



Exploration & Production

GENERAL SPECIFICATION

Drilling & Wells

GS EP FP 262

Organization and Safety during Stimulation Operations
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1. Scope

This document defines the basic principles to be applied when preparing and running stimulation operations, thus providing the safest and most efficient configuration to reach the objectives.

The rules and recommendations set out in this document are primarily issued for high-pressure pumping treatments performed either rig-less, through a permanent completion string, as well as for treatments conducted through a work string / DST string.

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.

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

Reference	Title
Not applicable	

3. Foreword

3.1 Preamble

Stimulation treatment is here used as a generic term and gathers in fact all operations related to the reservoir / well bore interface like acidizing, hydraulic fracturing or sand control installations.

As a matter of fact, stimulation treatments are carried out in order to:

- Improve, guarantee or restore well productivity or injectivity by treating the formation and/or cleaning the well conduit with various chemicals (acidizing, gas/water shut-off, scale treatments, etc.),
- Improve well productivity or injectivity by hydraulically fracturing the formation,
- Sustain well productivity or injectivity by installing sand control (gravel pack, frac-pack).

Any successful stimulation treatment creates a highly conductive path or area in the near-well bore region, which then improves the production or injection flow.

Stimulation works on a well are normally carried out by a Contractor operating under the supervision of the Subsidiary. As a result, standard operating procedures should be developed for each type of treatments. Such procedures should be based upon the requirements described in the present general specifications, the purpose of which is to:

- Ensure safe and effective stimulation operations,
- Improve stimulation performance and reduce stimulation treatment incidents,
- Provide data to enable improved diagnosis when incidents do occur,
- Obtain data that can be used to improve materials and methods.

Stimulation treatments can be either conducted through a work string / DST string (gravel pack, high rate water pack, frac-pack, stimulation of an exploration well, etc.) or through a permanent completion string (possible rig-less operation in this latter case).

3.2 Glossary

BHT	Bottom Hole Temperature
CT	Coiled Tubing
DP	Dynamic Positioning
DST	Drill Stem Test
ESD	Emergency Shut-Down
FSR	Flow lines Safety Restraints
HP/HT	High Pressure / High Temperature



ID	Internal Diameter
JRA	Job Risk Assessment
MSDS	Material Safety Data Sheet
PPE	Personal Protective Equipment
PRV	Pressure Relief Valve
RSES	Responsible for Safety and Environment on Site
SCSSV	Surface Controlled Subsurface Safety Valve
SIMOPS	Simultaneous Operations
SOR	Statement of Requirements
SPM	Stroke per minute
SWL	Safe Working Load

4. Definition of responsibilities

4.1 Operational program

As soon as feasible, Geosciences and Drilling & Wells (or Well Servicing) entities of the Subsidiary should jointly establish a statement of requirements (SOR) to define the objectives of the stimulation treatment and the corresponding general operational program.

Once the SOR is approved and issued, the stimulation program is elaborated by Senior Wells Engineers and approved by Drilling & Wells (or Well Servicing) Managers.

Whatever the importance and the size of the job could be, a dedicated stimulation program shall be issued for each well to be treated.

In addition to providing general reservoir data and specific well information (well schematic & completion data, safety concerns (hazards, presence of H₂S, etc.), pressure pumping limitations, etc.), this technical program is required to contain the following items:

- Summary of the sequence of operations,
- General rig up on location and detailed schematics of the equipment lay out,
- Detailed pressure tests program,
- Definition of the fluids & additives (proppant if any) to be used during the treatment, with detailing the fluid mixing & quantities and the QA/QC that needs to be performed by the Stimulation Contractor's crew prior to pump the job,
- Detailed pumping schedule (stage / type of fluid / volume / expected rate / expected duration / expected pressure / displacement volume / etc.),
- Role and responsibilities during the treatment and in case of contingency,
- Procedures in case of emergency situations (surface leak, tubing leak, breakdown of equipment, etc.).

Also, prior to performing a hydraulic fracturing or frac-packing stimulation, a numerical simulation of the treatment is carried out using a Company-approved model (NSI Stimplan 3-D



model). For matrix acidizing stimulation, a numerical simulation using Contractor's Stimulation software (such as StimCADE, Stim 2001, etc.) is recommended.

4.2 Leading and supervision of the operations

4.2.1 Drilling & Wells (or Well Servicing) Entity

The Drilling & Wells (or Well Servicing) entity of the Subsidiary is in charge of the execution of the stimulation operations in accordance with the technical program and the applicable safety rules.

To assist during the first treatments of a stimulation campaign or for a particularly large and/or dangerous job, a Stimulation Specialist could be requested from the Head Quarters, acting as a technical advisor. In that case, he will assist, at the base, the Senior Wells Engineer of the Drilling & Wells (or Well Servicing) entity to prepare the program. On the rig site, he will assist the Drilling & Wells (or Well Servicing) Supervisor to implement the program.

4.2.2 Drilling & Wells (or Well Servicing) Supervisor

A Drilling & Wells (or Well Servicing) Supervisor shall be on the location and be officially in charge of the operational progress of the job on site, from the initial site review and hook-up of the required equipment to the unloading of the well.

In addition, for operations on a producing well, a Production Representative shall be present and be responsible for operating all the production equipment.

The Drilling & Wells (or Well Servicing) Supervisor reports to the RSES for safety and environment matters and he coordinates the actions of the various service companies involved in the operation (Drilling Contractor, HP Pumping, Well Testing, Electrical Logging, etc.).

More particularly, he :

- Supervises the execution of the technical program, with respect to the safe limits,
- Ensures, conjointly with the RSES, that SIMOPS issues and work permit procedures are in line with the SIMOPS safety dossier and the bridging document,
- Supervises the pumping and flow back operations, in coordination with the Stimulation Specialist,
- Supervises the cleaning of the location after the treatment.

4.2.3 Senior Wells Engineer

The Senior Wells Engineer, located at the base, monitors the daily progress of the stimulation operation and ensure its objectives are being met. Necessary program amendments should be prepared and discussed with Geosciences and the Drilling & Wells (or Well Servicing) Supervisor.

4.2.4 Drilling & Wells Superintendent

In case of rig-based operations, the Drilling & Wells Superintendent in charge of the rig and located at the base helps the Senior Wells Engineer on equipment delivery / preparation, logistic issues and communication with the Drilling Contractor.



4.2.5 Stimulation Contractor's Supervisor

The Stimulation Contractor's Supervisor is in charge of all surface stimulation operations on the site. He operates under the direct supervision of the Drilling & Wells (or Well Servicing) Supervisor and provides him with all necessary information for reporting purposes including information on stimulation operations progress, HSE issues, quality control, stimulation equipment status, supplies and logistics, etc.

He ensures that all stimulation equipment is rigged up, tested and operated in accordance with current procedures and the stimulation program.

He is responsible for the quality of stimulation measurements, data collection and reporting, routine inspection and maintenance of equipment, on-the-job supervision and training of personnel, safe operating practices of stimulation crews, toolbox meetings, etc.

5. Organization on site

Stimulation treatments are potentially hazardous because of the high pumping pressures involved, the nature of the injected fluids (toxic, corrosive, energized with compressible gas, flammable, etc.) so as the chemicals handled and the number of people involved.

