thus avoiding biased results. The effort required in shipping logistics is not negligible, and has been achieved by the coordination with the regional offices of IBMETRO nationwide.

3. THE RESULTS

The following table shows the progress in the participation of laboratories through the years. It is important to highlight that since 2014 the EPSA participants have completely covered the costs of participation.

Table 1. Participations of EPSAS in Water Proficiency Test.

	2010	2011	2012	2013	2014	2015
Satisfactory results	11	24	8	18	46	36
Number of EPSA participants	8	11	5	7	17	14
Basic control parameters assessed	2	3	2	5	5	5
Indicator of success (*)	78	78	90	61	66	72

(*) Ratio of the parameter-number of laboratories with successful results divided by the total number of parameter–number of participating laboratories, multiplied by 100.

For each parameter the results of the proficiency tests are assessed through *Z*-score, formulated as follows:

– ,

X_{lab} : is the value reported by a participating laboratory.

X_{ref} : is the value set by the pilot laboratory.

: is the estimator of the dispersion of test results.

It is noted that the value is critical for assessing the results of the participants; hence it has to be firmly supported by technical criteria. In the first Proficiency Test in Water carried out, the value of σ calculated from the results of all the participants had to be used, since no data was available in any Bolivian technical standards or consensus of experts in the area of testing.

As shown in the Table 1, along five years the general trend is an increase of the satisfactory results, the number of EPSA participants and the number of parameters under assessment. The indicator of success has been fluctuating despite the above mentioned increments.

Figure 5. Water PT closing meeting.

It should be noted that through workshops held at the end of the proficiency tests, participants receive feedback to improve results, addressing topics like uncertainty estimates, quality control, validation of methods, and others.

Currently, a significant amount of data for σ is available, so it has been possible to set up target values to evaluate performance, as seen in the column 2015 in the table above. This set of values was agreed in 2014, through consensus of the participant's laboratories.

Table 2. Trends on σ

Parameter	2010	2011	2012	2013	2014	2015
pH (pH units)	0,17	0,22	0,11	0,06	0,02	0,05
Electrolitic conductivity (µS/cm)	8,94	6,95	7,15	5,12	5,75	5,00
Hardness (mg CaCO3/L)	5,17	11,2	2,74	2,58	1,87	1,9
Chlorides (mg/L)	3,30	2,41	1,26	1,82	1,09	1,00
Calcium (mg/L)	2,03	1,63	0,66	0,74	1,87	0,8
Sulphates (mg/L)	5,60	3,57	2,74	1,80	1,75	1,5

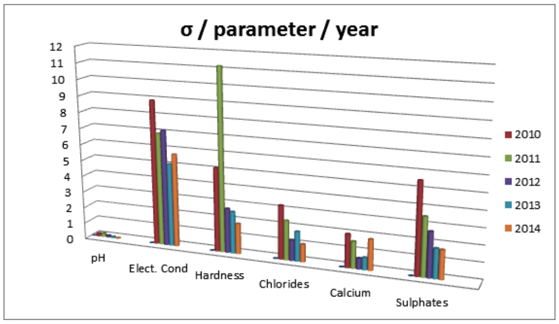

Figure 6. Evolution of σ through the years.

Table 2 and the figure 6 show the evolution in the laboratories performance over recent years, where in general the value of σ has being going downwards.

The third action line has been undertaken with the objective of proposing standards and quality criteria for the sector. Here, IBMETRO has reviewed the current test standards close to several national standardization and regulatory technical committees. Thus, clear procedures for internal quality control of the results, specifically pH and electrolytic conductivity, are stated in new standards.

Besides, IBMETRO works with authorities in the development of regulations for metrological control of water meters, for example, to perform the corresponding pattern approvals and initial verifications.

4. CONCLUSIONS

What has been achieved?

- To date, 12 laboratories of EPSAs have implemented their quality management systems through systematic work supported by training, and 9 of them have been accredited for two parameters.
- The Bolivian laboratories have now a nationwide provider of reference materials, allowing them to acquire opportunely these materials and avoiding the lengthy administrative import procedures.
- The Central Laboratory of EPSAS increased to 18 the parameters accredited by IBMETRO.
- After five proficiency tests, reliable data is available to establish a reliable parameter for assessing the performance in proficiency testing.
- IBMETRO has significantly strengthened its technical capabilities in the last three years to improve the organization, implementation and evaluation of proficiency test materials and to provide reference materials to laboratories in the country.

