INTRODUCTORY OJT

Welcome to the Fermilab Accelerator Division Operations Department! The Introductory On-the-Job-Training (OJT) manual is a checklist, guideline, and record of your Operations Department introductory training. **It is very important that you do not lose this document.** If you do, the training you have completed will have to be redone.

This training list has been successfully completed.

Department Head (Signature/Date)_____

Contents

Part 1: Overview of the Training Process

1.1 Operator's Role

Becoming an active participant in the training program, as well as in the Main Control Room (MCR), is important not only to you but also your crew, Crew Chief, and the Operations Department. You are encouraged to train with as many Operators, Operations Specialists, and experts as you can. Each of them will embrace different training methods, some of which may help you learn more readily than others.

Initially, you will have more experienced Operators guide you through the basics of manipulating each accelerator and troubleshooting issues that arise in day to day running. You should take the time to observe and tune each of the machines on your own. The only way to keep up with their subtleties is to keep in touch with them on a regular basis, and there is no substitution for operational experience. Each situation in the MCR is unique, and different problems arise every day.

Sometimes problems cannot be fixed from the MCR. Volunteer to visit the problem area accompanied by a more experienced Operator or Machine Expert so you can learn basic troubleshooting skills.

1.2 OJTs

The Introductory and Advanced OJTs ensure that you receive the basic training required to learn and develop safe and effective job skills as an Accelerator Operator. Throughout the OJTs, training topics are numbered and have descriptions of what is to be accomplished, along with signoff boxes to document these achievements. The signoff box identifies the person who ensures that the training you receive is correct and complete. Many signoff boxes identify this person simply as 'Trainer'. Any Operator II or more senior member of the Operations Department, or systems expert of another department, may assume this role.

When you have earned every signoff in an OJT, you will scan a copy of the completed OJT and send it to the Deputy Department Head. Upon completing the Introductory OJT, you will take the Introductory Operator II Exam, which you must pass with a score of 70% to receive the Advanced OJTs and continue your training. The Advanced OJTs, which require you to demonstrate deeper knowledge of each machine to earn signoffs, will expose you to the minimal amount of material required to safely and effectively operate the accelerator complex.

1.3 Walkarounds

Once you receive your Advanced OJTs, you may begin scheduling the Introductory Walkarounds with the specialists. During the Introductory Walkarounds, the specialists will walk with you to related areas of the accelerator complex and explain what they expect you to understand by the time you finish your training.

When you are nearing the completion of an Advanced OJT and begin to prepare for a Final Walkaround, you should notify, via email, the Department Head, relevant specialist, and Training Committee (opstrain@fnal.gov) of your intent to take the associated Final Walkaround and Operator II Exam, as well as the time frame in which you expect to do so. You may not take a Final Walkaround until the associated Advanced OJT has been

completed and **ALL** Introductory Walkarounds have been completed. During the Final Walkaround, the specialist will ask you questions about the material that was covered in their Introductory Walkaround and score your knowledge accordingly.

Achieving a passing score of 70% on the Final Walkaround will allow you to take the associated Operator II Exam. If you do not pass, the specialist will explain where your weak areas are, and the department head will determine what will be done to improve your proficiency in this area.

1.4 Operator II Exams

After passing a Final Walkaround, you will talk to the Department Head to schedule the associated Operator II Exam, which you must attempt within one week of passing the Final Walkaround. The exams, which you are given two hours to complete, typically cover more conceptual detail than the Final Walkarounds. The format of the exam questions is up to the discretion of the Training Committee. You may not talk about an exam to an operator who has not taken it.

A score of 70% is required to pass an exam. Like the Final Walkaround, if you do not pass, the Department Head will assess your case and determine what steps will be necessary before rescheduling that exam. If a retake is necessary, you will need to achieve a score of 80% to pass.

You will be officially ranked Operator II after you have passed all the Final Walkarounds and Operator II Exams. You are encouraged to finish the entire process within two years.

1.5 Learning Never Ends

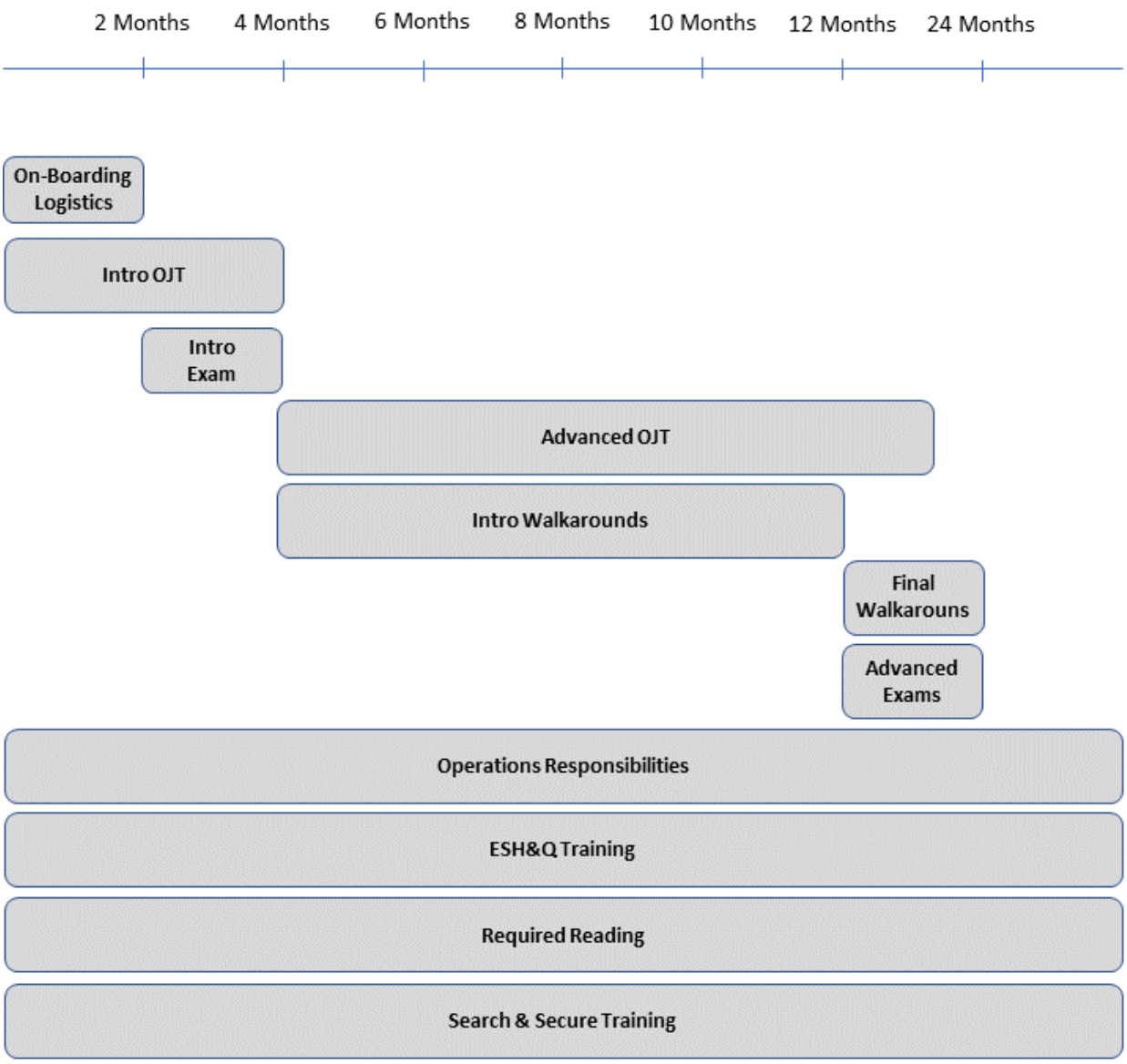
When necessary, an Operator II may be asked to temporarily fill in as Crew Chief, who must have a basic understanding of every accelerator system to wisely make decisions for the High Energy Physics program on their shift. This makes paying attention to the changes and upgrades made to the complex very important.

