BNL

HL-LHC Accelerator Upgrade Project

**Hazard Analysis Document**

**July, 2018**

**Approvals:**

**HL-LHC Accelerator Upgrade Project**

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P. Wanderer date

HL-LHC AUP Project Manager

**Brookhaven National Laboratory**

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**Table of Contents**

[1.0 Introduction 1](#_Toc234983269)

[2.0 Methodology 2](#_Toc234983270)

[3.0 Results and Assessments 3](#_Toc234983271)

[3.1 BNL Construction Activities to Support HL-LHC AUP 4](#_Toc234983272)

[3.1.1 Mechanical Hazards During Construction 4](#_Toc234983273)

[3.1.2 Electrical Hazards During Construction 4](#_Toc234983274)

[3.1.3 Static Magnetic Field Hazards 4](#_Toc234983275)

[3.1.4 Industrial Hygiene 5](#_Toc234983276)

[3.1.5 Cryogenics and Oxygen Deficiency Hazards 5](#_Toc234983277)

[3.1.6 Waste Handling, Storage and Disposal 5](#_Toc234983278)

[3.2 Decontamination and Decommissioning 6](#_Toc234983280)

[4.0 Conclusions 6](#_Toc234983281)

[5.0 Hazard List 7](#_Toc234983282)

[6.0 Hazard Analysis Worksheet 8](#_Toc234983283)

[7.0 References 11](#_Toc234983284)

8.0 Attachments ……………………………………………………………………………………….

 JRA-HL-LHC AUP-01, “Preparation and Loading of Typical HL-LHC AUP Magnet for Shipping”

JRA- HL-LHC AUP -02, “Electrical Assembly of HL-LHC AUP Magnets after coils are wound and prior to Magnet Testing”

JRA- HL-LHC AUP -03, “Managing Cryogenic Operations for Exp.Testing of HL-LHC AUP Magnets – Horiz. Test Facility”

 JRA- HL-LHC AUP -04, “Potting and Winding Coils”

 JRA- HL-LHC AUP -05, “Provide Cryogenic Argon for Coil Curing Gaseous Purge”

 JRA- HL-LHC AUP -06, “Magnetic Field Work for HL-LHC AUP Coils/Magnets”

# Introduction

There is no higher priority at Brookhaven National Laboratory (BNL) than safety.  It is the policy of the Laboratory to protect the environment and all persons, be they employees or visitors, from accident or injury while they are on site.   HL-LHC AUP is neither managerially nor fiscally responsible for the commissioning and operation of the accelerator at CERN, for which HL-LHC AUP is supplying components. Therefore the applicability of safety plans to HL-LHC AUP and identification and mitigation of hazards by HL-LHC AUP is limited to the construction of the components provided by HL-LHC AUP. BNL has experience building components similar to those being constructed for HL-LHC AUP, and has existing safety management systems.

At Brookhaven National Laboratory, the Safety and Health Services Division (SHSD) within the ESH&Q Directorate provides support in the areas of Safety Engineering (SE), Industrial Hygiene (IH), Integrated Safety Management Systems (ISMS), and Chemical Management Systems (CMS). Subject matter related to BNL safety is available in the SHSD Standard Operating Procedures and Standards-Based Management Systems (SBMS) Subject Areas.

The goal is to demonstrate that there is reasonable assurance that operations can be conducted in a manner that will limit risks to the health and safety of employees and the public and will adequately protect the environment. This BNL Hazard Analysis Document serves to identify typical hazards inherent in the BNL work required for HL-LHC AUP. Hazards specific to individual tasks will be addressed by a specific Job Risk Analysis for each major task including an analysis, job site walk down, pre-job briefing, post-job review, and work planning. Copies of the planned activity JRAs are attached in the Appendices.

It is important to note that the Hazard Analysis is not an evaluation of the actual risk from HL-LHC AUP construction activities, but is an evaluation of the hazards which might be encountered in such a construction project, in the absence of the engineered mitigations. Only passive mitigations are to be taken into account in evaluating the different hazards identified; it is to be assumed that engineered mitigations such as alarms, detectors, interlocks, ventilation, and operational procedures are all inoperative or compromised.

In Sections 2 and 3, the hazard identification and assessment methodology used is described, and the results of applying the process to the HL-LHC AUP project are detailed. Only local consequences for HL-LHC AUP activities at Brookhaven were considered; the off-site construction/assembly activities will be assessed according to the best practices and ES&H frameworks of the vendors and/or institutions involved. Section 4 presents the conclusion that HL-LHC AUP construction is characterized as low hazard.

# Methodology

The methodology used was selected to provide a uniform and thorough process for identifying and assessing the hazards present to personnel and the environment. The process consisted of three steps:

1. Development of a list of potential significant hazards.
2. Assessment of the HL-LHC AUP construction plans for the presence of these potential hazards.
3. Assessment of the probability for a possible mishap or equipment failure and the severity of the consequences.

Each of the three steps is described further below.

Detailed lists of potential hazards that may be encountered while performing work such as that in HL-LHC AUP were obtained from the Brookhaven SHSD Hazard List and the SMD historical record for previous design and construction of similar magnets. [Refs. 1&2] These analyses are based on the hazards present on the site and relevant statutory requirements, external and internal standards to be followed in order to mitigate these hazards. A list of potentially significant hazards was then prepared from these master lists for use in assessing the HL-LHC AUP project. Hazards that are only of a magnitude and type routinely encountered and/or accepted by the general public were not included nor were hazards that are mitigated by code compliance (National Electrical Code, International Building Code, etc.) or by OSHA compliance. The resulting potential hazard list is included here as Attachment A; it contains primarily risks that follow from the unusual technical aspects of the construction of a complex instrument.

