DET NORSKE VERITAS

TECHNICAL REPORT

# DNV-OS-F101:2013 SPREADSHEET VERIFICATION REPORT

REPORT NO.: 2012-1247
REV 01 , 2013-01-10

**MANAGING RISK**

# DNV-OS-F101:2013 Spreadsheet Verification Report

For:

Account Ref.:

Det Norske Veritas AS
P.O.Box 300
1322 Høvik, Norway
Tel: +47 67 57 99 00
Fax: +47 67 57 99 11
http://www.dnv.com

| | | | |
|---|---|---|---|
| Date of Current Issue: | 01.10.2013 | Project No.: | 31500013 |
| Revision No.: | 02 | Organisation Unit: | BDL Pipeline Systems |
| | | Report No.: | 2012-1247 |

Summary:

This report presents verification for the excel spreadsheet DNV-OS-F101-V3.2 which performs wall thickness calculations according to DNV Offshore Standard for Submarine Pipeline Systems DNV-OS-F101:2013.

| | | |
|---|---|---|
| Prepared by: | *Name and Position*<br>Erica Marley<br>Engineer | *Signature* |
| Verified by: | *Name and Position*<br>Olav Aamlid<br>Principal Specialist | *Signature* |
| Approved by: | *Name and Position*<br>Kåre Gulliksen<br>BDL Pipelines | *Signature* |

- ☐ Unrestricted distribution (internal and external)
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Keywords

| Rev. No. | Date | Reason for Issue | Prepared by | Verified by | Approved by |
|---|---|---|---|---|---|
| 01 | 11.09.12 | For use | OAAM | EISTI | KGULL |
| 02 | 01.10.2013 | For use | ERICA | OAAM | KGULL |

Reference to part of this report which may lead to misinterpretation is not permissible.

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# 1 INTRODUCTION

This report presents verification for the excel spread sheet DNV-OS-F101:2013 that performs wall thickness calculations for submarine pipelines according to DNV-OS-F101 version 2013.

# 2 MAIN SHEET

Figure 2-1 shows the main sheet in the spread sheet giving all input parameters and key results that are *minimum required nominal wall thickness* $t_{req}$ and *utilisation* with the specified wall thickness $t_{nom}$ for the eight defined limit states:

**HEADING** Sheet5

Open case | Save case | DNV-OS-F101:2013 V3.2-01 01.10.2013

**DIMENSIONS**

| OD | [mm]: 600.00 | $t_{nom}$ [mm]: 20.00 | $t_{fab}$: [%] 2.00 | $t_{corr}$ [mm]: 2.00 | $f_0$ [%]: 1.00 | $\alpha_{gw}$ [-]: 0.90 |
|---|---|---|---|---|---|---|

**MATERIAL**

| SMYS [MPa]: 450.0 | DNV 450 | $f_{y,temp}$ [MPa]: 50.0 | $E$ [MPa]: 2.10E+05 | $\alpha_h$ [-]: 0.93 | $\alpha_{fab}$ [-]: 0.85 |
|---|---|---|---|---|---|
| SMTS [MPa]: 535.0 | | $f_{u,temp}$ [MPa]: 50.0 | $\nu$ [-]: 0.3 | | Suppl. Req. U: ☑ |

**LOADS**

| $p_{design}$ [barg]: 200.0 | @ [m]: 40.0 | $\rho_{design}$ [kg/m³]: 200.0 | $\gamma_{inc}$ [-]: 1.10 | Depth [m]: 800.0 | Max. elevation: 0.0 |
|---|---|---|---|---|---|
| $p_{test}$ [barg]: 231.0 | @ [m]: 40.0 | $\rho_{test}$ [kg/m³]: 1025.0 | | $\rho_{ext}$ [kg/m³]: 1025.0 | Min. elevation: 0.0 |
| $p_{min}$ [barg]: 0.0 | @ [m]: 0.0 | $\rho_{min}$ [kg/m³]: 0.0 | | | |

**WALL THICKNESS DESIGN** Calculate ☑ Burst ☑ Collapse & Propagating Buckling

$p_{lt}$ [barg]: 231.0
$p_k$ [barg]: 291.8

| | Safety Class | Corr.: | Der.: | $P_{min}$: | Code Check | $t_{req}$ [mm]: | utility [-] |
|---|---|---|---|---|---|---|---|
| Burst, op.: | MEDIUM | ☑ | ☑ | | | 15.29 | 0.732 |
| Burst, sys. test: | SYSTEM TEST | ☐ | ☐ | | | 16.22 | 0.806 |
| Collapse: | MEDIUM | ☐ | ☐ | ☐ | | 18.62 | 0.830 |
| Prop. Buckling: | MEDIUM | ☐ | ☐ | | | 34.41 | 3.883 |

