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NUCLEAR POWER

SYSTEMS DIVISION

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HCP-10-82
MFN-016-82

February 23, 1982

U. S. Nuclear Regulatory Commission
Advisory Committee on Reactor Safeguards
Washington, DC 20555

Attention: Paul Boehnert

Gentlemen:

SUBJECT: RESPONSE TO REQUEST FOR INFORMATION

At the January 22, 1982 meeting of the Fluid Dynamic Subcommittee of the ACRS, Dr. Theofanus asked for information related to full scale data on Mark III LOCA loads. This information is addressed in a draft of Attachment D to Response 3B.32 for GESSAR. I have attached a copy for your information.

The attachment contains material which is the type General Electric maintains in confidence and withholds from public disclosure and is therefore identified as proprietary in the attached affidavit. As such, we request that it be withheld from public disclosure in accordance with the provisions of 10CFR2.790.

Also enclosed for your information is a copy of a 1972 ASME paper "Liquid Surface Motion Induced By Acceleration and External Pressure" by F. J. Moody and W. C. Reynolds. This work by Moody served as the basis for General Electric's current pool swell models.

Very truly yours,

H. C. Pfefferlen, Manager
PWR Licensing Programs
Nuclear Safety and Licensing Operation

HCP:hjr/C02024

Attachment

cc: L. S. Gifford (GE-Bethesda)
J. A. Kudrick (NRC), w/o Attachment
M. B. Fields (NRC), w/o Attachment
H. Faulkner (NRC), w/o Attachment
R. Villa (GE), w/o Attachment



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ATTACHMENT D

TO

RESPONSE 3B.32 - GENERAL ELECTRIC'S 2D MARKER-AND-CELL POOL SWELL ANALYTICAL MODEL

## 1.0 INTRODUCTION

General Electric's pool swell analytical model evaluates the suppression pool surface profile and velocity in a Mark III containment during the pool swell transient following a postulated LOCA. The code computes the two-dimensional potential flow field, representing the suppression pool and governed by the Laplace equation, with the Marker-And-Cell (MAC) techniques. Favorable comparisons have been obtained between model predictions and GE Mark III Pressure Suppression Test Facility (PSTF) test data.

## 2.0 MODEL DESCRIPTION

The pool swell analytical model simulates the two-dimensional flow field of the symmetry plane (plane AA in Figure D-1) in a Mark III containment unit cell, which is defined as the region bounded by the inner and outer containment walls radially, and by two adjacent symmetry planes circumferentially. Thus, a unit cell is a 9-deg sector of the containment.

Listed below are the individual components of the pool swell model. Some of these are not part of the pool swell code, and the details can be found elsewhere.