Depending on their nature, stimulation operations may require a large plot space to allow all the equipment to be placed on site at suitable distances from the well head. Plot size requirements should thus be identified as early as possible in the planning stage.

5.1 Site survey

A site survey carried out beforehand by a Drilling & Wells (or Well Servicing) Representative, together with Production and Safety Representatives, is a must. A survey report should then be issued with correctives actions, if any. This report would allow to list in particular all critical points noticed in the immediate vicinity of the site / well location: access (roads) for equipment and water haulages, other logistical constraints, platform, cellar, pits and flare pit, water well, wind direction, production and gas lift lines, cluster or isolated well, village near the site (if any), risk of pollution, overview of well maintenance history and previous in-the-hole operations.

A layout plan for the spread of the stimulation equipment is then to be provided by the Stimulation Contractor, taking into consideration hazardous areas and ensuring that access is possible for other services, e.g. perforating, coiled tubing, well pressure control equipment, etc.

5.2 Safety perimeter

A safety perimeter is defined, gathering all the HP equipment susceptible to induce projections of pressurized fluid in case of incident or leak: well heads, injection lines, clean-up lines and manifolds. If enough space is available on location, the safety perimeter radius is 30 meters and it is clearly delimited with dedicated barriers and signs.

During the operations, personnel movements are restricted around the pressurized equipment and only the designated Stimulation Contractor's personnel is allowed to circulate within this safety perimeter.

5.3 Operational perimeter

Since they are potential ignition sources for flammable fluids, HP pumps, engines and electrical appliances are excluded from the above safety perimeter. If feasible, they are located at a minimum distance of 30 meters from the well head, inside the so-called operational perimeter.



The stimulation control centre is also located at a minimum distance of 30 meters from the well head and preferably 15 meters away from the HP pumps and the mixing equipment, with a clear view of the whole installation.

Wind direction is obviously to be taken into account to locate the stimulation control centre and the engines. Positioning is done also according to the swinging effect of any parted line. Emergency escape direction and muster point for personnel are defined and indicated.

Suggested lay out schematics for stimulation equipment are presented for both onshore and offshore environments in Appendix 1 and Appendix 2.

6. Equipment

6.1 Well equipment

6.1.1 Integrity of well tubular equipment

The well architecture needs obviously to accommodate the injected fluids and corresponding pressures, so as the stresses and movements induced by the stimulation treatment.

Drilling & Wells (or Well Servicing) entity shall check the initial casing/tubing design and verify that both tubing and casing "as set" cope with the concerned load cases, (leak at upper part of completion tubing / DST string, while breaking down the formation and during a screen-out).

Burst calculations of the tubing are carried out based on the maximum expected pressure in case of screen-out (see part 6).

Collapse calculations of the tubing should also be made, as the tubing could be loaded with gas, with no pressure at surface and pressure in the annulus.

Such calculations should also be made to avoid exceeding the collapse rating of any down hole tools located below the packer (frac-packing case).

Tubing stress analysis, simulating the forces on the tubing during the various operations in the well, should be readily available during the stimulation operations.

6.1.2 Cement quality

Quality of cement is assessed in terms of sealing capabilities. Prior to perform a stimulation treatment, it is so advisable to record a CBL, USIT or equivalent log to get a proper indication of how the cement bond is over the zone of interest.

6.1.3 Down hole safety valve

The down hole safety valve is always a concern when performing stimulation treatments (especially hydraulic fracturing) through a permanent completion: it could be damaged during the treatment and also during the well clean-up operation. In any case, the tubing string should exhibit a fail safe closed type down hole safety valve when the well is naturally flowing.

On a production well, when this valve is wire-line retrievable, it is exchanged with a new valve after the unloading phase. When proppant is used, this valve is chosen for sandy service, low friction loss and easy retrieval.

In case of a tubing retrievable valve, the use of coiled tubing or the installation of a protection sleeve (which is not sealing) may be considered for a damage-free stimulation. Anyway, in case



a tubing retrievable valve is used in a 3 1/2" tubing, it is not recommended to run any protection sleeve due to diameter restriction.

It should also be highlighted that the control line and the control line connector in the tubing hanger are rated to the maximum wellhead pressure which could be observed during any course of the treatment (including screen-out or ball-out).

6.2 Storage and handling equipment

6.2.1 Rigging and lifting equipment

Cranes are not operated without work permits.

All baskets, containers and slings being sent on site are marked with identification number and display valid certification. In addition, SWL is clearly marked on each and every sling.

Documents are available at all times to support the validity of certification. Stimulation Contractor's personnel is available to ensure that all loads are properly certified, properly packed and suitable for lifting.

6.2.2 Storage tanks

All storage tanks are inspected for mechanical conditions, operational and non-leaking valves, safe and secure ladders, cleanliness. A visual level indicator is provided on all storage tanks and they are equipped with guard rails when access to the roof is required. They are electrically grounded and spotted correctly on lease, especially with respect to hazardous areas designations.

Active and dead volumes of the tanks should be checked. It is not recommended to use a tank showing more than 10% dead volume. If required, tanks could be tilted slightly forward so that most of the fluid will drain out of the front of the tank.

Enclosed heavy-duty tanks are used if the treatment calls for flammable hydrocarbon-base fluids with a specific gravity lower than 0.78 (50° API and above). Such flammable fluid storage tanks are fitted with a vent line and a spark arrestor and are interconnected and earth grounded together with the blender. They are placed in a distant position from any source of ignition and obviously be excluded from the safety perimeter. Embankment to contain fluid leakage is evaluated.

If it is planned to use acid, dedicated acid transport (live acids and premixed acids are brought to the location in purpose built containers) and acid storage tanks are used. Tanks susceptible to contain acid mixtures are enclosed and lined with an approved acid-resistant coating. The dead volume should be minimized and should not exceed 2% of the tank volume.

6.2.3 Transfer pumps

The transferring of acids and chemicals only takes place through the use of closed system transfer pumps. Chemicals are not added through the use of open top buckets. Also the transfer of drums with mechanical hand pump is banished.

An appropriate hydraulic, pneumatic or electrical transfer pump shall be used when transferring chemicals.

The operator is able to shut-down the transfer pump at any moment.

All transfer pumps and equipment are flushed with water after use.



6.2.4 Chemical hazard / data sheets

When performing stimulation treatments, various types of chemicals are used: their storage and handling is done according to their notice of use and with specific care.

Material safety data sheet (MSDS) of each chemical product delivered to the location shall be available on the location.

Copies of these MSDS is given to the medic (if any on location) and to the safety officer.

For dangerous substances, the official code of labelling is followed.

Also, in order to be able to neutralize a chemical during a leak (especially in an offshore situation) or a spillage, sufficient neutralizing agent (as per MSDS) is supplied by the Stimulation Contractor and available on site for each of the concerned chemicals.

6.3 Mixing and pumping equipment

Such category of equipment requires additional attention because of the hazards created by some of their rotating mechanical parts (pumps, blenders, etc.) and the possible build up of static electricity due the friction of dry granular (proppant) and liquid substances.

