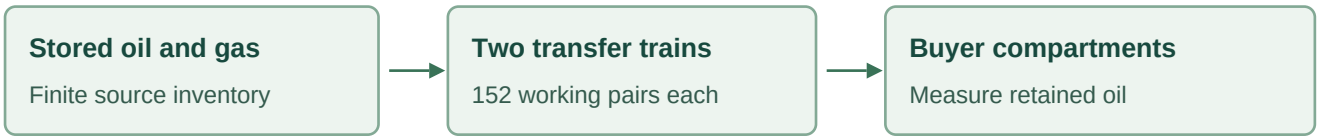
The Haven Protocol

The Haven Protocol is a proposed emergency piping and containment system for crude oil and produced fluids. Its purpose is to keep usable oil reaching a customer while damaged equipment is repaired, and to stop and contain the oil when safe delivery is no longer possible.



What it aims to achieve

For the modeled installation, normal transfer is 1,000 cubic metres an hour. If a safe route and a receiving tank survive, the goal is to deliver at least 400 cubic metres of usable oil every hour for 72 hours. That is 40% of normal flow and 28,800 cubic metres delivered over three days. The model checks every rolling minute so that a later surge cannot hide an interruption.

How it would work

Independent transfer lines, protected oil stocks and a local reserve maintain delivery into healthy final receivers. A monitored wall and a physical permit stop the damaged inlet. Each tagged part has an incident record that connects available measurements before, during and after an upset to its location and function. Missing evidence stays visible on the operator panel.

When delivery must stop

If the receiving tank fails, or the system loses the evidence it needs to continue, the affected inlet must close. Jackets, sumps and collection basins are intended to retain oil already in motion. The design target is 150 litres of measured and contained flow after failure, with a maximum of 200 litres per failed inlet over 72 hours. Across the entire site, the separate limit is one litre of oil escaping to the environment.

What the tests show

The separate hypothetical plant passed 20 of 20 registered numerical duties. A leak spread over 200 sensing patches gave 155.39 L of gross failed-inlet run-on. With one lane switching for six seconds, the weakest rolling minute delivered 401.89 reference m³/h. Field performance and the original site's end-to-end missions remain unverified.

What happened to this equipment?

The incident recorder gives every registered part an address. The operator selects a case and a component, sees its engineering units and acquisition time, and can switch between the evidence available at the incident and the evidence recovered later.

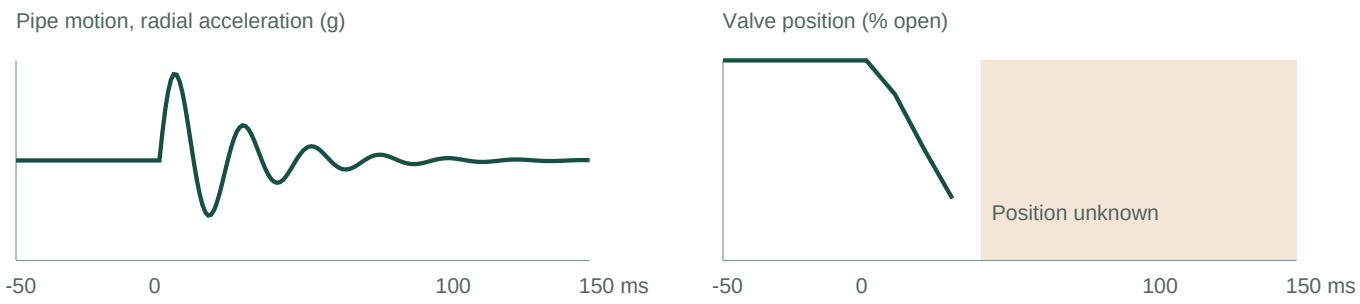
Operator selects	What the evidence shows
Receiver approach pipe, clamp 1	A 1 kHz radial-motion fixture generates 201 samples around a known stimulus. During a simulated link outage, 56 samples stay in local memory. At +8 s all 201 can be reconstructed in acquisition order. Acceleration alone cannot diagnose a wall crack.
Inlet valve, independent travel contact	The example valve reads 31% open at +0.03 s. Both copies lose its position from +0.04 s. The display leaves closure unknown. A separate downstream fluid witness is needed to establish tight shutoff.
Source train, gas store or catcher	All 20 cases expose time-stamped native outputs for these three assets on train A. The separate data download contains 160 CSV histories with all 22 native columns for all 4,320 minutes. One-minute process data cannot establish a six-second changeover.
Other components and passive supports	The register covers 931,635 addresses in 26 equipment families. The recorder demonstration includes four sampled channels and one unobserved support. Two additional traces show the calculated source latch and reserve delivery. A registered address can have no direct measurement.

From drawing to commissioning

Assign a permanent tag to every replaceable item and pipe spool on the as-built register. For each tag, record its sensing point, physical parent, calibration, clock error, redundancy and evidence needed to return it to service. Treat an untagged replacement, lost channel or unsupported damage inference as an open inspection item.

Two instruments during the recorder test

The pipe signal was retrieved from local memory. The valve-position record ends during closure.



Both charts use time relative to the applied fixture input. They show simulated measurements.

Evidence that survives a communications outage

Event data are captured where the equipment is located. Each bank has two independent recording domains and dry external instruments. The private console can go offline while field isolation and the local receipt checks continue.

Design item	Sizing and failure evidence
Stored data	Each bank keeps two independently powered 4 TB copies. The 72-hour budget is 3.314 TB per copy, including both 20 Hz wall channels, 2 Hz trends, 24 high-speed bursts and 25% overhead. Doubling the patch rate needs 6.588 TB per copy.
Ordering and replay	Each sample has an asset address, sequence, acquisition time, engineering unit and quality. Local capture preserves time when the network drops. The replay discarded a corrupt packet, deduplicated repeats and quarantined a contradictory packet. Two independent clocks drifting at ±2 ppm for 72 h can disagree by about 1.04 s.
Independent physical evidence	A forged sample shared by both recorders survives as a false record. Pressure or motor command alone cannot prove delivery. Genuine local displacement, dry-wall evidence and final product identity remain required by the field logic.
What already exists	NHTSA describes automotive event data recorders as recording selected information around a crash. Emerson DeltaV already offers time-stamped industrial sequences of events. The proposed integration connects those records to part identity, missing evidence, final buyer receipt and spill accounting. Market exclusivity has not been established.

Primary sources

NHTSA, Event Data Recorder (nhtsa.gov/research-data/event-data-recorder). Emerson, DeltaV Sequence of Events, official white paper. The downloadable incident evidence includes both direct source links.

A receiving wall that can detect a spread-out leak

When oil seeps through a receiving cell, it enters a monitored space inside that same customer cell. Local capacitance measurements detect oil at the wall. A physical source latch prevents a new stroke even when the indicated customer weight looks correct.

Challenge	Measured numerical result
A leak spreads across 200 patches	The challenge introduces 0.040 reference L/s of oil, while the inlet continues carrying bulk product. Local and summed wetting evidence inhibits new source permits by 1.583 s. Bounding the bulk flow from onset, committed strokes, trapped pockets and seepage gives 155.390 actual L at the failed inlet over 72 h. The maximum is 200 L and the preferred target is 150 L.
Independent dry references	Each local group contains at least 1,024 electrodes. A healthy majority supplies the background. The trip uses the 200 largest corrected readings plus individual alarms. Common drift and unfavorable individual offsets are applied together. At an individual 8 pF trip alone, the same distributed leak passes 230.040 L before the first indication.
One drain blocks	Two segregated paths feed collapsible sleeves within the same final customer cell. At the stated leak rate, 10.938 hot m³ can reach the guard in 72 h. One surviving sleeve has 1.687 m³ left including the full inlet allowance. Captured oil earns zero new sale credit.
When the wall evidence fails	Both readers can repeat a plausible dry pattern. A sufficiently slow distributed leak, a seam outside the guard or two obstructed drainage paths can defeat the assurance. The synthetic run does not establish performance for arbitrary hole size or fluid chemistry.

Qualification test

Wet a production panel with the actual crude at the viscosity and temperature limits. Distribute the oil across seams and electrode boundaries while loading the structure. Meter all positive oil at the original inlet independently for the full test.

Keeping oil moving while one inlet changes over

A separate, closed customer receiver on each train can take emergency oil directly from four prequalified seller cartridges. Three cartridges can run when one is unavailable. Existing customer oil earns no sale credit. The reserve oil first earns credit when it crosses a genuinely proved receiving boundary.

Condition	What reaches the customer
One active inlet fails	The failed lane receives zero credit from physical onset through detection, six full seconds of switching, and startup of the alternative. The entire interval is 8.682 s. After accounting for product grade, pulse timing and lost previously sold oil, the weakest rolling minute is 401.892 reference m³/h against 400.
Inside the six seconds	A mechanical stop limits an extra 0.56 s of high-rate plunger travel. After meter and timing allowances, the full six-second mean is at least 463.70 reference m³/h. Every sliding second entirely within that interval clears 408.78. During the first 0.48 s the healthy lane alone carries about 205. A constant-rate reserve only certifies 303.04 in its weakest second.
Oil, batteries and final storage	Each train buys 1.496 reference m³ of separate seller inventory. The new 16 m³ customer receiver has a 22 m³ blind catch and an integral dry gas cushion. The finite reserve has no replenishment connection to the damaged primary.
When the reserve itself fails	The small receiver uses 160 exposed electrodes and 864 sealed dry references. With short discharge passages the staged reserve admits at most 196.19 actual L at its own failed inlet. A stuck fast-stroke limiter admits 226.25 L. An extra 150 ms of delay reduces the weakest switching second to 336.53 reference m³/h.

Continuity at the right boundary

A counted sale is qualified oil held at a known final customer receiver. One lane can stop even while the other and a reserve contribute to the site total. The high-rate switching study and raw minute histories have different clocks and resolution.

Delivery during the six-second switch

Calculated net service at the healthy final receivers, expressed in reference cubic metres per hour.



The weakest sliding second inside this interval clears 408.8 after meter and clock allowances.

Can the combined equipment fit and contain a total loss?

The same installation pays for the cartridge receivers, wetting detection, twin drain paths, dry-gas preparation, recorders and local containment. Nine cases require immediate isolation. Five require 60 hours of service followed by 12 hours of containment. Six require service throughout.

Combined gate	Worst value or explicit limit
Exterior oil and new overpack	All positive outward flows are counted. The modeled site upper is 0.833995 actual L in 72 h, against 1 L. Each auxiliary receiver can expose 17.89 hot m³ to its blind catch. The screened pressure, including 35 kPa for inlet dynamics, is 276.2 kPa absolute against 350.
Space, water and soil	Excavation is 72,199,862.08 m³ against 72,200,000. Minimum remaining customer-cell space is 0.607 hot m³. Water entry reaches 0.69894939 L/h against 0.699. The moisture bound depends on trace-level commissioning of the dry gas.
Thermal and energy limits	The simultaneous station load is 485.66 kW against the 500 kW thermal run. Each active bank has at least 57.21 kWh left after 72 h and the loss of one cabinet. Separate finite motor packs fund the transfer stroke.
What can invalidate containment	If the integral gas cushion cannot accept the displaced volume, the pressure bound reaches 1671 kPa absolute. A common rupture through both outer and inner envelopes leaves the site release unverified. Hot leak tests, structural load tests and full-scale cold-flow commissioning remain necessary.

Practical significance

The original facility records leave final custody and the environmental balance incomplete. The hypothetical plant includes 614,508 passive drain gates whose travel has no individual sensor. Proving and maintaining that many small passages is a commercial constraint. The 1 L exterior bound also depends on measured hot leakage through intact outer barriers.

Integrated 72-hour results for cases 1 through 10

Both train assignments and both pressure rules are checked with eight piston pairs unavailable per train. The service column gives hours and the weakest rolling minute in reference m³/h. The source column gives the upper flow in reference m³/h after the 600-second isolation deadline.

Registered challenge	Duty / flow	Source	Result
01. Source closing energy lost and conventional valves jammed	Isolate	0.3840	Passed
02. Terminal closing energy lost and conventional valves jammed	Isolate	0.3840	Passed
03. Source and terminal closing energy lost with jammed conventional valves	Isolate	0.3840	Passed
04. Trigger inlets blocked with jammed conventional valves	Isolate	0.3840	Passed
05. Pilots blocked with jammed conventional valves	Isolate	0.3840	Passed
06. Sleeves torn with jammed conventional valves	Isolate	0.3840	Passed
07. Sleeve closing force tripled with jammed conventional valves	Isolate	0.3840	Passed
08. 5 mm² seat gaps with jammed conventional valves	Isolate	0.3840	Passed
09. Three route boundaries lost	72 h / 401.89	Full duty	Passed
10. Independent heat envelope penetrated	72 h / 401.89	Full duty	Passed

Meaning of a pass

A recoverable duty must meet the final-tank service, grade and containment limits together. A total loss must contain the oil and isolate on schedule. These are numerical duties for a particular hypothetical installation. No field survival rate is established.

Integrated 72-hour results for cases 11 through 20

Both train assignments and both pressure rules are checked with eight piston pairs unavailable per train. The service column gives hours and the weakest rolling minute in reference m³/h. The source column gives the upper flow in reference m³/h after the 600-second isolation deadline.

Registered challenge	Duty / flow	Source	Result
11. Closed catch boundary lost	Isolate	0.3840	Passed
12. Loaded collapse and outer-vault loss at 60 h	60 h / 401.89	0.3292	Passed
13. 100 mm source-gas wall breach	72 h / 401.89	Full duty	Passed
14. Gas heat transfer degraded	72 h / 401.89	Full duty	Passed
15. Catch heat transfer reduced at 60 h	60 h / 401.89	0.3292	Passed
16. Local pocket outer boundary lost	72 h / 401.89	Full duty	Passed
17. Catch heat transfer lost at 60 h	60 h / 401.89	0.3292	Passed
18. Enclosure gas starts at 86°C	60 h / 401.89	0.3292	Passed
19. Catcher shield fully open	60 h / 401.89	0.3292	Passed
20. All current quality evidence falsified	72 h / 401.89	Full duty	Passed

Meaning of a pass

A recoverable duty must meet the final-tank service, grade and containment limits together. A total loss must contain the oil and isolate on schedule. These are numerical duties for a particular hypothetical installation. No field survival rate is established.

Receiving arrangement without the emergency cartridges

The working fluid in this hypothetical installation is stabilized liquid crude. Three customer banks each contain forty closed cells. The receipt mechanism sits inside the final tanks, and the inventory records credit new, in-grade oil once where it arrives. Gas-rich produced fluid that can come out of solution requires its own pressure and quality test.