**LOAD INTERACTION** Calculate ☑ Load Controlled ☑ Displacement Controlled

$\gamma_c$ [-]: 1.07

| | Funct. | Envir. | Condition | Safety Class | Corr.: | Der.: | $P_{min}$: | Code Check | $t_{req}$ [mm]: | utility [-] |
|---|---|---|---|---|---|---|---|---|---|---|
| Moment [kNm] | 1.00E+03 | 3.00E+02 | OPERATION | MEDIUM | ☑ | ☑ | ☐ | LCC, comb. a: | 18.03 | 0.760 |
| Axial force [kN] | 1.40E+03 | 4.00E+02 | | | | | | LCC, comb. b: | 18.59 | 0.826 |
| Strain [%] | 3.00E+00 | 1.00E+00 | | | | | ☐ | DCC, comb. a: | 54.15 | 1.945 |
| | | | | | | | | DCC, comb. b: | 59.40 | 2.064 |

**END OF PAGE**

**Figure 2-1 Main sheet with all input and key results**

# 3 REPORT SHEETS

Figure 3-1, Figure 3-2, Figure 3-3 and Figure 3-4 gives, for the limit states, relevant input parameters, some intermediate results and key results for the case presented in Chapter 2.

| OS-F101 - SUBMARINE PIPELINE SYSTEMS - 2013 | | DNV-OS-F101:2013 | |
|---|---|---|---|
| Pressure Containment (bursting) | | V3.2-01 | |
| Developed by DNV TNTNO714 | | 01.10.2013 | |
| Prepared: Date: Sign: | | Verified: Date: Sign: | |
| **RELEVANT INPUT PARAMETERS:** | | **Operation** | **System test** |
| Nominal outer steel diameter: | OD | 600.00 mm | |
| Nominal steel wall thickness: | $t_{nom}$ | 20.00 mm | |
| Fabrication tolerance: | $t_{fab}$ | 2.00 % | |
| Corrosion allowance: | $t_{corr}$ | 2.00 mm | |
| Specified minimum yield stress: | SMYS | 450.0 MPa | |
| Specified minimum tensile strength: | SMTS | 535.0 MPa | |
| Derating in yield stress due to temperature: | $f_{y,temp}$ | 50.0 MPa | |
| Derating tensile strength due to temperature: | $f_{u,temp}$ | 50.0 MPa | |
| Material strength factor: | $\alpha_U$ | 1.00 | 1.00 |
| Internal pressure at reference level: | $p_{int,ref}$ | 200.0 barg | 231.0 barg |
| Reference level for internal pressure: | $z_{ref}$ | 40.0 m | 40.0 m |
| Density of internal fluid: | $\rho_{int}$ | 200.0 kg/m3 | 1025.0 kg/m3 |
| Incidental to design pressure ratio: | $\gamma_{inc}$ | 1.10 | 1.00 |
| Depth: | d | 800.0 m | 800.0 m |
| Density of external fluid: | $\rho_{ext}$ | 1025.0 kg/m3 | 1025.0 kg/m3 |
| Safety Class: | | MEDIUM | SYSTEM TEST |
| Corroded wall thickness: | | YES | NO |
| Derated material properties: | | YES | NO |
| **INTERMEDIATE RESULTS:** | | **Operation** | **System test** |
| Characteristic yield stress: | $f_y$ | 400.00 MPa | 450.00 MPa |
| Characteristic ultimate strength: | $f_u$ | 485.00 MPa | 535.00 MPa |
| Steel wall thickness used in code check: | $t_1/t_2$ | 17.60 mm | 19.60 mm |
| Pressure containment resistance, yielding limit state: | $p_{b,s}$ | 279.16 barg | 350.95 barg |
| Pressure containment resistance, bursting limit state: | $p_{b,u}$ | 294.33 barg | 362.81 barg |
| Pressure containment resistance, minimum of $p_{b,s}$ & $p_{b,u}$: | $p_b$ | 279.16 barg | 350.95 barg |
| Material resistance factor: | $\gamma_m$ | 1.15 | 1.15 |
| Safety class resistance factor: | $\gamma_{SC}$ | 1.138 | 1.046 |
| Local design pressure: | $p_{ld}$ | 216.48 barg | 315.46 barg |
| Local incidental/test pressure: | $p_{lx}$ | 236.48 barg | 315.46 barg |
| External pressure: | $p_e$ | 80.44 barg | 80.44 barg |
| Pressure difference: | $p_{lx} - p_e$ | 156.04 barg | 235.02 barg |
| **PRESSURE CONTAINMENT, BURSTING:** | | **Operation** | **System test** |
| Code check, utility: | | **0.73 OK** | **0.81 OK** |
| Minimum required nominal wall thickness: | | 15.29 mm | 16.22 mm |

