

GRAVIX FORM FIELD EXPANSION SPEC — ADDENDUM

Expanded Options for Load Type, Cure Constraints, Environment, Surface Prep & Other Fields

February 2026

Purpose: Expands the option sets for all constrained dropdown/select fields across both the Failure Analysis and Spec Engine forms. Applies on top of `gravix-form-ux-addendum.md` (which handles combobox, zone layout, photo upload). Agent should implement these changes to the Zone 2 field components on both `/failure` and `/tool`.

Priority: HIGH — these fields carry the most analytical weight for AI quality. Constrained option lists produce worse AI output.

Design Principle: Every field that currently restricts input to a short single-select dropdown should be evaluated against this question: *Does a real manufacturing engineer's answer fit neatly into one of these options?* If no — expand the list, switch to multi-select, add conditional sub-fields, or accept free-form.

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1. LOAD TYPE — MULTI-SELECT EXPANSION

Form: Spec Engine (/tool) Zone 2 — also referenced in Failure Analysis description prompts

Current: Single-select dropdown, ~5 options (Shear, Peel, Tensile, Compression, Cleavage).

Problem: Real bonds see combined loads. An automotive structural bond sees shear + peel + vibration fatigue + CTE mismatch stress simultaneously. Single-select forces the engineer to pick one, losing critical context.

Change: Single-Select Dropdown → Multi-Select Chips

Component type: Multi-select chip bar (same component as Environment)

Options (12):

Chip Label	Tooltip (on hover/long-press)	AI Context Sent
Shear	Lap shear, sliding forces parallel to bond plane	load:shear
Peel	T-peel, 90° peel, forces pulling bond apart at edge	load:peel
Tensile	Butt joint pull, forces perpendicular to bond plane	load:tensile
Compression	Forces pressing bonded parts together	load:compression
Cleavage	Uneven pull — one end of bond loaded, other end fixed	load:cleavage
Torsion	Rotational / twisting forces on the bond	load:torsion

Impact / Shock	Sudden high-energy loads, drop testing, crash loads	load:impact
Vibration / Fatigue	Cyclic loading over time, engine vibration, road vibration	load:vibration_fatigue
Creep (Sustained Static)	Constant load over weeks/months/years, dead weight, spring tension	load:creep
Thermal Stress (CTE Mismatch)	Stress from differential thermal expansion of dissimilar substrates	load:thermal_stress_cte
Flexural / Bending	Bending forces across the bond, panel flex	load:flexural
Not Sure	AI will assess based on application context	load:unknown

Visual spec:

- Chip bar: horizontal wrap layout, gap-2, same styling as Environment chips
- Each chip: `bg-brand-800` , `border 1px solid #374151` , `rounded-full`, `px-3 py-1.5`, 13px text
- Selected: `bg-accent-500/20` , `border 1px solid #3B82F6` , `text-accent-400`
- Tooltip: 200ms delay, max-width 240px, `bg-brand-700` , 12px text, appears below chip on desktop, long-press on mobile
- “Not Sure” chip: if selected, all other chips deselect. If any other chip is selected, “Not Sure” deselects. Mutually exclusive with specific selections.
- Multiple selection: any combination except “Not Sure” with others. Common: Shear + Peel + Vibration (3 selected simultaneously).

Label: “What loads does the bond experience? (select all that apply)”

2. CURE CONSTRAINTS — RESTRUCTURE

Form: Spec Engine (`/tool`) Zone 2

Current: Single-select dropdown, ~3 options (Room temperature, Heat cure, UV cure).

Conflates cure mechanism with process constraints.

Problem: The current field asks “how should the adhesive cure?” but what the engineer actually needs to express is “what can my production line accommodate?” An engineer who says “room temperature” might actually mean “we have an oven but can’t exceed 80°C because the plastic warps.” An engineer who says “UV cure” might mean “we have a UV station but the geometry has shadow areas.” These distinctions change recommendations dramatically.

