



Exploration & Production

GENERAL SPECIFICATION

ENVIRONMENT

GS EP ENV 270

Deep well disposal

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1. Scope

1.1 Purpose of the specification

The purpose of the present specification is to define the requirements for protecting the environment applicable when designing and implementing deep well disposal of liquid effluents produced on oil and gas production installations.

1.2 Domains of application

1.2.1 Installations concerned

The present specification applies to disposal wells drilled at onshore production sites. It can also be adapted to offshore installations.

1.2.2 Type of effluents to be disposed of

The principal effluents concerned are production water (produced water and process water). To a lesser extent and in certain specific conditions, this means of disposal can be used for drainage water and chemical effluents or "dissolved contaminants".

2. Reference documents

The reference documents listed below form an integral part of this General Specification. Unless otherwise stipulated, the applicable version of these documents, including relevant appendices and supplements, is the latest revision published at the EFFECTIVE DATE of the CONTRACT.

The latest edition or update of the relevant documents at the time of the project will be used.

Regulations applicable to deep well disposal

The regulations of the country where the disposal well is to be drilled will be applied.

The in force legislation should be reviewed in order to determine the technical and administrative constraints to which this type of disposal is subject, in particular any regulatory reports to be submitted to the Authority in charge:

- Request for authorization prior to disposal
- Environmental impact assessment (EIA)
 - Onshore activities (GS EP ENV 121)
 - Offshore activities (GS EP ENV 122).

If there are no local regulations in force, the disposal wells will be designed, drilled, and controlled according to the recommendations of French and/or European regulations.

Standards

Reference	Title
Not applicable	

Professional Documents

Reference	Title
Not applicable	

Regulations

Reference	Title
Not applicable	

Codes

Reference	Title
Not applicable	

Other documents

Reference	Title
Not applicable	

Total General Specifications

The present specification will be used in association with the General Company Specifications as well as with the standards and other documents to which it refers.

The following general environment-related specifications should be used in all cases:

Reference	Title
GS EP ENV 001	Onshore installations
GS EP ENV 121	Environmental requirements for oil and gas projects design
GS EP ENV 210	Environmental impact assessment onshore activities
	Liquid effluents drainage systems (under rev.); ref. GS EP SAF 228
	Offshore installations
GS EP ENV 122	Environmental impact assessment offshore activities

3. Specifications regarding deep well disposal (injection or reinjection)

3.1 General remarks on the elimination of liquid effluents

Technical and environmental constraints relating to the elimination of production water are mainly governed by the ultimate destination of these effluents. Subsurface or deep well disposal, i.e. reinjection into the reservoir or injection into a deep geological layer is, together with discharge (disposal in surface water), one of the main methods for disposing of liquid effluents.

The required conditions to be fulfilled regarding authorization of discharge will be specific to each of the two solutions. Whereas, in the case of surface discharge, conditions will mainly concern the treatment of water, especially de-oiling and compliance with imposed disposal standards, in the case of injection into a deep layer, the main conditions to be fulfilled concern:

- Selection of the disposal zone (see § 3.2)
- Protection of fresh water aquifers

whence the present specifications for designing a disposal well (§ 3.3) and recommendations implied by the use of this type of well (§ 3.4).

3.2 Choice of injection site

3.2.1 Regional and local geology

Before running any other study regarding injection conditions at great depth, a good knowledge of the deep geology of the region must be acquired and a synthesis file established.

The stratigraphic cross-section of the formations should be drawn giving the type of layer lithology and identifying the different cap rocks or impermeable formations, as well as all reservoirs or fresh or salt water aquifers.

3.2.2 Criteria for selecting the disposal zone

If there are no known stratigraphic or structural geological traps, or if it is not possible to reinject into the aquifer of the reservoir itself (see § 3.3.4), the reservoir selected for injection has to satisfy a certain number of criteria.

A receiving formation with good permeability must be found, limited by impervious layers to prevent any vertical displacement which could generate contamination of aquifers used for drinking water supply.

