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EVALUATION OF VARIOUS PADDING MATERIALS FOR CRASH PROTECTION

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I. Introduction.

The value of padding on rigid structures as a means of protection of occupants of transportation vehicles against crash impact forces has long been a subject of discussion. This study was conducted to shed some light on the question of whether we can depend on a feasible thickness of padding to reduce crash impact forces to a level tolerable to humans or whether we must redesign the structure beneath the padding to achieve this goal.

II. Procedure and Discussion.

A rigid base structure was constructed at the end of a simple catapult (Figure 1. All figures, 1 through 4, are in the Appendix) and impacted with and without padding materials by an instrumented dummy head at velocities of 15 ft/sec and 30 ft/sec. While it is generally known that head impacts in crash decelerations may be as high as 50 ft/sec, velocities of 15 and 30 ft/sec were chosen for this study because of limits of the accelerometers and it was felt that these velocities would allow adequate comparison of the compression characteristics of the various materials.

The rigid instrumented dummy head weighing about 12 pounds was attached to the sled with a ball bearing joint allowing a free movement of the head and simulated trunk in a forward arc as the sled was suddenly stopped by means of a friction brake. Propulsion of the sled was accomplished by using bungee cords.

Table 1 lists the materials and combinations of materials as well as their thickness for each specimen (1 through 37) tested. Figure 2 is a composite of the deceleration curves of all 74 tests.

Note that test 1 gives base line data obtained by impacting the rigid base structure without padding at velocities of 15 ft/sec and 30 ft/sec. Peak g forces for these impacts were 300g and 810g respectively with very rapid rise time and short duration.

The remaining data plotted in Figure 2 depict the energy attenuation available from each material tested. Note that there is very little reduction of peak g force (700g to 800g) when ¼″ and ½″ materials (tests 2 through 5) were impacted at 30 ft/sec. At 15 ft/sec the reduction is similarly negligible for these tests. Three-quarter inch thick padding (tests 6 and 7) offers little or no more protection.

A study of the eleven 1″ thick materials tested shows a few points of interest. First, tests 8, 9, and 10 were impacts on 1″ thick Koroseal (Shock foam manufactured by B. F. Goodrich Company, Akron, Ohio) medium #407, firm #407, and hard #334 respectively. With 30 ft/sec impacts the reduction of peak g readings from the base line reading were (a) medium 810g down to 550g, (b) firm 810g down to 430g, and (c) hard 810g down to 320g. Tests 13 through 18 were conducted with 1″ samples of rubber and other fairly soft materials and all peak g readings for 30 ft/sec impacts were over 500g. The high g readings in this latter group of tests were probably caused by the soft materials bottoming out with impacts of 30 ft/sec or more. This is borne out by a comparison of tests 14 and 29. Both tests were made with Koroseal HVS 400 (test 14–1″ thick, test 29–2″ thick). In test 29 the peak g reading dropped from 810g to 270g. Hence, one might conclude that if only one inch of padding is to be used it should be fairly rigid and of slow return material to obtain maximum energy attenuation. If the situation is such that two inches of padding may be used, a softer slow return material will provide considerable protection. Increasing the thickness of the padding material over 2″ (tests 32 through 37) further reduces the peak g force readings.

The corrugated cardboard used in the last three tests consisted of layers cut from cardboard boxes ⅛″ thick and glued together. The aluminum honeycomb was made up of hexagon shaped cells 5/16″ in diameter with a static crush force of 40 pounds per square inch.

Figure 3 summarizes the peak g readings for all the tests, and data presented in an earlier

