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Modeling, Fabrication, and Optimization of Niobium Cavities: Phase II

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Modeling, Fabrication, and Optimization of Niobium Cavities – Phase II

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Abstract

Niobium cavities are important parts of the integrated NC/SC high-power linacs. Over the years, researchers in several countries have tested various cavity shapes. They concluded that elliptically shaped cells are the most appropriate shape for superconducting cavities. The need for very clean surfaces led to the use of a buffered chemical polishing procedure for surface cleaning to get good performance of the cavities. This proposal discusses the second phase of research in the second year of the project. The first phase (starting Summer 2001) has resulted in improving the basic understanding of multipacting and the process of chemical etching. Based on our conclusions so far, as well as our interaction with personnel of Los Alamos National Laboratory (LANL), we propose to focus on the following topics in the second phase of this project:

1. Continue optimizing the cavity shape to reduce or minimize the possibilities of multipacting.
2. Redesign the etching process to maximize surface uniformity.
3. Experimental study of multipacting conditions.
4. Experimental study of the etching process and the resulting quality of the surface.

Introduction

The nuclear industry provides a significant percentage of electricity in the world, as well as the United States. Nuclear power plants produce thousands of tons of spent fuel. Some of this spent fuel can be radioactive for thousands of years. The U.S. DOE is currently exploring the possibility of creating a permanent storage site at Yucca Mountain, Nevada for nuclear spent fuel. The U.S. Congress has recently authorized exploring a complementary way to deal with spent nuclear fuel: accelerator-driven transmutation of waste as part of its Advanced Accelerator Applications program. In this approach, a particle accelerator produces protons that react with a heavy metal target to produce neutrons. These neutrons are used to transmute long-lived radioactive isotopes into shorter-lived isotopes that are easier to be managed. A major component of the system is a linear accelerator (linac) that can accelerate a 30-mA beam of protons up to 1 GeV [1]. Los Alamos National Laboratory (LANL) is an active participant in developing a superconducting radio-frequency (SCRF) high-current linear accelerator. SCRF has three major components: niobium cavities, power couplers, and cryomodules. This proposal mainly deals with niobium cavities.

Niobium cavities have several advantages including small power dissipation compared to normal conducting copper cavities. These cavities are usually made of multiple elliptical cells, see Figure 1. They are formed from sheet metal using various techniques such as deep drawing or spinning. The cells then are welded using electron-beams. Multi-cell units are usually tuned by stretching or squeezing them. Niobium cavities need very clean surfaces, which can be achieved by chemical polishing and high pressure rinsing with ultra-pure water.

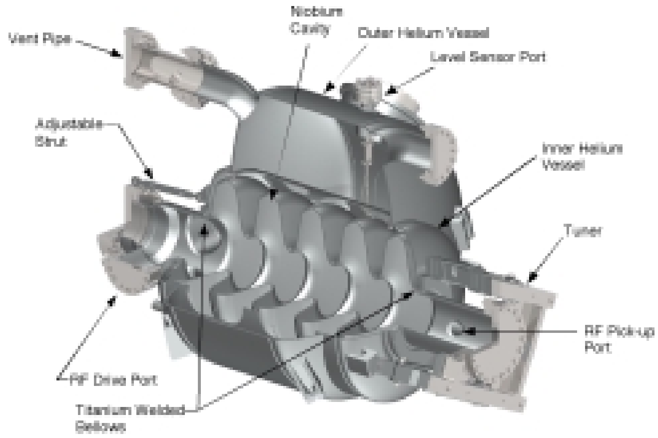

Figure 1. Schematic Diagram of Niobium Cavities (Executive Summary: Development and Performance of Medium-Beta Superconducting Cavities (LANL))

Under operation very high electromagnetic fields are present in these cavities. Besides the intended acceleration of a particle beam, these fields can also accelerate electrons emitted from the niobium surfaces. An electron emitted from the surface of the cavity wall is guided and accelerated by these RF-fields until it impacts on the cavity surface again. This re-impact can lead to the generation of a one or more secondary electrons that in turn act as primary electrons that possibly might generate more electrons in a localized region. The number of secondary electrons is determined by the impact energy of the electron and by the secondary emission coefficient of the cavity material. If secondary electrons are created in phase with the RF-fields, and the impact is localized, a rapidly rising multiplication of electron will occur. This localized resonant process is known as *multipacting* (multiple impacting). As a consequence, RF power is absorbed and it becomes impossible to increase the cavity fields by raising the incident power. The electron collisions with the structure walls lead to a temperature rise and eventually to a breakdown of the superconductivity. As a result, the Q_0 (quality factor) of the cavity is significantly reduced at the multipacting thresholds. Also, structural damage of the surface can occur. A good cavity design should be able to eliminate or at least to minimize multipacting. The factors that affect multipacting include: shape, surface finish, and coating.

While models have been suggested for minimizing multipacting [2], practical means of manufacturing the cavity walls to obtain optimal designs are still an issue. Attempting to improve the performance of multiple niobium cavities may be a daunting task because of the computational load associated with the evaluation of a particular design and the large number of variables and constraints involved. We propose approaching this task in a systematic way using principles of nonlinear programming. The consequence of this effort will allow the Superconducting RF Engineering Development and Demonstration group at LANL and the faculty at UNLV to target potential cavity cell configurations that improve upon existing designs.

Summary of Achievements of Phase I:

1. During the first year of the project we gained a better understanding of a multipacting modeling code (Track_RF). We are in the process of comparing experimental results from LANL with results of numerical simulation for three different cavity designs.
2. Track_RF was modified to examine localized secondary electron emission and impacting over the cavity surface. Figures 2a and 2b illustrates the field emission statistics for a cylindrical cavity when many electrons (50 electrons) with the same initial conditions are launched at the same time from the center of the end cap of the cylinder. A subroutine to plot single particle trajectories has been developed to help visualize whether multipacting exists.

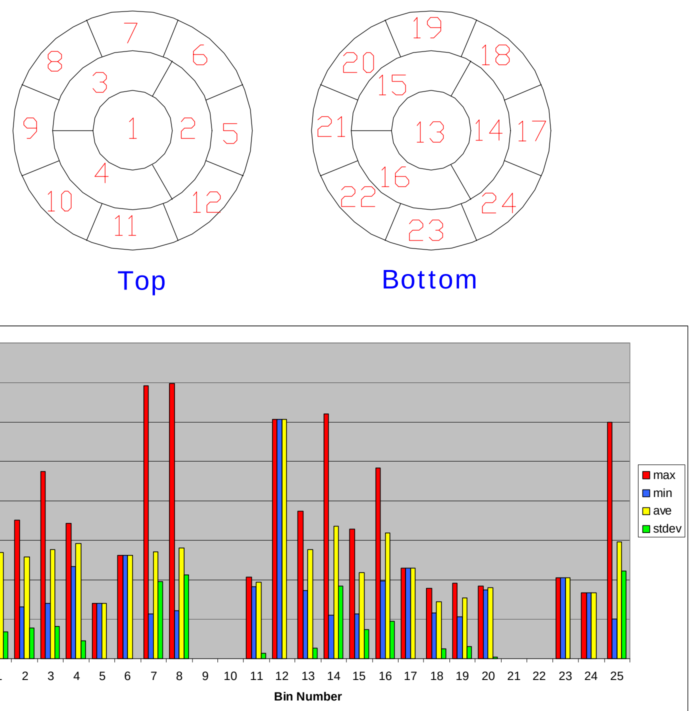

Figure 2 a) Binning of the surface of a cylindrical cavity, and **b)** Bin statistics of secondary electron emission.

3. Creation of a framework for minimizing multipacting and maximizing the uniformity of the surface finish. This step included creating a program in MATLAB environment that interfaces two separate software packages:
   - Track_RF: A two-dimensional Field Precision code
   - Femlab: A finite element analysis software.
4. Assessment of current etching techniques presently used in LANL. The current method uses a baffle to direct the etching fluid toward the surface of the cavity. Refer to Figure 3. Finite element analysis shows that the baffle partially succeeded in achieving its purpose as can be seen in Figure 4. The flow is however restricted to the right half of the cavity with very limited circulation in the left half, which results in more etching of

the iris region compared to that of the equator regions. These results confirm the observations of [3]. The current design also experiences flow circulation behind the baffles in the second through fifth cavity cells. There is a significant increase in velocity at the outlet.