While there has been significant progress, there are still many challenges ahead to solve: for example the analysis of organic parameters in water.

Importancia de la Calidad del Servicio en un Laboratorio Nacional de Metrología

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Resumen: *Los requisitos de calidad, en la actualidad, se han extendido en todos los niveles de desarrollo comercial, metrológico, académico y social, tanto a nivel nacional como internacional. En Costa Rica, el Laboratorio Costarricense de Metrología, apegado a las funciones establecidas por la ley y a las responsabilidades del Arreglo de Reconocimiento Mutuo de la Conferencia Internacional de Pesas y Medidas, ha implementado un sistema de calidad basado en el esquema ISO, que ha permitido enfocarse en el fortalecimiento de la relación con los clientes y usuarios. La importancia de definir los requisitos de calidad en el servicio así como obtener retroalimentación en cuanto a los mismos por parte de los clientes, ha mejorado la relación entre el laboratorio y sus usuarios y ha permitido la optimización de recursos. No obstante, conscientes de que existen muchos aspectos más que mejorar en cuanto a la calidad de los servicios, se analizan las entradas obtenidas, a fin de enfocar sistemáticamente el desarrollo del trabajo y contribuir al bienestar y buen desempeño de la organización.*

Palabras clave: Calidad, servicio, cliente, mejora.

1. INTRODUCCIÓN.

En Costa Rica, mediante la Ley N°8279 Sistema Nacional para la Calidad, se crea el Sistema Nacional para la Calidad con el propósito de establecer un "marco estructural para las actividades vinculadas al desarrollo y la demostración de la calidad, que facilite el cumplimiento de compromisos internacionales en materia de evaluación, de la conformidad, que contribuya a mejorar la competitividad de las empresas nacionales y proporcione confianza en la transacción de bienes y servicios" [1]. Este sistema está compuesto por cuatro entidades que ejecutan actividades vinculadas a los campos de la normalización, la acreditación, la metrología y la evaluación de la conformidad; y se conocen como el Ente Nacional de Normalización (designado al Instituto de Normas Técnicas de Costa Rica, INTECO), el Ente Costarricense de Acreditación (ECA), el Laboratorio Costarricense de Metrología (LACOMET) y el Órgano de Reglamentación Técnica (ORT).

En el campo de la metrología, cuya definición es "ciencia de las mediciones y sus aplicaciones" [2]; el LACOMET, es creado como el Laboratorio Nacional de Referencia en Metrología, cuyas funciones más importantes son "difundir y fundamentar la metrología nacional y promover el establecimiento de una estructura metrológica nacional; custodiar los patrones nacionales y garantizar su referencia periódica a patrones de rango superior".

Por otro lado se encuentra entre sus responsabilidades "promover la calibración, la verificación y el ajuste de los instrumentos de medición, así como la trazabilidad a patrones del Sistema Internacional de Unidades, y garantizar la trazabilidad de los instrumentos de medida" [1]. A continuación se expondrán algunas acciones desarrolladas en el LACOMET, para el cumplimiento de las funciones atribuidas por la ley, vinculadas con la calidad de los servicios que brinda a los usuarios.

2. EXPERIENCIAS EN LA CALIDAD DEL SERVICIO DEL LACOMET

El LACOMET, desde el año 2004 firma el Arreglo de Reconocimiento Mutuo del

Comité Internacional de Pesas y Medidas, tratado en el que se establece el reconocimiento entre países del grado de equivalencia de los resultados de medición, así como de los certificados de calibración [3]. Es parte de este tratado, que los laboratorio nacionales de metrología, demuestren su competencia técnica mediante la participación exitosa en comparaciones clave o suplementarias coordinadas por el Buró Internacional de Pesas y Medidas (BIPM) y la declaración de sus capacidades de medición y calibración (CMCs), una vez satisfechos procesos de evaluación de pares realizados por otros laboratorios o entes técnicos internacionales, bajo los requisitos de la norma internacional ISO/IEC 17025:2005 o la guía ISO Guide 34:2009, de acuerdo a la naturaleza de los servicios que desarrollen, calibraciones o producción de materiales de referencia certificados, respectivamente.

Desde el año 2005, el LACOMET se ha dedicado al desarrollo e implementación de un sistema de gestión de calidad basado en el cumplimiento de los requisitos de la norma ISO/IEC 17025:2005. Tal como se ha visto, actualmente la calidad se ha convertido en una demanda que los laboratorios nacionales de metrología deben atender para satisfacer las necesidades de sus clientes, en pro de la competitividad de un país.

