PETROLEUM ENGINEERING TECHNICAL MANUAL

H_2S SOUR SERVICE OCTG MATERIAL QUALIFICATION GUIDE

Integrity. Reliability. Safe Production.

WELLS
MATERIALS
CORROSION
PERFORMANCE

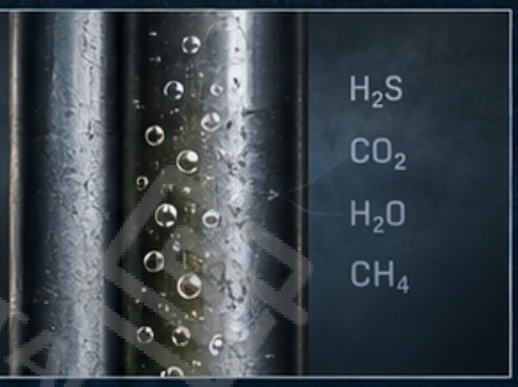
FOR A
SAFER AND
MORE RELIABLE
ENERGY FUTURE

ENGINEERING GUIDANCE FOR
SOUR SERVICE APPLICATIONS

- MATERIAL SELECTION
- ENVIRONMENTAL LIMITS
- TESTING & QUALIFICATION
- FIT-FOR-PURPOSE DESIGN
- OPERATIONAL CONSIDERATIONS

Sour Service Environment

H_2S-containing production fluid enters tubing



H_2S Exposure Zone

- Corrosion risk (sulfide stress cracking, general corrosion)
- Demanding environment for OCTG materials

