MANUAL

PIPELINE OVERPRESSURE PROTECTION

DEP 31.40.10.14-Gen.

March 1994

DESIGN AND ENGINEERING PRACTICE

USED BY

COMPANIES OF THE ROYAL DUTCH/SHELL GROUP

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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1. INTRODUCTION

1.1 SCOPE

This is a new DEP which provides guidance and specifies minimum requirements for the protection of pipelines against overpressure. The following subjects are covered:

- possible pipeline pressure sources;
- requirements for determining pipeline operating and incidental pressures;
- description of possible methods and guidance on selection;
- minimum engineering, maintenance and inspection requirements.

This DEP refers to DEP 31.40.00.10-Gen. for determining allowable pipeline pressures.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by SIPM, the distribution of this DEP 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 for use by Functions in the Group that are involved in the design, material procurement, construction and operation of pipelines.

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

Pressures

Accumulated Pressure - Pressure which is built up in a pipeline during the period of activation of an overpressure protection system.

Design Pressure - The internal pipeline pressure used in the determination of the pipeline wall thickness requirements.

Incidental Pressure - Pressure occurring in a pipeline with limited frequency and during limited periods of time. Incidental pressures include Surge Pressures, and Thermal Pressures if not occurring a significant portion of the time.

Maximum Allowable Incidental Pressure - The maximum pressure that is allowed by ANSI/ASME B31.4/8 to occur in a pipeline with a limited frequency and during limited periods of time.

Maximum Allowable Operating Pressure - The maximum pressure at which a pipeline is allowed to be operated under steady state process conditions, in accordance with ANSI/ASME B31.4/8.

Maximum Operating Pressure - The maximum pressure at which the line will be operated under steady state process conditions.

Surge Pressure - Pressure due to mass flow velocity changes, caused by operational activities, e.g. valve closures, pump shut-down or start-up.

Thermal Pressure - Pressure due to thermal expansion effects on the fluid in a blocked-in pipeline or blocked-in pipeline sections.

Others

High Integrity Protection System - Instrumented system with a high reliability for the isolation of the pipeline from pressure sources before allowable pipeline pressures will be exceeded.

Pressure Recorder Alarm (High) - System for warning and registering the occurrence of pressures in excess of allowable values.

Pressure Safety Relief Valve - Valve for protecting a pipeline against overpressure by releasing fluid from the pipeline.

Source - The facility located immediately upstream of the pipeline, characterised by the type and the pressure of the produced fluid. The Source may be a well or group of wells, a treatment facility, a pumping or compressor station, or a feeding pipeline.

Specified Minimum Yield Strength - Specified minimum yield strength of the pipeline material.

1.4 ABBREVIATIONS

PRA(H)	Pressure recorder alarm (High)
HIPS	High integrity protection system
MAIP	Maximum allowable incidental pressure
MAOP	Maximum allowable operating pressure
MOP	Maximum operating pressure
PSV	Pressure safety relief valve
SMYS	Specified minimum yield strength

1.5 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 (6).

2. PIPELINE PRESSURES

2.1 PRESSURE SOURCES

Pressure sources should, when determining operating and incidental pipeline pressures, be categorised as:

(i) well pressure; or

(ii) pressure from pressure boosting facilities such as pumps and compressors; or

(iii) pressure from pressure controlled process vessels; or

(iv) operating pressure from a feeding pipeline; or

(v) hydrostatic head due to change in pipeline elevation; or

(vi) surges as a result of operational activities, e.g. valve closure, pump start-up/shut-down; or

(vii) thermal expansion of blocked-in fluids; or

(viii) failure of the pressure control/trip of pumps, compressors, pressure controlled process vessels or feeding pipelines; or

(ix) incidental pressures from a feeding pipeline; or

(x) accumulation pressure during the activation of the overpressure protection safety relief or isolation valves.

