IMOA

INTERNATIONAL MOLYBDENUM ASSOCIATION
THE VOICE OF THE MOLYBDENUM INDUSTRY

ANNUAL REVIEW

2019/2020

www.imoa.info

IMOA Annual Review

Overview from the Secretary-General

Tim Outteridge
Secretary-General

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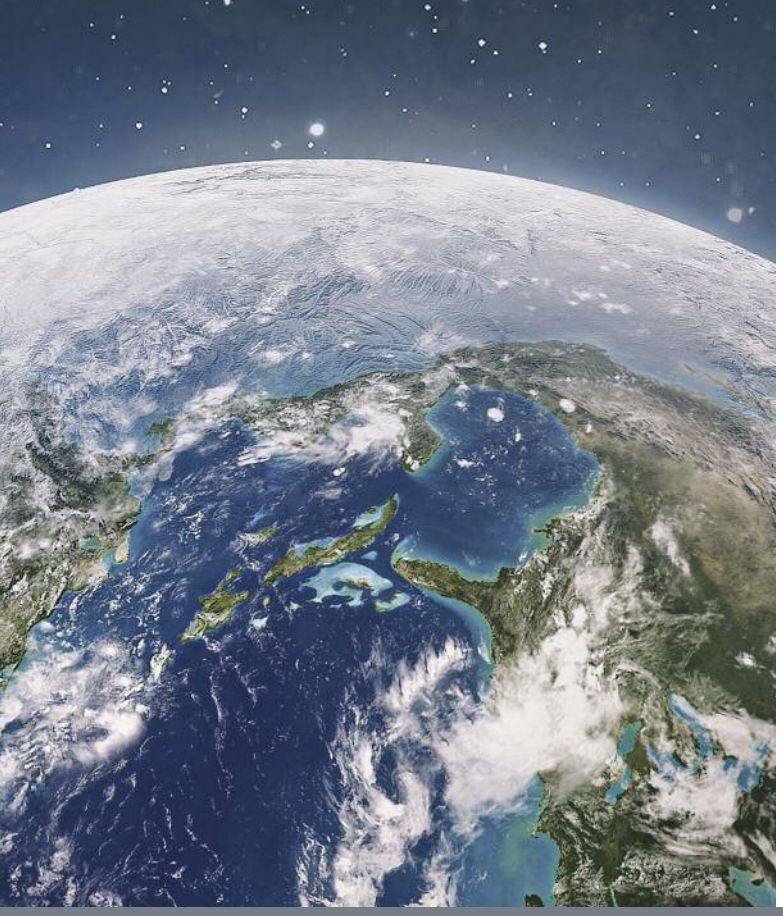


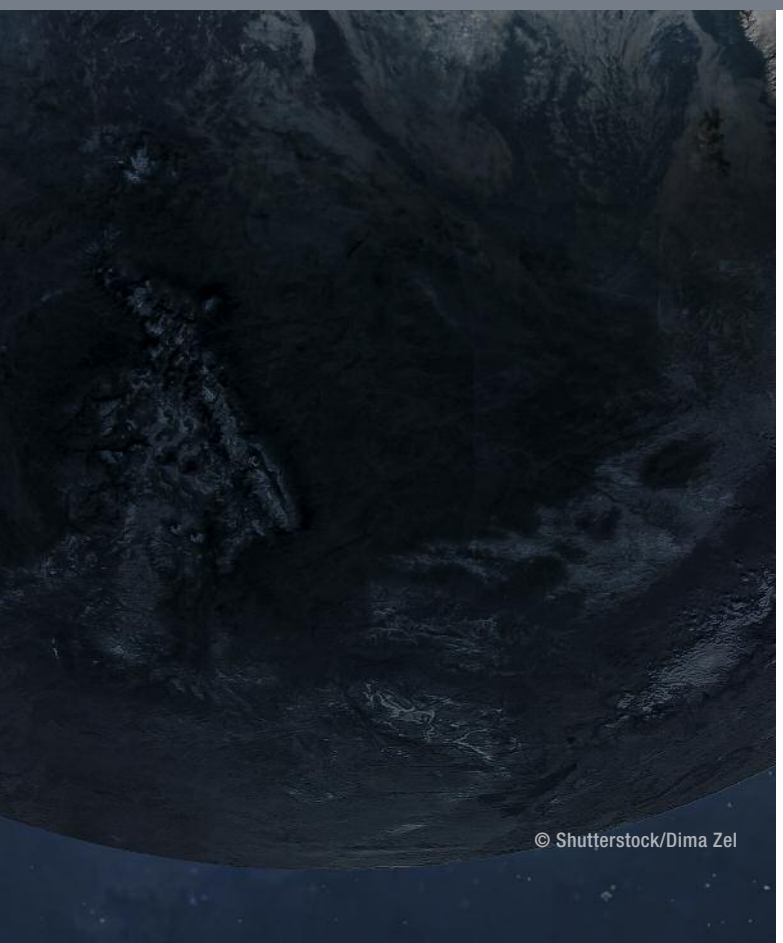
Our Annual Review highlights key achievements and milestones of the past year that demonstrate progress against actions identified in IMOA's strategic plan – available to download from the members' area of the website.

A robust approach to HSE

IMOA works diligently to ensure sound science and robust data is the bedrock for regulatory decision-making worldwide.

Over the last year, our engagement with regulators, particularly in the US, has produced very positive results. For instance, IMOA's datasets were used to inform many key parameters and outcomes in the Toxicological Profile for Molybdenum, published in May 2020 by the Agency for Toxic Substances and Disease Registry (ATSDR). A comprehensive data package was submitted to the US EPA (United States

2020 will be remembered as the year when the coronavirus swept the globe. Like other industries, the molybdenum industry has had to respond and adapt to the health, social and economic challenges of a world impacted by COVID-19. Against this backdrop, I'm pleased to report that IMOA has continued to advance its Market Development, HSE and other programs.



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Environmental Protection Agency) for future assessment of Mo/compounds under the US Toxic Substances Control Act, and a presentation was made to stakeholders in the State of Colorado about why IMOA's scientific data is a reliable basis for substance risk assessment.

Extracting the value of data for members on an individual basis is also a key objective. This was evidenced by dialogue with the relevant competent authorities, that led to the classification of molybdenum metal powder as 'not hazardous to water' under the German water hazard classification scheme.

Life Cycle Assessments (LCAs) are increasingly important as sustainable development continues to be a mantra of our times. As consumers become more conscious of the impact of their lifestyle choices, LCAs are frequently used to evaluate the sustainability credentials of competing materials. We have worked to ensure molybdenum's LCA data is widely disseminated and that our environmental effects datasets are embedded in relevant modeling software.

As the Molybdenum Consortium (MoCon), we have also delivered important updates to REACH Exposure Scenarios, extended Safety Data Sheets and technical dossiers for various molybdenum substances. MoCon delivers high quality results in a very cost-effective manner for all 61 members and we have important projects scheduled for completion next year.

Driving demand for molybdenum

Market development activities that demonstrate the value of molybdenum in our modern world remain as important as ever. Our programs promote the performance and sustainability credentials of molybdenum in a myriad of applications amongst fabricators, engineers, designers and material specifiers.

Education is a cornerstone of IMOA's market development work and despite the pandemic, we have succeeded in delivering an extensive program of educational workshops and webinars to around 2,500 attendees.

Outcomes of IMOA projects have triggered the development of new advanced flat steels as well as production trials of high-strength 'super-HSLA' steels and modified cast iron. These developments will, in time, result in lighter, safer, cleaner vehicles and more hard-wearing industrial applications.

Work on the Architecture, Building and Construction (ABC) sector continues to focus on guiding the selection of high-performing molybdenum stainless steel grades where they are needed.

Work has also continued at pace to publish the first American Institute of Steel Construction (AISC) stainless steel design specification, which will remove a significant barrier to the wider use of load-bearing stainless steel in buildings, bridges and other structures.

In regard to carbon steel, a new co-sponsored Steel Construction Institute (SCI) guide on the design and execution of high-strength steels (HSS) up to 700 MPa yield strength is being launched later this year and is expected to become the definitive guide for architects and specifiers using HSS.

China offers substantial opportunities for market growth. While China produced 55% of the world's steel in 2019 and their global market share of stainless steel production rose from 52% to 56%, its molybdenum use continues to be low, compared to other regions. In China, our efforts included the development of superior steel and cast iron grades, particularly for use in gear boxes and other automotive high-value parts, participating in information-sharing symposiums, and a study to support the use of molybdenum in Flue Gas Desulfurization (FGD) applications.

The role of communication

Our communications activity is designed to support HSE and, particularly, market development activity. The media outreach program continues to bear fruit with numerous articles placed in important industry publications, including Stainless Steel World, Stainless Steel World News, and Steel Times International.