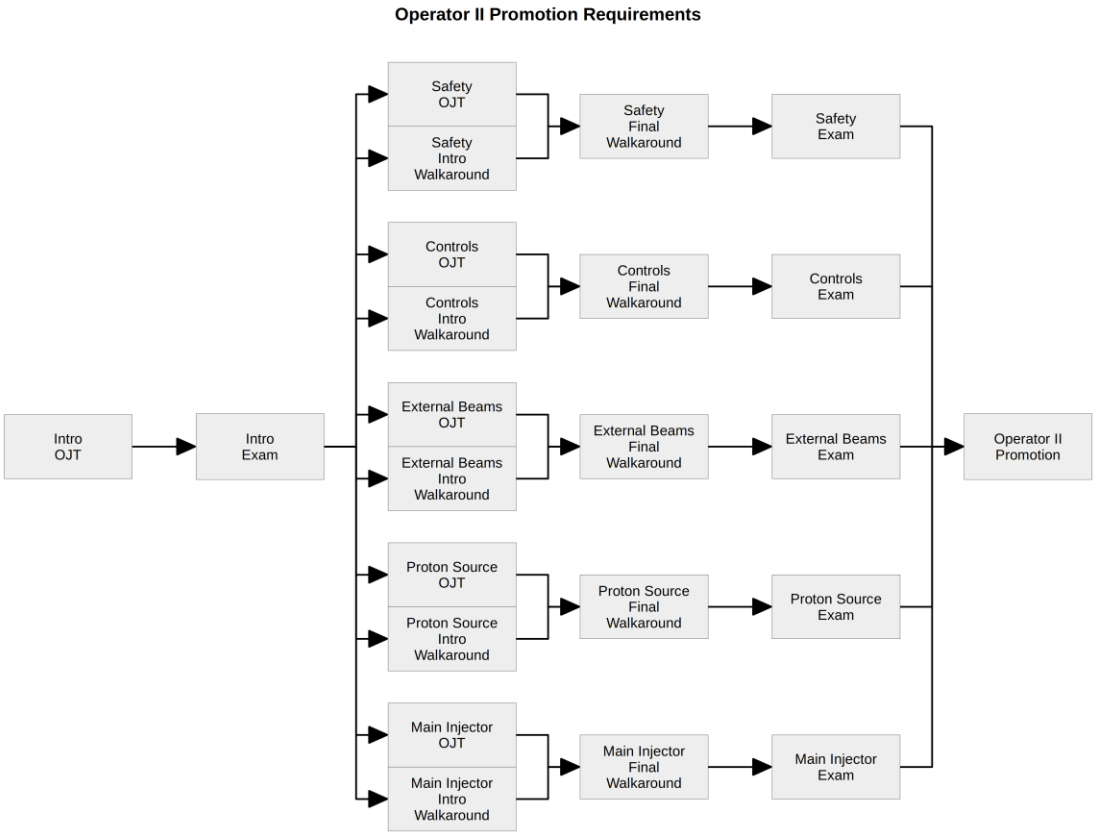
As an Operator II, you can gain the skills necessary to become a Crew Chief. A Crew Chief in turn can then enhance their knowledge of an accelerator system to the level necessary to become a specialist.

You will also be involved with training new operators, which will help you keep in touch with all of the accelerator systems. Make sure to inform the Training Committee of any mistakes you discover in the training material as systems change or new systems come online. In some cases, such as the Operations Wiki (operations.fnal.gov/wiki/), you can update material yourself.

The following chart shows the average timeline of an operator in going through the training program, with which you can compare your progress. Good luck!

Operator Training Timeline





Part 2: Personnel Introduction

We work with many individuals from various Accelerator Division departments on a regular basis. Depending on the mode of the accelerators, the frequency of repairs of a particular system, and the ever-changing responsibilities of system personnel, it is difficult enumerate appropriately. As an operator in the MCR, consider becoming familiar with system personnel and their department association as situations arise. With assistance from other operators, recognition of personnel as they frequent the MCR or actual visitation to department locations is recommended.

Resources available:

http://www-bd.fnal.gov/hq/OrgChart/fullChart.pdf

https://www-bd.fnal.gov/mcr/pic_board.html

https://www-bd.fnal.gov/cgi-bin/info.pl

Trainee	Date

You have used the above resources.

Part 3: Main Control Room

3.1 Administrative In-Processing

_____	
Trainer	Date

1. Signoff Verification

You have read the Overview of the Training Process section and any unclear areas have been discussed with Operator IIs, Crew Chiefs, or Specialists. When you understand what is expected of you and the training process, have your trainer sign off.