The reservoir should be selected on the basis of the ten following criteria:

- Uniformity of the reservoir
- Large horizontal extension
- Adequate thickness
- Sufficient depth
- High porosity and permeability
- Low injection pressure
- Salt water aquifer

- Insulation from the drinking water aquifers
- Good sealing properties of any wells existing in the vicinity
- Compatibility between the injected fluid and receiving zone.

3.2.2.1 Uniformity of the reservoir

The layer selected should be as continuous and homogeneous as possible, without any major lateral facies changes or faults.

3.2.2.2 Large horizontal extension

This characteristic is closely related to the above criterion.

3.2.2.3 Adequate thickness

The layer should have a thickness or height "h" of several dozen meters.

3.2.2.4 Injection at great depth

The injection zone should be a **deep reservoir**, lying, as far below the producing layer as possible so that injected fluids will not corrode the casing of producing wells.

3.2.2.5 High porosity/permeability

In all cases, porosity ϕ will be over 10 % and the permeability k over 25 md ($25 \cdot 10^{-3}$ Darcy's or $25 \cdot 10^{-8}$ m/s) (see graph, fig. 1).

3.2.2.6 Low injection pressure

The formation should have a good injectivity index (I_x)⁽¹⁾; injection pressure should be such as not to cause any hydraulic fracturing which could damage the receiving layer or cap rock (below lithostatic pressure).

(1) $I_x = \frac{Q}{\Delta P}$ where Q = injection flow rate and P = pressure increase

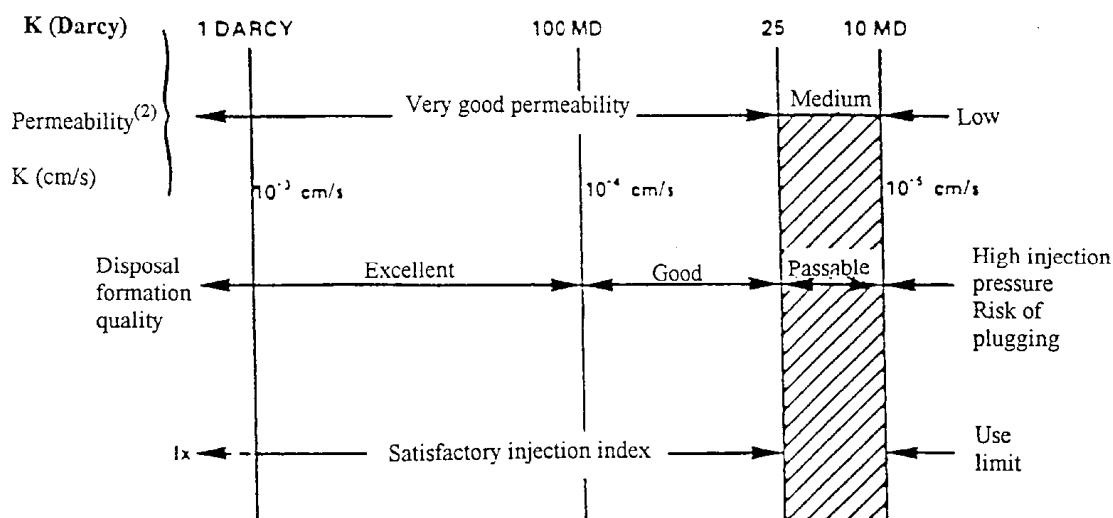


Figure 1 - Disposal formation characteristics ⁽¹⁾

Note (1): Table established from data taken from the following studies:

- E.C. DONALDSON and F.S. MANNING
Subsurface disposal of industrial wastes. University of Tulsa. Environmental protection project program, 1980
- Le courrier Johnson: special issue on the injection of effluents at great depth (No. 40), Dec. 73.

Note (2): Two concepts of permeability:

- In hydrogeology, permeability K expresses the circulation of fluid through a formation at a velocity $[L.T^{-1}]$.
- In reservoir engineering, permeability k refers to the characteristics of the porous medium in terms of a surface $[L^2]$. It is expressed in Darcys ($1 \text{ Darcy} = 10^{-8} \text{ cm}^2$).

