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Design And Analysis Of The PBFA-Z Vacuum Insulator Stack*

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Abstract

Sandia is developing PBFA-Z, a 20-MA driver for z-pinch experiments by replacing the water lines, insulator stack, and MITLs on PBFA II with new hardware. The design of the vacuum insulator stack was dictated by the drive voltage, the electric field stress and grading requirements, the water line and MITL interface requirements, and the machine operations and maintenance requirements. The insulator stack will consist of four separate modules, each of a different design because of different voltage drive and hardware interface requirements. The shape of the components in each module, i.e., grading rings, insulator rings, flux excluders, anode and cathode conductors, and the design of the water line and MITL interfaces, were optimized by using the electrostatic analysis codes, ELECTRO and JASON. The time-dependent performance of the insulator stack was evaluated using IVORY, a 2-D PIC code. This paper will describe the insulator stack design and present the results of the ELECTRO and IVORY analyses.

Introduction

Figure 1 is a drawing of the PBFA II[1] accelerator. The accelerator is contained in two concentric tanks. The outer tank is the oil tank which includes thirty-six Marx generators as the prime power source.

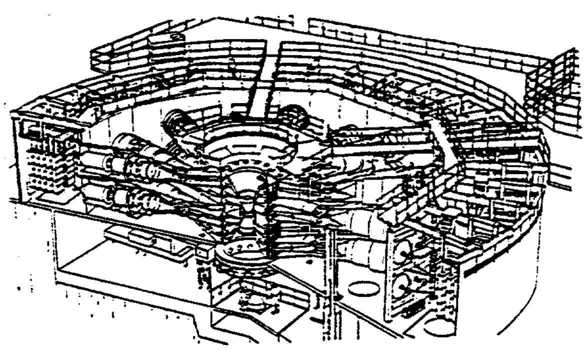

Fig. 1 PBFA II accelerator

The inner tank is filled with deionized water and contains the pulse compression and transmission network which provide the pulsed power to the vacuum insulator. The vacuum insulator on PBFA II contains the hardware needed to configure the machine for ion beam operation. In order to use the accelerator for magnetic implosions it is necessary to convert the electrical power flow to a low impedance, high current design. This is being accomplished by replacing the water lines, the vacuum insulator stack, and the magnetically insulated transmission lines on PBFA II with hardware of a new design. The reconfigured accelerator is identified as PBFA-Z[2]. The modified accelerator has been designed to deliver 20 MA of current to a 15-mg z-pinch load in

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100 ns. First shot is planned for late-July 1996.

Insulator Stack Design

The PBFA-Z insulator stack will be 340 cm in diameter and 172 cm high. The stack is subdivided into four levels, Level A through Level D. Each level will contain a set of Rexolite insulator rings and a set of aluminum grading rings. The bottom two levels, C and D, will be equipped with flux excluders to help grade the fields. A drawing of the PBFA-Z vacuum insulator stack, with the water line and MITL interface hardware, is shown in Figure 2.

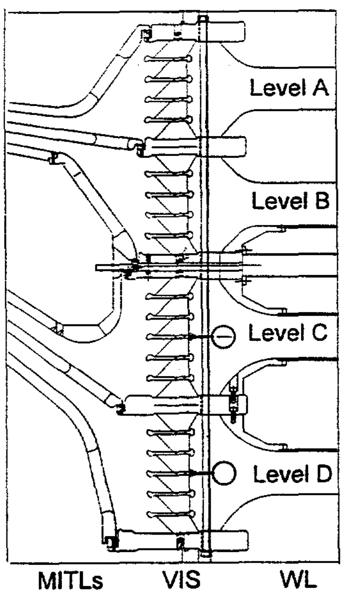

Fig. 2 PBFA-Z insulator stack

The stack grading rings were designed to keep the electric field stresses below 300 kV/cm on the vacuum side, below 250 kV/cm on the water side, and less than 30 kV/cm at the cathode triple points. The vacuum flares were designed to balance the peak fields on the grading rings. The number and shape of the grading rings, the radius of the water line-to-stack transition section, and the size and location of the flux excluders were selected to minimize field stresses and to keep the field grading below 10% in each module.

The PBFA-Z accelerator was modeled using circuit codes to determine the time-dependent voltage and current waveforms at the water lines, the insulator stack, and the MITLs. SCREAMER, a SNL-developed lumped element code was used to model the circuit from the Marx generators through the load and to optimize the Marx and water sections. TL code, a PSI transmission line code, was used to model the accelerator from the water transmission lines to the load, and to optimize the vacuum section design. The SCREAMER predictions of the stack voltages are presented in Figure 3.

