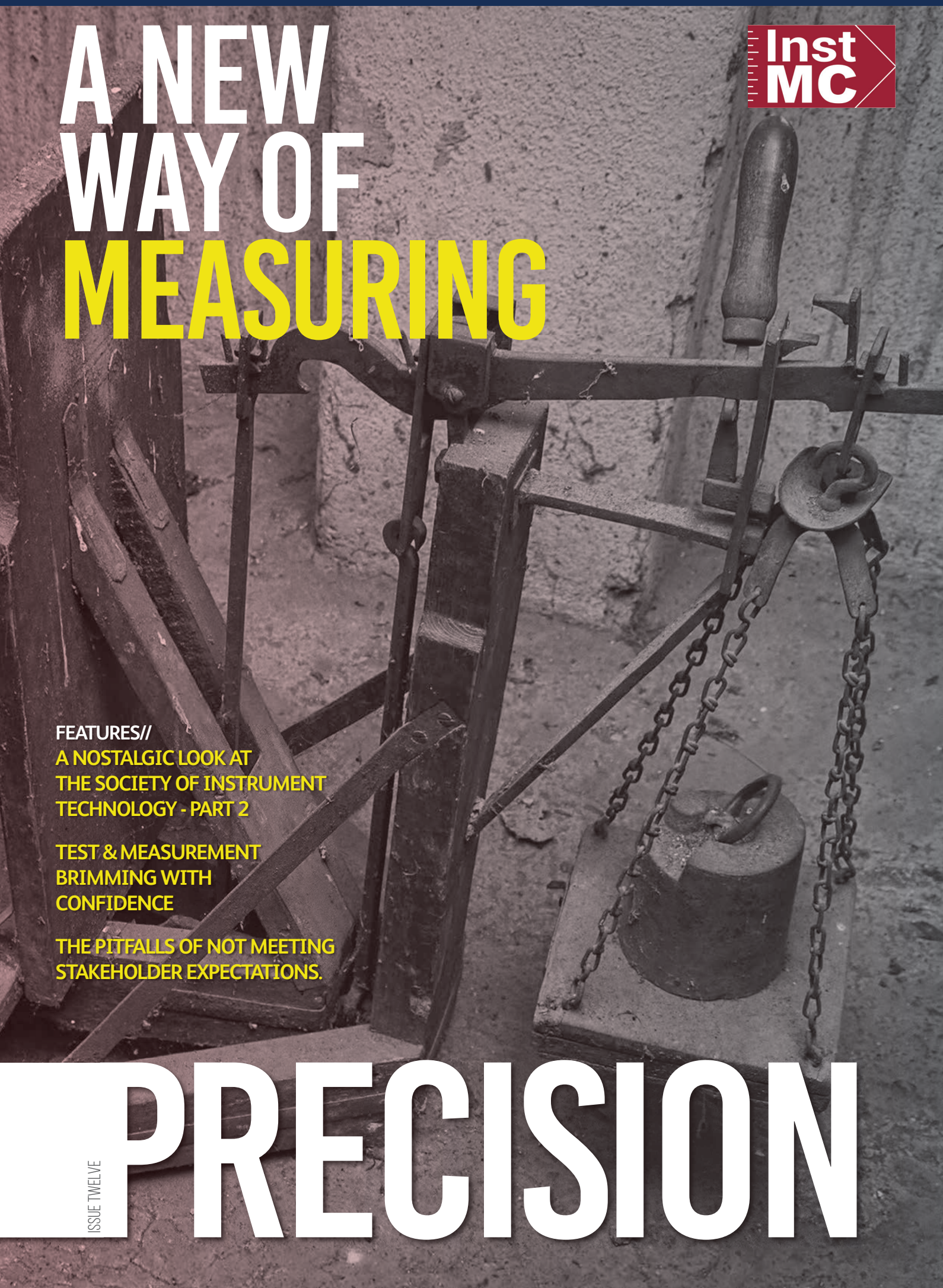
A NEW WAY OF MEASURING



FEATURES//

A NOSTALGIC LOOK AT THE SOCIETY OF INSTRUMENT TECHNOLOGY - PART 2

TEST & MEASUREMENT BRIMMING WITH CONFIDENCE

THE PITFALLS OF NOT MEETING STAKEHOLDER EXPECTATIONS.

ISSUE TWELVE

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FUNCTIONAL SAFETY IS COMING OF AGE

IEC 61508, the functional safety standard, will be 21 years old in December, and in that time it has effected a radical change in how we manage our safety systems across all industries and our homes.

When first released it was often assumed that the standard was only relevant to the Nuclear, and Oil and Gas sectors, or to companies that could realise Major Accident Hazards - this assumption was misguided.

Functional safety techniques are as equally applicable to devices used in trains and planes as they are to the domestic appliances you use in your home or the car you drive.

During the 21 years since its introduction, functional safety standards have been developed: for trains addressing RAMS, software and signaling (EN 50126 / 128 / 129), systems in planes (DO-178), the software we use in our domestic appliances (IEC 60730), the safety integrity of the devices in our cars (ISO 26262) , as well as the software used for the Space X program.

Many more functional safety standards are being developed covering a diversity of systems such as power drives (IEC 61800), medical equipment (IEC 60601), and connected home environments (IEC 63168).

If you are interested in functional safety and / or getting involved in standards development, the Functional Safety Special Interest Group (FS-SIG) is one of a number of special interest groups within the Institute. The FS-SIG is responsible for promoting the awareness and understanding of safety-related topics associated with measurement and control.

The FS-SIG is the body that represents the Institute in reviewing any safety-related submissions that it receives.

We invite or co-opt our membership from a wide spectrum of end users, regulators, vendors, contractors and consultants so that we may represent a broad range of interests in safety-related matters.