The relationship between these two concepts of permeability is given by the following equation:

$$K = \frac{k \rho g}{\mu}$$

where:

μ : absolute viscosity of the fluid

ρ : density

g : acceleration

For a water at 20°C, we have $K \text{ (m/s)} = 10^{-5} k \text{ (Darcy)}$.

3.2.2.7 Salt water aquifer, i.e. cannot be used as drinking water

If the disposal zone is not the reservoir aquifer (or in communication with it), the water of this formation should have temperature and salinity characteristics similar to or worse than those of the injected water (to impact).

3.2.2.8 Insulation from drinking water aquifers

The reservoir should be insulated from overlying and possibly underlying potential drinking water aquifers by an impermeable layer (aquitards, cap rock) of sufficient extension and thickness. In order to prevent any contamination of fresh water aquifers, these layers should be completely impermeable (permeability coefficient of less than 10^{-9} m/s).

The best cap rocks are usually marls, clayey formations or salt layers.

3.2.2.9 Good sealing properties of neighbouring wells

In the vicinity of the future injection site, all deep wells (old oil-gas wells, geothermal wells, etc.) should be listed and checked. The integrity of these wells should be checked and, when necessary, so should the procedures used to close in the wells (plugging). In some cases and under certain conditions, one or several of these could be used as observation wells.

3.2.2.10 Compatibility between injected fluids and receiving zone

Any risk of plugging the reservoir must be avoided. The following are possible causes of plugging:

- Deposition of suspended particles or aggregation of colloids
- Formation of precipitates (in certain cases chemical incompatibility between the effluent and formation water)
- Swelling or breakdown of clays
- Presence of gas bubbles
- Development of micro-organisms (bacteria, fungi).

Laboratory compatibility tests should be performed in order to define any pre-treatment of the effluent to be injected.

3.3 Drilling and use of disposal wells

3.3.1 Architecture of the disposal well

Throughout the drilling operation, necessary measurements should be taken, in particular, the mud program should be carefully studied to avoid any pollution of ground water levels crossed.

The well will be cased and cemented to guarantee insulation and protect the aquifers.

The various casing strings: surface casing and protection casing or liner will be run in and **cemented over their entire height** to ensure tightness of the well, avoid polluting fresh water aquifers, and also protect the casing against the corrosive action of certain formation waters.

The effectiveness of the **cement job will be verified by logging**.

During and at the end of the drilling phase, a number of tests should also be performed in order to assess the characteristics of the disposal zone and its aquifer (see following table).

The COMPANY also reserves the possibility to require cathodic protection to avoid corrosion of casings by corrosive water contained in the aquifers.

Table - Data needed to evaluate the receiving environment

Parameter	Method of characterization
Porosity	Core measurements, electric logs; radioactive logs (γ ray and neutron), sonic logs
Permeability k	Core measurements, pumping or injection tests
Fluid pressure in the formation	Drill Stem Tests (DST), Repeat Formation Tester (RFT), pumping or injection tests
Water sampling	DST, RFT, pumping tests
Geological characteristics of formations crossed and their thickness	Examination of cuttings and cores, penetration rate, electric logs, sonic logs, radioactive logs, dip meters
Formation temperature	Temperature logs

Note: Analysis of these tests and the interpretation of results obtained are the job of a Reservoir Engineer or specialist.

3.3.2 Equipment of the disposal well

3.3.2.1 Downhole completion (Figs. 2 and 3)

Depending on the geological characteristics of the reservoir, the completion of the well at the receiving formation should be one of the following three types:

- "Perforated": friable formations
- "Open hole": consolidated hard sandstone or compact limestone formations
- "Gravel pack": unconsolidated sands.

In order to avoid any risk of corrosion, the well should be fitted with a fibber glass reinforced epoxy resin tubing (or epoxy-coated steel).