2.2 OPERATING PRESSURE

In most cases, the pipeline operating pressure, that is the pressure at which the pipeline operates under steady state conditions, is the pressure resulting from a category (i) to (iv) source. When no pressure limiting or overpressure protection is provided, these pressures are:

- for (i) the closed-in tubing head pressure for pipelines conveying fluids directly from a naturally flowing well. The pipeline operating pressure will be higher if the pipeline is also to be used for well servicing duties like through-flowline-operations and killing;
- for (ii) the highest pressure which can be generated under steady state conditions by pumps, compressors and artificially lifted wells over the possible flow range;
- for (iii) the upper pressure level of the range in which the pressure is controlled;
- for (iv) the operating pressure of the feeding pipeline determined in accordance with this section.

In the case of multiple sources, the highest source pressure shall be taken.

Pipeline operating pressures are normally highest where the fluid enters the pipeline and decrease along the line due to friction loss. This may, however, not be true when transporting high density fluids in pipelines with an elevated inlet position, e.g. offshore platforms or mountainous terrain. For these pipelines the hydrostatic head due to change in elevation, source (v), may cause higher pressures down the pipeline which need to be added to the source (i) to (iv) pressures when determining the MOP. The possible contribution of the hydrostatic head to the operating pressure should be verified for the complete flow range as the effect is not necessarily highest at the maximum flowrate.

Surge pressures due to operational activities, source (vi), are normally of short duration and limited frequency and are therefore not included in the operating pressure.

Thermal pressures, source (vii), are included in the operating pressure only if blocking-in is a regular operational activity and occurs for a significant period of time.

2.3 INCIDENTAL PRESSURE

The incidental pressure is the pressure which may occur anywhere in the pipeline at any time and is calculated from the combined effect of the operating pressure (2.2), incidental pressures of feeding pipelines determined in accordance with this section and the source

(vi) to (x) pressures.

2.4 MAXIMUM ALLOWABLE PRESSURES

The MAOP shall be determined in accordance with DEP 31.40.00.10-Gen., which refers to ANSI/ASME B31.4 and B31.8 as the base documents for liquid and gas lines respectively. The MAOP relates to the design pressure and the test pressure.

The maximum allowable incidental pressure (MAIP) is 1.1 times MAOP for both liquid and gas lines provided, for gas lines only, that the hoop stress from incidental pressures does not exceed 75% of SMYS.

3. METHODS FOR OVERPRESSURE PROTECTION

3.1 OVERVIEW AND SELECTION

Designing a pipeline for the maximum source pressures without the need for overpressure protection equipment is the simplest method for safeguarding a pipeline against overpressure. This method should be applied whenever the additional life-cycle costs, compared with the installation of overpressure protection equipment, are minor. Examples of applications are short, small diameter pipelines where the difference between the additional pipeline material and construction costs will be offset by the life-cycle costs of overpressure protection equipment. Pipelines fed by pumps or compressors, source (ii), are other examples where matching source and allowable pipeline pressures may be obtained at low, if any, additional cost.

Overpressure protection of pipelines may be achieved by the installation of equipment for:

- pressure safety relief; or
- high integrity protection system (HIPS).

Pressure safety relief equipment has commonly been installed to protect pipelines against pressures in excess of MAIP. This protection method may be selected instead of the above inherent safe pipeline design if life-cycle costs are reduced. The costs for the installation, inspection and maintenance of the fluid disposal facilities shall be included when comparing costs.

More recently, pipelines have also been protected against overpressure with HIPS. HIPS consists of a fail-to-close valve activated to close at the set pressure by a redundant and highly reliable instrumented pressure sensing and transmitting system. This method may be applied where relief is not practical for safety or environmental reasons or the use of HIPS results in significant cost reductions. Gas transmission lines are an example where HIPS may result in a significant cost saving when compared with relief protection, due to a higher MOP as a percentage of MAOP.

Activation of the overpressure protection equipment from incidental pressure under normal operations shall be avoided by providing a sufficient margin between the MOP of the pipeline and the equipment set pressures. Besides overpressure protection, a pressure control and alarm system shall be installed for applications where the operating pressure of the source may exceed the MOP of the pipeline.

NOTE: PSV and HIPS activation during normal operations should be avoided in order to maintain the integrity of the seals.

