Australian Government

ANSTO Submission

to the Joint Standing Committee on Trade and Investment Growth's Inquiry into Australia's Transition to a Green Energy Super Power

ANSTO

11/30/2022

Introduction

As the custodian of Australia’s nuclear science, technology and engineering capabilities and expertise, ANSTO (the Australian Nuclear Science and Technology Organisation) is pleased to make this submission to the to the Joint Standing Committee on Trade and Investment Growth’s Inquiry into Australia’s Transition to a Green Energy Super Power (the Inquiry).

ANSTO is responsible for the operation and management of Australia’s landmark nuclear infrastructure and research facilities across its two main campuses (Lucas Heights, Sydney, and Clayton, Melbourne). These facilities include the Open Pool Australian Light-water (OPAL) Multi-purpose Research Reactor, the Australian Centre for Neutron Scattering, the Centre for Accelerator Science, the National Deuteration Facility, and the Australian Synchrotron.

ANSTO also has significant and world-leading expertise in the research and development of energy generation and storage systems and in the development and production of materials for use in those systems. Our work spans:

- **Minerals:** providing process development and consultancy services to the minerals processing industry, including in relation to critical minerals for renewable energy generation and storage systems
- **Materials:** the utilisation of our landmark research infrastructure in the characterisation, testing and development of materials for use in the renewable energy industry
- **Manufacturing:** the irradiation of silicon ingots, for use in high-power electronic switching devices

ANSTO is a Corporate Commonwealth Entity with accountability to the Minister for Industry, Science and Technology. The Organisation operates under the oversight of an independent Board of Directors, with members appointed by the Governor-General.

The Organisation is established under the *Australian Nuclear Science and Technology Organisation Act 1987 (Cth)* (the ANSTO Act) to facilitate the use of its landmark nuclear infrastructure by the academic, research, and scientific communities, as well as for or by government agencies and commercial clients. ANSTO’s functions also include the provision of advice on the application of nuclear science and technology. ANSTO provides such advice to Government, parliaments, departments and agencies, public inquiries and investigations, members of the public, and international, multilateral, and bilateral partners—in pursuit of Australia’s national interest.

Minerals

Critical minerals are vital for renewable energy, battery storage, energy supply and infrastructure, electric vehicle industry, advanced manufacturing, and services and technology. Australia is an established world-leading resource exporter and supplies numerous countries with high quality, ethically sourced critical minerals using environmentally sustainable practices. The Australian Government has recently announced a range of initiatives to support and grow Australia’s critical minerals sector which form part of Australia’s commitment to achieve net zero by 2050, these initiatives include:

- Australia’s National Critical Minerals Strategy;
- the Critical Minerals Development Program; and
- the Critical Minerals Research and Development Hub in collaboration with the CSIRO, Geoscience Australia and the Australian Nuclear Science and Technology Organisation

ANSTO through its Minerals group, **provides process development and consultancy services** to a diverse range of clients in the mining and minerals processing industries. ANSTO has been providing practical solutions and applying innovative technologies in ways that deliver financial and environmental benefits to our clients for over 40 years with a proven track record of applying expertise to challenging ores with complex mineralogy and to multi-commodity resources.

The work we undertake **supports Australian industry**. It includes all facets of critical minerals process development from mineralogy to laboratory scale testing through to continuous piloting, including demonstration plant design and operation. Our clients include an extensive range of domestic and international companies with deposits located both in Australia and overseas directly supporting numerous preliminary economic assessments (PEA), preliminary feasibility studies (PFS) to bankable feasibility studies (BFS), front end engineering design (FEED) studies, as well as support to numerous current operations.

Rare Earths

ANSTO has played a **key role** in the development of rare earth processing expertise in Australia, initially undertaking applied research studies associated with radionuclide deportment and waste disposal techniques and later developing a wide range of capabilities used by **all of the advanced** rare earth projects in Australia, as well as numerous international projects. Our project work has included all facets of rare earth processing including acid leaching, sulphation baking, caustic conversion, alkaline roasting, selective precipitation, impurity removal, solvent extraction, ion exchange, and process water treatment.

