## HELMET DESIGN:

# COMFORT OR SURVIVAL?

***If further proof was needed that a racing helmet needs to be more than an upholstered shell, the "G" impact tests are here to see. Here is the second test series in the Snell Foundation program.***

**By GRIFF BORGESON**

*A 16 pound weight suspended from wires drops at from 8 to 22 ft per sec velocity, depending on release height, and measures acceleration imparted to the head.*

WHEN SCI published Dr. George Snively's "Skull Busting for Safety" last July, we were convinced it would be one of the most shocking and influential articles in the history of automotive journalism. It has turned out to be just that. The story has shaken the crash-hat industry as it had never been "shook" before. It has been widely reprinted. It has wakened practically every racing organization in the country, pro and amateur, to the need for drastically revised regulations for protective headgear. Its effects have been felt in such unexpected quarters as the U. S. Air Force, the National Safety Council and the American Football Coaches Association.

Dr. Snively's blockbuster, based on the first of a series of tests he is making for the Snell Foundation of the San Francisco S.C.C.A., stated that no helmet on the civilian market could meet all the reasonable minimum safety standards, and he told why. Make by make he pointed out inadequate shells, harnesses, chinstraps and liners. He indicated which helmets would be useful in protecting against only minor, uncomfortable blows, and he emphasized his belief in the superiority of the non-resilient type of liner—the kind that absorbs impact force rather than storing it momentarily and then releasing it.

The first phase of Dr. Snively's test program was a very tough one, by the embryonic and often naive standards of the crash helmet industry. Each helmet was subjected to a single heavy-impact of 500 ft lbs, a compression equivalent to the head striking a heavy object at a speed of 34 mph. Before this, a 120 ft lb test was considered rugged by the industry. Even more significant, Snively tested the helmets on the heads of human cadavers for the first time, and the heads were X-rayed before and after testing.

The value of this realistic and unsentimental approach seems self-evident; but the doctor's tests and his bold conclusions were not met with undiluted praise. The loudest complaints, not surprisingly, came from some of the manufacturers whose headgear was not granted an unqualified pass. One of them said, "This is supposed to be a series of tests of *all* the aspects of helmet performance. Why draw conclusions from just the first test?"

To this Dr. Snively replies, "The first test was concerned with the basic issue of resistance to massive impact and compression. And this *is* basic. If these tests had come out so that there were various shades of gray, the niceties — a 5, 10 or 15 percent difference in resistance to penetration or abrasion, for example — would have seemed more important. But the tests came out black and white. They convince me that the first and primary requirements are a strong shell and a non-resilient liner. Only after you have these do you dare worry about the niceties."

Another argument was raised by it-can't-happen-to-me members of the racing fraternity. "Who cares," said one, "if a guy wants to race with a poor helmet? Let him. It's his business."

Says Snively, "This would be fine if it weren't for two things. In the first place, insurance rates for races are going up all the time. If we have more serious injuries — not fatalities, so much, but disfigurements that the companies have to pay on year after year — the rates will become completely prohibitive and racing will be in bad trouble. Second, a rash of lethal accidents is likely to bring about legislation that will outlaw racing entirely. So in order to protect racing as a whole, you may have to tread on individual liberties by making a certain good protective type of helmet mandatory."

The Snively massive compression test will go on as new helmets are received for testing. Meanwhile, other aspects of helmet performance are being explored. The second set of Snell Foundation tests was conducted last summer and was intended to deal with the same six helmet types used in the previous tests. It's a credit to the protective headgear industry's receptiveness to hard-to-get scientific data that 14