Change: Replace Single Dropdown with Two Sub-Fields

Sub-Field A: “What can your process accommodate?” — Multi-Select Chips

Chip Label	Tooltip	AI Context
Room Temp Only	No ovens, IR heaters, or heat sources available	<code>cure_constraint:room_temp_only</code>
Oven / Heat Available	Batch or conveyor oven on the production line	<code>cure_constraint:oven_available</code>
UV / Light Station	UV lamp or LED cure station; specify if shadow areas exist	<code>cure_constraint:uv_available</code>
Induction Available	Induction heating for metal substrates	<code>cure_constraint:induction_available</code>
Moisture-Initiated OK	Ambient humidity or applied moisture can trigger cure	<code>cure_constraint:moisture_ok</code>
Anaerobic OK	Metal-to-metal sealed gap, no air exposure during cure	<code>cure_constraint:anaerobic_ok</code>
Two-Part Mixing OK	Metering/mixing equipment available or manual mixing acceptable	<code>cure_constraint:two_part_ok</code>
One-Part Only (No Mixing)	Cannot do metering or mixing — single-component adhesive required	<code>cure_constraint:one_part_only</code>
Primer / Activator OK	Extra surface treatment step before bonding is acceptable	<code>cure_constraint:primer_ok</code>
No Primer	Cannot add surface	

(One-Step Only)	treatment steps — adhesive must bond as-is	cure_constraint:no_primer
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Label: "What can your production process accommodate? (select all that apply)"

Behavior notes:

- Some chips are mutually exclusive: "Room Temp Only" deselects "Oven / Heat Available" and vice versa. "Two-Part Mixing OK" deselects "One-Part Only" and vice versa. "Primer / Activator OK" deselects "No Primer" and vice versa.
- Other chips are freely combinable: "UV / Light Station" + "Primer / Activator OK" + "Two-Part Mixing OK" is a valid combination.
- If nothing selected, AI uses all constraint fields plus description to infer.

Sub-Field B: "Max cure temperature (°C)" — Conditional Number Input

Visibility: Only appears when "Oven / Heat Available" chip is selected. Slides in with 200ms animation below the chip bar.

Max cure temperature your substrate/process can tolerate

80

°C

Common: 60°C (most plastics), 80°C (engineering plastics), 120°C (metals/composites), 180°C (aerospace metals)

Spec:

- Input: number type, min 30, max 400, step 5, width 100px
- Helper text below: "Common: 60°C (most plastics), 80°C (engineering plastics), 120°C (metals/composites), 180°C (aerospace metals)"
- If user selects "Oven / Heat Available" but leaves max temp blank: AI receives `oven_available` without temperature limit — still useful context.

Sub-Field C: "UV shadow areas?" — Conditional Toggle

Visibility: Only appears when "UV / Light Station" chip is selected.

Does the bond geometry have shadow areas UV light can't

	reach?	
	[Yes — some areas won't get direct UV]	[No — full UV
	exposure possible]	

Impact: If shadow areas exist, AI recommends dual-cure adhesives (UV + secondary cure mechanism like moisture or heat) rather than UV-only adhesives. This is a critical distinction — a UV-only adhesive in a shadow area will never fully cure.

3. ENVIRONMENT — EXPANSION + CONDITIONAL DETAIL

Form: Both Failure Analysis (/failure) Zone 2 AND Spec Engine (/tool) Zone 2

Current: Multi-select chips, 6 options: High humidity, Chemical, UV/outdoor, Thermal cycling, Submersion, Vibration.

Problem: Missing critical environmental conditions that drive adhesive selection and failure analysis. “Chemical exposure” without knowing which chemical is nearly useless — IPA is benign, MEK destroys most adhesives. No cleanroom/outgassing option (critical for medical, aerospace, semiconductor). No sterilization option (critical for medical devices). No salt spray (critical for automotive, marine).

