

Development of a High Pressure (5000 psi) Gas Gun for H₂S and CO₂ Service

Norman W. Hein, Jr., P.E.
Oil & Gas Optimization Specialists, Ltd. (now with NPS - Norris/AOT),

James N. McCoy
Echometer, and

Lynn Rowlan
Echometer

ABSTRACT

Recently, an intrinsically safe, high pressure, gas gun was developed and presented at the 2010 SWPSC. This development was certified for Div 1/Class 1 well locations. Extending this development was the need to manufacture this gun for 5000 psi well service for operations in hydrogen sulfide and carbon dioxide fluid service. This presentation will discuss the industry requirements for materials selection according to standard NACE MR0175/ISO 15156. Also presented will be the main gas gun components in the fluid path and the appropriate selection of materials resistant to cracking and corrosion in this service.

INTRODUCTION

Recently, a high pressure gas gun for sending sound down a well casing-tubing annulus to determine operating practices was developed for certification in Div 1/Class 1 well locations.¹ While this equipment was intrinsically safe, it was not necessarily accepted as resistant to cracking in hydrogen sulfide (H₂S) or carbon dioxide (CO₂) fluid service. The manufacturer of this equipment was requested by production operating companies to extend the capabilities of this equipment to be able to also be installed in these potentially corrosive acid gas environments.

BACKGROUND MR0175 & ISO 15156

The development of industry standards for selection of materials to be used primarily in H₂S environments dates back to 1963 when NACE Technical Committee T-1B issued standard 1B163. This document was the first attempt to provide the industry with a list of referenced materials that showed acceptable performance and did not crack in hydrogen sulfide environments.

Industry work continued collecting materials for specific equipment that did not crack. In 1968, NACE Technical Committee T-1F released NACE Recommendation 1F166, "Sulfide Cracking Resistant Metallic Materials for Valves for Production and Pipeline Service."

The original issue of the NACE Materials Requirement (MR) standard 0175 was released in 1975. It was entitled "Materials for Valves for Resistance to Sulfide Stress Cracking in Production & Pipeline Service." The document expanded the various materials for valves and other production equipment that had proven resistance to cracking. This document became so popular and accepted in the industry, that in 1976, the Texas Railroad Commission adopted this standard and required it for equipment selection for H₂S service.

In 1978, a new standard was released. This document's title was: "Sulfide Stress Cracking Resistant Metallic Material for Oilfield Equipment."² However, since more than one material type was included in the standard, in 1984 a "s" was added by the NACE T-1F-1 committee to make "Materials" and the document was expanded to cover a variety of production and drilling equipment, many more materials and expanded temperature considerations.

In the mid-1990s, NACE approached ISO Technical Committee (TC) 67, who were responsible for development worldwide standard for oil and gas service, to see if the MR0175 standard could be modified and accepted as an international, worldwide standard. After much discussion, a co-chaired NACE & ISO group was formed with the goal to develop and expand the standard to include all mechanisms of cracking that can be caused by H₂S. These included:

- Sulfide Stress Cracking (SSC),
- Stress Corrosion Cracking (SCC),
- Hydrogen-induced Cracking (HIC),
- Step-wise cracking,
- Stress-oriented hydrogen induced cracking,
- soft zone cracking, and
- galvanically induced hydrogen stress cracking.

Also included in the standard were the effects of pH and temperature on the potential for cracking. The resulting ISO standard was 15156 and was entitled "Petroleum and Natural Gas Industries - Materials for Use in H₂S Containing Environments in Oil and Gas Production."³ After the first parts of this standard was approved in 2001, it was re-balloted and accepted as ANSI/NACE as an acceptable standard for USA applications and co-marked as NACE MR0175 / ISO 15156.

While the general requirements for materials type, cracking service and selection of materials was discussed in the first part, later parts were issued in 2003 covering carbon and low alloy steels in Part 2 and corrosion resistant alloys (CRAs) in part 3. Once these parts were completed and issued, it was generally accepted that 2003 would be used as the publication date.^{4,5} However, since these three parts were published, there were a number of editorial and technical changes made to each standard using technical circular and technical corrigendum document extensions. Now there are a total of 11 standard publications that include the original base part, and these other two types of documents.

SULFIDE STRESS CRACKING (SSC)

Sulfide stress cracking (SSC) is defined as "brittle failure caused by cracking under the combined action of tensile stress and corrosion in the presence of water and H₂S. SCC is actually a special case of hydrogen embrittlement that occurs when H₂S dissociates, in the presence of water, into hydrogen and sulfide ions. Diffusion of hydrogen into a metal is then catalyzed by the presence of sulfide ions which promotes the hydrogen embrittlement.

