

To:

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Subject: Proton Improvement Plan

Project Quarterly Summary FY16 Q1

Report #13 January 14, 2016

Project Milestones

There was 1 Linac scheduled milestones level 4 this quarter. *Completion of Final acceptance test.* This milestone was close to completion at the end of the quarter. A detailed explanation is given below within WBS 1.1.1.1 High Level RF report. One Level 4 delayed from the previous quarter, *Notch Beam Shaping*, is progressing and should meet the forecasted finish date. Booster had several high level milestones met in FY16 Q1. The Booster 20th cavity, completion of the level 2 cavity refurbishment task, Booster Anodes and the Booster Bias supply upgrade were all completed. These were significant milestones and have had an immediate positive impact to PIP and our HEP program. Booster had one level 3 milestone which had been delayed in previous quarters due to labor shortages, *BPM Production Procure*.

Table 1 PIP milestones

L	WBS	Description	Baseline	Fcst Fin
2	1.02.01.05.03.20	Booster RF Cavity Refurbishment Complete	12/3/15	12/8/15
3	1.02.01.02.03.16	Finish program of gutting & assembling within Bias supply enclosures	10/19/15	11/11/15
3	1.02.01.02.04.12	Complete Bias Supply testing	10/26/15	11/18/15
3	1.02.01.11.05	RF Station 20 Commissioned	10/6/15	10/6/15
2	1.02.01.02.05.12	Complete Bias Supply installation (upgrade ends)	11/2/15	11/25/15
2	1.02.01.01.13	Anode Power Supply Operational	10/21/15	10/14/15
2	1.02.01.01.14	All Anode Supply Documentation Complete	10/21/15	1/21/16
4	1.01.01.01.02.01.02	Completion of Final Acceptance Test (at CPI)	1/5/16	12/14/15
4	1.01.01.01.02.01	Final Cost Estimate for Linac Gallery Civil Construction	4/21/15	4/21/16
3	1.01.02.03.04.14	Linac Notch FSLA Operational on Bench - ready to install	4/23/15	9/28/15
3	1.02.01.02.03.16	Finish program of gutting & assembling Bias Supply enclosures	4/15/15	11/11/16
3	1.02.03.01.05.02	Booster BPM Production Procure/Assembly Complete	5/15/15	3/1/16
4	1.01.02.03.06.33	Linac Notch Beam Shaping, Diag., Dump ready for installation	9/21/15	3/16/16

PIP Highlights by WBS Section

WBS 1.1 Linac

The vulnerabilities associated with the LINAC are the 200 MHz accelerating system, including power amplifier tubes and other associated systems such as the modulator; utilities for power distribution and vacuum systems; better need for reliable instrumentation along the Linac to improve beam transport and realistic machine model supported by real beam measurements. There are four largest elements of WBS Level 2 in Linac which are further subdivided at Level 3.

WBS 1.1.1 200 MHz RF Power System

The 200MHz RF Power System represents approximately 40% of the total scope of the PIP project. There are 3 level 4 elements which will be described below.

WBS 1.1.1.1 High Level RF

During this quarter all cavities were brazed and cold tested in October and the klystron was assembled and sealed-in. The bake out was completed in the first week of November. The external (dress) hardware was installed and the klystron passed the hi-pot voltage hold off test. In mid-November it was installed in the test set and began DC processing. In early December the klystron began RF processing. The originally scheduled CSI date of 12/9/15 was pushed back to 12/11/15 at CPI's request.

