شرکت ملی گاز ایران

مدیریت پژوهش وفناوری

امور تدوین استانداردها

تابستان ۱۳۸۴

MANUAL

STEAM INJECTION SYSTEMS FOR SAFEGUARDING THERMAL CRACKING UNITS

DEP 10.02.51.11-Gen.

December 1994

DESIGN AND ENGINEERING PRACTICE

USED BY

COMPANIES OF THE ROYAL DUTCH/SHELL GROUP

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TABLE OF CONTENTS

APPENDICES

1. INTRODUCTION

1.1 SCOPE

This DEP describes the minimum requirements for the design and engineering of the steam injection facilities in various thermal cracking units, for safeguarding their integrity and operation. The purpose of the system is to protect the furnace tubes from coking up during an emergency situation, e.g. in the event of unexpected feed failure. After initiation, the steam-out operation should therefore be fast, reliable and automated.

This DEP is a revision of the publication with the same number dated October 1984. This DEP explains the principles of the steam-out system but it does not cover furnace control systems except where certain control features are necessary for the operation of the steam-out system.

These facilities consist of:

- Automated steam-out facilities for the radiant section coils of both residue and distillate cracking furnaces.
- Barrier-steam injection into furnace outlet lines in units with a soaker, in order to minimize backflow of soaker contents into the furnace if a tube rupture takes place.
- Steam injection upstream and downstream of relief valves, in order to ensure that the relief valves are fully reliable.

This DEP shall be used for all new designs and applied to existing installations if modifications are required. Some design details may need modification to suit the requirements of individual installations.

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 described in DEP 00.00.05.05-Gen.). This DEP is intended for use in oil refineries.

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, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this document 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 document as closely as possible.

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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.

1.4 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced section number is shown in brackets. Other documents referenced by this DEP are listed in (5).

2. AUTOMATED STEAM-OUT SYSTEM

2.1 PRINCIPLE OF OPERATION

After manual initiation, a number of switches and control valves are activated in a controlled sequence by an electrical/pneumatic automatic system as follows:

- The furnace feed pump is automatically tripped and the feed control valves are closed. The low-flow trip device then cuts out fuel supply to the burners.
- A back-pressure control valve, if present in the furnace or soaker outlet, is opened.
- After a delay to allow the above actions to be taken, a double block and bleed control valve set is operated to admit dry, medium-pressure steam to the inlet of each coil.

The steam valve opening is preset but can be monitored and, if necessary, adjusted from the control room. This steam flushes the tube contents into a vessel (the cyclone, soaker or column) downstream of the furnace. The furnace effluent can be pumped out of the thermal cracker by the bottoms pump of the cyclone or column through the residue rundown system.

If a soaker is installed downstream of a residue cracking furnace, its contents can be pumped out from the soaker bottom to the column bottoms pump via a separate pump-out line.

Provisions are made to operate the system even in the event of failure of mains electricity or instrument air, albeit with some manual intervention. Most of the equipment of the system will be used during routine shutdowns and steam-air decoking.

In case of loss of feed flow, if the feed pump can be restarted within about 5-10 minutes (for a coil cracker) or 10-20 minutes (for a soaker cracker) there is no need to use the system at all. If the pump remains out of action for longer periods, the steam-out system shall be initiated.

The same basic type of system may be used for all types of thermal cracking furnaces.

2.2 GENERAL FEATURES

For letters/numbers used in the text, see Appendices 1 and 2.

2.2.1 Steam supply

Steam for injection shall be taken from the normal refinery medium-pressure main, usually at about 18 bar (ga). Alternatively, high-pressure steam may be used instead. The steam supply pressure is independent of the inlet pressure of the furnace. To avoid surges in downstream equipment, it is most important that this steam is dry upon injection .

To remove condensate, the following measures shall be taken:

- A knock-out vessel shall be installed as close as possible to the injection point(s), having a condensate steam trap with bypass and a high-level alarm. A permanent water level is to be avoided and therefore an automatic level control is not required.
- For thermal crackers with more than one cracking furnace, one common knock-out vessel will be used for the steam supply to the furnace coils. However, each furnace shall have its own block valve and bleeder in the steam supply lines to different furnaces, because in certain circumstances leaking valves could let furnace feed into the steam system.
- The steam line between the knock-out vessel and the first control valve (A in Appendix 1) shall be as short as possible and slope towards the knock-out vessel.