**Figure 3-1 Report sheet for pressure containment**

| OS-F101 - SUBMARINE PIPELINE SYSTEMS - 2013<br>System Collapse and Propagating Buckling<br>Developed by DNV TNTNO714 | DNV-OS-F101:2013<br>V3.2-01<br>01.10.2013 |
|---|---|

| Prepared: Date: Sign: | Verified: Date: Sign: |
|---|---|

| RELEVANT INPUT PARAMETERS: | | Collapse | Prop. Buckling |
|---|---|---|---|
| Nominal outer steel diameter: | OD | 600.00 mm | |
| Nominal steel wall thickness: | $t_{nom}$ | 20.00 mm | |
| Fabrication tolerance: | $t_{fab}$ | 2.00 | |
| Corrosion allowance: | $t_{corr}$ | 2.00 mm | |
| Out-of-roundness: | $f_0$ | 1.00 % | |
| Young's modulus: | E | 2.100E+05 MPa | |
| Poisson's ratio: | ν | 0.30 | |
| Specified minimum yield stress: | SMYS | 450.0 MPa | |
| Derating in yield stress due to temperature: | $f_{y,temp}$ | 50.0 MPa | |
| Fabrication factor: | $\alpha_{fab}$ | 0.85 | |
| Material strength factor: | $\alpha_U$ | 1.00 | |
| Depth: | d | 800.0 m | |
| Density of external fluid: | $\rho_{ext}$ | 1025.0 MEDIUM | |
| Safety Class: | | MEDIUM | NO |
| Corroded wall thickness: | | NO | NO |
| Derated material properties: | | NO | NO |
| **INTERMEDIATE RESULTS:** | | **450** | **450** |
| Characteristic yield stress: | $f_y$ | 19.6 MPa | 20.0 MPa |
| Steel wall thickness used in code check: | $t_1/t_2$ | 160.89 mm | NA mm |
| Elastic collapse pressure: | $p_{el}$ | 249.9 barg | NA |
| Plastic collapse pressure: | $p_p$ | 127.1 barg | NA |
| Characteristic collapse pressure: | $p_c$ | 1.2 barg | 1.2 |
| Material resistance factor: | $\gamma_m$ | 1.14 | 1.14 |
| Safety class resistance factor: | $\gamma_{SC}$ | 80.44 | 80.44 |
| External pressure: | $p_e$ | 0.0 barg | 80.4 barg |
| Minimum sustainable pressure: | $p_{min}$ | 0.0 barg | - |
| **SYSTEM COLLAPSE AND PROPAGATING BUCKLING:** | | **0.829747536** | **3.88** |
| Code checks, utility: | | **18.62 OK** | **34.41 NOT OK** |
| Minimum wall thickness: | | 18.62 mm | 34.41 mm |

**Figure 3-2 Report sheet for collapse and propagating buckling**

| OS-F101 - SUBMARINE PIPELINE SYSTEMS - 2013<br>Load Interaction - Load Controlled<br>Developed by DNV TNTNO714 | DNV-OS-F101:2013<br>V3.2-01<br>01.10.2013 |
|---|---|

| Prepared: Date: Sign: | Verified: Date: Sign: |
|---|---|

| RELEVANT INPUT PARAMETERS: | | | |
|---|---|---|---|
| Nominal outer steel diameter: | OD | 600.00 | mm |
| Nominal steel wall thickness: | $t_{nom}$ | 20.00 | mm |
| Corrosion allowance: | $t_{corr}$ | 2.00 | mm |
| Out-of-roundness: | $f_0$ | 1.00 | % |
| Specified minimum yield stress: | SMYS | 450.0 | MPa |
| Specified minimum tensile strength: | SMTS | 535.0 | MPa |
| Derating in yield stress due to temperature: | $f_{y,temp}$ | 50.0 | MPa |
| Derating tensile strength due to temperature: | $f_{u,temp}$ | 50.0 | MPa |
| Young's modulus: | E | 2.100E+05 | MPa |
| Poisson's ratio: | $\nu$ | 0.30 | |
| Material strength factor: | $\alpha_U$ | 1.00 | |
| Internal pressure at reference level: | $p_{int,ref}$ | 200.00 | barg |
| Reference level for internal pressure: | $z_{ref}$ | 40.0 | m |
| Density of internal fluid: | $\rho_{int}$ | 200.0 | kg/m3 |
| Depth: | d | 800.0 | m |
| Density of external fluid: | $\rho_{ext}$ | 1025 | kg/m3 |
| Load condition factor: | $\gamma_C$ | 1.070 | |
| Functional bending moment: | $M_F$ | 1000.00 | kNm |
| Environmental bending moment: | $M_E$ | 300.0 | kNm |
| Functional effective axial force: | $S_F$ | 1400.0 | kN |
| Environmental effective axial force: | $S_E$ | 400.0 | kN |
| Safety Class: | | MEDIUM | |
| Corroded wall thickness: | | YES | |
| Derated material properties: | | YES | |

