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supply from the sky

Under modern concepts of mobile warfare with the probable non-existence of adequate transportation facilities by rail or truck, it became imperative to develop "supply from the sky." This is aerial delivery—the dropping of supplies [a] to ground troops from aircraft in flight, as distinguished from air freight or air cargo.

Initial efforts in aerial delivery research were devoted to studies of methods by which supplies can be packaged or prepared for airdrop. One method is to fasten cushioning material on all surfaces and drop the load free-fall. The proper amount of cushioning will protect the contents, regardless of which surface receives the landing impact. This is illustrated by example 1 in figure 1.

An improvement on this method would be to assure that the load will land on a pre-selected surface, thereby requiring cushioning material on only one surface. This is illustrated by the center picture in figure 1, which shows a type of device which might be used to orient or position the load during descent. In the case of a cubic load, the volume of cushioning material required for this method would be only one-sixth of that required in the free-fall method.

The extreme opposite of free-fall is the employment of a retarding device, such as the parachute shown at right in figure 1, which is capable of limiting the drop-velocity to a rate at which damage to contents will not exceed an acceptable maximum. As the research pro-

[a] Food, fuel, and ammunition are among the items to be supplied by aerial delivery. However, this discussion will be limited to food supplies, or, more specifically, to Combat Rations, often referred to as C Rations.

gressed, it became evident that a combination of an orienting and a retarding device would prove to be most acceptable.

Additional research by Institute personnel indicated that aerial delivery systems could be more effective if they employed drop velocities higher than the 25-feet-per-second rate of existing systems, and this conclusion was substantiated by results from an aerial delivery feasibility and economic study undertaken by the University of Texas under a QM contract.

The problem involved, therefore, a modification of the present system to adapt it to higher velocities, which would in turn require cushioning under the load to limit damage at impact. The "new" system then would be a combination of methods illustrated by examples 2 and 3 in figure 1, in that cushioning would be employed while at the same time a parachute would be used both as a retarding device to reduce the thickness of cushioning required under the load and as an orienting device to position the load in fall and to reduce to one the number of surfaces requiring protection.

So began the Institute's search for a satisfactory cushioning or energy absorbing material—one which would crush at a relatively constant force and not return an appreciable amount of impact energy to the load, thereby causing excessive rebound and damage. Studies were conducted on a number of foamed plastics, rubber based and metallic materials and devices, empty beer cans, and a cellular paperboard product known, because of its structure, as paper honeycomb.

A few of these materials are shown in figure 2. Items 1 and 2 are foam plastic before and after static compression tests in the laboratory. Items 3 and 4 are empty beer cans before and after static tests, and these were surprisingly effective in absorbing energy rather than returning it to the load upon impact. Item 5 is a sample of paper honeycomb with a paper facing on both top and bottom surfaces, and item 6 is crushed paper honeycomb with both facings removed.

a new use for honeycomb

Paper honeycomb finally was selected as the energy absorbing material for use in aerial delivery systems which were delivered under the short-range program.[b] Some conception of the comparative effectiveness and cost of paper honeycomb can be obtained from figure 3, which shows that the standard QM felt shock pad, costing $2.00, is 15 percent efficient compared to an ideal energy absorber, whereas an equal volume of paper honeycomb costs $.25, and is five times as efficient. Another advantage of paper honeycomb is that it can be purchased in an unexpanded form and expanded just prior to use. Figure 4 shows a one-inch piece of unexpanded honeycomb as item 1, and a honeycomb cushion of the same material after expansion as item 2. The volume ratio of expanded to unexpanded honeycomb is 20-to-1, which means that one carload of unexpanded honeycomb can be shipped to a forward area and expanded into 20 carloads of cushioning material.