Las mediciones realizadas en un laboratorio nacional de metrología tienen impacto directo en la sociedad, en los consumidores, en el ambiente, en la seguridad, en los alimentos, entre otros. Si el laboratorio de metrología no brinda la confianza necesaria a sus usuarios, en términos de calidad del servicio, traducido esto a ofrecer la incertidumbre de la medida que sus usuarios requieran, es probable que el esquema productivo se vea afectado negativamente, desde la confianza en las mediciones que realizan laboratorios secundarios, empresas, industrias, y finalmente en el producto o servicio que obtiene el usuario final.

Aunque podría afirmarse que el laboratorio nacional de metrología, LACOMET, es una entidad pública que por su naturaleza no tiene equivalente en el país, hay que tener en cuenta que el acercamiento con los clientes, su retroalimentación y la planificación de nuevos desarrollos, a partir de la evolución de las mediciones requeridas en el ámbito nacional, son factores preponderantes en las estrategias a corto, mediano y largo plazo que se plantean desde la Dirección, para poder solventar las necesidades de Costa Rica.

De esta forma, por medio de la implementación de un sistema de gestión de calidad, uno de cuyos pilares más importantes es la satisfacción del cliente, el LACOMET se ha visto obligado a mejorar tanto los procedimientos técnicos internos -esto es el desarrollo de nuevos servicios de calibración, capacitación y verificación-, como a la mejora de la atención propiamente dicha de nuestros clientes mediante la interacción directa.

La norma ISO/IEC 17025:2005 [4], en su apartado 4.7 "Servicio al cliente" establece que "el laboratorio debe estar dispuesto a cooperar con los clientes o sus representantes para aclarar el pedido del cliente y para realizar el seguimiento del desempeño del laboratorio en relación con el trabajo realizado, siempre que el laboratorio garantice la confidencialidad hacia otros clientes". Adicionalmente, indica que se debe "procurar obtener información de retorno, tanto positiva como negativa de sus clientes... (la cual) debe utilizarse y analizarse para mejorar el sistema de gestión, las actividades de ensayo y calibración y el servicio al cliente.". Es por esto que dentro del sistema de gestión de calidad, se han establecido desde la Alta Dirección, políticas, procedimientos y mecanismos para obtener esta información de retorno de los clientes, y asegurar, que a través de la misma se tomen en cuenta las necesidades del país.

Estos procesos se encuentran definidos, desde el manual de calidad, en el que se establece la política de confidencialidad de la información y de servicio al cliente, hasta los procedimientos para recolección y análisis de la información de retorno, que culmina en la toma de decisiones durante los procesos de revisión por la Dirección. Anualmente el LACOMET realiza encuestas de satisfacción de clientes en las que se destaca información sobre el proceso de prestación del servicio, y el cumplimiento de los contenidos técnicos de la calibración que el cliente solicita. Adicionalmente, se tiene implementado un sistema de atención de reclamos, en el que los clientes pueden manifestar su inconformidad con los resultados del servicio o del proceso; en consecuencia, internamente se realiza un análisis de causas, para evaluar la trascendencia de la queja, además de poner acciones que permitan solventarla, y acciones que prevengan su repetición, además de una evaluación posterior con el cliente sobre su percepción de cómo fue resuelto su planteamiento. Esto ha permitido conocer más ampliamente a nuestros clientes, y tomar conciencia de la respuesta del LACOMET ante la presencia de conflictos y hecho posible evaluar la robustez de nuestro sistema de calidad como un todo.

De estos procesos de retroalimentación, se han podido establecer acciones a lo interno para mejorar en los aspectos que los clientes han considerado como importantes para su servicio.

Por ejemplo respecto a los tiempos de programación y entrega de las calibraciones, aunque aún presentan debilidades, como se puede observar en la Figura 1, encuesta correspondiente a julio del 2015. De estos resultados, se ha tratado de maximizar los recursos tanto de infraestructura como de personal, para tener una estimación veraz de los tiempos en que puede ser entregada una calibración, mediante herramientas como los estudios de tiempos y movimientos en los laboratorios.

