LAUNCH SAFETY AGREEMENT

SYSTEM SAFETY ASSESSMENT

WP 5: TCLD

Abstract

The main function of the TCLD collimators is to improve the local collimation cleaning in the dispersion suppressor (DS) regions. Four TCLD will be installed in the DSs around IP2 and IP7.

They are designed, operated and maintained at CERN. They are built in the industry.

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Version History

List here all versions, including internal drafts:

Version	Date	Changes
0.1	2018-01-31	Very First Draft
0.2	2018-05-04	Several updates
0.3	2018-08-01	Several updates
0.4	2018-11-28	Update following the mSi evaluation by HSE-OHS and the meeting on 23/11/2018
0.5	2019-02-08	Update of chapter 4, and revised version to take into account the new TCLD locations, update of approvers list
0.6	2019-02-25	Addition of the noise hazard and ODH hazard in LSS2, Correction of EDMS number of transport procedure.
0.7	2019-04-10	Integration of comments from C. Adorisio, S. Redaelli, L. Dassa, Y. Loertscher
0.8	2019-04-18	Integration of comments from S. Gilardoni
0.9	2019-04-30	Rephrasing of hazard 2.1
1.0	2019-05-14	Document approved

1 DESCRIPTION OF THE SYSTEM

TCLD collimators will improve the collimation system by reducing the local collimation cleaning efficiency in the DSs.

- The main functions of the collimation system are:
    - Efficient cleaning of the beam halo;
    - Minimization of the halo background in the particle physics experiments;
    - Passive protection of the machine aperture against abnormal beam loss;
    - Cleaning of the physics debris around collisions points

- Breakdown of the system in subsystems, assemblies or equipment relevant for this document:

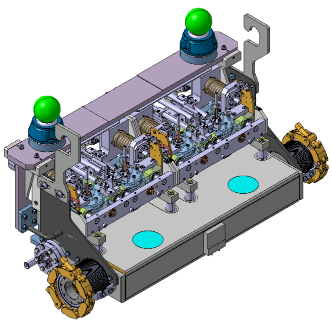


Figure 1: General overview

Figure 2: Prototype TCLD installed on the cryo-bypass (surface workshop)

- Collimation system
    - Vacuum Tank
        - Bellow and shaft assembly
    - Mechanical Table
        - Screw Roller Assembly
        - Pinion Assembly
        - Electrical Switches
    - Left equipped jaw
        - Left brazed jaw Assembly
        - RF Screen Assembly
        - RF Finger Assembly
        - Probe spring support
        - Beam Position Monitoring System
    - Right equipped jaw
        - Right brazed jaw Assembly
        - RF Screen Assembly
        - RF Finger Assembly
        - Probe spring support
        - Beam Position Monitoring System

- Where is it installed ?
    - 4 TCLDs will be installed in the DSs around IP2 and IP7 as a part of the HL-LHC collimation upgrade (1 TCLD per beam per DS for a total of 4 collimators).