Table 1

Padding Materials Impact Tested to Determine Energy Attenuation

Test #	Material
1	No padding—Block impacted for baseline.
2	Black Rubber (116) ¼″ thick (TULPLEX).
3	Koroseal M407—½″ thick.
4	Koroseal F407—½″ thick.
5	Black Rubber (116) ½″ thick (TULPLEX).
6	M407—½″ thick over H334—¼″ thick.
7	F407—½″ thick over H334—¼″ thick.
8	M407—1″ thick.
9	F407—1″ thick.
10	H334—1″ thick.
11	American latex #6060—1″ thick.
12	.025 aluminum sheet over H334—1″ thick.
13	X292–77 American Latex Urethane—1″ thick.
14	HVS400—1″ thick.
15	Black Hard Rubber—1″ thick.
16	Ensolite—1″ thick.
17	M407—½″ thick over H334—½″ thick.
18	F407—½″ thick over H334—½″ thick.
19	H334—¼″ thick over M407—1″ with 2″ holes.
20	Black rubber (116)—¼″ thick (TULPLEX) over M407—1″ thick.
21	F407—1″ over H334—¼″.
22	Urethane foam rubber—½″ over M407—1″.
23	Urethane foam rubber—½″ over .025 aluminum sheet over M407—1″ with 2″ holes.
24	H334—½″ over M407—1″ with 2″ holes.
25	F407—1″ over H334—½″.
26	Urethane foam rubber—½″ over M407—1″.
27	Black rubber (116)—¼″ (TULPLEX) over aluminum honeycomb—1½″.
28	Black rubber (116)—½″ (TULPLEX) over aluminum honeycomb—1½″.
29	HVS400—2″ thick.
30	HVS400—1″ over M407—1″.
31	M407—1″ over F407—1″.
32	Urethane foam rubber—½″ over .025 aluminum over M407—1″ with 2″ holes over M407—1″.
33	M407—½″ over .05 aluminum over H334 plugs—1″ thick over aluminum foil over H334—1″ with holes.
34	Ensolite—2½″ thick.
35	Corrugated cardboard—2″ thick over aluminum honeycomb—1½″.
36	Corrugated cardboard—2″ thick over ensolite—2½″.
37	4 layers aluminum honeycomb—1½″ thick separated by single sheets of cardboard.

study [1] have been utilized to group the tests into safe, those producing concussion, and those causing fatal injuries.

III. Conclusions.

Padding of less than 1″ thickness on a rigid structure offers little or no protection during crash impact. One inch of rigid, slow return material similar to Koroseal H334 greatly reduces impact g forces (to 300g) and distributes the impact load over the contours of the face (Figure 4) when used as protective padding on rigid structure, but is still borderline for survival without head injury. At impact velocities of 15 and 30 ft/sec against rigid structure padded with materials even six inches thick, unconsciousness, concussion, and/or fatal head injuries will be produced. Head impacts at greater velocities would increase the seriousness of the injury. Underlying structures must be redesigned to deform and dissipate the energy of head impact. *A combination of deforming "metal" to dissipate energy and firm padding to distribute pressure forces over the contour of the facial bones may be used successfully in preventing head injuries or even unconsciousness.*

REFERENCES

1. Swearingen, J. J.: Tolerances of the Human Face to Crash Impact. OAM Report AM 65–20. FAA, Oklahoma City, Oklahoma. July 1965.

