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RESIDUAL DOSE AND ENVIRONMENTAL MONITORING FOR THE FERMILAB MAIN INJECTOR TUNNEL USING THE DATA ACQUISITION LOGGING ENGINE (DALE)

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Abstract

The Recycler and the Main Injector are part of the Fermilab Accelerator complex used to deliver proton beam to the different experiments. It is very important to control and minimize losses in both machines during operation, to reduce personnel dose from residual activation and to preserve component lifetime. To minimize losses, we need to identify the loss points and adjust the components accordingly. The Data Acquisition Loss Engine (DALE) platform has been developed within the Main Injector department and upgraded throughout the years. DALE is used to survey the entire enclosure for residual dose rates and environmental readings when unrestricted access to the enclosure is possible. Currently DALE has two radiation meters, which are aligned along each machine, so loss points can be identified for both at the same time. DALE attaches to the enclosure carts and is continuously in motion monitoring dose rates and other environmental readings. In this paper we will describe how DALE is used to provide radiation maps of the residual dose rates in the enclosure. We will also compare the loss points with the Beam Loss monitor data.

INTRODUCTION

The Main Injector and the Recycler are circular accelerators that are used to deliver beam to multiple different experiments. They share the same tunnel and are used in combination to accelerate a proton beam from 8 GeV to 120 GeV [1]. The Recycler (RR) is mounted about 6 ft above the Main Injector (MI), stretching along about 2.1-mile circumference.

The Data Acquisition Loss Engine (DALE) platform has been developed within the Main Injector department to measure the residual radiation dose along the Main Injector and Recycler accelerators. Originally it consisted of one hand-held detector and was used to survey one machine (MI or RR) at a time. Currently DALE has two detectors which allows both machines to be surveyed simultaneously. Besides measuring the residual activation of the accelerators, DALE is also capable of measuring other environmental parameters in the tunnel.

The goal of DALE surveys historically have been to identify the loss points in the accelerators after beam operation. DALE surveys complemented so-called "Expert Surveys" which were detailed local radiation surveys performed by experts. The data gained from both allowed experts to adjust the accelerator components accordingly by alignment which would lower or eliminate the loss points.

DALE HARDWARE AND SOFTWARE COMPONENTS

DALE connects to two radiation detectors, one mounted high on a vertical rod and is aligned to the Recycler machine, and the lower one is mounted lower on the same rod to be aligned with Main Injector machine. This way simultaneous measurement of activation around the entire ring is possible. It houses a number of additional environmental sensors so it can collect those data while in the tunnel. It also includes two distance sensors, aisle side (wall) and machine side, that measure inner and outer distance to the tunnel walls from the detector, light, temperature, humidity, heat index and air quality sensors. It also uses a wheel counter to keep track of its position in the Main Injector tunnel. DALE has a Wi-Fi capability to connect to its live display and is based off an Arduino Mega 2560. It writes and saves its data to an onboard SD card. A picture of DALE is shown on Figure 1.

Figure 1: DALE on a cart.

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DATA ACQUISITION

DALE sits on the cart, is connected to the two radiation detectors and wirelessly linked to the Virtuino software running on the tablet device that gives a live display of readings. The data collection occurs on Arduino Mega which writes and saves data on an SD card. The DALE cart gets attached to the tunnel cart and is driven around the enclosure in the direction of proton beam.

The Main Injector is broken into six sectors around the ring. The MI10, MI20, MI30, MI40, MI50, and MI60 service buildings support each section and power the accelerator components in each area. The 30 tunnel section houses the MI collimators, the beam absorber is located in 40 section, beam injection from Booster to RR or MI happens at 10, RR to MI injections occurs at 30. The 60 tunnel section has the Recycler collimator system (RR), RF and NuMI extraction (MI) and 50 contains the lambertsons for slow spill and Muon campus extraction.

Saved data on an SD card is then imported into a relational database that is read through ACNET, which is a Fermilab control system interface for all the accelerator parameters and their operation. The details of the data import and export are described in the next section.