Test	Result
Two trains start with eight pairs unavailable each.	With 73% of the gas available on one train and 100% on the other, then the assignments reversed, the weakest rolling minute delivered 401.158 reference m³/h of usable oil. Both lanes start cold. At second 80 one buyer inlet diverts and a spare takes over.
The customer keeps oil in closed storage for 72 hours.	A full-duty run added 4.537 reference m³ to the first tank before changeover, 14,903.937 to the uninterrupted tank and 14,899.285 to the spare. The ring is primed with separately purchased, seller-owned oil. A sale occurs only on its first eligible entry into a final tank. Existing customer oil earns zero. Simultaneous customer withdrawal would need its own balance.
The replenishment and assay clocks run together.	The source can deliver at most 3.35 reference m³/minute per train into the stock ledger. Each batch takes 30 minutes to clear. Up to 2% may be rejected. With the original and standby lines primed, the highest seller requirement is 838.648 of 850 reference m³.
The changeover or receipt check degrades.	A six-second interruption on one lane reduces the rolling lower bound to 388.185 m³/h. Two percent meter bias gives 394.295. Losing the largest previously credited cell gives 396.042. All miss 400.

What the simulation establishes

20 of the 20 hypothetical duties pass the listed combined gates. Nine duties call for immediate isolation, five for delivery through hour 60 followed by isolation, and six for a full 72 hours of delivery. The original site has 20 unverified cases. Neither set gives a probability of physical survival.

Single-patch trip and receiver comparison tests

False scale readings can remain plausible while oil goes to the wrong destination. The receiving cells therefore use the displacement of the fluid in a group of forty small chambers, one in each final cell. Every chamber must fill, isolate and prove its end position before another group can earn credit.

Test	Result
All flow diverts at the failed inlet.	The distribution ring holds 338 L when flow stops. Allowing its oil to coast into the chambers and counting all pockets and 72-hour seepage gives a 80.034 L upper at the original inlet. The first genuine spare receipt arrives within 1.875 seconds. The lowest transient pressure was 73.96 kPa absolute; the site specifies stabilized oil with a bubble point of at most 60 kPa at operating temperature.
Oil has entered a correct chamber but its tank wall leaks.	A dry electrode behind each wall panel detects oil that displaces gas. A leak of 0.005 reference L/s reaching four patches gave a 118.437 L inlet upper. One bank needs over 100,000 patches. Local wetting, pressure compensation, the scanned area and the timing of the trip determine whether this can work.
A distributed leak crosses many patches.	With oil spread across 200 sensing patches, 230.040 L crossed before a patch tripped. A separate test hid a 0.04 reference L/s split with just 0.168 L of unrecorded movement in the surge equipment. After four seconds 252 L had crossed. An independently checked stroke test can bound that split to 131.684 L only if it also measures the movement of the surge equipment.
A practical timing constraint.	A prefilled spare has approximately 1.10 seconds to complete the first genuine receipt. All forty end stops have to prove in parallel. A contaminated sample, a mechanically misidentified lot, air in a measuring chamber, or a failed shared reference can invalidate that receipt.

Receipt and product grade

The maximum modeled water content is 0.61045% against 0.62%. The highest modeled hourly ingress is 0.698968 L/h against 0.699. Inputs include independently identified sealed stock, the full dose of moisture specified for the gas and continuous intercompartment mixing. The computed receipt does not establish that these assumptions hold in a plant.

Where oil can cross the property boundary

At this hypothetical site every oil exit has a destination. Local jackets collect liquid. Isolated guard spaces intercept leaks into the ground. Roof runoff passes through two treatment beds in series, and the model includes oil that escapes in the air. Every outward crossing counts over 72 hours, even if oil returns later.

Test	Result
Liquid, soil and air in the defined case envelope.	The total modeled upper is 0.795418 actual L. It includes 0.418111 L of airborne oil from the modeled gas paths, 0.239660 L in treated runoff and 0.001628 L in the guard gas. Any separate modeled fire allowance is included in the total.
A downstream obstruction or dirty storm bypass.	With two parts in a thousand of the storm stream bypassing treatment, that outlet alone can release 1.633 L. Two metres of floodwater admitted beneath a buyer roof would overflow the local containment by about 10,900 m³. A submerged outlet loses its proven discharge capacity.
A collapse after 60 hours.	In case 12, the two damaged primary receiver banks and outer vaults send 41,537 hot m³ into the outer enclosures. The native record separately identifies customer oil and oil held for testing. The new customer sales are reconciled against the historical customer entitlement and the separate seller reserve at reference temperature. The collected oil earns no sale credit.
Smoke and the condition of the enclosing structure.	The outer collector holds process oil and vapor. All exterior lubricator charges are separately released to air, adding 0.136 actual L. One additional kilogram of uncollected petroleum in smoke would raise the total to 2.030 L. A bulk fire outside the enclosing structures has no verified upper bound.

Why the original evidence has a different verdict

Two clean endpoint samples can bracket an intervening 1.222 L discharge. The original records do not trace all oil to the property line. The hypothetical site uses its own geometry, chemistry and physical fault assumptions.

Can the equipment share one installation?

Two dry cart yards stand 2.75 m above the original transfer rails. The wet docks and delivery inlets remain at their working elevations. The new-build calculation counts deeper beam clearances, head seats, pressure guards and the treatment works on the same site.

Test	Result
Excavation and supports.	The selected arrangement requires 72,199,820.34 m³, giving 179.66 m³ against a 72.20 million m³ cap. The dry-yard change avoids 4,174.26 m³ after paying for seats and cutoffs. The benefit requires unexcavated ground, two shared yard locations and the specified ground conditions.
Local pressure and the 72-hour power budget.	Peak station heat is 483.29 kW with one cabinet unavailable and three receiving banks energized. Each active bank retains 123.53 kWh. The 500 kW native thermal run gives a minimum 1.4095 kPa water-pressure margin against 1.33 kPa, including both gas assignments.
The drives or gas cover lose another safeguard.	If both dry-hoist rooms vent their full drive heat into the gas station, its demand reaches 615.41 kW, beyond the 500 kW run. A single surviving cover strip falls below the required water margin. Another 150 Pa of source resistance defeats cases 12, 18 and 19.
Sensitivity to the ground conditions.	With the same two shared yard locations on the weaker collector soil, excavation exceeds the cap by 17.38 m³. With the primary soil but no shared yards, the excess is 1,594.69 m³. This is a quantity estimate for a new build. It does not establish a saving on construction cost.

Full installation status

The roof and gas enclosure require independent support. The design adds 120 central rock sockets and about 1,355 tonnes of truss reinforcement per buyer. Loss of the central shaft or inadequate rock bond fails the structural screen. Oil moisture, sorbent performance, closed-tank metrology and fire behavior remain unvalidated physically.

Unassisted receiver results for cases 1 through 10

The sale column gives the lower bound in each rolling 60-second interval, expressed in reference m³/h. The stopped-source column gives residual forward flow after the 600-second deadline, also in reference m³/h. Oil caught within the site remains in the inventory.

Case and operating fault	Customer sale	Stopped source	Model outcome
01. Source closing energy lost and conventional valves jammed	Isolate	0.384	Passed
02. Terminal closing energy lost and conventional valves jammed	Isolate	0.384	Passed
03. Source and terminal closing energy lost with jammed conventional valves	Isolate	0.384	Passed
04. Trigger inlets blocked with jammed conventional valves	Isolate	0.384	Passed
05. Pilots blocked with jammed conventional valves	Isolate	0.384	Passed
06. Sleeves torn with jammed conventional valves	Isolate	0.384	Passed
07. Sleeve closing force tripled with jammed conventional valves	Isolate	0.384	Passed
08. 5 mm² seat gaps with jammed conventional valves	Isolate	0.384	Passed
09. Three route boundaries lost	401.16 for 72 h	Delivery	Passed
10. Independent heat envelope penetrated	401.16 for 72 h	Delivery	Passed

Scope for these outcomes

Each duty uses both gas assignments, both source-pressure rules and two trains. The limits are 400 reference m³/h for recoverable service, 0.4 reference m³/h at source after isolation, 200 actual L admitted per failed buyer inlet and one actual L across the property boundary. The adverse leakage and drainage tests have their own measured outcomes.

Unassisted receiver results for cases 11 through 20

The sale column gives the lower bound in each rolling 60-second interval, expressed in reference m³/h. The stopped-source column gives residual forward flow after the 600-second deadline, also in reference m³/h. Oil caught within the site remains in the inventory.

Case and operating fault	Customer sale	Stopped source	Model outcome
11. Closed catch boundary lost	Isolate	0.384	Passed
12. Loaded collapse and outer-vault loss at 60 h	401.16 for 60 h	0.329	Passed
13. 100 mm source-gas wall breach	401.16 for 72 h	Delivery	Passed
14. Gas heat transfer degraded	401.16 for 72 h	Delivery	Passed
15. Catch heat transfer reduced at 60 h	401.16 for 60 h	0.329	Passed
16. Local pocket outer boundary lost	401.16 for 72 h	Delivery	Passed
17. Catch heat transfer lost at 60 h	401.16 for 60 h	0.329	Passed
18. Enclosure gas starts at 86°C	401.16 for 60 h	0.329	Passed
19. Catcher shield fully open	401.16 for 60 h	0.329	Passed
20. All current quality evidence falsified	401.16 for 72 h	Delivery	Passed

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Site records for the remote buyer inlets

These 20 records follow the transfer equipment and its remote receiving hubs. The environmental record ends at intermediate outlets. The buyer record includes deliveries from oil already in storage. Both affect how much the records can establish about containment and usable delivery.

Question	Result under the stated model conditions
Can the customer still use 400 m³/h?	With a wet standby, one lost cell and one changeover, the proposed meter and grade limits give 400.443 reference m³/h of usable oil in the weakest rolling minute bound. At 1% meter bias a late fault delivers 398.604. Loss of a whole loaded buyer also fails.
Does the hot-water circuit keep its margin?	With two of four 44 kg/m² cover strips surviving and 450 kW of added station heat, the minimum water-pressure margin is 1.410 kPa against 1.33 kPa required. Another 150 Pa of source resistance causes three failures.
Does the installation fit?	The fully charged two-yard estimate is 72,199,988.1 m³ against 72.20 million m³. The site needs adequate bearing capacity and two genuine shared yard locations. The weak-soil layout without either shared yard exceeds the limit.
What happens when the buyer fails?	The inlet cap is 200 actual L over 72 hours. A full diversion gave a 54.208 L upper bound. Shortening the chambers and checking their travel bounded a defined partial split to 114.467 L. A downstream misconnection still passed 252 L in four seconds. All 20 full missions remain unverified.

System boundary

Two trains each retain 152 working piston pairs. Every case runs with 73% accessible gas on one train and 100% on the other, then with those assignments swapped. The line, receiving chamber, dry cart yard, cold-water plant, separate oil stocks and exterior receivers have distinct inventories.

Evidence

These are synthetic engineering simulations. A complete installation requires independent proof of genuine buyer receipt, product grade, pressure, supports, separation and exterior releases for the same duty.

Can a tank full of old oil conceal a new break?

At the original buyer inlet, paired displacement chambers exchange a measured batch of oil. A new batch requires an independent mechanical indication that the paired chamber emptied, filled and isolated that batch. Oil already held in the downstream feeder cannot produce this sequence.

Condition	Simulation result
The entire charge diverts, but pressure and buyer weights still look healthy.	The conservative run-on upper bound was 54.208 actual litres, including pockets, a startup charge and 72 hours of seepage. An extra second of uncertainty about the start gives 118.144 L. Both meet the 150 L design target.
Some oil reaches the chamber while 2 reference L/s diverts.	With 6.6 hot L already available to make up the shortfall, 501.830 actual L crossed the inlet while 16.728 L diverted. Short opposing chambers limit substitutable oil to 1.20 L and check each stroke separately. Their conservative upper bound was 114.467 L for the same persistent split, or 178.404 L with an extra second of onset uncertainty.
The connection beyond a genuine receipt goes to the wrong place.	All local receiving motions can be genuine while the correct terminal receives nothing from the new supply. The inlet passes 252 actual L in four seconds. A shared failure of both supply isolators also defeats the finite-charge limit.
The seller must pay for every primed chamber.	With the modeled paired fill sequence, the worst seller needs 849.985 of 850 reference m³. Independently filling both halves at once requires 850.033 m³ and fails. Pre-existing customer oil earns zero delivery credit.

Local containment

A receiver with the complete 3,807.554 L liquid inventory has 0.412 m³ spare. A rapid 20 L hydraulic-fluid pulse entering the same enclosure reached 151.474 kPa against a 150 kPa limit. A separate sealed actuator enclosure bounded its local pressure to 139.980 kPa, with the process catch at 144.751 kPa. Loss of their separation reproduces the exceedance. A 0.04 L/s split can still pass the chamber checks.

Can an idle receiver keep the first sale within grade?

Water can accumulate for three days in a standby cell before the first sale. The design assigns each cell 11.55 hot m³ of independently qualified, customer-owned starting oil and circulates it between the withdrawal well and the body of the tank.

Condition	Simulation result
Water enters the least favorable cell and compartment.	At 1.2 hot L/s effective exchange per cell, the highest water bound was 0.610348% against 0.62%. This covers 16 combinations of duty, changeover time and flow split, plus a fully idle cell. Each hour may direct the entire 0.699 L site allowance to one cell.
Check chloride and solids independently.	Assigning all 72 hours of trace fluid to the smallest compartment gives 4.255 mg/kg chloride and 0.02300% solids, below 5 mg/kg and 0.03%. This assumes the modeled incoming fluid chemistry and density.
The pump turns, but little oil moves between compartments.	At only 0.05 hot L/s effective exchange, continuous entry of 0.699 L/h gives at least 0.6534% water. The 0.62% limit fails. With the smaller 75 m³ bank inventory the same continuous entry can exceed 2.79%.
Space and operating power	The three banks require 1,161 hot m³ of additional prequalified customer oil. Raising the tank walls 0.35 m and paying for internal solids leaves 174.5 hot m³ working capacity per bank. Forty circulation loops use 4.95 kW per bank.

Meaning of a grade result

Both tank compartments must mix as specified. The test assumes no customer drawdown during accumulation and requires representative source and starting-oil assays. Pump indication and a clean sample from the wrong location cannot establish those conditions. The case records do not identify every final customer lot.