Change: Expand to 15 Chips + Conditional Sub-Fields

Options (15):

Chip Label	Tooltip	AI Context
High Humidity (>80% RH)	Sustained exposure to high relative humidity	env:high_humidity
Submersion / Water Contact	Partial or full water immersion, water spray, condensation cycling	env:submersion
Salt Spray / Marine	Salt fog, coastal atmosphere, de-icing salt, per ASTM B117	env:salt_spray
Chemical Exposure	Solvents, fuels, oils, cleaning agents — specify below	env:chemical

UV / Outdoor Weathering	Sunlight, rain, temperature swings, per ASTM G154/G155	env:uv_outdoor
High Temperature (Steady)	Continuous operation above 80°C — specify in Temperature Range	env:high_temp_steady
Low Temperature (Steady)	Continuous operation below -20°C — specify in Temperature Range	env:low_temp_steady
Thermal Cycling	Repeated hot-cold cycles, specify range in Temperature Range	env:thermal_cycling
Vibration / Dynamic	Engine vibration, road loads, machinery vibration	env:vibration
Cleanroom / Low Outgassing	Restricted outgassing per NASA ASTM E595 or ISO 14644 cleanroom	env:cleanroom_low_outgassing
Sterilization Required	Bond must survive sterilization cycles — specify method below	env:sterilization
Vacuum / Low Pressure	Space, high altitude, or vacuum chamber exposure	env:vacuum
Radiation Exposure	Gamma, X-ray, UV sterilization, or nuclear environment	env:radiation
Food Contact / FDA	Must comply with FDA 21 CFR or EU 10/2011 food contact regulations	env:food_contact
Electrical Insulation	Bond must provide or maintain electrical isolation	env:electrical_insulation

Conditional Sub-Field: Chemical Exposure Detail

Visibility: Appears when “Chemical Exposure” chip is selected.

Which chemicals? (select all that apply)
[Motor oil] [Hydraulic fluid] [Brake fluid] [Coolant/ glycol] [Gasoline/diesel] [Jet fuel] [IPA] [Acetone]
[MEK] [Toluene] [Bleach/NaOCl] [Acids] [Bases/Caustics]

[Cleaning agents]
Other chemicals: [_____]
e.g., hydrazine, Skydrol, specific customer fluids

Chemical chip options (14 + free-form):

Chip	AI Context
Motor Oil	chem:motor_oil
Hydraulic Fluid	chem:hydraulic_fluid
Brake Fluid (DOT 3/4)	chem:brake_fluid
Coolant / Glycol	chem:coolant_glycol
Gasoline / Diesel	chem:fuel_hydrocarbon
Jet Fuel (Jet-A, JP-8)	chem:jet_fuel
IPA (Isopropanol)	chem:ipa
Acetone	chem:acetone
MEK	chem:mek
Toluene / Xylene	chem:aromatic_solvent
Bleach / NaOCl	chem:bleach
Acids (specify below)	chem:acid
Bases / Caustics	chem:caustic
Cleaning Agents	chem:cleaning_agents

+ “Other chemicals” free-form text input — always visible at bottom of chemical chip section. Placeholder: “e.g., Skydrol, hydrazine, customer-specific fluids.”

Conditional Sub-Field: Sterilization Method

Visibility: Appears when “Sterilization Required” chip is selected.

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	Sterilization method (select all that apply)	
	[Autoclave (steam 121°C+)] [EtO (ethylene oxide)]	
	[Gamma radiation] [E-beam] [Hydrogen peroxide plasma]	
	[Dry heat]	

Chip	AI Context	Why It Matters
Autoclave (steam 121-134°C)	sterilization:autoclave	High temp + moisture + pressure — eliminates many adhesives
EtO (ethylene oxide)	sterilization:eto	Chemical attack — some adhesives absorb EtO and outgas later
Gamma Radiation	sterilization:gamma	Radiation degrades some polymers; dose matters (25-50 kGy typical)
E-beam	sterilization:ebeam	Similar to gamma but higher dose rate, different degradation profile
Hydrogen Peroxide Plasma	sterilization:h2o2_plasma	Oxidative — affects some silicones and acrylics
Dry Heat (160-180°C)	sterilization:dry_heat	Extreme temperature — limits adhesive choices severely

4. SURFACE PREPARATION — MULTI-SELECT EXPANSION

Form: Failure Analysis (/failure) Zone 2

Current: Single-select dropdown, probably ~5 options.