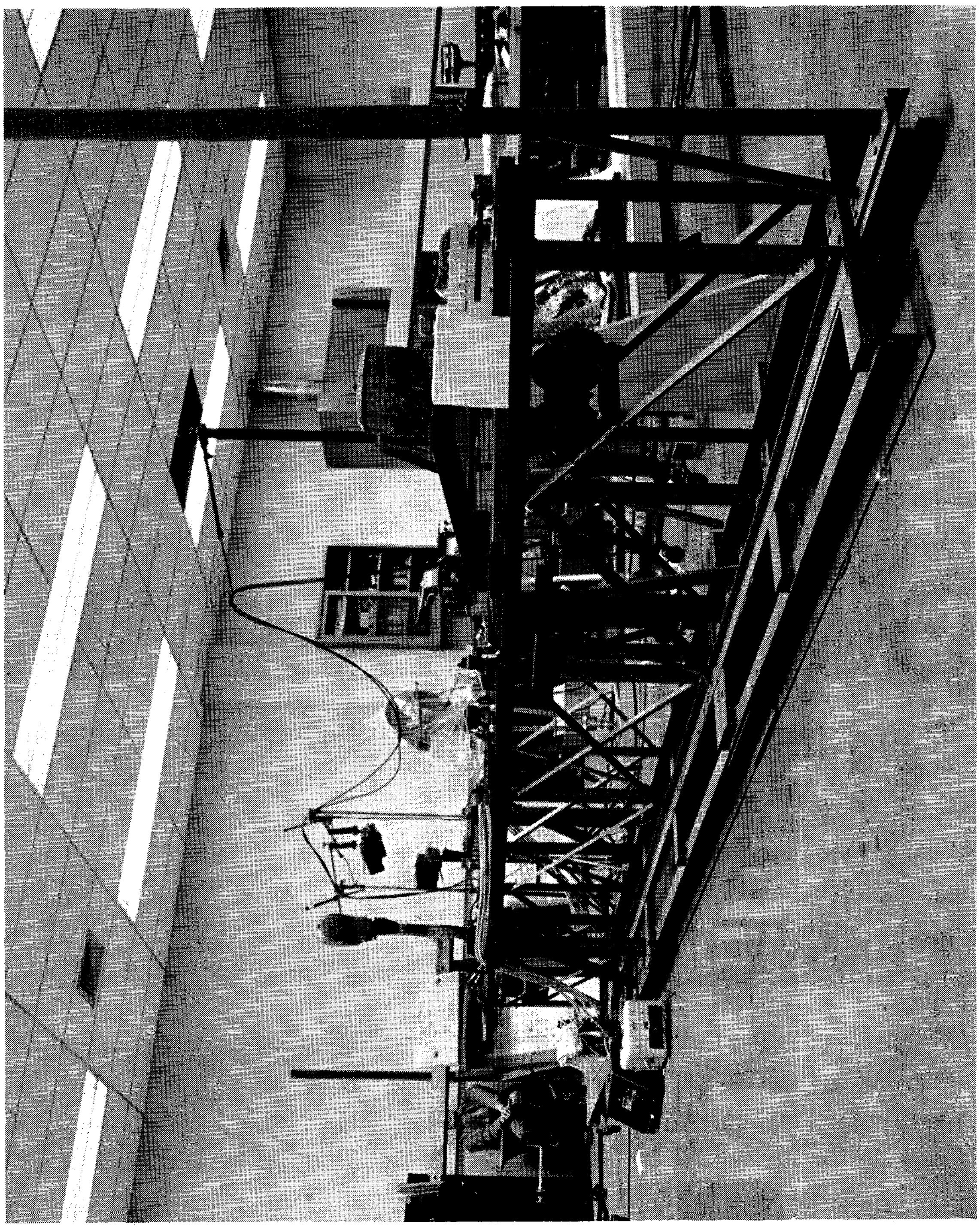

FIGURE 1. Photograph of small catapult used in head impact studies.

