LANSCE DTL LONGITUDINAL FIELD MEASUREMENTS AT HIGH-POWER*

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Abstract

Shifts in proton beam tuning were observed in the DTL portion of the Los Alamos Neutron Science Center (LANSCE) Accelerator corresponding with cooling system obstructions during the 2003 operational cycle. A diagnostic system was developed to measure longitudinal field changes at the operational field levels to confirm the source of the tune shifts and track the effectiveness of cooling system repairs. This paper describes the diagnostic system and the results of field distribution measurements at high RF power in the accelerating structures.

INTRODUCTION

During the 2002-2003 run cycle of the LANSCE Accelerator, the four 201.25 MHz Drift Tube Linac (DTL) accelerator sections exhibited unexpected tune shifts on the proton beam. The tune shifts were correlated to other parameters and events that pointed to problems with the water-cooling systems. The cooling systems are a deionized system for the drift tubes, post couplers, tuners and other copper components and a rust inhibitor based system for the copper-clad steel tank walls. The suspected problem was the plugging of the rust-inhibitor system for the tank walls.

In February of 2003, work commenced on flushing and cleaning of the coolant passages on the four DTL's. Portions of coolant passages could be examined with a optical bore scope; however, it was also deemed necessary to quantify the effect of coolant passage cleaning on the longitudinal field distribution, especially the high-power effects.

A series of RF measurements and visual inspections were made to check for structural damage from overheating and to check for changes resulting from the cleaning process. The measurement of the longitudinal field distributions at high-power was the most definitive RF measurement on the DTL tanks to ensure that no damage occurred during the cleaning process and to confirm that cleaning restored full duty factor operation.

THE DTL'S AND THE EXPERIMENTAL EQUIPMENT

The DTL tanks accelerate the proton beam from 750 Kev to 100 MeV in four structures. DTL1 and DTL2 share a common endwall and vacuum system. DTL1 is a ramped-gradient structure with no post couplers and DTL2, DTL3, and DTL4 are constant-gradient structures with post coupler field stabilization. Other parameters are listed in Table 1.

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Table 1: LANSCE Accelerator DTL Parameters

DTL #	Input Energy (MeV)	Output Energy (MeV)	Length (m)	Number of Cells
DTL1	0.75	5.4	3.26	31
DTL2	5.4	41.3	19.69	66
DTL3	41.3	72.7	18.75	38
DTL4	72.7	100.0	17.92	30

The limited maintenance period made it necessary to complete all testing in parallel with the coolant passage cleaning. High-power testing was done on only one DTL prior to cleaning due to time restrictions, but high-power testing was done on all DTL's after cleaning. Historically, DTL2 exhibited significant field changes as a function of duty factor since its original commissioning [1]; therefore, the before-and-after high-power measurements were done on that DTL. DTL2 is shown in Figure 1.

Figure 1: LANSCE Accelerator DTL2 with DTL1 in the background. The slug tuners can be seen mounted at their 45° angle between the drift tubes (top) and post couplers (side.)

The direct measurement of accelerating fields in each cell cannot be made at high-power; however, the magnetic fields near the tank wall correspond to the electric fields in the drift tube gaps. The magnetic fields were perturbed with the slug tuners at both low and high power at longitudinal positions along the DTL to measure the field changes.

Slug tuner ports were fabricated into the DTL walls at two positions on DTL1 and eight positions on DTL's 2, 3, and 4. During normal operations, both slug tuner ports in

DTL1 have moveable slug tuners, but the other three DTL tanks have moveable slug tuners only in the first, third, sixth, and eighth positions along their length with the remainder filled by fixed tuners. In order to sample the fields at more locations in DTL2, moveable slug tuners were taken from DTL3 and DTL4 such that all eight slug tuner positions were instrumented for field sampling. Following the measurements on DTL2, the slug tuners were returned to the original DTL locations such that field sampling after cleaning for DTL's 3 and 4 included four locations along their length.

Each of the slug tuners was independently calibrated such that the tuner insertion was correlated to a resistive potentiometer readout. This calibration was determined to be both accurate and repeatable. In the maximum out position, the slug retracted into the curved surface of the DTL wall. For measurement consistency of all slug tuners, the perturbations were measured at 1.0-inch and 3.4-inch slug insertions since low power measurements confirmed that frequency tuning was linear across that insertion range.

