Title
INVESTIGATION OF Re-X GLASS CERAMIC FOR ACCELERATOR INSULATING COLUMNS

Authors
Faltens, A.
Rosenblum, S.

Publication Date
1985-05-01

LBL-19526

Lawrence Berkeley Laboratory

UNIVERSITY OF CALIFORNIA

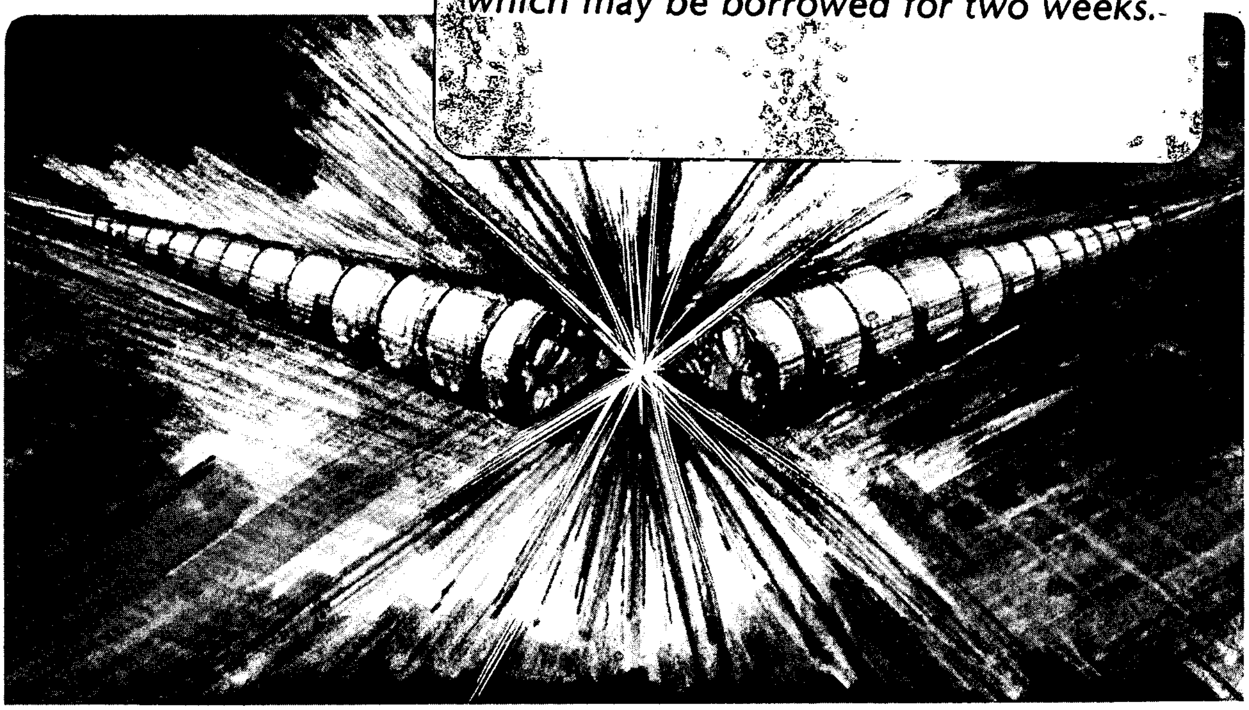
Accelerator & Fusion Research Division

Presented at the 1985 Particle Accelerator Conference, Vancouver, B.C., Canada, May 13-16, 1985

INVESTIGATION OF Re-X GLASS CERAMIC FOR ACCELERATOR INSULATING COLUMNS

A. Faltens and S. Rosenblum

May 1985



Prepared for the U.S. Department of Energy under Contract DE-AC03-76SF00098

LBL-19526
HIFAN-276

INVESTIGATION OF Re-X GLASS CERAMIC FOR ACCELERATOR INSULATING COLUMNS*

A. Faltens

Lawrence Berkeley Laboratory
University of California
Berkeley, CA 94720

S. Rosenblum
Varian Associates
611 Hansen Way
Palo Alto, California 94303

May 1985

*This was supported by the Office of Energy Research, Office of Basic Energy Sciences, U.S. Department of Energy under Contract DE-AC03-76SF00098.

