MANUAL

HOT-TAPPING ON PIPELINES, PIPING AND EQUIPMENT

DEP 31.38.60.10-Gen.

December 1998

DESIGN AND ENGINEERING PRACTICE

PREFACE

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The information set forth in these publications is provided to users for their consideration and decision to implement. This is of particular importance where DEPs may not cover every requirement or diversity of condition at each locality. The system of DEPs is expected to be sufficiently flexible to allow individual operating companies to adapt the information set forth in DEPs to their own environment and requirements.

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NOTE: In addition to DEP publications there are Standard Specifications and Draft DEPs for Development (DDDs). DDDs generally introduce new procedures or techniques that will probably need updating as further experience develops during their use. The above requirements for distribution and use of DEPs are also applicable to Standard Specifications and DDDs. Standard Specifications and DDDs will gradually be replaced by DEPs.

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APPENDICES

1. INTRODUCTION

1.1 SCOPE

This DEP specifies requirements and gives recommendations for the planning and execution of "hot-tap" branch connections onto piping systems and pipelines containing hydrocarbons under operating conditions. It has been developed to reflect current understanding of the technology and to improve safe practices in the field. It is intended to cover hot-tapping on carbon, carbon-manganese and high-strength low-alloy steels (e.g. API 5L grades B to X70), though many aspects may be relevant for other applications. Hot-tapping on other materials requires special consideration.

This DEP is a revision of the previous publication of the same number dated December 1991.

This DEP is not intended to cover subsea hot-tapping but many aspects would still be relevant for such applications.

Due to the distinction made in the relevant standards between on-plot piping and off-plot pipelines or flowlines, a similar distinction is sometimes made within this DEP, but this has been avoided wherever possible. Additionally, it is assumed that the piping/pipeline systems are designed and operated in accordance with ASME B31.3, B31.4, B31.8, or a combination thereof. The use of alternative standards would not be expected to conflict with any of the principles adopted in this DEP or most of the specific requirements. However, see (1.2) below.

It is assumed that all hot-tap branch connections will be welded.

Note: Where in accordance with the requirements of this DEP, or for other reasons, welding is not permitted, consideration may be given to the use of a non-welded system. Such systems are becoming increasingly available but require special considerations, including long-term integrity aspects.

This DEP mainly considers hot-tapping on pipes but it is possible to perform hot-taps on tanks and other equipment as outlined in (7).

It should also be noted that hot-tapping often requires the approval of the relevant statutory authorities.

This DEP is relevant to the hot-tapping aspects of "stoppling" operations; although the specific stoppling activities are excluded from the scope of this DEP, they should be subject to similar procedural detail as the hot-tapping activities described herein.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by SIOP and SIEP, the distribution of this document is confined to companies forming part of the Royal Dutch/Shell Group or managed by a Group Company, and to Contractors nominated by them (i.e. the distribution code is "C", as defined in DEP 00.00.05.05-Gen.).

This DEP is intended primarily for use in exploration/production facilities and oil refineries, but it may also be applied in chemical plants, gas plants and supply/marketing installations.

If national and/or local regulations exist in which some of the requirements may be more stringent than in this DEP, the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable as regards safety, environmental, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this DEP which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned with the object of obtaining agreement to follow this DEP as closely as possible.

1.3 DEFINITIONS

1.3.1 General definitions

The **Contractor** is the party which carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project or operation of a facility. The Principal may undertake all or part of the duties of the Contractor.

The **Manufacturer/Supplier** is the party which manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party which initiates the project and ultimately pays for its design and construction. The Principal will generally specify the technical requirements. The Principal may also include an agent or consultant authorised to act for, and on behalf of, the Principal.

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

1.3.2 Specific definitions and abbreviations

Asset operator	The individual within the Principal's organisation who is responsible for the operation of the pipeline, piping or equipment to be hot-tapped.
Branch pipe	The pipe which is to be connected to the run-pipe by means of the hot-tap.
Coupon	Section of pipe cut out during the hot-tap cutting operation.
HAZ	Heat Affected Zone
Hot-tapping	A method of making connections to piping (or other equipment) by attaching a fitting to the system, usually by welding, followed by cutting through the pipe wall at the point of attachment utilising an appropriate ("hot-tapping") machine. This operation is generally carried out on a live ("hot") system without decommissioning or interrupting flow.
Lock-O-Ring flange	Flange with internal segments which can be moved from the outside to lock into the circumferential recess of a Lock-O-Ring plug.
Lock-O-Ring plug	Plug which can be set into position inside a hot-tap connection flange in order to retain internal pressure.
NPS	Nominal Pipe Size
Off-plot Pipeline	Pipeline designed in accordance with ASME B31.4 or B31.8 (see Note below).
On-plot Piping	Piping system designed in accordance with ASME B31.3 (see Note below).

Note: Some parts of a pipeline system, although physically located "off-plot", may be designed in accordance with ASME B31.3. For the purposes of this DEP, such piping shall be considered to be on-plot. Similarly, some refinery piping, although physically located "on-plot", may be designed in accordance with ASME B31.4 or B31.8. For the purposes of this DEP, such piping shall be considered to be off-plot.

Operating conditions	All conditions of piping and equipment when containing hydrocarbons under a positive internal pressure.
Run pipe	The pipe into which a hot-tap is to be made.
Stoppling	A hot-tapping operation which includes the insertion and setting of a sealing plug in the pipe in order to stop flow and withstand a certain fluid pressure.

WPS	Welding procedure specification

1.4 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced section number is shown in brackets. Other documents referenced in this DEP are listed in (9).

1.5 SUMMARY OF MAIN CHANGES SINCE THE LAST REVISION

The most significant change is the transfer of the requirements for welding and inspection, previously covered in Section 6, to the new DEP 30.10.60.30-Gen. Associated figures have also been transferred.

Other main technical (i.e. non-editorial) changes are:-

3.2 contradictory statements clarified and “hydrogen” defined

3.4 requirements regarding hot-tap locations consolidated

7.4 simplified to a recommendation not to carry out hot-tap operations on miscellaneous equipment.

2. GENERAL CONSIDERATIONS

2.1 JUSTIFICATION FOR HOT-TAPPING

Hot-tapping is potentially hazardous and therefore should only be undertaken when shown to be technically feasible and to offer a clear advantage over alternatives. The advantage may be economic and, in some situations, the safety and environmental risks may be less than those associated with more conventional methods.

A decision on whether hot-tapping is to be applied shall be based on careful considerations including at least the following aspects:

- safety;
- condition of the pipe/equipment under consideration;
- configuration of the connection;
- code/statutory requirements;
- operating conditions;
- technical capabilities of the drilling equipment under the operating conditions (pressure, temperature, nature of product);
- related welding problems;
- economic aspects;
- environmental/pollution aspects.

If hot-tapping is to be applied under conditions approaching the technical or operational limits as defined in this DEP, specialist advice should be sought.

2.2 RESPONSIBILITIES

Hot-tapping is a multi-disciplinary activity, usually involving several departments, each carrying their own responsibilities. Coordination between departments and planning of activities is therefore of vital importance.

There should therefore be a general procedure for hot-tapping, including a hot work permit procedure, which shall be approved by the asset operator.

Subsequently, this general procedure shall form the basis for the specific procedure which shall be used for each particular application. This specific procedure shall include a form containing all relevant details, which shall be signed by all parties involved to indicate that all requirements have been fulfilled.

Finally, the authorization from the asset operator is required for the actual execution.

Responsibilities for dedicated activities required to assure personnel and plant safety, integrity of the work performed etc. will normally rest with the typical functions indicated below. It is however important that overall responsibility for the work is clearly assigned to a single individual.

Design Office
- technical design of the modification;
- set-up of procedures;
- documentation;
- hot-tap register.

Inspection
- gaining approval of the statutory authority (if applicable);
- condition of equipment/piping to be welded;
- inspection/testing of the construction;
- testing/checking of materials, welding; consumables, etc.;
- recording in the hot-tap register.

Field Organization
- suitability and condition of the drilling equipment to be used;
- selection of welding personnel, process and procedures;
- safety of the operation from an engineering point of view;
- overall coordination;
- hot work/site entry permits.

Operating Staff
- the assurance that the operating conditions laid down in the procedure will be maintained during the hot-tap operation;
- suitability of the product for the envisaged operation;

- safety of the operation from an operational stand point;
- contingency planning;
- emergency procedures.

2.3 DOCUMENTATION

The supporting documentation for a hot-tap operation shall consist of the following:

2.3.1 Design calculations

Design calculations shall be based on the requirements of (4).