The FS-SIG organises conferences, workshops and seminars and we publish articles in the Institute's journals. Two one-day briefing events ('FS Hints, Tips & Pitfalls') are planned for October; one in Bristol, Avon the other in Immingham, Lincs.

Our main focus is the safety-related UK and European Regulations, in particular, IEC 61508 and the associated sector-specific standards. All of these areas continue to develop and represent significant challenges for guidance and understanding.

We often review and comment on draft HSE publications and welcome this opportunity to add value.

The FS-SIG is managed by a small team of members, the FS-SIG Executive, who meet twice a year. Many members also belong to other professional bodies and this promotes an exchange of views and information throughout the discipline.

The SIG also administers the Institute's professional level qualification in FS; 'Registered Functional Safety Engineer' (RFSE). Details are available on the website.

Members can join the SIG through the InstMC website; the group will then provide you with notification of FS events and developments, and a series of briefing notes that are planned.

Colin Easton
CEng, RFSE
Member of the FS-SIG,
MC - Fellow of InstMC

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INTERVIEW

DR BRIAN MILLINGTON ANSWERS

I can remember building wonderful Meccano vehicles with ultra-low gearing systems that would climb the steepest of hills.

Specialising in the field of Measurement of Fluid Flow, this month's interviewee is Dr Brian Millington, Managing Director, National Engineering Laboratory, Chair of InstMC FlowSIG.

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REGULAR

ASK THE EXPERTS

Our experts wade through our 'post bag' to find interesting questions to answer. The query this issue is:

What are the pitfalls of not meeting stakeholder expectations? Nick Oliver CEng MInstMC, asks how we can ensure a project runs to plan and is not subject to scope growth or creep?

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PRECISION

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A nostalgic look at the Society of Instrument technology - Part 2

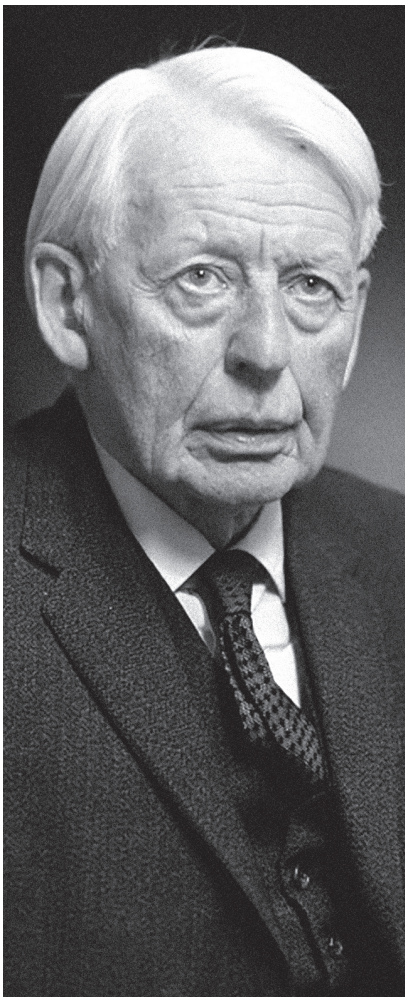
In 1994, as the Institute celebrated its Golden Jubilee, Stuart Bennett, Department of Automatic Control and Systems Engineering, took a look at the early years.

Why form a society of instrument technology?

There are really two questions here, why form a professional society and why in 1943-44? To answer the first we need to look briefly at the development in the use of industrial instruments. Instrument-making is one of the oldest engineering disciplines; however, until this century instruments were for the most part seen as 'scientific', for use in laboratories for experimental purposes. Since the turn of the century there has been a sustained growth in the application of indicating, recording and controlling instruments as an integral part of production processes.

It is difficult to give precise figures for the growth that has taken place (and even if it were possible such figures are difficult to interpret). Some indication can be seen from the change in instrument sales as a percentage of total machinery sales. These rose from 0.4% in 1919 to 1.6% in 1933 and 1.4% in I 9 3 5; and in the postwar years 194 7- 57 the following were reported:

Industry	Percentage of capital expenditure on instruments
Chemical	4.O
Petroleum	9.5
Public utilities	15.1
General manufacturing	24.3



The data refer to the USA and of course are difficult to interpret because of the cycles of general capital investment. They do indicate, however. the growing importance of instruments in industry. The reasons for this growth are complex and not fully understood, they include: a change in industrial operations from a craft-based structure to one based on a managerial hierarchy; incorporation of scientific knowledge into the production process; and the change from small-scale batch production to large-scale continuous operations. The need for some formal organization to represent and promote the interests of instrument users and manufacturers was recognized by Major E. Behar who, in 1924, formed a society for the promotion of 'instrumentation'. This society was soon disbanded but Behar, with Richard Rimbach, started the Instrument Publishing Company and began publishing, in 1928, the journal "*Instruments*."

Behar edited the journal for over 20 years and was an enthusiastic, tireless, proselytizer of the cause of instrumentation. He had no patience or mercy for those, be they governments, organized labour, or academics who doubted in any way that instrumentation, the 'science of measurement and control', was an unalloyed boon which would bring untold benefits to society. Some feel for Behar's zeal can be got from this extract taken from an editorial entitled 'Instrumentation benefits both capital and labour' which appeared in the May 1934 issue of Instruments.