INVESTIGATION OF Re-X GLASS CERAMIC FOR ACCELERATOR INSULATING COLUMNS*

Andris Faltens
Lawrence Berkeley Laboratory
Berkeley, California 94720

Stephen S. Rosenblum
Varian Associates
611 Hansen Way
Palo Alto, California 94303

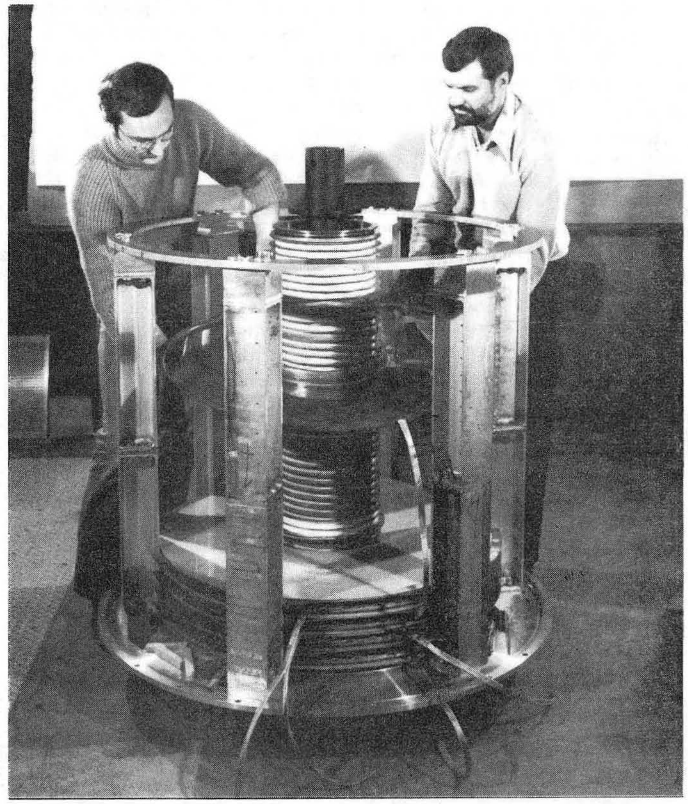
Abstract

In an induction linac the accelerating voltage appears along a voltage-graded vacuum insulator column which is a performance limiting and major cost component. Re-X glass ceramic insulators have the long-sought properties of allowing cast-in gradient electrodes, good breakdown characteristics, and compatibility with high vacuum systems. Re-X is a glass ceramic developed by General Electric for use in the manufacture of electrical apparatus, such as vacuum arc interrupters. We have examined vacuum outgassing behavior and voltage breakdown in vacuum and find excellent performance. The housings are in the shape of tubes with type 430 stainless steel terminations. Due to a matched coefficient of thermal expansion between metal and insulator, no vacuum leaks have resulted from any welding operation. The components should be relatively inexpensive to manufacture in large sizes and appear to be a very attractive accelerator column. We are planning to use a standard GE housing in our MBE-4 induction linac.

Re-X

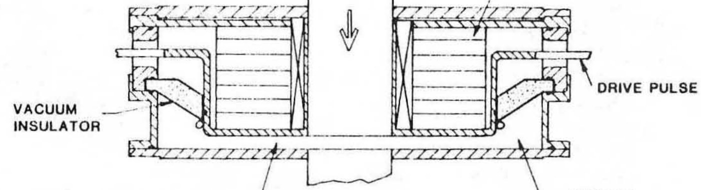
Induction linacs have very severe insulator column requirements due to the nature of their construction and operation. While rf linacs and induction linacs are both induction linacs, the common usage of the term induction linac refers to a transformer type of accelerator where the beam is usually thought of as constituting the secondary winding. In such an accelerator, the primary voltage is either the full voltage applied to the beam across an accelerating gap, or, depending on the core winding geometry, a few times smaller. In the more common rf accelerator utilizing resonant cavities, the drive voltage may be very small compared to the voltage applied to the beam at an accelerating gap. In an induction linac for long pulses, it is a practical necessity to fill the accelerating "cavity" with an induction core which is incompatible with vacuum requirements in the area occupied by the beam, therefore the full accelerating voltage appears across an insulator which separates the core from the beam. The voltage pulses are unipolar, of about 1 μs duration, applied a few times per second. The characteristic voltages of interest are about 1 MV/meter for the average rate of acceleration, which translate to comparable fields across the vacuum insulators.