Problem: Real processes have multiple prep steps in sequence. An aerospace bond: solvent degrease → abrade → primer → dry. A quick production line: IPA wipe only. The AI needs to know ALL steps to assess where prep went wrong. Single-select loses the sequence.

Change: Single-Select Dropdown → Multi-Select Chips + Optional Detail

Options (14):

Chip Label	Tooltip	AI Context
Solvent Wipe (IPA)	Isopropanol cleaning	prep:ipa_wipe
Solvent Wipe (Acetone)	Acetone degreasing	prep:acetone_wipe
Solvent Wipe (MEK)	Methyl ethyl ketone cleaning	prep:mek_wipe
Abrasion (Sandpaper)	Manual scuffing with sandpaper, Scotch-Brite, or similar	prep:abrasion_manual
Grit Blast (Media Blast)	Aluminum oxide, glass bead, or other media blasting	prep:grit_blast
Plasma Treatment	Atmospheric or vacuum plasma surface activation	prep:plasma
Corona Treatment	Corona discharge surface treatment (typically for films/plastics)	prep:corona
Flame Treatment	Brief flame exposure for surface activation (typically polyolefins)	prep:flame
Chemical Etch	Acid etch, chromic acid anodize, FPL etch, phosphoric acid anodize	prep:chemical_etch
Primer Applied	Separate primer/activator applied before adhesive	prep:primer
Anodize / Conversion Coat	Anodizing, chromate conversion, phosphate conversion	prep:anodize_conversion
No Preparation	Bonded as-received, no cleaning or treatment	prep:none
Unknown / Not Documented	Prep steps not recorded or unknown	prep:unknown
Other	Specify in text field below	prep:other

Label: "What surface preparation was done? (select all steps, in any order)"

Optional detail text input: Always visible below chips. Placeholder: "Optional: describe

prep sequence, abrasive grit, primer product, dwell time, etc." This catches details like "P320 sandpaper" or "3M AC-130 primer, 30 min flash-off" that chips can't express.

Behavior:

- "No Preparation" and "Unknown" are mutually exclusive with all other chips (selecting either deselects all others, and vice versa).
- All other chips are freely combinable.
- Common multi-select: Solvent Wipe (IPA) + Abrasion (Sandpaper) + Primer Applied (3 steps).

5. GAP FILL — CONTEXT SELECTOR

Form: Spec Engine (/tool) Zone 2

Current: Bare number input (mm).

Problem: Engineers think about gap fill differently depending on the application. A controlled aerospace bondline at 0.2mm, an automotive panel gap at 1-3mm, and a construction cavity fill at 15mm require completely different adhesive rheologies and chemistries. A bare number loses the context.

Change: Add Context Radio Selector Above Number Input

Bond gap characteristics
<input type="radio"/> Controlled bondline — shims, spacers, or fixtures maintain precise gap
<input type="radio"/> Variable gap — irregular surfaces, some areas thicker than others
<input type="radio"/> Zero gap — press fit, interference fit, threaded
<input type="radio"/> Large cavity — filling a void or potting (>5mm)
<input type="radio"/> Not applicable / unknown
Gap dimension (mm): [_____]
If variable, enter the maximum expected gap

Options (single-select radio):

Option	AI Context	Impact
Controlled bondline	<code>gap_type:controlled</code>	AI recommends adhesives with specific rheology for bondline control, may suggest film adhesives
Variable gap	<code>gap_type:variable</code>	AI recommends gap-filling pastes, thixotropic adhesives, may flag risk of starved bondlines
Zero gap	<code>gap_type:zero</code>	AI recommends low-viscosity wicking adhesives, anaerobics, retaining compounds
Large cavity (>5mm)	<code>gap_type:cavity_fill</code>	AI recommends potting compounds, foam adhesives, or multi-step filling
Not applicable / unknown	<code>gap_type:unknown</code>	AI infers from other fields

Number input: Same as current, but helper text updates based on radio selection:

- Controlled: "Target bondline thickness (mm), e.g., 0.15, 0.25, 0.5"
- Variable: "Maximum expected gap (mm)"
- Zero: input hidden (not applicable)
- Large cavity: "Cavity depth (mm), e.g., 10, 25, 50"
- Not applicable: input visible with generic placeholder "Gap in mm, if known"

6. APPLICATION METHOD — ADDITIONAL OPTIONS

Form: Spec Engine (`/tool`) Zone 2

Current: Single-select dropdown, 7 options: Manual (syringe/gun), Manual (brush/spatula), Automated dispense, Spray, Film/tape, Jetting, Screen print.