Propagandists of all shades from red to silver are at it loud and strong ... Two things are certain in connection with current propaganda: (1) Most of the sensational speeches, articles and editorials are built up of words and expressions which have been twisted until they have lost their original meanings; and (2) most of the inflammatory orators and writers cunningly use such words and expressions to gain unfair advantages..Unfortunately,such terms as "labor saving" and "technological unemployment" are in that category. Of all the nonsense belched out of the filthy mouths of prejudice-inciters, the most dangerous to our industrial civilization is the anti-science and anti-machinery propaganda. It behoves us all to keep on proclaiming that - **Instrumentation reduces the sum of total waste and drudgery, thereby enabling people to have more and better foods, clothes, houses, books, cars and goods of all kinds, and also to have more and more leisure. Instrumentation enables employers to pay high wages and to make the profits on which government must largely depend for "endowing leisure" and maintaining humanitarian and social betterment agencies.** [Behar's emphasis]

Behar was on this occasion reacting to some of the current analyses of the causes of unemployment which had identified mechanization and technology as partially responsible, and he was also seeking to oppose some of the interventionist ideas of the 'New Deal'.

The journal Instruments, according to Cronshaw, writing in 1947, had served and continued to serve the users and the industry well by bringing together information and concerns that are common to a fragmented user group, and seeking to unify ideas which span mechanical, electrical, chemical engineering and scientific disciplines. However, he argued, there is a limit to what a technical publication can do and 'something more is needed to weld instrument technologists into the live, corporate body essential both to material progress and to the possession of self-respect and professional pride', and he saw a professional society, which provided personal contact, as the something 'needed to overcome the lack of coherence that has long handicapped the industry'.

Cronshaw envisaged that one of the functions of the Society would be to bring users and manufacturers together, stating that personal contact is a powerful stimulant to thought and effort. Meetings and joint meetings are the most effective way of bringing together not only members of one technological group, representing users, manufacturers, and scientists, but also members of different groups. In this way, channels of communication are opened up for the flow of ideas and information, which is vital to progress and essential to industry. Meetings enable questions to be asked and replies given from more than one viewpoint. If papers are well chosen, the discussion is apt to bring to light some useful points which might otherwise lie hidden for years. It is unfortunate that discussions are not always published in full, nor submitted for written contributions, and there is often a considerable lag in publication.

This need for organized support for industrial instrumentation had been seen in several countries in the late 1930s when in 1938 Lambert and Cronshaw began discussing with friends in this country and Australia the founding of a society. Their plans were interrupted by the war. By the second half of 1943 it was becoming clear that the tide was turning and people and organizations began to turn their thoughts towards postwar reconstruction, and reviving activities interrupted by war. During the war years, people outside the small group of instrument engineers within the process industries began to realize that automatic measuring and controlling devices were going to play an important role in all aspects of manufacturing industries in the future. For example, in a paper produced towards the end of the war, Arthur Porter outlined the way in which he thought control systems might be applied in industry. He was concerned to ensure that the 'design techniques so successfully applied to military problems, are applied with equal success to the problems of peacetime industry'. He drew attention to the fact that designing instruments which would respond rapidly to changing data values was 'closely allied to the problem of control system design' and that instruments which have good static characteristics may have large dynamic errors. He stressed the importance of having good instruments: 'in the future, good instrumentation will become increasingly important in industry, and will inevitably become the key to good industrial practice'. In this paper he stressed the need for a central research group to study industrial control problems and made the point that in the USA industrial use of control systems was greatly in advance of their use in this country, and that the 'American industrialist appears to be more 'control- minded' than his opposite number in this country.'

Porter was right to draw attention to the extent to which automatic control had been adopted by industry in the USA. By 1945 there were 15 small societies concerned with instrumentation as well as the Industrial Instruments and Regulators Division of ASME. The smaller societies combined in 1945 to form the Instrument Society of America. It is not surprising, therefore, that when on hearing the news of the formation of the Australian Society Lambert and Cronshaw revived their plans of 1938, there was an excellent response to their initiative.

Measurement and control

Behar, in 1924, defined 'instrumentation' as the 'science of measurement AND control', and throughout his life argued that the two were inseparable. He did not necessarily require that control be automatic control - this was desirable

and preferable but not obligatory - but conditioned by the ideas of scientific management he saw no use for measurement unless it was used in some way for the purposes of control.

Had Behar's usage of the word instrumentation to mean 'the science of measurement and control' found acceptance then the Society might have been able to become the Institute of Instrument Technology and the dichotomy between measurement and control might have been avoided. Instead the word 'instruments' has taken on a narrower meaning. The journal *Instruments* has over the years reflected the change, firstly in the early 1950s adopting the title *Instruments and Automation*, and subsequently *Instruments and Control Systems*.

The growth in the use of the word 'control' was a consequence of the war. Military requirements during the war led to a concentration of effort on servomechanisms and similar systems for which measuring devices were simple and well understood: the new and interesting part was the 'control'. The leading experts in the field, Tustin, Whiteley, and Porter, had no experience of industrial instruments used in the process industries but were aware of the general importance of feedback control. They were looking for a 'home' for 'control' and it seemed at one point that the Society might provide such a home when, in 1949, in response to an approach from the Government's Inter- departmental Technical Committee on Servo Mechanisms it agreed to form a specialist control section. During 1949, the Committee asked whether it could meet under the auspices of the Society to discuss servomechanisms. Lambert and Moss agreed to grant them facilities to meet but on the understanding that members of the committee join the Society and pay the normal membership fee - the IDTC members had offered to pay 10/- at a time when the subscription was £2.2s. The members of the IDTC agreed to this proposal and asked the Society to proceed, the intention being to have an inaugural meeting of a Control Section no later than February 1950 (Minutes of 13th Meeting of Council (undated October/ November 1949)). The Society did not meet the required date for the inaugural meeting of the Control Section was held on 28 March 1950. At this meeting Professor Hayes, Dr Uttley and Professor Tustin presented excellent papers covering 'Basic theory and recent history of servo-mechanisms' (Hayes), 'Stabilisation of closed loop control systems' (Uttley), and 'Problems to be solved' (Tustin). In the latter the authors expressed the view.