2.2.2 Block and control valves for steam injection

In the automated steam supply to each furnace coil valves shall be lined up as a double block and bleeder system.

A + B and A + C are the double block valves, and D is a common bleeder to the flash zone of the distillation column. Tie-in shall be below the gas oil draw-off, but above the flash zone to prevent coking of "stagnant" nozzles.

These valves shall be of the tight shut-off type of the cheapest class. They shall be so located that the lines between A and the furnace inlets are as short as possible.

There shall be no pocket between valve B or C and the corresponding furnace inlet. The pipe connections of valve A with valves B, C and D shall have one common lowest point. This point shall be at or as close as possible to the branch to valve D. At this lowest point a drain valve shall be installed and opened at least once per day to check whether or not the non-return valves or control valves are passing.

Occasionally, on opening the drain valve some vapours or condensate may be vented. If a control valve or non-return valve is passing, this will be readily apparent from the composition of material draining from the valve.

The non-return valve at column inlet should prevent hot column vapours being vented via the bleed line.

All the lines between valve A and the furnace inlets and the bleeder inlet to the distillation column shall be steam-traced.

Bleed valve D shall be fitted with a restriction orifice to limit flow to approximately 25% of the total design steam flow through A. This will prevent all the steam passing through the bleeder should it have failed to close.

Locked-open isolating valves shall be installed, downstream of the non-return valves in the steam lines close to the injection point to the furnace feed, in the supply lines from the steam knock-out drum and in the bleed line. These will enable the non-return valves and the double block and bleeder control valves to be serviced.

The spring actions for the valves are shown in Appendix 1. Instrument air shall be supplied to each valve via solenoid-operated valves UZ-101 to UZ-104 for valves A to D respectively. The solenoid valves shall have electric manual resets and be electrically energized when plant operation is normal. Valves A to D will then be held in position as follows:

Valve A	-	Vented	by UZ-101	-	Normally closed
Valve B	-	Instr. air admitted	by UZ-102	-	Normally closed
Value C	-	Instr. air admitted	by UZ-103	-	Normally closed
Value D	-	Instr. air admitted	by UZ-104	-	Normally open

The operation of these solenoids is described in (2.3.2).

The purpose of HIC-001 and HIC-002 is to give a preset restriction to the opening of valves B and C. This will prevent an excessive steam flow to the furnace tubes when the system is in use, and ensure that the refinery steam demand does not increase to a level where the operation of other units is endangered.

The injection point shall be positioned immediately downstream of the furnace feed flow control valves so that the convection bank, if present, will also be protected, although the prime aim is protection of the more vulnerable radiant tubes.

2.2.3 Furnace feed control valves

The furnace feed control valves are marked by E and F. These valves are normally set by FRCs acting through solenoid valves UZ-105 and UZ-106. The solenoid valves are similar to UZ-101 to UZ-104, i.e. normally energized and with electric manual resets. The usual furnace fuel trips at low-low feed flow (FZA) are provided.

On reaching the low-low flow setting, these FZAs act on the fuel shut-off valves in the fuel supply lines to the furnace.

It is possible to override the furnace feed low-low flow signal to the fuel shut-off valves using panel-mounted decoking override switch HS-004, which is part of the fuel control system. This switch shall be used only during non-standard operating conditions, such as start-up and decoking operations.

2.3 RESIDUE CRACKING FURNACE WITHOUT BACK-PRESSURE CONTROL VALVE

2.3.1 General

Appendix 1 is a diagram of the system required for a residue cracking furnace having 2 coils. For coil arrangements with more than 2 coils similar equipment shall be installed, so that each coil will be equipped with an individual steam-out line.

2.3.2 Sequence of operation

When the steam-out system is initiated by HZA-001, the sequence of events will be fully automatic:

Immediately:

- The feed will be tripped (UZ-107).
- The condensate injection pump, if present, will be tripped (UZ-108).
- Solenoids UZ-104, UZ-105 and UZ-106 will be de-energized.
- De-energizing UZ-104 will vent bleed valve D, which will close.
- De-energizing UZ-105 and UZ-106 will switch full instrument air to furnace feed control valves E and F, thus closing them.
- Closing E and F will cut off the feed to the furnace, and the low-low flow FZAs will trip the furnace fuel supply shut-off valves.