These standards have provided a discussion of the major factors that need to be considered for SSC susceptibility. It used to be that the major factor to determine the potential for cracking was just the partial pressure of H₂S in either an oil or gaseous environment. The graph shown in Figure 1 was used to determine the cracking regions. However, the industry work to expand the standard has shown that there are six factors that need to be considered to determine the potential for SCC. These factors include:

1. Chemical composition, strength, heat treatment, and material microstructure,
2. Hydrogen ion concentration (pH),
3. H₂S concentration and total pressure (or H₂S partial pressure) of the process environment,
4. Total tensile stresses (accounting for both applied and residual stresses),
5. Process temperature, and
6. Exposure time.

COMPONENTS SERVICE CONDITION

While these factors may be considered, part 1 of this standard goes on to explain there were developed a number of exceptions to be concerned about the potential for SCC. Tables 2 and 3 provide examples of the industry applications along with the permitted exclusions to use these documents for the environments. Reviewing these tables showed that sucker rod pumps and rods, electrical submersible pumps and other artificial lift equipment had been provided an exclusion. Thus, it could be considered that the high pressure gas gun would not need to investigate and obtain acceptable SCC materials. However, the manufacturer discussed with the end users their concerns and it was decided that this equipment would be developed using the various standard parts to be assured there would be no potential for cracking and the gun could be certified for H₂S service.

Clause 6 in Part 1 of the standard discusses the need to establish the service condition to assure the proper selection of materials that will be exposed to the fluid path. Those materials not in the flow path and have no potential to be contacted by the produced fluids would have no concern for SCC. However, for those materials in the potential flow path, then the following factors need to be consider:

- H₂S partial pressure,
- in situ pH,
- the concentration of dissolved chlorides or other halides,
- The presence of elemental sulfur or other oxidant,
- Temperature,
- Galvanic effects
- Mechanical stress, and
- time of exposure to come in contact with a liquid water phase

It should be noted that the exposure time, especially with a liquid water phase, is critical to determine appropriate cracking potential.

When the environments in the casing - tubing annulus that the gas gun are exposed to are considered, it can be concluded that there typically is not liquid water phase present. As such, there should be no potential for cracking of any of the gun component materials. Using part 3 of the standard, it was recommended that the gas gun be made of standard certified materials for the most severe application to all the end user the possibility of using the gun system in any well location and producing condition.

GAS GUN COMPONENTS & MATERIALS SELECTION

There are four main components for the high pressure gas gun. These include the gun body or housing, the various valves (1/4" and 1/2" ball valves and a check valve), the pressure gauge, and the pressure transducer diaphragm.

The various materials listed in part 3 of the standard were reviewed to determine the condition and restrictions to the normal materials to see what adjustments were required to select the prequalified material to certify conformance.

The various materials that each of the four components that could be used for fabrication of the gun system were investigated. The following lists the materials described in Table A.7 of part 3 for the components that will not have SCC concerns.

- The gun case or housing should be made from austenitic stainless steel (UNS S0304 and S0316),
- The valving used Table A.4 for the valving and showed 316 acceptable,
- The pressure gauges in table A.16 should be made from nickel based (MonelTM), and
- Table A.40 showed that cobalt alloys for the diaphragms, pressure measuring devices, and pressure seals for the pressure transducer diaphragms would be acceptable.

CONCLUSIONS

1. It is possible to construct and certify a 5000 p.s.i. gas gun using acceptable standard materials for SSC/H₂S service.
2. CO₂ corrosion should not be an issue at any pressure if the materials used for SSC resistance are used since these materials also are resistant to this type of corrosion.
3. Additionally, there should not be corrosion from CO₂ gas especially since there typically is no liquid water phase at the field location where the equipment is installed.

RECOMMENDATIONS

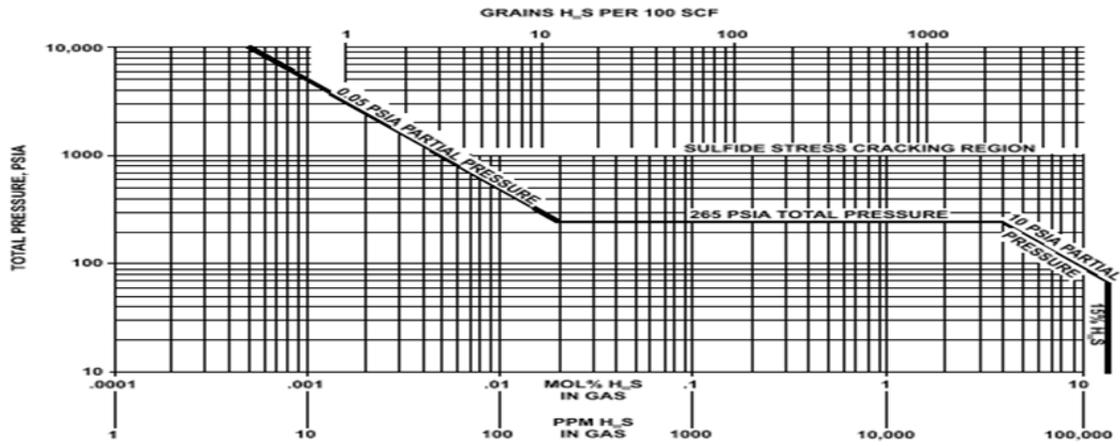
1. Some changes may be necessary for materials receiving department to either have the materials supplier or the company receiving department mark (permanently stamp or paint/color code) these resistant materials and components as H₂S resistant to assure separation from other materials not specifically certified.
2. The marked materials should be stored in separate bins from similar components and materials that are not certified for H₂S service.
3. An alternate solution for the manufacturer to consider is to order all materials for gas guns for H₂S service with the required certification documentation, if there truly is no major difference in cost compared to existing materials and components.