There is probably no branch of technology in which it is more important for this country to take a pre-eminent place than that of automatic control systems. This branch of engineering enters into so many productive activities, either as a direct contribution in the export of instruments, machinery and plant, or in making possible to this country a higher efficiency in a great variety of productive processes, that its advancement is a matter of national concern.

At the time the formation of a control section was a sensible decision as it brought within the ambit of the Society the mainstream activities in control systems while the larger professional institutions were still uncertain about how to accommodate and support this new discipline. During 1949, there were also discussions with the Department of Scientific and Industrial Research (DSIR) about holding a commercial exhibition of industrial instrumentation. In the latter part of 1949 and in 1950 the older institutions began to show a greater interest in control and the major conference on the subject, the 1951 Cranfield Conference, was organized by the DSIR with the assistance of the IMechE and the IEE. with no involvement by the Society.

Conclusion

The Society of Instrument Technology and the InstMC have had to negotiate a difficult terrain during the past 50 years. Maintaining independence has not been easy in the face of the competition from the other professional bodies. The Institute owes an immense debt of gratitude to the members who have served as officers and on its committees for their careful guidance over the years. Its continued independent existence is still vital, for one of the important lessons of the Second World War - the value of a holistic, systems approach to complex problems - has still not been fully learned. Behar constantly stressed the need to consider measurement and control during the design of the plant, not as an afterthought, and he argued that transducers, controllers, actuators and the plant had to be considered as one. The Institute, drawing its membership from those qualified in mechanical, electrical, electronic, and chemical engineering, is well placed to encourage and support the development of a systems engineering approach to problems, which transcends the traditional discipline boundaries. This was something that Gordon S. Brown, Professor of Electrical Engineering at MIT called for when he addressed the Cranfield conference in 1951: 'Control systems engineering requires an analysis of the whole system ... as well as integrated design of instrument, process reaction and controller, and the initiation of mechanical design, fabrication and test,' and he continued, 'the training of feedback - system engineers offers educators a real challenge ... Education for leadership at the broad engineering level cannot be accomplished by simply adding together the old specialities.' The Institute has played its part in trying to meet Brown's challenge but we have yet to achieve all that he asked. Perhaps in the next 50 years....

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- End-users' requirements and challenges

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- Thermocouples
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Application areas

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WORKSHOP HIGHLIGHTS

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A NEW WAY OF MEASURING

The recent revision of the International System of Units is a major shift in the way units are defined and creates numerous opportunities to improve the way we measure things.

In November last year the committee that oversees world measurement[1] met for the 26th time since its inception in 1875. Nothing remarkable there, but at this meeting about 60 representatives from the world's national measurement institutes (NMIs) approved the most significant change to the International System of Units (the SI) since it was established by the signing of the Metre Convention nearly 150 years ago.

The scientific background

The SI consists of seven base units which are;

- Time - second (s)
- Electric current - ampere (A)
- Temperature - kelvin (K)
- Amount of substance - mole (mol)
- Luminous intensity - candela (cd)
- Mass - kilogram (kg)
- Length - metre (m)

All derived units can be stated in terms of these base units. At November's meeting it was agreed that the world's definition of the kilogram, the ampere, the kelvin, and the mole would be revised to be derived from fixed values of fundamental constants of nature. As the other three base units were already defined in this way, this has allowed a major revision of the SI, which can now be realised from a set of seven constants with exactly specified numerical values rather than from definitions of the individual base units. The new SI came into operation on 20th May this year.

So what's really changed?

The short answer is nothing. Great care was taken by the metrology community to ensure that the value of each unit before and after the revision would be equivalent, so end-users would see no difference in the daily measurements they were making. What we have gained by fixing the values of the fundamental constants is the ultimate stability of the SI. If we take the kilogram as an example, the previous definition was the mass of a standard weight (the International Prototype Kilogram) which, as an artefact-based standard, was inherently unstable. Now we have a fixed numerical value for the Planck constant from which to derive the SI mass scale, and this will guarantee long-term stability.

All this is good news for NMIs but what is the benefit to the user community? The guarantee of stability of the SI will provide a stable measurement framework for long-term experiments: one obvious beneficiary of this is the measurement of temperature to chart climate change. Practical temperature measurement, based on a scale interpolated between a range of fixed points (such as the triple point of water), has undergone a number of changes over the last century making the comparison of measurements over time very difficult. By relating the unit of temperature, the kelvin, to a fundamental constant (in this case the Boltzmann constant) absolute temperature values will be comparable now and in the future. The fixing of the Boltzmann constant also means that there is the potential to make temperature measurements directly from the SI definition rather than in relation to a scale derived from fixed points. At high temperatures (above 1300 K) this is already being done with radiometry and, in the longer-term, approaches such as Johnson Noise Thermometry and Acoustic Gas Thermometry will be the basis of instruments which can directly realise the SI temperature scale and are effectively self-calibrating.

The Kilogram

The unit that underwent the most fundamental change as part of the SI revision was the kilogram, the unit of mass. As already noted the definition was directly linked to the mass of the International Prototype Kilogram. All mass measurements around the world were ultimately traceably to the mass of this cylinder of platinum-iridium alloy. However, as a physical object, the value of this standard was intrinsically unstable and, while fit for purpose in 1889, its potential instability was increasingly becoming an issue when making very accurate mass determinations. The new definition of the SI unit of mass relates it to a fixed numerical value of the Planck constant, h, and as such guarantees its ultimate long-term stability. The practical experiments which allow us to realise the kilogram from a fixed value of h are the X-ray crystal density (or Avogadro) experiment, which determines the number of atoms in a sphere of single-crystal single-isotope silicon, or the Kibble balance apparatus which balances the gravitational force on a mass standard with one generated electro-magnetically using very accurate quantum electrical standards. Of these two approaches it is the Kibble balance technology which offers the scope to extend the use of NMI level equipment to the shop floor and also to make measurements of masses over many orders of magnitude.