2.3.2 Drawings and records

The hot-tap design package shall, as a minimum, include a cross-sectional general arrangement to define the hot-tap connection.

Upon completion of the task, all drawings and manuals shall be updated according to the established standards of the Principal.

2.3.3 Safety plan

A safety plan shall be prepared for each hot-tapping operation by the Principal's field organisation and shall be agreed beforehand with other relevant departments and the Contractor. The safety plan should be brief, otherwise it becomes self-defeating. API RP 2200 covering safe practices relating to pipeline repairs shall also apply.

Topics to be addressed shall include:

- access to and around the hot-tap location for personnel and the welding and hot-tapping equipment, including requirements for scaffolding;
- roles of dedicated personnel and their responsibilities on site;
- monitoring of operating conditions (flow rate, pressure, welding temperature) and gas levels;
- foreseeable hazards and contingency actions;
- communications on site;
- warning system and emergency shutdown;
- means of escape;
- fire fighting equipment and personnel;
- safety equipment and services;
- first-aid facilities.

Emergency procedures shall also be specifically addressed, either in the safety plan or in a separate document.

2.3.4 Work procedures

Procedures shall be prepared for all aspects of the physical work, including items such as:

- site preparation;
- pipe preparation;
- welding;
- NDT;
- hydro-testing;
- drilling/perforation;
- reinstatement.

2.3.5 Hot-tap check list

The hot-tap procedure shall be supported by a check list based on that given in (Appendix 1), which shall be completed at each step by the relevant action party.

2.3.6 Final documentation

This shall include material certificates, test reports etc. and updating of as-built drawings and relevant design/operating manuals.

3. RESTRICTIONS ON APPLICATIONS AND OPERATIONAL CONDITIONS

3.1 MATERIALS

This DEP is relevant only to hot-tapping on carbon, carbon-manganese and high-strength low-alloy steels (e.g. API 5L grades B to X70). Materials for pipelines and on-plot piping shall comply with the requirements of the piping classes DEP 31.38.01.12-Gen. and DEP 31.38.01.15-Gen. If it is proposed to hot-tap other materials, specialist materials/welding engineers shall be consulted and a specific procedure shall be developed. Current experience is limited to X65 materials (see also BS 6990) and therefore special attention should be given to procedures to be developed for higher grade materials.

It shall be ensured that during the welding operation the material in the region of the weld pool has sufficient strength to contain safely the internal pressure and avoid a blow-out. The risk of blow-out is dependent upon a complex interaction of welding conditions, pipe material, pipe thickness, pipe temperature and hoop stress. For materials of yield strength not greater than 450 N/mm^2, operating at temperatures of not greater than 350 °C and with a hoop stress of not greater than 72% of the specified minimum yield stress, blow-out can be prevented during welding provided the minimum pipe thickness is not less than 5 mm. The actual minimum wall thickness shall be determined by ultrasonic testing. For other materials or conditions, a minimum pipe thickness shall be determined, based on either specific previous experience and/or data from trials.

Note: For some products, due to chemical reaction, the safe pipe temperature may be much lower than 350 °C (See also BS6990).

Fitting and branch material shall be of a type and grade compatible with the material of the run-pipe to be hot-tapped, including sour service requirements where applicable.

Hot-tap welding should not normally be performed on materials which require post-weld heat treatment. However, if stress relieving or post-weld heat treatment is required, a specialist shall be consulted to assess whether it is feasible to make the specific hot-tapping operation with post-weld heat treatment.

Note: Stress-relieving may be required if a material is susceptible to stress corrosion cracking and post-weld heat treatment may be specified by the design code if the wall thickness is greater than a certain limit.

Welding shall not be performed on lined, clad or internally coated pipe.

Hot-tap welding shall not be performed on the following materials:

- any material with a maximum allowable operating temperature greater than 370 °C;
- pipelines and on-plot piping where the minimum allowable operating temperature is less than -20 °C. For minimum allowable operating temperatures between -20 °C and 0 °C, additional attention shall be given to ensuring adequate material toughness.

3.2 PROCESS FLUIDS

Hot tapping shall only be performed under the following conditions:

- the contained process fluids remain stable when subjected to the high metal temperatures (see 3.3) during welding;
- the process fluids remain stable when in contact with air during drilling and perforation operations;
- there shall be no decomposition or chemical reaction between components of the contained fluid (explosion, ignition, exothermic reaction);
- there shall be no chemical reaction between the fluid and the hot containment wall (burning, (stress) corrosion, embrittlement).

These requirements lead to a number of situations in which welding operations are prohibited on equipment which contains:

- Mixtures of gases or vapours within their flammable range or which may become flammable as a result of heat input in welding operations.
- Substances which may undergo reaction or decomposition leading to a dangerous

increase in pressure, explosion or attack on metal. In this context, attention is drawn to the possibility that under certain combinations of concentration, temperature and pressure, acetylene, ethylene and other unsaturated hydrocarbons may decompose explosively, initiated by a welding hot spot.

- Oxygen-enriched atmospheres in the presence of hydrocarbons which may be present either in the atmosphere or deposited on the inside surface of the equipment or pipe.
- Compressed air in the presence of hydrocarbons which may be present either in the air or deposited on the inside surfaces of the equipment or pipe.
- Gaseous mixtures in which the partial pressure of hydrogen exceeds 700 kPa gauge, except where evidence from tests has demonstrated that hot-tapping can be done safely.

Based on the above, welding on equipment or pipe which contains hazardous substances or conditions as listed below (even in small quantities) shall not be performed unless positive evidence has been obtained that welding/hot tapping can be applied safely.

Substances:

- Acetylene;
- Acetonitrile;
- Butadiene;
- Caustic soda;*
- Chlorine;
- Compressed air at a pressure in excess of 3 000 kPa gauge;
- Ethylene;
- Ethylene oxide;
- Fat/lean DEA/MEA;
- HP steam (pressure in excess of 5 000 kPa (ga));
- Hydrogen (partial pressure in excess of 700 kPa (ga));
- Hydrogen sulphide;*
- Hydrofluoric acid;
- Oxygen;
- Propene;
- Propene oxide;
- Sulphuric acid;
- Toxic substances.*

*Constraint based on general hazard in the event of line puncturing during welding, not the welding process.

Conditions:

- Vacuum conditions;
- Dissolved hydrogen in the pipe wall (e.g. due to service history);
- Pyrophoric scale deposits.

Note: The above list is not exhaustive, but gives an indication only.

3.3 PROCESS CONDITIONS

3.3.1 General

Attention shall be paid to controlling the pipe wall temperature, fluid pressure and fluid velocity within the pipe during welding in order to avoid:

a) Blow-out of pressurized pipe due to the weakening effect of heat introduced during welding.

b) Deterioration of the micro-structure of the pipe material due to:

  - excessive heat input resulting in excessive metal temperature;
  - too rapid cooling of pipe during or after welding.

3.3.2 Maximum temperature of the pipe wall

An estimate of the maximum temperature of the inside of the pipe wall attained during welding may be derived from (Appendix 2 or Appendix 3), using the actual wall thickness of the pipe (see definition of t_a in 3.3.3) and the expected heat input as derived below.

For a specific hot-tap, the permitted ranges of voltage, current and welding speed shall be defined in the WPS (see DEP 30.10.60.30-Gen.). For manual shielded metal arc butt and fillet welds, the total heat input shall be calculated from:

$$HI = K * \frac{V * A}{S}$$

where:

HI = heat input (Joules per mm)
K = net factor = 0.85 for butt welds, and
= 0.57 (= 2/3 x 0.85) for fillet welds.
V = voltage (volts)
A = current (amperes)
S = travel speed (mm/s)

Note: Values of V, A and S shall be the actual values used in the welding procedure qualification. Alternatively, they may be taken as the mid-range values from the welding procedure specification.

Substitution of the calculated value of HI in the relevant graph in (Appendix 2 or Appendix 3) will give an estimate of weld penetration and maximum inner pipe wall temperature. If the estimated values are unacceptable or marginal (at the Principal's discretion) then a full-scale simulation test should be performed to determine actual temperature and penetration values.

Note: Regardless of the above recommendation, the simulation test **shall be performed** for pipelines (see DEP 30.10.60.30-Gen.).

Such a simulation test shall consist of performing the proposed welding operation on an empty pipe and measuring the maximum temperature attained on the inside surface of the pipe using a temperature probe. Materials, wall thickness, welding process, weld configuration, weld preparation and essential welding parameters shall be identical to the proposed hot-tap operation.