Water pressure, excavation and prolonged flooding

Both transfer trains were tested with eight piston pairs out. Each train took a turn at 73% gas availability while the other had full access. The receiving pumps, battery cabinets, transfer mechanisms and collection lifts share the thermal and excavation budgets.

Condition	Simulation result
Two of four water-cover strips survive.	At 450 kW local heat plus the registered background and short heat pulse, the lowest margin was 1.410 kPa against 1.33 kPa. Source head remained positive by 46.6 Pa. One strip gives 1.067 kPa. An additional 150 Pa of source resistance defeats cases 12, 18 and 19.
Three stations energize during handover.	The 1 Pa·s case uses up to 433.09 kW against the 450 kW heat test. Paid 72-hour electrical capacity leaves 97.25 kWh per active bank. The 12.1 m lift case runs short by 442.2 kWh.
Rain and both guard streams reach the same basin.	All ten collection bays receive taller braced walls. With 2 m of water over the whole parcel, two guard streams and doubled response water, 113.296 m³ remains. At 2.4 m the same basin overflows by 131.504 m³.
Gross oil at the property line	At a hypothetical 2 mL/h per bay, complete outward passage from all ten bays would total 1.44 L in 72 h even without overtopping. The actual outlet routing and total airborne and liquid flows are missing. No full site-wide pass follows from a full basin staying within its walls.

A high-lift option

The 12.1 m lift with 1 Pa·s viscosity needs 604.4 kWh more than the base design. Fitting ten 400 kWh cabinets in place of the ten 200 kWh units at each bank leaves 446.8 kWh with one cabinet lost. At 469.8 kW, the 500 kW thermal test applies. Each unit must fit its 3 m square pad at five tonnes and deliver the specified cooling and power. Peak pump demand is 22.9 kW. The pump curve and suction reserve remain unverified.

What must the customer’s receiving yard contain?

Each of three customer yards holds forty separate receiving cells. Its outer containment wall has to hold a loaded tank and response water even when the site collection basins still have room. Stored oil used to keep the cells ready belongs to the customer and earns no recovery credit.

Condition	Simulation result
The new oil inventory enters the original containment footprint.	Each customer yard starts with 462 hot m³, including the starting oil in all idle cells. The 0.35 m taller primary cells need more surrounding containment. At 0.30 m of rainfall the original outer guard is 120.409 m³ short.
Raise and reinforce the customer guard.	A 0.75 m extension with one metre of freeboard leaves 263.489 m³ spare at 0.60 m of rain. At 2 m of direct entry this yard is 6,950.708 m³ short, even though the separate site collection basins pass their 2 m test. A local overflow cannot be converted to a property-line oil quantity without a route and oil measurement.
Budget the foundations and transfer passages.	The buyer-yard option adds 717.590 m³ for supports, overflow passages and dry preparation. It requires about 259.5 tonnes of primary steel and 192.1 tonnes for the guard at each buyer yard. The three ring foundations need about 146.5 kPa during the full hydrostatic test, against the assumed 150 kPa allowable.
An independently drained weather deck covers the yard.	In 2 m of rainfall, 14 working sections out of 16 diverting at least 98% each leave 357.386 m³ spare per yard. A third lost section produces 446.359 m³ of local overflow. Water arriving beneath the deck bypasses it. The receiving storm channels have to accept 0.273 m³/s per yard. At 30 µg/L of oil their modeled combined discharge alone can carry 1.250 L across the site boundary.

Excavation and remaining tolerance

Including the three protected actuator enclosures and all weather works leaves 11.914 m³ on the primary 80 kPa site. With no shared yards the same arrangement exceeds the cap by 1,762.444 m³. An extra 50 mm cut under the thirty enlarged battery cabinets requires 15.120 m³ and consumes the entire primary margin.

Physical fit

The weather decks require about 4,657 m² of additional land in total. Their steelwork weighs about 2,760 tonnes per buyer before pile casings. The independent water covers add 384 tonnes across two trains. Bearing, flood entry, storm-channel capacity and the total outward oil concentration still require independent evidence.

Mission evidence for cases 1–10

Every row combines both gas assignments, both pressure assumptions and both transfer trains. The pressure is the lowest modeled hot-water margin. The stock quantity is the highest required at one seller, including the prefilled chambers.

Case	Required duty	Water margin, kPa	Seller stock, ref m³	Full mission
01 Source closing energy lost and conventional valves jammed	Isolate at onset	3.093	0.246	Unverified
02 Terminal closing energy lost and conventional valves jammed	Isolate at onset	3.093	0.246	Unverified
03 Source and terminal closing energy lost with jammed conventional valves	Isolate at onset	3.093	0.246	Unverified
04 Trigger inlets blocked with jammed conventional valves	Isolate at onset	3.093	0.246	Unverified
05 Pilots blocked with jammed conventional valves	Isolate at onset	3.093	0.246	Unverified
06 Sleeves torn with jammed conventional valves	Isolate at onset	3.093	0.246	Unverified
07 Sleeve closing force tripled with jammed conventional valves	Isolate at onset	3.093	0.246	Unverified
08 5 mm² seat gaps with jammed conventional valves	Isolate at onset	3.093	0.246	Unverified
09 Three route boundaries lost	72 h delivery	3.093	849.985	Unverified
10 Independent heat envelope penetrated	72 h delivery	3.093	849.985	Unverified

How to interpret a row

The delivery target is 400 reference m³/h of usable oil in each rolling minute of required service. A stopped case earns no delivery credit and still has to demonstrate safe containment. None of these records measures or bounds all outward oil at the original site boundary.

Conditions shared by the tests

152 of 160 piston pairs work per train. One train has access to 73% of its gas stock and the other 100%, then the assignments reverse. The documented failure controls also include a small continuing split and delivery beyond a correctly operating chamber to the wrong destination.

Mission evidence for cases 11–20

Every row combines both gas assignments, both pressure assumptions and both transfer trains. The pressure is the lowest modeled hot-water margin. The stock quantity is the highest required at one seller, including the prefilled chambers.

Case	Required duty	Water margin, kPa	Seller stock, ref m³	Full mission
11 Closed catch boundary lost	Isolate at onset	3.093	0.246	Unverified
12 Loaded collapse and outer-vault loss at 60 h	60 h, then isolate	1.426	726.102	Unverified
13 100 mm source-gas wall breach	72 h delivery	3.093	849.985	Unverified
14 Gas heat transfer degraded	72 h delivery	3.172	849.985	Unverified
15 Catch heat transfer reduced at 60 h	60 h, then isolate	3.093	726.102	Unverified
16 Local pocket outer boundary lost	72 h delivery	3.093	849.985	Unverified
17 Catch heat transfer lost at 60 h	60 h, then isolate	3.093	726.102	Unverified
18 Enclosure gas starts at 86°C	60 h, then isolate	1.410	726.102	Unverified
19 Catcher shield fully open	60 h, then isolate	1.426	726.102	Unverified
20 All current quality evidence falsified	72 h delivery	3.172	849.985	Unverified

How to interpret a row

The delivery target is 400 reference m³/h of usable oil in each rolling minute of required service. A stopped case earns no delivery credit and still has to demonstrate safe containment. None of these records measures or bounds all outward oil at the original site boundary.

Conditions shared by the tests

152 of 160 piston pairs work per train. One train has access to 73% of its gas stock and the other 100%, then the assignments reverse. The documented failure controls also include a small continuing split and delivery beyond a correctly operating chamber to the wrong destination.

How much usable oil reaches the customer?

The receiving test counts reference litres that reach an eligible customer cell and remain usable. Every rolling minute pays for water, solids, metering error, the restart delay and oil written off in one failed cell.

Test	Outcome in the simulation
One changeover and one lost cell	The bulk lower bound is 400.070 m³/h. At the starting assay it gives 397.990 m³/h of usable oil. A realizable late switch at 1% meter bias delivered 398.604 m³/h.
Terminal proof and tighter grade	With total positive bias limited to 0.25%, water to 0.62% and solids to 0.03%, the lower bound is 400.443 m³/h for any single switch time. At second 80 the rolling lower bound was 403.777 m³/h across the 60 h and 72 h duties.
Product reaches the ordinary contract limits	At 1% water and 0.05% solids, a late switch gave 399.446 m³/h even with the proposed meter. A lot can meet the sale specification and still miss the emergency net-oil rate.
Replenishment and ownership	All 160 lane histories were included. At each minute the seller receives the smaller of two candidate supply records. Wet lines, rejected lots, assay delay, finite stock and the failure reserve are charged. The pressure-isolation fittings bring the worst seller requirement to 849.778 of 850 reference m³. Buying preincident proof oil is a separate expense.

How to prove the proposed meter

Before service, collect 136, 192 and 196 complete strokes at three rates, twice each. Forty individually weighed cans reveal an uneven split that a common scale could miss. The modeled fixture caught both a gain error and uneven distribution. It consumes 1.572 reference m³ per bank and requires a 2.25 m³ mobile quarantine tank emptied between banks. Actual drift, viscosity response and terminal lot identity still need measurement.

Case 20

At the earlier receiving boundary the highest simulated chloride was 3.856 mg/kg. The new endpoint has no matched final lot tickets. A forged sample or reference cannot authorize continuing delivery.

What stops an open break at the buyer?

A spring-loaded pressure trip sits at the original inlet. A downstream check valve separates the buyer buffer from the broken feeder. A small mechanical piston tests a standby line before its bulk supply opens. A separate forward counter records the quantity across the inlet.

Test	Outcome in the simulation
A complete nearby break into low pressure	With no movement to pull a trip cord, lost electrical flow signals, false weights and one seat jammed, the worst timing allowance is 0.229 s to initiate closure. The three-second closure, pockets, seepage and startup allowance give a measured upper bound of 132.570 actual L.
A break keeps the healthy pressure and flow pattern	The pressure trip cannot distinguish where this fluid goes. With the hub still making genuine deliveries for two seconds, the independent counter gives 213.159 to 233.669 actual L. The 200 L inlet cap fails.
Commissioning without bulk pressure	The piston has a 0.75 L stroke. A flooded intact line must hold pressure on its own. Trapped gas can prevent a safe restart. A stuck-through charging connection admitted 375 L in one minute in the failure test.
Power and heat for viscous product	The added equipment costs 23 kPa of steady head and 2.095 kW per active station at the design limit. Supplementary 150 and 200 kWh cabinets leave 33.117 kWh at 1 Pa·s. Two 150 kWh cabinets fall short. The high-lift test also fails.

Where the oil goes

One intact local receiver offers 4.600 m³. The full package, including stored feeder oil and allowed run-on, needs 4.047 m³ with allowance. A separately charged 76 kPa absolute gas space and a 0.15 s relief stroke kept pressure to 143.402 kPa absolute at 0.35 Pa·s and 144.679 kPa at 1 Pa·s. A one-second relief stroke exceeded 154 kPa in both tests.

Where to test a different trip

Place a receiving chamber across the original inlet, ahead of the buffered line. Only physically captured fresh oil could authorize another charge. With 27 ms uncertainty in fault onset, the modeled measurement budget allows 1.427 s to start closing. The feeder already holds 754 hot L, enough for 11.97 s at maximum flow. Downstream receipts cannot establish freshness within this deadline. The direct chamber remains untested.

Can the site account for oil carried by water?

A protected sump at each train receives water from its own guard. Each sump has two separately powered lifts. Each lift has its own sleeved discharge line. Separate receiving basins prevent both trains from filling the same basin.

Test	Outcome in the simulation
The original nine initially isolated cases	Their records show 88.263 m³ of water leaving the guards. At the modeled oil concentration, one outward pass of this water carries 0.066197 L. The records end before the property boundary.
The level ends where it began	In an observability test, the same parcel can stay inside or cross outward and return 48 times. Both have zero ending exterior inventory. Gross outward oil is 0 or 1.152 L respectively. The original data establish neither the return connection nor that the repeated crossings occurred.
One failed tank, grid loss and one lift out	The surviving lift clears nearly twice the maximum single-guard inflow after a ten-second delay. The sump has 0.284 m³ spare. With 1.4 m rain, a separate basin has 30.669 m³ spare. Under double response-water loading only 0.669 m³ remains.
Both guards feed one basin, or rain reaches 2 m	The common basin overflows by 13.462 m³. The heavier rain case overflows by 336.531 m³. Local overtopping does not establish the quantity of oil that crosses the property.

Construction paid for in this comparison

Four 30 kWh lift batteries and the capture works add 55.400 m³ of excavation. Counting the complete inlet cabinet pads as well leaves 1,962.284 m³ under the 72.20 million m³ cap on the primary two-yard layout. Weak ground with no shared yards exceeds the cap by 33.745 m³. The figures assume adequate existing support and staging space.

What would close the exterior test

Trace every outlet, overflow, return and airborne oil path to the property line, log gross outward transfer with its uncertainty, and compare the synchronized sum over 72 hours with one actual litre. The original twenty records cannot establish that quantity.

How much oil may enter a failed buyer?

Each failed inlet may receive up to 200 actual litres over the 72 hours after failure. All of it must be measured and contained. The design target is 150 L. The separate one-litre limit counts all oil crossing the exterior of the installation.

Condition	Measured or calculated in simulation
Buyer stops capturing oil. Weights still read healthy and the nearest seat jams.	The upper bound from the simulated instruments is 112.708 L, including the larger pocket and 72 hours of seepage. A previously isolated inlet gives 8.857 L under the same pocket allowance.
A 2 L/s split while the hub still makes real deliveries.	An independently timed fault gives an upper bound of 155.817 L with one seat jammed. This meets the 200 L cap and exceeds the 150 L target. A one-second uncertainty in onset raises the upper bound to 217.647 L, leaving compliance unverified.
The original joint separates. A dry contact trips before its liquid seal disengages.	Two external mechanical triggers act independently of buyer weight and the downstream buffer. With one seat jammed, the measured upper bound is 112.834 L using a 90 ms trip and a three-second valve closure.
No relative movement trips the contact, meters and the liquid collar miss the break, and the hub still sells buffered oil.	The synthetic totalizer establishes at least 214.475 L of flow. The upper bound including pocket and seepage is 231.379 L. The 200 L cap fails.

How the measurement works

Start the gross forward counter at the earliest credible failure time. Count clock error, meter bias, the operating-temperature conversion and the entire drainable seat pocket. A sealed, separately weighed collector covers low flow after seating. A missing onset, counter or seep record leaves the inlet unverified.

Restart behavior

The failed inlet stays latched shut across power loss. An intact independent route can continue. Losing the latch and reopening the same failed inlet produced 215.912 L in two exposures. A reset cannot start a fresh allowance.

