Engineering Standard

SAES-B-062 13 November 2005

Onshore Wellsite Safety

Saudi Aramco DeskTop Standards

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1 Scope

1.1 This Standard covers the minimum mandatory requirements for site layout, wellhead protection, access, and flow isolation for all wells including oil and gas production wells, hydrocarbon injection wells, observation wells, abandoned wells, suspended wells, and wellsite facilities located onshore. Water injection, disposal, and supply wells, which are open to or pass through a geological zone that could produce hydrocarbons, are also covered by this Standard.

1.2 This standard shall apply in the following circumstances:

1.2.1 All new wellsites.

1.2.2 All new wells drilled at existing wellsites.

1.2.3 Re-activation of previously abandoned or suspended wells or re-drilling of existing wells such as drilling of new laterals or deepening.

1.2.4 Existing wells located in areas that have become populated per this Standard shall be upgraded with automated shut-in systems, vehicle crash protection, fencing, wind socks, and other items only when a workover is required for other remedial work.

2 Conflicts and Deviations

2.1 Any conflicts between this Standard and other applicable Saudi Aramco Engineering Standards (SAESs), Saudi Aramco Materials System Specifications (SAMSSs), Saudi Aramco Standard Drawings (SASDs), or industry standards, codes, and forms shall be resolved in writing by the Company or Buyer Representative through the Manager, Loss Prevention Department of Saudi Aramco, Dhahran.

2.2 Direct all requests to deviate from the Standard in writing to the Company or Buyer Representative, who shall follow internal company procedure SAEP-302 and forward such requests to the Manager, Loss Prevention Department of Saudi Aramco, Dhahran.

3 References

All referenced specifications, standards, codes, forms, drawings, and similar material shall be of the latest issue (including all revisions, addenda, and supplements) unless stated otherwise.

3.1 Saudi Aramco References

Saudi Aramco Engineering Procedure

SAEP-302	*Instructions for Obtaining a Waiver of a Mandatory Saudi Aramco Engineering Requirement*

Saudi Aramco Engineering Standards

SAES-B-064	*Onshore and Nearshore Pipeline Safety*
SAES-J-505	*Combustible Gas and Hydrogen Sulfide in Air Detection Systems*
SAES-L-410	*Design of Pipelines*
SAES-M-006	*Fencing*

Saudi Aramco Materials System Specification

45-SAMSS-005	*Wellhead Equipment*

Saudi Aramco Standard Drawings

AA-036247	*Windsock Pole*
AA-036454	*Remote Controls for Onshore Wells*
AB-036685	*Wellhead Guard Barrier*

3.2 Industry Codes and Standards

American Petroleum Institute

API RP 14B	*Design, Installation, Repair and Operation of Subsurface Safety Valve Systems*

4 Definitions

Absolute Open Flow (AOF): In general terms, the rate of flow that would be produced by a well if the only back-pressure at the surface is atmospheric pressure.

Choke: An adjustable pressure control valve that is used to control backpressure on the well. Controlling the backpressure adjusts the production rate of the well.

Drilling Island: A well site for drilling one or more wells, normally used in populated areas to minimize land usage. A drilling island is an exclusive land use area.

Drilling Pad: A compacted area of marl located at the well site. The drilling pad is required to be level for use by drilling and workover rigs.

Gas-Oil Ratio (GOR): The ratio of volume of gas produced from a well in a barrel of crude oil at standard conditions (14.7 psia, 15°C).

High Pressure Well: Wells where the shut-in wellhead pressure is expected to exceed 20,700 kPa (3000 psig).

Low Pressure Well: Wells where the shut-in wellhead pressure is not expected to exceed 20,700 kPa (3000 psig).

LFL: Lower flammable limit of a fuel vapor in air mixture. If a vapor/air mixture is above the LFL, a fire is likely in the presence of an ignition source.

Major Facility: The outer-most security fence, property line, or other demarcation of land-use claim of refineries, large gas treatment, NGL plants, larger oil processing facilities, and the property line of any third party manufacturing facilities (Refer to Table 1 below for examples).

Table 1 – Examples of Major Facilities

Refineries	Gas Treating	NGL	Oil Process	Terminals	Non-Aramco
Jeddah	Berri	Juaymah	Abqaiq Plants Complex	Juaymah	SCEC Power Generation (formerly SCECO)
Rabigh	Uthmaniyah	Yanbu	Safaniya Onshore GOSP Complex	Jeddah	SWCC Treatment
Ras Tanura	Shedgum		Tanajib Plants Complex	Ras Tanura (North & South)	Commercial International Airports
Riyadh	Hawiyah		Shaybah Central Process Facilities	Yanbu	Jubail or Yanbu Industrial Complexes
	Haradh				

Non-Associated Gas Fields: Areas that are developed for the primary purpose of producing natural gas. The produced gas is not a by-product of crude oil production.

Population: A grouping of people normally indicated by the existence of buildings. Separation spacing from a well shall be measured from the nearest fence or other land mark. For industrial, military, and other larger non-residential land claims, determine the spacing based on the nearest anticipated development within the confines of the fence during the anticipated period of drilling.

Populated Area: A well is in a populated area if the population density based on counting occupied buildings exceeds 20 occupied buildings inside the 30 ppm rupture

exposure radius (RER). In addition, for the purposes of this Standard, a well is in a populated area if a school, hospital, hotel, penal institution, or retail complex, whether existing or planned, is inside the 30 ppm RER of that well.

Rupture Exposure Radius (RER):

1) For toxic effects, the rupture exposure radius refers to the horizontal distance from a leak source to a specified level of hydrogen sulfide (H_2S) concentration in parts per million (ppm).

2) For a flammable gas hazard, the rupture exposure radius refers to the horizontal distance from a leak source to the ½ Lower Flammable Limit (LFL).

Surface Safety Valve (SSV): An automated spring-assisted fail-safe valve installed on a wellhead to automatically shut in flow during an abnormal condition such as high or low pressure of the flowline. This can be the upper master valve, a wing valve (upstream of choke), or a production valve (downstream of the choke).

Suspension Procedure: Wireline or workover rig procedures for securing a standing well from production on a long-term basis.

Subsurface Safety Valve (SSSV): An automated valve installed below ground level in the tubing string of an oil or gas well. The SSSV is used to shut in flow during an abnormal condition. SSSVs, when required, shall be installed 60 m or more below ground level per API RP 14B.

Wellhead: The valve manifold directly at the top of the well bore. The wellhead consists of several specialized valves including the following:

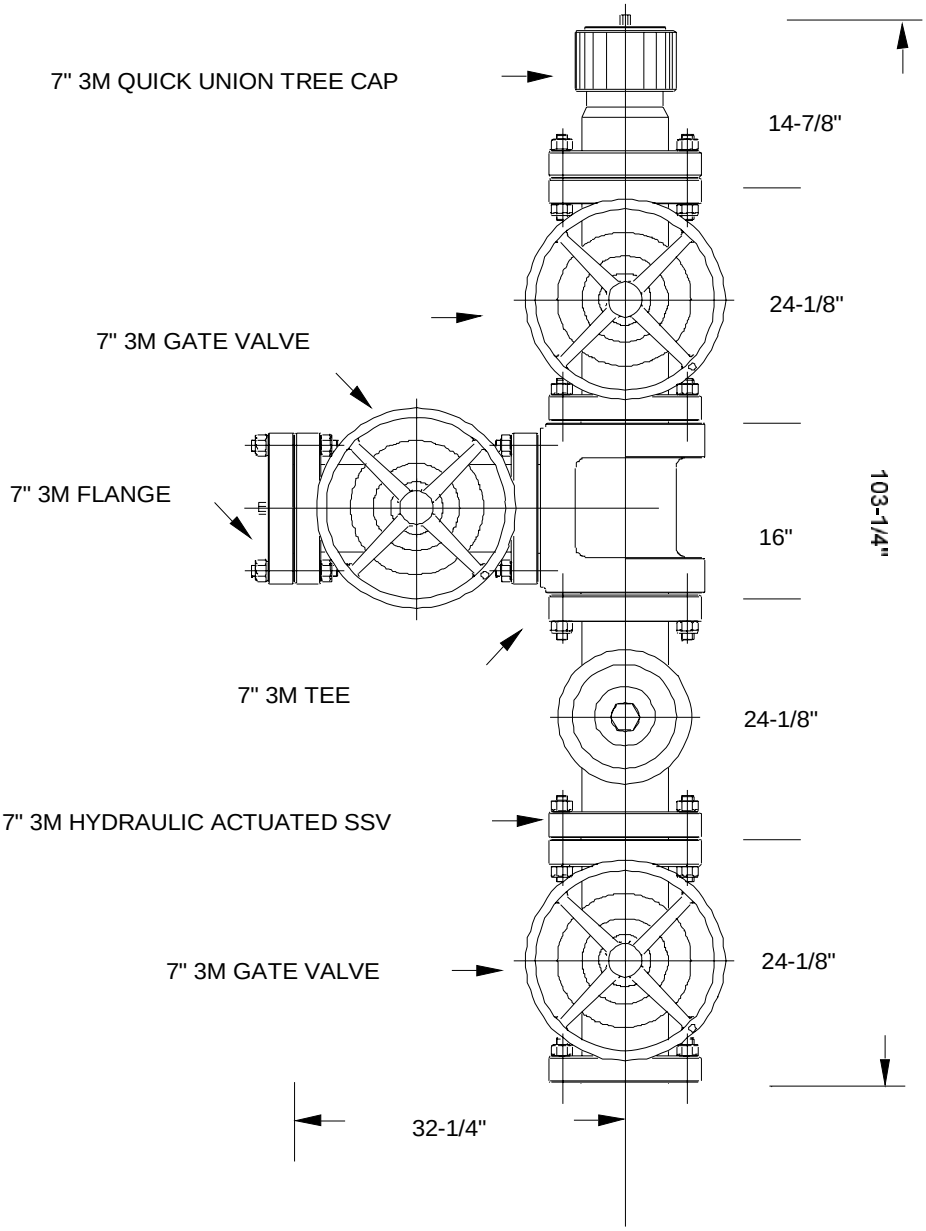
a) **Crown Valve:** Topmost valve of the wellhead. This valve is used for wireline and coil tubing access to the well.

b) **Lower Master Valve:** The first valve on a wellhead. This is not a surface safety valve (SSV).

c) **Upper Master Valve:** A second isolation gate valve just above the Lower Master Valve on a wellhead. If this is automated, it is considered a surface safety valve (SSV).

d) **Wing Valve:** The valve on the side branch of the wellhead, normally located immediately upstream of the choke.

7-1/16" 3M PSI Onshore Production Tree



SAUDI ARAMCO
3M PSI WP WOG
6M PSI TP

Figure 1 – Example of Wellhead (from 45-SAMSS-005, Figure 6)

Wellsite: A wellsite consists of wellhead(s), associated drilling pad, a well flare/burn pit area or areas, and flare/burn pit buffer zone(s). The entire wellsite constitutes an exclusive land use area. No other uses are permitted in this area, except as allowed by this Standard. Size of the wellsite and distances between wellheads shall be specified by Drilling and Workover Engineering, Drilling Operations, E&P Facilities & Technology, and the Proponent Operating Department, on a case-by-case basis.

Well Status: Wells that are not flowing oil or gas may be described by the following terms:

a) **Abandoned Well**: A well that is permanently plugged with cement. This well cannot be produced again.

b) **Observation Well**: A well drilled to monitor reservoir conditions such as bottom-hole pressure in the reservoir.

c) **Suspended Well**: A well that has been shut-in on a long term basis with all productive zones isolated and production shut-off on a long-term basis.

d) **Standing Well**: A well that is shut-in awaiting action, such as flowline tie-in or well perforation, before it can be returned to production.

5 Determination of Rupture Exposure Radius (RER)

5.1 Three concentric circles representing the three rupture exposure radii - 30 ppm, 100 ppm hydrogen sulfide (H_2S) and ½ lower flammable limit (LFL) shall be plotted from the well's proposed surface location as shown in Figure 2 below. Refer to Appendix 1 for procedures to determine the RERs.

5.2 For fields, reservoirs, or service not listed in Appendix 1, the rupture exposure radius shall be obtained from the Saudi Aramco Loss Prevention Department's Technical Services Unit. In order to calculate the RER, the following information should be provided with the request: Well composition of produced fluid (mole %), temperature (Flowing Wellhead Temperature, FWHT), and AOF for gas wells or maximum flow rate and GOR for oil wells.

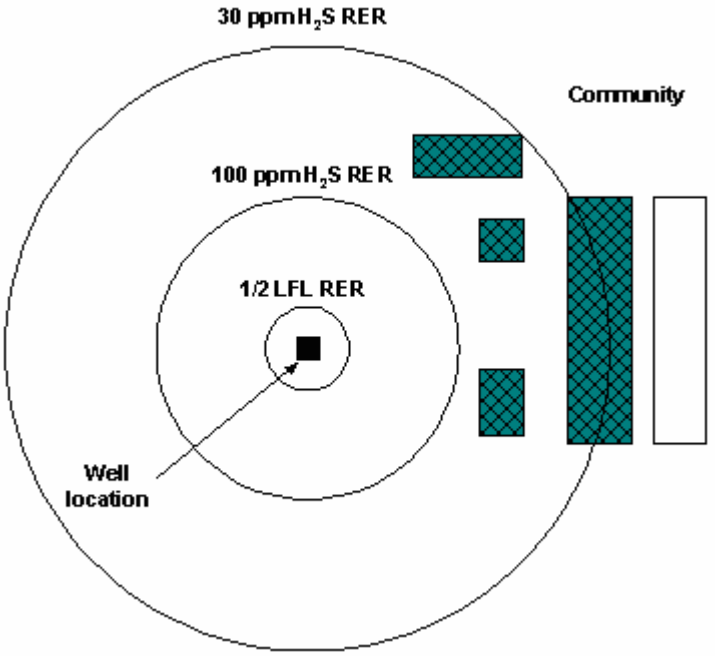


Figure 2 – RERs

A well with population inside the 30 ppm H_2S RER as shown above is considered to be in a populated area if the population index is above 20 or if a school, hospital, major facility, etc, are inside the RER (see 6.3).

6 Wellsite Location

6.1 Wells that are drilled through a hydrocarbon bearing formation shall be located so that no occupied building or major facility is within the well's 100 ppm H_2S or ½ LFL RER. Minimum spacing shall not be less than that stated in Table 2. The RER to be used for well spacing shall be based on the worst case of all hydrocarbon zones that are penetrated during drilling.

Exceptions:

Farms and other developments used primarily for agriculture.

GOSPs, manifolds, significant aboveground appurtenances for cross-country transportation pipelines such as junctions containing a several scraper launcher/receiver facilities, Khuff and Jouf gas distribution facilities, and their associated utilities are allowed to be within the 100 ppm H_2S circle but not within the ½ LFL RER nor closer than the minimum spacing stated in Table 2.

Table 2 – Spacing from Oil and Gas Wells [4]

Facility	Minimum Spacing from the Wellhead
Pipelines [1, 2]	60 m
Overhead powerlines for site-related CP, etc. (≤69 kV); site related rectifiers	100 m
Main overhead powerlines	200 m
Saudi Aramco or Government roadways [2]	100 m
Divided Limited-Access Expressways [2]	150 m
Railroads [3]	150 m
Major electrical distribution centers	450 m
Occupied buildings, major facilities	450 m
Non-well flares and burn pits	450 m
Hospitals and schools	1000 m

1) The existing elevated marl pad around wellhead(s) on a wellsite shall not be crossed by a pipeline. Rig access shall not be obstructed by installation of a pipeline. In addition, the minimum spacing does not apply to flowlines that are associated with a multi-well wellsite.
2) New wells may require additional spacing from existing flowlines for wellsite construction and drilling operations. Spacing shall be increased as needed at the request of the Drilling Services or Drilling Operations Departments.
3) Spacing from the well to the closest edge of right-of-way, such as a fence.
4) Minimum spacing applies to wells drilled after March 30, 2001.