As a consequence, the furnace inlet pressure as indicated by PRA-001 and PRA-002 will drop.

After 10 seconds:

- Solenoids UZ-101, UZ-102 and UZ-103 will be de-energized
- De-energizing UZ-101 will switch instrument air to steam valve A, opening it.
- De-energizing UZ-102 and UZ-103 will switch the air supply to steam valve B and C, from full instrument air supply pressure to a lower pressure supply from control stations HIC-001 and HIC-002, causing valves B and C to open partly.

The 10 seconds delay between the two steps of the valve-switching sequence is provided to ensure that the furnace feed valves and the steam bleed valve will be shut before the steam valves start to open.

The degree of opening of B and C is pre-set by HIC-001 and HIC-002, as indicated by their output indicators.

The preset values of HIC-001 and HIC-002 shall be determined during tests during commissioning of the furnace. HIC-001 and HIC-002 should set valves B and C such that about 1000 kg/h of steam flows into each coil during conditions where the coils are empty.

Steam will then be admitted into the furnace coils initially at a rate governed by the liquid discharge rate from the coils (1-5 min) and subsequently by the degree of opening of B and C as indicated on the panel by FR-003 and FR-004. If necessary, the flow rates can be adjusted by means of HIC-001 and HIC-002 to ensure adequate protection of the tubes.

The unit line-up assumes that the bypass block valves of the feed control valves FRC-001 and FRC-002 will normally be closed.

A condensate injection pump to supply condensate into the furnace coils may be present for process reasons. If a condensate pump is not present but HP process steam is injected via an FRC, this steam flow can remain in use.

The steam flow should be maintained for about 5 minutes to completely flush out the furnace tubes. The steam flow may be reduced to conserve steam, but should be continued for about 30 minutes to let the tubes cool down gradually.

2.4 RESIDUE OR DISTILLATE CRACKING FURNACE WITH BACK-PRESSURE CONTROL VALVE OR RESIDUE CRACKING FURNACE WITH SOAKER AND BACK-PRESSURE CONTROL VALVE

2.4.1 General

The arrangements for this type of line-up are shown in Appendix 2 and are basically the same as those for a residue cracking furnace without a back-pressure control valve.

The only difference is that the back-pressure control valve shall be fully opened to lower the furnace inlet pressure before steam can be admitted into a furnace coil.

Hence, compared with a residue furnace system without a back-pressure control valve, an additional solenoid is installed in the air supply to the back-pressure control valve.

Valves in Appendix 2 are designated similar to Appendix 1.

2.4.2 Sequence of operation

When the steam-out system is initiated, the sequence is the same as for residue furnaces without back-pressure control valves.

Panel-mounted switch HZA-001 is manually operated, and the following automatic actions will take place:

Immediately:

- The feed pump will be tripped (UZ-107).
- The condensate injection pump will be tripped (UZ-108).
- Solenoids UZ-104, UZ-105, UZ-106 and UZ-110 will be de-energized.
- De-energizing UZ-104 will vent bleed valve D, which will close.
- De-energizing UZ-105 and UZ-106 will switch full instrument air to furnace feed control valves E and F, thus closing them.
- Closing E and F will cut off the feed to the furnace, and the low-flow FZAs will trip the furnace fuel supply cut-off valves.

- De-energizing UZ-110 will vent furnace or soaker back-pressure control valve K, opening it fully.

As a consequence, the furnace inlet pressure as indicated by PRA-001 and PRA-002 will drop.

After 10 seconds:

- Solenoids UZ-101, UZ-102 and UZ-103 will be de-energized.
- De-energizing UZ-101 will switch instrument air to steam valve A, opening it.
- De-energizing UZ-102 and UZ-103 switches the air supply to steam valves B and C from full instrument air supply pressure to a lower pressure supply from control stations HIC-001 and HIC-002, causing valves B and C to open partly.

The steam-out operation is as described in (2.3.2).

2.5 UTILITY FAILURES

The furnace coil steam-out system is designed to remain operable in the event of either electricity or instrument air failures. The following description is for a residue furnace without back-pressure control valve (see Appendix 1), but it also applies to any cracking furnace system with a back-pressure control valve.

