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1 - AND 2-D COMPUTER ANALYSIS OF AN HDL STRESS WAVE SWITCH

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ABSTRACT

A series of one-dimensional and two-dimensional computer calculations was performed to analyze the performance characteristics of an H.D.L. - designed, normally-open type stress wave switch. The computer results show some differences with respect to the published experimental data.

INTRODUCTION

At the request of Harry Diamond Laboratory, a series of one-dimensional and two-dimensional machine calculations was performed using LLL computer codes KOELAS and HEMP (Ref. 1 & 2). These codes were used to evaluate the closure response of a model designed by H.D.L. for simulating the performance of a normally-open, stress wave impact switch (Ref. 3).

The two computer codes used in this analysis were developed for LLL by Mark L. Wilkins. They use the methods of finite differences and the Langrangian formulation to solve the conservation equations of one- and two-dimensional elastic-plastic flow.

In this report, the performance characteristics for this stress wave switch, as predicted by the codes, will be compared to the experimental data that were generated by H.D.L.

DISCUSSION

The model used by H.D.L. for generating experimental data on the performance characteristics of a normally-open, stress wave impact switch is described in Fig. 1. Prior to impact, a small gap separates the insulated contact from the switch plate. After being impacted by the projectile, a stress wave is generated in the switch plate. When this stress wave reaches the free surface of the plate, opposite the contact, it displaces this surface. If the stress wave is of sufficient magnitude and duration, it will cause the free surface to close the gap and activate the switch.

The experimental data and the results of two different one-dimensional analyses for the performance of this switch, as described in Reference 3, are shown in Fig. 2. The lower curve was generated by impedance matching methods, and the other curve was generated from a one-dimensional elastic stress-wave computer code.

The model used for the KOELAS 1-D calculations is described in Fig. 3. A series of infinite plates are used to model the various switch elements. Each element is sub-divided into zones, and the number of zones per element is indicated in the figure. Because of it's relative size, the gap was treated as a void instead of an element consisting of air. This eliminated zonal instability problems from occurring in the computer calculations and has no adverse effect on the results.

The lower curve in Fig. 4 shows the results of the KOELAS 1-D computer calculations for an impact velocity of 29.0 m/sec. This curve indicates a transient time for the switch plate of approximately 3 μsec. The longitudinal shock velocity for this plate was calculated at 5.3 mm/μs, which is in agreement with published data for stainless steel. The code's void routine indicates that a separation between the projectile and switch plate occurs at approximately 32 μsec. In general, the KOELAS results predict closure times much faster than the experimental data.

Figure 5 shows the diagram for the switch used in the HEMP 2-D computer calculations. In this case, each element was divided into a grid consisting of J- and K-lines. The K-lines 49,-52 and 52 represent, respectively, the free surface and impact surface of the switch plate and the impact surface of the projectile. The switch's axis of symmetry is represented by the line J-8. For simplicity in zoning, the brass contact was eliminated as one of the elements in the HEMP calculations.