Material Qualification

Fit-for-purpose OCTG materials qualified for sour service

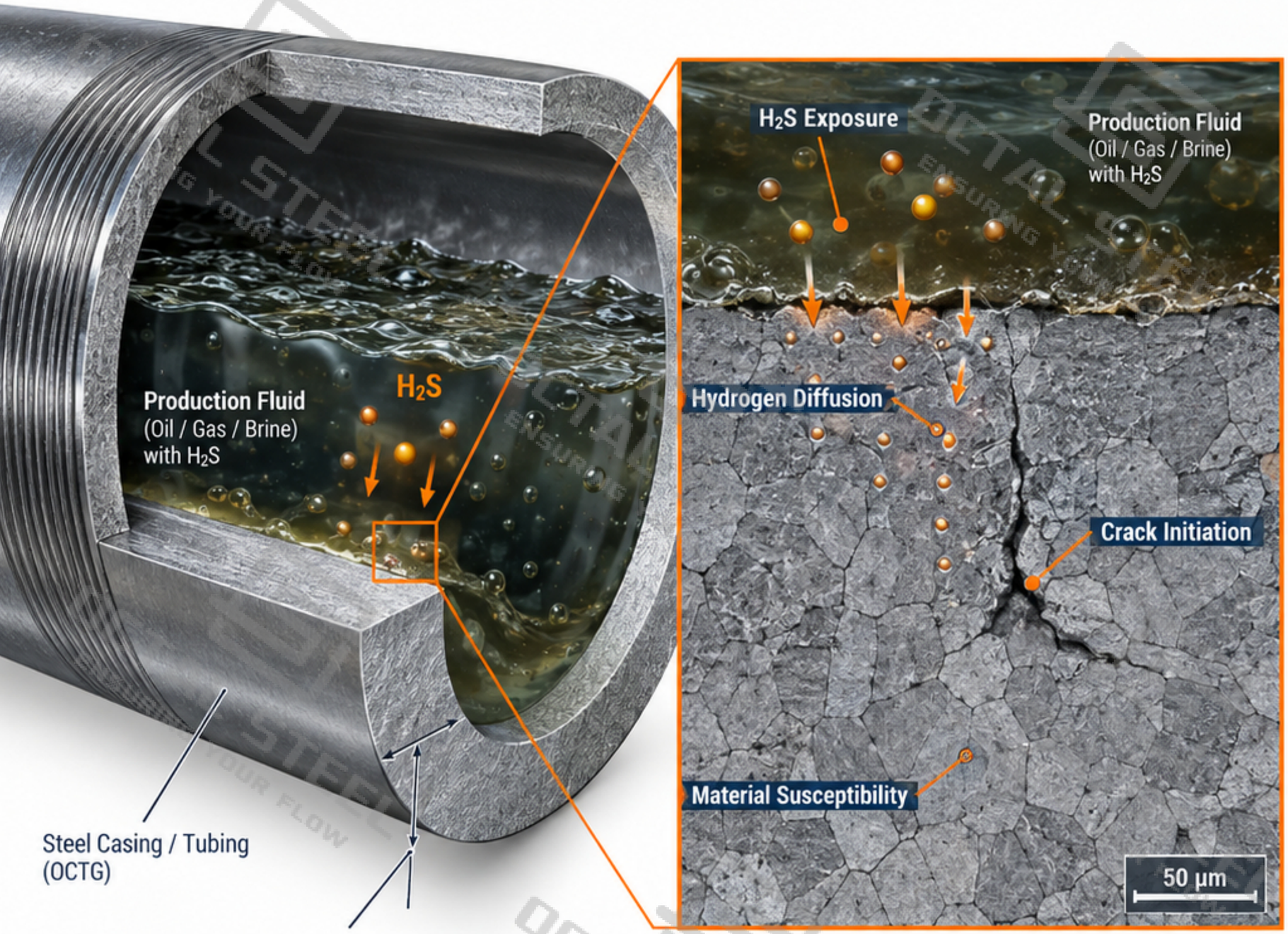
- SOUR SERVICE GRADE
- VERIFIED PERFORMANCE
- COMPLIANT WITH INDUSTRY STANDARDS

SUBSURFACE KNOWLEDGE.
STRONGER TOMORROW.

PEOPLE | TECHNOLOGY | RESPONSIBLE ENERGY

OCTG Sour Service Mechanism

From H_2S Exposure to Hydrogen-Assisted Cracking (HAC)



Metallurgical cross-section (schematic representation, realistic scale)
Showing H_2S at the fluid-steel interface, hydrogen ingress, and micro-crack initiation in a susceptible microstructure.

Key Influencing Parameters

H_2S Partial Pressure	• Higher H_2S increases hydrogen availability • Typically specified in psi or kPa
pH	• Lower pH (more acidic) increases H_2S dissolution and hydrogen ingress • Typically in produced water (pH ~ 3–7)
Temperature	• Higher temperature can increase reaction rates and hydrogen diffusion • Typically 50 – 200 °C in production environments
Applied Stress	• Tensile stress (internal pressure, bending, residual stress) promotes hydrogen-assisted cracking (HAC) • Includes operational and residual stresses
Hardness	• Higher hardness increases susceptibility to hydrogen cracking • Typically evaluated per NACE MR0175 (e.g., ≤ 22 HRC for sour service)
Heat Treatment	• Controls microstructure, hardness and residual stresses • Proper heat treatment reduces susceptibility (e.g., normalized or tempered condition)

OCTG SOUR SERVICE EVALUATION

INTEGRATING ENVIRONMENT, MATERIAL, AND LOADING FOR RELIABLE SERVICE

FIT FOR PURPOSE.
VERIFY FOR SERVICE.
SAFE AND RELIABLE PRODUCTION.

PRESSURE CONDITION

Pressure (P)

- Wellhead / downhole pressure
- Operating / design pressure
- Pressure fluctuations

TEMPERATURE CONDITION

Temperature (T)

- Bottomhole temperature
- Operating temperature
- Temperature cycling

FLUID CONDITION

Produced Fluid

- H_2S partial pressure / concentration
- CO_2 content
- pH
- Chloride (Cl^-)
- Other corrosive species (e.g. organic acids)
- Water cut / phase

MATERIAL CONDITION

OCTG Material

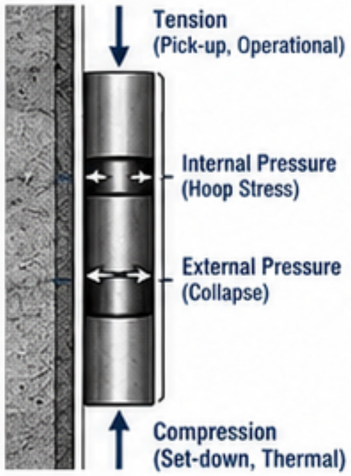
- Steel grade (e.g. J55, L80, P110)
- Metallurgy / microstructure
- Hardness / strength level
- SSC resistance (NACE TM0177)
- Manufacturing (seamless / ERW)
- Heat treatment condition

H_2S SOUR SERVICE ENVIRONMENT

OCTG IN CORROSIVE ENVIRONMENT

HIGH PRESSURE | HIGH TEMPERATURE | H_2S / CO_2 | AQUEOUS PHASE

APPLIED STRESS (LOADING)