Pipeline entry pressures shall be monitored when overpressure protection is provided to alarm the operator for corrective action when operating pressures exceed the predicted range. Pressures in excess of MAOP shall be recorded with duration and pressure value.

Figures 1 and 2 show example schemes of pipeline overpressure protection with pressure safety relief and HIPS respectively. Typical set pressures for gas lines with minimum setpoint margins in view of the low incidental pressures are shown in Figures 3 and 4. Incidental pressures can be significantly higher for lines containing liquids and consequently require lower set points for pressure control. Incidental pressures should be determined on a case-by-case basis. Incidental pressures shall be determined before MOP, MAOP and the corresponding set pressures for pressure control and overpressure protection are selected.

3.2 COMPARISON OF METHODS

The key differences between the two overpressure protection methods are:

- with a HIPS protection, fluids remain in the pipeline thus avoiding the need for disposal facilities and potential burden to the environment;
- with a relief protection, the pipeline remains continuously available for transport;
- HIPS is more complex and requires more stringent control, maintenance and inspection procedures;
- HIPS protected pipelines can operate closer to MAOP than relief protected lines, which require typically 10% of the set pressure for pressure accumulation (see Figure 5).

3.3 SURGE PRESSURES

Possible surge pressures in a pipeline system shall be estimated during the conceptual phase of a pipeline system transient flow analysis. Possible means for the control of surge pressures are:

- providing sufficient margin in the pipeline design for surge pressures;
- controlling the generation of pressure surges by reducing the rate at which mass flow velocities of the fluid changes. For example, in the case of valve closure this can be done by slowing down the valve actuator or installing a two-speed actuator reducing the valve closure speed over the last 10 to 20% of the valve travel movement;

  NOTE: This method of surge pressure control should not be applied to shut-off valves installed as part of HIPS.

- installation of a pressure relief system close to the point of surge initiation. This may consist of a vessel with a pressurised gas blanket or rapid actuation surge relief valve discharging into a surge tank which must be ready at all times to receive the relief fluid.

Operating procedures need to reflect that surge pressures should be avoided as far as practical, also when surge pressure protection equipment has been installed.

3.4 THERMAL PRESSURES

Unallowable thermal pressures may be avoided by the installation of thermal relief valves. These valves should be set to release thermal pressures before activation of the overpressure protection equipment.

Even if thermal relief valves are installed, operating procedures should be prepared to avoid thermal pressures where possible.

4. ENGINEERING REQUIREMENTS

4.1 LOCATION

The components for a pipeline overpressure protection system shall be installed between the source and the pipeline or included in the source facilities.

4.2 PRESSURE SAFETY RELIEF

4.2.1 Design requirements

Pressure safety reliefs shall comply with DEP 80.45.10.10-Gen. and the additional requirements of 4.2.2 and 4.2.3.

4.2.2 Number of relief valves

The PSV system may comprise one relief valve or, for higher capacities, multiple valves, always with the total relief capacity matching the maximum possible throughput from the source.

4.2.3 Set pressure requirements

The set pressures for the pressure controller, alarm and pressure safety relief valve(s) shall satisfy the following requirements.

Component	Requirements
pressure control	• set pressure shall not exceed MOP • the upper value of the pressure control range shall not exceed MAOP, and be below the reseat pressure of the PSV(s) • the margin between the set pressures of the controller and the PSV(s) shall be sufficient to avoid relief in case of incidental pressures during normal operations
pressure alarm	• set pressure shall not exceed 1.02 x MOP
pressure relief	• full flow relief shall be reached before the pressure exceeds MAIP

NOTE: Spring-loaded PSVs are typically specified to require 10% of their set pressure for accumulation and have a reseat pressure at 5-7% below the set pressure.

4.3 HIPS

4.3.1 General

HIPS requires design on a case-by-case basis and shall be applied only after a documented and independent reliability study incorporating failure mode and effect analysis has demonstrated that a target reliability of at least **ten times** greater than the equivalent relief system can be achieved. Failure of the relief valve to fully open at 110% of MAOP shall be the reference for determining the target reliability. Detailed engineering drawings, operating and maintenance procedures, test methods/frequencies, individual component reliability and target reliability criteria shall be provided as input to this study. Reliability data shall be

based on actual operating conditions where available.