Problem: Missing 3 common industrial methods. Still fine as single-select since an application typically uses one method.

Change: Add 3 Options

ADD to existing dropdown:

New Option	Position	AI Context
Roller Coat	After Spray	method:roller_coat
Robotic Bead / Swirl	After Automated Dispense	method:robotic_bead
Pre-Applied (Microencapsulated)	After Film/Tape	method:pre_applied

Updated full option list (10):

1. Manual (Syringe / Cartridge Gun)
2. Manual (Brush / Spatula / Trowel)
3. Automated Dispense (Meter-Mix)
4. Robotic Bead / Swirl Pattern
5. Spray
6. Roller Coat
7. Film / Tape
8. Pre-Applied (Microencapsulated)
9. Jetting
10. Screen Print

No other structural changes. Single-select dropdown is correct for this field.

7. REQUIRED FIXTURE TIME — MINOR ADDITION

Form: Spec Engine (/tool) Zone 2

Current: Dropdown with: <1 min, 1-5 min, 5-30 min, 30 min-2 hrs, >2 hrs, Not critical.

Change: Add One Option at Top

ADD as first option:

New Option	Position	AI Context
Instant / Contact Bond	First (before <1 min)	fixture:instant_contact

This covers contact adhesives, pressure-sensitive adhesives, and instant-bond cyanoacrylates used in rubber-to-metal, gasket bonding, and label/tape applications where parts bond on contact with no fixture period.

Updated full option list (7):

- 1. Instant / Contact Bond (zero fixture)
- 2. < 1 minute
- 3. 1-5 minutes
- 4. 5-30 minutes
- 5. 30 minutes - 2 hours
- 6. 2 hours acceptable
- 7. Not critical

8. INDUSTRY — EXPANDED LIST

Form: Failure Analysis (/failure) Zone 2

Current: Probably a short dropdown (~6 options).

Problem: Missing key verticals and missing the OEM vs supplier distinction that drives spec requirements (Ford WSS-M specs, VW TL specs, etc. only apply if you’re in their supply chain).

Change: Expand to 15 Options

Option	AI Context	Why Distinct
Automotive — OEM	industry:auto_oem	OEM specs (Ford, GM, VW, Toyota) drive adhesive selection
Automotive — Tier 1/2 Supplier	industry:auto_tier_supplier	Must meet OEM specs but works within process constraints
Automotive —	industry:auto_aftermarket	Less regulated, different failure

Aftermarket		profiles
Aerospace — Commercial	industry:aero_commercial	FAA/EASA certification, ASTM D1002/D3163, Nadcap
Aerospace — Defense / Military	industry:aero_defense	MIL-specs, classified processes, extreme environments
Medical Device	industry:medical_device	FDA, ISO 13485, biocompatibility, sterilization survival
Electronics / Semiconductor	industry:electronics	Outgassing, thermal management, CTE matching, cleanroom
Construction / Building	industry:construction	Large gaps, weathering, low-skill application
Marine	industry:marine	Salt water, constant submersion, biofouling
Rail / Transit	industry:rail_transit	Vibration, fire resistance (EN 45545), long service life
Energy (Wind / Solar)	industry:energy_renewables	Outdoor weathering, 20-30 year life, large structures
Energy (Oil & Gas)	industry:energy_oil_gas	Extreme chemicals, high temp, high pressure
Consumer Products	industry:consumer	Aesthetics, cost sensitivity, mass production
Packaging	industry:packaging	High speed, food safety, recyclability
Other / General Manufacturing	industry:other	Catch-all for niche industries

Single-select dropdown. Engineers work in one industry at a time.