Anchored at the wellhead and run in to the downhole completion, this injection tubing will be supported at the base of the inner casing string by a production packer.

The tubing-casing annulus will be filled with an anti-corrosive fluid (inhibited water), usually under pressure. This process guarantees the perfect seal of the casing and tubing and total integrity of the well.

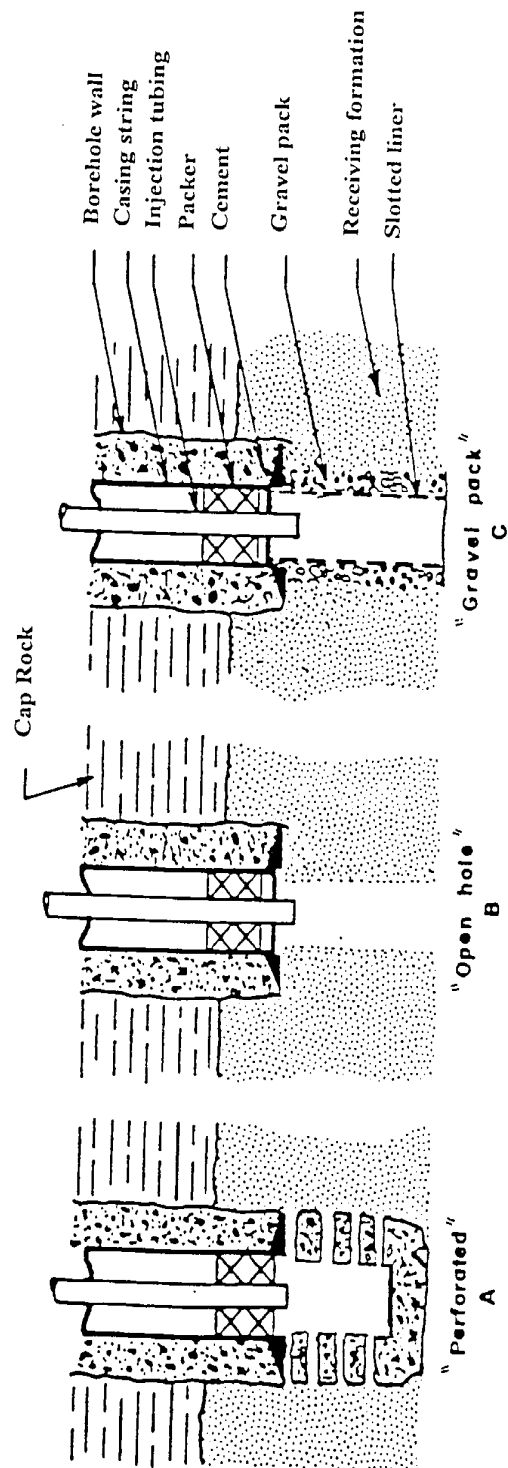
3.3.2.2 Wellhead and surface equipment

The wellhead should be designed to withstand any pressures likely to be encountered at this level considering the geological conditions down hole.



The wellhead will be equipped so that at any time, it is easy to take samples and measure the level, flow rate and pressure (injection pressure and the pressure or level of the annulus) (see paragraph 3.3.5 below).

In order to avoid any reflux of discharged water, in case of injection pump failure or wellhead pressure increase, a check valve will be installed on the pipe between the injection pump and the wellhead.



