



Cairo, Egypt. November 7-8, 2022

MENAPS 2022

MIDDLE EAST AND NORTH AFRICA PERFORATING SYMPOSIUM

An Industry Standard for Perforating Tools - API 19 PT Introduction



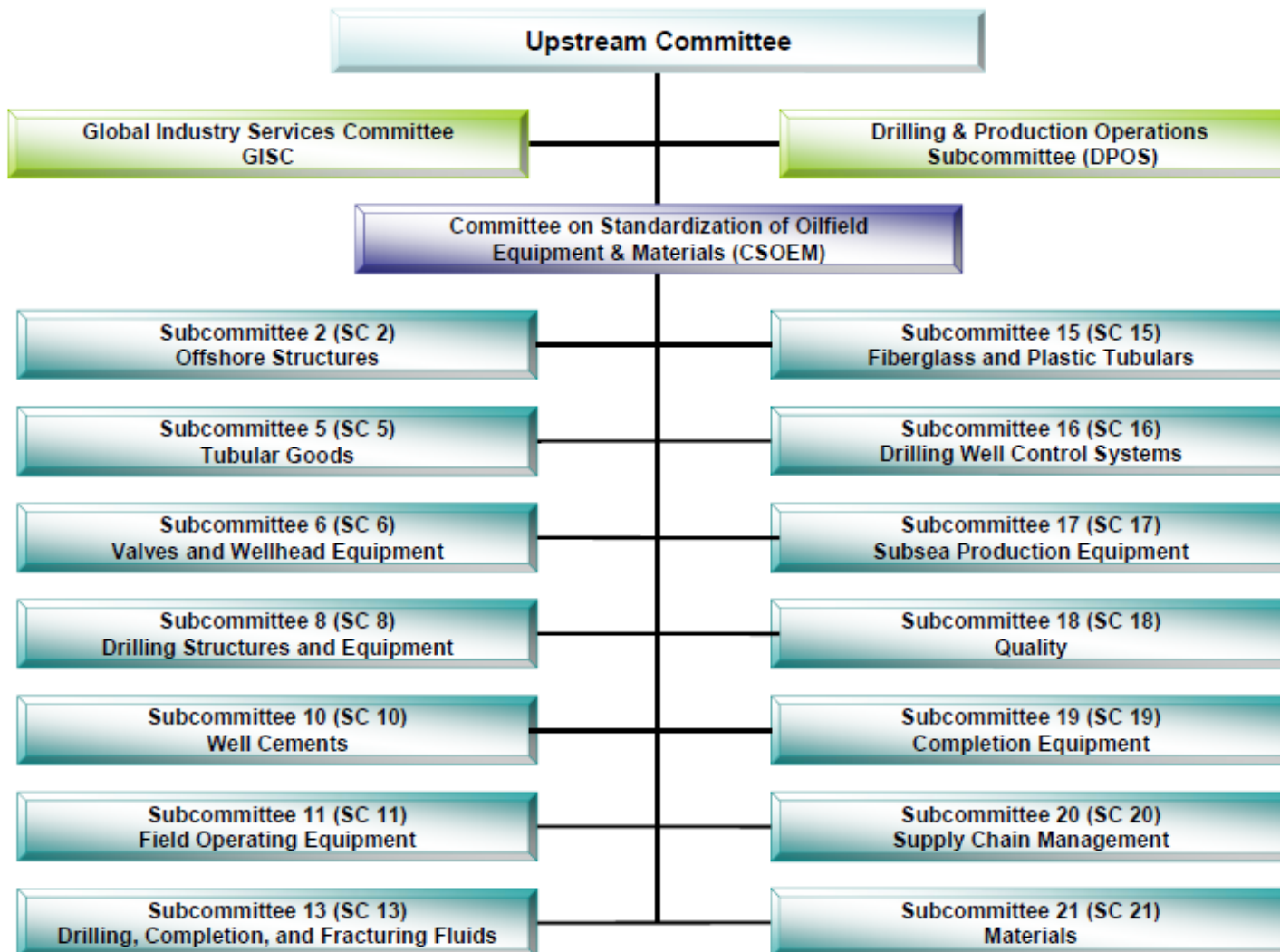
American Petroleum Institute Standard

- API publishes ~ 700 technical standards
- All aspects of the oil and natural gas industry
- Over 7000 active volunteers from over 50 countries