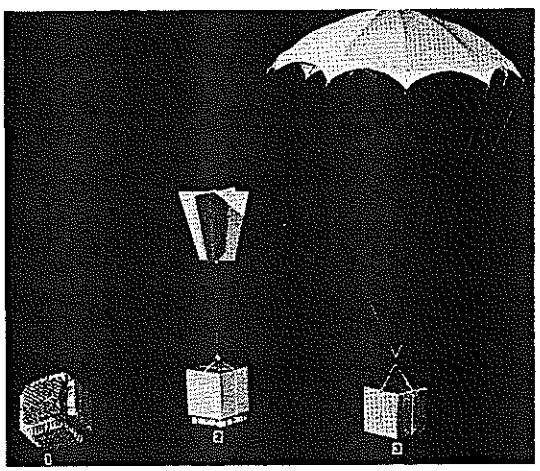


Figure 1. Various methods of preparing supplies for air drop. Left—cushioning on all surfaces for free-fall delivery. Center—cushioning on one pre-selected surface, used in combination with orienting device. Right—no cushioning and large parachute.

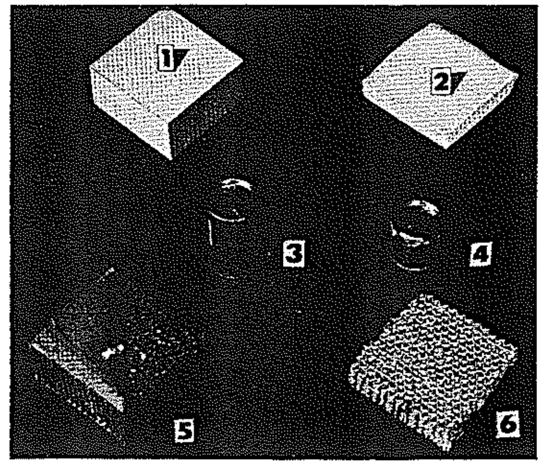


Figure 2. Materials tested as cushioning for aerial delivery. Items 1 and 2 are foam plastic before and after static compression tests. Items 3 and 4 are empty beer cans before and after static tests. Items 5 and 6 are paper honeycomb samples. Left — uncrushed with paper facings; right—crushed with facings removed.

[b] As explained in preceding issues of the *Activities Report*, the aerial delivery mission of the Food and Container Institute is divided into two phases—a long-range program and a short-range or "crash" program.

The long-range program deals with fundamentals such as: (1) What methods or devices are best for orienting and/or retarding loads during airdrop? (2) What is the best energy absorbing material to cushion airdropped supplies at impact? (3) What is the fragility of the items to be dropped, and how can we measure or determine this damage susceptibility of an item in order to combine the proper amount and retardation and cushioning material so as to assure a satisfactory airdrop? The major portion of research under this program is being carried out under QM contracts which take advantage of availability of research personnel and facilities at universities and private research organizations. Concurrently, research capabilities of the Quartermaster Corps are being employed to coordinate, evaluate, supplement, and utilize the results of the over-all program.

The short-range program is more immediate in that it directs the Institute to develop modifications to the existing method of aerial delivery, to produce a more effective and economical system, while employing, wherever possible, equipment which is under standard procurement. Immediate objective of this program is to get the most for the aerial delivery dollar at this time.

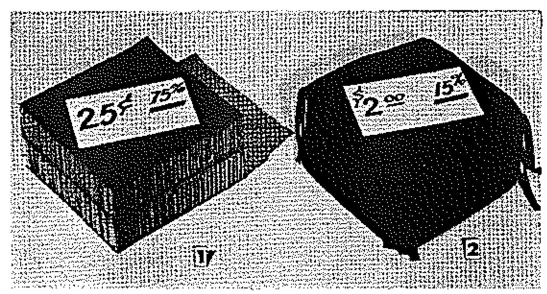
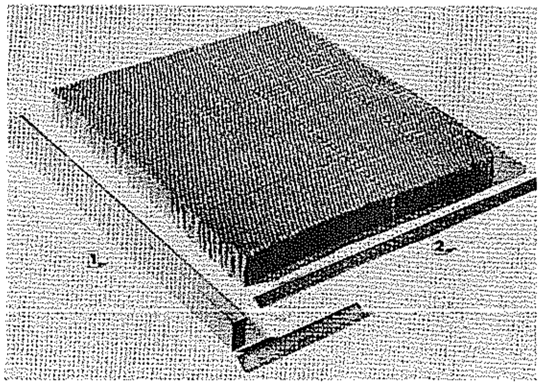


Figure 3. Comparison of relative efficiency and cost of paper honeycomb (left) and standard QM shock pad.

