DESIGN REQUIREMENTS FOR PRODUCTION EQUIPMENT FOR HYDROGEN SULFIDE SERVICE

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GENERAL

In order to meet the codes and standards regarding equipment to be used in hydrogen sulfide service, there are several basic design criteria which must be met. The regulations specifically referred to in this technical paper are the Statewide Rule 36(1) as established by the Texas Railroad Commission, and Standard MR-01-75(2), as established by the National Association of Corrosion Engineers (NACE). Other states are now establishing similar rules to Texas Rule 36 for the protection of the general public from the harmful effects of hydrogen sulfide when associated with the producing of oil and gas.

The design criteria covered in this paper are those which meet the minimum requirements of Texas Rule 36 and/or NACE MR-01-75. Additional design criteria should be added to these minimum standards if the producer or operator of the lease determines that the concentration of the hydrogen sulfide is high enough to warrant increasing design requirements.

As stated in NACE MR-01-75, "It is the responsibility of the user to determine the expected operation conditions and to specify when this standard applies." It is the opinion of the author that the user then has the responsibility to determine the occurrence of H_2S and its concentration. He then should inform the manufacturers and/or suppliers of equipment so that they may adequately design equipment with the proper safeguards to handle the oil and/or gas containing H_2S. The user also has the responsibility to provide proper training for operating personnel in using the equipment. The user is expected to provide warning signs and security to protect the general public from danger when handling oil and/or gas which contain H_2S.

CODES AND STANDARDS

Rule 36

In order to determine if the Texas Railroad Commission Rule 36 applies to any specific location, it is necessary to determine the amount of hydrogen sulfide present in the produced gas or liquid stream. It is also necessary to determine the radius of exposure of the hydrogen sulfide gas should it escape from the location of the equipment. Rule 36 does not apply to operations where the concentration of hydrogen sulfide in the system is less than 100 parts per million (100 ppm). Rule 36 does apply of the concentration of H_2S is over 100 ppm with a radius of exposure greater

than 50 feet. There is a special storage tank provision stating that Rule 36 applies if the vapor space H_2S concentration is greater than 500 ppm. No radius of exposure is to be determined for storage tanks.

Certain areas of operation are specifically exempted by Rule 36. These include operations subject to rules established by the Railroad Commission Gas Utilities Section or Department of Transportation Pipeline, or Transportation Safety Regulations. Also, operations such as refining, petrochemical plants, or chemical plants are excluded. Operations involving stablized liquid hydrocarbons do not fall under the criteria established by Rule 36.

In order to determine the radius exposure for hydrogen sulfide the following Pasquill-Gifford equation should be used.

1. For determining location of the 100 PPM radius of exposure.

$$X = \left[(1.589)\ (\text{mol frac } H_2S)\ (Q)\right]^{0.6258}$$

2. For determining location of 500 PPM radius of exposure.

$$X = \left[(0.4546)\ (\text{mol frac } H_2S)\ (Q)\right]^{0.6258}$$

Where: X = Radius of exposure, ft
Q = Maximum volume of gas available for escape, SCFD

According to Rule 36, if materials and equipment must comply with the Rule due to the concentration of H_2S in the system, the materials and equipment shall be designed and constructed in accordance with the National Association of Corrosion Engineers (NACE) Standard MR-01-75 and certain specific provisions of the American Petroleum Institute Standard API-RP-14E(3). These equipment provisions are designed specifically to make metal components resistant to hydrogen sulfide stress cracking. Other materials which are not susceptible to sulfide stress cracking such as fiberglass and plastics may be used in hydrogen sulfide service, providing such materials have been manufactured and inspected in a manner which will satisfy the latest published applicable industry standards.

Any oil and gas operations which are subject to the provisions of Rule 36 shall be subject to additional control and safety equipment provisions if the H_2S concentration and radius of exposure meets the following conditions:

1. A 100 ppm radius of exposure in excess of 50 feet and includes any part of a public area except a public road.

2. The 500 ppm radius exposure is greater than 50 feet and includes any part of a public road.
3. A 100 ppm radius of exposure is greater than 3000 feet.

If any of the above conditions apply the operator is required to install safety devices and maintain them which will prevent the undetected continuing escape of hydrogen sulfide.