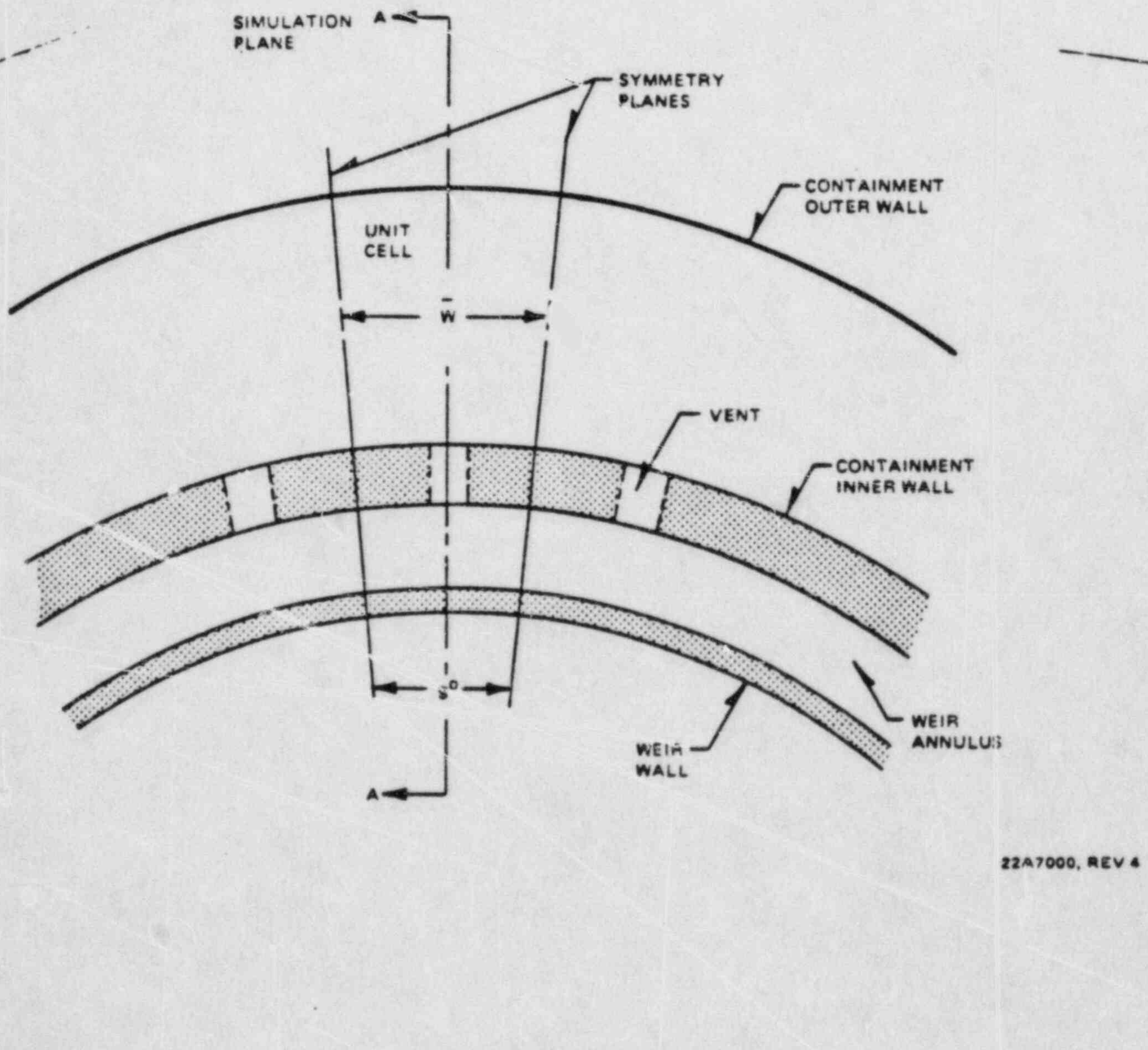


Figure D-1. Unit Cell Plan View

RESPONSE 3B.32 - GENERAL ELECTRIC'S 2D MARKER-AND-CELL POOL SWELL ANALYTICAL MODEL (Continued)

## 2.1 COMPONENTS OF POOL SWELL MODEL

The pool swell analytical model is composed of the following components:

- drywell response model
- vent clearing model
- vent clearing jet model
- vent flow model
- suppression pool hydrodynamic model
- bubble model

The drywell pressure response and vent clearing time, velocity and acceleration are obtained from the containment analytical model (Reference D-1), and are not part of the pool swell code. The drywell response following vent clearing is used as input by pool swell model as the driving force in the vent flow and bubble charging model.

The vent clearing jet model employs the transient, accelerating water jet model described in Reference D-2 to obtain the jet penetration, $\ell p$. The assumption is made that the initial shape of the bubble is cylindrical with a diameter $d_V$ and length $\ell p$, as shown in Figure D-2. The nose is rounded slightly to avoid possible computational difficulties in the pool hydrodynamic model. The following sections describe the analytical models in the code.

RESPONSE 3B.32 - GENERAL ELECTRIC'S 2D MARKER-AND-CELL POOL SWELL ANALYTICAL MODEL (Continued)

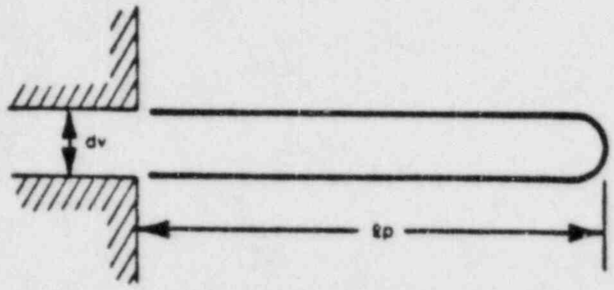


Figure D-2. Initial Loca Bubble Profile

## 2.2 VENT FLOW MODEL

The assumptions in the vent flow model are

1. Air flow only - this removes any condensable steam from the bubble and results in conservative bubble pressure response.