The klystron prototype development reached its completion. A new klystron (type CPI VKP-8201A serial no. 001) was successfully tested to **most of the agreed** contractual standards. During test the tube produced 5.04 MW peak RF output power at a frequency of 201.25 MHz with a corresponding gain of 36.6 dB and an efficiency of 43%. A team from Fermilab composed of the PIP Project Manager and Proton Source Department Head, William Pellico, AD RF Engineer, Alfred Moretti and PIP L2/L3 Manager for the 200 MHz system and Linac group leader, Fernanda G. Garcia visited CPI for klystron inspection and witness the acceptance test. Prior the test, a round table discussion on the manufacture process and future plans for both CPI and Fermilab took place. Some important points were raised such as the company inquired about the possibility of Fermilab initiate the upgrade, therefore, going for production mode. PIP Project Manager re-iterated the position that at this point PIP will not go ahead with the upgrade plan for this system based on the direction of the laboratory in building a new super-conducting linac (PIP-II project). Nevertheless, the successful demonstration of the 200 MHz single-beam klystron is seen as a promising device technology option to provide a continuity to the operations of the Fermilab room-temperature linac if the laboratory finds that a multi-year delay on the construction of PIP-II linac is possible. Along these lines Fermilab asked for a revised manufacturing cost estimate from the leading engineers and businessman so that PIP can update its planning schedule/cost for this upgrade.

Synopsis of the Acceptance Test -- The klystron had stable operation and was able to achieve full output power but the efficiency and gain were lower than expected. Additionally, the input drive to output power transfer curve had an irregularity in the linear region. The curve was within the specification limits, but additional tuning was performed to minimize the magnitude of the irregularity. During the testing period it was found that some of the type-n coaxial adapters in the output metering line did not have an adequate bandwidth response and that the bandwidth measurements were incorrect. This was validated by comparing steady-state calorimetric power levels to those measured through the power meter. After replacing the parts at fault CPI was able to establish consistent power measurements between methods. Based on the new bandwidth, CPI decided to re-tune the klystron and continue testing into January. Re-tuning the tube improved the gain, but it was still under the specification. As the last test, an x-ray survey, was about to be completed one of the high power coaxial loads started to arc at low powers. It was found that an internal water joint was corroded and an electrical connection was faulty. After rebuilding the load the final tests were completed January 15th. Pending acceptance of the test data by FNAL the klystron will be shipped in the end of January.

At Fermilab efforts continue on drafting of the linac north gallery floorplan layout. In addition a final document report on this system is in progress.



Figure 1. VKP8201A- S/N 001 positioned at CPI test stand.

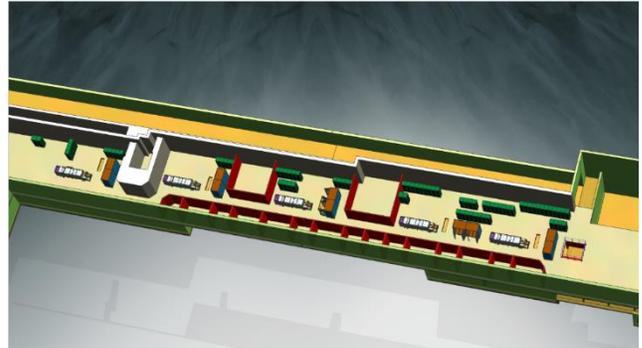


Figure 2. Linac north gallery floorplan showing a possible position for the new 200 MHz klystron.

WBS 1.1.1.2 Linac Modulator

Work is progressing well on developing a prototype modulator capable of replacing the present tube based design.

During the past quarter, progress on both the 54 cell design and testing the 28 cell design in LRF1 was accomplished. A final charging power supply specifications for the 54 cell design was created and submitted to the laboratory purchase office for entering into the competitive process. Bids were solicited and upon receipt were evaluated by the technical team. The awarded seller was Lumina Power, Inc. By the end of the quarter a purchase order for 24 units was submitted.

Cell assembly for the 54 cell prototype began. The controls cabinet for the 54 cell prototype was purchased and arrived on site. The cabinet for the 54 cell Marx charging power supply cabinet has been ordered and the design is being finalized.

The 28 cell prototype modulator was tested into a dummy load and then moved to the Linac gallery where it was connected to the 7835 at LRF1. The modulator was successfully operated to the required voltage and current to operate the 7835 at nominal gradient. In addition, beam was successfully accelerated to the end of Linac despite the incomplete controls available at the time of the test -- limited feedback and

no compensation for beam loading. Nevertheless, the test was a success and revealed various control and interlock issues which have been worked on at the end of the quarter.