DATA MEASUREMENTS

Low-power perturbation measurements were made using a network analyzer tracking the transmission phase at resonance. All low-power measurements were made with the water systems turned off, thereby making the DTL temperature very stable throughout the measurement period.

High-power perturbation measurements were made at the operating peak power; various duty factors were selected by varying the pulse repetition rate at 835 μsec RF pulse length. The pulse rates were 20 Hz (1.7% df), 40 Hz (3.3% df), 60 Hz (5.0% df), 90 Hz (7.5% df), and 120 Hz (10.0% df). During each frequency measurement, the slug tuner was held at a fixed position and the resonance tuning error from the slug tuner controller was passed through an integration and sample-and-hold circuit and input to the frequency modulation input of an RF signal generator. The circuitry kept the RF frequency locked on the DTL resonance during the slug tuner changes and perturbation measurements. The tank wall water control circuit had an oscillation cycle for every DTL that varied from three to fifteen minutes depending on the DTL and the duty factor, so data was taken at specific points in the oscillation where the water temperature passed through the operating value of 85°F. Although this cycling was problematic, it was found to be stable at any particular duty factor for all measurements on the DTL, and the resulting data was repeatable.

The data collection was done by moving each of the slug tuners individually to 1.0-inch insertion and 3.4-inches insertion and back to the starting position. The resonance frequency was measured at the two positions and the frequency change between the 1 inch and 3.4 inch insertions was used to determine the relative field strength at the slug tuner positions along the DTL length.

FIELD MEASUREMENT RESULTS

The field strength at any position is proportional to the square root of the frequency shift from the slug tuner insertion. Since the field strength measurements are a relative measurement along the DTL length, the data points were arbitrarily normalized to the design acceleration field (E_0) for each accelerating structure to aid in visualizing the measured results for the ramped gradient field of DTL1.

The field measurements for DTL2 prior to coolant passage cleaning are shown in Figure 2. The large changes in measured field strength near cells 40 and 60 in going from 5% to 7.5% duty factor were unwanted and unexpected, but probably corresponded to the beam tuning changes encountered during the 2002-2003 run cycle. The 7.6% field change for a 2.5% change in duty factor near cell 40 convinced us to avoid taking measurements at 10% duty factor.

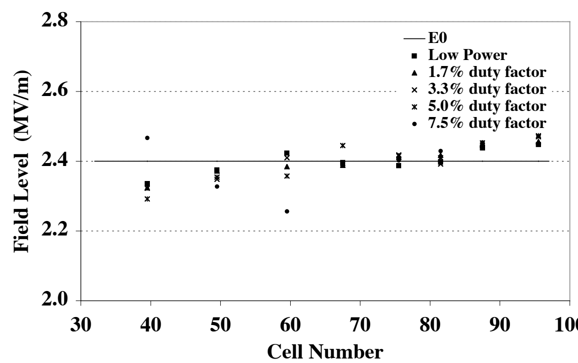

Figure 2: DTL2 Field Distribution versus Duty Factor before Coolant Passage Cleaning.

The field measurements for DTL2 after coolant passage cleaning are shown in Figure 3. The field changes with increasing duty factor were still large but consistent with duty factor steps. The largest measured change between low-power and 10% duty factor high-power was 5.8% near cell 96.

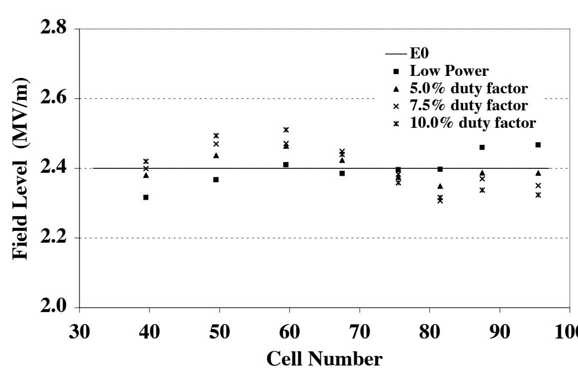

Figure 3: DTL2 Field Distribution versus Duty Factor after Coolant Passage Cleaning.