Note: Ideally, the simulation test should be made using materials from the same Manufacturer and in the same supply conditions (e.g. controlled rolled or normalised pipe/plate) as the main run-pipe and branch-pipe.

Afterwards, the simulation weld shall be sectioned at its most critical locations with respect to pipe blow-out and rapid cooling. Weld penetration and maximum hardness value shall be measured on a macro of the actual weld. Depth of penetration shall be checked against that predicted in (Appendix 2 or Appendix 3) to assess whether there is an adequate safety margin. Acceptance values for hardness shall be as specified in the pipe specification. Hardness shall be measured by the Vickers (HV 10) method in accordance with ASTM E 92.

Note It may be possible to reduce the maximum temperature attained during welding by modifying the welding procedure.

3.3.3 Pressure of process fluid

For general safety reasons, ***at any time*** during the hot-tap operation the pressure of fluid inside the run-pipe shall not exceed 7 000 kPa (ga) nor shall it exceed the maximum working pressure of the hot-tap equipment if this is lower.

During hot-tap welding the pressure of fluid inside the run-pipe shall not exceed the maximum allowable pressure, as detailed below.

Hot-tapping shall not be performed on equipment at sub-atmospheric pressures.

There are two ways to calculate the maximum allowable pressure during welding. The first is by temperature derating which allows for reduction in strength of the pipe wall at welding temperature, and is applicable to both on-plot and off-plot pipes. The second method is based on fracture toughness and is intended to prevent unstable crack propagation in pipelines. For off-plot pipeline applications, maximum pressures shall be calculated by both methods and the lower value taken as the maximum allowable pressure during the welding operation.

Method 1 - Temperature derating

The temperature derating calculation applies to both on-plot and off-plot pipe, the relevant formula being:

$$P = \frac{2\,S\,t\,F\,E\,T}{D}$$

where:

P = Maximum allowable operating pressure during welding operation, in MPa;

S = Specified minimum yield stress in N/mm^2 (ASME B31.4, ASME B31.8) or basic allowable stress, in N/mm^2 (ASME B31.3);

D = Nominal outside diameter of run pipe, in mm;

t = Reduced wall thickness (where $t = t_a - u$), in mm;

u = Reduction in wall thickness during welding, representing the weld pool penetration, in mm. This may be derived from Appendix 2 or Appendix 3, or conservatively assumed to be 3 mm;

t_a = Minimum actual wall thickness in mm. This value shall be determined in advance by ultrasonic measurement;

F = A safety factor for off-plot pipe (recommended maximum value 0.8) equivalent to the design factor. (In ASME B31.3 this factor is already included in the basic allowable stress);

E = Longitudinal joint factor, taken from the relevant ASME code;

T = Temperature derating factor, derived from Table 1 below. These data have been compiled from those in ASME B31.8 (Table 841.116A), ASME B16.5 and Bibliography reference 11.1. (Linear interpolation may be applied for the particular predicted maximum pipe temperature).

Table 1 Pipe temperature derating factor

(for use in the maximum pressure calculation)

Predicted maximum pipe temperature (°C) during welding (from Appendix 2 or Appendix 3 graphs)	Derating factor
More than 675	0.00
675	0.20
600	0.35
500	0.57
400	0.65
300	0.75
200	0.85
120	0.91
Less than 120	1.00

Method 2 - Charpy toughness

For off-plot pipelines, an alternative maximum pressure shall also be calculated to prevent failure by crack propagation.

The relevant formulae are dependent on the fluid in the pipeline and also on whether or not the line is buried (see Appendix 4). For all cases the pressure is given by:

$$P = \frac{2\,S_h\,t}{D} \quad (\text{i.e. Method 1 equation } F = E = T = 1)$$

where:

P = Maximum allowable operating pressure during welding, in MPa;

S_h = Maximum allowable hoop stress, in N/mm^2, calculated from the relevant toughness formula in (Appendix 4);

D = Nominal outside diameter of run pipe, in mm;

t = Nominal thickness, in mm;

P = Maximum allowable operating pressure during welding, in MPa.

3.3.4 Velocity of process fluid

3.3.4.1 Minimum velocity

Welding on a line under no-flow conditions (i.e. 0 m/s) or intermittent-flow conditions, e.g. a flare line, shall not be attempted unless it has been confirmed that no explosive or flammable mixture will occur during the welding operation. In this respect, it shall be confirmed that no ingress of oxygen in the line is possible.

In cases where this requirement cannot be met, purging shall be used. A minimum purge velocity of 0.4 m/s should be maintained.

3.3.4.2 Maximum velocity

High liquid flow will usually cause rapid cooling of the weld area during the hot-tap welding creating hard zones susceptible to cracking. Under these circumstances the minimum interpass temperatures may not be attainable, resulting in undesired material properties. A suggested maximum velocity for liquid flow during welding is 1.75 m/s. If the actual velocity is greater than this figure, heat loss tests should be performed at the actual hot-tap location. In the event of rapid cooling (i.e. if the cooling rate is such that the minimum specified interpass temperature is not achieved), special interpass heating techniques may be needed or the welding procedure amended.

There is no restriction on maximum velocity for gas lines, subject to the attainment of acceptable interpass temperatures.

3.4 HOT-TAP LOCATION

The hot-tap branch shall be installed at 90 degrees to the axis of the run-pipe.

On horizontal surfaces tapping is best performed in the vertically downward position (see Figure 1). The greater the deviation from this position, the more difficult it becomes to support the hot-tap machine and to fit and weld the nozzle. Tapping in positions below the 90° and 270° positions, where the machine is pointed upwards, shall be avoided because of the possibility of swarf and debris collecting in the nozzle attachment and possibly preventing closure of the isolating valve.

The separation of the attachment fillet welds from existing circumferential welds should be at least one run pipe outside diameter and shall not be less than 150 mm.

Hot-taps shall not be executed upstream of rotating equipment or other sensitive equipment (e.g. control valves) unless strainers, capable of removing machining swarf, are fitted or other protective measures are taken.

Interference with the longitudinal weld seam of the run-pipe shall be avoided wherever possible. If the run-pipe is of the spiral-weld type, the branch shall be located so that the spiral weld either cuts the area to be removed by the hot-tap perforation into two equal parts or avoids it completely.

A reduced branch fitting or reinforced set-on branch shall not be welded on top of a longitudinal or spiral weld seam. A distance (measured from the toe of the welds) of at least seven times the run-pipe wall thickness or 75 mm, whichever is the greater, shall be maintained between the connection to be installed and an existing connection or the longitudinal or spiral weld.

The chosen location on the run-pipe should be checked and verified as suitable for the hot-tap connection, taking into account at least the following factors:

- diameter and ovality;
- pipe wall thickness;
- internal and/or external corrosion;
- defects in the pipe wall (e.g. laminations);
- soundness of adjacent welds;
- internal deposits.

See Section (6.3) for assessment methods.

4. DESIGN

4.1 BASE MATERIALS

Base materials of the run-pipe and the branch connection shall be compatible in terms of weldability. Materials having the same P number, as defined in ASME IX, may be used as the basis of compatibility. However, if grades with special numbers (SP-1 etc.) are to be used, a materials/welding specialist should review the proposed materials.

4.2 DESIGN CALCULATIONS

Branch connections shall be designed in accordance with the appropriate design code, i.e.

1. on-plot piping : ASME B31.3
2. off-plot pipeline : ASME B31.4 (oil lines), or
   ANSI/ASME B31.8 (gas lines)

Note: The design methods in these codes are based on 'area replacement'. For pipelines with large branch diameter/pipeline diameter ratios in highly stressed critical situations, a more rigorous analysis, e.g. finite element elastic-plastic analysis, should be carried out to confirm that the stresses in the connection are acceptable.

For each hot-tap a complete design package should consist of a set of construction drawings, a material take-off and design calculations.

The design calculations shall include at least:

- process data/limitations;
- pipe data/welding suitability;
- maximum temperature and pressure;
- loading;
- configuration requirements (area replacement);
- test pressure.

Temperature-induced stresses may be significant for hot-taps onto high-temperature run-pipes.

The Principal loads which should be considered in the design are as follows:

(a) Piping-transmitted loads

A conventional pipe stress analysis should be performed to assess the effects of bending over supports, weight of valves and fittings, thermal expansion etc., unless these loads are obviously insignificant.

(b) Internal pressure

When a branch connection is drilled out, the loss of run pipe wall will result in decreased ability to retain internal pressure. A simple calculation is laid out in the codes mentioned above to assess the remaining strength of the pipe and to quantify any requirements for a reinforcing sleeve or saddle.