Source : from E.C. DONALDSON et F.S. MANNING

Figure 2 - Possible disposal well completions

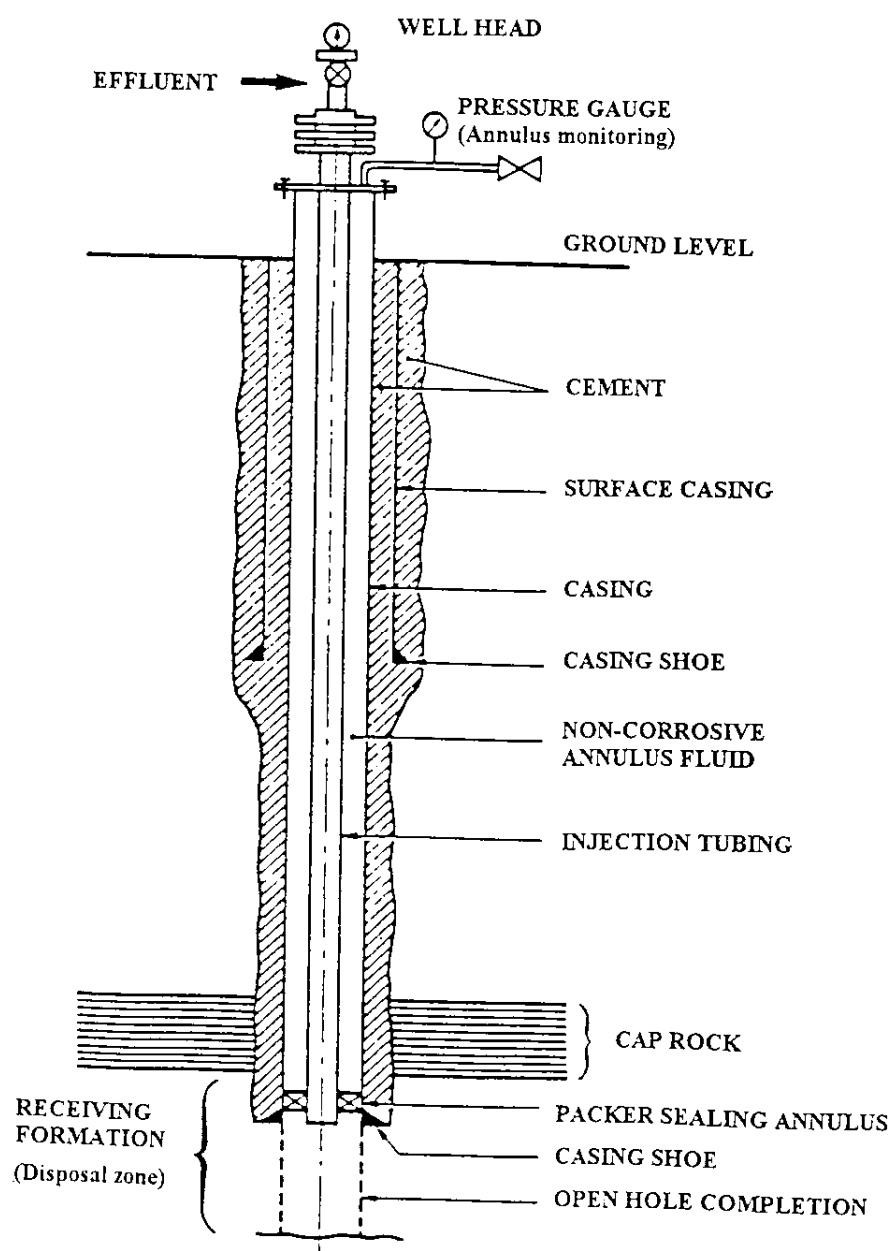


Figure 3 - Schematic drawing of typical disposal well

The well will be connected to the other surface installations:

- Injection pumps
- Buffer storage installation for effluents awaiting disposal

- Pre-treatment units:
 - Degassing or de-aeration (in certain cases)
 - De-oiling (decantation)⁽¹⁾
 - Elimination of suspended solids (coagulation, sedimentation or filtration)
 - Elimination of micro-organisms (bactericide injection).

Other treatments may prove necessary, such as:

- Pre-precipitation, oxidation
- Neutralization
- Injection of a corrosion inhibitor.

In a preliminary phase, a fluid or reagent (chemically compatible with the receiving formation water) can also be injected. The purpose is to create a liquid plug which, once injected forms a buffer zone in the reservoir preventing any injectivity loss by precipitation around the borehole (keeping salts in solution).