9. FAILURE MODE — TOOLTIP ENHANCEMENT

Form: Failure Analysis (/failure) Zone 2

Current (per form UX addendum): Visual cards with diagrams, NOT required, helper text: "Not sure? Leave blank."

No structural change. The cards and optional behavior are correct. But add richer tooltips/descriptions to help engineers self-identify:

Card	Current Label	Enhanced Description (shown below diagram)
Adhesive	Adhesive Failure	"Clean separation — adhesive peeled off one surface entirely. Little or no residue on one side."
Cohesive	Cohesive Failure	"Adhesive itself tore apart — residue on BOTH surfaces. The adhesive was weaker than its bond to either surface."
Mixed	Mixed Mode	"Combination — some areas show clean separation, other areas show torn adhesive. Inconsistent bond quality."
Substrate	Substrate Failure	"The substrate broke, not the bond — adhesive held but the material around it cracked or delaminated."

Also add a fifth card:

Card	Label	Description	AI Context
Unknown / Visual	Can't Determine	"Not sure from visual inspection. Upload photos and our AI will help identify the failure mode."	failure_mode:unknown_visual

This fifth card explicitly signals that the user wants AI assistance identifying the failure mode, distinct from simply leaving the field blank (which means "I didn't bother selecting").

10. SHARED COMPONENT: CONDITIONAL SUB-FIELD

Several fields above use conditional sub-fields (max cure temp, UV shadow areas, chemical

detail, sterilization method). These should share a consistent pattern.

ConditionalSubField Component

```
interface ConditionalSubFieldProps {  
  parentChipValue: string;           // Which chip selection triggers this  
  visible: boolean;                  // Controlled by parent chip state  
  children: React.ReactNode;         // Inner content (chips, input, etc.)  
  label?: string;                    // Optional sub-field label  
}
```

Visual behavior:

- **Hidden → Visible:** 200ms slide-down animation, height from 0 to auto. Opacity 0 → 1.
- **Visible → Hidden:** 200ms slide-up. Values NOT cleared on hide (user might re-select the parent chip).
- **Indentation:** sub-field content indented 16px from parent chip bar, left border 2px solid #1F2937 to visually nest.
- **Background:** bg-brand-900/50 subtle differentiation from parent section.

Example render (Chemical Exposure selected):

```
| Environment (select all that apply) |  
| [High humidity] [✓ Chemical Exposure] [UV/outdoor] ... |  
| | |  
| | Which chemicals? (select all that apply) |  
| | [Motor oil] [✓ Brake fluid] [MEK] [Jet fuel] ... |  
| | |  
| | Other chemicals: [Skydrol hydraulic fluid] |  
| | |
```

11. IMPLEMENTATION CHECKLIST

Phase 1: Shared Components

- ☐ Build ConditionalSubField component (slide animation, indented, values preserved)
- ☐ Verify multi-select chip component handles mutual exclusion rules (e.g., "Not Sure" deselects all others, "Room Temp Only" ↔ "Oven Available")

Phase 2: Spec Engine Form — Zone 2 Field Updates

- ☐ Load Type: replace single-select dropdown → multi-select chips (12 options)
- ☐ Cure Constraints: replace single dropdown with:
 - Sub-field A: multi-select chips (10 process capability options)
 - Sub-field B: conditional max temp input (appears when "Oven" selected)
 - Sub-field C: conditional UV shadow toggle (appears when "UV" selected)
- ☐ Environment: expand from 6 → 15 chips
 - Add conditional chemical detail (14 chemical chips + free-form text)
 - Add conditional sterilization method (6 chips)
- ☐ Gap Fill: add context radio selector above existing number input (5 options)
 - Number input helper text updates based on radio selection
 - Number input hides when "Zero gap" selected
- ☐ Application Method: add 3 options to dropdown (Roller Coat, Robotic Bead, Pre
- ☐ Required Fixture Time: add "Instant / Contact Bond" as first dropdown option
- ☐ Verify Zone 2 expand/collapse still works with taller content
- ☐ Verify all new fields included in form submission payload
- ☐ Verify localStorage persistence covers all new chip selections and sub-fields