To discharge any potential build-up of static electricity, all hopper(s), blender(s), pumping unit(s) and other major equipment items used on location shall be electrically bonded with copper-cored cable and grounded to the well.

Fluid mixing operation takes place prior to pumping the treatment, during the equipment rig up or when all the equipment has been rigged up.

For each fluid recipe to be pumped in the well, a detailed mixing procedure is provided by the Stimulation Contractor.

During mixing of chemicals, only the necessary people is present in the mixing area. Barriers are erected and warning signs are posted to delineate the area.

All pumped acids are adequately inhibited to protect the tanks, pumps, lines, coiled tubing and well tubular equipment. The concentration of inhibitor is chosen with consideration to the duration of the operation and to the bottomhole temperature.

6.3.1 Blenders

Blenders are used to mix granular solids with a liquid carrier. A blender may consist of vehicle-mounted feeding hopper and mixing tanks equipped with paddle agitators. The liquid with solids in suspension is subsequently fed from the blender to the pumping unit for injection to the well.

The paddles of a blender are mechanically driven and hence rotating parts are guarded to prevent entanglement of clothing, etc. It is furthermore expressly forbidden to mix any additive with a mechanical device (stick, hose, etc.) in a tank with moving paddles.

The blender is run by an operator located on the equipment. All the parameters are displayed in the stimulation control centre, from where it is possible to modify them. The ramping of proppant concentration should be automated.

It is not recommended to use any dry additive powder, except encapsulated breakers or fluid loss agents. As a matter of fact, dry additives are dusty and difficult to be transferred or mixed. They also render difficult an accurate monitoring of the pumping rate.



An enclosed blender system is used if the selected carrier fluid is flammable with a specific gravity lower than 0.78 (50° API and above) and a REID vapor pressure lower than 4 psi.

For any treatment, involving proppant (propped hydraulic fracturing or gravel-pack jobs), two densitometers (1-high pressure and 1-low pressure) shall be available in order to indicate the proppant concentration.

The first densitometer will be located on the return side of the blender and will indicate the concentration of the fluid in the blender. The second densitometer (HP) will be located close to the well head and is used primarily to indicate the beginning of the flush (by monitoring the sand concentration once the final proppant stage has been pumped).

6.3.2 High-pressure pumping units

Each HP pumping unit shall be equipped with an automatic over-pressure shut-down system (pressure limit switch or relief valve).

For hydraulic fracturing operations, an ESD of the HP pumping units will be available inside the stimulation control centre, where the pump operator is located along with the frac master, so to be able to react faster to any instruction given to him.

No flammable fluid shall be stored in the gauge tank of the HP pumping units.

In addition to the flow rate measurement derived from the number of revolutions of the pumps, an independent flow-meter will be available to monitor the dirty rate (proppant-laden fluid / mixed acid).

High pressure pumping units will be primed with water.

6.3.3 Re-circulating pumps

Re-circulating pumps should have a sufficient rate in order to re-circulate a complete tank in less than 20 minutes. A spare re-circulating pump on location is highly recommended.

6.3.4 Chemical additive pumps

Rates of all chemical additives are automatically linked to the main (clean flow) rate. For that purpose, electronic devices, such as mass or turbine flow-meters, are used to control the rate of the chemical additive pumps.

Also, it is highlighted that chemical additive pumps should have a back up.

6.3.5 Laboratory QA/QC container

A laboratory QA/QC container is required onsite when performing a stimulation treatment (especially for hydraulic fracturing and large acidizing jobs). And it is possible to monitor the whole treatment from this laboratory QA/QC container: a communication system is available between the Stimulation Contractor's Supervisor and the laboratory technician.

A safe and practical fluid sampling-point is made available to collect representative fluid samples from the treatment in a timely manner. Disposal of samples or any laboratory effluent is made to an appropriate collector (safe and environmentally sound).

The following equipment is the minimum equipment required in the laboratory:

- Fann 35 type viscometer,

- Water bath,
- pH meter with side glass probe,
- HP/HT portable cell, if it is planned to perform treatment for BHT > 100°C,
- Sand sieves,
- Lab-type sample bottles adequate for the fluids to collect,
- Samples of actual chemicals on location for fluid testing.

6.3.6 Internal combustion engines

All internal combustion engines, including diesel engines, are operated outside of the rig and/or well designated hazardous areas. Where it is unavoidable and such units are operated within a Zone 2 area (i.e. within 3 to 7 meters distant from the wellhead or a flammable liquid storage tank), they are constructed and equipped as follows:

- Exhaust with anti-spark device and cooling,
- Automatic shut-down by over speed detector system,
- Automatic closure of air intake and automatic shut-down in the event gas is detected,
- Conspicuous and easily accessible shut-down control.

6.4 Safety equipment for personnel (accident and fire prevention)

On the location, Stimulation Contractor's personnel shall wear adequate personal protective equipment (PPE). Wearing hard hat, safety shoes and long sleeves overalls is mandatory for all personnel.

In particular, all individuals dealing with handling or mixing of dangerous chemicals should wear protective equipment defined in the relevant MSDS and in local or Company's policy (example: safety goggles, rubber / insulated gloves, face shields, ear protectors, impermeable clothing, cuff less trousers (trousers to be worn over the boots), rubber safety boots, etc. Personnel operating a feeding hopper wears suitable dust protector masks to prevent inhalation of chemical dust. In the case of substances with hazardous fumes or vapors, suitable respiratory protection is worn.

When performing a stimulation treatment, a specific first aid kit is supplied by the Stimulation Contractor and is available in the stimulation control centre (if any) or in the laboratory. The content of this first-aid kit is depending on the chemicals used on the location. Calcium gluconate antidote-gel is available on location for jobs involving hydrofluoric acid (HF). Additional items such as O₂ resuscitator, perfusion kit, inflatable stretcher and splints may also be considered depending on the local environment (remote location).

Eye wash bottles and water safety shower are positioned at strategic points in the immediate area where the mixing takes place and near the discharge area. The safety shower is obviously connected to a working water line and the eyewash bottles are full of water. It is advisable to have a wash down water hose close by the area since, in case of personnel being exposed to an acid or chemical substance, the affected area should be immediately and continuously flushed with copious amounts of water until diluted and the medic informed. An additional safety shower should also be available next to the sampling point. All devices should be tested before the start of the operations.



For conventional stimulation operations, powder fire extinguishers and fire hoses should be judiciously positioned (one per pump unit and one for the blender). For treatment with flammable fluids, extra means such as fire hoses, fire truck, foam monitor, wheeled extinguishers, sand, etc. are required. In any case, the HSE Department of the Subsidiary is responsible for the definition of these means.

On a remote offshore well, a paramedic person having resuscitation training will be mobilized with the crew. On a remote onshore well, mobilization of a medivac in less than 20 minutes will should be made possible. Procedure for a medivac will be worked out in advance.

6.5 High-pressure pumping lines

Surface HP lines used during a stimulation treatment shall be of integral connection type or non-pressure seal thread (NPST) connection type.

Threaded connections are not approved for use in change over adapters to connect to the wellhead.

The use of cementing lines for stimulation purpose is not recommended.

Souring is prevented when bottomhole temperature is below 100°C and freezing of lines is taken into account in cold areas.

