Snell programs currently employ two distinct test procedures depending on the purpose of the test. Helmets submitted for certification receive a more stringent test so that passing results assure beyond a reasonable doubt that the model indeed meets Snell requirements. Units of certified models acquired for enforcement testing must pass a slightly less stringent test; failure indicates beyond a reasonable doubt that the model no longer meets Snell requirements and must be removed from the program. This two test procedure was first adopted in late 1991 shortly after the beginning of the M-90 and SA-90 programs. It was continued but remained a procedure rather than an explicit part of Snell standards until 2005 when it was first included in M2005 and SA2005. It is currently an explicit part of M2010 and SA2010.

The reason for this two test procedure is as follows. Tests are intended to divide objects into two categories, those which satisfy them and those which do not. However, there is almost always a third category between passing and failing, a gray area for which the test renders no reliable judgment. For this third category there will remain a reasonable doubt that a slight imprecision in the test conditions or in the measurements has lead to false positives and false negatives: that is, erroneous evaluations causing inadequate items to appear to pass or adequate items to appear to fail.

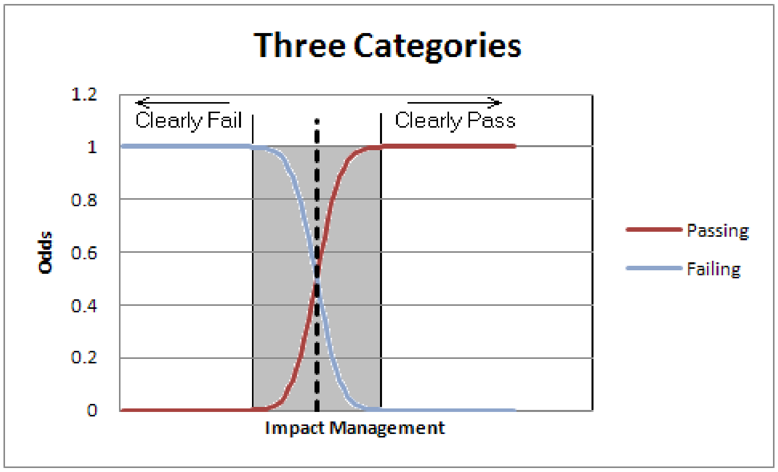

Figure 1

The effect is that if a single sample of an object happens to meet requirements in a test of a given stringency, there is at least a hypothetical possibility that an identical object might fail a test of the same stringency later. However, if identical objects are instead tested at lower levels of stringency, this hypothetical possibility diminishes quickly. If the stringency of later testing is reduced sufficiently, there is reasonable confidence that identical objects will almost always meet requirements. Conversely, if an object is seen to fail at a given level of stringency, there is reasonable confidence that identical objects will almost always fail at some at some higher level of stringency. The gap between these various levels of stringency depends on uncertainties inherent in the testing.

Snell relies on two critical measurements for the correctness of its helmet testing: the impact velocity measure which confirms the severity of the test and the peak acceleration measurement which governs the evaluation of the helmets protective capability. There are uncertainties associated with both. By judiciously selecting peak acceleration criteria so that certification testing is slightly more demanding than enforcement testing and by selecting test impact velocities so that certification testing is slightly more severe than enforcement testing; Snell can reasonably assure that units identical to those meeting certification requirements will continue to meet enforcement requirements. However, if performance deteriorates below that demanded in certification testing after Snell certified production begins; a later failure in enforcement testing becomes progressively more likely.

For other aspects of helmet performance, manufacturers may easily provide additional margins of capability over and above those demanded. That third category of test result mentioned above is still a possibility but the overwhelming majority of helmets will meet requirements clearly and almost all the observed failures will be the result of obvious production errors and material problems. For these aspects, false positives and negatives are not an issue so a single test procedure is sufficient.

But large margins of crash impact management are not feasible for most Snell certified helmets. Greater impact management implies greater helmet wall thickness and greater helmet weight. Snell looks for all the impact management capability an individual might reasonably be expected to wear while the public favors sleek, light weight helmets over heavier units meeting the same requirements. For Snell helmets, “favors” is too weak a word. During the first fifteen years of Snell programs, impact management and helmet weight increased steadily reaching a plateau in 1975. Since 1975, impact management demands have increased only slightly. Helmet users had been able to put aside aesthetic objections in favor of better protection but, after 1975, helmet weight and size appeared to be approaching people’s physical capabilities to wear them. Currently, if a helmet model is to remain competitive in the market, its impact management cannot reasonably exceed Snell demands by very much. As a result, margins of impact management capability will often be too slight to eliminate the possibility of false positives and negatives in Snell testing. That is, Snell cannot reasonably ignore the possibility that a helmet might be mistakenly accepted for Snell certification or that, once accepted, a helmet might be mistakenly decertified afterwards.