2. Fanno flow - That is, the flow is one-dimensional, compressible, adiabatic, frictional and follows the perfect gas law.

Vent flow is needed to provide bubble charging and evaluate bubble pressure.

## 2.3 SUPPRESSION POOL HYDRODYNAMIC MODEL

It is assumed that the flow is two-dimensional, incompressible, inviscid and irrotational. Thus, the governing equation is the Laplace equation for the velocity potential, $\phi$:

$$\nabla^2\phi = 0$$

RESPONSE 3B.32 - GENERAL ELECTRIC'S 2D MARKER-AND-CELL POOL SWELL ANALYTICAL MODEL (Continued)

The boundary conditions are

At rigid walls:

$$\frac{\partial \phi}{\partial n} = 0 \qquad \vec{n} \text{ normal to walls}$$

At free surfaces:

$$\frac{\partial \phi}{\partial t} + \frac{1}{2}\left[\left(\frac{\partial \phi}{\partial y}\right)^2 + \left(\frac{\partial \phi}{\partial z}\right)^2\right] + g_c \frac{P}{\rho} + g_z = 0$$

$$P = \text{constant}$$

Using finite differences (Figure D-3), the Laplace equation is transformed into a set of simultaneous algabraic equations. Given the initial values of velocity potential on the free surfaces, these simultaneous algebraic equations are then solved by overrelaxation for the velocity potentials in the interior region, which in turn permits velocity components and potential rates to be calculated at the free surfaces. Markers used to describe the position and shape of each free surface are then moved with their given velocities, providing the boundary conditions for flow field computation at the new time step. The process is repeated until finished.

2.4 BUBBLE MODEL

The assumption of a perfect noncondensable gas in the bubble allows the determination of bubble pressure through the relationship