The choice of processing route has to be adapted to the different types of mineralogy present in the ore. Rare earth processing has long been associated with monazite recovered from mineral sands, but many deposits that are currently being investigated have different mineralogy, and thus, need specific process flowsheets. ANSTO has had broad exposure to projects based on a range of minerals other than monazite, such as cheralite (Mt Weld, WA, Australia), rare earth hosted fluoroapatitte (Nolans, NT, Australia), bastnasite (Ngualla, Tanzania), xenotime (Browns Range, WA, Australia), eudyalite (Norra Kärr, Sweden) and Ionic Adsorption Clays (Australia, South America and Uganda).

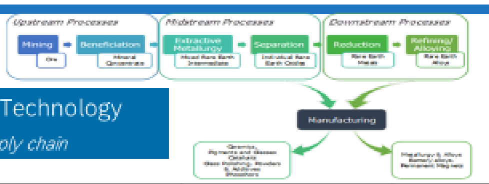
Environmental Stewardship

There have been reports of wide scale environmental pollution problems associated with the rare earth industry. This is a particular issue with the small-scale mining activities of ionic clays in Southern China, many of which are in-situ leach operations causing contamination of soil and water. Australian mining industry is well regulated and the same standards are applied to rare earth processing projects. Australia has therefore the potential to provide an alternative source of rare earths while adhering to worlds' best practice environmental standards.

The management of naturally occurring radioactivity (NORM) is an important aspect of rare earth processing. ANSTO has more than 40 years' experience in the handling of ores, concentrates and other metallurgical products in a diverse range of industries where radioactivity is present. ANSTO also has extensive knowledge of local, national and international regulations with regard to radiation protection and in the trade, transport and import of mineral commodities containing NORM. This knowledge is continually updated to meet the requirements of our clients and is a consequence of our links with organisations such as Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) and the International Atomic Energy Agency (IAEA).

Rare Earth Separation Technology

Crucial link in alternative supply chain



Critical Metals

CHALLENGE	R&D SOLUTION	IMPACT	NATIONAL BENEFIT	MINERALS TEAM
High purity Rare Earth (RE) elements are essential for the manufacture of components in renewable technologies and electric vehicles (EVs). The supply chain for the production of high purity RE's is dominated by China and the technology is not readily accessible. Many countries have recently recognised this as a strategic issue.	The separation of RE using solvent extraction (SX) is very complex technology with a refinery needing to separate all 15 RE elements and typically comprising in excess of 1000 individual separation stages. Minerals has developed a modelling capability for these separations that allows for detailed design and enables evaluation of specific circuits at ANSTO's purpose built SX mini-pilot plant facility.	Minerals has worked with three major domestic projects which have the potential to increase the downstream processing capacity within Australia and establish Australia as an ethical responsible supplier of rare earths. The *Critical Metals Facility Office (CMFO)* has recognised the importance of this technology and provided a grant to explore options for rare earth production in Australia	**Dubbo Project** **New South Wales** Planning to produce a range of high purity separated products such as NdPr, Dy and Tb **Arafura Project** **Northern Territory** Planning to produce NdPr, La and Ce **Browns Range Project** **Western Australia** Planning to produce mixed RE concentrate and Dy	• Chemists • Engineers • Analytical Various Senior and Junior Professionals supported by technical staff and Year in Industry Students

ANSTO STRATEGIC OBJECTIVE	Scientific outcomes to benefit Australia and support a sustainable sovereign capability
IP GENERATION and TECHNOLOGY TRANSFER	Some projects have evaluated the technology through piloting

Lithium

Over the last decade, ANSTO has undertaken a significant amount of work on the processing of lithium deposits from around the world to produce saleable lithium chemical concentrates for Australian and oversea-based mining and technology companies. ANSTO personnel are arguably amongst some of Australia's experts in lithium processing, particularly the hydrometallurgical processing of hardrock and brine deposits for the production of high purity chemical concentrates used in the production of high-performance Lithium Ion Battery (LIB) cathode materials. ANSTO expertise encompasses all aspects of lithium processing including roasting, pressure treatment (autoclaving), leaching, purification / neutralisation, crystallization, ion exchange, membrane separation, electrolysis and process water treatment unit processes.

Works undertaken for ANSTO's lithium clients has directly supported numerous preliminary economic assessments (PEA), preliminary feasibility studies (PFS), definitive feasibility studies (DFS) and bankable feasibility studies (BFS), as well as several currently operating lithium and speciality metals operations. These works have encompassed everything from bench-top process development, through to continuous piloting and to demonstration plant design and operation (e.g. 2 m3/h brine feed). For several of our clients we have also supported their on-site programs and operations.