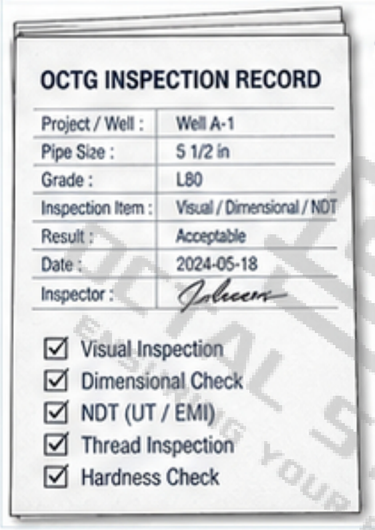
Mechanical Loading

- Tension / compression
- Internal / external pressure
- Bending (dogleg, well path)
- Torque (make-up, running)
- Cyclic / fluctuating loads
- Residual stress (manufacturing, welding)

SOUR SERVICE EVALUATION LOGIC

Environment Condition (P, T, Fluid) + **Material Condition** (Steel / SSC Resistance) + **Applied Stress** (Mechanical Loading) = **Sour Service Qualification Requirement**

QUALIFICATION / VERIFICATION



OCTG INSPECTION RECORD

Project / Well :	Well A-1
Pipe Size :	5 1/2 in
Grade :	L80
Inspection Item :	Visual / Dimensional / NDT
Result :	Acceptable
Date :	2024-05-18
Inspector :	

- ☑ Visual Inspection
- ☑ Dimensional Check
- ☑ NDT (UT / EMI)
- ☑ Thread Inspection
- ☑ Hardness Check

Verification Activities

- Material test reports (chemical, mechanical)
- SSC testing (NACE TM0177)
- NDT (UT, EMI, MT, PT)
- Dimensional / thread inspection
- Compliance with standards (NACE MR0175 / ISO 15156, API 5CT, etc.)
- Fitness-for-service assessment

KEY STANDARDS AND REFERENCES

- NACE MR0175 / ISO 15156 – Materials for use in H_2S-containing environments
- API 5CT – Specification for Casing and Tubing
- NACE TM0177 – Laboratory testing of metals for resistance to sulfide stress cracking
- API 571 / API 579 – Fitness-for-service (as applicable)

ENGINEERING DECISION BASIS

- Evaluate combined effect of environment, material and applied stress.
- Determine if OCTG meet sour service requirements per NACE MR0175 / ISO 15156.
- Apply appropriate mitigation (material selection, design control, operating envelope) if required.
- Verify through inspection and testing before deployment.

SOUR SERVICE MATERIAL QUALIFICATION FLOWCHART (OCTG)

IN ACCORDANCE WITH
API 5CT AND ISO 15156

API 5CT Grade

Select appropriate API 5CT grade (e.g. J55, K55, N80, L80, P110) for intended sour service.

KEY CONSIDERATIONS

- API 5CT latest edition
- Grade and product type (casing / tubing)
- Dimensions and tolerances
- Sour service intent (ISO 15156)

Steel Manufacturing Route

Verify steelmaking and pipe manufacturing route (e.g. EAF/BOF, casting, rolling, seamless).

MANUFACTURING ROUTE VERIFICATION

- Steelmaking process (EAF / BOF)
- Casting and ingot/strand practice
- Pipe forming route (seamless or welded)
- Secondary metallurgy (e.g. LF, VD)
- Cleanliness and inclusion control

Heat Treatment

Confirm heat treatment condition (e.g. normalizing, quenching & tempering) per API 5CT and manufacturer procedure.

HEAT TREATMENT CONTROL

- Furnace type and atmosphere control
- Temperature and soaking time
- Quench and temper parameters
- Records and traceability

Mechanical Property Verification

Verify mechanical properties meet API 5CT requirements (tensile, yield, elongation, hardness, etc.).

MECHANICAL TESTING

- Tensile test (ASTM E8 / E21)
- Hardness test (e.g. Rockwell C, ASTM E18)
- Impact test (if required)
- Dimensional and NDT verification

ISO 15156 Sour Service Qualification

Demonstrate compliance with ISO 15156 (material selection and testing) for sour service environment (H_2S).

QUALIFICATION EVIDENCE

- ISO 15156 compliance (Parts 1, 2, 3)
- SSC / HIC / SOHIC testing (as applicable)
- Metallurgical evaluation
- Material certificate / inspection report
- Final acceptance for sour service

OCTG Material Routes for Corrosion Service Applications

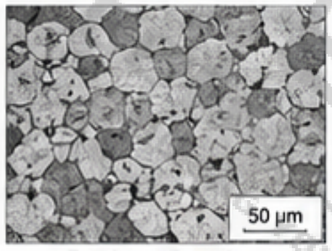
From Conventional Steel to Engineered Corrosion Resistance — Material Selection Based on Service Environment