_____	
Trainee	Date

2. Workbench Assigned

A workbench has been assigned to you.

_____	
Trainee	Date

3. Safety Shoes

Operations personnel will show you what form to fill out and explain the safety shoe procedure. Sign yourself off when you have safety shoes.

_____	
Trainee	Date

4. Mailbox Assigned

You have been assigned a mailbox.

_____	
Duty Asst	Date

5. Operations Required Reading Database

Your name has been added to the operations required reading database.

_____	
Duty Asst	Date

6. Individual Training Plan (ITP) Database

Your name has been added to the ITP database.

_____	
Duty Asst	Date

7. Permanent Film Badge

The form requesting your permanent film badge has been completed. Use a visitors' film badge from the Communications Center until you receive your permanent badge.

_____	
Duty Asst	Date

8. Pocket Dosimeter

You have received a pocket dosimeter from the duty assistant.

Duty Asst Date

9. Key Request

The duty assistant supplies you with the documentation to receive an AC4 key. Have them sign off when the forms are completed and the request is made.

Duty Asst Date

10. Personal Lock and Key

You have received a personal lock and key for Lock Out Tag Out (LOTO) of equipment.

Trainer Date

11. Training Resources

Know how access to the following training resources:

____ Operations Rookie Books

____ Operations Wiki

____ Know that you are encouraged to make edits to the Wiki

____ AD document databases (Doc DB)

____ AD department webpages

____ Operations required reading database

____ ESH&Q ITP database

Dept Head Date

12. Training Orientation

Set up an appointment with the department head as soon as possible after you have been assigned to a crew. During that meeting, the department head ensures the following are done:

____ Both you and your crew are present

____ Discussion of training program

____ Discussion of responsibilities

____ All crew members should help with your training

____ Discuss OJT signoff procedures

____ Clarify what signatures mean for OJT

____ Discussion completed on importance of working safely

Duty Asst Date

13. Computer Account Management

Set up the following:

____ Fermi Domain account

____ FNAL Services account

____ Kerberos principal

Duty Asst Date

14. Tool Bag and Tools

You have received a tool bag.

Trainer Date

15. Browser Usage

Understand how to use a browser on a console or remote desktop to perform the following tasks:

____ Access information on the AD/Ops homepage

____ Help key (F7)

____ Know how to start a remote desktop to access outside the controls firewall (general internet)

____ Be able to access your Fermi Mail email account

____ Be able to access the Fermilab Time and Labor (FTL) system in order to complete your weekly time sheet and for effort reporting

3.2 Laboratory and Division Required Training

Trainer Date

1. Controlled Access vs. Supervised Access Rules

You have reviewed and understand the rules governing controlled access and supervised access. You understand the three steps that must be completed to turn a controlled access into a supervised access.

Duty Asst Date

2. Controlled Access Qualification

You have completed your controlled access training and this status has been updated in the key logger.

Trainer Date

3. Access Hazards

You have completed a discussion on the hazards associated with making an access. This includes radiation, electrical, oxygen deficiency hazard (ODH), and underground hazards.

Trainer Date

4. Waste Handling (Operations)

Your training on the use of the operations temporary waste storage cabinet has been completed, including:

____ Temporary Waste Storage Cabinet Procedure (ADDP-OP-0301) has been read and signed off

____ Operations Waste Coordinator lecture and worksheet have been completed

Trainer Date

5. Interlocked Detector Change Out (Operations)

Your training on interlocked detector change out has been completed, including:

____ Radiation Detector Change Procedure (ADSP-10-0101) has been read and signed off

____ Interlocked detector lecture and worksheet have been completed

Trainer Date

6. Warning Lights

You have completed a discussion on the meaning of flashing warning lights. This includes:

____ Red flashing lights for danger (high voltage hazards or ODH conditions)

____ White flashing lights indicating the detection of a fire

____ Blue lights indicating the presence of hydrogen

Trainer Date

7. Electrical Safety Equipment

You have completed a discussion on the following personal safety equipment:

____ Personal protective equipment (PPE) for the mitigation of arc flash hazards (NFPA 70E)

____ Ground sticks for electrical shock protection

____ Hot sticks for electrical shock protection

3.3 Operator Task Training

Trainer Date

1. Search and Secure Introduction

You have completed a discussion outlining your role as an operator in the search and secure of enclosures. Your discussion should include:

____ Purpose and **importance** of search and secure and that search and secure is the most important job that operators perform

____ General search and secure procedure

____ How to become qualified to search and secure an enclosure

Trainer Date

2. Keys

You have completed a discussion on the definition, function, and keys found in the following locations, including personnel to whom these keys may be issued.

____ Crew chief cabinet

____ MCR key tree

____ Remote key trees

____ Vehicle keys

Trainer Date

3. Phone Numbers

You have completed a discussion on the methods used to find an individual's home, lab, or pager numbers via:

____ The Call-in Book hard copy

____ Fermilab Telephone Directory webpage

____ Call-in lists on the MCR ScratchPad, or search from the Ops homepage

____ Telephone Index program (D17)

____ Know what is meant by “MCR Only, CTL Rooms, Anywhere”

____ Add your name to the index

____ Understand the confidentiality of this information

Trainer Date

4. Emergency Phone Numbers

Know what phone number to dial in an emergency.

____ 3131 for any emergency

____ 3414 for Security Dispatch

Trainer Date

5. Telephone Protocol

You have completed a discussion of the proper way to conduct a phone conversation in the MCR.

____ Understand proper etiquette for phone conversations in the MCR

____ Know how to transfer a phone call

____ Know how to establish a three-way phone call

____ Know how to exercise many possible ways to contact people.

Trainer Date

6. Pagers

____ Placing a page via the long-distance pagers (numerical message)

____ Placing a page via the long-range pagers (dial 72 then the pager number, then speak message)

____ Be able to page someone in any enclosure using the tunnel paging system

____ Know that some enclosures can be paged using a phone number

Trainer Date

7. Shift Saves

You have completed a discussion of the motivation and procedure for making a shift save.

Trainer Date

8. Shift Plots

You have completed a discussion and have been shown a demonstration of the methods used to make and label shift plots.

Trainer Date

9. Rebooting Procedures

You have completed a discussion and have been shown a demonstration of the procedures used to reboot the various types of computers and programs in and around the MCR.