6.5.1 Rigging up the HP pumping lines

Basic rules for the rig up of HP lines are shortening piping lengths and minimizing fluid transfer as far as practicable. Special precautions are taken for operations with toxic (acids, solvents, etc.) or flammable fluids: injection and discharge lines are rigged up so that they do not prevent circulation of personnel and, if available, remotely-operated HP pumps are used.

A schematic of recommended hook-up for HP pumping lines before a stimulation treatment is displayed in Appendix 3.

When rigging up the main treating (injection) line, a valve is available on the line in order to isolate the pumps from the well. One check valve is at least inserted in the main injection line between the pumps and the wellhead. The purpose of this check valve is to ensure that, in case of surface incident or in case of pressure release from a PRV, there is an automatic system to stop any back flow of fluid (cross-linked gel with proppant, acid) from the well. If a nitrogen-loaded PRV is installed downstream the check valve (i.e. close to the well head), a hydraulic remote-actuated valve is installed below the PRV along with the traditional plug valve, in order to be able to control the well in case of PRV failure. Moreover, an additional remote-actuated hydraulic valve should be installed above the crown valve on the wellhead. This would allow a redundant safety system should the PRV fail in an overpressure situation. If remote-actuated valves cannot be installed below the PRV(s) and above the crown valve, the check valve on the main injection line is installed between the PRV and the wellhead.

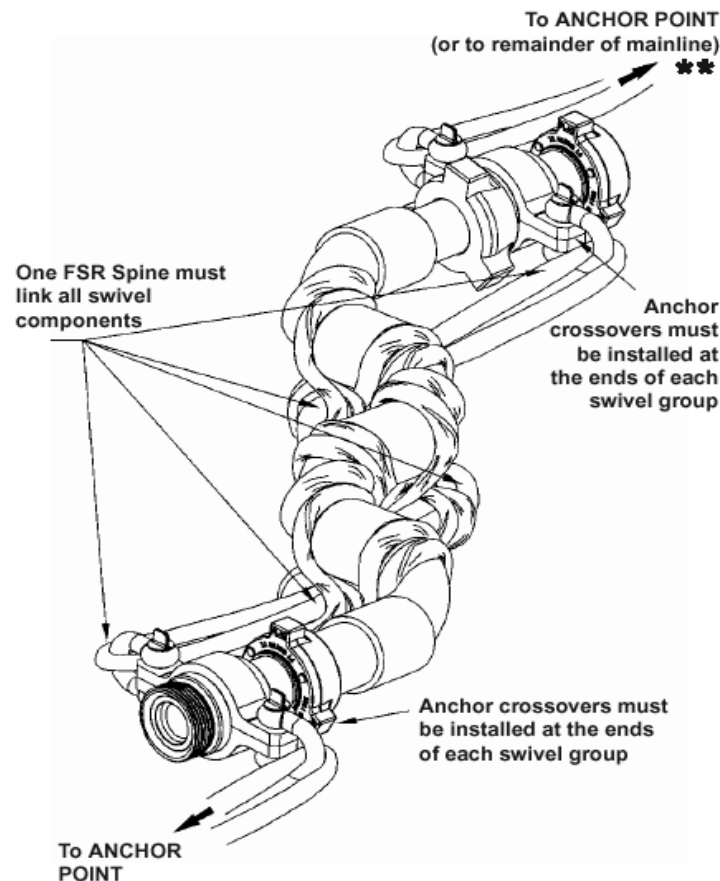
The injection line is fitted with a bleeding circuit lined up between the check valve and the well head. This bleed off line is as straight as possible and as close as possible to the wellhead / stimulation head. It is highly recommended to install a ball valve and a choke valve on this bleed off line. Bleed off fluid is sent to a recovery tank adapted to the returned fluid (it should not be disposed overboard or pumped to the cellar). When and if ever the rig up of equipment interferes with a part of the production network (for instance, bleed off lines through a cluster manifold), ensure that check valves do protect the well and the stimulation equipment from any overpressure or flow from the production installation.

An independent line is tied in to the tree for unloading the well to pit, flare, burner or tank (see part 8). This line is as straight as possible and rigidly anchored to the ground. Liquid trap is avoided. A correctly rated HP hose is used on the HP production line between the Xmas tree / flow head and the production manifold (chiksans or fixed (or temporary secured) hard piping are prohibited) and no swivel are mounted on these HP clean-up lines.

6.5.2 Securing the HP lines

All temporary high pressure piping sections shall be secured with appropriate safety device (preferably to rig/platform structure if possible, including the lines downstream the PRV's). Surface high pressure lines shall not be stacked.

Preferred method for securing HP lines is the Flow lines Safety Restraints (FSR) system from SPM (or equivalent).



This system provides for much greater personnel protection than the nylon strapping: rated to 15,000 psi and 212°F (-22°F on the low end) in an energized fluid environment, it provides continuous “shock cords” that are anchored at both ends to the HP pumps and wellhead to thus restrict vertical and lateral movements (one line for vertical restraint, two lines for lateral restraint). The high-pressure lines are tied to the shock cords with high tensile strength wraps to provide integrity of the entire injection line.



If ever the FSR system is not available, suitable wire ropes and clamps are utilized on the treating iron: clamps are minimum 8000 lb SWL and wire rope to be used for securing is minimum 8000 lb SWL with a core of 18 mm. One clamp is placed at the centre of a straight treating iron length with a maximum distance between clamps of 8 ft (long joints over 8 ft requires a clamp fitted 12 – 18 inches behind each union end). Where 1 or 2 swivels are positioned together, one clamp is utilized on either swivel; where 3 or 4 swivels are positioned together, two clamps are utilized (in any configuration). Best practice would omit the use of 'half inches' along the wire rope. The wire rope is secured at the end to a significant anchor. Anchor points along the treating iron includes one at either end of the rig up and any other available points along the treating iron route. A significant anchor could be the wellhead (for the injection line), a dead man anchor, a cement block anchor, the rig frame or a truck. Where the wire rope is to be anchored, a loop may be made with the end of the rope. This loop is secured with three correct sized 'bulldog grips'. The configuration of the grips is such that the bolts and saddle on the grips face the 'live' side of the wire rope (the long side). Where two wire ropes are connected, the ends are to be laid over-one-another and secured again with three "bulldog grips". The configuration of these grips is such that the centre one is of a 180° orientation away from the other two. In addition, the line is anchored on the ground with guy line anchors or other adequate restraints every 15 to 20 ft. Each anchor is 6 to 8 ft in length and the top of each anchor is set flush with the ground surface to minimize obstructions on location. It is important that the pressurized line(s) be as close to the anchors as possible to keep them from gaining momentum and breaking the wire rope if the line fails. When enough notice allows their preparation in advance, a sufficient number of cement blocks can advantageously replace wire ropes, clamps and anchors.

6.5.3 Maximum pumping rates through high pressure piping

As a general rule of thumb, the service companies do not pump any faster than $2 \times ID^2$ (in bpm) down the treatment lines, in connection with the risk of excessive erosion that can occur when pumping through high pressure piping with or without proppant-laden fluid.

