

# Risk Assessment Report

## Nanolgnite Chamber

|                                     |                                   |
|-------------------------------------|-----------------------------------|
| <b>Project name</b>                 | Nanolgnite                        |
| <b>Facility name</b>                | Nanolgnite Chamber                |
| <b>Building and room number</b>     | EPT- C086                         |
| <b>Project leader</b>               | Karl Oskar Bjørgen                |
| <b>Facility responsible</b>         | Karl Oskar Bjørgen                |
| <b>HES coordinator</b>              | Morten Grønli                     |
| <b>HES responsible</b>              | Terese Løvås                      |
| <b>Risk assessment performed by</b> | Karl Oskar Bjørgen/David Emberson |

### *Approval:*

|  |  |
|--|--|
| <b>Apparatur kort (UNIT CARD) valid for:</b>                 |  |
| <b>Forsøk pågår kort (EXPERIMENT IN PROGRESS) valid for:</b> |  |

| <b>Role</b>            | <b>Name</b>        | <b>Date</b> | <b>Signature</b> |
|------------------------|--------------------|-------------|------------------|
| <b>Project leader</b>  | Karl Oskar Bjørgen |             |                  |
| <b>HES coordinator</b> | Morten Grønli      |             |                  |
| <b>HES responsible</b> | Terese Løvås       |             |                  |

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## 1 RISK MANAGEMENT IN THE PROJECT

| Main Activities Risk             | Necessary measures, documentation                    | DATE |
|----------------------------------|--|------|
| Project initiation               | Project initiation template                          |      |
| Guidance Meeting                 | Form for Guidance Meeting with pre - risk assessment |      |
| Initial Assessment               | Hazard identification – HAZID<br>Form rough analysis |      |
| Evaluation of technical security | Process HAZOP<br>Technical documentations            |      |
| Evaluation of operational safety | Procedure - HAZOP<br>Training plan for operators     |      |

## 2 INTRODUCTION

The Nanolgnite project aims to ignite a gas mixture of methane and air using the photo-ignition of carbon nanotubes.

This stage of the project is an exploration of the ignition capability of the nanotubes- using Xe flash tubes as the light source. The nanotubes will ignite a gas mixture of methane and air inside a combustion chamber.

The chamber is fitted with a gas system to introduce the gases in known mixture fractions, using temperature and pressure as the measurement techniques.

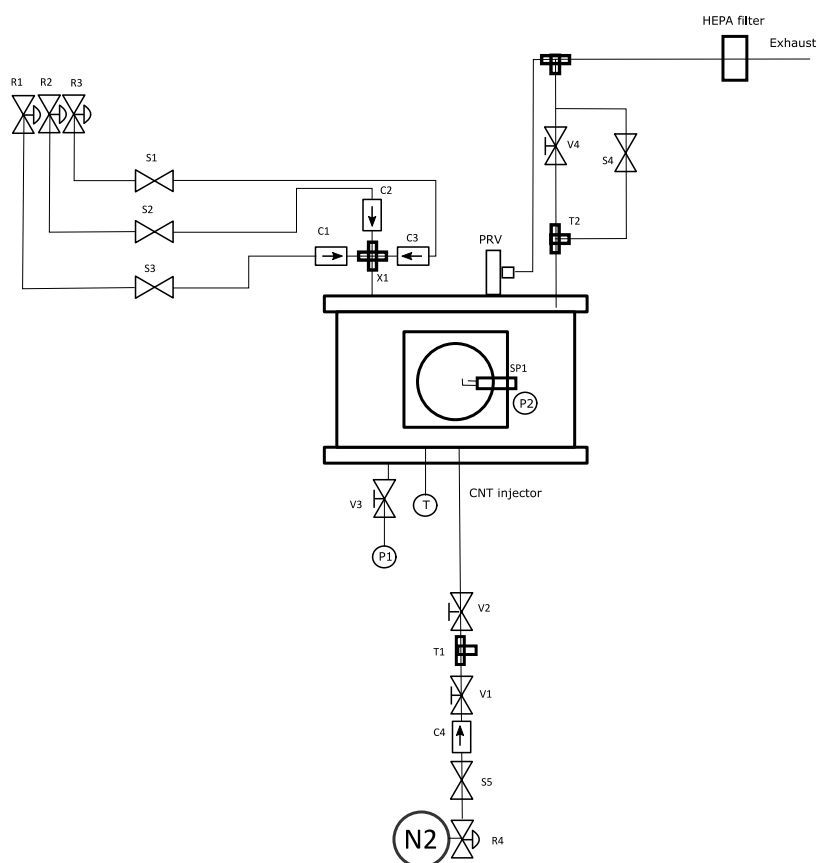
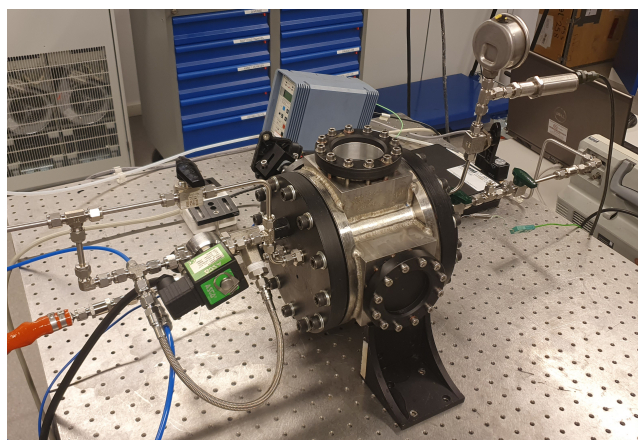
The chamber is fitted with a spark plug to ignite the mixture in the traditional method as a control to compare the nanotube ignition to.

The chamber is fitted with quartz windows to allow optical access to introduce the light and also to film the ignition at high speed.

This stage of the test involves considerable testing of the Xe and the Xe drive circuit to achieve the high light output required.

Experiments involving injecting nanotubes into the chamber and igniting them with light will take place in the coming phase of the project.

### 3 DESCRIPTIONS OF EXPERIMENTAL SETUP



## 4 EVACUATION FROM THE EXPERIMENTAL AREA

Evacuate at signal from the alarm system or local gas alarms with its own local alert with sound and light outside the room in question

Evacuation from the rigging area takes place through the marked emergency exits to the assembly point, (corner of Old Chemistry Kjelhuset or parking 1a-b.)

### Action on rig before evacuation:

All gas supply valve closed  
Gas bottle reg closed  
Stop run of control program.  
LED drive circuit power off

## 5 WARNING

### 5.1 Before experiments

Send an e-mail with information about the planned experiment to:  
[experiments@ept.ntnu.no](mailto:experiments@ept.ntnu.no)

#### The e-mail must include the following information:

- Name of responsible person:
- Experimental setup/rig:
- Start Experiments: (date and time)
- Stop Experiments: (date and time)

You must get the approval back from the laboratory management before start up. All running experiments are notified in the activity calendar for the lab to be sure they are coordinated with other activity.

### 5.2 Abnormal situation

#### FIRE

If you are NOT able to extinguish the fire, activate the nearest fire alarm and evacuate area. Be then available for fire brigade and building caretaker to detect fire place.  
If possible, notify:

| NTNU                            |
|---------------------------------|
| Morten Grønli, Mob: 918 97 515  |
| Terese Løvås: Mob: 918 97 007   |
| NTNU – SINTEF Beredskapstelefon |

#### GAS ALARM

If a gas alarm occurs, close gas bottles immediately and ventilate the area. If the level of the gas concentration does not decrease within a reasonable time, activate the fire alarm and

evacuate the lab. Designated personnel or fire department checks the leak to determine whether it is possible to seal the leak and ventilate the area in a responsible manner.