____ It is important to contact an expert before rebooting computers in the computer room.

____ Know various computer passwords

____ Console operation

____ Know how to reboot the console PC

____ Know when and how to perform a CnsRun

____ Know how to access and reboot the following computers:

____ Channel 13

____ SiteStat

____ Mister House

Trainer Date

10. Oxygen Monitors and Alarms

You have completed a discussion of the naming convention used for the oxygen monitors, and the methods used to ascertain which monitor is in alarm via the control system have been demonstrated. This discussion included the proper procedure for changing a faulty oxygen monitor and how to locate spares.

Trainer Date

11. Department Vehicles

A discussion and demonstration on the procedures for maintaining the Operations Department vehicles has been completed, including:

____ Refueling the vehicles

____ Cleaning Materials

____ Regular Maintenance

____ Accident reporting

____ Emergency response kits and their contents

____ Remember to transfer the emergency response kits and other items to and from loaner vehicles

Trainer Date

12. Safety Data Sheet

A discussion has been completed on the Safety Data Sheet, including:

____ Know how to access the SDS index via the ESH&Q Industrial Hygiene webpage (https://www-esh.fnal.gov/pls/cert/msds_search.html)

____ Know what SDS means

____ Know why this information is available

Trainer Date

13. Hot Item Book

You have completed a discussion of the Hot Item Book. This discussion included its purpose as well as how and when to make entries.

Part 4: Walkaround

Trainee	Date

1. Common Cross Gallery Locations

Be able to locate the following locations in the Cross Gallery:

____ Operations Backrooms

____ Specialists' and Crew Chiefs' offices

____ Vending Machines

____ Elevator

____ Kitchen

____ Bathrooms

____ Dungeon

____ Huddle

____ Copying room

____ Operations' tool storage room. Know what equipment can be found in the storage room located between the two back rooms, what key is needed to access the room, and how to use the sign-out board

____ Equipment pool room. Know what equipment can be found in the downstairs equipment pool room and what key is needed to access the room

____ Safety Interlock Department offices

Trainee	Date

2. Common High Rise Locations

Be able to locate the following locations in the High Rise:

____ Underground Path to the High Rise

____ Cafeteria

____ Vending Machines

____ One West

____ Curia II

____ Communications Center (Ground Floor)

____ Library (3rd Floor)

____ Payroll (4th Floor East Side)

____ Auditorium

____ Credit Union (Ground Floor)

____ Medical Office (Ground Floor)

____ Neutrino Experimental Remote Operations Center (ROC-West) (Atrium)

Trainer	Date

3. MCR Console

Understand how to use a console. Your knowledge should include:

____ Know what the Index pages are

____ Know what the Utilities window is

____ Know how to start programs

____ Know how to start Fast Time Plots and Snapshot Plots and know when you would use each

____ Know how to start the Real Time Plotter from the MCR ScratchPad and know its basic functions

____ Have a general understanding of how the alarm screen works and under what conditions alarms are cleared

____ Know how to access the Elog. Your knowledge should include:

- ____ How to begin a shift
- ____ How to make Elog entries, including inserting graphics
- ____ What information should be logged or not logged
- ____ Elog etiquette https://cdcvs.fnal.gov/redmine/projects/elog/wiki/ElogEtiquette

____ Know how to use the Autocopy program

____ Know how and when to use the Boss-O-Gram application

____ Know how to access the Boss-O-Schedule application

____ Know how to use the Lumberjack Plotter application (D44) to look at the history of a given set of parameters sources

____ Know how to launch the Critical Device Controller (CDC) and Electrical Safety System (ESS) displays

Trainer Date

4. Common Console Tasks

You have been introduced to the following ACNET programs to complete common tasks. Your knowledge should include:

____ Know the basic functions of a parameter page. This includes knowledge of:

- ____ Parameter names
- ____ Text descriptions
- ____ Analog and digital controls and readbacks
- ____ Analog alarm limits
- ____ How and when to bypass analog alarms
- ____ How to find associated nodes

____ Understand the procedure for logging downtime using the Downtime Logger program (D18)

____ Understand the purpose and use of Channel 13

- ____ Be able to update Channel 13 messages from the Notify Channel, http://www-bd.fnal.gov/servlets/messages/

____ Receive an introduction on how to use the following programs to troubleshoot common issues:

- ____ Alarm and Event Reporting System program (D59)
- ____ Digital Status program (S53)
- ____ CAMAC Link Status program (D20)
- ____ ACNET Node Poll program (D31)
- ____ Save/Restore (D1) and RAD Save/Restore (D2) programs

Trainer	Date

5. MCR Equipment

Be able to identify the following items in the MCR area:

- ____ Know the location and significance of the Beam Budget Monitor (BBM) and how to read the display
- ____ Complete a discussion on what FIRUS is, how it is monitored, and under what circumstances you may acknowledge an alarm
- ____ Radios
  - ____ Know the difference between the operations radio and the Facilities Engineering Services Section (FESS) radio
  - ____ Discussion completed on proper conduct while transmitting on the radio
  - ____ Weather radio
- ____ Be familiar with the 113 Emergency Pager
- ____ Be familiar with the Mister House, SiteStat and Channel 13 computers
- ____ Important MCR books
  - ____ Emergency response book
  - ____ Beam permit binder
  - ____ Call-in book
  - ____ Power outage book
  - ____ Vehicle sign-out book and keys
  - ____ Radiological Work Permits (RWPs)
- ____ Tunnel access equipment
  - ____ Oxygen escape packs
  - ____ Oxygen monitors
  - ____ Log Survey Meters (LSM)
- ____ Safety system equipment
  - ____ Key trees
  - ____ Key logger
  - ____ Tunnel paging system
  - ____ Safety Alert Monitors (S.A.M.)
  - ____ Red emergency phone
  - ____ Interlocked radiation detectors and safety reset button

____ Back racks

- ____ Radios
- ____ Hard hats
- ____ Flashlights
- ____ Safety vests

____ MCR printers

- ____ Know where the commonly used MCR printers are
- ____ Know how to change their consumables
- ____ Know who to contact with printer problems

_____
Trainer Date

6. Cross Gallery Computer Room

Know the location of the Computer Room and be able to point out the following equipment:

____ CAMAC front ends

____ Pump room

____ CLX nodes that run console instances

_____
Trainer Date

7. Downstairs Cross Gallery

Be aware of the following locations:

____ MAC room

- ____ Know that the MAC room is the Alternate Emergency Command Post area

____ FIRUS room

____ TV room

_____
Trainer Date

8. Pre-Accelerator (Pre-Acc)

Be able to identify the following equipment in the Pre-Acc area:

____ Pre-Acc control room

____ Pre-Acc area

- ____ Know where the RWP for this area is located.