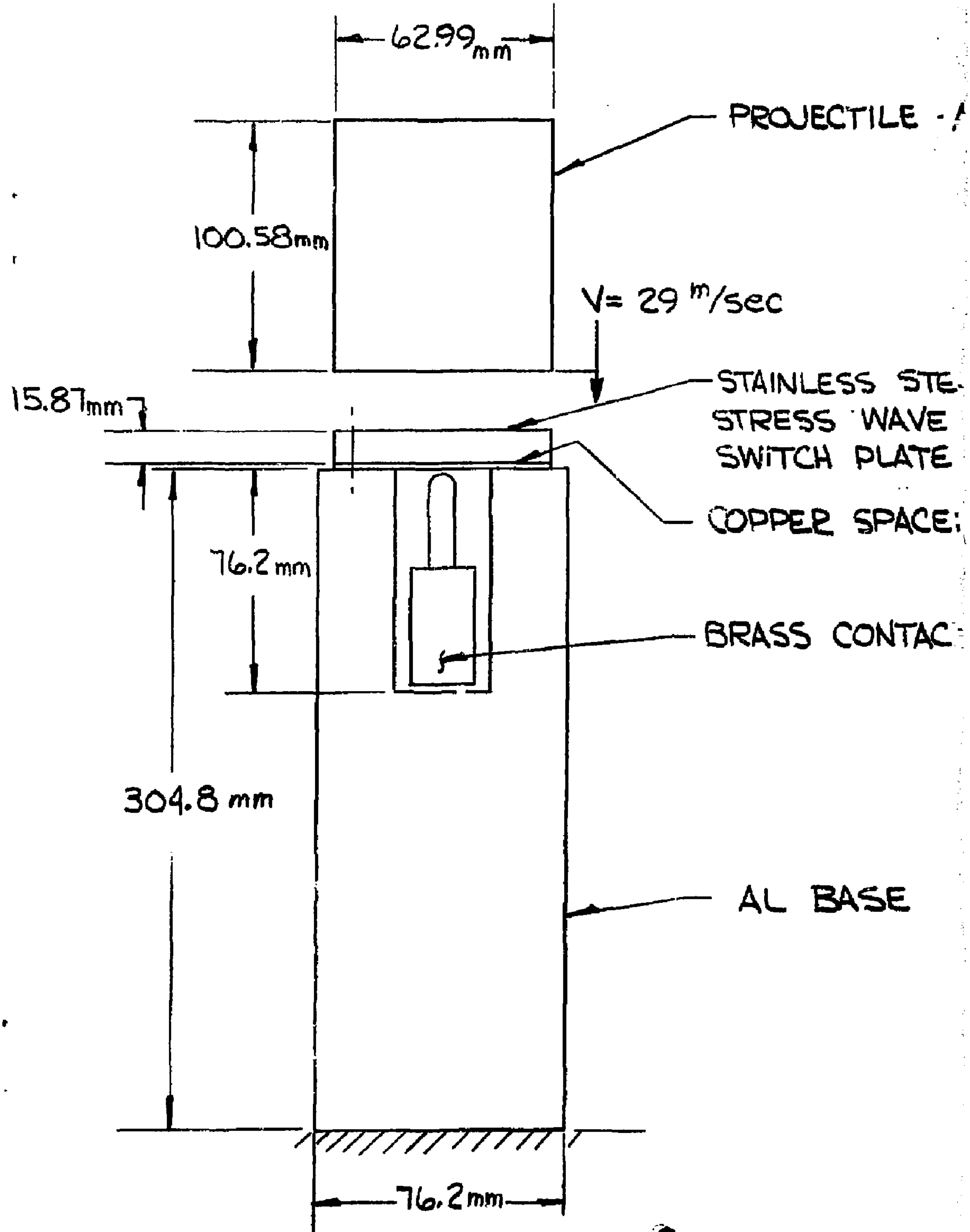
The upper two curves in Fig. 4 were generated by HEMP, and they represent the position-time history of the node point K-49, J-8 for impact velocities of 24.0 and 29.0 m/sec. As expected, the HEMP calculations compute closure times slower than the 1-D calculations, but still much faster than the experimental data. HEMP also shows a gradual change of slope in the curves at about 40 to 45 μsec, while the experimental data indicate a step change at 50 μsec. This change in free surface velocity can be attributed, as shown in Fig. 6, to the separation of the switch plate from the projectile. Figure 6 shows the separation occurring at about 39 μsec for the 29.0 m/sec impact velocity.

SUMMARY

The KOELAS 1-D computer calculations for the stress wave switch performance showed limited agreement with the experimental data. The closure times were considerably faster than the raw data, and, also, they showed no indication of a step change in performance at 50 μsec.

The HEMP results, which are more representative of the system, also showed closure times faster than the raw data, but they did indicate a slight change in performance at approximately 45 μsec.

Since neither KOELAS, HEMP or the H.D.L. 1-D analysis were capable of predicting the switch operation with adequate accuracy, a question must be raised as to the accuracy of the experimental points, especially since each point represents the results of only one experiment. Additional experiments would provide data which could aid in resolving the discrepancy between the computer predictions and the experimental data.



62.99mm
PROJECTILE - /
100.58mm
V= 29 m/sec
STAINLESS STE-
STRESS WAVE
SWITCH PLATE
15.87mm
COPPER SPACE:
76.2 mm
BRASS CONTAC
304.8 mm
AL BASE
76.2mm