The after cleaning measurements for DTL's 1, 3, and 4 are shown in Figures 4, 5, and 6 respectively. The largest measured field changes between low-power and 10% duty factor high-power for these three DTL's were 0.3%, 2.1%, and 0.9% respectively. The stability of DTL1 without post couplers is thought to be due to its short length in comparison to the other three DTL's. Scaling the data relative to E_0 also shows that the measured fields appear to correlate to the ramped gradient of the structure. DTL3 has larger field variation with duty factor, but seems to follow E_0 at the tank wall. DTL4 appears to have a small ramp but is relatively stable with duty factor.

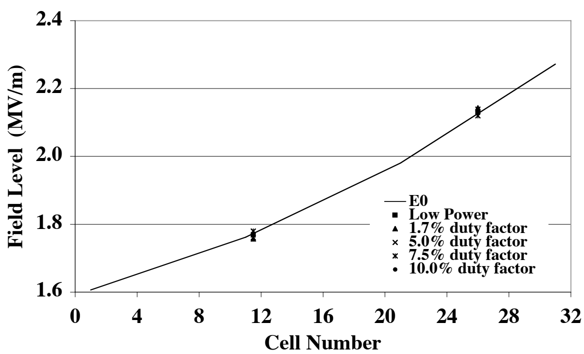

Figure 4: DTL1 Field Distribution versus duty factor after coolant passage cleaning.

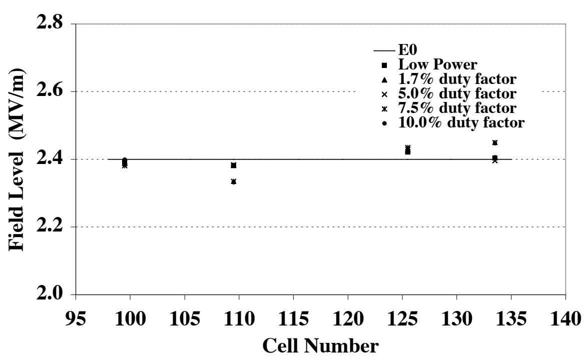

Figure 5: DTL3 Field Distribution versus duty factor after coolant passage cleaning.

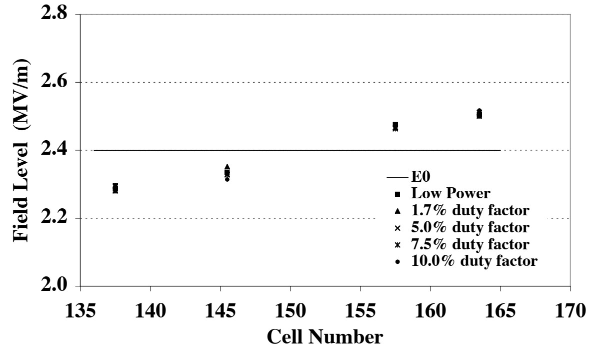

Figure 6: DTL4 Field Distribution versus duty factor after coolant passage cleaning.

Since this type of low-power tuner perturbation measurements were not made in conjunction with the bead pulls during original DTL tuning [2], it is impossible to extrapolate these measurements to predict the field strengths in the acceleration gaps.

The measured field strengths show changes with duty factor but were determined to be small enough to operate the drift tube linac sections at 10% duty factor.

CONCLUSIONS

The field measurements at low and high-power did provide the verification that the DTL fields were more stable after the coolant passages were cleaned. The historical indications of significant DTL2 field changes were also confirmed by a data comparison across all four DTL's.

Long term changes over the accelerator lifetime could not be checked since field measurements at the outer walls could not be directly compared to the bead pull measurements during original DTL tuning. When the DTL's are refurbished in the future, it is the intention of the accelerator staff to make this form of low-power field measurements along with the bead pulls to establish a baseline for measuring long term changes over subsequent years of accelerator operations. High-power measurements using the method described in this paper immediately following DTL refurbishment will also provide a baseline for checking the structure stability and performance under operating conditions over a period of time.

REFERENCES

[1] A. Browman, LANL, Private Communication.

[2] R. Jameson and J. Halbig, "LAMPF 201.25-MHz Linac Field Distribution", Los Alamos National Laboratory Document, LA-6919, January 1978.