The deliverables of the HL-LHC AUP project carried out at Brookhaven, consist of fabricating, and testing one D1 magnet and one D1 cold mass, both with 8 cm aperture. The scope of HL-LHC AUP is to fabricate, and ship the above deliverables to CERN. Completion is defined as acceptance of the deliverables and documentation by CERN.

# Results and Assessments

The results of the second step in the Hazard Analysis methodology, hazard identification, are presented in Table 1 using a matrix of hazard type versus HL-LHC AUP Subproject activity. During HL-LHC AUP construction, one can expect to encounter mechanical hazards, electrical hazards, fire hazards, oxygen deficiency hazards, cryogenic hazards, flammable material hazards, toxic material hazards and static magnetic field hazards.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  **WBS Number** | **WBS Description** | **Mechanical Hazards** | **Leak & Spill Hazards** | **Electrical Hazards** | **Fire Hazards** | **Oxygen Deficiency Hazards** | **Cryogenic Hazards** | **Impact Hazards** | **Radiation Hazards** | **Flammable Material** | **Toxic Material Hazards** | **Environmental Hazards** | **Magnetic Field Hazards** |
| **1.0** | **Management****Management support (financial & budget), travel, workshops, review preparation** |  |  |  |  |  |  |  |  |  |  |  |  |
| **2.0** | **Winding and Curing, Reaction, Impregnation, MQXFA Magnet Assembly, MQFXA Vertical Test, Coil Handling and Shipment** | **X** |  | **X** | **X** | **X** | **X** | **X** |  | **X** | **X** |  | **X** |

Table 1

The next step in the analysis involves ranking these hazards by assessing various risks related to environment or safety and health activities. Classification of the identified hazards was documented using a Hazard Analysis worksheet. Each identified hazard was characterized according to hazard type, mishap consequences, and initiating event. Assignment of a risk ranking in accordance with the guidance of the BNL SBMS Hazard Analysis Subject Area was done in consultation with the SMD staff and matrixed ES&H Support. Also included are descriptions of the installed hazard mitigation measures, both passive and active (engineered). In the risk ranking procedure, credit will only be taken in the assessment for all passive mitigation features, but the active mitigations planned are included for completeness. The set of Hazard Analysis worksheets is included as Attachment B. The specific Job Risk Assessments applicable to the HL-LHC AUP work are included in the Appendices.

## BNL Construction Activities to Support HL-LHC AUP

Safety and health hazards associated with superconducting magnet design and construction that have been encountered historically at BNL have been considered in analyzing the hazards for HL-LHC AUP construction. A hazard analysis was conducted as part of the job planning process to evaluate the hazards to personnel during the construction and testing of these components and to identify the means to mitigate the hazards.

### *Mechanical Hazards During Construction*

Construction of the magnets will involve transporting, lifting, moving, positioning, and assembly of some large, heavy, and awkward components.

### *Electrical Hazards During Construction*

Testing of the magnets and will require hipot tests and operation of high current power supplies. Existing test equipment and facilities used routinely for this purpose will be used at BNL under some existing safety procedures while others will be specifically developed for this project; nevertheless vigilance is required as always.

### *Static Magnetic Field Hazards*

Testing of the magnets will require establishment and measurement of high static magnetic fields where there is a potential for exposure at or above the levels requiring time limits and/or determination of Time Weighted Average exposure levels. Compliance with the BNL SBMS Subject Area guidance on Exposure to Static Magnetic Fields will be enforced.

### *Industrial Hygiene*

Industrial Hygiene issues to be addressed during the construction and testing of HL-LHC AUP components include handling of cryogenic liquids and working with vacuum systems and vacuum vessels (not at high pressure).

Soldering operations within HL-LHC AUP may contain small amounts of lead in the solder used for assembly. Welding may produce metal fumes. BNL SMD ES&H will evaluate these incidental exposures and advise personnel on any PPE, procedures or training that may be required.

The control of hazards in these categories is addressed through the application of OSHA and other relevant standards, such as ANSI and ACGIH, as well as the BNL OHSAS Program. Hazards in the Industrial Hygiene category can be mitigated by insuring that all personnel working on HL-LHC AUP construction have received the applicable Brookhaven safety training for their assignments.

### *Cryogenics and Oxygen Deficiency Hazards*

The magnet and cold powering equipment testing activities for the HL-LHC AUP project will use liquid helium. Testing infrastructure for these cold tests exists at the testing facilities at BNL. Established controls at BNL-SMD for Cryogenic and ODH Hazards, based on SBMS Subject Area guidance, will be implemented and enforced.

### *Waste Handling, Storage and Disposal*

For many years, Brookhaven has been carrying out comprehensive programs for the handling, storage, and disposal of hazardous chemical wastes. The controls associated with waste handling, storage and disposal are described in the Brookhaven SBMS Subject Area on Hazardous Waste. No radioactive wastes will be generated by the HL-LHC AUP construction. Small amounts of hazardous chemicals may be generated, and disposal will be handled according to the BNL SBMS Subject Area and associated SMD Procedure.

## Decontamination and Decommissioning

Equipment provided by HL-LHC AUP to CERN will become property of CERN. Therefore HL-LHC AUP will not be directly responsible for decontamination and decommissioning.