#### **PERSONAL INJURY**

- First aid kit in the fire / first aid stations
- Shout for help
- Start life-saving first aid
- **CALL 113** if there is any doubt whether there is a serious injury

#### **OTHER ABNORMAL SITUATIONS**

##### **NTNU:**

You will find the reporting form for non-conformance on:

<https://innsida.ntnu.no/wiki/-/wiki/Norsk/Melde+avvik>

## **6 ASSESSMENT OF TECHNICAL SAFETY**

### **6.1 HAZOP**

The experiment set up is divided into the following nodes:

|        |                    |
|--------|--------------------|
| Node 1 | Combustion chamber |
| Node 2 | Nanotube handling  |

#### **ATTACHMENTS A-B: HAZOP**

**Conclusion:** Safety taken care of.

### **6.2 Flammable, reactive and pressurized substances and gas**

Are any flammable, reactive and pressurized substances and gases in use?

|     |  |
|-----|--|
| YES | Combustion chamber filled with Ex gas mixture. |
|-----|--|

**Attachments A:** ATEX diagram; Use of chamber

**Conclusion:** The rig can be operated safely.

### **6.3 Pressurized equipment**

Is any pressurized equipment in use?

|     |   |
|-----|---|
| YES | All chambers and connection are designed to operate well above operational pressure. Fill pressure of max 5 bar, combustion pressure estimated in range of 30 bar. The equipment has to undergo pressure testes in accordance with the norms and be documented. |
|-----|---|

#### **ATTACHMENTS D: TEST CERTIFICATE FOR LOCAL PRESSURE TESTING**

**Conclusion:** Chamber can be safely operated.

## 6.4 Effects on the environment (emissions, noise, temperature, vibration, smell)

Will the experiments generate emission of smoke, gas, odour or unusual waste?

Is there a need for a discharge permit, extraordinary measures?

|     |   |
|-----|---|
| YES | Experiments generate small amounts of exhaust gases from complete or combustion process. Permanently ventilated through the exhaust ventilator. Carbon nanotubes are filtered from exhaust using high efficiency filter. Carbon nanotubes are handles in glove box and never freely in the room. Cleaning of chamber is done with personal protective gear (gloves, dust mask, safety glasses). |
|-----|---|

### Attachments A-B: HAZOP

**Conclusion:** No need for special permits or extraordinary measures.

## 6.5 Radiation

|     |   |
|-----|---|
| YES | Radiation Sources need to have an own risk assessment |
|-----|---|

**Attachments:**

**Conclusion:**

## 6.6 Chemicals

Will any chemicals or other harmful substances be used in the experiments? Describe how the chemicals should be handled (stored, disposed, etc.) Evaluate the risk according to safety datasheets, MSDS. Is there a need for protective actions given in the operational procedure?

|     |  |
|-----|--|
| YES | Do a risk assessment of the use- carbon nanotubes, methane |
|-----|--|

**Attachments E:** MSDS of Methane,  
MSDS carbon nanotubes

**Conclusion:** When working with the carbon nanotubes, gloves should be worn, and all handling conducted in the glovebox. Removal from the glovebox must be done with nanotubes in sealed container, until placed in combustion chamber. Procedures for handling nanotubes has been developed using the guidelines "Rutiner for håndtering av nanomaterialer" provided by Arbeidstilsynet.

The two most important risks connected with the use of methane is the asphyxiation danger and fire hazard in case of an undetected leakage.

The ventilation will minimize the risk of dangerous concentrations of these gases occurring. Further lowering the risk is the fact that the test rig will be checked for leaks on a regular basis. Methane is not corrosive, and there is no danger related to contact.

The room is fitted with methane detection and alarms.

## 6.7 Electricity safety (deviations from the norms/standards)

|     |                                     |
|-----|-------------------------------------|
| YES | Xe driver is within norms/standards |
| NO  |                                     |

**Attachments:**

**Conclusion:** Experiment can be conducted safely.

## 7 ASSESSMENT OF OPERATIONAL SAFETY

Ensure that the procedures cover all identified risk factors that must be taken care of. Ensure that the operators and technical performance have sufficient expertise.

### 7.1 Procedure HAZOP

The method is a procedure to identify causes and sources of danger to operational problems.

#### ATTACHMENT C: HAZOP PROCEDURE

### 7.2 Operation procedure and emergency shutdown procedure

The operating procedure is a checklist that must be filled out for each experiment. Emergency procedure should attempt to set the experiment set up in a harmless state by unforeseen events.

#### ATTACHMENT E: PROCEDURE FOR RUNNING EXPERIMENTS

**Emergency shutdown procedure:**

### 7.3 Training of operators

A Document showing training plan for operators

- *What are the requirements for the training of operators?*
- *What it takes to be an independent operator*
- *Job Description for operators*

**Attachments:** Training program for operators

### 7.4 Technical modifications

- *Technical modifications made by the operator (e.g. Replacement of components, equal to equal)*
- *Technical modifications that must be made by Technical staff (for example, modification of pressure equipment).*
- *What technical modifications give a need for a new risk assessment (by changing the risk picture)?*



**Conclusion:** Chamber can be modified by trained operators and technical staff with no need for new risk assessment to be conducted.

### 7.5 Personal protective equipment

- *It is mandatory use of eye protection in the rig zone*
- *It is mandatory use of protective shoes in the rig zone.*
- *Use gloves when there is opportunity for contact with hot/cold surfaces.*
- *Use of respiratory protection apparatus*

**Conclusion:** PPE is in lab and to be used. Gloves, googles, lab coats.

### 7.6 General Safety

- *The area around the staging attempts shielded.*
- *Gantry crane and truck driving should not take place close to the experiment.*
- *Gas cylinders shall be placed in an approved carrier with shut-off valve within easy reach.*

#### **In place**

- *Monitoring, can experiment run unattended, how should monitoring be? - No*

### 7.7 Safety equipment

- *Have portable gas detectors to be used during test execution? - NO*
- *Warning signs, see the Regulations on Safety signs and signalling in the workplace - In place*

### 7.8 Special predations

For example:

- *Monitoring.*
- *Safety preparedness.*
- *Safe Job Analysis of modifications, (SJA)*
- *Working at heights*
- *Flammable / toxic gases or chemicals*

## 8 QUANTIFYING OF RISK - RISK MATRIX

See ATTACHMENT I GUIDANCE TO RISK ASSESSMENT

The risk matrix will provide visualization and an overview of activity risks so that management and users get the most complete picture of risk factors.

| IDnr | Activity              | Consequence | Probability | RV |
|------|-----------------------|-------------|-------------|----|
|      | Leakage of methane    | B           | 1           | B1 |
|      | Spillage of CNT       | B           | 2           | B2 |
|      | Uncontrolled ignition | B           | 1           | B1 |

**Conclusion:** The Participants has to make a comprehensive assessment to determine whether the remaining risks of the activity/process is acceptable.