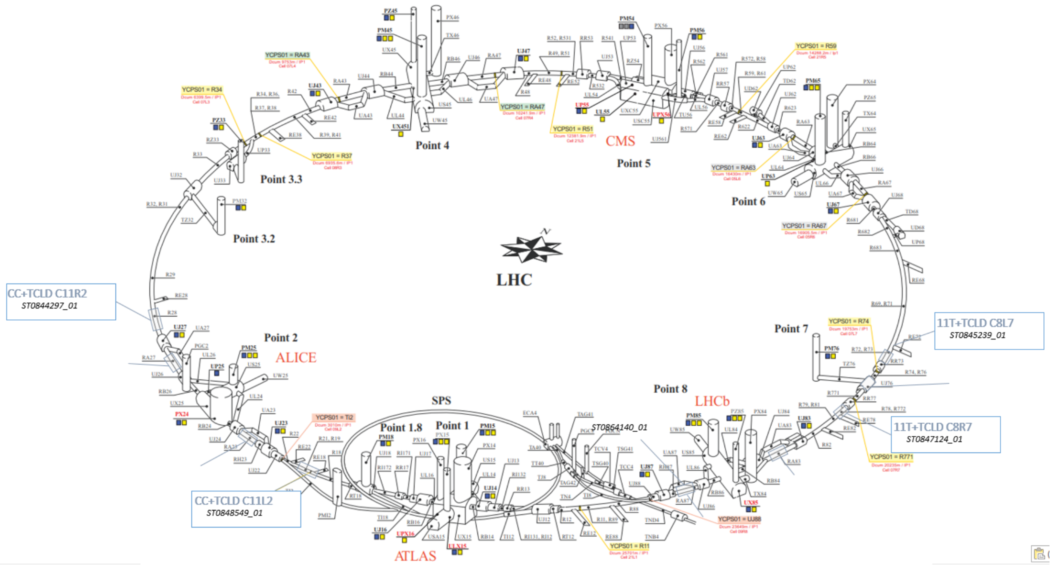


Figure 3 – Location of TCLD collimators for LS2

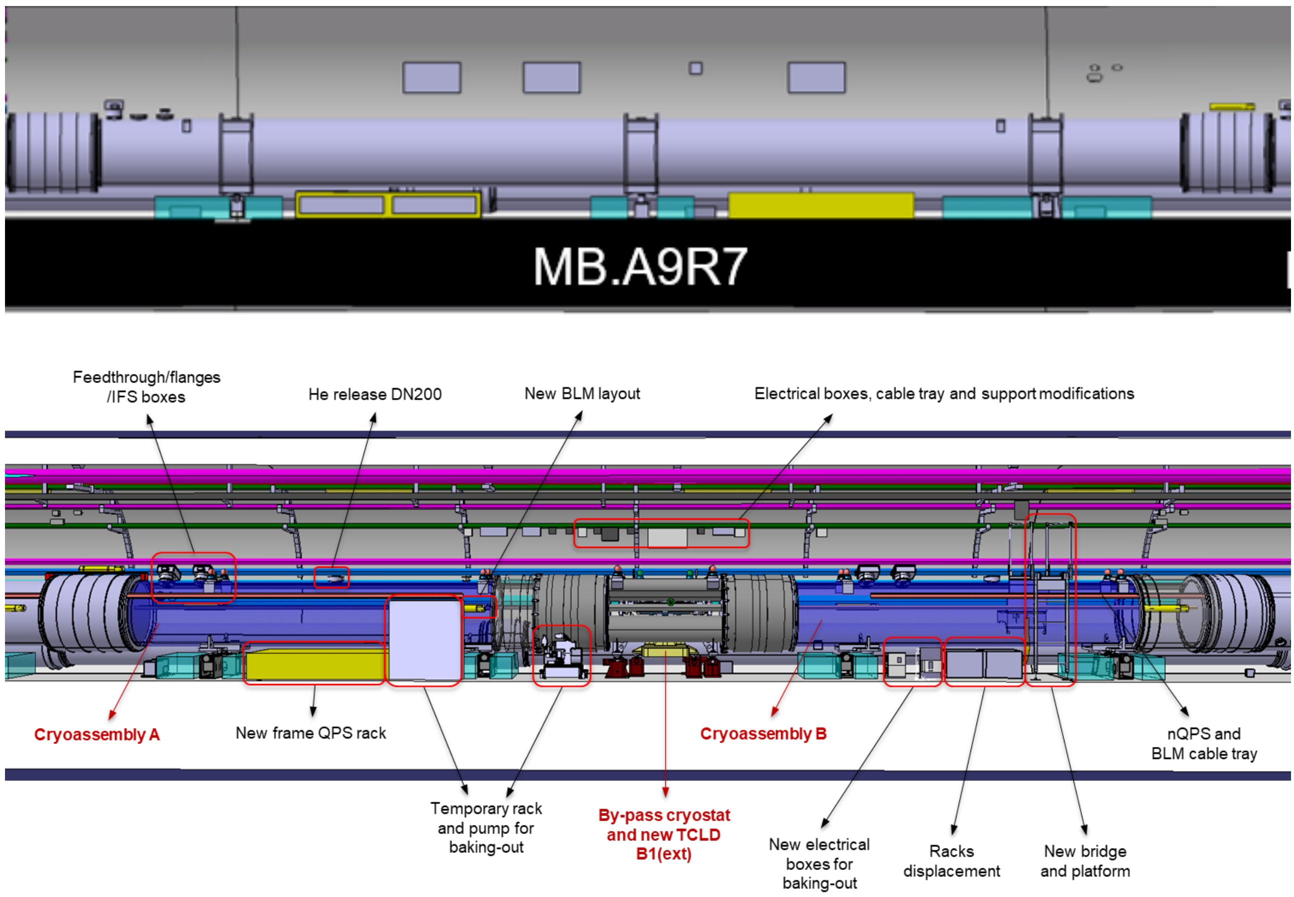


Figure 4 - Top: present layout in R7. Bottom: RUN 3 configuration in R7 (new 11T+TCLD)

- Which organic unit / collaboration partner / industry will be in charge of design, construction, installation, operation and maintenance ?