FIGURE 1

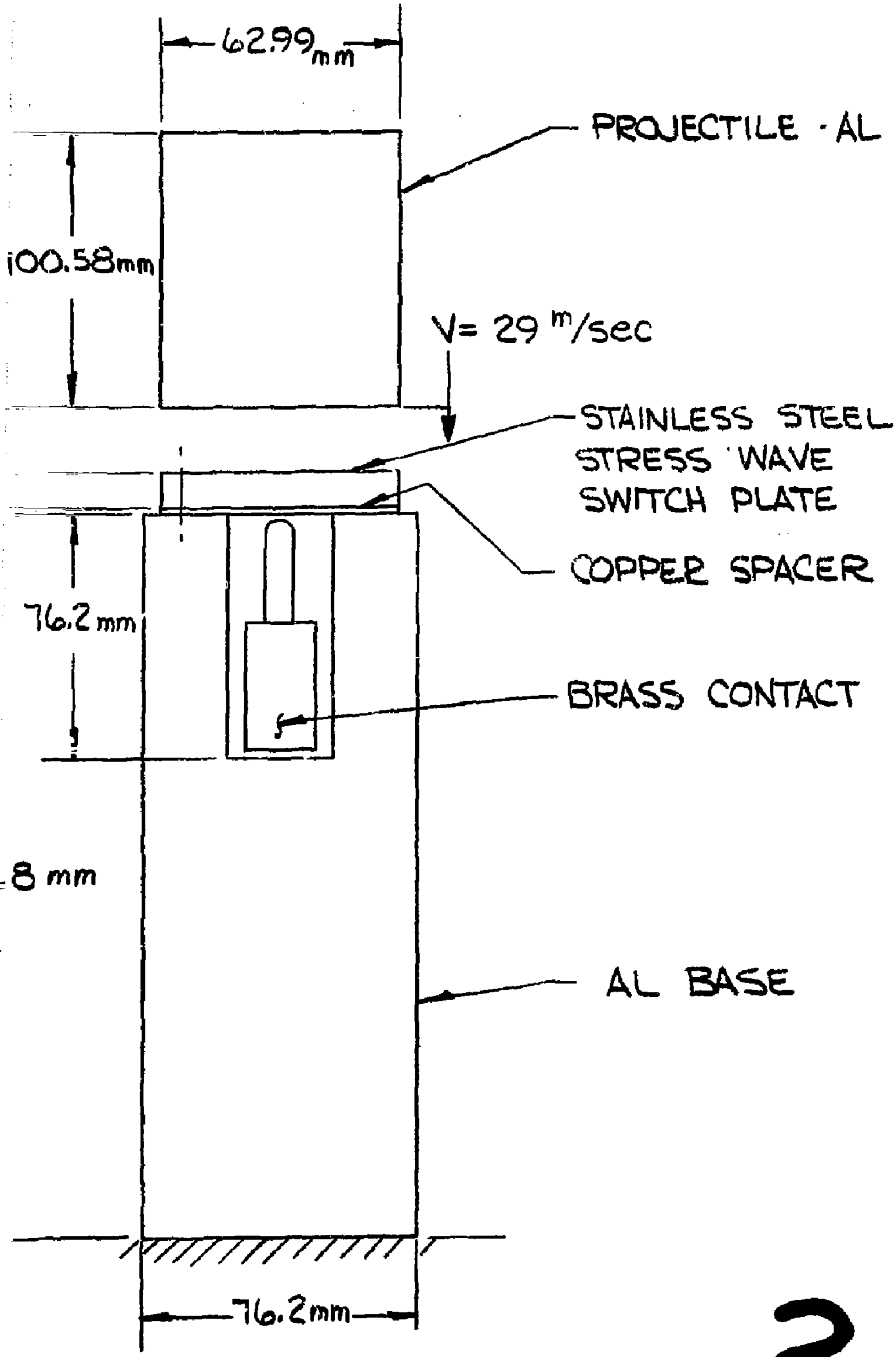