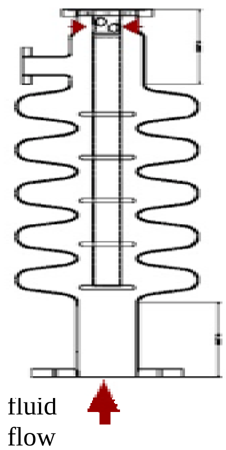

Figure 3. Current Etching Configuration of Niobium Cavities

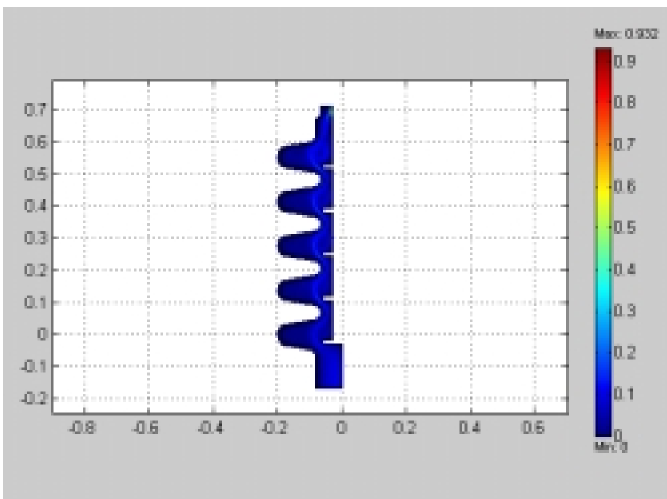

Figure 4. Finite Element Analysis of Current Etching Configuration of Niobium Cavities

5. An alternative design is proposed and modeled. The new baffle is angled near the inlet of each cavity cell. The proposed design is also modified so that it can be extended inside the cells of the cavity. The exit flow is now parallel to flow inlet. Preliminary FEA results (Figure 5) show that flow circulation is eliminated. The flow is now closer to the surface of the cavity. We are currently using optimization techniques to improve this design.
6. These research activities are disseminated through:
   - Three presentations (two at UNLV and one at LANL)
   - One student paper in the ANS Conference in Reno, November 2001

- One poster presentation at the AAA Quarterly Technical Review at UNLV, Jan. 2002
- One paper is currently under review for presentation in International Congress on Advanced Nuclear Power Plants (ICAPP), Hollywood, Florida, June 2002. The title of the paper is, "Modeling and Optimization of the Chemical Etching Process in Niobium Cavities."

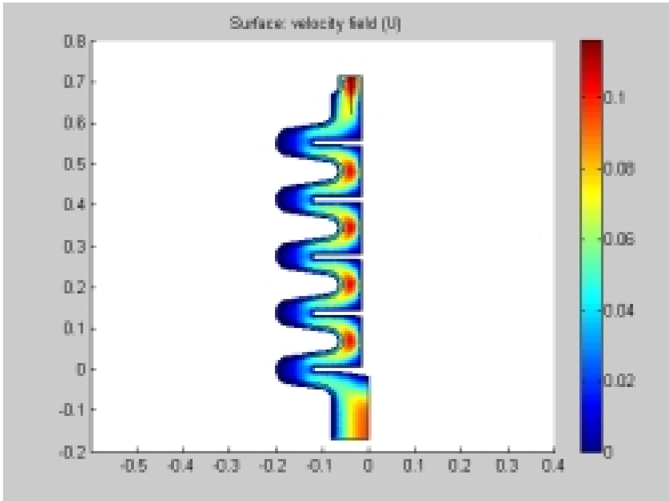

Figure 5. Finite Element Analysis of a Modified Etching Configuration of Niobium Cavities

Research Objectives

The research objectives are:

1. Continue current research on the phenomenon of multipacting.
2. Optimization of the cavity shape to minimize the possibilities for multipacting.
3. Optimization of the chemical etching process to maximize surface uniformity.
4. Within the limits of the funding level, modify, repair, and attempt to operate an existing vacuum system obtained from DOE's surplus equipment list. The system will be used to perform secondary electron emission studies on niobium material that has been surface conditioned at LANL. We anticipate that secondary electron investigations to begin in year three (2003-2004 academic year) of this research.
5. Setting up a flow visualization experiment to evaluate flow patterns of the etching fluid inside a plastic model of the niobium cavity with various baffle designs. The model already exists. LANL is willing to loan it to UNLV.
6. Collaborating with LANL personnel to setup a high frequency (RF/microwave) test facility for studying the characteristics of niobium cavities. A scaling law relating experimental studies at high frequencies to frequencies of interest to LANL will be investigated. We anticipate that multipacting investigations in such cavities will begin in year four (2004-2005 academic year) of this research.
7. Experimental studies of the etching process and the resulting quality of the surface. We are discussing possibilities of conducting this experiment in LANL. We anticipate that this study will begin in year three (2003-2004 academic year) of this research.

Technical impact

The proposed work will make a major contribution to the understanding and the design of niobium cavities. This area is very critical with many recent developments [4, 5, 6]. The proposed research will provide a means to benchmark the codes for LANL's specific objectives. Also, empirical data obtained from experiments will be incorporated into the Track_RF code. The proposed research will result in a method for optimal design of superconducting RF-resonators. Our research is multi-disciplinary, combining expertise from three distinct areas (electromagnetics, fluid dynamics, and optimization). Graduate students involved in this project will be exposed to these three areas and will be expected to work as a team. It is expected that this interaction will result in several publications gaining recognition of UNLV activities in this area as well as attracting additional funds to the university.

It is anticipated that the developed modeling tool will impact the efficiency of future superconducting cavity designs of interest to the Superconducting RF Engineering Development and Demonstration (SRFEDD) group at LANL and elsewhere. Such a study will guide the (SRFEDD) group and their UNLV collaborators to establish fabrication strategies for manufacturing. These efforts should also lay the foundation for examining multipacting in RF windows in the future.

Research Approach

The proposed research can be divided into several interconnected tasks as shown in Figure 6. The remainder of this section details our approach to each task.

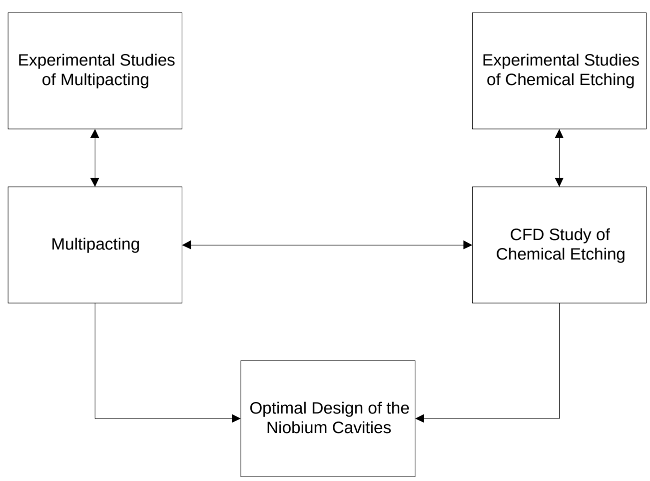

Figure 6. Research Tasks

Task 1. Multipacting

Numerical models of multipacting are of great interest for the design of RF cavities for high-energy proton accelerators. Multipacting is a resonant phenomenon of an electron avalanche as a result of localized impact due to secondary electron emissions. The growth of a localized current originating and terminating on the cavity wall absorbs and dissipates a part of the electromagnetic energy stored in the cavity. Multipacting lowers the Q_0 of the cavity limiting the energy stored by the cavity. It can also cause damage to the RF surface. By conditioning the cavity (operating the RF cavity at its highest achievable field level in the absence of the beam) for soft barriers, healing of the cavity may be possible by cleaning the RF surface and lowering the secondary emission coefficient.. This may be a time intensive process. The shape of the cavity structure, its material composition and surface treatment play significant roles in mitigating multipacting processes. It has been shown that cavities with a more circular wall geometry along the cavity axis inhibits multipacting relative to elliptical cavities [7]. The SEE (Secondary Electron Emission) curve for niobium is well known. Even so, multipacting is dependent of the surface treatment of the cavity. Different niobium surface treatments can alter the SEE coefficient by nearly a factor of three [8]. This is significant since niobium has a maximum SEE coefficient of 1.1 at an electron impact energy of about 500 eV. Further, the surface treatments examined in 1986 [8] are not necessarily the same types of treatments currently used on superconducting cavities at LANL. Moreover, it is known that surface kinetics plays a significant role in the secondary emission, besides the impact energy, also the impact angle might have to be considered for proper modeling [9].

It is therefore proposed to study the SEE from the surface of niobium samples treated at LANL. During the duration of this fiscal year, an old vacuum system will be refurbished for SEE experiments to begin in the next fiscal year (funding allowed). In the SEE experiments, an electron beam, generated from an electron gun source, will impinge with both normal and oblique incidence on the sample surface now termed as the target. It is intended that the target be of a cylindrical geometry held at various negative potentials relative to a set of collecting anode segments surrounding the target. With proper potential adjustments, ampere meters will be used to measure the primary current at the target and the secondary currents at the segmented anode plates. Information on the SEE trajectories, distribution and amount is to be determined by the study. Figure 7 illustrates a typical experimental setup. A highly sensitive current amplifier with an extremely low current sensitive switching network will be used to amplify and covert the current signals to measurable voltage signals. The target under testing must be held at cryogenic temperatures in a vacuum environment. Experimental conditions similar to that in RF superconducting cavities are sought. One or more investigators will be trained at LANL on the handling and use of liquid nitrogen and helium. Due to the high potentials required, radiation shielding will be an issue. Current infrastructure already exists for radiation shielding of 550 keV photons. The Duane-Hunt rule [10] states that the minimum energy that an electron can have to generate such a photon is 550 keV. This assumes a stationary target configuration. The potential differences within the system will not exceed nor come close to such conditions. The radiation will be monitored with existing radiation meters with the approval of the UNLV Radiation Safety Officer.