Complementary to media outreach is our online communications program that has gathered significant momentum year-on-year. The website attracts over 10,000 visitors a month, while social media saw a 36% growth in followers. Bespoke video content, accessed via the IMOA YouTube channel, has been watched by over 3,000 viewers. In China, our online presence has gained pace, with the successful WeChat channel now attracting over 2,400 followers.

Market insight

Our regular market updates are valued by members. This information is bolstered by the popular market analysis session delivered by SMR at our Annual General Meeting. Each quarter we collate and publish global molybdenum production and use statistics. Annual and quarterly summaries are also released to the media generating consistent media coverage, cementing our role as a reliable source of information on the molybdenum market.

Better together

Our market development, HSE and MoCon programs are driven forward by the members serving on our various MD, HSE and MoCon committees and expert technical support. We are grateful for their continued dedication and support. Their expertise and experience are key to the delivery of our successful, targeted programs of work.

Our well-established working partnerships with organizations that have common goals, such as Team Stainless, the Nickel Institute (NI) and Eurometaux, enable us to deliver significant results for our members in a coordinated and cost-efficient way. We continue to build on these alliances to further our objectives.

The Year's Highlights
2019/2020

Membership

Existing membership represents

95%

of production outside China, CIS and Mongolia

HSE

Molybdenum was **successfully** **de-regulated** from the US State of Minnesota's list of Chemicals of High Concern

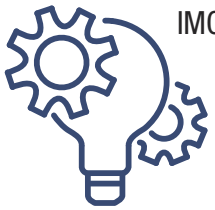
IMOA contributed **significant** data to the US **ATSDR's Toxicological Profile** for Molybdenum

REACH technical dossiers **comprehensively updated** for **3** substances

New Exposure Scenarios for RMC & Mo Trioxide

IMOA molybdate effects dataset was embedded in USEtox software, facilitating **accurate life cycle environmental impact assessments**

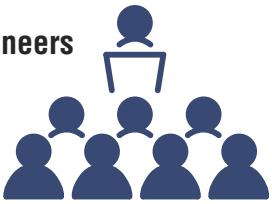
Market development



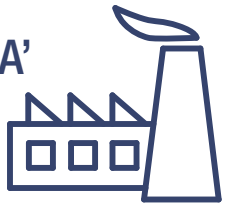
IMOA **research projects** informed advanced flat steel product development including 1000–2000 MPa direct quenchable and press hardened steels

4,000 downloads of papers from **2018 International Molybdenum Symposium** in Shanghai

1,200 **structural engineers** attended the AISC annual conference workshop on stainless steel structural design



Innovative concepts for **producing 'super-HSLA'** steel using molybdenum will be tested at several mills in Europe and North America



Communications

On average, **10,000** people visit the **IMOA website** each month

Social media following increased by **35%**

IMOA authored articles in **trade media publications** reached an audience of around **240,000**

Health Safety and Environment

Key Activities and Achievements in 2019/2020

Sandra Carey
IMOA HSE Executive

IMOA HSE Committee activities

A key cornerstone of the work undertaken by our HSE Committee is addressing toxicology misconceptions about molybdenum and its compounds. If left unattended, regulatory constraints based on poor-quality scientific studies have a negative effect in the marketplace. Impacts range from increased production and transportation costs through to material de-selection, reporting requirements and phase-outs at the user end of the supply chain. Regulation rooted in sound science is always our goal.

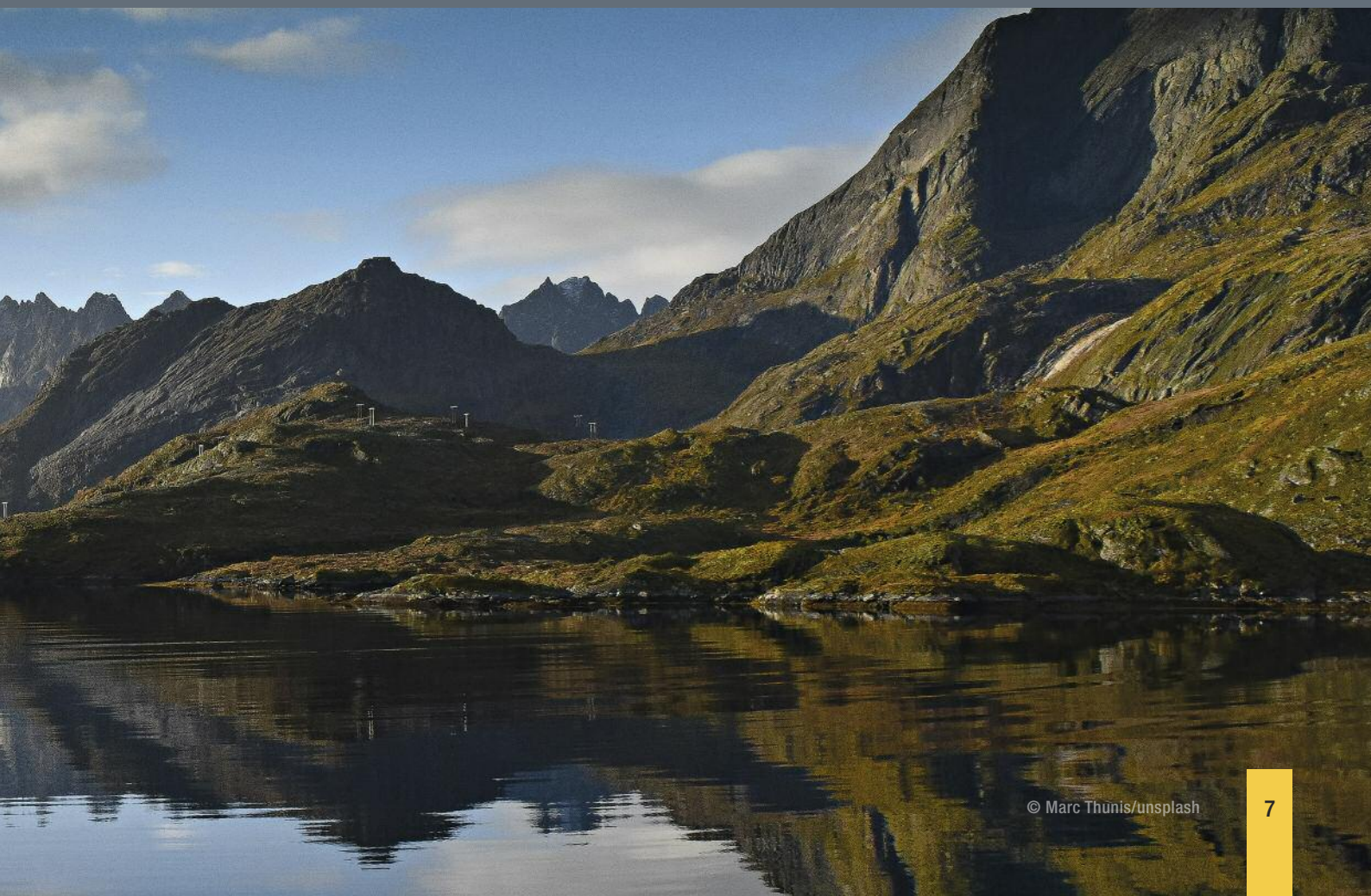
Dialogue with US regulatory authorities featured prominently during the past year:

Agency for Toxic Substances and Disease Registry (ATSDR) Toxicological Profile for Molybdenum

ATSDR Toxicology Profile for Molybdenum was published in May 2020. In 2017, as part of a public consultation period, we began dialogue with the ATSDR regarding the content of their draft Profile. After submitting a wide-ranging feedback document, we also worked to ensure they received IMOA's new study on reproduction toxicity to address significant data-gaps.

At the beginning of their drafting process in 2015, we also provided ATSDR with a significant number of IMOA studies to contribute towards the health effects risk assessment.

"Our Health and Safety Committee works to ensure that regulation of molybdenum across the globe is appropriate and based on sound science. Our programs of work generate robust scientific data to inform regulatory decision-making and ensure compliance with legal requirements."



© Marc Thunis/unsplash

It was essential for IMOA to proactively engage with ATSDR during the development of their 2020 ATSDR Toxicological Profile for Molybdenum because it will be a 'go-to' document for both regulatory authorities worldwide and the general public seeking toxicological information about molybdenum.

State of Minnesota

IMOA made a technical submission to the Minnesota Dept. of Health (MDoH) in April 2019 requesting the de-regulation of molybdenum from their list of Chemicals of High Concern (CHC) included in their Toxic-Free Kids Legislation. August brought the news that, similar to our earlier submissions to Washington and Oregon States, our de-list rationale and request had been successful.