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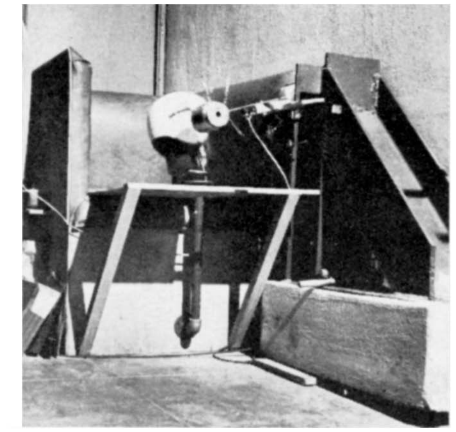
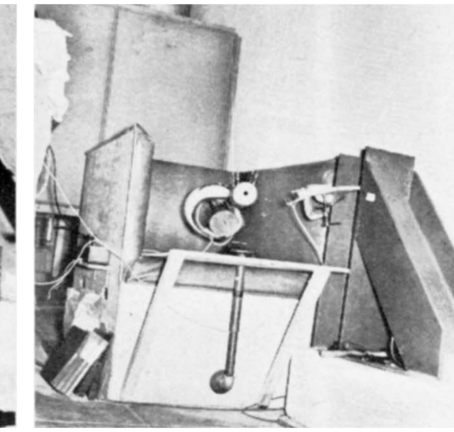
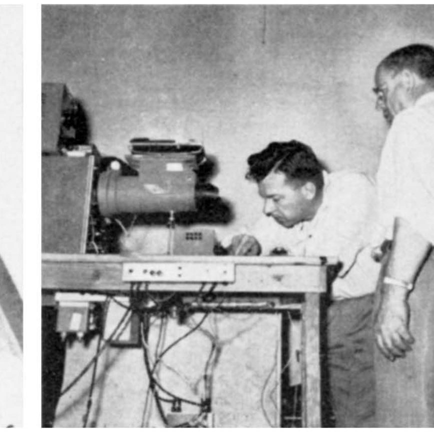


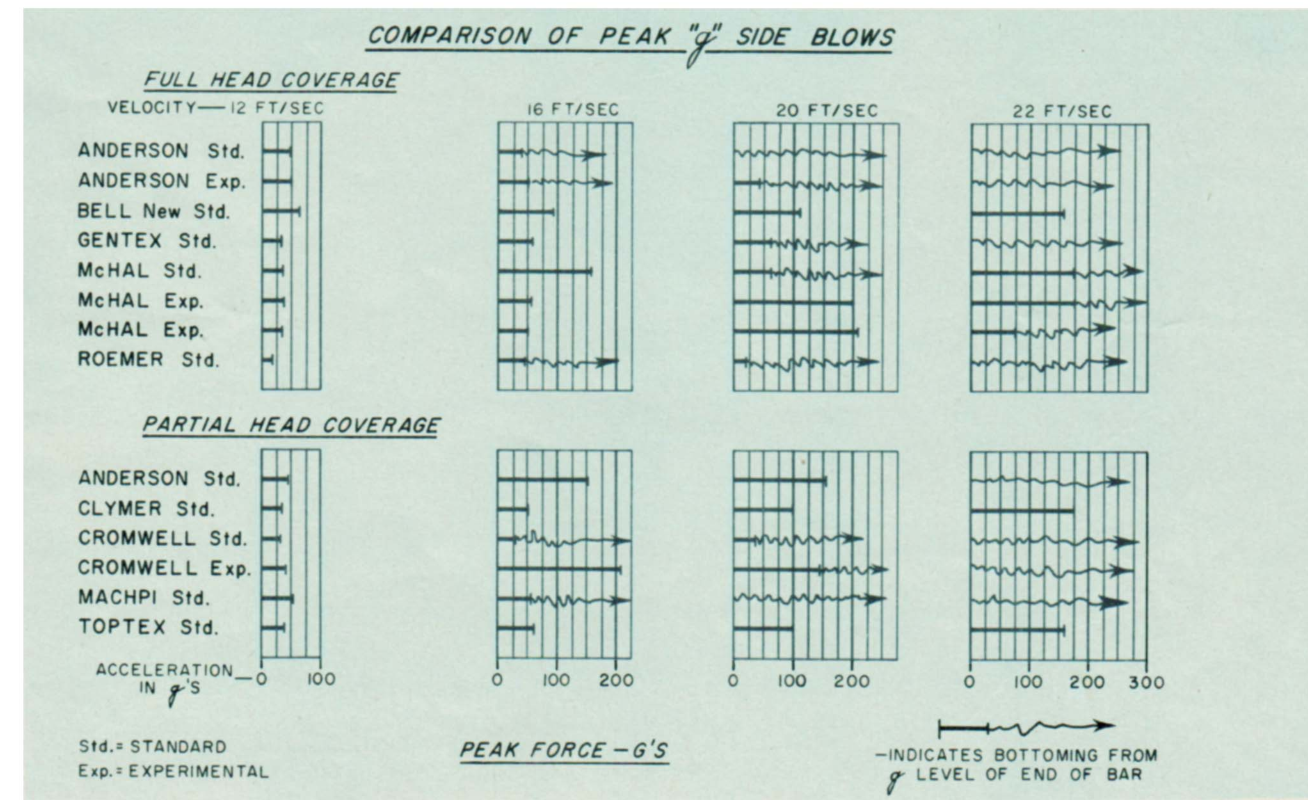
*At the bottom of its travel arc, weight strikes its target — helmet mounted on a metal head form.*