Our specialist knowledge in hydrometallurgical flowsheet design has allowed us to provide tailored solutions for many of our clients, which in some cases has led to patented new technology.

Production of battery grade materials

Continuous programs conducted at ANSTO have produced between 5–500 kg of battery grade lithium carbonate, 5 – 10 kg of lithium hydroxide and >500 kg of lithium phosphate for product testing. With respect to lithium phosphate, this material has been further processed into Lithium Ferro-Phosphate (LFP) cathode material at Lithium Australia's cathode powder manufacturing facility (VSPC in Brisbane) and shown to outperform commercially available LFP cathode materials. The significance of the 'direct' and seamless production of LFP from lithium phosphate is that this removes the need for further processing into other lithium chemical precursors and the contained phosphorus is ultimately required for the LFP battery chemistry.

CHALLENGE	R&D SOLUTION	IMPACT	NATIONAL BENEFIT	MINERALS TEAM working with Lithium Australia
Australia supplies a majority (>60%) of the world's lithium from world-class 'hard rock' mines in Western Australia. However, at least 30% of the *in-situ* lithium of these resources is wasted due to the processing technologies employed. An alternative technology for the downstream processing of these wastes was required by industry.	A process flowsheet was developed using caustic conversion of waste lithium 'hard rock' material producing lithium phosphate suitable for production of lithium ferro phosphate (LFP) cathode powder. The process is unique as it is tolerant of a wide range of 'waste' and normal feedstocks, avoids the considerable CO_2 footprint of conventional processing, and directly produces a 'battery grade' product suitable for lithium ion battery (LIB) manufacture.	Provides the only alternative processing technology for 'hard rock' lithium increasing Australia's role in the LIB supply chain. Combined with other indigenous LIB production and recycling technologies, this allows Australia to realise more of the value generated in in the LIB supply chain.	Increased lithium resource base worth >$100M/a exports Increased LIB supply chain exposure worth $10B/a E2E participation in LIB supply chain using indigenous technologies	Over the 6 years that ANSTO has been working with Lithium Australia (LIT), essentially all facets of the Minerals team have been engaged including: • R&D • Engineering • Analytical • Mineralogy

ANSTO STRATEGIC OBJECTIVE 2	Scientific outcomes to benefit Australia and support a sustainable sovereign capability
IP GENERATION and TECHNOLOGY TRANSFER	Comprehensive technology portfolio with ANSTO support built into commercialisation steps

Specialty and Rare Minerals

ANSTO's industrial experience with speciality and rare metals encompasses the hydrometallurgical and pyrometallurgical processing of zirconium, niobium, hafnium and vanadium, both as stand-alone flowsheets, and as by-products of uranium, rare earth and mineral sands processing.

Hafnium: Three quarters of hafnium metals is produced in France and the USA as a by-product of zirconium metal manufacture. ANSTO has succeeded in developing a technology for the separation of zirconium and hafnium, producing both oxides of high purity.

Zirconium and niobium: Extensive process development and pilot scale testing targeting niobium and zirconium has been carried out over a period of 10 years for Australian Strategic Materials Dubbo Project in NSW. The work conducted on the recovery of niobium involved selective precipitation through purification to ferro-niobium production. Solvent extraction of zirconium has been developed and extensively tested. A range of products including zirconium basic sulphate (ZBS), zirconium oxychloride (ZOC) and high purity zirconia has been produced.

Vanadium: Recovery of vanadium via alkaline leaching and ion exchange from uranium/vanadium (carnotite) ores has complemented our extensive work carried out on the processing of uranium ores, with application of our solvent extraction and ion exchange expertise for the production of high purity vanadium oxide suitable for Vanadium Redox Flow Battery (VRFB).