Conclusions

It is the intent of the HL-LHC AUP project management that the technical and scientific goals of the project be achieved in a safe and environmentally sound manner. This document summarizes the variety of potential ES&H hazards that can be encountered in the construction and testing of the HL-LHC AUP Project at Brookhaven National Laboratory. The conclusion of the HL-LHC AUP project management is that all major hazards have been identified and can be addressed by the means discussed here and in the references. This document will serve as a basis, for further refining the hazard analysis/job risk assessments included here, so that no unanticipated nor unmitigated risks are encountered during construction or testing.

# Hazard List

The following list is a synopsis of potential hazards that may be associated with operation of the Brookhaven construction project. This list was assembled by consulting Brookhaven SHSD Hazard List documents and by review of the Job Risk Assessments of past projects with similar scopes. The intent is to provide a checklist that ensures potential hazards that might be encountered in high tech facilities and high-energy physics in particular are certain to be identified. The list is in no way intended to substitute for a thorough on-site facility inspection; it serves as a catalogue of watchful experience and "mind jogging" alerts.

**Mechanical Hazards**

Moving large awkward heavy equipment

Handling large awkward heavy components.

**Thermal Energy**

High temperature equipment

Vacuum pumps

**Kinetic Energy**

Power tools and equipment

Movement of large objects

Overhead structures and equipment

motor generator equipment and

Flywheels

**Potential Energy**

Crane operations

Compressed gases

Vacuum/pressure vessels

**Flammable/Combustible Materials**

Wire insulation

Cable insulation and jackets

Flammable liquids

Combustible liquids

**Toxic Materials**

 Chemical agents

 Lead and other heavy metals

**Fire Hazards**

 Combustible Liquids

 Combustible Materials PVC

**Oxygen Deficiency Hazard**

Cryogenic system in use in test areas

**Cryogenic Hazards**

Cryogenic system in use in test areas

**Magnetic Field**

Magnet testing

**Electrical Hazards**

High current electromagnets

Energized electrical equipment

# Hazard Analysis Worksheets

**Risk Assessment Calculations for Risk Assessments**

**Risk Scoring System for Job Risk Assessments**

1. Determine the associated point value for Parameters B, C, and D based on the following chart:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Point Value →Parameter ↓ | 1 | 2 | 3 | 4 | 5 |
| Frequency (B) | <once/year | <once/month | <once/week | <once/shift | >once/shift |
| Severity (C) | First Aid Only | Medical Treatment | Lost Time | Partial Disability | Death or Permanent Disability |
| Likelihood (D) | Very Unlikely | Unlikely | Possible | Probable | Multiple |
|

Note: A = # of People: the number of people affected by injury/illness if the event occurs.

B = Frequency: the number of times the activity is conducted per unit of time.

C = Severity: the consequence of the injury/illness if the event occurs.

D = Likelihood: the potential of the negative consequence occurring.

2. Determine the Risk score by multiplying:

**# of People (a) x Frequency (B) x Severity (C) x Likelihood (D) = Risk Score**

3. Calculate the risk with no controls in place, Recalculate the Risk with the existing controls in place, and Recalculate the risks if additional controls are added.

4. Determine the % Risk Reduction if Additional Controls are added by:

**Risk\* AxBxCxD Before Additional Controls (i.e., with existing controls) x 100**

**Risk\* AxBxCxD After Additional Controls**

5. Record each scoring in the following format. (Example: sample data is filled in)

| Without Controls | Before Additional Controls | After Additional Controls |  |
| --- | --- | --- | --- |
| # of People A | Frequency B | Severity C | Likelihood D | Risk\* AxBxCxD | Control(s) | **Stressor** | **# of People A** | **Frequency B** | **Severity C** | **Likelihood D** | **Risk\* AxBxCxD** | Control(s) Added to Reduce Risk | Stressors | # of People A | Frequency B | Severity C | Likelihood D | Risk\* AxBxCxD | % Risk Reduction |
| 2 | 1 | 4 | 2 | 16 | Guard on blade | N | 2 | 1 | 3 | 2 | 12 |  |  |  |  |  |  |  |  |

6. Rank the Risk Score into the appropriate risk group based on the following scale:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| \*Risk: | 0 to 20 | 21 to 40 | 41-60 | 61 to 80 | 81 or greater |
|  | Negligible | Acceptable | Moderate | Substantial | Intolerable |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  **Hazard Type** | **Severity/ Probability** | **Risk** | **Activities / Comments** | **Hazard Mitigation/Safety Procedures** |
| Cuts, Amputation | Marginal / Occasional | Low | Using cutters to cut superconducting cable produces potential amputation; sharp edges of cut cables produce potential for personnel receiving cuts on their hands when handling the cable | Only trained, experienced technicians will use the cutting tools; Personnel will wear leather gloves when cutting and handling the cable |
| Burns | Marginal / Occasional | Low | Soldering and welding produce hot surfaces that could cause a burn if touched | Personnel will wear heavy leather gloves or welding gloves when soldering and welding |
| Fumes | Negligible / Occasional | Routine | Soldering cable and welding during the assembly process will produce metal fumes, the content of which is dependent on types of solder used and materials soldered and/or welded | Soldering and welding will be performed in well ventilated areas; Portable local ventilation units are available if needed; Only qualified welders will be used |
| Flying objects | Marginal / Occasional | Low |  The machining of tooling may produce flying metal chips that could get into the eye | Machine Shop activities will follow Standard Operating Procedures, and SBMS guidance including the use of safety glasses with side shields and brow guards, and machine guards. |
| Magnetic FieldHazard | Marginal /Occasional | Low | Field testing of the magnets at BNL requires generation of high fields potentially exceeding ACGIH exposure limits to individual over extended period of time. | Testing of the magnetic field strength and focus/alignment will follow established procedures with area postings alerting co-located workers to potential hazard. |
| Pressure / VacuumHazards | Marginal /Occasional | Low | Hydrostatic testing of pressure vessels and leak-testing of systems could fail components creating flying metal debris that could penetrate flesh.  | Testing of pressure vessels and leak tests of systems will follow established procedure and be performed by trained and qualified personnel with proper PPE. |

1Risk Codes were determined by using the BNL SBMS Risk Screening Matrix Questions and corresponding table. The table is reproduced on the following page.