Implementation of HIPS requires the creation of rigorous management procedures to control the testing, maintenance and the recording of results. In addition, records shall be kept for at least five years of all system failures and trips, whether spurious or not. This log shall be reviewed annually to confirm the validity of the criteria and data used to determine the system reliability.

NOTE: Local regulatory authorities may either prohibit HIPS systems or impose additional requirements and may have to approve the design before issuing a certificate of fitness.

4.3.2 System requirements

HIPS shall always be applied in combination with pressure alarm (3.1).

4.3.3 Component requirements

The detailed design of HIPS, with the necessary redundancy, shall be determined on a case-by-case basis from the independent reliability study (4.3.1). All HIPS instrumentation shall be functionally separate from the other instrumentation.

The following minimum requirements apply for the components, see also Figure 2:

- **manifold:**
  - shall be installed in the 12 o'clock position;
  - connections and fittings shall have a nominal diameter of at least 50 mm;
  - provisions for in-situ internal cleaning shall be provided;
  - insulation or heat tracing shall be provided where hydrate formation or wax deposition is possible;
  - provisions against unauthorised and unnoticed access shall be installed, e.g. combination of lock and seal.

  NOTE: A flange connection should be provided between the manifold(s) and the pipeline nozzle for easy replacement for maintenance.

- **pressure sensing:**
  - at least two pressure sensors (redundant or diverse) shall be installed;
  - it shall not be possible to isolate more than one pressure sensor from the pipeline;
  - isolation of a sensor shall result in a "trip signal".

- **voting system:**
  - shall be fail safe.

- **solenoid valve:**
  - cut in electrical power supply shall result in closure of shut-off valve.

- **shut-off valve:**
  - shall be fail-to-close;
  - shall pass tight shutoff requirements during strength and seal tests;
  - potential for seal damage from particles in the fluid shall be addressed;
  - shall be provided with facilities for in-situ testing of required initial torque without full valve closure;
  - shall not be located in piping which may be pigged;
  - shall have facilities for in-situ leak testing, e.g. a downstream valve with connection for pressure sensor in between the valves;
  - source facilities shall be able to pressure the upstream piping for valve reopening without unacceptable pressure differential over the valve;
  - may be used for other non-routine operational duties provided the reliability, tight seal performance and fail-to-close principle are not compromised.

4.3.4 Redundancy

A single HIPS shall be installed for application where the incidental source pressure is not

higher than 1.1 x MAIP.

An independent HIPS shall be required downstream and as backup of the primary HIPS, meeting the reliability criteria if the incidental pressure of the source exceeds 1.1 x MAIP.

4.3.5 Backup relief

Reduced capacity relief shall be installed for applications of HIPS where valve leakage can lead to pipeline pressure buildup in excess of MAIP. The need and required capacity shall be determined taking into account maximum anticipated leak rates, the accumulation capacity of the pipeline and the shutdown logic of the source facilities.

The relief shall be set to open at MAIP.

4.3.6 Set pressure requirements

The set pressure for the pressure controller alarm and HIPS shall satisfy the following requirements:

Components	Requirements
pressure control	• set pressure shall not exceed MOP • the upper value of the pressure control range shall not exceed MAOP • the margin between the set pressures of the controller and HIPS shall be sufficient to avoid HIPS activation in case of incidental pressures during normal operations
pressure alarm	• set pressure shall be as close as possible above the set pressure of the controller and not exceed 1.02 x MAOP
single HIPS	• full source isolation shall be achieved before the pressure exceeds MAIP
double HIPS	Primary HIPS • as for single HIPS Backup HIPS • full source isolation shall be achieved before the pressure exceeds 1.2 x MAOP

5. REQUIREMENTS FOR OPERATIONS

5.1 PRESSURE SAFETY RELIEF

An annual visual external inspection should be systematically carried out in situ to ensure that the relief valve has no obvious defects (e.g. seal is intact and the valve is not heavily corroded). A complete inspection and test should be carried out every two to four years, dependent on service history. These inspection periods may be the subject of local statutory regulations, which shall be followed.