El tiempo de respuesta de LACOMET fue satisfactorio

Opciones	Porcentaje
Totalmente en desacuerdo	25,00
En desacuerdo	6,25
Neutral	18,75
De acuerdo	37,50
Totalmente de acuerdo	12,50
	Total

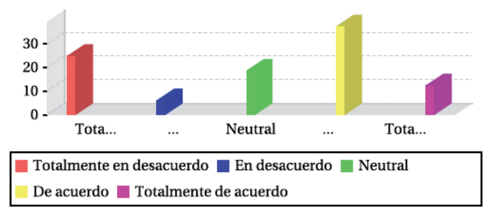

Figura 1. Resultados encuesta al cliente 2015 sobre tiempo de respuesta de servicios. [5]

Como establecen algunas filosofías de calidad, un sistema es un ente vivo que presenta continuas transformaciones con miras a la mejora continua, es por esto, que no nos hemos quedado con los clientes satisfechos por ejemplo, o con ese 69 % de clientes a los que sí se se encuentran de acuerdo con los el cumplimiento de los plazos reportados en la entrega del servicio; el sistema de calidad va más allá y es una herramienta de gestión del LACOMET, para establecer acciones que permitan revertir ese 31 % de clientes que no están del todo satisfechos con los tiempos de entrega y obtener la completa satisfacción.

La trazabilidad con la que cuenta LACOMET es ideal

Opciones	Porcentaje
Totalmente en desacuerdo	6,25
Neutral	18,75
De acuerdo	50,00
Totalmente de acuerdo	25,00
	Total

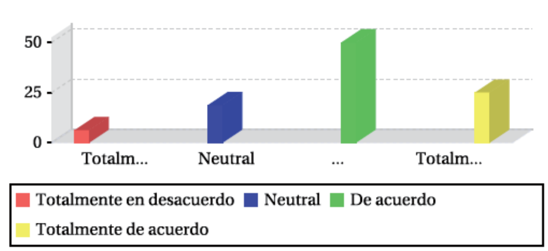

Figura 2. Resultados encuesta al cliente 2015 sobre la satisfacción con respecto a la trazabilidad que se brinda mediante los servicios de calibración. [5]

Sobre los resultados indicados en la figura 2, se han destinado acciones con respecto a estudios de los clientes, para detectar nuevas necesidades metrológicas, que unidas al plan estratégico institucional, permitan la justificación requerida para compra de patrones, mantenimiento de instalaciones mejora y desarrollo de nuevos servicios, como por ejemplo, ensayos de aptitud.

Estos casos y características de calidad son muestras en las que, por medio de mecanismos implementados, el sistema de gestión propicia la mejora continua.

3. CONCLUSIONES Y RECOMENDACIONES.

Como conclusiones se podría asegurar que dada la naturaleza pública del LACOMET, su entero funcionamiento tiene que deberse al país, por lo que en una época de crisis del sector público, la implementación de requisitos de calidad, de la mano con la atención a los clientes y la mejora en la calidad de los servicios, son factores imprescindibles, que además, permiten que se vinculen de manera positiva todo el personal del LACOMET con sus usuarios, tratando de construir servicios adecuados a la necesidad del país y con esto promoviendo el desarrollo de nuestra economía.

Finalmente, la participación de LACOMET de los procesos de mejora de la calidad de sus servicios, estableciendo mecanismos reales de interacción con los clientes, y utilizándolos como herramienta de crecimiento le ha traído beneficios que se están transfiriendo al país.

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NOTISIM

COMPARACIONES ENTRE LABORATORIOS

CAMET se refuerza
La comparación suplementaria entre laboratorios en volumen de líquidos de 100 mL y 5 mL promovida por CAMET concluyó exitosamente con la participación de Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, y Panamá con el apoyo de México.

SIM.EM-K3 Comparación Clave en Patrones de Inductancia de 10 mH a 1 kHz.
Esta comparación inició en 2013 y concluyó en 2016 con la participación de 7 laboratorios nacionales. Los resultados ya están publicados en la KCDB del BIPM.

Patrones de masa de alta exactitud
Con la participación del Bureau of Standards of Jamaica, Trinidad & Tobago Bureau of Standards y del Instituto Dominicano para la Calidad, coordinados por el CENAM, finalizó en marzo de 2016.

SIM WG10 Volumen y flujo
Estudio piloto en mediciones de flujo de gas a baja presión, en el intervalo de 2 m^3/h a 100 m^3/h, acordado en 2012 y financiado parcialmente por el PTB, se realizó como una primera exploración de las capacidades del INACAL y del INTI con la colaboración del NIST y la coordinación del CENAM. Participó en calidad de invitado el laboratorio de calibración CdT de Gas.