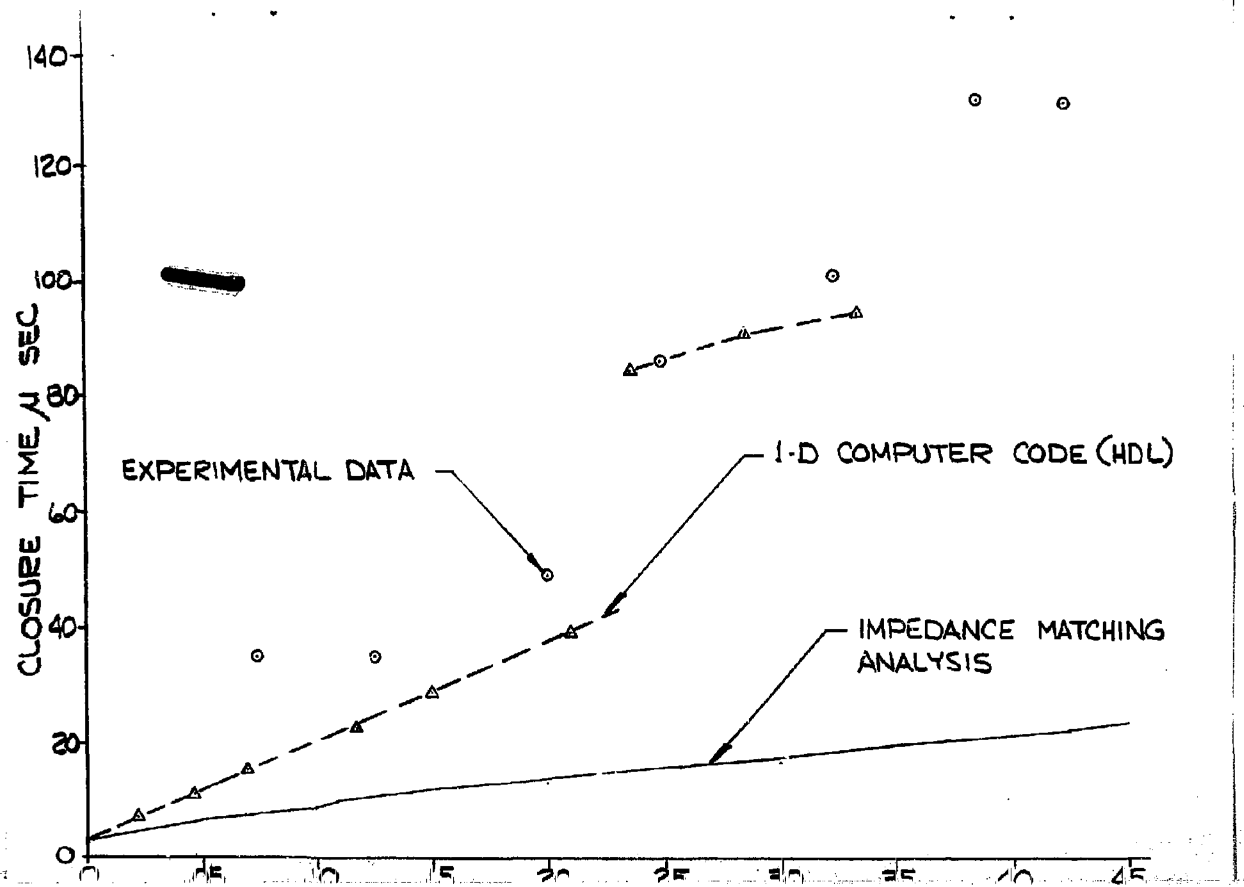
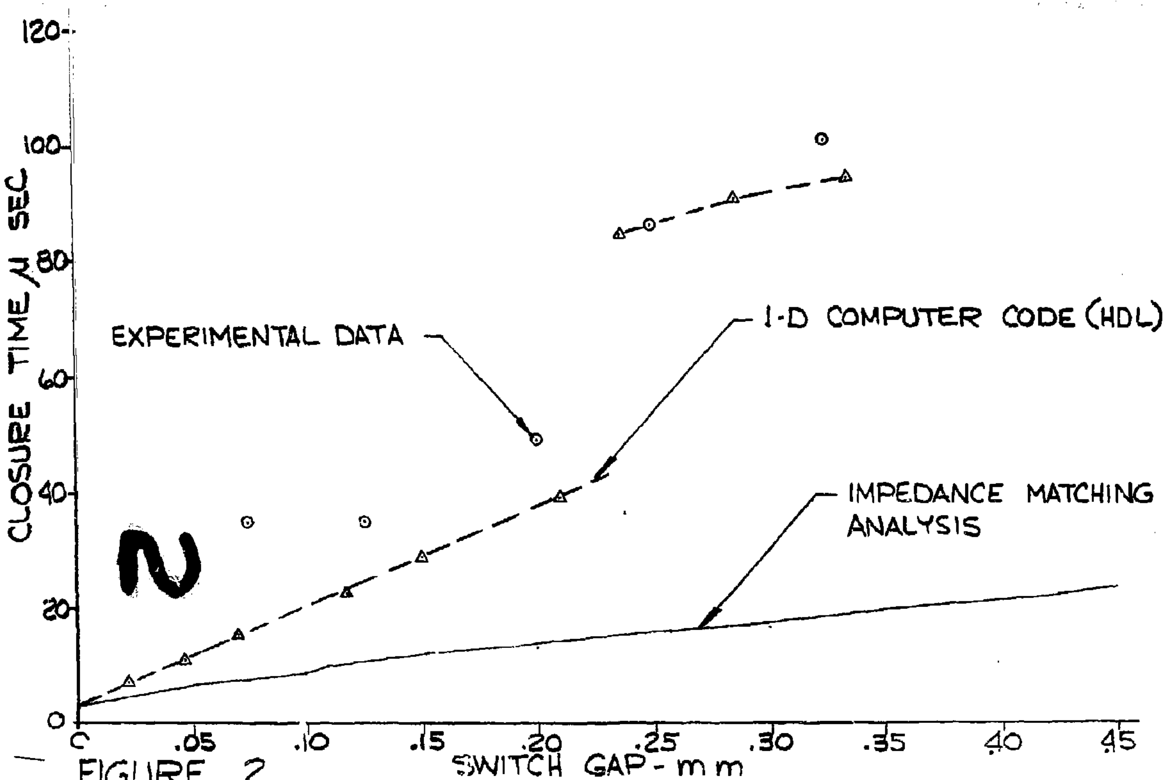