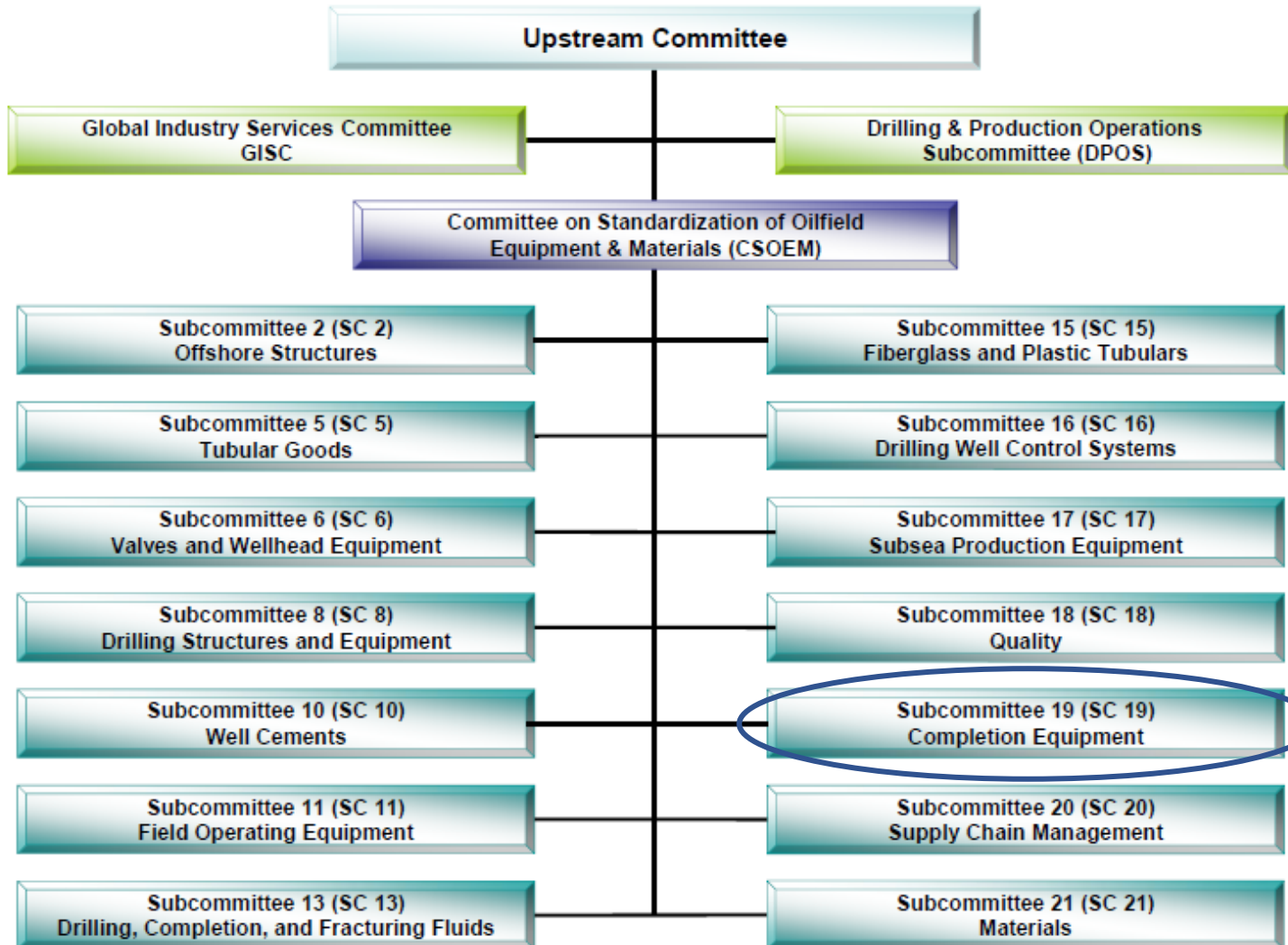


Upstream Standards Committees





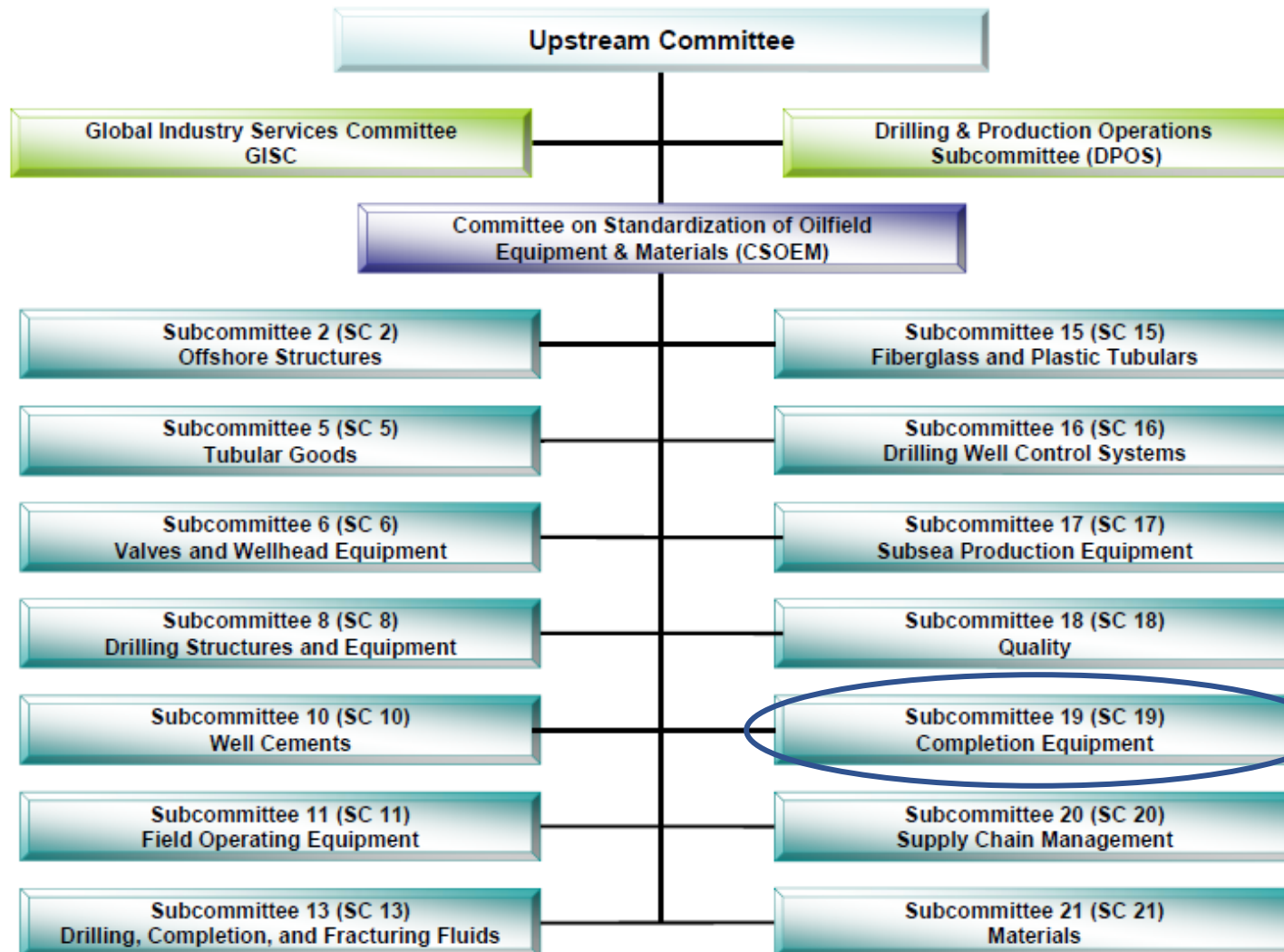
Upstream Standards Committees



SC19 - Subcommittee on Completion Equipment



Upstream Standards Committees

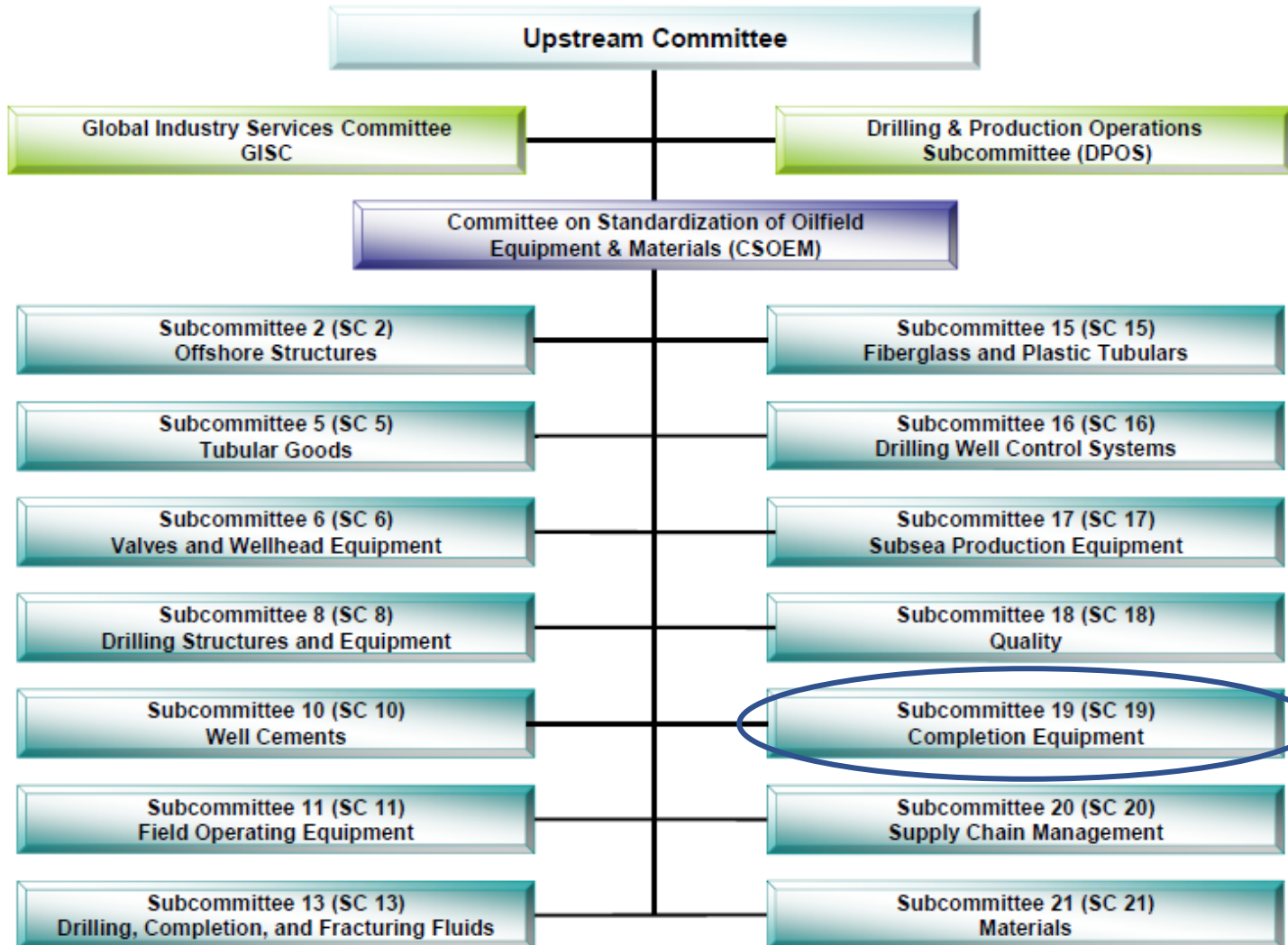


SC19 - Subcommittee on Completion Equipment

- Packers and Bridge Plugs - Spec 11D1
- Electric Submersible Pumps - RP 11S1
- Subsurface Flow Control Equipment - Spec 14A, RP 14B, Spec 14L
- Completion Accessories - Spec 19AC
- Perforator Evaluation - RP 19B
- Chemical Injection Valves - Spec 19CI
- Downhole Electronic Components - Spec 19E
- Gas Lift Equipment - Spec 19G1, Spec 19G2, Spec 19G3, RP 19G4, RP 19G5, RP 19G6, RP 19G9, RP 19G10, RP 19G11, 19G15, 19GLHB