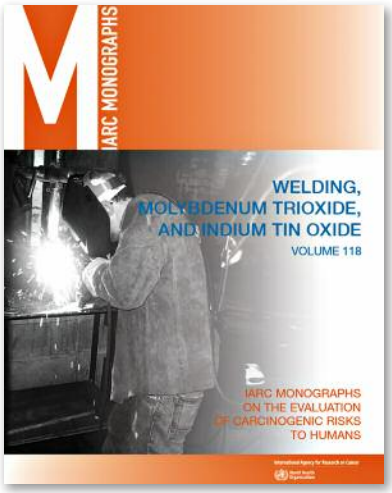
MN TOXIC FREE KIDS PROGRAM – 2019 UPDATE REPORT

Appendix B - Chemicals Removed

Table 2: Chemicals Removed from the 2019 Minnesota Chemicals of High Concern List

No.	CAS RN	Chemical Name	Use Exemption	Authoritative Source Delisted
41	7439-98-7	Molybdenum		WA CHCC

Also noteworthy is the MDoH decision to add molybdenum trioxide (CAS No. 1313-27-5) to their CHC list. This follows the International Agency on Research into Cancer (IARC), decision in 2018 to determine a Group 2B ranking for this substance, indicating it is possibly carcinogenic to humans. The substance already carries an EU-wide hazard classification of Category 2 Carcinogen, with which the IARC ranking is similarly aligned.



IRIS Risk Assessment for Molybdenum

Our main concern with the Integrated Risk Information System (IRIS) entry about molybdenum is that it is extremely outdated and therefore an inadequate tool for risk assessment. It has not been updated since it was produced in 1992. Since 2007, we have been generating very robust datasets according to international test protocols and making them available to regulatory authorities, but due to molybdenum not being an IRIS priority substance for updating, the IRIS molybdenum assessment does not benefit from the recent datasets. Despite being so outdated, IRIS is nevertheless often the first port of call for other US Agencies seeking Mo risk assessment data for regulatory rule-making purposes, so access to updated information is vital.

Working together with the North American Metals Council (NAMC), we met with the US EPA Office of Research and Development in November 2019. A compromise solution was reached whereby a new tab on each substance webpage in IRIS now links to further sources of risk assessment information. For molybdenum, the tab was introduced in March 2020. We will continue to seek dialogue with IRIS to communicate the importance of updating the molybdenum entry to ensure regulatory authorities have the most up-to-date, robust scientific information on which to base regulatory decisions.

US TSCA

Molybdenum and compounds are listed for future risk assessment under US TSCA (Toxic Substances Control Act). In preparation for the assessment, a public data call-in concluded in December 2019. We met TSCA representatives prior to the deadline to understand their data and formatting needs. We then submitted a comprehensive data package including our OECD-endorsed dataset about molybdate effects on human health and the environment, accompanied by an open invitation to maintain contact with IMOA.

State of Colorado

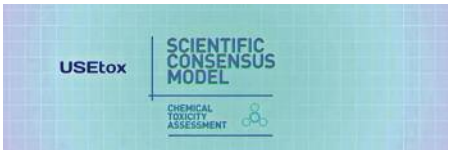
In September 2019, our HSE Executive Committee fulfilled a stakeholder engagement invitation arising from specific local community interest on the subject of why IMOA's scientific data is a reliable basis for substance risk assessment. The topic relates to an ongoing rule-making process that is reviewing a Mo water quality standard in Colorado.

Causal Analytics project

A recent HSE Committee project sought to examine the statistical robustness of a claimed inverse association between levels of molybdenum and testosterone in blood serum. The data source was the US NHANES database (National Health and Nutrition Examination Survey). Multiple statistical analyses using the Causal Analytical Toolkit methodology demonstrated and concluded the absence of any causal association. The project is currently in manuscript development phase, with a view to publication in a peer-reviewed technical journal.

USEtox project

August 2019 saw the successful conclusion of the USEtox project. This was a joint initiative by several metals associations which began in 2015. The goal of each association was to embed their environmental effects datasets into the USEtox modeling software, which is itself embedded within proprietary Life Cycle Assessment softwares. The inclusion of IMOA's molybdate effects dataset in the USEtox software, Version 2.11, will greatly facilitate more accurate environmental impact assessments for molybdenum. This is important because inaccurate assessments can adversely impact decisions in areas such as material selection for product development, or de-selection/substitution from existing applications.



Life Cycle Inventories

We have worked to enhance the accessibility of IMOA's 2018 updated Life Cycle Inventory Datasets for roasted molybdenite concentrates in powder and briquette form, and ferromolybdenum, by securing its inclusion into well-known proprietary software used by LCI practitioners, such as Gabi and SimaPro.

Process name	Country	Type	Data source
Roasted Molybdenite Concentrate (Molybdenum tech oxide) Molybdenum tech oxide powder; Mining through roasting ; Global production mix, at plant ; ca. 60% Mo content	GLO	agg	IMOA
Roasted Molybdenite Concentrate Briquette (Molybdenum tech oxide) Molybdenum tech oxide briquette; Mining through roasting & briquetting ; Global production mix, at plant ; ca. 59% Mo content	GLO	agg	IMOA
Ferromolybdenum (FeMo) Mining through FeMo production; Global production mix, at plant; ca.67% Mo content;	GLO	aggregated process	IMOA

Database: Professional database 2020

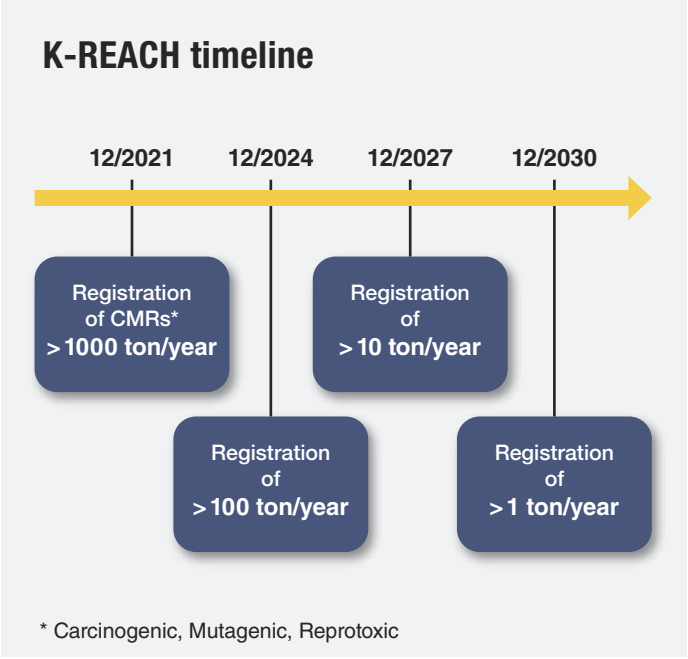
German Water Hazard Classification Scheme

In 2019, we saw another successful outcome of regulatory dialogue. We supported one of our members in presenting technical data to their competent authority which led to the classification of molybdenum metal powder as 'not hazardous to water' under the German water hazard classification scheme.

Looking ahead

Over the coming year, we will continue to support members by:

- Preparing for data-sharing activities in relation to Korea-REACH, where the first compliance date is the end of December 2021.
- Updating the molybdenum chapter of a well-known industrial hygiene reference book.
- Regulatory dialogue with the State of Wisconsin during their ongoing review of their existing Mo water quality standard.



REACH Molybdenum Consortium (MoCon)

Enhancing the protection of human health and the environment from adverse impacts of chemicals, (which includes metals and their compounds), is the essence of the EU REACH Regulation. Over the last 14 years, since its inception as an independently financed IMOA initiative, our REACH Molybdenum Consortium has worked for its 61 members to generate robust datasets and technical dossiers about the effects of the molybdate ion both physiologically and on the environment. The datasets enable detailed hazard and risk assessment by industry and the regulatory community, and the setting of safe use conditions and exposure limits, for the 12 chemicals in MoCon's substance portfolio.

Environment compartment	PNEC* value
Aquatic compartment – freshwater	11.9 mg Mo/L
Aquatic compartment – marine	2.28 mg Mo/L
Sediment compartment – freshwater	21.2 g Mo/kg dw**
Sediment compartment – marine	2.37 g Mo/kg dw**
Terrestrial compartment	9.9 mg Mo/kg dw**
Sewage Treatment Plant	21.7 mg Mo/L
Exposure pattern and population	**DNEL*** value**
DNEL for **long-term, systemic effects after oral exposure for the general population**. Valid for all molybdenum substances considered by MoCon, expressed in terms of molybdenum content in mg molybdenum per kg bodyweight per day.	3.4 mg Mo/kg_{bw}/day
DNEL for **long-term local effects after inhalation, for workers**. Valid **only for pure molybdenum trioxide and the technical oxide** "roasted molybdenite concentrate". Expressed in terms of mg of substance (MoO_3) per cubic meter.	3 mg MoO_3/m^3

* Predicted No Effect Concentration
** Dry weight
*** Derived No Effect Level

The values in the above table reflect that, in general, low toxicity is a highly positive characteristic of MoCon substances. Just two substances are hazard classified as a GHS Category 2 Carcinogen by inhalation: molybdenum trioxide and RMC. Each, therefore, has its own eSDS (extended Safety Data Sheet), required by EU REACH for dissemination along user supply chains, setting out the conditions that ensure their safe handling and use.