# References

 Brookhaven Safety and Health Services Division (SHSD) Hazard List, January 20, 2009

2 **Job Risk Assessments for C-AD and SMD**

**[http://www.c-ad.bnl.gov/ESSHQ/SND/job\_risk\_assessments.htm]**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **PROBABILITY****CONSEQUENCE**  | **FREQUENT**Likely to occur repeatedly in life cycle | **PROBABLE**Likely to occur several times in life cycle | **OCCASIONAL**Likely to occur some time in life cycle | **REMOTE**Unlikely to occur in life cycle but possible | **EXT.REM**.Likelihood of occurrence ~ zero | **IMPOSSIBLE**Physically impossible to occur |
| **CATASTROPHIC**Radiological or chemical exposure causing multiple deaths or serious injury, off-site evacuation, > 100 rem to an individual, > $1,000,000 damage, > 4 mos. Facility downtime, total loss of mission data, or having a public impact that closes the Department buildings or a User Facility. | **HIGH****RISK** | **HIGH****RISK** | **HIGH****RISK** | **MODERATE****RISK** | **LOW****RISK** | **ROUTINE****RISK** |
| **CRITICAL** Radiological or chemical exposure causing a death or serious injury, > 25 rem to an individual, > $250,000 damage, 3 weeks to 4 months program downtime, severe loss of experimental data, or having a public impact that closes down an experiment or program. | **HIGH****RISK** | **HIGH****RISK** | **MODERATE****RISK** | **LOW****RISK** | **LOW****RISK** | **ROUTINE****RISK** |
| **MARGINAL** Radiological or chemical exposure causing moderate injuries, local evacuation, > 5 rem to an individual, > $50,000 damage, 4 days to 3 weeks program downtime, major loss of experimental data, or having a public impact that brings the experiment to the attention of the community and activist groups. | **MODERATE****RISK** | **MODERATE****RISK** | **LOW****RISK** | **LOW****RISK** | **ROUTINE****RISK** | **ROUTINE****RISK** |
| **NEGLIGIBLE**Radiological or chemical exposure causing minor injuries, no on-site or off-site evacuation, < 2 rem to an individual, < $50,000 damage, < 4 days program downtime, minor loss of experimental data, or having a public impact that is below public perception. | **ROUTINE****RISK** | **ROUTINE****RISK** | **ROUTINE****RISK** | **ROUTINE****RISK** | **ROUTINE****RISK** | **ROUTINE****RISK** |

# References

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Name(s) of Specific Application Risk Team Members:** M. Anerella, H. Hocker, J. Schmalzle, S. Plate, J. Escallier, and M. Samms | **Point Value →****Parameter ↓** | **1** | **2** | **3** | **4** | **5** |
| **Job Title:** Mechanical Technicians**Job Number or Job Identifier:** JRA HL-LHC AUP-01 | **Frequency****(B)** | **<once/year** | **<once/month** | **<once/week** | **<once/shift** | **>once/shift** |
| **Job Description:** Preparation and Loading of Typical HL-LHC AUP Magnet for Shipping | **Severity****(C)** | **First Aid Only** | **Medical Treatment** | **Lost Time** | **Partial Disability** | **Death or Permanent Disability** |
| **Training Procedures List (Optional):**  | **Likelihood****(D)** | **Very Unlikely** | **Unlikely** | **Possible** | **Probable** | **Multiple** |
| Approved by: Date: Rev. No.:  |
| **Stressors (if applicable, please list all):** Working in tight quarters. | **Reason for Revision (if applicable):**  | **Comments:**  |