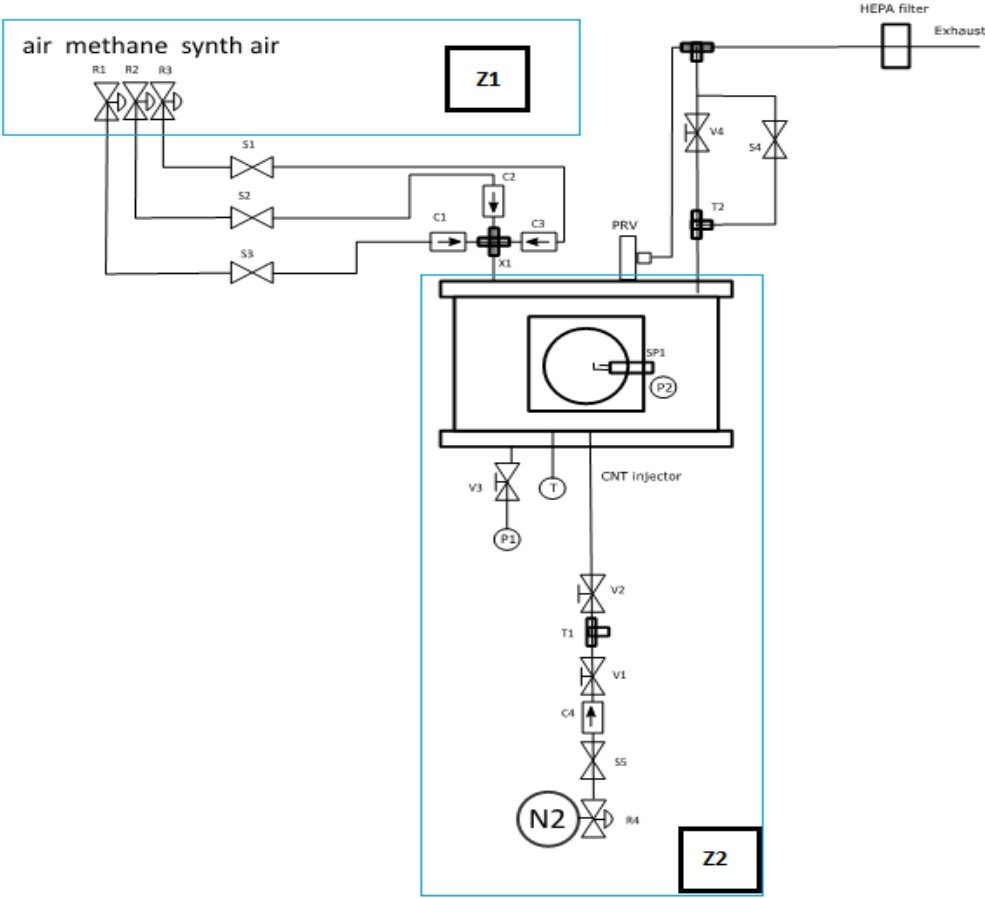
### RISK MATRIX

| CONSEQUENCE | (E) Catastrophic  | E1          | E2           | E3           | E4         | E5                 |
|-------------|-------------------|-------------|--------------|--------------|------------|--------------------|
|             | (D) Extensive     | D1          | D2           | D3           | D4         | D5                 |
|             | (C) Moderate      | C1          | C2           | C3           | C4         | C5                 |
|             | (B) Negligible    | B1          | B2           | B3           | B4         | B5                 |
|             | (A) Insignificant | A1          | A2           | A3           | A4         | A5                 |
|             |                   | (1) Rare    | (2) Unlikely | (3) Possible | (4) Likely | (5) Almost certain |
|             |                   | PROBABILITY |              |              |            |                    |

The principle of the acceptance criterion. Explanation of the colors used in the matrix

| COLOUR | DESCRIPTION  |
|--------|--|
| Red    | Unacceptable risk Action has to be taken to reduce risk      |
| Yellow | Assessment area. Actions has to be considered                |
| Green  | Acceptable risk. Action can be taken based on other criteria |

ATTACHMENT A: PROCESS AND INSTRUMENTATION DIAGRAM (PID), ATEX AND CONTROL PROGRAM.



|             |                         |
|-------------|-------------------------|
| R1-R4       | Gas regulator           |
| S1-S5       | solenoids               |
| T1-T2       | T junctions             |
| X1          | Cross junctions         |
| C1-C4       | Check valves            |
| V1-V4       | Manual valves           |
| PRV         | Pressure relief valves  |
| HEPA filter | Quartz filter in holder |
| P1-P2       | Pressure transducers    |
| SP          | Spark plug              |

Z1- explosive atmosphere possible if leakage present- low probability.  
Z2- explosive atmosphere possible if leakage and valve use incorrect- low probability.

## Control Program

Mode and ignition setting. Manual/Automatic mode, CNT/Sparkplug ignition

Modus

Chamber modus

Ignition mode

Create new file

LOG

File and folder specifications and log activation

State machine controls

Start combustion sequence

START

ABORT

Flush chamber

Exhaust chamber

CNT injection

Spark ignition

Automatic combustion sequence

Gas switch

CH4/synair

Switch between different gasmixtures

CHAMBER FILLING

Flush with synair time (s)

60

Duration of the process that cleans the chamber of impurities, pre-ignition

Syn air filling pressure setpoint (bar)

2,10001

20,0006

Hold time (s)

20

CH4 filling pressure setpoint (bar)

1,70001

Equivalence ratio

0,8

Pre-combustion parameters,  $\Phi$

Ignition

CLOSE PRES VALVE

Ignition activation

IGNITION

Spark ignition delay (ms)

1000

Time between ignition activation and actual ignition

CNT injection duration (ms)

2000

Carbon NanoTubes injection duration to the chamber

Hold after (s)

5

Dynamic pressure sensor logging duration after ignition

EXHAUST

Exhaust time (s)

240

17,3067

Flush time (s)

240

5,84697

Duration of the processes that cleans the chamber of impurities, post-ignition

Manual solenoid valve controls

Solenoid N2

Solenoid exhaust

Solenoid synair

Solenoid compair

Solenoid CH4

Chamber temperature (degC)

23,42

Chamber pressure (bar)

-9,315

ii

## ATTACHMENT B: HAZOP TEMPLATE

| Project: Nanolgnite<br>Node: 1 (Combustion chamber) |               |   |  |   |   | Page   |           |
|---|---------------|---|--|---|---|--|-----------|
| Ref   | Guideword     | Causes  | Consequences   | Safeguards  | Recommendations   | Action   | Date/Sign |
| 1   | No flow       | <ul style="list-style-type: none"> <li>- No air pressures</li> <li>- No methane pressures</li> <li>- Solenoid valve closed</li> </ul> | <ul style="list-style-type: none"> <li>- Cannot carry out experiments</li> <li>- Wrong mixing ratio</li> </ul> | <ul style="list-style-type: none"> <li>- Gas detectors in the room</li> <li>- Good ventilation</li> <li>- Check for leaks each time the rig is used</li> <li>- All equipment where pressure can build up is certified for pressure significantly higher than typical working pressures</li> </ul> | <ul style="list-style-type: none"> <li>- Monitor pressures</li> </ul> | <ul style="list-style-type: none"> <li>- Repair solenoid valve if it is causing the problem</li> <li>- Repair leak if present</li> </ul> |           |
| 2   | Reverse flow  | NA  |  |   |   |  |           |
| 3   | More flow     | <ul style="list-style-type: none"> <li>- Pressure set too high</li> <li>- Operator error</li> </ul>                                   | <ul style="list-style-type: none"> <li>- Possible change in gas mixture</li> </ul>                             | <ul style="list-style-type: none"> <li>- No problem if too much air flow</li> <li>- Solenoid emergency switch for fuel supply</li> </ul>  | <ul style="list-style-type: none"> <li>- Check regulators</li> </ul>  | <ul style="list-style-type: none"> <li>- Repair or replace mass flow controllers</li> </ul>  |           |
| 4   | Less flow     | Ref. 1  |  |   |   |  |           |
| 5   | More level    | NA  |  |   |   |  |           |
| 6   | Less level    | NA  |  |   |   |  |           |
| 7   | More pressure | Ref. 3  |  |   |   |  |           |
| 8   | Less pressure | Ref. 1  |  |   |   |  |           |

| Project: Nanolignite<br>Node: 1 (Combustion chamber) |                    |   |   |  |   |  | Page      |
|--|--------------------|---|---|--|---|--|-----------|
| Ref  | Guideword          | Causes  | Consequences  | Safeguards   | Recommendations   | Action   | Date/Sign |
| 9  | More temperature   | - Fire inside the combustor chamber.  | - pressure rise   | - Rig is made out of stainless steel, which can withstand high temperatures<br>- quartz glass used | - Check all pressures and regulators<br>- Be extra alert of internal fire                   | - flood chamber with nitrogen  |           |
| 10   | Less temperature   | NA  |   |  |   |  |           |
| 11   | More viscosity     | NA  |   |  |   |  |           |
| 12   | Less viscosity     | NA  |   |  |   |  |           |
| 13   | Composition Change | - pressures set incorrectly<br>- Run out of methane or air<br>- solenoid closed<br>- Operator error | - Not the right combustion conditions                                   | - solenoid switch off for fuel supply  | - Check all pressures   | -check regulator   |           |
| 14   | Contamination      | NA  |   |  |   |  |           |
| 15   | Relief             | NA  |   |  |   |  |           |
| 16   | Instrumentation    | - No power to instrumentation<br>- Defective instrumentation  | - Cannot get data<br>- No gases flow if the solenoid valve has no power | - Not major problem if it happens, no particular safeguards  | - Check if all of the required power cords are connected<br>- Check if equipment is damaged | - Plug in power cords if equipment seems fine<br>- Change/repair damaged equipment |           |
| 17   | Sampling           | NA  |   |  |   |  |           |
| 18   | Corrosion/erosion  | NA  |   |  |   |  |           |