Figure 3: Linac Marx-Modulator cabinet positioned by FPA at Linac LRF1 station.

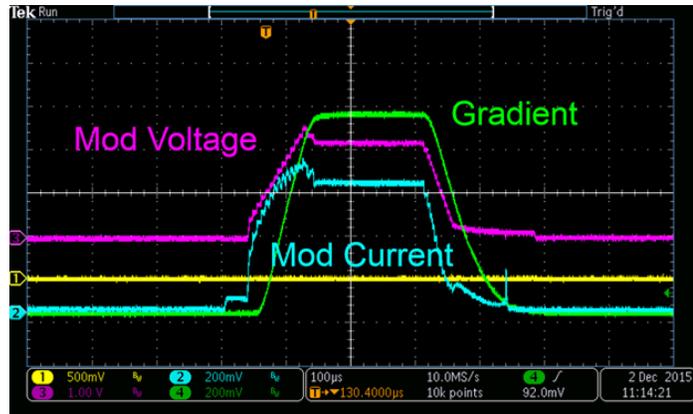


Figure 4: Linac Marx-Modulator wave form while driving the LRF1 station.

WBS 1.1.1.3 7835 Procurement

Linac Level-4 WBS completed (FY15-Q1).

WBS 1.1.2 Accelerator Physics

WBS 1.1.2.1 Simulations and Studies

Linac Level-4 WBS completed (FY15-Q1).

WBS 1.1.2.2 Not Used

Some WBS numbering is nonconsecutive at lower levels because of account closings and rearrangements after financial codes were initially established during the period of setting up PIP.

WBS 1.1.2.3 Linac Notch Creation

Work continues with the development of the laser notch system.

At the end of FY15 both solid state Grumman amplifier modules were commissioned with low seed power to measure the small signal gain. The original 6 μm gain fiber in the power amplifier of the PriTel fiber amplifier unit had been replaced with a 10 μm large mode area (LMA) fiber and output looked

stable. Starting in FY16 the PriTel fiber amplifier (PFA) was connected to the pulsed Optical Engine amplifier (OEA) through an FC/APC connector with 10 μm core fiber on either side of the connector.

Alignment of the optical board proceeded with the OEA being used as a delivery fiber. After the alignment and during the OEA power commissioning, the FC/APC connectors between the PFA and the OEA were burned. Although the cause cannot definitively be determined, the team confidently determined that it was most likely caused by contamination on the ferrule tip at the point of the highest optical power density. Three solutions were investigated with the aid of optical and fiber experts; a high power connector which reduces power density at the connection, a fiber to free-space connection, and fiber fusion splice between the amplifiers. The third option for connection was selected. Although this option is the least convenient, it provides the smallest optical loss at the connection and is felt to be the most robust.

In addition to solving the connector issue, numerous other tasks were accomplished. The laser system safety interlock module was installed in the laser electronics rack and is used to provide permits for all lasers and amplifiers. The Safety System Critical Device Controller module was installed in the RFQ Injector Line (RIL) control Room and cables pulled to the location of the notcher system next to the RFQ. We developed an optical BPM system (OBPM) when coupled with our piezoelectric launch mirrors will allow us to steer the IR laser beam into the optical cavity with a few micron accuracy.