Lifecycle	Organic unit / collaboration partner / industry
Design	CERN: EN-MME
Construction	Industry: STRUMENTI SCIENTIFICI CINEL S.R.L.
Installation, operation and maintenance	CERN (EN-STI, BE-OP)

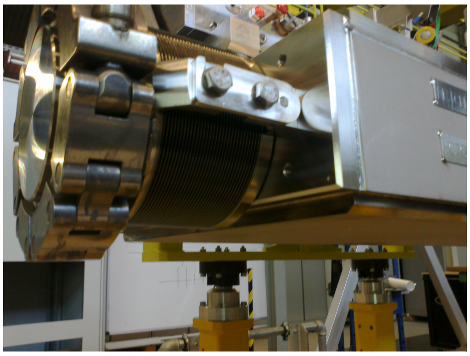
- What equipment, substances, activities characterise the use of the item during the phases of installation, operation, maintenance, dismantling ?

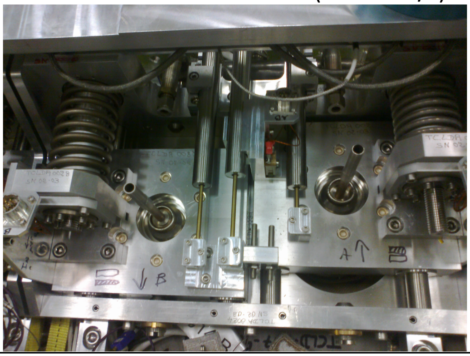
Lifecycle	Equipment, substances, activities involved
Installation	• Transport ○ Pal finger + Palonier + Trolley ○ Installation procedure [3] ○ A bridge over the beam line and a platform over the QRL will be installed at R7. The structural analysis is available in [4]. • Equipment ○ Water connectors ○ Bake out equipment ○ Heating jackets ○ Pumping groups • Survey ○ Survey-laser tracker ○ Survey operations
Commissioning	• Local + check list • Bake-out • Remote
Operation	• Remote from CCC
Maintenance	• Mechanical tools A risk assessment [5] will help define the cryogenic conditions depending on maintenance activities.
Dismantling/ Removal	• A risk assessment [5] will help define the cryogenic conditions to exchange the TCLD.

2 HAZARDS TABLE

The “SBP”column lists the Standard Best Practice. Numbers in the from 5.n.m. refer to chapter 5 of the document **“Safety Requirements for HL-LHC hardware systems , EDMS Nr. 1827925 Ver. 1.0 of 13/11/2017**.

	Hazard	SBP	Details and description of the mitigation measures S = Measure in order to **Suppress** the danger T = **Technical** protection measure O = **Organizational** measure P = **Personal** protection measure	**Further actions** If a risk analysis required, indicate yes and complete chapter 4
1.	**Physical Hazards**			
1.1	Field, electrical	5.8.5.	During operating time. **Technical** protection measure : The fixed support is discharged to the ground.	No
1.2	Temperature: Heat radiation		During bake out Mitigation measures taken by the vacuum group as part of their standard activities	No
1.3	Temperature: Surface, hot		During bake out Given that the cold bore of the 11 T will be heated up by conduction through the cold-warm transition during bake-out, a risk assessment should define the safety measures to prevent a He leak. Cf. [10]	A risk assessment [5] evaluates if the bake out can be done with the adjacent magnets at cryogenic temperatures. See chapter 4.2 below
1.4	Noise (Workplace)	5.11., 5.14.2.7	When the jaws are moved manually, there is no noise. When the jaws are moved by the motors, the sound of the motors is audible and remains inferior to 70 dB(A) [18]	No
1.5	Motor voltage level		230V, Current per phase 0-4 Amps rms **Design** protection measure: IP22 min. required **[11]** **Technical** protection measure: The equipment has been developed with CERN and has become standard for CERN collimators. **Organizational** measure: Lock-out procedure [6]	No
2	**Radiation, ionising**			
2.1	Activated solids	[1,2]	The expected activation in Point 2 will be mainly caused during the ion runs. The activation of the collimators in Point 7 will be different since they will be used also during proton runs.	No