Can every litre of the allowed run-on be contained?

The full inlet allowance is purchased and reserved at each receiving bank. Simultaneous failures can use 200 L per inlet. The facility still has one shared exterior allowance of one litre.

Condition	Measured or calculated in simulation
All stored oil plus the full 200 L enters one local receiver.	The demand is 3,659.628 hot L. Including a 10% allowance requires 4.026 m³. The near receiver has 4.600 m³ available. With one relief path lost, the peak is 145.291 kPa absolute, below the 150 kPa trial ceiling.
The surviving relief opens one second late, or two full events feed one receiver.	The pressure reaches 162.470 kPa in the slow-opening case. Sending both complete packages to one receiver falls short by 3.451 m³ including contingency.
Two full 200 L reserves charged to the limiting seller.	The 850 m³ starting stock retains only 0.261 reference m³. This covers the stated trials. Long-duration unseen leakage and unqualified replenishment remain independent failure modes.
External paths and low-level witnesses.	The six-station subtotal is 0.996173 L under the assumed capture and seepage limits. If five other outlets are physically separate, even zero readings bring their combined upper bound to 0.999989 L. The five positive synthetic readings give 1.005179 L.

What has been demonstrated

The inlet fixture and the simulated catch satisfy their separate tests in the selected configuration. None of the 20 complete missions has a measured gross exterior total. A positive upper bound above the limit can leave the result undecided. A measured lower bound above the limit establishes failure.

Engineering basis

The inlet allowance applies to this study. Field acceptance also depends on oil properties, ignition and exposure consequences, local catch integrity, detection time and every credible route. These factors are covered in the UK Health and Safety Executive guidance on emergency isolation.

Water pressure and excavation on the same installation

A four-strip moving cover transfers ballast load to the hot-water surface. Its full opposing load is charged to the source. Ten shallower containment bays preserve the process nozzles at their original elevations. The estimate includes new walls, foundations, sockets and the three reserve-battery pads.

Condition	Measured or calculated in simulation
73% gas accessible on one train, 100% on the other, then reversed. Eight unavailable piston pairs on each train.	Three surviving strips give 1.710 kPa of margin. Two give 1.383 kPa against the required 1.33. At 425 kW of station heat the source retains 149.7 Pa. Another 300 Pa of source resistance defeats cases 12, 18 and 19.
Only one strip survives, or the cover opens.	The minimum margin drops to 1.055 kPa with one strip and 0.915 kPa with zero. The pressure calculation requires an intact thermal interface. Actual contact between hot steel and water is a separate failure.
Ten new shallow bays, 100 mm site preparation and two genuine common yard locations.	All ten original mat cuts remain in the bill. Net excavation falls by 3,058.9 m³, giving 72,197,968.5 m³ overall and 2,031.5 m³ under the cap. If neither yard coincides, 257.2 m³ remains. Previously dug soil earns no saving.
Added loads and power.	The covers add 1,248 tonnes. At 1 Pa·s local oil viscosity, each active bank needs its own 150 kWh nominal reserve cabinet. After losses, cooling and 30 W of continuous inlet monitoring, the limiting bank has 45.897 kWh left.

Ground and load transfer

The main design requires 76.05 kPa of ground capacity during hydrotest. Where only 45 kPa is available, 92 new piles per bay reduce modeled soil pressure to 40.32 kPa. This option leaves 1,809.9 m³ of excavation margin with two common yards and 35.5 m³ with none. Half contact with the soil fails.

Installation conditions

The ten bays require 2,520 m² of extra land. A site-wide 50 mm strengthening excavation for the covers exceeds the primary cap by 656.5 m³. Verify socket and raft resistance, actual pad contact, cover loads and initial cover temperature.

Finding a leaking line while the buyer still receives oil

A meter at the original inlet and another at the hub measure actual feeder transfer. A separate pressure switch observes the sealed space between the two pipe walls. Either channel can request isolation. The buyer’s weight reading has no role in either trip.

Operating condition	Test outcome
A 2 L/s split while genuine oil still reaches the hub.	Across the stated meter, temperature, pressure and clock tolerances, the two-meter trip begins closure within 0.7643 s. The calculated upper limit on original inlet transfer is 135.856 reference litres during detection and closure. Of this, 4.755 hot litres enter the leak if the split falls proportionally with supply.
Only the pressure switch operates. The whole leak enters the intact jacket.	The 24 m sealed jacket can need 14.349 hot litres to trip. At 2 reference L/s the command takes up to 7.139 s. Pressure can continue driving leakage during valve movement. The persistent-branch control admits up to 21.187 hot litres from new supply into the leak.
Healthy line starting or changing rate.	All 180 aligned healthy deterministic tests avoided a false trip. Comparing packet arrival times instead of synchronized measurement times tripped a healthy ramp at 0.320 s. An excessive 5 K mismatch between jacket and reference also tripped a dry line.
A small release over three days.	A 1.2 L rise in jacket oil can give the same differential-pressure history as a dry line within the modeled thermal mismatch. If oil bypasses the jacket, 1.2 L can also escape while both end meters and jacket pressures appear normal. No complete exterior measurement exists.

Practical test

Verify the actual meter response and clock alignment with genuine liquid transfers. Test reference drift, external vacuum loads, wet pickup and the two independent trip paths. The US EPA describes pressure, vacuum and liquid sensing in secondary containment for underground storage-tank piping. This simulation uses its own crude-oil conditions. Source: US EPA, In-Depth Discussion of Automated Interstitial Monitoring Systems, 2022.

Keeping the buyer supplied during isolation

While the meters diagnose the leak, the hub can continue making genuine deliveries from its opening stock. When the trip occurs, a separately prefilled standby begins accepting oil. The two feeder rates together remain within the seller’s 60 L/s limit.

Operating condition	Test outcome
One interruption and one receiving cell written off.	Confirmed forward receipt reaches 405.347 m³/h in the limiting rolling minute. Retained qualified oil reaches 400.070 m³/h. The standby starts with 120 L and has 5.320 L left at the lowest point of the specified handover.
Wait for complete valve closure before starting the standby.	A realized minute delivers 395.455 m³/h. A drained line also falls short. Its first-minute upper limit is 322.643 m³/h with authorized priming.
Meter baseline first established at the start of duty.	Holding the feeder closed for 1.07 s and then ramping it for one second uses 90.093 L of qualified hub oil. Two starts without replenishment would exceed the 120 L opening stock by 60.187 L.
The meters agree despite a 0.20 L/s split, and the jacket misses the release.	Over 72 hours the shortfall is 51.84 m³. With a realizable set of rejected product lots, six cases require 854.106 m³ of starting stock. Only 850 m³ are available per seller.

Resources

The ordinary funded replay used 849.644 m³ at the limiting seller and left 112.830 kWh in the limiting active battery. The 1 Pa·s control falls short by 49.368 kWh. Recuperating the pressure lost to both meters is necessary to preserve the modeled minimum liquid pressure during closure.

Catching the oil already inside the pipe

Even after flow stops, the line contains 753.982 hot litres. The two meter cavities add another litre. A backfeeding hub can add its inventory. The test charges the full hub shell, pipe, fittings, cavities and the adverse cutoff allowance to one receiving station.

Operating condition	Test outcome
Carry the entire sudden release 24 m along a flooded jacket to a distant catch.	Under a 150 kPa absolute trial ceiling, the modeled single path carries at most 30.293 hot L/s. A stress case needs at least 56.124 hot L/s on average after the jacket fills to its usable gas-compression limit. Even giving the entire jacket volume as storage leaves a shortfall above 1,000 L in that case.
Two short passive relief branches feed an empty receiver at the original inlet. One branch is unavailable.	With 3,610.491 hot litres entering at 63 L/s, the refined simulated peak is 145.291 kPa absolute. The jacket and the near receiver together account for the full event. A one-second valve delay raises the peak to 162.470 kPa, above 150.
Rain and containment. The inner receiver and outer guard hold separate inventories.	The near receiver has 4.600 m³ available against 3.972 m³ including a 10% allowance. If the inner shell fails, the tall outer guard has 0.706 m³ spare after 600 mm rain. A 2.15 m outer guard falls short. The distant hub catch still fails its separate 600 mm storm case.
Construction and foundations for the meters and all three inlet receivers.	The whole-site excavation estimate leaves 87.358 m³ below 72.20 million m³ at 75 mm preparation. At 100 mm, it exceeds the cap by 210.285 m³. With one anchor lost, each of the three remaining anchors needs 83.1 kN of verified resistance.

Oil beyond the site

Counting all six local and distant stations, the named subtotal is 0.995878 L if each lets one part per million of the offered oil escape plus 0.05 mL/h at its seams. An extra 0.020 mL/h at each of three pot vents raises this to 1.000198 L. These leakage rates are assumed. An unobserved outlet leaves total release unknown.

Conditions for containment

Both branches discharge only to the local pot. The calculation requires a wetted surviving inlet, an intact receiver and low gas backpressure. Loss of both outlets can exceed the trial pressure while catch space remains empty. Actual pressure capacity, installation and fire exposure require physical qualification.

Following the oil through the receiving station

One governing valve limits each steady feeder to 60 reference litres per second. Oil crosses the original receiving inlet, travels 24 m through a jacketed line and enters a small buffer. Four heads at the far end deliver measured amounts into forty independently enclosed cells. Only a genuine receipt earns delivery credit.

Test condition	Simulated result
Qualified oil in the short tubes, feeder and buffer before the emergency. One temporary interruption and one lost cell.	After writing off every earlier delivery to the failed cell, the two active banks give at least 400.070 m³/h of confirmed oil over a rolling minute. Two trains each have eight unavailable pairs.
The same stations start empty.	Even with separate permission to fill them, the first minute can reach at most 322.756 m³/h. The recovery target begins in that first minute.
The buyer stops catching oil at second 80. Its weights continue to indicate normal.	Physical receipt stops. The valve starts closing 0.083 s after the incident. During detection and the three-second closing stroke, 91.800 reference litres cross one failed inlet.
Failure at an adverse point in the cycle.	At one inlet, 99.922 hot litres cross. Adding drainable pipe and assumed seat seep gives 101.853 hot litres over 72 hours. Two simultaneously failing inlets admit up to 203.706 under these assumptions.

Where monitoring can be fooled

A bank kept making genuine sales from its 120 L buffer after the feeder broke. With the local collector unavailable, 207.300 reference litres crossed during the example. A separate collector intercepting the full break limits the exposure to 104.611 hot litres. A hidden 2 L/s split lost 120 reference litres in a minute while the bank made genuine sales. Falsely renewed independent confirmation admitted 630 hot litres in a 10 s open-feed test.

What the trip achieves

Closing the feeder stops further bulk supply in the successful trip tests. The oil that crossed during the response counts in full against the 200 actual litre inlet limit, even if it is subsequently caught. The separate site-exterior allowance remains one litre.

Can the receiving station operate for three days?

Three independent receiving banks provide two operating paths and one standby. The model charges qualifying oil already in the lines and local buffers, pump work, controls, local collection and the works needed to reach each hub.

Test condition	Simulated result
Land and excavation	Two usable foundations and ten genuinely avoidable digs leave 127.179 m³ below the cap at 75 mm preparation. At 100 mm the estimate exceeds it by 170.263 m³. The narrow duct and the positions of existing piles require a site survey.
Energy and elevation	Moving the heads to the hub allows steady flow through the long pipe. It needs 43.023 kPa at the assumed viscosity and 0.6 m rise. A one-second start needs 89.226 kPa. Adding the duty of the receiving heads and sensors leaves about 161 kWh per working bank. A 12.1 m rise exceeds the available energy.
Clean oil and water	The modeled water entry through the listed paths is 0.698690 L/h. One additional 1 mL/h wet connection raises it to 0.699690 L/h, over the 0.699 limit. Grade, dryness and outlet identity need independent confirmation.
One bank releases its full accessible inventory to the local enclosure.	After 300 mm rain, standing water and 110% of the oil event, the enclosure has 4.123 m³ spare. At 600 mm rain it is short by 6.919 m³.

Boundary conditions

Only 120 reference litres of the 2 m³ buffer capacity are available at startup in each bank. The limiting seller has 0.4245 m³ spare after line fill, fitting cavities and the full-break allowance for two stations. At 1 Pa·s oil viscosity the limiting battery falls short by 0.77 kWh. The larger hidden-split exposure exceeds the assumed cutoff allowance.

How would an operator know that oil stayed on site?

Emergency isolation has two tests. The first limits continuing supply after the stop. The second counts all oil that crosses the property boundary during the next 72 hours. A tank level by itself cannot answer either question.

Test condition	Simulated result
Fourteen source stops. Thirty existing connections and sixteen potential additional connections are counted.	With every additional opening bounded by 0.20 mm and differential pressure at most 350 kPa, the largest named source subtotal is 0.383606 m³/h against 0.4 after ten minutes. One 0.50 mm opening raises it to 0.401626. Timing and physical separation of added connections require proof.
Nine cases start isolated.	Two monitored exits show zero process oil. The native rooms still hold 28.217 m³ of oil. The 88.263 m³ of outgoing guard water could carry 0.0662 L if it contained 0.75 ppm oil by volume. Its actual assay and ultimate destination are unknown.
Five separate one-way sample collectors. Synthetic readings, independent tare and fully captured test routes.	The five proposed gauges allow 9.006 mL across their routes. A 20 g reading at one gauge puts the selected native subtotal above one litre. An unmeasured 2 L outward spill followed by a 2 L return leaves zero net change.
Three new stations discharge into their enclosures.	With assumed one-part-per-million escape and 0.05 mL/h external seams per yard, the listed route subtotal is 0.974139 L. At ten parts per million it reaches 1.070651 L.

Decision

A missing sample, a lost tare, overflow or an unobserved outlet leaves the total exterior release unknown. Each route subtotal uses its stated boundary. Their overlapping estimates cannot be added to certify the site. The nine initially isolated cases remain open.

How much oil is still usable after the buyer fails?

An oil receipt records delivery at one instant. A buyer that subsequently loses the tank can also lose everything it received earlier. The mission ledger therefore reports cumulative receipt, stock still usable at hour 72 and oil entering the site catch separately.