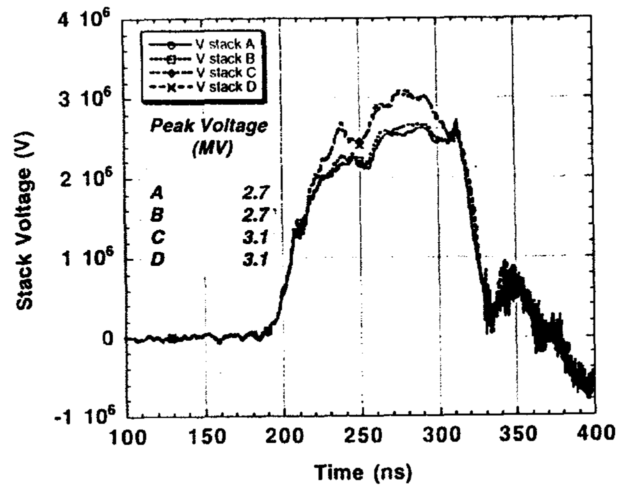

Fig. 3 Stack voltage predictions

Analysis Results

The electrostatic computer codes, ELECTRO[3] and JASON, were used to calculate the electric field stresses and the field grading during the various design iterations. The peak voltages predicted by SCREAMER and the TL code were used in the ELECTRO and JASON calculations. IVORY, a 2-D PIC code developed by MRC, was used to evaluate the time-dependent performance of the insulator stack.

Each level of the insulator stack was modeled separately. The geometry of the Level C model is shown in Figure 4. ELECTRO solves for the voltage and electric field distributions for specified geometries, media, media permittivities boundary conditions, and boundary elements.

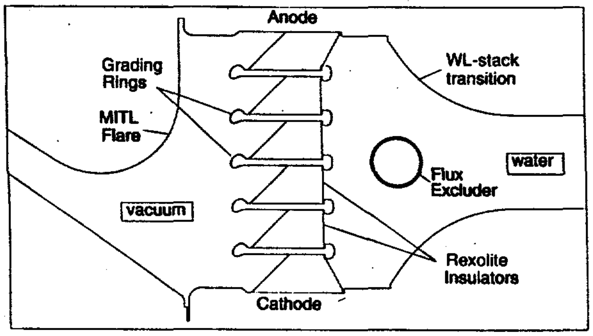

Fig. 4 Level C model

Figure 5 is a plot of the equipotential contours near the top grading ring on Level A. The shape of the grading ring edge was designed to follow the voltage contours, thereby minimizing the field stresses.

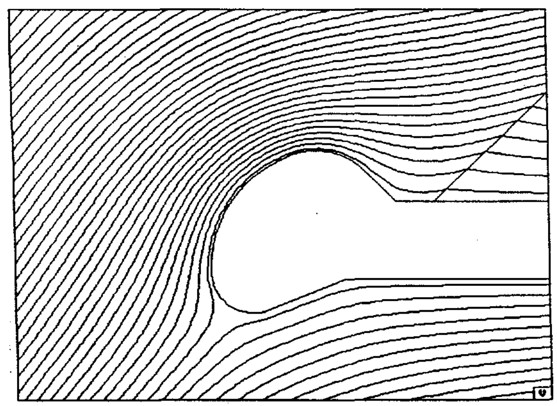

Fig. 5 Equipotential contour plot

The constant voltage contours for Level C of the PBFA-Z stack are plotted in Figure 6. The plot shows the grading to be uniform. Each insulator contains the same number of contour lines and the insulator voltages vary from -2.3% to +3.6% from the average.

The electric fields normal to the grading rings and the fields tangent to the insulator rings were plotted for each ring of the stack. Figure 7 presents the normal E-field plot for Grading Ring 3 on the vacuum side of Level C. Figure 8 presents the tangent E-field plot for Insulator Ring 1 on the vacuum side of Level C.

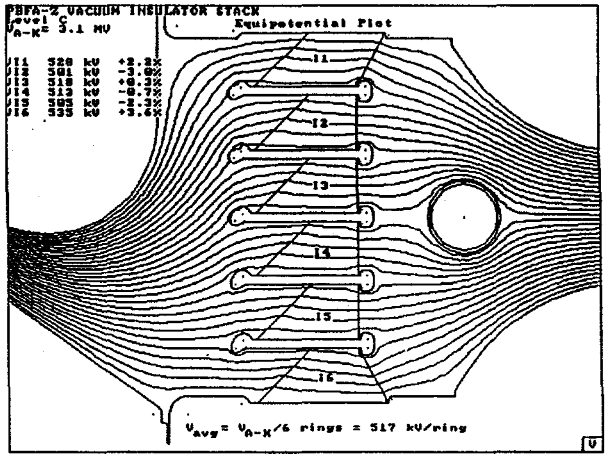

Fig. 6 Level C equipotential contours

IVORY was used in a 2-D mode to simulate the PBFA-Z insulator stack and MITL flares. The vacuum and dielectric interfaces and grading rings were centered in the simulation region. Figure 9 shows the IVORY stack model with grading ring emission.