6.2 Water gravity injector, power injector and supply wells that penetrate hydrocarbon formations shall be spaced the same as hydrocarbon producing wells. Injector and supply wells that do not penetrate hydrocarbon bearing formations shall have a basic 60 m minimum spacing requirement from plant equipment, buildings, etc. Gas injection wells shall use the same location criteria as producing gas wells.

6.3 A well is in a populated area if the population density index within the 30 ppm H_2S rupture exposure radius exceeds 20, or if a school, hospital, hotel, penal institution, retail shopping mall, or major facility, existing or planned, is included within the 30 ppm H_2S rupture exposure radius of that well (see Figure 2).

Commentary Notes:

For purposes of this Standard, roads are not deemed to generate populated areas.

Where wells are located near areas of potential concern, such as roads, parking areas, or camp sites, the Proponent Operating/Engineering Department shall determine whether additional precautionary measures, such as subsurface safety valves, fencing, etc., are required.

6.4 Wells to be drilled or wells subject to workover in a populated area shall implement the following additional precautionary measures in addition to the normal drilling safety program during drilling of hydrocarbon zones. Other drilling precautionary measures may be added at the request of the Manager, Loss Prevention or the General Manager of Drilling and Workover.

Precautionary measures during drilling in a populated area:

1. Rig-site H_2S monitoring systems with 24-hour safety man coverage.
2. Placement of remote H_2S monitors in the vicinity of populations and nearby facilities to monitor H_2S levels at those locations in an emergency.
3. An additional one-hole volume of kill-weight mud available at the drillsite for immediate use.
4. Capability of cutting the drill pipe with shear rams.
5. On-site coverage 24 hours a day by on-site foremen (minimum 2-man coverage on 12-hour shifts) with authority for immediate ignition of the well without prior approval in the event of loss of well control.
6. Capability of burning gas in a controlled release using a properly designed separation system and an elevated flare with pilot (Only for wells to protect population within the 30 ppm H_2S RER; the use of this equipment is not required for drilling near GOSPs, process plants or major facilities).
7. An enhanced rig-site emergency contingency action plan.
8. Other applicable safeguards as needed.

Commentary Note:

The requirements of 6.4 are not intended for non-rig flaring.

6.5 Under no circumstances shall population be exposed to over 30 ppm H_2S gas concentration for more than 1 hour.

6.6 Well burn pits shall be subject to the same spacing from population and major facilities as well spacing. The exceptions to 6.1 shall also apply to burn pits. Minimum spacing shall meet Table 3.

6.6.1 Oil wells and low-pressure gas wells shall have at least one flare while being drilled.

6.6.2 High-pressure gas well shall have two flares while being drilled.

6.6.3 Burn pits shall be at predominantly downwind and crosswind locations, at least 60 meters from the well (300 m for high-pressure gas wells)

ranging from 60 to 270 arc degrees from true North. Burn pits shall be placed to point away from populations and facilities as much as possible.

6.6.4 If there are two flares, they should be a minimum of 90 degrees and a maximum of 180 degrees from each other and pointing away from populations and facilities as much as possible.

Table 3 – Spacing from Well Burn Pits (3)

Facility	Minimum Spacing from Oil & Gas Well Burn Pits
Well and Well Burn Pits (1)	60 m (Oil & LP Gas) 300 m (HP Gas Well)
Existing Wellheads	60 m (Oil & LP Gas) 150 m (HP Gas Well)
Pipelines (Above Ground)	60 m
Pipelines (Buried) (2)	15 m
Main Overhead Powerlines	200 m
Overhead Powerlines for Site-Related CP, etc., (≤69 kV); Site Related Rectifiers	100 m
Powerlines (Buried) (2)	15 m
Saudi Aramco or Government Roadways (3)	100 m (Oil Wells and LP Gas) 200 m (HP Gas Wells)
Divided Limited-Access Expressways (3)	450 m (Oil and Gas Wells)
Railroads (3)	200 m
Population	450 m
Non-well Flares and Burn Pits	450 m
Hospitals and Schools	1000 m

1) Spacing of any well related burn pit from a well being drilled shall be a minimum distance of 60 m for an oil well and 300 m minimum for a high-pressure gas well. Wells are to be spaced a minimum of 60 m from the closest edge of a burn pit for an oil well or LP gas well and 150 m from a flare for a HP gas well. A minimum of 60 m buffer zone shall be maintained around the outside of each burn pit (not on the wellsite side). The edges of the burn pits shall have a 2 m high berm (minimum elevation above flare outlet center).

2) Buried CP powerlines, flowlines, and trunklines related to a wellsite shall have no other spacing restrictions provided the powerlines do not interfere with rig access or future production flare operations.

3) Spacing from the closest edge of the burn pit to the edge of the right-of-way.

6.7 For existing wells in populated areas, the special precautions in 6.4 shall be used for workovers. Precautions appropriate for stimulation and wireline work on existing wells shall be as requested by the Proponent Operating Department, Drilling and Workover Services, and Loss Prevention as needed.

7 Population Analysis Procedure

7.1 The boundaries of Saudi Aramco and non-Saudi Aramco development areas, present and planned, within the rupture exposure radius of a well location shall

be obtained from the Land and Lease Division of Government Affairs Services Department.

7.2 The population density index at a well location is defined as the sum of the existing density index and the virtual density index values for the site.

7.3 Buildings having more than 4 stories shall be included in the population density index as a number of equivalent buildings. The number of equivalent buildings shall be calculated by dividing the number of stories in the building by 3 and rounding up to a whole number.

7.4 To determine the existing density index for a well location, count the number of buildings lying within the rupture exposure radius of the well. The resulting whole number is the existing density index value.

7.5 For areas within the rupture exposure radius of a well which are planned for development, the virtual density index shall be calculated as follows:

7.5.1 Calculate the land area in square meters (m^2) of each development which is included within the rupture exposure radius of the well.

7.5.2 Multiply the included area by 0.00075 and round up. The resulting whole number is the virtual density index for this well location.

7.6 Not to be included in these calculations are temporary buildings that will be in place for less than 6 consecutive months or that will be gone by the time the well is spudded.

8 Well Safety Valves and Wellsite Hardware

8.1 Hydrocarbon Producing and/or Hydrocarbon Injection Wells - General Requirements

8.1.1 All well installations shall be in accordance with the specifications prepared by Saudi Aramco Drilling and Workover Engineering. Refer to 45-SAMSS-005 for the minimum requirements for Saudi Aramco oil and gas production trees, wellheads, valves and miscellaneous equipment relating to the wellhead. Naturally flowing hydrocarbon wells shall be completed in a manner that permits flow only through a tubing string equipped with a downhole packer or polished bore receptacle.

8.1.2 Requirements for wellhead piping, flowlines, trunklines, and testlines are covered in SAES-L-410.

8.1.3 All wells shall have a manual lower master valve.

8.1.4 At the discretion of the Proponent Operating Department, oil wells may be equipped with manual remote operators attached to the master valve and/or wing valve. If manual remote operators are installed on oil wells, they shall be in accordance with Standard Drawing AA-036454.

8.1.5 Any lockout device used to temporarily hold a surface safety valve (SSV) in the open position by restricting movement of the valve stem shall be constructed of fusible materials with a melting point 30°C above the higher of the flowing wellhead or maximum design ambient temperature.

8.2 Safety Valves for HP Gas Producing Wells

8.2.1 All high-pressure gas production wells shall have at least two spring-assisted failsafe surface safety valves (SSVs).

8.2.2 The two SSVs shall be triggered when an abnormally high or low pressure is sensed in the piping to the well. Fusible devices, with a set point 30°C above either the flowing wellhead or the maximum design ambient temperature, whichever is highest, shall be installed on the wellhead to close the safety valves.

8.2.3 At the discretion of the Proponent Operating Department, addition of other automated valves, such as subsurface safety valves, shall be installed as requested.

8.3 Safety Valves on Oil Wells and Low Pressure Gas Wells

8.3.1 Where an oil well or low pressure gas well is in a populated area or where the associated flowline has Location Class 3 or 4 populations (as specified in Tables 1 and 2 of SAES-B-064), the wellhead shall be provided with an SSV and SSSV.