Dubbo Project -Critical Metals Production in NSW

ANSTO's innovation put into practice

Energy and Resources

CHALLENGE	R&D SOLUTION	IMPACT	NATIONAL BENEFIT	MINERALS TEAM working with ASM
The Dubbo Project seeks to develop a large polymetallic resource to produce rare earths (RE), zirconium (Zr), niobium (Nb) and hafnium (Hf). The valuable metals are present in low concentrations and the ore is not amenable for upgrading by conventional mineral processing techniques.	A novel process flowsheet was developed to address the specific project challenges. The process incorporates many conventional unit operations as well as two new patented processes: 1. New solvent extraction technology to separate Zr and Nb, and 2. Combined nanofiltration and solvent extraction technology to separate Zr and Hf.	New Australian manufacturer of value-added critical materials for global markets with potential to improve the robustness of global supply chains of critical metals. The four products, Zr, Nb, RE and Hf are all critical metals for the defence, aerospace, electronic and renewable energy industries, and are important for the manufacture of electric vehicles (EVs).	**Dubbo Project** Economic boost for NSW of $60M/annum Regional Jobs 450 jobs during construction 200 jobs during operation $25M infrastructure upgrades	Over the 15 years that ANSTO has been working with Australian Strategic Materials (ASM), essentially all facets of the Minerals team have been engaged including: • R&D • Engineering • Analytical • Mineralogy

ANSTO STRATEGIC OBJECTIVE	Scientific outcomes to benefit Australia and support a sustainable sovereign capability
IP GENERATION and TECHNOLOGY TRANSFER	Technical Readiness Level Project fully approved and Construction ready

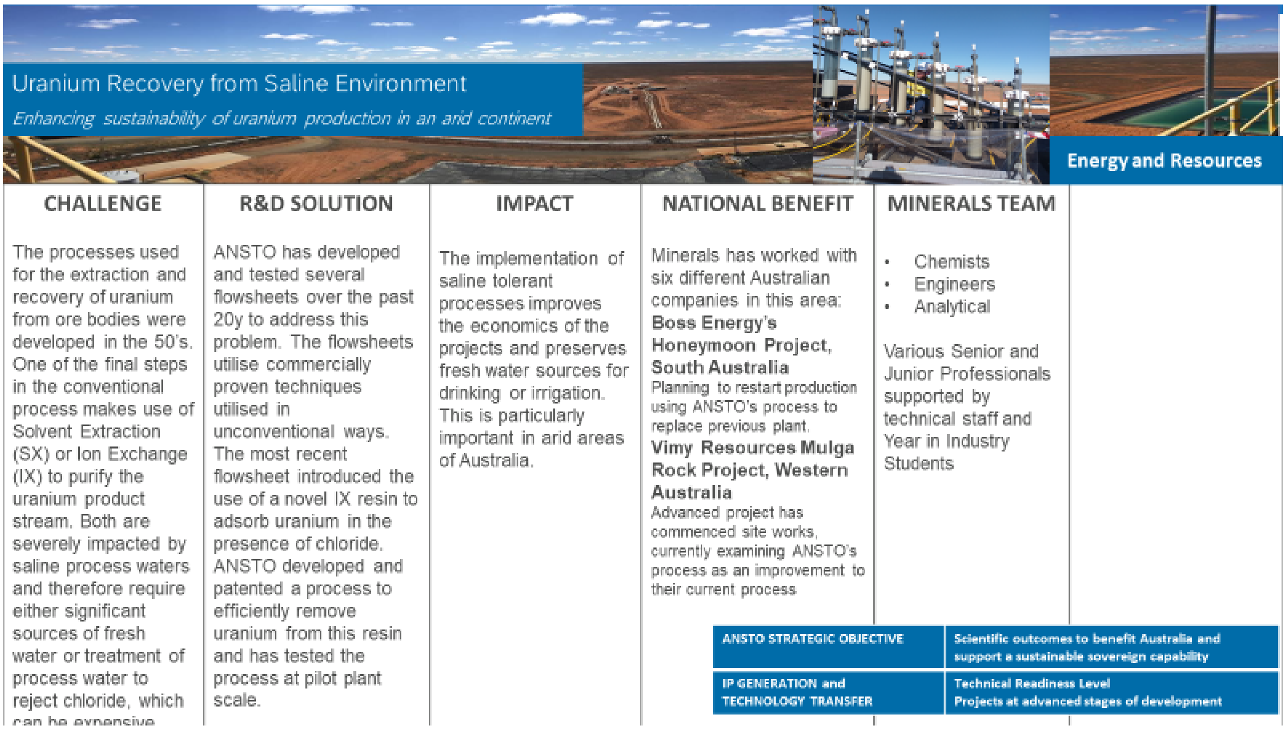
Uranium

ANSTO has been active in the development and application of technologies for the uranium industry for over 50 years. Our project work has included all facets of the uranium flowsheet, including leaching (acid and alkaline, heap and in-situ), solvent extraction, ion exchange, resin-in-pulp, product precipitation, impurity control (including radioactivity) and process water treatment, including nanofiltration and reverse osmosis.