- Inflow Control Devices - Spec 19ICD
- Interval Control Valves - Spec 19ICV
- Liner Hangers - Spec 19LH
- Openhole Isolation Equipment - Spec 19OH
- Downhole Perforating Tools - Spec 19PT
- Sand Screen Equipment - Spec 19SS
- Downhole Well Test Tools - Spec 19TT
- Subsurface Completion Isolation (Barrier) Valves and Related Equipment- Spec 19V
- Explosives Safety - RP 67



Upstream Standards Committees

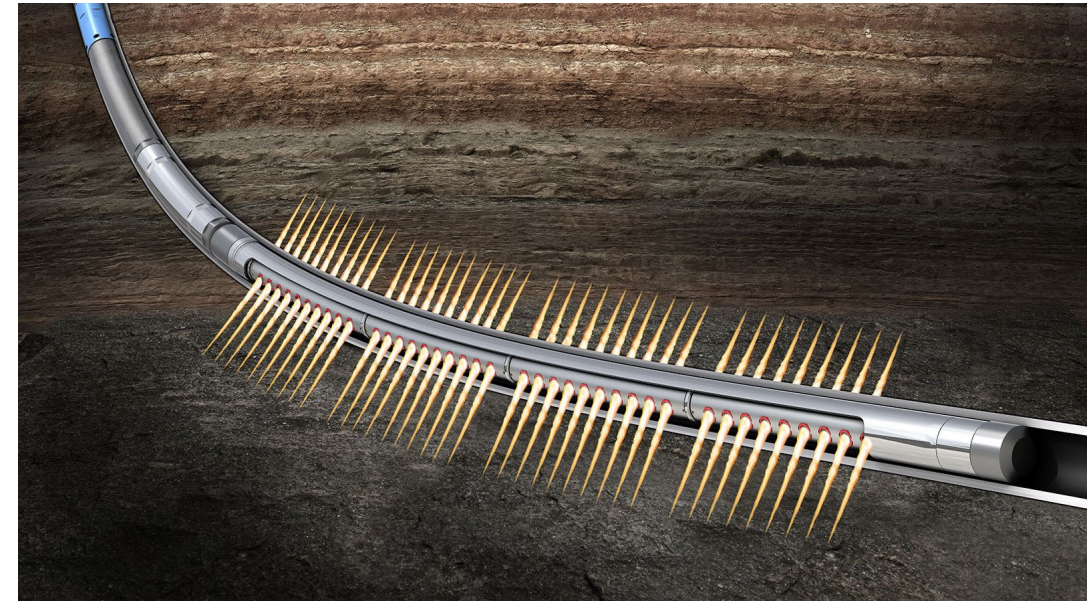


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- Packers and Bridge Plugs - Spec 11D1
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- **Explosive Safety – RP 67**

SCOPE

- Downhole perforating tools and related equipment
- Requirements & guidelines for design and use of tools
- Reporting and validating operation ratings
- Define operational ratings
- Define levels of quality control



CONTENTS

- 1) Functional Specification
 - User/purchaser
- 2) Technical Specification
 - Design
 - Validation
- 3) Supplier/Manufacturer Requirements
 - Documentation
- 4) Redress and Repair
- 5) Shipment and Storage
- 6) Service Center Requirements

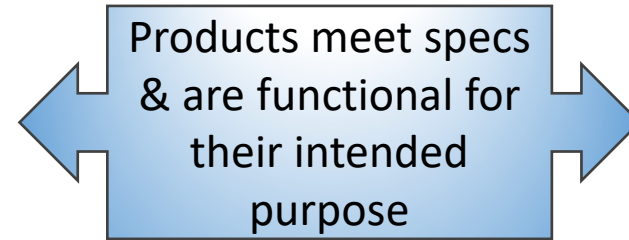


Functional Specification

User / Purchaser

- Product type
- Well parameters
- Operational parameters
- Environmental compatibility
- Design Validation grade
- Quality Control level