8.3.2 For all existing oil wells and low pressure gas wells in populated areas or where areas become populated due to growth of communities, those wells shall remain active, but shall require installation of a SSV and SSSV. The upgrade shall be done only when other needs justify the use of a rig on the well.

8.3.3 The upper wellhead master valve shall be a spring-assisted fail-safe surface safety valve (SSV), triggered when an abnormally high or low pressure is sensed.

8.3.4 A subsurface safety valve (SSSV), per API RP 14B specification, shall be installed more than 60 m below ground level in oil wells. The SSSV shall be triggered when an abnormally high or low pressure is sensed.

8.3.5 A fusible device with a melting point 30°C above the higher of the flowing wellhead temperature or maximum design ambient temperature, shall be installed on the wellhead to trigger the SSV and SSSV systems.

Commentary Note:

Values for pipeline associated RERs are found in SAES-B-064, Tables 1 and 2. Location Class 3 is where the pipeline RER includes areas with a population index greater than 30. Location Class 4 is where the pipeline RER includes 4-story or greater buildings, schools, hospitals, hotels, prisons, shopping malls or similar retail complexes.

Table 4 – Well Safety Valves

	Additional Drilling Precautions	Automated SSV	Automated SSSV
Oil/LP Gas Well – Unpopulated Area (a)	No	No [(a)]	No [(a)]
Oil/LP Gas Well – Populated Area	Yes	Yes	Yes
HP Gas Well	No	Yes, 2 SSVs	[(b)]
PWI Well – Unpopulated Area	No	No	No
PWI Well – Populated Area	Yes	No	No

Note a Even if the well is in an unpopulated area, if the flowline passes through a populated area per 8.3, an SSV and SSSV shall be required.

Note b HP gas production wells shall have at least two spring-assisted failsafe SSVs. Addition of other automated valves, such as subsurface safety valves, shall be installed where required by the Proponent Operating Department per Section 8.2.

8.4 Hydrocarbon Injection Wells

Hydrocarbon injection well flowlines shall each be provided with a check valve in the wellhead piping.

8.5 Observation Wells

Wells shall be equipped with the relevant safety devices equivalent in function to those that would be required for a producing well unless suspended with a subsurface plug or other acceptable method.

8.6 Suspended Wells

Wells shall be suspended in accordance with Producing Engineering requirements. Suspension procedures for wells shall be documented by Producing Operations and shall be available for review.

8.7 Vehicular Crash Protection and Fencing

8.7.1 All wellheads shall be protected with a guard barrier per Saudi Aramco Standard Drawing AB-036685.

8.7.2 Wellsites and associated burn pits in populated areas shall be enclosed by a fence meeting the specifications of SAES-M-006 (Type III). The fence shall have four lockable vehicle gates, one in each quadrant locked at all times. Keys shall be kept with the Proponent Operating Department. Two gates shall be a minimum of 18 m wide rig-access gates. The locations of these rig-access gates shall permit access to all wells on the wellsite from either gate.

8.8 A wind sock pole per Saudi Aramco Standard Drawing AA-036247 and a wind sock per SAMS Catalog Number 21-590-600 are to be permanently installed at each hydrocarbon production or injection wellsite in populated areas.

9 Abandoned Wells

The following requirements apply to a wellsite only if all its wells have been permanently plugged and if it is located in a populated area:

9.1 The perimeter of the drilling pad shall be provided with a fence (SAES-M-006, Type III) if there is no fence at the perimeter of the buffer zone.

9.2 The fence shall have one lockable vehicle gate 10 m wide.

9.3 One access route 10 m wide shall be maintained to the wellsite gate.

10 Drilling Rig Access Routes

Two access routes shall be available to each wellsite. These shall meet the following requirements:

10.1 Each access route shall be 18 m wide, terminating at a rig access gate.

10.2 Vertical clearance over the access routes shall be 14 m minimum.

10.3 An access route shall not include grades or transverse slopes of more than 5%.

10.4 No obstruction is allowed on an access route.

10.5 The minimum radius of curvature of access routes shall be 70 m. The center point of all access route curves shall be outside the wellsite served.

10.6 One of the access routes required by paragraph 10.1 above shall have within it a prepared roadway consisting of a compacted marl running surface 0.3 m thick and 9.0 m wide with 2.5 m wide shoulders, giving a total clear road width of 14 m.

10.7 The two access roads shall have a separation of from 90 to 270 arc degrees from each other through the 100 ppm RER.

Revision Summary

13 November 2005	Revised the "Next Planned Update". Reaffirmed the contents of the document, and reissued with minor clarifications.

Appendix 1 – Procedure for Determining RER of Oil and Gas Wells

Introduction

To allow for more cost-effective well spacing, while at the same time maintaining a safe distance between wells and exposed populations, SAES-B-062 provides variable rupture exposure radii (RER) that are based on field and well conditions (i.e., the well fluid composition and maximum potential release rate).

This appendix is based on a comprehensive analysis of RERs for Saudi Aramco oil and gas wells. Exploration and Producing Facilities and Technology Department (E&P FTD) (PRED/1-099-99) provided the data used for the RER calculations. Tables A7 and A8, at the end of this Appendix, summarize the data provide by E&P FTD. The RER calculations were made in accordance with LPD Guidelines for Determining the Consequences of Well Blowouts. Note that the information in Tables A7 and A8 are based on the latest LPD gas dispersion model PHAST (Version 6.0). The RERs may change in future updates of SAES-B-062 as a result of changes in well data or refinements in the models. If the information for the well or production zone needed is not in Appendix 1, contact the Supervisor, Technical Services Unit, Loss Prevention Department.

The following sections illustrate the use of the correlations for predicting RERs for oil and gas wells. The correlations are of the form $RER = aQ^b$, where a and b are field-specific constants and Q is based on the release rate of gas from the well. Correlations are provided for the following oil and gas fields:

Non-Associated Gas Fields

North Ghawar Areas-Ain Dar and Shedgum	South Ghawar Area-Haradh
Central Ghawar Areas-Uthmaniyah	Qatif
South Ghawar Area-Hawiyah	Berri

Oil Fields

Abqaiq (Abqaiq Cap Gas)	Haradh
Abu Hadriyah	Harmaliyah
Abu Jiffan	Hawiyah
Ain Dar	Khurais
Berri Onshore	Khursaniyah
Dammam	Mazalij
Fadhili	Qatif
Fazran	Shedgum
	Uthmaniyah

The following sections explain and demonstrate the process of RER calculations. Worksheets for calculating RERs are provided at the end of this Appendix.

Procedure for Determining RER of Gas Wells

Sour gas wells are considered in this Standard to have three Rupture Exposure Radii (RER): a 100 ppm H_2S RER ($RER_{100\ ppm}$), a 30 ppm H_2S RER ($RER_{30\ ppm}$) and a ½ LFL RER ($RER_{½\ LFL}$). Sweet gas wells would only have a $RER_{½\ LFL}$. These radii are used in SAES-B-062 to determine spacing requirements. Follow these steps when determining the RER for a gas well.

1. Identify the gas field and reservoir for the well of interest (Contact the General Supervisor, Oil or Gas Facilities & Projects Division, E&P FTD) and obtain the Absolute Open Flow (AOF) and mole fraction of hydrogen sulfide (H_2S) in the gas stream. Note that the correlations included in this appendix are based upon the expected upper and lower range of AOFs and H_2S content in the gas stream.

2. Determine release rate of H_2S (Q_{H2S}) from the following:

   $Q_{H2S} = (Q_{AOF})(x_{H2S})$

   Where x_{H2S} = mole fraction of H_2S in gas stream

   Q_{AOF} = Absolute Open Flowrate of gas from the well, MMscfd

   Q_{H2S} = maximum release rate of H_2S, MMscfd

3. Use the constants in Table A6 to calculate $RER_{100\ ppm}$, $RER_{30\ ppm}$ and $RER_{½\ LFL}$ from the following

   $RER_{100\ ppm} = e(Q_{H2S}{}^{f})$;

   $RER_{30ppm} = g(Q_{H2S}{}^{h})$;

   $RER_{½\ LFL} = l(Q_{AOF})^{m}$

The AOF or H_2S concentration of a gas mixture must fall within the limits presented in Table A6. If an AOF or the H_2S concentration is outside the limits, then LPD/TSU will calculate RER values specifically for the well of interest (users need to supply LPD/TSU with well name, AOF, gas composition (mole%), and flowing wellhead temperature).