*Upon impact, helmet and head form wired to an acceleration-measuring device, is propelled off pedestal.*



*Acceleration transmitted to the head is registered by oscilloscope and simultaneously photo'd.*




*This eloquent chart shows the bottoming characteristics of helmets tested for the Snell Foundation. "Bottoming" occurs when the helmet shell comes into firm contact with the head, regarded as an "intolerable" condition. Shortness of the bars indicates helmet's ability to absorb impact, thereby not transmitting it to the head form containing the accelerometer. Wavy arrows indicate bottoming at "g" level at end of bar, with continuing acceleration. Last column shows that only helmets with non-resilient liners resisted bottoming.*

## Monza

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Jaguar was kicking up a reasonable facsimile of 150 mph at the time. Scratch one Indiana invasion.

The Americans put on a display of high-speed racing that had not been seen in Europe for a long time—perhaps never. The ruggedness of the cars, the spirit of the drivers and mechanics, and the fantastic speeds they set up in practice impressed all of the European journalists and spectators present. Several negative voices were heard, one was that of Gunther Molter in "Das Auto, Motor und Sport," a popular German bi-weekly automotive magazine. Molter called the race "a farce before it was even started" and repeated much of the arguments about track safety and lack of European equipment to meet the American cars on an even basis. Did the Americans stay away from Roosevelt Raceway in 1937 when the Europeans came to America in their road racing giants to win against our track racers?

The French newspaper, L'Equipe dubbed the Indianapolis racers as "le cirque Americain", or "the American circus". But these were small voices. On the whole, the European press responded in a positive fashion, in particular one English journal.

One thing that impressed the Europeans was the openness in which the "Yanks" agreed to discuss anything mechanical or technical about the race cars. Bad points, as well as good, were pointed out in a frankness that is unknown among European racing teams. One can only hope that this attitude is contagious, and that the American cars and drivers will somehow become more of a part of the European racing scene.

Most impressive in training were the two Novis driven by Bettenhausen and Russo. These supercharged V-8's were coming off the bankings at 190 mph and pushing 200 before the drivers would lift their foot ever so little to go onto the South Banking. Russo threw his flywheel in training; it just disintegrated, and Jean Marcenac, chief Novi mechanic, still hasn't found the pieces. Tony Bettenhausen broke his frame while turning a record lap of 176.8 mph, 53.7 seconds around the bankings; Linden did 54.6, as well as Pat O'Connor; and interestingly enough, these lap speeds exceeded those set by Hermann Lang on the Berlin Avus track before the war. Alfred Neubauer was on hand at Monza and appeared to enjoy himself immensely, talking to drivers and mechanics. The Mercedes racing manager was most impressed by the high lap speeds being knocked off in practice.