Maximum recommended pumping rate is thus 8 bpm when pumping through a 2" line, 18 bpm through a 3" line and 32 bpm through a 4" line.

6.6 Specific equipment

6.6.1 Tree saver (or well head isolation tool)

Essentially when planning a hydraulic fracturing treatment on a well, it is highly recommended to use a temporary 10 or 15K flow head (instead of the production Xmas tree if it is not rated for the treatment pressure) during the time necessary to perform the treatment. If no temporary flow head could be made available, it is then recommended to use a tree saver (or well head isolation tool).

The following points should be ensured when using a tree saver:

- The mandrel seal is new and the tree saver is aligned correctly to the wellhead,
- The internal diameter of the production tubing is sufficient for the mandrel to fit,
- The internal diameter is consistent with the treatment designed pumping rate in case of proppant-laden fluid, as fluid velocity should be below 200 ft/sec to minimize erosion,
- The mandrel extension is of sufficient length to reach the production tubing,



- Written procedures for the installation of the tree saver are appropriate for the well configuration and the type of tool being used.

In particular, if a tree saver is required and used, it is ensured that the rig up can be achieved with two valves installed on the tree saver while stabbing in.

An autonomous hydraulic unit should preferably be used to operate the tree saver. In this case, a crown hydraulic valve is not anymore required as it is replaced by the tree saver hydraulic valve (but hydraulic valves below the PRV(s) are still required).

6.6.2 Ball launcher

Any ball launcher system used for stimulation purpose shall be remote-actuated.

The compatibility of the ball sealers with the check valve installed in the main injection line close to the wellhead is confirmed in advance.

6.6.3 Ball catcher

Whenever used, characteristics of the ball catcher should conform to those of the well clean-up lines, i.e. working pressure, acid/sour service, etc.

6.7 High-pressure equipment certification

It shall be ensured that the high pressure parts of the equipment are correctly certified for high pressure work (pump fluid end, coflex hose, all Weco parts, etc.).

The most recent certification documents are provided by the Stimulation Contractor for all the equipment planned to be used.

In particular, all the high pressure irons used for the operations are inspected and certified annually, preferably by a third party Company. This is also true for the surface well testing equipment (de-sander in particular) and any permanent rig production hard piping (valid certification and stamp tagging).

7. Tests and preliminary operations

7.1 Control of well tubing / casing annulus

7.1.1 Work / DST / completion string

Maximum allowable surface pumping pressure is determined with considering the limitations of the surface equipment and of the work / DST / completion string and with taking also the pressure relief system being used into account.

It is necessary to determine the back pressure that the system will experience for full flow relief in order to determine the size, type and setting of the Pressure Relief Valves (PRV's) and relief lines.

All pumps shall be equipped with centralized electronic shut-down devices (kick-outs).

PRV(s) shall be sized to provide full discharge at the designed injection rate and shall be located as close as possible to the Xmas tree / treatment head. The ID of the PRV(s) shall be identical to the ID of the pumping line.



Specifically for hydraulic fracturing jobs, nitrogen loaded PRV(s) are highly recommended to be inserted in the high pressure lines

When pumping proppant / ball sealers into a well bore, there is a possibility of getting a well bore screen-out / ball-out, with a resulting water hammer effect. The magnitude of the pressure wave resulting from this water hammer effect will depend on a certain number of factors and should be estimated or calculated whenever possible. To allow for the water hammer, the PRV(s) in the injection lines is set below the maximum allowable surface pressure (a setting value of 90% of the maximum allowable pressure at surface is given as a guideline).

Fluids discharged from PRV(s) are directed to an adequate storage tank / area.

7.1.2 Annulus between work / DST / completion string and production casing

In order to maintain string integrity, it may be necessary to apply annulus pressure during pumping operations. In such a case, the annulus pressure relief system is able to relieve the maximum expected pumping rate through the annulus, in order to vent excessive pressure and thus stop catastrophic failure of the production casing (if not rated to full treating pressure).

Sizing of the relief system depends on the particular application. In general:

- It is better to have both side outlets open to flow to reduce back pressure,
- Larger relief lines gives lower back pressure,
- Restrictions around SCSSV and tubing hanger are taken into account when sizing the relief system (this should have been already considered during the well design phase, particularly for compact wellheads with tension hangers where clearances are much less than for other wellhead types).

Dual spring operated PRV(s) should always be inserted in the annulus line. For hydraulic fracturing operations carried out with a packer set in the well, it is highly recommended to use a burst disk type PRV or a nitrogen-loaded type PRV installed in a 3" HP line connected to the annulus, in order to be able to bleed off rapidly any pressure increase, in case anything happen during the treatment.

A dedicated adjustable choke assembly shall be installed on the tubing/casing annulus (or annulus of a mono-bore completion) to provide well control in the event of a catastrophic failure and/or reverse capability when performing a sand control treatment.

The annulus pressure is continuously recorded during the treatment and monitored on a daily basis when no activity is taking place on the well.

7.1.3 Annulus between production casing and intermediate casing (dry trees)

The pressure of the annulus between the production casing and the intermediate casing is monitored on a daily basis when no activity is taking place on the well and closely whilst the well is being pressured up, prior to commencing the treatment operation.



7.2 Pressure tests and settings

All lines are fluid tested before pressure testing and HP pumping units are function tested at their full power for at least 5 minutes.

Pressure testing of standard equipment and HP lines shall be conducted with water and at minimum to 110% of the maximum expected surface pressure during the treatment. The work / DST / completion string and the wellhead shall also be tested to the same pressure as above prior to initiate the job.

The area is cleared of personnel during the pressure build up. The pressure is built up in small increments in relation to the maximum test pressure. If a leak is detected, pumping is stopped immediately and all the pressure is bled down before repairing. Only personnel directly involved in the test should be present, all other individuals should clear the area when HP lines are pressurized.

Low pressure lines to the flare / burner / pit area are tested to their working pressure.

Where the scheduled treatment involves pressure being held on the annulus between the treatment string (DST, completion or work string) and the first casing, the fluid used for maintaining the pressure (and for the pressure test) is adequate vis-à-vis the casing (corrosion inhibition, bacteria) and the packer fluid in place if any. Packer sealing is controlled and it is recalled, for obvious reasons, to perform this test before rigging up the stimulation equipment.

In order to monitor and record the pressures, two pressure transducers are installed on the high pressure injection line (on upstream the check valve, one downstream the check valve) and one pressure transducer is installed on the annulus pressurized line (back-up being the mechanical gauge on the annulus pump). All the pressure parameters are recorded in the stimulation control centre.

As long as there is no stimulation fluid in the injection line, it is preferable to use the well test choke manifold for bleeding off purpose instead of the bleed off line located close to the wellhead.

Pump overpressure safety devices and pop off valves are set to the desired pressures and properly checked at that time. Calibration of all nominal and back up pressure transducers is also checked.

7.3 Injectivity test

Prior to massively bull-heading dangerous treatment fluids (acid, solvent, etc.) from surface and also prior to a hydraulic fracturing job, the injectivity into the formation is evaluated with a neutral fluid (water, brine, gel, etc...) and proven sufficient.