| INTERMEDIATE RESULTS: | | Load comb. a | | Load comb. b | |
|---|---|---|---|---|---|
| Local internal pressure: | $p_i=p_{id}/p_{it}$ | 236.5 | barg | | |
| Local external pressure: | $p_e$ | 80.4 | barg | | |
| Local minimum sustainable pressure: | $p_{min}$ | - | barg | | |
| | | internal overpressure | | | |
| Characteristic yield stress: | $f_y$ | 400.0 | MPa | | |
| Characteristic ultimate strength, circumferential: | $f_u$ | 485.0 | MPa | | |
| Characteristic ultimate strength, longitudinal: | $f_u$ | 485.0 | MPa | | |
| Steel wall thickness used in code check: | $t_2$ | 18.00 | mm | | |
| Design bending moment: | $M_d$ | 1494.0 | kNm | 1567.0 | kNm |
| Design effective axial force: | $S_d$ | 2077.6 | kN | 2167.8 | kN |
| Local net pressure: | $p_i - p_e$ | 156.0 | barg | 156.0 | barg |
| Plastic moment resistance: | $M_p$ | 2438.8 | kNm | | |
| Characteristic plastic axial force resistance: | $S_p$ | 13164.5 | kN | | |
| Pressure containment resistance, yielding limit state: | $p_{b,s}$ | 285.7 | barg | | |
| Pressure containment resistance, bursting limit state: | $p_{b,u}$ | 301.2 | barg | | |
| Pressure containment resistance, minimum of $p_{b,s}$ & $p_{b,u}$: | $p_b$ | 285.7 | barg | | |
| Hoop stress utilisation: | $q_h$ | 0.631 | | | |
| | $\beta$ | 0.296 | | | |
| Flow stress parameter: | $\alpha_c$ | 1.063 | | | |
| Pressure factor: | $\alpha_p$ | 0.704 | | | |
| Material resistance factor: | $\gamma_m$ | 1.15 | | | |
| Safety class resistance factor: | $\gamma_{SC}$ | 1.14 | | | |

| LOAD INTERACTION - LOAD CONTROLLED | Load comb. a | | Load comb. b | |
|---|---|---|---|---|
| Code check: | 0.76 | OK | 0.83 | OK |
| Minimum wall thickness: | 18.03 | mm | 18.59 | mm |

**Figure 3-3 Report sheet for load controlled load combination**

| OS-F101 - SUBMARINE PIPELINE SYSTEMS - 2013 | | DNV-OS-F101:2013 | |
|---|---|---|---|
| Load Interaction - Displacement Controlled | | V3.2-01 | |
| Developed by DNV TNTNO714 | | 01.10.2013 | |
| Prepared: Date: Sign: | | Verified: Date: Sign: | |
| **RELEVANT INPUT PARAMETERS:** | | | |
| Nominal outer steel diameter: | OD | 600.00 mm | |
| Nominal steel wall thickness: | $t_{nom}$ | 20.00 mm | |
| Corrosion allowance: | $t_{corr}$ | 2.00 mm | |
| Out-of-roundness: | $f_0$ | 1.00 % | |
| Girth weld factor: | $\alpha_{gw}$ | 0.90 | |
| Specified minimum yield stress: | SMYS | 450.0 MPa | |
| Derating in yield stress due to temperature: | $f_{y,temp}$ | 50.0 MPa | |
| Young's modulus: | E | 2.100E+05 MPa | |
| Poisson's ratio: | $\nu$ | 0.30 | |
| Maximum yield to tensile ratio: | $\alpha_h$ | 0.93 | |
| Material strength factor: | $\alpha_U$ | 1.00 | |
| Internal pressure at reference level: | $p_{int,ref}$ | 200.0 barg | |
| Reference level for internal pressure: | $z_{ref}$ | 40.0 m | |
| Density of internal fluid: | $\rho_{int}$ | 200.0 kg/m3 | |
| Depth: | d | 800.0 m | |
| Density of external fluid: | $\rho_{ext}$ | 1025.0 kg/m3 | |
| Load condition factor: | $\gamma_C$ | 1.070 | |
| Functional compressive strain: | $\varepsilon_F$ | 3.00 % | |
| Environmental compressive strain: | $\varepsilon_E$ | 1.00 % | |
| Safety Class: | | MEDIUM | |
| Corroded wall thickness: | | YES | |
| Derated material properties: | | YES | |
| **INTERMEDIATE RESULTS:** | | **Load comb. a** | **Load comb. b** |
| Local internal pressure: | $p_i=p_{ld}/p_{lt}$ | 216.5 barg | |
| Local external pressure: | $p_e$ | 80.4 barg | |
| Local minimum sustainable pressure: | $p_{min}$ | - barg | |
| | | internal overpressure | |
| Characteristic yield stress: | $f_y$ | 400.0 MPa | |
| Steel wall thickness used in code check: | $t_2$ | 18.00 mm | |
| Design compressive strain: | $\varepsilon_d$ | 4.55 % | 4.83 % |
| Elastic collapse pressure: | $p_{el}$ | 124.6 barg | |
| Plastic collapse pressure: | $p_p$ | 204.0 barg | |
| Characteristic collapse pressure: | $p_c$ | 98.5 barg | |
| Plastic strain capacity. | $\varepsilon_c$ | 5.852 % | |
| Resistance strain factor: | $\gamma_\varepsilon$ | 2.50 | |
| Material resistance factor: | $\gamma_m$ | 1.15 | |
| Safety class resistance factor: | $\gamma_{SC}$ | 1.14 | |
| **LOAD INTERACTION - DISPLACEMENT CONTROLLED** | | **Load comb. a** | **Load comb. b** |
| Code check: | | **1.94 NOT OK** | **2.06 NOT OK** |
| Minimum wall thickness: | | 54.15 mm | 59.40 mm |