<table>
<tr><th colspan="2">Hazard</th><th>SBP</th><th>Details and description of the mitigation measures
S = Measure in order to Suppress the danger
T = Technical protection measure
O = Organizational measure
P = Personal protection measure</th><th>Further actions
If a risk analysis required, indicate yes and complete chapter 4</th></tr>
<tr><td>3</td><td>Mechanical Hazards</td><td>5.3.</td><td></td><td></td></tr>
<tr><td>3.1</td><td>Pressure equipment (PS > 0.5barg)</td><td>5.3.1</td><td>Cooling pipes and manifold for demineralised water. Internal Diameter ~ 23.7 mm, Service pressure ~15 bar.
Design measure: By design the manifold is conforming with SSI-M-2-4. Cf. [7]</td><td>No.</td></tr>
<tr><td>3.2</td><td>Fluid under pressure</td><td>5.3.1</td><td>Demineralised water, supplied from the LHC demineralised water distribution.</td><td>No</td></tr>
<tr><td>3.3</td><td>Machinery</td><td>5.3.3</td><td><u>Motorised jaws</u>
Suppress the danger: the collimator is delivered at CERN with the tank closed. The inner part of the tank is not accessible anymore.

<u>Springs to move the jaws</u>
Suppress the danger: The springs are located behind the motors. It is very difficult to access them.
Organisational measure: installation procedure [3]

<u>Motorised mechanical table</u>
The table has a slow motion (~1.5 mm/s)
</td><td>Yes, see chapter 4.1 below</td></tr>
</table>

	Hazard	SBP	Details and description of the mitigation measures S = Measure in order to **Suppress** the danger T = **Technical** protection measure O = **Organizational** measure P = **Personal** protection measure	Further actions If a risk analysis required, indicate yes and complete chapter 4
			Technical protection measure: Its movement is limited to be slow and access is protected by a bar. The mechanical table is located towards the beam line, not on the passage side. 	
3.4	Oxygen deficiency		- Given that the cold bore of the 11 T will be heated up by conduction through the cold-warm transition during bake-out, a risk assessment should define the safety measures to prevent a He leak. Cf. [10] - Interventions on the TCLD when cold adjacent elements are at cryogenic temperatures require an assessment to define the conditions to prevent a He leak.	The risk assessment [5] will define the cryogenic conditions for regular maintenance, bake out, collimator installation and exchange. See chapter 4.2 below
3.5	Dangerous surface	5.3.3.	Due to sharp edges (low hazard) **Technical** protection measure: All sharp edges are protected by a plate	No
4	**Electrical Hazards**	**5.7**		
4.1	Electrical contact, indirect	5.7	During operating time. **Design** protection measure: IP22 min. required **[11]** **Technical** protection measure: The fixed support is connected to ground. **Organizational** measure: Lock-out procedure [6]	No
4.2	Electrostatic phenomena	5.7	Electric logging **Technical** protection measure: The fixed support is connected to ground.	No