7.4 Onsite quality control of chemicals and products

As soon as they arrive on location, the quality and the quantity of the delivered products are checked to conform to the stimulation program. For this reason, the Stimulation Contractor provides the Drilling & Wells (or Well Servicing) Supervisor with a complete documentation on all the products planned to be used (i.e. function, limit of use, range of concentration, etc.).

Procedure to perform quality check of the treatment fluids shall be available on the location.

Procedure or specifications allowing performing quality check of each separate chemical product delivered to the location are available on the location.



Water analysis is performed on a representative sample whenever deemed necessary and required by the Drilling & Wells (or Well Servicing) Supervisor. Water analysis includes tests for relative density, pH, magnesium, chloride, calcium and solid contents.

Compatibility tests are typically performed for salts, solids and borates with treatment chemicals in order to ensure that no adverse reaction or precipitation can occur.

When using cross-linked gels, it is imperative to conduct cross-linking tests and to check that the cross-linking time is adapted to the planned tubing / work string transit time.

A physical chemical inventory is at last conducted after each job.

8. Realization of the operations

8.1 Pre-job meeting

Prior to start the operation, a pre-job meeting shall be conducted by the Drilling & Wells (or Well Servicing) Supervisor. The following people shall be present: the RSES, the Production Representative and the Safety Representative, the Stimulation Contractor's Supervisor and the necessary other Contractor's Supervisors (Drilling Contractor, Well Testing, Electrical Logging, Coiled Tubing, etc.).

During this pre-job meeting, among other things, the following points are recapped:

- Role, responsibilities and positioning of each of the stimulation and testing crew members, of tree saver Specialist, of Production Supervisor, etc.,
- General safety rules, specific hazards (those in particular which are linked to fluid returns), muster point, location and use of fire extinguishers, first aid kit, eye wash facilities and other safety equipment,
- Emergency and abandon procedures, in particular:
 - What to do if the radio communications become inoperative,
 - Procedure to be followed in case of screen-out, leaks, H₂S release, etc.,
 - In case, method for withdrawing the tree saver in case of a leak above the master valve.
- Rig up of equipment and valves tested / to be tested,
- Results of the injectivity test(s) if ever performed beforehand,
- Treatment program objectives with the anticipated pumping parameters,
- Maximum pressure not to be overcome, setting point of the pressure limit switches and limits of the PRV(s),
- Test of annular equipment and annular pressure to be maintained,
- "Routes" for pumped and circulated out fluids, disposals, absence of liquid in wellhead cellar and water drains (if any),
- Confirmation of full opening of tree valves (number of turns controlled), actuated master valve lock opened, amount of pressure to trap on the wing valve assembly (to assist in opening the wing assembly after the treatment is completed),
- List of on-site personnel,



- Meteorological / oceanographic forecast.

8.2 Operational instructions

A general “high pressure” Public Address announcement should be made at the beginning of the treatment (as well as at the beginning of a new shift) and should continue every 30 minutes until the operation is complete and the system is vent down.

The crane operator is on stand-by in its crane and no helicopter is authorized to land on the site while pumping the treatment.

Pump operators, coiled tubing operator (if any), choke manifold operator and burner operator are in constant touch with the operational responsible (radio head set for example). The radio used in the stimulation control centre should have an override system.

Treatment procedures are strictly followed (fluid volumes, pumping rate, pumping pressures).

Tree valves are prevented to be operated under full acid pressure. Opening and closing valves is always done carefully and slowly to avoid any sudden pressure changes in the lines. During pumping, there should be an assigned person to observe and to operate valves.

An operation carried out with anchored and DP vessels is initiated with a sufficient weather window.

If ever used, coiled tubing should not be left unattended or motionless.

8.3 Parameters to be recorded when pumping the treatment

The following parameters are recorded when pumping the treatment:

- Treating pressure (2 transducers),
- Annulus pressure,
- Pumping rate (from the tachometer of the pump) & rate from a LP or HP flow-meter,
- Density,
- Time,
- Depth of the coiled tubing if a coiled tubing is used,
- Nitrogen rate if nitrogen is used.

The entire treatment data (from the initial pressure test to the final displacement) is recorded, with job files secured thereafter. These treatment data are used to determine the effectiveness of the job and to optimize fluid volumes and types for future treatments. For this reason, it is strongly advised not to stop the pumps while changing fluids during the treatment; otherwise the evaluation cannot be performed correctly.

8.4 Night time operations

Safety aspects of stimulation operations can be affected by night or more specifically by bad lighting, so stimulation operations may be performed at night when allowed by local regulations and if a full risk assessment has shown that the additional risk is acceptable.

This JRA includes considerations on lighting, environment (support of a drilling rig or a well pulling hoist), personnel fatigue, potential intruders, leak detection, emergency conditions



(down-graded situations, etc.) and access to emergency control systems (ESD) in case of SIMOPS.

Hydraulic fracturing of tight formations and HP pumping of non conventional (diesel-based, methanol-based, flammable) fluids shall be done at daylight only.

An acid job may be done at night if the injectivity test on the concerned interval has been positively done beforehand.

9. Well clean-up / unloading

9.1 General

Flow back after a stimulation treatment is conventionally directed to a flaring system through a specific line. Unloading any acid in a process system shall receive formal approval from the Head of Production.

This system is linked to the well via a clean-up network independent from the injection lines. The clean-up network is compatible with the nature of the spent treatment fluids and by-products (H_2S , CO_2 , acid, hydrocarbons, sand, proppant, etc.).

9.2 Specific flow back equipment for hydraulic fracturing

It is always a challenge to flow back a well producing an effluent loaded with proppant for an obvious safety reason. As a matter of fact, there is indeed a high probability to cut valves due to the abrasive properties of the proppant. It would then be very unsafe to have to close a well during the clean-up phase.

Thus dedicated flow back equipment should be selected.

Flow back after a hydraulic fracturing treatment with proppant shall not be performed through permanent offshore installations. A dedicated temporary test separator shall in particular be used for at least the first 3 days.

The maximum rating pressure of the flow back equipment should be the maximum pressure that could be observed on the well, after a screen-out.

When performing a hydraulic fracturing treatment (especially on a gas well), a primary clean-up line (with targeted T, heavy duty manifold) should be used for the first step of the post-frac well flow back (combined production of liquid, gas and proppant at high velocity) to prevent the flow back of gas and proppant to cut the surface lines. When BSW is reduced below 5 to 2% (variable with Contractors, equipment, well situation, flow rate, etc.), the well can be flown through separator or testing device. It is then usually recommended to use sand catchers or hydro-cyclones at that stage to trap the remaining proppant content, thus protecting the testing equipment.

A dedicated manifold is used to perform forced fracture closure operation. Fluid is recovered in a dedicated recovery tank. Forced closure is usually performed at a rate around 10% of the pumping rate.

For any hydraulic fracturing treatment, an ESD valve shall be installed directly on the flow back side of the Xmas tree.

In case of screen-out after a hydraulic fracturing treatment, whatever the sand catcher system used, it is most probably not able to cope with such a high amount of proppant (from



experience, sand catchers are not efficient during the initial part of the clean-up due to a too large amount of proppant, not enough gas, unbroken gel), mainly after a screen-out. In such case, provided the produced effluent does not contain H_2S , it is recommended to:

- Either flow back the well directly to a gas buster and start diverting the flow to the sand catcher once the gas arrives at surface,
- Or clean the proppant out of the well bore with a coiled tubing unit, keeping the hydrostatic pressure always higher than the reservoir pressure.