$$P_B = \frac{M_B \; R \; T_B}{V_B}$$

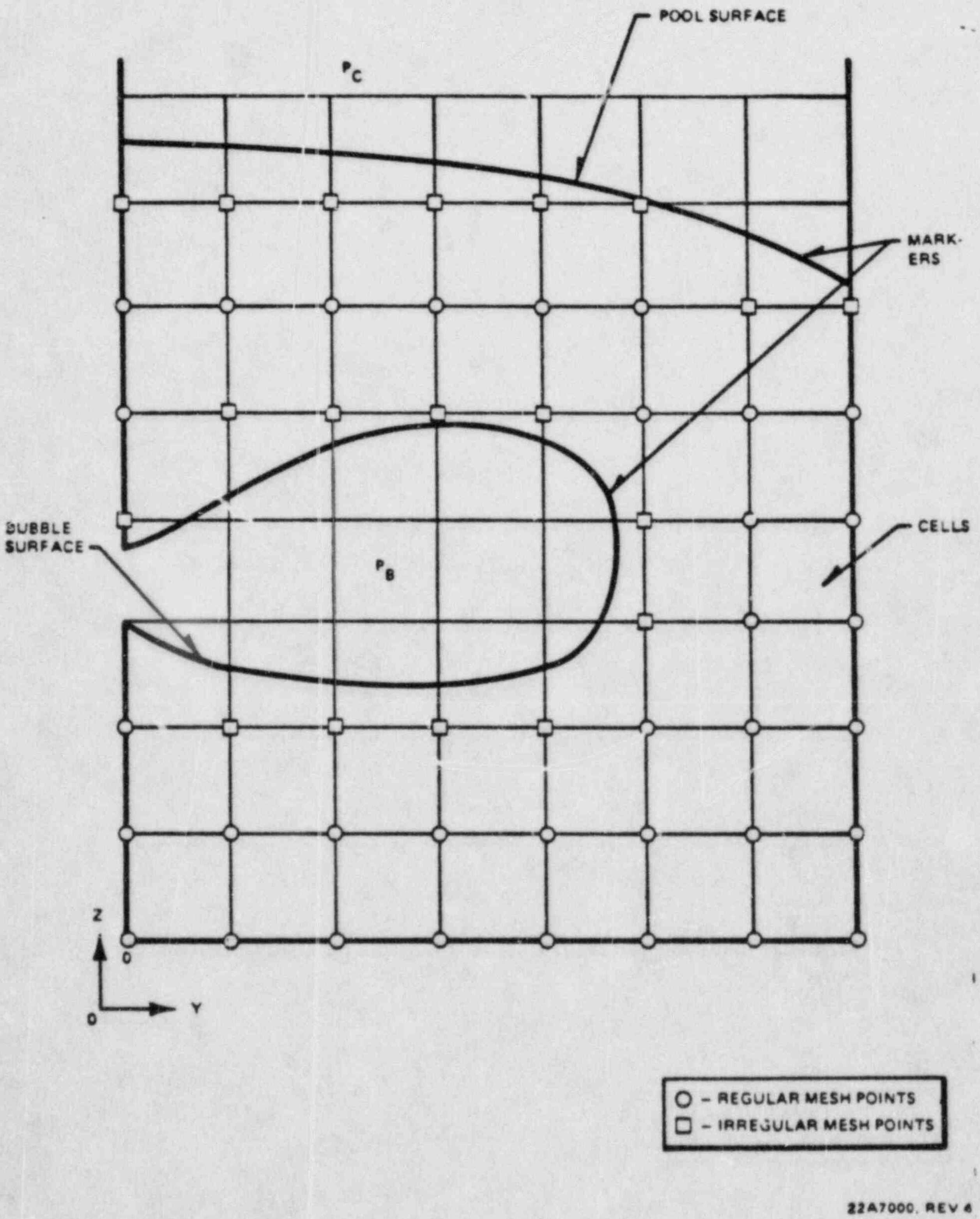


Figure D-3. Marker-and-Cell Representation of Flow Field

RESPONSE 3B.32 - GENERAL ELECTRIC'S 2D MARKER-AND-CELL POOL SWELL ANALYTICAL MODEL (Continued)

where

$P_B$ = bubble pressure

$M_B$ = bubble air mass = $\int_{t_{vc}}^{t} m_{vent}\, dt$

$T_B$ = drywell temperature (assumed to remain constant)

$R$ = gas constant for air

$V_B$ = bubble volume

To define $V_B$, the bubble growth is divided into two phases. In the early phase the bubble is relatively small compared to the cell size, thus the bubble growth is predominantly three-dimensional and the cell walls (i.e., symmetry surfaces dividing adjacent bubbles) do not have a strong influence on the bubble expansion. The bubble volume during this phase is given by the expression (Refer to Figure D-4).

$$V_B = \frac{4}{3} K_B \sqrt{\frac{b}{a} \quad \frac{A_B}{\pi}} \cdot A_B$$

in which the two-dimensional area, $A_B$, is given by Green's theorem

$$A_B = \left| \oint_c ydz - zdy \right|$$

and $K_B$ is an empirical constant (to be described later).

RESPONSE 3B.32 - GENERAL ELECTRIC'S 2D MARKER-AND-CELL POOL SWELL ANALYTICAL MODEL (Continued)