Requirements for Application



Technical Specification

Supplier / Manufacturer

- Product Datasheet
- Drawings & Specifications
- Functional performance
- Materials
- Design Validation grade
- Quality Control level

Product Design / Ratings

Tubulars for Gun Carriers

- Product Specification Level (PSL)
- Steel tubing used in the manufacture of perforating gun carriers shall be defined by a documented and traceable material technical specification (MTS).
- Testing Requirements: Mechanical, Chemical
- Process & Heat Treatment

Item	Product Specification Level		
	PSL1	PSL2	PSL3
Heat Treatment	Normalized, or Normalized and Tempered, or Quench & Tempered.	Normalized, or Normalized and Tempered, or Quenched & Tempered.	Quenched & Tempered.
Straightening Methods	Gag-press or Hot Rotary-Straightened, or Cold Rotary Straightened	Gag-press or, Hot Rotary-straightened, or Cold Rotary Straightened followed by Stress Relief	Gag-press or Hot Rotary-straightened, or Cold Rotary Straightened followed by Stress Relief

PSL1

PSL2

PSL3



Item	Product Specification Level		
	PSL1	PSL2	PSL3
Steel Chemical Composition	Certificate of Conformance or MTR showing conformance to a unified numbering system UNS, or chemical composition limits agreed between by the gun designer and the material supplier.	PSL1 plus: Phosphorous P ≤ 0.020%; Sulfur S ≤ 0.005%.	PSL1 plus: Phosphorous P ≤ 0.015%; Sulfur S ≤ 0.003%.
Clean Steel	No Requirements	Test as per ASTM E45 Method A – informative results	Test as per ASTM E45 Method A Limits defined by MTS
Austenitic Grain Size	No Requirements	Test as per ASTM E112, result shall be 5 or finer	Test as per ASTM E112, result shall be 7 or finer
Tensile Test	Tensile test according to ASTM E8 or ASTM A370. Limits defined by MTS	Tensile test according to ASTM E8 or ASTM A370. Limits defined by MTS	Tensile test according to ASTM E8 or ASTM A370. Limits defined by MTS.
Impact Toughness	No Requirements	Charpy V-Notch test according to ASTM E23. Limits and condition defined by MTS. For welded pipes, the impact test specimen shall be machined with the notch at the weld heat affected zone.	Charpy V-Notch test according to ASTM E23. Limits and condition defined by MTS. For welded pipes, the impact test specimen shall be machined with the notch at the weld heat affected zone.
Hardness Test	Test ASTM E18, (Rockwell C, 1 quadrant, 9 readings), API 5CT figure D.10. Hardness shall be lower than 23 HRC for this PSL only. ^a	Test ASTM E18, (Rockwell C, 1 quadrant, 9 readings), API 5CT	Test ASTM E18, (Rockwell C, 4 quadrants, 9 readings), API 5CT figure D.10. Limits defined by MTS.

a The maximum hardness requirement applies to PSL1 as an approximation of minimum ductility and impact toughness requirements, since those limits are not prescribed for this PSL level.

Tubulars for Gun Carriers

- Testing Frequency
- Traceability
- Non-Destructive Testing requirements

PSL1

PSL2

PSL3



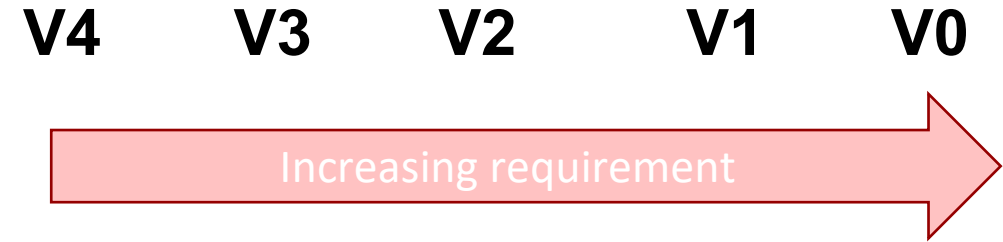
Item	Product Specification Level		
	PSL1	PSL2	PSL3
Chemical Composition Testing Frequency	1 ladle analysis per Heat	1 ladle analysis per heat 2 product analysis per heat from two different tubular products	1 ladle analysis per heat 2 product analysis per heat hardness from two different tubular products
Clean Steel Testing Frequency	Not applicable	1 test per heat/manufacturing lot	1 test per heat/manufacturing lot
Grain Size Testing Frequency	Not applicable	1 test per heat/heat treatment lot	1 test per heat/heat treatment lot
Tensile Testing Frequency	1 test per heat/heat treatment lot	2 test per heat/heat treatment lot	3 test per heat/heat treatment lot
Charpy Impact Testing Frequency	Not applicable	1 test per heat/heat treatment lot	2 test per heat/heat treatment lot
Hardness Testing Frequency	1 test per heat/heat treatment lot	2 test per heat/heat treatment lot	3 test per heat/heat treatment lot
Traceability	Material traceable to heat.	Material traceable to heat and lot.	Material traceable to heat and lot.