The two most common solutions for the vacuum insulator problem for induction linacs are shown in Fig. 1(a), where the insulator is either centrally located and is close to the beam, or peripherally located where the beam can not strike it directly, Fig. 1(b). In this latter version, the accelerating field in the region of the beam appears across a vacuum gap formed by metal electrodes which are capable of supporting much higher voltages and fields than possible along the insulator surfaces. The average electric field along a surface and the voltage at one location can be substantially increased by subdividing the insulator in many short sections separated by metal gradient rings, as in the insulator shown in Fig. 1(a).



CBB 831-582

Fig. 1(a). Central insulator column as used in Astron Injector



XBL 854-2255

Fig. 1(b). Peripheral insulator as used in ERA, ETA, and ATA.

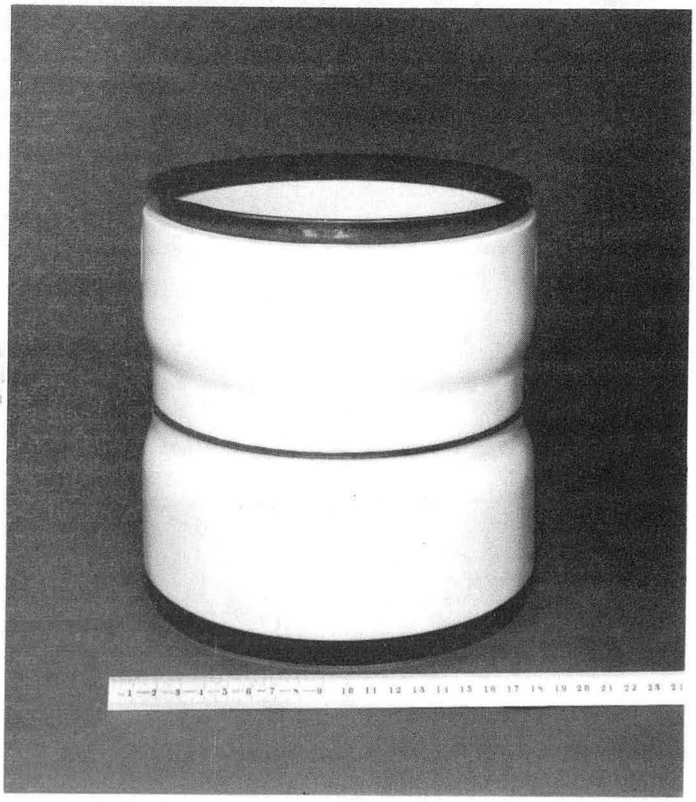
*This was supported by the Office of Energy Research, Office of Basic Energy Sciences, U.S. Department of Energy under Contract DE-AC03-76SF00098.

There is a conflict between placing the insulator far from the beam and the size and cost limitations of existing insulators. The frequently used ceramic insulators are difficult to obtain in sizes larger than 26" ID, 28" OD, and cost in the range of $10,000 per meter of structure. Conceptual designs of fusion driver accelerators[1] require of the order of 1-1.5 meters for the beam hole diameter in the central-insulator designs, and the peripheral-insulator design has heretofore not been seriously considered because of the even larger size requirement. For more than a decade we have been considering and occasionally trying to make an insulator with cast-in gradient rings of either of the two designs shown in Fig. 1 for various real and proposed machines. We were actively engaged in pursuing several inorganic material loaded castable plastics without being aware of the existence of the commercially manufactured Re-X material which has many of the sought-after properties, which are listed in the manufacturer's data sheet, Table 1.[4] An example of an existing insulator is shown in Fig. 2. The insulator has the desirable properties of low outgassing, high mechanical strength, a cast-in gradient ring, and the possibility of inexpensive joining to other components of a beam line by welding. The current use of the material in vacuum switch gear housings is similar to that required in accelerating columns, but, because there is no apparent requirement to use them at high surface fields the design details do not appear to have been optimized for high-voltage high-field use. For test purposes we have sawed apart and reassembled short sections of the material into a few sections of accelerator column. We have also taken a longer insulator and measured the breakdown voltage as a function of distance by changing the electrode separation. The results of voltage breakdown tests as a function of insulator length are shown in Fig. 3. In the breakdown tests, the samples were conditioned to progressively higher voltages over a period of a few hours. We would intend to use them at one-half of the breakdown voltage or less. The attained values are acceptable for near