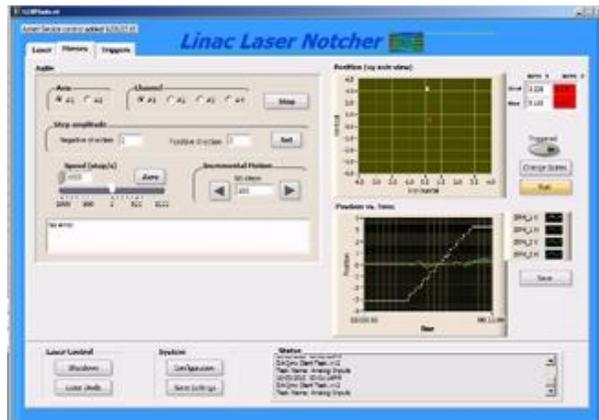
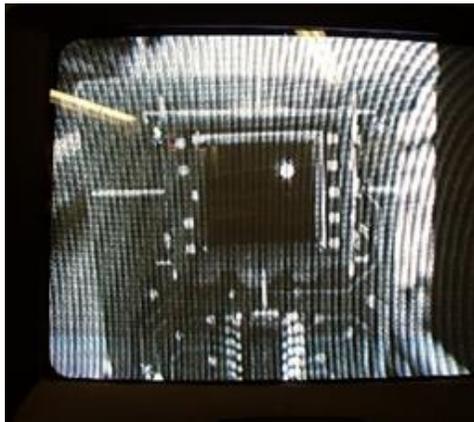


Figure 5. Video image of the laser on the OBPM and the OBPM response from the piezoelectric mirror vertical movement.

Figure 6. Image of IR laser beam out of the optics box [1 mm grid]

A real time USB video monitoring system was developed to monitor the IR beam position and transverse profile in the optics box, transport enclosure, and laser dump enclosure (Fig. 6)

The transport and dump enclosure designs were finalized and manufacturing prints were delivered to the shop. The controls software used for the control of the complete laser system continued to be upgraded and debugged (Fig. 7)



Figure 7: The electronics rack and control program talking to several of the devices

WBS 1.1.3 Instrumentation

WBS 1.1.3.1 Beam Position Monitors

First Linac Level-3 WBS completed (FY13-Q2).

WBS 1.1.4 Not Used

Some WBS numbering is nonconsecutive at lower levels because of account closings and rearrangements after financial codes were initially established during the period of setting up PIP.

WBS 1.1.5 Utilities

The Linac Utilities, such as power distribution, water and vacuum systems are composed of mostly 40 year-old equipment beyond its practical service life. There are three Level 4 elements in this WBS.

WBS 1.1.5.1 Power Distribution

Linac Level-4 WBS completed (FY14-Q4).

WBS 1.1.5.2 LCW distribution

Linac Level-4 WBS completed (FY15-Q1).

WBS 1.1.5.3 Vacuum System

Linac Level-4 WBS completed (FY14-Q4).

WBS 1.2 Booster

Part of the PIP effort for the Booster Accelerator is to address the increase proton beam flux that will be demanded by the Fermilab program in the upcoming years. The increased flux will be achieved by providing beam on more/all of the Booster cycles; certain equipment will increase from an average 7.5 Hz to 15Hz. Overheating of old components is a major concern; several Booster PIP tasks are to upgrade/refurbish equipment to run at 15 Hz. Enough PIP tasks have been completed so that in FY16Q1 the Booster was capable of operating at 15 Hz.

The aging original equipment and infrastructure of the Booster are vulnerable due to obsolescence and increase wear due to the increase of flux. Some of the PIP effort is to replace these possible reliability problems.

WBS 1.2.1 RF

WBS 1.2.1.1 Anode Supply

Both anode supplies were being installed during the 2015 accelerator shutdown. The first supply was used to shake out the process of installation and testing. The lessons learned from the first installation was applied to the second anode supply installation. The completion of the installation, testing and commissioning of both anode supplies were done early in FY16Q1. There have been no problems with the anode supplies since they have been put into operation. This task is essentially complete with the exception of the final documentation.

WBS 1.2.1.2 Bias Supply

The last bias supply retrofit was finished and the supply has been commissioned. All retrofitted bias supplies are used in operations. This task is complete.

WBS 1.2.1.3 Not Used

Some WBS numbering is nonconsecutive at lower levels because of account closings and rearrangements after financial codes were initially established during the period of setting up PIP.