____ Radio frequency quadrupole (RFQ) Injection Line (RIL)

____ Start of low energy (LE) Linac

Trainer Date

9. Linac Upper and Lower Galleries

Be able to identify the following equipment in the Linac upper and lower galleries.

____ Water skids

____ LE Linac RF (LRF) stations

- ____ LRF station numbers
- ____ Buncher station

____ Neutron Irradiation Facility (NIF) treatment area

____ Quadrupole power supplies

____ High Energy (HE) Klystron Linac RF (KRF) stations

- ____ Know the location of the emergency off button at each KRF station and understand when this is used
- ____ Transition Buncher and Vernier stations

Trainer Date

10. 400 MeV Area

Be able to identify the following equipment in the 400 MeV area:

____ Chopper and Lambertson power supplies

____ Allen-Bradley vacuum valve controller

____ 400 MeV quadrupole power supplies

____ Linac beam dump line power supplies

Trainer Date

11. Booster Galleries

Be able to identify the following equipment in the Booster galleries:

____ RF stations

____ Period signs

____ Reference magnet

____ Gradient Magnet Power Supply (GMPS) racks

Trainer Date

12. Booster Utility Yards

Know the location of the Booster utility yards and be able to identify the following equipment:

____ GMPS transformers and disconnects

____ Anode power supplies and disconnects

Trainer Date

13. Booster Low Level RF (LLRF) Room

Know the location of the Booster LLRF Room:

____ Understand that the LLRF electronics are **very** temperature-sensitive, and the effect this can have on beam operation

Trainer Date

14. MI-8 Service Building

Know the location of the MI-8 service building and be able to point out the following equipment.

____ 8GeV Line tunnel entrance

____ Power supplies

____ Electronics room

____ Water system

Trainer Date

15. Booster Neutrino Beamline (BNB) Service Buildings

____ MI-12

- ____ Power supplies
- ____ Tunnel entrance

Trainer Date

16. MI-10, 20, 30, 40, and 50 Service Buildings

Know the location of the MI service buildings and be able to point out the following equipment:

____ Tunnel entrance

____ Power supplies

____ Electronics room

____ Kicker room

____ Water system

Trainer Date

17. MI-14 Service Building

____ Kicker room

____ Power supplies

Trainer Date

18. MI-31 Service Building

____ Pit entrance

____ MI-31 Stub enclosure

____ Recycler 2.5 MHz RF equipment

Trainer Date

19. MI-39 Service Building

____ Kicker room

Trainer Date

20. MI-52 Service Building

Know the location of the MI-52 service building and be able to point out the following equipment:

____ Tunnel entrance

____ Power supplies

____ Electronics room

____ Water system

Trainer Date

21. MI-60 Service Building

Know the location of the MI-60 service building and be able to point out the following equipment.

____ Main Injector tunnel entrance

____ Power supplies

____ Electronics room

____ Water system

____ RF gallery

____ MI-60 control room

Trainer Date

22. MI-62 Service Building

Know the location of the MI-62 service building and be able to point out the following equipment:

____ Main Injector tunnel entrance

____ Power supplies

____ Electronics room

____ Water system

Trainer Date

23. MI-65 Service Building

____ Underground power supply room
____ Underground RAW room
____ Shaft and elevator
____ Enclosure entrance

Trainer Date

24. MINOS Service Building

____ Electronics room
____ Shaft and elevator
____ Enclosure entrance

Trainer Date

25. Muon Campus Service Buildings

Know the locations of the following Muon Campus service buildings. Be able to identify the following equipment:

____ AP-10
- ____ Control room
- ____ Enclosure entrances

____ AP-30
- ____ Enclosure entrances
- ____ Power supplies

____ AP-50
- ____ Power supplies
- ____ Enclosure entrances

____ AP-0
- ____ Pre-Vault and Transport enclosure entrances
- ____ Target Vault area
- ____ Power supplies
- ____ Airborne contamination monitor

____ MC-1
- ____ Enclosure entrance
- ____ Power supplies

Trainer Date

26. Transfer Gallery (TG) Area

Know the location of TG and be able to identify the following equipment:

____ TG period numbering

____ A0 Kicker room

____ Beam loss monitor (BLM) and beam position monitor (BPM) racks

____ Enclosure B tunnel entrance

Trainer Date

27. Switchyard Service Building (SSB)

Know the location of SSB and be able to identify the following equipment:

____ Typical power supplies

____ Tunnel entrance and elevator

Trainer Date

28. G2 Service Building

Know the location of the G2 service building and be able to identify the following equipment:

____ Typical power supplies

____ F1 Manhole enclosure entrance

____ G2 enclosure entrance

Trainer Date

29. F2 and F3 Manholes

Know the location of the F2 and F3 manholes and know that they are confined spaces.

Trainer Date

30. Master and Kautz Rd Substations

Know the locations of these substations.

____ Know when we enter the substations, and with whom

Trainer	Date

31. Meson Service Buildings

Know the locations of the major Meson line service buildings and receive a basic tour inside each of them.

____ MS1

- ____ M01 enclosure entrance
- ____ Power supplies

____ MS2

- ____ M02 enclosure entrance
- ____ Power supplies

____ MS3

- ____ M03 enclosure entrance
- ____ M04 enclosure entrance
- ____ Power supplies

____ Meson Detector Building (MDB)

- ____ Water pumps and heat exchangers
- ____ CAMAC crates
- ____ Power Supplies
- ____ Meson Center (MCenter) enclosures (MC6, MC7-North, MC7-South, and MB7)
- ____ MS4
- ____ Meson Test (MTest) enclosures (MT6-1 and MT6-2)
- ____ MS5

____ MS6 Worm

____ MS7

Trainer Date

32. Neutrino-Muon Service Buildings

Know the locations of the Neutrino-Muon line service buildings and receive a basic tour inside each of them.

