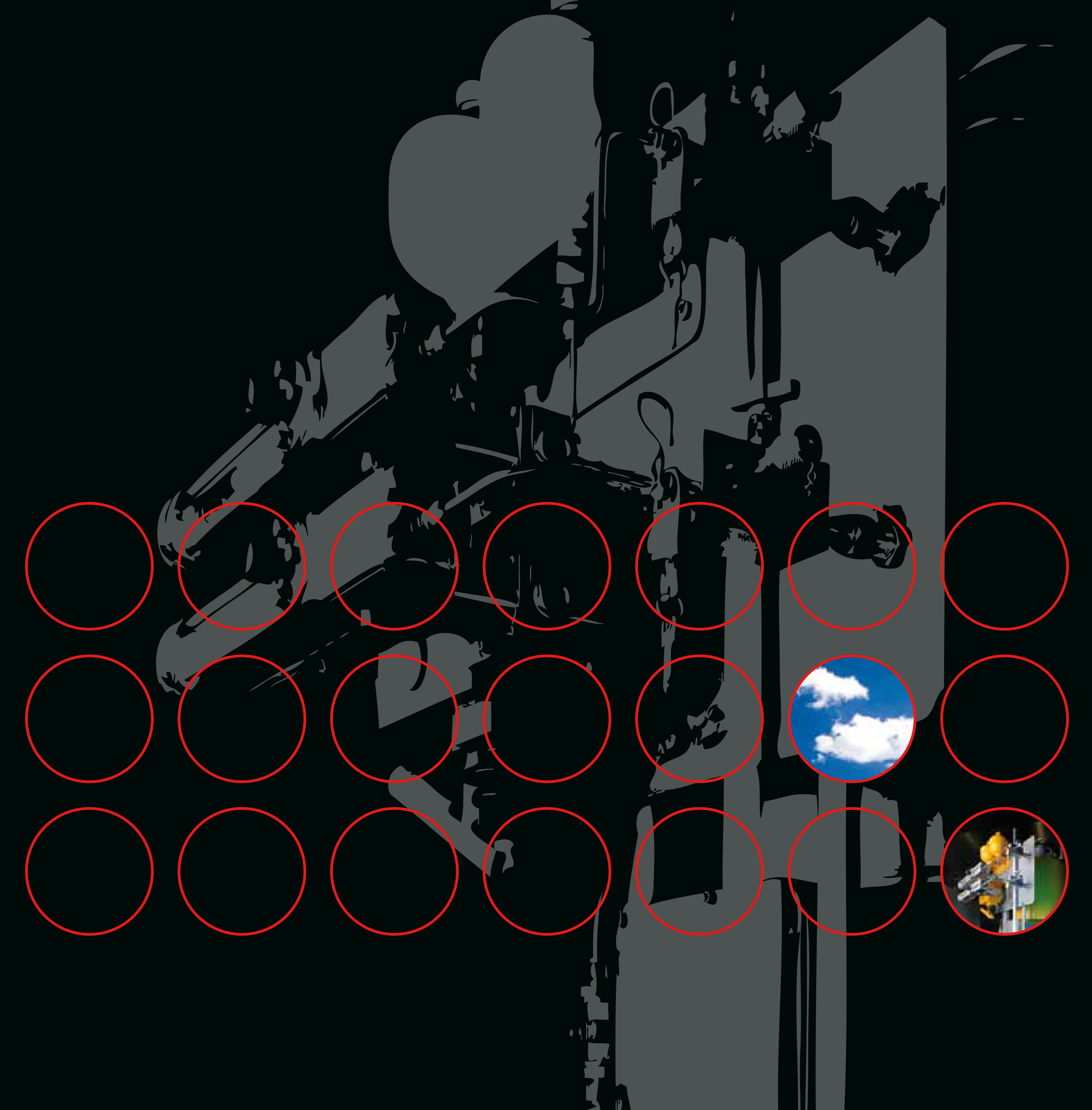


first in safety

safety instrumented system - HIPPS

mokveld

Introduction to HIPPS

HIPPS is an abbreviation of 'High Integrity Pressure Protection System'. HIPPS are applied to prevent over-pressurisation of a plant by shutting-off the source of the high pressure. In traditional systems over-pressure is dealt with through relief of venting systems. These systems have obvious disadvantages such as release of (flammable and toxic) process fluids in the environment and often a large footprint of the installation. With the increasing environmental awareness relief systems are no longer an acceptable solution.