**Figure 3-4 Report sheet for displacement controlled load combination**

# 4 CASE SHEETS

The DNV-OS-F101 spreadsheet also includes a so-called case sheet where the user can generate (column wise) a large set of cases to be calculated, and this sheet uses exactly the same visual basic subroutines and functions as the main sheet. This sheet is used to verify the calculations for a large set of input parameters.

In the commercially available version, this sheet is organised as follows:

- Rows 10-75 contain all the input parameters presented also on the main sheet.
- Rows 78-94 contain the eight key results also presented on the main sheet.
- Rows 89-117 contain some intermediate and auxiliary results.

In a special version made for verification, this sheet is extended to include results which are based on other excel calculations and visual functions developed independently of the subroutines and functions used in the standard version, but the results are based on the same input. Typically, these additional calculations calculate

- utilisation based on the given input and
- utilisation based on the minimum required thickness calculated by the standard code.

Utilisation based on given input (wall thickness) should of course equal the utilisation produced by the standard code, and utilisation based on the minimum required thickness calculated by the standard code should yield a utility equal to unity.

The results are presented in the tables below. It is not meant that the reader shall be able to read the numbers when this report is printed on paper, an electronic and readable version can be received on request to Software.Support@dnv.com.

One can see four rows in each table that are coloured; these are the comparison between the standard visual basic code and the independently developed verification codes. When these are coloured green the verification calculations arrive at the same number as the standard code, and red if a different number occurs.