____ NS0

- ____ N01 enclosure entrance

____ NS1

- ____ N01 enclosure entrance
- ____ LCW pump room

____ NS7

- ____ NM2 enclosure entrance

____ NS2

- ____ LCW pump room
- ____ Glycol heat exchange system

____ KTeV (SpinQuest)

- ____ NM4 enclosure entrance
- ____ NM3 enclosure entrance
- ____ NM3 radioactive water (RAW) skid

Trainer Date

33. Tevatron F-Sector Service Buildings

Know the location of the Tevatron service buildings and be able to identify the following equipment:

____ Electronics room

____ Tunnel door

____ Low conductivity water (LCW) pump and pond pumps

____ Ceiling heaters

____ Refrigerator building

Trainer Date

34. F0 Service Building

Know the location of the F0 service building and be able to identify the following equipment:

____ P1 and P2 line power supplies

____ LCW pump room

Trainer Date

35. B0 Service Building

Know the location of the B0 service building and be able to identify the following equipment:

____ Compressors (ODH area)

____ Electronics room

Trainer Date

36. Assembly Buildings

Know the locations of the following areas:

____ Heavy Assembly Build (HAB)

____ C0 Assembly Building and Radiation Handling Facility

____ D0 Assembly Building

Trainer Date

37. Fermilab Accelerator Science and Technology (FAST) Facility

Know the location of the New Muon Lab (NML) building and be able to point out the following equipment:

____ FAST Cave

____ Remote key trees

____ Control room

____ Laser room

____ Electrical Service Building (ESB)

____ Remote key tree

Trainer Date

38. Cryomodule Test Facility (CMTF)

Know the location of the CMTF building and be able to point out the following equipment:

____ PIP2 Injector Test (PIP2IT) enclosure

- ____ PIP2IT beamline

____ Control room

____ Compressor room

____ Cryo pit

Trainee Date

39. Miscellaneous Locations

Be able to find the following locations:

____ Site 38

- ____ Fire Department
- ____ Stockroom
- ____ Vehicle Maintenance
- ____ Gas pumps

____ Village

- ____ Gymnasium
- ____ Pool and tennis courts
- ____ Users' Center
- ____ Kuhn Barn

Trainee Date

40. Beamline and Accelerator Enclosures

Access as many of the following beamline and accelerator enclosures as you can. Ideally, have any important equipment pointed out. Sign yourself off when complete.

NOTE: It is very important to visit every enclosure; however, depending on operating conditions, you may not access every enclosure before completing this training book.

____ Proton Source
- ____ Linac
- ____ Booster

____ Tevatron
- ____ F-Sector
- ____ Transfer Hall

____ Main Injector
- ____ MI-10
- ____ MI20-62
- ____ 8 GeV

____ NuMI
- ____ MI-65

____ BNB
- ____ MI-12A and B

____ MINOS
- ____ Alcoves
- ____ Absorber Room
- ____ Decay Pipe Walkway
- ____ Detector Hall

____ Switchyard
- ____ Enclosure B
- ____ Enclosures C, D, and E
- ____ F1
- ____ F2 and F3 (confined spaces)
- ____ G2

____ Muon

- ____ Delivery Ring
- ____ Transport Line (US/DS, Mid)
- ____ Pre-Target
- ____ Pre-Vault
- ____ Extraction
- ____ M4 Enclosure
- ____ MC-1

____ Meson Line

- ____ Meson Primary (M01-M05)
- ____ Meson Test (MT6-1 and MT6-2)
- ____ Meson Center (MC6, MC7-North, MC7-South, and MB7)

____ Neutrino Line

- ____ Neutrino-Muon (N01-NM3)
- ____ SpinQuest detector hall (NM4)

____ FAST

Part 5: Accelerator Concepts

The following is a study guide for accelerator concepts that will be covered in the Introductory Operator II Exam. For a full explanation of these concepts, refer to the Concepts Rookie Book and be sure to talk to your crew members.

Trainer	Date

1. Basic Terminology

Know common accelerator terminology associated with accelerators and beam lines.

____ **Beam** is a focused group of particles all travelling in the same general direction.

____ A **bucket** is the stable space created by the RF that can capture and accelerate beam. This is equivalent to an area in longitudinal phase space.

____ A **bunch** is the beam within a bucket; think of it as a cloud of particles.

____ A machine's **harmonic number** is the number of times the RF field oscillates in one beam orbit of a circular machine. This is equivalent to the number of RF buckets in a machine, and thus the maximum number of bunches in an accelerator. It can be calculated by multiplying the beam revolution period by the RF frequency.

____ A **batch** is the full output of one Booster cycle, which is equivalent to 84 bunches.

- ____ **Partial-batching** is the process of sending less than a full batch to the 8GeV Line and sending the remaining bunches to the Booster dump.
- ____ **Multi-batching** is the process of sending more than one successive batch out of Booster to RR or MI.

____ A **Booster turn** is one circumference of Booster beam. Multiple turns mean that injected beam is combined with already circulating beam; the more turns, the higher the beam intensity. We control the number of turns by changing the pulse length of the beam injected into Booster.

____ **Transverse** refers to the horizontal and vertical plane, perpendicular to the direction of beam travel.

____ **Longitudinal** is parallel to the direction that beam travels.

____ **Emittance** is a beam parameter related to the size of particle betatron or synchrotron oscillations.

____ A **synchrotron** is an accelerator that guides beam on a circular path and uses RF cavities to accelerate beam over many revolutions. The dipole magnetic field and RF frequency of a synchrotron increase together with beam kinetic energy.

____ The **ideal orbit** is the path of the beam through the center of the magnets. In a synchrotron, the synchronous particle travels on the ideal orbit.

____ A **closed orbit** is the average beam path that returns to the same point on every revolution around a circular machine. It is the beam trajectory which may include intentional bumps and corrections.

Trainer Date

2. Magnet Terminology

Know what devices we use to manipulate beam in beam lines and accelerators.

____ **Dipole magnets** have two pole faces that create a magnetic field which bends beam horizontally or vertically.

____ **Ramping** the magnets means increasing the dipole bending field in a synchrotron to follow the increase in particle momentum, keeping the bend radius constant and the beam in the machine.

____ **Bumping** is a way to use three or more dipoles to create a beam position or angle change in a specific area without affecting the rest of the orbit.