HIPPS provides a technically sound and economically attractive solution to protect equipment in cases where:

- High-pressures and / or flow rates are processed
- The environment is to be protected.
- The economic viability of a development needs improvement
- The risk profile of the plant must be reduced

What is HIPPS?

HIPPS is an instrumented safety system that is designed and built in accordance with the IEC 61508 and IEC 61511 standards.These international standards refer to safety functions and Safety Instrumented Systems (SIS) when discussing a device to protect equipment, personnel and environment.
Older standards use terms like safety shut-down systems, emergency shut-down systems or last layers of defence. A system that closes the source of over-pressure within 2 seconds with at least the same reliability as a safety relief valve is usually called a HIPPS.

A High Integrity Pressure Protection System is a complete functional loop consisting of:

- The initiators that detect the high pressure. These initiators may be electronic or mechanical
- For electronic HIPPS a logic solver, which processes the input from the initiators to an output to the final element
- The final elements, that actually perform the corrective actions in the field by bringing the process to a safe state. The final element consists of a valve + actuator and possibly solenoids or mechanical initiators.

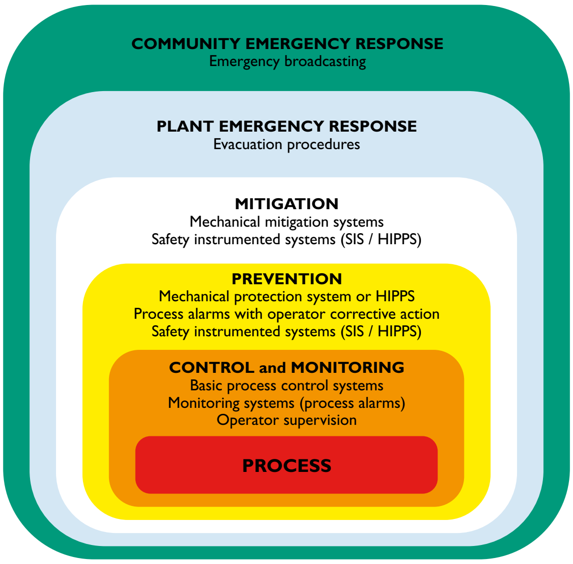
Flaring of hydrocarbons causes damage to the environment and the CO_2 production is not in line with the Kyoto Protocol.

HIPPS prevent over-pressurization by shutting down the source of the high pressure.

Standards & Design Practices

The ever-increasing flow rates in combination with the environmental constraints initiated the wide-spread and rapid acceptance in the last decades of HIPPS as the ultimate protection system.

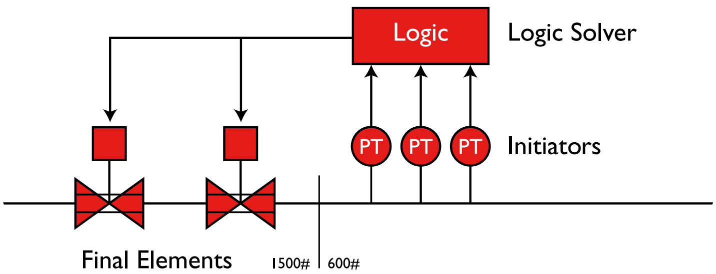
The International Electro technical Commission (IEC) introduced the IEC 61508 and the IEC 61511 standards in 1998 and 2003. These are performance based, non-prescriptive, standards which provide a detailed framework and a life-cycle approach for the design, implementation and management of safety systems applicable to a variety of sectors with different levels of risk definition. These standards also apply to HIPPS.



The IEC 61508 mainly focuses on Electrical/Electronic/Programmable Safety-related systems. However it also provides a framework for safety-related systems based on other technologies including mechanical systems. The IEC 61511 was introduced by the IEC specifically for designers, integrators and users of safety instrumented systems and covers the other parts of the safety loop (initiators and final elements) in greater in detail.