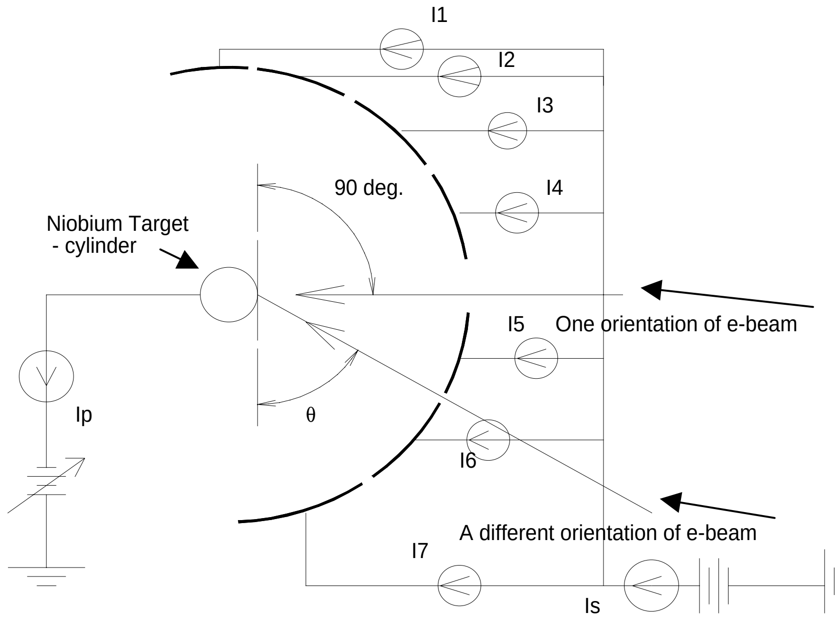

Figure 7. Typical SEE (Secondary Electron Emission) experimental setup.

Some of the experimental infrastructure is already in place. A medium sized vacuum chamber with vacuum system already exists. The pumps (roughing pump, turbomolecular, and cryogenic) and operating systems have not been in operation for over five years and have not been operated at UNLV. Some of the smaller pieces do not exist. The system needs to be partially back engineered to understand how it was operated in the past. This equipment, see Figure 8, was acquired from local industry (through DOE equipment list) for research purposes.

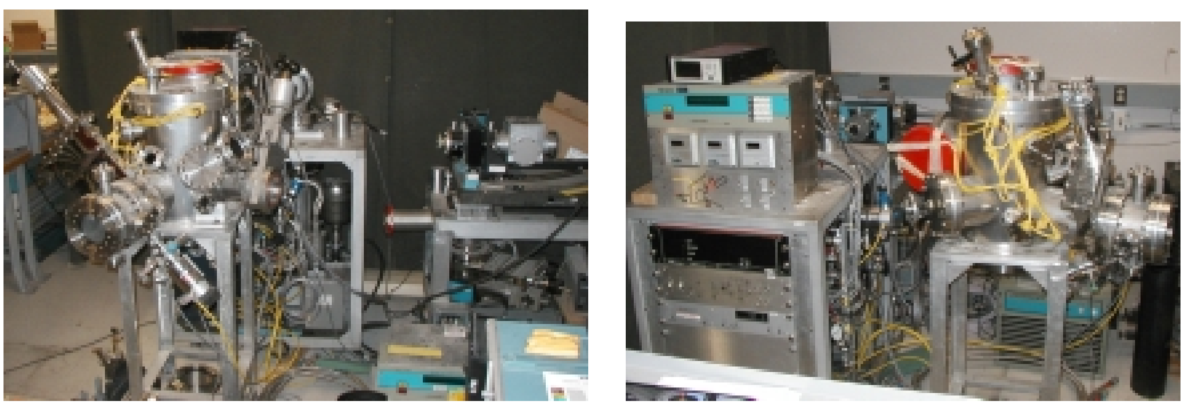

Figure 8. Existing vacuum system in the Electromagnetics Laboratory. Vacuum system includes a turbomolecular pump, roughing pump, a cryogenic pump, controls and gauges, and a VUV grazing incidence monochromator/spectrograph

Experimental data will be fit to generic theoretical curves (see Figure 9) whenever possible and used in computational multipacting studies currently being developed at UNLV based on 2D codes provided to us from Field Precision.

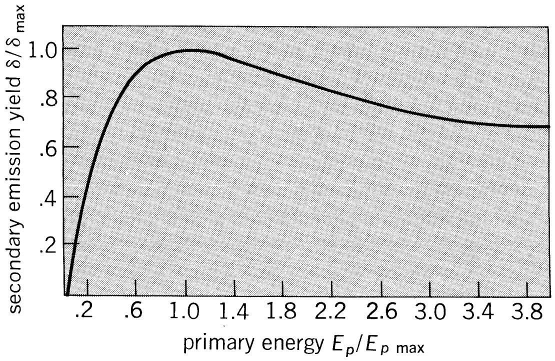

Figure 9. Generic SEE curve.

Based on [9], it is anticipated that some of the experimental data sets will not follow the geometry of the generic theoretical curve of Figure 9. It is anticipated that new results will be obtained with our experimental setup. The literature does not appear to contain experimental studies on the angular distribution of the scattered secondary electrons emitted from a surface treated sample relative to the incident angle of the primary electron beam.

A scaling law will be sought for performing multipacting experiments at higher frequencies without the presence of the accelerating beam. At higher frequencies, the size of the experiment becomes manageable in a university laboratory. Further, this RF/microwave setup can be used to interest and train undergraduate and graduate students for future work in this field. Students gaining practical experience on experimental equipment similar to LANL will be more prepared and more useful as summer interns at LANL. One or more investigators intend to become familiar with LANL's 3GHz cavities and sources already in existence. It is anticipated that this effort will lead to further experimental research efforts on multipacting in the following year.

Task 2: Optimal Design of Niobium Cavities

There are a number of criteria that need to be considered when optimizing niobium cavities. The most important ones are the quality factor Q_0 [2] and the ratios of peak surface fields to the average accelerating field in the cavity. As a first step in optimizing the niobium cavities the quality factor is used as a performance measure. It is defined as

$$Q_0 = \frac{\omega_0 U}{P_c}$$

where U is the stored energy, P_c is the power both dissipated in the cavity walls and absorbed by the multipacting electrons, and ω_0 is the angular frequency of the accelerating mode. The peak field ratios will be considered according to a strategy that will be defined in collaboration with LANL. The above equation shows that minimizing the lost energy and maximizing the stored energy can maximize the quality factor. An alternative measure of multipacting used is the *global multipacting factor* [11] which is the averaging over the total number of initially emitted electrons over the distributed cavity surface:

$$N_0 \prod_{m=1}^{k} \delta(K_m)$$

Because we are optimizing the geometry of the cavity to reduce or eliminate multipacting, the above measure will be modified to monitor multipacting at localized regions on the cavity surface. To take into consideration that secondary electrons may be responsible for initiating multipacting, a number of particles with varying phase will be launched at positions where the secondary electron emission is greater than unity, refer to Figure 2. This will allow us to artificially track secondary electrons that may potentially cause multipacting.

The parameters that affect the quality factor include the geometry of the cavity and its surface finish. While spherical cavities yield the best performance with respect to multipacting, elliptical cavities are usually used because they can be easily manufactured and tuned. They also offer higher mechanical stability [2, 3]. The proposed research defines the shape of the cavity by using ten variables as shown in Figure 10. The design is subject to these constraints:

$$\left|\omega_0 - 700MHz\right| \le \varepsilon$$
$$A_1 \le y_a + r_a \le B_1$$
$$A_2 \le x_e + L_o \le B_2$$
$$A_3 \le y_e - b_e \le B_3$$
$$A_4 \le x_e \le B_4$$
$$A_5 \le \frac{a_e}{b_e} \le B_5$$
$$A_6 \le r_a \le B_6$$
$$A_7 \le \phi_a \le B_7$$
$$A_8 \le \phi_L \le B_8$$

Additional constraints for mechanical stability of the cavity and manufacturing will be also added.