NACE MR-01-75

The original NACE Standard MR-01-75 has been revised to include material requirements to prevent sulfide stress cracking in oilfield equipment. Equipment selection may be specified to be in accordance with Rule 36. If the minimum H_2S conditions are encountered it would then require design in accordance with this NACE Standard. Or the purchaser of equipment may designate the NACE Standard as the original design specification. The NACE Standard is applicable to all of the pressure containing components or parts of the system. In order to determine the applicable provisions of the NACE Standard it is first necessary to determine the hydrogen sulfide concentration in the system to be covered to see if the minimum requirements of this Standard must be met.

In natural gas systems, the minimum design requirements of the NACE Standard must be met if the partial pressure of the H_2S in the system is greater than 0.05 psia and the operating pressure of the system is greater than 65 psia (50 psig). This relationship of H_2S concentration to pressure is graphically shown in Figure 1 for sour gas systems (lower curve).

For multiphase systems including oil, gas and water, the NACE Standard applies if the partial pressure of the H_2S in the system is greater than 10 psia or the operating pressure is greater than 265 psia (250 psig) or the gas/liquid ratio (GOR) is greater than 5,000 or the H_2S is greater than 15 mol percent. These relationships have been graphically shown in Figure 2 (lower curve).

The partial pressure of the H_2S in the gas or multiphase system can be calculated as follows:

$$\rho P = X\ (P_t)$$

Where: ρP = Partial pressure of H_2S, psia

X = Mol fraction of H_2S in system = $\dfrac{\text{Mol \% } H_2S}{100}$

P_t = Total system pressure, psia

Certain items of production equipment that are not covered under the NACE MR-01-75 Standard include storage tanks and water handling facilities.

EQUIPMENT DESIGN

Standard Equipment

When applying the NACE Standard MR-01-75 to gas systems, if the total pressure of the system versus the H_2S concentration places it under the lower curve on Figure 1, then standard off-the-shelf equipment may be used. Likewise, for low pressure multiphase systems, if the total pressure versus the H_2S concentration places the system under the lower curve on Figure 2, then standard equipment may be used.

NACE Equipment

If the conditions are such that the H_2S concentration versus the total system pressure is above the lower curve on Figure 1 or Figure 2, then the NACE Standard must be used. There are several general material requirements that are required to be met throughout the NACE Standard. Most carbon steels are acceptable materials with minimum grade as specified within the NACE Standard and heat treated to a maximum hardness of Rockwell C22. Ductile iron is an acceptable material if it meets the specification ASTM A-395. Most stainless steels are acceptable in annealed condition with a maximum hardness of Rockwell C22. Some specific stainless steels may have a higher Rockwell hardness. Certain materials are generally not allowed such cast iron. Bronze, copper, or brass is allowed by the NACE Standard since it is not susceptible to hydrogen sulfide stress cracking. However, this material should not be used, due to the material being susceptible to severe weight loss corrosion in hydrogen sulfide service.

Various components of oil and gas production systems need special design requirements to meet the provisions of NACE MR-01-75. Remember that these are minimum design requirements only. Storage tanks, either atmospheric or low pressure are not covered by the NACE MR-01-75 Standard.

In order to meet the requirements of the NACE Standard as well as those of the Occupational Safety and Health Standards (OSHA)(4), all pressure vessels must be designed in accordance with the ASME Code for pressure vessels(5). Standard carbon steel material can be used in the pressure vessels such as Grade SA-285-C, SA-515 Grade 70, or SA-516 Grade 70 heat treated to a maximum hardness of Rockwell C22. Pressure vessels may have to be stress relieved after fabrication if they meet specific conditions in the NACE Standard.

For process piping systems, material must be carbon steel such as Grade A-53-B, A-106-B, or A-106-C seamless steel pipe heat treated to a maximum hardness of Rockwell 22. For flanged connections, material must be steel such as Grade 105 heat treated to a maximum hardness of Rockwell C22. Bolts used in flanges are to be carbon steel Grade ASTM A-193 Grade B7M, 80,000 psi minimum yield with a

maximum hardness of Rockwell C22. Nuts used on the bolts are to be carbon steel Grade ASTM A-194, Grade 2M, with a maximum hardness of Rockwell C22.