The basis for the design of safety instrumented system is the required Safety Integrity Level (SIL). The SIL is obtained during the risk analysis of the plant or process and represents the required risk reduction. The SIS shall meet the requirements of the applicable SIL level which ranges from 1 to 4. The IEC standards define the requirements for each SIL level for the lifecycle of the equipment, including design and maintenance. The SIL level also defines a required Probability of Failure on Demand (PFD) for the complete loop and architectural constraints for the loop and it's different elements.

In practice the required protection level for HIPPS in Oil and Gas applications is often SIL3. But this is not cast in stone and should always be the result of a Hazard and Operability study (HAZOP). The requirements of the HIPPS should not be simplified to a PFD level only, the qualitative requirements and architectural constraints form an integral part of the requirements to an instrumented protection system such as HIPPS.



A typical HIPPS safety loop consisting of 2oo3 initiators (Pressure Transmitters), a logic solver and 2 final elements being valve and actuator.

The European standard EN 12186 (DIN G491) and more specific the EN 14382 (DIN 3381) has been used for many years in (mechanically) instrumented overpressure protection systems. These standards prescribe the requirements for the over-pressure protection systems, and their components, in gas plants. Not only the response time and accuracy of the loop but also safety factors for over-sizing of the actuator of the final element are dictated by these standards. Independent design verification and testing to prove compliance to the EN 14382 standard is mandatory. Therefore users often refer to this standard for HIPPS design. The German DVGW certified the Mokveld final element including a mechanical initiator in 1974 in accordance with DIN 3381 (now EN 14382). Since that date Mokveld has field experience with safety shut-off loops (valves + actuator + initiator) closing within 2 seconds.

Reliability

Mokveld's vast experience in fast stroking final elements totals over of 19 000 operational years (with more than 1000 valves). The Mokveld final elements (a functional unit consisting of valve + actuator and possibly solenoids or mechanical initiators) are therefore proven-in-use for high reliability safety applications in natural gas and 2-phase hydrocarbons. Third parties, like the German TÜV and Atomic Energy Agency, have validated the Mokveld database and the derived reliability data, this includes failure rates for clean and unclean fluids.

The certified Mokveld failure rate for the final element (being the valve + actuator) for a failure to deliver a full stroke in 2 seconds for applications in untreated hydrocarbons is: $\lambda = 2{,}98 \times 10^{-4}$ / year. The failure rate for the Mokveld hydraulic mechanical initiator mounted on the final element is: $\lambda = 7{,}72 \times 10^{-4}$ / year. This data enables Mokveld to supply a HIPPS to suit SIL 3 or even SIL 4 with a proof test interval of 1 year or a system fully in accordance with EN 12186 or EN 14382.

The Mokveld final elements do not require additional electronic systems, like partial stroke testing device, to meet SIL 3 with a 1 year test interval. A separate technical datasheet on this subject is available.