Operating condition	Simulated outcome
A whole buyer fails at hour 71. Both trains had been running, with no downstream withdrawal.	Earlier deliveries to the failed buyer total 14,697 ref m³. Of 29,807.942 ref m³ credited as it arrived, 15,110.942 ref m³ is still in healthy tanks. The 72-hour quantity target is 28,800 ref m³.
A single independently sealed cell fails at hour 71. Each stroke divides between 40 cells and each share stays within 2% of equal.	Write off every delivery ever credited to the lost cell, totaling 374.774 ref m³. The healthy cells retain 29,433.169 ref m³ at the end of the original established-flow replay.
Two fully loaded shares of 2.55% are lost on one lane.	A steady minute before the incident falls to 399.350 ref m³/h when those historical receipts are removed. Loss of a shared roof, outlet or floor can affect more than one cell.

Where the boundaries lie

Each of four displacement heads feeds forty dedicated bores. The proposed steel cells have separate walls, floors and roofs. A buyer that still drives the weight indicator but no longer captures oil cannot renew a valid stroke. The separate test at the original active inlet still admits 4.222 L at second 80. Local oil caught outside a failed buyer earns no delivery credit.

Conditions for a sale

The operating ledger must identify the receiving cell, product grade, physical capture time and subsequent loss of eligibility. A falsified confirmation or shared leaking divider can defeat this accounting. The site boundary needs its own complete release measurement.

Real confirmation delays and the first sale

Four metering chambers start empty at each bank. Before the mission, independently qualified seller oil fills the short outlet tubes. During the first two minutes the bank uses the equivalent of 116 loads per minute, followed by 115.1. False weights have no release permission.

Operating condition	Simulated outcome
One transient interruption, one lost cell and independent stroke confirmations arriving 20 to 50 ms after capture.	Writing off all historical receipts by the damaged cell leaves a floor of 400.431 ref m³/h at physical capture and 400.070 ref m³/h when confirmations post. The rolling-minute target is 400.
Two transient interruptions and one cell written off.	One explicit test delivered 396.133 ref m³/h after the write-off. Losing both independent routes permanently also exceeds the single-standby design case.
All outlet branches start dry.	Each bank has 160 tubes, each 0.55 m long with a 50 mm bore. Filling them requires 164.560 ref L per bank. With both operating banks dry, even ideal sale credit is limited to 393.815 ref m³/h in the first minute.
Three separately isolated banks start with previously uncredited, qualified oil in their tubes.	Prefill is 0.493679 ref m³ in total. The worst historical outlet supply requires 847.583 of 850 ref m³ per seller lane, including two banks of prefill charged to one seller. The alternative upstream supply needs 794.244 ref m³.

What must be measured

The point of sale sits beyond the delivery line. Oil already owned by the buyer earns no new credit. Prefill must stay under seller custody, have verified quality and reach the healthy receiver. A charge with a missing, duplicate or late confirmation cannot release another stroke.

Limits of the result

The local model has only 1.724 ms of timing headroom at its fastest cadence. One incorrect confirmation, a different wet volume, loss of a second compartment or a shared structural failure can change the result. The modeled 24 m route has no verified end-to-end capture time.

Starting with empty metering chambers

The model starts with pressure-ready qualified seller stock and empty chamber banks. It charges the buffer and chambers, diverts the commissioning charge, and waits for a genuine receiving-side confirmation. Only subsequent completed captures earn sale credit.

Operating condition	Simulated outcome
First two minutes at a cadence equivalent to 116 loads/min, then 115. One transient loss and another 30 L withheld.	The conditional floor is 405.311 ref m³/h before writing off damaged storage. Removing one lost cell from every rolling minute gives 400.039 ref m³/h with fixed receipt timing and verified short branches.
Two transient losses with one shared spare. One original route recovers in time.	Forward sale reaches at least 400.820 ref m³/h. The lower bound falls to 395.548 after also writing off one cell. This estimate cannot establish the combined requirement.
Constant cadence 115. Both receiving lanes lose capture about one second after startup.	The tested first minute delivers 398.396 ref m³/h. A three-second startup delay also fails under the two-minute high-rate program.
All 160 original train assignments. Each active lane starts with 850 ref m³.	The two-minute program needs 780.702 ref m³ per lane at the upstream tap or 834.041 from the alternative receiving-outlet record. The two taps are separate supply cases.

Timing and isolation

The one-loss margin is 0.039 m³/h. Receipt arrival time and physical oil capture time must be recorded separately. A delayed display can change the score when it moves a receipt across a minute boundary. A stale receipt must never release another charge. The signed inlet record and whole-site exterior collection have separate acceptance limits.

Can forty independent cells fit the installation?

Each proposed yard divides a 24 m-radius receiver into forty isolated cells around a service hub. The construction estimate keeps the original anchors and adds 1,920 driven shafts, independent cradles and raised weather enclosures across three yards.

Operating condition	Simulated outcome
Two paid yard locations coincide, ten unbuilt tray excavations can be omitted, and new ground preparation averages 50 mm.	The modeled cut is 72,199,502.828 m³, leaving 497.172 m³. At 100 mm the bill exceeds the cap by 91.528 m³.
A 116-cadence pulse runs through a 50 mm outlet with 350 kPa available.	A 0.55 m branch needs 185.1 kPa in the simple model. The 24 m route from the perimeter to the hub needs 2,145.1 kPa and fails.
Widen the 24 m line to 160 mm to reduce acceleration head.	The requirement drops to 330.5 kPa. The liquid alone can store 140.7 mL across the pressure range. A full hot charge is only 39.4 mL, so upstream displacement cannot establish prompt receipt at the far end.
Commission the finite nitrogen holder fill and its two purges to at most 0.10 ppmv moisture. Include new metal surfaces and moving seals.	Modeled ingress is 0.698686 L/h. At 0.20 ppmv after storage it becomes 0.699705 L/h, above 0.699. The product-facing witnesses, actual moisture and unmodeled paths remain unverified.

Qualification decision

The local timing model and the pulsed perimeter-to-hub connection have different hydraulic responses. The long pulsed route has no demonstrated 400 m³/h retained flow. Twenty cases were evaluated with both gas assignments and eight pairs unavailable per train. The nine preclosed cases still require whole-site proof of safe containment.

Support and retention

The purchase estimate adds approximately 11,698 t of steel. One simulated support group withstands its selected hydrotest but fails the higher uneven-loading control. The oil guard has static capacity under the specified storm and simultaneous inventory. Transient overtopping and gross release across the site exterior remain unverified.

Power loss and oil escaping a terminal

The station test adds the load of every moving divider bore and each independent capture monitor. A separate containment test follows the oil already inside the outlet tubes when a terminal loses pressure.

Operating condition	Simulated outcome
Two active banks at fastest cadence, one idle bank, existing station services, 1 J extra drag per reciprocating bore cycle and 5 W per active bore monitor.	The sustained station load reaches 302.953 kW. With 350 kW of station heat assigned to the affected gas region, the minimum hot-water margin is 1.582274 kPa across all 160 states. The remaining source head is 485.564 Pa. The 300 kW run understates this duty.
Three separate 5 MWh packs. Each active bank has 4,050 kWh usable after derating.	At the 116-to-115.1 cadence one active bank has 476.3 kWh left after 72 hours. Adding a continuous 8 kW per active bank exhausts the available energy.
One 0.55 m outlet tube drains freely. Four tubes, committed strokes, residual oil, expansion and seat leakage can reach one local collector.	One freely draining tube holds 1.080 hot L. The four-branch challenge amounts to 4.965 hot L. With 3 L of existing water and 10% obstruction, the proposed 12 L collector has 7.8 L available with its drain blocked.
One terminal, 99.5% capture, exterior seam leakage at most 5 mL/h over 72 hours.	The modeled oil outside the collector is 0.385 hot L. With 20 mL/h seam leakage it is 1.465 hot L. A lost sleeve exposes the full 4.965 hot L.

Total-loss decision

The collection space has no return to qualified product. If a full buyer sector can drain back through the manifold, its inventory overwhelms the local collector. A 1 L limit at the property boundary needs evidence from every exterior route for the same case. The site-wide result remains unknown.

Remaining installation evidence

The 350 kW result assumes the modeled heat distribution and a supported cover. A control with concentrated heat and coincident pump peaks exceeds that input. Local oil temperature, independence of the collectors, cell support and the pressure response at the actual receiving plane require physical tests.

A measured charge at the buyer inlet

Four small chambers take turns feeding each receiving lane. If a buyer stops capturing oil while its scale still reports normal weight, each chamber can spend only the permission earned by its previous captured charge. Oil already in motion can still enter the failed inlet.

Failure at 80 seconds	Oil crossing the original inlet after failure
Both original liquid inlets continue to feed failed buyers.	1,442.857 reference L across both.
Two chamber banks lose capture. False weights stay normal. Independent confirmation stops.	4.222 L per inlet; 8.444 L across both. The last forced discharge ends 87.0 ms after failure.
Failure occurs at any point in the chamber cycle.	3.750 to 5.250 L of forced discharge per inlet. At the assumed heel, expansion and seat leakage, the 72-hour upper estimate is 5.710 L per inlet.
Independent confirmation also continues falsely.	580.775 L crosses one failed inlet in 10.1 seconds. A downstream rupture beyond the confirmed compartment can produce the same symptom.

Physical sequence

Each 1.5 L sending chamber charges with its discharge port closed. Both ports close before the outlet opens. A separate receiving compartment must capture that individual stroke and return a fresh, single-use confirmation. Weight readings cannot authorize another stroke. A mechanically jammed common charging and discharge path can reconnect bulk oil.

What the bound includes

The 5.710 L estimate adds 0.080 L of drainable passages, 0.020 L of fluid and wall expansion, and 0.005 L/h of aggregate seat leakage for 72 hours. These are proposed hardware limits. Oil crossing the inlet, saleable oil retained by the buyer and oil reaching the site exterior are three separate measurements.

Can the chamber banks sustain emergency service?

Two healthy lanes would transfer 414 reference m³/h before allowances. The design needs a third, charged and independently powered receiver ready to take over a failed lane. The simulation counts qualified oil arriving at a healthy receiver.

Receiving condition	Calculated service
One buyer fails, the separate receiving bank is ready and one extra 30 L fails to arrive.	At least 406.173 ref m³/h in every rolling minute in the established-flow waveform, including a 1% meter allowance.
Independent confirmation takes 60 ms on both lanes. Each chamber waits for its next permitted slot.	207 ref m³/h gross. The emergency target is 400.
A single chamber remains out and no substitute is available.	358.564 ref m³/h after allowances. A spare bank or a faster verified repair is necessary.
A 0.05% diversion evades receipt verification on one lane for 72 hours.	7,452 reference L diverted. An intact local witness cannot clear the rest of the receiver.

Test the hardest assumptions

At this cadence one chamber makes 2,484,000 strokes in 72 hours. A working inlet needs a genuine receipt by 52.17 ms after discharge ends; the nominal example allows 20 ms. An independent rig must measure pressure transients, returned receipts, seat leaks and cycle life with real product. Starts, switches, jams and a damaged receiving compartment need separate measurements.

Twenty-case decision

The source replay covers 691,200 train-minutes with eight pairs unavailable per train. Six duties require 72 hours of sale, five require 60 hours followed by isolation, and nine isolate immediately. All eleven flowing cases have positive post-failure crossing. Nine preclosed cases still lack a site-wide release bound. No complete mission qualifies.

Where the oil and power go over 72 hours

The model follows qualified seller stock through loss of one working buyer into a separate, healthy receiving bank. Each original gas assignment is tested with each buyer failing in turn. Authentic capture and grade evidence, adequate storage and a primed start are prerequisites.

Measured quantity or engineering allowance	Result in this simulation
Six original full-duration duties, eight assignments per duty.	In 48 simulations, the healthy tanks received 29,807.942 ref m³ in 72 hours. The lowest aligned minute was 406.356 ref m³/h. The conservative floor for any rolling minute is 406.173.
850 ref m³ of initial clean stock per lane with delayed upstream assay and whole-lot rejection.	The smallest remaining clean inventory was 115.307 ref m³ in these replays. The limiting receiving tank held 15,649.2 hot m³ of new oil. Product already in a buyer tank earns no sale credit.
Isolated refill header with 8 L working capacity, initially half full.	At a steady 57.5 ref L/s replenishment rate its simulated inventory stayed between 3.896 and 4.104 L in periodic operation.
Independent 5 MWh power pack per bank, 350 kPa delivery head, 50% efficiency and 5 kW for controls.	Each fully active bank needs 3,402.9 kWh for 72 hours. At full charge the margin is 647.1 kWh. At half charge the shortfall is 1,377.9 kWh.

Failure at the actual receiving boundary

Product entering the failed buyer is excluded from healthy receipt. Each active test also withholds 30 L after switching to the standby. If every receiving path is lost, the required outcome is isolation and containment. The inlet test cannot establish total site release.

Heat and construction

With 300 kW of station heat in the affected gas volume, the modeled water margin is 1.583 kPa across 160 source states. The same heat with an open water cover gives 0.928 kPa, below 1.33 in cases 12, 18 and 19. The gas-side calculation leaves local oil contact, new pump foundations and three battery installations unverified. The underlying batch-yard excavation reserve is 75.621 m³.

What the site evidence can establish

The original twenty simulations distinguish source flow, local capture and exterior release. The result needed for a complete containment pass is cumulative oil crossing the entire exterior boundary, including oil that later returns.

Question	Findings from the retained records
Do the recorded zero exits cover the full exterior?	All 20 pipe and receiving-room guard records show zero modeled process-oil exit. Seventeen have bounded identified paths below 1 L. None has an observation covering the entire site.
Can endpoint inventory alone settle the release limit?	In cases 12, 18 and 19 a 2 L parcel could travel out and back between recorded samples while ending at the same location. This is an ambiguity in the records. It does not establish an actual spill.
Does the 88°C water start measure product temperature?	The product-oil contact criterion is 85°C. The separate historical oil-side model reached 84.339°C under its own cooling assumptions. The 88°C record is utility water. If the contract caps every liquid interface at 85°C, the water fails at startup.
Which excavation can be avoided at a new site?	If two existing receiving foundations coincide and all ten redundant, unbuilt tray cuts can be omitted, the batch yard gains 846.720 m³. At 50 mm surface preparation that leaves 771.536 m³. With no qualifying foundation overlap, the same case exceeds the cap by 219.662 m³.

How to close the site test

A full replay needs the same time base for actual flow at the failed inlet, positive outward crossing at every exterior route, and retained qualified stock at each working buyer. Every scheduled isolation and loss of a receiving compartment must stay in the case register.

Implication for construction

Already excavated soil earns no retrofit credit. The excavation savings require evidence that the cuts will actually be avoided. Footings, shelters and buried services added for the chamber banks draw on any verified reserve.