|  |  | **Before Additional Controls** | After Additional Controls |  |
| --- | --- | --- | --- | --- |
| **Job Step / Task** | **Hazard** | **Control(s)** | **Stressor** | **# of People A** | **Frequency B** | **Severity C** | **Likelihood D** | **Risk\* AxBxCxD** | Control(s) Added to Reduce Risk | Stressors | # of People A | Frequency B | Severity C | Likelihood D | Risk\* AxBxCxD | % Risk Reduction |
| Manually remove restraints from shipping container | Overexertion – injuries caused by excessive lifting, pushing, pulling, holding, carrying | Back Safety Training  | Y | 1 | 2 | 4 | 3 | 24 |  |  |  |  |  |  |  |  |
| Moving magnet to Prep Stand (rigging) | Getting struck by dropped load or hitting other objects or people with load while moving. | Training;Equipment;2-Man job | N | 2 | 2 | 5 | 1 | 20 |  |  |  |  |  |  |  |  |
| Moving magnet to Prep Stand (rigging)  | Falls to same level. | Training;2-Man job | N | 2 | 2 | 2 | 1 | 8 |  |  |  |  |  |  |  |  |
| Moving magnet to Prep Stand (rigging)  | Overexertion – injuries caused by excessive lifting, pushing, pulling, holding, carrying. | Back Safety Training; 2-Man job; Equipment | N | 2 | 2 | 3 | 1 | 12 |  |  |  |  |  |  |  |  |
| Manually lift post support onto table | Overexertion – injuries caused by excessive lifting, pushing, pulling, holding, carrying. | Back SafetyTraining; 2-Man job | N | 2 | 2 | 3 | 2 | 24 |  |  |  |  |  |  |  |  |
| Install post support and torque bolts | Ergonomics - Overexertion | Proper Tools; Training | N | 1 | 2 | 2 | 2 | 8 |  |  |  |  |  |  |  |  |
| Move end restraints into position using crane | Getting struck by dropped load or hitting other objects or people with load while moving. | Training;Equipment;2-Man job | N | 2 | 2 | 3 | 2 | 24 |  |  |  |  |  |  |  |  |
| Move end restraints into position using crane | Overexertion – injuries caused by excessive lifting, pushing, pulling, holding, carrying | Training;Equipment;2-Man job | N | 2 | 2 | 3 | 2 | 24 |  |  |  |  |  |  |  |  |
| Install end restraints and torque bolts | Ergonomics – repetitive motion | Proper Tools; Training | N | 1 | 2 | 2 | 2 | 8 |  |  |  |  |  |  |  |  |
| Lift magnet and move into container using crane | Getting struck by dropped load or hitting other objects or people with load while moving. | Training;Equipment;2-Man job | N | 4 | 2 | 5 | 1 | 40 |  |  |  |  |  |  |  |  |
| Install container roof supports | Getting struck by falling object | Training;Equipment;2-Man job | N | 2 | 2 | 3 | 3 | 36 |  |  |  |  |  |  |  |  |
| Install container roof supports | Overexertion – injuries caused by excessive lifting, pushing, pulling, holding, carrying | Training;Equipment;2-Man job | N | 2 | 2 | 3 | 3 | 36 |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

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| --- | --- | --- | --- | --- | --- |
| **\*Risk:** | **0 to 20** | **21 to 40** | **41-60** | **61 to 80** | **81 or greater** |
|  | **Negligible** | **Acceptable** | **Moderate** | **Substantial** | **Intolerable** |

|  |
| --- |
| Further Description of Controls added to Reduce Risk: |

|  |
| --- |
| Lessons Learned from this Risk Assessment; Improvements, Positive Feedback: |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Name(s) of Specific Application Risk Team Members:** M. Anerella, H. Hocker, J. Schmalzle, S. Plate, J. Escallier, and M. Samms | **Point Value →****Parameter ↓** | **1** | **2** | **3** | **4** | **5** |
| **Job Title:** Electrical Assembly of HL-LHC AUP Magnets**Job Number or Job Identifier:** JRA HL-LHC AUP-02 | **Frequency****(B)** | **<once/year** | **<once/month** | **<once/week** | **<once/shift** | **>once/shift** |
| **Job Description:** Electrical Assembly of HL-LHC AUP Magnets after coils are wound and prior to Magnet testing  | **Severity****(C)** | **First Aid Only** | **Medical Treatment** | **Lost Time** | **Partial Disability** | **Death or Permanent Disability** |
| **Training Procedures List (Optional):**  | **Likelihood****(D)** | **Very Unlikely** | **Unlikely** | **Possible** | **Probable** | **Multiple** |
| Approved by: Date: Rev. No.:  |
| **Stressors (if applicable, please list all):** N/A | **Reason for Revision (if applicable):**  | **Comments:**  |

|  |  | **Before Additional Controls** | After Additional Controls |  |
| --- | --- | --- | --- | --- |
| **Job Step / Task** | **Hazard** | **Control(s)** | **Stressor** | **# of People A** | **Frequency B** | **Severity C** | **Likelihood D** | **Risk\* AxBxCxD** | Control(s) Added to Reduce Risk | Stressors | # of People A | Frequency B | Severity C | Likelihood D | Risk\* AxBxCxD | % Risk Reduction |
| Initial Testing / Hi-potting | Shock. | Training ; Procedures; Two-Man Rule; Barriers; PPE | N | 2 | 2 | 2 | 1 | 8 |  |  |  |  |  |  |  |  |
| Initial Testing / Impulse Testing of coils | Electrocution. | Training ; Procedures; Two-Man Rule ; Barriers; PPE | N | 2 | 2 | 5 | 1 | 20 |  |  |  |  |  |  |  |  |
| Initial Testing / Resistance Testing of coils | Shock | Training ; Procedures; Two-Man Rule ; Barriers; PPE | N | 2 | 2 | 2 | 1 | 8 |  |  |  |  |  |  |  |  |
| Initial Testing / Water, Hydrostatic and Flow of Coils | Pressure | Training; Procedures, Two-Man Rule; PPE | N | 2 | 2 | 2 | 1 | 8 |  |  |  |  |  |  |  |  |
| Electro-Mechanical Assembly / soldering | Burns; fumes. | Smoke-Eaters; Ventilation; PPE Training; Procedures; Barriers | N | 1 | 4 | 2 | 1 | 8 |  |  |  |  |  |  |  |  |
| Electro-Mechanical Assembly / insulating & securing conductors | Cuts. | Use of PPE; Procedures; Training | N | 1 | 4 | 2 | 1 | 8 |  |  |  |  |  |  |  |  |
| Final Testing / Hi-potting | Shock | Training; Procedures; Two-Man Rule; Barriers; PPE | N | 2 | 2 | 2 | 1 | 8 |  |  |  |  |  |  |  |  |
| Final Testing / Hydrostatic | Pressure | Training; Procedures; Two-Man Rule; Barriers; PPE | N | 2 | 2 | 2 | 1 | 8 |  |  |  |  |  |  |  |  |