It should be noted that the radiation detectors (the Geiger-Muller tubes) come with the calibration curve from the manufacturer. When the dose rates reach about 1 R/hr, the counts seen on the detector start to saturate (see Figure 2). Saturation shown on the calibration curve itself is not usually reached in our case as the carts are driven about 1 m away from the accelerator components. Since DALE is always in motion and it only integrates counts every second, it has a tendency to underestimate the actual dose rates. It does a very good job below about 150 mR/h, then a combination of calibration curve saturation and the speed of DALE cause the readings to be less accurate. For this reason, after identifying the loss points, performing the localized survey is beneficial.

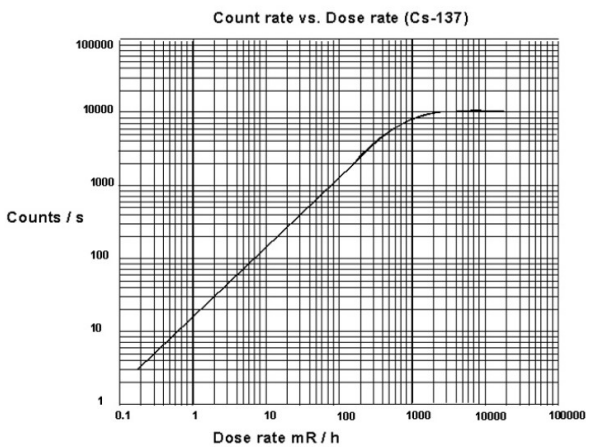

Figure 2: Calibration curve.

CLIENT PROGRAM

A client program was written in Java to import, view and export DALE survey data.

Importing Surveys

During survey import, the user supplies information regarding the tunnel surveyed, the direction traveled, and the approximate time when beam was disabled. On submit, the survey data, including the user supplied meta data, is saved to a relational database table for later retrieval. Surveys are grouped by enclosure, and sorted in chronological order in the survey tree on the main page of the client.

Viewing Surveys

The program has separate tabs for each type of data recorded during a survey and multiple display options per chart to view the data as the user would like. Multiple surveys can be viewed at once, and functions exist to plot data on the same domain axis for comparison. For dose rate comparison between surveys, a feature exists to normalize the Geiger Mueller tube readings by distance from the machine and time from beam turn off. The dose rate normalization by time uses a cool down curve found from previous studies [2] to approximate what the dose rate would have been after the user supplied amount of time since beam turn off. A feature exists to also view the dose rate history, normalized or not, of any tunnel location over all DALE surveys taken. In addition to dose history, any locations dose can be projected into the future.

Client Uses

The data generated by DALE along with the client features have proved useful for a number of tasks. Normalized dose rate difference plots are used to identify new or problematic loss points. Light level readings identify issues with lighting and help ensure lighting problems are mitigated before work occurs in the tunnel. Dose projections are used for ALARA (As Low As Reasonably Achievable) work scheduling and planning.

RESULTS AND SURVEY MAPS

The survey results shown on Figure 3 were the latest results collected around the ring. It gives the dose rates along the Main Injector and the Recycler sections mentioned above starting from component 101 to 641. Figure 4 represents the schematic of the same survey data around the ring for a better visual illustration. There are four MI collimators in 300 section and this area has the highest dose rates around the accelerator. RR collimators are located at 613 and 616 sections and also have relatively high dose rates and are considered the area of interest. The rest of the peaks belong to the MI beam abort lambertson (400 region), Muon extraction and slow spill loss (520 region) and RF related losses around the ring.