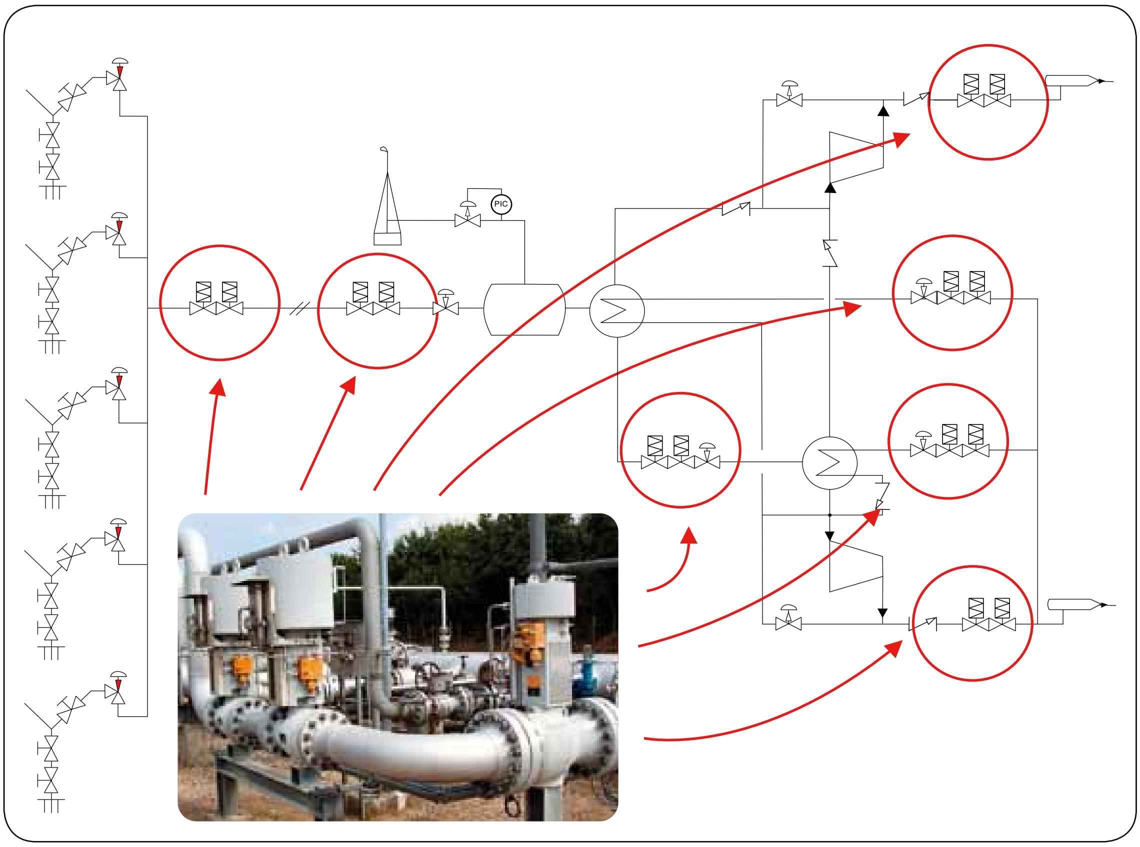
SIL Safety Integrity Level	**PFD** Probability of Failure on demand
4	$\geq 10^{-5}$ to $< 10^{-4}$
3	$\geq 10^{-4}$ to $< 10^{-3}$
2	$\geq 10^{-3}$ to $< 10^{-2}$
1	$\geq 10^{-2}$ to $< 10^{-1}$

The corresponding PFD to each SIL. The required redundancy is not shown here.

Two types of HIPPS

Based on our vast experience and expertise Mokveld offers two types of HIPPS

1. Integral mechanical HIPPS, since 1974
2. Full electronic HIPPS, since 2000



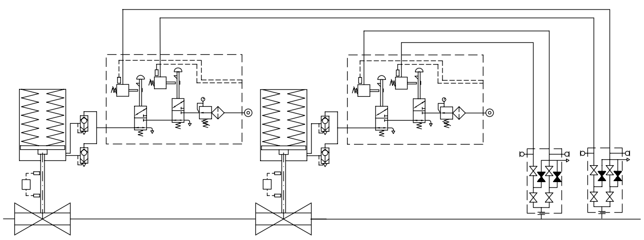
An example of how and where HIPPS can be implemented in, typical production facility.

Initiators

The initiators detect the high pressure (or high level, or temperature). For the mechanical HIPPS this will be Mokveld's mechanical initiators. For the electronic HIPPS this will be safety related pressure transmitters. The safety loop may consist of one or more sensors to achieve the required safety level.

The Mokveld mechanical initiators are certified to EN 14382 (DIN 3381) and have a setpoint accuracy better than 1% of the setpoint. For both the pneumatic and the hydraulic version third party validated reliability data are available. The safety systems based on these initiators are easily identifiable in the plant, easy to operate and relatively simple. This makes it inherently safe systems. As an option a full stand-alone system requiring no external energy is available for applications in remote areas.

HIPPS with two Mokveld mechanical initiators protecting Shell Tutong metering station in Brunei.



Example of a HIPPS consisting of 2 final elements each having two mechanical initiators, SIL 4 is obtained. Testing can be done via the high integrity manifold block with key interlock system.