| Project: Nanolgnite<br>Node: 1 (Combustion chamber) |                    |  |  |   |  | Page   |           |
|---|--------------------|--|--|---|--|--|-----------|
| Ref   | Guideword          | Causes   | Consequences   | Safeguards  | Recommendations  | Action   | Date/Sign |
| 19  | Service failure    | - No pressure in the central air system in the building<br>- Power outage for the laboratory                               | - No chamber purge available<br>-no solenoid opening-no gas flow.                |   | - Check messages and mail for information about routine power shutdowns and shutdown of the central pressurised air system |  |           |
| 20  | Abnormal Operation | See all other references   |  |   |  |  |           |
| 21  | Maintenance        | - Malfunctioning solenoids or other valves   | - Cannot conduct experiment  | - Solenoids are serviced in house   | - servicing valves   | -  |           |
| 22  | Ignition           | - Should ignite the combustible fuel-air mixture in the combustor<br>- If not igniting the ignition conditions are not met | - Cannot run the rig hot<br>- Build-up of combustible gas in the laboratory room | - Follow the detailed shut down procedure within 5 seconds of opening the fuel supply if the combustor does not ignite<br>- Exhaust ventilator to extract the unburnt fuel from the laboratory room | - Test ignition equipment before opening the fuel supply<br>- Follow the shut-down procedure step by step                  | - After the room has been ventilated well check ignition equipment<br>- Check there is fuel in the fuel canister |           |
| 23  | Spare equipment    | NA   |  |   |  |  |           |
| 24  | Safety             |  |  |   |  |  |           |

| Project: Nanolgnite<br>Node: 2 (Nanotube handling) |               |                       |                      |  |  | Page   |           |
|--|---------------|-----------------------|----------------------|--|--|--------|-----------|
| Ref  | Guideword     | Causes                | Consequences         | Safeguards   | Recommendations  | Action | Date/Sign |
| 1  | Contamination | Spillage of nanotubes | Exposure to operator | <ul style="list-style-type: none"> <li>-All handling of nanotubes occurs in globebox</li> <li>- Double layer of gloves are used in glovebox.</li> <li>- Nanotubes are never used freely in the room.</li> <li>- Remaining nanotubes in chamber is combusted.</li> <li>- Cleaning of chamber requires double layer of gloves, goggles, dust mask and protective suit.</li> <li>-Equipment used for handling nanotubes are thoroughly cleaned with wet wipes.</li> </ul> | <ul style="list-style-type: none"> <li>-Make sure that protective gear is available at all time in room.</li> <li>-Vacuum cleaner with certified HEPA filter should be used if spillage of nanotubes occur.</li> </ul> |        |           |



## ATTACHMENT C: HAZOP PROCEDURE

| Project: Nanolgnite<br>Node: 1 (Combustion chamber) |                                  |   |  |                               |                 |                                   | Page      |
|---|----------------------------------|---|--|-------------------------------|-----------------|-----------------------------------|-----------|
| Ref#  | Guideword                        | Causes  | Consequences   | Safeguards                    | Recommendations | Action                            | Date/Sign |
|   | Not clear procedure              | Procedure is too ambitious, or confusingly                              | - Potential ignition<br>- Potentially no ignition        | - shut off to cut fuel supply |                 | - Shut off fuel supply to the rig |           |
|   | Step in the wrong place          | The procedure can lead to actions done in the wrong pattern or sequence | - Potential ignition<br>- Potentially no ignition        | - shut off to cut fuel supply |                 | - Shut off fuel supply to the rig |           |
|   | Wrong actions                    | Procedure improperly specified  | - Potential flame flashback<br>- Potentially no ignition | - shut off to cut fuel supply |                 | - Shut off fuel supply to the rig |           |
|   | Incorrect information            | Information provided in advance of the specified action is wrong        | - Potential ignition<br>- Potentially no ignition        | shut off to cut fuel supply   |                 | - Shut off fuel supply to the rig |           |
|   | Step missing                     | Missing step, or step requires too much of operator                     | - Potential flame flashback<br>- Potentially no ignition | shut off to cut fuel supply   |                 | - Shut off fuel supply to the rig |           |
|   | Step unsuccessful                | Step has a high probability of failure                                  | - Potential ignition<br>- Potentially no ignition        | - shut off to cut fuel supply |                 | - Shut off fuel supply to the rig |           |
|   | Influence and effects from other | Procedure's performance can be affected by other sources                |  |                               |                 |                                   |           |
|   |                                  |   |  |                               |                 |                                   |           |

| Project: Nanolignite<br>Node: 2 (Nanotubes) |                         |   |                                   |  |                 | Page   |           |
|---|-------------------------|---|-----------------------------------|--|-----------------|--------|-----------|
| Ref#  | Guideword               | Causes  | Consequences                      | Safeguards   | Recommendations | Action | Date/Sign |
|   | Not clear procedure     | Procedure is too ambitious, or confusingly                              | Exposure of nanotubes to operator | Always handle nanotubes in glovebox. Never handle nanotube freely in the room.   |                 |        |           |
|   | Step in the wrong place | The procedure can lead to actions done in the wrong pattern or sequence | Exposure of nanotubes to operator | When there is a risk of exposure, such as handling the nanotubes outside the glovebox in a container that could break, protective gear must be used. |                 |        |           |
|   | Wrong actions           | Procedure improperly specified  | Exposure of nanotubes to operator | When there is a risk of exposure, such as handling the nanotubes outside the glovebox in a container that could break,                               |                 |        |           |

| Project: Nanolgnite<br>Node: 2 (Nanotubes) |                       |  |                                   |  |                 | Page   |           |
|--|-----------------------|--|-----------------------------------|--|-----------------|--------|-----------|
| Ref#                                       | Guideword             | Causes   | Consequences                      | Safeguards   | Recommendations | Action | Date/Sign |
|  |                       |  |                                   | protective gear must be used.  |                 |        |           |
|  | Incorrect information | Information provided in advance of the specified action is wrong | Exposure of nanotubes to operator | When there is a risk of exposure, such as handling the nanotubes outside the glovebox in a container that could break, protective gear must be used. |                 |        |           |
|  | Step missing          | Missing step, or step requires too much of operator              | Exposure of nanotubes to operator | When there is a risk of exposure, such as handling the nanotubes outside the glovebox in a container that could break, protective gear must be used. |                 |        |           |
|  | Step unsuccessful     | Step has a high probability of failure                           | Exposure of nanotubes to operator | When there is a risk of exposure, such as handling   |                 |        |           |

| Project: Nanolignite<br>Node: 2 (Nanotubes) |                                  |  |                                   |  |                 | Page   |           |
|---|----------------------------------|--|-----------------------------------|--|-----------------|--------|-----------|
| Ref#  | Guideword                        | Causes   | Consequences                      | Safeguards   | Recommendations | Action | Date/Sign |
|   |                                  |  |                                   | the nanotubes outside the glovebox in a container that could break, protective gear must be used.  |                 |        |           |
|   | Influence and effects from other | Procedure's performance can be affected by other sources | Exposure of nanotubes to operator | When there is a risk of exposure, such as handling the nanotubes outside the glovebox in a container that could break, protective gear must be used. |                 |        |           |

## ATTACHMENT D: TEST CERTIFICATE FOR LOCAL PRESSURE TESTING

The pressure test should be carried out according to en 13445 part 5 (Inspection and testing).  
See also pressure testing procedure applicable for VATL lab

Printed equipment: Nanolgnite Chamber

Used in rig: Nanolgnite

Design print for equipment-50bar

Maximum permissible pressure: 30bar

Maximum operating pressure in this rig: 20 bar

**The proof pressure must be determined according to the standard and with respect to the maximum permissible pressure.**