2.5.1 Instrument air failure

The spring actions of valves B, C and D are such that when local or total air failure occurs, the valves affected move to their fail-safe positions, D closes, B and C will open fully since the pre-setting devices, which limit the steam flow, depend on instrument air. However, the first steam valve A will remain shut, preventing steam from entering the system. The furnace feed control valves E and F open fully, so the feed pump will continue to supply feed to the furnace.

If desired, it is possible to steam-out the coils in these circumstances. Switch HZA-001 will trip the feed pump and condensate pump (if the furnaces are still being fired, the loss of feed will shut the fuel supply) and de-energize the solenoids, but the steam will not flow because valve A remains shut.

When the pump has stopped, steam can be admitted and controlled by opening valve A using its handwheel. The steam flow is controlled by the degree of opening of this valve.

Valves E and F will still be open, and the non-return valve downstream of the feed pump is relied upon to prevent steam backing up the feed line through the pump. Hence, the block valve on the pump discharge should be closed at the first opportunity.

2.5.2 Electricity failure

The system is based on the use of an uninterrupted instrument electricity supply. However, the possibility of instrument electricity failure has been allowed for in the design of the steam-out system, without increasing its complexity.

The solenoid-operated valves UZ-101 to UZ-106 are normally energized and, upon instrument electricity failure, will take up their de-energized positions. Furthermore, the feed pump will be tripped by the absence of instrument electricity supply to a relay in the mains supply to the pump. The same holds for the condensate injection pump. The system then comes into operation automatically. Controllers HIC-001 and HIC-002 can be used to control the steam flow.

Interruptions of the main electricity supply will not affect the steam-out system, only the feed pump and the condensate injection pump.

The furnace feed FZAs will therefore trip the furnace fuel shut-off valves.

In case of loss of feed flow, if the feed pump can be restarted within about 5-10 minutes (for a coil cracker) or 10-20 minutes (for a soaker cracker) there is no need to use the system at all. If the pump remains out of action for longer periods, the steam-out system shall be initiated.

2.6 INSTRUMENTATION

The instruments for the steam-out system shall be grouped together with the relevant furnace instrumentation.

The logic diagrams are shown in Standard Drawings S 31.008 and S 31.009.

2.7 RESET OF SYSTEM AFTER USE

After activation of the steam-out system, the solenoids will remain de-energized until the electric circuit is reset manually, also from the panel room. This resetting system is divided into two groups, one for the steam supply valve solenoids (HS-003), and the other for the furnace feed and back-pressure control valves (HS-002). First reset the steam supply solenoid and then the furnace feed and back-pressure control valves.

If, in case of instrument air failure, the steam valve A has been forced (partly) open, its handwheel should be used to ensure that, upon resetting, this valve is indeed returned to its original position: closed by the spring action of valve A, and decoupled from its handwheel.

2.8 USE OF FACILITIES FOR STEAM-AIR DECOKING

For steam-air decoking, the same steam lines are used as for steam-out of the furnace coils.

During steam-air decoking, the steam-out system is put in the de-energized (i.e. steaming-out) position. This is a good opportunity to test the equipment and set the position of HIC-001 and HIC-002; steam flows are regulated by means of the control valves B and C.

Provision is made to allow for local as well as control room indication of decoking air flow to each coil.

The furnace fuel control system includes an operational override switch for the low-low feed flow to the furnace, to prevent the fuel being cut out by the FZAs during decoking.

3. BARRIER-STEAM INJECTION INTO RESIDUE FURNACE TRANSFER LINE OF SOAKER-TYPE THERMAL CRACKING UNITS

3.1 PRINCIPLE OF OPERATION

For residue cracking furnaces equipped with a soaker vessel, the eventuality, however remote, of a furnace tube rupture and consequent backflow of the soaker contents through the rupture has to be taken into account. Such an event is to be countered primarily by depressurizing the soaker as quickly as possible and by pump-out of the soaker contents, but the latter cannot be done immediately.

To provide for additional safety, a barrier-steam injection system is installed in the transfer line from furnace to soaker. The purpose of this injection system is to create sufficient pressure build-up by steam to prevent backflow of the soaker contents as much as possible. The system is in permanent use through a small flow via a restriction orifice, whilst a control valve can immediately admit more steam once a tube rupture has been detected.