(c) Hot-tapping loads

During hot-tapping, the weight of the isolation valve and the drilling machine may tend to bend the run-pipe, if unsupported, and possibly buckle the pipe wall at the base of the branch. Also, if the branch is not in the vertical plane the cantilevered weight will tend to twist the run-pipe. The stresses induced by these loads should be calculated, multiplied by an arbitrary dynamic factor of 2, and combined with the internal pressure stresses. Typical weights and dimensions of hot-tapping equipment are given in (Appendix 5).

4.3 TYPE OF HOT-TAP CONNECTION

The type of hot-tap connection depends on pipe size and service; three types are shown in (Figure 1). The following guidelines should be applied :

(a) **Reduced branch fittings** (weldolets, nippolets, etc.) may be used only under the following conditions:

- For on-plot piping the branch pipe NPS shall be 3 inches maximum and the ratio of branch pipe diameter to run pipe diameter shall be less than or equal to $^1/_3$ (See also DEP 31.38.01.12-Gen.).
- For off-plot pipelines the branch pipe NPS shall be 2 inches maximum and the ratio of branch pipe diameter to run pipe diameter shall be less than or equal to $^1/_4$.

Reduced branch fittings shall not be used where vibration is expected.

The minimum NPS for reduced branch fittings shall be 1 inch.

(b) **Reinforced set-on branches** may be used for branch pipe sizes larger than those defined in (a). Full encirclement sleeves should be used rather than reinforcing pads or saddles.

(c) **Pre-formed split tees** designed to withstand full pipeline pressure may also be used. These are desirable when plugs or flow-through plugs are to be installed in the branch opening to assist the passage of pigs in the mainline. They are essential for full-bore stopple operations. However, these preformed tees form a small annular gap between the tee and the run pipe which may lead to corrosion problems with some types of fluid.

The diameter of a set-on branch should be at least one nominal pipe size smaller than the diameter of the run pipe (except for stopple connections). It should be realized that the hole drilled into the run pipe will be smaller than the internal diameter of the branch.

The branch shall be kept as short as possible

For reduced branch fittings and pre-formed split tees the circumferential weld between flange and branch pipe shall be prefabricated and pre-inspected in the shop in accordance with the same specification as that covering the run pipe (i.e. ASME B31.3, 31.4 or 31.8). This should also be considered for reinforced set-on branches but this would normally require the branch-side half shell to be sectioned (preferably along the pipe axis direction).

A full-bore valve should be specified for the branch, with an internal diameter large enough to allow the passage of the tapping drill. The use should be considered of a temporary sandwich valve in combination with "Lock-O-Ring" flanges for non-permanent hot-tap/stopple connections.

4.4 SPECIFICATION OF FITTINGS

All permanent components used in the hot-tapping operation shall conform to the same code as that covering the run pipe (i.e. ASME B31.3, 31.4 or 31.8), including sour service requirements if applicable.

4.5 COUPON REINFORCEMENT

For large diameter pipes, and particularly for spiral-welded pipe, the pipe coupon may "spring" after cutting and become jammed. This can be prevented by welding a coupon reinforcement device to the run pipe, prior to the branch connection or split-tees being installed.

5. JOB EXECUTION

A hot-tap is a potentially hazardous activity and therefore each hot-tap should be individually executed on the basis of the following phased activities:

(a)	Justification	-	agreement that the hot-tap is, for the particular case, technically feasible and economically justified.
(b)	Design	-	data gathering, connection design, confirmation of technical feasibility, setting hydrotest pressure.
(c)	Construction planning	-	welding procedure, welder qualification, safety plan, on-site checks, e.g. inspection of the hot-tap and weld area by visual inspection and NDT.
(d)	Operations planning	-	control of operating conditions, work permits, emergency procedures.
(e)	Execution	-	welding, inspection, pressure testing, perforation.
(f)	Completion	-	reinstatement, updating records.

These activities are listed in detail in the Hot-Tap Procedure Check List (Appendix 1.)

6. WELDING AND INSPECTION

The requirements for welder qualification, welding procedure qualification, welding and weld inspection shall be in accordance with DEP 30.10.60.30-Gen.

7. SPECIAL APPLICATIONS

7.1 GENERAL

The information in this DEP is in general intended to be used for making hot-tap connections on pipes. Although the principles can also be applied to vessels, tanks or other equipment, hot taps should be avoided wherever possible. Safe practices to be followed during hot-tapping on equipment are covered in API Pub 2201.

7.2 PRESSURE VESSELS

Hot-taps should not be performed on pressure vessels.

7.3 TANKS

The main danger in applying external heat to tanks is ignition of a flammable atmosphere in the vapour space or release of flammable vapours from vents.

Welding should be carried out only on mild steel (yield strength not greater than 240 N/mm^2) shell plates of maximum 12.5 mm thickness (carbon content $\leq$ 0.23%). For welding on other steel, approval of the Principal is required.

The lower courses of storage tanks may be made of impact-tested steel to prevent brittle fracture. In this case, all major wall penetrating nozzles are very often concentrated in one or two plates which are post-weld heat-treated. Hot-tapping shall not be carried out on these plates because the integrity of the construction could be destroyed by affecting the ductility by welding.

Required hot-tapping shall be preceded by hardness and impact testing in a simulated procedure test on identical material having the same thermo-mechanical history as the tank wall plate chosen to be perforated.

At least 1 m of liquid head shall be maintained above the hot work area when welding or hot-tapping is being carried out. (i.e. hot work shall not be carried out on a tank roof or on the cylindrical wall above the liquid level).

The maximum nozzle diameter shall be determined by the applicable design code requirements. Pumping in or out of tanks shall not be carried out while hot work is in progress.

7.4 MISCELLANEOUS EQUIPMENT (VALVES, PUMPS, STRAINERS, MIXERS, TURBINE HOUSINGS)

In view of the complicating factors arising from the fabrication process and configuration, hot-tapping on such equipment should not be carried out.

7.5 FLARE LINES

Because of insufficient flow or unstable operating conditions, hot-tap welding on flare lines is feasible only with special precautions.

Special precautions are:

- purging of the flare line with steam or an inert gas during the welding operations, creating a gas velocity of at least 0.4 m/s;
- application of additional instrumentation (e.g. flow meter, hydrocarbon gas detector) including a quick-acting warning system.

8. PRESSURE TESTING

8.1 GENERAL

All hot-tap fittings, nozzles, sleeves and split tees shall be pressure-tested after completion of all welding, before perforation of the run-pipe.

The objective of the test is primarily to indicate leak tightness of the hot-tap branch weld. Additionally, it should demonstrate the strength of the hot-tap weld at the highest practical test pressure. This test pressure will depend on the actual internal pressure of the run pipe at the time of the hot-tap and the ability of the run pipe to withstand external pressure, i.e. resistance to buckling. Since off-plot pipelines are normally constructed with thin wall/highly stressed pipe, the possibility of buckling is greater than with on-plot piping.

In the most favourable case, the maximum value of the test pressure would be calculated in accordance with the particular design code (and this pressure would be different for on-plot piping and off-plot pipelines).

The general testing procedure to be followed shall be:

(1) Leak testing of the hot-tap valve, preferably with the valve not installed on the branch (so that the correct seal is tested), for a duration of at least 5 minutes.

(2) Testing of the branch connection, with the valve installed and in the open position, to demonstrate leak tightness and strength. Duration should be at least 30 minutes.

(3) Leak testing of the drilling machine mounted on the valve (with valve closed), for a duration of at least 5 minutes.

Leak test pressures for tests (1) and (3) shall be equal to the highest operating pressure in the run-pipe which could occur during the hot-tap operation. The pressure for test (2) shall be determined as detailed below.

8.2 STRENGTH TEST PRESSURES

The following requirements apply to the strength/leak test (2) described above.

8.2.1 Split tees

For split tees, the maximum allowable pressure differential (ΔP) with respect to buckling of the run-pipe should be calculated as defined in ASME VIII, Division 1, Section UG-28.

Therefore $PT = PA + \Delta P$

where PT = test pressure
and PA = actual operating pressure in the run-pipe

8.2.2 Set-on branch connections

The American Gas Association (AGA) has carried out research on the appropriate pressure for testing set-on branch connections, as presented in report EP 90-3562. This work has resulted in the graphs shown in (Appendix 6), where, in consistent units:

PT = test pressure in the branch pipe;
PA = actual operating pressure in the run-pipe;
F = ratio of actual operating stress level in the wall of the run-pipe to the material specified minimum yield strength (SMYS);
D = outside diameter of the run pipe;
d = outside diameter of the branch pipe;
t = actual wall thickness of the run-pipe.