TABLE 1

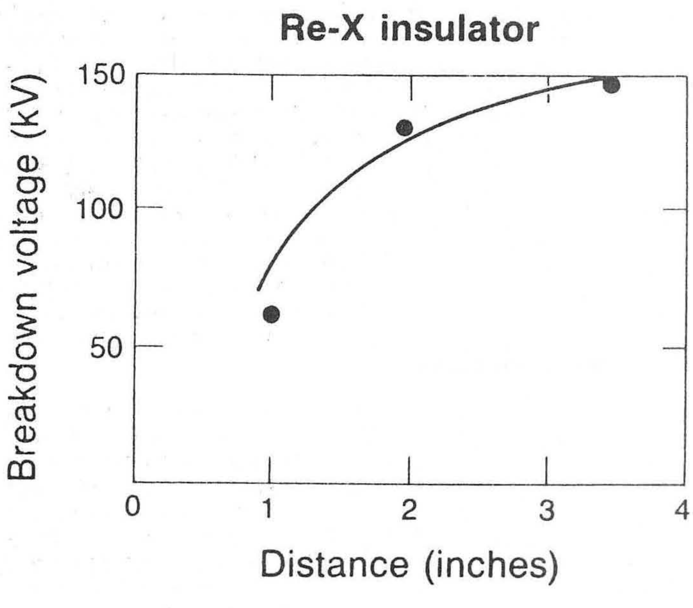
Physical and Mechanical Properties of Re-X Glass Ceramic

Coefficient of Thermal Expansion	8.6×10^{-6} in/in°C
0 - 200°C	9.4 "
0 - 400°C	10.7 "
0 - 600°C	12.6 "
Safe Temperature at Continuous Heat	830°C
Crystal Size	.5 - 1 μ
Modulus of Rupture	25,000 lbs./in.
Porosity	0.00%
Density 2.37 gm/cc - glass	
	2.42 gm/cc - ceramic
Anneal Pt. (Glass)	456°C
Strain Pt. (Glass)	424°C
Softening Pt. (Glass)	Undefinable
Softening Pt. (Ceramic)	850°C (Est.)
Hardness DPH 100 g Load	630 Kg/MM
Tensile Strength	-
Compressive Strength	150x10 PSI Est.
Modulus of Elasticity	12.6x10 PSI Est.
Impact Strength 1 cm x 1 cm x 8 cm	.54 Ft. lbs. (20°C) Est.
Coefficient of Friction	
Static	.19 Static Est.
Dynamic	.16 Dynamic Est.
Thermal Conductivity	.007 cgs units Est.
Specific Heat	.22 cal/gm/°C
	.28 "
Outgassing Schedule for Tubes, Gaps	800°C - 1 Hr. < 10^{-6} Torr
Weathering Resistance	Better than glass, as good as glazed porcelain.



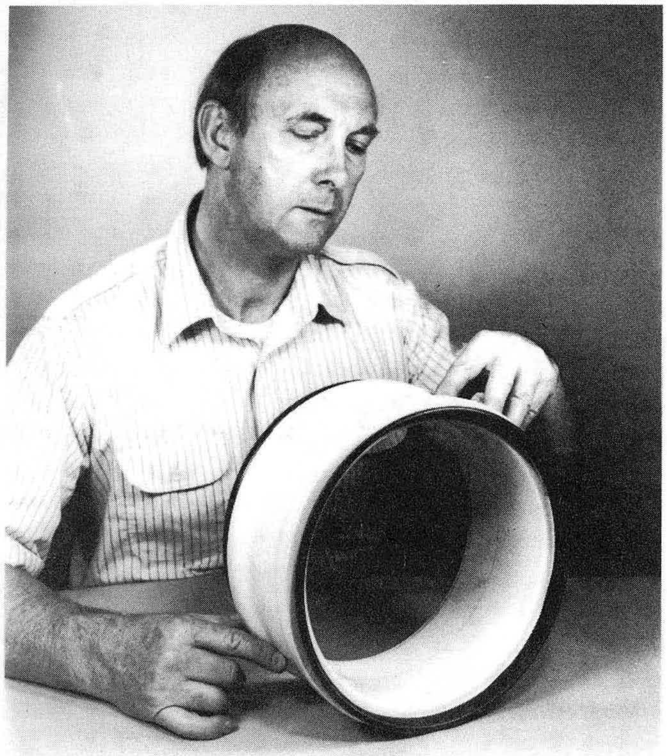
CBB 841-234

Fig. 2. Re-X Insulator with cast-in gradient ring.



XBL 844-10444

Fig. 3. Surface breakdown voltage versus distance for Re-X insulator.