What actually enters a failed buyer

Three measurements answer different questions. Count oil passing the original inlet after failure, free oil outside containment, and saleable oil actually unloaded into a healthy buyer. A litre can cross the inlet while it is still sealed inside a moving carrier.

Simulated operating condition	Measured or calculated outcome
Original liquid connection, two buyers lost at peak flow and their weights still report normal receipt.	Unprotected crossing was 1,442.857 ref L. The independent liquid trip and closing seats reduced paired main-inlet crossing to 8.539 ref L. If the independent signal also mimics receipt, 1,437.143 ref L crosses in the comparison.
Sealed 30 L carriers pass the same inlet. A real independent stop signal arrives after 39.75 ms.	At second 80, 5.764 ref L in a moving shell crossed one failed inlet. The worst timing gave 13.164 ref L per inlet. Intact closed shells gave zero free oil at the dry gap.
Empty pass-through mechanically locked before the failure.	Zero newly crossing cargo. Continuing sales require an independently healthy receiving dock. A receiver can also rupture at its own decant nozzle.
One complete 30 L decant missed in a rolling minute. Repeat with two missed decants.	Tank receipt after meter allowance was 400.891 ref m³/h with one missed load and 399.109 with two. Simulating the independent standby dock opening gave 401.423 ref m³/h. Losing one further load during that changeover gave 399.640.

Can the source feed the carriers for 72 hours?

Two lanes dispatch 113 loads of 30 reference litres per minute each. Replaying the registered source with eight piston pairs down per train, and admitting each minute's oil at minute-end, required up to 122.437 ref m³ initially per lane. A new, dedicated 135 ref m³ seller reserve per lane left 12.563 ref m³ at the lowest point. The 1.25 m³ buffer alone missed the first minute. Dock preloads are separate. Foundations and containment for this extra stock have yet to be qualified.

Higher delivery rate with a delayed trip

At 115 loads per minute per lane, a separate healthy dock and 16 staged carriers gave a modeled 400.335 ref m³/h with a 0.8 s delay, one further missed load, 1% off-spec oil spread proportionally through each minute, and 1% meter error. A second missed load gave 398.570. At second 80, 53.281 ref L crossed one failed inlet in sealed carriers. Some timings gave 60 ref L. The 400 ref m³ start per lane applies to the identified upstream supply model. Receiving from a different physical outlet changes the necessary stock.

Equipment and containment

The 115-load option assumes three potential 18,800 m³ receiving tanks and three independent 4.5 MWh power supplies. The excavation estimate for the wet-pipe design excludes these works. Both designs still admit oil to an active inlet after a failure with no advance warning. Only a previously locked, empty pass-through achieved zero in that test.

Holding oil until its grade is known

Three off-spec loads can arrive in the same minute even when the 72-hour average looks clean. The test follows actual eligible oil into the receiving tank during a change of buyer. Only an independently released batch can feed a loading station in the proposed arrangement.

Condition during the 60-second changeover	Tank receipt in reference m³/h
Two 30 L loads off spec, one further load missed, 0.8 s notice and a 1% meter allowance.	400.815 across all phases.
Three entire off-spec loads occur together under the same conditions.	399.033 in a simulated minute. Target missed.
The station loads from segregated, independently qualified stock. Rejected incoming lots remain isolated.	404.379 minimum on the specified healthy-receiver waveform.
Doubt affects one load in every incoming lot. Every whole lot is held.	Starting clean stock alone misses a dispatch in minute 247.

How the station works

Each lane has four 65 m³ vessels. Each takes 15 minutes to fill, 15 more for a grade result, 15 to discharge and 15 for turnaround. A separate 375 m³ tank retains rejected material. The immediate-release comparison starts with 801.2 ref m³ including dock loads. The batch system starts with 850 ref m³ in each lane and 1.2 ref m³ of separate dock loads, a total of 1,701.2 ref m³ of independently qualified seller oil.

Stock, energy and measurements

The replay of 160 upstream source records required at most 780.590 ref m³ per lane including rejection of up to 298.08 ref m³ on either lane. That limit counts the entire volume of held lots. Two transfer stages plus mixing and controls consume up to 3,395.1 kWh per lane over 72 hours. Each additional 5 MWh supply has 654.9 kWh spare under the modeled derating. Half charge fails.

False grade evidence

Case 20 supplied distinct oil streams with identical displayed readings. With a 5% dirty admixture, true chloride reached 5.113 mg/kg against a 5 mg/kg limit. The model assumes representative sampling, genuine grade evidence and physical segregation after release. ASTM D4177 describes automatic sampling of petroleum. It supplies no test result for this station.

Which outlet supplies the loader?

The model records both displacement at an upstream sale port and oil that actually reaches the original buyer. The pipe supplying the loader determines which record may be used. Oil previously delivered to a buyer can earn sale credit only once.

Boundary and test	Initial clean stock per lane
Upstream sale port, finite batch handling, any timing of the full rejection allowance.	780.590 ref m³ for 72 hours.
Original buyer outlet, immediate release of every litre with no quality loss, 115 loads/minute.	435.35 ref m³. Starting with 400 misses scheduled loads.
Original buyer outlet, 15-minute lots, separate assay and finite discharge, full rejection allowance on one lane.	833.93 ref m³ over 72 hours and 712.25 over 60 hours. Buying 850 leaves 16.07 in the limiting replay.
Original buyer outlet, rejection restricted to whole equal 50.25 m³ lots.	787.10 ref m³. Five whole lots fit the 298.08 m³ rejection allowance. Starting at 800 leaves 12.90.

What the outlet recorded

The two original receivers supplied 172,800 lane-minutes of records. Each working lane received 201 ref m³/h. The carrier option requires a physical connection carrying seller-owned, independently graded oil. Without replenishment, 850 ref m³ per lane is sufficient for 246 complete minutes. Supplying all 72 hours from prequalified stock alone takes 14,904 ref m³ per lane before the separate dock loads. The three receiving tanks are on the buyer side.

Heat entering the source station

Both 73%/100% gas assignments and eight unavailable pairs per train were retained. The four-strip water cover was tested with a five-second 2 GJ local pulse plus sustained heat. Adding 200 kW to the hot quarter throughout the 72 hours left 1.584 kPa against the 1.33 kPa design requirement. The minimum remaining source head was 488.9 Pa in 160 states. The heat reaching an actual station has yet to be measured.

Fitting the batch receiving yards on site

The layout reuses two receiving foundations at their original locations, enlarges both containment structures and adds a third receiving yard. The earthwork includes the batch grading stations and a separate water-cover drain.

Construction or operating case	Outcome
Two foundations are suitable for reuse and average ground preparation is 35 mm.	72,199,924.379 m³ of cut including the drain. Reserve against 72.20 million m³ is 75.621 m³.
Ground preparation increases to 50 mm.	The combined installation exceeds the cap by 75.184 m³.
All ten retired cell pairs are disconnected and twenty dry transfer booths stay within their water carryover limits.	0.698963402 L/h including the drain surfaces against a 0.699 L/h limit. With only 75% of the old wetted area disconnected, ingress reaches 0.699003609 L/h.
75 hot L/s at the dock. Available pressure is 200 kPa.	A 1.5 m inlet needs 164.602 kPa. A 4 m inlet needs 236.326 kPa and exceeds supply.

Cover water and retirement of old cells

The hourly result assumes that the separate water cover has no path into the product. If 20% of its 48,000 m² can transfer water at the inherited rate, the combined result is 0.699004471 L/h. The calculated maximum fraction is 17.82%. Retiring the original cell outlets also removes their 5.20 m³/h potential service contribution. The carrier stock balance uses a distinct original receiver record.

Containment, materials and dry commissioning

After subtracting occupied space, secondary storage holds 25,535.5 m³. The inventory and rain test leaves 1,267.0 m³. The yard scheme requires about 9,925 tonnes of steel and 4,079 m³ of new concrete. A 1 micrometre water film on the fresh wetted surfaces holds 18.65 L, enough to exceed the hourly ingress limit if released in one hour. Soil, anchors, drainage and removal of residual water require installed tests.

Keeping bulk water out of the local catch

The water cover needs a place to drain even when a service connection admits water from a much larger reservoir. A divider reserves a bay for the local spill. The bulk service line enters a separate bay through a restriction and two independent high-level shutoffs.

Simulated drain fault	Quantity at the named boundary
One automatic shutoff jams. The independent shutoff works. The drain remains open to local spill.	At most 3.699 m³ reaches the service bay in 72 hours. Remaining room is 2.475 m³ there and 0.486 m³ in the spill bay.
Assessed routes with one shutoff operating and trace oil in water.	0.952615 oil-equivalent L. Whole-site exterior release remains unmeasured.
Both mechanisms jam, the source stays connected and the modeled water carries 500 micrograms of oil per litre.	The path subtotal reaches 2.534 L in 12 hours and 10.478 L in 72 hours. Both exceed 1 L.

Removing the maintenance connection before operation

The operating return continues to its covered reservoir. With the separate bulk service spool removed, both level trips may jam. Allowing 9.373 hot L in the cut ends per train gives 0.952628 oil-equivalent L across the assessed paths over 72 hours. A 5 mm source-blank defect gives 1.070315 L. An as-built trace must confirm the operating return and every exterior route.

Positive source flow at the ten-minute deadline

The fourteen scheduled stops have a separate 0.4 ref m³/h limit. Charging two possible outward paths for each of fifteen new vessels, with 0.20 mm equivalent apertures after closure at up to 350 kPa differential, gives a 0.328688 m³/h subtotal. One 1 mm bypass raises it to 0.411065. Timing, actual apertures and additional flow paths require installed measurements.

Construction boundary

The partition and manifold add 21.907 m³ of excavation. On the wet-transfer footprint with suitable existing cover and basin supports, that leaves 755.473 m³ of the 72.20 million m³ allowance. The carrier installation and its additional storage require their own foundation assessment.

Keeping hot water under pressure

Loose ballast on four interleaved strips presses a sealed moving cover against each water reservoir. Each remaining strip follows the liquid as its level changes. Exposed water or a jammed guide can lose the pressure that keeps hot water below boiling.

Water starts at 88°C. Required pressure margin is 1.33 kPa.	Lowest margin
One of four ballast strips and one insulation skin lost. The cover and its displaced space are charged to the same gas system.	1.586 kPa.
Fourfold concentrated heat pulse and 50 Pa extra opposing pressure. All 160 states across the 20 source cases were checked.	1.584 kPa. Source head remaining 488 Pa.
The cover opens to the surrounding atmosphere.	0.931 kPa. Cases 12, 18 and 19 miss the requirement.
Half the ballast is lost, or heat concentrates eightfold.	1.305 and 1.190 kPa respectively. Both controls fail in cases 12, 18 and 19.

Water inventory and transfer

The covers add 146 m³ of water. Each local catch has 91.8 m³ usable and 7.485 m³ spare after expansion. If the bulk isolation fails, 20,000 m³ on that train can communicate with the catch. If all added water enters the product, its 72-hour mean is 2,027.8 L/h against the 0.699 L/h limit. At 0.75 ppm oil by volume, the same added water carries 0.1095 L of oil if it leaves the site.

Commissioning and proof

The dry parts start at or below 70°C. The design requires sealed edges, working guides and 16 m of travel. Grade at the actual receiving tank and oil crossing the exterior require independent measurements.

Supporting the rig and the water covers

Above-grade workyards and removable steel bridge girders carry the shaft rig on four 12 × 16 m ground mats. The 80 selected bores keep their original wet levels and linings. The estimate includes both receiving-tank starters and the full 400 mm replacement at the cold storage yard.

Construction condition	Paired excavation or ground pressure
Existing basin walls and guides can carry the four-strip cover. Two catch pads are added.	72,199,222.6 m³. 777.4 m³ remains below the 72.20 million m³ limit.
The basin instead needs a new 200 mm support mat across all 48,000 m².	10,752 m³ added. The estimate exceeds the limit by 9,974.6 m³.
Only half the ground area of the four rig mats carries load. At 35% contact the bearing control fails.	42.04 and 58.41 kPa respectively, against 45 kPa.
Twenty extra millimetres of trimming across the shaft work surfaces, plus both cover catch pads.	Exceeds the limit by 865.0 m³.

Material and fit

The covers use 6,912 tonnes of ballast, or 8,256 tonnes with skins and rails. The two rigs and workyard haul surfaces require about 2,841 tonnes of temporary steel. The model allows 18,269 m³ for the covers, plus vertical travel.

Decision before construction

Proof-load the actual saturated ground, confirm settlement, survey the bore and verify basin anchor loads. This excavation estimate covers the liquid-transfer and tank-starter arrangement. The separate sealed-carrier experiment needs its own receiving tanks, charged stock, foundations and containment.

Counting oil at the receiving tank

Two customers receive oil until one fails at second 80. The surviving original inlet keeps working. A lift pump sends oil from a surge chamber to a separate receiving tank. Delivery is counted when oil crosses a genuine receiving inlet. Oil waiting for the lift earns no tank credit.

Transfer arrangement, seconds 59.915–119.915	Actual rate during this minute
Original main inlets before loss, surviving inlet afterward, plus the standby tank. The four separate cell outlets do not qualify.	328.728 reference m³/h.
Same lift, also crediting four separately accepted cell outlets. The lift waits 5.16 s and ramps up over 15 s.	333.928 m³/h. The shortfall is 1,101.2 L in this minute.
Start immediately and keep the 15 s pump ramp. All four cell outlets qualify.	351.442 m³/h.
Start instantly at full operating rate with no acceleration period. All four cell outlets qualify.	376.897 m³/h. Even this ideal limit misses 400.

Why the minutes differ

The intact main delivers in pulses. The standby lift delivers at a steady mean rate once it starts. A minute that includes part of the missing pulse can receive less than either the long-run average or the upstream surge chamber. A slower arrival cannot repair a missed minute.

Test scope

These controls assume pure product and perfectly accurate meters. The switch uses one shared subsecond test waveform. Each of the 11 initially flowing source schedules is exposed to this added test. The native registers provide minute-by-minute source volumes for each gas assignment and pressure rule.

A starter at the final tank

A seller-owned cylinder at each standby tank can deliver one charge directly through a short nozzle while the main lift comes up to speed. Four separately powered feeds then deliver through qualified tank connections. Oil crosses the sale boundary once. The upstream surge chamber still serves the lift.