Exposure Scenario updating

A significant activity for MoCon's Technical Working Group over the last year has been the updating of the REACH Exposure Scenarios (ES) and the eSDS for MoO_3 and RMC. A dynamic questionnaire was issued to all REACH-registrants of these two substances, to map their chemical processes using appropriate REACH Use Descriptors, and to report exposure monitoring data. This enabled the generation of individual Exposure Scenarios for each reported use, detailing the necessary conditions for safe use.

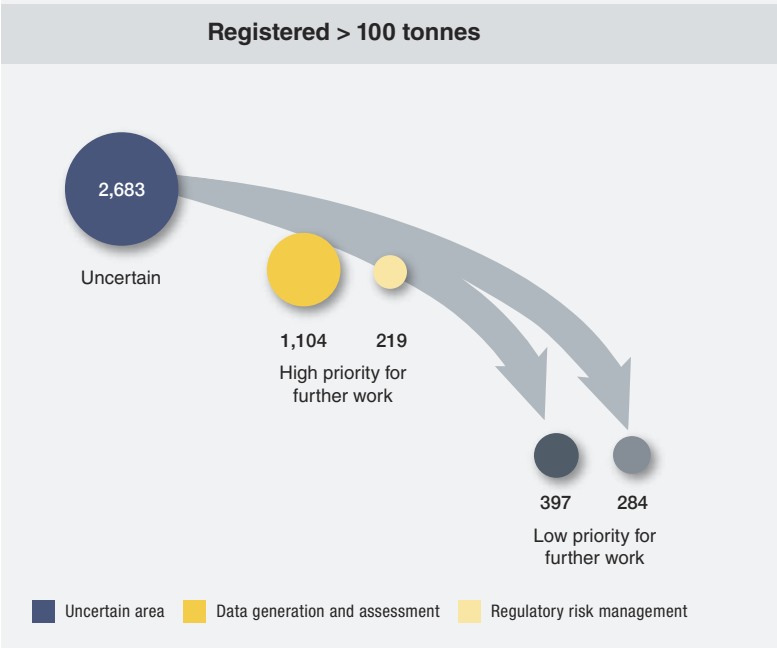
The REACH exposure assessment and risk characterization not only ensures that workers directly handling substances are protected against adverse effects, but also takes account of members of the general population potentially coming into contact with hazardous substances. To assess the latter, MoCon has also completed a substantial update of its 'Man via the Environment' report. Based on emission modeling and a literature review, this report demonstrates that there is no adverse exposure risk to the general population due to industrial emissions. Furthermore, no professional or consumer uses are identified for MoO_3 or RMC.

Our updated ES and eSDS documentation is now available for active dissemination by all actors in the supply chain to ensure the safe use of both substances throughout their life cycle. All ES documentation is submitted to the European Chemicals Agency (ECHA) within the joint Registration Dossier submitted by the Lead Registrant for each substance. ECHA can elect to submit this information to near-forensic regulatory scrutiny via its compliance check and evaluation processes.

Technical Dossier updating

ECHA aims to assess all REACH-registered substances by 2027. The scope of this 'Mapping the Chemical Universe' activity includes almost 23,000 REACH-registered chemicals. In 2019, it made a preliminary allocation of MoCon substances into the following categories:

ECHA mapping of chemical universe

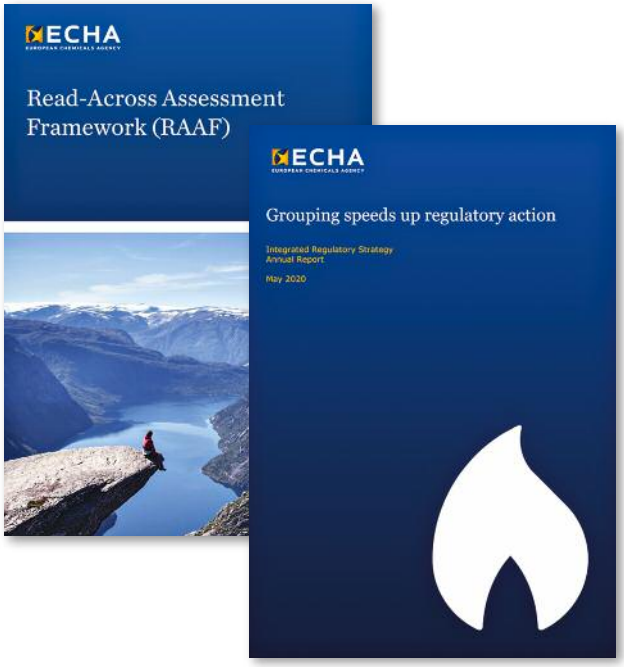


Sodium molybdate was allocated to the 'data generation' category due to ECHA's requirement for more Prenatal Developmental Toxicity data. Molybdenum trioxide is in the 'risk management under consideration' category due to its inclusion on the PACT List (Public Activities Coordination Tool). The remainder of MoCon substances are all in the 'not yet assigned' category.

Whilst ECHA is assessing the Technical Dossier (TD) for a substance, it is not possible to submit further data, so it is important to ensure the TD remains updated in case it is selected for scrutiny. MoCon's Technical Working Group has focused on preparing updates relevant for inclusion in all its dossiers, but in 2019–2020, specific focus was on submitting updates for the following three:

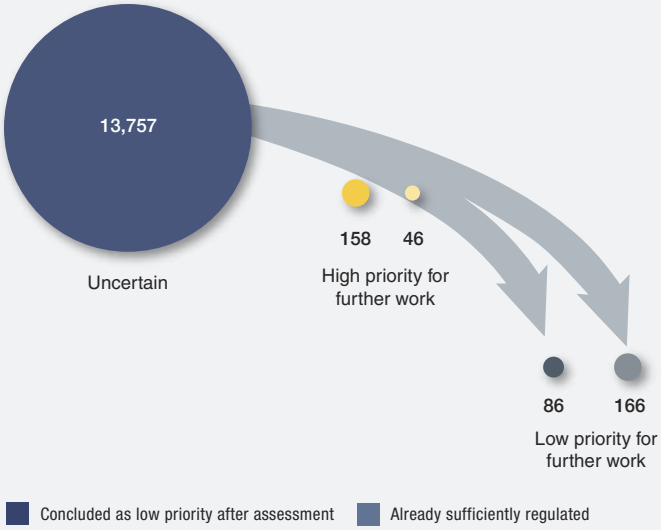
- ***sodium molybdate*** – because its test data is read-across, where appropriate, to all the MoCon technical dossiers;
- ***molybdenum trioxide*** and ***RMC*** – these two hazard classified substances required updated Exposure Scenarios.

Two significant new technical documents we recently generated are the 'Human Health' and the 'Environment' read-across grouping rationale. We expanded our previously robust, but succinct, rationale into two reports detailing the assessment elements that underpin our 'read-across grouping' approach. This now complies with ECHA's current guidance document on the 'Read-Across Assessment Framework' (RAAF) issued in 2017. MoCon dossiers were originally submitted to ECHA in 2010. The RAAF aligns with ECHA's integrated regulatory strategy 'Grouping speeds up regulatory action' announced in its May 2020 report.



Data from May 2018

Registered < 100 tonnes



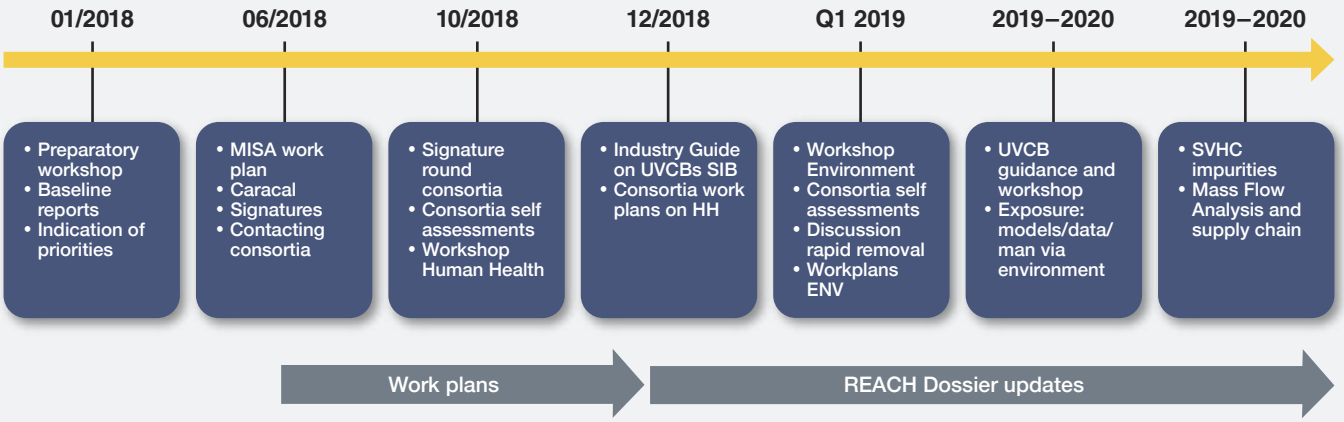
Counter-ion toxicity

The RAAF document also stipulates that read-across reports must contain sections assessing any impact of counter-ions to human health and to the environment. For MoCon, this means sodium, calcium, iron, and ammonium. This particular task was undertaken as a multi-consortia project, because counter-ions like ours are common across many metals. Multi-consortia projects enable the workload and costs to be shared. The counter-ions have negligible toxicological impact as components of MoCon molybdenum substances.