Phase 3: Failure Analysis Form – Zone 2 Field Updates

- ☐ Surface Preparation: replace single-select → multi-select chips (14 options)
 - Add optional detail text input below chips
 - Implement mutual exclusion: "No Preparation" / "Unknown" deselect all other
- ☐ Environment: same 15-chip expansion as spec form (shared component)
 - Same conditional sub-fields (chemical detail, sterilization method)
- ☐ Industry: expand dropdown to 15 options with OEM/supplier distinction
- ☐ Failure Mode: add "Unknown / Visual" as 5th card
 - Add enhanced descriptions below each diagram
- ☐ Verify Zone 2 expand/collapse works with taller content
- ☐ Verify all new fields included in submission payload
- ☐ Verify localStorage persistence

Phase 4: Backend

- ☐ Update spec engine request schema to accept:
 - load_types: string[] (was load_type: string)
 - cure_constraints: string[] (was cure_constraint: string)
 - max_cure_temp_c: number | null (new)
 - uv_shadow_areas: boolean | null (new)
 - environment: string[] (expanded options)
 - chemical_exposure_detail: string[] | null (new)
 - sterilization_methods: string[] | null (new)
 - gap_type: string | null (new, alongside existing gap_mm)
 - application_method: string (expanded options)
 - fixture_time: string (new option added)
- ☐ Update failure analysis request schema to accept:
 - surface_preparation: string[] (was surface_prep: string)
 - surface_prep_detail: string | null (new)
 - environment: string[] (expanded options)
 - chemical_exposure_detail: string[] | null (new)

- sterilization_methods: string[] | null (new)
- industry: string (expanded options)
- failure_mode: string (new "unknown_visual" option)
- Update AI prompt templates to include all new fields as structured context
 - Multi-select fields formatted as: "Load types: shear, peel, vibration/fatig
 - Conditional sub-fields included when present
 - Chemical detail formatted as: "Chemical exposure: brake fluid (DOT 3/4), ME
- Add normalizer mappings for new environment/chemical/sterilization values
- Test: all new fields pass through to AI, results reference them

Phase 5: Validation

- Verify all existing TC-3.x and TC-4.x tests still pass (modified forms)
- Run TC-57.11 (spec new fields) – update to include load type, cure constraint
- Run TC-57.4 (Zone 2 values submit when collapsed) – verify expanded fields su
- Run TC-47.1, TC-47.3 (auth gate) – verify new fields persist through auth
- Test: select 4 load types + 3 environment chips + cure constraints with max t
→ analysis results reference all inputs
- Test: chemical exposure detail "Skydrol" → AI warns about specific Skydrol co
- Test: sterilization "Autoclave" selected → AI eliminates non-autoclave-safe a
- Test: gap type "Zero gap" → number input hidden, AI recommends wicking/anaero
- Test: mobile layout – chip bars wrap correctly, conditional sub-fields access

FIELD CHANGE SUMMARY

Field	Form	Was	Now	Options
Load Type	Spec	Single-select, ~5	Multi-select chips	12
Cure Constraints	Spec	Single-select, ~3	Multi-select chips + conditional max temp + conditional UV shadow	10 chips + 2 sub-fields
Environment	Both	Multi-select, 6	Multi-select, 15 + conditional chemical detail + conditional sterilization	15 chips + 14 chemical chips + 6 sterilization chips + free-form
Surface Preparation	Failure	Single-select, ~5	Multi-select chips + optional detail text	14 + free-form

Gap Fill	Spec	Number input	Context radio (5) + conditional number input	5 radios + number
Application Method	Spec	Single-select, 7	Single-select, 10	+3 options
Fixture Time	Spec	Single-select, 6	Single-select, 7	+1 option
Industry	Failure	Single-select, ~6	Single-select, 15	+9 options
Failure Mode	Failure	4 visual cards (optional)	5 visual cards (optional) + enhanced descriptions	+1 card + descriptions

Fields NOT changed (confirmed fine): Product / Adhesive Used, Product Considered, Production Volume, Time to Failure, Required Strength, Additional Context, Temperature Range.

END OF FORM FIELD EXPANSION SPEC