ANSTO has carried out studies for all of Australia's past and current operating sites, including Mary Kathleen, Nabarlek, Olympic Dam, Ranger, Beverley, Honeymoon and Four Mile, and undertaken development work for Jabiluka, Koongarra, Mt Gee, Kintyre, Crocker Well, Westmoreland, Yeelirrie, Lake Way, Wiluna, Valhalla, Anderson's Lode, Samphire, Bigryli, Mulga Rock, Bennet Well and Honeymoon.

Site works, including surveys, audits and plant trials, has been an important feature of our involvement with the industry, and plant trials have continued to be a significant factor in transferring the results of our laboratory research to industry. We have carried out site work for all of Australia's past uranium operations.

Fresh water availability is scarce at most remote Australian mining operations, in contrast saline (brackish to briny) waters are readily available. ANSTO has development technologies where saline waters can be utilised in uranium ore processing that will deliver environmental and economic benefits to uranium operators.



Critical Minerals Research and Development Hub

The Australian Government has recently repurposed $50.5 million over four years from previous commitments to develop the Australian Critical Minerals Research and Development (R&D) Hub. The R&D Hub will build on Australia's world-leading research capabilities, by drawing together critical minerals expertise in CSIRO, ANSTO and Geoscience Australia. This will enable it to prioritise and advance projects of strategic significance. By coordinating and aligning critical minerals research efforts, the R&D Hub will help to:

- build Australian intellectual property in critical minerals processing
- progress international R&D collaboration and science diplomacy
- connect critical minerals projects to technical and research expertise.

ANSTO was awarded $5.3 million in 2022 as part of the Tranche 1 funding to lead an initial program on High Purity Silica (HPS) to develop the high-end technology, facilities and know-how required for the assessment of Australian quartz and silica sand deposits and their applicability to global markets pertaining to fused quartz products, solar cell, and elemental silicon production required for renewable energy and advanced manufacturing sectors.

Materials

ANSTO has established significant capability in the characterisation, testing and development of materials including for the energy industry. Through the use of its landmark research facilities, the organisation is leading the development of renewable energy technologies, battery materials, and the study of the structure of materials.

ANSTO's Australian Synchrotron

ANSTO's Australian Synchrotron is one of Australia's most significant pieces of scientific infrastructure. The Australian Synchrotron produces powerful beams of light that are used at individual experimental facilities to examine the molecular and atomic details of a wide range of materials. The advanced techniques are applied to research in many important areas including green energy. Experiments with synchrotron light offer several advantages over conventional techniques in terms of accuracy, quality, robustness and the level of detail that can be seen and collected, and are much faster than traditional methods.

ANSTO's Australian Centre for Neutron Scattering

ANSTO's Centre for Accelerator Science is a national facility for ion beam accelerator capabilities, delivering a range of radioisotope dating techniques, trace element and actinide identification, surface engineering and characterisation, and radiation exposure and damage testing. The facility informs policy, provides critical services in nuclear forensics and air pollution monitoring, and enables discovery and innovation in areas such as environment, climate and health sciences, space technologies, advanced materials for biotech, energy, nuclear and quantum, and cultural heritage. Ion beams deliver precision irradiation via a suite of ion beam implantation and irradiation modalities. Surface modification, doping, and defect engineering at CAS is used by researchers from across Australia to induce properties that enhance functionality for applications in green energy such as improving catalysts used in water splitting for hydrogen generation, and improving electroconductivity in advanced energy storage materials. Ion beam radiation hardness and damage testing is used for ANSTO research that assesses the performance of critical materials, components, or devices in challenging nuclear energy environments for developing advanced materials solutions.