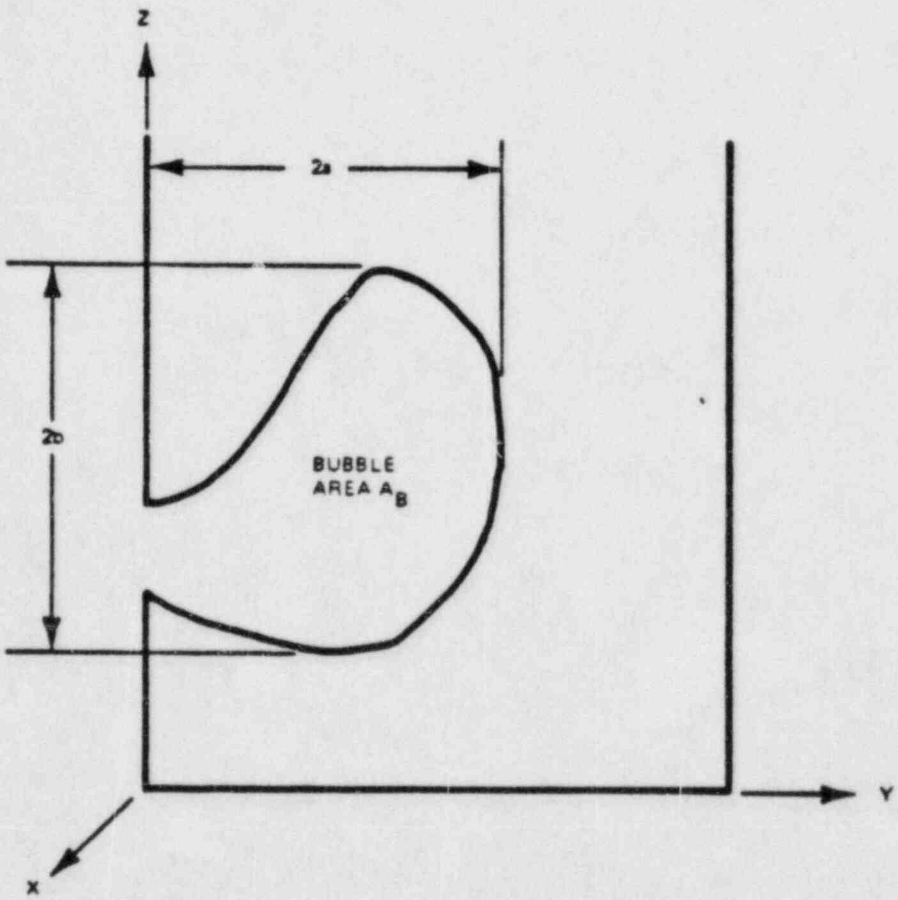


Figure D-4. Two-Dimensional Bubble Profile

For the special case where the two-dimensional bubble profile is an ellipse with semi-axes a and b,

$$A_B = \pi ab$$

and $V_B$ reduces to

$$V_B = K_B \frac{4}{3} \pi ab$$

RESPONSE 3B.32 - GENERAL ELECTRIC'S 2D MARKER-AND-CELL POOL SWELL ANALYTICAL MODEL (Continued)

which corresponds to the volume of an ellipse rotated about the y axis if $K_B$ is set equal to 1.0.

The bubble growth enters the second phase when the lateral expansion is constrained by the side walls (that point being when the lateral dimension equals $\bar{w}$) and is forced to expand upward. The bubble volume is then calculated as

$$V_B = \frac{4}{3} K_B \frac{\bar{w}}{2} A_B$$

For the special case where the two-dimensional bubble profile is an ellipse, the bubble volume reduces to

$$V_B = \frac{4}{3} K_B \pi ab \frac{\bar{w}}{2} A_B$$

which is the volume of an ellipsoid with semi-axes equal to a, b, and $\bar{w}/2$ if $K_B$ is set equal to 1.0.

For the bubble constant $K_B$, a value of 1.25 is recommended based on data comparison and physical argument.

## 3.0 MODEL-DATA COMPARISONS

The pool swell analytical model predictions have been compared to PSTF test data. A total of 11 test cases were used in the model-data comparisons. Only air blowdown tests were used in the comparisons. The parameters compared are the pool surface elevation history, the surface velocity as a function of elevation, the pool surface and bubble profiles and the water ligament thickness.

**UNION OF CONCERNED SCIENTISTS** 1346 Connecticut Avenue, N.W. • S. 1101 • Washington, DC 20036 • (202) 296-5600

30 March 1984

FREEDOM OF INFORMATION ACT REQUEST
FOIA-84-237
Rec'd 4-3-84

Mr. J. M. Felton, Director
Division of Rules and Records
Office of Administration
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

RE: Freedom of Information Act Request for Documents Concerning NRC FIN A-3320, "Mark III LOCA Pool Dynamics" [Sholly FOIA 84-19]

Dear Mr. Felton:

Pursuant to the Freedom of Information Act, please make available at the Commission's Washington, D.C., Public Document Room copies of documents in the following categories:

1. All documents submitted to the NRC under a research program at Brookhaven National Laboratories, NRC FIN A-3320, "Mark III LOCA Pool Dynamics". This request specifically includes the Form 189 application, all periodic progress reports, letter reports, draft reports, final reports, correspondence, memoranda, and other documents pertaining to the work done in this program.

2. All correspondence among NRC, utilities (and their consultants and contractors), and Brookhaven National Laboratory in which any draft reports prepared under NRC FIN A-3320 were transmitted to any one outside the NRC and any comments upon such draft reports.

Should you or your staff have any questions regarding this request, please contact me at (202) 296-5600. Your cooperation in responding to this request is appreciated.

Sincerely,

Steven C. Sholly

Steven C. Sholly
Technical Research Associate

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