Figure 4. Remarkable logistical advantage of paper honeycomb is illustrated. Item 2 is the expanded form of item 1.

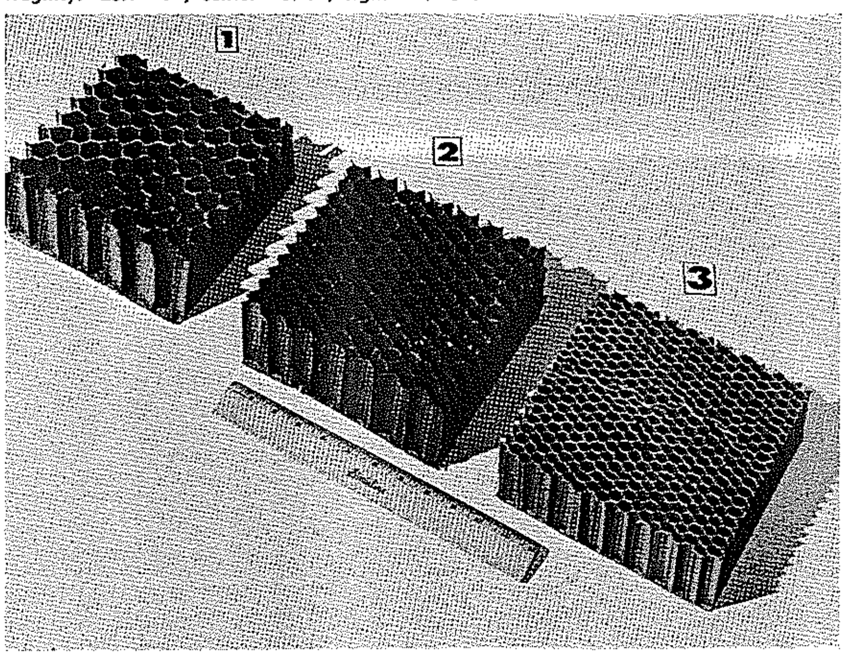


Paper honeycomb is available in various cell sizes as illustrated in figure 5, which shows paper honeycomb of one-inch cell size (left), $\frac{3}{4}$-inch cell size (middle), and $\frac{7}{16}$-inch cell size. The larger cell size honeycomb, which crushes under a lower force level than the smaller cell size, is therefore used under more fragile items.

The problem of selecting the proper honeycomb for different types of loads was difficult because of the lack of "fragility" ratings for the items to be airdropped, so honeycomb selection was accomplished by empirical methods. For example, drop tower tests of C-Ration cases stacked three high indicated that the ration cans were damaged by rupture at a force of 10,000 pounds per square foot. Dynamic compression tests of paper honeycomb with the $\frac{7}{16}$-inch cell size revealed that this material crushed at a constant force level of 8,000 pounds per square foot and should therefore protect the C Rations from damage during airdrops. The energy absorbing cushion under the new system for aerial delivery of C Rations consequently was made of $\frac{7}{16}$-inch cell size paper honeycomb. The other grades of honeycomb with larger cell sizes and lower values of constant dynamic stress would have necessitated a greater thickness of material to protect the load.

The foregoing research, conducted in the laboratory and at drop-tower facilities, was followed by field research and observation of the present method of aerial delivery by Airborne Troops at Camp Pickett, Virginia.

Figure 5. Paper honeycomb is available in various cell sizes for items of varying fragility. Left—1"; center—3/4"; right—7/16".



watch out below!