Snell has split the tests into separate requirements for certification and enforcement solely to minimize these mistakes. The demands of the certification test are elevated beyond those of enforcement testing to reduce the chance that, once a model is certified, an identical unit might fail to satisfy enforcement testing. The certification test levels assure that only those helmets with high levels of impact managing capability will be accepted into the Snell program. The slightly lower enforcement levels apply only to those Snell certified helmets produced after the model is certified and allow only those which continue to meet requirements any assurance of remaining certified.

Since there are two different tests in the program, one for certification and another for enforcement, it is reasonable to ask which of the two best represents Snell’s requirement. The clearest answer is that Snell’s demands are expressed in Snell certification testing. A Snell certified helmet model gets one certification test but may receive a number of enforcement tests once it gets into production. Unless that helmet model remains capable, sooner or later an enforcement test result will sweep it from the program.

Snell enforcement is a little more complex than implied above; it actually consists of two rounds. The first of these is calls out exactly the same test severities as the certification test but applies the slightly less stringent enforcement peak G criteria. If a unit of a certified model passes this test, the model continues in the program and will not be tested again until enough time has passed and enough additional units have been produced to warrant another look. However, if the unit fails this test, three additional units of the same model and size will be acquired and brought in for the second round of testing. These three units will be subjected to testing at the lower enforcement severities but, otherwise, the tests will be identical to the first phase testing. If any of these three also fails to meet requirements, Snell's directors are notified and the manufacturer is required to stop production and shipment of the model immediately. The directors will also consider whether there is any hazard to the public and may require the manufacturer to take any necessary remedial action. When necessary, the directors themselves will issue public warnings unilaterally.

Reconfiguring a model after certification so that a lighter, sleeker version might still satisfy enforcement requirements is not really a viable option. The necessary reduction in impact management would greatly increase the chances of a first round failure and appreciably increase those of a second round failure as well as very expensive consequences. A first round failure by itself is insufficient cause to drop a helmet from the program but it does invite scrutiny. The unit is compared to a sample saved in the Snell archive from the original certification set. Any visible difference in the shell, liner or other critical elements such as a significant reduction in total weight would be taken as an immediate violation of the License Agreement. Even a relaxation of internal quality control would be foolish. The gap between certification and enforcement requirements is just sufficient to accommodate Snell test uncertainties. There is no room left for production variability. If these exist, and they surely do, they are the manufacturer's problem, he must minimize this variability however he can and then build into his helmets whatever performance margins may be necessary to prevent production variability causing his units to fail Snell testing.

Failing Snell enforcement is potentially very expensive, even when no reasonable hazard is implied. Production and shipments are still halted and dealers and distributors disappointed and demoralized. Unless the manufacturer moves swiftly to recertify, the model names will be removed from the Snell listings. Even if no public warnings appear directly, the mere disappearance of these model names will excite rumors in the industry and among the public. If the manufacturer does choose to recertify, there is an additional hurdle to be negotiated. Once samples of the model have newly passed certification testing, Snell imposes an additional test on the first short run of production. The manufacturer must produce and store on his premises at least one hundred units of the passing model. Then he must arrange either for an inspection and sampling of this first run. Either a Snell representative or a third party agreeable to Snell must be invited in at the manufacturer's expense to inspect this first run of production. Once the inspector has compared several units at random to assure that they are reasonably identical, he selects and marks four samples from this production which will be sent to Snell for a second certification test series. Only if these four samples meet requirements will the model become recertified. Generally, bringing in a Snell representative is not an option. We can rarely spare anyone for the task and, when we can, the reimbursements to Snell for flights, lodging and for the loss of the employee's time are prohibitive. Instead, we recommend third parties such as from internationally recognized organizations such as TUV and SGS perform this function.

The Snell enforcement program is the least expensive and intrusive system we can devise to assure the continuing capabilities of Snell certified helmets. But the consequences of an enforcement failure are always severe and always profit no one. The Snell certification and enforcement test policy has been devised to minimize the possibility that these consequences would be imposed mistakenly on anyone.