Bio-accessibility

Understanding the extent of bio-accessibility of different substances is another important criterion in MoCon's grouping approach. It demonstrates that reading-across toxicological data from sodium molybdate to other – less bio-accessible substances – is a worst-case approach. In 2019, we therefore commissioned a specialist laboratory to complete the full suite of MoCon bio-accessibility data. Our earlier dataset comprised information about 7 of our 12 substances. Those assessed in 2019 were ammonium dimolybdate, ammonium heptamolybdate, calcium molybdate, iron molybdate and FeMo slags.

MISA timeline and progress



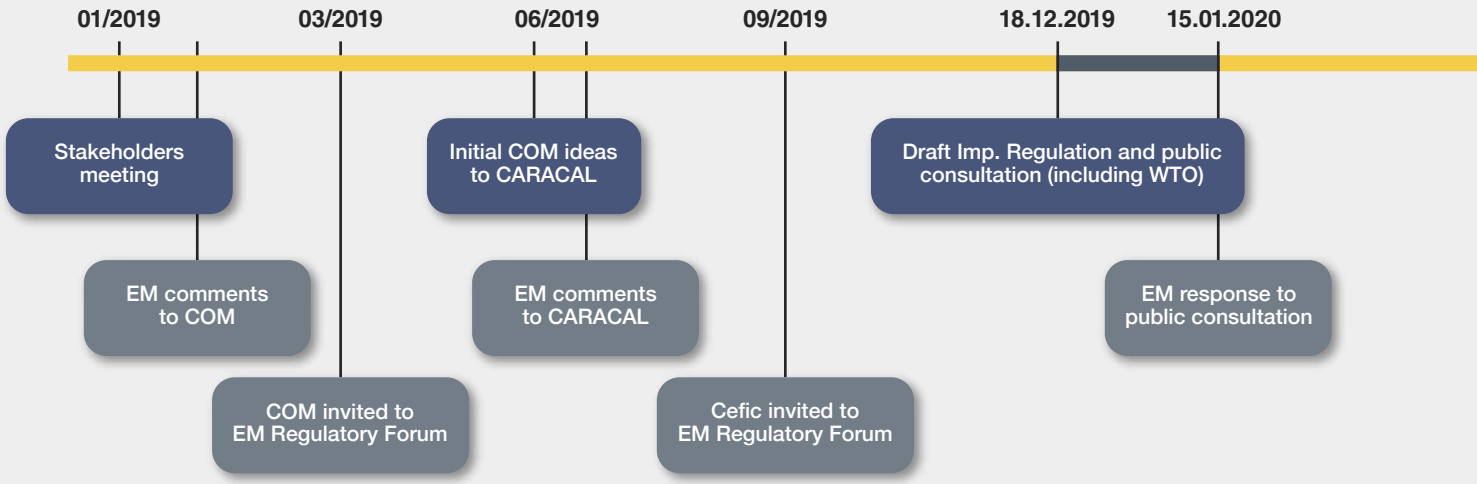
New studies

Highly noteworthy is the IMOA 2-generation reproduction toxicity study. This extensive and significantly costly test (>US$1million) is a mandatory requirement for all REACH registrations over the 100 tonnes band. This oral study using sodium molybdate, via both diet and drinking water, addresses an earlier REACH dossier data-gap about this critically important human health endpoint. Rigorous testing, compliant with OECD test guideline protocols, revealed no female or male reproductive hazard from systemic exposure to this highly soluble molybdenum salt.

MISA initiative

Over the last two years, MoCon has participated in the Metals and Inorganics Sectoral approach known as MISA. It is coordinated by the EU non-ferrous metals trade association Eurometaux, an accredited ECHA stakeholder, under whose auspices, the metals consortia jointly progress the plethora of REACH topics. MoCon's REACH Manager and Secretariat, Sandra Carey, is currently co-chairing the Eurometaux REACH Registration Maintenance Task Force. MISA is an industry/ECHA cooperative program which addresses remaining technical and scientific challenges to REACH technical dossier updating, and fosters continuous

EU implementing regulation on REACH dossier updating: overall legislative process



improvement in dossier quality. We submitted our MoCon task list of intended updating activities for sodium molybdate, and successfully fulfilled it by the end of 2019.

More regulation ahead

Industry is preparing for the 2020 advent of the REACH Implementing Regulation on Dossier Updating. Having assessed that insufficient numbers of technical dossiers are being regularly updated, ECHA and the EU Commission are working to introduce a new mandate that will legally compel industry to update its technical dossiers when certain trigger events occur, such as changes in substance composition, new identified uses, new data relating to environment or human health hazard/risk assessment, and changes in classification and labelling.

Funding

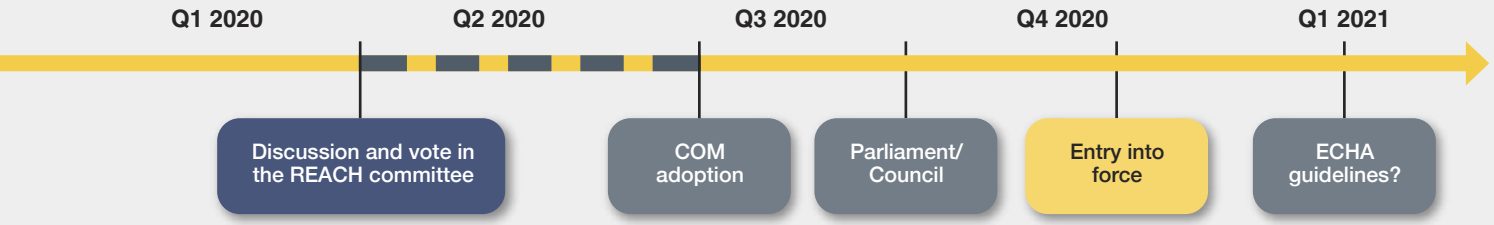
For almost a decade there have been no IMOA funding calls to REACH registrants of MoCon substances. During this period, the technical dossiers have nevertheless been updated three times.

In April 2020, the MoCon Steering Committee agreed a request for further funding was appropriate and necessary to support upcoming work programs. Accordingly, 2020 invoices accompanied by an explanatory letter have been issued to all REACH-registered MoCon members, Letter of Access and Licence to Use holders, in order that MoCon can continue its role of working where necessary to maintain regulatory compliance of its technical dossiers for all co-registrants.

MoCon funding will support necessary technical activities such as:

- Actively preparing for the forthcoming ECHA dossier compliance check for Unknown or Variable Composition (UVCB) substances. RMC and Ferromolybdenum Slags are UVCB substances under REACH.
- Monitor ECHA activities in relation to molybdenum trioxide on the Public Activities Coordination Tool (PACT), to alert the registrants and respond to ECHA if required.
- Complete the 1st species Prenatal Developmental Toxicity (PNDT) suite of testing that MoCon is legally compelled to undertake. This is in response to the ECHA Board of Appeal requirement to generate data about any potential hazard at higher dose concentrations beyond the 40 mg Mo/kg bw/day already tested with no PNDT adverse findings.
- Remaining actively engaged in any further MoCon dossier compliance checks, so that action can be taken immediately, reducing the likelihood of further necessary and costly interaction with the European Chemicals Agency.
- Comply with the new Implementing Regulation on Dossier Updating that reiterates the duties of all co-registrants in relation to the REACH registration dossiers. These dossiers must not remain as ‘a snapshot in time’ but be ‘living documents’. While this is already MoCon standard practice, 2020 funding will enable this to continue for the benefit of all REACH registrants.

Next steps ... possible timeline



Market Development

Key Activities and Achievements in 2019/2020

Carbon Steel

This year's activity, centered on the development of the carbon steel market, resulted in multiple visits, events and in-house seminars. IMOA consultant Professor Hardy Mohrbacher held meetings focused on disseminating results from IMOA research projects, as well as promoting innovative ideas based on newly discovered metallurgical functionalities of molybdenum. Product development activities focused on automotive and structural applications.