Prøvetrykk: (1, 5 x maximum drift strykk) According to standard

Test medium: water  
Temperature: 20°C  
Start Time: 16:00  
Pressure: 30 bar



Closed Time: 17:00  
Pressure: 29.7 bar



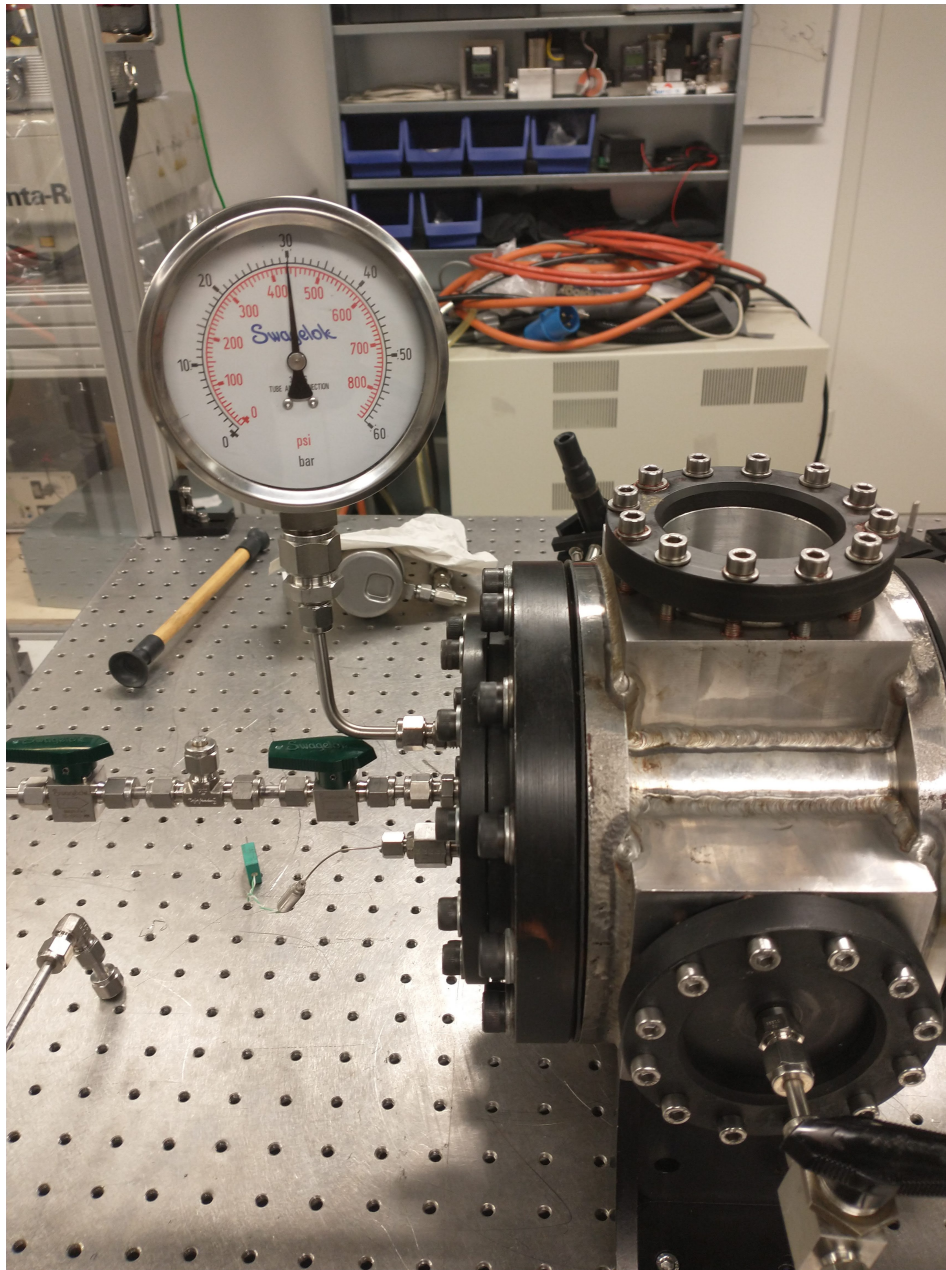
Any repetitions from atm. press to maximum proof-no

Test pressure, date of testing and maximum permissible operating pressure should be marked on (separated or switched on)

Location and date: Trondheim 20.09.21

Signature

D. Emberson



## ATTACHMENT E: MSDS METHANE, FERROCINE, CNT

Making our world more productive



### SAFETY DATA SHEET Methane, compressed

Issue Date: 16.01.2013  
Last revised date: 12.05.2020

Version: 3.0

SDS No.: 000010021692  
1/29

#### SECTION 1: Identification of the substance/mixture and of the company/undertaking

##### 1.1 Product identifier

**Product name:** Methane, compressed

**Trade name:** Methane 2.5 Chemical, Methane 3.5 Instrument, Methane 4.5 Detector, Methane 5.5 Scientific, Metan

**Other Name:** G20 (EN 437)

##### Additional identification

**Chemical name:** Methane

**Chemical formula:** CH<sub>4</sub>

**INDEX No.** 601-001-00-4

**CAS-No.** 74-82-8

**EC No.** 200-812-7

**REACH Registration No.** 01-2119474442-39

##### 1.2 Relevant identified uses of the substance or mixture and uses advised against

**Identified uses:** Industrial and professional. Perform risk assessment prior to use. Transfiling gas or liquid, Use as a fuel Use as an Intermediate (transported, on-site isolated). Use for electronic component manufacture. Using gas alone or in mixtures for the calibration of analysis equipment. Using gas as feedstock in chemical processes.

**Uses advised against** Consumer use.

##### 1.3 Details of the supplier of the safety data sheet

**Supplier**  
Linde Gas AS  
Postboks 13 Nydalen  
N-0409 Oslo Norway

**Telephone:** +4723177200

**E-mail:** sds.ren@linde.com

##### 1.4 Emergency telephone number: +47 22 59 13 00 (24h - Giftinformasjonssentralen)

#### SECTION 2: Hazards identification

##### 2.1 Classification of the substance or mixture

Classification according to Regulation (EC) No 1272/2008 as amended.

##### Physical Hazards

SDS\_NO - 000010021692


[www.sigmaaldrich.com](http://www.sigmaaldrich.com)

## SIKKERHETSDATABLAD

I henhold til Forordning (EF) nr. 1907/2006

Utgave 6.0

Revisjonsdato 26.10.2019

Utskriftsdato 19.02.2021

### AVSNITT 1: Identifikasjon av stoffet/stoffblandingen og av selskapet/foretaket

#### 1.1 Produkt identifikatorer

Produktnavn : Ferrocene

Produktnr. : F408

Merke : Aldrich

REACH nr. : Registreringsnummeret er ikke tilgjengelig for dette stoffet eller dets bruk er fritatt for registrering, årlig tonnasje krever ikke registrering eller registreringen er forutsatt for en senere registreringsdato

CAS-nr. : 102-54-5

#### 1.2 Relevante identifiserte bruksområder for stoffet eller stoffblandingen og bruk som frarådes

Identifiserte bruksområder : Laboratoriekjemikalier, Produksjon av stoffer

#### 1.3 Opplysninger om leverandøren av sikkerhetsdatabladet

Foretaket : Merck Life Science AS  
Drammensveien 123, 5th floor,  
N-0277 OSLO

Telefon : +47 23 1760-70

Faks : +47 23 1760-10

E-post adresse : TechnicalService@merckgroup.com

#### 1.4 Nødtelefonnummer

Nødtelefon : +(47)-22591300 (Giftinformasjonen)  
+(47)-21930678 (CHEMTREC)  
Brann og større ulykker 110  
Ambulanse medisinsk nødtelefon - 113

### AVSNITT 2: Fareidentifikasjon

#### 2.1 Klassifisering av stoffet eller stoffblandingen

Klassifisering i henhold til Forordning (EF) nr 1272/2008

Brennbare faste stoffer (Kategori 1), H228

Akutt giftighet, Oral (Kategori 4), H302

Akutt giftighet, Innånding (Kategori 4), H332

Reproduksjonstoksitet (Kategori 2), H361

Spesifikk målorgan systemisk giftighet - gjentatt utsettelse, Innånding (Kategori 2), Lever, H373

Langsiktig (kronisk) fare for vannmiljøet (Kategori 1), H410

Aldrich- F408

Side 1 av 9

The life science business of Merck operates as MilliporeSigma in the US and Canada







MATERIAL SAFETY DATA SHEET

Date of Issue: 17.05.2019

## NANOGRAFI NANOTECHNOLOGY

## SECTION 1 IDENTIFICATION OF THE SUBSTANCE/MIXTURE AND OF THE COMPANY

## 1.1 Product identifiers

|                |   |
|----------------|---|
| Product Form   | Substance   |
| Trade Name     | Multi Walled Carbon Nanotubes, >96%, OD:<br>8-18 nm |
| Product Number | NG01MW0301  |
| CAS Number     | 308068-56-6   |

## 1.2 Relevant identified uses of the substance or mixture and uses advised against

|                              |          |
|------------------------------|----------|
| Use of the substance/mixture | Research |
|------------------------------|----------|