Kibble balance history and future exploitation of the technology

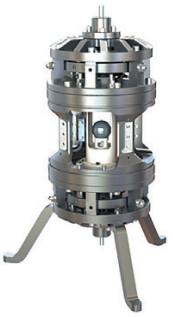
The Kibble balance was originally called the watt balance and was devised by Dr Bryan Kibble at the National Physical Laboratory (NPL) in the UK in the 1970s. Over the years NPL and other NMIs have built and optimised balances to make more and more accurate measurements of the Planck constant with the ultimate aim of redefining the SI unit of mass in terms of this fundamental constant. By 2016 the various experiments had reached a level where the NMI community was happy that the value of the Planck constant could be fixed, and the kilogram could be redefined. Thus, at the 26th meeting of the CGPM in November 2018, the revision of the SI, including the redefinition of the kilogram, was ratified.

[1]The General Conference on Weights and Measures (Conférence générale des poids et mesures, CGPM)

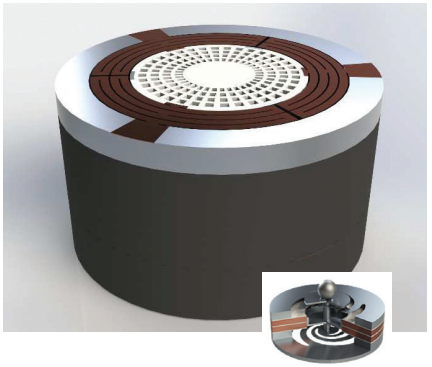
The change opens opportunities for the development of new devices, based on the Kibble balance principle, to meet the future mass, force and torque measurement needs of industry and research. Initially NMIs will develop more usable instruments for realising the SI unit of mass and disseminating it to their calibration customers. Here NPL is ahead of the game as it has been working on a next-generation Kibble balance for about four years. This device will operate at the same accuracy as the Planck determination experiments but is based on new measurement principles and has an innovative seismometer type construction meaning that it will be much easier to set up and use. However, the real impact will come when direct measurement with respect to the SI can be performed on the shop floor as well as in the research laboratory. NPL is looking into designs for both macroscopic and micro-Kibble balances which will provide direct SI traceability for mass measurements at any location and over a wide range of mass (or force) values. Such a balance could be used to make mass and force measurements in the mass range from 1 g to a few hundred grams (a force range of 0.01 N to a few newtons) and would be calibrated against a standard voltage source. It could be used in harsh environments or embedded in a production process where conventional calibration could not be undertaken. Additionally, its operating principle means that it responds more quickly than conventional balances and force sensors to changes in the input force, making it more suitable for dynamic, in-process measurements.

A major feature of the Kibble balance principle is that it is scaleable so can also be applied to measuring micro-masses and forces. For masses below about 100 mg an electrostatic rather than an electromagnetic balance would perform better but the operating principles are very similar. An electrostatic micro-Kibble balance would have the in-situ calibration and dynamic response advantages of the macroscopic electromagnetic device but with the additional benefit that it could also improve on the uncertainties currently achievable by traditional mass and force measurement devices, which are ultimately traceable back to the kilogram. With current technology, small mass values have to be derived, via a series of sub-divisions, from the 1 kg level. At each stage of sub-division, the uncertainty increases, so at 1 mg the relative uncertainty will be about 0.1 %. Since the Kibble balance can make SI traceable measurements at any nominal value, a micro-Kibble balance operating in the milligram or microgram range would be able to provide direct traceability to the SI unit of mass and significantly improve the accuracy of measurement achievable. Users interested in measuring relatively small amounts of substance very accurately, reliably, and reproducibly would benefit. Potential applications include pharmaceutical research and production (especially for personalised medicine), real-time particulate measurement for environmental monitoring, semiconductor and micro-fabrication, micro- and nano-robotics, production of trace element reference materials, calibration of atomic force microscopes, and biomedicine (cell and gene therapy).

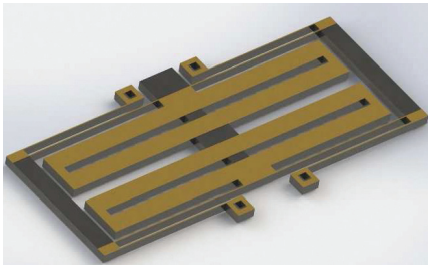
So, whilst the kilogram redefinition has made no difference as yet, in the future it will bring safer medicines, more efficient production lines, and improved environmental monitoring. Kibble balance instruments offer the opportunity for direct traceability to the SI at the point of measurement which can improve the accuracy and reliability of measurements. The Kibble balance is self-calibrating and offers improved dynamic performance over current technology. Furthermore, the technology can be scaled so direct SI traceable measurements of micro - and nano - masses and forces become possible for the first time.

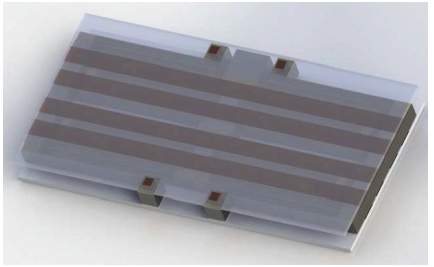


NPL's next generation Kibble balance will realise the SI unit of mass at NPL and give traceability to all mass measurements made in the UK



Design concepts for commercial Kibble balances. The balances would use electromagnetically generated force compensation and could measure masses from tens of milligrams up to a few hundred grams.