The last test date and set pressure should be stamped on a firmly secured tag. Relief valve exchange for testing should be arranged to coincide with inspection of the protected equipment or other shutdown, to avoid installation of twin relief valves with upstream and downstream isolation.

Where exchange of a relief valve is possible, the valve orifice size shall also be stamped on the tag.

Records shall be kept for each relief valve, showing the inspection dates, lifting pressure as found, defects, remedial action taken and location installed.

5.2 HIPS

The frequency, scope, and procedures for the inspection and testing of HIPS need to be identified from the reliability analysis (4.3.1).

The minimum requirements shall always be:

- **partial functional check**

  Every six months a functional check shall be made of the pressure sensing and voting system, fail-safe function of valve and initial torque required for closure of shut-off valve.

- **complete functional check**

  Every 12 months a complete functional check shall be made, including a full closure of the shut-down valve and leak tightness test.

- **records**

  Reports of inspection, testing and maintenance shall be made and retained for at least five years. These records shall be evaluated at the time of the complete functional check and confirm the validity of the conclusions of the reliability analysis for the next year of operation.

- **inspection after activating**

  The shut-off valve may only be reopened by authorised personnel and after the cause of the overpressure has been identified and removed.

6. 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.
Pipeline engineering	DEP 31.40.00.10-Gen.
Pressure relief and flare system	DEP 80.45.10.10-Gen.

AMERICAN STANDARDS

Liquid transportation systems for hydrocarbons, liquid petroleum gas, anhydrous ammonia, and alcohols	ANSI/ASME B31.4
Gas transmission and distribution piping systems	ANSI/ASME B31.8

Issued by:
The American Society of Mechanical Engineers
345 East 47th Street
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USA.