## 1.3 Details of the supplier of safety data sheet

|         |   |
|---------|---|
| Company | Nanografi Nanotechnology  |
| Address | ODTÜ Teknokent İkizler Binası B-1/H<br>ODTÜ Teknokent 06531- ANKARA |
| Phone   | +90 312 285 85 09   |
| Fax     | +90 312 210 13 09   |

## 1.4 Emergency Telephone Number

|                            |                   |
|----------------------------|-------------------|
| Emergency Telephone Number | +90 312 285 85 09 |
|----------------------------|-------------------|

## SECTION 2 HAZARDS IDENTIFICATION

## 2.1 Classification of the substance or mixture

GHS Classification in accordance with 29 CFR 1910 (OSHA HCS)

Eye irritation (Category 2A), H319

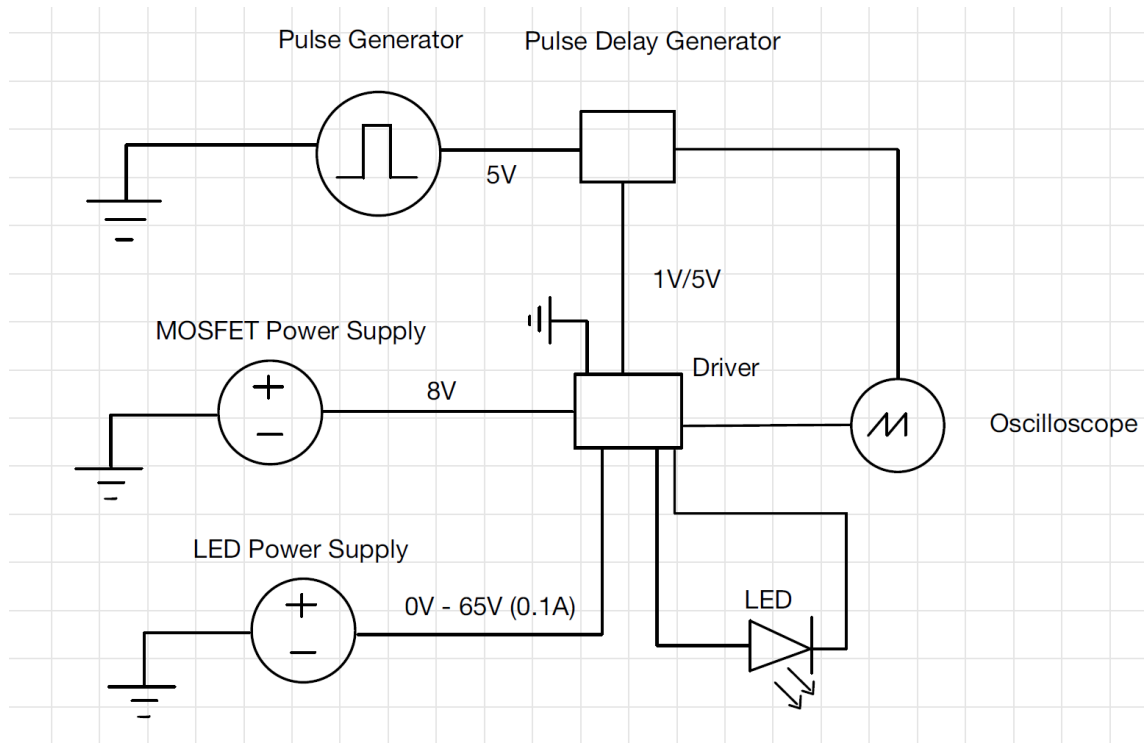
Respiratory system, H335

For the full text of the H-Statements mentioned in this Section, see Section 16.

17.05.2019

EN (English)

## ATTACHMENT F: XE CIRCUIT



Connections to high voltage meet required standard.

## ATTACHMENT G: PROCEDURE FOR RUNNING EXPERIMENTS

|   |             |                  |
|---|-------------|------------------|
| <b>Project</b><br>Nanolgnite                | <b>Date</b> | <b>Signature</b> |
| <b>Facility</b><br>Nanolgnite Chamber       |             |                  |
| <b>Project leader</b><br>Karl Oskar Bjørgen |             |                  |

|  | <b>Conditions for the experiment:</b>   | <b>Completed</b>   |
|--|---|--------------------|
|  | Experiments should be run in normal working hours, 08:00-16:00 during wintertime and 08.00-15.00 during summer time.<br>Experiments outside normal working hours shall be approved. |                    |
|  | One person must always be present while running experiments and should be approved as an experimental leader.   |                    |
|  | An early warning is given according to the lab rules and accepted by authorized personnel.  |                    |
|  | Be sure that everyone taking part of the experiment is wearing the necessary protecting equipment and is aware of the shutdown procedure and escape routes.                         |                    |
|  | <b>Preparations</b>   | <b>Carried out</b> |
|  | Post the "Experiment in progress" sign.   |                    |
|  | Remove unnecessary objects not related to the experiment around the rig.  |                    |
|  | <i>Start up procedure</i>   |                    |
|  | Open labview control program, make sure the solenoid valves are closed and all parameters are set to the desired values.  |                    |
|  | Open the gate valves for manometer, synthetic air, methane, air and exhaust, right next to the chamber.   |                    |
|  | Open the gate valves for methane and synthetic air at the supply and monitor the pressures. The pressures should be constant, a pressure drop could mean leakage.                   |                    |
|  | While the supply valves are open be aware of sound or smell that could be related to leakage.   |                    |
|  | <b>During the experiment</b>  |                    |
|  | Every participant should be behind the Plexiglas during the entirety of the experiment.   |                    |
|  | Start the experiment by flushing the chamber with synthetic air.  |                    |
|  | Fill the chamber with synthetic air up to the setpoint pressure, wait for temperature to drop to the reference temperature before proceeding to the next part.                      |                    |
|  | Fill the chamber with methane using the solenoid valve.   |                    |
|  | Close the gate valve for the manometer, the manometer is not suited for high pressures and could be broken if not turned off.   |                    |
|  | Ignite the fuel-air mixture by activating the sparkplug   |                    |

|  |   |  |
|--|---|--|
|  | Open the solenoid exhaust valve to get the exhaust gases out of the chamber and then flush the chamber for any impurities |  |
|  | <b>End of experiment</b>  |  |
|  | <i>Shut down procedure</i>  |  |
|  | Open the gate valve for the manometer and make sure the pressure in the chamber is close to zero.                         |  |
|  | Close the valves for methane and synthetic air supply.  |  |
|  | Remove all obstructions/barriers/signs around the experiment.   |  |
|  | Tidy up and return all tools and equipment.   |  |
|  | Tidy and cleanup work areas.  |  |
|  | Return equipment and systems back to their normal operation settings (fire alarm)   |  |
|  | <b>To reflect on before the next experiment and experience useful for others</b>  |  |
|  | Was the experiment completed as planned and on scheduled in professional terms?   |  |
|  | Was the competence which was needed for security and completion of the experiment available to you?                       |  |
|  | Do you have any information/ knowledge from the experiment that you should document and share with fellow colleagues?     |  |

**Operator(s):**

| Navn | Dato | Signature |
|------|------|-----------|
|      |      |           |
|      |      |           |

## ATTACHMENT H: TRAINING OF OPERATORS

|   |             |                  |
|---|-------------|------------------|
| <b>Project</b><br>Nanolgnite                | <b>Date</b> | <b>Signature</b> |
| <b>Facility</b><br>Nanolgnite Chamber       |             |                  |
| <b>Project leader</b><br>Karl Oskar Bjørgen |             |                  |

|  |  |  |
|--|--|--|
|  | <b>Knowledge about EPT LAB in general</b>  |  |
|  | Lab <ul style="list-style-type: none"><li>• Access</li><li>• routines and rules</li><li>• working hour</li></ul> |  |
|  | Knowledge about the evacuation procedures.   |  |
|  | Activity calendar for the Lab  |  |
|  | Early warning, <a href="mailto:experiments@ept.ntnu.no">experiments@ept.ntnu.no</a>                              |  |
|  |  |  |
|  | <b>Knowledge about the experiments</b>   |  |
|  | Procedures for the experiments   |  |
|  | Emergency shutdown.  |  |
|  | Nearest fire and first aid station.  |  |
|  |  |  |
|  |  |  |
|  |  |  |

I hereby declare that I have read and understood the regulatory requirements has received appropriate training to run this experiment and are aware of my personal responsibility by working in EPT laboratories.