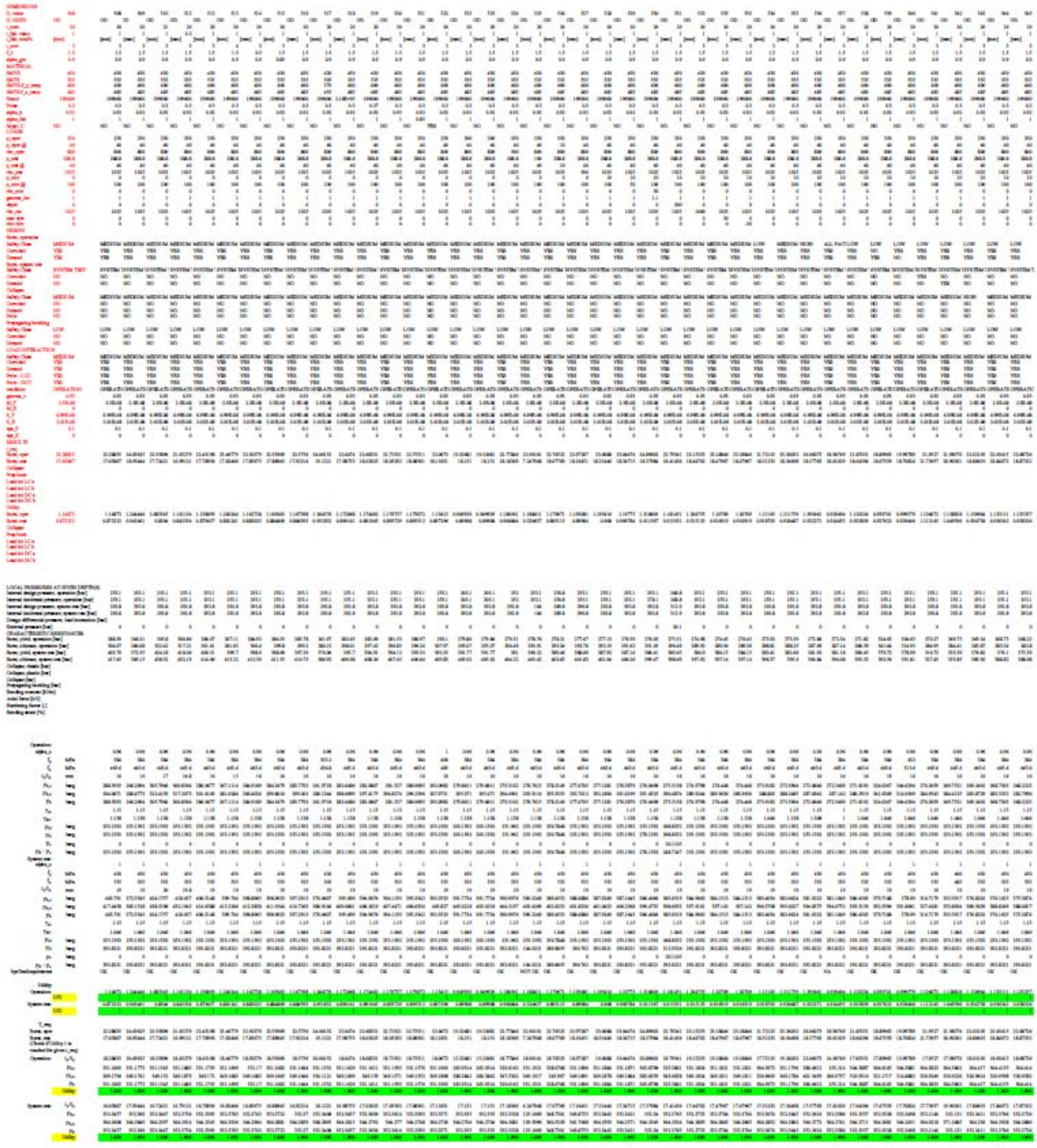


**Figure 4-1 Case sheet for verification of burst.**

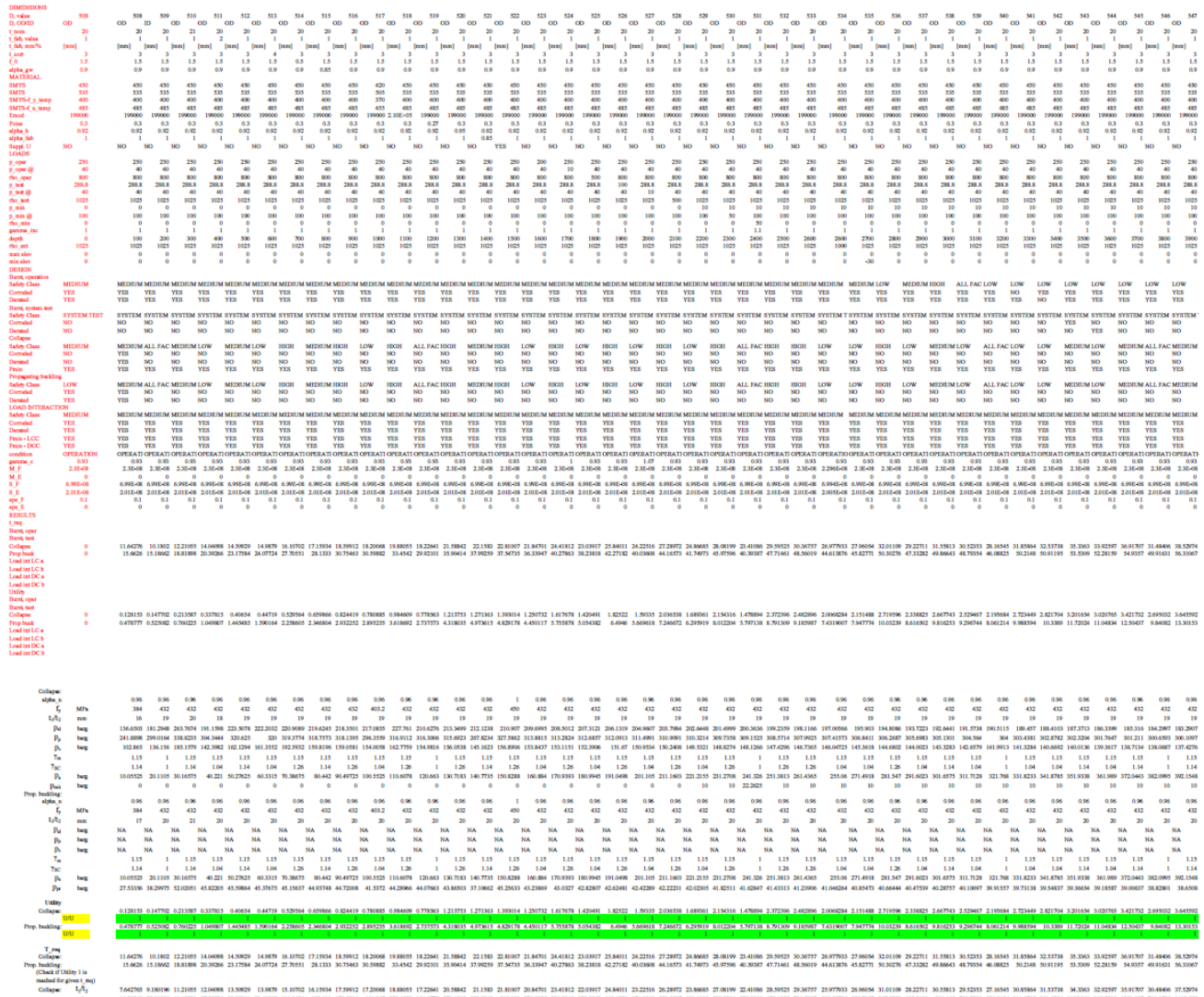


**Figure 4-2 Case sheet for verification of collapse and propagating buckling.