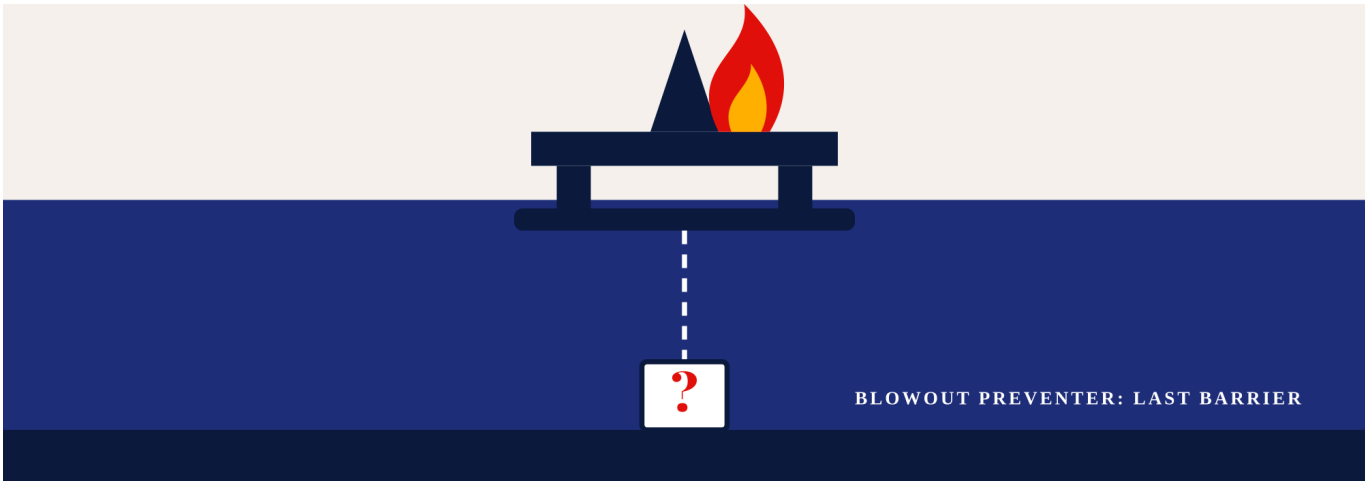


Deepwater Horizon, 2010: when unverified barriers and delayed detection compounded

A reliability and asset management reading of the Macondo blowout, with five practical checks for operators

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ABSTRACT

On 20 April 2010 the Macondo well in the Gulf of Mexico blew out beneath the drilling rig Deepwater Horizon. Gas reached the rig and exploded; 11 workers died and 17 others were critically injured [1]. A cemented shoe-track barrier at the bottom of the well was not effective, a test of that barrier was misread, and the blowout preventer (BOP) did not seal the well [1][2]. We review the case with a bow-tie view, a contributing-factor map, RCM and an ISO 55001:2024 lens, and turn it into five checks.

KEY FINDINGS

1. The shoe-track cement barrier was not effective, and a negative pressure test was misread as a success [1][2].
2. Hydrocarbons flowed for almost an hour without detection [1].
3. The BOP's emergency system had wiring and battery faults, and buckled pipe stopped the shear ram from sealing [1].
4. Personal safety was tracked and rewarded more than process safety [1].

115 people were evacuated. The rig sank on 22 April, and oil flowed until the well was capped on 15 July 2010 [1][2][6]. Other official summaries report 16 injured, on a different counting basis [2].

01 Context and purpose

Deepwater Horizon was a semi-submersible drilling rig owned by Transocean and working for BP in Mississippi Canyon Block 252 [1][3]. The crew had finished drilling the Macondo exploration well and was preparing to leave it temporarily abandoned for later production [1][3]. That step depends on barriers in the well: cement, tested pressure seals and, as a last line, the BOP on the seafloor.

About this brief. A practitioner interpretation from public sources by AFDARA & Co.; not legal or engineering advice, not peer-reviewed. Figures, evidence check and indicators are AFDARA tools, not taken from the investigation reports.

02 The sequence

A cemented shoe-track barrier in the production-casing string was intended to isolate formation fluids. The investigations concluded that this barrier was not effective; the precise failure mechanism remained contested or unresolved in the public record [1][2].