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| **\*Risk:** | **0 to 20** | **21 to 40** | **41-60** | **61 to 80** | **81 or greater** |
|  | **Negligible** | **Acceptable** | **Moderate** | **Substantial** | **Intolerable** |

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| Further Description of Controls added to Reduce Risk: |

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| Lessons Learned from this Risk Assessment; Improvements, Positive Feedback: |

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| **Name(s) of Specific Application Risk Team Members:** M. Anerella, H. Hocker, J. Schmalzle, S. Plate, J. Escallier, and M. Samms | **Point Value →****Parameter ↓** | **1** | **2** | **3** | **4** | **5** |
| **Job Title:**  Cryogenic Operations during Experimental Magnet Test**Job Number or Job Identifier:** JRA HL-LHC AUP-03 | **Frequency****(B)** | **<once/year** | **<once/month** | **<once/week** | **<once/shift** | **>once/shift** |
| **Job Description:** Managing Cryogenic Operations for Experimental Testing of HL-LHC AUP Magnets – Horizontal Test Facility | **Severity****(C)** | **First Aid Only** | **Medical Treatment** | **Lost Time** | **Partial Disability** | **Death or Permanent Disability** |
| **Training Procedures List (Optional):** Applicable SOPs and/or Traveler(s) | **Likelihood****(D)** | **Very Unlikely** | **Unlikely** | **Possible** | **Probable** | **Multiple** |
| Approved by: Date: Rev. No.:  |
| **Stressors (if applicable, please list all):** Noise, Low Light Levels | **Reason for Revision (if applicable):**  | **Comments:**  |

|  |  | **Before Additional Controls** | After Additional Controls |  |
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| **Job Step / Task** | **Hazard** | **Control(s)** | **Stressor** | **# of People A** | **Frequency B** | **Severity C** | **Likelihood D** | **Risk\* AxBxCxD** | Control(s) Added to Reduce Risk | Stressors | # of People A | Frequency B | Severity C | Likelihood D | Risk\* AxBxCxD | % Risk Reduction |
| Hook up of new sample | Working with hand tools. | Training; PPE | Y | 2 | 4 | 1 | 2 | 16 |  |  |  |  |  |  |  |  |
| Hook up of new sample. | Tripping. | Training;Safety Shoes;House-keeping | Y | 2 | 4 | 1 | 2 | 16 |  |  |  |  |  |  |  |  |
| Leak Check system. | Pressurized system (10 psi). | Training;PPE | Y | 1 | 4 | 1 | 1 | 4 |  |  |  |  |  |  |  |  |
| Pump and Purge. | Noise | Training; Procedures; PPE; Minimize time near source | Y | 2 | 4 | 4 | 1 | 32 |  |  |  |  |  |  |  |  |
| Cool-down of system. | Quench – frigid temperature | Training; Leak check | Y | 2 | 4 | 4 | 1 | 32 |  |  |  |  |  |  |  |  |
| Electrical Testing Quench. | Quench – frigid temperature | Training; Leak check; Quench valves | Y | 2 | 4 | 4 | 1 | 32 |  |  |  |  |  |  |  |  |
| Warm-up; completion of test. | Quench – frigid temperature | Training;Leak check;Quench valves | Y | 2 | 4 | 4 | 1 | 32 |  |  |  |  |  |  |  |  |
| Warm-up; completion of test. | Hand tools | Training; PPE | Y | 2 | 4 | 1 | 2 | 16 |  |  |  |  |  |  |  |  |

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| **\*Risk:** | **0 to 20** | **21 to 40** | **41-60** | **61 to 80** | **81 or greater** |
|  | **Negligible** | **Acceptable** | **Moderate** | **Substantial** | **Intolerable** |

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| Further Description of Controls added to Reduce Risk: |

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| Lessons Learned from this Risk Assessment; Improvements, Positive Feedback: |

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| **Name(s) of Specific Application Risk Team Members:** M. Anerella, H. Hocker, J. Schmalzle, S. Plate, J. Escallier, and M. Samms  | **Point Value →****Parameter ↓** | **1** | **2** | **3** | **4** | **5** |
| **Job Title:** HL-LHC AUP**Job Number or Job Identifier:** JRA HL-LHC AUP-04 | **Frequency****(B)** | **<once/year** | **<once/month** | **<once/week** | **<once/shift** | **>once/shift** |
| **Job Description:** Potting and winding coils  | **Severity****(C)** | **First Aid Only** | **Medical Treatment** | **Lost Time** | **Partial Disability** | **Death or Permanent Disability** |
| **Training Procedures List (Optional):**  | **Likelihood****(D)** | **Very Unlikely** | **Unlikely** | **Possible** | **Probable** | **Multiple** |
| Approved by: Date: Rev. No.:  |
| **Stressors (if applicable, please list all):** N/A | **Reason for Revision (if applicable):**  | **Comments:**  |