These graphs make the simplifying assumption that the branch pipe wall thickness equals the run pipe wall thickness, which is conservative in terms of buckling for the normal case where the branch pipe wall thickness is the lesser of the two. If this is not the case the test pressure should be calculated from formulae (7) or (8) in EP 90-3562. In any event, the test pressure (PT) shall not be greater than the design code test pressure of the branch pipe.

It should be noted that the AGA work was carried out in the context of set-on branch configurations for pipelines. For this reason, the graphs show curves for F = 0.5, 0.6, 0.72 and 1.0. For on-plot piping applications, where F is generally less than 0.5, the use of a value F = 0.5 will lead to a conservative test pressure (in terms of buckling).

Similarly for branch/run-pipe diameter ratios of less than 0.1 the graphs will give conservative test pressures.

8.3 TESTING MEDIA

Where practical, the testing medium shall be water. In some applications where it is desirable to avoid water in the split-tee annulus, the use of liquid hydrocarbons may be suitable, subject to acceptable safety precautions.

Air or other gases shall not be used for test pressures greater than 7 bar (ga).

9. PERFORATION AND COMPLETION

After welding and hydrotesting, the drilling machine (see Figure 2) shall be checked to confirm its suitability and correct operation, as explained in the Hot-Tap Check List (Appendix 1).

After the drilling machine has been mounted and leak-tested, perforation may proceed. During drilling the machine shall be monitored for correct operation and removal of debris.

When perforation is accomplished, the coupon should be retrieved, and if not re-used (e.g. as with a "Lock-O-Ring" flange) it should be kept in the location of the hot-tap until commissioning is finished and then submitted to the Principal's corrosion engineer for information on the internal condition of the pipe. If a coupon drops into a pipeline or pipe, all relevant parties in the organisation should be notified so that appropriate actions can be taken with respect to pigging and prevention of possible damage to downstream equipment.

The branch shall be blanked off immediately upon removal of the drilling machine.

When the hot-tapping operation has been completed, the pipe surfaces shall be cleaned and recoated, the work site reinstated and the cathodic protection switched on.

10. REFERENCES

In this DEP, reference is made to the following publications:

NOTE: Unless specifically designated by date, the latest edition of each publication shall be used, together with any amendments/supplements/revisions thereto.

SHELL STANDARDS

Index to DEP Publications and Standard Specifications	DEP 00.00.05.05-Gen.
Welding on Pressurised Pipes (Amendments/supplements to API RP 1107)	DEP 30.10.60.30-Gen.
MF Piping Classes	DEP 31.38.01.12-Gen.
EP Piping Classes	DEP 31.38.01.15-Gen.
SIPM Report: Proof Testing of the Pre-Hot-Tap Branch Connection" by M.J. Rosenfeld and W.A. Maxey, Committee of the American Gas Association	EP 90-3562

AMERICAN STANDARDS

Chemical Plant and Petroleum Refinery Piping	ASME B31.3
Liquid Transportation Systems for Hydrocarbons, LPG; Anhydrous Ammonia and Alcohols	ASME B31.4
Gas Transmission and Distribution Piping Systems	ASME B31.8

Issued by:
American National Standards Institute
Sales Department
1430 Broadway
New York NY 10018
USA.

Specification for Linepipe	API Spec 5L
Repairing crude oil, liquefied petroleum gas, and product pipelines.	API RP 2200
Procedures for welding or hot-tapping on equipment containing flammables	API Pub 2201

Issued by:
American Petroleum Institute
Publications and Distribution Section
1220 L Street Northwest
Washington DC. 20005
USA.

ASME Boiler and Pressure Vessel Code: Section VIII, Division 1 - Pressure Vessels	ASME VIII
Section IX - Welding and Brazing Qualifications	ASME IX

Issued by:
American Society of Mechanical Engineers
345 East 47th Street
New York NY 10017
USA.

Standard test method for Vickers hardness of metallic materials	ASTM E 92

Issued by:
American Society for Testing and Materials

1916 Race Street, Philadelphia, 19103
USA.

BRITISH STANDARDS

Welding on steel pipes containing process fluids or their residuals	BS 6990

Issued by:
British Standards Institution
389 Chiswick High Road
London W4 4AL
UK.

11. BIBLIOGRAPHY

The following documents are for information only and do not form an integral part of this DEP:

11.1 "British Gas Studies of Welding on Pressurized Gas Transmission Lines" by B. Phelps.

11.2 Hot work. Welding and cutting on plant containing flammable materials - HS(G)5 (Health and Safety Executive document. ISBN 0 11 883229 8)

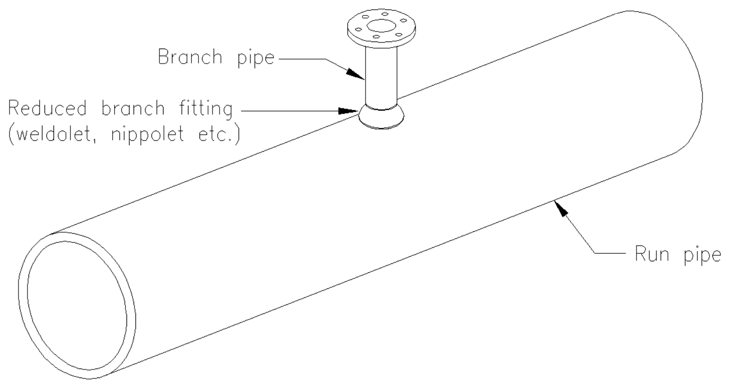
Issued by:
Her Majesty's Stationery Office
London
England.

11.3 "Guide for Hot-tapping on Piping and other Equipment" Publication No. 185: 1996

Issued by:
EEMUA
Engineering Equipment & Materials Users Association
45 Beech Street
London EC2Y 8AD
United Kingdom

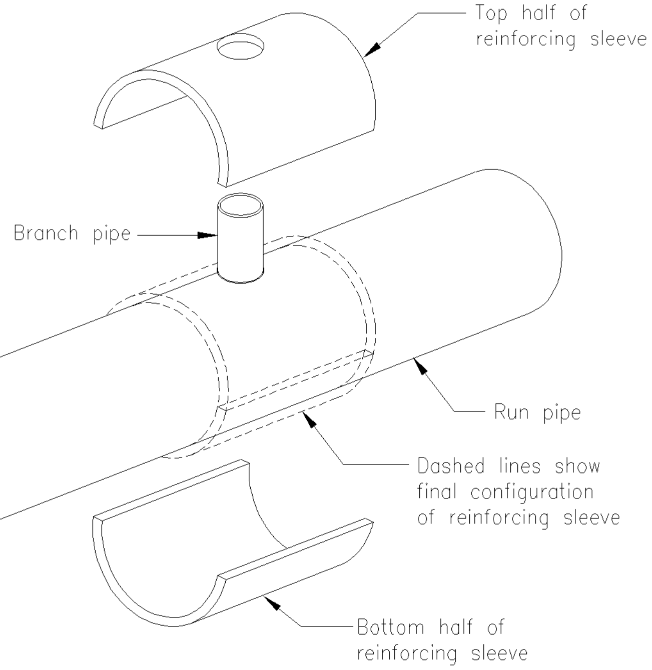
FIGURE 1 TYPES OF HOT-TAP CONNECTION

1. Reduced branch fitting



2. Reinforced set-on branch

Note: 1. Fluid is not in contact with the reinforcing sleeves
2. Branch pipe flange not shown