A negative pressure test checks whether the well is sealed. The pressures were inconsistent: the drill pipe showed pressure while the kill line did not. Around 19:45 the crew concluded the test was successful [1][2]. BP's

forward plan of 16 April did not include the test; instructions were sent on the afternoon of 20 April [1].

The crew then replaced the heavy drilling mud with seawater. With the cement already failed, the open BOP became the main remaining physical barrier [1]. Hydrocarbons flowed for almost an hour without detection [1]. At about 21:40 mud flowed onto the rig floor; the crew routed the flow to the mud-gas separator and activated BOP elements, but gas already above the BOP kept coming. The first explosion was at 21:49 [2].

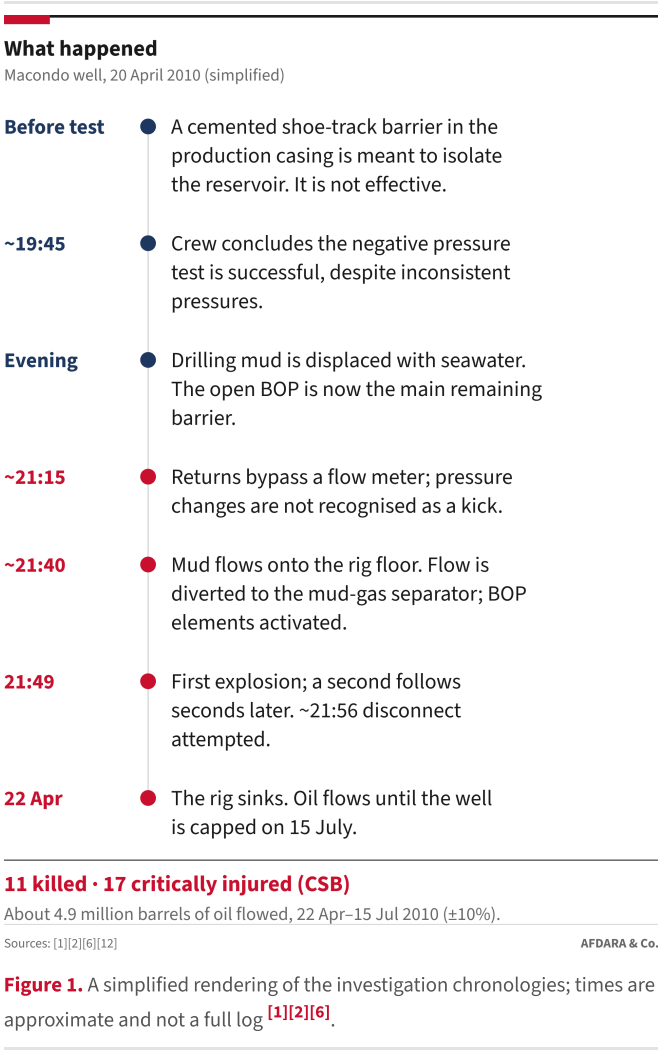


Figure 1. A simplified rendering of the investigation chronologies; times are approximate and not a full log [1][2][6].

03 Reliability and barrier analysis

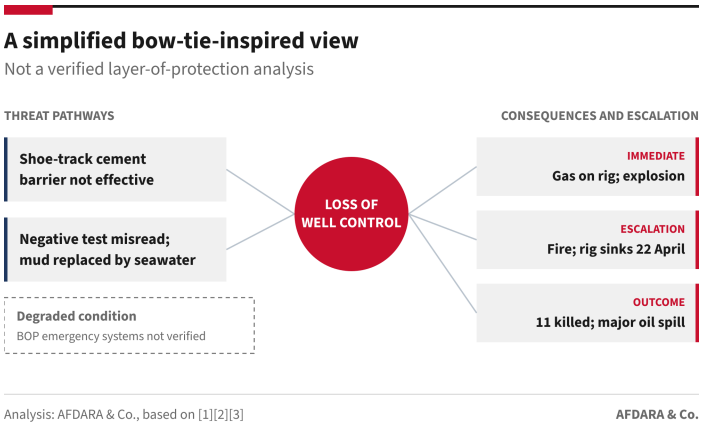


Figure 2. A qualitative cause–consequence sketch, not a safety-case demonstration, LOPA or QRA [10]. Controls that failed or were unavailable: *prevention* — the bottom cement barrier, a correctly interpreted negative pressure test, kick detection during displacement; *mitigation* — diversion overboard rather than to the mud-gas separator, the BOP emergency (AMF/deadman) function, emergency disconnect [1][2].