Valves and controls and other instrumentation components must be made out of carbon steel material heat treated to a maximum hardness of Rockwell C22 or made out of ductile iron Grade ASTM A-395. Trim in the valves and controls may be stainless steel provided the maximum hardness of Rockwell C22 is maintained. However, higher hardness is allowed on some specific stainless steels. Aluminum material is also allowed to be used in valves and controls, and will meet the provisions of the NACE Standard.

In the instrument systems, manual valves must be carbon steel or stainless steel heat treated to a maximum hardness of Rockwell C22. Tubing and fittings may be carbon steel or stainless steel. Other accessories such as regulators, thermometers, pressure gauges, et cetera, must be made out of carbon steel material, aluminum or stainless steel. Remember that no copper, brass, or bronze should be used due to the severe weight loss corrosion of these materials in hydrogen sulfide service.

Other components of lease production systems such as pumps and heat exchangers must be made out of carbon steel or ductile iron. If carbon steel is used it must be heat treated to a maximum hardness of Rockwell C22.

NACE Plus Equipment

When high H_2S concentrations are encountered, additional design and criteria should be considered by the purchaser and/or user of the equipment to protect the public and operating personnel who may be around the operations. There are no specific guidelines as to higher H_2S concentrations in any recognized standards to indicate when additional design criteria should be used. Good engineering practice and many years of field experience has caused this author to establish a design limitation at a maximum of H_2S partial pressure of 5 psia for either sour gas or sour multiphase systems. A second line has been drawn on both Figure 1 and Figure 2 of the basic NACE MR-01-75 criteria graphs. If the H_2S concentration versus the total systems pressure is above this line on either chart, additional design criteria should be utilized in the construction of production equipment. For lack of any additional guidelines the author has coined the phrase "NACE Plus" for this type of equipment. The following equipment design requirements that are covered are those which should be incorporated in addition to those already outlined above for NACE requirements.

All general guidelines for material requirements as described for NACE designed equipment should be met. Even though NACE does not specifically address storage tanks, certain conditions other than

standard construction should be observed for good operation. It is recommended that air breathing apparatus for operators be provided and used when gauging tanks. All vent lines from tank should be piped to a sufficient distance away from the tanks to prevent high concentrations of vented vapors around the tank battery area. Wind socks should be provided on the tank battery vent lines to indicate direction of wind currents to the operator when approaching the tank battery.

Additional requirements for pressure vessels indicate that all vessels should be stress relieved after fabrication. To ensure sufficient life of the equipment, corrosion allowances should be applied to the design. It is recommended that up to an operating temperature of 200°F, a 1/16" corrosion allowance be included in the required minimum design wall thickness of pressure vessels. Over 200°F and up to 500°F operating temperature, a corrosion allowance of 1/8" should be included. There are certain types of connections and fabrication details which are normally used on standard equipment, but due to being susceptible to corrosion pockets should not be used for this type of equipment. Couplets or grooved connections are not recommended as well as non-consumable backing rings should not be used in vessels for this type of services.

For process piping systems all of the NACE requirements should be met. In addition threaded connections in piping is allowed thru 2" nominal pipe size. No size limitation is considered on threaded piping systems operating below 50 psi operating pressure. Socket weld connections in piping systems should not be used. Also, backing rings in welded piping should not be used. However, weldneck and slip-on flanges are acceptable. All piping systems and API 12K heater coils should be 5% random radiographed and all welded piping should be stress relieved after fabrication. It is recommended that a corrosion allowance of 0.05" be included in the design of all piping systems.

All NACE requirements for valves and controls should be met. In addition, full capacity safety relief valves should be used on all pressure vessels. Safety heads are not to be used. Relief valve discharges should be piped to a safe location by the user. Any relief valve piping system must be designed by a qualified engineer. All liquid level controllers, regulators, and other instruments should be of a "non-constant bleed type." All pressure regulators, filter relief valves, level controls, and other instruments when enclosed in a cabinet or house must be piped to one or more common bulkhead connections and vented to the outside of the enclosure. The user is then responsible for piping this discharge to a safe location from the operation of the equipment. All fired equipment should have auto ignition controls with automatic restart and flame failure shutdowns to turn off both the pilot and burner gas in event of a flame failure. The comments regarding non-bleed level controls, piping instruments outside enclosures, and shutdown of fired equipment need not be followed when sweet gas or instrument air is used.