Example of RER for Gas Well

As an example, consider a high-pressure gas well in the South Ghawar Area, Hawiyah. Information available indicates that the anticipated Absolute Open Flow of the well is 100 MMscfd and the H_2S concentration is expected to be 3 mole%.

The following steps are necessary to determine the RER:

1. Data Requirements

   The AOF and the H_2S concentration are within the ranges specified in Table A6. Table A6 indicates that the appropriate constants for this field are as follows:

Table A1 - RER Constants for South Ghawar Area, Hawiyah Field (from Table A6)

$RER_{100\ ppm}$		$RER_{30\ ppm}$		$RER_{½\ LFL}$	
e	f	g	h	I	m
245	0.79	700	0.77	11.7	0.54

2. Calculate maximum H_2S release rate

   The maximum H_2S release rate is given by the following:

   $Q_{H2S} = (Q_{AOF})(x_{H2S})$

   $= (100\ MMscfd)(3 / 100)$

   $=3\ MMscfd\ of\ H_2S$

3. Calculate RERs

   $RER_{100\ ppm} = 245[(3)^{.79}] = 583\ m$

   $RER_{30\ ppm} = 700[(3)^{.77}] = 1{,}631\ m$

   $RER_{½LFL} = 11.7[(100)^{.54}] = 141\ m$

   The RER for this example well are in Table A2.

Table A2 - RER for Example Well

Rupture Exposure Radii	Distance, m
$RER_{100\ ppm}$	583
$RER_{30\ ppm}$	1,631
$RER_{½LFL}$	141

Procedure for Determining RER of Oil Wells

Gas is flashed during a large release of crude and is then dispersed downwind. As with gas wells, oil wells have three Rupture Exposure Radii (RER): a 100 ppm H_2S RER ($RER_{100\ ppm}$), a 30 ppm H_2S RER ($RER_{30\ ppm}$) and a ½ LFL RER ($RER_{½LFL}$). Sweet oil wells only have a $RER_{½\ LFL}$. These radii are used in SAES-B-062 to determine spacing

requirements and to assist in determining emergency response planning and notification. Follow these steps when determining the RER for an oil well:

1. Identify the oil field and reservoir for the well of interest (Contact the General Supervisor, Oil or Gas Facilities & Projects Division, E&P FTD) and obtain the maximum oil flow rate, Gas-Oil Ratio (GOR) and mole fraction of hydrogen sulfide (H_2S) in the oil. The correlations included in this appendix are based upon the expected upper and lower range of maximum flow rates, gas-oil ratios, and H_2S content in the oil.

2. Use the following equation to calculate the rate of gas flashed from the crude released at the maximum flow rate:

   $Q_{gas} = (Q_{oil})(GOR) /1{,}000$

   Where:

   Q_{gas} = Release rate of flashed gas, MMscfd

   Q_{oil} = Maximum oil release rate, Mbpd

   GOR = Gas-Oil Ratio, scf/stb

3. Calculate the concentration of H_2S in the flashed gas from the following equations:

   $[x_{H2S}]_{gas} = \phi[x_{H2S}]_{oil}$

   where:

   $\phi = a(GOR)^b$ (Note: a, b are obtained from Table A7)

   Determine release rate of H_2S (Q_{H2S})

   $Q_{H2S} = (Q_{gas})\ ([x_{H2S}]_{gas})$ [MMscfd of H_2S]

4. Calculate $RER_{100\ ppm}$

   $RER_{100\ ppm} = e(Q_{H2S})^f$ (Note: e, f are obtained from Table A7)

5. Calculate $RER_{30\ ppm}$

   $RER_{30\ ppm} = g(Q_{H2S})^h$ (Note: g, h obtained from Table A7).

6. Calculate $RER_{½\ LFL}$

   $RER_{½\ LFL} = l(Q_{gas})^m$ (Note: l, m obtained from Table A7)

If the AOF or H_2S concentration do not fall within limits of Table A7, then LPD/TSU will calculate RER values specifically for the well of interest (users need to supply

LPD/TSU with well name, maximum oil flow rate, oil composition (mole%), gas-oil ratio, and flowing wellhead temperature).

Example of Oil Well RER Determination

As an example, consider an oil well that is producing Arab-D in the Khurais field. Available information indicates the well will have a maximum flow rate of 30,000 bpd, the oil will have an H_2S concentration of 2.9 mole %, and the GOR is 277. What are the RER values for this well?

1. Available information

   The available information is summarized below. The maximum flow rate and the H_2S concentration are within the limits specified in Table A7.

Maximum Flow Rate, Mbpd	30
GOR, scf/stb	277
Mole percent of H_2S in Oil	2.9%

   Constants for evaluating this well are summarized in Table A3.

Table A3 - RER Constants for Khurais Field (From Table A7)

H_2S in Flashed Gas		$RER_{100\ ppm}$		$RER_{30\ ppm}$		½ LFL	
a	b	e	f	g	h	l	m
2.2	0	1,285	0.69	2,656	0.64	47.3	0.63

2. Calculate flashed gas release rate

   The flow rate of released gas may be estimated by the following:

   Q_{gas} = (30 Mbpd) x (277 scf/stb) = 8.31 MMscfd

3. Calculate the H_2S concentration in flashed gas

   $\phi = a(GOR)^b = (2.2) \times (277)^0 = 2.2$

   $[x_{H2S}]_{gas} = \phi[x_{H2S}]_{oil} = (2.2) \times (2.9\ \%) = 6.4\%$

4. Calculate H_2S release rate

   Q_{H2S} = (8.31 MMscfd) x (.064) = 0.53 MMscfd H_2S

5. Calculate RERs

   $RER_{100\ ppm} = e(Q_{H2S})^f$
   $RER_{100\ ppm} = (1285)(0.53)^{0.69} = 829$ m

$RER_{30\ ppm} = g(Q_{H2S})^h$
$RER_{30\ ppm} = (2656)(0.53)^{0.64} = 1{,}769$ m

$RER_{½LFL} = l(Q_{gas})^m$
$RER_{½LFL} = (47.3)(8.3)^{0.63} = 180$ m

Table A4 - RER for Example Oil Well

Rupture Exposure Radii	Distance, m
$RER_{100\ ppm}$	829
$RER_{30\ ppm}$	1,769
$RER_{½LFL}$	180

Method of Using RER Results

Saudi Aramco uses the maximum of the 30 ppm RER (100 ppm RER with additional drilling precautions) or the ½ LFL RER to establish the minimum distance between wells and population or major facilities (note that spacing can never be less than the minimums stated in Table 2 of the Standard – see Section 5 for more details). The purpose for this RER method of spacing is to minimize the possibility of exposing people to either potentially lethal or flammable vapor clouds. Table A5 summarizes the effects of hydrogen sulfide exposure to people.

Once the $RER_{100\ ppm}$, $RER_{30\ ppm}$, and $RER_{½LFL}$ are known, draw the RERs as circles with the well at the center (see Figure A1). For sour gas wells, the ½ LFL RER will not dominate, but it should still be drawn on the map showing RERs.