CBB 854-3210

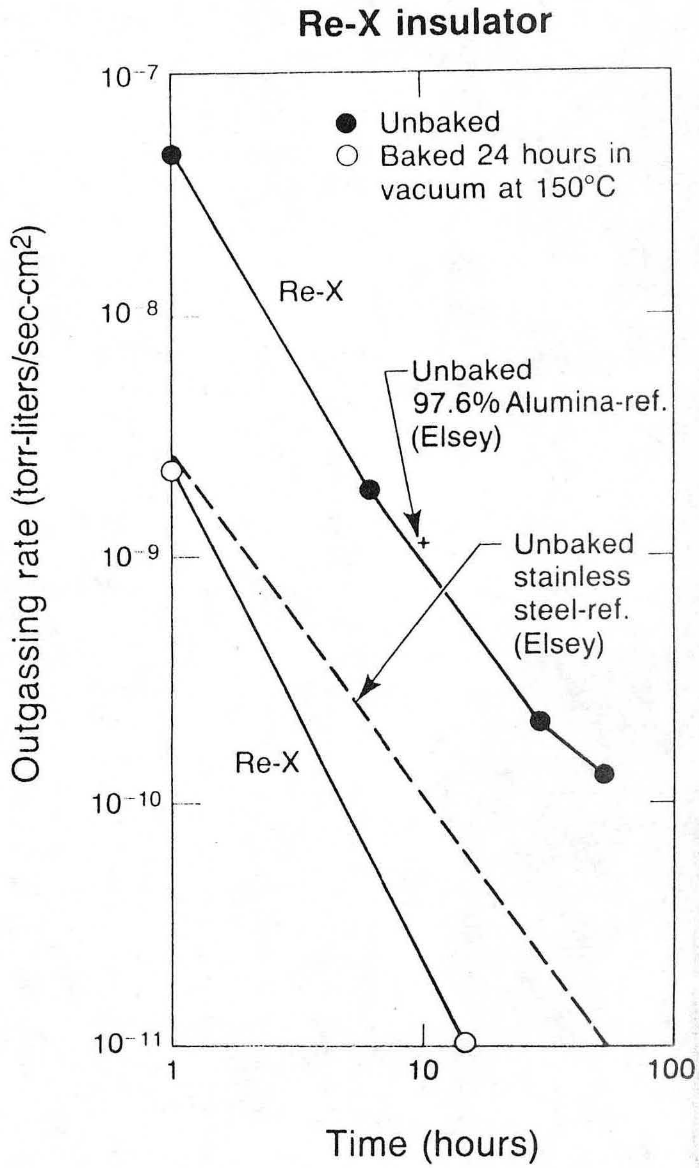
Fig. 4. MBE-4 Insulator

term applications such as the MBE 4[2] experiment which is presently under construction, where the insulator to be used is shown in Fig. 4. The main motivation and interest in the material is of course for the HTE [3] and fusion driver machines, where we would be interested in the performance of a full size, cast-in-one-piece section of accelerating column with the gradient electrodes and end flanges resembling the column shown in Fig. 1(a).

The outgassing measurement results are shown in Fig. 5. The outgassing rates are compared to those of unbaked stainless steel and unbaked alumina, and are similar. These values are acceptable for the desired operating pressures of better than 10^{-7} Torr for the near-term requirements and for the longer term 10^{-8} Torr that would be required for a linear induction accelerator fusion driver.

Acknowledgement

We would like to thank Rolf Dethlefsen for bringing this material to our attention, and for the co-operation of the Bushing and Arrester Products Section of General Electric.



XBL 844-10443

Fig. 5. Outgassing data for Re-X insulator

References

[1] A. Faltens, E. Hoyer, and D. Keefe; Proc. 4th Int. Topical Conf. on High Power Electron and Ion Beam Research and Tech., Palaiseau, 1981, H.J. Doveet and J.M. Buzzi (Ecole Polytechnique, 1981), p. 751.

[2] Program Plan for the MBE-4 Multiple Beam Experiment, Lawrence Berkeley Laboratory, PUB-5142.

[3] Heavy Ion Fusion Accelerator Research Program Plan for FY 84- FY 89, Los Alamos National Laboratory, LA-UR-83-1717.

[4] Bushing Products Business Section, pamphlet, February 11, 1969.

LAWRENCE BERKELEY LABORATORY
TECHNICAL INFORMATION DEPARTMENT
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720