WBS 1.2.1.4 Cavity Test Stand

The cavity test stand task will not be done since there will be no benefit to PIP.

WBS 1.2.1.5 Cavity and Tuners Refurbishment

During this last quarter, the 19th cavity-tuner set refurbishment and testing was completed. This cavity was installed near the end of this quarter. All of the planned cavity-tuner sets refurbishments have been completed, tested and placed into operation.

WBS 1.2.1.6 New Tuners

Previously, a high power test stand for ferrite cores showed that one of four different core sets (two different permeabilities from two vendors) was acceptable. The acceptable core samples have been

implemented into a tuner and been certified. The tuner was installed on a re-furbished cavity; the cavity has been operation since FY14Q4. A purchase order for enough ferrite cores to build twenty tuners was placed. During FY15Q4, the vendor has delivered, and we have accepted, the balance of one set of ferrites. The vendor has encountered a problem making the second set of ferrites (low value of permeability). The vendor has corrected the problem but delivery of the balance of ferrites will not occur until FY16Q2.

Fermilab Technical Division is using the ferrite cores with other sub-assemblies to build new tuners. The assembly group has gained experience building the new tuners. Now, assembly is about three weeks to complete a tuner. Eleven tuners have been built and passed acceptance tests.

WBS 1.2.1.7 Replacement Cavities

Comparison of a model developed for the current Booster RF cavities and the temperature measurements taken as part of the refurbishment task continues. Further tests of cooling rates were done to compare with the simulation. Detailed temperature measurements were done during cavity and tuner set refurbishment certification (WBS 1.2.1.5); the last set of measurements were done during the final refurbished cavity tuner set certification. Simulation model verification continues.

The task has been renamed from new to replacement. Fermilab has recognized that any new/replacement cavities should work with PIP II. Requirements satisfying now and for the future have been determined. A review of the technical specifications was held as well as presented to the Fermilab Accelerator Advisory Committee (AAC). The review panel and AAC agreed that the specifications meet the needs of PIP and PIP II.

WBS 1.2.1.8 Cavity 1013

The cavity was put into operation in FY14Q4 and was operational during FY15Q1. There have been no problems with this reworked cavity. This task is considered complete.

WBS 1.2.1.9 Second Harmonic Cavity

The investigation of possible benefits of using a higher order harmonic cavity continues; in particular, for beam capture and transition crossing. The investigation is focused upon a perpendicular biased cavity. Work previously done at SSC and TRUIMF was our starting point. Modelling and simulations progress has led to improvement over the old designs. Garnet sample testing show that it is suitable for a perpendicular biased cavity. A mock-up of the tuner was built and measurements have been made. An analysis of the measurements is underway to compare with the simulations. A fixture is being built to test the final power amplifier (PA) to make certain that the PA will work sufficiently at the higher frequencies.

WBS 1.2.1.10 Rework of Two Cavities

Although not new cavities, PIP has decided to reclaim two other cavities and rework them to be the 21st and 22nd Booster cavities (similar to the rework done for cavity 1013; WBS 1.2.1.8). Long lead time items are being procured. This work has commenced with the completion of the refurbishment task (1.2.1.5). Tuners will be provided by work done by the New Tuner task (1.2.1.6).

WBS 1.2.1.11 Three New RF Stations

In addition, PIP will implement three additional RF stations to bring the total number of Booster RF stations to 22. This requires electrical work, water cooling work, assembly of power equipment and cable pulling.

The 20th RF station was completed during the 2015 shutdown. This new station was commissioning and put into operation in FY16Q1.

The remaining two RF stations will be completed in the 2016 summer shutdown. An initial conceptual layout has been done for these two stations. Clearing of space and preparing these areas has begun.

WBS 1.2.2 Accelerator Physics

WBS 1.2.2.1 Simulations and Studies

The people assign to the task of organizing, performing and analyzing beam studies has been consistent for the last few quarters. The main work is being done by an accelerator scientist in the Proton Source Department. There are several physicists from the Accelerator Physics Center also involved. The control programs for adjusting the lattice and tunes have been combined. The resulting application can adjust either the lattice or tune without affecting the other. Testing of this application is on-going and has to not affect operations.