Electrostatic micro-Kibble balance concept for mass measurement from a few milligrams down to picograms

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Discover the way forward - Hints, Tips and Pitfalls

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Date: Tuesday 15th October 2019
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Location Two

Date: Thursday 17th October 2019
Location: HCF Catch, Redwood Park Estate
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This event is designed to brief the end user on good practice in Functional Safety.
Recognised authorities will provide concise briefings focused on distinct aspects of functional safety.
Each briefing will be followed by a Q&A panel session in which the experts will respond to questions from the audience.

Briefings will cover:

- SIL Determination, Tolerable Risk & ALARP
- SIF Design & Compliance Evaluation
- SIS Product Selection
- SIS Cyber Security
- SIS Operation & Maintenance
- Professional Development with the InstMC
- Functional Safety Management

The briefings will all be unbranded and non-commercial. They will not promote any proprietary solutions but will identify possible approaches, the associated pros and cons, and the traps to avoid. A concurrent exhibition will allow exploration of a range of related vendor offerings in the Functional Safety arena.

(An awareness of Functional Safety principles will be assumed)

FUNCTIONAL SAFETY 2019

Q&A

Dr Brian Millington

Specialising in the field of Measurement of Fluid Flow, this month's interviewee is Dr Brian Millington, Managing Director, National Engineering Laboratory. Chair of InstMC FlowSIG.

What was the root of your interest in Engineering?

I grew up in 1960's Britain, a time when kids played with Meccano, Lego, Scalextric and Tri-ang Hornby model trains rather than iPhones and iPads. These were the things that first grabbed my interest in all things mechanical, but perhaps more importantly they encouraged delving into understanding how things worked. I can remember building wonderful Meccano vehicles with ultra-low gearing systems that would climb the steepest of hills. It was a great introduction to some of the physics I later learned in secondary school, but during my early teenage years I would say that engineering was never really on my horizon as a career, despite being brought up in Liverpool with its long industrial heritage.

When I entered 6th form at school at the age of 17, I was lucky enough to have a teacher for the following two years who was inspirational, not in engineering, but mathematics. But as I was to find out later, the boundaries are often blurred. That was probably the start of my formal journey to an engineering qualification and passion for the subject in a professional sense. He encouraged me and provided a lot of support in his own time, culminating in heading off to university to study Applied Mathematics. Again, chance played a major role. Liverpool University at the time had major strength in the subject of fluid mechanics and my undergraduate courses were heavily biased towards this topic, which is at the heart of many engineering systems. The next step was to build on the fluid mechanics knowledge by undertaking a Mechanical Engineering PhD at Southampton University. This was perhaps the most enjoyable and stimulating 4-years of my life, learning so much about the practical application of fluid mechanics and being able to bring it to life through the sponsorship I had from the Central Electricity Research Laboratory in Leatherhead. This is when my professional engineering career really started, and it was at Southampton University I first came across the National Engineering Laboratory (NEL) through one of the Professors who had previously been a director at NEL.

I wanted to move to Scotland to work at NEL after completing the PhD because the scientific challenge remained in the broad area of fluid mechanics, but the Laboratory brought added practical dimensions most notably around the major flow measurement challenges in the upstream oil and gas industry of the time.

And the next 34 years have been about driving practical engineering flow measurement forward, through a major involvement with the UK's National Measurement System. Today the NMS is part of the Department for Business, Energy and Industrial Strategy and over many decades has led ground-breaking areas of metrology that people now take for granted. It is one of the most successful aspects of Government Science policy, and the three principle laboratories involved – NEL, LGC and NPL – are world-leading in their science and engineering fields.

What is your vision of Engineering in Britain in 2020?

I would like to see three things happening:

Firstly, at school level, the creation of far more awareness of the critical role of engineering in the seamless underpinning of everyday life. The traditional STEM subjects are fine, but there needs to be greater explanation of the role of these subjects in all branches of engineering; inspiring the next generation of engineers.

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Secondly, I would like to see encouragement of ambitious and longer-term planning within engineering and less short-term make-do. Singapore has an enviable pedigree in this respect with some highly visible and stunning engineering projects. It has also supported and embedded their vision with major investment in top-class engineering universities. A lot can be learned through study of their modern history.

Thirdly, in my vision I would see a resolution of the perennial negative perception and image of professional engineering. This is a peculiarly UK attribute. Other countries have learned to celebrate great engineering achievements and have created far greater esteem and prestige for the profession. This I would like to see happening in the UK.

What should the UK government do to address the shortage of UK engineers?

Before reflecting on this, it is important to examine why there is a shortage in the first place. What factors are turning the younger generation away from pursuing a career in engineering in the UK?

I strongly believe that it is at secondary school level where greater focus is required to stimulate and encourage people to appreciate the astonishing achievements that have been made and inspire interest in engineering as a career. For example, take students to Electric Mountain in North Wales to see a fabulous piece of civil and mechanical engineering with great practical and economic value to the UK. Then relate the study of topics in physics and mathematics directly to how it works, bringing the world of engineering to life for students and making the connection to school and university learning.

Government policy can clearly assist in this objective through support and direction of appropriate learning institutions, but it should also engage far more with the media in pursuit of positive recognition of engineering achievements.

Presently Government has a target of increasing public sector R&D funding which is laudable, but it needs guidance to support long-term strategic engineering projects and initiatives that will bring sustained economic value to the whole of the UK. Communicating these visions effectively is essential.

What do you do in your free time to relax?

I started playing golf in my mid-40s and the bug has certainly bitten. If you can avoid the frustration of balls flying in every direction, it is a great way to switch-off and see some good countryside, especially in Scotland.

