APPLICATION OF A SURFACE EXPLOSION CRATERING MODEL TO IMPACT CRATERING. R. P. Swift, Earth Sciences Division, Lawrence Livermore Laboratory, Livermore, CA. 94550.

A phenomenological model developed for surface explosion cratering,[1] is applied to impact cratering. The model is based on the following features of the cratering flow field after passage of the explosive induced shock wave as observed in numerical calculations using continuum mechanics codes: (1) A near-steady-state flow field is established in the cratering region, (2) The material density has attained or is approaching a final constant value, and (3) The radial component of the flow velocity may be approximated to the first order by

$$\dot{R} = \alpha/R^Z$$

where $\alpha$ and Z are parameters associated with the intensity and shape of the flow field. Satisfaction of the steady-state incompressible process (i.e., $\nabla \cdot \vec{u} = 0$) implied by these observations provides the tangential velocity component

$$R\,\dot{\theta} = (Z-2)\,\dot{R}\,\sin\theta/(1 + \cos\theta)$$

and the corresponding stream function

$$\psi(R,\theta) = \alpha(1 - \cos\theta)/R^{Z-2}$$

associated with the flow field, where R and $\theta$ are the radial and angular coordinates in a spherical axisymmetric system. For surface explosions the origin is at the axis of symmetry on the original ground surface, while for impact cases it may be necessary to translate it downward to coincide with the effective depth-of-burial associated with the impact.

The first order model where $\alpha$ and Z are constant has been successfully applied to surface explosion cases to predict time-dependent cratering, displacement, and ejecta.[1,2] The case of Z = 2 describes an irrotational flow field of a spherical source with strength $\alpha = Q/4\pi$, where Q is the volume flow rate of the source. The flow field is rotational for values of Z other than 2. For surface explosion cratering flow, a value of $Z \simeq 2$ describes the flow field reasonably well in the region directly below the charge. Near the surface $Z \simeq 4$ is more representative of the flow field shape, and an average value of $Z \simeq 3$ is representative of the average flow below the ground plane and gives zero vertical momentum.

To assess the applicability of the surface cratering flow model to impact cratering as well as to buried explosive cratering, the flow fields generated by calculations of impact events and buried charges are compared to the flow field of a surface explosion. Similarity of the calculated flow fields for an impact event and an energy equivalent buried charge at some effective depth-of-burial is shown in [3]. The first order surface model appears reasonably suitable to describe the impact and buried explosive flow

field in regions below and up to the effective depth-of-burial. However, the flow field above and slightly out from the effective depth-of-burial is poorly represented. The remainder of the flow field near the surface is characterized fairly well by the first order model, however, as with surface explosion cases, the resulting flow fields indicate a spatial dependence for the shape parameter Z with the value of Z increasing as the surface is approached. Final crater dimensions are derived by employing the conservation of energy as a constraint to account for the dissipation of kinetic energy in the flow field through material strength and gravity effects. The importance of the gravitational influence as compared to the material strength influence in retarding crater formation has been illustrated in calculations of surface explosions.[4] The first order model provides a useful and convenient means to determine the time-dependent formation of the cratering flow field and to evaluate the interacting roles of material strength and gravity.

## REFERENCES

1. D. Maxwell and K. Seifert (1976), "Modeling of Cratering, Close-In Displacements, and Ejecta," Defense Nuclear Agency Report No. DNA 3628F.

2. D. L. Orphal (1977), "Calculations of Explosive Cratering-II Cratering Mechanics and Phenomenology," Impact and Explosion Cratering, Eds. D. J. Roddy, R. O. Pepin, R. B. Merrill, Pergamon Press (New York) pp 307-317.

3. J. B. Bryan, D. E. Burton, and L. A. Lettis, Jr. (1979), Lunar and Planetary Science X, This volume.

4. R. P. Swift (1977), "Material Strength Degradation Effect on Cratering Dynamics," Impact and Explosion Cratering, Eds. D. J. Roddy, R. O. Pepin, R. B. Merrill, Pergamon Press (New York) pp 1025-1042.

"Work performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore Laboratory under contract number W-7405-ENG-48."