APEX
RELIABILITY ENGINEERING

RCM QUICK-START SAMPLE

A complete worked RCM analysis, the consequence method explained, and ten library failure modes.

Free sample package

Apex Reliability Engineering

What RCM is, and what this sample shows

Reliability Centered Maintenance (RCM) is a structured way to decide what maintenance an asset needs. SAE JA1011, the standard that defines which processes may be called RCM, requires every analysis to answer the same seven questions, in order:

1. What is the asset required to do, and to what standard? (Its **functions**.)
2. In what ways can it fail to do that? (Its **functional failures**.)
3. What causes each functional failure? (Its **failure modes**.)
4. What happens when each failure occurs? (Its **failure effects**.)
5. In what way does each failure matter? (Its **consequences**.)
6. What can be done to predict or prevent each failure? (**Proactive tasks**.)
7. What should be done if no suitable proactive task exists? (**Default actions**: failure-finding, a one-time change, or a deliberate decision to run to failure.)

RCM is neither a cost-cutting exercise nor a criticality ranking. An analysis sometimes calls for *more* maintenance, most often proof tests of protective devices that have never been tested.

Inside this sample

This package reproduces one complete analysis from the **RCM Analysis Workbook**: BFP-2, a boiler feed pump at the fictional Harborview District Energy plant, carried through the whole method. It covers 5 functions, 7 functional failures, and 12 failure modes sorted into consequence categories, with the tasks those consequences justify. It also explains the workbook's consequence-evaluation method in plain language and gives ten centrifugal-pump failure modes in the format of the companion **Failure Mode Library**, so you can judge both products on real content.

Everything in the worked example is fictional and internally consistent. Change any input in the full workbook and the whole chain re-derives itself: categories, task types, intervals, annual hours, and priced consequences.

Scope. This sample presents the JA1011 process structure for analysis and program design. It is professional-development and decision-support material. It is not a certification product, a JA1011 compliance claim, or engineering advice for any specific installation.

The worked asset: Harborview BFP-2

No. 2 boiler feed pump (BFP-2) is a motor-driven multistage centrifugal pump in the powerhouse of the fictional Harborview District Energy plant. It is one of two 100% pumps in weekly duty/standby rotation and delivers feedwater at 1,250 psig; loss of both pumps trips the boiler. Every analysis starts with the operating context, because every conclusion depends on it. The same pump in standby service is a different maintenance problem than in continuous duty.

Functions: what the asset must do, and to what standard

ID	Function statement	Performance standard	Type
F1	Deliver feedwater to the boiler drum	400-520 gpm against 1,200-1,250 psig discharge pressure, on demand, continuously	Primary
F2	Contain feedwater within the pump pressure boundary	External leakage no more than the seal manufacturer's design weep rate	Primary
F3	Shut the pump down on low suction pressure (protective trip)	Trip actuates at or above the minimum safe suction pressure, before cavitation damage	Protective
F4	Prevent reverse flow through the stopped pump (discharge check valve)	No sustained reverse flow with the pump stopped and the header pressurized	Protective
F5	Start and reach full load on a start demand	Full load within 30 seconds of the start signal	Secondary

Functional failures: every way each function can fail

Fn	FF	Functional failure	Kind
F1	A	No flow at all	Total
F1	B	Flow below 400 gpm (partial delivery)	Partial
F2	A	External leakage beyond the design weep rate	Excess
F3	A	Trip fails to shut the pump down on low suction pressure	Total
F4	A	Check valve passes reverse flow	Total
F5	A	Fails to start on demand	Total
F5	B	Starts but does not reach full load within 30 seconds	Partial

Note the two protective functions, F3 and F4. Nobody sees their failures, and those failures dominate the consequence discussion on the next page.

How consequences are evaluated

Question 5 asks *in what way each failure matters*. Here an RCM analysis earns or loses its credibility. Each failure mode goes into exactly one of four consequence categories. The team answers three questions **in a fixed order**, from the failure-effect narrative alone, before anyone discusses tasks:

1. **Is the failure evident?** Would the operating crew, on normal duties, know the failure has occurred? If not, the mode is **Hidden**. Stop here.
2. **Could it hurt someone or breach an environmental limit?** Judge credibly, not fancifully. A credible path from this failure to harm puts the mode in **Safety / Environmental**.
3. **Does it cost production?** Lost output, throttled rates, quality excursions, or a forced outage of something else make the mode **Operational**. If none applies, it is **Non-operational**: it costs its own repair and little else.