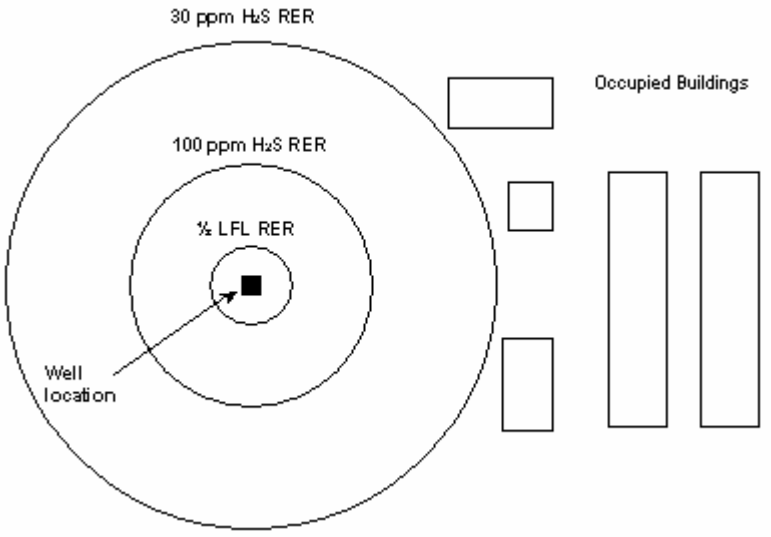


Figure A1 - RER Circles Superimposed Over Well Site Map

Table A5 - Effects of Hydrogen Sulfide on People

H_2S Concentration (ppm)	Effect on People
0.10	ERPG-1*: The maximum airborne concentration below which it is believed that nearly all adult males could be exposed for up to 1 hour without experiencing other than mild transient adverse health effects or perceiving a clearly defined objectionable odor.
4	Moderate odor, easily detected.
10	Time Weighted Average (TWA) exposure limitation, beginning of eye irritation. Setting for Warning low level H_2S alarm for control rooms and other indoor areas protected by air intake sensors. Saudi Aramco work permit procedures require use of SCBA for work in areas with 10 ppm or greater H_2S.
15	Short Term Exposure Limit (STEL) for 15 minutes.
20	Warning High H_2S Level alarm setting at Saudi Aramco plants per SAES-J-505.
30	ERPG-2*: The maximum airborne concentration below which it is believed that nearly all adult males could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action.
50	Inhalation limit for 60 minutes, threshold limit of possible eye injury. Setting for Warning High-high Level H_2S alarm at Saudi Aramco plants per SAES-J-505.
70 – 150	Headaches, dizziness, sore throat and increasing stress.
100	ERPG-3*: The maximum airborne concentration below which it is believed that nearly all adult males could be exposed for up to 1 hour without experiencing or developing life-threatening health effects.
150	Loss of sense of smell.
150 – 300	Severe irritation of eyes and lungs.
300	Immediately Dangerous to Life and Health Concentration: The maximum airborne concentration to which a healthy male worker can be exposed for as long as 30 min and still be able to escape without loss of life or irreversible organ system damage.
500	Loss of sense of reasoning and balance, loss of consciousness and possible death in 30 – 60 minutes.
1,000	Immediate loss of consciousness and death within a few minutes.

* Emergency Response Planning Guideline (ERPG), American Industrial Hygiene Association.

Table A6 – Gas Field Constants for RER Calculations

	Properties				Constants					
	H_2S (mole%)		AOF or Q_{gas} (MMSCFD)		100 ppm		30 ppm		½ LFL	
Field	**min**	**max**	**min**	**max**	**e**	**f**	**g**	**h**	**l**	**m**
Abqaiq Cap Gas	1.0	5.0	50	150	268	0.73	729	0.73	14.8	0.49
Berri	20	20	50	120	789	0.63	1894	0.64	11.7	0.49
North Ghawar (Ain Dar and Shedgum)	0.72	6.0	50	150	273	0.75	689	0.81	14.0	0.48
South Ghawar (Haradh)	0.50	2.0	50	125	242	0.71	654	0.67	14.6	0.49
South Ghawar (Hawiyah)	0.5	4.5	50	150	245	0.79	700	0.77	11.7	0.54
Qatif	7.23	11.2	50	120	376	0.74	1032	0.72	11.1	0.50
Uthmaniyah	2.28	9.27	50	175	295	0.80	855	0.76	16.1	0.46

Equations for Oil and Gas Wells:

$RER_{100\ ppm} = e(Q_{H2S})^f$

$RER_{30\ ppm} = g(Q_{H2S})^h$

$RER_{½LFL} = l(Q_{AOF})^m$

Equations for Oil Wells Only:

$[x_{H2S}]_{gas} = \phi[x_{H2S}]_{oil}$

where $\phi = a(GOR)^b$

Note: All RER distances are in meters. Q_{H2S} = release rate of H_2S, MMSCFD. Q_{gas} = release rate of gas, MMSCFD

Table A7 – Oil Fields Constants for RER Calculations

	Properties				Constants							
	H_2S (mole%) in Oil		Qoil (MBD)		Flash		100 ppm		30 ppm		½ LFL	
Field	**min**	**max**	**min**	**max**	**a**	**b**	**e**	**f**	**g**	**h**	**l**	**m**
Abqaiq	0.93	3.19	2.9	85	11.7	-0.29	815	0.58	1,895	0.58	49.4	0.59
Abu Hadriyah	0.21	2.23	1.9	88	2.2	0	1,024	0.57	2,249	0.55	63.8	0.57
Abu Jiffan	2.58	3.61	10	50	2.5	0	1,182	0.56	2,470	0.55	51.2	0.58
Ain Dar	0.25	2.7	6.9	37	1.7	0	897	0.76	2,251	0.84	45.5	0.42
Berri	1.06	8.92	15	143	33.5	-0.48	1,152	0.53	2,474	0.52	59.1	0.59
Dammam	1.04	2.18	8	52	2.8	0	432	0.48	725	0.49	24.1	0.47
Fadhili	4.13	11.1	5	31	1.5	0	878	0.77	1,949	0.71	51.7	0.54
Fazran	0.66	2.15	4.5	27	1.8	0	273	0.25	911	0.37	38.4	0.29
Haradh	0.02	0.79	5	32	2	0	2,741	0.77	3,825	0.37	50.4	0.52
Harmaliyah	1.69	5.3	6	32	1.6	0	856	0.61	1,980	0.59	45.3	0.44
Hawiyah	0.21	1.05	5	30	2	0	1,173	0.73	2,617	0.71	48.8	0.56
Khurais	0.58	2.94	9	36	2.2	0	1,285	0.69	2,656	0.64	47.3	0.63
Khursaniyah	1.96	4.77	7	43	2	0	1,079	0.59	2,346	0.58	47.9	0.53
Mazalij	1.9	5.47	6.3	37.8	2.2	0	1,232	0.71	2,565	0.67	50.6	0.65
Qatif	3.72	11.95	4	90	1.9	0	1,708	0.34	3,488	0.32	64.6	0.55
Shedgum	0.75	1.57	9	46	1.8	0	630	0.51	1,511	0.49	50.0	0.38
Uthmaniyah	0.23	1.55	9	29	1.8	0	1,438	0.83	3,279	0.83	36.5	0.70