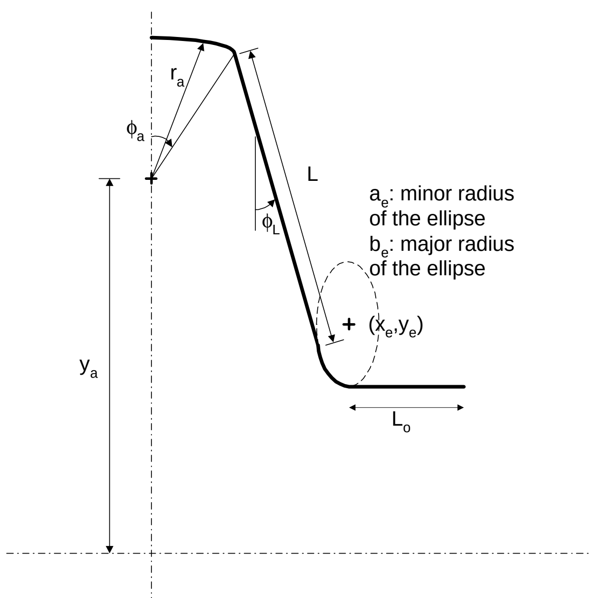

Figure 10. Variables that Describe the Cavity

Once a performance index is determined, other design constraints will be considered. These constraints include geometrical constraints and surface finish constraints. Geometrical constraints ensure that the shape of the cavities is acceptable while the surface finish constraints present the lowest acceptable and the highest possible surface finish quality. The problem of maximizing the performance of the niobium cavities will be solved on several stages. The first stage is to determine the appropriate optimization approach by calculating the quality factor for several values of the problem variables. The results will be analyzed, if it is linear or moderately nonlinear, a pattern search method will be used. We will start with an algorithm such as Fuzzy Simplex [13], which incorporates fuzzy logic to make the simplex search flexible. Another possible approach is the Twinkling Simplex [14]. In this method a subset of the problem variables are randomly selected for the subsequent simplex movements. If the problem proves to be highly nonlinear, the Successive Heuristic Quadratic Approximation (SHQA) technique [15] will be used. This quasi-random method proved very effective in getting the optimal design for a complex system where the objective function is a result of finite element analysis as in this problem. As familiarity with the problem increases, it may be possible to propose an optimization algorithm that fits with the particulars of this problem.

Task 3: Optimal Design of the Etching Process

The ultimate goal of the primary optimization is a cavity shape that fulfills all mechanical and RF requirements. The optimization of the chemical etching process will be conducted for this cavity design. The velocity of the flow should be as uniform as possible in the case of laminar flow to ensure a uniform etching. Velocity distribution will allow mass transfer rates to be calculated to determine etching rates of the surface.

3.1. Mass Transfer Calculations for the Erosion of Material from the Niobium Cavity:

FEMLAB, FIDAP, and STAR-CD are capable of modeling heat transfer as well as fluid flow. Mass transfer rates at the surface of the niobium cavity can be predicted through the Reynolds Analogy by using these software packages to predict heat transfer rates. Through the use of these numerical codes, the rate of mass transfer can be predicted from the surface of the cavity due to the acid etchant. This information may be included in the optimization process to predict the nominal shape of the niobium cavities that will produce the best surface finish upon acid etching.

Convection is the mechanism that allows a moving fluid to remove heat from a surface. Advection, an analogous phenomenon, is the mechanism that allows a moving fluid to remove mass from a surface. Most fluid flow computer codes, such as FEMLAB, allow the user to predict heat transfer rates from a surface for a given surface and fluid temperature. Both phenomena are strong functions of the Reynolds number in the flow. The Reynolds number represents the ratio of inertial forces in the flow to viscous force and is given by:

$$Re = \rho V D / \mu$$

Where: ρ = density of the fluid (kg/m3)
V = fluid velocity (m/s)
D = characteristic dimension (m)
μ = dynamic viscosity (kg/m-s)

Another dimensionless property of a fluid is the Prandtl number, Pr, that expresses the rate of momentum transfer to heat transfer within a fluid:

$$Pr = \nu / \alpha$$

Where: ν = kinematic viscosity of a fluid (m^2/s)
α = thermal diffusivity (m^2/s)

The heat transfer rate, dq/dt, is usually defined as a function of the surface area and a convective heat transfer coefficient, h.

$$dq/dt = h\, A\, (T - T_\infty)$$

Where: q = convective heat transfer (W)
h = convective heat transfer coefficient (W/m^2-K)
A = surface area (m^2)
T = surface temperature (K)
T_∞ = ambient fluid temperature (K)

On the other hand, the mass transfer rate, dm/dt, of substance A into fluid B is given by a very similar equation:

$$dm/dt = K\, A\, (x_A - x_{Ao})$$

Where: K = mass transfer coefficient, (m/s)
x_A = concentration of substance A in fluid B, (kg/m^3)
x_{Ao}= concentration of substance A in fluid B at the wall, (kg/m^3)

Relationship Between Momentum, Heat, and Mass Transfer

The equations governing the transfer of momentum, heat, and mass within a fluid are all analogous varying only with ν (dynamic viscosity), α (thermal diffusivity), or D_{AB} (diffusivity of substance A into fluid B):

$$v_x \frac{\partial \vec{V}}{\partial x} + v_y \frac{\partial \vec{V}}{\partial y} = \nu \frac{\partial^2 \vec{V}}{\partial y^2}$$

$$v_x \frac{\partial T}{\partial x} + v_y \frac{\partial T}{\partial y} = \alpha \frac{\partial^2 T}{\partial y^2}$$

$$v_x \frac{\partial x_A}{\partial x} + v_y \frac{\partial x_A}{\partial y} = D_{AB} \frac{\partial^2 x_A}{\partial y^2}$$

The Reynolds Analogy is used to relate mass transfer and heat transfer rates to shear stress at the walls of a flow. The convective heat transfer coefficient, h, may be computed from the friction coefficient, C_f, at the wall and the Prandtl number which is a function of the fluid properties.

$$\frac{h}{\rho U_{\infty} C_p} \Pr^{2/3} = \frac{C_f}{2}$$

Where, ρ = density of the fluid (kg/m^3)
U_∞ = free stream velocity (m/s)
C_p = specific heat at constant pressure (W/kg-K)

The mass transfer coefficient, K, may also be expressed in terms of a dimensionless property, the Schmidt number (Sc), and the friction coefficient:

$$\frac{K}{U_{\infty}} Sc^{2/3} = \frac{C_f}{2}$$

The Schmidt number is related to the viscosity of the fluid and the diffusion rate of A into B.

$$Sc = \nu / D$$

It is possible to obtain the mass transfer coefficient, K, from the heat transfer coefficient, h:

$$K = h \left(\frac{Le^{-2/3}}{\rho C_p} \right)$$

Where the Lewis number, Le, is given in terms of fluid properties:

$$Le = Sc / Pr$$

For a given velocity distribution, FEMLAB and other computational heat transfer codes can predict the heat transfer rate, dq/dt, along the surface to be acid-etched. By analogy, it is possible to compute the mass transfer rate of material from the surface of a niobium cavity due to the action of an acid etchant.

In FEMLAB, concentration differences are replaced by temperature differences. The Reynolds Analogy is used to obtain the mass transfer rates through equations given above. Through the use of the numerical code, FEMLAB, the mass transfer rates will be estimated from the Reynolds Analogy. The mass transfer may be used in the optimization code to predict the ideal profile of the pre-etched cavity. Mass transfer rates will also be compared to experimental results for validation.

3.2. Optimization Performance Index:

To mathematically describe this phenomenon, we create internal boundaries parallel to the inner walls of the cavity, see Figure 11. Each cavity is divided into six sections. As shown in Figure 12:

- Bottom iris
- Bottom straight
- Bottom equator
- Top equator
- Top straight
- Top iris

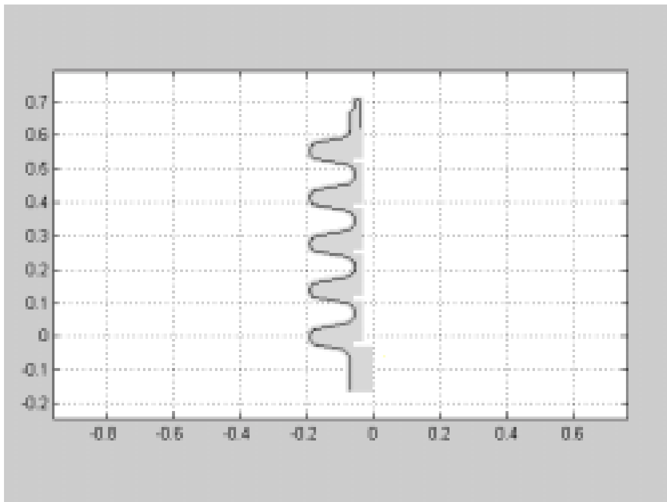

Figure 11. Internal Boundaries Used to Describe Flow Along the Internal Walls of the Cavity