3. Preformed split tee

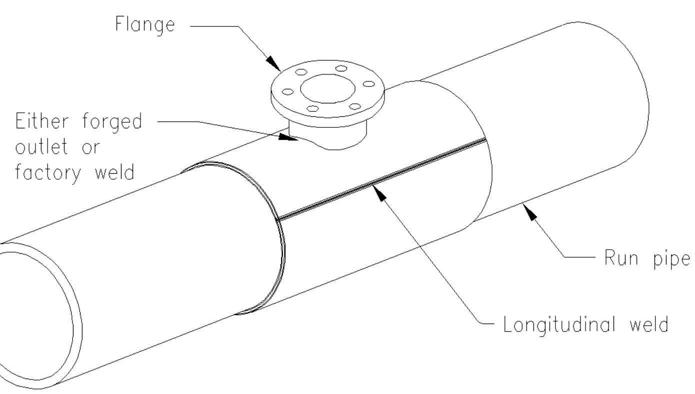
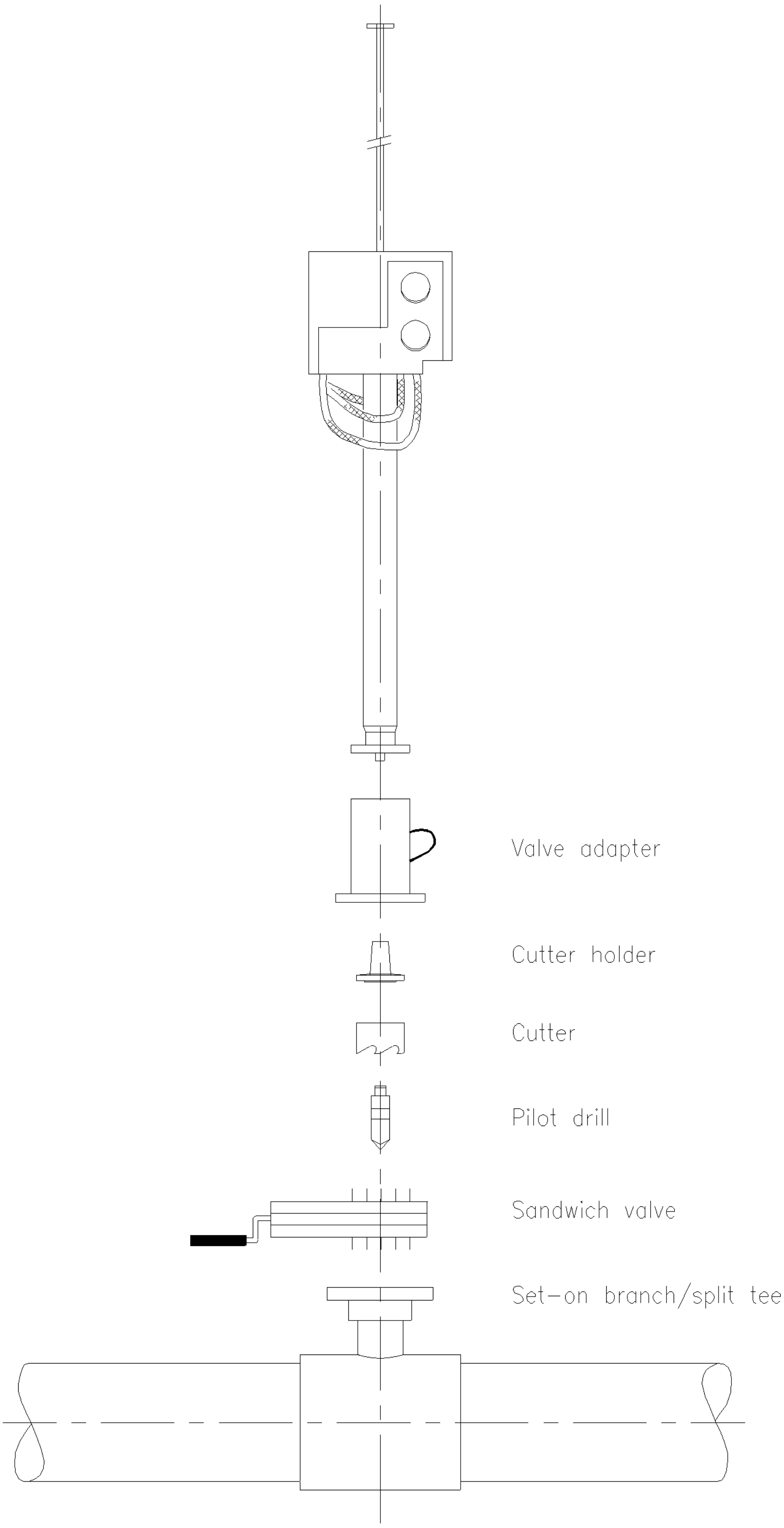


FIGURE 2 DRILLING MACHINE SCHEMATIC



APPENDIX 1 HOT-TAP PROCEDURE CHECK LIST

Project No.: Project Title:

Hot-tap description/identification:

Date:

Notes:

1. This Checklist comprises:
   - Part A: Feasibility and Design
   - Part B: Operational Feasibility
   - Part C: Pre-Execution Checks
   - Part D: Execution
2. Job Titles are indicative only
3. This checklist may require some minor modification in view of local requirements.
4. Nm^3/d refers to "normal" m^3 i.e., at 1.013 bar (abs) and 0 °C

APPENDIX 1 Continued..

PART A: FEASIBILITY AND DESIGN

A1. Justification

Use of hot-tap in place of other methods of connection must be fully justified. A summary shall be given below.

A2. Pipe data

2.1 Run pipe

Identification: ....

Diameter:	....	inch or	mm
Nominal wall thickness		....	mm
Material specification/grade:		....	
Design pressure		....	kPa (ga)
Normal operating pressure		....	kPa (ga)
Normal operating temperature (fluid):		....	°C
Fluid (oil, gas)		....	
Normal flow rates of main components	oil	....	m^3/d
	gas	....	Nm^3/d
Fluid O_2 contents:		....	ppm (vol)
	H_2 content:	....	ppm (vol)
	H_2S content:	....	ppm (vol)
Other fluid contents		....	ppm (vol)

APPENDIX 1 Continued..

PART A (cont.)

2.2 Branch pipe

Identification:..

Diameter: ....inch or ....mm

Nominal wall thickness: .... mm

Material specification/grade: ....

A3. Inspection

Project Engineer shall request an examination of the run pipe at the proposed location for the hot-tap.

3.1 Minimum wall thickness from ultrasonic examination: .... mm
(minimum 4.8 mm is required for hot-tapping).

3.2 Check run-pipe for laminations.
(Attach ultrasonic inspection report on thickness and lamination).

A4. Process conditions and design

4.1 Maximum pipe wall temperature

Maximum heat input during welding: .... J/mm

Preheat required: .... °C

Therefore from (Appendix 2), predicted maximum wall temperature .... °C

4.2 Maximum pressure

a) Temperature derating method

S, specified minimum yield stress (B31.4 or B31.8), or basic allowable stress (B31.3) .... N/mm^2

u, thickness reduction (from Appendix 2): .... mm

therefore $t = t_{actual} - u$: .... mm

Safety factor
(not applicable to B31.3) ....

E, longitudinal joint factor: ....

T, temperature derating factor: ....

Therefore, the maximum allowable pressure according to temperature derating = ... kPa (ga)

APPENDIX 1 Continued..

PART A (cont.)

b) Charpy toughness method - Off-Plot pipelines only

MCV, minimum specified average Charpy value: ....J

$S_{h,}$ hoop stress (from Appendix 3): ....ksi, or ....N/mm^2

therefore, the maximum allowable
pressure to prevent crack propagation = ...kPa (ga)

c) The maximum allowable pressure during hot-tapping is the lower of the values defined in a) and b) above.

............................kPa (ga)

4.3 Chemical stability of fluid

The fluid is acceptable for hot-tapping, ...confirmed/not confirmed

4.4 Fluid velocity

The fluid cannot form an explosive or flammable mixture during welding ....confirmed/not confirmed

Purging is required/is not required.

Minimum purge rate is........m/s

4.5 Suitability and compatibility of pipe materials

Pipe materials are 'standard' ....confirmed/not confirmed

4.6 Type of connection

Branch pipe diameter = ... mm

Ratio of branch pipe diameter/run pipe diameter = ...

Other factors:

Therefore connection type selected: ....

Temporary support required .... yes/no

APPENDIX 1 Continued..

PART A (Cont.)

4.7 Hydrostatic strength test pressure

a) Test pressure from relevant design code .... kPa (ga)

b) To prevent buckling of run pipe:
- Test pressure for split tees, calculation using ASME VIII, Div. 1, UG 28 .... kPa (ga)
- Test pressure for set-on branches, using EP 90-3562 .... kPa (ga)

c) Strength test pressure, the lower of a) and b) .... kPa (ga)

4.8 Drawings
The relevant drawing numbers for the hot-tap are:

Cross-sectional general arrangement of hot-tap connection:

Process Flow Diagram(s):

Piping plan:

Branch details:

Support details:

Items A1 to A4 of this Appendix certified by: ....
Design Engineer

A5. Summary of feasibility and process requirements

5.1 Type of connection specified: ....
(set-on branch, split tee, weldolet)

5.2 Confirm chemical stability of fluid.

5.3 Confirm suitability of pipe material for hot-tapping.

5.4 Summarise process conditions:

Maximum pressure: .... kPa (ga)

Fluid temperature (not welding temp.): .... °C

Flow rate limits: (Oil) .... m^3/d, (Gas) .... Nm^3/d
(.............. m/s) (................... actual m/s)

Items A5 certified by: ....
Project Engineer

APPENDIX 1 Continued..