The circuit itself was terribly hard on the equipment. Jim Bryan seemed to think that if they had known exactly how rough it was going to be, they would have brought stiffer torsion bars as well as rubber stops for the suspensions. Everything was bottoming in practice until adjustments were made. Shock absorber brackets bent badly under the stresses and strains and it is interesting to note that the three Indianapolis cars that finished were not Kurtis-built cars. Bryan's Dean Van Lines Special was built by Kuzma as was Parson's Agajanian Special. Ruttman's John Zink Special was built by A. J. Watson.

Most of the retirements were due to fuel tank mountings coming adrift with resultant tank-splitting. Pat O'Connor finally came in with fuel just pouring out of his tank. Ray Crawford retired with a holed tank, but not without a fight. His mechanics worked like beavers during the hour-long interval between the second and third heat to repair the damage. Bob Veith broke his steering as he came off the banking, but luckily escaped crashing when the car took its natural line, steered itself down and headed directly for the pits. Only one Novi got to the starting line, Bettenhausen's car, but he retired early in the race when the throttle linkage fell apart.

The first two heats were Bryan's, while the third belonged to Troy Ruttmann. High spots of the race were the sight of two Indianapolis cars running almost wheel to wheel, charging down the pit straight and up onto the turns, roaring onto the banking and passing a Jaguar. One man would go low, the other high—an incredible and thrilling sight.

Consensus was that the intervals between heats were indispensible and if there had not been this time to make repairs, the field would have been practically eliminated in a very short time.

The wonder of every one was the Jaguars. They experienced no trouble whatsoever, and it's significant that they suffered no chassis failure. Towards the end of the race, Jack Fairman in his Jaguar had a short duel with Parsons, the Jag even passing the Agajanian special at one point.

The Automobile Club of Italy and the Milan Automobile Club deserve every credit for going ahead with the Monza 500 Mile race against the heavy European opposition that developed at the last minute. They lost money due to a terribly poor crowd, undoubtedly from lack of adequate advertising and also because of the time of year; temperatures were high and countless Italians had gone off to the seashore for the weekend to escape the heat. Also, Maserati and Ferrari did not run.

The organizer's loss is estimated at 80 million lira ($13,000). Also, the organizers have informed SCI that absolutely no starting bonuses were offered any of the drivers, and only expenses – tourist class for one car, two drivers and one mechanic – were paid by the club. This, in addition to the prize money, was the only attraction.

The sportsmanship shown by David Murray and his Ecurie Ecosse in coming to Monza as the sole European entry was terrific, and they took part in a motor race unique in history. Whether it will come about again is not known at this writing. The Americans want to come back, but they would prefer some real competition. The ten gallon hats, the multi-colored race cars, and most of all, the warm friendliness of the Americans disarmed the Europeans. Hard as it is for some of the continentals to admit it, they would like to see the Indianapolis boys back again next year.

*Jesse L. Alexander*

**Results: Monza 500**

**First heat**

**63 laps; 2.64 mile high-speed circuit**

1. Bryan; Dean Van Lines; 162.15 mph
2. O'Connor; Sumar Special
3. Linden; McNamara Special

**Second heat**

**(63 laps)**

1. Bryan; 160.21 mph
2. Ruttmann
3. Parsons

**Third heat**

**(63 laps)**

1. Ruttmann; 158.41 mph
2. Bryan
3. Parsons

**Fastest lap**

**Bryan in second heat; 175.73 mph; 54.1 seconds**

**Overall results**

1. Bryan; 189 laps; 3 hr. 7 min., 5.9 sec; 160.01 mph
2. Ruttmann; 187 laps; 3 hr. 7 min., 56 sec.
3. Parsons; 182 laps; 3 hr. 7 min., 29 sec.
4. Fairman; Jaguar; 177 laps
5. Lawrence; Jaguar; 171 laps
6. Sanderson; Jaguar; 159 laps

## Helmets

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different helmets had been voluntarily submitted when the tests began. They were conducted in Inglewood, California, at the of the Mine Safety Appliances Company. Protection Inc. manufactures the Toptex aircraft helmet, and owns specialized test instrumentation that is almost unique. The second set of tests used the lab's Impact Pendulum Facility, a complex device for measuring acceleration imparted to the head.