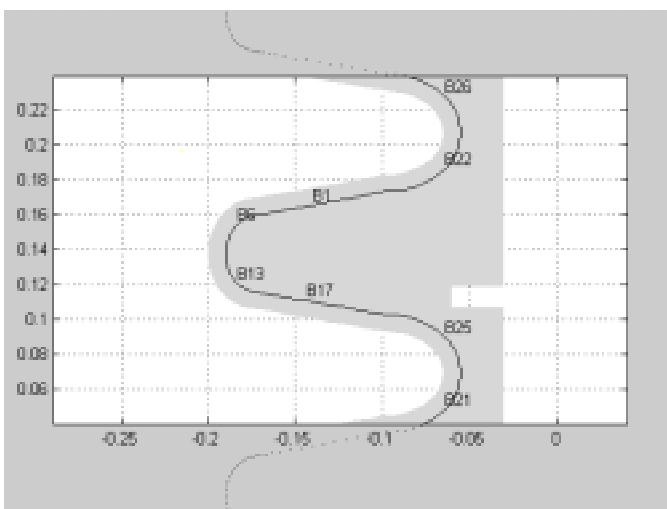

Figure 12. Close-up of the Internal Boundaries Used to Describe Flow Along the Internal Walls of the Cavity

Inlet and outlet are represented using one boundary each. The velocity is integrated along each section. A performance index is defined using two quantities as follows:

$$PI = F\left(\frac{v_{av}}{\frac{\sum_{i=1}^{n}\frac{\int vds}{\int ds}}{n}}\right) + \frac{\sum_{i=1}^{n}\left[\frac{\int vds}{\int ds} - V\right]^2}{nV}$$

Where: *F* is a factor to allow combining the two quantities in the same performance index.
v_{av} is the average inlet velocity.
v is the velocity at any point along the internal boundaries.
n is the number of sections (total of thirty-two).
V is the average velocity along the walls of the cavity, which can be expressed as:

$$V = \frac{\sum_{i=1}^{n}\frac{\int vds}{\int ds}}{n}$$

The first quantity describes the average velocity along the internal boundaries of the baffle while the second one defines its standard deviation. The objective of the optimization is to maximize the first and minimize the second variable.

A second possibility that will be explored is to use the mass transfer rate instead of velocity as the basis for the objective function

Using the Fuzzy Simplex optimization method [13] and varying the variables of the original baffle design (Figure 13) resulted in no significant improvement of the objective function, which led to proposing a new baffle design as shown in the next section.

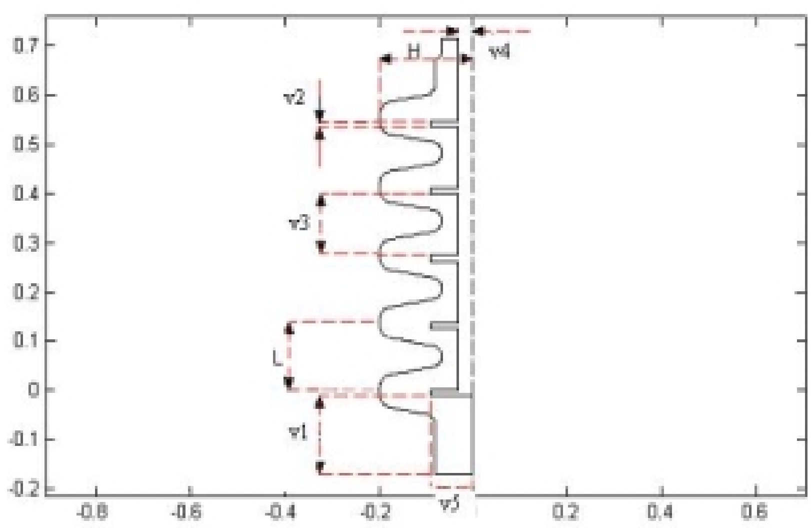

Figure 13. Variables for Optimal Design of the Baffle Problem

Task 4: Redesign the Etching Process to Maximize Surface Uniformity

The surface finish of the niobium cavity plays an important role for achieving the best performance. Even microscopic contaminants on the surface of the cavity can seriously affect its performance due to magnetic heating or electron field emission. As a consequence, a surface finish treatment is needed after fabrication of the cavity. Studies in the first phase of this project using computational fluid dynamics (CFD) helped in better understanding the process. Our preliminary studies also showed that the quality of etching could be further improved. We propose to look at several issues during this phase of the project including:

1. Redesign of the Baffle
2. The effect of turbulence on etching
3. Flow visualization

The remainder of this section details the proposed approach for these subtasks.

4.1. Redesign of the Baffle:

As seen in an earlier section, we already started the process of redesigning the baffle. The new design results in a more laminar flow (Figure 5), which is achieved by extending the baffle inside the cavities. Design of an expanding baffle represents a challenging problem due to space limitations and the chemically aggressive environment. Figure 14 represents a possible design for an expanding baffle. This design is cam-activated. It has the baffle made of four sections. Each section can be expanded or retracted by rotating a cam that moves a spring-loaded follower, which is attached to the baffle section. This design, and other possible alternatives, will be analyzed using Working Model 3D, which is a simulation tool for mechanical systems. We will be designing and manufacturing a prototype during this phase of the project. The design should also consider avoiding contamination by the particles falling from the baffle during the movement.

4.2. The effect of turbulence on etching:

The current etching configuration results in a fluid flow that is at the borderline between laminar and turbulent flow. No research has considered the effect of turbulence on chemical etching. The flow could be made turbulent by adding a rotation to the baffle. This process may however be restricted by the practical consideration of the limitation on the velocity of the baffle rotation. CFD simulation of the process will be conducted to assess the usefulness of turbulent flow.

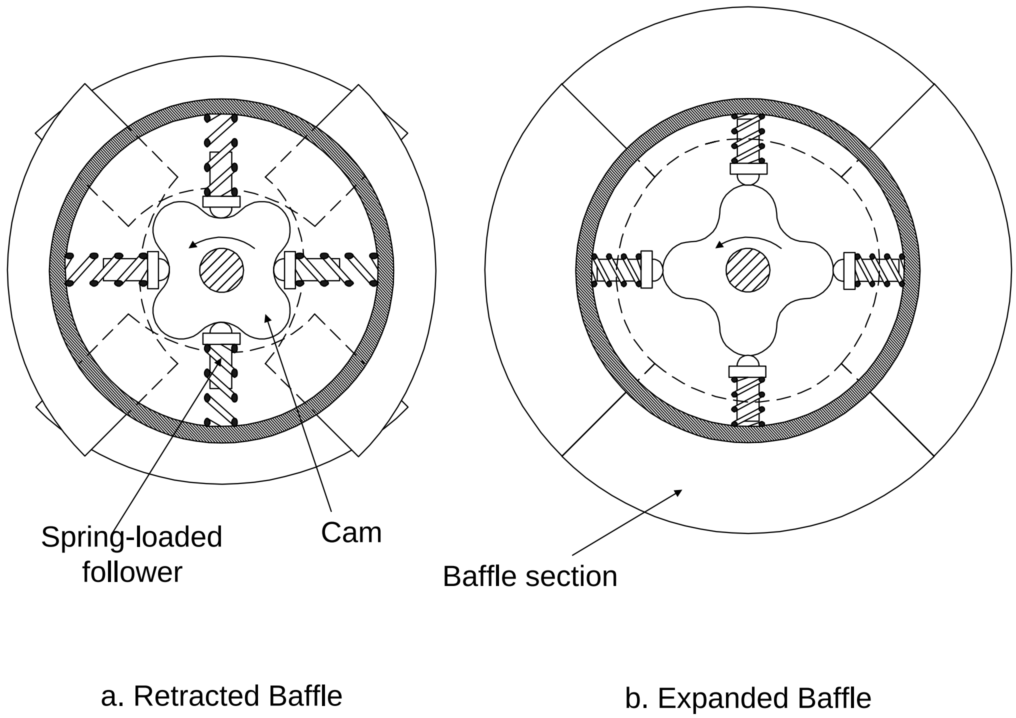

Figure 14. Possible Design for an Expanding Baffle

4.3. Flow visualization:

In a recent visit to LANL, discussions with LANL personnel lead us to the conclusion that flow visualization is needed to help verify the FEA simulations and to give better insight to the problem. Dr. Tajima has agreed to loan us a transparent plastic cavity that will be used at UNLV to simulate different etching conditions. The previous year's numerical work produced velocity distributions within the etchant used to produce the final finish in the niobium cavities. The flow is laminar and pockets of recirculating flow were reduced by changing the baffle design. Verification of the predicted velocity distributions can be done on a prototype niobium cavity using acid etchant at great expense. Fortunately, laminar and turbulent flow distributions can be verified experimentally through dynamic similitude by choosing a "model" fluid that has the same Reynolds number for the desired flowrate.

Water, for example, has a viscosity and density that is similar to that of the acid etching fluids at the desired flow velocities. The Reynolds number is a dimensionless quantity that relates the inertial forces in a fluid to viscous forces. By matching the Reynolds number of the flow in a model to the prototype cavity, the resulting flow patterns will be the same. The velocity of the "model" fluid must be adjusted for differences in fluid density and viscosity:

$$V_m = V_p \left(\frac{\rho_p}{\rho_m} \right) \left(\frac{D_p}{D_m} \right) \left(\frac{\mu_m}{\mu_p} \right)$$

In this expression, the subscripts for the model (m) and prototype (p) system are related through dimension D, density ρ, and dynamic viscosity μ.