**Operator(s):**

| Navn | Dato | Signatur |
|------|------|----------|
|      |      |          |
|      |      |          |
|      |      |          |
|      |      |          |

## APPARATURKORT / UNITCARD

**Dette kortet SKAL henges godt synlig på apparaturen!**  
***This card MUST be posted on a visible place on the unit!***

|  |   |
|--|---|
| <b>Apparatur (Unit)</b><br>Nanolgnite Chamber  |   |
| <b>Prosjektleder (Project Leader)</b><br>Karl Oskar Bjørgen                          | <b>Telefon mobil/privat (Phone no. mobile/private)</b><br>+4790861780 |
| <b>Apparaturansvarlig (Unit Responsible)</b><br>Karl Oskar Bjørgen                   | <b>Telefon mobil/privat (Phone no. mobile/private)</b><br>+4790861780 |
| <b>Sikkerhetsrisikoer (Safety hazards)</b><br>Metangass, karbonnanopartikler.        |   |
| <b>Sikkerhetsregler (Safety rules)</b>   |   |
| <b>Nødstopprosedyre (Emergency shutdown)</b><br>Steng metangasstilførsel, forlat rom |   |

**Her finner du (Here you will find):**

|                                      |            |
|--------------------------------------|------------|
| <b>Prosedyrer (Procedures)</b>       | I rom C086 |
| <b>Bruksanvisning (Users manual)</b> | I rom C086 |

**Nærmeste (Nearest)**

|  |             |
|--|-------------|
| <b>Brannslukningsapparat (fire extinguisher)</b> | I rom C086  |
| <b>Førstehjelpsskap (first aid cabinet)</b>      | I gang B025 |

**NTNU**  
**Institutt for energi og prosessteknikk**

**Dato**

---

**Signert**

---

# FORSØK PÅGÅR /EXPERIMENT IN PROGRESS

**Dette kortet SKAL henges opp før forsøk kan starte!**

***This card MUST be posted on the unit before the experiment startup!***

|   |   |
|---|---|
| <b>Apparatur (Unit)</b><br>Nanolgnite Chamber   |   |
| <b>Prosjektleder (Project Leader)</b><br>Karl Oskar Bjørgen   | <b>Telefon mobil/privat (Phone no. mobile/private)</b><br>90861780                |
| <b>Apparaturansvarlig (Unit Responsible)</b><br>Karl Oskar Bjørgen  | <b>Telefon mobil/privat (Phone no. mobile/private)</b><br>90861780                |
| <b>Godkjente operatører (Approved Operators)</b><br>Karl Oskar Bjørgen,<br>Stian Ranøyen Bratsberg,<br>Patrick Jørgensen  | <b>Telefon mobil/privat (Phone no. mobile/private)</b><br><br>90861780, 41635744, |
| <b>Prosjekt (Project)</b><br>Nanolgnite   |   |
| <b>Forsøkestid / Experimental time (start - stop)</b><br>08:00-17:00  |   |
| <b>Kort beskrivelse av forsøket og relaterte farer (Short description of the experiment and related hazards)</b><br>Forbrenning av forblandet metan i lukket kammer. Bruk av karbonnanorør. |   |

**NTNU**  
**Institutt for energi og prosessteknikk**

**Dato**

---

**Signert**

---

## ATTACHMENT I GUIDANCE TO RISK ASSESSMENT

### Chapter 5 Assessment of technical safety.

Ensure that the design of the experiment set up is optimized in terms of technical safety.

Identifying risk factors related to the selected design, and possibly to initiate re-design to ensure that risk is eliminated as much as possible through technical security.

This should describe what the experimental setup actually are able to manage and acceptance for emission.

#### 5.1 HAZOP

The experimental set up is divided into nodes (eg motor unit, pump unit, cooling unit.). By using guidewords to identify causes, consequences and safeguards, recommendations and conclusions are made according to if necessary safety is obtained. When actions are performed the HAZOP is completed.

(e.g. "No flow", cause: the pipe is deformed, consequence: pump runs hot, precaution: measurement of flow with a link to the emergency or if the consequence is not critical used manual monitoring and are written into the operational procedure.)

#### 5.2 Flammable, reactive and pressurized substances and gas.

*According to the Regulations for handling of flammable, reactive and pressurized substances and equipment and facilities used for this:*

|   |
|---|
| <b>Flammable material:</b> Solid, liquid or gaseous substance, preparation, and substance with occurrence or combination of these conditions, by its flash point, contact with other substances, pressure, temperature or other chemical properties represent a danger of fire.   |
| <b>Reactive substances:</b> Solid, liquid, or gaseous substances, preparations and substances that occur in combinations of these conditions, which on contact with water, by its pressure, temperature or chemical conditions, represents a potentially dangerous reaction, explosion or release of hazardous gas, steam, dust or fog. |
| <b>Pressurized:</b> Other solid, liquid or gaseous substance or mixes having fire or hazardous material response, when under pressure, and thus may represent a risk of uncontrolled emissions  |

Further criteria for the classification of flammable, reactive and pressurized substances are set out in Annex 1 of the Guide to the Regulations "Flammable, reactive and pressurized substances"

<http://www.dsb.no/Global/Publikasjoner/2009/Veiledning/Generell%20veiledning.pdf>

[http://www.dsb.no/Global/Publikasjoner/2010/Tema/Temaveiledning\\_bruk\\_av\\_farlig\\_stoff\\_Del\\_1.pdf](http://www.dsb.no/Global/Publikasjoner/2010/Tema/Temaveiledning_bruk_av_farlig_stoff_Del_1.pdf)

Experiment setup area should be reviewed with respect to the assessment of Ex zone

- Zone 0: Always explosive atmosphere, such as inside the tank with gas, flammable liquid.
- Zone 1: Primary zone, sometimes explosive atmosphere such as a complete drain point
- Zone 2: secondary discharge could cause an explosive atmosphere by accident, such as flanges, valves and connection points



## 5.4 Effects on the environment

With pollution means: bringing solids, liquid or gas to air, water or ground, noise and vibrations, influence of temperature that may cause damage or inconvenience effect to the environment.

Regulations: <http://www.lovdato.no/all/hl-19810313-006.html#6>

NTNU guidance to handling of waste: <http://www.ntnu.no/hms/retningslinjer/HMSR18B.pdf>

## 5.5 Radiation

Definition of radiation

|   |
|---|
| <b>Ionizing radiation:</b> Electromagnetic radiation (in radiation issues with wavelength <100 nm) or rapid atomic particles (e.g. alpha and beta particles) with the ability to stream ionized atoms or molecules.   |
| <b>Non ionizing radiation:</b> Electromagnetic radiation (wavelength >100 nm), og ultrasound <sub>1</sub> with small or no capability to ionize.  |
| <b>Radiation sources:</b> All ionizing and powerful non-ionizing radiation sources.   |
| <b>Ionizing radiation sources:</b> Sources giving ionizing radiation e.g. all types of radiation sources, x-ray, and electron microscopes.  |
| <b>Powerful non ionizing radiation sources:</b> Sources giving powerful non ionizing radiation which can harm health and/or environment, e.g. class 3B and 4. MR <sub>2</sub> systems, UVC <sub>3</sub> sources, powerful IR sources <sub>4</sub> .   |
| <sub>1</sub> Ultrasound is an acoustic radiation ("sound") over the audible frequency range (> 20 kHz). In radiation protection regulations are referred to ultrasound with electromagnetic non-ionizing radiation.<br><sub>2</sub> MR (e.g. NMR) - nuclear magnetic resonance method that is used to "depict" inner structures of different materials.<br><sub>3</sub> UVC is electromagnetic radiation in the wavelength range 100-280 nm.<br><sub>4</sub> IR is electromagnetic radiation in the wavelength range 700 nm - 1 mm. |

For each laser there should be an information binder (HMSRV3404B) which shall include:

- General information
- Name of the instrument manager, deputy, and local radiation protection coordinator
- Key data on the apparatus
- Instrument-specific documentation
- References to (or copies of) data sheets, radiation protection regulations, etc.
- Assessments of risk factors
- Instructions for users
- Instructions for practical use, startup, operation, shutdown, safety precautions, logging, locking, or use of radiation sensor, etc.
- Emergency procedures
- See NTNU for laser: <http://www.ntnu.no/hms/retningslinjer/HMSR34B.pdf>

## 5.6 The use and handling of chemicals.

In the meaning chemicals, a element that can pose a danger to employee safety and health

See: <http://www.lovdato.no/cgi-wift/ldles?doc=/sf/sf/sf-20010430-0443.html>

Safety datasheet is to be kept in the HSE binder for the experiment set up and registered in the database for chemicals.