Ever since the age of five I have really enjoyed walking in the hills. I cycle too, and take the time to do daily fitness routines down at the gym. Outside of active sports, I enjoy reading novels of all sorts.

Given one wish what would that be?

I'd like to return every couple of hundred years to see how things progress. I think that would be fascinating in so many ways.

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TEST & MEASUREMENT BRIMMING WITH CONFIDENCE

Test & Measurement delivers a solid Q1 performance for M&A remarks Roger Buckley, corporate finance partner at BDO LLP.

Political turmoil has become 'normal' in the UK and the twists and turns of the Brexit negotiations, played out in the glare of public scrutiny, has made business planning more difficult. However, as the drama unfolds, the mergers & acquisitions market has shrugged its shoulders and decided to 'carry on' as usual. Companies are getting on with their business, and the M&A market continues to hum with activity, buoyed with a notable surge of private equity investment.

Analysis of M&A transactions by accountancy and business advisory firm BDO LLP reveals ongoing confidence in the market in the first quarter of 2019, with deal volumes holding firm, PE valuations remaining robust and trade valuations only dipping slightly. 599 transactions completed in Q1, an increase of 7% compared with the first quarter of 2018. Trade deal volumes saw a moderate increase of 5% compared with the previous year, while private equity activity rose by an impressive 22%.

Valuations of target businesses likewise held firm overall in Q1. BDO's Private Equity Price Index (PEPI) recorded a multiple of 12x, in line with the two previous quarters, and maintaining its premium profile compared to trade valuations. In contrast, BDO's Private Company Price Index (PCPI) revealed a decline in valuations, from 10.4x seen in Q4 2018 to 9.8x in Q1.

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Given the current geo-political backdrop, the M&A market delivered a very creditable performance in Q1. There is a smattering of hesitancy from vendors and delay in some investment decisions, but the number of acquirers in the marketplace continues to exceed the number of businesses for sale. Across the market, we see sector-specific dynamics being a stronger determinant of value and success than Brexit uncertainty. Although we would expect some reduction in activity and possibly a further softening in values during 2019, we believe this will not affect a quality business seeking good value. Ultimately, the PE and debt markets remain open for business and ready to deploy cash.

Test & Measurement market brimming with confidence

We see these dynamics playing out in the Test & Measurement (T&M) sector that saw a steadfast performance in Q1 with 95 deals completing, maintaining the high volumes seen through 2018. The strong sector dynamics drive a confident outlook and continue to underscore a compelling investment case. The number of cross-border deals increased to 39 %, underlining the importance of international reach to so many T&M businesses. Deals ranged from very large transformational acquisitions, to small tuck-in buys, often by serial acquirers.

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The largest deal in the quarter was the acquisition of Thermo Fisher Scientific's anatomical pathology business by Japanese company PHC Holdings for US$1.14bn. The acquired division is a provider of microscope slides, instruments and consumables, with 1,200 employees. Another sizeable deal was the acquisition of Roper Technologies' scientific imaging business by Teledyne for $225m, which adds complementary industry-leading brands to Teledyne, including Princeton Instruments, Photometrics and Lumenera.

In the UK market, AIM-listed player Scientific Digital Imaging had a busy quarter, acquiring three small businesses. Its first acquisition of the year was of DeepMatter's scanning ion conductance microscope business, followed by Thermal Exchange which specialises in process cooling and temperature control equipment, and then MPB Industries, which designs and manufactures flowmeters and process control instrumentation for a range of industries including water treatment, oil & gas and scientific analysis. Scientific Digital Imaging has a strategy to continue making acquisitions that strengthen its product range and existing technologies, and offer new and attractive routes to market.

Another serial acquirer is Indutrade, a listed Swedish industrial conglomerate that has derived much of its growth from acquisitions. Alongside other deals outside the T&M sector, Indutrade acquired Acumo, a leading Nordic supplier of automation solutions in the areas of positioning, measurement and detection, and Adam Equipment.

Adam Equipment achieves a new platform for growth with Indutrade

Adam Equipment is one of the world's leading measuring companies, manufacturing and supplying precision balances and scales to more than 100 countries. Over the last 45 years, Adam has developed a strong brand and leading position in the weighing systems market, and it is a key brand in a number of geographies and sectors. Adam has now become part of Indutrade's Measurement & Sensor Technology division headed

by Patrik Stolpe, joining seventeen other groups in the division, including Datum Electronics, which develops shaft power measurement solutions, Vacuum Engineering that specialises in leak detection equipment, and Flintec, a manufacturer of sensors, and measuring equipment.

The existing management team of Adam Equipment will continue to drive the business forward under the new ownership and will benefit from the backing and opportunities that exist as part of a larger group.

Many happy homes to choose from in T&M

Sometimes justifiably, large corporate acquirers and particularly private equity have a bad press for buying businesses, mercilessly squashing them into their empire, and squeezing them for every ounce of value. However in the T&M market, there is a significant population of acquirers such as Indutrade and Scientific Digital Imaging with a gentler ethos, keen to retain management teams, foster entrepreneurial spirit, nurture technologies and promote brands, providing the means for a fledgling business to take flight and achieve much more, much faster than could have been achieved independently. Halma, Judges Scientific, Battery Ventures and Union Park are just a few other names that surface regularly and offer attractive propositions to management teams. Different organisational cultures and personalities will suit different businesses - and fortunately, in the T&M market, there is no shortage of potential homes for quality businesses seeking a new platform for growth.

> The strong sector dynamics drive a confident outlook and continue to underscore a compelling investment case. The number of cross-border deals increased to 39%, underlining the importance of international reach to so many T&M businesses.