FIGURES

FIGURE 1 EXAMPLE OF PRESSURE CONTROL AND RELIEF PROTECTION

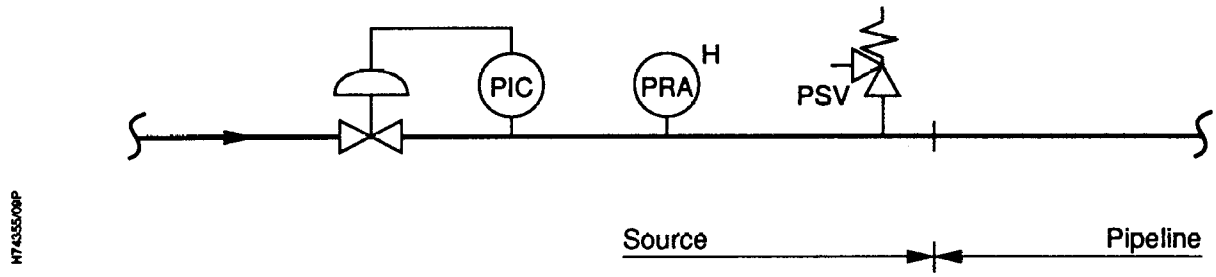

FIGURE 2 EXAMPLE OF PRESSURE CONTROL AND HIPS PROTECTION

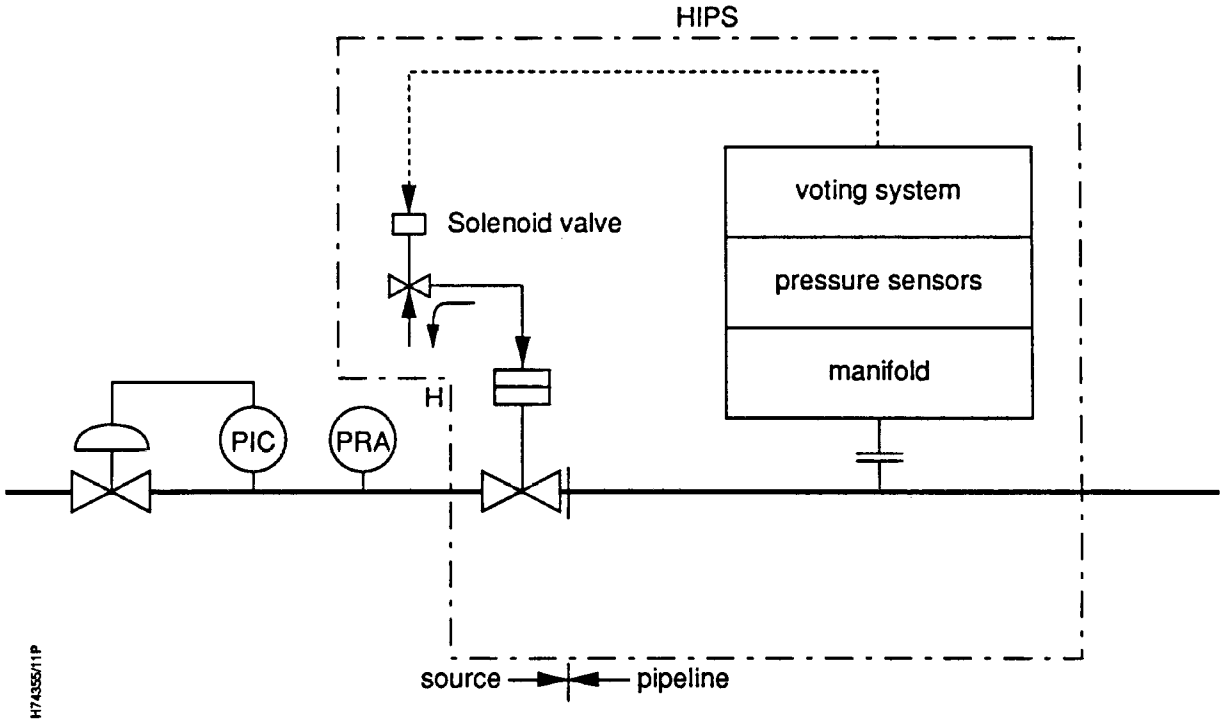

FIGURE 3 TYPICAL SET PRESSURES FOR PRESSURE SAFETY RELIEF (GAS LINE)