Most of the U. S. crash helmet manufacturers are located in the Los Angeles area. They were invited to submit helmets for testing and to be present during the tests, and most of them came. Also present were representatives of the Civil Aeronautics Authority, the National Safety Council, various motor sport clubs, and motoring publications. While the tests were arranged by Dr. Snively, the highly technical test procedures were supervised by George Nichols, Chief of Associated Projects at Northrup Aircraft, and consultant to Colonel Stapp in his rocket sled research. Nichols was aided by Herman Roth, distinguished human factors engineer, pioneer in aeromedical research, co-designer of the impact pendulum device, and an executive of Protection Inc. The description of the tests which follows draws heavily from Nichols' report.

These tests were conducted to establish the performance under impact and repeated impact of the types of crash helmet currently available. The data obtained is decisive and critical but of course cannot represent the total range of impacts that may occur in actual service. This type of test applies a very localized load to the shell of the helmet by means of a 16 pound weight suspended from four steel wires. The weight can be made to move at speeds of from 8 to 22 feet per second, depending on the height from which it is released. At the bottom of its arc of travel it strikes its target: a helmet placed over a metal head-form. This head contains an acceleration-measuring device whose responses are registered by an oscilloscope and simultaneously photographed. The weight has a round striking surface which serves to localize the force on the shell and establish the shell's ability to spread the load over a larger area of the liner. It makes for a more severe test than a flat weight would.

The ability of the shell-liner system to cope with forces of impact is indicated by the amount of acceleration transmitted to the head and acceleration and deceleration are extremely important factors in the mechanics of brain injury. The lower or gentler these factors are, the less strain, obviously, will be imposed on the brain. Accelerations become most violent when the helmet "bottoms" — when the liner is totally compressed and there is no more shock-absorbing action between the head and the helmet shell. Acceleration in these tests is measured in gravities or "g's," and a normal curve of "g vs time" looks like a low hill. As the g's increase and the liner begins to lose its "give," a small peak appears on the curve. But when the impact-absorbing action of the liner is gone, the curve abruptly shoots up to a very high peak "g" reading. The speed of the head itself has no special relation to brain damage, but *changes* in speed — acceleration — do, and the sudden, violent change that occurs when a helmet bottoms against the skull is downright intolerable.

It can, in fact, be lethal. On the test rig there is a sort of metal-to-metal sound when the weight strikes with enough force to compress the liner totally. When this happens, the liner, harness and internal webbings of the helmet often disintegrate in the area where pressure is greatest. And this can happen, with some helmets, under surprisingly light loads.

The highest speed of the Protection Inc. pendulum, 22 feet per second, gives impact equivalent to a case where the head is moving at 15 mph in relation to an unrestrained 16 pound object like the test-rig weight. This is not much impact. Even so, it is more than most helmets can stand without bottoming. It is a more severe test than it may seem because the helmet's physical strength is tested by confining the blow to a very small area, and the data it provides compares well with much flight-helmet data.

The second tests consisted of blows of increasing force to the sides and backs of the helmets. The results, in the case of all the helmets tested, showed that the g's rise rapidly as the liner or sling approaches 100 percent compression. In helmets having "soft" liners or slings, the sudden upsurge of g's is most pronounced. A blow just short of bottoming will have a reasonable peak g, while one at a slightly higher energy level will bottom and apply a very high force to the head.

It was found that achieving low peak g's under low-energy blows, on the one hand, and non-bottoming action under high-energy blows, on the other, is impossible in a single helmet. The hats with the best, "most comfortable," low-energy performance bottomed early. Low acceleration requires considerable movement of the striking object in relation to the head. This movement or displacement is provided by the liner or sling, and is limited by considerations of helmet size. The tests indicated that low-acceleration "comfort" qualities have to be sacrificed for maximum protection against lethal-range blows. Dr. Snively says, "Actually, the performance throughout the energy range need only be at or below reasonable tolerance levels. In this regard, all the helmets tested could be modified with very probable increase in high energy level protection, but with an increase in low energy peak acceleration."