Experiments are proposed using a flow visualization technique to visualize the flow of a "model" fluid through a plastic prototype of the niobium cavity provided by LANL. PLIF, PIV, or dye injection will be used to verify that the numerical codes accurately predict the flow behavior seen in the experimental model system.

For verification of the etchant velocity distributions predicted by FEMLAB, various flow visualization techniques are available. PLIF or dye injection provide quantitative verification that laminar flow exists within the niobium cavities during etching. Both techniques also verify the absence of recirculation pockets within the cavities. Several factors will be considered including, different flow rates and flow patterns, i.e. laminar or turbulent flows, with or without agitators or baffles.

4.4. Measurement of Etching Rates and Surface Roughness:

Etching rates of the niobium are not well documented. We propose measuring the etching rates and surface roughness of niobium under different etching conditions using metal coupons under different flow velocities. This experiment will be done in LANL since they have the necessary expertise and hardware for the etching process.

Capabilities at the University and Los Alamos:

LANL is already active in the area of designing SCRF cavities. Lab personnel collaborated with U.S. industry in the area of cavity fabrication. Some of the research facilities needed to pursue this project are available at UNLV except for the Flow Visual System identified in Table 1. The test system is listed in this proposal for information purposes only. The equipment is not included in this budget of the proposed research. The UNLV AAA Ad Hoc Committee on Infrastructure will be reviewing and making equipment-funding recommendations regarding this test system in the near future. The cost estimate is listed here to provide detailed information to these committees. Short delays in obtaining the equipment may not have an impact on the progress of this project. The investigator planning to use the equipment will spend some time at Los Alamos undergoing intensive training in the field during the initial period of the research and design studies will need to be conducted for adequate operation of the system. The flow visualization system finds applications in many mechanical engineering and chemical problems. It will be especially helpful in studying the lead-bismuth loop that may be installed in UNLV.

Minor Equipment Requested for AAA User Labs:

- In preparation for future secondary electron emission experiments modest overall clean up and maintenance cost are requested to refurbish a surplus vacuum system that has not been operated for many years. A mass spectrometer and an electron gun will be installed on the vacuum chamber.

Table 1: Flow Visualization Equipment Needs for this Project*

Equipment	***Cost***
Flow Visualization System Traverse Mechanism ($15,500) CCD Camera ($13,000) Computer ($2,500)	$ 31,000.00

*These costs are being requested through the Research Infrastructure Augmentation funds of the UNLV AAA University Participation Program and are intentionally excluded from the proposed budget for this project.

- Flow Visualization: pump, viscous fluids to simulate the etching fluid and dyes, seeding particles, and cavity supporting structures. These materials will be in support of the equipment listed in Table 1.

Project Timeline:

Timeline Narrative

The proposed research is planned to cover one year, starting in Summer 2002. Research will be conducted with close interaction with appropriate personnel at LANL. We have allocated travel funds for research collaboration with LANL personnel.

The first stage of this project will be dedicated to familiarize researchers and graduate students with new hardware and software packages that will be used in this project. In the second stage researchers will set up experiments. The last part of the project will be spent in assessing the results. Based on the results at the end of the year, we expect to expand the project into a more experimental direction as stated in the proposal.

Expected Technical Results:

- A study of multipacting in niobium cavities with multiple cells.
- A study of the relationship between the shape and surface condition of a cell and its performance.
- Suggestions for improving the results of chemical etching.
- A systematic approach for optimizing the performance of niobium cavities.

Milestones (Based on starting date of May 15th, 2002)

- Continue current research on multipacting phenomenon, September 2002.
- Optimization of the cavity shape to minimize the possibility for multipacting, November 2002.
- Optimization of the chemical etching process to maximize surface uniformity, November 2002.
- Set up a flow visualization experiment to evaluate flow patterns of the etching fluid, December 2002.
- Vacuum system operational, February 2003.
- Evaluation of the flow visualization experiment March 2003.
- Preparing final report: May 2003.

Note: Researchers will submit to the UNLV AAA director monthly updates and quarterly progress reports to help monitor the progress of the project.

Deliverables

In addition to monthly updates and the quarterly and annual reports, researchers expect to publish the results of this project at the appropriate technical conferences and journals. This project will lead to M.S. theses for the graduate students participating in this project.

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[14] Mekhilef, M., and M. Trabia, "Successive Twinkling Simplex Search Optimization Algorithms," ASME 27th Design Automation Conference, Pittsburgh, Pennsylvania, September 2001.

[15] Ceylan, Z., and M. Trabia, "Optimization of the Closure-Weld Region of Cylindrical Containers for Long-Term Corrosion Resistance," ASME 27th Design Automation Conference, Pittsburgh, Pennsylvania, September 2001.

Biographical Sketch (Curriculum Vitae)

ROBERT A. SCHILL, JR., P.E.

Associate Professor
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PROFESSIONAL LICENSING:
Professional Engineer (Wisconsin)

EDUCATION:
University of Wisconsin - Madison
Ph.D. in Electrical Engineering (Aug. 1986)
Major Area: Plasma and Controlled Fusion; Secondary Area: Electrodynamics
Thesis Title: Free Electron Sources of High Frequency Radiation

University of Wisconsin - Madison
M.S.E.E. in Electrical Engineering (May 1981)
Project Paper: A Comparison of the Orbits in a Modular and a Continuous Coil Stellarator

Milwaukee School of Engineering
B.S. in Electrical Engineering (May 1979)

PROFESSIONAL EXPERIENCE:
Associate Professor, University of Nevada Las Vegas (UNLV)
July 1997 – Present
Department of Electrical and Computer Engineering; Director and founder of the Electromagnetic Laboratory which houses nearly a million dollars of test equipment including subnanosecond real time scopes, optical equipment, a vacuum system. Along with Dr. Culbreth and in part Dr. Venkat, a pulse power facility is currently be developed using Blumlein and Marx Bank technology to generate 550 KV, 60 KA, in a 50 ns pulse. Principle Director of the DOE EPSCoR Radiography Research Project netting $1.6 million for the University System.

Assistant Professor, University of Nevada Las Vegas (UNLV)
Aug. 1993 – June 1997
Department of Electrical and Computer Engineering. Developed research in quasi-electrostatic arena to with application to soil remediation. Research on inverse Compton scattering and magnetic interaction with biological tissue were under investigation leading to journal papers in refereed journals.

Assistant Professor, University of Illinois Chicago (UIC)
Sept. 1986 - Aug. 1993
Taught courses in microwaves, charge particle beams, modern optics, and transmission lines. Published many journal articles. Interacted with physicist and engineers at Fermi National Laboratory and Argonne National Laboratory.

AWARDS/HONORS:
Awarded IEEE Senior Member Status, Jan. 1994.
Received Professor Worthy of Recognition at the UNLV Alumni Association: April, 1995 and April, 1996.

PROFESSIONAL AFFILIATIONS:
Institute of Electrical and Electronic Engineers (IEEE)

PUBLICATIONS (partial list: 20 refereed journal articles; 10 conference papers):

1. R.A. Schill, Jr. and K. Hoff, “Characterizing and Calibrating a Large Helmholtz Coil at Low AC Magnetic Field Levels With Peak Magnitudes Below the Earth’s Magnetic Field,” **Review of Scientific Instruments 72**, 6 (2001) pp. 2769-2776.

2. R.A. Schill, Jr., W. Culbreth, and R. Venkat, *Insulator Surface Features Resulting from Cutting Techniques,* **Pulsed Power Plasma Science (PPPS) – 2001 [28th International Conference on Plasma Science (ICOPS) and 13th International Pulsed Power Conference (IPPC)]**, Las Vegas Nevada, June 17-22, 2001.

3. K. Hoff and R.A. Schill, Jr., *Behavioral Response of the African Clawed Frog (Xenopus Laevis) to Immersion in a Low Amplitude 60 Hertz Magnetic Field,* **The Bioelectromagnetics Society 23rd Annual Meeting,** St. Paul Minnesota, June 10-14, 2001.

4. R.A. Schill, Jr., *A Novel Technique to Move a Dust Plasma Plume,* **Pulsed Power Plasma Science (PPPS) – 2001 [28th International Conference on Plasma Science (ICOPS) and 13th International Pulsed Power Conference (IPPC)]**, Las Vegas Nevada, June 17-22, 2001.

5. R.A. Schill, Jr., *A Simplistic Plasma Dust Removal Model*, **Nevada Science & Technology Symposium**, Reno, March 3-5, 1999.

6. R. Venkat and R. A. Schill, Jr., *Investigations of Various Approaches to Gamma Ray Detection Using Optical Methods,* **6th Scientific Symposium on Room Temperature Semiconductor X-ray, Gamma Ray, and Neutron Detectors**, Livermore, California, June 10-11, 1998.