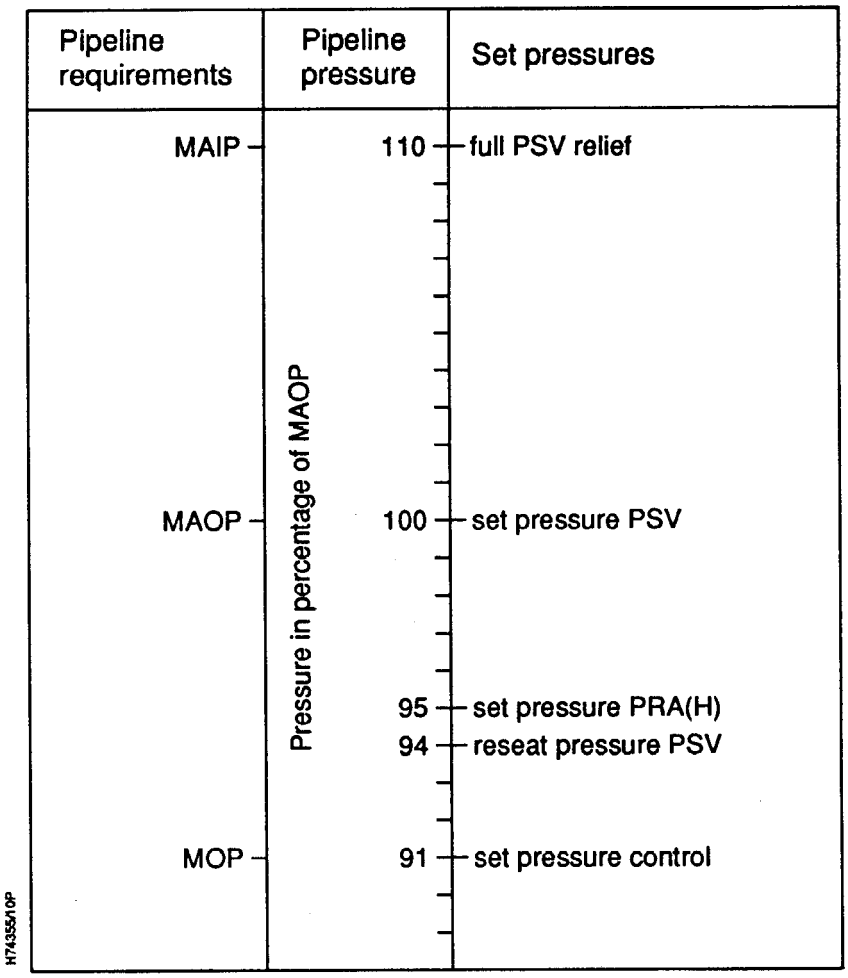

FIGURE 4 TYPICAL SET PRESSURES FOR HIPS (GAS LINE)

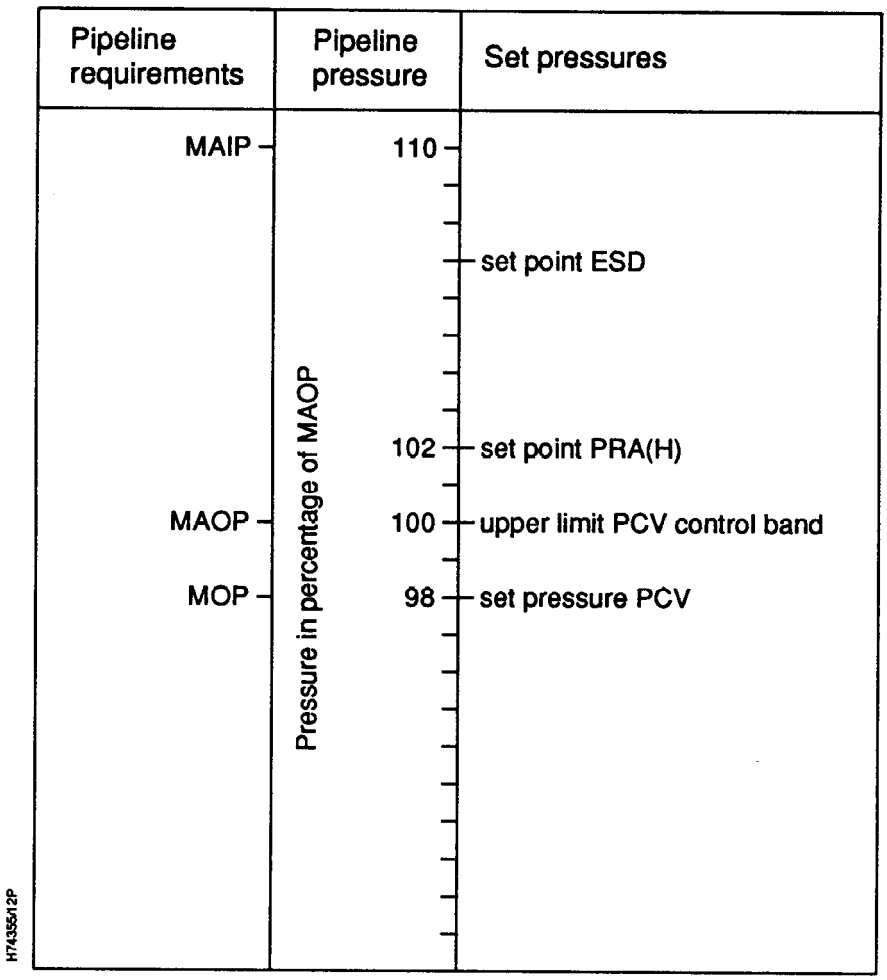

FIGURE 5 COMPARISON OF TYPICAL PIPELINE PRESSURE FOR RELIEF AND HIPS (GAS LINE)