**

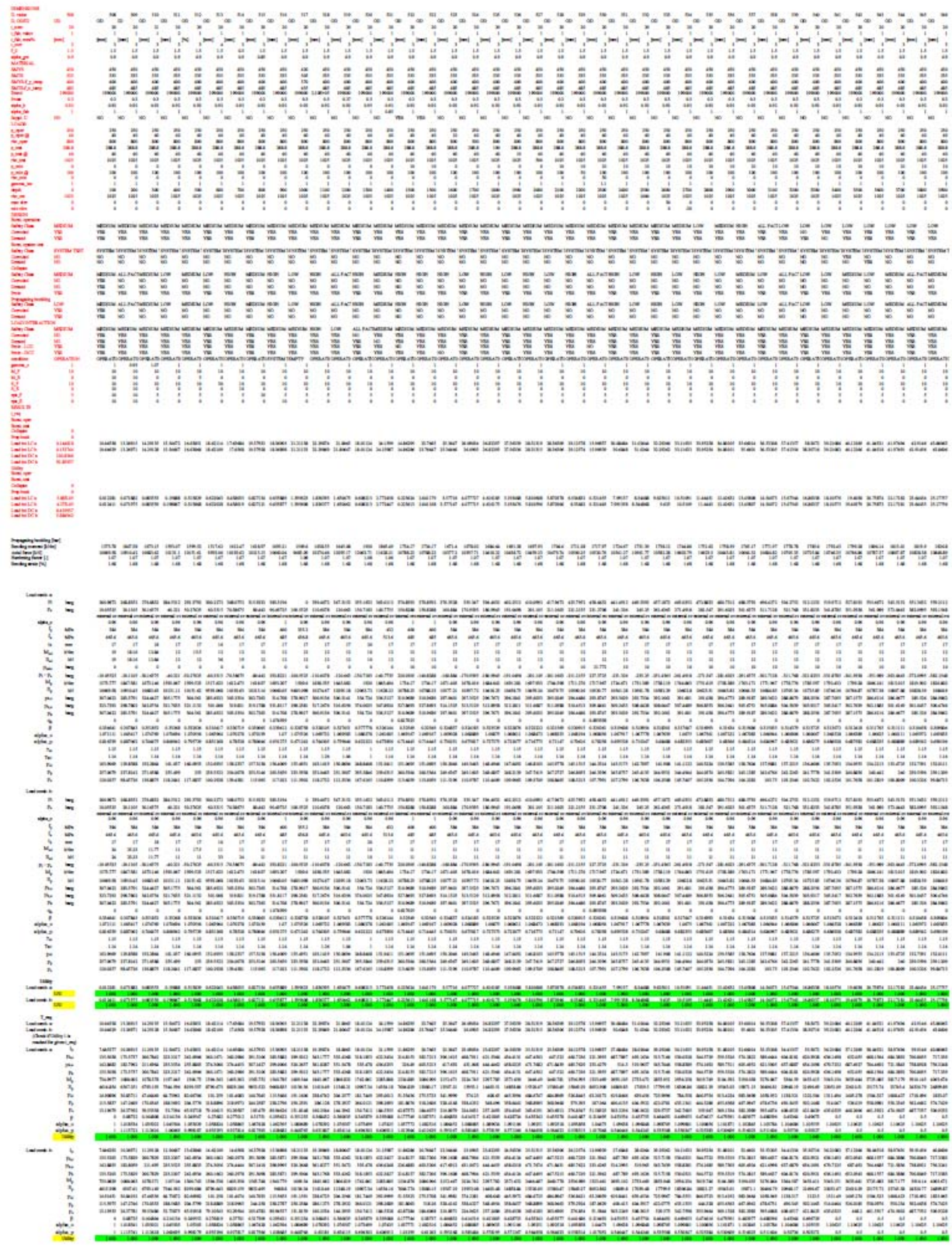


**Figure 4-3 Case sheet for verification of load controlled load combination.**

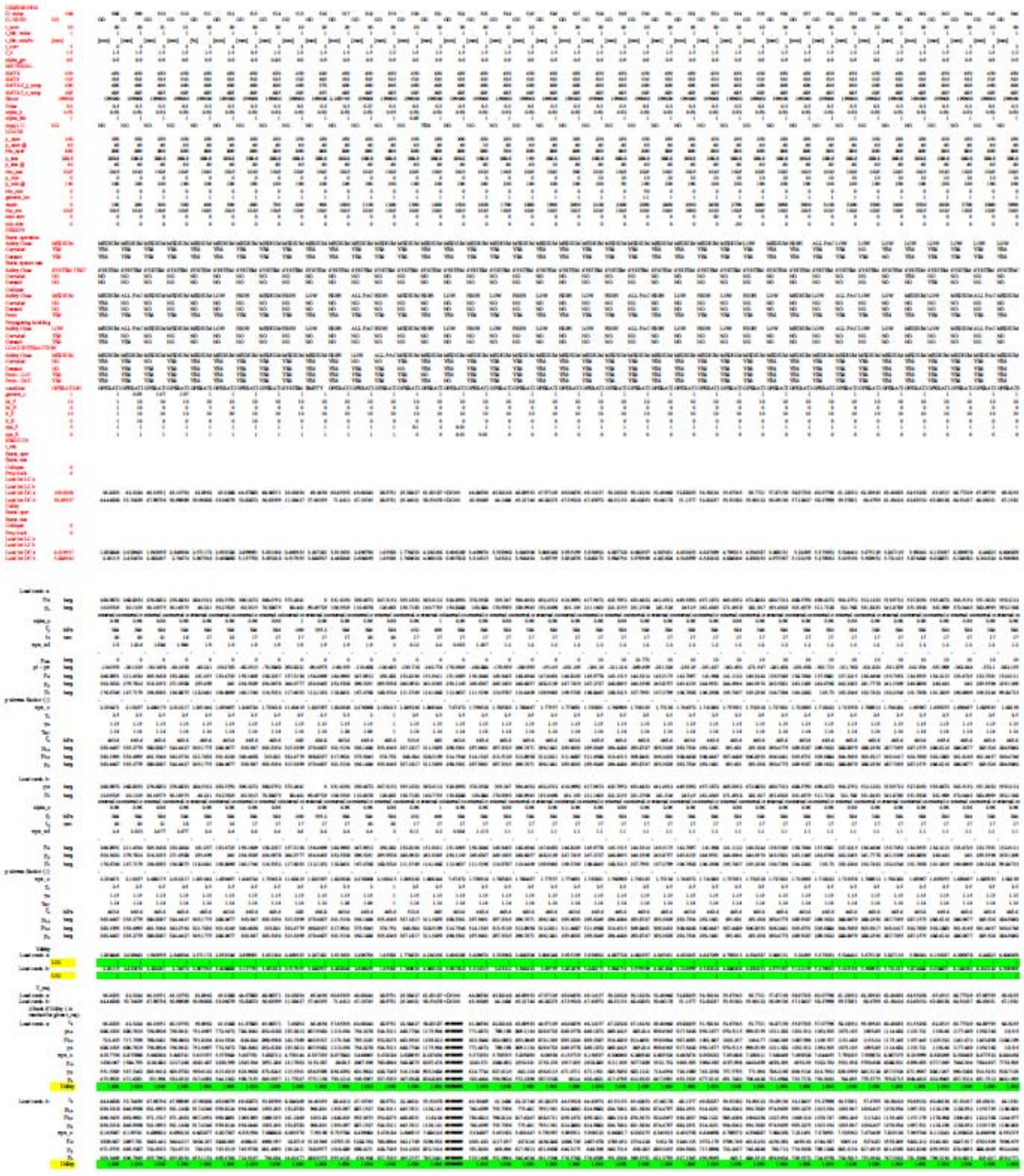


**Figure 4-4 Case sheet for verification of displacement controlled load combination.**



# 2 REFERENCES

/1/ Det Norske Veritas, Offshore Standard DNV-OS-F101, Submarine Pipeline Systems.

**MANAGING RISK**

Det Norske Veritas:

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