Furthermore, in order to prevent siphoning back of hydrocarbons into the furnace, the highest part of the transfer line should be at least 1 metre above the mid-height of the soaking vessel.

3.2 FEATURES OF THE BARRIER-STEAM INJECTION SYSTEM (see Appendix 3)

The injection system should be located on the common furnace transfer line as close to the furnace as possible. The MP-steam supply system consists of a control valve, which can be controlled from the panel. The control valve is equipped with a bypass in which are installed a panel-mounted low-flow indicator/alarm and a restriction orifice of 3 mm minimum diameter, preferably in a vertical line with the flow upwards. The continuous steam purge flow shall be such that the purge velocity in the injection point is at least 0.3 m/s. In practice, the minimum steam flow will be approximately 700 to 1000 kg/day for a DN 80 injection line.

The steam connection to the transfer line is equipped with a non-return valve and an isolation valve. The injection point should be located on the top part of the transfer line.

It is essential that a permanent steam purge is maintained via the bypass, since otherwise coke build-up may occur in the injection line near the injection point. The MP steam supply line should come from the emergency steam knock-out vessel.

When a tube rupture occurs, the system will be used as follows; in addition to the actions for a normal tube leak (which is not covered by this DEP):

- depressurize the soaker completely by opening the back-pressure control valve, and depressurize downstream cyclone or fractionator;
- fully open the barrier-steam control valve.

Steam flow with full opening of the control valve shall be approximately 120 tonnes/day. This flow is based on a 4-inch OD schedule 80 furnace tube; for other tube diameters the maximum steam flow should be adjusted in accordance with the cross-sectional area of the ID of the tube.

4. STEAM INJECTION INTO RELIEF VALVE INLET/OUTLET CONNECTIONS

4.1 PRINCIPLE OF OPERATION

In thermal cracking units, there are a number of locations where relief valves are installed on process lines containing hot (above 350 °C) cracked residual liquid and/or cracked vapours where plugging by coke can take place. Such locations are:

- back-pressure control valve of residue cracking furnace;
- back-pressure control valve of soaking vessel;
- back-pressure control valve of distillate cracking furnace;
- isolation valves of residue cracking furnaces (multi-string units).

Relief valves shall be fully reliable at all times. In the above-mentioned locations, coke build-up may occur in the dead-end connections of the relief valve which is installed across the control/isolation valve. To prevent such coke build-up, a steam purge system shall be installed on these dead-end connections, which shall be in continuous use.

4.2 FEATURES OF THE PURGE-STEAM SYSTEM (see Appendix 3)

The injection system on each relief valve connection consists of:

- an injection point as close to the relief valve as possible;
- an isolation valve and a non-return valve;
- a restriction orifice (of 3 mm minimum diameter) preferably installed in a vertical line with the flow upwards;
- a panel-mounted low-flow indicator/alarm.

The steam line has a dedicated supply header, which may be the same as for the barrier-steam injection.

The continuous steam purge shall be such that the purge velocity in the relief valve connections is at least 0.3 m/s. In practice the minimum steam flow will be approximately 1.5 to 2.0 tonnes/day for DN 150 inlet connections and 1.0 to 1.5 tonnes/day for DN 200 outlet connections.

5. 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.

STANDARD DRAWINGS

Automatic steam injection system of distillate (thermal) cracking furnaces	S 31.008
Automatic steam injection system of residue cracking (visbreaker) furnaces	S 31.009

APPENDIX 1 AUTOMATED STEAM INJECTION SYSTEM - RESIDUE CRACKING FURNACE COILS WITHOUT BACK-PRESSURE CONTROL VALVE

APPENDIX 2 AUTOMATED STEAM INJECTION SYSTEM - RESIDUE OR DISTILLATE CRACKING FURNACE COILS WITH BACK-PRESSURE CONTROL VALVE IN FURNACE OR SOAKER OUTLET LINE

APPENDIX 3 BARRIER-STEAM INJECTION IN TRANSFER LINE OF RESIDUE CRACKING FURNACES FOLLOWED BY SOAKERS, AND PURGE STEAM INJECTION INTO RELIEF VALVE CONNECTIONS