7. R.A. Schill, Jr. and E. McCrea, *Theoretical Study of a Linear Accelerator Used as a VUV/X-Ray Source Employing the Inverse Compton Scattering Mechanism: Comparisons and Applications,* **Laser and Particle Beams 15** 1 (1997) pp. 179-196.

8. R.A. Schill, Jr., *Conservation of Energy for a Weakly Irregular, Open- or Close- Bounded, Dispersive Medium*, special issue of the **Microwave and Optical Technology Letters 4** 11 (1991), pp. 433-439.

9. L. Jiang and R.A. Schill, Jr., *Theory for Cylindrical, Open-Ended, Complex Cavities Supporting All TE_{on} Modes: Gyrotron Application,* **IEE Proceedings Part H: Microwaves, Antennas and Propagation 138** 4 (1991), pp. 297-306.

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11. R.A. Schill, Jr., *A Kinetic Theory for the Electron Cyclotron Maser Interaction in a Lossy Cylindrical Waveguide: Mode Coupling Among All Supported Waveguide Modes*, **Physics of Fluids B 2** 11 (1990), pp. 2798-2817.

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Education

1987	Ph. D. in Mechanical Engineering, Arizona State University.
1983	M. S. in Mechanical Engineering, Alexandria University, Alexandria, Egypt.
1980	B. S. in Mechanical Engineering, Alexandria University, Alexandria, Egypt.

Employment

2000-	Professor, Department of Mechanical Engineering, University of Nevada, Las Vegas.
1993-2000	Associate Professor, Department of Mechanical Engineering, University of Nevada, Las Vegas.
1987-93	Assistant Professor, Department of Mechanical Engineering, University of Nevada, Las Vegas.

Research Interests

- Kinematic Analysis and Design of Robots.
- Dynamic Analysis and Control of Flexible Robots.
- Path Planning and Obstacle Avoidance of Mobile Robots.
- Kinematic Analysis of Mechanisms.
- Optimization Applications to Engineering Design.
- Fuzzy-Logic Control.

Professional Honors

2001	Tau Beta Pi Outstanding Teacher of the Year Award.
1999	Board of Regents Recognition of an Outstanding Faculty Member.
1998	Outstanding Teacher, Department of Mechanical Engineering.
1998	Tau Beta Pi Outstanding Teacher of the Year Award.
1996	College of Engineering Distinguished Teaching Award.

Research Grants Funded (Most Recent)

2001	"Identification of the Dynamic Properties of Materials for the Nuclear Waste Container," Department of Energy," $120,030. (Principal Investigator, with B. O'Toole)
2001	"Delayed Hydride Cracking of Spent Fuel Cladding under Repository Conditions," Department of Energy, $341,810. (member of a four-faculty group)
2001	"Modeling, Fabrication, and Optimization of Niobium Cavities – Phase I," Department of Energy, $ 161,148. (Principal Investigator, with R. Schill and Y. Chen)
2001	"Compressor Impeller P/A 107805-1 Tail-shaft Structural Optimization Analysis," Walker Power System, $3,000. (Principal Investigator)
2001	"Delayed Hydride Cracking of Spent Fuel Cladding under Repository Conditions," Department of Energy, $250,000. (member of a four-faculty group)
2000	"Structural Integrity of Explosion-Proof Containers," Bechtel, $11,000. (with B. O'Toole)
2000	"Identification of the Dynamic Properties of Materials for the Nuclear Waste Container," Department of Energy, $112,964. (Principal Investigator, with B. O'Toole)
1998	"Diagnostics Test & Analytical Methods," American Society of Heating, Refrigeration, and Air-Conditioning, $88,944. (with D. Reynolds)

Publications (Partial List)

Book Chapters

1. Nalley, M. and M. Trabia, "Optimal Placement of a SCARA-Type Robot for Traversal of a Prescribed Path in Near-Minimum Time with Actuator and Obstacle Constraints," Advances in Manufacturing System: Design, Modeling and Analysis, R. S. Sodhi, editor, Elsevier, Amesterdam, 1994, pp. 253-261.

Refereed Journal Publications

1. Trabia, M., and L.Z. Shi "Design and Tuning of a Distributed Fuzzy Logic Controller for Flexible-Link Manipulators," accepted for publication in the Journal of Intelligent & Fuzzy Systems.
2. Trabia, M. and X. Lu, "A Fuzzy Adaptive Simplex Search Optimization Algorithm," ASME Journal of Mechanical Design, Vol. 123, June 2001, pp. 216-225.
3. Trabia, M., M. Kaseko, and A. Murali, "A Two-Stage Fuzzy Logic Controller for Traffic Signals," Transportation Research Part C, Volume 7, Number 6, March 2000, pp. 353-367.
4. Nalley, M. and M. Trabia, "Control of Overhead Cranes Using Fuzzy Logic Controller," Journal of Intelligent & Fuzzy Systems, Volume 8, Number 1, January 2000, pp. 1-18.
5. Trabia, M. and M. Kathari "Placement of a Manipulator for Minimum Cycle Time," Journal of Robotics Systems, August 1999, pp. 419-433.
6. Trabia, M. and W. McCarthy, "Design of Fuzzy Logic Controllers for Optimal Performance," Journal of Intelligent & Fuzzy Systems, Volume 6, Number 4, December 1998, pp. 459-470.
7. Li, J. and M. Trabia, "Adaptive path planning and obstacle avoidance for a robot with a large degree of redundancy," Journal of Robotics Systems, March 1996, pp. 163-176.

Refereed Conferences

1. Q. Xue, S. Subramanian, M. Trabia, Y. Chen, and R. Schill, "Modeling and Optimization of the Chemical Etching Process in Niobium Cavities," International Congress on Advanced Nuclear Power Plants (ICAPP), Hollywood, Florida, June 2002.
2. Mekhilef, M., and M. Trabia, "Successive Twinkling Simplex Search Optimization Algorithms," 27th Design Automation Conference, Pittsburgh, Pennsylvania, September 2001. *(CD-ROM Proceedings)*
3. Ceylan, Z., and M. Trabia, "Optimization of the Closure-Weld Region of Cylindrical Containers for Long-Term Corrosion Resistance," 27th Design Automation Conference, Pittsburgh, Pennsylvania, September 2001. *(CD-ROM Proceedings)*
4. Trabia, M., "A Hybrid Fuzzy Simplex Genetic Algorithm." 26th Design Automation Conference, Baltimore, Maryland, September 2000. *(CD-ROM Proceedings)*
5. Shi, L. Z., and M. Trabia, "Genetic Tuning of Fuzzy Logic Controller for a Flexible Link Manipulator," Proceedings of the International Conference on Mathematics and Engineering Techniques in Medicine and Biological Sciences (METMBS'00), Las Vegas, Nevada, June 2000, CSREA Press, pp. 579-585.
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7. Venkatesh, R., W. Yim, and M. Trabia, "Control of Multiple Teleoperated Robotic Bridge Transporters for Remote Handling," IASTED International Conference on Robotics and Manufacturing, Honolulu, Hawaii, August 1996, pp. 111-114.
8. Venkatesh, R., W. Yim, and M. Trabia, "A Minimum-Time Collision-Free Path Planning for Two Teleoperated Robotic Bridge Transporters," IASTED International Conference on Robotics and Manufacturing, Honolulu, Hawaii, August 1996, pp. 115-118.

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AREAS OF SPECIALIZATION

1. Radiation Transport Calculations and Nuclear Criticality Safety
2. Laser Doppler Velocimetry
3. Engineering Aspects of Nuclear Waste Management
4. Heat Transfer and Fluid Dynamics of Jets
5. Microprocessor Controllers in Acoustics (Adaptive Cancellation) Computer-Aided Data Acquisition
6. Shape Memory Alloys for Robotic Actuators

EDUCATIONAL BACKGROUND

Ph.D. 1981 **Mechanical Engineering**
University of California, Santa Barbara
Dissertation: "Heat Transfer near the Dispersed Phase Nozzle of a Liquid-Liquid Direct-Contact Heat Exchanger".

M.S. 1979 **Nuclear Engineering**
University of California, Santa Barbara
Thesis: "The Design, Construction, and Testing of a Laser Doppler Anemometer for Annular Flow Measurements".

B.S. 1975 **Physics**, California State Polytechnic University, Pomona

TEACHING AND ADMINISTRATIVE EXPERIENCE

8/89-9/91 Interim Director, National Supercomputing Center for Energy and the Environment, UNLV.