SIM WG10 Volumen y flujo
En mayo de 2016 inició la comparación suplementaria SIM.M.FF-S9, para flujo de líquidos desde 10 m^3/ hasta 130 m^3/h. Participan CiSA, INACAL, IBMETRO, INTI, PTB y CENAM, siendo PTB y CENAM co-pilotos de la comparación. Este proyecto es apoyado financieramente por el PTB.

SIM-QM-K111 Propano en N_2
Comparación clave diseñada como soporte a las correspondientes CMC núcleo en análisis de gases del CENAM, coordinada por el INMETRO.

SIM-QM.S5 Gas Natural Sintético
Coordinada por el CENAM, esta comparación inició en 2015, con la participación de IBMETRO, INACAL, INM, INMETRO, INTI and CENAM.

SIM-QM.S6 – Emisiones de Gas de Automóviles en nitrógeno
Bajo la coordinación de INMETRO, esta comparación está dirigida a dar soporte a las CMCs en la categoría de "mezclas de gases" de sus participantes que incluyen CENAM,

LABORATORY COMPARISONS

CAMET strengthens
Promoted by CAMET, the supplementary comparison on liquid volume at 100 mL and 5 mL was successfully carried out with participations of Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua and Panama, technically supported by Mexico.

SIM.EM-K3 Key Comparison of 10 mH Inductance Standards at 1 kHz.
This comparison was carried out in 2013 - 2016 by 7 NMI participating. The results are already published in the KCDB and the report can be found in the Metrologia Special Supplement.

High accuracy mass standards
The Bureau of Standards of Jamaica, the Trinidad & Tobago Bureau of Standards and the Instituto Dominicano para la Calidad, participated in this comparison, coordinated by CENAM, and ended on March 2016.

SIM WG10 Volume and flow
Pilot study on gas flow measurements at low pressure in the interval 2 m^3/h to 100 m^3/h, agreed on 2012 and partially funded by PTB, was carried out to support the CMCs of INACAL and INTI with the NIST collaboration and coordinated by CENAM. The calibration laboratory CdT de Gas participated as an invited one.

SIM WG10 Volume and flow
On May 2016, the supplementary comparison SIM.M.FF-S9, for liquid flow in the range 10 m^3/h up to 130 m^3/h started. CiSA, INACAL, IBMETRO, INTI, PTB and CENAM participate, with PTB and CENAM as co-pilots. This project is partially funded by PTB.

SIM-QM-K111 Propane in N_2
On-going key comparison aimed to support CMC claims in analysis of gases provided by CENAM. This comparison is coordinated by INMETRO.

SIM-QM.S5 Synthetic Natural Gas
Coordinated by CENAM, this comparison started in 2015, with the participation of IBMETRO, INACAL, INM, INMETRO, INTI and CENAM.

SIM-QM.S6 – Automotive Gas Emissions in nitrogen
Coordinated by INMETRO, this comparison aims to support CMC claims in the category of "core gas mixtures". Participants include CENAM, IBMETRO, LATU, INACAL,

IBMETRO, LATU, INACAL, INMETRO, INTI, INM y NIST.

SIM-QM.S7 Trazas de metales en agua para beber
Esta comparación está en proceso, bajo la coordinación del NRC, con apoyo del CENAM en algunos parámetros.

SIM-QM-Kxxx Etanol en matrices acuosas
Para ser coordinada por el INMETRO, la realización de esta comparación e4stá prevista para 2016.

COMPARTIENDO CONOCIMIENTO EN EL SIM

TALLERES Y CURSOS

Química clínica
Este taller ofrecido por el NIST está orientado a los miembros del Grupo de Trabajo SIM-TC-MWG8 (Metrología en QUÍMICA), del 18 al 22 de julio en las instalaciones del NIST.

Evaluación de Especificaciones Técnicas para Desarrollar Capacidades de Medición en las Verificaciones de Medidores de Emisiones de Vehículos
Se realizará del 20^{t} Junio al 1^{o} de Julio del 2016 en el CENAM para representantes de los INM de Argentina, Bolivia, Colombia, Ecuador, Perú y Uruguay

Modelos y Métodos Estadísticos de Apoyo a la Producción de Materiales de Referencia Certificados
Orientado a los miembros del SIM TC-MWG13 (Estadística e Incertidumbre) y otros representantes del SIM, será coordinado por el NIST en una fecha y lugar por determinarse.