Category	What it means
Hidden	The failure is not evident in normal operation. It is almost always a protective function that has failed silently. The risk is the *multiple failure*: the protective device is dead on the day the demand arrives. Failure-finding tasks manage these modes, with intervals calculated from the availability you require.
Safety / Environmental	The only category where economics does not decide. If no applicable proactive task exists, the default is a mandatory one-time change (redesign), never run-to-failure.
Operational	Evident and costly in production terms. Here the comparison between task cost and failure cost belongs, so the workbook prices these modes: events per year × (downtime hours × your hourly rate + repair cost).
Non-operational	Evident, with no safety or production consequence. Run-to-failure is most often the correct answer here, provided it is a deliberate decision with the repair cost on the record.

Two disciplines keep the sort honest

First, answers come from the effect narrative. If the narrative does not establish that the crew would notice, the "evident" answer is not yet earned; finish the narrative. Second, the safety question always comes before the operational question. A seal failure that stops the line *and* sprays hot feedwater across a walkway is Safety / Environmental, and its task never has to survive a cost-benefit argument.

Do not negotiate a category to steer the outcome. A room that answers "not safety" to avoid redesign work corrupts the analysis. The workbook's formulas enforce the precedence regardless.

Modes & effects register: BFP-2 (1 of 2)

Mode	FF	Failure mode	Cause / mechanism	Failure effect	Cat.
M1	F1 B	Wear-ring and impeller clearance growth	Erosion-corrosion of wear-ring surfaces in treated feedwater	Flow and head fall gradually. The first evidence is the performance trend and rising energy per ton of feedwater. No safety threat; operations loses boiler capacity margin at peak demand. Repair: open the pump, renew wear rings, measure the impeller.	Operational
M2	F1 A	Drive-end bearing fatigue spalling	Subsurface fatigue of the rolling elements at end of bearing life	Vibration and temperature rise over weeks before seizure. Run to failure, it damages the shaft and bearing housing too. The pump trips or is stopped, and boiler load swings to the standby pump. Repair: bearing change, shaft inspection.	Operational
M3	F1 A	Flexible coupling element fatigue cracking	Cyclic flexing of the elastomer element	Drive is lost suddenly when the element fails; the guard contains the fragments. The coupling gives no warning. Repair: element renewal, alignment check.	Operational
M4	F1 A	Motor stator insulation thermal aging	Long-term thermal degradation, accelerated by blocked cooling passages	Ground fault: the motor trips on protection and the pump stops without warning. Repair: motor rewind or replacement.	Operational
M5	F1 B	Suction strainer debris blockage	Debris and corrosion products carried to the strainer	Cavitation noise and falling flow; impeller cavitation damage if sustained. Evident on the differential-pressure trend. Repair: isolate and clean the strainer.	Operational
M6	F2 A	Mechanical seal face wear	Abrasive wear of the seal faces by feedwater solids	Leak rate grows past the design weep. Hot feedwater escapes to the seal drain and, as wear progresses, to atmosphere at up to 194 °F, a scald hazard at the pump. Operations also loses treated water. Repair: seal renewal.	Safety / Environmental

E / S / O answers for these six: M1–M5 are evident, not safety-related, and operational (Y/N/Y). M6 is evident and operational, but escaping hot feedwater makes it Safety / Environmental (Y/Y/Y). The safety answer wins by precedence.

Modes & effects register: BFP-2 (2 of 2)

Mode	FF	Failure mode	Cause / mechanism	Failure effect	Cat.
M7	F3 A	Low-suction trip pressure-switch setpoint drift	Aging and vibration drift of the switch mechanism	Nothing announces it: the switch does not actuate at the trip point. A proof test finds it, or the day suction pressure is lost and the pump cavitates: the multiple failure. Repair: switch recalibration or renewal.	Hidden
M8	F4 A	Discharge check-valve hinge-pin wear	Wear of the hinge pin and disc seat faces	Reverse flow through the stopped pump spins it backward and can water-hammer the header at the next start. It stays hidden until a reverse-flow test or a start problem. Repair: valve overhaul.	Hidden
M9	F1 A	Bearing lubricant oxidation and contamination	Oil aging; water ingress past the breather	Bearing wear accelerates silently; this mode is M2 arriving years early. Only the oil sample reveals it. Repair: oil change; bearing inspection if debris is present.	Operational
M10	F1 A	Deadhead operation: discharge valve closed in error with the pump running	Human error at start-up; no thermal relief path on the casing	Trapped feedwater overheats rapidly: seal failure, then casing distortion and, in the limit, a hot-water release at pressure. This is a safety event, not just damage. Repair: casing inspection, seal renewal, possible casing replacement.	Safety / Environmental
M11	F2 A	External coating breakdown and casing corrosion (non-pressure surfaces)	Coating age and mechanical damage	Slow external corrosion of non-pressure-retaining casing surfaces, found on inspection. No leak and no operational effect at the observed rate; the cost is repair and appearance. Repair: prepare and recoat.	Non-operational
M12	F5 A	Start-circuit control relay contact failure	Contact erosion in the start relay	The pump does not start on demand. On its own nothing else happens: BFP-1 carries the load, and the failure surfaces at the next start attempt. The multiple failure (both pumps unavailable together) trips the boiler and stops steam output, with no safety or environmental consequence at this plant.	Hidden