PART B: OPERATIONAL FEASIBILITY

Confirm that fluid data and operating conditions specified in Part A above are correct and that the proposed hot-tap is acceptable from an Operations viewpoint.

Confirmed by: ....

Area Operations Coordinator

and for main oil/gas pipelines only ....

Head of Pipeline Operations

APPENDIX 1 Continued..

PART C: PRE-EXECUTION CHECKS

(Prepared by Principal's Field Representative)

		Action completed
C1.	**Weld procedure**	
	Confirm that Welding Procedure has been agreed and qualified.	.....
C2.	**Safety plan**	
2.1	Contractor has prepared a safety plan for hot-tapping operation, approved by the Principal Field Engineer (plan to be attached).	.....
2.2	Initiate Permit to Work procedure.	.....
C3.	**Pipework/equipment**	
3.1	Confirm correct pipe identification and that the location has been clearly marked.	.....
3.2	Confirm that area to be welded has been inspected for actual thickness and laminations and is satisfactory (attach test reports).	.....
3.3	Confirm that branch components and flange, isolation valve and drilling machine comply with requirements, i.e. dimensions, pressure rating, material, weld quality, fit-up.	.....
3.4	For large diameter pipes where the coupon may "spring" after cutting, ensure that a coupon reinforcement device is attached to the run pipe before the branch fitting is welded in place to avoid the coupon becoming jammed.	.....
3.5	Check proper operation of drilling machine, sharpness and security of bit, and presence of coupon catcher.	.....
3.6	Check provision for cooling and lubricating bit.	.....
3.7	Check cutting depth and clearance through block valves.	.....

APPENDIX 1 Continued..

PART C (Cont.)

C4. Site conditions

4.1	Ensure that site conditions are acceptable (room for equipment, ventilation, drains, lighting).	.....
4.2	Discuss Safety Plan with Construction and Operations personnel on site and confirm who does what.	.....
4.3	Ensure provision of adequate safety equipment (e.g. fire-fighting, first aid, H_2S monitors).	.....
4.4	Ensure that personnel escape routes are adequate.	.....
4.5	Confirm that supports are present for the run pipe, branch, isolation valve and drilling machine, as specified in the Engineering Calculation Summary.	.....
4.6	Confirm that sufficient equipment and services have been provided (e.g. craneage, power, welding consumables, back-up equipment, etc.). Check equipment for correct operation.	.....
4.7	Check welder and inspector.	.....
4.8	Arrange to have cathodic protection switched off (24 hrs before welding operations).	.....
4.9	Ensure that two-way communication is open with the parties responsible for monitoring operating conditions and isolation.	.....

Action confirmed by: ....
Field Engineer

Agreement from Operations to proceed with execution: ....
Field Operations Representative

APPENDIX 1 Continued..

PART D: EXECUTION

(Prepared by Principal's Field Engineer)

		Action completed
D1.	**Final checks**	
1.1	Check that Permit to Work is valid.	.....
1.2	Ensure that pressure and flow rate within the run pipe are within the limits stated in the Hot-Tap Procedure and are being monitored.	.....
1.3	Ensure that hydrocarbon gas and H_2S levels in the working environment are tolerable.	.....
1.4	Ensure that cathodic protection switched off.	.....
D2.	**Welding**	
2.1	Perform welding according to the approved Welding Procedure.	.....
D3.	**Inspection**	
3.1	Perform visual inspection and magnetic particle detection of welds.	.....
D4.	**Hydrotesting**	
4.1	Perform hydrotests of valve and branch.	
a)	Leak test of valve at...................kPa (ga)	.....
b)	Strength pressure test of branch at.....................kPa (ga)	.....

APPENDIX 1 Continued..

PART D (Cont.)

D5. Perforation

5.1	Mount drilling machine and check alignment to prevent fouling in valve or branch.	.....
5.2	Leak test drilling machine at kPa (ga).	.....
5.3	Perform drilling operation and ensure withdrawal of coupon.	.....
5.4	If applicable, install 'Lock-O-Ring' plug or 'flow-through' plug (pigging guide). Leak test 'Lock-O-Ring' plug.	.....
5.5	Remove drilling machine (and temporary valve, if applicable) and immediately install blind flange/spade.	.....

D6. Completion

6.1	Re-coat exposed pipe.	.....
6.2	Reinstate cathodic protection (if applicable).	.....
6.3	Remove all temporary aids and paint exposed surface.	.....
6.4	Clean-up work site.	.....
6.5	Send coupon to Principal's corrosion engineer.	.....
6.7	Advise completion to all parties involved.	.....
6.8	Update relevant drawings and records.	.....

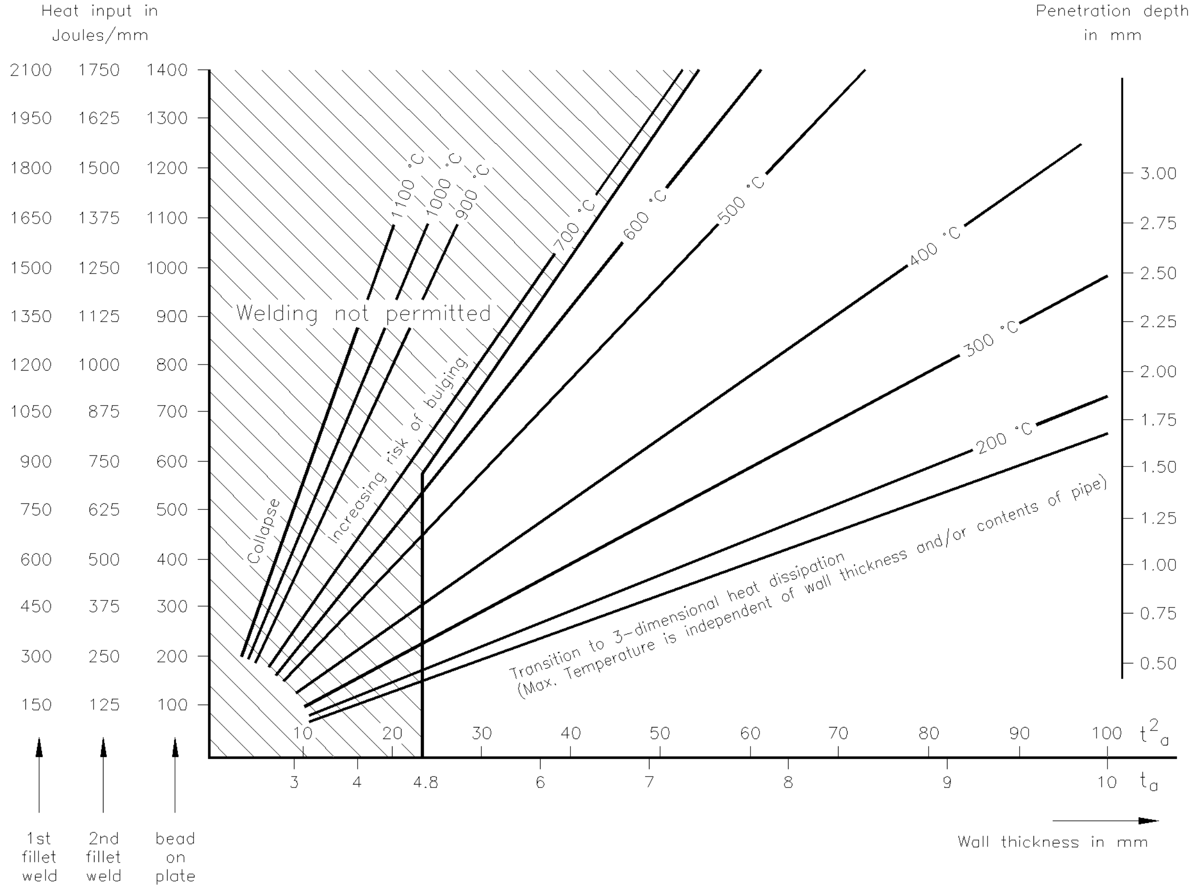
Action confirmed by: ....

Field Engineer

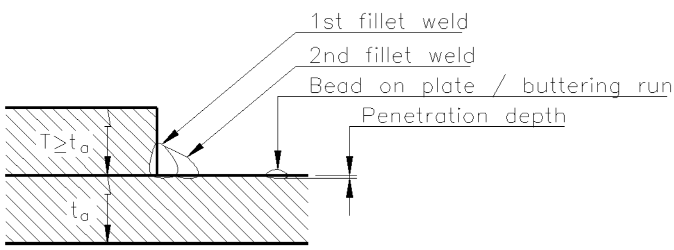
Job Acceptance: ....