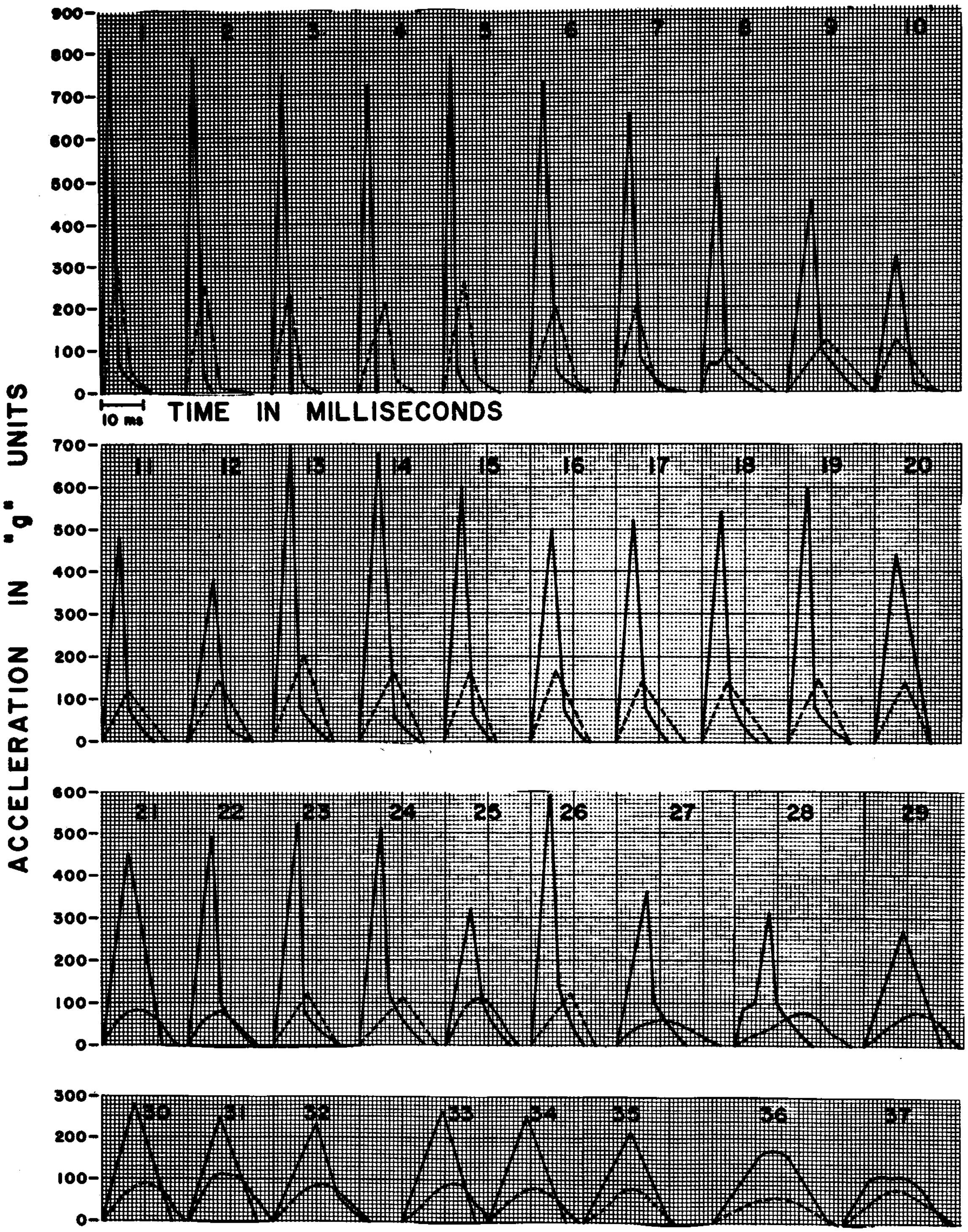

Figure 2. Deceleration Curves For 37 Different Padding Materials Impacted At 15(---) And 30(—) Feet Per Second.

FIGURE 2. Deceleration curves for 37 different padding materials impacted at 15 (----) and 30 (----) feet per second.

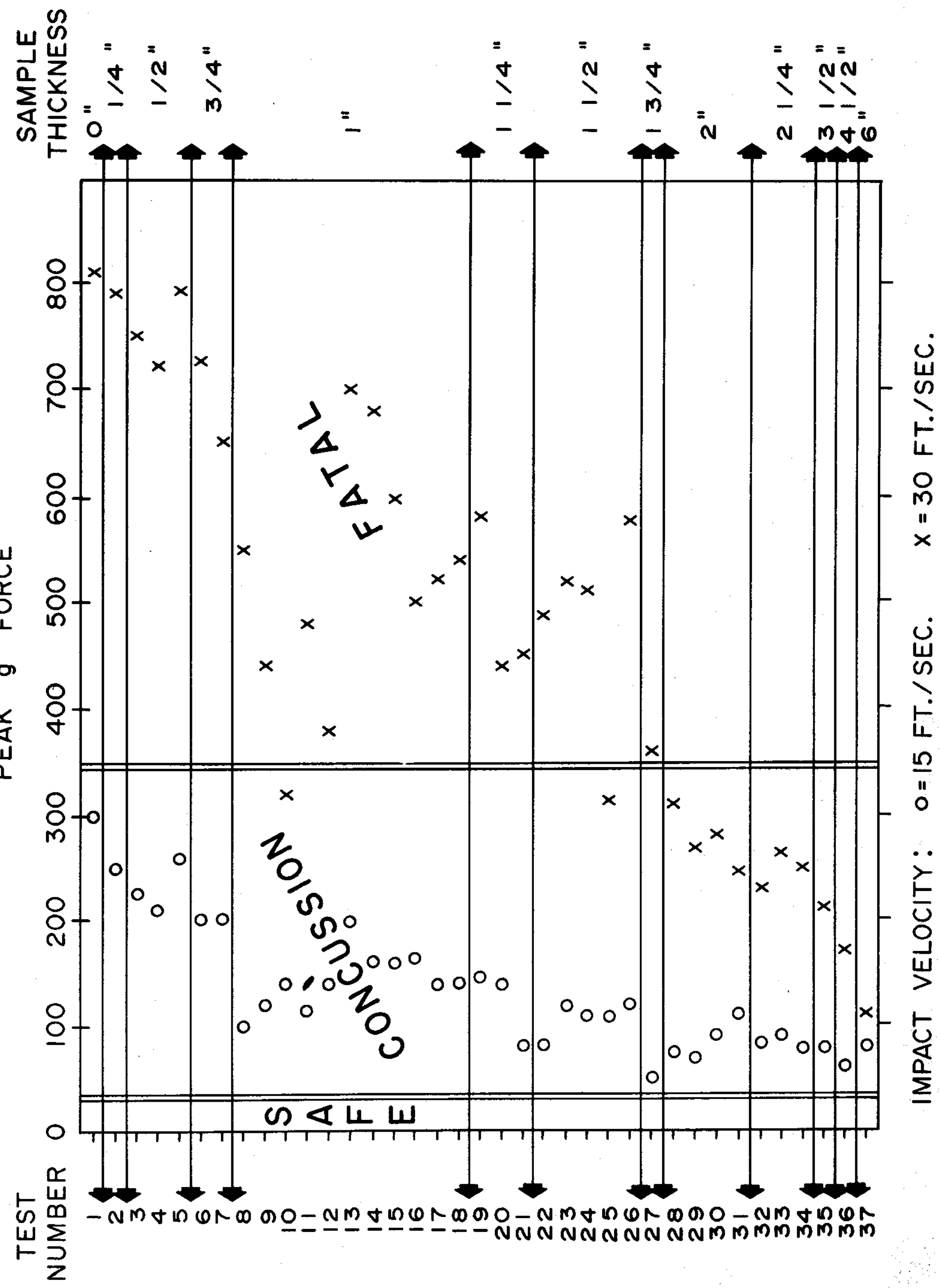

FIGURE 3. Summary of head impacts on padding materials.