Materials Research and Renewable Energy

Energy materials research at ANSTO focuses on advancing energy technologies through the tools unique in Australia such as neutron, synchrotron X-ray and ion beam, coupled with other capabilities and expertise at ANSTO, such as modelling of materials properties under extreme conditions. Neutron-scattering tools are extremely well suited for the study of functional materials for energy and excel particularly in the study of hydrogen amongst other systems. This research encompasses energy systems using hydrogen (hydrogen production, storage, and use in fuel-cells), solar-energy materials, and the study of energy-transport mechanisms in battery and ion-conductive materials. In addition, ion-scattering tools are very well suited for hydrogen detection on and under surfaces of energy-related existing and new materials.

- Material researchers at ANSTO use a range of in-house capabilities in the development, testing and characterisation of existing and emerging materials for extreme environments of the novel nuclear (fission/fusion) based energy-generation systems. These materials are required to withstand a combination of challenging in-service environmental conditions such as high temperature, corrosion/oxidation, high-energy particle radiation and photon gamma irradiation. In addition, the use of advanced numerical modelling techniques validated by the above experimental methods, provide powerful tools for predicting materials properties in extreme environments, and the remaining operating life for entire engineering systems.
- ANSTO is a specialist centre for batteries research offering both capabilities and expertise. Instruments at the Australian Centre for Neutron Scattering and the Australian Synchrotron are being used to characterise the properties of materials such as lithium-ion used in energy storage and delivery systems. Neutron-scattering tools have several unique advantages over other analyses techniques for studying lithium-conducting materials. The first is their sensitivity to lithium atoms in the crystal structure, and the second is their high penetration, allowing in-situ experiments with real commercial products instead of specially-designed electrochemical cells that only simulate battery processes.
- Semiconductor materials form the basis of solar cells. By studying these materials in detail, the mechanisms of photocurrent generation can be understood, and better materials devised. Advanced X-ray techniques performed on the Soft X-ray spectroscopy beamline at the Australian Synchrotron have revealed new structural details about the specific arrangement of atoms in conjugated polymers, an important class of materials that are used in LEDs, organic solar cells, transistors, sensors and thermoelectric power devices. In addition, the ion implantation tools available in ANSTO are routinely used to modify the surface properties (electric, magnetic, optic) of advanced functional materials.
- Solid-state ionic conductors are ceramic materials through which specific ions (charged species) can move while leaving their frameworks essentially unchanged. They are critical components in solid-oxide fuel cells (SOFC's), which use hydrocarbons and other fuels more efficiently by bringing them into contact with oxide anions in a direct and controllable manner, rather than simply burning them in air. This minimises pollution due to incomplete combustion and dramatically improves efficiency by producing electricity directly, rather than indirectly by using the heat of combustion to boil water to drive turbines to turn generators. Of particular interest is the use of fuel cells to "burn" pure hydrogen gas, with water as the only by-product. The aim of this project is to obtain a better understanding of ionic-conduction mechanisms in materials used for SOFC's, both currently used and proposed for the future, and thereby contribute to optimising the performance of those materials and possibly discovering/developing new ones.

Manufacturing

ANSTO irradiates over 50% of the world's Neutron Transmutation Doped (NTD) silicon. After further processing by power electronics manufacturers, irradiated silicon is used in high-power electronic switching devices. These devices are used in a range of high-power semiconductor applications such as power grid infrastructure, industrial automation, inverters for solar systems, wind turbine systems, high-speed trains and the automotive industry (including for electric vehicles and infrastructure for charging stations).

Silicon irradiation also known as Neutron Transmutation Doping (NTD) is conducted in the OPAL reactor. Through this process thermal neutrons react with the silicon atoms, changing some of those atoms to phosphorus, which reduces the resistivity of the silicon crystal and allows its ability to conduct electricity to be tailored to a set specification.

The NTD process produces a high level of precision and uniformity in dopant (phosphorous) distribution allowing the achievement of a better, more reliable performance in those electronic devices that utilise it. This is particularly critical for high power and very high-power devices.

ANSTO delivers a high-quality service to our customers located around the world, who then deliver this key material for high power electronics to numerous electronic device manufactures around the world.

Year on year growth has been achieved through continuous incremental improvements and a number of more formal end-to-end process reviews identifying key areas of investment to release constraints in the production capacity. ANSTO will continue to achieve increased production throughput by investing in key areas of our production process which need modernising to achieve more efficient use of resources and improved plant utilisation. This will ensure ANSTO maintains growth in concert with the markets.

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