Duty or fault	Calculated result
One buyer fails during flow. An independent physical signal triggers the tank starter in 160 ms. Four direct feeds remain available.	400.247 reference m³/h over the rolling-minute screen for 72 hours. The model assumes independently eligible oil and the stated grade and meter allowances.
One activation. Each yard reserves 3.25 hot m³ from its five stocked cells and starts with 5 m³ of gas at 650 kPa absolute.	2.8124 hot m³ enters the tank. End-of-stroke gas pressure exceeds the calculated requirement by 64.634 kPa. A second activation has no funded charge.
Gas begins at half charge in the cold-start test. The buyer fails at second 80.	The gas supply falls 12.827 kPa below the pressure needed during the shot.
75 hot m³ initial oil remains in the receiving tank. Repeat with the original 150 m³ heel.	The smaller heel leaves 27.819 hot m³ of room. The larger heel overfills by 47.181 hot m³. Removed oil needs separate storage before startup.

Oil quality and ownership

Commissioning uses 14 hot m³ of genuine seller-owned oil per yard, separately from the starter shot. If the 90 m header still holds the customer’s oil or off-grade oil, eligible receipt between seconds 140 and 200 is only 208.841 m³/h. The same oil can earn sale credit only once.

Power and loss of a feed

The main lift reached 42.31°C and retained 49.34 kWh after the 72-hour replay. With three qualified feeds, a specific simulated run still delivered 410.276 m³/h gross in its weakest sampled minute. Across the wider phase, quality and meter allowances, only 398.960 m³/h could be assured.

After a total loss

At the 600 s cutoff, ten effective 0.5 mm cell openings at 175.675 kPa and two new effective 0.25 mm starter openings at 650 kPa give 0.388099 m³/h together with the other named sources. Only 0.011901 m³/h remains below the 0.4 limit. Two 0.5 mm starter openings raise this subtotal to 0.430841 m³/h.

Buyer loss during transfer

The original wet inlet is the counting point. Oil that crosses after a receiver fails counts against isolation even if a later catch retains it. Only oil genuinely accepted at an intact buyer counts toward delivery.

Condition at the time of loss	Forward oil crossing	Outcome
Two original buyers fail during a high-flow stroke. The weights continue to indicate receipt.	1,442.857 L paired	Unprotected comparison
Independent liquid signal at 39.75 ms activates two spring-driven seats. Weights stay false.	8.539 L paired main	Finite closure limits transfer
A single buyer fails. Independent notice takes 160 ms. Count the original supplementary feed.	12.872 L single	Failed buyer receives zero usable oil
Both weights and the independent liquid signal mimic receipt for the matched interval.	1,437.143 L paired main	Hidden loss persists

During the changeover

A charged 500 L chamber feeds the standby receiver. A separate 500 L chamber accepts incoming oil. At peak flow, 2.839 L crossed each inlet during the 39.75 ms before the first independent signal. Closing a seat at that instant would still leave those litres across the boundary.

Removing both original connections before startup

Both capped original inlets admitted zero oil. At two already-open alternate receiving chambers, the conditional floor was 400.352 m³/h over 72 hours, assuming 98% usable main flow and four separately stocked cells per yard. When a live alternate failed at peak flow and its weight stayed falsely healthy, 2.839 L crossed that inlet before detection. Downstream tank receipt requires a separate flow balance.

A coupling that closes before it separates

A sleeve on the receiving connection releases two normally closed valve faces as the receiver withdraws. The surrounding seal stays engaged during this movement. The mechanism acts directly on the moving parts even when both weighing systems falsely indicate normal transfer.

Test at the same two receiving inlets	Oil crossing after loss of receipt
24 mm of sealed movement at 0.75 m/s. The 24 ms closing sequence finishes 8 ms before separation.	0 L with ideal seats and zero escaping face inventory.
Same movement at 1.50 m/s. The seal opens with 8 ms of valve travel remaining.	0.229 L for a linear closure. Up to 1.143 L if flow stays at peak until seated.
Slow closing stroke; 40 ms at 0.75 m/s.	0.257 L with linear closure.
Timely seating, but 5 mL trapped at each face enters the failed receiver.	0.010 L crosses.
Internal loss while the sleeve stays engaged. Each failed inlet remains at 75 hot L/s for the 39.75 ms before independent notice.	2.839 L at one failed inlet. If both fail simultaneously at that flow, 5.679 L crosses the two.

Flow sensitivity at the surge chamber

A uniform 0.05% reduction of chamber intake leaves 400.139 m³/h at that chamber. A 0.10% reduction leaves 399.938 m³/h. The lift and pipe after the chamber determine how much of that oil reaches the customer’s tank.

Commercial reference and prototype assumptions

MannTek’s Dry Disconnect Couplings operating manual describes a valve interlocked to close before ordinary disconnection. The 24 mm travel, 4 ms of lost motion and 20 ms closing stroke above are proposed test inputs. No manufacturer performance is credited. The simulation measures oil at the original inlet and counts any oil released from a face pocket.

Small-cell flow at the chamber

This comparison counts main flow at the upstream receiving chamber plus qualifying flow at small cell outlets. Each small cell starts with 16 hot m³ of seller-owned product. Only one surviving yard is credited. Oil waiting upstream of the lift must still travel to the final tank.

Matched test, eight pairs unavailable per train	Chamber and cell rate	Result
39.75 ms notice, 30 ms opening, three-second changeover, five channels	401.029 m³/h	Meets 400
160 ms notice, 110 ms opening, five-second changeover, four channels	400.142 m³/h	Meets 400
Same slow changeover, three channels	399.942 m³/h	Below 400
Same slow changeover, original native delivery and existing supplementary feed only	399.342 m³/h	Below 400

Stocks, electrical power and pressure

Four prequalified channels supply 57.6 reference m³ over 72 hours. Each channel has its own 2 kWh nominal battery and 500 kg thermal mass. At 86°C outside, the modeled pack reached 43.62°C and used 1.021 of 1.312 accessible kWh. Starting a drive at 86°C or losing its entire power supply fails that channel.

Main receiving chamber

A 3.25 m³ oil stroke and a guaranteed 30 m³ gas volume covered early, established and late transfer interruptions. The conservative chamber maximum was 2.539 m³. A 2.50 m³ working stroke missed its level allowance. The main buyer pump and its finite drive reserve were replayed at the same 160 ms notice and five-second switch.

Pressure with 88°C water

Three independently stocked cooling bays serve each train. The operating case loses a complete bay. The original water remains at 88°C initially, while prior cooling keeps the separate backing at or below 75°C. Finite heat transfer through the backing is included.

Condition	Weakest modeled margin	Affected cases
Both gas-access assignments, commissioned backing, one bay out	1.894 kPa	All 20 clear 1.33 kPa
Additional 0.1°C and 5 mm of adverse elevation	1.593 kPa	Case 18 governs
Additional 0.2°C and 10 mm	1.290 kPa	12, 18 and 19 fail
94°C backing and a 15-minute delay	0.400 kPa	12, 18 and 19 fail
120°C contacting backing and a 15-minute delay	–5.122 kPa	All 20 fail

Seventy-two-hour inventory

Each train installs 3,600 tonnes of ice in three bays. With two bays surviving and 85% of their ice accessible, 679.32 GJ is available against 651.23 GJ required. Each surviving battery has 11.2 MWh accessible against 5.596 MWh demand. The pumping head reserve is 58.51 kPa.

Temperature and elevation together

The limiting case can tolerate about 31.8 mm of adverse water-level error at +0.1°C, falling to 6.0 mm at +0.2°C. Construction accuracy and operating levels share that allowance. Charging the cooling plant takes 168.1 hours in the modeled commissioning environment.

Storage after physical disconnection

Full carts leave the original-grade transfer dock only after the oil path is physically disconnected. Raising the dry storage deck and its underlying catch together by 2.40 m preserves the liquid depth and avoids raising the process water, gas or working buyer inlet.

Paired construction or movement test	Calculated result
Selected estimate including new grade, upstream gas preparation, cold guards and 500 mm replacement below the two auxiliary stock yards	72,196,594.48 m³ excavated
Remaining against the 72.20 million m³ limit	3,405.52 m³
Weak ground requiring deeper removal under the cold guards	72,204,994.48 m³. Limit exceeded.
One dry hoist and one 850 kWh pack available	45.86 seconds left per 17-minute exchange. 75.29 kWh left.
Both dry lifts arrested	Transport fails. A full cart cannot occupy a storage position.

Space and materials

The thermal installation requires 6,240 m² of land per train. Its exterior water collectors occupy an additional 14,728 m² per yard in the synthetic layout. Their guard steel alone is about 12,898 tonnes paired. Excavation savings therefore carry considerable land, material and lifting requirements.

Commercial qualification

The model has no supplier bids or installed-price comparison. Site soil, bearing, settlement, electrical black start, source charging, cart cycle life, thermal conditioning and independent acceptance of seller-owned reserve oil determine whether the calculated design can provide a commercial delivery service.

Exterior containment and product quality

Liquid, oil residue on surfaces and the modeled gas leakage are counted at the exterior. Capturing product inside the facility does not establish the total amount that can leave in vapor or aerosol.

Contamination or containment case	Result
Two preloaded buyers, separately captured meltwater and pipe inventory, closed drains	0.999534 reference-equivalent L on modeled paths. At the 1.05 volume stress this is 1.049511 actual-equivalent L.
Concentrated oil reaches the tested small through-defects in the cold collectors	1.000486 L. Limit exceeded.
All ice melt and circulating water escape	6.532219 L. Limit exceeded.
Both buyer inventories enter the same blocked compartment	The model overflows. The paired calculation exceeds 27 million litres.
Water reaching qualified product with separate incident collectors	0.698834 L/h. Criterion 0.699 L/h.
Raised dock communicates with product, or all guarded surfaces communicate	0.699179 and 0.706957 L/h. Both exceed the limit.

Quality at the buyer

All 27,152 assigned incoming lots met the modeled water, solids and chloride limits. A hidden 5% water heel in the main buyer makes the first mixed lot about 3.96% water, above the 1% grade limit. A bad starting inventory must prevent authorization of sale.

Additional release paths

The selected gas charge uses upstream polishing and an independent assay. Releasing the spent polishing material inside the process boundary exceeds 1 L. A full exterior verdict also needs measured seal leakage, vapor composition, aerosol carryover and all bypass paths.

Isolating hot steel and moving seals

Two further prototype changes address heat entering through a structural plate and vapor leaving a moving gas seal. The estimates below charge both pieces of hardware to the same excavation and surface budgets.

Prototype condition	Simulated result
Dry structure, posts and radiation shields at 120°C. Four wetted skin faces initially at 88°C and 11.13 m³ of secondary coolant at 65°C per train.	1.558 kPa minimum with an additional 0.1°C and 5 mm. All 20 pressure cases clear 1.33 kPa.
The original steel face touching 88°C water itself starts at 120°C.	First-contact temperature 115.15°C. All 20 fail the liquid-phase check.
Independent gas-seal enclosures, one loaded at 101 g/m³ of vapor and mist, seven at 1.1 g/m³, plus new cassette surface residue.	0.999972 reference-equivalent L on the tested exterior paths. Warm-liquid volume requires a separate conversion.
All eight enclosures at 101 g/m³, or finite single-seal enclosure exhausted.	1.001766 L at all eight high, before the added cassette trace. A 10 mm² local leak reaches the enclosure pressure limit after 54.78 hours.
Both added structures in the 2.40 m raised-yard estimate	72,196,815.58 m³ excavated. 3,184.42 m³ remains.

Costs paid in the model

The thermal break adds 33.91 tonnes per train and leaves 21.04 GJ of usable cold reserve. The seal change charges 79,469 m² of additional material across the two yards. If those new guard surfaces reach sale product, modeled water ingress rises to 0.699222 L/h.

Scope of the combined result

The pressure and excavation screens assume dry guards and conditioned coolant. The release figure uses a reference density. A lost cooling charge, a thermal bridge, a wet starting face at 120°C or an uncounted release can defeat the result. Full-scale seal travel and clearances remain unverified.

What counts as usable delivery

Case 20 keeps both buyers physically intact. It tests whether saleable crude can be distinguished from off-spec fluid when the current samples and reference readings can all be forged. The buyer-loss test adds a separate fault to this schedule.

Receiving condition	Simulated result
Known good starting oil. Drive fluid stays isolated from saleable stock throughout four alternative 72-hour histories.	2,672 lots evaluated. Minimum receipt over aligned minutes 400.151 reference m³/h.
Five percent of the mass in the worst lot comes from the dirty side. All displayed readings still look healthy.	True chloride reaches 5.113 mg/kg. The buyer limit is 5 mg/kg.
One original receiving nozzle survives and four independent cells deliver at the nominal rate. No new receiving main is available.	The physical ceiling is 262.343 m³/h. Another independently qualified inlet must accept at least 137.657 m³/h.
Both weigh systems report normal receipt after genuine acceptance stops.	A displayed increase earns zero credit at the failed buyer. Good stock, isolation and actual receipt must each be established.

Seventy-two hours of stock

The target requires 28,800 reference m³ at genuine buyers. With four independent cells, good product and a 1% positive meter error, at least 28,429.307 reference m³ must arrive through other qualified receiving routes. The aligned case-20 result uses two intact buyers. The added single-buyer loss requires a separate rolling-minute check at the surviving destinations.

Holding water and oil together

A tray can receive oil from its seller and buyer at the same time that incident water arrives. The model gives the tray no drain credit. Oil overtopping a tray and oil crossing the site boundary are measured separately.

Test for one tray	Result
Existing tray, two full paid stocks and 200 mm of incident water.	40.531 m³ overtops.
Floor recessed 2.10 m, two tanks full to working level, 1.40 m of incident water and another 30 m³ inflow.	545.272 m³ held. 10.784 m³ remains.
Same recessed floor with 60 m³ additional inflow.	19.216 m³ overtops.
Ten direct aligned paths from the wet assembly to the exterior. Increase the assumed gap from 40 to 80 micrometres.	Defined oil releases rise from 0.953 to 3.093 L. The latter exceeds the 1 L limit.

Construction allowance

The deeper trays add 8,364.9 m³. The wet-pipe tank-starter estimate of 72,199,222.6 m³ includes the rig workyards, both tank starters and both water-cover catches. The batch yards and their separate drain have a distinct estimate. Installed bearing, anchors and liquid paths require verification.

Space for the tank starter

Each standby tank needs a dedicated starter, four working feed connections, supply equipment and a catch for liquid released at the starter. The collection floor is 1.20 m below grade. A 3.05 m continuous wall allows the receiving nozzle to stay at its original elevation.