Almost without exception the helmet *shells* performed satisfactorily. Although fractures developed in most shells they are not considered too detrimental. During repeated blows some helmets showed better performance after the shells had begun to crack or flex, and this extra cushioning effect made for a lower average force. But the improvement applied only to low and medium force blows, and the ability to handle high-energy blows decreased.

Snively and Nichols sum up the test results to date as follows. Both the accelerometer tests and the massive compression tests show the importance of non-resilient liners. This importance increases as impact force increases, and becomes greatest at those energy levels where protection is against death rather than headache or bruises.

Protection against the several effects of impact is the prime objective of the crash helmet. At present it's felt that such protection has been scientifically demonstrated only with the use of non-resilient lining material. Sling suspensions, resilient liners and slow rebound liners have been shown to be inadequate.

Several problems exist with non-resilient liner materials. The best thickness depends upon the particular material used; non-resilience by itself is no guarantee of good helmet performance. And because these materials are permanently crushed when they absorb severe impacts, users must be educated to replace them, and safety regulations should be passed to make their replacement compulsory.

Many of the partial head-coverage helmets tested do not provide adequate area protection, although very deep shells of the partial coverage type can be considered acceptable. Better is the full-face type, which not only protects the vital parts of the head but also protects the upper jaw region. The ideal would be a helmet tailored to the user's own head.

The Snell Foundation's crash helmet test program will continue, and when it's complete it should provide the first set of scientifically derived specifications for the design and construction of protective headgear. And these we need—badly. As the Snell tests are proving, an upholstered shell is *not* a racing helmet.

*Griff Borgeson*

## *Rex Hays*

*(Continued from page 21)*

picture of every important racing car — most American types unfortunately excepted — that has hit the circuits since the first World War, plus many of earlier vintage. With this shadowy dossier to draw on, he would be about as likely to commit hari-kari on his own scalpel as to dress a G.P. Delage in Monsieur Bugatti's exclusive shade of French Blue, or vice versa.

But back from the general to the particular, detail features that were exactly simulated on the Prince Charles Jaguar included the green upholstery hide, which was specially tanned for Hays; the foam-rubber seat interiors; and a full array of minutely calibrated instruments. There was only one thing that really fashed the Jaguar officials: they wanted it implied, if not actually stated, that the model was representative of Coventry craftsmanship. Hays, however, is a prideful burgher of the little Sussex community of Steyning, said to be the oldest town in England (its recorded history starts from a three figure date). Steyning, pronounced Stenning, is nowhere near Coventry, and Rex was unwilling to adopt honorary citizenship of the place even for the edification of TV viewers and newspaper readers. In the end they compromised by having him photographed at work in the Jag plant, omitting to say he wasn't a Jag employe, and hoping people would think he was.

From the fact that it has taken Hays himself, in his sideline journalistic capacity, tens of thousands of words merely to outline his craft and mystery in the model makers' shoptalk magazines, it can be appreciated that the subject hugely outruns the scope of this rundown. Here, the most you'll get for your 35 cents is a random handout of vignettes, picked to mirror the greatness of a real-life Gulliver and the mechanical Lilliput that his brains and hands have created.

One of the surprising and engaging things about Hays is that although a perfectionist in the limited human sense, he is no pedant. *Talis certitudo certitudinem* —punctilious exactitude destroys exactness. On the one hand he is a stickler for fidelity in three-dimensional portraiture and scaling: on the other, since his customers and audiences don't spend their lives with watchmakers' glasses stuck in their right eyes, he draws a line between the minute and the miniscule. For instance, on models as small as one-twentyfourth scale — which is the smallest he normally essays—he doesn't claim that his wire wheels will necessarily have the right number of spokes. Another example of his acceptance of compromise concerns the hood catches for a Tipo 158 Alfa Romeo (powered by a 1.48 cc Frog motor) that he made to one-twelfth scale some years back. The authentic hood fastening consisted of four spring-loaded clips; but Rex knew that these, if reproduced in full

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