Curso en Metrología Dimensional
Del 10 al 12 de mayo de 2016, 10 metrólogos procedentes de 10 INM tuvieron la oportunidad de conocer conceptos de medición aplicables a todos los campos de la metrología dimensional en los laboratorios del NIST.

Curso sobre Fundamentos de la Metrología
La Oficina de Pesas y Medidas del NIST, en coordinación con la Oficina de Asuntos Académicos e Internacionales del NIST, llevaron a cabo este curso en Gaithersburg, Md., con la participación de metrólogos de los INM NRC, CENAME, CENAMEP AIP, SLBS, INM, BHN, INTN, INMETRO, BBSQ y ABBS. Este curso acreditado ante ANSI/IACET se enfoca a conceptos de la metrología relevantes en todos los campos de la medida.

INMETRO, INTI, INM and NIST.

SIM-QM.S7 Trace Metals in Drinking Water
This comparison addresses measurements of copper, strontium, lead and sodium in drinking water, and is being carried out under the coordination of NRC with CENAM support.

SIM-QM-Kxxx Ethanol in aqueous matrices
This comparison is in process under the coordination of INMETRO.

SHARING KNOWLEDGE IN SIM

WORKSHOPS AND COURSES

Clinical Chemistry
To be held on July 18-22 2016, the workshop targets the SIM-TC-MWG8 (Metrology in Chemistry) members under the coordination of NIST, at the NIST premises.

Evaluation of Technical Specifications to Develop Measurement Capabilities in the Verifications of Instruments for Measuring Vehicle Exhaust Emissions
To be held from 20th June to 1st July 2016 in CENAM for representatives of NMIs from Argentina, Bolivia, Colombia, Ecuador, Peru and Uruguay

Statistical models and methods supporting the production of Certified Reference Materials
To be held on 2016, it targets the SIM-TC-MWG13 (Statistics and Uncertainty) members and other NMI representatives from SIM. It will be coordinated by NIST, at a venue to be defined.

Dimensional Metrology Course
On 10 – 12 May 2016, 10 metrologists from 10 SIM NMIs were exposed to measurement concepts and methods applicable to all scopes of dimensional metrology at NIST laboratories.

Course on Fundamentals of Metrology
From 18 – 22 April 2016, NIST's Office Weights and Measures, in coordination with the International and Academic Affairs Office, brought to Gaithersburg, MD metrologists from NRC, CENAME, CENAMEP AIP, SLBS, INM, BHN, INTN, INMETRO, BBSQ and ABBS to participate in this course. The ANSI/IACET accredited course focuses on key metrology concepts important to all fields of measurement.

Curso en Temperatura y Análisis de la Incertidumbre
Con el propósito de colaborar con los INM del SIM en sus esfuerzos por desarrollar sus capacidades en termometría y en ampliar las existentes, bajo el enfoque de "aprender haciendo" este curso estuvo orientado a ofrecer capacitación intensiva para la realización de celdas de punto fijo según la ITS-90. En el curso, impartido por personal del NIST de 18 al 22 de abril de 2016, destaca la dedicación de 90 % del tiempo en laboratorio y el 10 % en aula. Los asistentes procedieron de los INM CENAM, CENAME, INACAL, INM, INMETRO, INTN LATU y TTBS.

Demanda de una Infraestructura de la Calidad para Mediciones Trazables de Gases de Efecto Invernadero en Soporte a las Estrategias de Medida, Reporte y Verificación.
Del 24 al 25 de Febrero de 2016 en la Ciudad de México, con participantes representando a reguladores, usuarios e INM de Argentina, Costa Rica, Bolivia, Brasil, México, Perú y Uruguay, entre otros ponentes nacionales e internacionales. Presentaciones disponibles:
https://www.ptb.de/lac/index.php?id=6892

Taller Inter Americano sobre la Seguridad del Software y Hardware para Metrología Legal
En octubre de 2015, con el propósito de compartir experiencias sobre aspectos del software para la metrología legal, en el INTI se llevó a cabo este taller con la presencia de representantes de Brasil, Colombia, Costa Rica, Ecuador, Guyana, Haití, México, Panamá, Perú y Trinidad y Tobago.

Taller sobre el Proceso de Revisión de CMCs
En Noviembre 18, 2015, en Punta Cana, República Dominicana, se llevó a cabo este evento coordinado por la Coordinadora del Comité Técnico del SIM, Claudia Santo.