On instrument systems, of course, the NACE Standards must be followed. In addition, any excess gas that is not used for instrument or fuel gas should not be injected into the firebox or stack. The excess gas or vapors must be piped to a safe location by the user. Any flash gas that is used for fuel gas must be connected to the piping upstream of the fuel gas control valve.

The same comments regarding pumps and heat exchangers under NACE requirements apply when meeting these conditions.

Sour Gas Trim

Historically, the oil and gas producing industry has used the term "Sour gas trim" in referring to equipment provided for operation in hydrogen sulfide service. This terminology bears no relation to the amount of hydrogen sulfide present in the produced system. Therefore, it is impossible to design equipment to meet any specific concentration of hydrogen sulfide when only the term "sour gas trim" is used.

When equipment is specified by a user or operator with only the provision "sour gas trim" the manufacturers will normally provide this equipment to meet only certain minimum design criteria. All material components will normally be of standard carbon steel construction. Any pressure vessels would be constructed under the provisions of ASME pressure vessel code. Any brass, bronze, or copper components in pressure containing parts or components normally furnished on standard oilfield equipment would be replaced with components of carbon steel.

Sour Gas Sweetening Units

When no specific design codes are referenced by a purchaser or user, good engineering practice will make several design criteria mandatory on "sour gas sweetening units" to extend the service life of the equipment. Typical equipment that would fall in this category would be MEA, DEA, DGA acid gas treating units, iron sponge units, caustic gas treating units, or any other process units for removing hydrogen sulfide from natural gas streams.

For this type of equipment all material components would be of standard carbon steel construction. Any pressure vessels would be constructed in accordance with the provisions of the ASME pressure vessel code. Any brass, bronze, or copper components containing parts that normally would be furnished on standard oilfield equipment would be replaced with components of carbon steel. A minimum corrosion allowance of 1/16" would be included in the design of all pressure vessels in the sweetening system except reboilers which would have a minimum of 1/8" corrosion allowance. All vessels and welded piping would be stress relieved after fabrication.

CONCLUSION

The foregoing discussions outline the minimum design requirements required for oil and gas production equipment to meet the provisions of either the Texas Railroad Commission Rule 36 or the NACE Standard MR-01-75. In addition, additional design requirements have been discussed where high concentrations of H S are encountered and additional precaution should be taken to protect operators and general public from the normal operation of the equipment. The specific Standards described should be consulted in more detail to make sure all specific detailed considerations are met. This paper outlines only the basic general criteria which are included in these Standards.

REFERENCES

1. Railroad Commission of Texas, Oil and Gas Division General Conservation Rules of Statewide Application 051.02.02.036, "Oil, Gas or Geothermal Resource Operation in Hydrogen Sulfide Areas", March 15, 1976.

2. National Association of Corrosion Engineers Standard MR-01-75 (1978 Revision), "Material Requirements, Sulfide Stress Cracking Resistant Metallic Material for Oil Field Equipment."

3. American Petroleum Institute Recommended Practice, API RP-14E, December 1981, "Design and Installation of Offshore Production Platform Piping Systems."

4. Occupational Safety and Health Standards, 29CFR Part 1910, General Industry Standards.

5. American Society of Mechanical Engineers Boiler and Vessel Code, Section VIII Division 1, Pressure Vessels, 1983 Edition.