Most importantly, as steels in the high-strength range have a very pronounced sensitivity to hydrogen embrittlement, molybdenum was shown to be one of the most powerful alloying elements in combating hydrogen-induced cracking.

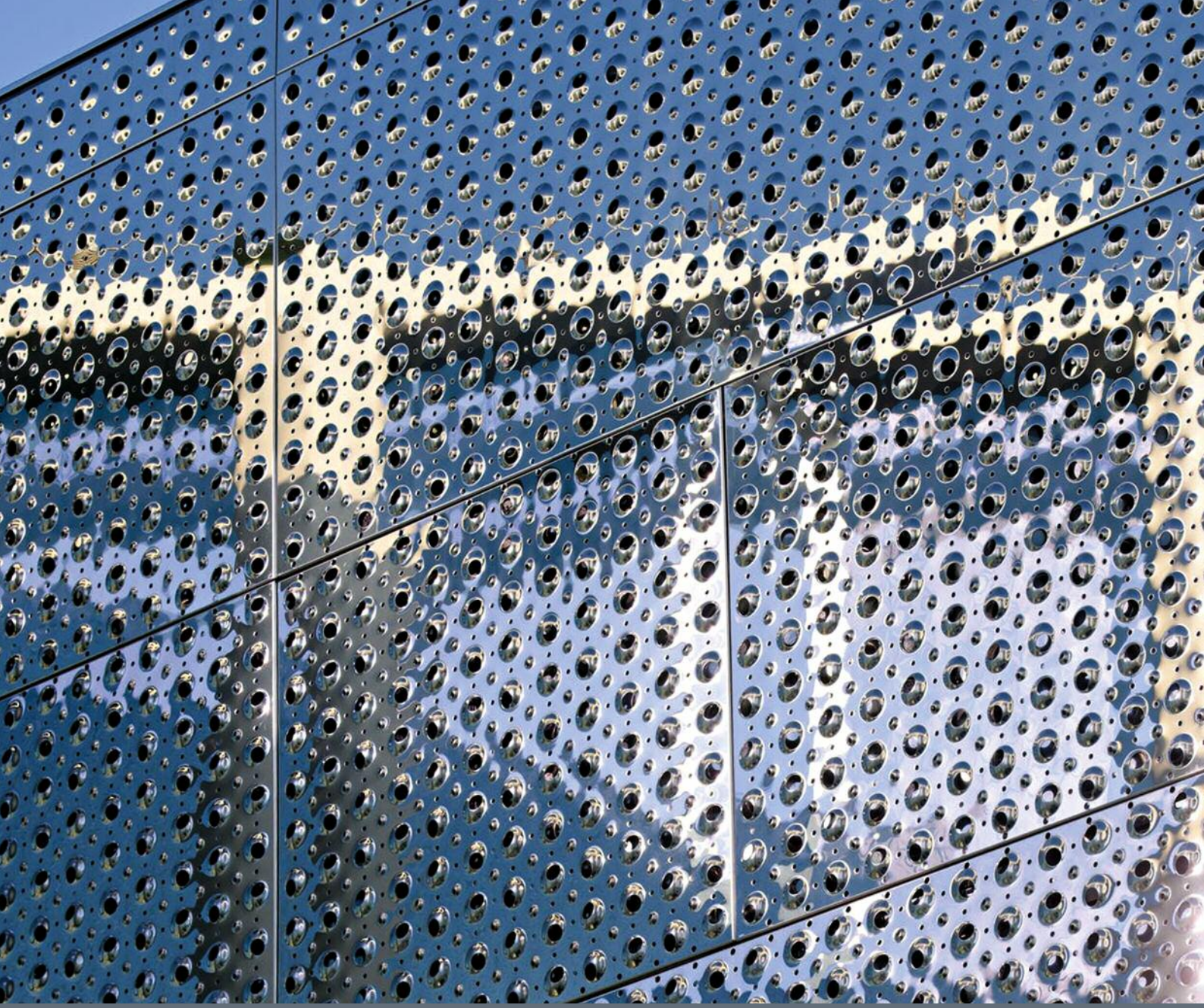
Based on the results of the IMOA project undertaken in co-operation with Okayama University, a paper on the details of how molybdenum interacts with hydrogen-induced damage mechanisms was published by Metals journal. This knowledge is also being used in the development of a 2000 MPa zinc coated press hardening steel at a European steelmaker.

Dr Nicole Kinsman
IMOA Technical Director

Flat steel development

Knowledge obtained from IMOA research projects informed advanced high-strength flat steel product development, in particular direct quenchable and press hardenable steels, covering the strength range of 1000–2000 MPa (mega-pascal). Molybdenum is a major contributor to processing robustness, as well as delivering superior product properties.

An innovative concept for producing 'Super-HSLA' steel using molybdenum will be tested at several mills in Europe and North America exceeding the maximum strength of 460 MPa in standard HSLA grades. These cold-rolled steel grades will typically be used in car body construction targeting the strength range of 500–700 MPa and will compete with lower range dual phase steels.



"IMOA delivers a comprehensive market development program which focuses on raising the profile of molybdenum and promoting its applications in alloys amongst fabricators, engineers, designers and material specifiers. Over the last year, this work has delivered significant, demonstrable benefits to members."

© Thinair Studio, Korea

Recent activities in North America focused on the upgrading and improvement of several automotive and structural flat steel grades. This work will result in a stronger domestic supply of higher-end grades and improved product profitability. The majority of the producers involved are based on a mini-mill concept. Molybdenum can help overcome the inherent limitations of this processing route.

Cast iron development

In addition to our research project with Shanghai University, a new development in cast iron alloys has been driven by the requirements of turbocharger housing manufacturers. A higher temperature limit of the well-established SiMo alloy (approx. 1% Mo) would allow partial substitution of the considerably more expensive Ni-Resist alloys in this application. Pilot trials with modified SiMo alloys are in progress. Further information is contained in the Research projects section on page 25.

SCI design guide

Within the construction industry, understanding about the design and fabrication of high-strength steels (HSS) with a yield strength of 700 MPa remains limited. This is despite the many potential savings arising from the reduction in structural weight offered by these stronger steels. The development and dissemination of more cost-effective design rules, complemented by simple design tools, will facilitate growth in the market for structures made from these steels.

Steel plate with a yield strength of 700 MPa typically contains between 0.15 and 0.4% Mo. This application therefore offers substantial potential market growth. For this reason, we are co-sponsoring the preparation of an SCI guide on the design and execution of steels of yield strength up to 700 MPa. Based on extensive consultation with designers, fabricators and producers, the guide gives practical and holistic guidance on how to maximize the benefits of HSS. It covers a wide range of topics such as the design of members and connections, fire resistance and fatigue performance. The guide is due for completion in the Fall of 2020 and will be launched at a seminar in association with the UK's Institution of Civil Engineers.

Architecture, Building and Construction (ABC)

We have continued to build on the success of our long running program to promote the benefits of molybdenum-containing stainless steel in ABC. Much of that work has targeted the US and European architectural and engineering firms which dominate global design.

Delivering stainless steel workshops

IMOA has nine ABC courses accredited by the American Institute of Architects (AIA), which provide architects and engineers with continuing education credit. All but one qualify for sustainable design (Health, Safety and Welfare) continuing education credit. In North America, IMOA and the Nickel Institute (NI) jointly sponsored workshops and project meetings at some of the world's most influential architecture and engineering firms in New York. Our live events, presented by IMOA consultant Catherine Houska, attracted about 160 attendees.

While some face-to-face workshops have been cancelled due to Covid-19, live multi-office webinars are being discussed with several firms. The ongoing interaction provided by live organization-specific workshops builds and strengthens relationships, influences global projects and has actively increased the use of molybdenum-containing stainless steel in building and construction in North America and elsewhere.

In early 2020, an agreement was reached with the AIA's online university to develop an initial recorded webinar that could eventually form a series. This will enable IMOA and the NI to dramatically increase the number of firms accessing educational materials. The AIA has an automatic cooperative professional certification program with the Royal Institute of British Architects (RIBA) and the US-based professional engineering associations. These certificates are required for professional and state licensing. Other global architecture associations typically accept AIA certificates of completion.

Together with Nancy Baddoo from SCI, Catherine Houska presented a workshop on stainless steel structural design at '2020 NASCC: The Steel Conference', AISC's annual conference. Due to COVID-19, the conference itself was cancelled but our presentation was among those selected for an online event. The one-hour live webinar attracted nearly 1,200 structural engineers specializing in buildings, energy, manufacturing, infrastructure and public works and can be viewed in the educational area of the AISC website. Nancy Baddoo also presented two well attended face-to-face seminars in Singapore which were jointly sponsored with NI. She spoke to the Singapore Structural Steel Society and the Singapore Institute of Architects.