Taller sobre la Medición de Concentraciones de Gas para el Monitoreo de la Calidad del Aire y el Cambio Climático
Organizado conjuntamente por NIST-OEA-CENAM, se llevó a efecto del 8 al 15 de septiembre, 2015, en las instalaciones del CENAM. Presentaciones disponibles próximamente en:
http://www.oas.org/en/sedi/dsd/Energy/RECS-eng/GEI%20Measurements%20Workshop.asp

Calidad de las mediciones en Alimentos y presupuesto de incertidumbre
Training delivered by CENAM to SIM NMIs personnel.

ESTADÍAS
Sigue prevaleciendo la sinergia entre los INM del SIM.

Course on Temperature and Uncertainty Analysis
With the purpose to assist SIM NMIs currently developing new thermometry capabilities or expanding existing laboratory capabilities, this course was aimed to provide intensive "hands-on" laboratory training in the realization of ITS-90 fixed-point cells. The course was delivered by NIST from April 18 to 22, highlighting that the time was split between laboratory (90%) and lecture (10%) sessions. The attendees came from CENAM, CENAME, INACAL, INM, INMETRO, INTN LATU and TTBS.

Demand of a Quality Infraestructure for Traceable Measurements of Greenhouse Gases to Support their Measurement, Report and Verification Strategies.
Mexico City, February 24-25, 2016, with participants representing regulators, users and NMIs from Argentina, Costa Rica, Bolivia, Brazil, Mexico, Perú and Uruguay, between more national and international speakers. Presentations available at:
https://www.ptb.de/lac/index.php?id=6892

Inter American Workshop Safety Software And Hardware for Legal Metrology
In order to share experiences on software and hardware for legal metrology, this workshop was held in INTI on October 2015, with participants from Brazil, Colombia, Costa Rica, Ecuador, Guyana, Haiti, México, Panama, Peru y Trinidad &Tobago.

Workshop CMCs Review Process
On November 18, 2015, at Punta Cana, Dominican Republic, this event was held under the coordination of the SIM TC Chair, Claudia Santo.

Training Workshop on Measurement of Gas Concentrations for Monitoring Air Quality and Climate Change
Organized by NIST-OAS-CENAM, this workshop was held on September 8-15, 2015 at CENAM premises. Presentations available soon in:
http://www.oas.org/en/sedi/dsd/Energy/RECS-eng/GEI%20Measurements%20Workshop.asp

Calidad de las mediciones en Alimentos y presupuesto de incertidumbre
Training delivered by CENAM to SIM NMIs personnel.

INTERNSHIPS
The SIM community keeps the synergy among the SIM NMIs.

En 2015 y 2016 hubo intercambios fructíferos de experiencias mediante estadías.

Along 2015 and 2016, fruitful exchanges of experiences and knowledge through internships were done:

visitante / visitor	anfitrión / host	tema / topic
TTBS	INMETRO	volumen / volume
CENAME	INTI	temperatura / temperature
LATU	NRC	
INTI	NIST	sincrofasores / sinchro-phasors
CESMEC S.A.	CENAM	temperatura / temperature
INTI	CENAM	tiempo y frequencia / time and frequency
INTI	CENAM	Química / Chemistry
INEN	CENAM	longitud / length
Centro de Investigaciones de Metrología	CENAM	temperatura / temperature
CENAM	TEMPMEKO	temperatura / temperature
CENAMEP	CENAM	radiofrecuencia / radiofrequency
CENAM	NIST	acústica / acoustics
INM	INMETRO	elementos en matrices alimentarias / elements in food matrices
CENAM	NIST	masa / mass

Están previstas las siguientes:

The following have been arranged:

visitante / visitor	anfitrión / host	tema / topic
NIST	CENAM	Visita de experto en mediciones en vitaminas hidrosolubles y liposolubles, vitamina D y ácidos grasos en alimentos / Visit of expert on measurements of water-soluble, fat-soluble vitamins, vitamin D and fatty acids in food
CENAM	NIST	método de medición de proteínas / method for measuring proteins

OTRAS REUNIONES DEL SIM

Asamblea General
Con LATU como anfitrión, en noviembre 14-15, 2016, tendrá lugar la siguiente Asamblea General del SIM.
En noviembre de 2015, se llevó a efecto la Asamblea General del SIM en Punta Cana, República Dominicana.