____ **Dispersion** is the way in which beam momentum spread leads to a transverse deviation from the ideal orbit. This is due to the velocity-dependent nature of the magnetic field: low-momentum particles are bent more than high-momentum.

____ **Quadrupole magnets** have four pole faces that create a magnetic field which focuses the beam, like a lens, in one transverse direction but defocuses beam in the other. Quadrupoles are arranged in a repeating alternating pattern known as a lattice, and control the tune of an accelerator. They provide the restoring force that causes betatron oscillation.

____ **Betatron oscillation** is the transverse oscillation around the ideal orbit and is due to the restoring force provided by the quadrupole magnets.

____ The **lattice** is the arrangement of an accelerator's quadrupole magnets into a periodic pattern. In a synchrotron, this involves the repetition of alternating focusing and defocusing quadrupoles.

____ A **cell** is the smallest repeating pattern in a lattice.

____ The **tune** is the number of betatron oscillations per beam revolution. The tune is controlled by quadrupole magnets.

____ **Chromaticity** is the effect that beam momentum spread has on the tune spread. This is due to the velocity-dependent nature of the magnetic field. For a given quadrupole, low-momentum particles have a lower focal length than high-momentum particles. Chromaticity can be controlled with sextupole magnets.

____ **Sextupole magnets** have six pole faces. Sextupoles control the chromaticity by compensating for the momentum-dependence of quadrupole focusing.

____ **Octupole magnets** have eight pole faces. Octupoles can control the tune spread's dependence on particle betatron oscillation amplitude.

____ **Combined-function (gradient) magnets** create a field that provides simultaneous bending and focusing in a single device.

Trainer Date

3. Injection and Extraction

Know the common injection and extraction devices.

____ A **chopper** is a device used to deflect a portion of a continuous stream of beam.

____ A **kicker** is a pulsed magnet whose field can rise and fall very quickly. In conjunction with a Lambertson or septum magnet, kickers are used to either place beam onto a closed orbit (injection) or to take beam off a closed orbit (extraction).

____ **Magnetic septa** are magnets with at least two separate apertures. One aperture, called the field-free region, does not deflect beam. The other aperture, called the field region, acts as a dipole. There is a conducting plate between the two regions that blocks the magnetic field from entering the field-free region.

____ A **Lambertson** is a type of septum magnet that is commonly used during the injection or extraction process to bend beam toward or away from a circulating path, respectively. The field-free region of a Lambertson is created by placing a hole in the iron core.

____ **Electrostatic septa** are tanks made up of thin wires at ground with high-potential electrodes to either side. Electrostatic septa can be used to split a single incoming beam into two lower intensity beams, or to peel MI beam off to Switchyard during resonant extraction.

____ **Injection** is the process of placing beam into an accelerator or beam line. Common combinations of devices used for injection are:

____ Magnetic septa → kicker

____ Lambertson → kicker

____ **Extraction** is the process of quickly removing beam from an accelerator or beam line. Common combinations of devices used for extraction are:

____ Kicker → magnetic septa

____ Kicker → Lambertson

____ Electrostatic septa → Lambertson

____ **Resonant extraction**, also known as "slow-spill," extracts high intensity MI beam out in a long low intensity stream to Switchyard. By driving the beam at a betatron resonance, we can cause the beam to become unstable and slowly fall into the aperture of an electrostatic septum to be "peeled" off for extraction.

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Trainer Date

4. Radio Frequency (RF) Terminology

Know the following about the devices used to accelerate and manipulate beams of particles:

____ **Acceleration** is the use of an RF electromagnetic standing wave to increase the kinetic energy of the beam. In a synchrotron, the RF frequency increases to keep up with accelerating beam's increasing momentum.

____ An **RF cavity** is a resonant structure that efficiently produces a standing electromagnetic wave. The oscillating electric fields produced in these cavities capture or accelerate the beam.

____ **Bias tuners** change an RF cavity's resonant frequency in a synchrotron to follow the acceleration of beam.

____ **Phase** is the difference between the timing of the RF cycle and a particle arrival time in the RF cavity. In other words, an incoming particle arrives at a certain point or phase in the RF waveform due to the timing of when it arrives in the cavity.

____ The **synchronous phase** is the particle phase around which the accelerator is designed and provides stable particle acceleration.

____ **Phase focusing** is the process that drives off-momentum or mistimed particles into stable longitudinal oscillations about the synchronous phase. Phase focusing provides the restoring force that causes synchrotron oscillations.

____ **Synchrotron oscillation** is a longitudinal oscillation about the synchronous phase. This is due to the phase focusing process from the restoring force of the RF electric field.

____ **Paraphasing** is the process through which the Booster RF cavities, initially out of phase with one another, are slowly phased together after injection in order to capture 37.8 MHz bunches out of injected Linac beam.

____ **Bucket-to-bucket transfer** refers to the synchronized way in which bunches of beam are precisely sent from one machine to another with very little loss.

____ **Bunch rotation** is an RF manipulation that reduces the beam momentum spread before extraction out of Booster. This is accomplished by modulating the RF gradient of all the Booster cavities to drive synchrotron oscillation. Bunch rotation is performed to help with slip-stacking.

____ **Slip-stacking** is an RF beam manipulation performed to combine bunches to effectively double beam intensity.

____ **Transfer cogging** is the process by which a machine's RF phase is synchronized that of a downstream machine in order to place transferred beam into a targeted bucket.

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Trainer Date

5. Basic RF System

Draw a block diagram of a basic RF system that includes a low level oscillator, phase shifter, power amplifier, anode supply, modulator, RF cavity, beam feedback, and cavity tuning.

_____
Trainer Date

6. Transition

Be aware of the concept of transition and how it applies to circular and linear accelerators. Know where transition occurs in both Booster and Main Injector, and know what you can plot to see exactly when transition occurs.

Trainer Date

7. Injection/Extraction Energies

Know the injection and extraction energies of the following machines and beamlines:

____ Machines

- ____ Pre-Acc
- ____ Linac
- ____ Booster
- ____ Main Injector
- ____ Recycler
- ____ Delivery Ring

____ Beamlines

- ____ NIF (Neutron Irradiation Facility)
- ____ MTA (MeV Test Area)
- ____ BNB (Booster Neutrino Beamline)
- ____ NuMI (Neutrinos at the Main Injector)
- ____ Meson Test
- ____ Meson Center
- ____ Neutrino Muon

Trainer Date

8. Machines

____ Be able to draw and label the general geographical layout of the accelerator complex. This should include all of the active beamlines.