The blue trace on Figure 3 represents the lower (MI) rad detector, and the red trace represents the upper rad detector

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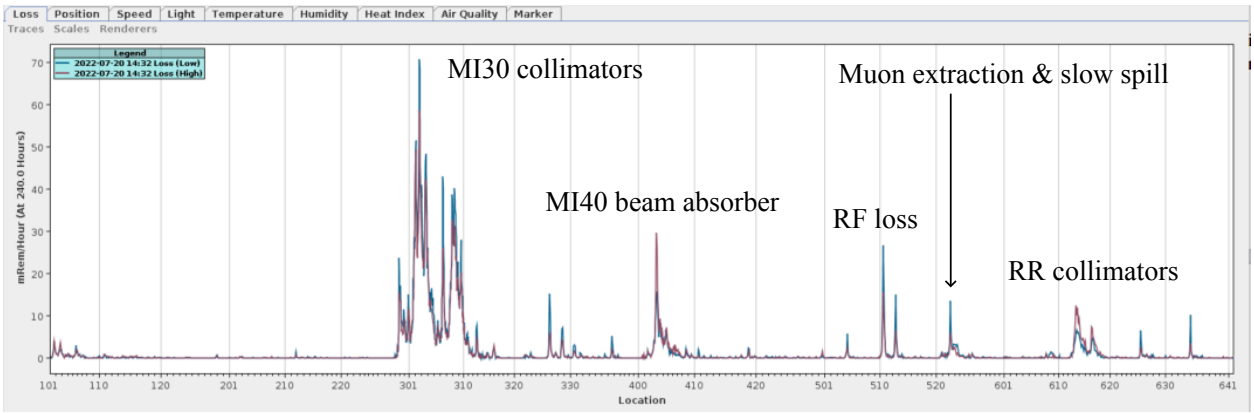

Figure 3: DALE results around the ring.

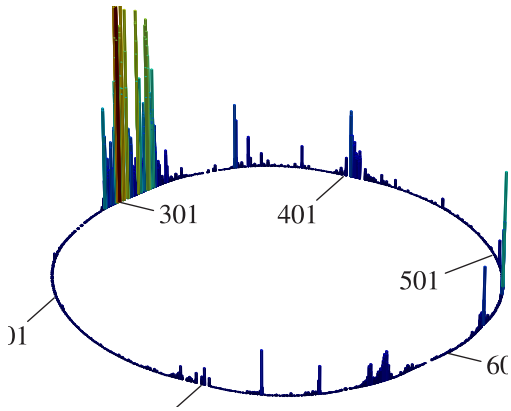

Figure 4: DALE survey around the Main Injector.

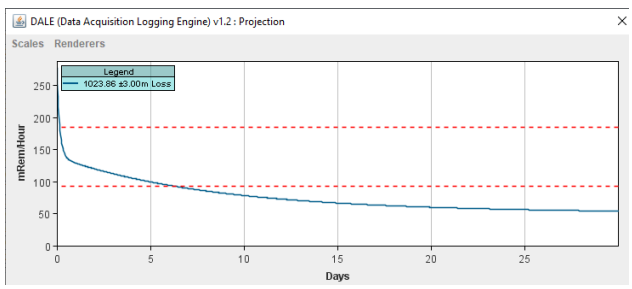

Figure 5: Cooldown curve.

(RR). The data is normalized against the time beam was turned off. During normalization the cool down curve is also considered (Figure 5) which is used in the program for every single point around the ring based on the measurement data [2].

LOSS POINTS VS BEAM LOSS MONITOR (BLM) DATA

There are number of real time Beam Loss Monitors (BLM) installed all around the ring along Main Injector and Recycler components [3]. Data from BLMs generally match well with the DALE survey results, however, localized loss points are not always well represented by them. The intensity of losses picked up by BLMs are not always significant in between accelerator components. DALE is a good way to find those loss points and make appropriate adjustments.

SUMMARY

This paper explains what a DALE survey is and how it is utilized for the MI/RR accelerators. After the beam operation, when the enclosure is accessible for the tunnel carts to drive all the way around the entire enclosure, DALE survey is performed along the ring to identify the loss points around both MI and RR machines. For the newly found loss points it is suggested to adjust the components accordingly to minimize losses in the area. Due to safety procedure changes, tunnel access is not always available, so identifying quick changes in loss points and corresponding adjustments become somewhat challenging. It is very important to continue DALE surveys as frequently as possible so the machines continue to have minimal and known losses, recognize changes in a timely manner and address them accordingly.

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