Design Validation

- Five grades of design validation
- V4 is the lowest level

Tools / Products

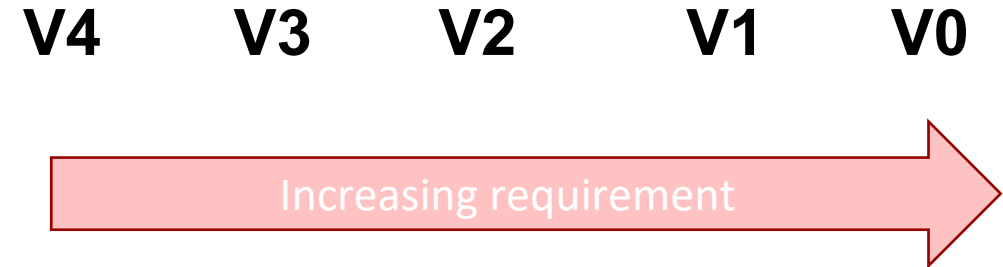
- Tandems & Connecting Hardware
- Perforating Guns
- Pipe Recovery Cutters
- Items not specified
 - defined and documented by the manufacturer.



Design Validation Grade	Grades Covered
V0	V0, V1, V2, V3, V4
V1	V1, V2, V3, V4
V2	V2, V3, V4
V3	V3, V4
V4	V4

Tandems & Connection Hardware Design Validation

- V4:
 - Validation by design calculation only
- V3 to V0:
 - Design calculation methodology
 - Pressure Test Required



Perforating Gun Design Validation

Validation Grade	Validation Test Requirements for Perforating Guns		
	Static Collapse Pressure	Dynamic Survivability	Drop Impact
V4	Supplier/ manufacturer-defined	Supplier/ manufacturer-defined	Supplier/ manufacturer-defined
V3	Single Collapse Test	Single test with nominally loaded charges	Single Drop Test
V2	Single Collapse Test	Single test with over-loaded charges defined by supplier/manufacturer	Single Drop Test
V1	Single Collapse Test	Single test with 3% min. over loaded charges	Single Drop Test
V0	Single Collapse Test	Single test with 5% min. over loaded charges	Single Drop Test

Increasing requirement



Perforating Guns

- Static Collapse Pressure
- Dynamic Survivability
- Drop Impact

Static Collapse Pressure

- V4: Supplier/manufacturer defined
- V3 to V0: Single Collapse Test
 - Collapse Pressure Test
 - Adjusted Pressure Test Value – Proof Test Methodology
 - Legacy method from RP 19B (old section 3.14)
- Collapse Pressure Service Factor
 - P_t/P_r
 - P_t = calculated per External Pressure Resistance API-5C3
 - P_r = gun operational pressure rating

Static Collapse Pressure

- Test Temperature:
 - Rating +/-10°F
 - 1 hr. minimum soak
- Test Pressure:
 - 1.05 x P_r (rated operational pressure)
 - Five-minute hold stabilized test pressure
- P_{CA} (Actual test pressure value) = Last pressure held for five minutes.
- C_A (Calculated collapse value) = based on actual gun test specimen.
- C_{LCM} (Calculated Least Material Conditions) = hypothetical gun based on worst case conditions as permitted by design specifications.
- Gun system length minimum = 8x nominal diameter

$$P_T = P_{CA} \times \frac{C_{LMC}}{C_A}$$

Dynamic Survivability Test

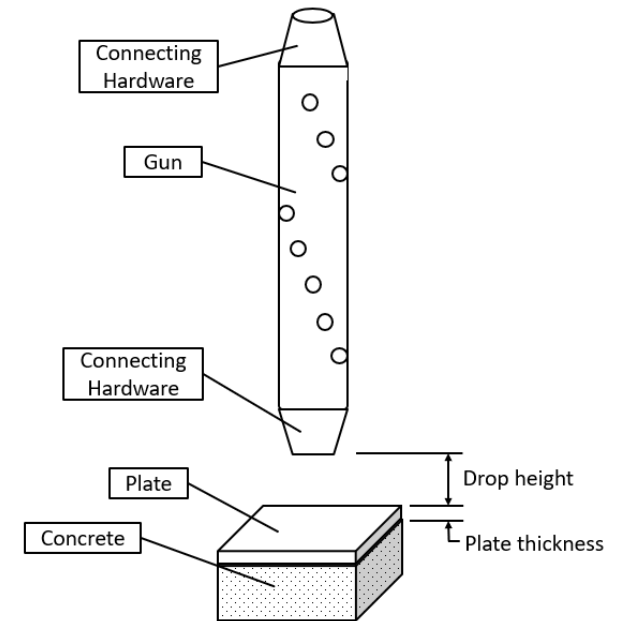
- Purpose: validation of system exposed to explosive detonation
- Validate each variation of raw tubular material by supplier/mill, OD size, and grade.
- May use a “worst-case” system to validate a product family.
- Fluid or Air: Validated by shooting in air is also validated for fluid.
- Pass / Failure Criteria is defined by the manufacturer/supplier.