Table A8 – Oil Field Data from Exploration and Producing

			Components (mole %)												
Well Name	Reservoir	Range	N_2	CO_2	**H_2S**	C_1	C_2	C_3	i-C_4	n-C_4	i-C_5	n-C_5	C_6	C_7+	GOR
Abqaiq	Arab-D	Min.	0.3	4.9	**0.9**	27.4	10.7	4.4	1.6	3.7	2.6	1.8	4.2	37.4	860
Abqaiq	Arab-D	Wt. Avg.	0.1	4.6	**1.8**	29.6	10.3	6.6	0.6	4.3	1.0	3.0	3.1	35.1	860
Abqaiq	Arab-C	Max.	0.6	5.1	**3.2**	6.1	4.7	7.4	1.2	5.1	2.1	3.5	4.6	56.6	135
Abu Hadriyah	Arab-A&B	Min.	0.2	1.0	**0.2**	3.5	2.9	6.7	1.4	5.4	2.2	3.9	4.3	68.3	57
Abu Hadriyah		Wt. Avg.	0.4	1.2	**1.4**	14.5	8.1	8.1	1.1	4.9	1.8	3.2	3.4	52.0	260
Abu Hadriyah	Arab-C	Max.	0.3	1.3	**2.2**	17.2	8.4	7.8	1.1	4.6	1.6	3.1	2.8	49.6	57
Abu Jiffan	Arab-D	Min.	0.2	1.7	**2.6**	9.6	9.6	9.3	1.2	4.9	1.7	3.0	3.9	52.4	253
Abu Jiffan	Arab-D	Wt. Avg.	0.2	1.9	**3.1**	9.2	8.9	8.8	1.2	4.7	1.7	3.1	4.4	52.7	253
Abu Jiffan	Arab-D	Max.	0.3	2.1	**3.6**	8.9	8.3	8.3	1.2	4.6	1.8	3.1	5.0	53.0	253
Ain Dar	L. Fadhili	Min.	0.1	3.9	**0.3**	34.3	13.8	8.5	1.0	4.0	1.1	2.1	1.6	29.3	730
Ain Dar	Arab-D	Wt. Avg.	0.1	5.9	**1.7**	25.1	10.4	7.7	1.0	3.8	1.2	2.2	3.0	37.8	550
Ain Dar	Arab-D	Max.	0.2	6.3	**2.7**	24.0	10.2	7.0	0.9	3.5	1.2	2.1	3.2	38.7	550
Berri	Arab-B	Min.	0.1	1.2	**1.1**	4.3	6.7	9.7	1.7	6.1	2.3	3.6	3.5	59.8	139
Berri		Wt. Avg.	0.1	1.5	**2.1**	4.6	6.4	9.2	1.5	5.7	2.2	3.6	3.7	59.3	145
Berri	Hanifa	Max.	0.1	6.6	**8.9**	24.9	10.2	7.2	0.9	3.5	1.2	2.1	2.8	31.6	659
Dammam	Arab-D	Min.	0.2	2.8	**1.0**	21.9	2.0	1.5	0.3	1.3	0.4	0.9	4.7	63.1	353
Dammam		Wt. Avg.	1.4	4.8	**1.7**	22.6	2.1	1.6	0.4	1.4	0.8	1.3	3.6	58.4	360
Dammam	Arab-D	Max.	1.5	5.5	**2.2**	22.4	1.6	1.1	0.2	0.8	0.4	0.9	3.4	60.0	353
Fadhili	Arab-D	Min.	0.0	2.9	**4.1**	33.4	11.1	6.8	0.5	3.9	0.8	2.5	3.2	30.7	955
Fadhili		Wt. Avg.	0.1	2.3	**5.5**	31.8	12.8	8.3	0.9	3.8	1.0	2.0	1.4	30.3	962
Fadhili	Arab-D	Max.	0.1	9.8	**11.1**	25.8	9.3	7.1	0.9	3.5	1.2	2.0	1.8	27.4	955
Fazran	L. Fadhili	Min.	0.3	3.8	**0.6**	21.0	11.3	9.3	1.2	5.2	1.8	3.4	3.7	38.5	1100
Fazran		Wt. Avg.	0.2	4.5	**1.5**	21.5	11.3	8.5	1.0	4.1	1.3	2.5	4.0	39.5	565
Fazran	L. Fadhili	Max.	0.1	2.1	**2.2**	34.0	11.7	6.8	0.8	3.7	1.3	2.2	2.1	33.0	1100
Haradh	Arab-D	Min.	0.3	1.4	**0.0**	19.5	10.5	10.0	1.2	5.1	1.6	2.8	2.8	44.7	470
Haradh	Arab-D	Wt. Avg.	0.2	3.8	**0.4**	22.2	9.5	8.5	1.1	4.5	1.6	2.8	3.9	41.4	470
Haradh	Arab-D	Max.	0.2	4.8	**0.8**	27.4	10.7	8.2	1.0	3.9	1.3	2.3	2.0	37.6	470
Harmaliyah	Arab-D	Min.	0.1	4.8	**1.7**	25.5	11.8	8.3	0.9	3.8	1.2	2.3	3.1	36.6	772
Harmaliyah	Arab-D	Wt. Avg.	0.1	5.1	**4.1**	27.7	11.4	7.8	0.9	3.7	1.3	2.4	3.0	32.7	772
Harmaliyah	Arab-D	Max.	0.1	5.3	**5.3**	24.9	10.6	7.6	0.9	3.8	1.2	2.3	3.2	34.8	772
Hawiyah	Arab-D	Min.	2.1	4.8	**0.2**	29.4	6.9	5.8	0.8	3.5	1.2	2.2	3.0	40.2	485
Hawiyah	Arab-D	Wt. Avg.	1.0	4.8	**0.8**	22.8	9.1	7.9	1.0	4.1	1.4	2.6	3.5	40.9	485
Hawiyah	Arab-D	Max.	0.4	4.1	**1.1**	15.9	8.3	7.6	1.0	4.3	1.7	3.4	6.0	46.1	485
Khurais	Arab-D	Min.	0.3	1.4	**0.0**	13.8	9.2	8.9	1.3	4.8	1.7	3.1	4.0	51.4	277
Khurais	Arab-D	Wt. Avg.	0.5	1.9	**0.6**	13.7	9.3	9.2	1.2	4.9	1.7	3.0	3.8	50.1	277
Khurais	Arab-D	Max.	0.8	4.5	**2.9**	12.8	6.1	8.9	1.4	4.9	1.9	3.0	3.9	48.7	277

Table A8 – Oil Field Data from Exploration and Producing (Cont'd)

			Components (mole %)												
Well Name	Reservoir	Range	N_2	CO_2	**H_2S**	C_1	C_2	C_3	i-C_4	n-C_4	i-C_5	n-C_5	C_6	C_7+	GOR
Khursaniyah	Arab-D	Min.	0.1	2.5	**2.0**	19.4	9.8	8.6	1.1	4.5	1.7	3.1	3.2	44.0	350
Khursaniyah		Wt. Avg.	0.2	3.1	**2.4**	21.5	9.8	8.5	1.1	4.2	1.5	2.6	2.8	42.3	380
Khursaniyah	Arab-B	Max.	0.1	4.7	**4.8**	15.8	7.2	6.9	1.0	3.8	1.5	2.7	2.9	48.7	350
Mazalij	Arab-D	Min.	0.1	3.4	**1.9**	28.7	5.8	6.4	1.0	3.7	1.4	2.2	3.2	42.1	398
Mazalij	Arab-D	Wt. Avg.	0.3	2.6	**3.2**	19.2	8.0	7.5	1.1	4.3	1.7	2.7	4.0	45.4	398
Mazalij	Arab-D	Max.	0.3	1.6	**5.5**	5.3	8.7	8.3	1.2	5.0	2.1	3.4	5.6	53.0	398
Qatif	Fadhili	Min.	0.2	3.5	**3.7**	38.2	12.3	7.4	0.9	3.6	1.2	2.2	3.0	23.8	1266
Qatif		Wt. Avg.	0.9	6.6	**7.9**	14.4	7.0	7.2	1.0	4.1	1.6	2.7	3.8	43.0	330
Qatif	Arab-D	Max.	0.3	6.7	**11.9**	20.8	9.0	7.1	1.0	3.6	1.4	2.2	3.6	32.5	870
Shedgum	Arab-D	Min.	0.3	5.4	**0.8**	25.0	10.0	7.7	1.0	3.9	1.3	2.4	3.3	38.9	540
Shedgum		Wt. Avg.	0.2	5.3	**1.1**	24.4	9.9	7.8	1.0	4.0	1.4	2.4	3.2	36.2	540
Shedgum	Arab-D	Max.	0.2	5.4	**1.6**	24.3	9.8	7.6	1.0	3.9	1.3	2.4	3.3	39.3	540
Uthmaniyah	Arab-D	Min.	0.1	3.8	**0.2**	26.1	9.7	7.7	0.9	4.2	1.6	3.0	3.4	39.4	515
Uthmaniyah	Arab-D	Wt. Avg.	0.2	4.5	**0.8**	24.6	10.0	8.1	1.0	4.1	1.4	2.5	3.3	39.3	515
Uthmaniyah	Arab-D	Max.	0.1	5.2	**1.6**	23.9	9.2	7.7	1.1	4.4	1.5	2.7	4.1	38.7	515