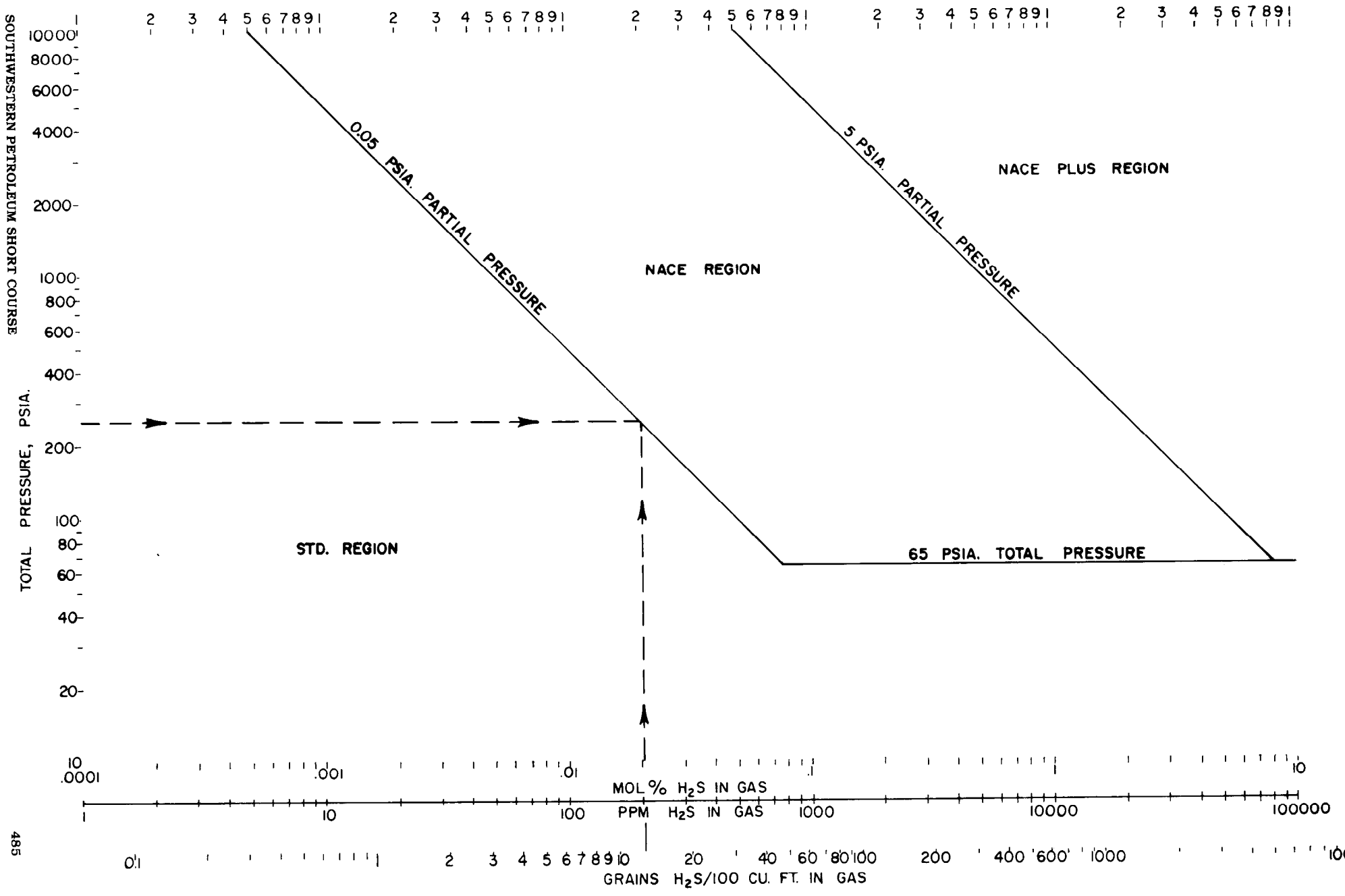
SOUR GAS SYSTEMS (NACE MR-01-75 1.3.1)
SOUTHWESTERN PETROLEUM SHORT COURSE
TOTAL PRESSURE, PSIA.
10000
8000
6000
4000
2000
1000
800
600
400
200
100
80
60
40
20
0.05 PSIA. PARTIAL PRESSURE
5 PSIA. PARTIAL PRESSURE
NACE PLUS REGION
NACE REGION
STD. REGION
65 PSIA. TOTAL PRESSURE
MOL % H2S IN GAS
.0001
.001
.01
.1
10
1
10
100
PPM H2S IN GAS
1000
10000
100000
0.1
1
2
3
4
5
6
7
8
9
10
20
40
60
80
100
200
400
600
1000
GRAINS H2S/100 CU. FT. IN GAS
485