At present, when heavy loads are airdropped, they are pulled or "extracted" from the plane by a horizontal-ribbon, vented-canopy extraction parachute, which then floats free while the load is being lowered on a large solid-canopy parachute.[c] During the Institute's field research in aerial delivery, it was decided to use the 24-foot diameter extraction parachute to lower the one-ton load of rations in lieu of the 64-foot diameter chute presently used. This resulted in an increase in the average descent velocity from the present 25 feet per second (approximately the velocity of a paratrooper in a normal jump) to 75 feet per second.

Increasing the descent velocity magnified the problem of absorbing the kinetic energy at impact of this one-ton load tremendously, since kinetic energy increases as the square of the velocity. The present system attains an actual impact velocity of 30 feet per second, which results in approximately 28,000 foot-pounds of kinetic energy. When impact velocity is increased to 60 feet per

[c] The present one-ton load of C Rations consists of 48 cases stacked six high. Each case is a standard overseas pack, consisting of a regular slotted container of V2 solid fiberboard with sleeve. The cases are placed inside a sling of two-inch webbing which is attached to a 64-foot diameter solid-canopy cargo parachute.

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During World War II, Mr. Roffee was a Naval lieutenant serving at the Radar Laboratory, Philadelphia Navy Yard, and as a design engineer in the Process Development Division of the Electromagnetic Separation Plant, Oak Ridge, Tenn.

Returning to civilian life, he was employed by Office of Naval Research, Chicago, and subsequently established and operated the St. Louis Resident Office for this organization. In this position, he was responsible for administration of research contracts at the major institutions in the Missouri-Kansas-Colorado area. In 1951, he returned to Chicago, transferring to the District Public Works Office at Great Lakes, where he engaged in economic and engineering studies and ultimate negotiation and administration of contracts for utility services required by Naval activities in the Ninth Naval District. He is a registered professional engineer in the state of Illinois.

second, the kinetic energy is approximately 112,000 foot-pounds, and at 90 feet per second one is dealing with over 250,000 foot-pounds of kinetic energy at impact.

Some of our ration loads impacted at 88 feet per second, which is 60 miles per hour, and frequently landed on concrete runways. Had we been told before starting this research that our problem would be to design an energy absorbing cushion which would protect a one-ton load of rations placed on a truck and driven into a solid concrete wall at 60 miles per hour, we probably would have been reluctant to attempt to meet such fantastic requirements. However, our new system for aerial delivery is effective under comparable conditions.

In the newly developed system for aerial delivery of a one-ton load of C Rations, the cases are stacked three high in a new configuration, which provides a larger base and a more stable load less likely to tumble after impact. This new load uses the same sling with two-inch webbed strapping which is currently in use. The ends of the webbing are attached to a 40-foot riser, which in turn is fastened to the 24-foot diameter extraction parachute. The purpose of the long riser between load and parachute is to decrease the tendency of the load to develop a pendulum motion, although a 24-foot vented canopy chute is in itself more inherently stable in this regard than a solid-canopy parachute. Figure 6 is a diagram of the complete system developed for dropping C Rations, and gives some load dimensions. This figure also shows that the paper honeycomb energy absorber under this load is one-foot thick and is composed of four layers of paper honeycomb, each three inches thick. This combination was based on results of a large number of field tests of various weights and

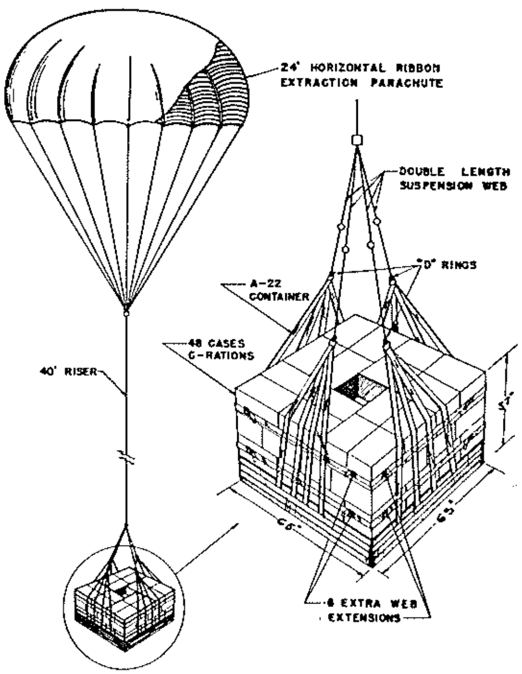


Figure 6. Diagram of the complete system developed for dropping C Rations.