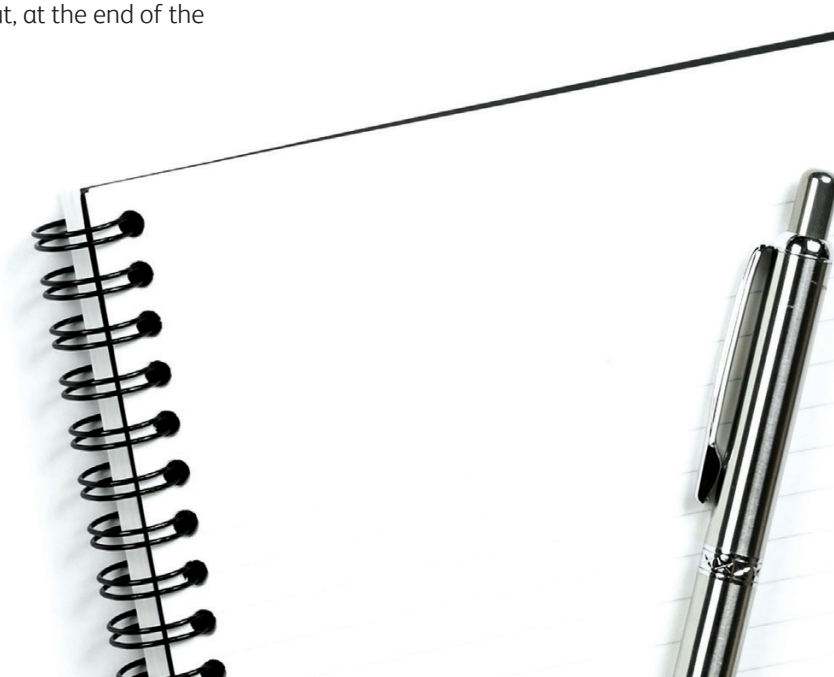
ASK THE EXPERTS

What are the pitfalls of not meeting stakeholder expectations? Nick Oliver CEng MInstMC, asks how we can ensure a project runs to plan and is not subject to scope growth or creep

It's human nature to be competitive and, in our engineering world, we all tend to be Alpha males or females and competitively show our superior engineering/management/safety consciousness skills be it in a subtle, inadvertent or overt way.

We also want to implement a cost-effective solution that meets a defined risk without adding unnecessary mitigation layers that become irrelevant when the solution is applied. The trouble is, in our world of group design and stakeholder buy in, we have to accept that everyone's perception of the risk and how it should be managed is different. Tools such as LOPA and fault tree analysis help define what is real and what is redundant but, at the end of the day, we not only have to make a safe system but it has to be seen to be safe.

The men and women exposed to the risk will also want to see a safe system. They are the persons checking in for the chopper or entering the site gate. Sometimes you have to add that extra gas detector or target tee. The feeling of being safe and looked after by the engineering team is as important to those at risk as the parts of the system validated to give that benefit. To provide that perception, nothing beats the physical presence of extra equipment, especially if this has been designed in at their request.



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What has to be thought of however is the ownership costs of these extra measures. A target tee has little future cost but an extra gas detector has to have an ATEX inspection and regular proof tests throughout its life. Even so, an extra one or two detectors on a maintenance round should not stretch the budget too much.

Where extreme caution always has to be applied is in the response to the familiar calls of 'well let's we go up a level in ESD' or 'take out the whole plant instead of just that stream'. That is when we have to look closely at what is providing benefit in terms of risk reduction and what is just a warm and cosy blanket of unnecessary levels of outage. With reference to my opening gambit it could be termed competitive safety conciseness. It's an emotional beast, difficult to negotiate with and you can be on the back foot from the start if you are not fully prepared and armed with good statistics and even diagrams.

What can happen, and almost inevitably does happen, with a change to a safety system or fire and gas system is that once the new system is delivered, the court of stakeholder opinion gives its verdict. This can be a tricky time. What you thought was a fully agreed specification and design with all of your compromises already settled gets its last attempted re-design. Suddenly, technicians are on site installing instruments, panels are ripped out with new ones poised to be slotted in and the E-mails come in saying it must be wrong because it does not look/feel safe, or even familiar. The 'what ifs', 'wouldn't it be better ifs' and the inevitable 'the old system didn't work like this' cannot be easily dismissed. They must be worked through and addressed and you might even have to, with consent of the asset owners, take a few more hits in cost or resilience just to get the job done.

At this point we have not failed to deliver the project but we have failed to keep stakeholder involvement throughout the project. It can be tricky especially in a project that is delayed. Our industry's work practices, staff turnover and shift cycles make it even more problematic. It is critical from the outset of the project to explain philosophies, rationale, new concepts or novel equipment to all the stakeholders. You need to reinforce that message throughout the project life if you want to avoid delays and overspend.

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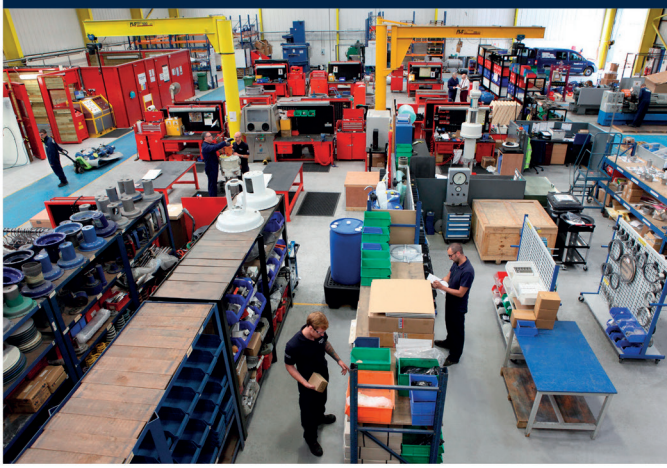

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