- V4: supplier/manufacturer defined
- V3: nominally loaded charges
- V2: over-loaded charges per mfg. definition
- V1: 3% over-loaded charges
- V0: 5% over-loaded charges




Drop Impact Test

- Purpose: validate gun system will not be susceptible to distortion or buckling of components.
- Distortion or buckling- that may present a safety or performance concern.
- V4: supplier/manufacturer method.
- V3 to V0:
 - Drop height = 1 ft.
 - Plate = 1" thick ASTM A36 (or equivalent)
 - Longest unsupported internal structure member
 - May be inert system of equivalent weights
 - Gun may be closed or open.
 - Record measurements & conditions
- Failure Criteria:
 - Determined that the system would not perform as designed or if an explosive safety concern.



Cutter Design Validation

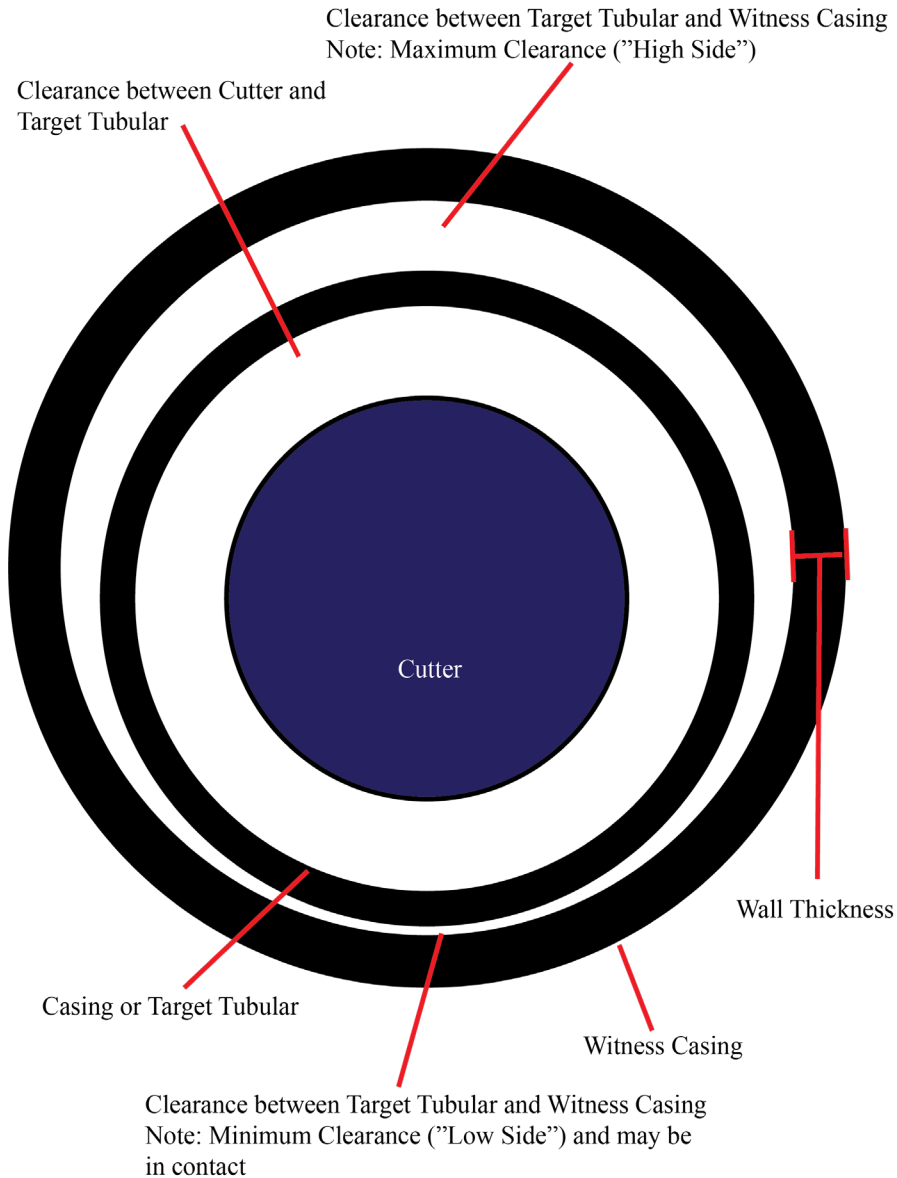


Validation Grade	Validation Test Requirements for Cutter
V4	Supplier/ manufacturer- defined
V3	Collapse Survival at ambient, Functional Test at ambient Pressure and Temperature
V2	Functional test at operational pressure, ambient temperature
V1	Functional test at operational pressure with witness plate
V0	Functional test at operational pressure and temperature with witness plate

Cutter Functional Test

- Explosive/energetic components aged 28 days.
- Percentage of wall remaining (% or sq. in.)
- Swell: largest diameter of target
- Cutting tool integrity & swell
- Witness Casing damage
- Radial clearance to Witness
- Debris

Cutter Functional Test



- Standardized Test Set-Ups

Target & Witness	Pipe Size, OD	Casing or Tubing
	in.	API Grade
Tubing	2 3/8 – 4 1/2	P-110
Casing	5 – 13 5/8	P-110
Drill pipe	2 7/8 – 6 5/8	S-135
Witness	All	L-80