configurations of loads, which were drop-tested with a wide range of velocities.

systematic superiority

During the first series of drops, the statistical analysis of damage was confined to the number of cans actually ruptured; however, as improvements in the system were made, it was necessary to establish criteria for damage evaluation which had a wider range.[d] The new criteria are shown in figure 7—where A is a normal undamaged can, B is a dented can, C a so-called "crimped" can, and D is a ruptured can of rations. The new scale of damage values permitted a more accurate analysis for comparison of the effectiveness of the systems which were drop tested.

The superiority of the new system for aerial delivery developed by the Quartermaster Corps is demonstrated by the insignificant amount of damage experienced in the last 10 loads of C Rations which were airdropped over a period of weeks under different climatic and ground surface conditions. Eight of these loads had no ruptured ration cans after airdrop, and there was only one ruptured can among 2016 cans in each of the other two loads, as compared to a total of 14 ruptured cans of rations in the last five loads which were air-dropped using the present system.

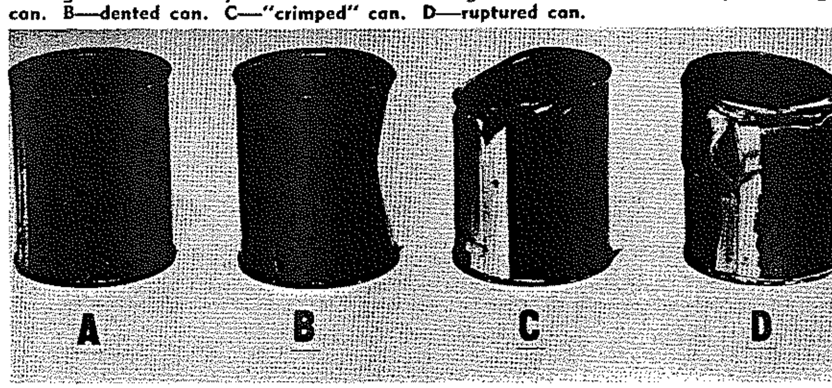
Performance differences which have tactical value between the new system and the present system are illustrated in figure 8. This shows that the present system with the 25-foot-per-second rate of descent will require 60 seconds to descend from a 1500-foot height, and during that time the load would drift 2025 feet in a 20-knot wind, whereas the new system, with a 75-foot-per-second rate of descent, would require only 20 seconds to descend from the same height and, consequently would drift only 675 feet in the same 20-knot wind. This may make the difference between supplying our own troops or enemy troops or prevent the landing of our supplies in a contaminated area.

Additional advantages of the new system are illustrated in figure 9 which shows that the 64-foot-di-

[d] In the initial stages of the field research, detailed information of the damage to the ration cans was obtained by opening the individual cases and extracting every can for examination. This required the opening of each of the 16 cases in the bottom layer, the four corner cases in the next layer, and continuing the process upward throughout the entire load, whenever the extent of damage warranted it.

A considerable savings in the man-hours involved in obtaining data on ration damage due to airdrop was effected by introduction of the Quartermaster Inspection Van. With this X-ray unit, individual cases of rations were placed on the conveyor system and passed through the van. The operator inside was able to examine the contents of each case on a screen and thereby determine extent of damage to the contents and to classify the cases as either damaged or satisfactory for use in additional drop tests.

Figure 7. Presently used criteria for damage evaluation. A—normal, undamaged can. B—dented can. C—"crimped" can. D—ruptured can.