M7, M8, and M12 are not evident (N), so they are Hidden whatever else is true of them; their consequences arrive as multiple failures. M10 is Safety / Environmental (evident, could injure). M11 is evident with no production effect: Non-operational. In the full workbook your three answers calculate the category, and modes you leave unpriced stay visibly unpriced.

From consequences to decisions

The decision logic walks each mode through JA1011's task-selection questions in the standard's order. Condition-directed tasks are set from the P-F interval: inspect at half the interval, so a developing failure is caught with time to act. Failure-finding intervals are calculated: FFI = 2 × (1 – target availability) × MTBF of the protective device. A Safety / Environmental mode with no applicable proactive task defaults to a mandatory one-time change; the logic never proposes run-to-failure for one.

Mode	Category	Decision (task type)	Interval	Priced consequence
M1	Operational	Condition-Directed	3 months	$23,000 / yr
M2	Operational	Condition-Directed	Monthly	$55,600 / yr
M3	Operational	Time-Directed Discard	5 years	$9,840 / yr
M4	Operational	Condition-Directed	12 months	$37,000 / yr
M5	Operational	Condition-Directed	2 weeks	$20,800 / yr
M6	Safety / Environmental	Condition-Directed	Weekly	$40,250 / yr
M7	Hidden	Failure-Finding	8 weeks	Not priced (hidden)
M8	Hidden	Failure-Finding	12 months	Not priced (hidden)
M9	Operational	Condition-Directed	6 weeks	$27,800 / yr
M10	Safety / Environmental	One-time change	—	$44,500 / yr
M11	Non-operational	Run-to-Failure	—	$600 / yr
M12	Hidden	No scheduled task	—	Not priced (hidden)

The analysis reconciles

12 modes sorted: **Hidden 3 · Safety / Environmental 2 · Operational 6 · Non-operational 1**. Nine scheduled tasks (6 condition-directed, 1 time-directed discard, 2 failure-finding), one mandatory one-time change, one deliberate run-to-failure, and one no-scheduled-task decision with its reasoning on the record. The priced modes carry **$259,390 per year** of consequence at the plant's $5,000/hour downtime rate, against a recurring program of **55.6 craft hours per year**. The two proof tests show the arithmetic: M7's trip switch calculates to 0.16 years at a 99% availability target and is packaged at 8 weeks; M8's check valve calculates to 1.0 year at 95% and is packaged annually.

The program those decisions produce

Tasks are packaged into routes and outages a planner can issue. Each interval below traces to a P-F interval or a calculated failure-finding interval.

Mode	Task	Interval	Package	Hrs/yr
M1	Performance test: flow, discharge pressure, and power against the commissioning curve. Acceptance: flow within 5% of curve at the duty point.	3 months	Quarterly test route	12.0
M2	Vibration route measurement at the drive-end bearing: overall level plus spectrum against alarm limits.	Monthly	Monthly PdM route	6.0
M3	Renew the flexible coupling element; inspect hubs and guard; check alignment.	5 years	5-year outage	1.6
M4	Insulation-resistance and polarization-index test on the stator winding; trend against previous results.	12 months	Annual outage	2.0
M5	Read and trend suction strainer differential pressure; clean the strainer if DP passes the action level.	2 weeks	Weekly operator round	6.5
M6	Inspect the seal area and drain: leak rate against the weep standard; report any growth since the last round.	Weekly	Weekly operator round	13.0
M7	Proof test: simulate falling suction pressure at the switch; verify trip at setpoint and pump stop; record the as-found condition.	8 weeks	8-week proof-test route	6.5
M8	Reverse-flow test with the pump stopped and the header pressurized: verify no sustained reverse rotation or flow; record the result.	12 months	Annual outage	4.0
M9	Oil sample from the bearing housing: viscosity, water, particle count, wear metals. Change oil on condition.	6 weeks	Monthly PdM route	4.0

The three decisions that produce no recurring task

M10: one-time change. Deadhead operation can distort the casing and fail the seal, and no inspection prevents a human error. The analysis raises a project for thermal relief or a casing-temperature trip: a design answer to a design problem.