Installation or adverse condition	Local result
Both starter assemblies and routes, 2.10 m cell-tray recesses, revised workyards and two hot-water catches.	Estimated excavation is 72,199,222.6 m³, leaving 777.4 m³.
One starter catch with all drains closed. Count source oil and fixtures, 1.4 m of water over its catchment and another 30 m³.	7.785 m³ remains. Another 15 m³ causes 7.215 m³ to overtop.
Add the separate optional thermal-port pads.	664.5 m³ of excavation remains before routing.
Extend each oil outlet route by 20 m.	The extra routes cost 201.6 m³. Any local alignment or fitting still needs physical proof.

Limits of the local catch

The model counts full support over the landing area. Halving effective soil contact raises the design pressure above the assumed ground capacity. The 72-hour exterior oil limit also covers other paths, including any outward route around the starter. The site-wide volume remains unverified.

Heat at an open water reference

The gas temperature depends on how quickly heat arrives and how much gas initially receives it. Each test uses both gas-storage assignments, both pressure rules and the same 20 source schedules. The hot-water pressure margin must exceed 1.33 kPa.

Thermal load per affected cluster	Weakest modeled margin
Sustained heat from the 80-shaft option, bounded above by 18 kW throughout 72 hours.	1.557 kPa.
225 kW sustained plus a separate 2 GJ over five seconds, spread uniformly through all active gas.	1.457 kPa.
Same total heat over five seconds, absorbed by one quarter of the active gas.	1.164 kPa. Cases 12, 18 and 19 fall below 1.33.
225 kW plus a 2 GJ pulse, with no gas element receiving more than twice the average heat per unit heat capacity.	1.358 kPa under the stated model and mixing constraint.
Separate passive port limits the combined heat reaching the gas to 425 kW even in the degraded case.	1.553 kPa if the port intercepts the entire separate pulse.

Alternative with an open reference

The distribution bound needs independent evidence. A direct gas bypass defeats the passive port. If the four-strip water covers are also installed, adding the separate 112.896 m³ of thermal-port pads leaves 664.484 m³ before routing. Shaft ground conditions and foundation depth determine whether the installation fits.

What the exterior record can establish

The original 20 missions limit oil reaching the site exterior to one actual litre. The added buyer test measures oil entering a failed inlet from the instant of failure. Each test needs evidence at its own boundary.

Original case	Internal oil transfer	Exterior quantities consistent with the same internal transfer
12	40,702,013 reference L	0 or 2 reference L
18	40,702,013 reference L	0 or 2 reference L
19	40,728,919 reference L	0 or 2 reference L

Why the case stays open

Each pair of oil balances conserves the same starting inventory. Moving two litres from the retained inventory to the exterior leaves the recorded interior transfer exactly unchanged. The terminal destination was unobserved. The two balances describe possible outcomes. Neither measures a release.

Which volume counts

The contractual litre is actual liquid oil at the exterior. The bookkeeping above uses oil volume at reference conditions. A traceable oil temperature or density at the boundary is needed for the conversion. An exterior result must cover all outward routes and measurement uncertainty during the same 72 hours.

Water from the pressure covers

The two trains add 146 m³ of utility water. If all of it exits carrying at most 81 micrograms of oil per litre, the defined oil-equivalent subtotal rises to 0.968 L on the ten 40-micrometre path test. At 500 micrograms per litre the subtotal is 1.047 L. These concentrations are assumed controls.

How to read the score

Eleven service cases receive an added mid-flow failure test. In the original duties six require 72 h, five isolate after 60 h and nine begin isolated. The measured-volume fixture meets the 200 L inlet cap under the specified instrument conditions. Whole-site release and full-mission safety remain unverified in all twenty.

Source isolation at the original cell pressure

The combined forward flow from all sources must fall to 0.4 reference m³/h or less within 600 seconds. This comparison uses the original 75 kPa cell pressure. The direct tank starter and higher-pressure feed pumps are counted separately in the final-tank source calculation.

Source or fault	Model evidence
Registered main sources	All 14 schedules requiring a stop reached cutoff in 65 s. The worst subsequent combined rate was 0.217814 m³/h.
Ten enlarged auxiliary sources	Each must be closed by 600 s. At 75 kPa differential, 800 kg/m³ minimum liquid density and a single 0.50 mm equivalent opening per source, the ten add at most 0.096791 m³/h.
Two starter supplies	Two 0.25 mm equivalent openings at 200 kPa contribute up to 0.007903 m³/h. The model gives no continuing-flow credit for the finite 500 L charge.
Total of these paths	0.322508 m³/h, leaving 0.077492 m³/h for every other simultaneous source. Physical isolation of return and bypass paths remains open.
One enlarged cell keeps pumping	1.30 m³/h from that cell alone. Fails the full cutoff limit.

Required evidence

The two old 0.20 m³/h feeds are removed and capped on each side. Both new and original components require independent evidence of closure, effective leak area, pressure and positive flow at the same times. Returns do not subtract from forward oil leaving a source.

Registered and additional faults

All 20 complete missions remain unverified. Eleven cases face an unexpected wet-buyer loss and nine begin isolated. Each failed inlet has a 200 actual litre maximum for measured, contained run-on over the next 72 hours.

Space below the excavation limit

The proposal retains the 8 m clear gas bore, the 350 mm concrete ring, the 20 mm steel liner and the original operating elevations. The quantity change comes from limiting rock removal outside the finished lining in eligible shaft intervals.

Construction or ground condition	Calculated outcome
272 of 1,088 shafts, 80 m per eligible interval; 75 mm target radial overcut, 15 mm survey allowance and 1.2% additional breakout.	63,326 m³ net saving after excavation for working pads, temporary access and collars.
272 altered shafts with both yards, weak-soil removal and supplier works.	72,144,153 m³. A rapid gas heat load in this design failed three hot-water cases.
80 altered shafts, 40 per train, with the full cost of fixed mobilization and the 0.4 m weak-soil replacement.	72,190,961 m³ estimated. 9,039 m³ below the cap.
Overcut reaches 220 mm, or unsurveyed rock breakout reaches 10%.	Both construction controls exceed the cap even on the lower-excavation micropile foundation option.
Wet rock and gas bore	The retained ring screens at 5.59 MPa against a 2.70 MPa external proof pressure. A 250 mm ring gives only 2.43 MPa. A rough 7.40 m bore loses the calculated gas head.

Thermal coupling

In the 272-shaft comparison, an additional 31.5 GJ spread over 72 hours gave 1.556 kPa. The same heat entering one gas cluster promptly gave 0.009 kPa, failing cases 12, 18 and 19. The bounded 80-shaft tests gave 1.373 kPa. Actual ground heat rate, transient load, bore profile and bond require measurement.

Ground acceptance

On 80 shafts, +225 kW over 72 hours plus a +2 GJ prompt load gave 1.457 kPa. A complete +3.75 GJ prompt load gave 1.373 kPa. The two opposite-sign controls also passed. Increasing the prompt load to +5 GJ while retaining +225 kW gave 1.309 kPa and failed cases 12, 18 and 19. Site heat profiles must fall within the tested envelope.

Paid foundations

The quantity includes 846.72 m³ for ten 350 mm stock-cell mats and 47.5 m³ for the separate supplier-water pad. Preliminary distributed bearing is 68.5 kPa loaded and flooded. Ground rated at 45 kPa fails. Mat bending, local reactions and settlement remain open.

Protecting the stored oil

The oil-contact temperature limit is 85°C. The new vessels, previously empty receiving steel and pump are tested with a 120°C exterior for 72 hours.

Condition	Calculated outcome
One insulation layer degraded and poor inner thermal contact.	83.11°C at the hottest assessed wetted location. The pump starts with its independent heat bank at 30°C or less.
Both insulation layers lose their protection, or a metal bridge conducts heat directly to the wet shell.	107.10°C with both layers lost and 114.24°C with the direct bridge. Both exceed 85°C.
Thermal equipment in both yards.	3,329 t of added material plus 7.1 t allowed for mounting hardware. Each tray retains 2.67 m³ above the tested paired stock load.
Isolation between sale oil and the new jackets holds.	0.698979 L/h calculated water ingress. Limit 0.699 L/h.
The new jacket and mat faces communicate with sale oil.	0.699250 L/h under the common wetting assumption. Fails.

Heat at the pump

The 30°C heat bank and its thermal connection remove 170.73 W at the limit against 150.37 W required. A damaged connection can remove only 17.51 W. Oil, sheltered gas and steel elsewhere must start at 75°C or cooler.

Coverage

The recorded 84.339°C oil-contact bound applies to the previously tested components. Separate component results cannot establish that every oil contact stays below 85°C during the same incident.

How much oil can reach the exterior?

The signed liquid limit is one actual litre at the outside boundary over the mission. The component ledger expresses carryover and surface residue as equivalent oil at 810 grams per litre. The distinction matters for warm oil and light condensate.

Test	Result for the defined paths
Fresh guard-water supply and old trapped water	3,680.03 m³ fresh water must test at 27 µg/L or less with at most 2 µg/L positive uncertainty. The 319.97 m³ remaining in place must independently meet 81 µg/L.
Two preloaded yards, conditioned water and modeled gas and surface paths.	0.763734 reference-equivalent L. With a 1.05 conversion ceiling this becomes 0.801920 actual-equivalent L.
One part per million of the added 860 hot m³ of seller oil crosses the exterior.	An additional 0.860 actual L. Combined estimate 1.662 L. Fails.
Both supplier beds fail and the fill is admitted.	The inherited component ledger exceeds 1.011 L equivalent before accounting for the extra stock or temperature.
Other vapor, aerosol, common routing and bulk-liquid escapes	No measured whole-site upper bound. Coincident loss of the retaining boundaries remains a failure.

Measurement at the boundary

The 1.05 screen needs a lower liquid density of 771.4 g/L for every component reported by oil mass. Oil in air must be tracked by mass. The extra stock may lose only 0.230 ppm if every other uncounted release is zero.

Qualifying the water

A routine EPA Method 1664B result cannot verify this water charge. Its minimum quantitation level is 5 mg/L and volatile material can be lost. The project needs validated recovery of the relevant dissolved, dispersed and volatile hydrocarbons and representative sampling of the full batch.

Meter error at the surge chamber

The flowmeter in this calculation measures oil entering the surge chamber. The destination tank receives oil after the lift starts and accelerates. Dividing the chamber reading by 1.01 covers the specified common positive meter error at the chamber.

Receiving arrangement	Conservative flow under 1% over-registration
Four independent 0.20 m³/h cells and the surviving main route.	396.180 m³/h. The indicated margin covers only 0.0355%.
Four independent 1.30 m³/h cells available on one yard. Eight piston pairs remain down per train.	400.339 m³/h at the chamber accounting boundary. The tank changeover has a separate receiving limit.
Three larger cells remain available.	399.052 m³/h. The lower bound falls below target.
All buyer evidence is fabricated.	No positive receipt bound. A failed buyer earns zero credit.

What supplies the additional oil

Each yard has five independently powered cells, each with 102 hot m³ of seller oil. Four cells supply 374.4 reference m³ over 72 hours. Each working drive used 9.32 of 13.12 available kWh. The two yards add 860 hot m³ of source oil. Both older 0.20 m³/h supply branches are physically removed and capped.

What the test can establish

After 1% over-registration, 5.70 additional litres of positive error per minute would use all remaining chamber margin. Saleable delivery needs genuine flow through an intact final receiving inlet. Oil held in the surge chamber earns no tank delivery credit.

Measurement benchmark

OIML R 117-1:2019, Tables 2 and 3, specifies accuracy classes for complete liquid measuring systems under rated conditions. One percent is a stress case here. A field uncertainty budget must also cover absolute quantity deviations and operating conditions.

Cases with a service duty

The source column gives measured model flow in reference m³/h after the 600-second cutoff deadline on the registered source equipment. The last column shows the additional unannounced buyer-loss test. All 20 original whole-system missions remain unverified.

Case	Defined condition	Flow duty	Source after 600 s	Added inlet test
09	Three route boundaries lost	72 h	No cutoff due	112.708 L modeled upper
10	Independent heat envelope penetrated	72 h	No cutoff due	112.708 L modeled upper
12	Loaded collapse and outer-vault loss at 60 h	60 h	0.162987	112.708 L modeled upper
13	100 mm source-gas wall breach	72 h	No cutoff due	112.708 L modeled upper
14	Gas heat transfer degraded	72 h	No cutoff due	112.708 L modeled upper
15	Catch heat transfer reduced at 60 h	60 h	0.162988	112.708 L modeled upper
16	Local pocket outer boundary lost	72 h	No cutoff due	112.708 L modeled upper
17	Catch heat transfer lost at 60 h	60 h	0.162988	112.708 L modeled upper
18	Enclosure gas starts at 86°C	60 h	0.162987	112.708 L modeled upper
19	Catcher shield fully open	60 h	0.162999	112.708 L modeled upper
20	All current quality evidence falsified	72 h	No cutoff due	112.708 L modeled upper

How to read the duty

Six cases require 72 hours of delivery. Five deliver for 60 hours and then isolate for 12. Nine start with the buyer inlet closed. Each scheduled source stop still has a final 0.5628 reference m³ stroke per train. It earns zero sale credit. The replay compared 15,206,400 values over 691,200 train-minutes.

Open gates

For the 11 flowing cases, an additional buyer fault at second 80 admitted oil after loss. Nine initially closed inlets had zero new crossing. The prospect of safe total-loss containment depends on every release path at the exterior. The operator panel lists the unresolved gates from each registered case.

Cases isolated from onset

The source column gives measured model flow in reference m³/h after the 600-second cutoff deadline on the registered source equipment. The last column shows the additional unannounced buyer-loss test. All 20 original whole-system missions remain unverified.

Case	Defined condition	Flow duty	Source after 600 s	Added inlet test
01	Source closing energy lost and conventional valves jammed	Isolate	0.217814	8.857 L modeled upper
02	Terminal closing energy lost and conventional valves jammed	Isolate	0.217814	8.857 L modeled upper
03	Source and terminal closing energy lost with jammed conventional valves	Isolate	0.217814	8.857 L modeled upper
04	Trigger inlets blocked with jammed conventional valves	Isolate	0.217814	8.857 L modeled upper
05	Pilots blocked with jammed conventional valves	Isolate	0.217814	8.857 L modeled upper
06	Sleeves torn with jammed conventional valves	Isolate	0.217814	8.857 L modeled upper
07	Sleeve closing force tripled with jammed conventional valves	Isolate	0.217814	8.857 L modeled upper
08	5 mm² seat gaps with jammed conventional valves	Isolate	0.217814	8.857 L modeled upper
11	Closed catch boundary lost	Isolate	0.217814	8.857 L modeled upper

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