REFERENCES

1. McCoy, J.N., et al, "Intrinsically Safe Fluid Level Instrument for Hazardous Environments, SWPSC, Lubbock, TX., 2010.
2. ANSI NACE Standard MR0175, "Metals for sulfide stress cracking and stress corrosion cracking resistance in sour oilfield environments," Houston, TX.
3. NACE MR0175/ISO 15156 - 1, "Petroleum and natural gas industries—Materials for use in H₂S-containing environments in oil and gas production—Part 1:General principles for selection of cracking-resistant materials," NACE, Houston, TX., 2001.
4. NACE MR0175/ISO 15156 - 2, "Petroleum and natural gas industries —Materials for use in H₂S-containing environments in oil and gas production — Part 2: Cracking-resistant carbon and low alloy steels, and the use of cast irons," NACE, Houston, TX., 2003.
5. NACE MR0175/ISO 15156 - 3, " Petroleum and natural gas industries —Materials for use in H₂S-containing environments in oil and gas production — Part 3: Cracking-resistant CRAs (corrosion resistant alloys) and other alloys," NACE, Houston, TX. 2003.

ACKNOWLEDGEMENTS

The author appreciate their respective management for allowing this paper to be presented.



Figure

1. NACE MR0175 prior edition chart to determine potential for material to sulfide stress crack. (Ref. 2)

Table I. NACE MR0175/ISO 15156 Table on Exceptions

Application	Permitted Exclusions
Drilling, well construction & well servicing equipment	<ul style="list-style-type: none"> •Equipment only exposed to controlled composition drilling fluids •Drill bits •BOP shear blades •Drilling riser systems •Wireline & wireline equipment •Surface & intermediate casing
Wells including subsurface equipment, gas lift equipment, wellhead, and Christmas tree	<ul style="list-style-type: none"> •Sucker rod pumps & sucker rods •Electrical submersible pumps •Other artificial lift equipment •Slips

Table II. NACE MR0175/ISO 15156 Table on Exceptions (cont)

Application	Permitted Exclusions
Flowlines, gathering lines, field facilities, & field processing plants	<ul style="list-style-type: none"> •Crude oil storage & handling facilities operating at gauge pressure below 4.3 bar (~65 psi)
Sour water handling equipment	
Natural gas treatment plant	

Table III. NACE MR0175/ISO15156 Table A.1 (Ref. 2)

Table A.1 — Guide to the use of the materials selection tables of Annex A

Equipment or components	Materials groups									
	Asusten stainless steels (see A.2)	High alloy austenitic stainless steels (see A.3)	Solid solution treated low alloy steels (see A.4)	Ferritic stainless steels (see A.5)	Martensitic stainless steels (see A.6)	Duplex stainless steels (see A.7)	Precipitation-hardening stainless steels (see A.8)	Precipitation-hardening nickel-based alloys (see A.9)	Cobalt-based alloys (see A.10)	Titanium and titanium alloys (see A.11)
Any equipment or component	A.2	A.3	A.4	A.5	A.6	A.7	A.8	A.9	A.10	A.11
Additional materials selection tables for casing, tubing and downhole equipment										
Downhole tubular components		A.9	A.14		A.19	A.25				
Packers and other subsurface equipment		A.9	A.14		A.20, A.21	A.25	A.27			
Gas lift equipment	A.7	A.10	A.16						A.37	
Injection tubing and equipment	A.7									
Downhole control line tubing and downhole screens	A.7	A.11								
Additional materials selection tables for wellheads, christmas trees, valves, chokes and level controllers										
Wellhead and tree components (with various specified exclusions)			A.13		A.23		A.27	A.34		
Valve and choke components (with various specified exclusions)					A.23		A.27	A.34		
Shafts, stems and pins	A.3									
Non-pressure-containing internal-valve, pressure-regulator, and level-controller components							A.28	A.35		
Additional materials selection tables for process plant										
Compressor components	A.6				A.22		A.30			
Additional materials selection tables for other equipment										
Instrument tubing and associated compression fittings, surface control line tubing and surface screens	A.4	A.11								
Springs								A.36	A.39	
Diaphragms, pressure measuring devices and pressure seals									A.40	
Seal rings and gaskets	A.5									
Snap rings							A.29			
Bearing pins			A.15							
Miscellaneous equipment as named in the tables (including hardware (e.g. set screws, etc.), downhole and surface temporary-service tool applications)	A.7		A.16				A.28	A.35		

Notes: See Table A.11