The last barrier was assumed, not proven. The BOP's automatic mode function (AMF) is meant to close the blind shear ram if control links to the rig are lost. It uses two control pods. On the day, the blue pod had a miswiring and a drained battery, and a solenoid in the yellow pod was miswired [1]. The CSB found the AMF most likely activated, but buckled, off-centre drill pipe stopped the shear ram from sealing the well [1].

The emergency function was not assured. Routine BOP functions were tested, but at the time neither recommended industry practices nor U.S. regulations required testing of the AMF/deadman system; no effective assurance activity verified the redundant emergency function. The CSB judged that the miswirings could not have passed factory acceptance testing [1].

The diverter choice mattered. The diverter was preset to route flow to the mud-gas separator on the rig, not

overboard. The separator was overwhelmed and hydrocarbons escaped at several points on the rig [1].

04 Contributing causes and organisational learning

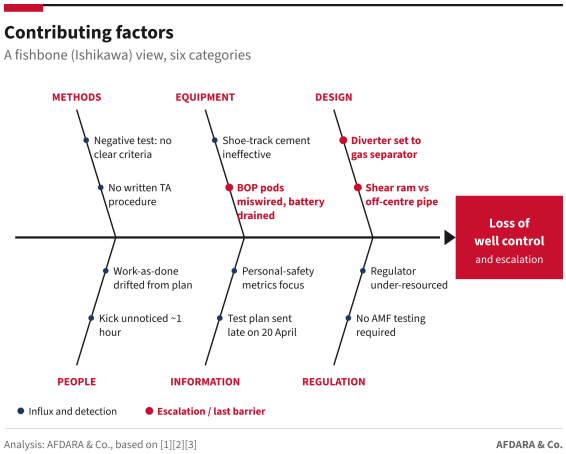


Figure 3. A workshop aid by AFDARA & Co.: a contributing-factor map for structuring discussion. It is a practitioner interpretation, not the investigators' causal analysis [1][2][3].

One selected branch (workshop aid). Why did gas reach the rig? The well flowed for almost an hour unnoticed. Why could it flow? The shoe-track cement barrier was not effective and the mud was removed. Why was the mud removed? A negative test was read as a success. Why was it misread? There were no clear success criteria and no written procedure for the job [1]. Real causation had several branches.

Recorded signals. In 2009 Transocean recorded 121 well control events across 32 operators, including 71 kicks [1]. The CSB found that temporary abandonment planning did not account for human factors, that written work plans and safety-critical procedures were missing, and that the gap between work-as-imagined and work-as-done was not closed [1].

A recurring measurement and assurance gap. Both companies tracked and rewarded personal safety metrics but gave process safety less attention; the CSB found that personal-safety and lagging indicators did not adequately address safety-critical elements and major-accident risk [1]. The CSB also found the regulator under-resourced, and its post-Macondo safety-management rule weak and activity-based [1].

RCM QUESTION	APPLIED TO THE BOP EMERGENCY (AMF) FUNCTION
1 Function	Close the blind shear ram and seal the well if control links are lost.
2 Functional failure	Ram closes but does not seal; or does not close.
3 Failure mode	Pod miswiring and drained battery; buckled, off-centre pipe in the ram [1].
4 Effect	Nothing visible in normal drilling; shows only on demand.
5 Consequence	Hidden failure: exposure to a multiple failure with safety and environmental consequences.
6 Proactive task	Battery condition monitoring and replacement at a justified interval.
7 If no proactive task	Failure-finding is one possible policy: a functional test of the AMF that covers the full function, with justified interval and test risk. Redesign may be required where pipe position defeats the ram.
Operational rule	Separately: do not rely on a last barrier whose function has not been verified.