To increase awareness of the benefits of structural stainless steels and promote their use for bridge, industrial, building and other structural engineering specialist applications, we focused on promoting the high quality content available in the recorded AISC Design Guide 27 webinar, the 2017 bridge webinar and the 2020 NASCC conference.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Publications

The 2018 edition of the jointly-developed IMOA and NI ABC Stainless Steel Library, containing over 550 PDFs, has been distributed to a total of more than 7,900 industry decision-makers globally. Feedback from architectural and engineering firms confirmed that this comprehensive library is highly valued.

Two of Catherine Houska's previously published Construction Specifier articles, were selected by the magazine for re-publication in their annual 'Best of Series' two years in a row. The 2018 Exploring Steel Structures issue featured 'Duplex Stainless Steel Revolutionizes Structural Design' and the 2019 Building with Steel issue featured 'Cleaning and Maintaining Stainless Steel'. Articles in this influential publication support the effective dissemination of information about molybdenum-containing stainless steel to a wide audience.

Structural market development

Structural stainless steel has significant market growth potential, particularly through the development of the new AISC standards, 370 and 313. They will remove barriers to stainless steel use for everyday larger structural sections. The significant revision of AISC/SEI 8 for thinner cold-formed stainless steel, potentially expands its use for structural industrial roofing, platforms and decks; blast and fire barriers; and curtain wall and support systems by making design more cost-effective (see Team Stainless section on page 24).

Catherine Houska provided technical support for many structural projects during the past year. These included potential US vehicular and pedestrian bridge projects, Indian rail and vehicular bridges as well as sculptures, monuments, and building applications. Continued support was provided to the US Army Corps of Engineers in their assessment of duplex stainless steels for a new sea and brackish water lock and dam design. Support was also provided to the American Wood Council in revision of their specification for supported exterior structures, such as decks. Due to changes in the corrosivity of specific environments, it is expected that the new edition will recommend molybdenum-containing stainless steel structural sections and fasteners for a much larger coastal area than the previous issue.

Market development in China

Over the last year, Chinese steel makers produced 55% of the world's steel. With molybdenum use comparatively lower in this region, there is significant opportunity for market growth. In light of this, we have continued our focus on increasing engagement within China.

In May 2020, the China Iron and Steel Association (CISA) announced a new phase for the Chinese steel industry. Our focus on supporting the development of stronger steel grades, and with that lighter and thinner designs, as well as their superior welding properties and corrosion resistance, complements the technological ambitions of the Chinese steel industry.

It is widely recognized that China is likely to be the quickest economy to recover as the world emerges from the coronavirus pandemic. To capitalize on this, we are launching a series of webinars on stainless and special steels in autumn 2020. The online delivery of these seminars will ensure our high-quality content reaches the widest possible audience. Further dissemination of information about the benefits of molybdenum will continue to take place via our popular WeChat channel.

Molybdenum-containing special steels

Over the last year, the majority of our engineering steel activities in China focused on the development of superior special steel grades, particularly for application in gear boxes. We participated in a special steel symposium held by CITIC Metals in Beijing, where we presented the results of the IMOA gear steel project with the support of two German experts. Chinese industry leaders emphasized the importance of this development. The same team of experts delivered an in-house seminar at FAST Gear Co. in Xian which was attended by around 100 company employees. A number of visits to special steel making companies also took place throughout the year, enabling us to disseminate detailed information about the advantages of molybdenum alloying in special steel alloys.

Molybdenum and steel symposiums

Four summary papers from the 2018 Molybdenum and Steel Symposium, organized by IMOA in cooperation with Shanghai University in November 2018, were published

in the 'Journal of Advances in Manufacturing'. To date, the papers have been downloaded almost 4,000 times. The proceedings are also available on the IMOA website and a Chinese translation is underway.

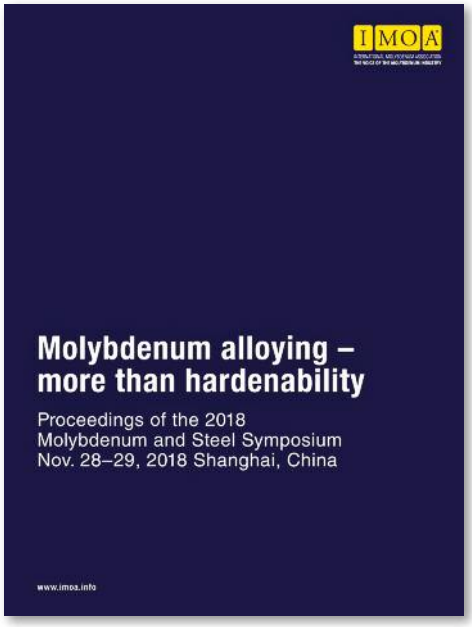
Following the success of the inaugural event, IMOA co-organized, with our member Jinduicheng (JDC), the second Molybdenum and Steel Symposium in Xian in December 2019. Over 120 metallurgy experts and Chinese metal industry leaders, as well as representatives of the molybdenum industry attended the event where renowned foreign speakers and leading Chinese experts highlighted molybdenum's benefits in flat and special steels.

Stainless steel in China

In 2019, China's stainless steel output was 29 million tons and the global market share of Chinese stainless steel rose from 52% to 56%. The Chinese stainless steel industry is modernizing and the development of high-strength stainless steel grades was announced as one of the government's 35 priority areas.

In our Chinese Architecture, Building and Construction program, Dr Gaetano Ronchi's team continued to focus activities on China's greater bay area (Guangdong, Hong Kong, Macau) to promote molybdenum-containing stainless steels. The 'Spring Bamboo Shoot' is a new Shenzhen landmark building, where a molybdenum-containing stainless steel has been selected for the curtain wall. The 400-meter-tall building is the headquarters of China Resources, a major state-owned group. It was a fitting location for the field trip of the 120 attendees of our 'Application of Stainless Steel in Buildings and Curtain Walls' seminar in October 2019. This event was jointly funded with the Nickel Institute and organized by AT 'Architectural Skills, Building Curtain Wall' Magazine, the Academic Committee of the China Architecture Society for Building Curtain Wall and the China Stainless Steel Council (CSSC).

Large, low slope roofing is an emerging application of molybdenum-containing stainless steel in China. Airports, stadia, exhibition halls, stations, museums are typical applications of flat, low slope metal roofing, where designers and architects focus on three distinctive attributes: light weight, leak tightness and wind resistance. For the first time in China, the continuous welding of a 220,000 square meter molybdenum-containing ferritic stainless steel standing seam roof has been successfully applied at the new Qingdao Jiadong Airport project. This could be a good solution for many infrastructure projects that are on the drawing boards in China. Other roofing systems suffer from leaking or insufficient resistance to strong winds. We therefore are working with the designer of the Qingdao roof, who is also a main author of the corresponding standard, to document the success and disseminate the information among designers of large public buildings.



High-performance stainless steels

The Chinese translation of our updated brochure "Practical Guidelines for the Fabrication of Austenitic Stainless Steels" will be available at the 3rd International Conference on Super Austenitic Stainless Steels and Nickel-Based Alloys organized in autumn 2020 in Beijing by the CSSC.

The ‘Survey of wet Flue Gas Desulfurization (FGD) and corrosion of coal-fired power plants in China’ study is expected to be concluded soon. The study, commissioned with CSSC in 2018, aimed to better understand the potential for the use of high-performance stainless steel in this important application. This greater understanding coincides with China’s current consolidation of fossil fuel plants. China’s top state-owned asset watchdog has required 40 coal-fired power plants in five western provinces to be consolidated into the leading power generator in each province. Upon completion of the plan, the selected five power generators will operate the vast majority of fossil fuel plants in each one of the five provinces.

Stainless steel service water pipe

Water utilities worldwide lose an estimated 30% of freshly treated drinking water through leaks in their distribution network. Most of the loss occurs in the service pipe which connects the water main under the road to the water meter on each property. This is not only costly, but also wasteful and environmentally problematic, especially in light of dwindling freshwater resources, further heightened by climate change. This kind of water loss reduces the resilience of a system to cope with unexpected events such as instances of extreme weather. It also places a huge burden on the environment due to wasted energy in pumping and purifying water.