Theoretical Discussion

The Snell impact management tests involve many complications. There are several impact surfaces and a number of helmet conditionings available to the test technician as well as a broad range of impact sites. Certification calls for testing on several samples while enforcement testing actually starts with single samples stressed at certification severities and moves to rounds of three samples stressed at lower levels only after a failure is observed in the initial phase. All these complications are ignored in the following discussion.

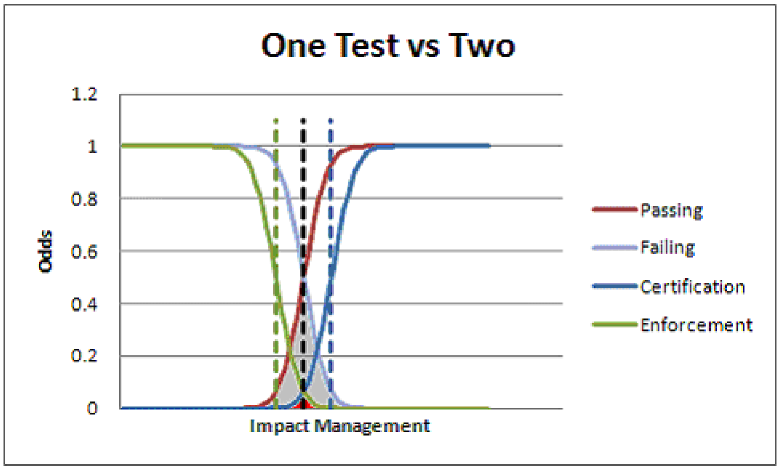

Figure 2

Figure 2 compares odds of passing versus failing for a single test to a pair of tests in which the test for certification has been shifted one and a half standard deviations to the right and the test for enforcement has been shifted one and a half standard deviations to the left. The X-axis is the sample's impact management. The dashed lines represent the impact management demanded in the test specifications but, due to measurement uncertainties, some samples with slightly lower impact managements will appear to pass the tests while others with greater impact management will appear to fail. The curves marked “Failing” and “Enforcement” show the odds of a helmet with a given energy management failing the test and the “Passing” and “Certification” curves show the odds of success.

The filled regions represent units which pass initial testing and are included in the program but which fail the first enforcement series conducted afterwards. The much smaller region filled in red shows how separating the tests reduces the chances that a helmet will be accepted into the program and then fail the first enforcement test afterwards.

The next figure shows odds for a helmet model being accepted into the program and then failing enforcement afterwards when certification and enforcement demands are the same. All the action is in the center near the impact management level specified in the test. Much to the left and the helmets always fail certification and much to the right, they always pass enforcement. But helmets whose capabilities are nearly those called out by the tests have significant chances of passing certification and failing soon afterwards. After a single test the odds peak at 25% for a helmet whose impact management is precisely that specified for the test. But the odds of failing increase considerably for two, five and ten enforcements and the peaks shift to the right indicating that a series of enforcements is more demanding than the initial certification.

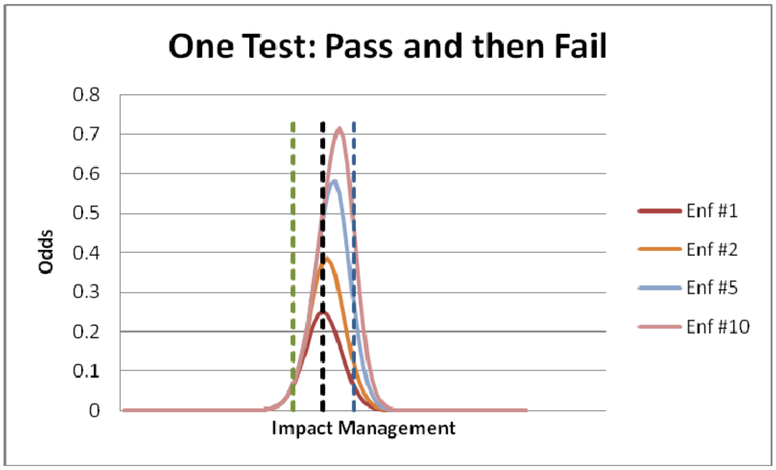

Figure 3

Figure 4 shows something similar if the certification test levels and enforcement levels are separated by three times the standard deviation of the odds distribution determined by measurement uncertainty. The odds of a helmet being certified and failing later still increase rapidly for more enforcement series but the peak is still less than 4% that a model passing certification would be rejected after a series of ten enforcement tests. The rightward shift of the peaks as the enforcement series lengthens is also much less pronounced.