Hazard		SBP	Details and description of the mitigation measures S = Measure in order to **Suppress** the danger T = **Technical** protection measure O = **Organizational** measure P = **Personal** protection measure	**Further actions** If a risk analysis required, indicate yes and complete chapter 4
5	**Working Environment**			
5.1	Limited stay area		Installation, maintenance and dismantling in a limited stay radiation area **Technical** protection measure: remote handling, quick connection **Organizational** measure: workers are habilitated to work in the LHC tunnel, work and dose planning to be prepared, optimization to be evaluated	In the framework of LS2 activities, the work package analysis for collimation activities (EDMS 2006148) addresses installation activities.
5.2	Climate in closed environment	5.6., 5.12.	Installed into the LHC tunnel **Organizational** measure: workers are habilitated to work in the LHC tunnel	
5.3	Insufficient lighting	5.12.1.	Installed into the LHC tunnel	
5.4	Oxygen deficiency		Hazard present in LSS7 and LSS2 **Organizational** measure: workers are habilitated to work in the LHC tunnel	
6	**Physiological Constraints**			
6.1	Manual lifting and handling	5.14.2.6.	During transport EN-HE develops specific handling tools for the TCLD. The safety documentation is available on EDMS [12]. **Suppress** the danger : Use transport service and Pal finger + specific Palonier (shorter than the one usually used) + Trolley are CE marked. The specific lifting equipment are delivered by WP17.7. **Organizational** measure: - Transport instructions for Pal Finger [17] - Specific TCLD installation procedure, including conditions for access to the QRL side [3]	See chapter 4.3 below
6.2	Movement under constraint	5.12.	During commissioning, work under the beam line is necessary. **Organizational** measure: working time is optimized by design (plug and play connectors)	No
7	**Unexpected events**			
7.1	Loss of cooling		In case of leak. **Technical** protection measure: Online monitoring by T° sensor	No
7.2	Loss of power		In case of lack of electrical supply. This event has no impact on safety.	n.a.

	Hazard	SBP	Details and description of the mitigation measures S = Measure in order to **Suppress** the danger T = **Technical** protection measure O = **Organizational** measure P = **Personal** protection measure	Further actions If a risk analysis required, indicate yes and complete chapter 4
7.3	Rupture of mechanical device		Due to long working time (fatigue). **Technical** protection measure: Preventive replacement of the components identified as likely to be broken (Roller Screw). A campaign to validate other suppliers started in 2017.	No
8	**Organisation**			
8.1	Constraining schedule		Depending on commissioning activities into the tunnel. **Organizational** measure : Co-activities scheduled by planning.	No
8.2	Lack of collaborator participation		Whenever another equipment group participation is needed. **Organizational** measure: Co-activity meeting organized every week.	No

3 DECISION ON MAJOR SAFETY IMPLICATION

Parts of the TCLD are moved by electrical force and the TCLD will not be delivered with the CE marking [13]. Therefore, based on the review of the HSE Safety experts, the HSE Unit classifies the installation/equipment/hardware system as :

☐ standard

☒ liable of having major Safety implications (mSi) and therefore needs a HSE Safety Clearance before operation.

The memorandum of safety checks issued by HSE-OHS is available on EDMS [9].

4 RISK MANAGEMENT

This chapter documents the risk assessments for the TCLD collimators.

4.1 Risk assessment for machinery

- For **machinery safety**, the following risks have been evaluated based on HSE risk matrix [15] :

Source	Motorised mechanical table	Motorised mechanical table	Angular or sharp edges	Falling objects
Possible consequences	Crushing or shearing of extremities	Crushing or shearing of extremities	Cutting or severing	Crushing
Mitigation measures	<u>During transport</u> The table is fixed with screws to block the movement. <u>Local control</u> EN-STI engineers may locally operate the collimators. This is as part of the commissioning activities or during maintenance. Experts are onsite and the risk for a nearby worker to be injured by the jaw is inexistent. Experts have their procedure to test and commission their system.	<u>Remote control</u> The collimators are remotely piloted from the CCC. Access to the table is protected by a plate, and there is no space for the fingers to access the springs. 	All sharp edges are protected by a plate	<u>During transport</u> Transport and installation done by EN-HE experts. EN-HE use CE marked lifting equipment Transport instructions are available ([17] and [3])
Probability after implementation of mitigation measure	1	1	1	1
Severity after implementation of mitigation measure	B	B	A	B
Final risk evaluation [15]	B1 - Acceptable	B1 - Acceptable	A1 - Acceptable	B1 - Acceptable

All identified hazards related to machinery are deemed acceptable, therefore no further action needs to be taken. [15]

4.2 Risk assessment for cryogenic hazards (incl. ODH)

Cryogenic hazards may have several origins :

- During bakeout:
  - heat up of cryogenic components located nearby the TCLD in Points 2 and 7 due to thermal conduction or an accidental direct contact between magnet components and bakeout elements
  - the thermal radiations from the bakeout jackets will generate a heat flow that is likely to overtake the cryogenic capacity of the bypass cryostat.
- The regular maintenance such as the replacement of sensors, switches and cables of the TCLD collimators may generate mechanical and cryogenic hazards.
- An exceptional replacement of a TCLD collimator during run periods may lead to mechanical damage to the surrounding Connection Cryostats or the bypass cryostat and result in a cold jet of Helium.