Asset Operator

APPENDIX 2 WELDING TEMPERATURE OF PIPEWALL - INITIAL PIPE WALL TEMPERATURE OF 25 °C

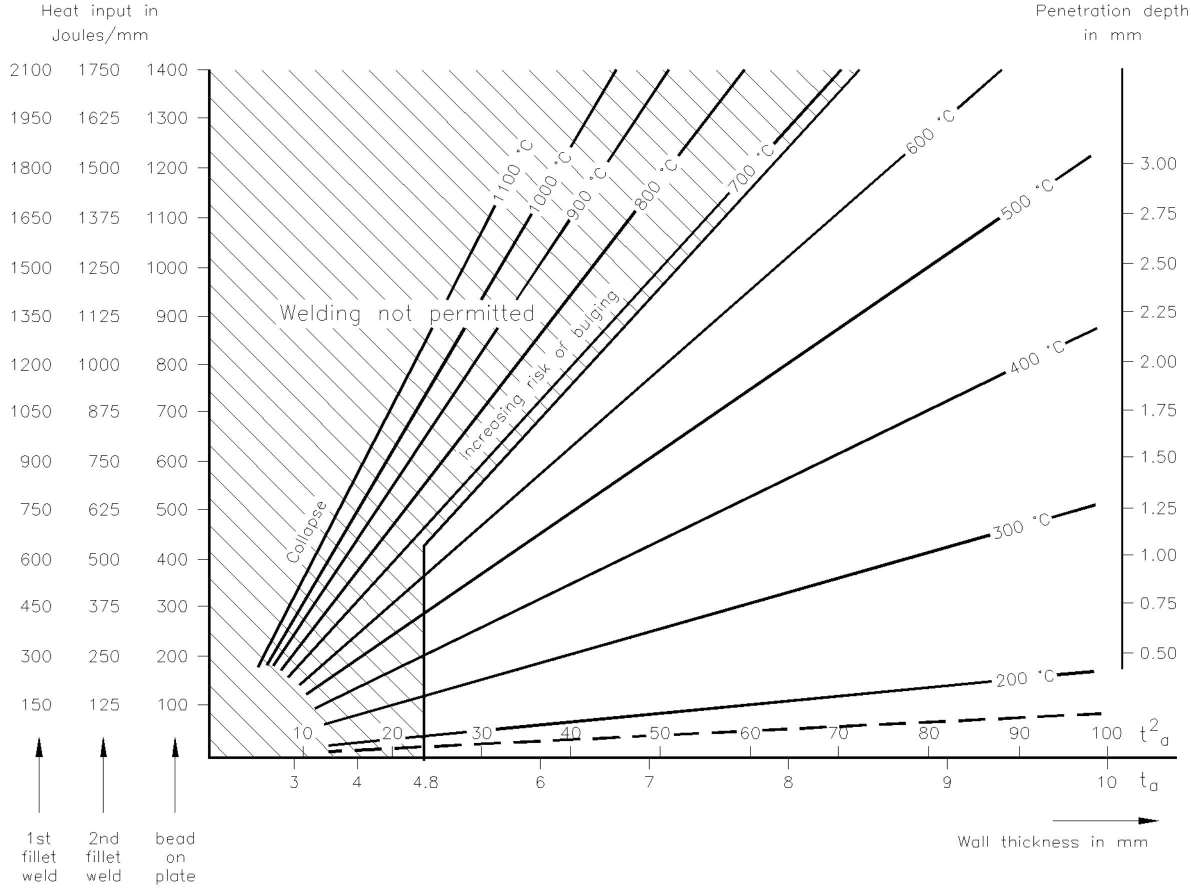


Maximum prevailing temperature at the inner side of carbon or carbon–manganase steel pipe when welding with covered electrode, starting from an initial pipe wall temperature of 25°C

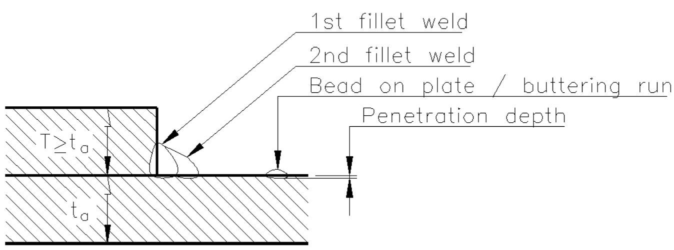


NOTE: 1. t_a = actual measured wall thickness.
2. Lines may be extrapolated horizontally for increased wall thickness.

APPENDIX 3 WELDING TEMPERATURE OF PIPEWALL - INITIAL PIPE WALL TEMPERATURE OF 150 °C



Maximum prevailing temperature at the inner side of carbon or carbon–manganase steel pipe when welding with covered electrode, starting from an initial pipe wall temperature of 150°C



NOTE: 1. t_a = actual measured wall thickness.
2. Lines may be extrapolated horizontally for increased wall thickness.

APPENDIX 4 FORMULAE FOR MAXIMUM PRESSURE CALCULATION BASED ON FRACTURE TOUGHNESS PROPERTIES (OFF-PLOT PIPELINES ONLY)

This Appendix gives details of crack propagation formulae referred to in (3.3.3), Method 2, Charpy Toughness.

The formulae are taken, for four different application types, from "Fracture Control Testing and Acceptance Criteria for Line pipe" by D.A. Hansen of Aramco, March 1981.

Type 1 - water and stabilized crudes and products with a vapour pressure less than 700 kPa;

Type 2 - liquids with high vapour pressure, in excess of 700 kPa (e.g. NGL);

Type 3 - gases and two-phase buried lines;

Type 4 - gases and two-phase above-ground lines.

In the above publication, the formulae are expressed in terms of the minimum acceptable level of toughness (MAL), in ft-lbf, for a given pipe configuration and pressure level. They are based on formulae from the Battelle Institute, modified by a statistical method, for a large number of pipes. Note that a minimum toughness of 10 ft-lbf (14 Joules) is required for Types 2, 3 and 4.

Type 1

No requirement for land pipelines.

Type 2

The type 2 formula is complex and based on several assumptions. Reference shall be made to the above publication for checking the assumptions and the use of graphs.

Type 3

The minimum acceptable level of toughness (MAL) is given by:

$$MAL = 7.88 \times 10^{-3}\ S_h^2 \left(\frac{Dt}{2}\right)^{0.333} \qquad \text{ft-lbf}$$

This can be reformulated to determine the maximum allowable hoop stress (S_h) for a given level of pipe material toughness, as follows:

$$S_h = \left[126.9\ MCV \left(\frac{Dt}{2}\right)^{-0.333}\right]^{0.5} \qquad \text{ksi}$$

where:

MCV = minimum specified Charpy toughness (ft-lbf) at the minimum pipeline design temperature (or lower)

S_h = maximum allowable hoop stress (ksi)

D = pipe diameter (inches)

t = nominal wall thickness (inches)

(1 ksi = 1 000 psi = 6 895 kN/m^2)

APPENDIX 4 Continued..

Type 4

$$MAL = 10.73 \times 10^{-3} \; S_h^2 \left(\frac{Dt}{2}\right)^{0.284} \qquad \text{ft-lbf}$$

or

$$S_h = \left[93.19 \; MCV \left(\frac{Dt}{2}\right)^{-0.284} \right]^{0.5} \qquad \text{ksi}$$

with the same units as above in Type 3

If possible, the minimum average Charpy values specified in the Purchase Order (and confirmed by material certificates) shall be used. Test values shall be at the minimum pipeline design temperature or lower, using full-size (10 mm x 10 mm) transverse specimens.

APPENDIX 5 TYPICAL WEIGHTS AND DIMENSIONS OF HOT-TAPPING EQUIPMENT

Tap size (mm)	Mass (kg)	Max. height (mm)
50	20	-
80	75*	1 270
100	308	2 390
150	310	2 440
200	312	2 440
250	320	2 745
300	330	2 800
350	1 000	3 180
400	1 004	3 180
450	1 008	3 300
500	1 018	3 300
600	1 090	3 400
750	1 182	3 550
900	1 220	3 800

Note: The above table applies to convential hot-tapping machines

* Indicates air or manually operated machines; other machines are hydraulic

APPENDIX 6 HOT-TAP SAFE TEST PRESSURE RATIO