Comité Técnico y Grupos de Trabajo

SIM WG16 Flujo y volumen
Con la finalidad principal de presentar informes de comparaciones y planificar nuevas, y discutir mecanismos de aprobación de CMCs, se celebró la reunión del Grupo en Arlington, Virginia, EEUU, el 12 de abril de 2016, aprovechando la participación en el 9th International Fluid Flow Symposium.

OTHER SIM MEETINGS

General Assembly
The upcoming the SIM General Assembly will be held on November 14 and 15, 2016, hosted by LATU.
On November 2015, at Punta Cana, Dominican Republic, the SIM General Assembly was held.

Technical Committee and Working Groups

SIM WG16 Flow and volume
This WG met to address comparison results and plan new ones, and to discuss mechanisms to approve CMCs. The meeting was held on April 2016 in Arlington, Va, USA, as a satellite event of the 9th International Fluid Flow Symposium.

SIM MWG8 Química (cantidad de substancia)
Mayo 16-19, 2016
LACOMET/San José – Costa Rica
El objetivo de esta reunión fue presentar el estado de las comparaciones propuestas y definir nuevas; revisar el estado las CMC declaradas; revisar los resultados derivados de la reunión del COLABIOCLI – Traceability in Clinical Analysis realizada en Ecuador; actualizar la información sobre la capacitación que dará el NIST sobre química clínica en 2016; y discutir los proyectos propuestos y en proceso con apoyo del BID. Como parte de la reunión se ofrecieron dos eventos de capacitación: una sobre mediciones y estimación de la incertidumbre en calidad alimentaria, y otra sobre el proceso y la revisión en la declaración de CMC. Como parte de la reunión el 16 de mayo se realizó el *Awareness Seminar – Metrology in Chemistry and Nanometrology*.

Quality Management Systems Working Group
The Chair of the QMSWG will promote a discussion on key issues for peer reviewing during the upcoming SIM TC meeting. Este Grupo de Trabajo ha llevado a cabo una encuesta para conocer más acerca de las necesidades de los INM e ID sobre sistemas de gestión, con la intención de apoyarlos en el proceso de publicar sus CMCs en la KCDB.

Quality Systems Task Force
El QSTF ha celebrado reuniones en Santa Cruz, Bolivia en abril de 2015; Punta Cana, República Dominicana en noviembre de 2015, y en Halifax, Canadá en mayo de 2016.

En Santa Cruz, estuvieron agendadas las solicitudes de NRC, INTI, CNEA, INMETRO y NIST.
En Punta Cana, los institutos nacionales de metrología e institutos designados NRC, TCC, INACAL, CENAMEP, INTN, IBMETRO, CENAM, NOAA, CESMEC, CISA, UDEC, INTI, INEN and NIST presentaron sus solicitudes, mismas que fueron resueltas.
En Halifax, se hizo lo propio con las solicitudes de NIST, CENAM, INM e IDIC.

SIM MWG8 Chemistry (amount of substance)
May 16-19, 2016
LACOMET/San José – Costa Rica
This busy meeting was aimed to report proposed and new comparisons, update of CMCs claims, update after the COLABIOCLI – Traceability in Clinical Analysis meeting carried out in Ecuador, update the clinical chemistry training arranged to be done at NIST, discuss the proposed and in process projects supported by IDB.
In addition, two training on Food Quality measurement and uncertainty budget and on CMC claim process and review were carried out. Besides, an Awareness Seminar – Metrology in Chemistry and Nanometrology was held on May 16th, 2016.

Quality Management Systems Working Group
The Chair of the QMSWG will promote a discussion on key issues for peer reviewing during the upcoming SIM TC meeting. This WG has promoted an inquiry to better know the needs of NMIs and DIs for the process of publishing their CMCs in the KCDB.

Quality Management Systems Task Force
The QSTF has met at Santa Cruz, Bolivia in April 2015; Punta Cana in the Dominican Republic in November 2015, and in Halifax, Canada, on May 2016.

At Santa Cruz, NRC, INTI, CNEA, INMETRO and NIST were scheduled to present their submissions.
At Punta Cana, submissions by NRC, TCC, INACAL, CENAMEP, INTN, IBMETRO, CENAM, NOAA, CESMEC, CISA, UDEC, INTI, INEN and NIST were discussed and solved.
At Halifax, NIST, CENAM, INM and IDIC presented their submissions.

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