Trainer Date

9. Experiments

Know the primary experiment for the following:

____ BNB

____ NuMI

____ Meson Test

____ Meson Center

____ Neutrino Muon

____ Muon Campus

Trainer Date

10. Linac

Know the following information about the Linac accelerator:

____ The source produces a beam of H- ions, from a bottle of hydrogen, which are then accelerated to 750 keV by the RFQ.

____ Linac accelerates the beam from 750 keV to 400 MeV using a linear series of RF cavities.

____ There are two types of RF cavities in Linac: Drift Tube Linac (DTL or Low Energy) and Side-Coupled Cavity Linac (SCL or High Energy).

____ The DTL cavities have a fixed resonant frequency of 201.24 MHz. The SCL cavities have a fixed resonant frequency of 804.96 MHz.

____ In the DTL, quadrupoles are located inside the drift tubes, which are inside the RF cavities. The SCL cavities have quadrupoles between the cavity modules.

____ Extraction takes place in the 400 MeV transport line that sends beam to Booster, the Linac dumps, and MTA.

____ Toward the end of the 400 MeV line is the Debuncher RF cavity that is phased to help remove the 804.96 MHz bunch structure. This facilitates paraphasing in the Booster.

____ Beam energy to NIF is 66 MeV.

Trainer Date

11. Booster

Know the following information about the Booster accelerator:

____ Booster accelerates beam from 400 MeV (2.2 μs revolution period) to 8 GeV (1.6 μs revolution period).

____ H- ions are stripped of electrons at injection, leaving protons to circulate in the machine.

____ RF adiabatically (slowly) captures beam into buckets just after injection through a process called paraphasing.

____ RF frequency increases from 37.8 MHz at injection to 52.8 MHz at 8 GeV to accelerate protons.

____ The MI-8 line carries beam into the Booster dump, BNB, Recycler, or Main Injector.

____ Booster has gradient magnets that both bend and focus the beam.

____ The magnets are arranged in a FOFDOOD lattice.

Trainer Date

12. Main Injector

Know the following information about the Main Injector:

____ Operational beam energy range of 8 GeV to 120 GeV

____ Revolution period is about 11μs at all energies.

____ RF frequency is approximately 53 MHz. The RF cavities are located at MI-60.

____ The magnets are arranged in a FODO lattice.

____ Main. Injector has eight straight sections (10, 22, 30, 32, 40, 52, 60, and 62).

Trainer Date

13. Recycler

Know the following information about the Recycler:

____ The Recycler is an 8 GeV proton ring that is primarily composed of permanent gradient magnets.

____ The magnets are arranged in a FODO lattice.

____ The Recycler performs RF manipulations on the beam.

____ Protons in the Recycler can be sent to the abort through the RR-40 abort line.

Trainer Date

14. NuMI

Know the following information about Recycler and Main Injector for NuMI operations:

____ Recycler is injected with multiple Booster batches and performs slip-stacking.

____ MI accelerates the beam from 8 GeV to 120 GeV.

____ MI extracts the beam near MI-60 and the NuMI beamline directs the beam towards the NuMI target hall.

Trainer Date

15. Muon Campus

Know the following information about Recycler and Muon Campus for Muon g-2 operations:

____ Recycler is injected with 52.8 MHz bunches from Booster which are recaptured into 2.5 MHz bunches.

____ Each recaptured bunch is individually extracted from the Recycler at MI-52 into the P1 line and then travels down the P2 and M1 lines to the Muon Campus target.

____ 3.1 GeV/c secondary particles travel down the M2 and M3 lines to the Delivery Ring where the differences in energy between muons and protons separate them in time, allowing the protons to be sent to a cleanup abort.

____ The remaining muons are extracted toward the M4 and M5 lines and injected into the g-2 ring at the MC-1 hall for measurement.

Trainer Date

16. Switchyard

Know the following information.

____ For Fixed Target, beam is extracted from Main Injector at MI-52, down the P1 line, during a process called “resonant extraction” which occurs at 120 GeV. Beam then travels through the P2 and P3 lines and on to Switchyard.

____ Beam is not accelerated in the Switchyard, but it remains at a constant energy.

____ Electrostatic septa and Lambertson magnets split the beam into multiple beamlines feeding the Fixed Target experiments.

Trainer Date

17. Beam Permits and Run Conditions

You have completed an introductory discussion about beam permits and run conditions. This should include:

____ How to find the official limits and which beamline devices are used to monitor them

____ Reading and signing every beam permit and run condition

____ The method of calculating the amount of beam delivered and estimate hourly rates

____ Several ways to monitor hourly beam intensity

____ Purpose of interlocked radiation detectors and under what conditions they may be reset

Trainer Date

18. Critical Devices

You have completed a discussion on the need and use of critical devices and the operator's role in the process of critical device work.

Trainer Date

19. Water

Be aware of how LCW is used in the cooling of various systems around the lab. Know the role of the following with LCW:

____ Central Utility Building (CUB)

____ Draw a simplified diagram of an LCW system. Your drawing should include:

- ____ Water pump
- ____ Heat exchanger
- ____ Power supplies
- ____ Magnets

Trainer Date

20. Power Distribution

Be aware of general power distribution on site and how it relates to the following:

____ Master Substation

____ Kautz Road Substation

____ Transformers outside of the service buildings

____ Know where to locate drawings of the high voltage power distribution feeder systems.

Trainer Date

21. Cryogenics

____ Understand the use of cryogenics at Fermilab

- ____ Which areas use cryogens
- ____ Which buildings and enclosures are affected

Trainer	Date

22. Vacuum

Be familiar with the following vacuum components and their purpose:

____ Understand that the beam pipe must be under vacuum in order to reduce the interaction of beam with air molecules

____ Roughing pump

____ Turbo pump

____ Ion pump

____ Vacuum gauges

____ Vacuum valve

____ CIA crate

Trainer	Date

23. Instrumentation

Be familiar with the function and purpose of the following:

____ BLM

____ BPM

____ Toroid

____ Wire Profile Monitors

- ____ Multiwires
- ____ SWIC