62.99mm
PROJECTILE - AL
100.58mm
V= 29 m/sec
STAINLESS STEEL
STRESS WAVE
SWITCH PLATE
COPPER SPACER
76.2mm
BRASS CONTACT
8 mm
AL BASE
76.2mm

FIGURE 1


CLOSURE TIME μ SEC
140
120
100
80
60
40
20
0
EXPERIMENTAL DATA
1-D COMPUTER CODE (HDL)
IMPEDANCE MATCHING ANALYSIS



120
100
80
60
40
20
0
CLOSURE TIME μ SEC
EXPERIMENTAL DATA
1-D COMPUTER CODE (HDL)
IMPEDANCE MATCHING ANALYSIS
2
0
.05
.10
.15
.20
.25
.30
.35
.40
.45
SWITCH GAP - mm

FIGURE 2

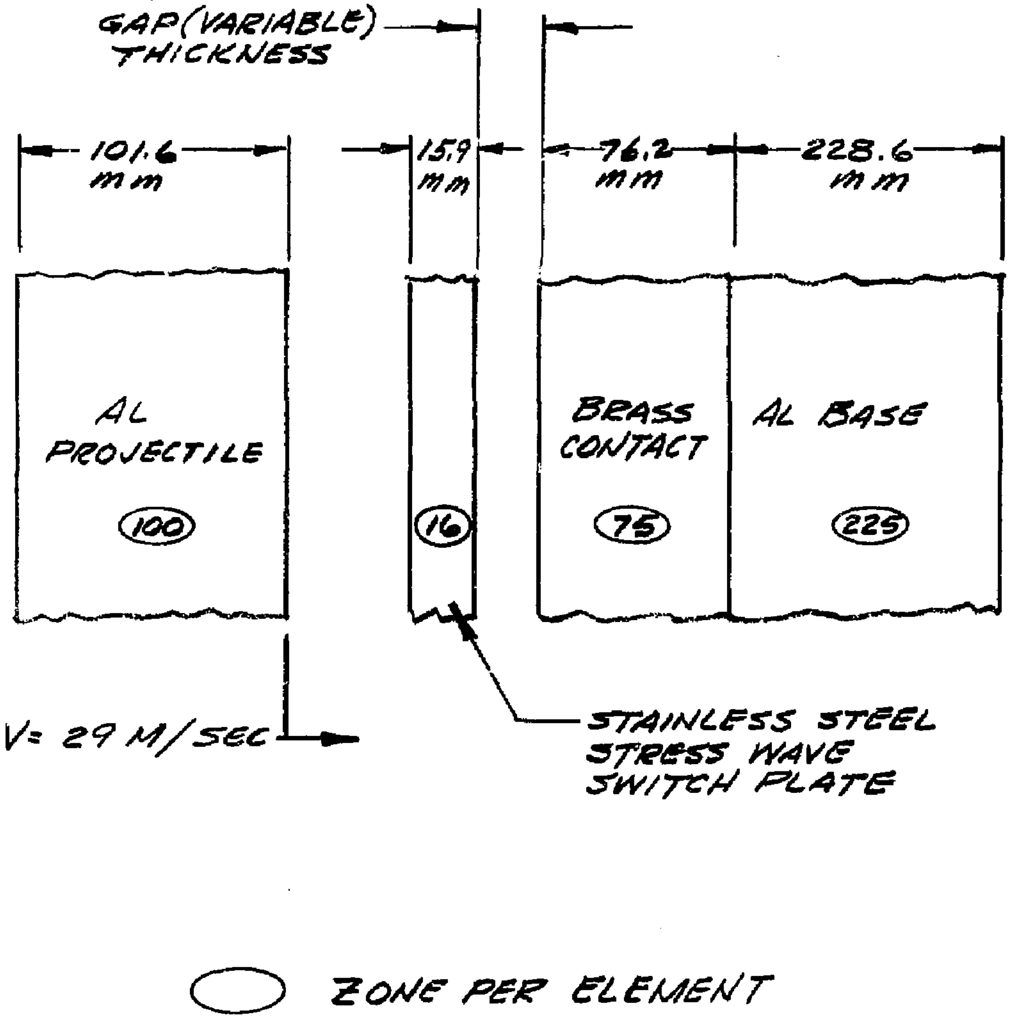
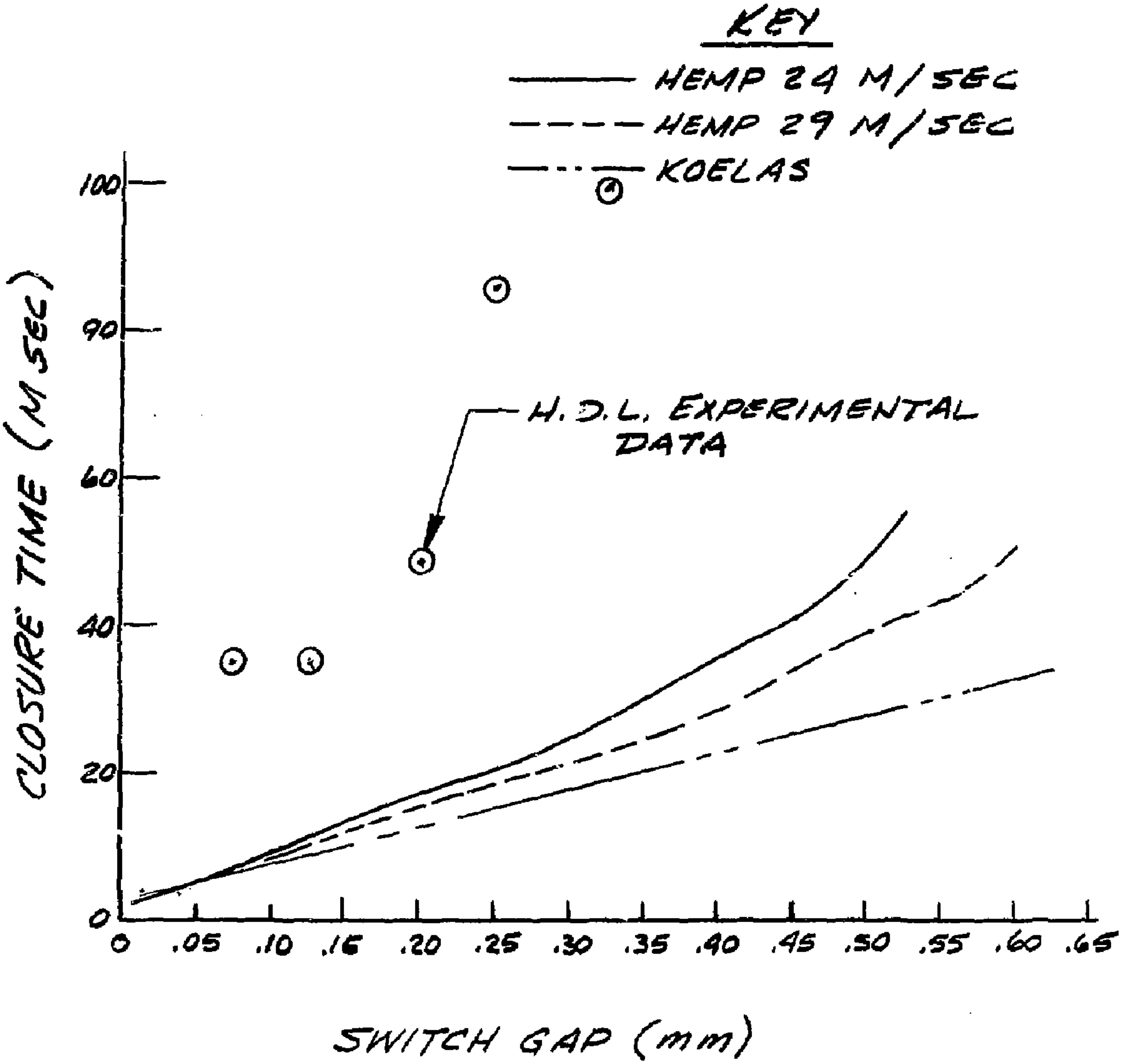
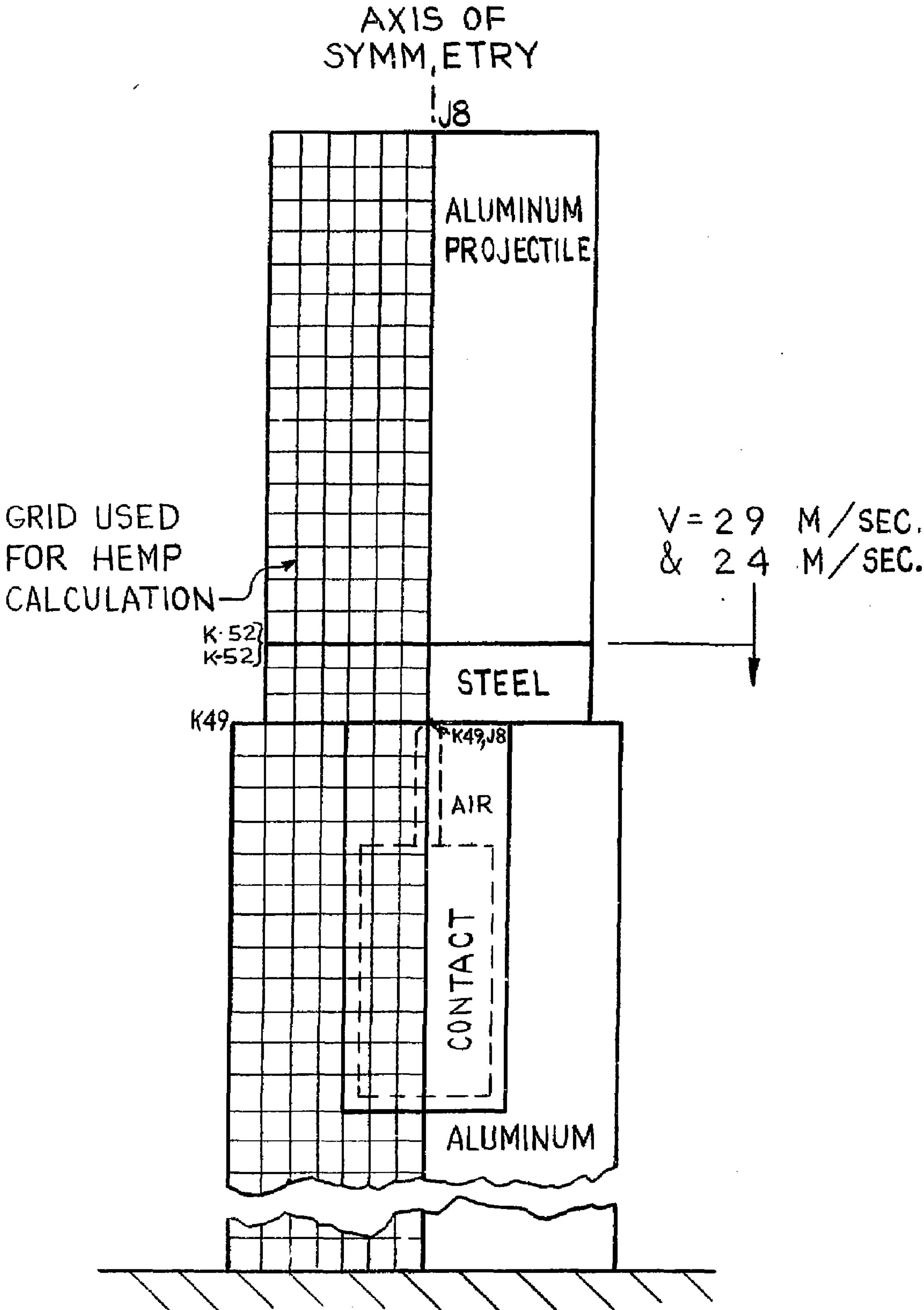