In addition, it is recommended to verify in advance that proppant clean-out (transport back to surface) is possible in the event of a screen-out, considering the well trajectory, the CT size, the nature of the gel and the recommended clean-up rate.

9.3 Recovery and destruction of treatment fluids (acids, hydrocarbons, etc.)

A recovery (dedicated tanks, pits, etc.) or destruction (flare, flare pit, burner, etc.) system shall be available to handle the treatment fluids, when back-produced.

Any tank receiving fluid from the well shall be equipped with vent line, spark arrestor and safety relief valve.

Any oil spilled should immediately be covered with absorbent material. Any oil bled from the well or pump lines should be piped towards a suitable pit or tank.

Procedure guidelines for the handling of chemicals and disposal of waste are given in the MSDS supplied by the Stimulation Contractor. More particularly, regarding the recovery of acid, special care should be exercised when the neutralizing solution is mixed since soda ash can easily be blown away with the wind and is very corrosive.

Some wells have radioactive scales (sulphate scales). Typically their activity is low but, if the scales are allowed to concentrate, the activity can be highly increased to levels above normal. It is recommended to properly flush with water all the lines through which the returned fluids have been produced, in addition it is recommended to verify for any accumulation of solids in the sumps of the tanks.

10. Specific cases

10.1 Offshore – Use of a stimulation vessel

Offshore stimulations often require the use of a stimulation vessel / floating support.

In such cases, a HP coflex hose links the vessel to a fixed point on the rig or on the platform (coflex hanger) and not to the production tree. Remaining hose on the reel will accommodate the extreme drifting of the vessel. The link between the fixed point and the wellhead is then made with temporary-piping sections secured to the rig/platform structure.

From a stimulation vessel, HP hoses used are fluids compatible (refer to the manufacturer specifications). The minimum weight that the coflex hanger withstands is the weight of the coflex hose in the air, full of the heaviest fluid. The certification of the coflex hanger is performed by a recognized third party Company.

When performing an offshore treatment from a stimulation vessel or a barge, the HP coflex hose shall be equipped with a quick disconnect system.



This quick disconnect system may be manual or automatic and should preferably be located at vessel end. There is two remote controls for the quick disconnect: one on the boat deck and one in the stimulation control cabin. There is also one manual release system in case the remote control is not working.

The check valve is located downstream of the quick disconnect.

The Drilling & Wells (or Well Servicing) Supervisor should ensure that there is no underwater equipment directly located below the coflex hanger, which could be damaged should the coflex hose be released in an emergency situation.

For spot operations, the quick disconnect system is physically tested in the vessel home port prior to departure for the job. When the vessel is hired through a long term contract, the quick disconnect system is physically tested twice a year.

It is ensured that the working length of the coflex reel will allow sufficient movements of the vessel (roll, pitch, etc., according to weather forecast), should the vessel for instance not be equipped with DP capabilities. With a DP vessel, a constant watch prevails to activate the hose emergency disconnect in case of a DP failure.

Fire fighting system of the vessel is tested before each job.

The vessel anchoring pattern (if any) should also be prepared long time in advance. It should in particular be compatible with the equipment on the sea floor. Also the operating sea limitations of the vessel should be known. Marine Operations Department of the Subsidiary should so be involved in the preparation of the job.

Rig Safety Management System (SMS) applies when the vessel is working with a rig.

During operations, the treatment data should be available on the rig/platform, in order to allow the people assigned there to be able to monitor the treatment. In particular, the display of numerical data and charts should be available at the rig floor level for sand control operations carried out from an offshore vessel. Displays should be at least Zone 2 approved.

10.2 Precautions when using nitrogen and/or CO₂

The use of nitrogen and/or CO₂ during stimulation operations induces specific risks, such as overpressure of the lines by heating, brutal movement of the lines in case of rupture, asphyxia by reduction of the oxygen content in the air and burning due to low storage temperatures.

10.2.1 Spotting equipment on location

Equipment is positioned at least 15 meters from the well head, in such a way as to allow for escape routes for operating personnel. This will keep the well safe from any possible liquid spills and also keep the injection line exposure to a minimum. In particular, CO₂ and nitrogen storage tanks are separated as far as possible from other equipment and working areas and in downwind position. Barriers and signs should be erected to cordon of work site.

Liquid nitrogen is transported in vacuum jacketed cryogenic tanks which maintain insulation of the liquid. Specifically on offshore installations, liquefied nitrogen leak is prevented, isolating the nitrogen tanks and cryogenic hoses from the rig structure with wood (in case of leak, it is flushed with water). Whatever the environment is (onshore or offshore), a readily available water supply (LP water hose) is present near the liquid nitrogen storage.



10.2.2 Rigging up lines

The CO₂ and nitrogen surface lines are short and firmly anchored at regular intervals to fixed objects. No vibration should impart the tree. Crossing other service injection lines with high pressure CO₂ and nitrogen lines is avoided as much as possible

Cryogenic hoses are supported off the deck with wooden planks. Stainless steel drip pans filled with water are installed below each liquid nitrogen transfer hose connection and other potential leak point. This will help protect the deck from any accidental spillage.

With CO₂ liquefied gas, a remotely operated valve is installed between the CO₂ unit and the main injection line (for cooling surface lines). The pressure in the liquid CO₂ increases quickly when the line heats to the air temperature. Therefore, a vent is installed between any two valves, either on discharge or suction sides. More generally, the Contractor's procedure is carefully reviewed to ensure a safe state-of-the-art execution of any operation involving the pumping of liquid CO₂.

A discharge manifold collects all the pumps with valves to isolate any of them. A bleed valve is installed on any cryogenic line able to be isolated.