M11: run-to-failure, on the record. External coating breakdown costs about $600 a year in expectation; recoating happens alongside other work. The decision and its basis are written down. That record separates run-to-failure from neglect.

M12: no scheduled task. The start relay's failure is hidden, but no feasible failure-finding task exists and the multiple failure has no safety or environmental consequence. The residual risk is accepted explicitly and revisited at each living review.

From the Failure Mode Library: centrifugal pumps (1 of 2)

Component	Failure mode	Cause / mechanism	Detection methods	Candidate task directions
Mechanical seal	Seal face wear and scoring	Abrasive solids in the seal chamber erode the faces; flatness is lost	Leak-rate trending on rounds; seal-chamber temperature	Condition-directed leak inspection with a leak-rate action limit
Mechanical seal	Seal face thermal cracking after dry running	Loss of prime or closed suction runs faces dry; heat checks the hard face	Gland leak observation; low-flow and dry-run protection checks	Condition-directed leakage checks plus dry-run protection review
Rolling-element bearings	Bearing fatigue spalling	Subsurface fatigue after long service at load; races flake	Vibration route; oil analysis debris count	Condition-directed vibration monitoring
Lubrication system	Oil oxidation and varnish foul the system	Hot running and long oil life oxidize the charge; varnish plates out	Oil analysis (acid number, varnish potential)	Oil analysis with time-directed change at condition limit
Impeller and wear rings	Erosion-corrosion opens the wear-ring clearances	Velocity and corrosive attack enlarge the ring gap; internal recirculation grows	Performance test (flow, head, power) against the curve	Condition-directed performance testing

Ten rows from the companion Failure Mode Library, in its working format. A full library row also carries five failure-effect columns (evidence, safety/environment, operations, physical damage, repair action), three consequence hints, and a typical P-F range. Those columns make a row ready to paste into an RCM analysis.

From the Failure Mode Library: centrifugal pumps (2 of 2)

Component	Failure mode	Cause / mechanism	Detection methods	Candidate task directions
Casing and pressure boundary	Casing gasket creep leaks at the joint	Thermal cycles relax the joint; gasket creeps and weeps	Round leak inspection	Condition-directed joint inspection after restarts
Coupling	Flexible element fatigue cracking	Cyclic flexing at misalignment fatigues the element or disc pack	Guard debris check on rounds; vibration trend	Condition-directed guard inspection
Suction strainer and suction path	Strainer blocks with debris	Process debris, scale, or maintenance leftovers load the element	Suction differential-pressure trend	Condition-directed DP trending with clean limit
Discharge check valve	Hinge-pin wear lets the disc pass reverse flow	Pin and bush wear lets the disc sit off its seat	Standby rotation observation; reverse-flow test	Failure-finding reverse-flow test at a calculated interval
Trips and instruments	Low-suction trip switch drifts and fails to trip	Setpoint drift, blocked impulse line, or contact failure disables the trip	Loop proof test with simulated low suction	Failure-finding proof test at a calculated FFI

The library's hints are starting points, not answers. Re-test every Evident? / Safety? / Operational? hint against your own operating context before you use it. The library contains no failure rates or MTBF figures; those belong to your plant.

The full products

RCM Analysis Workbook: $49.99

The analysis engine this sample is drawn from: a 9-tab Excel / Google Sheets workbook (Functions, Functional Failures, Modes & Effects, Decision Logic, Task Packaging, Calculators, and a 150-mode starter library across 10 equipment classes), plus the 19-page companion guide covering the method, the mathematics, facilitation, living review, and two printable workshop worksheets. The BFP-2 example has its own tab with live formulas: change any input and watch the chain re-derive before you trust it with a real asset.

Failure Mode Library: $24.99

450 failure modes across six equipment classes (centrifugal pumps, AC induction motors, industrial air compressors, gearboxes, fans and blowers, and belt conveyors), each written as a complete analysis row in the workbook's field order so rows paste straight into an RCM analysis. A free 28-row pump mini-library lets you test the format first.

Both are available at **shop.thetidyblueprint.com**; search "RCM" on the store. Apex Reliability Engineering is the professional line; the store sells and delivers the files.

Scope. These products implement the SAE JA1011 process structure for analysis and program design. They are professional-development and decision-support material. They are not certification products, JA1011 compliance claims, or engineering advice for any specific installation. All organizations, assets, and figures in the worked example are fictional.

Your email is used only to deliver your files. Apex Reliability Engineering never sells or shares your information and does not send spam.