Logic Solver

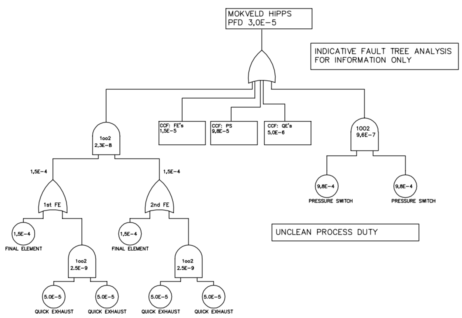
The Logic Solver processes the signals from the initiators (pressure transmitters) and closes the final element for instance by de-energising the solenoids. A system based on mechanical initiators does not require a separate logic solver. A SIS or HIPPS utilising pressure transmitters and a logic solver are typically used when remote sensing is required. Usually 3 pressure transmitters are used and the Logic Solver de-energises the solenoids when 2 give a high signal (2 out of 3 voting). The logic solver is probably the most complex device in the loop, especially the programmable ones. At present many are available with certificates showing suitability in SIL 3 safety loops. In general Mokveld uses hard-wired solid-state logic solvers based on the magnetic core technology. These systems are inherently fail-safe and are therefore certified for applications in SIL 4 loops.

Final Element

The IEC 61508 does not give the final elements the attention they deserve, the IEC 61511 already has more focus on this part of the loop. Whereas this is specifically required for fast acting safety loops (requiring shut-off within 2 seconds) in a low demand mode. The EN 12186 recognises this and refers to the EN 14382 for the design of the final element.

Slam-shut valves in HIPPS applications usually have long periods of inactivity (valve remains fully open for a long period). The design shall be such that this does not influence the response time of the valve, nor the stroking speed once a demand occurs. A regular partial stroking cycle is not a solution as this may result in a partial closure upon a demand as well.

Typical logic solver panel.



Mokveld engineering assistance will provide a fault tree analysis of your system during proposal stage.

The following features make the Mokveld axial on-off valve inherently safe and suitable for HIPPS applications:

a) The break-away thrust is minimal, even after long periods of inactivity.

b) Erosion and subsequent degradation into leak tightness is avoided.

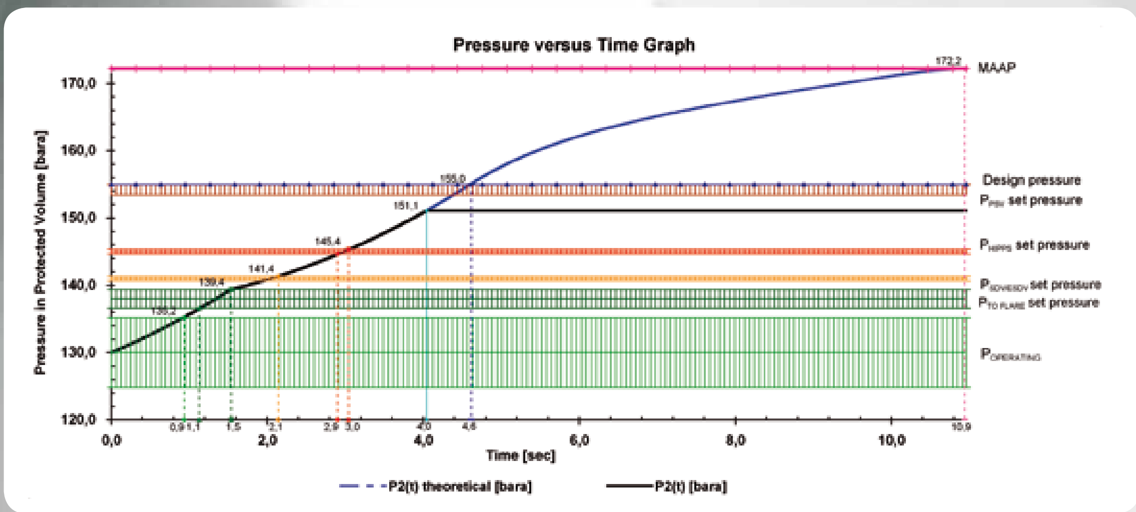
c) The required actuator thrust is low and independent of the pressure differential across the valve.

d) Very short stroking times (e.g. 2 seconds for 24 inch valves) are possible due to the low mass of the moving parts.

e) The piston does not slam onto the seat but slides into the seat.

f) The integrated design of valve and actuator assures that the thrust safety margin is sufficient at all times.

Please refer to the Mokveld axial on-off valve brochure for more detailed explanation of the specific benefits.



Mokveld can assist in defining the response time of your system in the proposal stage.

Mokveld Engineering Assistance

Mokveld engineers can provide support in an early phase of the project. We can assist in defining suitable HIPPS architecture, fault tree analysis, determining the pressure rise in the protected volume and the required stroking times and set points of the entire system.

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