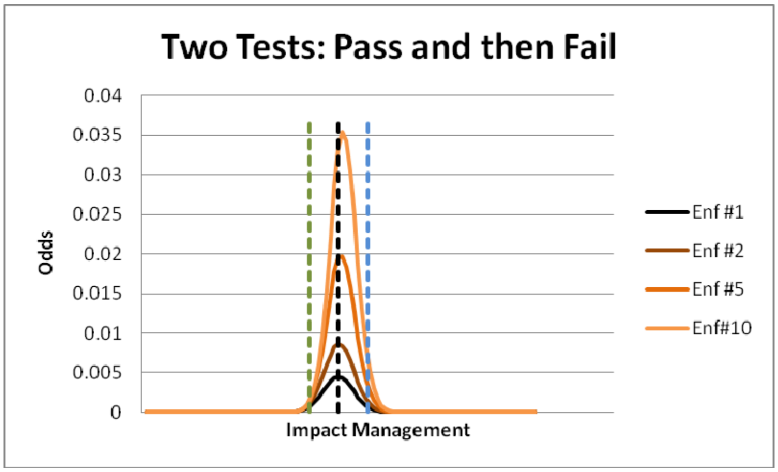

Figure 4

Figure 5 shows successful helmets for the single test protocol after certification and then successively longer series of enforcement tests. The curve separating success from failure shifts steadily to the right until, for a series of up to ten or so enforcement tests, the odds distribution centers at about one and a half standard deviations to the right although with a steeper slope. Figure 6 shows the same breakout for the two test protocol. There is hardly any change in the curve after successive enforcement procedures. Once a helmet has been accepted, it will remain accepted so long as its capabilities are maintained.

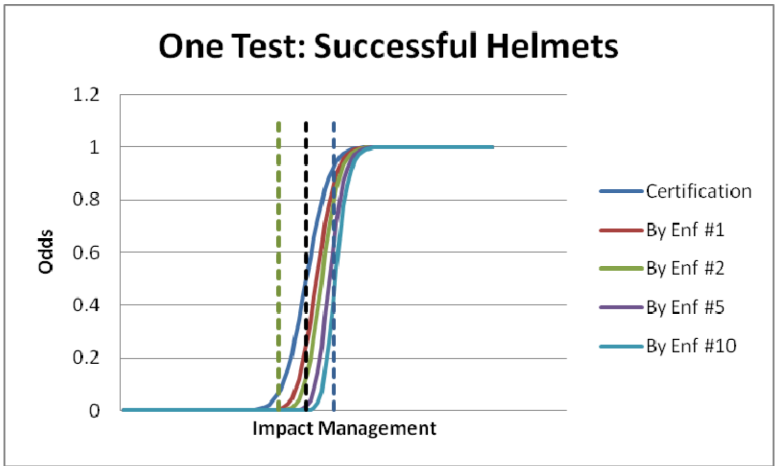

Figure 5

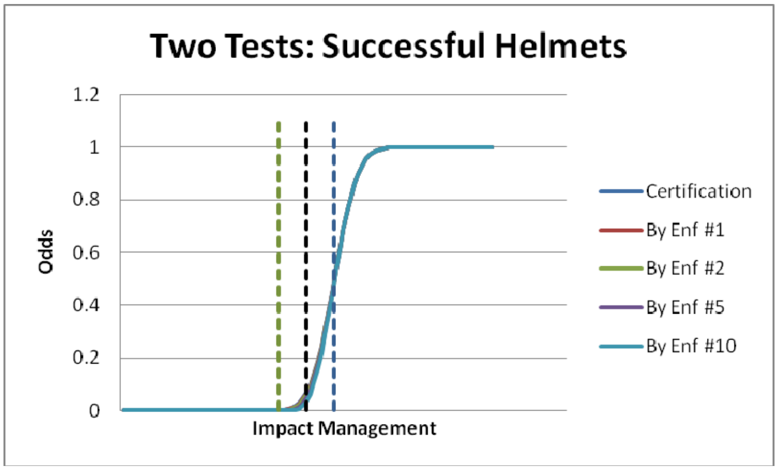

Figure 6

Figure 7 shows what might be expected if a helmet is deliberately detuned after certification so that later production has less impact management capability. In essence, the detuned helmet is a counterfeit but there is limited latitude to the detuning. At three standard deviations below the impact management set for certification, a detuned helmet has only a 50% chance of passing and these odds diminish rapidly for successive tests. With an impact management capability one and a half standard deviations below that demanded by the certification test, there's a fifty percent chance of that the detuned helmet will survive ten enforcement tests but the odds of remaining in the program don't approach certainty until the helmet capability actually meets certification requirements. Furthermore, one and a half standard deviations is a particularly narrow band, especially considering that the manufacturer must also allow for production variations. Ultimately, the saving in helmet weight and wall thickness would be virtually imperceptible and not worth the risk.