Figure 1

SOUR MULTIPHASE SYSTEMS (NACE MR-01-75 1.3.2)

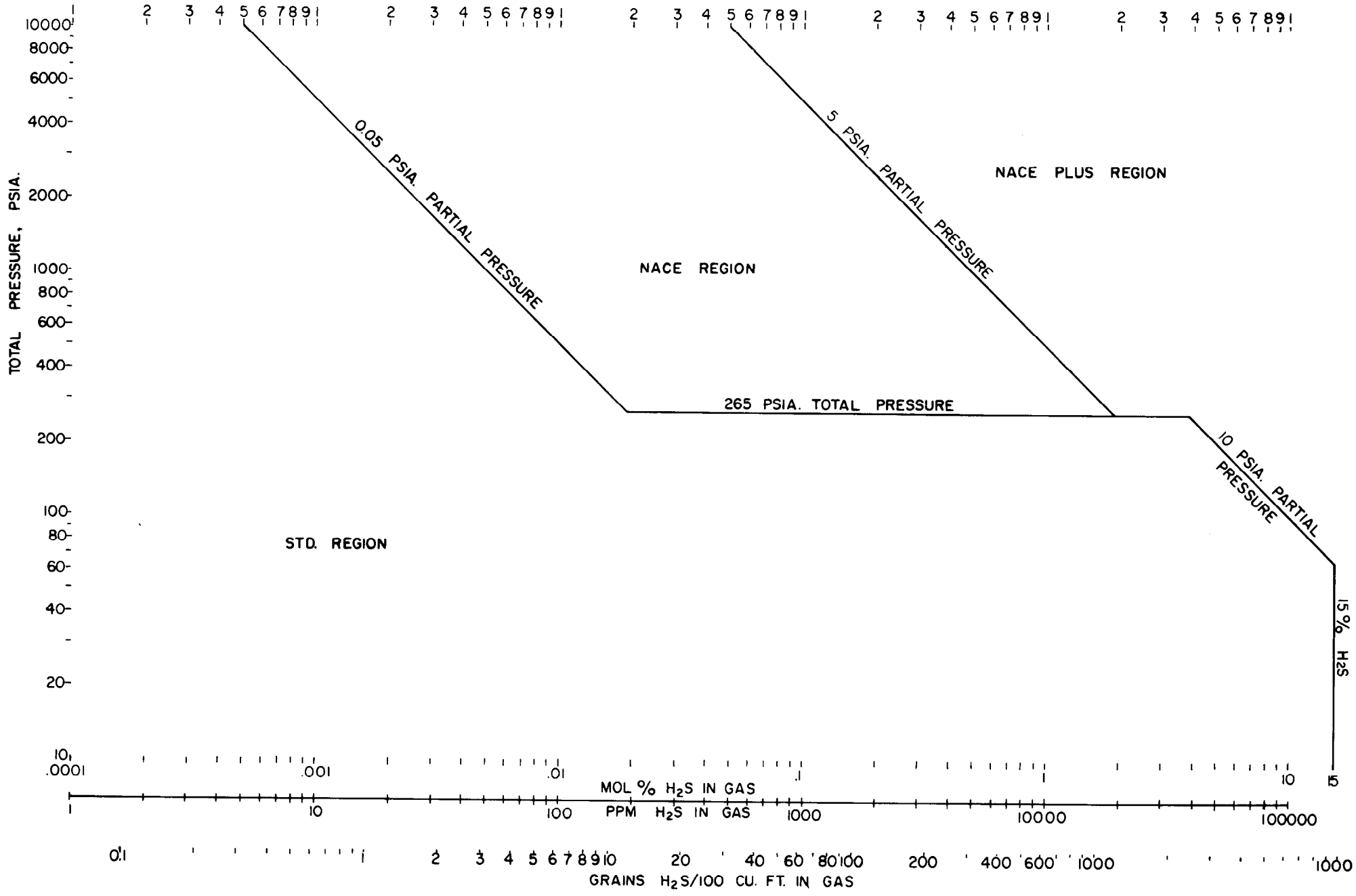

Figure 2