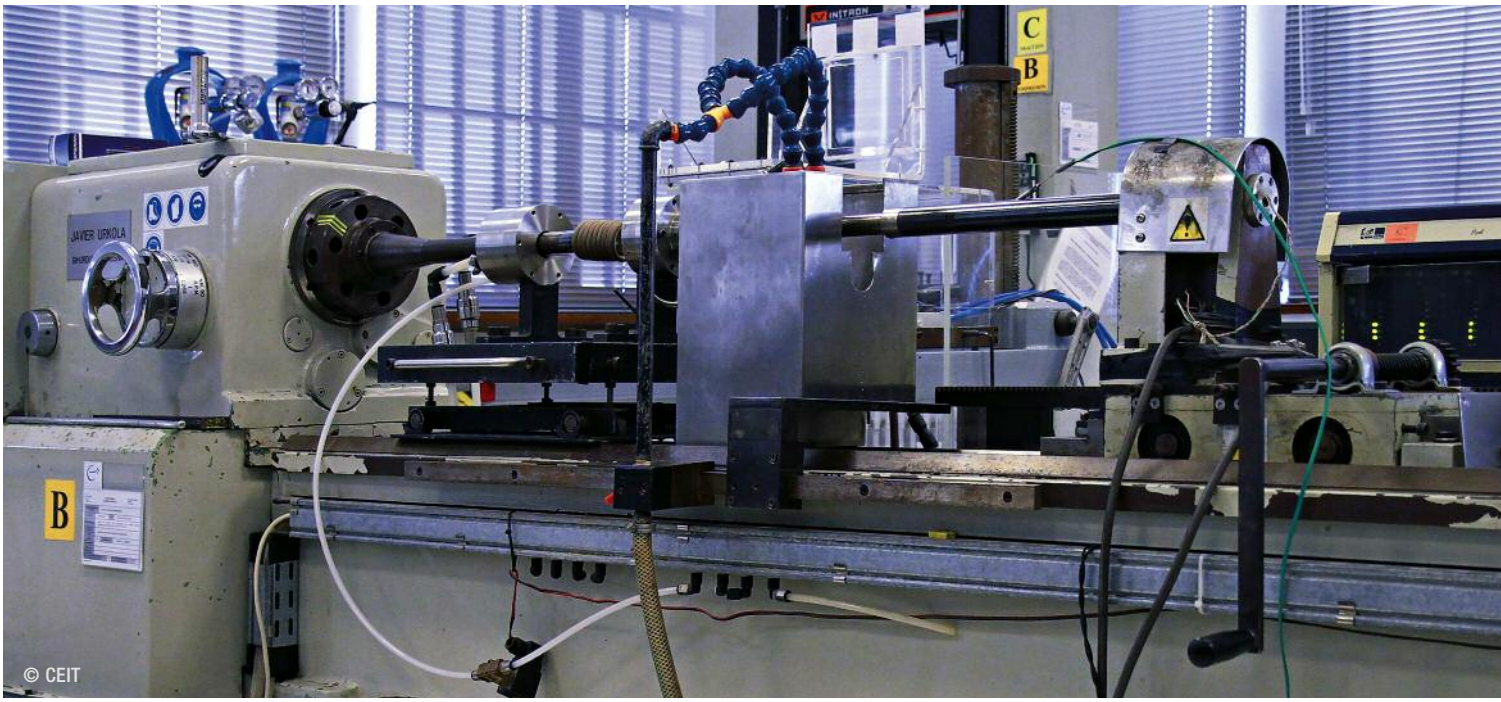
Partially corrugated Type 316 stainless steel service pipe, a solution developed and implemented with great success in Japan, could help solve this problem. Together with the NI, we are promoting this solution to water utilities in several world regions. Utilities in the UK, Australia, China, the US and Canada have shown interest in testing the service pipe and projects are under development at these utilities. A step-by-step installation video is in production to explain how to install the system.

However, each region and each utility are different, so the system needs some adaptation to local requirements. For example, Tokyo and Taipei service piping is typically less than four meters long, which is the standard production length of the tube. Many other countries have longer service lines. To accommodate this, without joining lengths of standard pipe with fittings, which would add potential leakage sites, we successfully tested orbital welding as a solution to produce longer length tube. Many places have also moved to trenchless installation: instead of digging up the road along the full length of the service pipe from the main to the meter, only two small pits are dug at the water main and the meter, saving cost and time. The pipe is then installed underground with a boring machine or by drawing the new line into place while pulling the old one out. In a test, we showed that this can easily be achieved with partially corrugated stainless steel service piping which has been orbitally welded to 16 meter length.

Promoting the system is an important part of the program which we do through industry conferences, workshops and trade media articles. We have contributed to a new standard in China which was published at the end of 2019 and have begun work on a fittings standard there. We are also working on an ASTM standard in the US.

Team Stainless

IMOA continues to be a member of Team Stainless, an informal alliance of global trade associations of the stainless steel and alloying element industries to promote the benefits of stainless steel. A key milestone was the preparation of the ‘Comprehensive Multilevel Cycle of Stainless Steel in 2015’, by B.K. Reck of Yale university – an in-depth study on the global stocks and flows of stainless steel. A four-page overview of the study’s main findings is available on the IMOA website.



Structural stainless steel specifications development

Led by Nancy Baddoo of the Steel Construction Institute, work has continued on preparing the first stainless steel design specification for the AISC with the support of IMOA consultant, Catherine Houska.

A fully comprehensive and user-friendly set of structural design rules is being developed for hot rolled and welded sections, based on research carried out in universities in Europe, China and Singapore. The availability of an AISC design specification, approved by the International Code Council (ICC), will remove a significant barrier to the wider use of load-bearing stainless steel in buildings, bridges and other structures. The specification is accompanied by a commentary, which explains the basis for the rules and, in future, will permit further development to the specification. In parallel with this, Nancy Baddoo and Catherine Houska are also contributing to a major revision of the American Society of Civil Engineers design specification for lightweight cold-formed structural stainless steel (SEI/ASCE 8-02). In addition to Team Stainless, AISC and several stainless steel producers are contributing to the funding of the project.

Research projects

IMOA continues to sponsor part of SCI's role leading a three-and-a-half-year collaborative European research project called STROBE (Stronger Steels in the Built Environment). Through an extensive program of laboratory tests and numerical modelling, the project seeks to overcome specific obstacles to the wider use of HSS in construction, primarily focusing on ductility, stability and dynamic response. As well as developing design rules, simple tools have been created to help designers maximize the advantage of HSS members. Partners include three European universities, the steel producer Dillinger and the global construction company Hochtief.

Our project in cooperation with the Spanish research center, Ceit and a German steel producer is generating alloying and processing design guidelines for direct quenchable heavy plate in the 1000 MPa strength class. Molybdenum alloying will be essential to reach the target properties. Typical use will be in mechanical engineering and specific applications like mobile cranes, and heavy chassis.

The ongoing project on grey cast iron development at Shanghai University (SHU) showed first results, allowing further refinement of the alloy design in the next steps. It appears that the addition of 0.4–0.5% molybdenum has the best potential for achieving an optimum mix of mechanical and thermal properties. High strength combined with good thermal conductivity are required in some promising automotive applications such as break disks, fly wheels and cylinder heads. SHU's Centre for Advanced Solidification Technology (CAST) is well connected with Chinese foundries. This will help us to disseminate the results of the project and to promote the advantages of molybdenum-alloying in cast irons.

Financial Report 2019

Income and expenditure account

For the year ended 31 December 2019

IMOA/Molybdenum Consortium

	2019 $	2018 $
Turnover	2,946,472	3,347,030
Operating and administrative expenses	2,818,195	3,019,157
Operating surplus/(deficit)	128,277	327,873
Other interest receivable and similar income	24,477	25,551
Surplus/(deficit) on ordinary activities before taxation	152,754	353,424
Tax on surplus/(deficit) on ordinary activities	6,682	4,480
Surplus/(deficit) on ordinary activities after taxation	146,072	348,944

Balance sheet

For the year ended 31 December 2019

IMOA/Molybdenum Consortium

	2019 $	$	2018 $	$
Fixed assets				
Tangible assets		788		15,584
Current assets				
Debtors	72,887		155,333	
Cash at bank and in hand	3,765,583		3,606,074	
	3,838,470		3,761,407	
Creditors – amounts falling due within one year	(580,435)		(664,238)	
Net current assets		3,258,035		3,097,169
Total assets less current liabilities		3,258,823		3,112,753
Reserves				
Profit and loss account		3,258,823		3,112,753
Accumulated funds		3,258,923		3,112,753

Financial commentary

The 2019 audited accounts presented here are consolidated figures for IMOA and the Molybdenum Consortium and are subject to approval at the 2020 AGM. Income from subscriptions and other revenue amounted to US$2,946,472. After expenses of US$2,828,195 a surplus (after taxation) of US$146,072 was carried forward bringing the combined accumulated funds to US$3,258,823. Of this US$2,773,792 was attributable to IMOA and US$485,031 to the Consortium.

In the case of IMOA, below-budget expenditure resulted in a surplus accruing to the reserves, bringing the year-end balance in line with the Executive Committee's objective of one year's expenditure. The Molybdenum Consortium reserves will contribute to funding the Consortium's essential activities around reprotoxicity testing, standard information requirements and maintaining dossier compliance. In April 2020, the Molybdenum Consortium Steering Committee instructed a funding call to Consortium members and Letter of Access holders which was duly actioned in 2Q 2020.

IMOA
INTERNATIONAL MOLYBDENUM ASSOCIATION
THE VOICE OF THE MOLYBDENUM INDUSTRY

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