Risk mitigation

The risk assessment to define the **cryogenic conditions** for regular maintenance, bake out and collimator installation and exchange is available in [5].
This document lists the control measures to implement to reduce the risk to an acceptable level.

4.3 Lifting equipment conformity

- The specific **lifting equipment** provided by WP17.7 undergo HSE-OHS verification of conformity.

	Equip/Tooling	ST number	HE-HH code	CDD Drawing	EDMS	Manufacturer
TCLD	Mobile crane	ST1055805_01	CRCH-00678	-	-	Palfinger
	Spreader	ST0893588_01	CRR-02762	LHCHHCTC0060	-	Mona Lifting

4.4 Conclusions

All risks (machinery, mechanical, cryogenics, etc.) can be reduced to an acceptable level, either by design, conformity compliance or by implementing the risk control measures arising from the specific risk assessment [5].

5 SAFETY INFORMATION MANAGEMENT

- **Design documents** and general technical information on the TCLDs can be found in WP5 EDMS folder [8].
    - Overall manufacturing drawings of the collimator and sub-assemblies, manufacturing procedures, manufacturing records, and inspections and test procedures.

Information	EDMS link
Engineering drafts & notes	https://edms.cern.ch/project/CERN-0000096386
Fabrication, Assembly and Verification drafts & notes	https://edms.cern.ch/project/CERN-0000170013
Manufacturing and Inspection Plan	https://edms.cern.ch/document/1832254
Technical specification for Manufacturing and Supply of LHC Collimators: IT-4272	https://edms.cern.ch/document/1821032/

- **Specific information and reports** for each collimator is available in its MTF folder including a structure of the main collimator sub-assemblies, commercial components, material certificates and reports of tests performed along the production.

Equipment name / MTF link	Slot name
HCTCLDA001-CZ000001	TCLD.11L2.B2
HCTCLDA001-CZ000002	TCLD.11R2.B1
HCTCLDA001-CZ000003	TCLD.9L7.B2
HCTCLDA001-CZ000004	TCLD.9R7.B1

- **Instruction manual**
    - Description of the machine: available in the design documentation
    - Installation and transport procedure: [3]
    - Maintenance requirements
        - Maintenance procedure [16]
    - Replacement or dismantling - instructions included into procedure [3]
    - Shipment to waste: according to the CADRA procedure [14]

6 REFERENCES

[1] EDMS 1741285, HL-LHC Radiation Protection Guideline for Cobalt content in Stainless Steel, Cristina Adorisio

[2] EDMS 1836097, HL-LHC - Cobalt content in Stainless Steel contribution to H*(10) [sensitive], Cristina Adorisio

[3] EDMS 2065159, Installation procedure

[4] EDMS 2061080, Bridge and platform structural analysis

[5] EDMS 1969909, TCLD bake out and exchange Failure Mode Effect Analysis study

[6] EDMS 1570532, LHC Collimators – Collimator electrical Lock-out, J. Lendaro

[7] EDMS 1789301, Cooling circuit manifold - safety requirement, L. Gentini

[8] WP5 EDMS folder - https://edms.cern.ch/project/CERN-0000096386

[9] EDMS 2051202, Memorandum of Safety Checks - TCLD collimation system, C. Arregui

[10] EDMS 1881779, TCLD bakeout discussion, P. Santos Diaz

[11] EDMS 625158, Supply of Radiation Hardened stepping motors and contactless resolvers for the LHC Collimation Project, R. Losito

[12] WP17.7 EDMS folder for WP5 handling tools - https://edms.cern.ch/project/CERN-0000177585

[13] DIRECTIVE 2006/42/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 17 May 2006 on machinery

[14]EDMS 1364231, Critères internes au CERN pour l'acceptation des déchets radioactifs (CADRA), L. Bruno

[15] HSE Unit, "Safety Guideline OHS-0-0-1 - Risk Assessment", EDMS 1114042

[16] EN-SMM, Maintenance procedure (In work)

[17] EDMS 1065796, Échange d'un collimateur avec la remorque-grue PALFINGER, Jean-Louis GRENARD

[18] EDMS 2089765, Mesure de bruit dans le bâtiment 272, Jordan Cumin