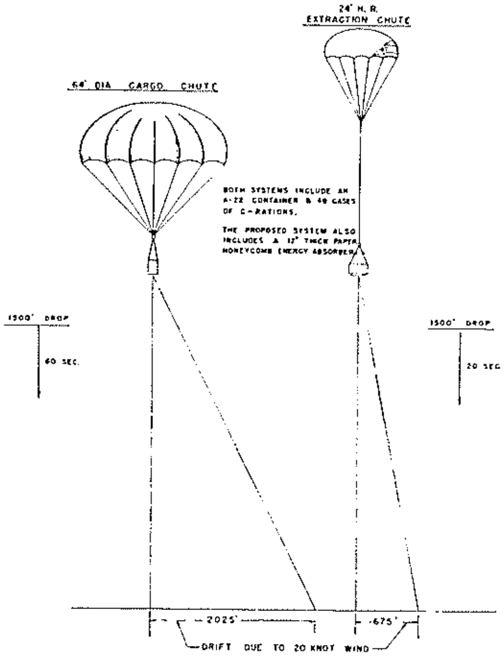


Figure 8. Diagram illustrating performance differences between present air drop system (left) and new system.

ameter parachute which weighs 125 pounds requires three men to recover it, whereas one man can pick up the 24-foot-diameter parachute and run with it, since it weighs only 35 pounds. When these parachutes have been returned to the pack shed, it requires a three-man team one hour to repack the 64-foot parachute, while one man can repack the 24-foot parachute in 20 minutes. The large difference in sizes of the shipping containers for each parachute is shown also.

As an additional factor, a higher rate of recovery is anticipated for the 24-foot ribbon parachute because to date the servicemen have

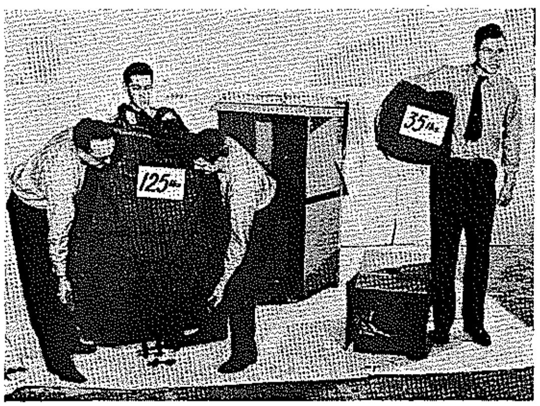


Figure 9. Comparative weight and bulk of 64-foot diameter and 24-foot diameter parachutes are dramatically illustrated.

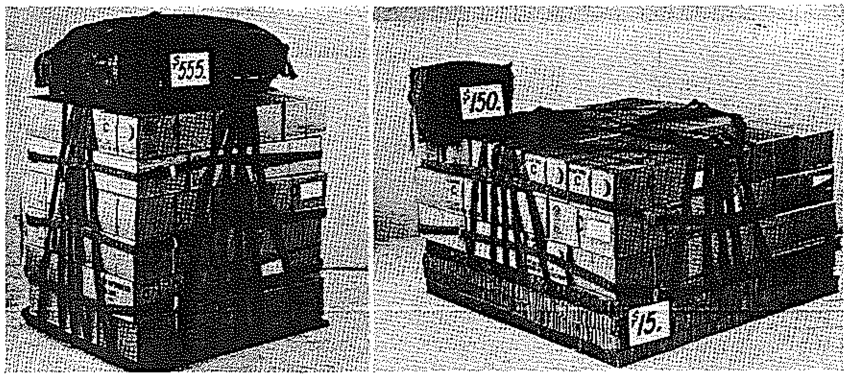


Figure 10. Comparison of costs for delivery of identical ration load using present system (left) and newly developed system.

not figured a way to make petticoats or scarves from the ribbons in this chute.

Finally, we have a comparison of costs of the two systems. Figure 10 shows the present system with the 64-foot-diameter parachute, which costs the Government $555, and the newly developed system with the 24-foot-diameter parachute costing $150, plus $15.00 worth of paper honeycomb.

The savings from a single load may not be very impressive; however, when we realize that one division requires 500 tons of food, fuel, and ammunition per day, the savings by the use of the new system would total $1,000,000 per week for every division supplied by airdrop.