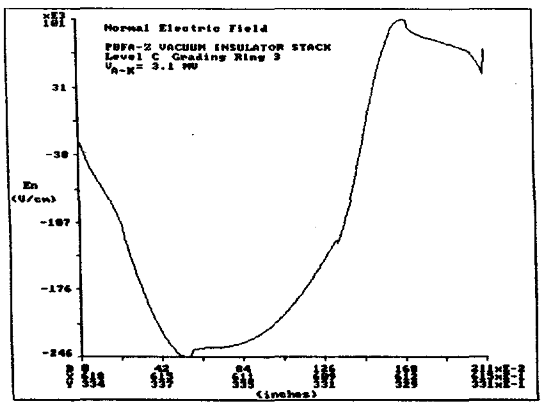

Fig. 7 Normal E-field plot

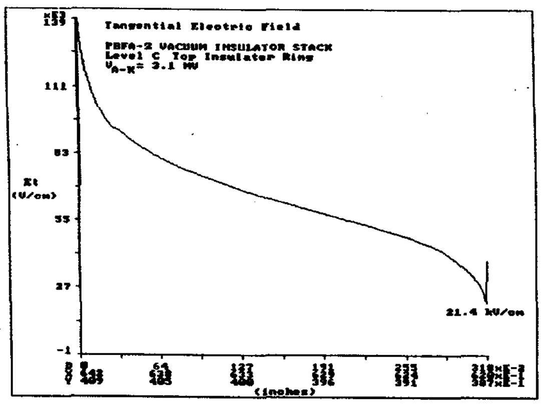

Fig. 8 Tangential E-field plot

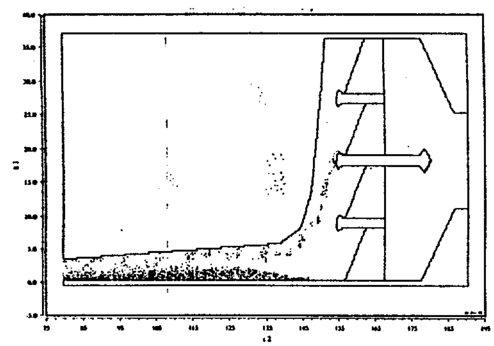

Fig. 9 IVORY insulator stack model

The grading calculations for the PBFA-Z stack are shown in Figure 10. The peak electric fields on Levels A and C are summarized in Figure 11. The peak fields on Levels B and D are comparable to those shown.

Insulator Ring	A - Level Va-k=2.7 MV Variation %	B - Level Va-k=2.7 MV Variation %	C - Level Va-k=3.1 MV Variation %	D - Level Va-k=3.1 MV Variation %
I1	+0.7	+3.2	+2.2	+2.9
I2	-5.6	-4.8	-3.0	-1.5
I3	+6.5	+6.3	+0.3	-1.0
I4	-4.6	-5.7	-0.7	0
I5	+3.0	+1.1	-2.3	-3.1
I6			+3.6	+2.3

Fig. 10 Grading Summary

Conclusions

Based on the results of the ELECTRO analysis, the peak electric fields on the grading rings are less than 260 kV/cm on the vacuum side and less than 200 kV/cm on the water side. The cathode triple point fields are less than 30 kV/cm. The grading of the baseline design is less than 6.5% on modules A and B and less than 3.7% on modules C and D. According to the results of the IVORY analysis, the voltage between rings on the baseline design can vary up to 10% without field emission and up to 19% with field emission. If the MITL gap is decreased by a factor of two, the voltage between rings can vary up to 50% from average and risk insulator breakdown.

References

[1.] B.N. Turman, et al., "PBFA II, A 100-TW Pulsed Power Driver for the Inertial Confinement Fusion Program," *Proc. 5th IEEE Pulsed Power Conference*, Arlington, VA, June 10-12, 1985, pp. 155-161, IEEE#85CH2121-2.

[2.] R.B. Spielman, et al., "PBFA II-Z: Conceptual Design Report," January 17, 1995, Sandia National Laboratories, Albuquerque, NM.

[3.] Integrated Engineering Software, Winnipeg, Manitoba, Canada R3H 0X4.

VIS Rings	A - Level Va-k=2.7 MV E-Normal (kV/cm) (Vac Side)	A - Level E-Normal (kV/cm) (Water Side)	A - Level E-Tangent (kV/cm) (CTP)	C - Level Va-k=3.1 MV E-Normal (kV/cm) (Vac Side)	C - Level E-Normal (kV/cm) (Water Side)	C - Level E-Tangent (kV/cm) (CTP)
I1			22.6			21.4
GR1	236	153		209	152	
I2			21.5			20.9
GR2	239	195		234	185	
I3			23.8			21.7
GR3	258	193		246	169	
I4			20.4			20.9
GR4	211	158		215	185	
I5			17.6			19.1
GR5				177	155	
I6						21.7

Fig.11 Peak electric fields on PBFA-Z Stack

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