|  |  | **Before Additional Controls** | After Additional Controls |  |
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| **Job Step / Task** | **Hazard** | **Control(s)** | **Stressor** | **# of People A** | **Frequency B** | **Severity C** | **Likelihood D** | **Risk\* AxBxCxD** | Control(s) Added to Reduce Risk | Stressors | # of People A | Frequency B | Severity C | Likelihood D | Risk\* AxBxCxD | % Risk Reduction |
| Apply Kapton to tube | Trip Hazard | Housekeeping  | N | 1 | 2 | 1 | 2 | 4 |  |  |  |  |  |  |  |  |
| Move to and install in oven | Trip Hazard  | Training;Housekeeping | N | 2 | 2 | 1 | 2 | 8 |  |  |  |  |  |  |  |  |
| Move to and install in oven  | Getting struck by dropping or moving load | Training;2-Man job | N | 2 | 2 | 1 | 2 | 8 |  |  |  |  |  |  |  |  |
| Cure in oven  | Burn when removing from oven | PPE; allow to cool prior to touching | N | 1 | 2 | 2 | 1 | 4 |  |  |  |  |  |  |  |  |
| Hi-potting coil  | Exposure to electrical shock (1000 v @ 1 mA) | Procedures; allow discharging prior to removing leads; PPE;Training; 2-Man job;  | N | 2 | 2 | 3 | 2 | 24 |  |  |  |  |  |  |  |  |
| Mount on stand and verify true | Getting struck by dropping or moving load  | Training; 2-Man job | N | 2 | 3 | 1 | 2 | 12 |  |  |  |  |  |  |  |  |
| Apply substrate  | Trip Hazard  | Housekeeping | N | 1 | 2 | 1 | 2 | 4 |  |  |  |  |  |  |  |  |
| Calibration of winder | Bump Hazard  | Awareness;Training | N | 1 | 3 | 1 | 1 | 3 |  |  |  |  |  |  |  |  |
| Wind coil  | Pinch hazard  | Computer limits; Speed of rotation; Lockout of computer | N | 1 | 4 | 1 | 2 | 8 |  |  |  |  |  |  |  |  |
| Epoxy coil  | Sensitization hazard  | Epoxy mixed in hood; applied with mechanical ventilation; nitrile gloves  | N | 1 | 3 | 2 | 2 | 12 |  |  |  |  |  |  |  |  |
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| **\*Risk:** | **0 to 20** | **21 to 40** | **41-60** | **61 to 80** | **81 or greater** |
|  | **Negligible** | **Acceptable** | **Moderate** | **Substantial** | **Intolerable** |

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| Further Description of Controls added to Reduce Risk: |

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| Lessons Learned from this Risk Assessment; Improvements, Positive Feedback: |

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| **Name(s) of Specific Application Risk Team Members:** M. Anerella, H. Hocker, J. Schmalzle, S. Plate, J. Escallier, and M. Samms | **Point Value →****Parameter ↓** | **1** | **2** | **3** | **4** | **5** |
| **Job Title:** HL-LHC AUP **Job Number or Job Identifier:** JRA HL-LHC AUP-05 | **Frequency****(B)** | **<once/year** | **<once/month** | **<once/week** | **<once/shift** | **>once/shift** |
| **Job Description:** Provide cryogenic Argon for coil curing gaseous purge  | **Severity****(C)** | **First Aid Only** | **Medical Treatment** | **Lost Time** | **Partial Disability** | **Death or Permanent Disability** |
| **Training Procedures List (Optional):**  | **Likelihood****(D)** | **Very Unlikely** | **Unlikely** | **Possible** | **Probable** | **Multiple** |
| Approved by: Date: Rev. No.:  |
| **Stressors (if applicable, please list all):** N/A | **Reason for Revision (if applicable):**  | **Comments:**  |

|  |  | **Before Additional Controls** | After Additional Controls |  |
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| **Job Step / Task** | **Hazard** | **Control(s)** | **Stressor** | **# of People A** | **Frequency B** | **Severity C** | **Likelihood D** | **Risk\* AxBxCxD** | Control(s) Added to Reduce Risk | Stressors | # of People A | Frequency B | Severity C | Likelihood D | Risk\* AxBxCxD | % Risk Reduction |
| Delivery of Argon dewars to Bldg 902 | Struck by delivery vehicle | Work Planning; Training  | N | 1 | 3 | 3 | 2 | 18 |  |  |  |  |  |  |  |  |
| Delivery of Argon dewars to Bldg 902 | Falls from same level  | Safety Shoes; Housekeeping; Floor surface maintenance | N | 1 | 3 | 2 | 2 | 12 |  |  |  |  |  |  |  |  |
| Offload dewars from truck to floor using liftgate | Struck by liftgate. | Work Planning; Training;Only authorized personnel in area | N | 2 | 3 | 3 | 2 | 36 |  |  |  |  |  |  |  |  |
| Offload dewars from truck to floor using liftgate  | Dewar falls off liftgate | Work Planning; Training;Only authorized personnel in area Equipment | N | 2 | 3 | 3 | 2 | 36 |  |  |  |  |  |  |  |  |
| Move full Argon dewars to HL-LHC AUP oven | Crane operations including selection of rigging, connection to hook, movement of load | Crane Ops JRA; Work Planning | N | 2 | 3 | 3 | 2 | 36 |  |  |  |  |  |  |  |  |
| Connect Argon dewars to manifold | Use of hand tools | Proper Tools; Training | N | 1 | 4 | 1 | 2 | 8 |  |  |  |  |  |  |  |  |
| Connect Argon dewars to manifold  | Cryogenic hazards  | Training;PPE | N | 1 | 4 | 2 | 2 | 16 |  |  |  |  |  |  |  |  |
| Changeout dewars when one is empty | Use of hand tools  | Training;Proper Tools | N | 1 | 4 | 1 | 2 | 8 |  |  |  |  |  |  |  |  |
| Changeout dewars when one is empty  | Cryogenic hazards  | Training;PPE  | N | 1 | 4 | 2 | 2 | 16 |  |  |  |  |  |  |  |  |
| Move empty Argon dewars to loading dock area | Crane operations including selection of rigging, connection to hook, movement of load  | Crane Ops JRA; Work Planning  | N | 2 | 3 | 3 | 2 | 36 |  |  |  |  |  |  |  |  |
| Load empty dewars onto truck | Struck by delivery vehicle | Training;Work Planning  | N | 1 | 3 | 3 | 2 | 18 |  |  |  |  |  |  |  |  |
| Load empty dewars onto truck  | Falls from same level  | Safety Shoes; Housekeeping; Floor surface maintenance  | N | 1 | 3 | 2 | 2 | 12 |  |  |  |  |  |  |  |  |
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| Further Description of Controls added to Reduce Risk: |