Studies have been done investigating of injecting beam earlier. By injecting beam earlier, the resulting beam should have a smaller energy spread. A plan to slowly implement the early beam injection scheme has been developed. At the end of FY16Q1, several successful tests and implementation of steps of the plan has occurred.

WBS 1.2.2.2 Alignment and Aperture

Currently, no further magnets are scheduled to be moved. There are a few candidate magnets, but current simulation and beam studies (WBS 1.2.2.1) do not suggest that there will be noticeable improvement. The centers of the apertures have been designated as the ideal orbit (see WBS 1.2.2.1). We may return to this task in the future.

WBS 1.2.2.3 Booster Notcher

This task would be considered complete with the exception of some modified components are more activated than expected. Part of the upstream absorber mask was removed. By removal, of the activated mask, the area upstream of the absorber will hopefully not be susceptible to as much gamma ray shine from activated components. The part of the mask that remained, is further into the absorber shielding and hence workers in the area will have less exposure. During FY16, activation measurements of components of the absorber and the near the absorber will be done to see if the activation caused by the notch beam is contained within the absorber. We will continue studies to understand.

WBS 1.2.2.4 Booster Cogging

Studies of the new cogging board and code were concluded in FY15Q3. The cogging board was put into operation. This task is finished with the exception for interfacing with Linac laser notching system in FY16.

WBS 1.2.2.5 Booster Collimation

The collimation task is to control Booster beam loss after implementing the above notcher and cogging systems. A group has started studies of using existing collimation components. These studies include simulations, beam loss observations and exercising collimators movements. A new primary collimator has been built; it will be installed during FY16Q2.

WBS 1.2.2.6 Radiation Shielding

Beam studies concerning the beam loss profile and measurements of beam loss radiation through penetrations have been done. Simulation studies involve the effectiveness of the passive shielding, active detectors and radioactive source terms for penetrations are nearly complete.

A Total Loss Monitor (TLM) system of eight long detectors has been installed; each detector covers three Booster periods. The assembly, testing and installation of the needed electronics was completed during FY15Q2. Beam loss tests and measurements have continued. The analyses and write-up investigating beam loss as well as TLM responses continue. The TLM and radiation shielding assessment need to be concluded before much more proton flux can be attempted.

WBS 1.2.3 Instrumentation

WBS 1.2.3.1 Beam Position Monitors

The design work for the beam position monitor system is complete and procurement has started.

WBS 1.2.3.2 Dampers

Studies were conducted which showed that the damper board and code work and will perform the needed function. During FY15Q4, the final programming was done. The dampers were commissioned in FY16Q1 and are part of operations. This task is essentially complete with the exception of the final documentation.

WBS 1.2.4 *Not Used*

Some WBS numbering is nonconsecutive at lower levels because of account closings and rearrangements after financial codes were initially established during the period of setting up PIP.

WBS 1.2.5 Utilities

WBS 1.2.5.1 Low Conductivity Water System

The task is done.

WBS 1.2.5.2 Power Distribution

The last power transformer has been manufactured. The transformer is identical to the two transformers previously purchased by PIP. The installation was completed during the 2015 shutdown. There have been no issues using the transformers during operations. This task is complete.

WBS 1.2.5.3 Vacuum System

The aged components will be replaced as opportunities present themselves with downtime of the Booster. Previously purchased vacuum equipment awaits opportunities for installation. During the shutdown, some vacuum work was done. The last procurement was started at the end of FY15. The end of the PIP vacuum work will be done during the 2016 summer shutdown.

WBS 1.2.7 Solid State Upgrade

The task is done.