## Chapter 6 Assessment of operational procedures.

Ensures that established procedures meet all identified risk factors that must be taken care of through operational barriers and that the operators and technical performance have sufficient expertise.

### 6.1 Procedure Hazop

Procedural HAZOP is a systematic review of the current procedure, using the fixed HAZOP methodology and defined guidewords. The procedure is broken into individual operations (nodes) and analyzed using guidewords to identify possible nonconformity, confusion or sources of inadequate performance and failure.

### 6.2 Procedure for running experiments and emergency shutdown.

Has to be prepared for all experimental setups.

*The operating procedure has to describe stepwise preparation, startup, during and ending conditions of an experiment. The procedure should describe the assumptions and conditions for starting, operating parameters with the deviation allowed before aborting the experiment and the condition of the rig to be abandoned.*

*Emergency procedure describes how an emergency shutdown have to be done,*

- *what happens when emergency shutdown, is activated. (electricity / gas supply) and*
- *which events will activate the emergency shutdown (fire, leakage).*

## Chapter 7 Quantifying of RISK

Quantifying of the residue hazards, Risk matrix.

To illustrate the overall risk, compared to the risk assessment, each activity is plotted with values for the probability and consequence into the matrix. Use task IDnr.

Example: If activity IDnr. 1 has been given a probability 3 and D for consequence the risk value become D3, red. This is done for all activities giving them risk values.




In the matrix are different degrees of risk highlighted in red, yellow or green. When an activity ends up on a red risk (= unacceptable risk), risk reducing action has to be taken

### RISK MATRIX

| CONSEQUENCE | (E) Catastrophic  | E1 | E2 | E3 | E4 | E5 |
|-------------|-------------------|----|----|----|----|----|
|             | (D) Extensive     | D1 | D2 | D3 | D4 | D5 |
|             | (C) Moderate      | C1 | C2 | C3 | C4 | C5 |
|             | (B) Negligible    | B1 | B2 | B3 | B4 | B5 |
|             | (A) Insignificant | A1 | A2 | A3 | A4 | A5 |

|  |  |                    |              |              |            |                    |
|--|--|--------------------|--------------|--------------|------------|--------------------|
|  |  | (1) Rare           | (2) Unlikely | (3) Possible | (4) Likely | (5) Almost certain |
|  |  | <b>PROBABILITY</b> |              |              |            |                    |

The principle of the acceptance criterion. Explanation of the colors used in the matrix

| COLOUR |   | DESCRIPTION  |
|--------|---|--|
| Red    |  | Unacceptable risk Action has to be taken to reduce risk      |
| Yellow |  | Assessment area. Actions has to be considered                |
| Green  |  | Acceptable risk. Action can be taken based on other criteria |

## ATTACHMENT J PROCEDURES FOR NANOIGNITE (SINTEF 2021)

CH<sub>4</sub> gassalarm:

- HØY: Evakuer rom
- LAV: Steng CH<sub>4</sub> tilførsel, evakuer rom

Tap av ventilasjon (oransje varsellampe):

- Steng CH<sub>4</sub> tilførsel

Brannalarm:

- Steng CH<sub>4</sub> tilførsel og evakuer bygningen

Generelle sikkerhetsrutiner:

- Bruk vernebriller

CNT-håndteringsprosedyrer:

- All CNT-håndtering foregår i hanskeboks.
- Bruk engangshansker inni "hanskebokshansker".
- CNT skal til enhver tid ikke være åpent tilgjengelig i laben.
- Ved søl i laben skal verneutstyr brukes. Heldekkende drakt, vernebriller, maske og engangshansker. Innkjøpt støvsuger med HEPA-filter kan brukes for å grovrengjøre. Finregjøring gjøres med en våtservietter.
- Avfall med CNT samles i egen pose og avhendes.
- Ved eksponering av CNT på hud vaskes hud godt med såpe og vann.
- Maske skal brukes ved åpning av hanskeboks.
- Rengjøring av hanskeboks skal foregå med beskyttelsesutstyr på. Dette bør gjøres regelmessig avhengig av hyppighet av bruk.
- Generell rengjøring av hanskeboks skal gjennomføres etter hver bruk, og avfall skal tømmes regelmessig.

Kjøring av forbrenningskammer:

Fylleprosedyre:

- Åpne ventil for komprimert luft og gasstilførsel av CH<sub>4</sub> og syntetisk luft montert på veggen.
- Still inn alle regulatorer til 6 bar montert på veggen.

- Sørg for at V1 ventil er stengt.
- Åpne Labview program.
- Still inn Flush time, equivalence ratio, initial pressure, hold times.

#### Antenningsprosedyre:

- Sørg for å sitte bak beskyttelsesskjerm.
- Velg antenningsmetode.
- Ved bruk av Spark plug antenning må ventil V2 stenges før antenning.
- Ved bruk av CNT-antenning må ventil V2 stenges før antenning.
- Etter antenning velges flush i labview, som åpner ventil for komprimert luft og eksos.

#### Avslutte forsøk:

- V1 ventil åpnes.
- Regulatorer stilles til 0 bar.
- Ventiler for CH4 og syntetisk luft stenges.

#### Rengjøring av forbrenningskammer:

- Utfør forbrenningsforsøk uten injeksjon av CNT 3 ganger.
- Flush gjennom kammeret tilstrekkelig.
- Bruk verneutstyr: heldekkende drakt, vernebriller, maske og engangshansker.
- Rengjør ved å bruke støvsuger og våtservietter.



Organisatorisk enhet SINTEF Energi/Termisk energi/Bioenergi

Lokasjon C086

Utstyr / Aktivitet Nanoignite

| Delaktivitet   | Mulig uønsket hendelse   | Eksisterende barrierer   | Risikoverdi med eksisterende tiltak |            |         |                     |
|--|--|--|-------------------------------------|------------|---------|---------------------|
|  |  |  | Personlig                           | Ytre miljø | Økonomi | Økologi / materiell |
| Forbrenning av metan i kammer med tennplugg eller CNT/lys. | Vinduer på kammer kan sprekke. Åpen flamme. Høy lyd. Splinter fra vindu.   | Operatør sitter på avstand bak pleksiglass, med vernebriller og hørselsvern. Operasjon er automatisert via Labview. Vinduer sjekkes regelmessig for skader. Vinduer er dimensjonert til forventede trykk/temperatur som oppnås.              | B1                                  |            |         |                     |
| Gasslekkasje metan   | En lekkasje kan føre til personskade i form av brannskade.   | Metandetektor installert.  | B2                                  |            |         |                     |
| Gasstilførsel av metan                                     | Brann i rom  | Metanrør som ledes til kammeret er i stål og fleksibelt rør med brannisolasjon (anbefalt av swagelok).   |                                     |            |         | B1                  |
| CNT eksponering  | Høy eller moderat eksponering av CNT over lengre tid kan føre til senskader.   | CNT håndteres aldri i det åpne rom. Hanskeboks benyttes til all direkte håndtering. Små mengder benyttes. Ventilasjon i rommet vil gjøre at det ikke akkumuleres CNT i lufta. Regelmessig renhold av gulv og overflater vil bli gjennomført. | A1                                  |            |         |                     |
| Bruk av CNT i kammer                                       | CNT som luftes ut av kammeret vil alltid gå via et filter som skiftes regelmessig. Den filterte avgassen går i ventilasjonen. Mengden CNT i avgassen før filter er antatt å være svært lav siden den gjennomgår forbrenning før kammeret evakueres, og fordi mengden CNT per forsøk er svært lav, ca 100 mg. |  | A1                                  | A1         |         |                     |

Figur 1: Risk assessment at Sintef for Nanoignite activity.