Table 1. RCM questions (after SAE JA1011 [8]; not a quotation), applied by AFDARA & Co. to the BOP emergency function described by the CSB [1].

> **TAKEAWAY**
>
> A barrier you have never tested is a hope, not a barrier. Verify the last line of defence before you need it.

05 A retrospective ISO 55001 lens

Viewed retrospectively through ISO 55001:2024, the case raises questions about risk, change, information, operational control and performance evaluation. These are illustrative questions, not a historical audit or a finding of nonconformity. ISO 55001 complements rather than replaces well-control and legal requirements [4].

HISTORICAL CONTROL ISSUE IN THIS BRIEF	ILLUSTRATIVE ISO 55001:2024 QUESTION TODAY
Negative test with no clear success criteria	8.1 Operational planning and control
Late change to the temporary abandonment plan	6.3 Planning of changes · 8.2 Control of change
BOP emergency function never verified	6.1 Actions to address risks · 9.1 Monitoring, measurement, analysis and evaluation
Contractor and operator roles unclear	5.3 Roles, responsibilities and authorities · 7.4 Communication
Personal-safety metrics dominated	9.1 Monitoring, measurement, analysis and evaluation

Table 2. Selected illustrative mappings [4]. The clauses do not prescribe a specific well test, BOP test or indicator set.

06 A well-state screen

CONDITION	POSSIBLE EFFECT	SAFER ACTION
Pressure test result ambiguous	Failed barrier accepted as sound	Written success criteria; stop and escalate if not met
Heavy fluid removed above an untested barrier	Well becomes underbalanced	Confirm the required, verified barriers before displacement
Flow monitoring bypassed or distracted	Kick goes unnoticed	Keep monitoring on during all fluid moves
Diverter routed to equipment on the rig	Gas released among people and ignition	Pre-agreed diverter policy for large influx
Emergency BOP function untested	Last barrier fails on demand	Functional test and battery checks at set intervals

Table 3. Illustrative condition–effect–action screen; not a complete FMEA or well-control standard. Methods and limits come from the well operator's procedures and applicable standards.

Evidence check (AFDARA heuristic). For each critical control, look for evidence that it *exists*, is *understood*, is *implemented* (sampled records and observations) and *performs* under defined conditions. The Macondo crew ran a negative test and had a BOP [1]; the gaps lay in interpretation, verification and performance.

07 Five practical checks and risk-linked monitoring

1. **Test criteria before the test.** Write down what a pass looks like, in numbers, before any barrier test. If the result is unclear, stop and escalate [1].
2. **Credited barriers, verified.** Before displacement or removal of a barrier, verify the site-specific minimum barrier requirement in the well-control program and applicable regulation, confirm that the credited barriers are available under the planned conditions, and stop if the test evidence is ambiguous [1][2].
3. **Monitoring during every fluid move.** Do not bypass flow monitoring during displacement or other activities [2].
4. **Test the last line of defence.** Functionally test emergency shutdown and BOP emergency systems, including batteries and wiring, at a justified interval [1].
5. **Track barrier health, not only injuries.** Report well-control and barrier indicators to senior management alongside safety statistics [1][9][11].

Illustrative indicators

INDICATOR	DEFINITION TO SET	RESPONSE RULE
Barrier tests with unclear results	Tests accepted without meeting written criteria	Independent review; repeat test
Overdue emergency-system tests	BOP or ESD emergency functions past their test date	Owner restores or approves compensating measures
Kick detection time	Minutes from influx to shut-in, from drills and real events	Training and equipment review
Open well-control events	Kicks and losses investigated and closed	Trend and share lessons
Plan changes in the last 48 hours	Late changes to safety-critical procedures	Formal change review

Thresholds and monitoring frequencies are AFDARA heuristics and must be set by site risk assessment, not read as ISO 55001 or statutory limits. For each indicator define scope, numerator and denominator, time window, owner, response and closure evidence. Indicators give early warning, not prediction [9].

QUESTION FOR YOUR TEAM

Which barrier are you relying on today that has never been tested on demand?

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