Booster Budget – Costs, Labor and Obligations Updates (FY16 Q1)

The FY16 fourth quarter started with news that due to funding issues PIP would not retain carryover funds and in addition would need to reduce planned FY16 M&S by 1.5 M. Managers re-assessed all

remaining tasks in an effort to reduce M&S but maintain projected labor. A RLS was developed to meet the new funding guidance that had minimal impact to labor and PIP progress. A final budget has not yet been provided but PIP is proceeding under the reduced funding profile guidance provided in Oct 2015. PIP to PIP II alignment discussions are still ongoing with plans to complete a document describing the necessary work to be released soon.

As mentioned above the final PIP budget for FY16 and even out years has not yet been formally provided. A final decision is pending and should be ready for release soon – but we have modified our plans based upon the numbers shown in the table below.

Table 1 PIP FY16 (through Dec) budget table

FY16 PIP OBL BUDGET K\$ **	OBL BUDGET	YTD OBL	RIP	BUDGET BAL
M&S	6,659.0	221.1	230.1	6,207.8
Labor	4,956.9	1,799.8		3,157.1
FY15 Sums	11,615.9	2,020.9	230.1	9,364.9

Chart 1 and 2 below shows that labor has been consistent this past quarter except for instrumentation – which was pulled off of PIP to resolve issues with the Recycler DCCT and other items. We expect this to be remedied in the next quarter. Overall forecasted labor and actual has been in very good agreement.

Chart 1 Labor: Forecasted vs Actual

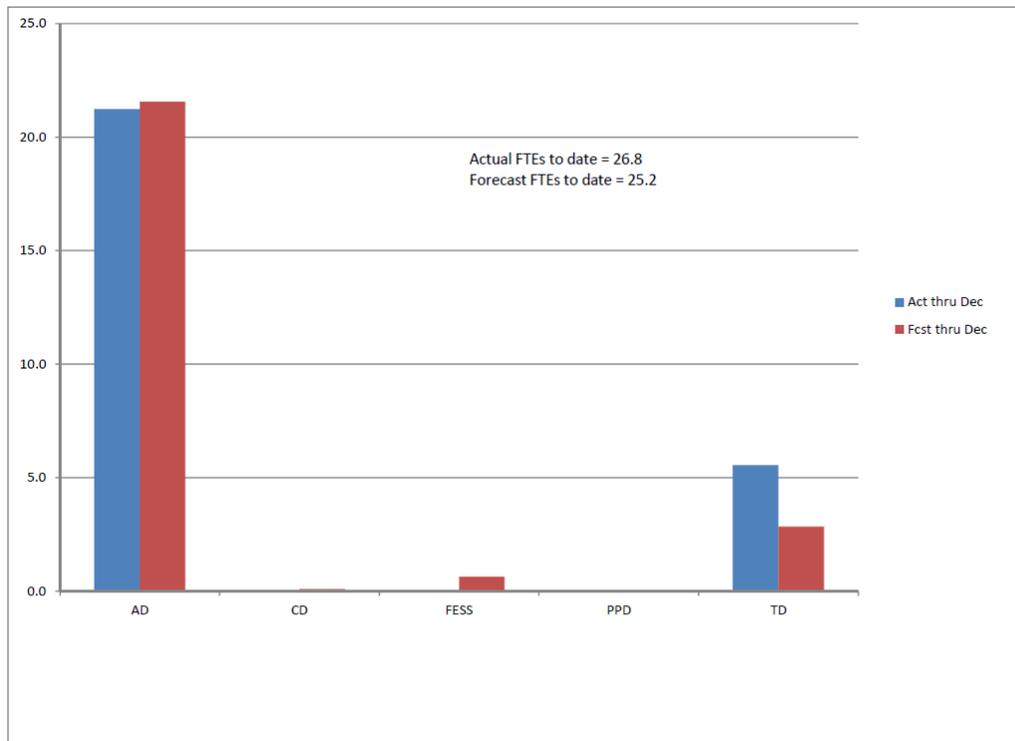


Chart 2 Labor trends - note the Anode task bump at end of FY15 – line designates start of FY16