OIL & GAS PRODUCTION
MATERIALS ENGINEERING
CORROSION MANAGEMENT
RELIABLE WELL INTEGRITY

Conventional Steel → *Material Development and Application* → **Enhanced Corrosion Resistance** → *Application Driven for More Severe Environments* → **CRA**

API 5CT Carbon Steel

WIDELY USED FOR CONVENTIONAL SERVICE



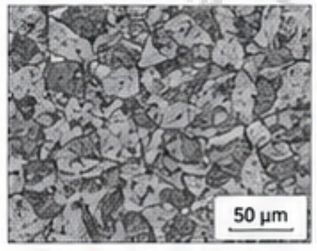
Ferrite + Pearlite
(carbon steel)

Typical CO_2 corrosion
with $FeCO_3$ scale

Material structure	Ferrite + pearlite (low alloy carbon steel)
Corrosion environment	CO_2, H_2S (low to moderate), chloride, formation water
Typical service condition	Conventional oil and gas wells Mild to moderate corrosion Moderate temperature and pressure

Chromium Bearing OCTG

IMPROVED CORROSION PERFORMANCE
FOR DEMANDING CONDITIONS



Tempered martensite
(with chromium)

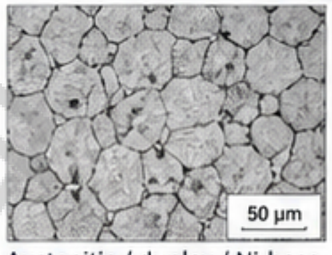
Typical protective scale
(e.g. Cr-rich oxide / mixed scale)

Material structure	Tempered martensite (with chromium, controlled alloying)
Corrosion environment	CO_2, H_2S (moderate to high), chloride, higher temperature
Typical service condition	Sour service and higher temperature More demanding environments than conventional carbon steel

Common grades: 3Cr 9Cr 13Cr

CRA Material

FOR HIGHLY CORROSIVE AND SPECIALIZED APPLICATIONS



Austenitic / duplex / Ni-base
(varies by alloy)

Minimal general corrosion
in aggressive media
(service dependent)

Material structure	Austenitic, duplex, super austenitic, or nickel-base alloy (varies by grade)
Corrosion environment	High CO_2, high H_2S, high chloride, organic acids, extreme temperature, complex / multiphase environments
Typical service condition	Severe corrosive service (e.g. HP/HT, high chloride, acid gas, specialized environments)

Examples: Stainless alloy (e.g. 304L, 316L, 317L, duplex)
Nickel alloy (e.g. Alloy 625, 825, C-276)

SELECT THE APPROPRIATE MATERIAL ROUTE BASED ON SPECIFIC SERVICE ENVIRONMENT, PERFORMANCE REQUIREMENTS AND LIFE-CYCLE COST

MATERIALS | ENVIRONMENT | DESIGN | OPERATION | INTEGRITY

OCTG | METALLURGY | CORROSION | APPLICATION ENGINEERING

MATERIAL SOLUTIONS
FOR A SAFER TOMORROW

OCTG SOUR SERVICE
PROCUREMENT AND VERIFICATION CHECKLIST

ENSURE MATERIAL INTEGRITY FOR DEMANDING ENVIRONMENTS

RELIABLE MATERIAL
SAFER WELLS
LONGER SERVICE LIFE

PROCUREMENT AND VERIFICATION CHECKLIST

Item	Key Considerations	Requirement / Record
Material Grade	API 5CT grade (e.g. JJ55, K55, N80, L80, P110)	As per purchase order
Standard Edition	API 5CT latest edition	e.g. API 5CT (2023)
Sour Service Requirement	NACE MR0175 / ISO 15156	Yes / No Specify version
H_2S Condition	H_2S partial pressure Total pressure	psi or MPa As per project data
Temperature	Operating temperature	°C / °F Minimum / Maximum
Pressure	Internal / external pressure	psi or MPa Design condition
Inspection Requirement	Visual, dimensional, NDT, hydrotest, drift, mechanical and chemical test	As per PO / standard Third-party if required
Traceability	Heat number, lot number, marking, documents	MTC, inspection report Full traceability

TRACEABILITY FROM MELT TO DELIVERY

Heat
Steelmaking and casting
Heat number generated

Manufacturing Lot
Pipe production
Lot identification

Test Record
Chemical, mechanical, NDT
Inspection reports

Pipe Marking
Grade, size, heat number
Permanent markings

Shipment
Packing, documentation
Ready for delivery

TRACEABLE MATERIAL
TRUSTED PERFORMANCE

OCTAL
PIPE | STEEL | SOLUTION