8/85-Now Associate Professor of Mechanical Engineering
Associate Professor of Civil Engineering
University of Nevada, Las Vegas

7/81-7/85 Assistant Professor of Mechanical Engineering
Naval Postgraduate School, Monterey, CA

REFEREED PUBLICATIONS (Partial List)

1. Culbreth, W. G., and Zielinski, P. R., "The Importance of Criticality in the Design of the Spent Fuel Waste Container," Scientific Basis for Nuclear Waste Management XVI, Materials Research Society, pp. 73-78, vol 294, 1993.
2. Culbreth, W. G., "Computational Heat Transfer Studies of the Proposed Nuclear Waste Repository," Ninth ICMCM, Berkeley, CA, July 1993.
3. Culbreth, W. G., and Ranz, A., "System Identification of an Elastic Robot using Computer Control and Analysis," Ninth ICMCM, Berkeley, CA, July 1993.
4. Culbreth, W. G., and Rivera, M., "Application Programs in the Engineering Curricula: The Freshman Experience," Ninth ICMCM, Berkeley, CA, July 1993.
5. Culbreth, W. G., and Zielinski, P., "Analysis of the Criticality of a Spent Fuel Waste Package using Mathcad for Windows," Ninth ICMCM, Berkeley, CA, July 1993.

6. Culbreth, W. G., and Wells, H. G., "Development of an Introductory Computer Laboratory for Engineering Students," Proceedings of the 1993 Annual Meeting and Conference of the ASEE/PSW, pp. 143-148.
7. Culbreth, W. G., and Zielinski, P. R., "The Effect of Fuel Burnup and Dispersed Water Intrusion on the Criticality of Spent High-Level Nuclear Fuel in a Geologic Repository," Scientific Basis for Nuclear Waste Management XVII, Materials Research Society, vol 333, pp. 445-454, 1993.
8. Culbreth, W. G., and Zielinski, P. R., "Long-Term Effects of Poison and Fuel Matrix Corrosion on Criticality," Proceedings of the Fifth Annual International High-Level Radioactive Waste Management Conference, pp. 634-641, 1994.
9. Zielinski, P. R., and Culbreth, W. G., "Calculation of keff for Vitrified Plutonium Waste Packages," Proceedings of the Fifth Annual International High-Level Radioactive Waste Management Conference, pp. 679-683, 1994.
10. Culbreth, W. G., Pattisam, S., Jones, M. J., "Experimental Heat Transfer and Fluid Flow over Drift-Emplaced Canisters," Proceedings of the Fifth Annual International High-Level Radioactive Waste Management Conference, pp. 772-779, 1994.
11. Culbreth, W. G., and Bhagi, "Review of Advanced Techniques for Waste Canister Labeling", Proceedings of the Fifth Annual International High-Level Radioactive Waste Management Conference, pp. 1791-1796, 1994.
12. Culbreth, W. G., Wells, H. C., "Impact of ABET Accreditation on Student Retention," Proceedings of the 1994 ASEE Annual Conference Pacific Southwest Section, pp. 96-101.
13. Culbreth, W. G., and Wells, H. C., "Multimedia Laboratory for Fluid Mechanics," Proceedings of the 1994 ASEE Annual Conference Pacific Southwest Section, pp. 29-36.
14. Culbreth, W. G., "The Development of Engineering Coursework on Nuclear Waste Management," Proceedings of the Sixth Annual International High Level Radioactive Waste Conference, American Nuclear Society, pp. 741-743, 1995.
15. Culbreth, W. G., and Wang, Q., "Experimental Investigation of Natural Convection about Drift-Emplaced Waste Canisters," Proceedings of the Sixth Annual International High Level Radioactive Waste Conference, American Nuclear Society, pp. 290-292, 1995.
16. Ventresca, J., Culbreth, W., and Lawson, C., "Mixed Convection Heat Transfer Coefficients for Horizontally Emplaced Waste Packages," 1996 International High Level Radioactive Waste Conference.
17. Culbreth, W., and Ventresca, J., "Drift Apex Temperature Distributions due to Cylindrical Heat Sources," 1996 International High Level Radioactive Waste Conference.
18. Culbreth, W., Ventresca, J., and Kanjerla, A. "Experimental Assessment of Fluid Flow in Plant Xylem," ASME Fluids Engineering Division Annual Summer Meeting, July 7-11, 1996
19. Ventresca, J., and Culbreth, W., "Computational Assessment of Fluid Flow in Plant Xylem," ASME Fluids Engineering Division Annual Summer Meeting, July 7-11, 1996.
20. Culbreth, W., and Steeps, L., "Nuclear Criticality Studies of the Oklo Natural Reactors," to be presented at the International Conference on Nuclear Enginering, May 10-14, San Diego, California.
21. Culbreth, W., and Glew, T., "Assessment of Radionuclides in Enclosed Pipes and Vessels," Proceedings of RPS 2000, American Nuclear Society, Spokane, Washington, September 2000.
22. Culbreth, W., and Viggato, J., "Determination of the Depth and Pressure within the Oklo Natural Reactors," Proceedings of RPS 2000, American Nuclear Society, Spokane, Washington, September 2000.
23. Culbreth, W., "Radiation Shielding and Calculations for the TriMev X-Ray Source," Proceedings of RPS 2000, American Nuclear Society, Spokane, Washington, September 2000.

PATENTS

Culbreth, W. G., Hendricks, E. W., and Hansen, R. J., United States Patent H 1445, "Method and Apparatus for Active Cancellation of Noise in a Liquid-Filled Pipe using an Adaptive Filter," June 6, 1995.

Statement of Current and Pending Support

Statement of Current/Pending Support – Robert A. Schill, Jr.

Academic Year (9 mo.): UNLV – Academic duties, Electrical and Computer Eng. Dept. 9 months
Projected Teaching Load (Fall)
EEG 430 Engineering Electromagnetics
EEG 435 Modern Optics
Projected Teaching Load (Spring)
One course and Dept. Graduate Coordinator

Summer (3 mo.) Modeling, Fabrication, and Optimization of Niobium Cavities – Phase II 2/3 mo. (pending)
UNLV AAA UPP Grant

Laboratory Experience for AAA Applications (LEAP) 2 wks. (pending)
UNLV AAA UPP Grant

DOE EPSCoR – Radiography 0 mo.
Department of Energy (Although some of my time will be devoted to this research, there is no committed time or funding involved with this research.)

Statement of Current/Pending Support – Mohamed Trabia

Academic Year (9 mo.): UNLV – Academic duties, Mechanical Eng. Dept. 9 months
Projected Teaching Load (Fall)
Two mechanical engineering courses.
Projected Teaching Load (Spring)
One course and Dept. Graduate Coordinator

Summer (3 mo.) Modeling, Fabrication, and Optimization of Niobium Cavities – Phase II 2/3 mo. (pending)
UNLV AAA UPP Grant
"Identification of the Dynamic Properties of Materials for the Nuclear Waste Container," Department of Energy, 1mo. (current)
"Delayed Hydride Cracking of Spent Fuel Cladding under Repository Conditions," Department of Energy, 1mo. (current)

Statement of Current/Pending Support – William Culbreth

Academic Year (9 mo.): UNLV – Academic duties, Mechanical Eng. Dept. 9 months
Projected Teaching Load (Fall)
Two mechanical engineering courses.
Projected Teaching Load (Spring)
Two mechanical engineering courses.

Summer (3 mo.) Modeling, Fabrication, and Optimization of Niobium Cavities – Phase II 2/3 mo. (pending)
UNLV AAA UPP Grant
"Nuclear Criticality Analyses of Separations Processes for the Transmutation Fuel Cycle**,**" UNLV AAA UPP Grant, 1mo. (current)
"Radiation Transport Modeling of Beam-Target Experiments**,**" UNLV AAA UPP Grant, 1mo. (current)
"Development of a Cryogenic Vehicle Research Program at the University of Nevada, Las Vegas and the Community College of Southern Nevada," UNLV, 0mo. (current)
DOE EPSCoR – Radiography, Department of Energy (Although some of my time will be devoted to this research, there is no committed time or funding involved with this research.) 0 mo. (current)

Dear Dr. Schill and Dr. Trabia,

I have received your proposal on superconducting (SC) RF cavity development, "Modeling, Fabrication, and Optimization of Niobium Cavities – Phase II." The proposed research fits well with the SC RF development work ongoing in the AAA Project.

Especially, the following items would match the efforts being made at LANL as well as contribute to the SC RF community.

1. Study conditions for best chemical etching, e.g., increase the uniformity of the flow of the chemical etching solution to get smoother surface of the SC cavity. This may contribute to getting higher quality factor and higher gradient. Designing an expandable baffle sounds like a good theme for a graduate student.
2. Perform a multipacting study using available codes and compare with experimental results, together with the tests to get secondary emission coefficients of realistic niobium surfaces. An integration of these results and an optimization of RF properties of a cavity would enable one to design a multipacting-free cavity, which will result in a higher accelerating gradient.
3. Develop a cavity design optimization algorithm. This may enable cavity designers to eliminate some iterative efforts, although similar programs may already exist.

We, SC RF team at LANL, will support your efforts and provide help in carrying out the proposed work.

Yours Sincerely,

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Tsuyoshi Tajima on behalf of SC cavity team at LANL

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