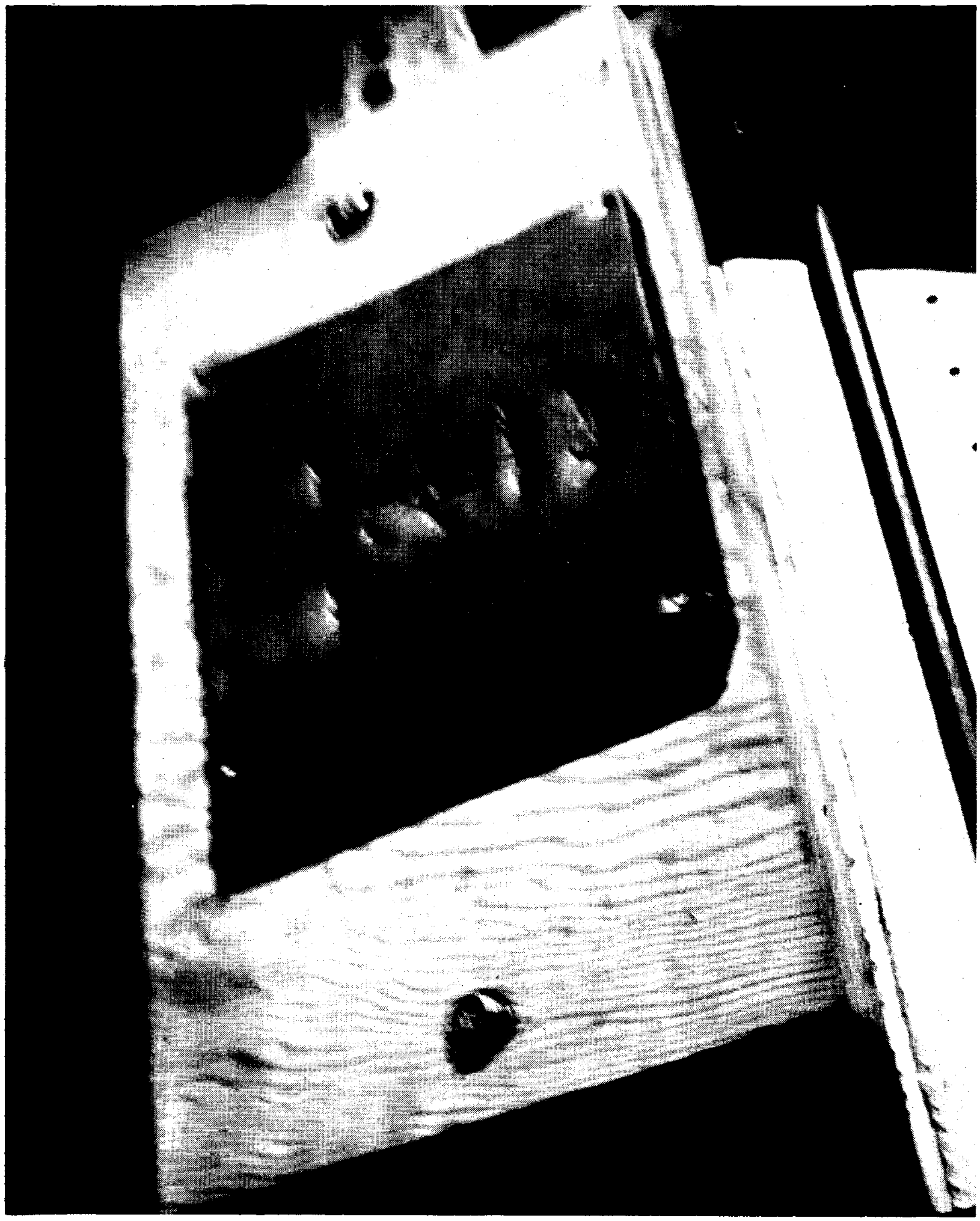

FIGURE 4. Photograph of 1″ thick H334 Koroseal taken immediately after a 30 ft/sec head impact showing depression made by the face to distribute the impact force over the contours of the face.