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| Lessons Learned from this Risk Assessment; Improvements, Positive Feedback: |

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| **Name(s) of Specific Application Risk Team Members:** M. Anerella, H. Hocker, J. Schmalzle, S. Plate, J. Escallier, and M. Samms | **Point Value →****Parameter ↓** | **1** | **2** | **3** | **4** | **5** |
| **Job Title:** HL-LHC AUP **Job Number or Job Identifier:** JRA HL-LHC AUP-06 | **Frequency****(B)** | **<once/year** | **<once/month** | **<once/week** | **<once/shift** | **>once/shift** |
| **Job Description:** Magnetic Field Work  | **Severity****(C)** | **First Aid Only** | **Medical Treatment** | **Lost Time** | **Partial Disability** | **Death or Permanent Disability** |
| **Training Procedures List (Optional):**  | **Likelihood****(D)** | **Very Unlikely** | **Unlikely** | **Possible** | **Probable** | **Multiple** |
| Approved by: Date: Rev. No.:  |
| **Stressors (if applicable, please list all):** N/A | **Reason for Revision (if applicable):**  | **Comments:**  |

|  |  | **Before Additional Controls** | After Additional Controls |  |
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| **Job Step / Task** | **Hazard** | **Control(s)** | **Stressor** | **# of People A** | **Frequency B** | **Severity C** | **Likelihood D** | **Risk\* AxBxCxD** | Control(s) Added to Reduce Risk | Stressors | # of People A | Frequency B | Severity C | Likelihood D | Risk\* AxBxCxD | % Risk Reduction |
| Operating power supplies | See JRA-HL-LHC AUP-02, “Electrical Assembly of HL-LHC AUP Magnets” for hazards and mitigations associated with electrical power supplies  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Operating high current electromagnets | Possible arcing, with ejection of molten metal  | Work Planning, Procedure, insulation of exposed conductors carrying high current, NRTL Approved Equipment or EEI Inspection, appropriate PPE, SBMS subject area on Electrical Safety | N | 2 | 2 | 2 | 2 | 16 |  |  |  |  |  |  |  |  |
| Performing a magnetic survey on a high current electromagnet | Shock | Work Planning; Procedure, Training;Warnings signs and tape, Pre-job brief, Only authorized personnel in area, NRTL Approved Equipment or EEI Inspection, appropriate PPE, SBMS subject area on Electrical Safety | N | 2 | 2 | 2 | 2 | 16 |  |  |  |  |  |  |  |  |
| Working with magnetic fields  | Exposure to magnetic fields > 600 gauss | Work Planning; Training; Procedure, SBMS subject area on Static Magnetic Fields, only authorized personnel in area , secure ferromagnetic objects, field maps, “tell tales”, posting/barriers. | N | 2 | 3 | 1 | 2 | 12 |  |  |  |  |  |  |  |  |
|  | Being injured (struck, pinched, etc.) by interaction of: - a magnet & ferromagnetic object; - by two magnetsBeing startled (avoidance reaction to unexpected exposure to field) | Work Planning; Training; Procedure, SBMS subject area on Static Magnetic Fields, only authorized personnel in area , secure ferromagnetic objects, field maps, “tell tales”, posting / barriers, storing magnets in wooden boxes | N | 2 | 3 | 2 | 1 | 12 |  |  |  |  |  |  |  |  |
|  | Erasing magnetic encoding on ID & credit cards; jamming electronic watches | Work Planning; Training; Procedure, SBMS subject area on Static Magnetic Fields, only authorized personnel in area , removal of personal magnetically encoded or electronic devices before approaching magnetic field area, field maps, “tell tales”, posting / barriers, storing magnets in wooden boxes | N | 2 | 3 | 1 | 2 | 12 |  |  |  |  |  |  |  |  |
|   | Medical or ferromagnetic implants exposed to fields > 5 gauss:-pacemaker-defibrillator-insulin pump-cochlear implant-surgical plates, rods, staples or pins, etc.  | Work Planning; Training; Procedure, SBMS subject area on Static Magnetic Fields, only authorized personnel in area , posting / barriers / signage, OMC clearance to work in high magnetic fields | N | 2 | 2 | 2 | 1 | 8 |  |  |  |  |  |  |  |  |
| Work with superconducting magnets: Quenching | See JRA-HL-LHC AUP-03, “Cryogenic Operations during Experimental Magnet Test” for hazards and mitigations associated with Quenching  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

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| **\*Risk:** | **0 to 20** | **21 to 40** | **41-60** | **61 to 80** | **81 or greater** |
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| Further Description of Controls added to Reduce Risk: |

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| Lessons Learned from this Risk Assessment; Improvements, Positive Feedback: |