Table A9 – Gas Field Data from Exploration and Producing

Well Name	Reservoir	Mol Wt. Range		Component (mole %)														
				N_2	CO_2	**H_2S**	C_1	C_2	C_3	i-C_4	nC_4	iC_5	nC_5	C_6	C_7	C_8	C_9	C_{10}+
North Ghawar (Ain Dar and Shedgum)																		
ANDR-277	Khuff-B	23.1	Min.	14.7	3.8	**0.7**	70.4	4.9	1.8	0.4	0.6	0.2	0.2	0.2	0.3	0.4	0.3	1.1
SDGM-226	Khuff-C	23.7	Med.	11.8	3.7	**3.6**	69.4	5.1	2.0	0.5	0.8	0.3	0.3	0.4	0.4	0.4	0.3	1.1
SDGM-212	Khuff-C	24.6	Max.	11.5	3.9	**6.0**	66.6	5.0	2.1	0.5	0.8	0.4	0.3	0.5	0.6	0.6	0.4	1.0
Central Ghawar Area (Uthmaniyah)																		
UTMN-622	Khuff-B	25.5	Min.	10.5	1.7	**2.3**	68.4	6.7	3.0	0.6	1.2	0.5	0.5	0.7	0.8	0.8	0.6	1.8
UTMN-616	Khuff-C	24.9	Med.	11.5	3.3	**5.2**	66.0	5.8	2.5	0.5	1.0	0.4	0.4	0.6	0.6	0.6	0.5	1.3
UTMN-2000	Khuff-C	26.4	Max.	10.2	3.1	**9.3**	62.0	6.2	2.7	0.5	1.0	0.3	0.3	0.6	0.9	0.8	0.6	1.5
South Ghawar Area (Hawiyah)																		
	Khuff-C	27	Avg.	9.6	2.2	**2.5**	68	6.7	2.9	0.5	1.1	0.4	0.4	0.7	1.0	1.0	0.7	2.2
	Khuff-C	26.6	Min.	9.8	2.3	**0.5**	69.4	6.8	3.0	0.5	1.1	0.4	0.4	0.7	1.0	1.0	0.7	2.2
	Khuff-C	27.1	Med.	9.6	2.2	**3.0**	67.7	6.6	2.9	0.5	1.0	0.4	0.4	0.7	1.0	1.0	0.7	2.2
	Khuff-C	27.2	Max.	9.4	2.2	**4.5**	66.6	6.5	2.8	0.5	1.1	0.4	0.4	0.7	1.0	1.0	0.7	2.1
South Ghawar Area (Haradh)																		
	Khuff-C	25	Avg.	9.0	1.5	**0.6**	71.1	7.4	3.3	0.6	1.4	0.5	0.5	0.6	0.8	0.8	0.6	1.2
	Khuff-C	25	Min.	9.0	1.5	**0.5**	71.2	7.4	3.3	0.6	1.4	0.5	0.5	0.6	0.8	0.8	0.6	1.2
	Khuff-C	25	Med.	9	1.5	**1.0**	70.9	7.4	3.3	0.6	1.4	0.5	0.5	0.6	0.8	0.8	0.6	1.2
	Khuff-C	25	Max.	9	1.5	**2.0**	70.1	7.3	3.3	0.6	1.4	0.5	0.5	0.6	0.8	0.8	0.6	1.2
Qatif																		
QTIF-51	Khuff-A	20.9	Min.	6.5	9.1	**7.2**	75.8	1.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
QTIF-152	Khuff-B	24.7	Max.	42.2	2.0	**11.2**	42.2	0.9	0.2	0.0	0.2	0.0	0.0	0.1	0.8	0.0	0.0	0.0
Abqaiq																		
Abq Cap Gas	Abqaiq			0.7	8.6	**2.3**	64.5	14.1	6.1	2.2	0.9	0.3	0.1	0.1	0.1	0.0	0.0	0.0
Berri																		
Berri Khuff	Berri	23.2		10.0	8.2	**19.8**	61.4	0.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

The table below shows examples of the maximum RERs for some fields. The RER values shown are based on the calculation information above and the maximum open flow and highest sour gas concentration typically expected the fields listed. The values below are for example only.

Gas Fields	RER_{100ppm} (meters)	RER_{30ppm} (meters)	$RER_{½LFL}$ (meters)
Abqaiq Gas Cap	1170	3170	170
North Ghawar (Ain Dar and Shedgum)	1420	4090	160
South Ghawar (Haradh)	460	1210	160
South Ghawar (Hawiyah)	1110	3050	180
Uthmaniyah	2740	7110	170

Oil Fields	RER_{100ppm} (meters)	RER_{30ppm} (meters)	$RER_{½LFL}$ (meters)
Abqaiq	1780	4140	620
Abu Jiffan	1270	2660	220
Ain Dar	850	2130	160
Dammam	460	770	100
Fazran	280	960	100
Haradh	910	2250	210
Harmaliyah	1340	3060	190
Hawiyah	490	1130	220
Khurais	950	2010	200
Khursaniyah	1340	2890	200
Mazalij	1880	3820	300
Shedgum	530	1270	170
Uthmaniyah	700	1590	240

Gas Field RER Work Sheet

Information	Value
Well Name	
Field	
Absolute Open Flow, Q_{gas} MMSCFD	
Mole % of H_2S in Gas, $[x_{H2S}]_{gas}$	
DATA from Table A6	
Minimum AOF, MMSCFD, per Table A6	
Maximum AOF, MMSCFD, per Table A6	
Is AOF for well greater than minimum and less than maximum AOF for field?	( ) Yes (continue) ( ) No (stop: Contact LPD/TSU)
Minimum mole percent (%) of H_2S per Table A6	
Maximum mole percent (%) of H_2S per Table A6	
Is H_2S mole % for well greater than minimum and less than maximum flow rate for field?	( ) Yes (continue) ( ) No (stop: Contact LPD/TSU)
Constants from Table A6	
e	
f	
g	
h	
l	
m	
Calculate H_2S Release Rate	
$Q_{H2S} = (Q_{AOF})(x_{H2S})$ [MMscfd of H_2S]	
Calculate RERs $RER_{100\ ppm} = e(Q_{H2S})^f$: $RER_{30\ ppm} = g(Q_{H2S})^h$ $RER_{½\ LFL} = l(Q_{AOF})^m$	
Results	
$RER_{100\ ppm}$	
$RER_{30\ ppm}$	
$RER_{½\ LFL}$	

Oil Field RER Work Sheet

Information	Value
Well Name	
Field	
Maximum Flow Rate, Q_{oil} Mbpd	
GOR, scf/stb	
Mole % of H_2S in Oil, $[x_{H2S}]_{oil}$	
DATA from Table A7	
Minimum Flow Rate, Mbpd, per Table A7 or Q_{oil}	
Maximum Flow Rate, Mbpd, per Table A7 or Q_{oil}	
Is flow rate for well greater than minimum and less than maximum flow rate for field?	( ) Yes (continue) ( ) No (stop: Contact LPD/TSU)
Minimum mole percent (%) of H_2S per Table A7	
Maximum mole percent (%) of H_2S per Table A7	
Is H_2S mole % for well greater than minimum and less than maximum flow rate for field?	( ) Yes (continue) ( ) No (stop: Contact LPD/TSU)

Constants from Table A7			
a		b	
e		f	
g		h	
l		m	

Calculate flashed gas release rate	
$Q_{gas} = (Q_{oil})(GOR)/1{,}000$ [MMscfd]	
Calculate the H_2S concentration in flashed gas	
$\phi = a(GOR)^b$	
$[x_{H2S}]_{gas} = \phi\,[x_{H2S}]_{oil}$	
$Q_{H2S} = (([x_{H2S}]_{gas})/100)Q_{gas}$ [MMscfd of H_2S]	
Calculate RERs $RER_{100\ ppm} = e(Q_{H2S})^f$ $RER_{30\ ppm} = g(Q_{H2S})^h$ $RER_{½\ LFL} = l(Q_{gas})^m$	
Results	
$RER_{100\ ppm}$	
$RER_{30\ ppm}$	
$RER_{½\ LFL}$	