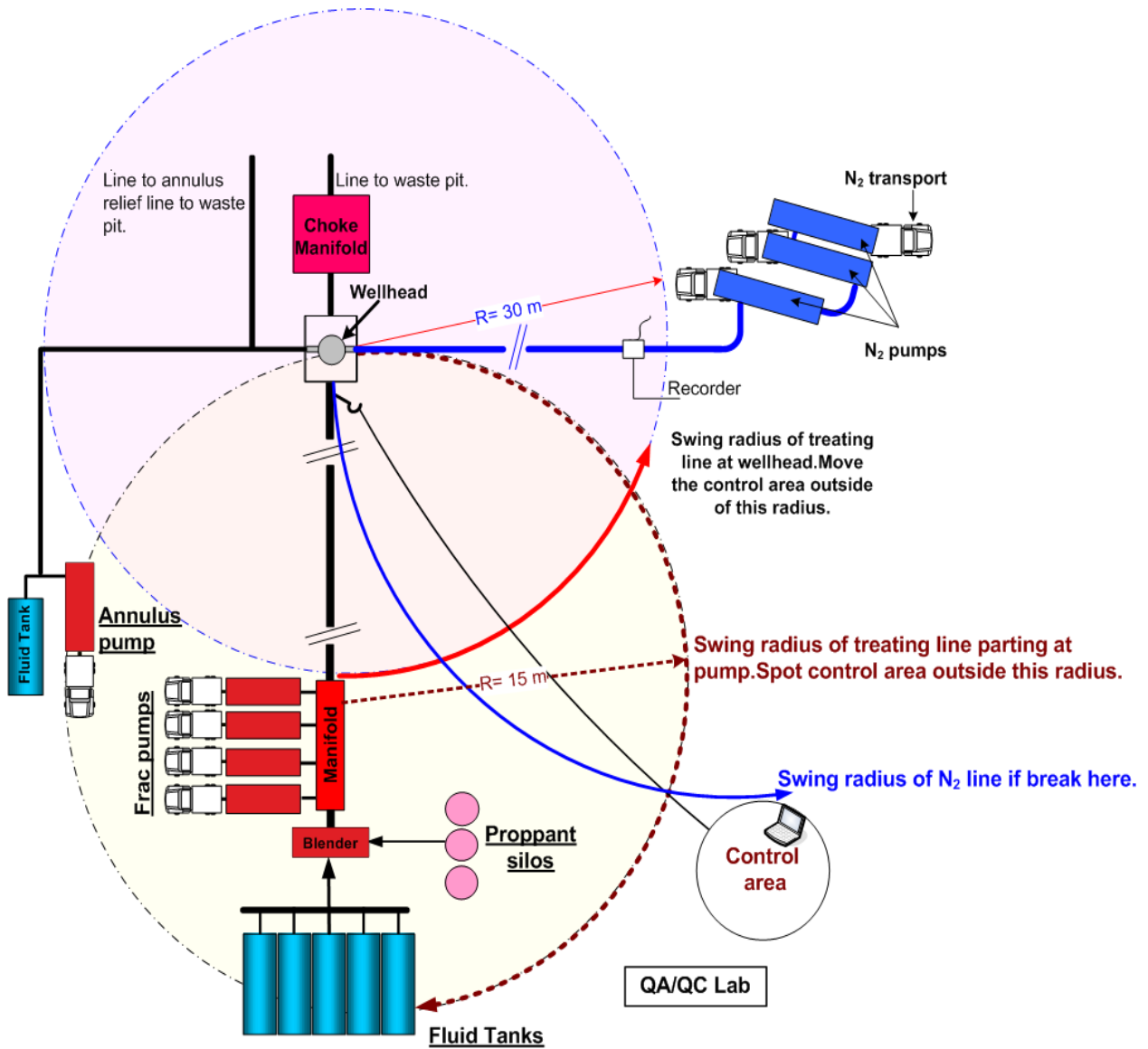
Any part of the installation where liquid nitrogen may be trapped (even momentary) is fitted with a safety relief valve. At completion of work, a complete bleed off of the installation is performed.

10.2.3 Pressure testing

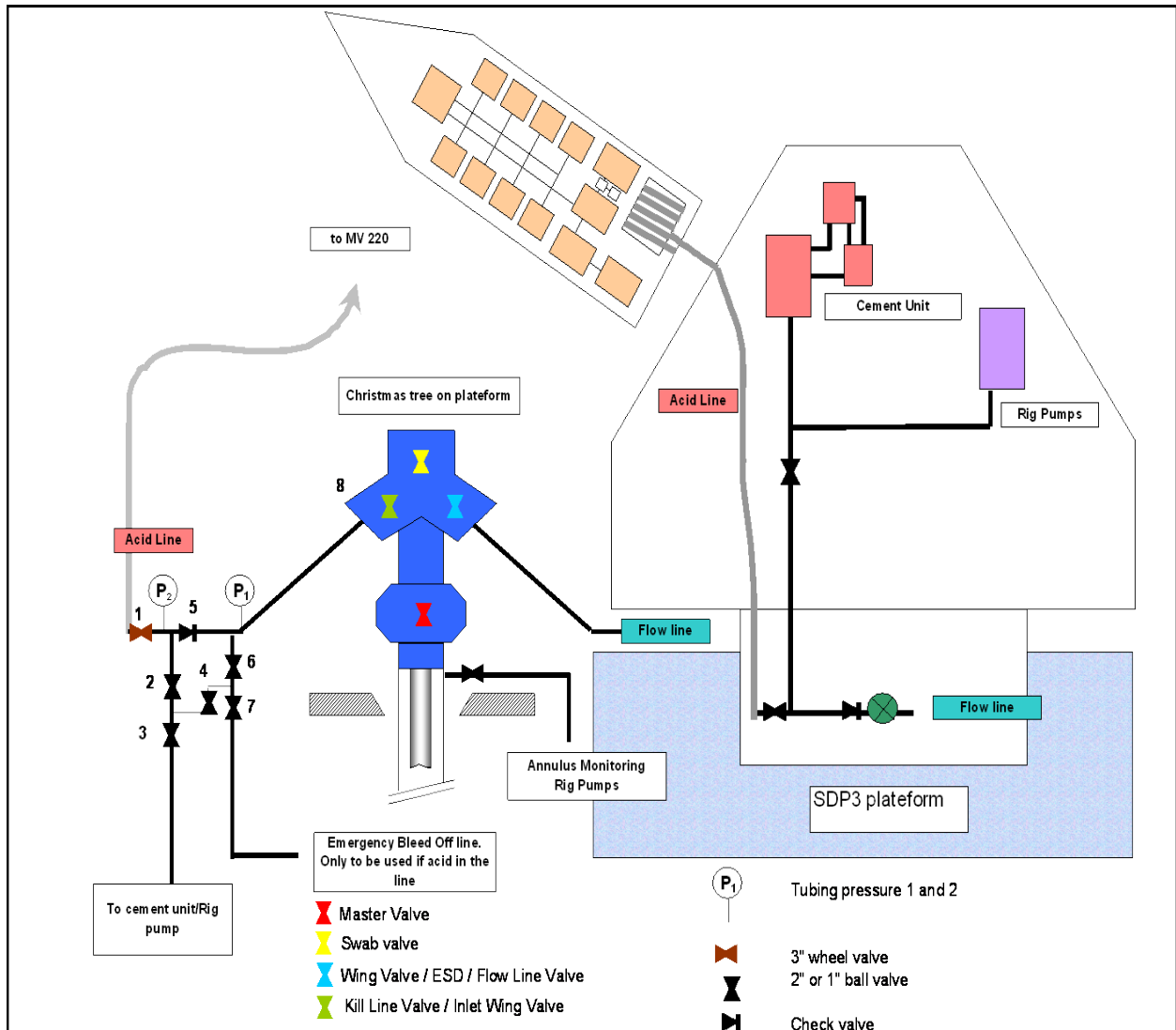
Pressure testing of nitrogen or CO₂ equipment is conducted with nitrogen. All lines are fluid tested before pressure testing with nitrogen.

Before commencing any job, injection lines are tested to expected pressure +10%. The nitrogen converter is disconnected during hydro-testing to prevent fluid entering the converter.

Appendix 1 Suggested lay out schematic for stimulation (onshore)



Appendix 2 Suggested lay out schematic for stimulation (offshore)



Appendix 3 Schematic of recommended hook-up for HP pumping lines before a stimulation treatment