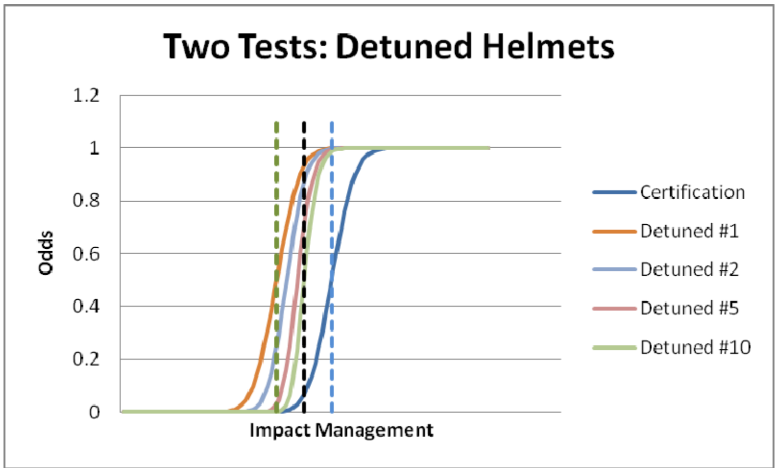

Figure 7

Implementation

There are two critical measures in Snell impact testing: impact velocity which is a measure of the severity of the test and peak acceleration of the head form in response to the shock transmitted through the helmet. Depending on the impact surface, one or the other of these bears more strongly on the outcome. In impact testing on flat, load spreading surfaces, the peak acceleration measurement is most critical. If the helmet wall resists compression too strongly, the peak acceleration may be pushed up beyond the test criterion causing the helmet to fail. However, for load concentrating surfaces like the hemispherical anvil, impact velocity is the critical element. If the impact severity does not overwhelm the helmet and crush the wall to its minimum thickness possible, the peak acceleration will not exceed that of a similar impact against a flat surface. But if the helmet wall is compressed to its minimum before the impact is managed, the peak acceleration will skyrocket to levels well in excess of any reasonable criterion.

Effectively, acceleration uncertainties apply to impacts against load spreading surfaces and velocity uncertainties apply to impacts against load concentrating surfaces. Accelerometer uncertainties range from 3% to 5% and the measurement is also affected by head form mass which can vary as much as 3% depending on the size of the head form selected for testing. The 10 G difference between certification and enforcement criteria is certainly narrower than the three standard deviations proposed earlier but there are two factors which may offset this. In flat impact, peak acceleration increases steadily with impact severity so that the lower levels of impact severity called out for enforcement add to the two standard deviation gap between certification and enforcement criteria. Also test results in a passing test reliably show when calls are close so that passing certification test results will warn when enforcement testing might lead to problems. Generally, the demands of local mandatory standards which helmets must also meet are such that few enforcement problems are encountered.

Impact velocity issues are more problematic. Snell tests at higher severities than any mandatory requirement and the results of a passing test rarely yield any clue whether the helmet was nearing the limits of its capability. Failure is generally an energy phenomenon; the work done crushing the helmet wall must equal the kinetic energy of the falling head form. Any reckoning is complicated by the fact that the helmets must withstand two impacts at a site and that the helmet may recover between impacts. Twenty years test experience suggests that a helmet recovers about half the capability necessary to manage the first of two hemispherical impacts before it must manage the second. The differences in the total energies necessary to pass certification and enforcement testing amount to approximately 10% of the certification demand. The standards require that the impact energy as measured be within 3% of the specified amount but the measured value is usually lower than 1.5%. The velocity measurement itself is held to be within 1% of the true value. The total uncertainty works out to about 3% so that the gap between certification and enforcement test severities is about three standard deviations.

Conclusion

The separation between the demands for the certification testing and the enforcement tests is based on estimates of what is necessary to keep Snell lab uncertainties from interfering with efficient management of the Snell programs. There is no real room for production variability which must remain the manufacturer's problem. And there is no real benefit in detuning a helmet and expecting to survive in the gap between certification and enforcement. Snell is watching the helmets and comparing certification samples to later production. There is no real reward for attempting to game the program and the penalties can be very costly. The truest advantage of the two test protocol is that testing issues beyond Snell's control will not cause honest and capable manufacturers to suffer these penalties unjustly.