3.3.3 Use of an existing well as disposal well

The use of an oil or gas well may be considered in certain cases after checking that:

- Disposal zone selection criteria are all respected
- The casing and cement characteristics are suitable
- The well has the necessary equipment to act as a disposal well (downhole completion, injection tubing etc.).

This solution is subject to prior agreement by the Authorities.

3.3.4 Use of an injection well (reinjection into the reservoir)

The recycling of production waters as injection water (repressurized to reservoir and enhanced recovery pressure), will, in all cases, be the preferred solution.

Therefore, right from the design phase of the de-oiling treatment, these hypotheses must be taken into account, separating the effluents according to type (avoid mixing drainage and reservoir water), selecting treatment processes and keeping injection of necessary additives to a minimum⁽²⁾.

Plugging and compatibility (in the case of mixing with other injection waters) studies should be undertaken.

Finally, the injection wells should be designed with the same specifications as the disposal well (see paragraphs 3.3.1 and 1.2).

⁽¹⁾ The COMPANY reserves the possibility to go beyond a simple gravity separation and to impose complementary de-oiling treatment in order to limit the plugging effect of oil droplets. The oil content of the injected effluent could have an impact on the disposal well treatment operation frequency (restoration of injectivity through well stimulation operations).

⁽²⁾ Reinjection of reservoir water into the original site when it has not been contaminated or received any additives is usually exempt from administrative authorization prior to disposal.

3.3.5 Use of a dual completion well

A well specifically equipped with a dual completion (injection/production) could also be considered after checking, within the scope of the project, that this solution is technically feasible and after agreement by the COMPANY.

This option should be taken into consideration when defining the drilling and casing programs. The injection tubing should be run in down to the **receiving layer, which, in all cases, should be well below the producing layer.**

All the recommendations for choosing the site and the characteristics of the well given in chapters 3.2 and 3.3 must be respected.

The injection and production tubings will have packers providing protection for each of the two layers.

3.4 Inspection, monitoring and maintenance

Proper application of the operating procedures will demand that suitable control systems be applied from the design phase of the well.

- Control system for annulus pressure/level
- Control system for injection pressure
- Observation well
- Sampling.

3.4.1 Inspection for well integrity

The sealing properties of the well should be inspected periodically by measuring the pressure or level in the annulus.

Any pressure variation or variation in the level of the annular space will generally be an indication of fluid loss in the disposal well:

- Increase in pressure or level in the annulus: fluid loss in injection tubing
- Drop in pressure or level: fluid loss via the casing (in the hypothesis of injection under pressure).

3.4.2 Inspection while operating

When operating, injection pressure and flow rate will be checked regularly. In particular, it is important to ensure constant monitoring of the injection pressure and detect, in good time, any abnormal rise in pressure following plugging which could demand treatment of the reservoir (or stimulation) by doing an acid job (hydrochloric acid for limestone formations and hydrofluoric acid for sandstone reservoirs).

3.4.3 Assessment of operating effects

Old wells listed, having been drilled down as far as the disposal zone and lying in the vicinity of the disposal well will be surveyed at regular intervals. Any anomaly (seepage at the wellhead) should, after discussions with the Authorities, be the object of a workover on the defective well (plugging).

With the purpose of assessing the impact of injection, and in particular to monitor hydraulic behaviour of the reservoir (overpressures, injection front), periodic observations will be carried

out. One or several of these neighbouring wells, lying if possible downstream in relation to the regional hydrodynamics, could be designated as observation or monitor well for pressure measurements, recording water levels and taking water samples for analysis.

3.4.4 Monitoring inspection of discharged effluents (self-program)

Analyses must be carried out prior to disposal. These analyses will be performed on a representative average sample of the discharged effluents over a period of 24 hours. Samples will be taken from a sampling point fitted in the wellhead.

Analyses will cover:

- pH measurement: daily
- Suspended matter determination: daily
- Measurement of hydrocarbon content: monthly

The particular specification will stipulate any necessary extra analyses, and the basic procedures and standards for control analyses.