Target To Be Cut		Witness Casing			
OD (in.)	OD (in)	OD (in.)	Weight (lb/ft)	OD (in)	Wall Thickness (in)
2-3/8	2.375	3-1/2	9.20	3.500	0.254
2-7/8	2.875	4	10.70	4.000	0.262
3-1/2	3.500	5	15.00	5.000	0.296
4	4.000	5-1/2	17.00	5.500	0.304
4-1/2	4.500	7	32.00	7.000	0.453
5	5.000	7	32.00	7.000	0.453
5-1/2	5.500	7	32.00	7.000	0.453
7	7.000	9-5/8	47.00	9.625	0.472
7-5/8	7.625	9-5/8	47.00	9.625	0.472
8-5/8	8.625	13-3/8	61.00	13.375	0.430
9-5/8	9.625	13-3/8	61.00	13.375	0.430
10-3/4	10.750	13-3/8	61.00	13.375	0.430
11-3/4	11.750	13-3/8	61.00	13.375	0.430
13-3/8	13.375	18-5/8	87.50	18.625	0.435
13-5/8	13.625	18-5/8	87.50	18.625	0.435

Supplier / Manufacturer Requirements

- Quality Requirements
 - Defines three quality levels, (QL)
 - QL3: Supplier/Manufacturer Defined
 - Type 1 components or weld: isolates pressure and/or loaded in tension
 - Type 2 components or weld: not Type 1

QL3

QL2

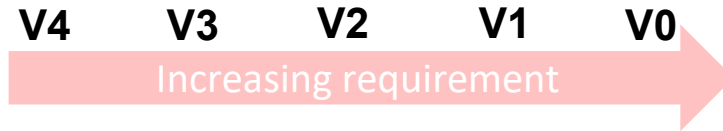
QL1



Item	QL3	QL2	QL1
Metallic material	Supplier/Manufacturer defined	COC or MTR	MTR for Type 1 components COC or MTR for Type 2 components
Nonmetallic material	Supplier/Manufacturer defined	COC or MTR	COC or MTR
Castings	Supplier/Manufacturer defined	COC	MTR for Type 1 components COC or MTR for Type 2 components
Heat treatment	Supplier/Manufacturer defined	COC (subcontractor) Job lot results verification (supplier/manufacturer)	COC (subcontractor) Job lot results verification (supplier/manufacturer)
Component traceability	Supplier/Manufacturer defined	Job lot traceable for Type 1 components	Job lot traceable for Type 1 components
Component dimensions	Supplier/Manufacturer defined	Sampling plan	Sampling plan
Welding			
Type 1 welds	Supplier/Manufacturer defined	Visual	Surface NDE per sampling plan and visual
Type 2 welds	Supplier/Manufacturer defined	Visual	Visual
Hardness			
Type 1 components	Supplier/Manufacturer defined	Supplier/Manufacturer defined	Per sampling plan
Type 2 components	Supplier/Manufacturer defined	Supplier/Manufacturer defined	Supplier/Manufacturer defined
Component NDE			
Type 1 components	Supplier/Manufacturer defined	Supplier/Manufacturer defined	Surface NDE per sampling plan
Type 2 components	Supplier/Manufacturer defined	Supplier/Manufacturer defined	Supplier/Manufacturer defined
Shear devices	Supplier/Manufacturer defined	Shear verification	Shear verification
Assembly/General			
Assembly verification	Supplier/Manufacturer defined	Supplier/Manufacturer defined	Supplier/Manufacturer defined
Assembly traceability	Supplier/Manufacturer defined	Supplier/Manufacturer defined	Supplier/Manufacturer defined
QC documentation	Supplier/Manufacturer defined	Supplier/manufacturer retained	Supplier/manufacturer retained

Design

- Validation Grades
 - Bullets
 - Bullets

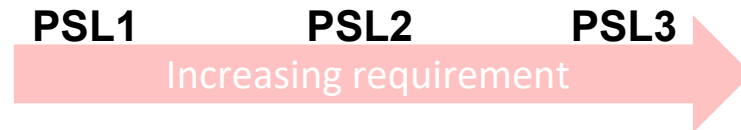


Scaling, Calculations,
Testing (Pressure, Collapse, Drop, Survivals)

- V4: supplier/matrix defined
- V3: nominally loaded charges
- V2: over-loaded charges per mfg. definition
- V1: 3% over-loaded charges
- V0: 5% over-loaded charges

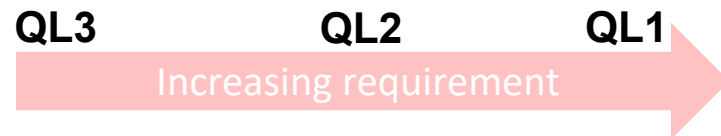
Material

- Gun Raw Material



Heat Treat, Chemical, Mechanical, Testing frequency,
Traceability, NDE

Quality Levels



Specifications, Material Test Reports,
Non-Conformances

Shipment and Storage

Specifications, thread protectors, moisture protection

Service Center Requirements

Field Camps: QC, Manuals, traceability, documentation & records retention

Future Additions for Future Editions

- Firing Head Design & Validation
- Tubulars for Gun Carriers – Raw Material
 - Fracture Toughness
 - API specifications for guns tubulars
- Shaped Charges
 - Validation Grades
 - Quality Levels
- Standard Gun Threads
 - API Gun 3-3/8" ...



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Q&A



SUBTITLE

- Bullets
- Bullets