GAP (VARIABLE) THICKNESS
101.6 mm
15.9 mm
76.2 mm
228.6 mm
AL PROJECTILE
100
16
BRASS CONTACT
75
AL BASE
225
V= 29 M/SEC
STAINLESS STEEL STRESS WAVE SWITCH PLATE
ZONE PER ELEMENT

FIGURE 3



KEY
HEMP 24 M/SEC
HEMP 29 M/SEC
KOELAS
H.D.L. EXPERIMENTAL DATA
CLOSURE TIME (M SEC)
100
90
60
40
20
0
0
.05
.10
.15
.20
.25
.30
.35
.40
.45
.50
.55
.60
.65
SWITCH GAP (mm)

FIGURE 4



AXIS OF SYMMETRY
J8
ALUMINUM PROJECTILE
GRID USED FOR HEMP CALCULATION
K-52
K-52
STEEL
V = 29 M/SEC. & 24 M/SEC.
K49
K49,J8
AIR
CONTACT
ALUMINUM

FIGURE 5

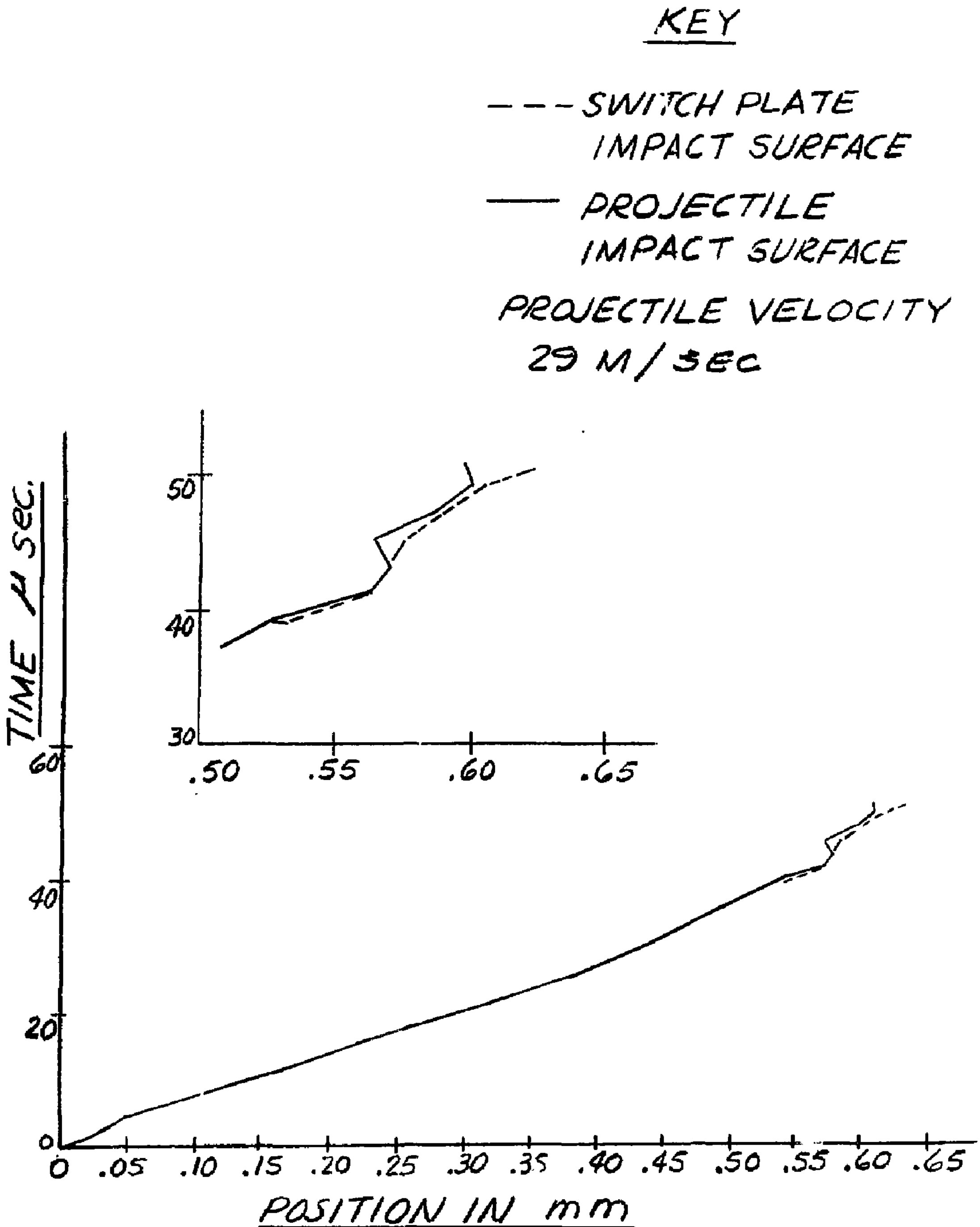

KEY
- - - SWITCH PLATE IMPACT SURFACE
—— PROJECTILE IMPACT SURFACE
PROJECTILE VELOCITY 29 M/SEC
TIME μ SEC.
POSITION IN mm
0
20
40
60
30
50
0
.05
.10
.15
.20
.25
.30
.35
.40
.45
.50
.55
.60
.65

FIGURE 6

REFERENCES

1. Wilkins, M. L., "Calculation of Elastic-Plastic Flow," UCRL-7322 Lawrence Livermore Laboratory, Livermore, California.

2. Giroux, E. D., "HEMP User's Manual," UCRL-51079, Lawrence Livermore Laboratory, Livermore, California.

3. Neily, D. W., "Investigation of Stress Wave Impact Switches for Electronic Fuzing," Report No. HDL-TM-73-8, Harry Diamond Laboratories, Washington, D.C.