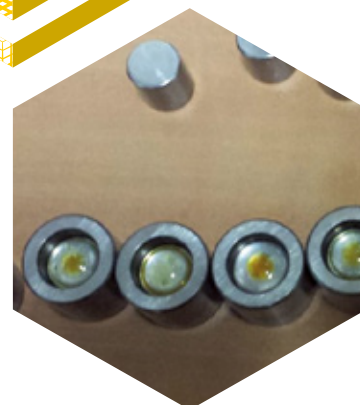
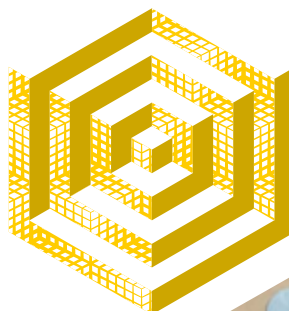


PROCESS SAFETY SOLUTIONS



TNO innovation
for life

The TNO product team Process Safety Solutions (PSS) is a multidisciplinary team of experts with state-of-the-art facilities and all necessary permits to assist companies in the chemical and food industry, governments and insurance companies. The PSS team is specialized in customized testing, process and incident analysis and product qualifications. The quality and speed of our work will enable your company to increase production, improve efficiency, extend your operating windows, analyze and prevent incidents and enter into new markets without high R&D costs.

PSS is part of the Energetic Materials Research Group, which investigates and develops energetic materials and dangerous substances and the products in which these are applied for safe, secure and sustainable use, cost effective production, and countering their misuse by prevention and detection. The PSS team has over 40 years of expertise and a safe track record in working with energetic and toxic materials, for instance pyrotechnics, organic peroxides, ammonium nitrate fertilizers, self-reactive and self-heating substances and flammable gases, dusts and liquids. Our facilities, including test setups, laboratories and facilities for (gas) explosions, are designed for energetic materials synthesis, analysis and handling. Our worldwide customer base of both SMEs and multinationals values our rapid response, multidisciplinary expertise, independence and our effort

to go that extra mile. The presentation of our research findings is accompanied by a thorough analysis and interpretation of the results, answering the question: what do these figures actually mean for your business?



TESTING AT EXTREME CONDITIONS

PSS can help you identify whether certain materials, equipment or processes can withstand extreme temperatures, pressure or explosions. Our facilities, permits and expertise allow us to handle these complex issues. We are able to execute tests in conditions ranging from -165 °C to 1000 °C, from 0 to 600 bar and from no hazard to high explosive. With this broad range of possibilities, we facilitate our customers, for instance, to explore new markets.

Case study: for a client in the oil & gas industry, we developed a cryogenic test setup to store flammable liquid gas at cryogenic temperatures for at least two weeks. This unique facility is specially built for this purpose. The test tank contains 200 L of liquefied gas in contact with material samples. How does the long-term cryogenic exposure affect the samples? With this test, TNO has proven that the material can continue to perform for at least two weeks. The client now has the necessary validation to use the sample material in its operations.

EXTENDING OPERATING WINDOWS

Many industries do not utilize the full potential of their chemical plant, because their processing windows are based on standard tests with wide safety margins. However, these tests do not always accurately reflect the actual situation. Because of our extensive knowledge of the design and execution of standard tests, we are able to adjust the tests so they will more accurately reflect the actual situation. With this knowledge, it is possible to intensify your process without compromising safety. This enables you to increase the process output.

Case study: for a client in the chemical industry, we investigated whether a flow of a certain liquid was potentially detonable. Standard tests are not able to deal with this type of flow because of its mixed character. An adjusted test developed in-house was able to accurately mimic the actual conditions, showing that the flow was not detonable. This allowed the client to increase its production capacity without any investment in the existing hardware.

INCIDENT AND PROCESS SAFETY ANALYSIS

What are the safety risks of your process? We combine theoretical knowledge about the potential impact of explosions with our experimental facilities. This enables us to calculate beforehand how safe your process will be and validate the prediction by testing. We can also analyze accidents that have already taken place, such as explosions caused by fireworks or fertilizer. Our terrain has the facilities to mimic explosions.

Case study: a client in the oil & gas industry developed a process in which two components come together, that could – in theory – create a hazardous or even explosive intermediate product. In a test setup, we mimicked this situation by creating a low temperature and a high pressure. Our test revealed that the intermediate did not form, which ensured the client that its process is safe.

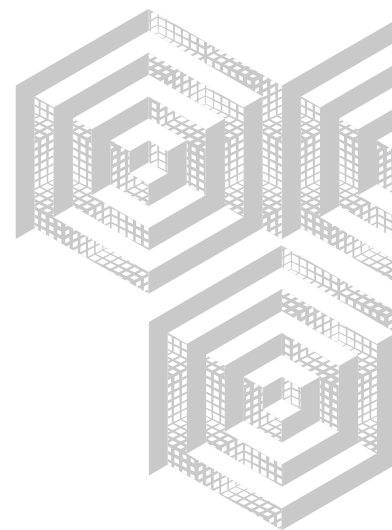
NEW WAYS TO OLD PRODUCTS

Driven by fierce global competition, the chemical industry is searching for new processes with higher margins. However, R&D costs for new developments are high. The PSS team can assist you in looking for alternative approaches, for instance by exploring whether using certain materials will allow you to skip intermediate steps in your process. Processes that appear to be unsafe, might turn out to be safe after all, as well as more efficient and profitable. We perform synthesis experiments in the laboratory for the development of new chemical products and subsequently design and run continuous flow pilot plants in which the hazardous chemistry is being investigated on a larger scale. Examples are fluorine, bromine and phosphorous chemistry, as well as working with chemicals like hydrazine, acetylene, ammonia and hydrogen under various process conditions (temperature, pressure).

PRODUCT TESTING (DANGEROUS GOODS)

PSS has contributed to the development of many test methods, criteria and guidelines in the field of hazardous material handling, transport of dangerous goods, classification and storage (e.g. ADR, CLP). We have a thorough knowledge of these tests and their background and can execute them efficiently and effectively on short notice.

Case study: before ammonium nitrate fertilizer can be released into the market, the ease of detonation has to be verified to prevent easy misuse. For this purpose, PSS has developed a standard test method, which is an accepted and approved method of verification. We initiate detonation of the fertilizer in a standard manner and measure the explosive effects. Our rapid qualification of ammonium nitrate enables customers to quickly release their product into the market.

**TNO.NL/PROSAFE****DEFENCE, SAFETY AND SECURITY**

The independent Netherlands Organisation for applied scientific research (TNO) supports the Dutch comprehensive protection model. Our work in Defence, Safety & Security focuses on technological and behavioural innovations.

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